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The Raft River Geothermal Project Groundwater Monitoring Program Progress Report

Piotr Skiba
Dennis Goldman
Susan Spencer
Laurence Hull

July 1981

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Prepared for the
U.S. Department of Energy
Idaho Operations Office
Under DOE Contract No. DE-AC07-76IDO1570

EG&G Idaho

Printed in the United States of America

Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
NTIS Price Codes: Printed Copy A03
Microfiche A01

EGG-2119
Distribution Category: UC66d & e

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ABSTRACT

The Raft River 5 MWe geothermal power plant will use 150 L/s of geothermal fluid at 140°C, and an estimated 130 L/s will be discharged to intermediate-depth injection wells during normal plant operation. A monitoring program has been established to investigate the effects of geothermal fluid disposal on shallow irrigation wells at Raft River. This annual progress report summarizes data collected from seven monitor wells during 1980 (including the first quarter of FY 1981) and discusses the potential effects on shallow aquifers of the production and injection of geothermal fluids.

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INTRODUCTION

The Raft River 5 MWe binary geothermal power plant at the Raft River Known Geothermal Resource Area (KGRA), which is scheduled to begin operation in 1981, will use 150 L/s of geothermal fluid at 140°C. An estimated 130 L/s will be discharged to intermediate-depth injection wells during normal plant operation. Consequently, a monitoring program has been established to evaluate the effects of geothermal fluid disposal on shallow irrigation wells at Raft River. This annual progress report, which also covers the first quarter of FY 1981, includes a summary of data collected from seven monitor wells during 1980 and discusses the potential effects on shallow aquifers of the production and injection of geothermal fluids.

PREVIOUS STUDIES

The Raft River monitor well program has been described in detail (Spencer and Callan, 1980). Included in the report were discussions on the geology, hydrology, and water quality of the Raft River KGRA. Lithologic logs and construction diagrams of seven monitor wells; chemical analysis of selected monitor, irrigation, and geothermal wells; and analysis of monitor well water level fluctuations during 1979 were presented. The response of the monitor wells to geothermal fluid injection was examined in detail. This present report is designed to continue the discussion of groundwater fluctuations, with emphasis on response to geothermal injection.

HYDROLOGIC SYSTEM AT THE RAFT RIVER KGRA

The Raft River KGRA lies in a north-south trending, structurally-downwarped basin. The bounding mountain ranges differ stratigraphically, being composed of (a) primarily Paleozoic limestones (Black Pine Range), (b) Precambrian gneiss mantled by allochthonous Paleozoic metamorphosed and nonmetamorphosed sediments (Raft River Range), (c) Tertiary rhyolites and tuffaceous sediments (Jim Sage Mountains). The basin fill, consisting of poorly consolidated sediments derived from the surrounding mountain ranges, is approximately 1,900 m thick. The upper 300 m are lenticular deposits of alluvial, fluvial, and loessal origin called the Raft Formation. The lower 1,600 m are marine deposits of sand, silt, minor conglomerate, and tuff of the Tertiary Salt Lake Formation. These directly overlie a series of Precambrian metasediments capping a quartz monzonite basement that is partially remobilized and intruded (Williams et al., 1976).

The KGRA lies at the intersection of two major geologic structures which are thought to control the geothermal resource. One is a series of steep normal faults trending northward called the Bridge Fault (Figure 1). The other is a poorly understood, northeast-trending feature, the Narrows structure, that provides the southern terminus for the north-trending structures. This feature has not been distinctly defined by geophysical surveys, but is thought to be a basement shear (Williams et al., 1976). Several other faults inferred from geophysics, surface geology, and the behavior of the geothermal reservoir provide additional controls.

Groundwater in the basin occurs both in unconfined and confined conditions in the poorly consolidated sediments of the Salt Lake Formation, the sands and gravels of the Raft Formation, and recent alluvial deposits. Recharge to these aquifers results directly from local precipitation and from infiltration of surface water and irrigation runoff.

The shallow aquifers are considered phreatic, although some wells reveal locally confined conditions. Nearly all water encountered below 300 m is confined. Static water levels in these deeper aquifers in the geothermal area range from 30 m to more than 100 m above land surface. Because of the increase in head with depth, each aquifer is probably recharged in part by upward leakage from underlying aquifers. This is especially evident in the geothermal area, where wells as

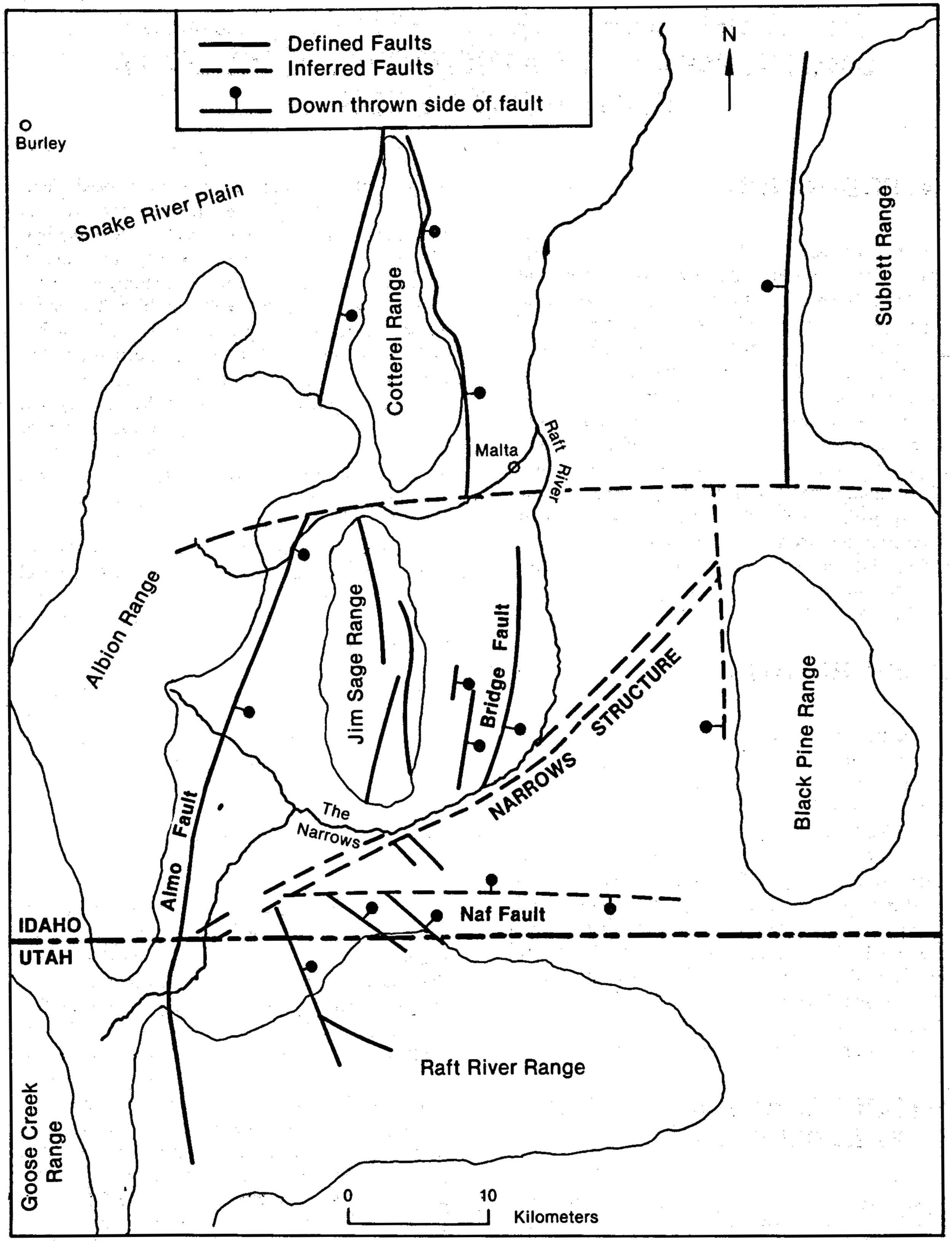

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Figure 1. Generalized geological map of the Raft River valley region.

shallow as 120 m tap hot water. Nearly all irrigation wells in the area show some thermal and chemical evidence of upward leakage from the geothermal resource.

MONITOR WELL PROGRAM

The monitor well program is designed to provide the data necessary for evaluating and predicting the impact of geothermal development on the shallow aquifer system. Seven monitor wells (MW-1 through MW-7) were drilled during 1978 within the vicinity of the injection wells (Figure 2). The locations of the monitor wells were selected to detect response to geothermal injection before it is detectable at irrigation or domestic wells. The wells were designed to provide data enabling projection of the long-term impacts of geothermal injection in upper aquifers.

The monitor wells are equipped with continous reading water level recorders. MW-1 and MW-2 have digital-readout quartz pressure transducers installed for monitoring wellhead pressure; installed well head pressure monitoring digital quartz pressure transducers installed at the well head; wells MW-3 through MW-7 are equipped with Stevens type F water level recorders. The water samples for chemical analysis are collected using submersible pumps and a downhole sampler.

1980 PRODUCTION-INJECTION TESTING

In 1980, two long-term production-injection tests were conducted. The first test was conducted from May 14 through June 17, 1980. Fluids produced from RRGE-3 were injected into RRGI-6. The average pumping-injection rate was 47 L/s. On June 12, injection was switched from RRGI-6 to RRGI-7 for the duration of the test.

The second long-term production-injection test was conducted from August 19 through September 10. Fluids produced at RRGE-1 were injected alternately into RRGI-6 and RRGI-7. The average pumping injection rate was 57 L/s.

Several short-term production-injection tests were conducted throughout 1980, but these test were not of sufficient length to have an effect on the monitoring wells.

GROUNDWATER HYDROGRAPHS

General Trends

Groundwater level changes observed in the Raft River valley consist of long-term trends and seasonal fluctuations. Water levels in the shallow aquifer near the Raft River have declined over the past 30 years due to extensive irrigation pumping (Nichols, 1979). Analysis of 5 years of water level data from USGS-2 (a 240-m-deep core hole) suggests that there has been a long-term decline in shallow groundwater levels in the injection area (Figure 3). Two years of groundwater records from the monitor wells are inconclusive for long-term trends.

Seasonal water-level changes are apparent in several monitor wells. A water-level high occurs in early spring, reflecting shallow recharge. Water levels decline between midspring and the end of the irrigation season. A steady water-level rise then occurs as a result of the termination of irrigation pumping.

The seasonal fluctuations observed in the monitor wells are listed in Table 1.

Table 1. Observed seasonal fluctuations in monitor wells

Well Number	Seasonal Fluctation (m) 1979	1980
MW-1		2.07
MW-2		2.60
MW-3	2.44	1.83
MW-4	3.05	2.10
MW-5	5.98	4.76
MW-6	2.84	2.04
MW-7	2.74	2.16

Monitor Well Hydrographs

Monitor Well 1 (MW-1). The hydrograph for 1980 indicates a general rise of about 0.5 m (Figure 4). The static water level ranged from about 30 to 32 m above the wellhead. A decline in

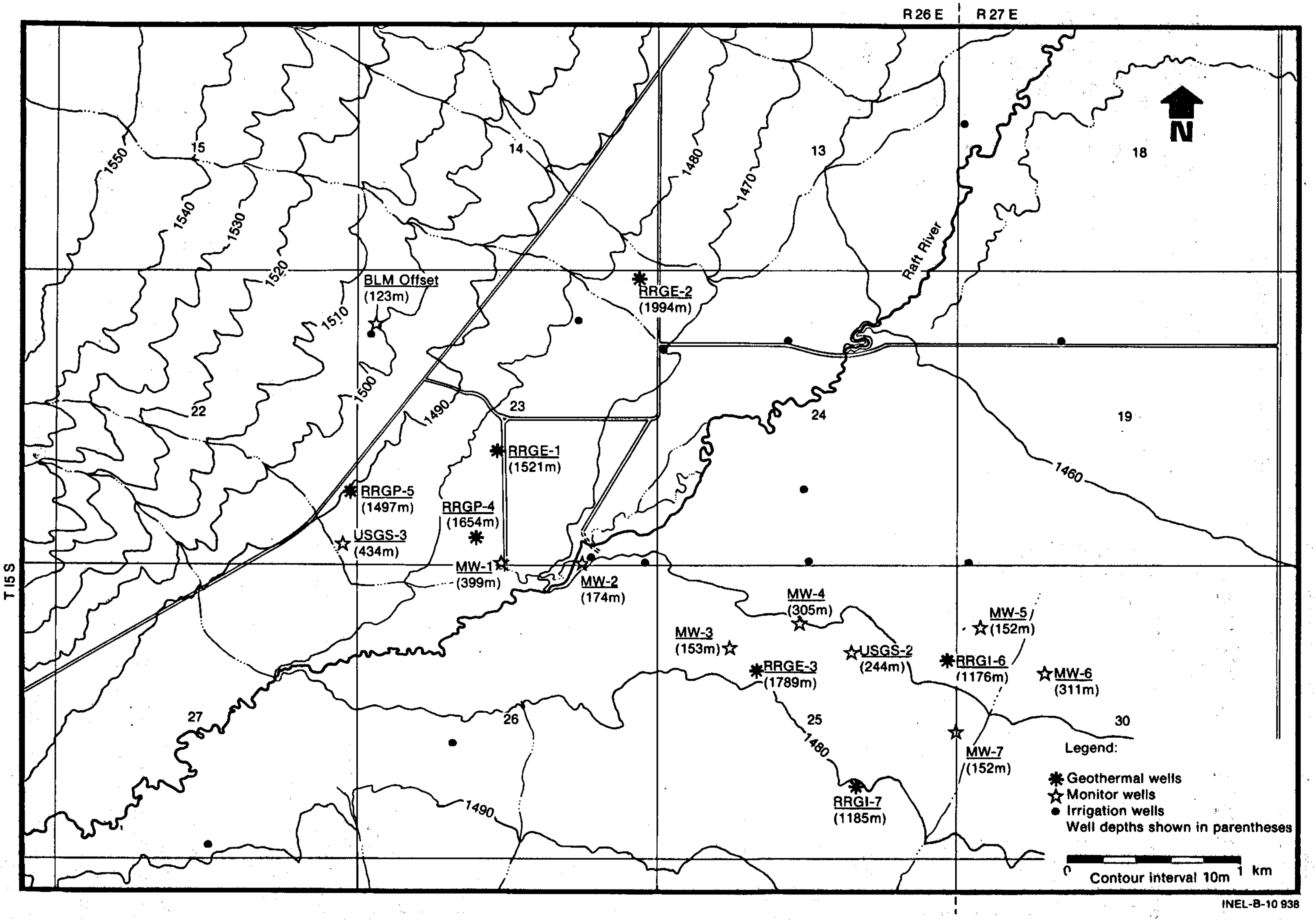

Figure 2. Raft River KGRA site map.

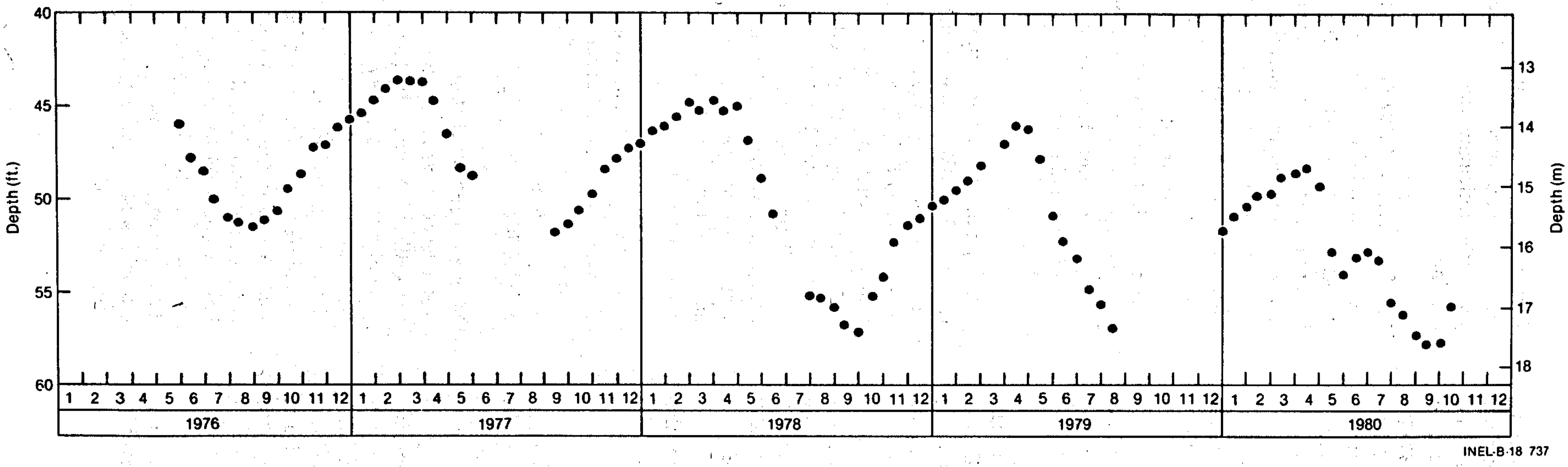

Figure 3. USG-S-2 long-term hydrograph.

water level that began in mid-May appears to have been caused by interference due to pumping. Because the well shows recovery during July and August, the interference is probably not due to irrigation pumping. The decline and recovery coincide with the RRGE-3 to RRGI-6 test. It is suspected that MW-1 may be responding to pumping at RRGE-3. Additional testing is required to confirm this suspicion.

The two years of data from MW-1 are inconclusive for determining long-term trends (Figure 5). Variations in water levels for the two years do not coincide.

Monitor Well 2 (MW-2). The hydrograph for 1980 indicates a definite rising trend of 2.5 m (Figure 6). The static water level ranged from about 11 to 13.5 m above the wellhead. The hydrograph is affected by the production of thermal fluids from the Crook well (T15S, R26E, Section 23 ddc). A rise in water level beginning in June is caused by the termination of pumping from the Crook well. However, the subsequent decline in mid-July suggests the possibility of effects from the RRGE-3 to RRGI-6 test. A similar rise and decline occurred in MW-4 during the same period (see MW-4 discussion). Additional testing and monitoring at the Crook well would aid in understanding these responses.

The two years of data from MW-2 are also inconclusive (Figure 7). Variations in water levels for the two years do not follow a recognizable pattern.

Monitor Well 3 (MW-3). During 1980, the static water level ranged from 14 to 16 m below the wellhead (Figure 8). The hydrograph shows a steady rise of 0.3 m per month through April. From May through September, the hydrograph shows a general decline. Aquifer dilation may have occurred during the RRGE-3 to RRGI-6 test. However, the major responses correlate with apparent irrigation pumping as seen in MW-5 (see MW-5 discussion). The hydrograph shows 1.5 m of recovery from October through the end of the year, apparently due to the termination of irrigation pumping.

The two years of data are not sufficient to determine a long-term trend (Figure 9). However, a comparison of 1979 and 1980 fluctuations shows similar slopes and magnitude of response. Water-level highs and lows occur at the same time each year. We anticipate that this annual cycle will continue.

Monitor Well 4 (MW-4). The 1980 hydrograph shows a general rise of slightly greater than 0.1 m throughout the year (Figure 10). The static water level ranged from 0.5 to 2.5 m below the wellhead, Superimposed on the general trend is a 4-week water level rise beginning in mid-May, with subsequent recovery. This water level rise and recovery is coincident with the RRGE-3 to RRGI-6 test. The response correlates with that observed during previous injection tests and has been defined as fracture communication (Spencer and Callan, 1980). The magnitude of the response is similar to that observed during previous injection tests at RRGI-6.

During the August-September injection test, the response in MW-4 was much less than that observed during previous tests. Injection into RRGI-6 lasted only 8 days, at which point injection was switched to RRGI-7. The hydrograph response during this period was affected by recovery from the RRGI-6 injection and possibly, by buildup from injection at RRGI-7. The response at MW-4 to injection at RRGI-7, if present, is of a lower magnitude because of the greater distance and, possibly, smaller hydraulic communication.

The two years of data from MW-4 are inconclusive (Figure 11). In general, there has been a water-level rise of more than 2 m during this period. A continuation of this trend will cause the well to flow.

Monitor Well 5 (MW-5). During 1980, the static water level ranged from about 20 to 24 m below the wellhead (Figure 12). The hydrograph shows a general rise of 0.3 m per month through April. During the irrigation season, the hydrograph shows a general decline. Sharp responses are due to interference effects from a nearby irrigation well. A rise and decline in water level in June are coincidental with the RRGE-3 to RRGI-6 test; however, it is felt that this response is not due to injection but to changes in irrigation pumping. The hydrograph shows 3 m of recovery between October and December, apparently due to the termination of irrigation pumping.

The two years of data are not sufficient to determine a long-term trend (Figure 14). However, a comparison of 1979 and 1980 fluctuations shows similar slopes and magnitude of response. Water-level highs and lows occur at the same time each year. We anticipate that this annual cycle will continue.

Monitor Well 6 (MW-6). During 1980, the static water level ranged from 21 to 23 m below the wellhead (Figure 15). The hydrograph shows a general rise of about 0.3 m per month through April. During the irrigation season, the hydrograph shows a general decline. Aquifer dilation may have occurred during the RRGE-3 to RRGI-6 test; however, the major responses correlate with apparent irrigation pumping. The hydrograph shows less than 1 m of recovery from October through December.

The two years of data suggest declining water levels (Figure 15). A comparison of 1979 and 1980 fluctuations shows similar slopes and magnitudes of response. Water-level highs and lows occur at about the same time each year. We anticipate that this annual cycle will continue.

Monitor Well 7 (MW-7). During 1980, the static water level ranged from 24 to 26 m below the wellhead (Figure 16). The hydrograph shows a steady rise of 0.3 m per month through March. The annual response in MW-7 is very similar to that at MW-3 and MW-6.

The two years of data suggest declining water levels similar to those of MW-6 (Figure 17). The annual fluctuations show similar slopes and magnitudes of response. Again, water-level highs and lows occur at the same time each year. We anticipate that this annual cycle will continue.

WATER CHEMISTRY

Water samples for chemical analyses were collected twice during 1980. MW-1, MW-2, and the BLM and Crook wells are artesian wells, and samples were collected from the natural flow. The remaining monitor wells were pumped using a submersible pump.

Results of the chemical analyses are shown in Table 2. The general character of the data indicates little change in water chemistry over time. Specific variations between the January and December samples appear to be a result of different laboratories analyzing the samples. Additional samples, however, will be needed to adequately determine whether any changes are indeed occurring. Current plans are to initiate quarterly sampling of the monitor wells, which should allow better delineation of changes with time.

DISCUSSION

Characteristics of MW-1 and MW-2 indicate direct hydraulic connection with the geothermal system. In general, hydraulic responses in these wells are related to geothermal production activity rather than to injection or irrigation pumping. We anticipate that geothermal production could decrease local upward geothermal leakage. This would result in declining water levels in MW-1, MW-2, and the BLM and Crook wells. On the basis of data to date, we do not expect to see response to geothermal injection in this area.

MW-3, MW-5, MW-6, and MW-7 appear to respond to seasonal changes and irrigation pumpage. The magnitude of response varies, apparently because of distance from irrigation wells. We do not expect to see any major effects in these wells from geothermal production or injection.

MW-4 responds rapidly to geothermal injection. This is explainable only by anisotropic hydraulic communication, possibly via soft-sediment fractures. The bottom hole temperatures and water chemistry from all monitor wells confirm that the interconnection between shallow and deep aquifers varies spatially (Table 3). We expect the water level in MW-4 to continue to rise during injection. With limited spatial data and insufficient understanding of the nature and extent of shallow fractures, we cannot project the effects of geothermal injection on the shallow aquifers.

RECOMMENDATIONS

To clarify uncertainties in monitor well responses, it would be best to conduct injection and production testing only from December through March. Testing during the irrigation season increases, the number of variables that must be taken into consideration for respondse analysis. An alternative approach may be to instrument several of the local irrigation wells to quantity their potential interference.

Specific recommendations to aid in future analysis include:

1. Quarterly chemical analyses and temperature logging of the monitor wells
2. Establishment of a reference datum at each monitor well
3. Installation of tilt and strain meters to evaluate shallow aquifer distortion
4. An RRGE-3 to RRGI-7 pumping injection test.

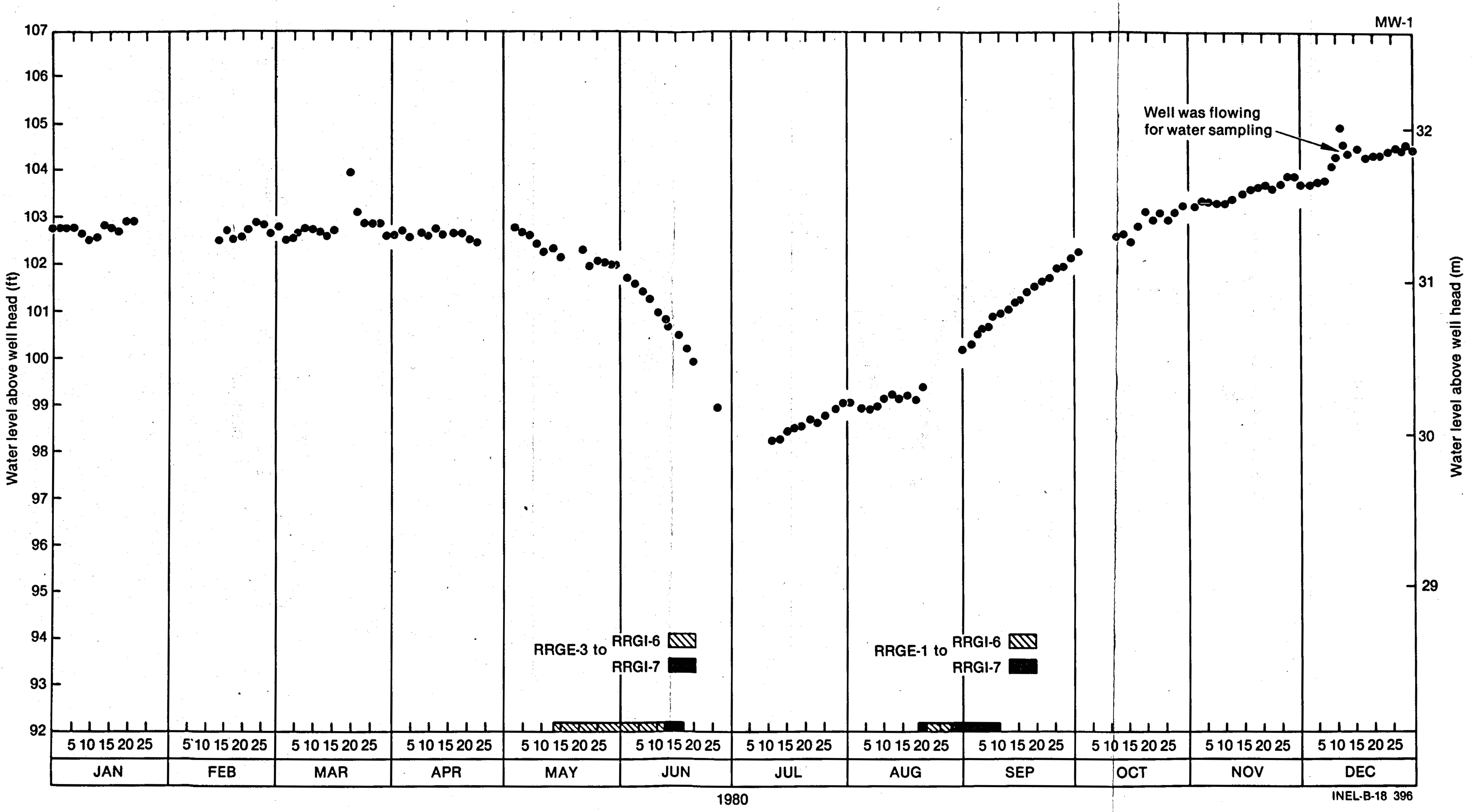

Figure 4. MW-1 hydrograph for 1980.

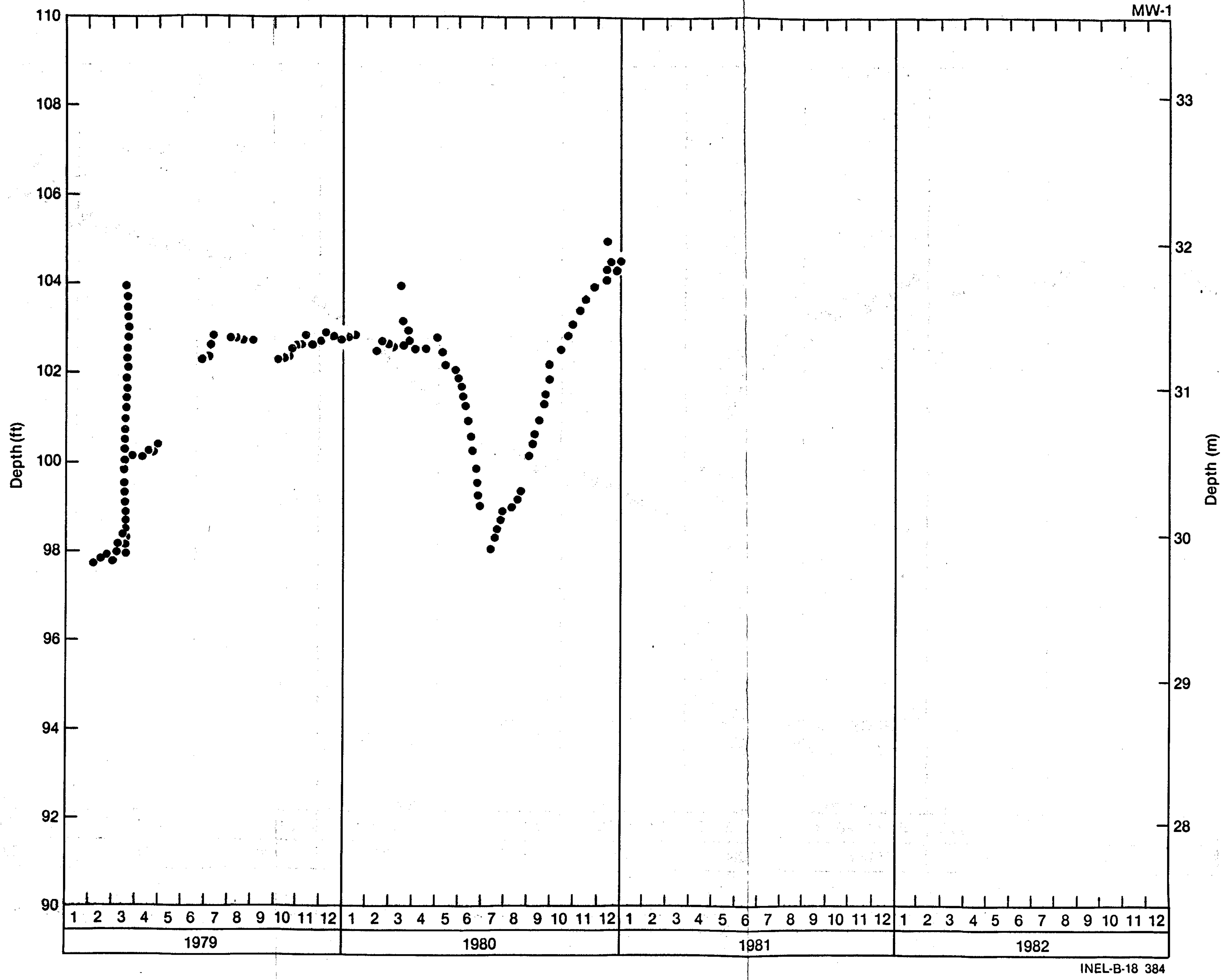

Figure 5. MW-1 long-term hydrograph.

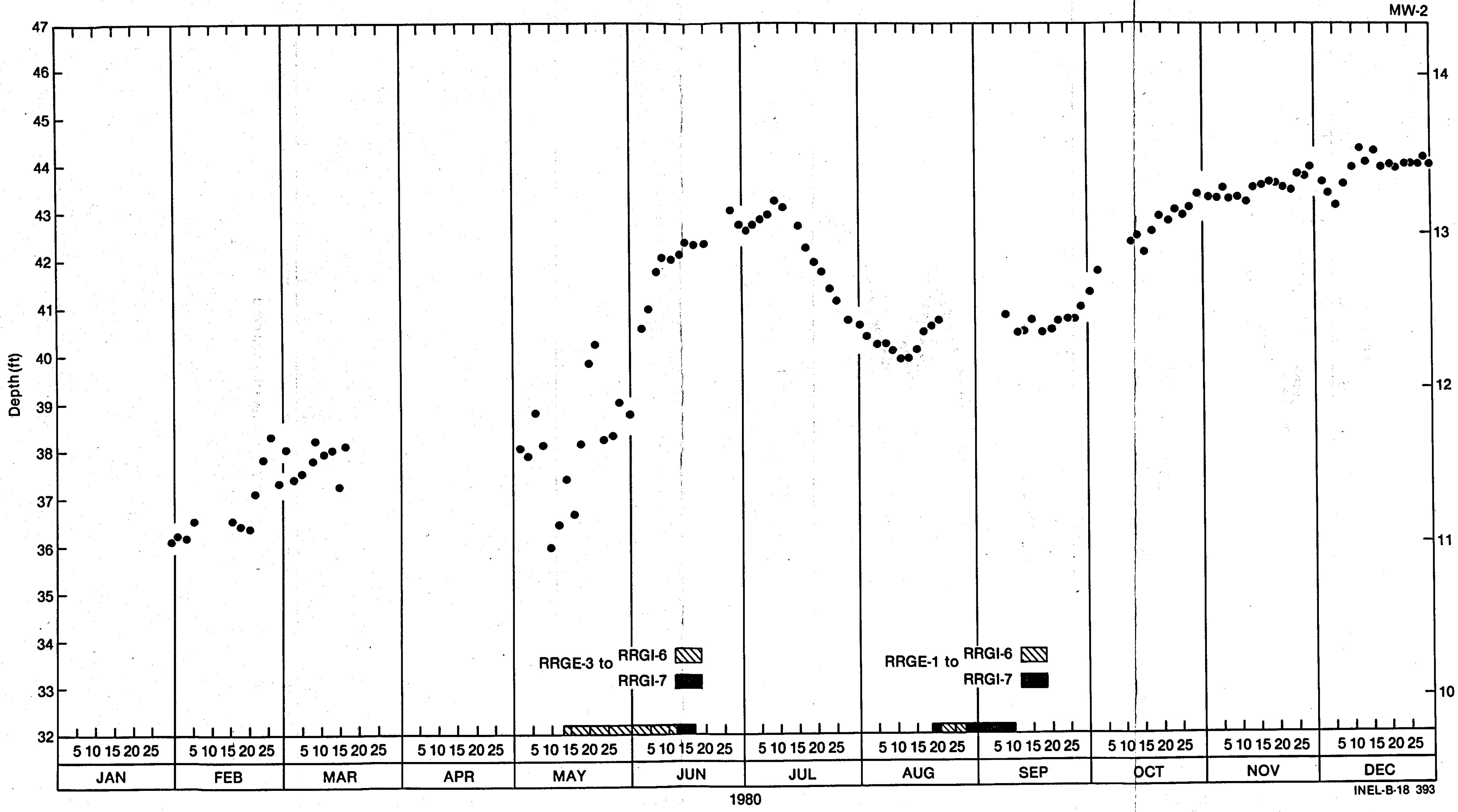

Figure 6. MW-2 hydrograph for 1980.

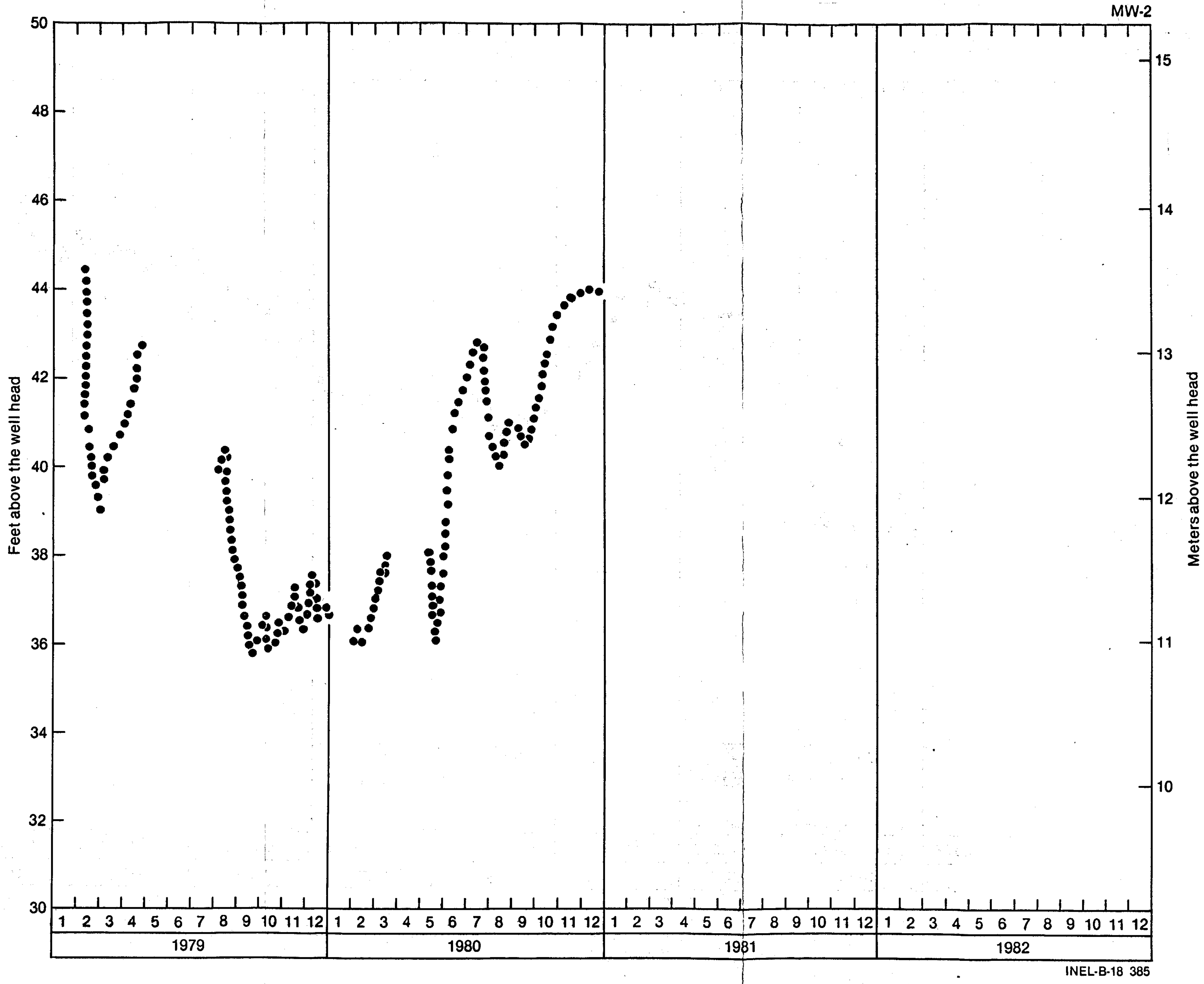

Figure 7. MW-2 long-term hydrograph.

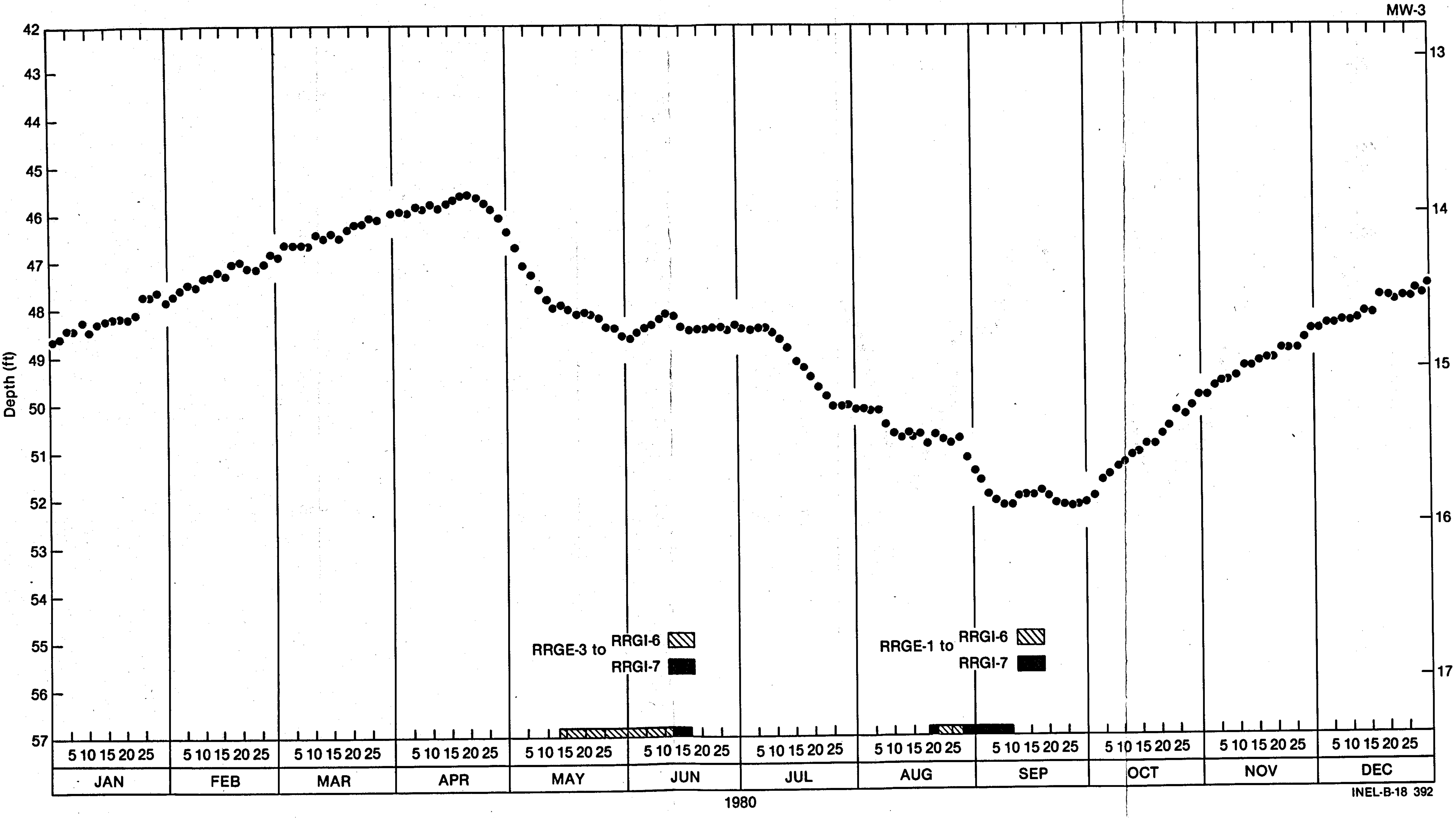

Figure 8. MW-3 hydrograph for 1980.

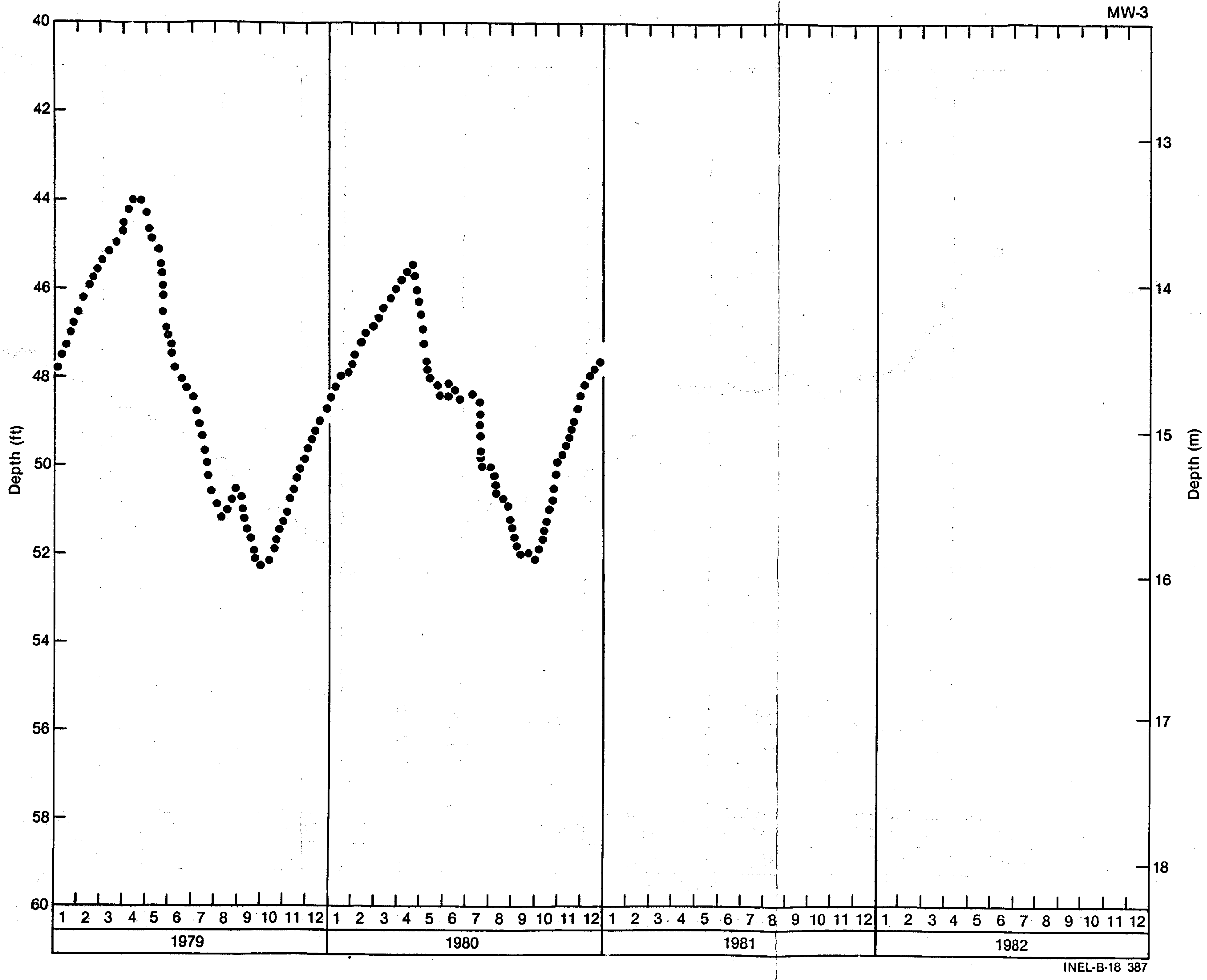

Figure 9. MW-3 long-term hydrograph.

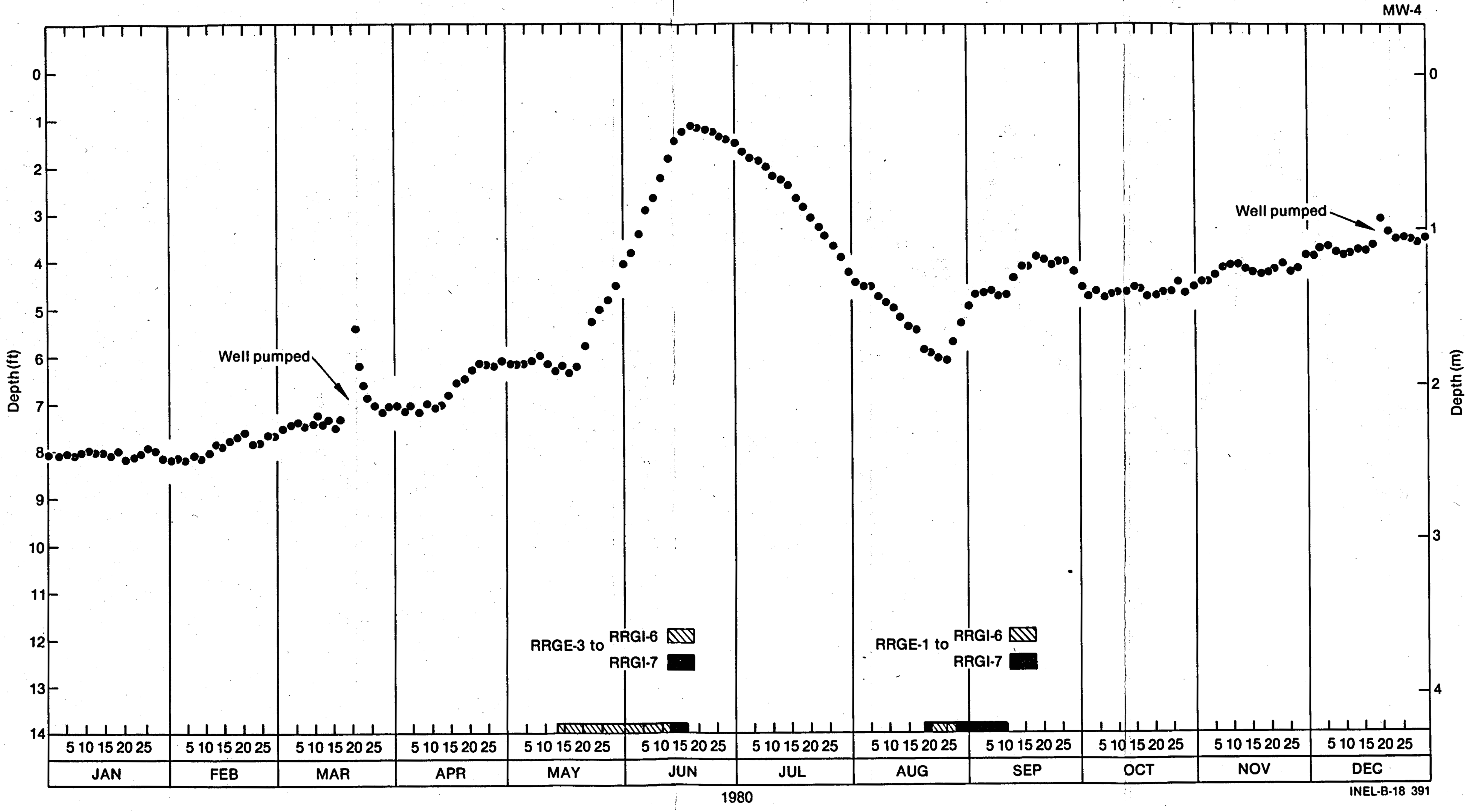

Figure 10. MW-4 hydrograph for 1980.

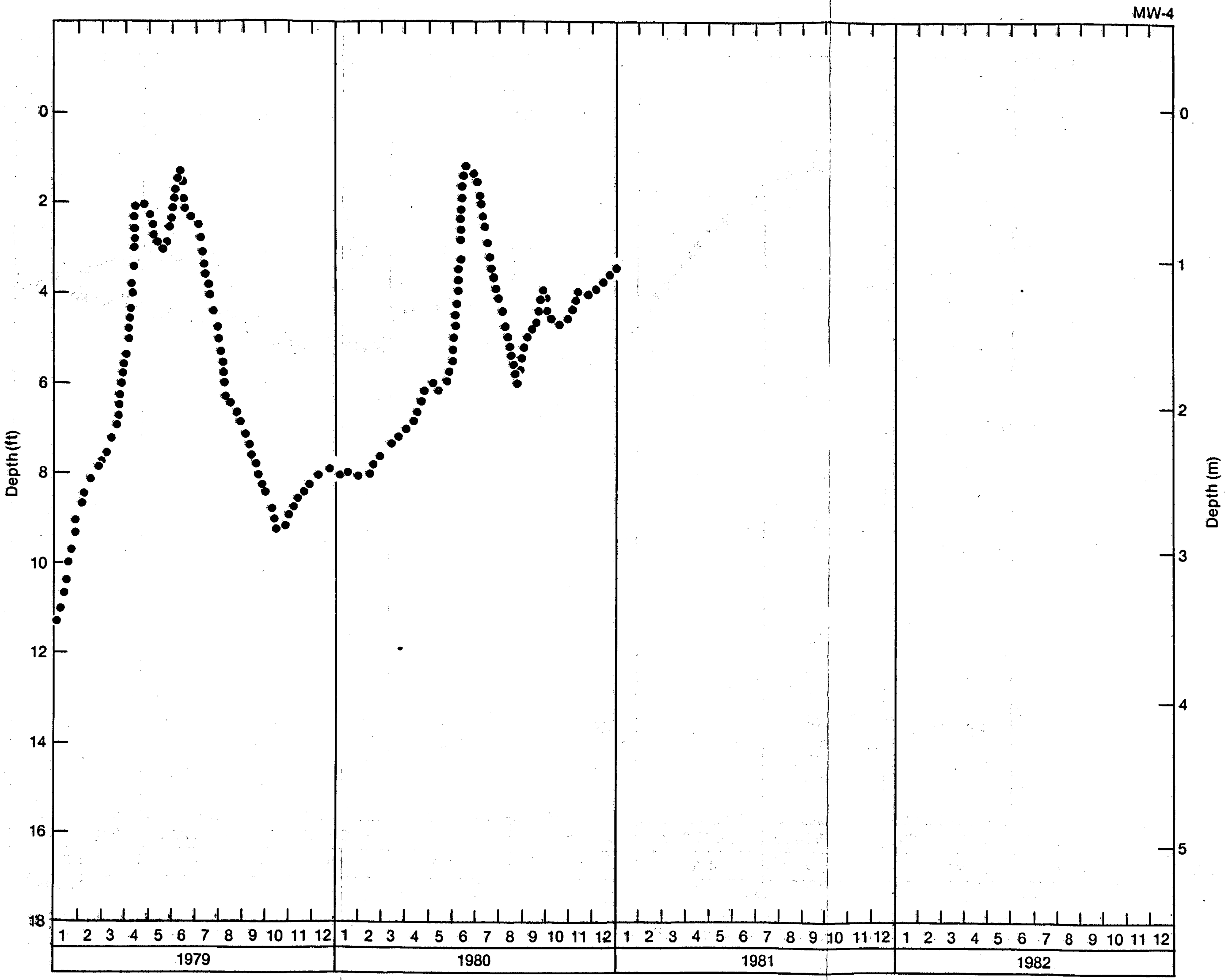

Figure 11. MW-4 long-term hydrograph.

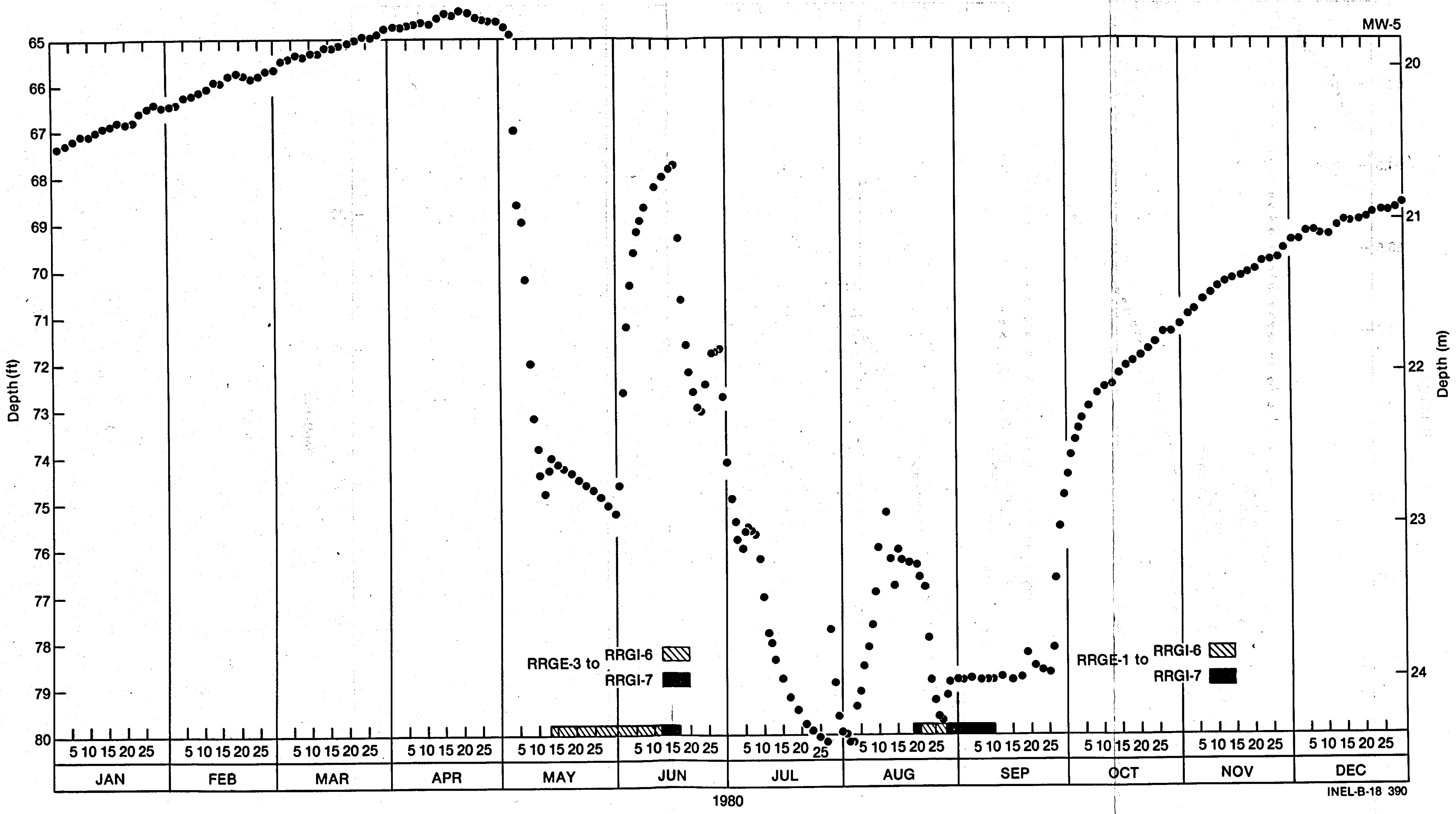

Figure 12. MW-5 hydrograph for 1980.

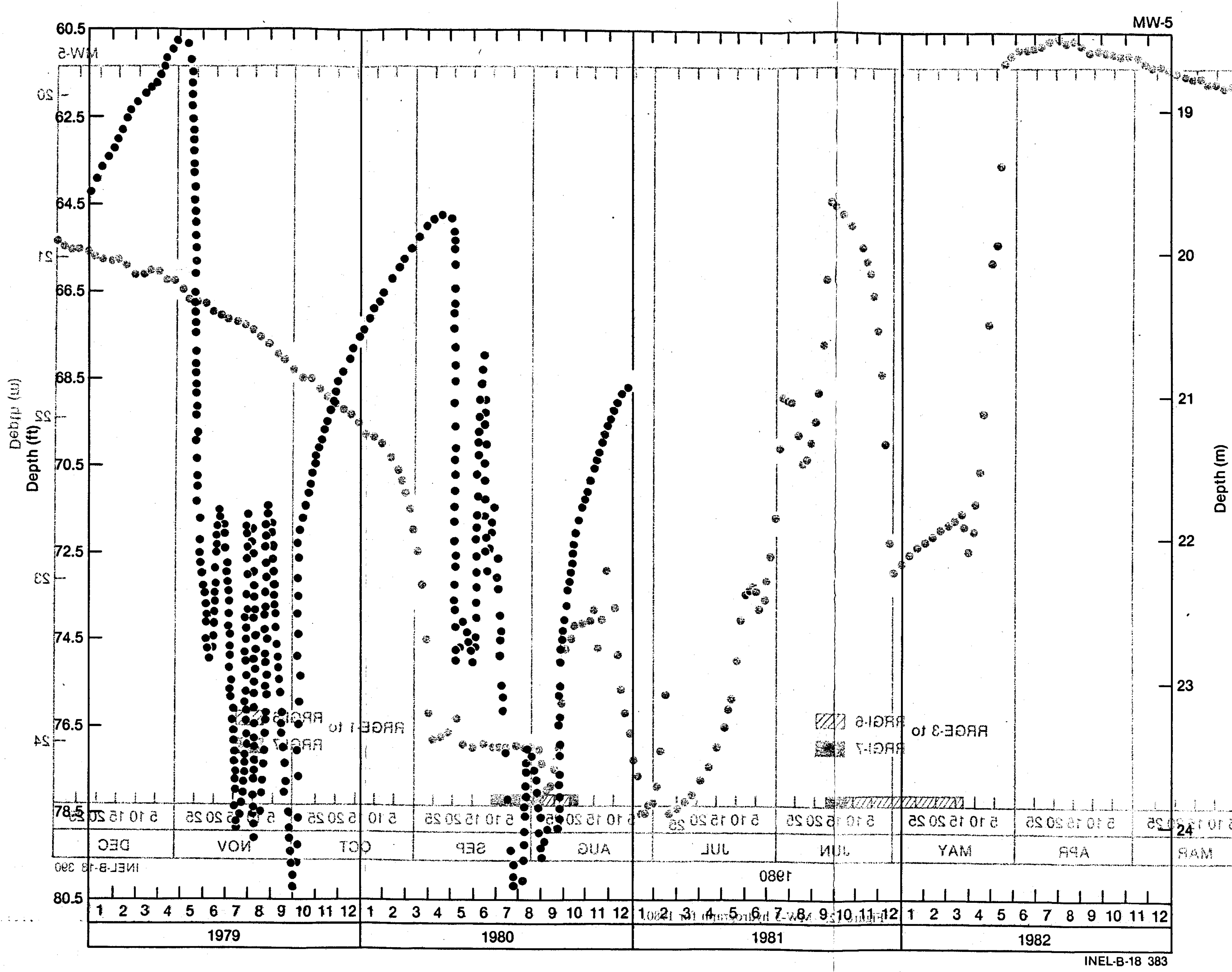

Figure 13. MW-5 long-term hydrograph.

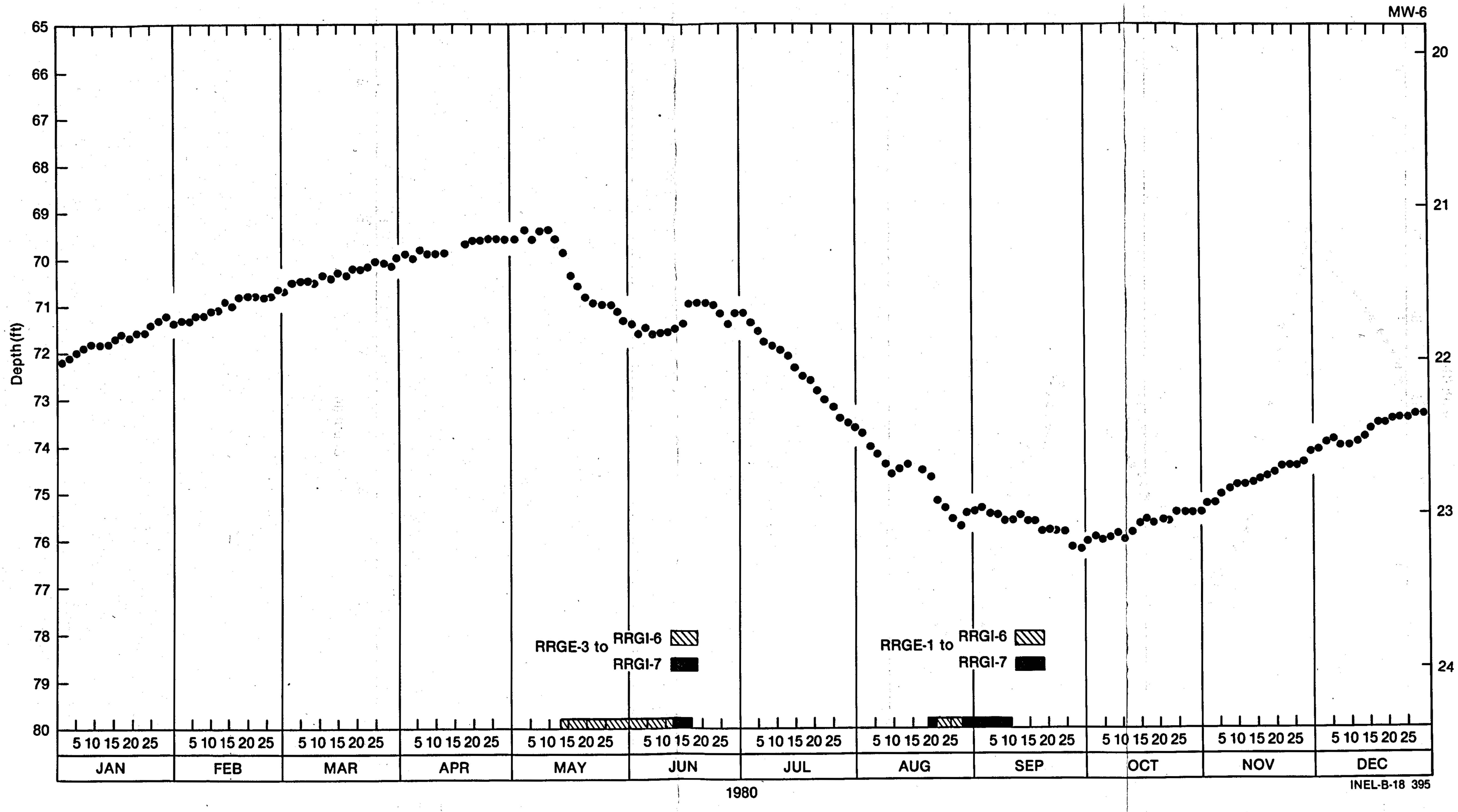

Figure 14. MW-6 hydrograph for 1980.

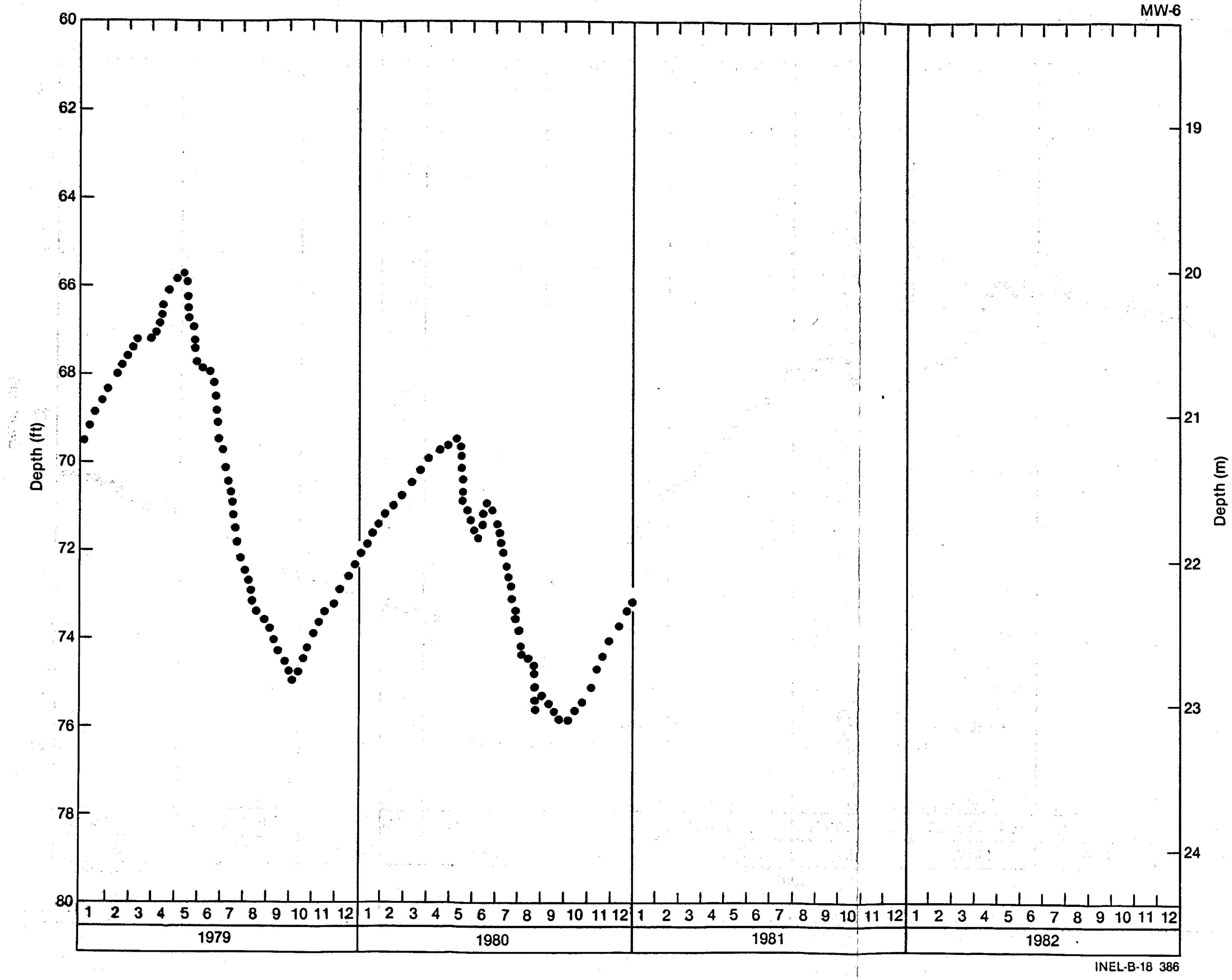

Figure 15. MW-6 long-term hydrograph.

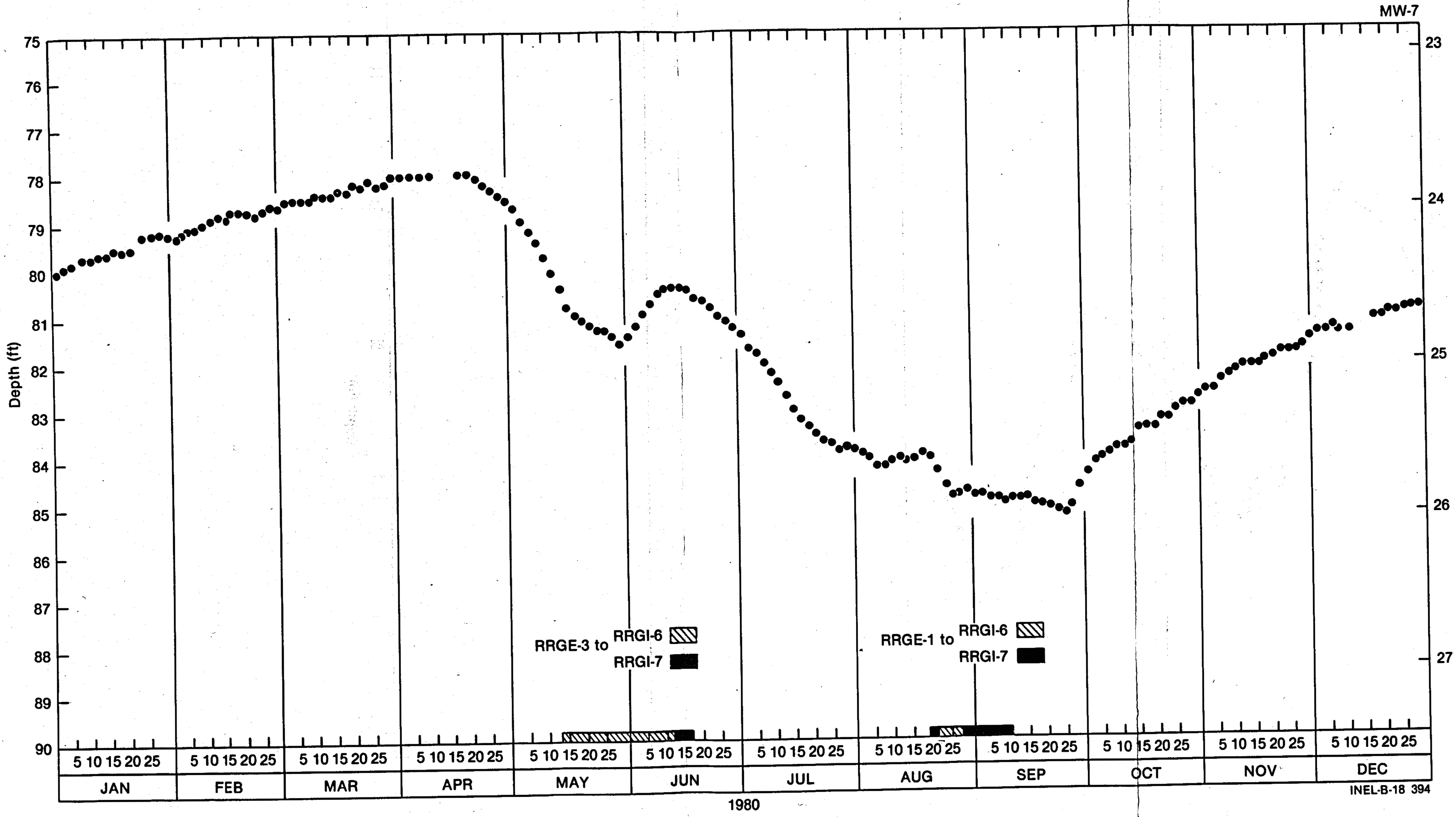

Figure 16. MW-7 hydrograph for 1980.

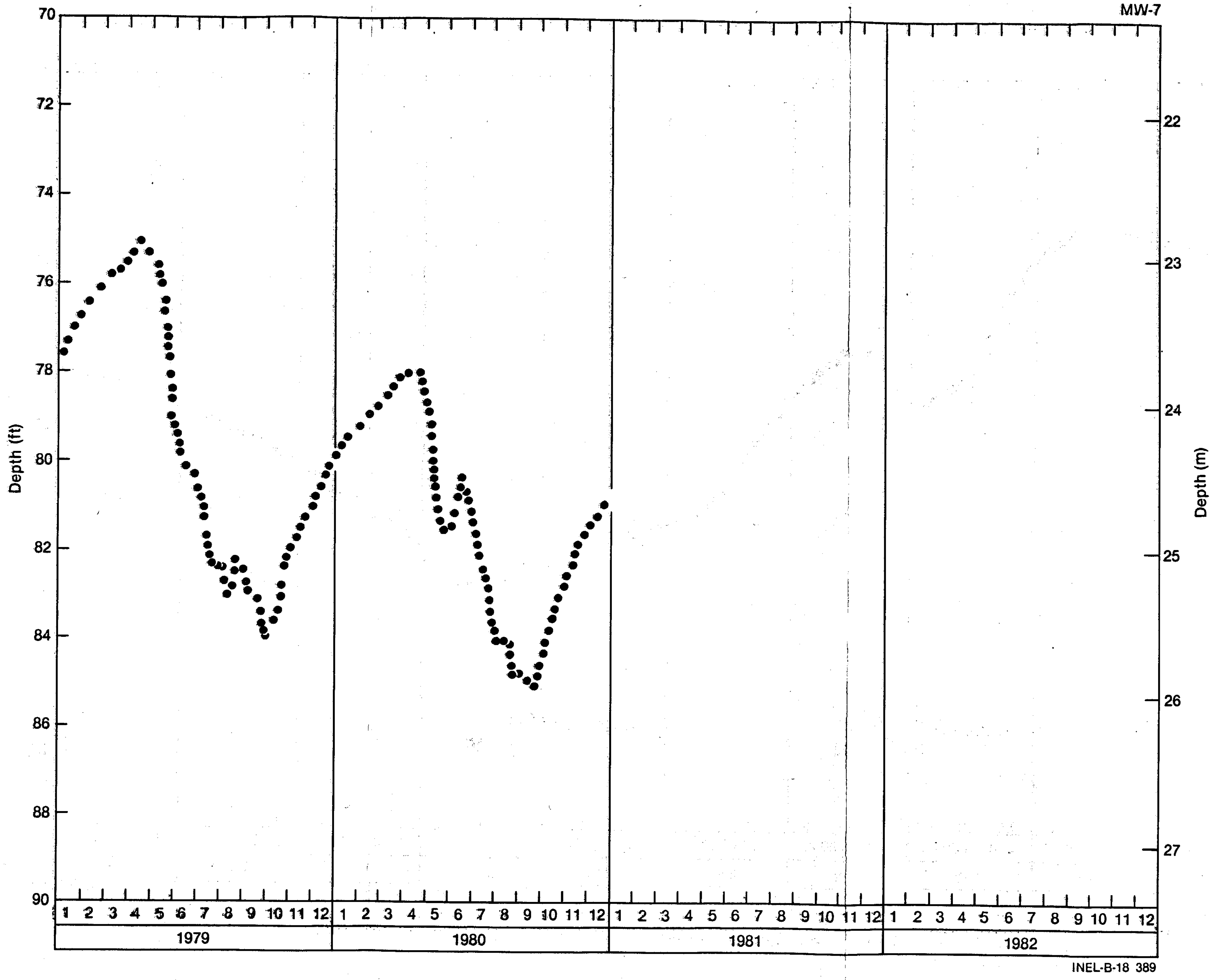

Figure 17. MW-7 long-term hydrograph.

Table 2. Chemical analyses from monitor wells, December 1980

	MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	GLM	Crook
SpC	10,900	6,000	7,600	7,600	2,200	8,600	2,500	3,500	6,200
Temperature	74	56	46	—	25	27	—	94	95
Hardness	530	300	440	380	370	550	250	130	300
Alkalinity	30	35	40	26	100	49	92	40	34
Ca^{2+}	205	130	170	150	125	210	96	53	120
Mg^{2+}	0.35	0.36	2.5	2.7	1.8	1.6	3.5	0.24	0.42
Na^{+}	2,050	1,010	1,250	1,290	230	1,350	260	460	1,030
K^{+}	34	31	33	34	25	51	27	21	33
HCO_3^-	37	43	49	32	120	60	110	49	42
SO_4^{2-}	70	48	48	47	19	71	14	51	48
Cl^-	3,640	1,670	2,330	2,450	600	2,620	620	890	1,820
F^-	2.5	5.1	4.8	4.7	0.6	4.2	0.9	6.7	5.4
SiO_2	112	95	115	95	48	124	50	106	99

All concentrations are in mg/L except for SpC in micromhos and temperature in degrees centigrade. Hardness and alkalinity are in mg/L as $CaCO_3$.

Table 3. Monitor well summary

Well Number	Ground Level Elevation (m)	Ground-Water Level Elevation (m)	Well Depth (m)	Bottom Hole Temperature (°C)	TDS (ppm)
MW-1	1,475	1,506	399	—	6,270
MW-2	1,469	1,481	174	106	5,190
MW-3	1,472	1,457	153	71	4,300
MW-4	1,468	1,466	305	97	4,370
MW-5	1,466	1,445	152	28	1,229
MW-6	1,469	1,447	305	44	4,820
MW-7	1,474	1,450	152	35	1,380