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ORIGINAL REPORT AND ADDENDUM

HYDROGEOLOGIC ASSESSMENT

DETERMINATION OF GROUNDWATER IN STORAGE
WITHIN THE MONTECITO WATER DISTRICT

For

Montecito Water District
1991



RICHARD C. SLADE
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October 18, 1991

Mr. Edward "Bud" Girard
Engineering Manager
Montecito Water District
Post Office Box 5037
Santa Barbara, California 93150

Job S8410-Sa

Dear Mr. Girard:

Presented herein are the following two documents:

- No. 1 Our April 1991, "Hydrogeologic Assessment, Determination of Groundwater in Storage Within the Montecito Water District."
- No. 2 Our October 1991, "Addendum to April 1991 Hydrogeologic Assessment, Determination of Groundwater in Storage in August 1991 Within the Montecito Water District."

The District originally received a draft copy of Report No. 1 for their review in April 1991. In early October, the District requested an updated determination of "current" groundwater in storage based on their August 1991 water level readings, the data from which were recently provided to our office.

This updated determination of groundwater in storage represents Report No. 2 listed above. For the District's convenience, and based on their request, both of these reports have been bound into this single volume.

By comparing usable groundwater in storage between the February/March 1991 and the August 1991 water levels, we conclude there was a total increase in usable groundwater in storage in the District's four storage units of about +960 AF, principally as a result of the March 1991 rains. Most of that rainfall likely was lost from the basin via surface water runoff.

Of the total storage increase in the District, most occurred in Storage Unit No. 1 (80% of the total); an additional 17 percent of the total occurred in Storage Unit No. 3. Storage Unit



No. 2 and Toro Canyon showed little volumetric increase in groundwater in storage during the period of study.

We trust this information meets the needs of the District at this time.

Very truly yours,

A handwritten signature in cursive script, which appears to read "Richard C. Slade", is written over the typed name.

Richard C. Slade
Professional Registered Hydrogeologist

Attachments



RICHARD C. SLADE
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Our Job S8410-S

April 1991



TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION.....	1
GENERAL STATEMENT.....	1
PURPOSE AND SCOPE OF WORK.....	1
PREVIOUS WORK.....	3
WELL CANVASS EFFORT.....	3
FINDINGS	4
MONTECITO GROUNDWATER BASIN.....	4
PRECIPITATION.....	4
WATER LEVELS.....	5
Water Levels.....	5
Hydrographs.....	5
Water Level Contour Maps.....	6
WATER WELLS.....	8
HISTORIC WELL PRODUCTION.....	9
WELL PRODUCTION CAPACITY.....	11
USABLE GROUNDWATER IN STORAGE.....	13
Definitions.....	13
Storage Units and Sediment Thicknesses.....	14
Specific Yield Values.....	18
Quantity of Usable Groundwater in Storage.....	19
EXTRACTIONS VS. SAFE YIELD.....	22
CONCLUSIONS AND RECOMMENDATIONS.....	24
REFERENCES.....	29
FIGURES	
Figure 1	Rainfall at MWD Office Gauge
Figure 2	Hydrographs - Storage Unit No. 1
Figure 3	Hydrographs - Storage Unit No. 2
Figure 4	Hydrographs - Storage Unit No. 2
Figure 5	Hydrographs - Toro Canyon Storage Unit
Figure 6	Total MWD Groundwater Production, 1947-1990
Figure 7	MWD Groundwater Production by Storage Unit, 1972-1990
Figure 8	Total Private Groundwater Production, 1980-1990
Figure 9	MWD and Private Groundwater Production by Storage Unit, 1980-1990
Figure 10	Total MWD and Private Groundwater Production, 1980-1990



TABLES

Table 1	Estimated Production Capacity of District Wells
Table 2	Calculations for Usable Groundwater in Storage
Table 3	Summary of Usable Groundwater in Storage
Table 4	Comparison of Groundwater in Storage from Previous Studies

PLATES

Plate 1	Storage Units Within Montecito Groundwater Basin
Plate 2	Map of Storage Subunits for Storage Calculations
Plate 3	Water Level Elevation Contours - Spring 1983
Plate 4	Water Level Elevation Contours - February/March 1991

APPENDIX - Individual Water Level Hydrographs



INTRODUCTION

GENERAL STATEMENT

This report presents the results of our hydrogeologic assessment of the service area of the Montecito Water District in order to determine the usable volume of groundwater in storage. This service area is underlain by three main storage units in the Montecito Groundwater Basin (known as Storage Unit Nos. 1, 2, and 3) and one additional storage unit (the Toro Canyon Storage Unit) which lies in the Carpinteria Groundwater Basin.

Utilization of the groundwater resources in the Montecito Groundwater Basin is affected by customer demand and by availability of water from other sources. Thus, long-term management of the basin must take these and other factors into account.

As a result of the recent five-year drought, the Montecito Water District (MWD) has been investigating other non-groundwater sources to meet their current and proposed water demands. Because the potential new sources are considerably more costly than traditional sources, it is important to have a detailed and well documented assessment of the storage capabilities of the groundwater basin. Such an assessment may minimize the need for large expenditures for imported water from non-traditional sources.

PURPOSE AND SCOPE OF WORK

This study was conducted for the primary purpose of determining the amount of usable groundwater in storage in the four storage units of the Montecito Groundwater Basin for the historic high and low groundwater periods and for current drought-related conditions. This information will be utilized



to evaluate the ability of the basin, in drought conditions, to yield water at various production rates considered in several water supply options proposed by MWD.

In order to make these types of assessments, numerous aspects of the basin were studied including: geology, basin boundaries, precipitation, water well construction data, water levels in wells, extraction data, and water quality. The scope of work included the following tasks:

- Review available geologic and hydrogeologic studies in order to verify groundwater basin and storage unit boundaries.
- Review water level data; prepare groundwater elevation contour maps for historic high, low, and current water level conditions; prepare water level hydrographs for representative wells throughout the basin.
- Review water quality data as they pertain to usable basin depths, that is, to the maximum depth of usable quality in each storage unit.
- Review well drilling and construction data for such information as formation materials, total well depths, and casing perforation depths.
- Review well production data for MWD wells and private pumpers, and plot data graphically.
- Define and determine usable groundwater in storage in the Montecito Basin, including maximum and current amounts of usable groundwater in storage.
- Prepare this report presenting the findings, conclusions, and recommendations.
- Attend meetings with you, your staff, and the Board of Directors to discuss the project and collect data, and to present and discuss the findings, conclusions and recommendations.



PREVIOUS WORK

For the Montecito Basin, maximum groundwater in storage, or groundwater storage capacity, was calculated previously in studies by Muir (1968), Geotechnical Consultants, Inc. (GTC, 1974), and Hoover and Associates (1980). These studies presented greatly differing volumes of groundwater storage capacity ranging from approximately 9000 acre feet (AF) to about 120,000 AF for the Montecito Groundwater Basin, not including the Toro Canyon Subunit of the Carpenteria Basin which also underlies the MWD service area. This wide range of storage values resulted from significant variations in previous determinations of the surface area, vertical depth, and specific yield of the basin and its sediments, as well as differences in the definitions of groundwater storage capacity as used by the previous investigators.

WELL CANVASS EFFORT

Starting in late 1990, MWD personnel began to collect data on private wells in the basin for the purpose of expanding the District's Groundwater Monitoring Program. This program was invaluable in providing an increased level of information on the status of the groundwater basin. Toward this end, MWD staff acquired data from well permit files of the Santa Barbara County Environmental Health Department. From these files, information such as well permit applications, field reports, and drillers' logs was obtained. Specific wells to be monitored by MWD were selected with the intention of getting a widespread distribution of wells with known construction data (such as depth and casing perforation intervals).

District staff then contacted well owners to determine which were willing to participate in the monitoring program



and to arrange an initial site visit. At the initial site visit, access for sounding the water level was determined. If accessible, a measuring reference point (the access point) was established, depth to water from that point was measured, and the elevation of that point was surveyed. District staff then updated the groundwater elevation spreadsheet, prepared a well location map showing the current water level elevations (for February and early March 1991) and provided these and other materials to this investigation.

FINDINGS

MONTECITO GROUNDWATER BASIN

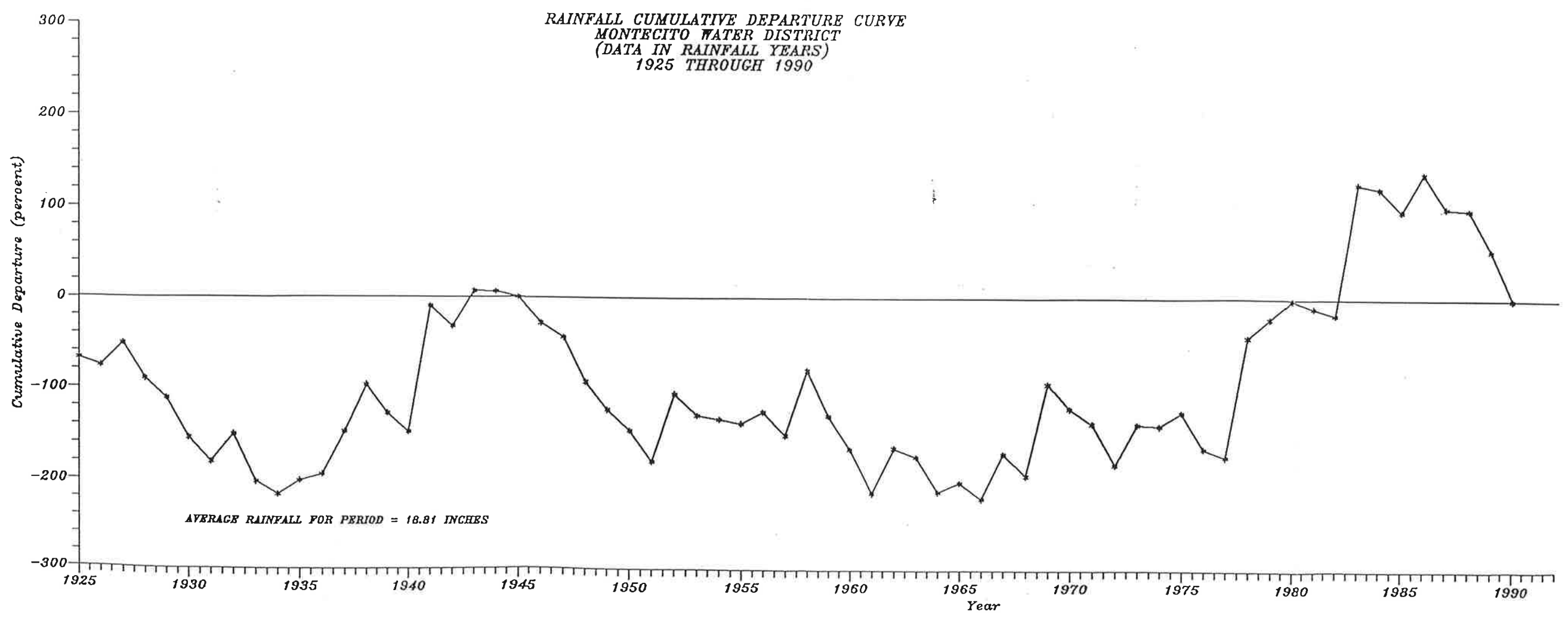
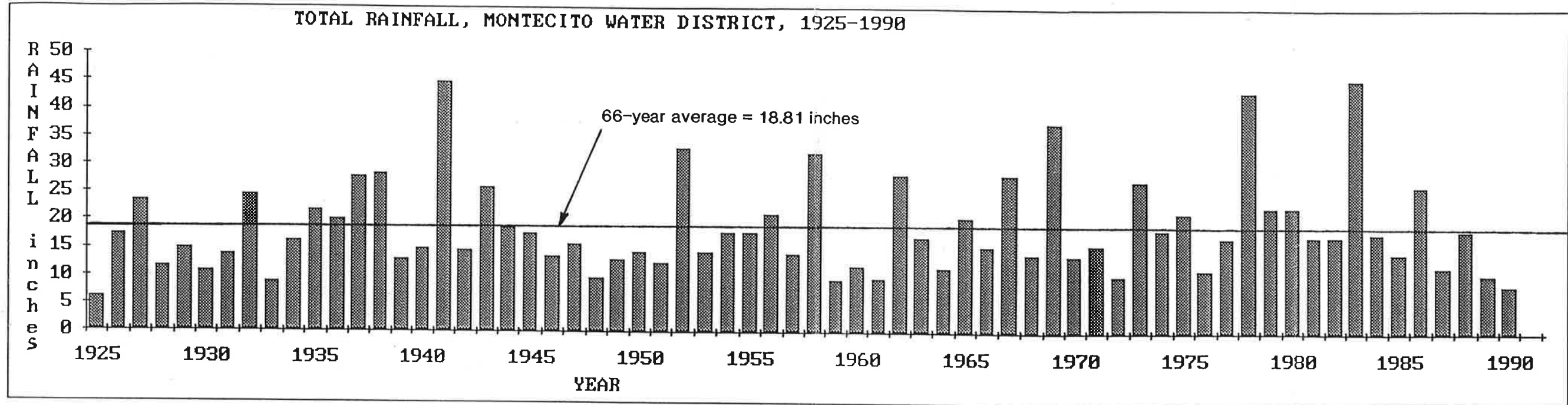
For the purposes of this study, basin boundaries defined by previous investigations and those in use by MWD were reviewed. Based upon our study of recent water level and water quality data and of more recent geologic mapping by others, we have modified the basin and storage unit boundaries as necessary to represent our interpretation of more recent data and to rectify incorrectly adapted bedrock boundaries shown on the existing MWD map base. Plate 1 - Storage Units Within Montecito Groundwater Basin - has been prepared to show the basin and storage unit boundaries defined for this study. It is recommended that these boundaries be utilized in future MWD plots of well locations, water levels, etc.

PRECIPITATION

Rainfall data for the MWD office gauge were available for the period 1924-25 to 1989-90. By rainfall year, these data are plotted on Figure 1 - Rainfall at MWD Office Gauge. For the 66-year period of record, the average rainfall is 18.81 inches.

Figure 1.

RAINFALL AT MONTECITO WATER DISTRICT OFFICE GAGE





As shown on the Figure 1 graph of total rainfall, 67 percent of the years had below average amounts of rainfall. Although there were fewer above-average rainfall years, many of those above-average years had considerably above-average rainfall (up to 45.72 inches) which tended to raise the overall average.

The rainfall cumulative departure curve on Figure 1 also reflects the fact that most years had below average rainfall and that their accumulated departures from the normal rainfall are predominantly negative. Each data point on the cumulative departure curve represents the arithmetic sum of percent departures from the average for that year and all previous years in the given period of record. The cumulative departure curve is useful to show trends in periods of deficient rainfall and periods of above average rainfall.

On the cumulative departure curve, periods of excess (above average) precipitation are shown as a sloping upward trend to the curve (more positive) with time, while periods of deficient (below average) rainfall are seen as a sloping downward (more negative) trend to the curve with time. General trends shown on the cumulative departure curve are as follows:

1927 to 1934	below average precipitation;
1935 to 1944	above average;
1945 to 1966	below average;
1967 to 1986	above average; and
1987 to 1990	below average.

WATER LEVELS

Water Levels. Water level elevation data plotted herein on hydrographs and contour maps came from MWD records and spreadsheets, and from U. S. Geological Survey records acquired for this study. There were numerous instances where MWD and USGS data existed for the same well at the same time,



but these elevation data did not agree. The differences appeared to be due to the reported reference point elevations and whether these reference points were at land surface or top of casing, and whether the reference datum appeared to have been surveyed or just estimated. Where these discrepancies occurred, the data selected was that from the source whose data implied that a reference elevation survey might have been done.

Hydrographs. For this investigation, hydrographs were prepared for twenty-three wells to provide graphic representation of static (non-pumping) water levels over time for a widespread selection of wells throughout the basin. Of these hydrographs, seven are for Storage Unit (SU) No. 1, four are for Storage Unit No. 2, nine are for Storage Unit No. 3, two are for the Toro Canyon Storage Unit, and one is for a well within the Carpinteria County Water District adjacent to Toro Canyon. Historic water level data are particularly meager in Storage Unit No. 2 and Toro Canyon where MWD previously had not operated any wells. For ease of comparison, the hydrographs have been reduced photographically and placed together on Figures 2, 3, 4, and 5. Individual full-size hydrographs are included in the Appendix section of this report.

With a very few minor exceptions, the hydrographs show that the highest recorded water levels occurred in wells throughout the basin in 1983. For the majority of the hydrographed wells, water levels were higher in spring than in fall of that year, especially in Storage Unit No. 1 where water levels are seen to respond more directly and rapidly to winter and spring precipitation events.

Water level data prior to 1962 are especially meager for the basin, but suggest that 1943-44 and 1959-60 were also high groundwater levels. Muir (1968) indicated that in 1959,

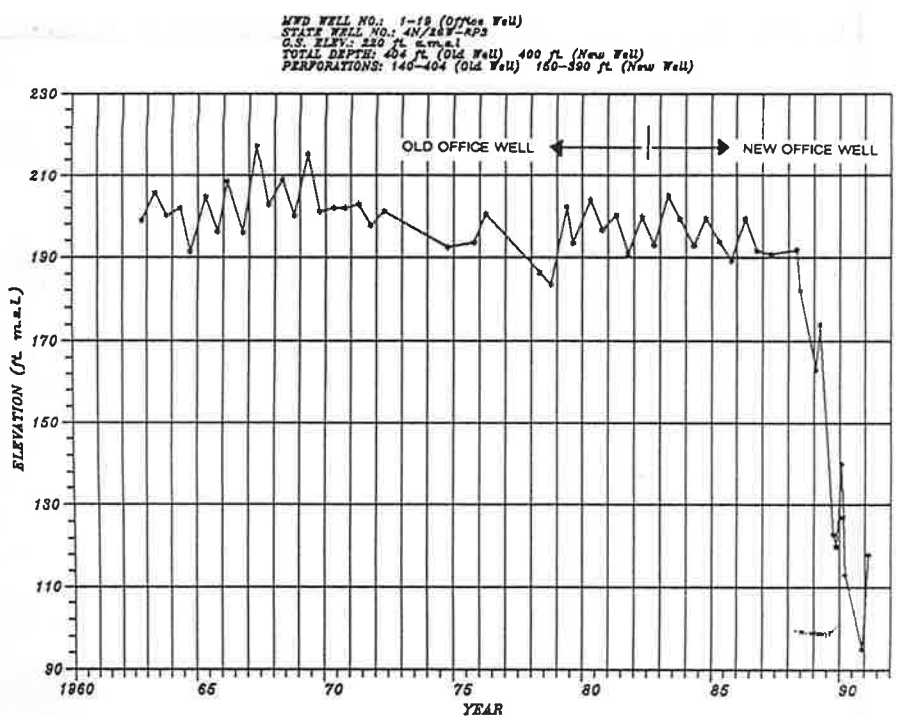
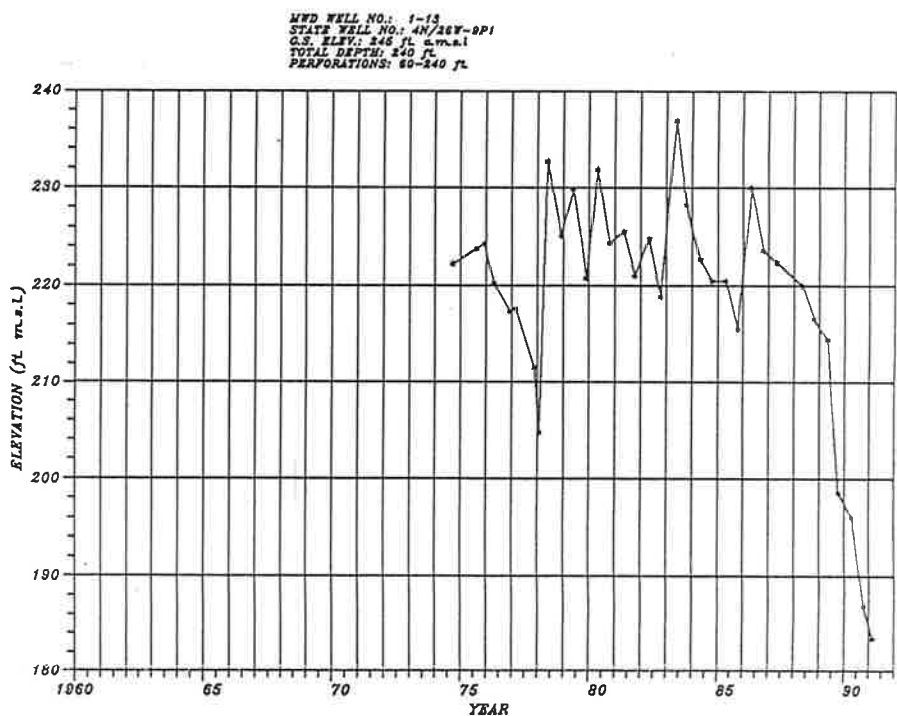
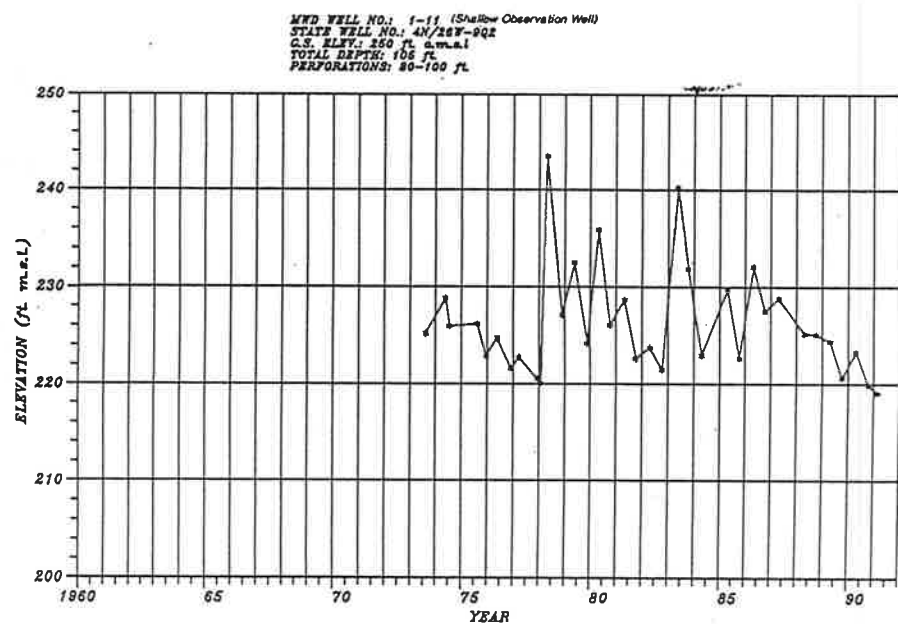
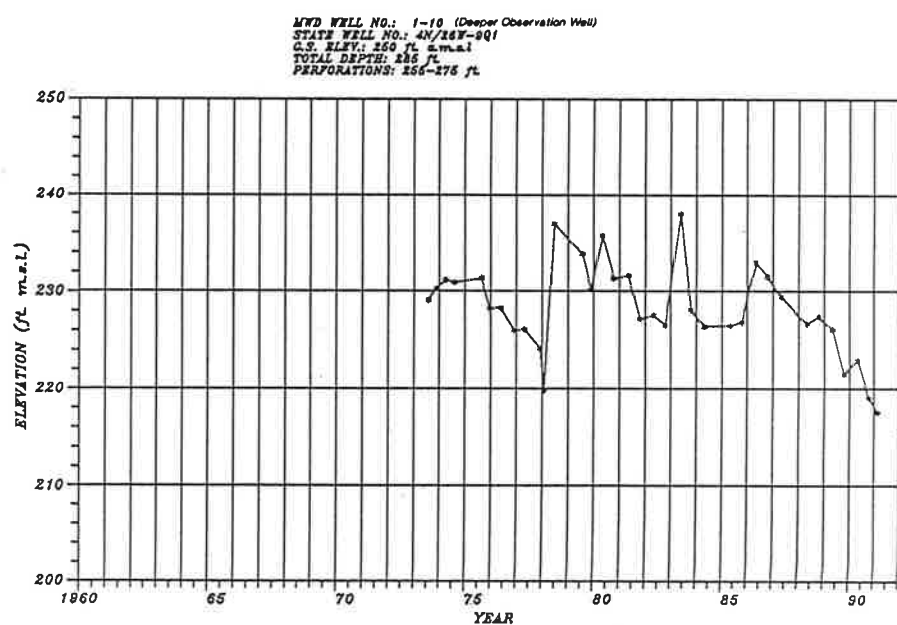
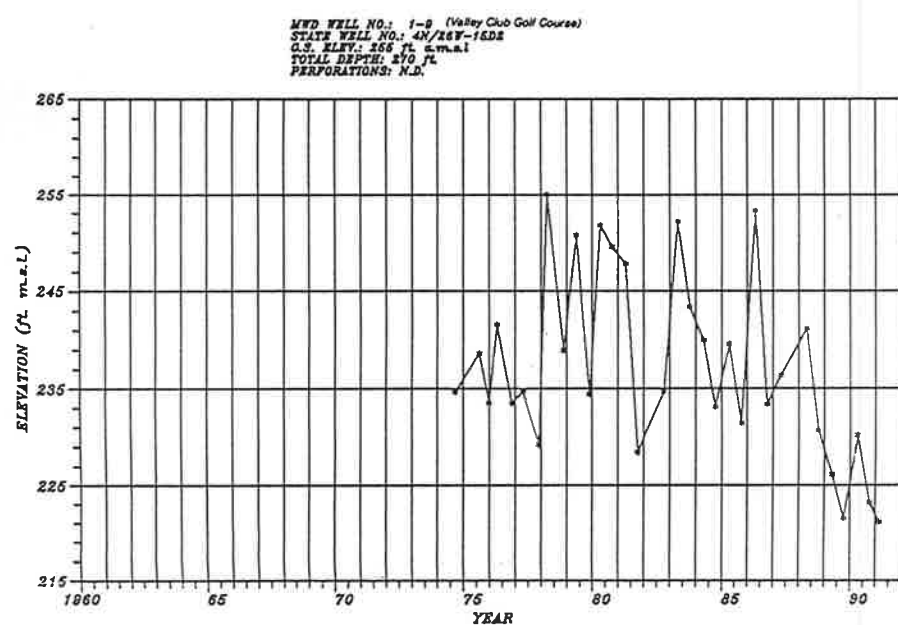
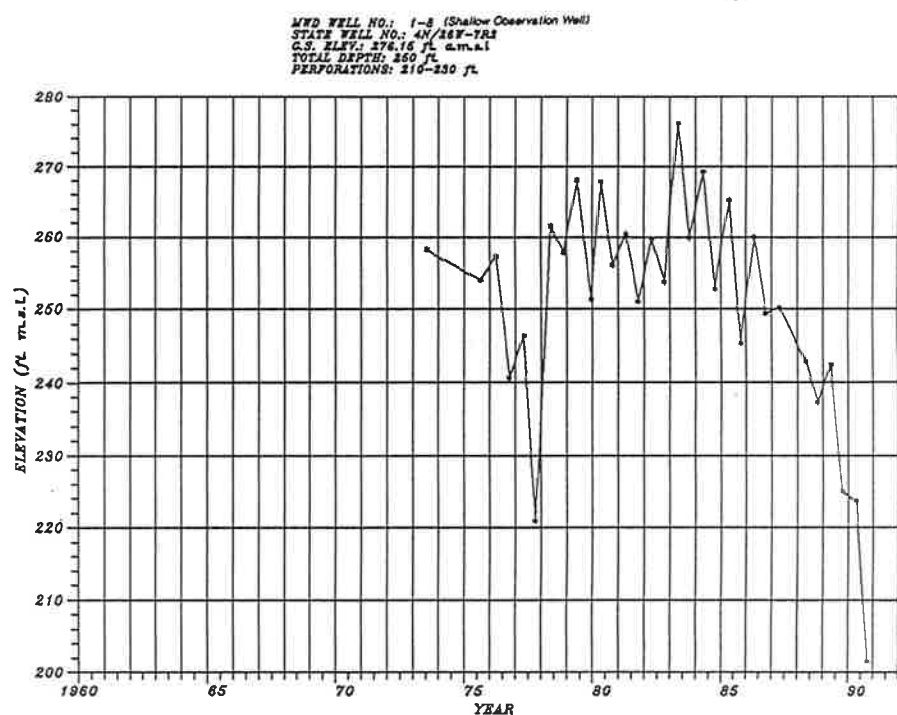
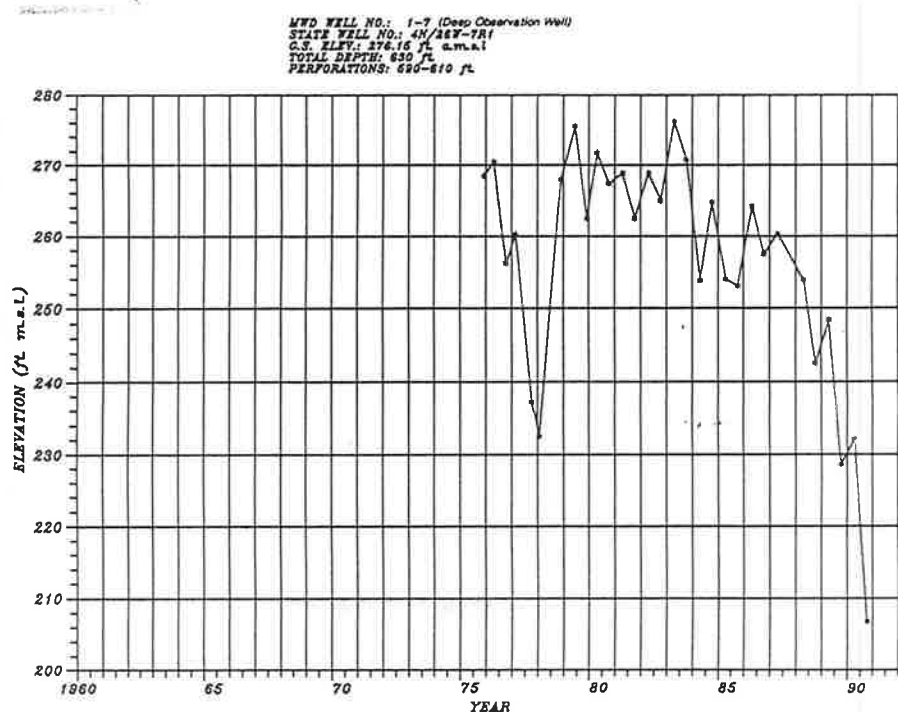


Figure 2 - HYDROGRAPHS
Storage Unit No. 1

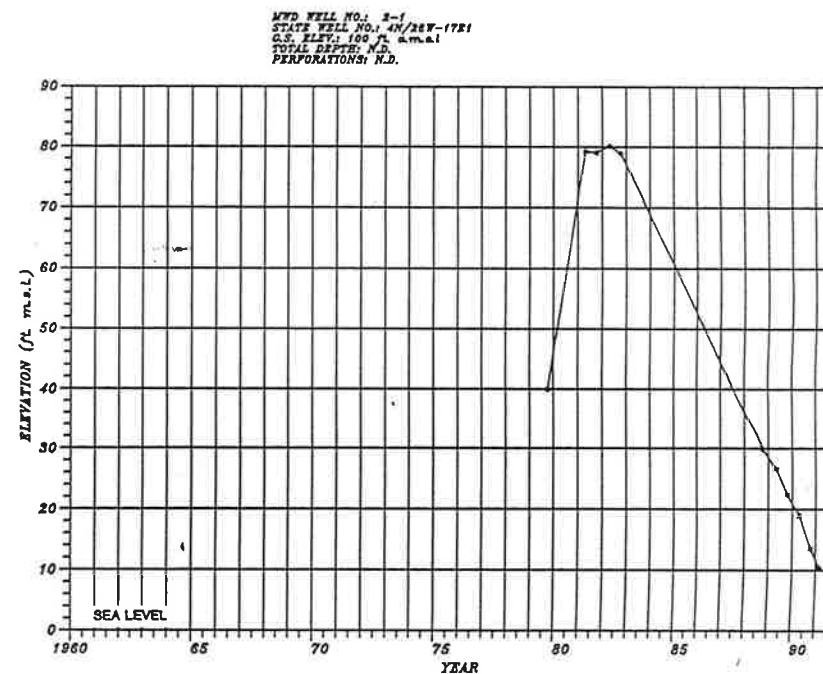
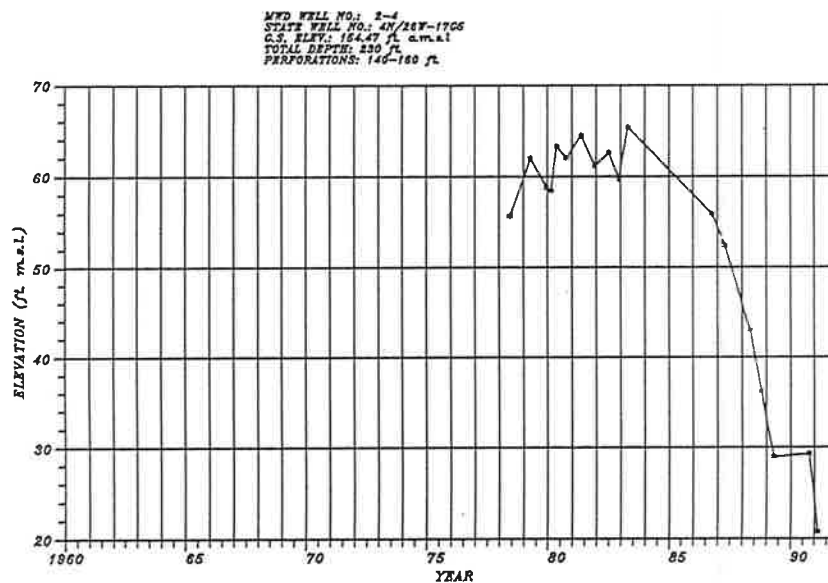
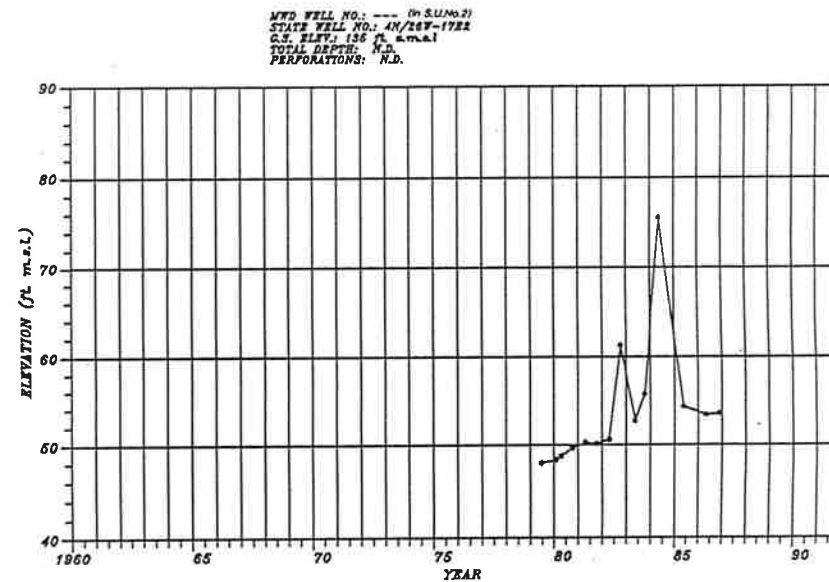
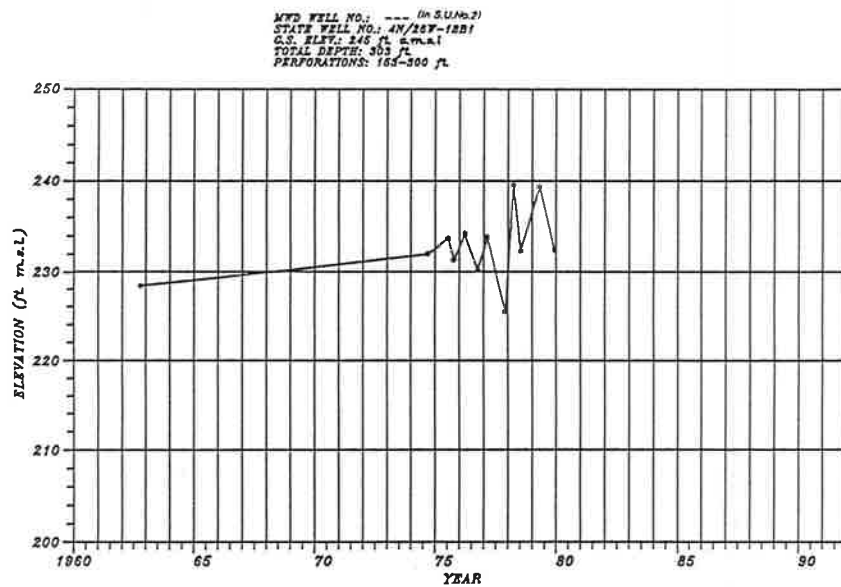


Figure 3 - HYDROGRAPHS
Storage Unit No. 2

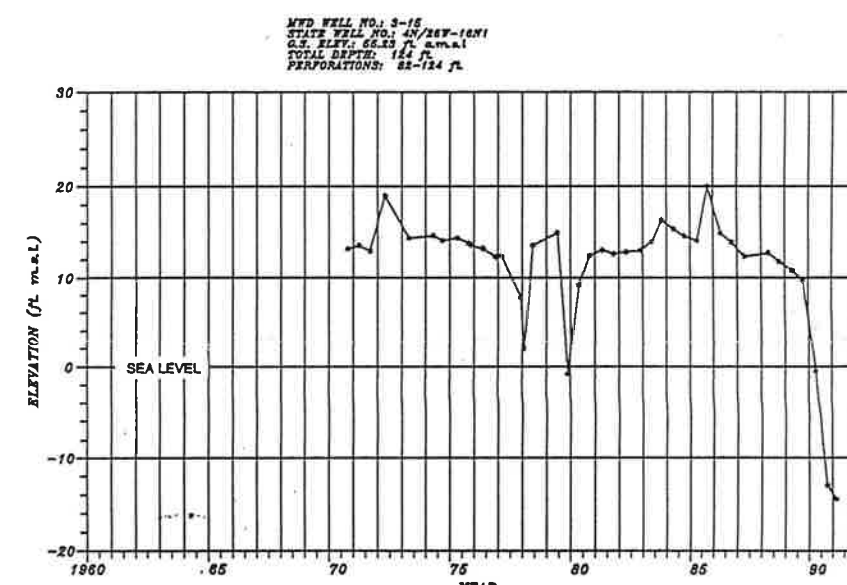
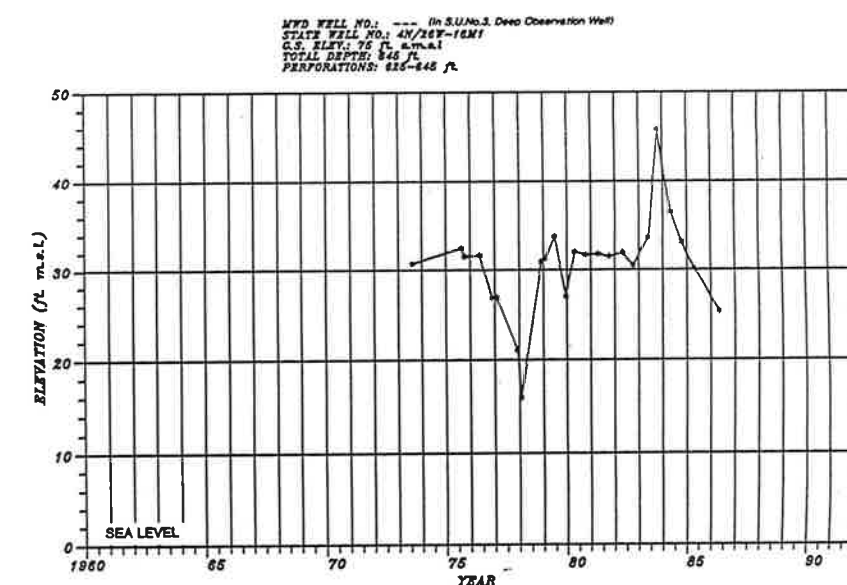
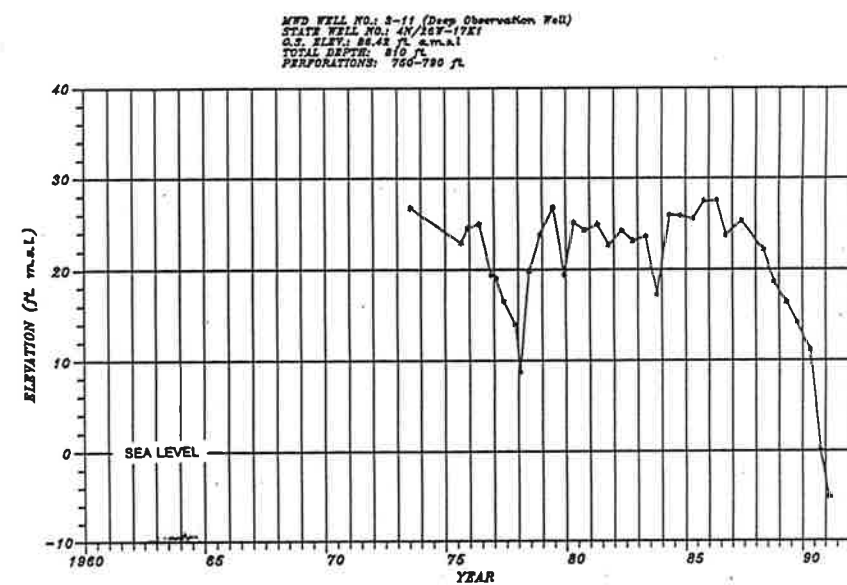
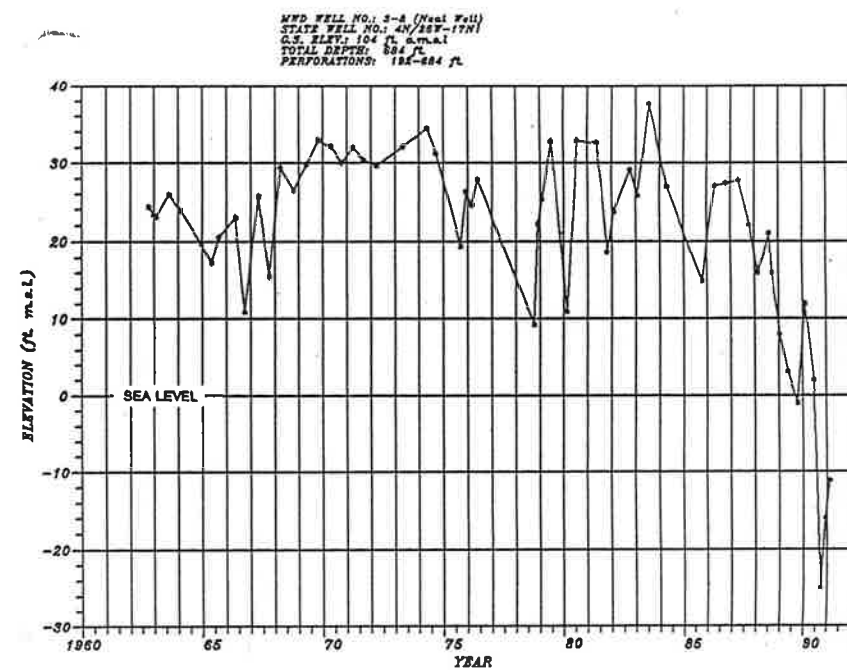
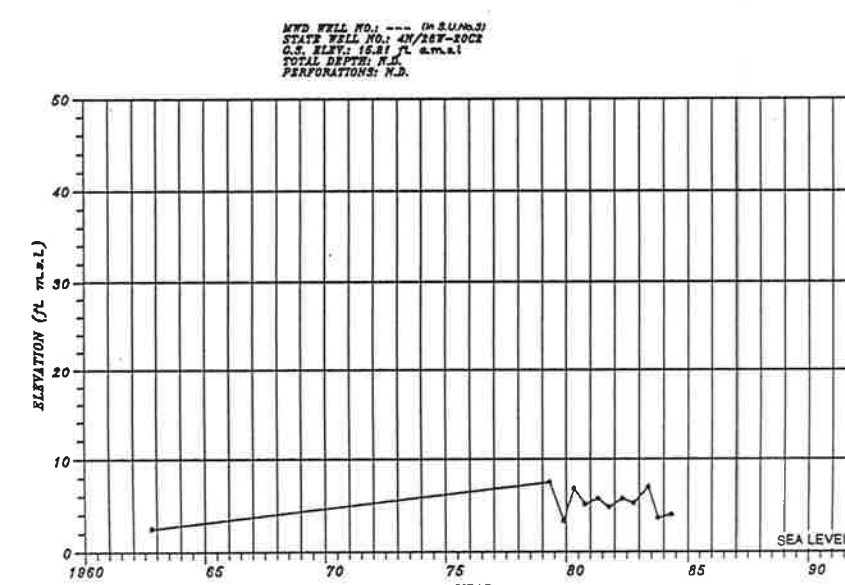
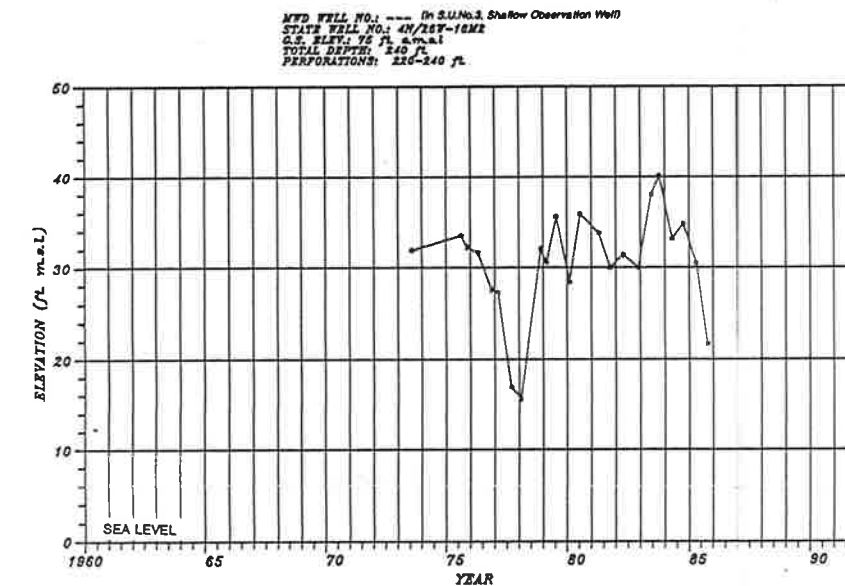
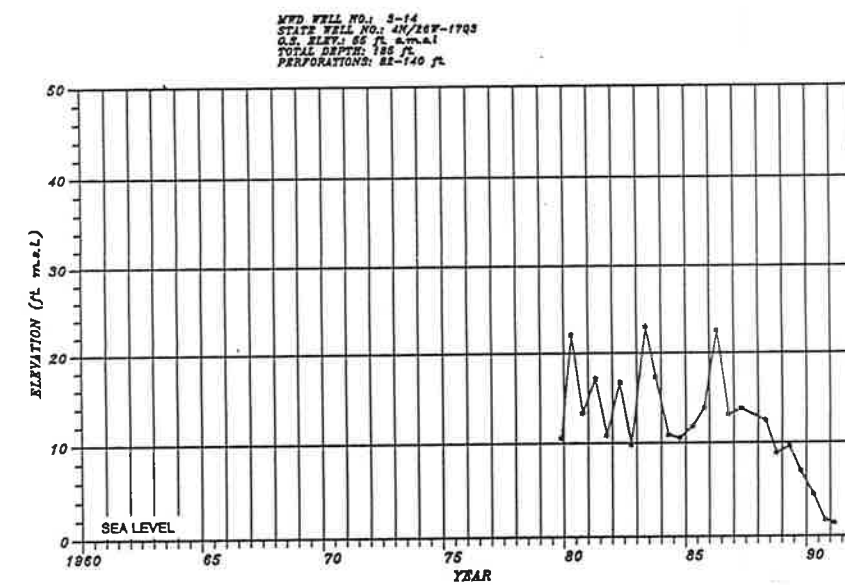
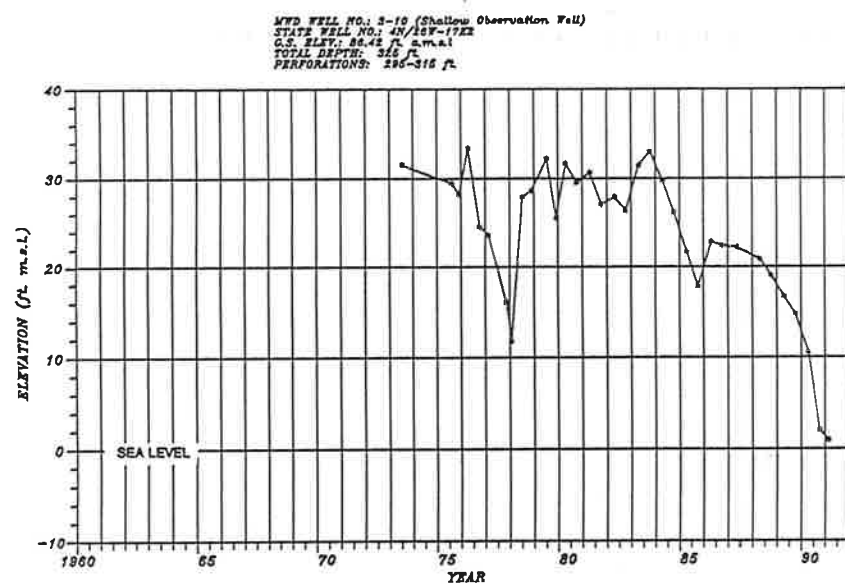
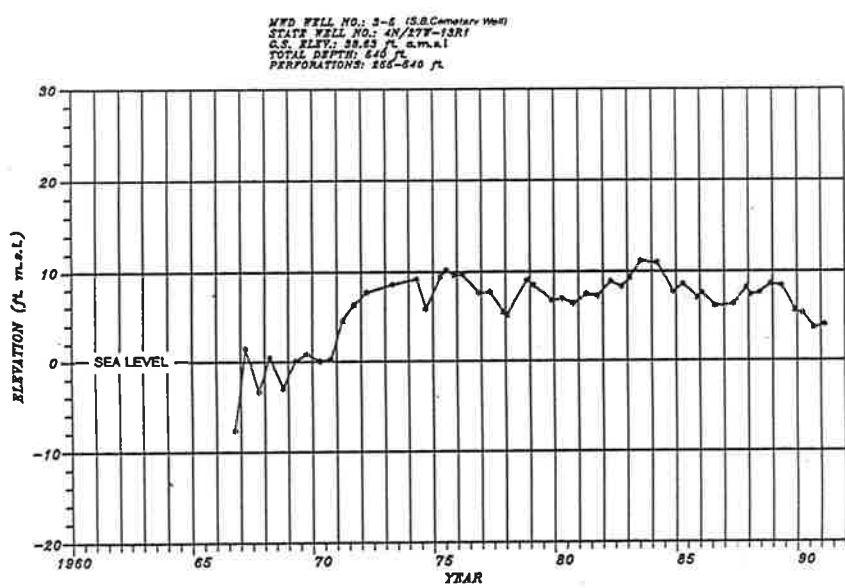
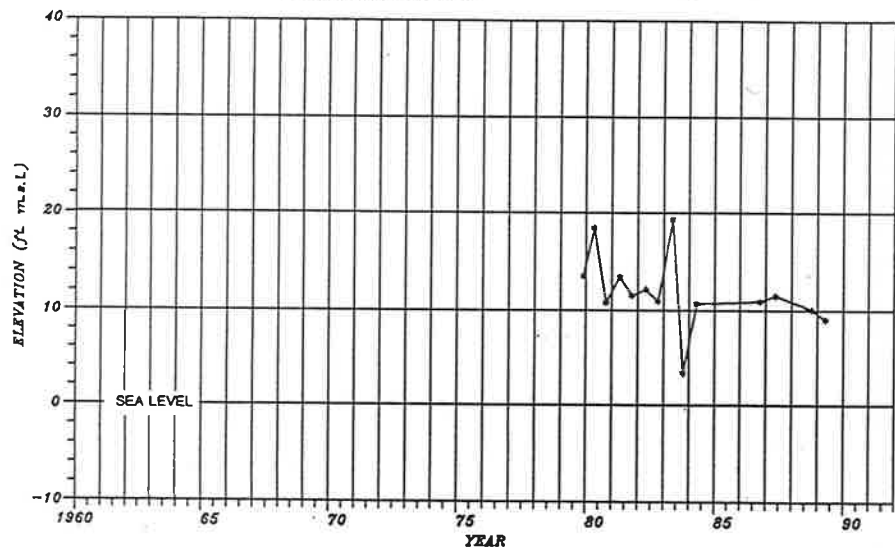


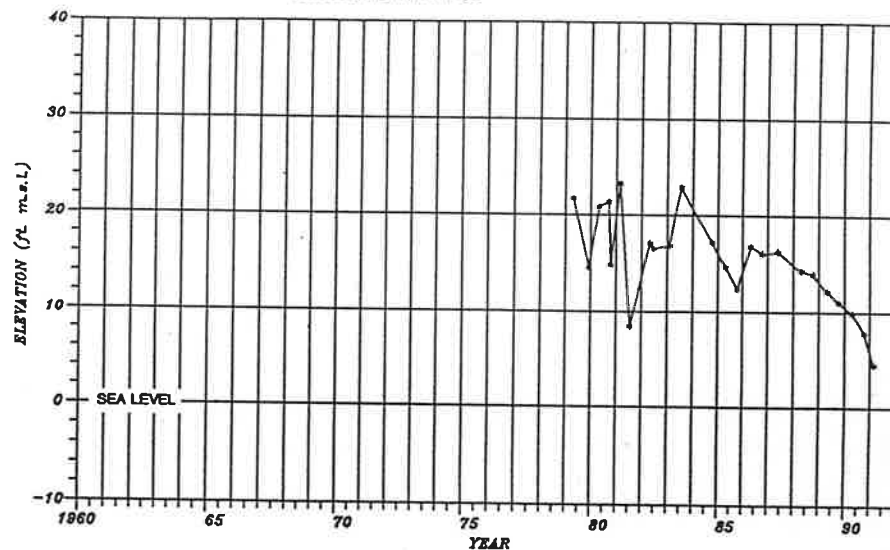
Figure 4 - HYDROGRAPHS

Storage Unit No. 3

MWD WELL NO.: 4-1
 STATE WELL NO.: 4N/26W-2563
 G.S. ELEV.: 39.18 ft a.m.s.l.
 TOTAL DEPTH: 200 ft
 PERFORATIONS: 140-200 ft



MWD WELL NO.: 4-2 (Edgewood No. 2)
 STATE WELL NO.: 4N/26W-2378
 G.S. ELEV.: 45.14 ft a.m.s.l.
 TOTAL DEPTH: 400 ft
 PERFORATIONS: 136-170 ft



MWD WELL NO.: — (CCWD - Zangor Well)
 STATE WELL NO.: 4N/26W-2312
 G.S. ELEV.: 63 ft a.m.s.l.
 TOTAL DEPTH: N.D.
 PERFORATIONS: N.D.

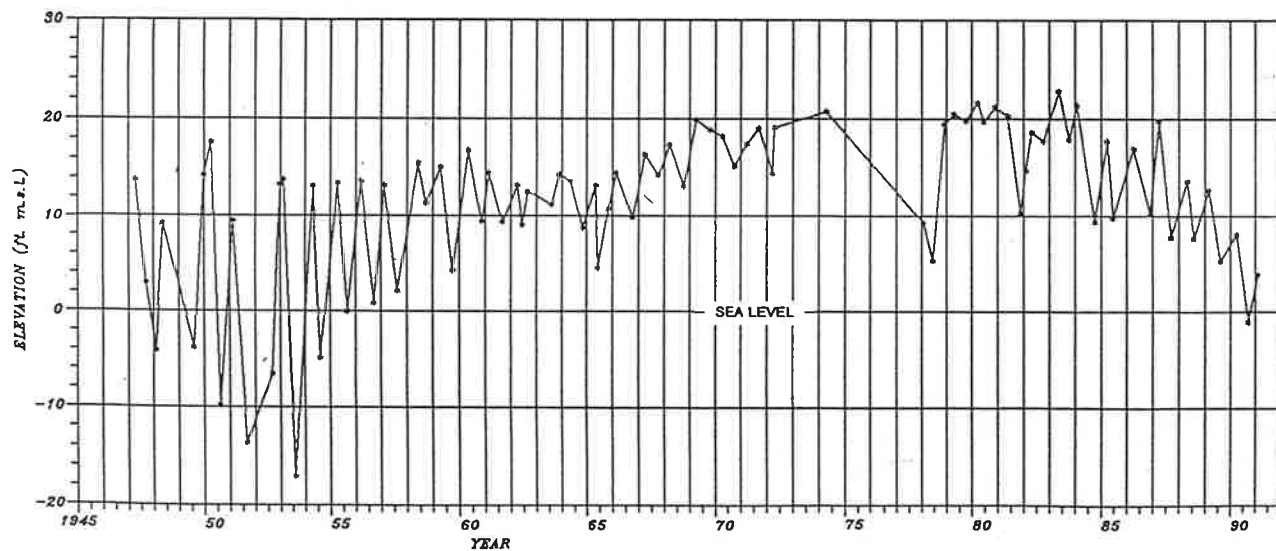


Figure 5 - HYDROGRAPHS
 Toro Canyon Storage Unit

the groundwater basin(s) were "full." In general, Spring 1983 water levels in Montecito Basin were slightly higher than those in 1959.

Virtually all the hydrographs with data up through 1990 or early 1991 show that this present time period represents, by far, the lowest water levels in recorded basin history. Thus, for the purposes of this study, February and early March 1991 water levels are considered to represent both the historic low water levels as well as the current water level conditions for the four storage units of Montecito Basin.

Water level records for MWD wells indicate that static water levels typically are not fully recovered in the two(consecutive) days per week that most of their wells are shut off. As suggested by 1990 and 1991 static water level fluctuations (e.g., Office Well and Neal Well hydrographs), water level recovery in two days is especially incomplete under current low water level conditions. Although not fully shown on the hydrographs, water level records indicate that the two-day recovery levels are approximately 20 to 40 ft below full recovery for the Office Well and about 4 to 12 ft below full recovery for the Neal Well. Under current conditions, these wells appear to require three to seven days to as much as two weeks for complete water level recovery. Such occurrences strongly suggest that the deeper sediments in the basin are much less permeable and transmissive than the shallower and, hence, younger sediments.

Water Level Contour Maps. Water level contour maps were prepared to show groundwater elevations in the basin for the historic high water level period and the current, historic low water level period. Plate 3 - Water Level Elevation Contours, Spring 1983 - displays the historic high groundwater



elevations, and Plate 4 - Water Level Elevation Contours, February/March 1991 - shows the current, historic low groundwater conditions.

As a result of the recent MWD well canvass and the expansion of their groundwater monitoring program, Plate 4 contains considerably more water level data points from which to generate contour lines than does Plate 3. Because of this, many Plate 3 contours were estimated very generally to be able to provide high water level input into the calculations for maximum groundwater in storage, especially in some areas of Storage Unit No. 1. A few water level data points on Plates 3 and 4 were estimated in cases where exact measurement data levels were not available but enough previous and/or later data exist to make a reasonable estimate.

In Storage Unit No. 1, Spring 1983 average maximum levels typically were 30 to 70 ft higher than in February/March 1991. In Storage Unit No. 2, maximum water levels typically were 20 to 45 ft higher than current minimum levels. Storage Unit No. 3 average water levels ranged from 2 to 35 ft higher in Spring 1983 than are revealed by current Plate 4 data. Average water levels in the Toro Canyon Storage Unit ranged from 10 to 30 ft higher in Spring 1983 than for current low level conditions.

WATER WELLS

MWD well locations are shown on Plates 1 and 2. All currently active MWD wells are located in either Storage Unit No. 1 or Storage Unit No. 3. Table 1 lists some pertinent construction and activity data for the active MWD wells including depth interval of casing perforations, current pump setting depth, February 1991 static water levels, February



1991 pumping levels and pumping rates, and estimates of production capacity.

As shown on Plates 3 and 4, private wells are found in all four storage units. Those private wells shown do not represent all the existing private wells in the basin, only the ones included in the MWD Groundwater Monitoring Program to date. Construction data for private wells is limited with available records primarily coming from Santa Barbara County Environmental Health Department files. Records of production data for private wells are virtually nonexistent.

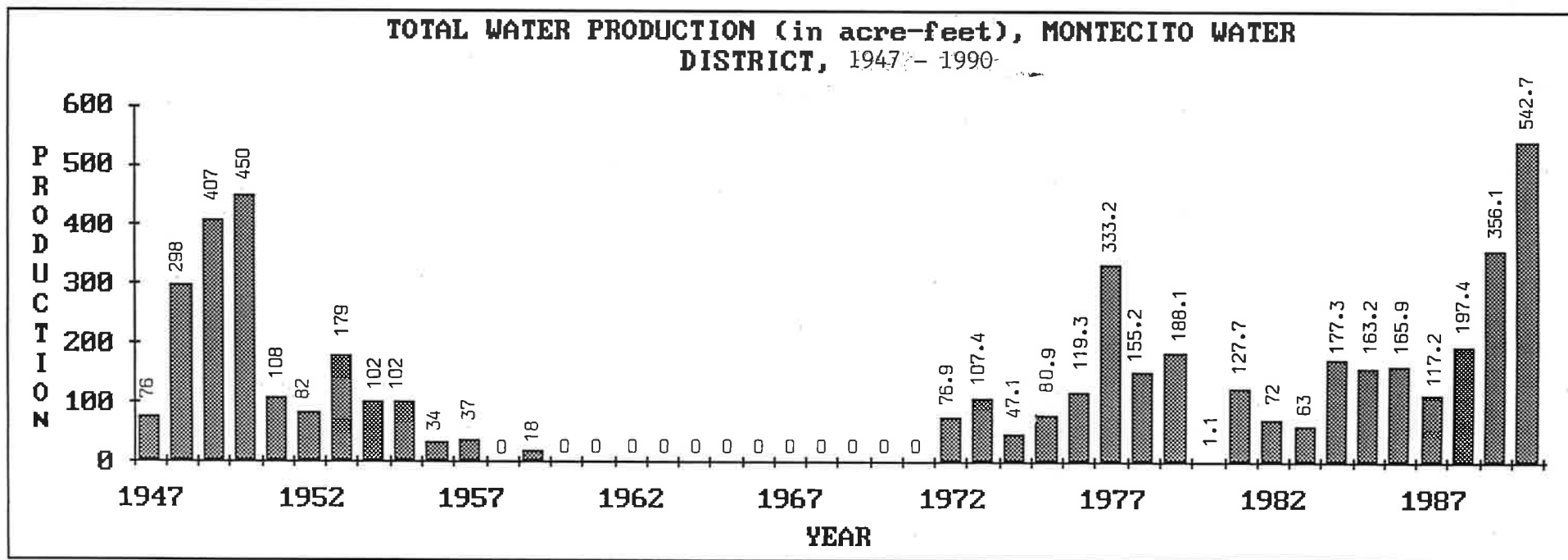
HISTORIC WELL PRODUCTION

Groundwater production data for MWD reportedly date back to 1947. Total historic groundwater production by MWD is shown on Figure 6 - Total MWD Groundwater Production, 1947-1990. This figure contains data recently obtained from MWD for 1972 to present and data from Muir (1968) and our files for the period before 1972. MWD pumpage before 1960 shown on Figure 6 differs slightly from that contained in the 1980 report by Hoover which, by contrast, displays no MWD production for 1947, 1954, and 1959 and has different production volumes for some years.

Per data shown on Figure 6, yearly MWD groundwater production ranged from zero throughout the 1960s to the historic high in 1990. During the recent drought years, MWD production has increased steadily from 117.2 AF in 1987 to 542.7 AF in 1990 for all their active wells in the entire basin.

For the period 1947 through 1990, total groundwater extractions by MWD from all storage units in the District have been 4985 AF; this represents an average of 113 AF/yr for this 44-year period.

Figure 6
TOTAL MWD GROUNDWATER PRODUCTION, 1947-1990





From the 1972 to 1990 production data provided by MWD, Figure 7 - MWD Groundwater Production by Storage Unit, 1972-1990 - was prepared to graphically show District production by storage unit. As shown, there has been no historical MWD production from Storage Unit No. 2 or from the Toro Canyon storage unit. Most of the production each year was from Storage Unit No. 1 with the exception of 1990, at which time the majority of MWD production came from Storage Unit No. 3. Average annual District groundwater extraction has been 163 AF/yr for this 1972-1990 period. For later comparison with private production data, the average annual MWD extraction for 1980 through 1990 has been 180 AF/yr.

Private pumpage in the basin was computed by Hoover (1980) for the years 1929, 1954, 1962, and 1979, with private pumpage interpolated for the intervening years. In that study, private groundwater production was calculated to be approximately 1658 AF in 1929, 1322 AF in 1954, 872 AF in 1962, and 458 AF in 1979. Hoover (1980) indicated a generally declining private pumpage between 1929 and 1979.

Figure 8 - Total Private Groundwater Production, 1980-1990 - has been prepared to show private pumpage in the MWD service area from 1980 through 1990. Using data from MWD Table 1 prepared by Mr. Keith Johnson in 1988 and updated in the Supplement to the MWD Water Supply Management Report, we find groundwater extractions by private pumpers in the District to be 907 AF in 1989 and 1025 AF in 1990; this assumes a 1 percent growth rate in the District.

For the period 1980 through 1988, the average annual private groundwater extractions were determined on the above-referenced District Table 1 to be 709 AF (the sum of 158 AF per year for each year from 1980 to 1988 by Johnson, plus 458 AF/year for 1979 by Hoover), plus 93 AF per year by Johnson

Figure 7
MWD Groundwater Production by Storage Unit, 1972-1990

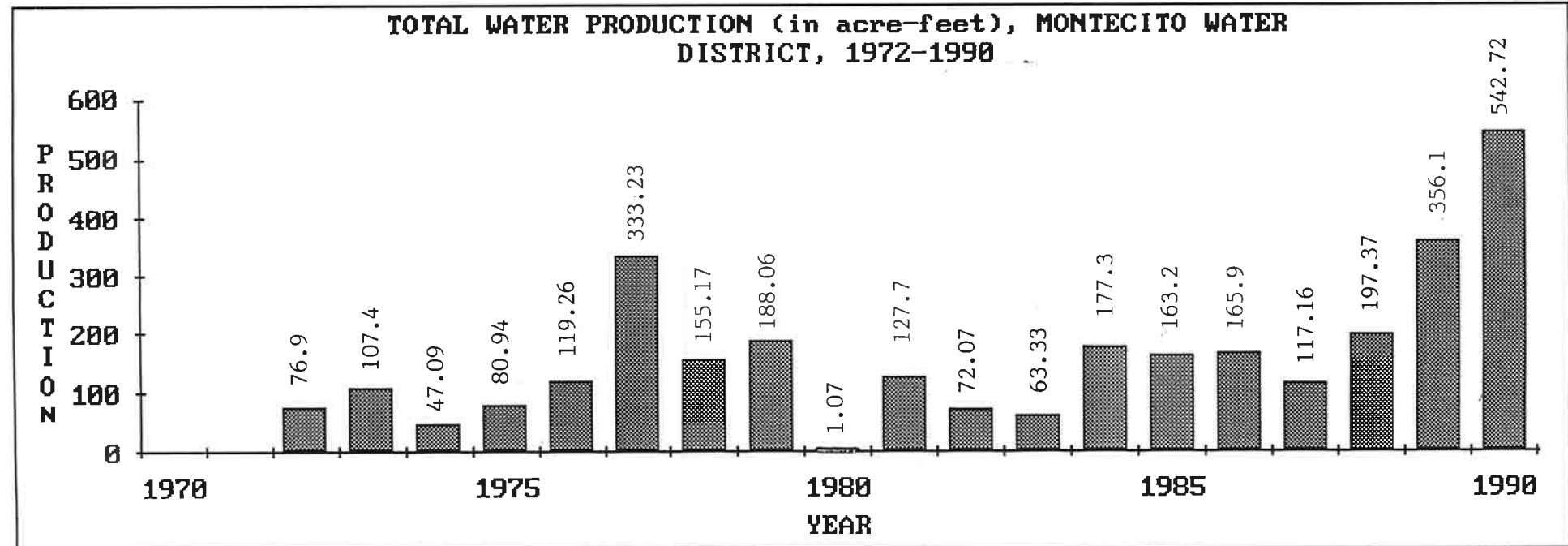
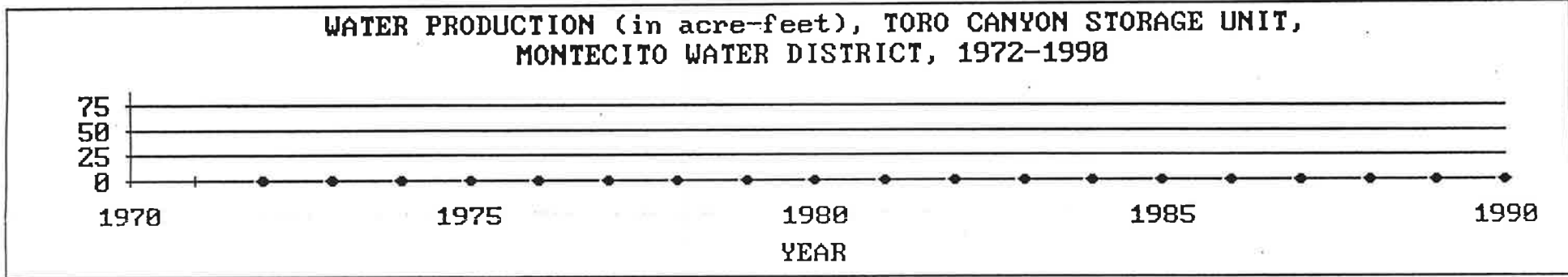
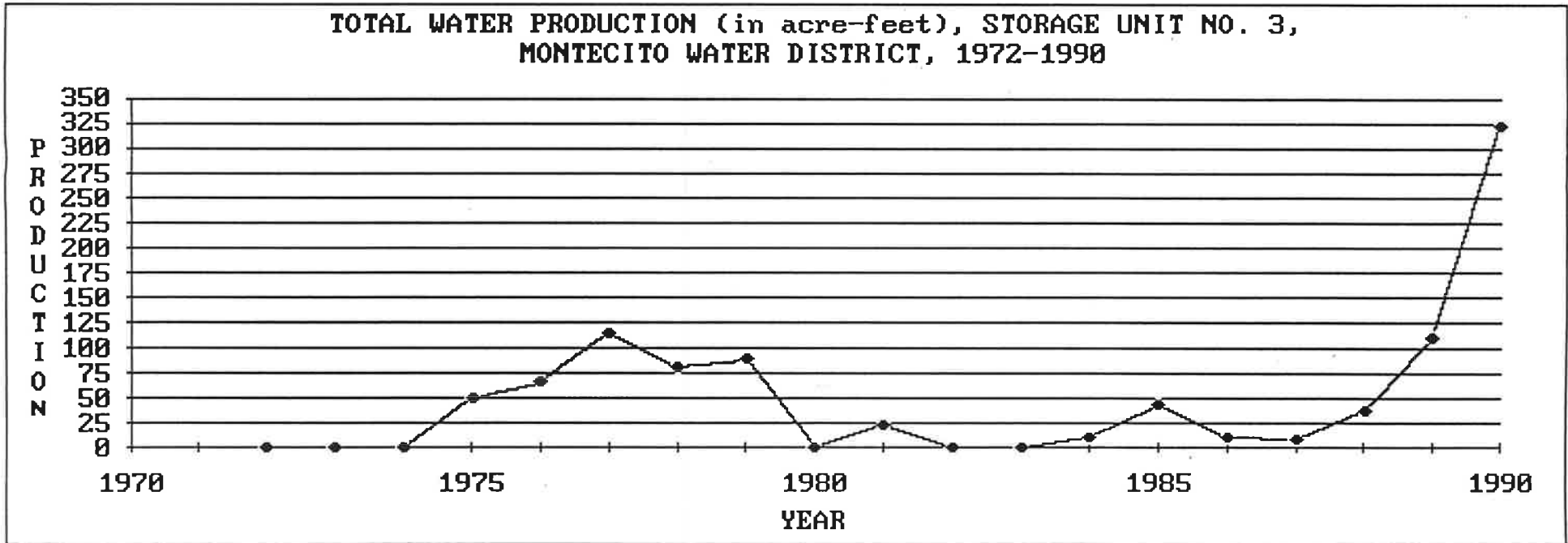
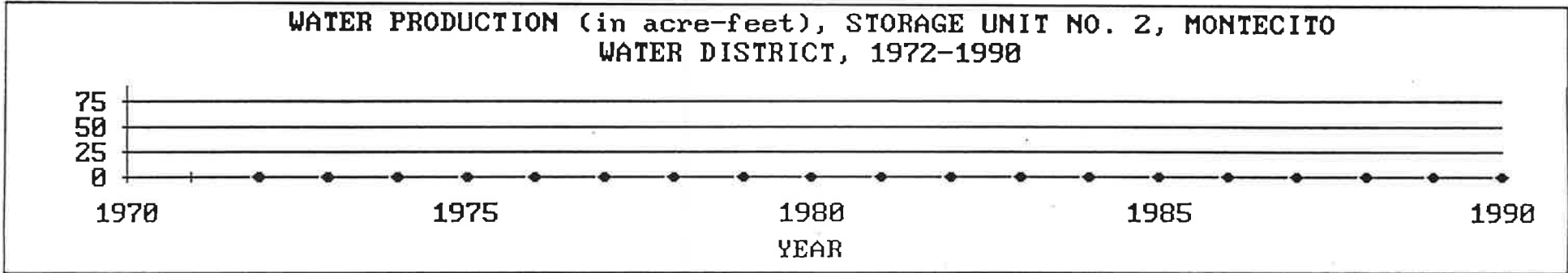
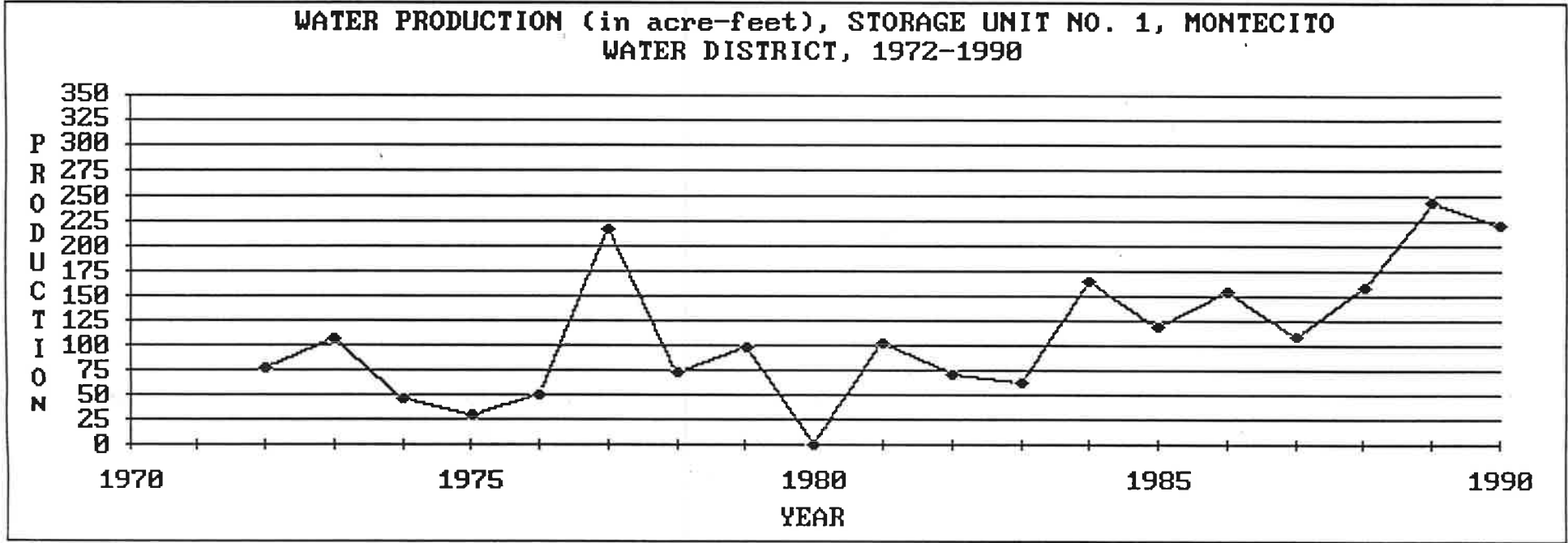
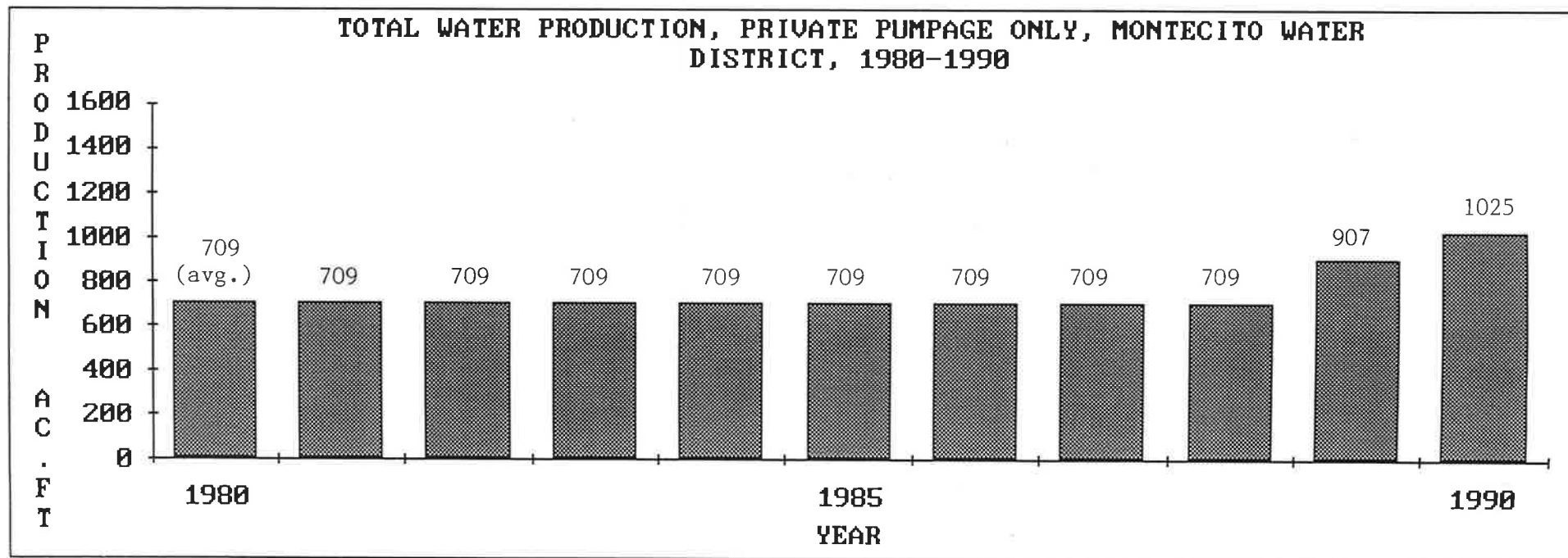


Figure 8
TOTAL PRIVATE GROUNDWATER PRODUCTION, 1980-1990





which represents the sum of the existing potential and existing committed seasonal meter pumpage in the District. From the data tabulations, according to Mr. Johnson, it appears that the above private extractions include mutual water companies within the District. Average private pumpage for the 1980 to 1990 period was calculated to be 756 AF/yr. As indicated previously, MWD pumpage in this 1980 to 1990 period averaged 180 AF/yr.

Figure 9 - MWD and Private Groundwater Production by Storage Unit, 1980-1990 - has been prepared to graphically show MWD and calculated private production by storage unit. As is the case for historic MWD production, most private production has been from Storage Unit No. 1.

Total groundwater extractions (MWD plus private pumpers) have averaged 936 AF/yr for the eleven-year period of 1980 through 1990 since the previous study by Hoover (1980). Figure 10 - Total MWD and Private Groundwater Production, 1980-1990 - has been prepared to show the combined production for this period.

WELL PRODUCTION CAPACITY

In a January 31, 1991 MWD staff memorandum, estimated District water well production capacity was tabulated. After reviewing our in-house files, we prepared Table 1 - Estimated Production Capacity of District Wells. Table 1 lists, by well, the estimated production rates (in gpm) and estimated yearly capacity (in AF) of District wells from our file review, and compares these to the data contained in the MWD staff memorandum. With a few exceptions, our estimations agree with those by MWD; where different, our estimates were slightly lower. Where available, February 1991 pumping rates

Figure 9
MWD and Private Groundwater Production by Storage Unit, 1980-1990

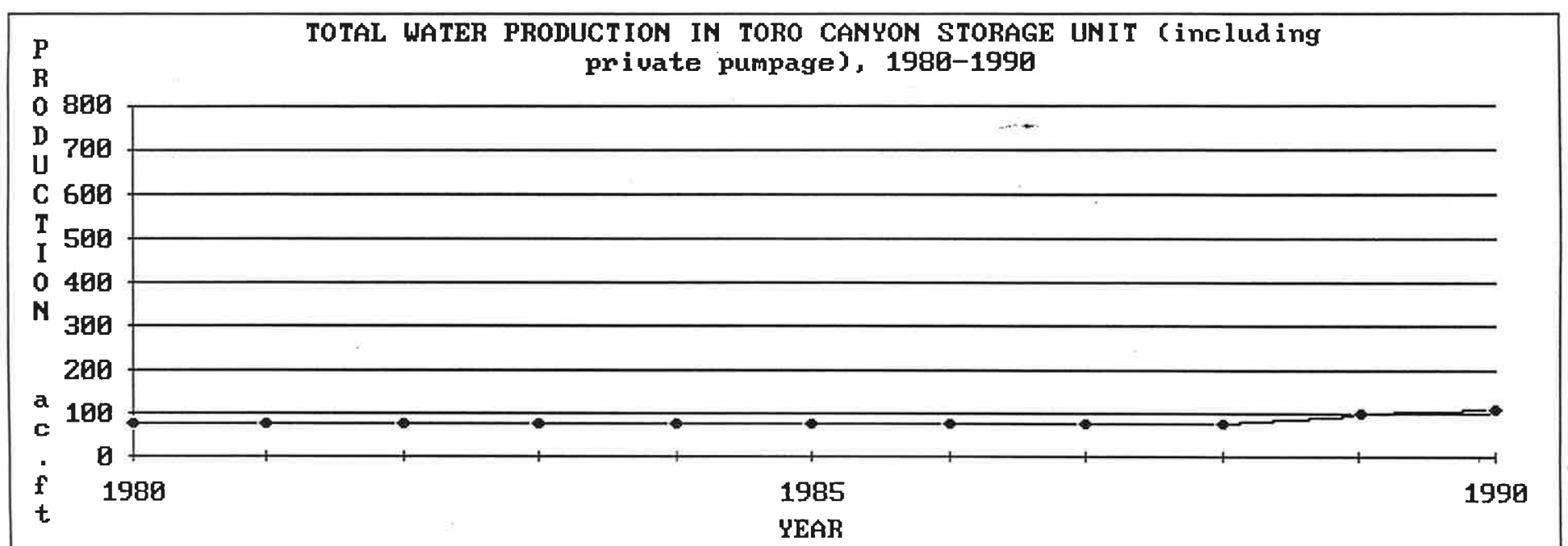
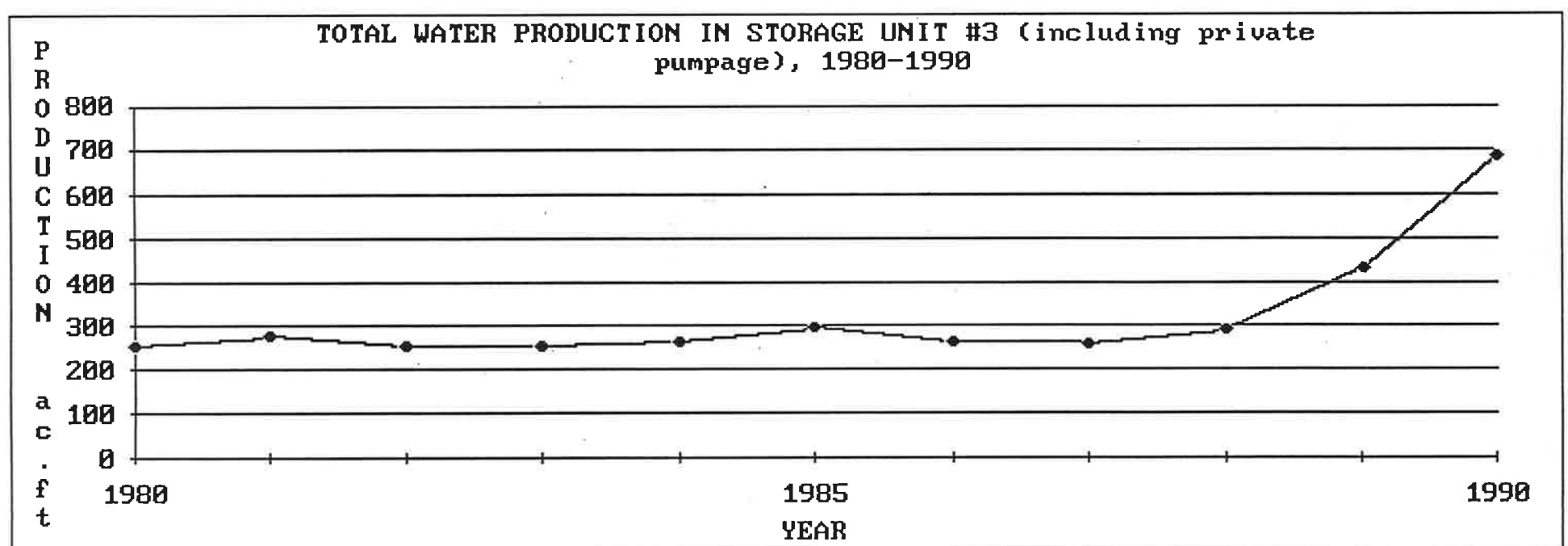
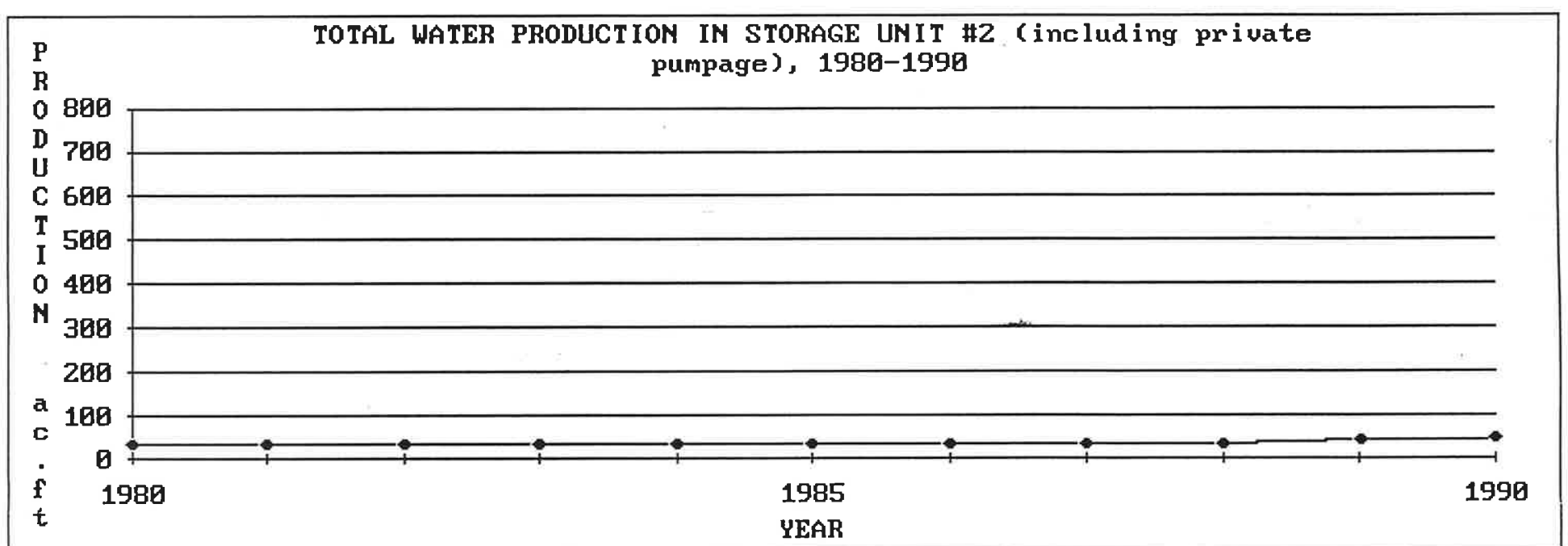
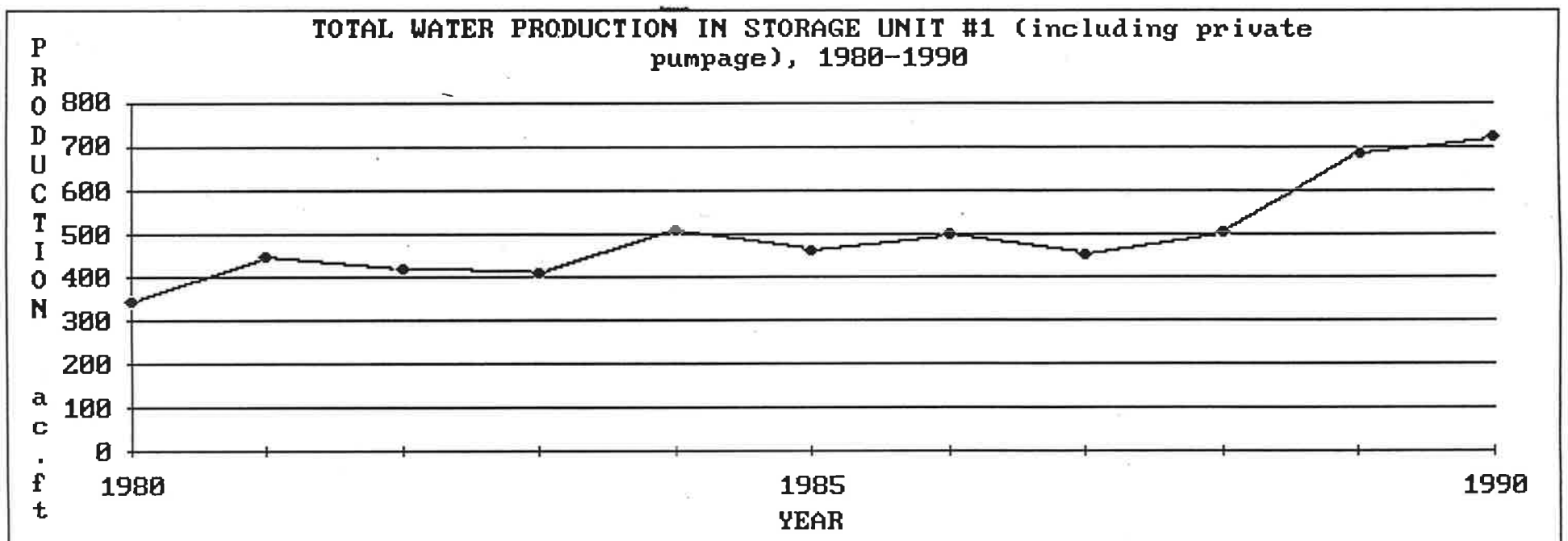
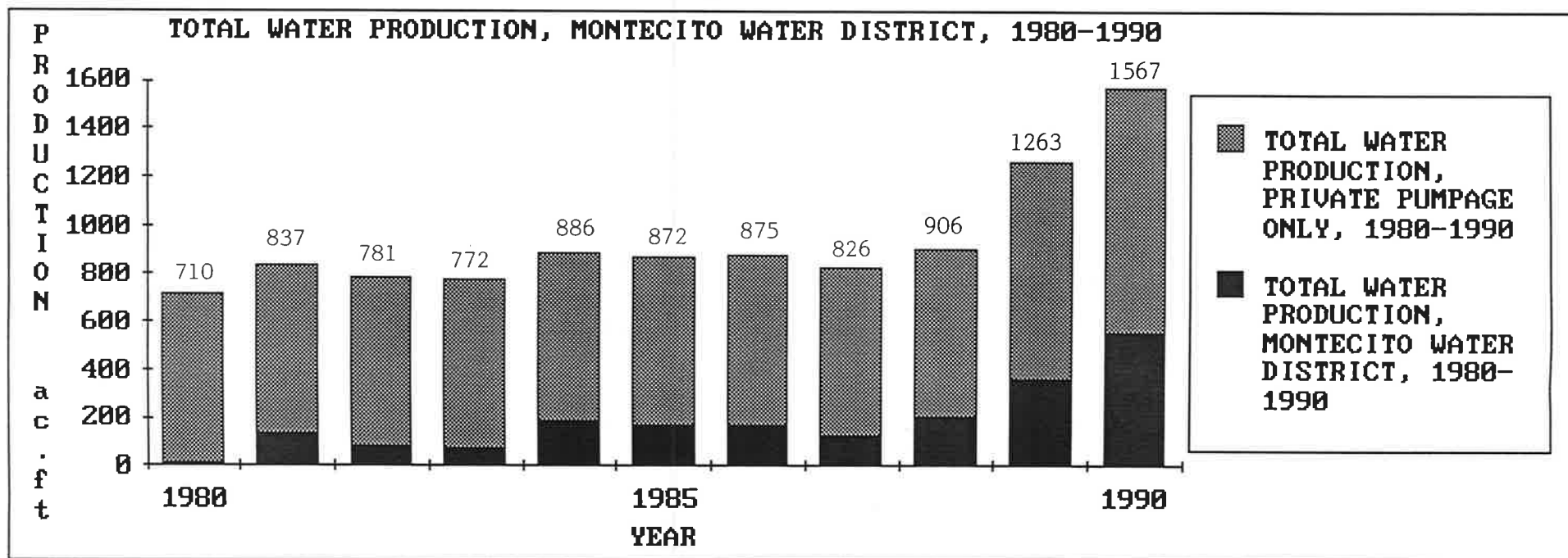


Figure 10
TOTAL MWD AND PRIVATE GROUNDWATER PRODUCTION, 1980-1990





are included in the table. Estimated yearly production capacities are based on the service cycle percentage (either 70% or 80% for operational usage) which are listed for each well in the MWD staff memorandum. According to that memorandum, the production rate for wells with treatment facilities is reduced by ten percent to account for backwashing.

As shown on Table 1, the total estimated production capacity of the wells scheduled to be in service by the 1991-1992 water year is in the range of 1048.8 to 1238.4 AF/yr, depending on the actual production during current drought conditions of wells that are not yet on line (Ennisbrook 3, and Morgan), or that are currently under-produced (e.g. Amapola). For comparison, the total production listed in the MWD staff memorandum is 1275.9 AF/yr. Four future water supply options under current consideration by MWD require a District groundwater production of either 1000 or 1050 AF for the 1991-1992 water year.

Of note is that the MWD staff memorandum does not include the currently active Las Entradas II (LE II) well, located very close to the soon-to-be active Morgan well. It is unknown whether LE II will be used once Morgan is put on line. Table 1 also includes our production capacity data for LE II, which is not included in the previous totals. Our estimate of yearly production from LE II is 101.6 AF/yr. However, due to the proximity of LE II and Morgan, some mutual drawdown interference is expected which may reduce the capacity of those wells when operated simultaneously. Our firm has previously submitted a review of those issues in a report on the Morgan Well No. 2 project dated December 8, 1986.

Table 1 - ESTIMATED PRODUCTION CAPACITY OF DISTRICT WELLS

WELL	Estimated Production Rate (gpm)		Percent Service Cycle	Estimated Yearly Capacity (AF)		2/91 Static Water Level Depth (ft)	2/91 Pumping Water Level Depth (ft)	Current Pump Depth Setting (ft)	Perforation Depth Interval (ft)	Ground Surface Elevation (ft)
	RCS	MWD		RCS	MWD					
STORAGE UNIT #1										
Office Well	50	50	70%	56.4	56.4	102	200 (at 50 gpm)	350	150 - 390	220
Hodges	50	50	70%	56.4	56.4	75	110 (at 52 gpm)	231	57 - 404	194
Seaview East 1	40	40	70%	45.1	45.1	90	120 to 144 (at 45 gpm)	150	90 - 200	195
Valley Club	40	45	80%	51.6	58.0	61	145 (at 42 gpm)	210	88 - 495	255
Live Oaks	20	20	80%	25.8	25.8	80	137 (at 22 gpm)	146	69 - 634	205
Ennisbrook 3	65-100	100	70%	73.3-112.9	113.0	?	?	?	105 - 320	
S. U. #1 SUBTOTAL				308.6-348.2	354.7					
STORAGE UNIT #3										
Neal Well	50	55	80%	64.5	71.0	116	170 (at 60 gpm)	380	192 - 684	104
Ennisbrook 2	80-100	115	70%	90.3-112.9	129.8	69	134 (at 116 gpm)	?	160 - 500	
Ennisbrook 5	120	120	80%	154.8	154.8	88	138 (at 145 gpm)	?	170 - 460	
Amapola	150-205	210	80%	193.6-264.5	272.0	74	82 (at 95 gpm)	350	160 - 610	74
Underwood	70	70	70%	79.0	79.0	33	73 (at 72 gpm)	126	120 - 325	
Paden	60-90	90	70%	67.7-101.6	101.6	72	119 (at 90 gpm) 106 (at 60 gpm)	?	90 - 470	66
Morgan	80-100	100	70%	90.3-112.9	113.0	?	?	?	95 - 425	
S. U. #3 SUBTOTAL without LE II				740.2-890.2	921.2					
TOTAL S.U. #1 and S.U.#3				1048.8-1238.4	1275.9					
+Las Entradas II	90	?	70% ?	101.6	?	100	125 (at 97 gpm)	330	130 - 450	

PLUS



USABLE GROUNDWATER IN STORAGE

Definitions. Within a groundwater basin, the available groundwater storage capacity represents the total volume of water that can be held in underground storage at a given period of time. The groundwater storage capacity potentially available for extraction by wells depends on the volume of the water-bearing deposits that are, or can become, saturated in the groundwater reservoir, and on the specific yield of those sediments. Hence, the groundwater in storage is a constantly changing value which fluctuates in response to both seasonal and long-term changes in recharge to, and discharge from, the groundwater reservoir. A rising water table increases the thickness of the saturated water-bearing section, which results in a greater volume of groundwater in storage; the reverse is true for a declining water table (a decreasing saturated thickness).

To be usable, the void space or reservoir space for ground-water storage in a given volume of sediments must have at least two capabilities: it must be economically capable of being dewatered during periods of deficient surface supply; and it must be capable of being re-saturated either naturally or artificially during periods of excess surface supply. In addition, the groundwater reservoir must contain usable water, which may be defined as that having a satisfactory quality for prevailing beneficial uses and that occurring in sufficient quantity in the underground reservoir to be available without uneconomic yield or excessive drawdown.

The definition of usable groundwater in storage utilized in this study is consistent with that found in the 1978 report by Todd prepared for the City of Santa Barbara. For the base of usable sediments, this definition takes into account the water quality by specifying a certain depth below



which: the quality is naturally poor; or sea water intrusion might occur if pumping levels fell below these maximum depths. For this study, the top of maximum usable sediments is the Spring 1983 historic high water level, while the February/March 1991 historic low levels represent the top of the current usable sediments.

To quantify the volume of groundwater in storage that is potentially available for extraction, it is necessary to multiply the total volume of water-bearing sediments by the specific yield of the various strata. In this assessment, specific yield represents the ratio of the volume of water which can be drained by gravity from a saturated stratum to the unit volume of that stratum. The procedure for calculating usable storage capacity involved the following steps:

1. Subdivision of the four storage units into individual groundwater subunits within the alluvium and also within the terrace deposits. *what constitute terrace deposits in alluvium*
2. Assessment of the total usable thickness of potentially saturated sediments in each of the storage subunits.
3. Grouping of earth materials described on geological drillers' logs into categories based on grain size.
4. Assignment of specific yield values to each category of earth materials.
5. Computation of groundwater storage capacity (SC) using $SC = A m S_y$, where A = surface area of the storage subunit, m = thickness of potentially saturated deposits in that subunit, and S_y = the assigned specific yield.

Storage Units and Sediment Thicknesses. The first step in determining usable storage capacity is to subdivide the study area into individual groundwater storage units. Starting with the existing four groundwater storage units (as



modified during this study and shown on Plate 1), we then subdivided the storage units into a total of 20 subunits for calculation purposes based on gross similarities in lithology, geologic structure, and well data. Plate 2 illustrates the locations and areal extents of each of the storage subunits.

Actual basin boundaries were modified to make the subunit surface areas representative of usable areas consistent with the definition of usable groundwater in storage. As shown on Plate 2, several subunit exterior boundaries do not coincide with the defined basin boundaries. In Storage Unit No. 1, the northern subunit boundaries are generally 500 ft or more inboard of the basin boundary because basin sediments in those margins would be too shallow for a well penetrating only basin sediments. The typically poor-producing bedrock wells are entirely excluded from this investigation.

In Storage Unit Nos. 2, 3, and Toro Canyon, the subunit boundaries are, in places, also inboard of the basin boundaries because of shallow depths to bedrock. Along the coastal portions of Storage Unit No. 3 and Toro Canyon, the subunit boundaries are 500 ft landward from the coast for water quality protection. Wells located inside this coastal strip (south of the boundary) would be expected to induce sea water intrusion.

Definition of the elevation of the base of usable groundwater-bearing sediments varied by storage unit and, in some cases, within a storage unit. In Storage Unit No. 1, the theoretically water-bearing Casitas Formation attains thicknesses of over 400 ft. However, much of the deeper Casitas sediments are very fine grained and display very poor water transmitting characteristics. In our [December 1990 study (Slade, 1990)], we prepared a cross section of the basin that incorporated geophysical electric log data where available.



This cross section notes a marker horizon (labeled CC) below which the Casitas sediments appeared to be consistently finer grained. Thus, the elevation of this marker horizon is used as the base of usable groundwater in Storage Unit No. 1. If no Casitas Formation sediments are present, the base of the fan-glomerate deposits is used as the base of usable groundwater in Storage Unit No. 1.

Storage Unit No. 2 represents a relatively upthrown, fault-bounded block with relatively shallow depths to bedrock. The base of usable groundwater in Storage Unit No. 2 was selected to be approximately 50 ft above the geologic contact with the underlying bedrock. This was done primarily for water quality purposes as the bedrock is strongly suspected of containing very poor quality water that: is under artesian head; and may also leak into portions of Storage Unit Nos. 1 and 3 that lie adjacent to the faults bounding Unit No. 2.

In Storage Unit No. 3, the base of usable groundwater was generally selected to preclude sea water intrusion. The base of usable groundwater was estimated for each subunit to be the pumping level depth below which sea water intrusion would be expected. Additional protection for this storage unit from possible sea water intrusion is provided by the 500-foot wide strip along the coastline where we are assuming: no wells are located; where no groundwater is in storage; and where no extractions will occur to lower water levels.

In the Toro Canyon storage unit, the base of usable groundwater was selected to preclude likely poorer quality fresh water at depth as well as the possibility of sea water intrusion. Thus, base of usable groundwater is considered to be 50 ft above the geologic contact with underlying Sespe Formation. Usable thickness in Toro Canyon includes some fan-glomerate deposits assumed to be water-bearing.



The saturated thickness used by Muir (1968) is the interval between the highest recorded static groundwater level and the lowest recorded pumping level, in other words, the zone of maximum recorded water level fluctuation. Thus, the base of each storage unit represented the lowest recorded pumping levels within the unit. As discussed previously, the base of usable groundwater for our study was estimated using different criteria and, in some cases, our base was approximately equal to the lowest pumping levels and, in other cases, was either higher or lower than the lowest recorded pumping levels.

To assess the quantity of groundwater in storage at any given time that is potentially available for extraction by wells, it was necessary to assign specific yield values to each subunit and to multiply this figure by the volume of saturated sediments in the subunit. The volume of saturated material is the product of the area of the individual subunit (determined by planimetering the subunit areas shown on Plate 2) and the saturated thickness of the material underlying the particular subunit.

To ascertain the thickness of the saturated material, it is necessary to determine the base of fresh water-bearing sediments and the elevation of the water table at a specific time period within each of the subunits. Maps depicting the elevation of the water table for specific time periods (Spring 1983 and February/March 1991 as seen on Plates 3 and 4) were used for these purposes. As discussed earlier in the text, Spring 1983 represents the historic water-level high period while February/March 1991 represents both the current period and simultaneously the historic water-level low period.



Lastly, the following important assumptions were used:

1. All subunit boundaries were considered to be vertical planes.
2. The groundwater level in each storage subunit was averaged across the subunit to create a flat water table and a uniform thickness of saturated sediments across each particular subunit.
3. The elevation of this base of usable water for each storage subunit was averaged across that subunit to create a flat bottom for each particular subunit; however, the volume of saturated material was corrected, as described above.

Specific Yield Values. Specific yield in water-table environments represents the quantity of water that a unit volume of the material will release from storage when drained by gravity. The part of the water that is not removed by gravity during drainage is held against the force of gravity by such conditions as molecular attraction and capillarity; this water is not available to wells.

For this study, specific yield (S_y) values were generated for each of the nearly 60 wells for which a geologic log or drillers' formation log was available. Average S_y values used in storage calculations represent only those sediments in the depth intervals for which we have defined as usable. That the upper sediments typically have higher S_y than deeper ones is shown on Table 2 where the "maximum usable thickness" generally has a higher S_y than is calculated for the "current usable thickness." In addition, our experience in the Montecito area with well performance versus what is indicated on formation logs and geophysical electric logs made it appropriate to further interpret and modify our calculated average S_y to reflect the generally poor transmissivity of study area sediments.



As shown on Table 2, average specific yield values for our individual storage subunits ranged from 3 to 9 percent.

By storage unit, the weighted average specific yield values used in our calculations for usable groundwater in storage are 4.3 percent, 4 percent, 4.5 percent, and 6 percent for Storage Units 1, 2, 3, and Toro Canyon, respectively.

Specific yield values presented by previous investigators varied with each successive study modifying the values downward to better represent actual aquifer characteristics of sediments penetrated by wells in the basin. These previous investigators include:

- 1) Muir (1968), who used weighted average S_y for different depth zone intervals and, based on his review of 30 well logs, he reported weighted average S_y values of 8.7 to 11.8 percent.
- 2) Geotechnical Consultants, Inc. (1974) which listed calculated S_y values from 27 well logs and provided average S_y values of 7 or 8 percent for each of the four storage units. In that report, GTC stated that they modified and lowered their theoretically calculated S_y values to reflect the poorly sorted nature and high clay content of the water-bearing deposits in the basin.
- 3) Hoover (1980), who presented average S_y values by storage unit that ranged from 5 to 8 percent. In a personal communication with Mr. Hoover in late 1990, we learned that in his storage calculations he assigned S_y values from 2 to 8 percent to his individual subunits within each storage unit. No S_y selection criteria were provided in the Hoover (1980) report, but it is assumed that Mr. Hoover drew upon his experience in the area when he estimated or calculated values for S_y .

Quantity of Usable Groundwater in Storage. The quantity of usable groundwater in storage within the investigation area was computed by multiplying the area of each storage sub-



unit by the saturated thickness of that storage subunit (based on the water-table elevation for that particular period), and by the specific yield value, in percent, assigned to the subunit. Table 2 - Calculations for Usable Groundwater in Storage - presents our calculations of groundwater in storage for all four storage units for the periods of Spring 1983 and February/March 1991. Table 3 - Summary of Usable Groundwater in Storage - summarizes the results of our calculations.

Review of Tables 2 and 3 reveals the following:

1. The total usable area for the four storage units is 3915 acres, approximately half of which is contained in Storage Unit No. 1
2. Maximum (Spring 1983) usable groundwater in storage for all four storage units is 16,110 AF, with just over half of that amount in Storage Unit No. 1.
3. Current (February/March 1991) usable groundwater in storage is 7760 AF, with nearly half of that storage in Storage Unit No. 3.

If it is assumed that production of MWD wells will be from only those storage subunits that have MWD wells, then the groundwater in storage in only two subunits in Storage Unit No. 1 and five subunits in Storage Unit No. 3 constitutes the usable groundwater in storage for MWD wells planned to be operating in the 1991-92 water year.

In Storage Unit No. 1, subunits 1E and 1F together contain a maximum usable groundwater in storage of 4310 AF and a current usable groundwater of 1590 AF. Storage Unit No. 3 subunits 3B, 3C, 3E, 3G, and 3I contain a total maximum groundwater in storage of 3890 AF, and a current usable amount of 2980 AF. Thus, the total usable groundwater in storage for those subunits which contain MWD wells is a maximum of 8200

Table 2 - CALCULATIONS FOR USABLE GROUNDWATER IN STORAGE

Subunit	Usable Area (acres)	Maximum Usable Thickness (feet)	Average Specific Yield	Maximum Usable Groundwater in Storage (acre-feet)	Current Usable Thickness (feet)	Average Specific Yield	Current Usable Groundwater in Storage (acre-feet)
Storage Unit No. 1							
1A	373	75	4%	1119	25	3%	280
1B	585	75	4%	1755	25	3%	439
1C	190	75	4%	570	25	3%	142
1D	253	100	4%	1012	50	3%	380
1E	461	150	5%	3458	80	3%	1106
1F	178	120	4%	854	90	3%	481
S. U. No. 1 Subtotals:	2040 acres	Wtd. Avg. 99	Wtd. Avg. 4.3%	8768 AF			2828 AF
Storage Unit No. 2							
2A	244	20	4%	195	0	3%	0
2B	244	55	4%	537	10	3%	73
S. U. No. 2 Subtotals:	488 acres	Wtd. Avg. 38	Wtd. Avg. 4%	732 AF			73 AF
Storage Unit No. 3							
3A	52	90	4%	187	75	4%	156
3B	95	85	4%	323	50	4%	190
3C	126	80	7%	706	55	6%	416
3D	151	120	4%	725	101	3%	458
3E	275	225	4%	2475	199	4%	2189
3F	75	30	7%	158	22	6%	99
3G	103	40	7%	288	23	7%	166
3H	66	5	7%	23	3	7%	14
3I	84	14	8%	94	3	8%	20
3J	13	12	9%	14	0	9%	0
S. U. No. 3 Subtotals:	1040 acres	Wtd. Avg. 107	Wtd. Avg. 4.5%	4993 AF			3708 AF
Toro Canyon							
TC-A	111	20	6%	133	10	5%	56
TC-B	236	105	6%	1487	93	5%	1097
Toro Canyon Subtotals:	347 acres	Wtd. Avg. 78	Wtd. Avg. 6%	1620 AF			1153 AF



Table 3
SUMMARY OF USABLE GROUNDWATER IN STORAGE

Storage Unit	Maximum Usable Groundwater in Storage ¹ (AF)	Current Usable Groundwater in Storage ² (AF)
1	8,770 ³	2,830
2	730	70
3	4,990	3,710
Toro Canyon	1,620	1,150
Totals:	16,110	7,760

- 1) Maximum usable storage is for Spring 1983 water levels (highest on record).
- 2) Current usable storage is for February/March 1991 water levels (lowest on record).
- 3) Storage values above have been rounded off in each case to the nearest 10 acre-feet.



AF, and has a current usable groundwater in storage of 4570 AF. These amounts of current usable groundwater in storage exceed the 1991-1992 estimated production of MWD wells shown on Table 2 and proposed in the four MWD supply options.

According to Mr. Hoover (personal communication 1990), his groundwater in storage determination (Hoover, 1980) was not intended to be a detailed or sophisticated calculation but merely a "very broad brush" assessment based on where MWD wells were located and their pumping effects on nearby wells.

Table 4 - Comparison of Groundwater in Storage from Previous Studies - has been prepared to show the results and some of the differences in storage calculations from this and previous investigations.

Previous studies estimated or calculated total groundwater in storage to be on the order of 100,000 to 130,000 AF. Hoover (1980) presented a relatively small usable amount of groundwater in storage of 9480 AF. For our current study, amounts of maximum usable and current usable groundwater in storage were calculated to be 16,110 AF and 7700 AF, respectively.

As shown on Table 4, differences between the Hoover study and the present study exist in the basic factors used to calculate groundwater in storage. Differences in usable area and specific yield are not great. The most significant differences are in the usable thickness calculations where our maximum (Spring 1983) usable saturated thicknesses are greater than Hoover's.

Water levels used in groundwater storage calculations by Hoover (1980) apparently were the 1979 water levels obtained during that investigation. As shown on the hydrographs prepared for the current study, 1979 water levels were relatively high but generally lower than Spring 1983 levels.

Table 4 - COMPARISON OF GROUNDWATER IN STORAGE FROM PREVIOUS STUDIES

Storage Unit	RCS Usable Area (ac)	Hoover Usable Area (ac)	RCS Maximum Usable Thickness Weighted Average (ft)	Hoover 1979 Usable Average Thickness (ft)	RCS Maximum Usable Average SY	Hoover Average SY	RCS Maximum Usable Groundwater in Storage (AF) Sp. 1983	RCS Current Usable Groundwater in Storage (AF) Feb/March 1991	Hoover 1979 Usable Storage (AF)	Hoover 1979 Total Storage (AF)	6TC 1974 Total Storage (AF)	Muir 1959 Total Storage (AF)
No. 1	2040	1982	99	44	4.3%	5%	8770	2830	4360	18,227	25,000	67,800
No. 2	488	600	37	25	4%	5%	730	70	750	3,186	2,600	(included in S.U. No. 3)
No. 3	1040	1224	107	38	4.5%	8%	4990	3710	3720	81,424	92,600	29,000
Toro Canyon	347	580	78	16	6%	7%	1620	1150	650	9,081	8,680	Not Calculated
TOTAL	3915 acres	4386 acres					16,110 AF	7760 AF	9480 AF	111,918 AF	128,880 AF	97,000 AF

NOTES: RCS data from this study.
Hoover data from Hoover 1980.
6TC data from 6TC 1974.
Muir data from Muir 1968.



Thus, this explains part of the difference between volume of groundwater in storage determined by Hoover (1980) and the maximum amount determined in this investigation.

EXTRACTIONS VS. SAFE YIELD

Estimates or calculations of safe yield (also called perennial yield) were made by several previous investigations and were not considered a part of the scope of work of the current study.

Muir (1968) reported that insufficient data prevented a firm estimate of perennial yield for the Montecito area, but indicated that the long term perennial yield may be on the order of 2500 AF/yr (not including Toro Canyon). GTC (1974) termed the Muir estimate of 2500 AF/yr to be a theoretical value. Their study considered more recent subsurface information and established a practical perennial yield of 1200 AF/yr for the Montecito Groundwater Basin and assigned an additional estimate of 200 to 300 AF/yr for the perennial yield of the Toro Canyon storage unit.

The 1980 report by Hoover was for the express purpose of evaluating safe yield in the Montecito Basin and Toro Canyon area. By storage unit, the calculated safe yield values by Hoover (1980) are as follows: Storage Unit No. 1 = 550 AF/yr; Storage Unit No. 2 = 100 AF/yr; Storage Unit No. 3 = 700 AF/yr; and Toro Canyon = 300 AF/yr for a total of 1650 AF/yr.

To represent current conditions, the following table shows MWD and private groundwater production for 1990 compared to the Hoover safe yield values (in AF) by storage unit.

Pumper	<u>Storage Unit</u>				Total
	No. 1	No. 2	No. 3	Toro Canyon	
MWD	221	0	321	0	542
Private	502	50	359	114	1025
Total	723	50	680	114	1567
Hoover's Safe Yield	550	100	700	300	1650
1990 Balance Remaining	-173	50	20	186	83

This table shows that currently there is a significant overdraft condition in Storage Unit No. 1 (173 AF) but slight surpluses in Storage Unit Nos. 2 (50 AF) and 3 (20 AF), and a moderate surplus in Toro Canyon (186 AF). It should be noted that the safe yield values presented by Hoover (1980) were calculated using a base period during the early 1920s. Reportedly, this was a time when: basin utilization was at a maximum with no adverse environmental effects reported; pumpage was influenced primarily by weather conditions; and rainfall was below average, thus indicating a base period time of maximum possible pumpage under adverse weather conditions.

In order to meet 1991-1992 MWD production goals of 1000 or 1050 AF as proposed in the four MWD supply options, District groundwater production would need to be increased to near the maximum estimated capacity shown on Table 1. For Storage Unit No. 1, this represents an increase of approximately 90 AF, from 221 AF in 1990 to about 310 AF. Even if private production does not change, total Storage Unit No. 1 production would then exceed the safe yield by approximately 263 AF. Increasing MWD production to near capacity in Storage Unit No. 3 requires an increase of about 420 AF, from 321 AF



in 1990 to about 740 AF. Thus, total production from Storage Unit No. 3 would exceed the safe yield by at least 400 AF.

CONCLUSIONS AND RECOMMENDATIONS

Based upon review and analyses of data for the area, we submit the following conclusions and recommendations.

- Spring 1983 is considered the historic high water level period.
- Current (February/March 1991) water levels are considered the lowest in basin history.
- Wells typically have higher production rates when the water levels are high due to the higher specific yield and transmissivity of the younger shallower sediments. Conversely, when water levels decline due to drought conditions, production rates and specific capacities tend to decline because the deeper sediments are less permeable, more consolidated, and less transmissive.
- Total groundwater extractions (MWD plus private pumpers) have averaged 936 AF/yr for the eleven-year period of 1980 through 1990 since the previous study by Hoover.
- Combined MWD and private groundwater production for the four storage units for 1990 was 1567 AF, a total of 83 AF below the assumed safe yield of 1650 AF for these storage units.
- Water levels in the basin tend to show more response to precipitation events than to changes in pumping. Water level hydrographs show generally decreasing water levels since 1987, coincident with the current drought period. In 1989 and 1990 the rate of water level decline increased suggesting that significant increases in MWD and private groundwater production in those last two years have exacerbated the situation. Lower specific yield and transmissivity at depth likely have also contributed to the more rapid rate of water level decline in the last two years.



Groundwater in Storage
Montecito Water District

25

- Historically, most groundwater production (MWD and private) has come from Storage Unit No. 1. In most years, more than half of MWD production has been from Storage Unit No. 1. Approximately half of the private production has been from Storage Unit No. 1.
- During the maximum water level period, more than half of the usable storage was in Storage Unit No. 1. During the current historic low water level period, nearly half of the usable storage is in Storage Unit No. 3, indicating that most of the water taken out of storage came from Storage Unit No. 1 where most production has occurred.
- Existing MWD wells appear to have enough production capacity for 1991-92 amounts proposed in the MWD Water Supply Options, but increased production to meet those options will exceed Hoover's safe yield values by a considerable amount (at least 600 AF more than the safe yield of 1650 AF).
- Maximum (Spring 1983) usable groundwater in storage for all four storage units is 16,110 AF. This amount is considerably greater than that in the 1980 study by Hoover; the difference is primarily due to greater saturated thickness calculated in the current study.
- Current (February/March 1991) usable groundwater in storage for all storage units is 7760 AF which is also considered the historic low groundwater storage.
- Proposed MWD Water Supply Options call for varying amounts of groundwater production for the years following the 1991-92 water year. From a hydrogeologic viewpoint, the plans which minimize exceeding the safe yield for those following years are preferred.
- Because MWD has wells in only certain storage subunits, to get all of the usable groundwater in storage would require a large number of wells in all subunits each with relatively close spacing due to the low specific yield of the sediments and the low transmissivity and specific capacity of the aquifer system. Thus, a large number of wells could get more of the usable groundwater in storage but at a high cost for property, construction, and pipelines. Also, groundwater production should not consistently exceed the safe yield value. Any depletion of groundwater in storage by pumpage should be only for short time periods; thus, it is not considered economically feasible to

REVISE
OUR
PLAN
TO MEET
SAFE
YIELD
LIMIT

* Does This change The safe yield when Basin
is relatively full?
* Supports my contention that - private pumps needed for full basin utilization



add a large number of MWD wells, pipelines, and treatment systems for such relatively short-term use.

- Constructing additional MWD wells will not change the fact that safe yield is being exceeded, but adding wells would spread out the production network allowing more of the usable storage to be available for short-term periods of groundwater mining (to be replenished later with excess water). Additional MWD wells would allow a reduction of pumpage from existing wells which may be negatively impacting nearby private wells.
- If another MWD well is desired in order to access more of the usable storage as well as minimize increased pumping effects near existing wells, the recommended location is within Storage Unit No. 3, approximately midway between the Neal Well and the Amapola/Paden Well area. NEW
WELLS
- Because Storage Unit No. 1 currently is relatively more depleted than Storage Unit No. 3, it is recommended that as much of the short-term increased production as possible should come from Storage Unit No. 3. ADJUST
NOW
- The increased groundwater production required in the proposed MWD Water Supply Options will create lower pumping water levels in the wells that have increased production and, possibly, also in other MWD and private wells. These deeper pumping levels may require that pumps be lowered to continue production. At this time, with the data available, it appears that the Seaview East Well may soon benefit from a lower pump setting. Deepening the existing wells is not recommended due to likely poorer specific yield, transmissivity, and quality at greater depths.
- Increased production by MWD wells likely will affect some private wells in the basin, particularly those that are closest to MWD wells. The effect will tend to be maximized in wells that are shallow, or that have high casing perforations and/or that have shallow pump settings. The best way to assess the magnitude of any drawdown interference due to increased MWD pumping is to continue to add private wells, especially the proximal ones, to the basinwide water level monitoring program. Data from regular water level monitoring of these private wells should be plotted as hydrographs at the same scale as MWD production graphs of static level, pumping level, and pumping rate versus time. From the comparison and interpretation of these graphs and precipitation graphs



Groundwater in Storage
Montecito Water District

27

made at the same scale, a determination can be made as to whether lowered water levels in individual private wells are due to lack of precipitation and recharge or due to pumping interference. *Enter We should do this on pump off meter to affect wells*

- It is recommended that MWD not increase pumping duration. The current five days on and two days off schedule does not allow full recovery in two days (e.g., Office and Neal Well records). In some cases, three to seven days or longer are required for full or near-full water level recovery.
- Down-the-well testing with pump and packers or a flowmeter at various depths in select deeper wells throughout the basin would give actual practical information about production (and quality) from deeper zones that would be useful in verifying and/or refining the elevation of the base of usable groundwater assumed in this study.
- For the purposes of this study, Toro Canyon groundwater is considered to be of suitable quality to be of beneficial use and, as such, is considered to be usable. Very limited available data suggest that this water may show significant seasonal quality variations, and it is recommended that this be considered when use of Toro Canyon groundwater is planned. *CHECK PERIODICALLY*
- It is recommended that MWD perform a continuing District-wide field canvass to locate all active privately-owned wells. With this known, and with knowledge of the respective acreage for that parcel, one can then make an estimate of individual well extraction on an annual basis in order to update and verify estimated or projected amounts of private production. *SUMMER INTEREST??*
- It is recommended that MWD continue its ongoing efforts to add and accurately locate wells for the District's current well monitoring program, including surveying the elevation of the water level reference point atop each casing. *ATTN*
- It is recommended that MWD continue to obtain non-pumping water levels in all wells in the District's current well monitoring program. Water levels would be collected at least semi-annually in each well. For the first year or two of the program, more frequent measurement is desirable. These data can then be plotted and evaluated, and then the program can be modified as necessary.



- It is recommended that the map base used for this study that shows the modified basin boundaries and fault locations be adopted by MWD for their future projects. At the District's request, we will provide a mylar map base for reproduction purposes.

The attachments which complete this report are listed in the Table of Contents.

Respectfully submitted,

A handwritten signature in black ink that reads "Mark Whitten". The signature is written in a cursive, flowing style.

Mark Whitten, Geologist

A handwritten signature in black ink that reads "Richard C. Slade". The signature is written in a cursive, flowing style.

Richard C. Slade

Registered Professional Hydrogeologist



REFERENCES

- David Keith Todd Consulting Engineers, Inc., October 1978, Groundwater Basin Data: Status and Needs: an unpublished consultant's report to the City of Santa Barbara, California.
- Dibblee, Thomas W., Jr., 1986, Geologic Map of the Carpinteria Quadrangle, Santa Barbara County, California: Dibblee Foundation Map #DF-04.
-, 1986, Geologic Map of the Santa Barbara Quadrangle, Santa Barbara County, California: Dibblee Foundation Map #DF-06.
- Geotechnical Consultants, Inc., January 31, 1974, Hydrogeologic Investigation of Montecito Ground Water Basins, County of Santa Barbara, California, for Montecito County Water District: unpublished consultant's report.
- Michael F. Hoover Consulting Geologist, March 21, 1980, Safe Yield Evaluation of the Montecito Basin and Toro Canyon Area: letter-report to Montecito Water District.
- Muir, K. S., 1968, Ground-Water Reconnaissance of the Santa Barbara-Montecito Area, Santa Barbara County, California: U. S. Geological Survey Water-Supply Paper 1859-A.
- Richard C. Slade Consulting Groundwater Geologist, December 8, 1986. Hydrogeologic Assessment, Proposed District Water Rights acquisition, Morgan Well No. 3 Project, Morgan Property, Montecito: unpublished letter-report for Montecito Water District.
-, August 5, 1987, Hydrogeologic Assessment, Proposed Water Augmentation Measures, Item No. 4 - Seaward Migration of Groundwater: unpublished consultant's report for Montecito Water District.
-, December 1990, Interpretation of Data from Live Oaks #2 Well and Significance to District: letter-report to Montecito Water District.



APPENDIX

Individual Water Level Hydrographs

HYDROGRAPHS

Storage Unit No. 1

M.W.D. Number	State Number	Local Designation
No. 1-7	4N/26W-7R1	Deep Observation Well
No. 1-8	4N/26W-7R2	Shallow Observation Well
No. 1-9	4N/26W-15D2	Valley Club Golf Course
No. 1-10	4N/26W-9Q1	Deeper Observation Well
No. 1-11	4N/26W-9Q2	Shallow Observation Well
No. 1-13	4N/26W-9P1	
No. 1-19	4N/26W-8P3	Office Well

Storage Unit No. 2

M.W.D. Number	State Number	Local Designation
No. 2-1	4N/26W-17E1	
No. 2-4	4N/26W-17G5	
_____	4N/26W-17E2	
_____	4N/26W-18B1	

Storage Unit No. 3

M.W.D. Number	State Number	Local Designation
No. 3-5	4N/27W-13R1	S. B. Cemetary Well
No. 3-8	4N/26W-17N1	Neal Well
No. 3-10	4N/26W-17K2	Shallow Observation Well
No. 3-11	4N/26W-17K1	Deep Observation Well
No. 3-14	4N/26W-17Q3	
No. 3-15	4N/26W-16N1	
_____	4N/26W-16M1	Deep Observation Well
_____	4N/26W-16M2	Shallow Observation Well
_____	4N/26W-20C2	

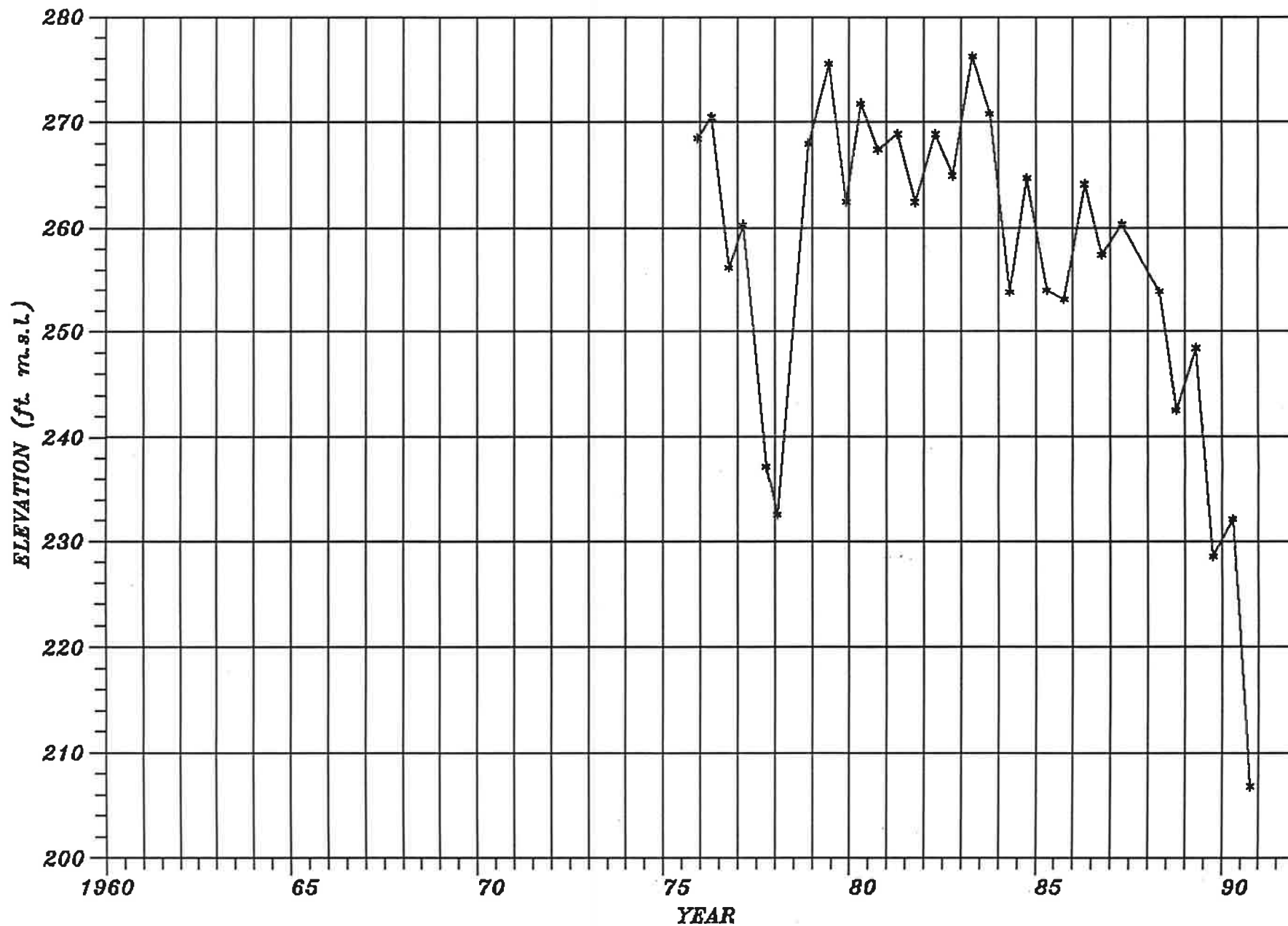
Storage Unit No. 4 (Toro Canyon)

M.W.D. Number	State Number	Local Designation
No. 4-1	4N/26W-23G3	
No. 4-2	4N/26W-23F6	Edgewood No. 2

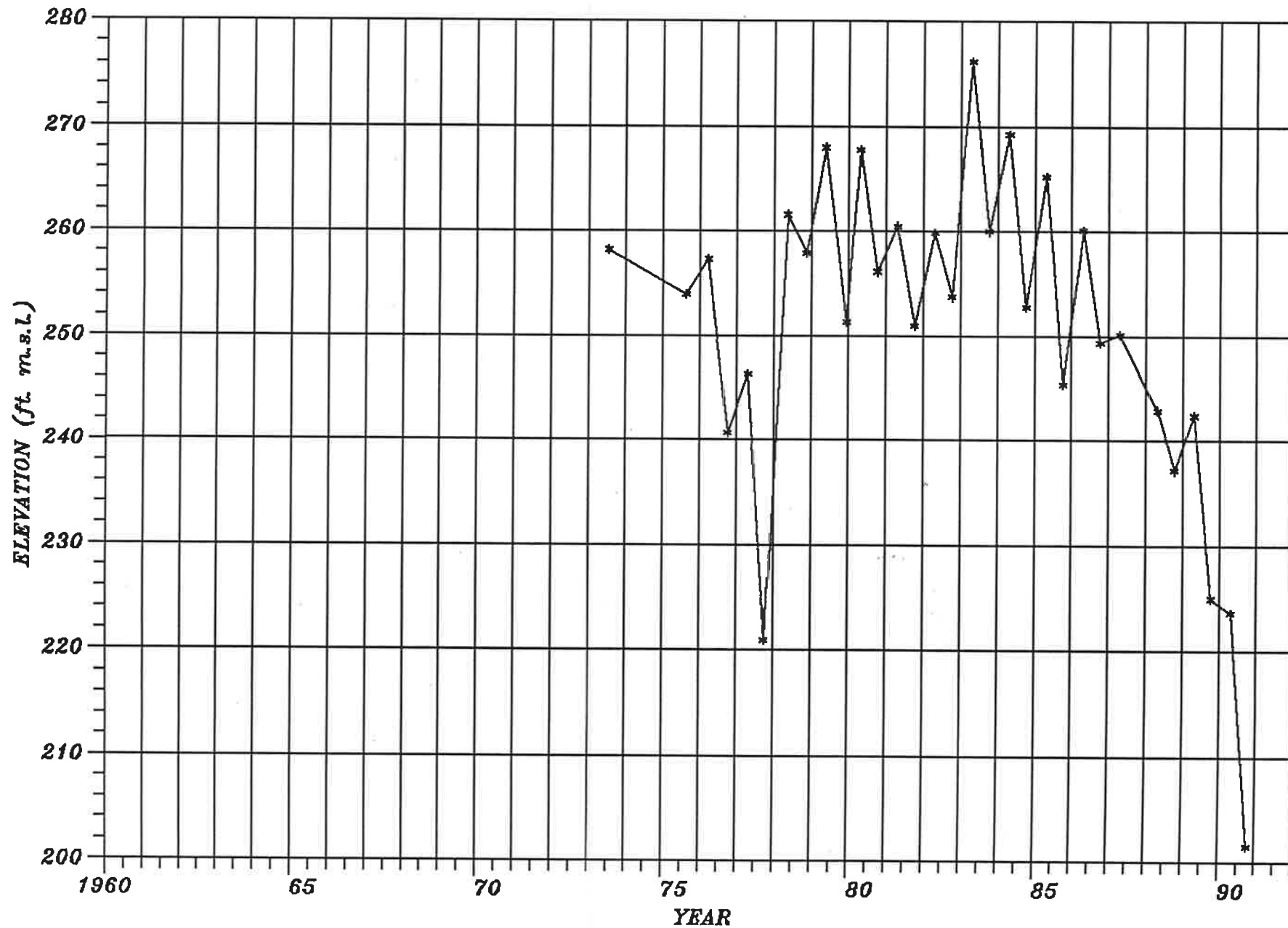
Carpinteria County Water District

State Number	Local Designation
4N/26W-23A2	Zangger Well

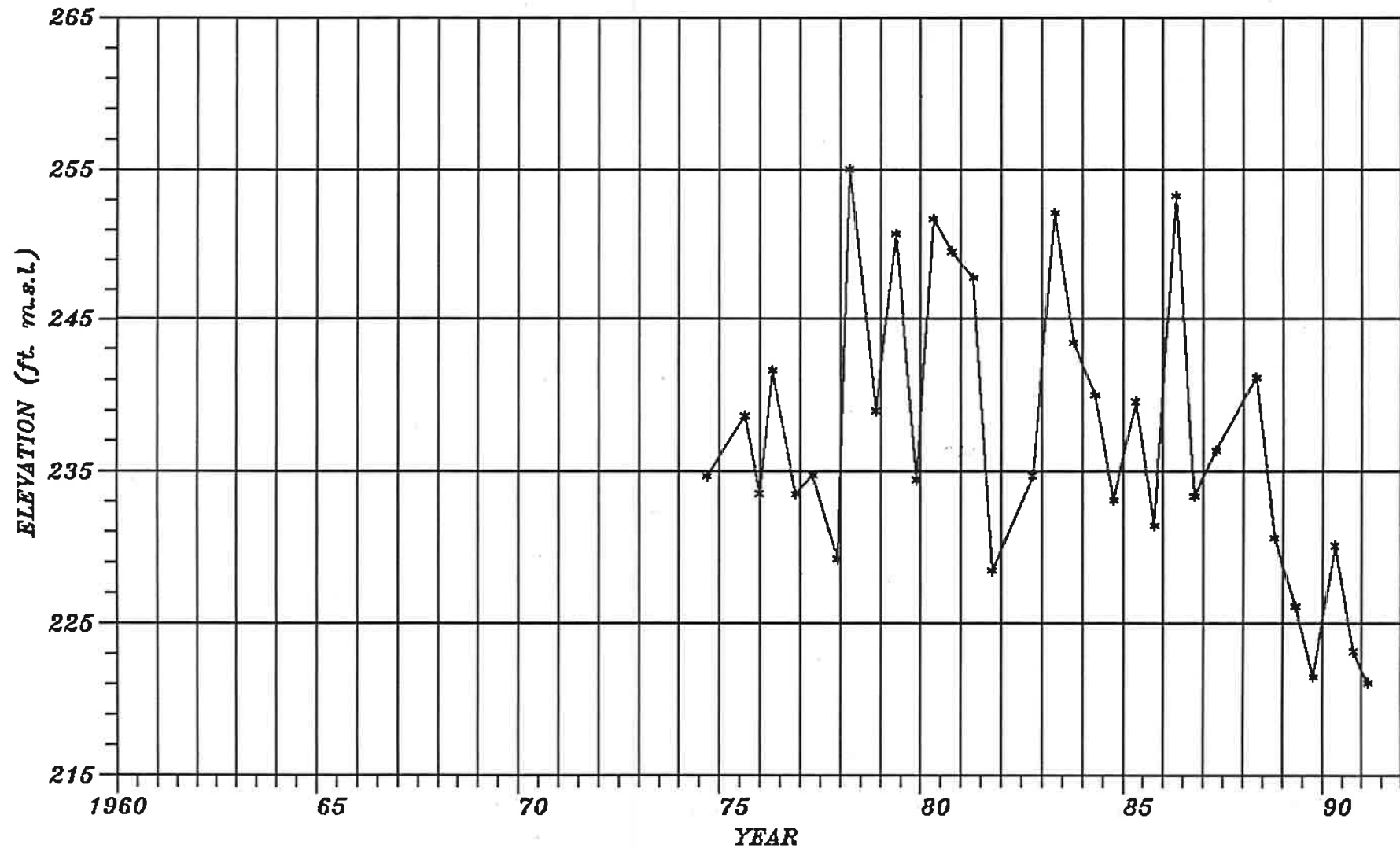
MWD WELL NO.: 1-7 (Deep Observation Well)
STATE WELL NO.: 4N/26W-7R1
G.S. ELEV.: 276.15 ft. a.m.s.l
TOTAL DEPTH: 630 ft.
PERFORATIONS: 590-610 ft.



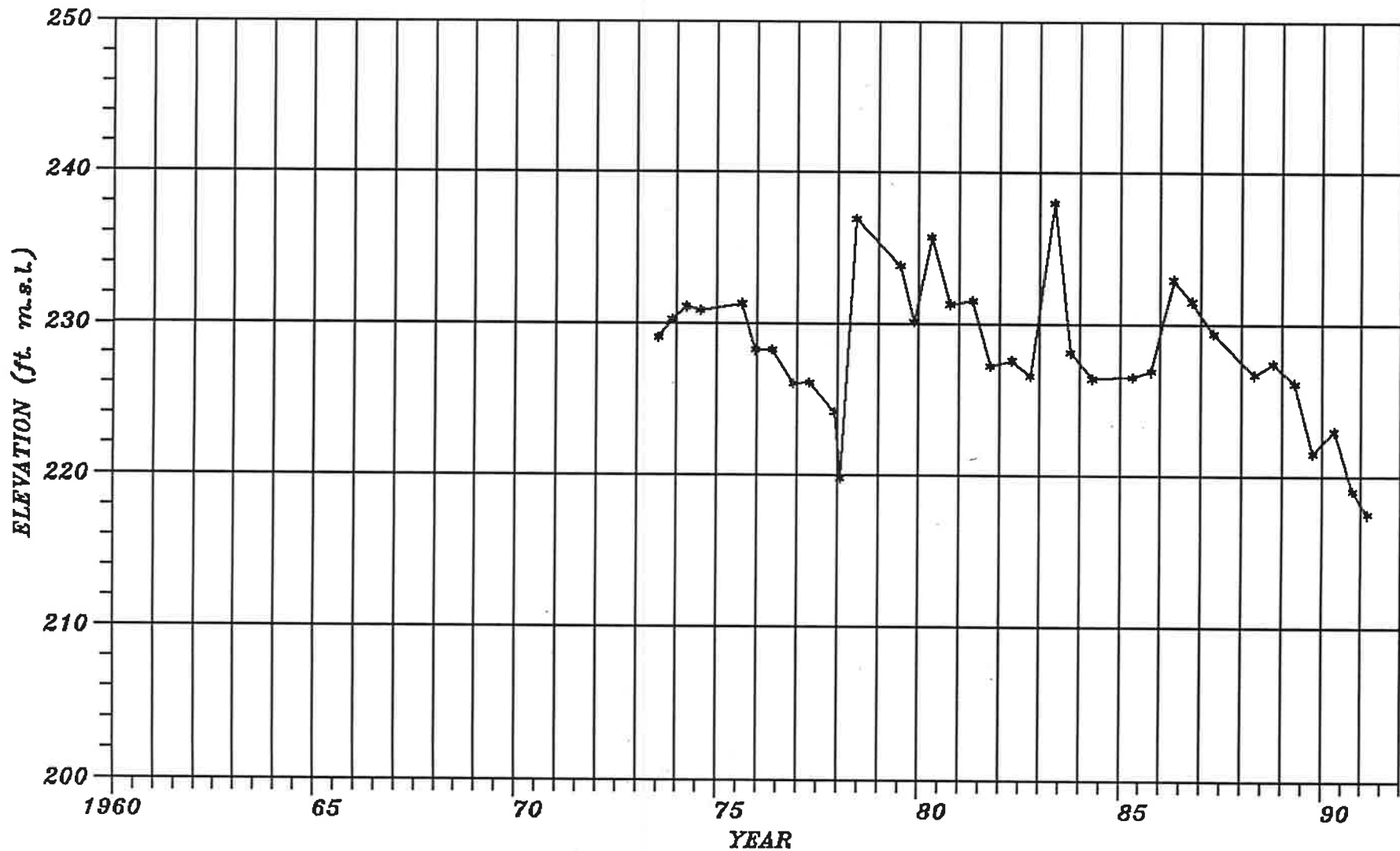
MWD WELL NO.: 1-8 (Shallow Observation Well)
STATE WELL NO.: 4N/26W-7R2
G.S. ELEV.: 276.15 ft. a.m.s.l.
TOTAL DEPTH: 250 ft.
PERFORATIONS: 210-230 ft.



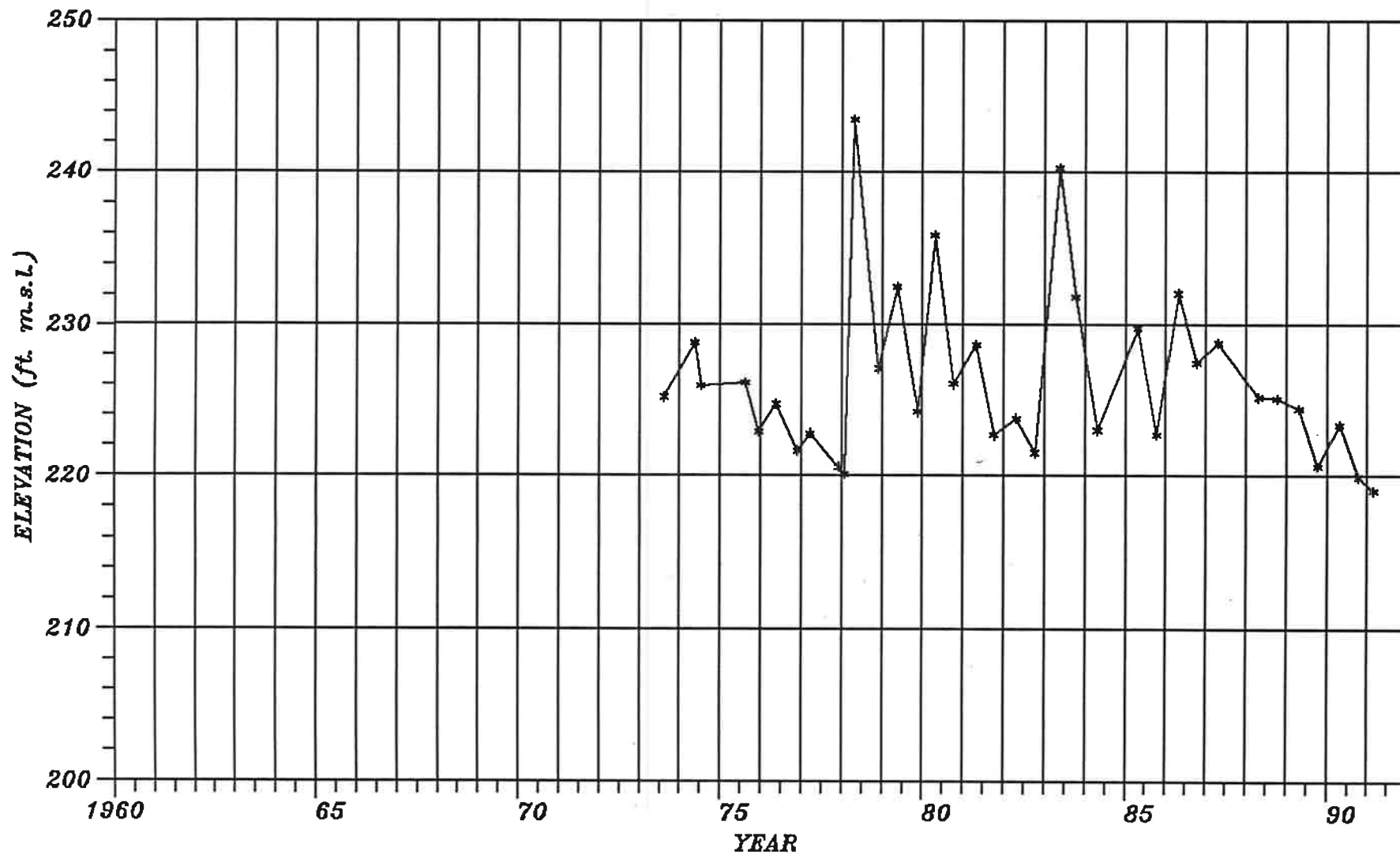
MWD WELL NO.: 1-9 (Valley Club Golf Course)
STATE WELL NO.: 4N/26W-15D2
G.S. ELEV.: 255 ft. a.m.s.l.
TOTAL DEPTH: 270 ft.
PERFORATIONS: N.D.



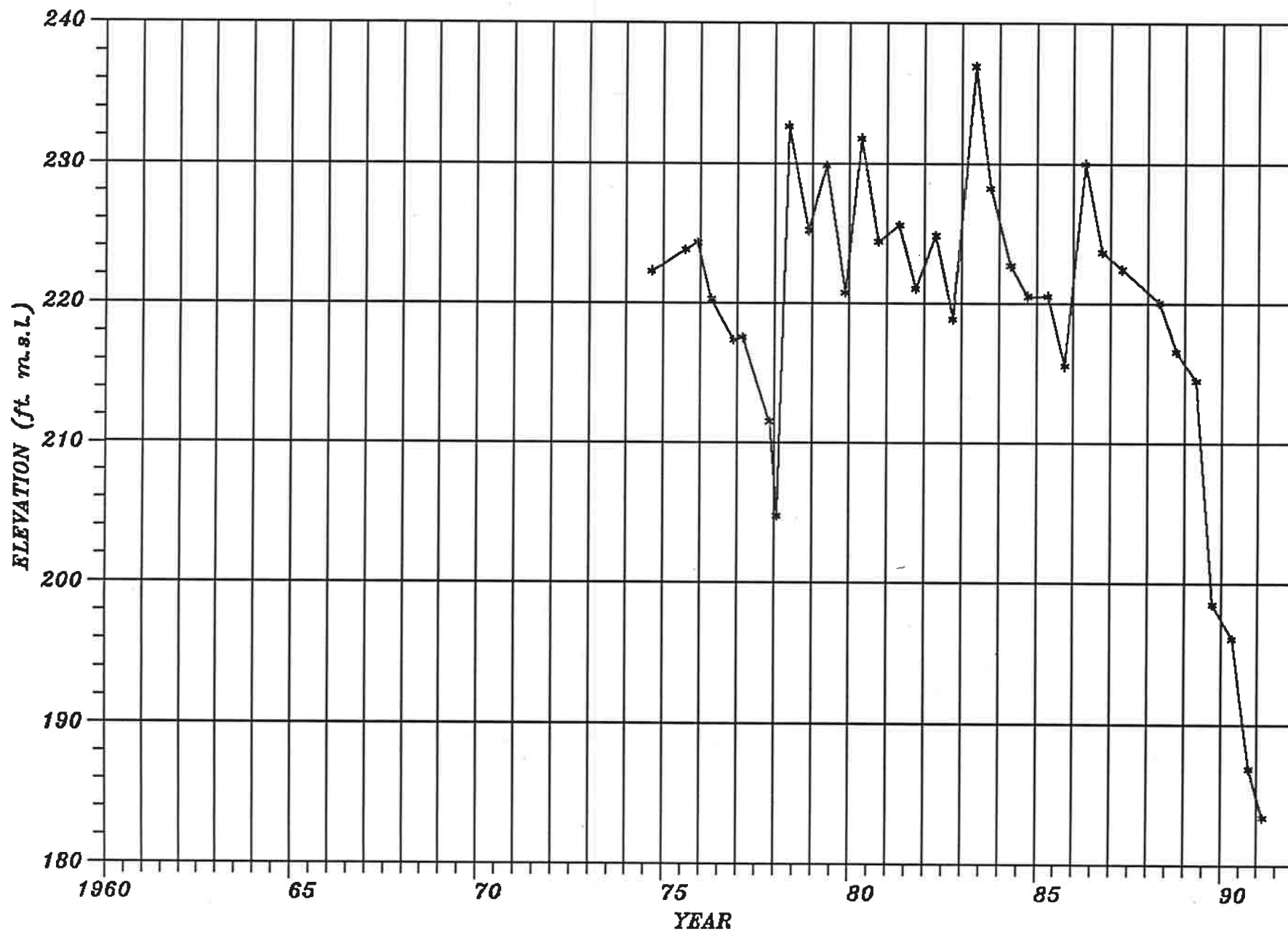
MWD WELL NO.: 1-10 (Deeper Observation Well)
STATE WELL NO.: 4N/26W-9Q1
G.S. ELEV.: 250 ft. a.m.s.l.
TOTAL DEPTH: 285 ft.
PERFORATIONS: 255-275 ft.



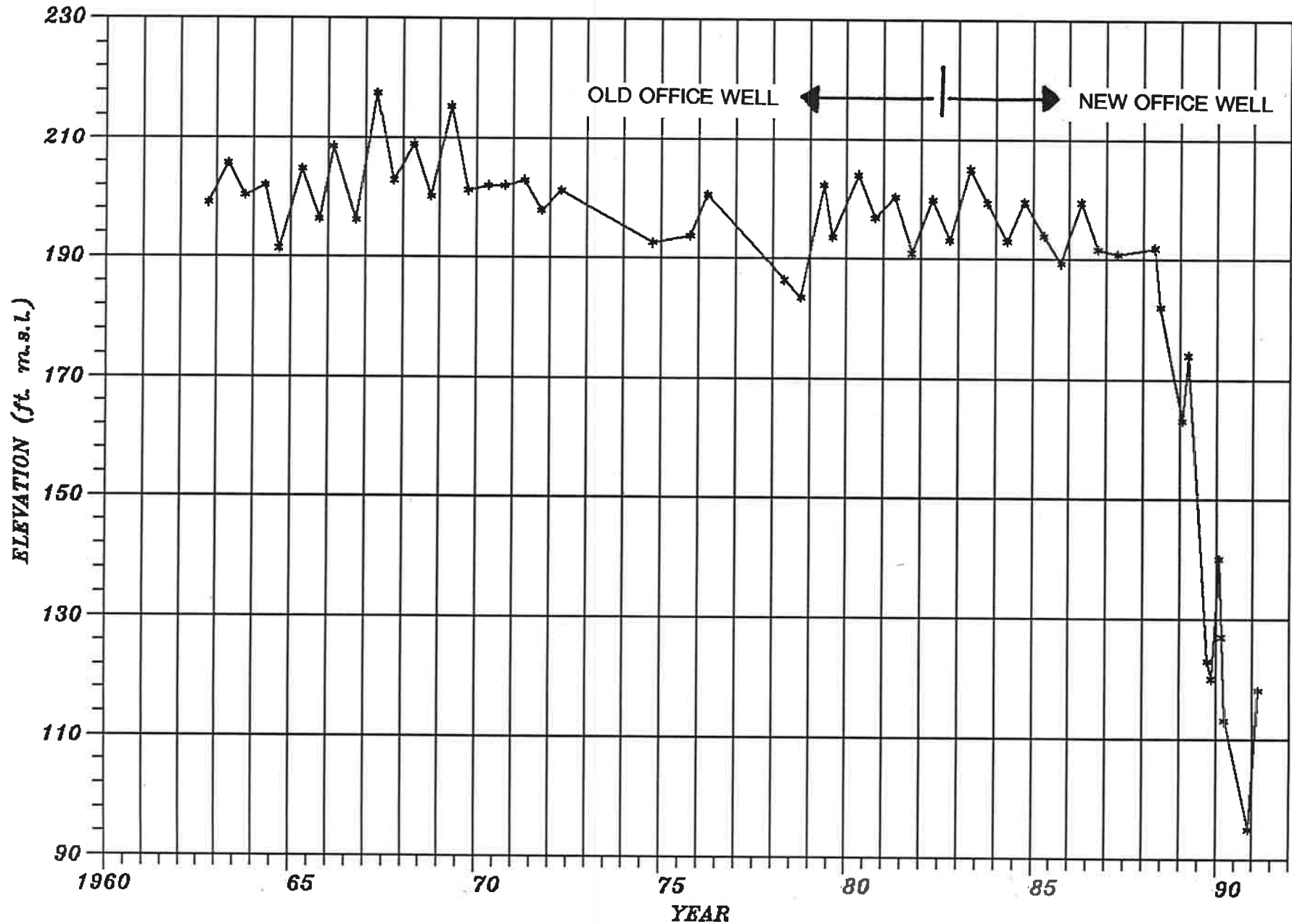
MWD WELL NO.: 1-11 (Shallow Observation Well)
STATE WELL NO.: 4N/26W-9Q2
G.S. ELEV.: 250 ft a.m.s.l
TOTAL DEPTH: 105 ft
PERFORATIONS: 80-100 ft



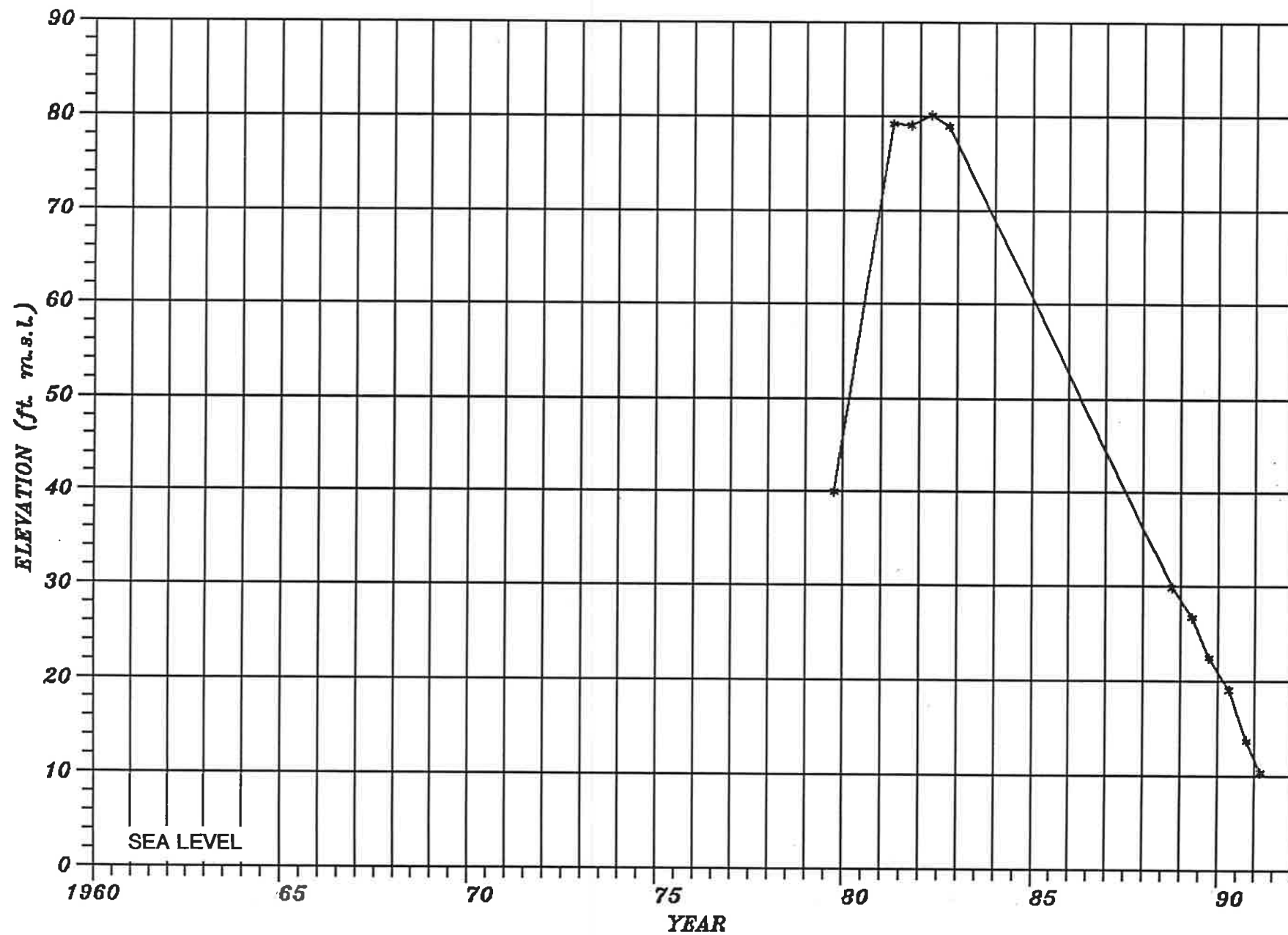
MWD WELL NO.: 1-13
STATE WELL NO.: 4N/26W-9P1
G.S. ELEV.: 245 ft a.m.s.l
TOTAL DEPTH: 240 ft
PERFORATIONS: 60-240 ft



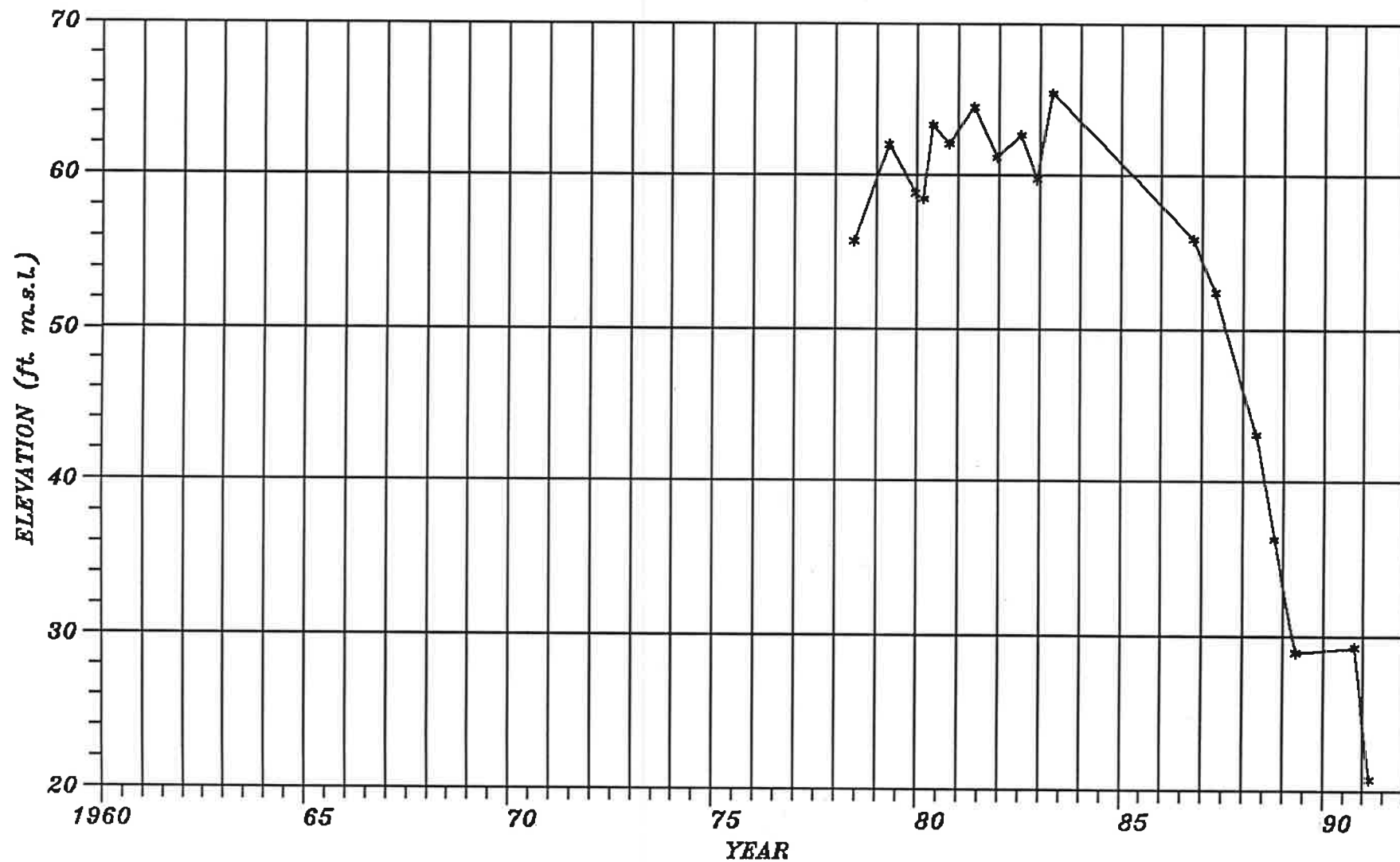
MWD WELL NO.: 1-19 (Office Well)
STATE WELL NO.: 4N/26W-8P3
G.S. ELEV.: 220 ft. a.m.s.l.
TOTAL DEPTH: 404 ft. (Old Well) 400 ft. (New Well)
PERFORATIONS: 140-404 (Old Well) 150-390 ft. (New Well)



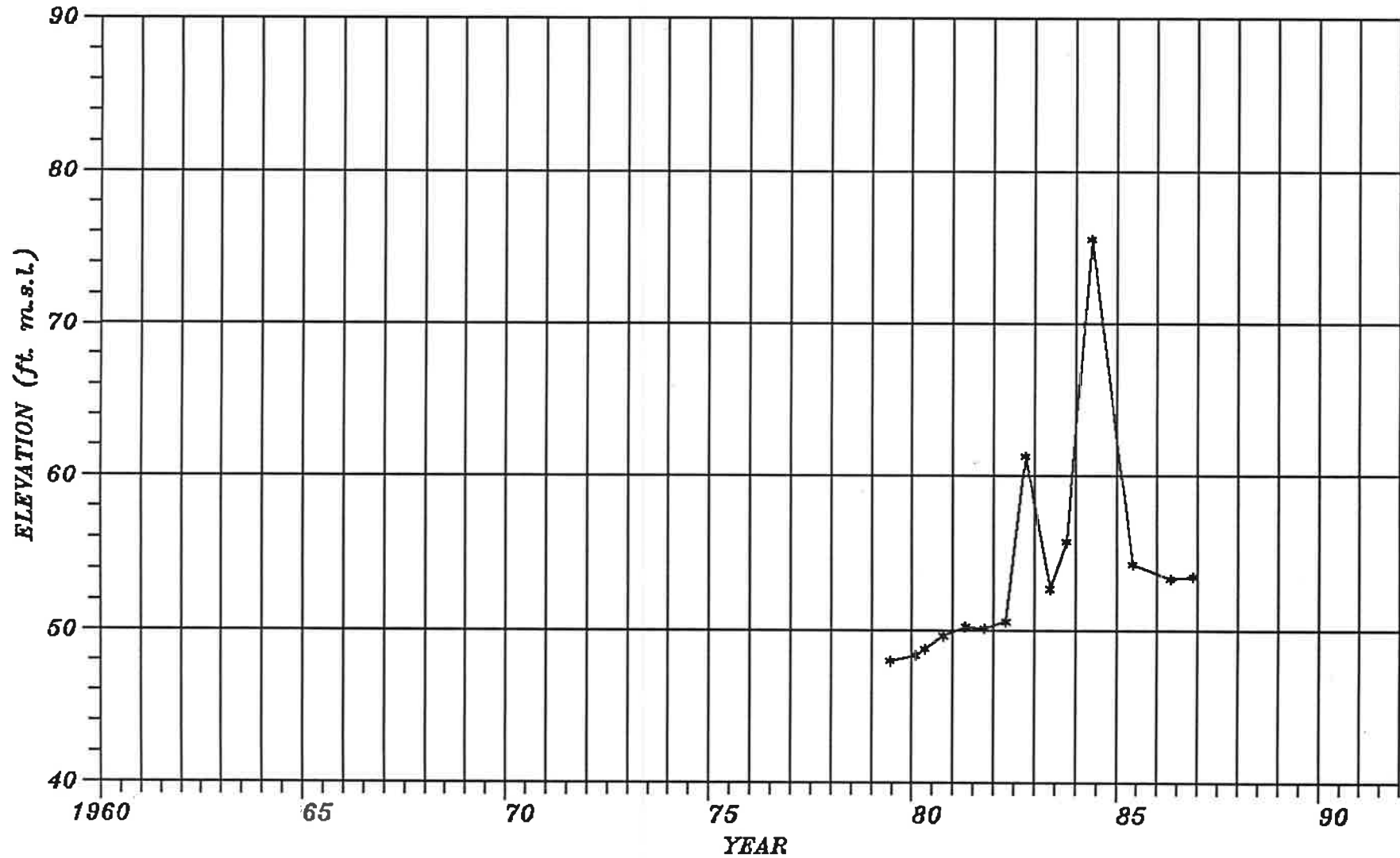
MWD WELL NO.: 2-1
STATE WELL NO.: 4N/26W-17E1
G.S. ELEV.: 100 ft a.m.s.l
TOTAL DEPTH: N.D.
PERFORATIONS: N.D.



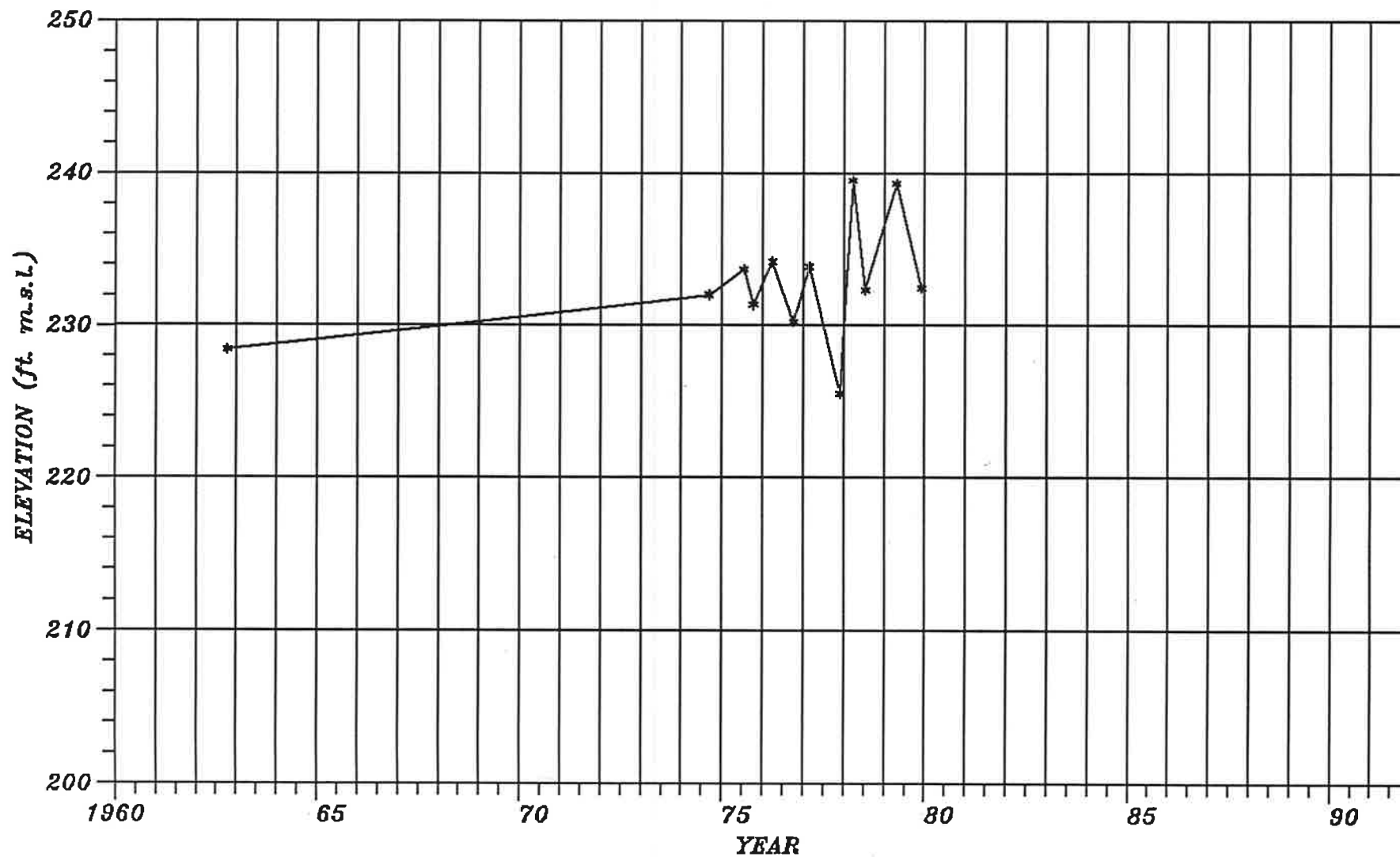
MWD WELL NO.: 2-4
STATE WELL NO.: 4N/26W-17G5
G.S. ELEV.: 154.47 ft a.m.s.l
TOTAL DEPTH: 230 ft
PERFORATIONS: 140-160 ft



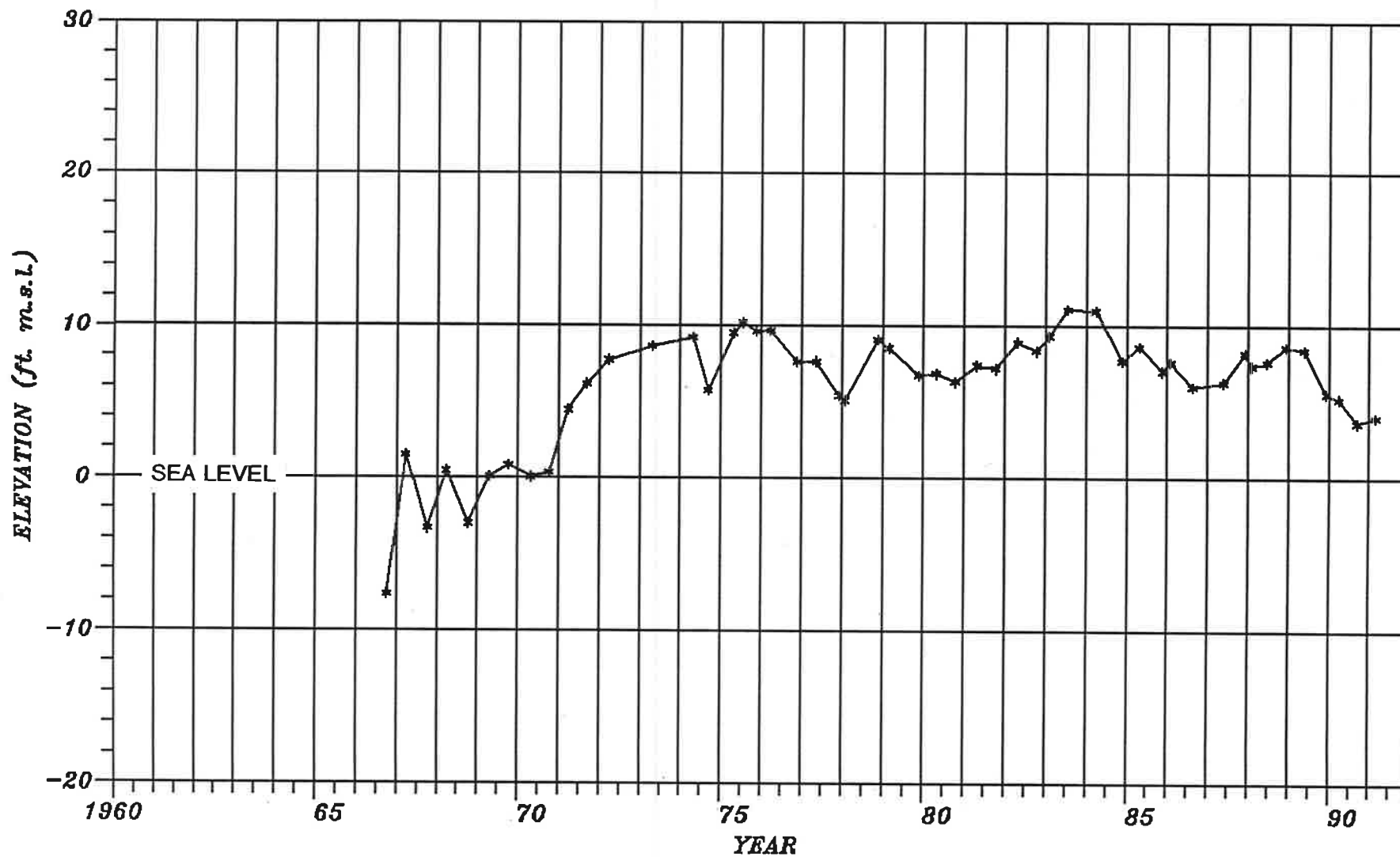
MWD WELL NO.: --- (in S.U.No.2)
STATE WELL NO.: 4N/26W-17E2
G.S. ELEV.: 135 ft. a.m.s.l
TOTAL DEPTH: N.D.
PERFORATIONS: N.D.



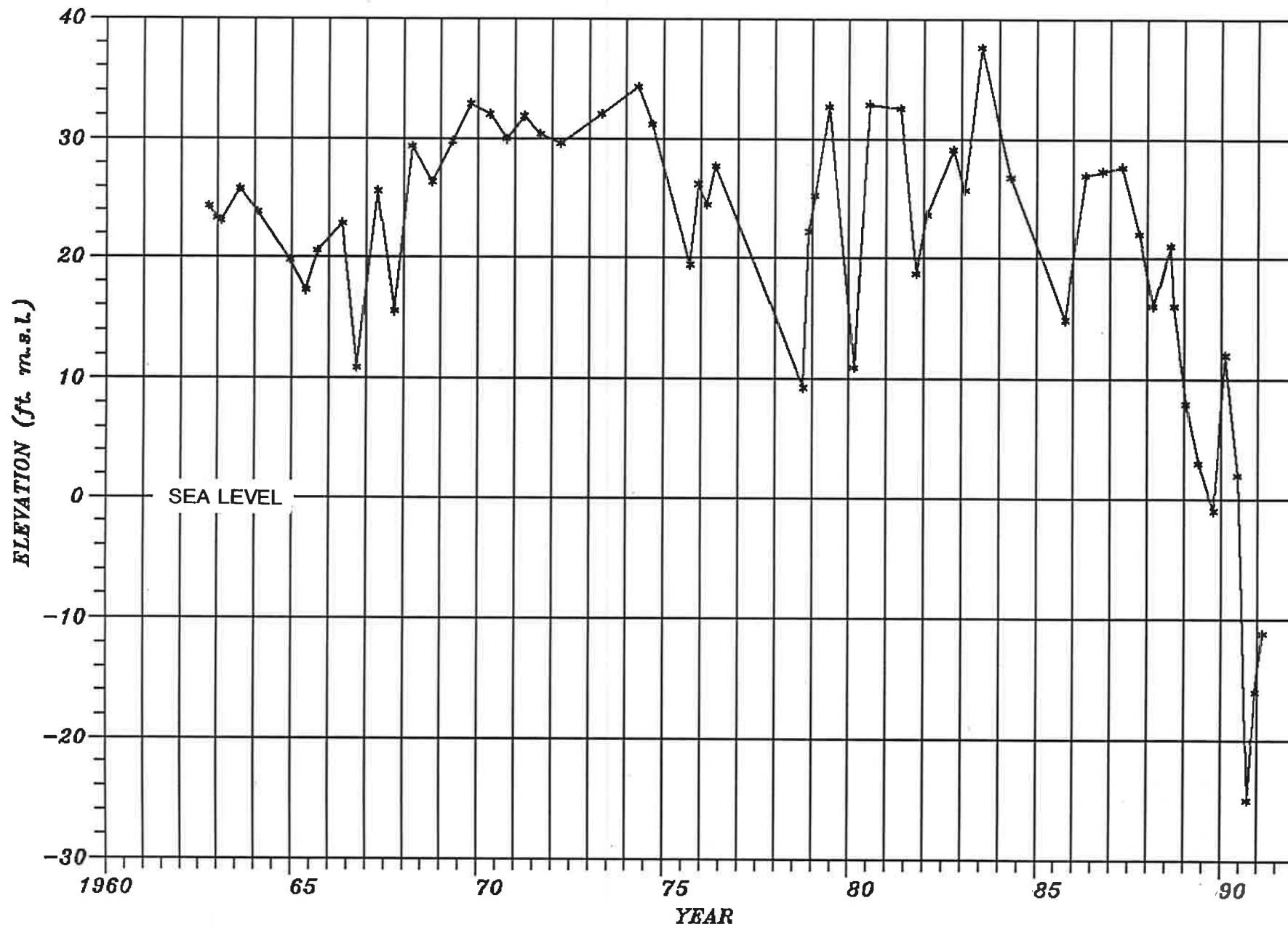
MWD WELL NO.: ---- (in S.U.No.2)
STATE WELL NO.: 4N/26W-18B1
G.S. ELEV.: 245 ft. a.m.s.l
TOTAL DEPTH: 303 ft.
PERFORATIONS: 153-300 ft.



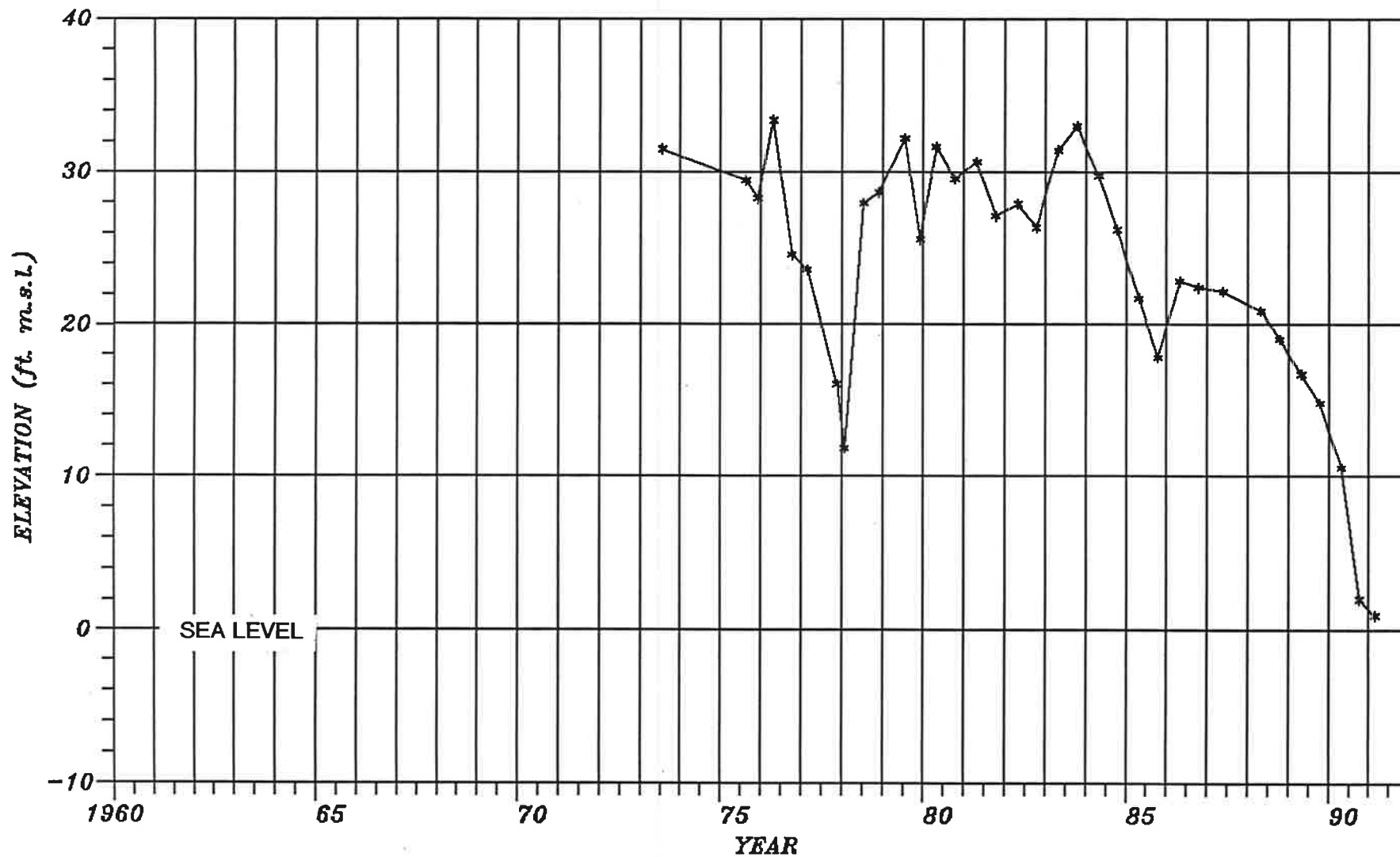
MWD WELL NO.: 9-5 (S.B. Cemetary Well)
STATE WELL NO.: 4N/27W-13R1
G.S. ELEV.: 98.63 ft a.m.s.l
TOTAL DEPTH: 540 ft
PERFORATIONS: 255-540 ft



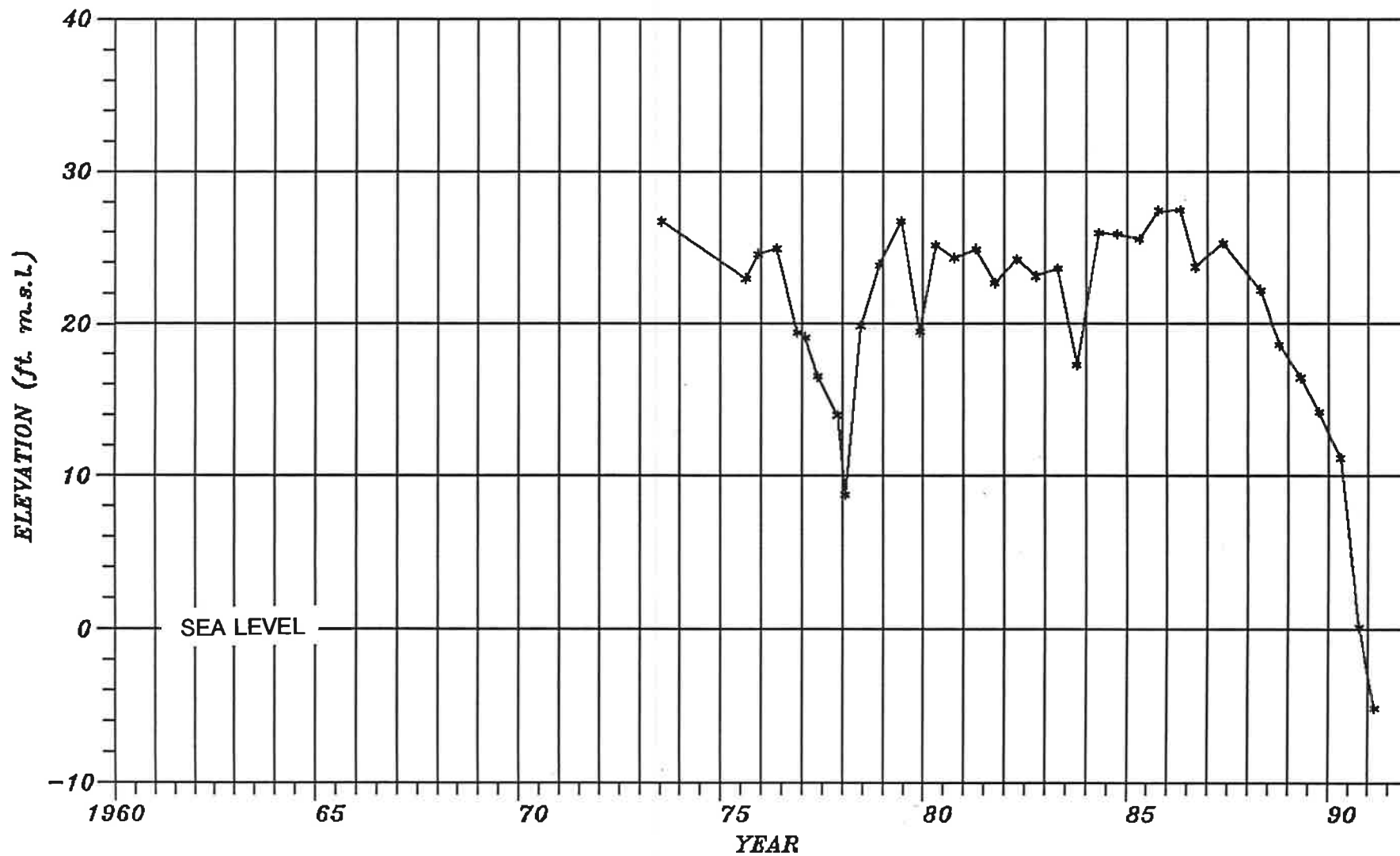
MWD WELL NO.: 3-8 (Neal Well)
STATE WELL NO.: 4N/26W-17N1
G.S. ELEV.: 104 ft. a.m.s.l
TOTAL DEPTH: 684 ft.
PERFORATIONS: 192-684 ft.



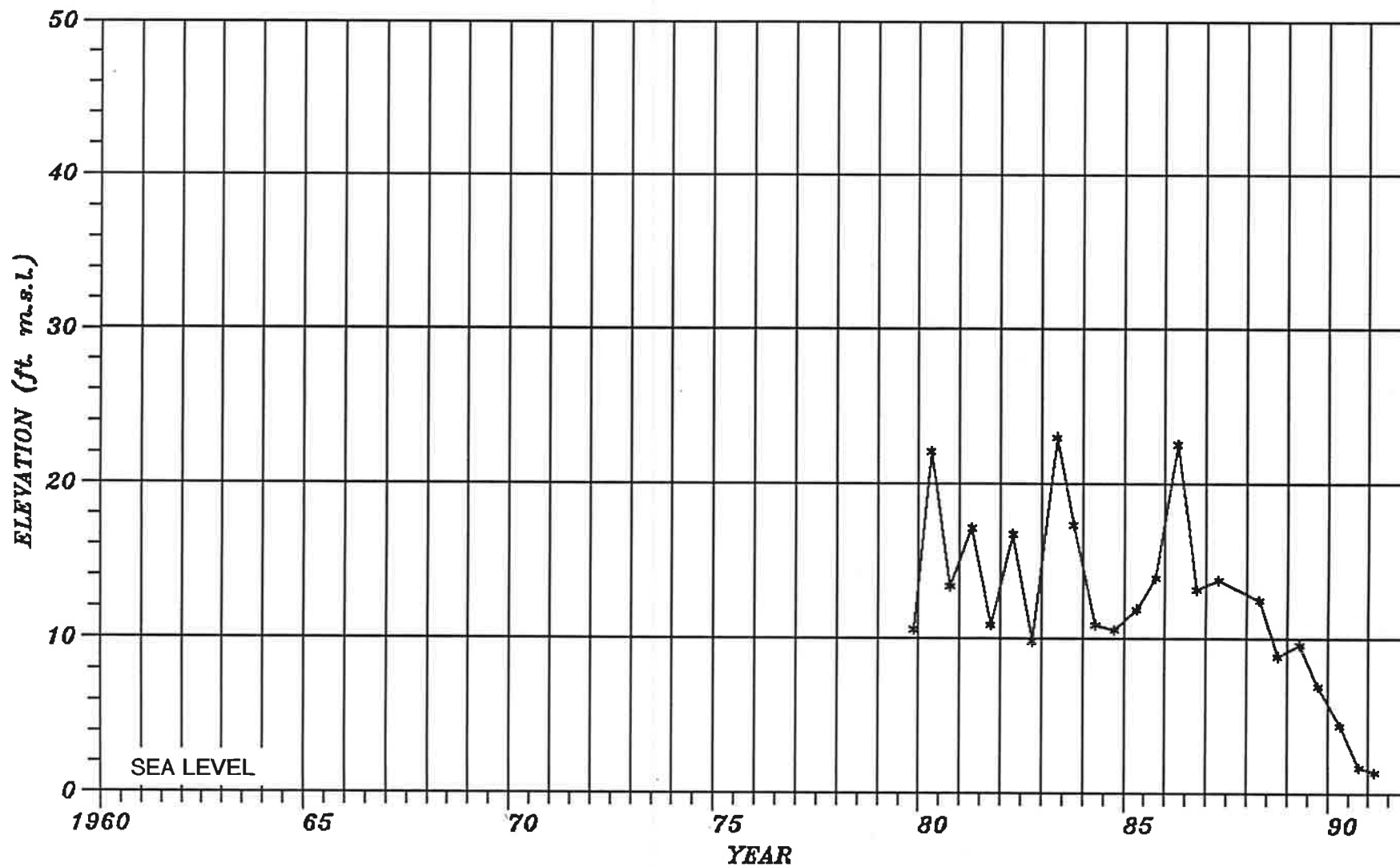
MWD WELL NO.: 3-10 (Shallow Observation Well)
STATE WELL NO.: 4N/26W-17K2
G.S. ELEV.: 86.42 ft. a.m.s.l.
TOTAL DEPTH: 325 ft.
PERFORATIONS: 295-315 ft.



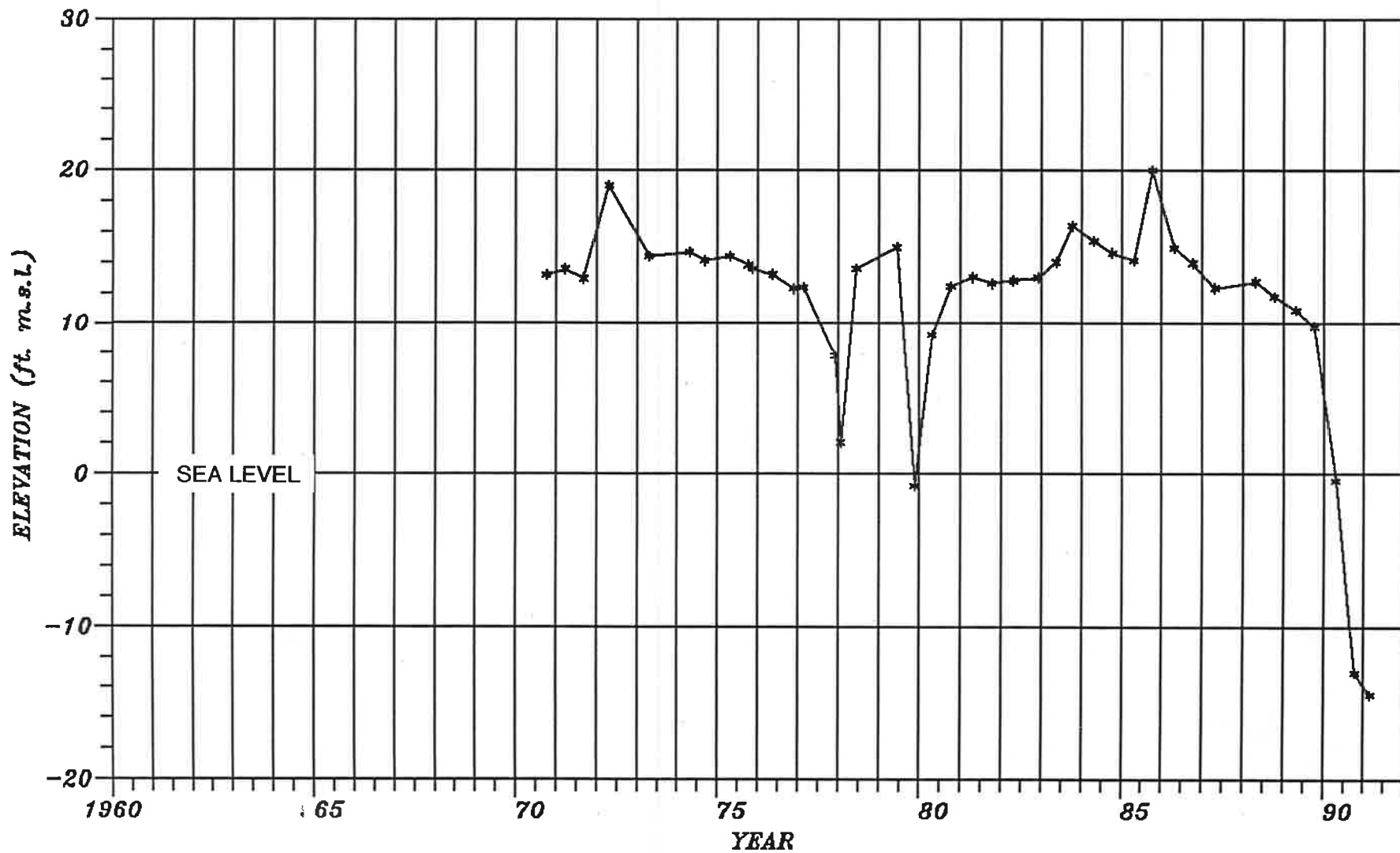
MWD WELL NO.: 3-11 (Deep Observation Well)
STATE WELL NO.: 4N/26W-17K1
G.S. ELEV.: 86.42 ft a.m.s.l.
TOTAL DEPTH: 810 ft.
PERFORATIONS: 750-790 ft.



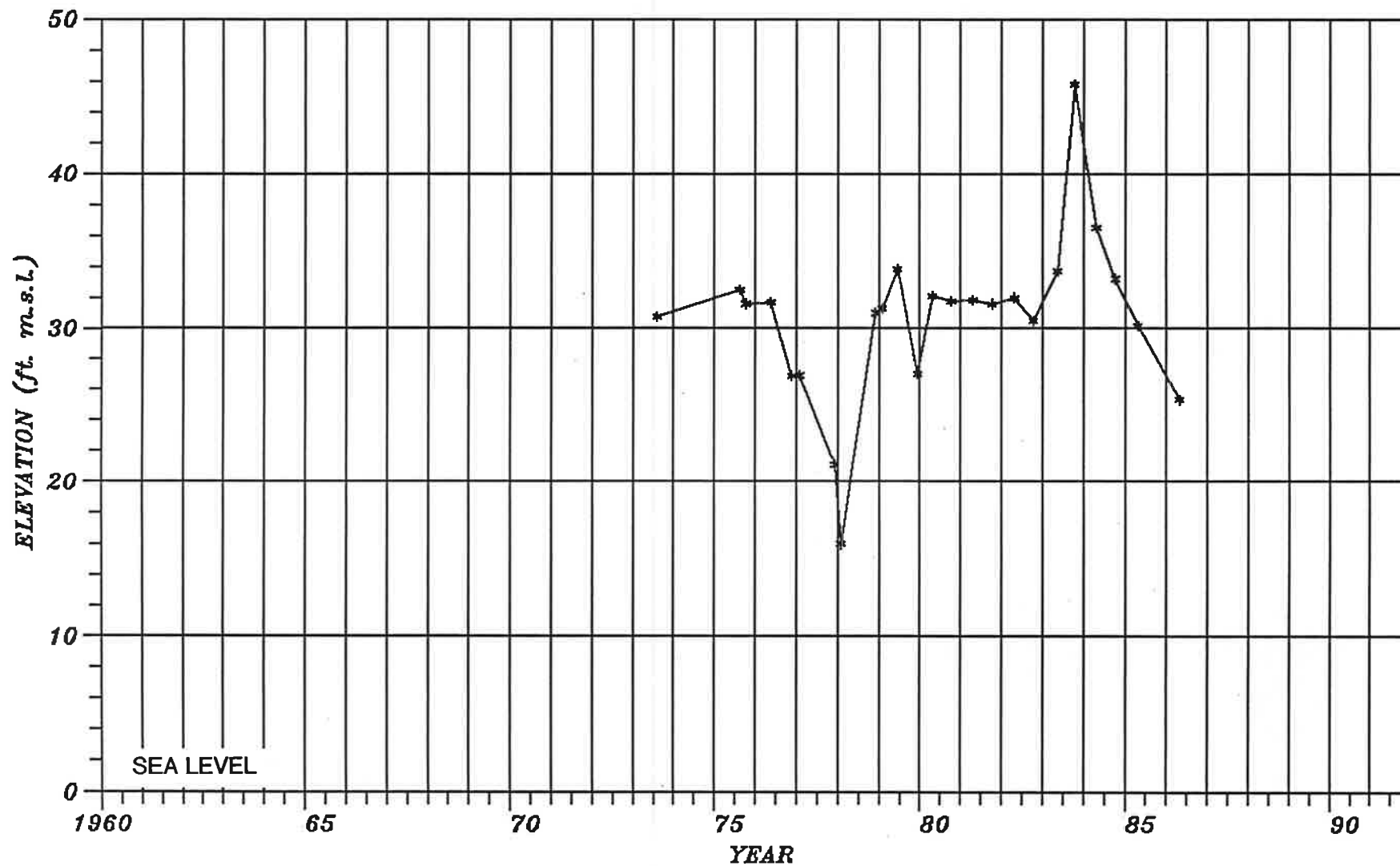
MWD WELL NO.: 3-14
STATE WELL NO.: 4N/26W-17Q3
C.S. ELEV.: 55 ft. a.m.s.l
TOTAL DEPTH: 185 ft.
PERFORATIONS: 82-140 ft.



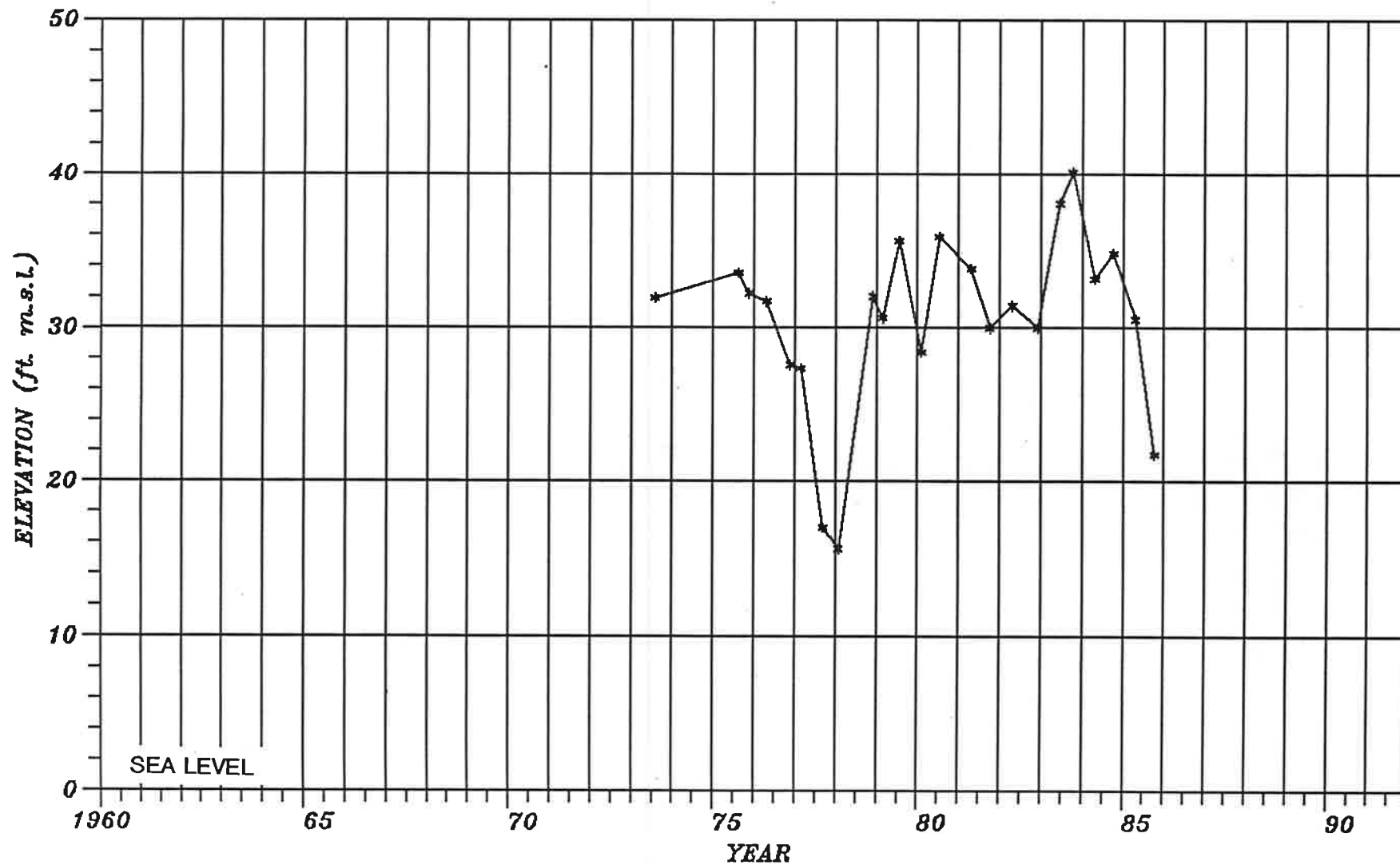
MWD WELL NO.: 9-15
STATE WELL NO.: 4N/26W-16N1
G.S. ELEV.: 55.23 ft. a.m.s.l.
TOTAL DEPTH: 124 ft.
PERFORATIONS: 82-124 ft.



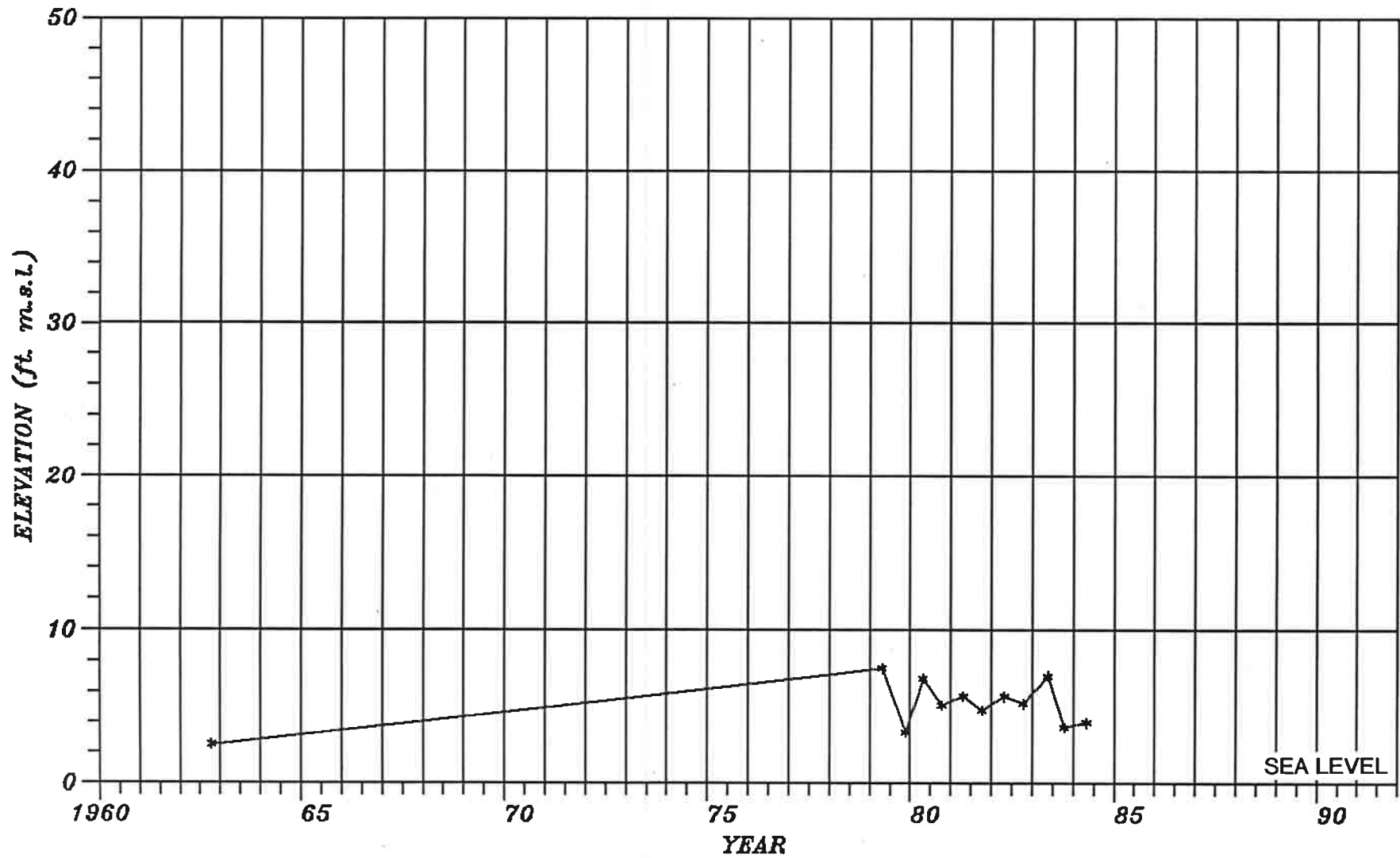
MWD WELL NO.: --- (in S.U.No.3, Deep Observation Well)
STATE WELL NO.: 4N/26W-16M1
G.S. ELEV.: 75 ft. a.m.s.l.
TOTAL DEPTH: 845 ft.
PERFORATIONS: 625-645 ft.



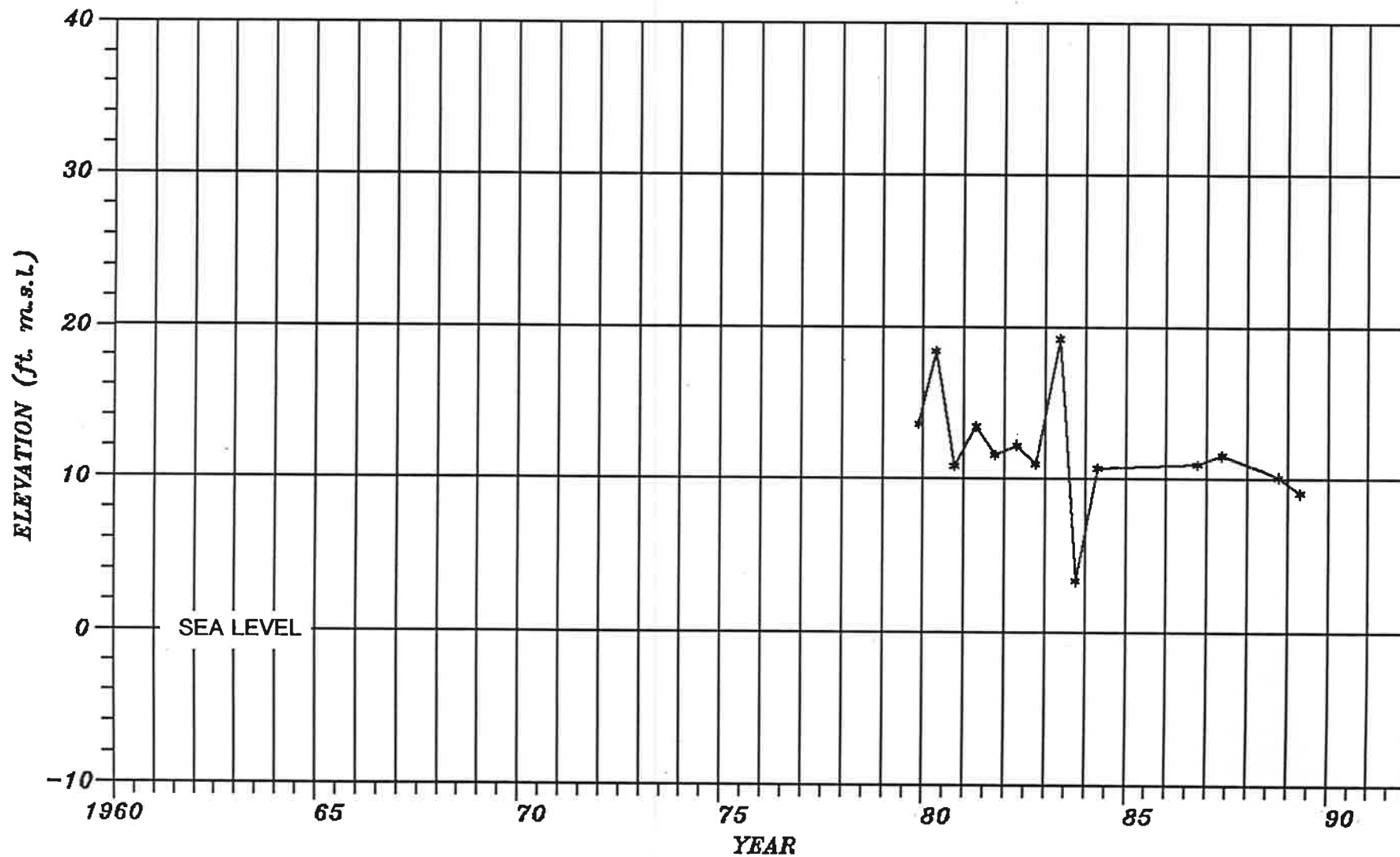
MWD WELL NO.: --- (in S.U.No.3, Shallow Observation Well)
STATE WELL NO.: 4N/26W-16M2
G.S. ELEV.: 75 ft. a.m.s.l.
TOTAL DEPTH: 240 ft.
PERFORATIONS: 220-240 ft.



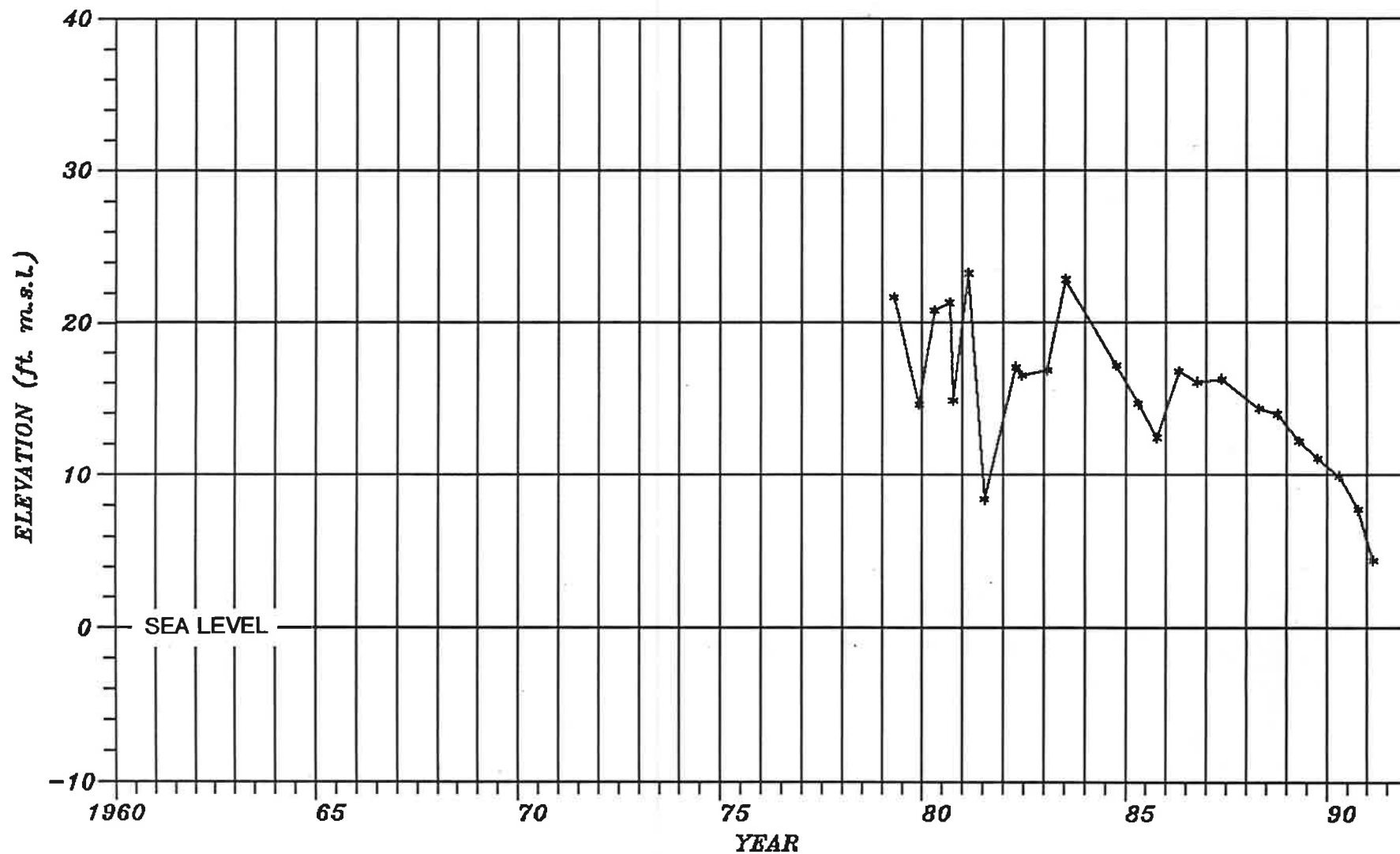
MWD WELL NO.: --- (in S.U.No.3)
STATE WELL NO.: 4N/26W-20C2
G.S. ELEV.: 15.81 ft. a.m.s.l
TOTAL DEPTH: N.D.
PERFORATIONS: N.D.



MWD WELL NO.: 4-1
STATE WELL NO.: 4N/26W-23G3
G.S. ELEV.: 39.28 ft a.m.s.l
TOTAL DEPTH: 200 ft
PERFORATIONS: 140-200 ft



MWD WELL NO.: 4-2 (Edgewood No.2)
STATE WELL NO.: 4N/26W-23F6
G.S. ELEV.: 65.24 ft. a.m.s.l.
TOTAL DEPTH: 400 ft.
PERFORATIONS: 130-170 ft.



MWD WELL NO.: ---- (CCWD - Zangger Well)
STATE WELL NO.: 4N/26W-23A2
G.S. ELEV.: 63 ft. a.m.s.l.
TOTAL DEPTH: N.D.
PERFORATIONS: N.D.

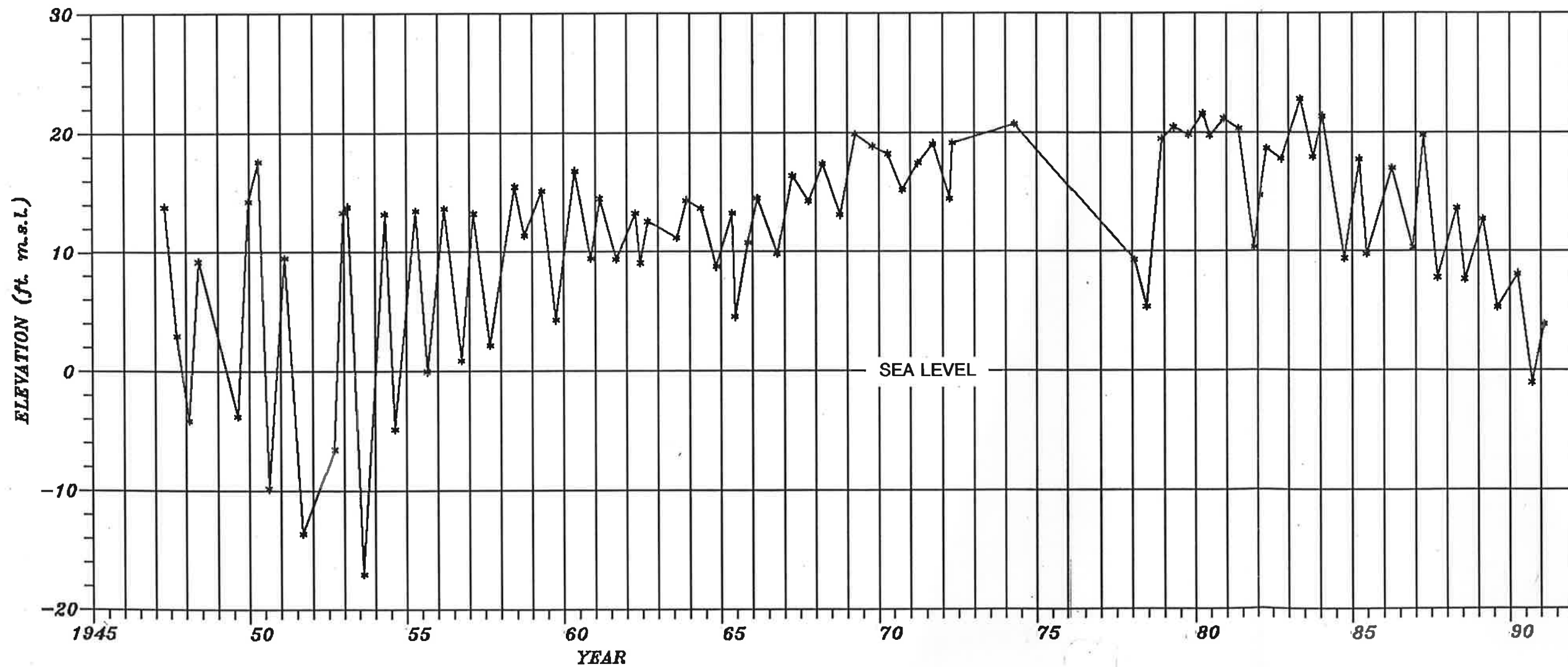


Plate 1 - Storage Units within Montecito Groundwater Basin - too big to scan
Plates 2-4 missing



RICHARD C. SLADE
CONSULTING GROUNDWATER GEOLOGIST

4960 BELLAIRE AVENUE
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(818) 508-0418

ADDENDUM TO
APRIL 1991 HYDROGEOLOGIC ASSESSMENT
DETERMINATION OF GROUNDWATER IN STORAGE
IN AUGUST 1991
WITHIN THE MONTECITO WATER DISTRICT
For
MONTECITO WATER DISTRICT

Our Job S8410-Sa

October 1991



INTRODUCTION

In early October 1991, the Montecito Water District requested an updated determination of a "current" groundwater in storage within the four groundwater storage units comprising the Montecito Water District. The stated purpose of this current storage determination is to assess the effects of the heavy rains in March 1991 on the amount of groundwater in storage. Water level measurement data for this update were collected by District personnel in August 1991.

FINDINGS

Table 1 - Calculations for Usable Groundwater in Storage, August 1991 vs Feb/Mar 1991 - has been prepared to show the calculations for usable groundwater in storage for August 1991 versus those done previously for February/March 1991 water level data. The definition of "usable" groundwater in storage for this report is the same as that used in our April 1991 report, and which is explained in detail in that report.

As seen on Table 1, only the columns titled "August 1991, Usable Thickness," "August 1991, Usable Groundwater in Storage," and "Increase in Storage" represent new calculations for this study. The remaining data on Table 1 are taken verbatim from the April 1991 report (Table 2 in that report). To help assess the recent water level data, we prepared a groundwater elevation contour map (not presented herein) using the August 1991 water level data provided by the District.



Review of Table 1 data reveals that changes in storage for the twenty individual storage subunits in the District range from no change to increases of up to about 350 acre-feet (AF). The majority of the subunit increases are less than 75 AF.

Table 2 - Summary of Usable Groundwater in Storage - has been prepared to summarize the volumes of usable groundwater in storage that we have calculated for this study and for the April 1991 study. Maximum usable storage (Spring 1983) and February/March 1991 storage amounts shown on this table are taken verbatim from the April 1991 report (Table 3 in that report).

As shown on Table 2 herein, the August 1991 data result in a significant storage increase in Storage Unit No. 1, a much smaller increase in Storage Unit No. 3, and very little increase in both Storage Unit No. 2 and the Toro Canyon Storage Unit.

A comparison of the August 1991 groundwater in storage calculations to those for February/March 1991 (just prior to the heavy March rains) shows the following:

- Total usable groundwater in storage for all four storage units is 8720 AF for August 1991 water levels, and 7760 AF for February/March 1991 water levels.
- The +960 AF difference between the August 1991 (8720 AF) and February/March 1991 (7760 AF) storage values represent a 12 percent increase in the total usable groundwater in storage in the four storage units during that period of time.
- Approximately 80 percent of the total increase in storage that resulted in the four storage units occurred in Storage Unit No. 1. In this storage unit, usable groundwater in storage increased by about 27 percent between the two water level periods, likely as a result of the heavy March 1991 rains.



- An additional 17 percent of the total increase in storage that resulted in the four storage units occurred in Storage Unit No. 3. In this storage unit, usable groundwater in storage increased by about four percent between the two water level periods.
- Storage Unit No. 2 accounted for 2 percent of the total increase in storage. In this storage unit, usable groundwater in storage increased by about 21 percent, an apparently high percentage but still representing a relatively small volumetric increase.
- Approximately 1 percent of the total increase in District-wide storage occurred in the Toro Canyon Storage Unit. Groundwater in storage in this storage unit increased by about 1 percent.

CONCLUSIONS

For the August 1991 data compared to those for February/March 1991, the majority of the recent increase in groundwater in storage occurred in Storage Unit No. 1, with much less increase in Storage Unit No. 3, and very little volumetric increase in both Storage Unit No. 2 and Toro Canyon.

The total volumetric increase of 960 AF was principally due to the heavy rains in March 1991. Any reduction in groundwater extraction (as a result of the rains and decreased demand) can also contribute to an increase in storage and, thus, the total increase seen may not be entirely due to deep percolation of rainfall and surface water runoff.

The spring 1983 maximum usable groundwater in storage resulted from several months of above-average rainfall, not just a few weeks of intense rainfall as was seen in March 1991. As a result, much of the March 1991 rainfall likely did not percolate into the groundwater reservoir, but rather was lost from the basin via surface water runoff.



Addendum - Groundwater in Storage
Montecito Water District, April 1991

4

In addition, the August 1991 water level data resulted in a determination of groundwater in storage that likely is less than had the water levels been measured in May or June, before the start of summer. Typically, spring months in the basin generally show the highest water levels compared to other seasons of the year.

Respectfully submitted,

Mark Whitten
Mark Whitten, Geologist

Richard C. Slade
Richard C. Slade

Registered Professional Hydrogeologist

Attachments

Table 1 - CALCULATIONS FOR USABLE GROUNDWATER IN STORAGE, AUGUST 1991 vs FEBRUARY/MARCH 1991

Subunit	Usable Area (acres)	Average Specific Yield (%)	Feb/Mar 1991 Usable Thickness (feet)	Feb/Mar 1991 Usable Groundwater in Storage acre-feet	August 1991 Usable Thickness (feet)	August 1991 Usable Groundwater in Storage (feet)	Increase in Storage Feb. to August (acre-feet)
Storage Unit No. 1							
1A	373	3	25	280	25	280	0
1B	585	3	25	439	45	790	351
1C	190	3	25	142	37	211	69
1D	253	3	50	380	50	380	0
1E	461	3	80	1106	100	1383	277
1F	178	3	90	481	104	555	74
S. U. No. 1 Subtotals:	2040			2828		3599	771
Storage Unit No. 2							
2A	244	3	0	0	0	0	0
2B	244	3	10	73	12	88	15
S. U. No. 2 Subtotals:	488			73		88	15
Storage Unit No. 3							
3A	52	4	75	156	80	166	10
3B	95	4	50	190	51	194	4
3C	126	6	55	416	64	484	68
3D	151	3	101	458	106	480	22
3E	275	4	199	2189	201	2211	22
3F	75	6	22	99	25	112	13
3G	103	7	23	166	25	180	14
3H	66	7	3	14	4	18	4
3I	84	8	3	20	4	27	7
3J	13	9	0	0	0	0	0
S. U. No. 3 Subtotals:	1040			3708		3872	164
Toro Canyon							
TC-A	111	5	10	56	10	56	0
TC-B	236	5	93	1097	94	1109	12
Toro Canyon Subtotals:	347			1153		1165	12



Groundwater in Storage - Job S8410-Sa

Table 2
SUMMARY OF USABLE GROUNDWATER IN STORAGE

Storage Unit	Maximum Usable Groundwater in Storage ¹ (AF)	Feb/March 1991 Usable Groundwater in Storage ² (AF)	August 1991 Usable Groundwater in Storage (AF)
1	8,770 ³	2,830	3,600
2	730	70	90
3	4,990	3,710	3,870
Toro Canyon	1,620	1,150	1,160
Totals:	16,110	7,760	8,720

- 1) Maximum usable storage is for Spring 1983 water levels (highest on record).
- 2) February/March 1991 water levels are lowest on record (prior to March rains).
- 3) Storage values above have been rounded off in each case to the nearest 10 acre-feet.