Barry Hull

Half Moon Bay/Pillar Point Marsh Ground-Water Basin Report Phase II

Prepared for:
Citizens Utility Company of California
and
Coastside County Water District

Prepared by:
Luhdorff and Scalmanini
Consulting Engineers
and
Earth Sciences Associates

September, 1991

LSCE 87-1-074

LUHDORFF & SCALMANINI
Consulting Engineers

Eugene E. Luhdorff, Jr., P.E.
Joseph C. Scalmanini, P.E.

CITIZENS UTILITIES
OF CALIFORNIA

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October 28, 1991
File No. 87-1-074

Mr. Larry D'Addio
General Manager
Citizens Utilities Company of California
P. O. Box 15468
Sacramento, CA 95851

SUBJECT: **HALF MOON BAY AIRPORT/PILLAR POINT MARSH GROUND-WATER BASIN REPORT, PHASE II**

Dear Mr. D'Addio:

Transmitted herewith are five copies of the subject final report. The main conclusions of the study are that: 1) Pillar Point Marsh has not shown signs of plant stress despite the drought and current pumping conditions; 2) the continued drought and ground-water pumping have lowered ground-water levels in the area and have decreased ground-water storage; however, an upward ground-water gradient in the marsh and subsurface outflow to the marsh and harbor areas have continued; 3) pumpage away from the marsh could be increased by at least 45 acre-feet per year, and as much as 87 acre-feet; 4) ongoing ground-water basin management should include monitoring of ground-water levels and quality, particularly near the marsh, to maintain acceptable conditions as additional ground-water development occurs.

We would be happy to discuss the contents and conclusions of the report at your convenience.

Sincerely,

LUHDORFF AND SCALMANINI
CONSULTING ENGINEERS

J. Scalmanini

Joseph C. Scalmanini

JCS/rh

Enclosures

cc: E. Nelson, W. R. Hail, Earth Science Associates
cc: project file.

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Ground-Water Hydrology, Development and Management

HALF MOON BAY/PILLAR POINT MARSH

GROUND-WATER BASIN REPORT

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. EXECUTIVE SUMMARY

The Phase I study and report on the Half Moon Bay Airport/Pillar Point Marsh Ground-Water Basin was completed in June, 1987. That report determined the availability of data on ground water, surface water, and precipitation; and it identified wells with lithologic logs in and adjacent to the Basin. The Phase I data evaluation resulted in the following conclusions:

- the basin could apparently support additional pumpage without affecting the Pillar Point Marsh,
- the preliminary range of "safe yield" values was determined to be 650 to 1,300 acre-feet per year,
- new well development should be staged and combined with monitoring of ground-water responses to increased pumping, and
- the first stage of additional ground-water development should be restricted to approximately 150 acre-feet per year of additional pumpage.

As part of the Phase I report, a number of monitoring and data evaluation tasks were identified to determine a reliable estimate of the safe yield and to develop management practices required to use and protect the ground-water resources of the basin. Completion of these tasks in the second phase of the study was made a condition by the California Coastal Commission prior to the development of two new water supply wells by Citizens Utilities Company of California.

Phase II data collection activities were conducted following completion of the Phase I report through early 1991. Following completion of the biological assessment in May 1991, the Phase II analysis and interpretation of ground-water and biological conditions was performed to more reliably define the safe yield of the Basin, which as defined by the local Coastal Plan is "the amount of water that can be removed without adverse impacts on marsh health".

The Phase II evaluation of biological and ground-water conditions in the Half Moon Bay Airport/Pillar Point Marsh Basin has resulted in the following conclusions:

- no significant premature or unseasonal plant stress was observed in the wetland plant communities during the marsh monitoring period from December 1989 to April 1991;
- soil moisture levels in the marsh remained at levels sufficient to support seasonal hydric plants;
- general observations related to plant health and vigor suggest that significant impacts to the marsh attributable to the current level of pumping, even during the drought, have not occurred;
- an upward ground-water gradient still exists in the marsh despite current drought conditions;
- the continuing drought and ground-water pumping have lowered ground-water levels in the area and have decreased ground-water storage;
- despite the drought and pumping conditions, subsurface outflow to the Pillar Point Marsh and Harbor continued, but probably at lower rates than during non-drought conditions;
- the Basin has historically demonstrated the ability to recharge following periods of drought;
- ground-water pumpage is estimated to have averaged 436 acre-feet per year from 1987 to 1990;
- based on the ground-water budget developed for the Basin, pumping could be increased at least 45 acre-feet per year, and possibly up to 87 acre-feet per year, without causing adverse impacts to the marsh or inducing sea-water intrusion as long as that additional pumping is maintained reasonably distant from the marsh.
- basin management should include attention to the location of any increased pumping, ongoing monitoring and analysis of ground-water conditions, and

development of contingency plans to manage pumping during drought conditions; pumping should continue to be managed such that outflow is maintained to the marsh and harbor areas, and upward gradients are maintained in the marsh.

II. INTRODUCTION

2.1 Purpose and Scope

The Phase II Study was performed for Citizens Utilities Company of California (CUCC) and Coastside County Water District (CCWD) jointly by Luhdorff and Scalmanini, Consulting Engineers (LSCE) and Earth Sciences Associates (ESA). Completion of a study of the Half Moon Bay Airport/Pillar Point Marsh Ground-Water Basin (the Denniston Creek Sub-basin of the Half Moon Bay Aquifer) was made a condition by the California Coastal Commission prior to CUCC's development of two new production wells (Permit No. CDP 85-59, Condition No. 7).

The purpose of the overall study, as specified in Condition 7(a) of CDP 85-59, is to determine the safe yield of this basin. Safe yield is defined in the San Mateo County Local Coastal Plan as "the amount of water that can be removed without adverse impacts on marsh health" (LCP), Section 7.20.b). In addition, Section 2.32.c of the Local Coastal Plan requires that the amount of water pumped from new wells operated by municipal utilities located in the basin "be limited to a safe yield factor which will not impact water-dependent sensitive habitats, riparian habitats and marshes."

To meet these conditions requires definition of the best development and management practices to optimize ground-water usage, while protecting the water supply to the Pillar Point Marsh and the aquifer system against sea-water intrusion. Thus, the yield of the basin is defined by not only the natural ability of the basin to recharge, store, and transmit ground water, but also by how the resource is developed and managed in order to achieve the goals of providing municipal/domestic water supplies, protection of the marsh, and prevention of overdraft and sea-water intrusion. These goals can be considered compatible because maintaining the fresh-water portion of the marsh will cause ground-water levels to be maintained sufficiently high to limit or prevent significant sea-water intrusion, which in turn assures a more reliable and long-term ground-water supply.

At the outset, it was recognized that the availability of sufficient data upon which to base a reliable estimate of yield was questionable. Consequently, the study was divided into two phases:

1. Review and evaluation of available data in order to determine appropriate methodology for defining the basin yield.

2. Collection of additional data as necessary for estimation of yield and development of management practices required to use and protect the ground-water resources.

The Phase I Report was completed in June 1987 and recommended monitoring and analysis in Phase II, including a continuation of current water-level and water-quality monitoring as well as the following components:

1. Completion of multiple well pumping tests to determine aquifer transmissivities and storage coefficients.

2. Installation of continuous water-level recorders in observation wells, prior to nearby well testing, to determine any barometric and tidal effects.

3. Development of ground-water level contour maps to estimate storage changes.

4. Establishment of a monitoring program to evaluate ground-water conditions in Pillar Point Marsh.

5. Survey of Denniston Creek for locating stream-gauging sites to define stream losses to infiltration.

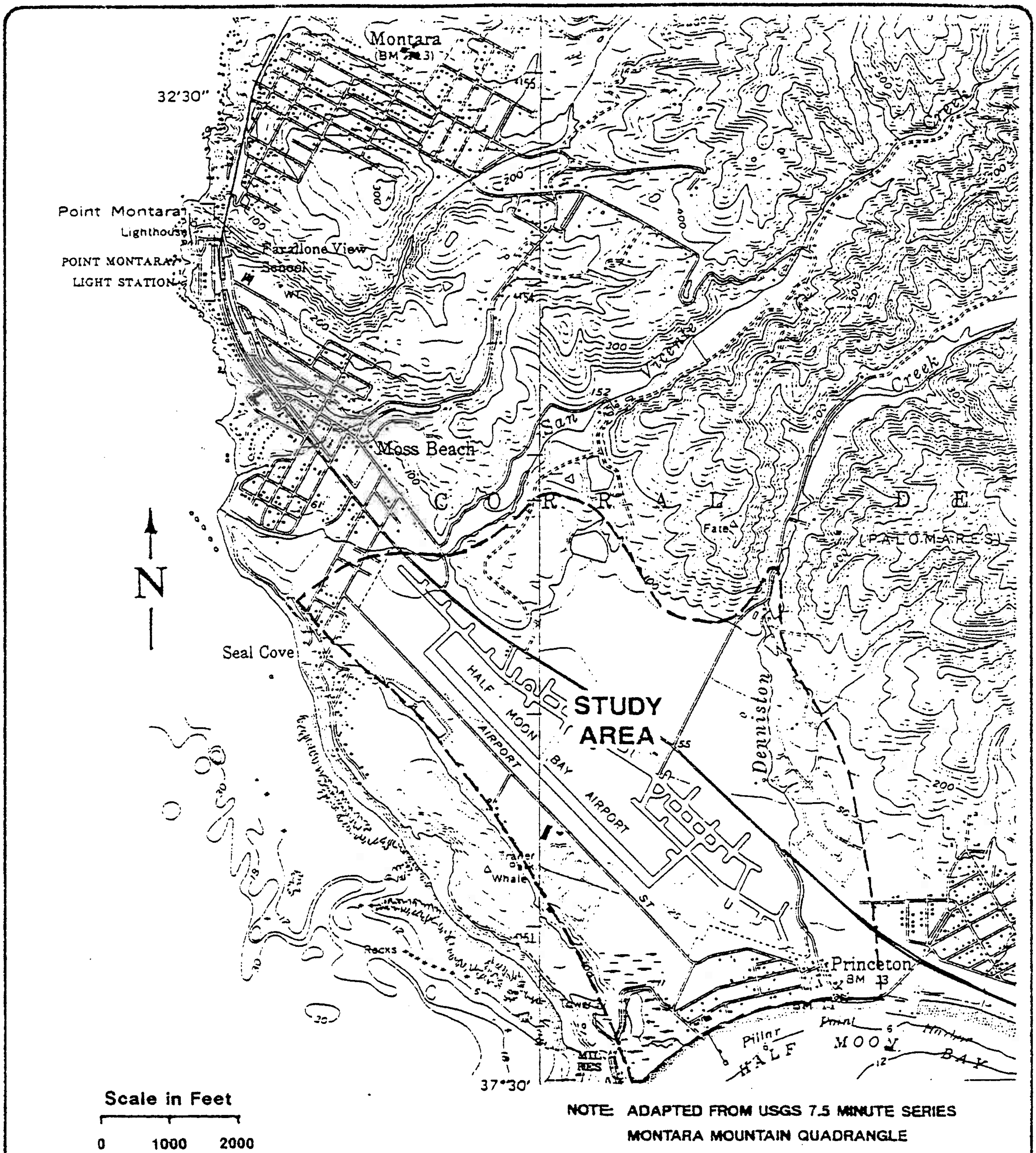
It should be noted that Phase II was originally intended to be completed in about a year after completion and acceptance of the Phase I report. However, implementation of all components of Phase II was not possible, particularly with regard to the biological assessment of Pillar Point Marsh, because the privately owned marsh property was not made accessible until late 1990. Hence, the analysis and interpretation of ground-water and biological conditions, as documented herein, was not commenced until completion of the biological assessment of the marsh in May, 1991.

2.2 Study Area

The study area herein called the Half Moon Bay Airport/Pillar Point Marsh Ground-Water Basin (also called the Denniston Creek Sub-basin in some previous studies) is defined as the coastal plain between Moss Beach and Princeton in San Mateo County, as shown in Figure 2.1. The Half Moon Bay Airport occupies a large portion of the basin. This basin borders the San Vicente Creek Basin to the northwest along a low topographic divide by the base of the mountains. On the east, there is no firm geologic boundary; however, ground-water contours in the area are all parallel to the coastline, indicating no subsurface flow in an east-west direction. Consequently, the eastern boundary was selected as a no-flow line east of Denniston Creek, to include the creek in the study area, and west of the town of El Granada. On the southwest, the basin is bounded by the Seal Cove Fault along the northeast edge of the rock mass that forms Pillar Point. The Pillar Point Marsh occupies a few acres between Princeton and Pillar Point at the extreme southern tip of the basin. Denniston Creek crosses the coastal plain near the eastern edge of the basin and discharges to Half Moon Bay within Pillar Point Harbor.

2.3 Previous Studies

The principal reference and most widely quoted previous study of the basin is "Groundwater Investigation, Denniston Creek Vicinity" by Lowney-Kaldveer Associates which was prepared for CCWD in April, 1974. This report presents a good description of geologic conditions



STUDY AREA LOCATION MAP

HALF MOON BAY AIRPORT/PILLAR POINT MARSH

FIGURE 2.1

Luhdorff & Scalmanini Consulting Engineers

PHASE II PILLAR POINT GROUND-WATER STUDY

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87-1-074

SEPT. 1991

within the basin. Estimates were also made of a hydrologic balance and storage capacity of the basin. These estimates were in turn used to estimate the ground-water basin's yield. Although this study was based on very limited historic data and was primarily a geologic exploration effort, the reported values for components in the hydrologic balance have been accepted as a reference base for decisions since its publication.

Of significance in the Lowney-Kaldveer report relative to basin yield were the reported facts that ground-water pumpage at that time was estimated to be 850 acre-feet per year and the basin was "in balance", i.e. ground-water storage was not changing. Based on those conditions, additional ground-water development of 400 acre-feet per year was thought to be possible without significantly reducing the hydraulic gradient or removing significant amounts of ground water from storage. Lowney-Kaldveer recommended staged additional ground-water development toward that 400 acre-feet per year value, along with a monitoring program that appeared technically sound.

However, some serious misconceptions have developed as a result of erroneous estimates of water inflow, outflow, and usage presented in this report. For instance, agricultural pumpage was estimated at 500 acre-feet per year in 1974, when it was probably negligible. At present, no ground water is pumped for irrigation from the ground-water basin. All irrigation supplies are diverted from San Vicente Creek, and total ground-water pumpage at present is considerably less than the total pumpage reported in 1974. Further, the 1974 estimate of municipal and domestic pumpage, which was 350 acre-feet, was substantially higher than the nearest recorded values (1976), when pumpage was about 250 acre-feet. Finally, the 1974 report may have over-estimated subsurface inflow, storage, and outflow.

The ESA/LSCE Phase I Report, dated June 1987, determined the availability of ground-water, surface water, and precipitation data, and identified wells with lithologic logs in and adjacent to the Airport/Pillar Point Basin. This report concluded that ground-water levels had remained essentially constant near the Half Moon Bay coastline over the past twelve years with no apparent long-term changes in water levels or ground-water storage.

The Phase I Report found that the basin could support additional pumpage without affecting the Pillar Point Marsh and identified a preliminary range of "safe yield" values from approximately 650 to 1300 acre-feet per year. It was also proposed that new well development be staged and combined with close monitoring of ground-water responses to the increased pumping. The first stage of new development would be restricted to approximately 150 acre-feet per year of additional pumpage.

III. AVAILABLE DATA

3.1 Surface Water

There is no gauging station on Denniston Creek that would allow determination of either surface flows into the basin or percolation rates from the stream bed into the underlying ground water. Detailed records of surface-water diversions from the creek are maintained by CCWD, which has diverted between 300 and 900 acre-feet per year for water supply between 1975 and 1985. Surface-water flows since then have been very low or non-existent due to the current drought and pumping of production wells adjacent to the creek. Thus, any diversions since 1985 are probably negligible.

Several survey locations were selected in March 1989 along Denniston Creek and its tributaries (Figure 3.1). Flow measurements were collected in March 1989 and June 1990 (Table 3.1).

3.2 Well Data

Well logs within and adjacent to the study area were obtained and reviewed in order to determine the potential for use of selected wells in water-level and water-quality determinations. Most of the wells with logs, however, are located outside the study area. Noteworthy wells within the study area are located in Figure 3.2 and include:

1. Three wells owned and operated by CUCC on the airport property; these wells have records of water levels, pumping capacity, well yield and ground-water quality.

2. Several wells owned and operated by CCWD throughout the basin, the majority of which are production and monitoring wells on and adjacent to Denniston

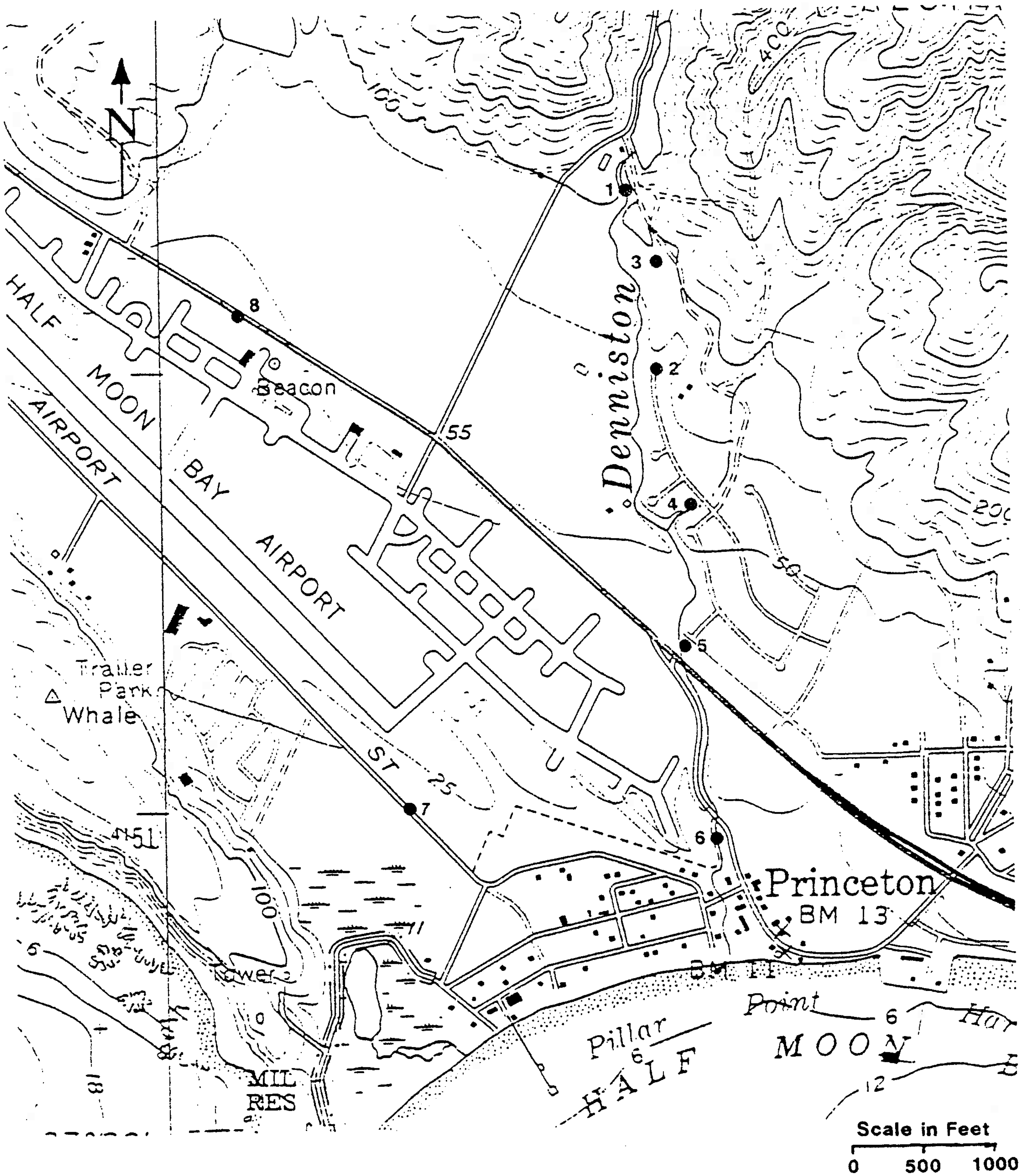

FIGURE 3.1

DENNISTON CREEK SURVEY LOCATIONS
HALF MOON BAY AIRPORT/PILLAR POINT MARSH

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87-1-074
SEPT 1991

Table 3.1
Surface-Water Flow Measurements in Denniston Creek
Half Moon Bay Airport/Pillar Point Marsh

Station	Stream	Location	Flow (3/16/89)	Flow (6/20/90)
1	Denniston Creek	NE Edge of Basin	4,934.0	35
2	Denniston Creek Tributary	E Edge of Basin	717.6	0
3	Denniston Creek Tributary	E Edge of Basin	0	0
4	Denniston Creek Tributary	E Edge of Basin	269.1	0
5	Denniston Creek	Highway 1 Culverts	3,408.6	55
6	Denniston Creek	At Princeton	0	0
7	Drainage from Airport	At Airport Road	0	0
8	Drainage to Aiport	At Highway 1	314.0	0

Note: All flows in gpm
Adapted from Earth Sciences Asociates, 1990, 1991

Table 3.2
Ground-Water Production
Half Moon Bay Airport/Pillar Point Marsh

Year	CCWD (Acre-Feet)	CUCC (Acre-Feet)	Total Production CUCC & CCWD (Acre-Feet)
1976	171.60	82.20	253.80
1977	194.30	60.20	254.50
1978	114.80	167.30	282.10
1979	135.30	169.90	305.20
1980	81.00	232.30	313.30
1981	172.20	147.70	319.90
1982	191.80	187.40	379.20
1983	98.50	223.30	321.80
1984	151.90	211.00	362.90
1985	122.40	232.20	354.60
1986	186.60	218.80	405.40
1987	169.42	237.39	406.81
1988	140.34	291.05	431.39
1989	147.00	265.00	412.00
1990	162.75	229.31	392.06

Creek.

There is a general lack of wells near the northwestern end of the airport near San Vicente Creek, and there are no known agricultural wells within the basin. Two low-yield agricultural wells were identified along the north side of San Vicente Creek outside the study area; these wells are reported to supplement the surface flows which are diverted from San Vicente Creek, collected in a series of surface impoundments, and later pumped for irrigation.

3.3 Ground-Water Pumpage

The predominant pumpage within the basin is for municipal water supply by CCWD and CUCC. Since 1976, when CCWD began to pump ground water, the combined pumpage has increased nearly linearly from about 250 acre-feet per year to about 430 acre-feet per year in 1988 before decreasing slightly in both 1989 and 1990 (Table 3.2 and Figure 3.3). As noted above, there is no agricultural pumpage in the study area and individual domestic pumpage is probably no greater than 20 to 25 acre-feet per year.

3.4 Ground-Water Levels

Ground-water level data are available for a relatively large number of wells considering the size of the basin. A total of 26 wells have been monitored for various periods of time (Table 3.3). Well 5S/6W-10J1 has been monitored by the Department of Water Resources since 1953, bi-annually, spring and fall, during most years. A hydrograph of this well is shown on Figure 3.4, along with historic precipitation data. Since about December 1975, CCWD has conducted bi-annual water-level measurements in up to seven monitoring wells. In addition, water levels in two CUCC production wells have been regularly monitored since 1975, and in additional production wells since late 1987. Hydrographs of selected wells are presented in Figures 3.5, 3.6, and 3.7, and all hydrographs are in Appendix I.

Three piezometers were installed in Spring 1989 to monitor ground-water conditions in the Pillar Point Marsh. Water levels were measured several times per year in 1989 and 1990 (Table 3.4), and a hydrograph is presented in Figure 3.8. The hydrograph indicates upward vertical gradients have existed throughout this period.

Ground-water elevation contour maps were prepared for May 1987, March 1990, and December 1990 (Figures 3.9, 3.10, 3.11, respectively) to determine the relationship between ground-water levels and sea level. In addition, contour maps with changes in ground-water elevations from 1987 to 1990 and from spring to fall 1990 (Figures 3.12 and 3.13, respectively) illustrate how ground-water elevations remain above sea level along the Half Moon Bay coastline, despite the current drought. Significant declines are present in a pumping depression that has formed around the production wells along Denniston Creek.

Water-level data are very important, since they show direct responses to seasonal recharge and discharge, along with pumpage. Generally, the hydrographs and contour maps do not indicate downward water-level trends over the periods of record that would indicate overdraft conditions. Instead, the declines appear to be the result of four straight years of below-average rainfall from 1988 to the present, as seen in Figure 3.4. Responses to increased pumpage have caused larger seasonal fluctuations, but it is impossible to pump significant amounts of ground water without responses of this type.

It is important to note that water levels within the basin have recovered seasonally, except during temporary periods of drought. Figure 3.4 illustrates the recovery of ground-water levels with increased precipitation following the drought of 1976 and 1977.

3.5 Ground-Water Quality

There is a relatively long history of water quality data for the basin. Table 3.5 summarizes selected ground-water quality indicator parameters, chloride and specific conductance, for wells in the study area that have been monitored by DWR, CUCC, and CCWD, as well as the three piezometers sampled in March 1991. As indicated in Table 3.5, chloride concentrations in the study area range from 35 to 159 mg/l, while specific conductance values range from 314 to 1210 umhos/cm. The two CUCC wells and well 5S/6W-11E1, which have been sampled every two to three years over a period of approximately 11 years, indicate stable concentrations of the above indicator constituents. The six CCWD wells sampled bi-annually since 1989 and the three piezometers show stable constituent concentrations. The shallowest piezometer (P3, 14.9 feet deep) shows the highest constituent concentrations. There has been no apparent change in the quality of the ground-water produced from the basin.

Table 3.3
Ground-Water Elevations in Monitoring Network
Half Moon Bay Airport/Pillar Point Marsh

Well	Reference Point Elevation	5/14/87	4/11/88	10/6/88	3/21/89	3/30/90	12/13/90
W1	45					7.58	-0.21
W2	52				4.48	4.57	0.24
W3	60					7.74	2.41
W4	58						-1.95
W5	50	21.35	28.85	34.42		1.76	-1.88
W6	65						
W7	75					60.47	57.60
W9	40				21.29	16.50	11.74
M1	25				18.10	11.15	6.71
M2	50	31.75	13.95	29.74	10.85	2.47	-1.49
M3	70	43.1	34.82	32.53	44.47	28.33	21.90
M4	28	20		6.96	22.21	10.31	5.93
M5	22	16.45	9.79	11.96	10.45	5.73	1.98
M6	45	33.45	20.04	35.72	26.60	21.78	17.90
M7	25				16.68		
CUCCN	59	26.5	-12.66p	9.75	13.56	11.22	7.23
CUCCS	57	21.75	-20.98p	5.41	9.17	7.17	3.20
CCWDN	59	48.62	46.69	45.92	45.23	44.01	41.40
FV	32	14.65	6.47	10.58	6.59	5.82	-0.09
Michaelson	19.25	16.45	11.63	7.85		10.85	5.77
Romeo	16	9.45					
Baranca	26	17.61	13.19	9.23	14.52	9.59	6.41
CODO	22		11.13	7.21	12.56	7.64	3.80
EG New	40	25.12	17.30	14.55	18.62	14.55	10.73
EG Old/DWR	36	23.18	14.87	11.43	15.13	11.56	7.71
Airport 3	50			3.42		4.27	0.39

Note: 1) Elevations are in Feet, MSL. 2) "p" indicates pumping level.

Table 3.4
Ground-Water Elevations in Piezometers
Half Moon Bay Airport/Pillar Point Marsh

	Piezometer P-1	Piezometer P-2	Piezometer P-3
Total Depth (Feet)	48.35	23.09	14.90
Reference Point Elevation	8.99	9.22	9.48
05/01/89	6.09	4.82	4.48
05/03/89	6.04	4.47	4.19
05/10/89	6.04	4.32	4.19
07/21/89	5.15	1.84	1.89
10/24/89	4.17	3.02	3.28
12/07/89	4.66	3.84	4.06
01/12/90	4.20	3.94	4.29
02/19/90	4.95	4.49	4.31
06/20/90	4.91	3.72	3.67
08/23/90	3.41	1.94	2.45
10/10/90	2.75	0.72	1.11

Note: Elevations are in Feet, MSL.

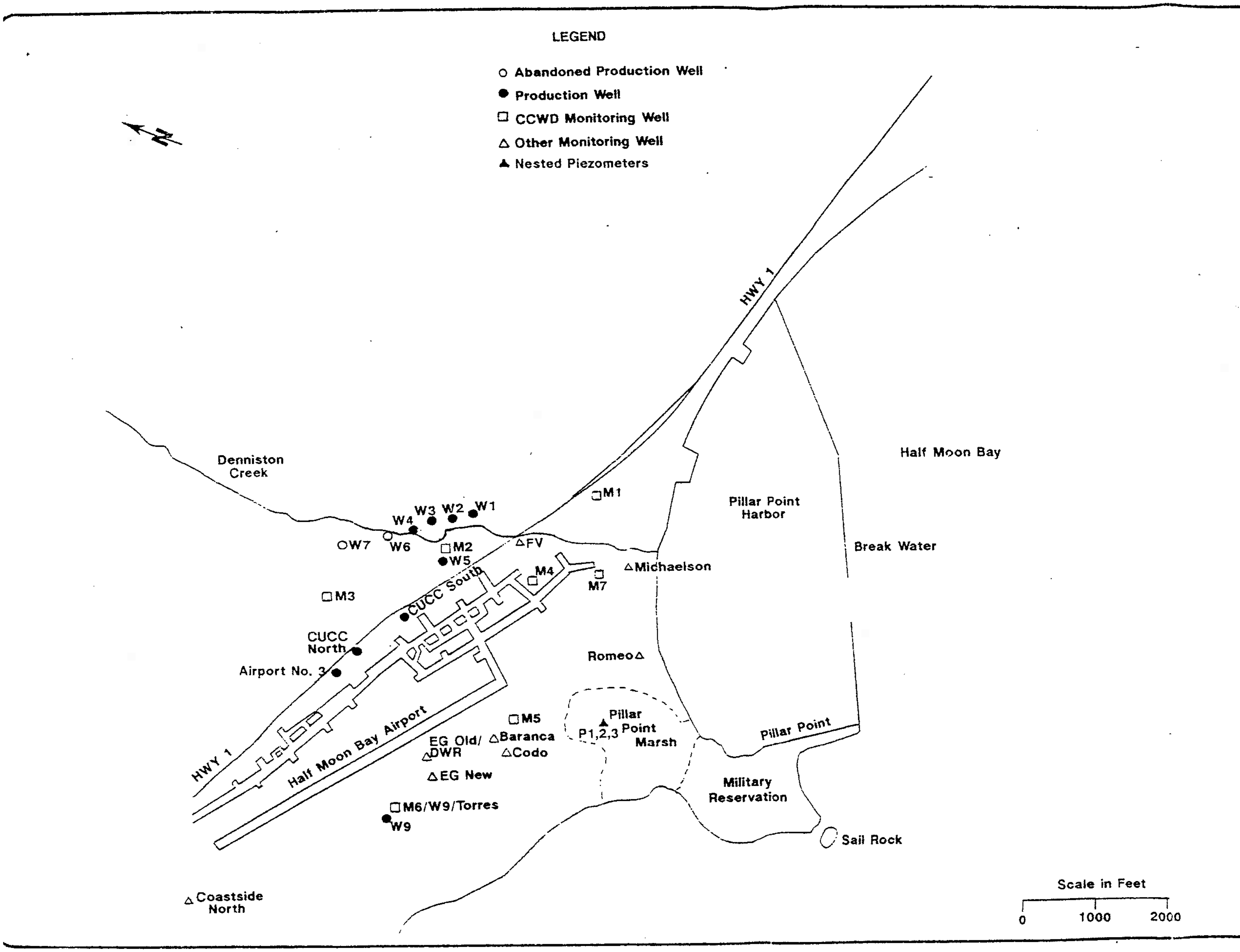

FIGURE 3.2

MONITORING NETWORK LOCATION
HALF MOON BAY AIRPORT/PILLAR POINT MARSH

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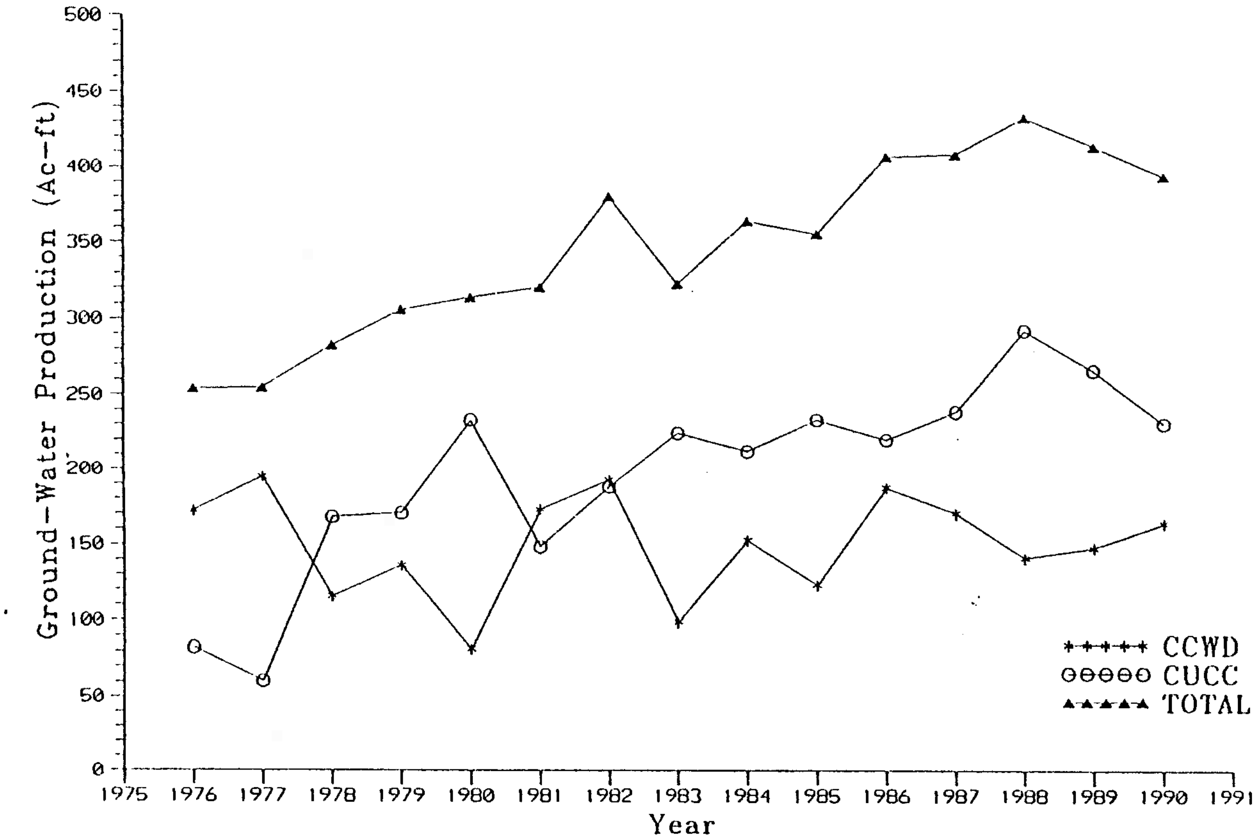

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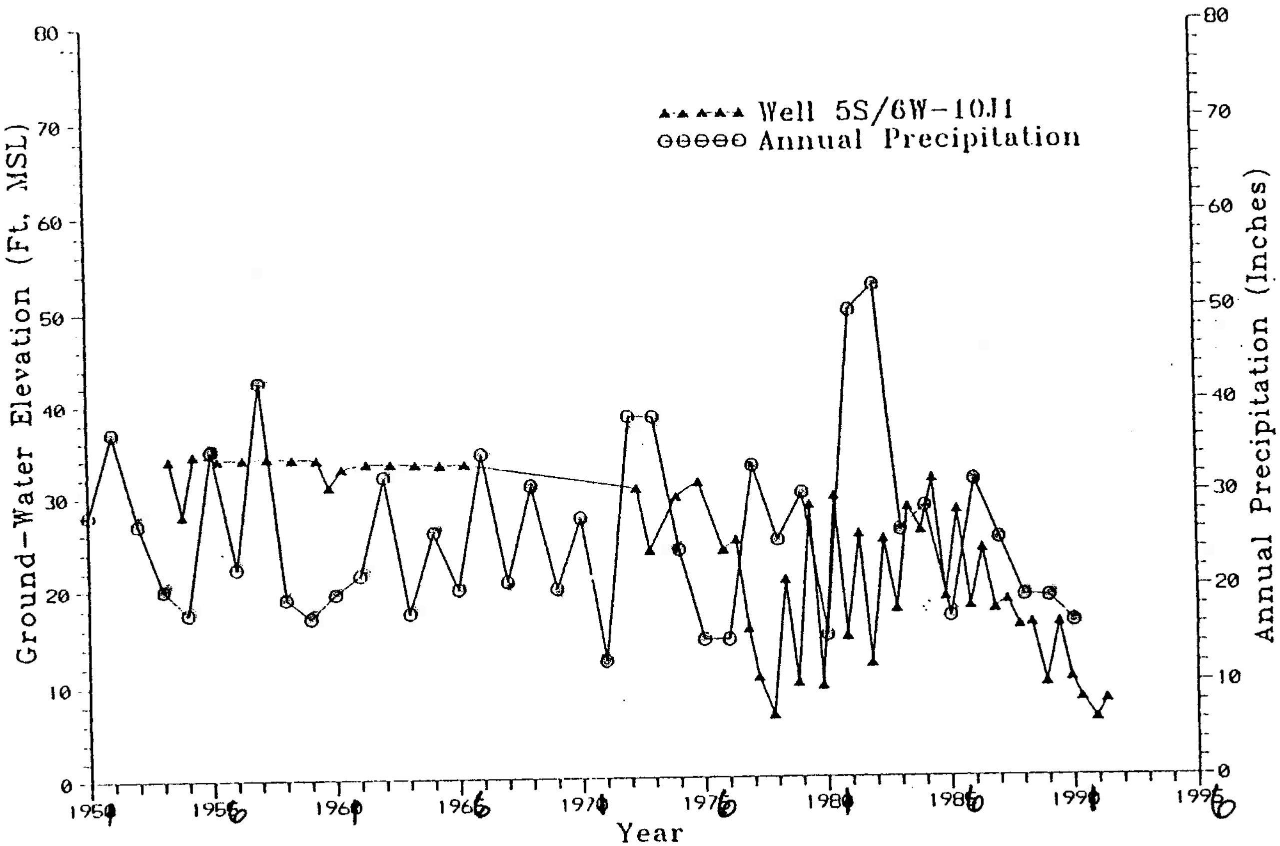
GROUND-WATER PRODUCTION HYDROGRAPH

87-1-074
SEPT 1991

FIGURE
3.3



GROUND-WATER ELEVATION HYDROGRAPH
FOR DWR WELL 5S/6W-10J1
HALF MOON BAY AIRPORT/PILLAR POINT MARSH
PHASE II PILLAR POINT GROUND-WATER STUDY
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FIGURE
3.4

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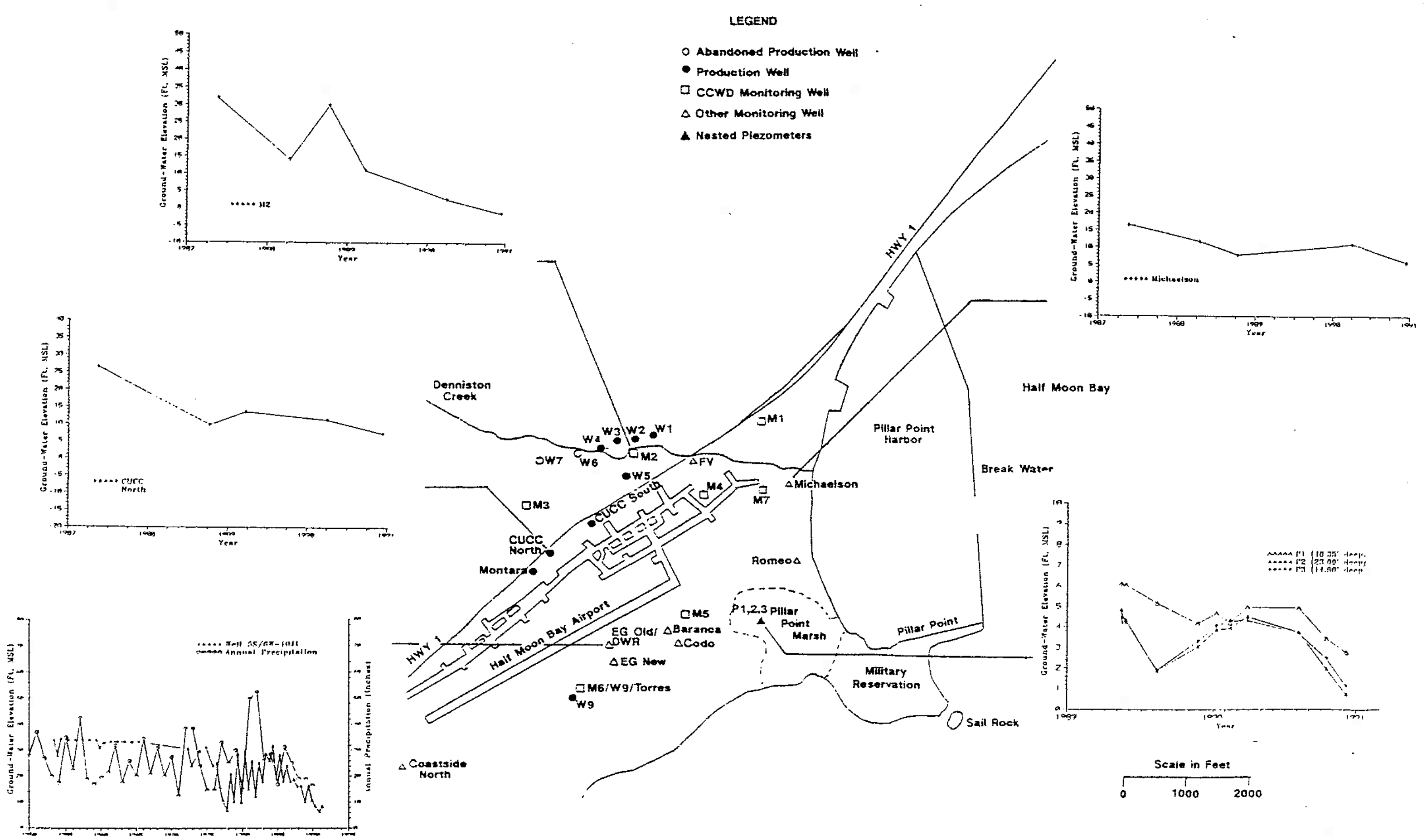

FIGURE 3.5

GROUND-WATER LEVEL HYDROGRAPHS
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87-1-074
SEPT 1991

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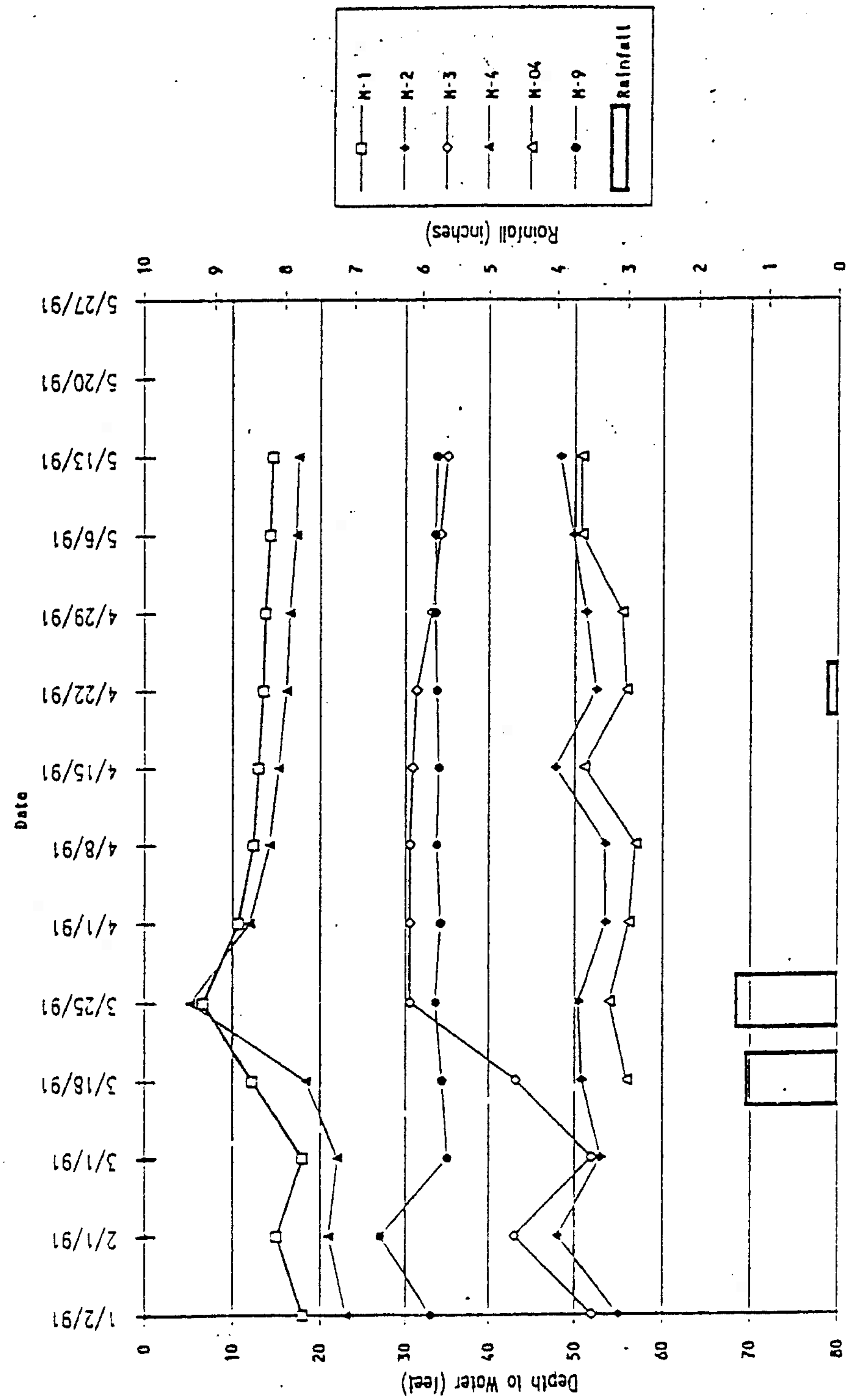

GROUND-WATER ELEVATION HYDROGRAPH
FOR MONITORING WELLS
HALF MOON BAY AIRPORT/PILLAR POINT MARSH
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FIGURE
3.6

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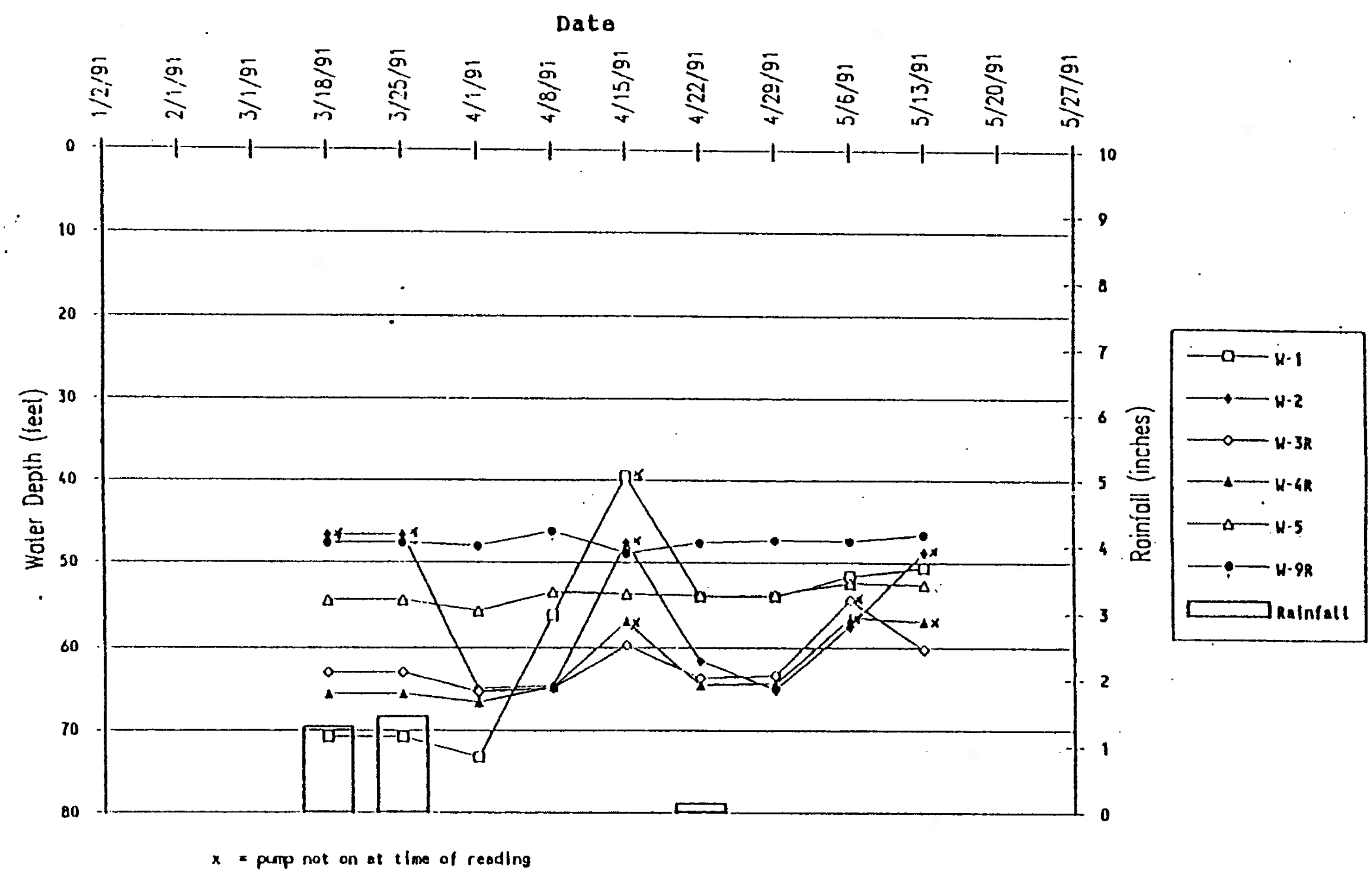

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GROUND-WATER ELEVATION HYDROGRAPH
FOR PRODUCTION WELLS
HALF MOON BAY AIRPORT/PILLAR POINT MARSH
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FIGURE
3.7

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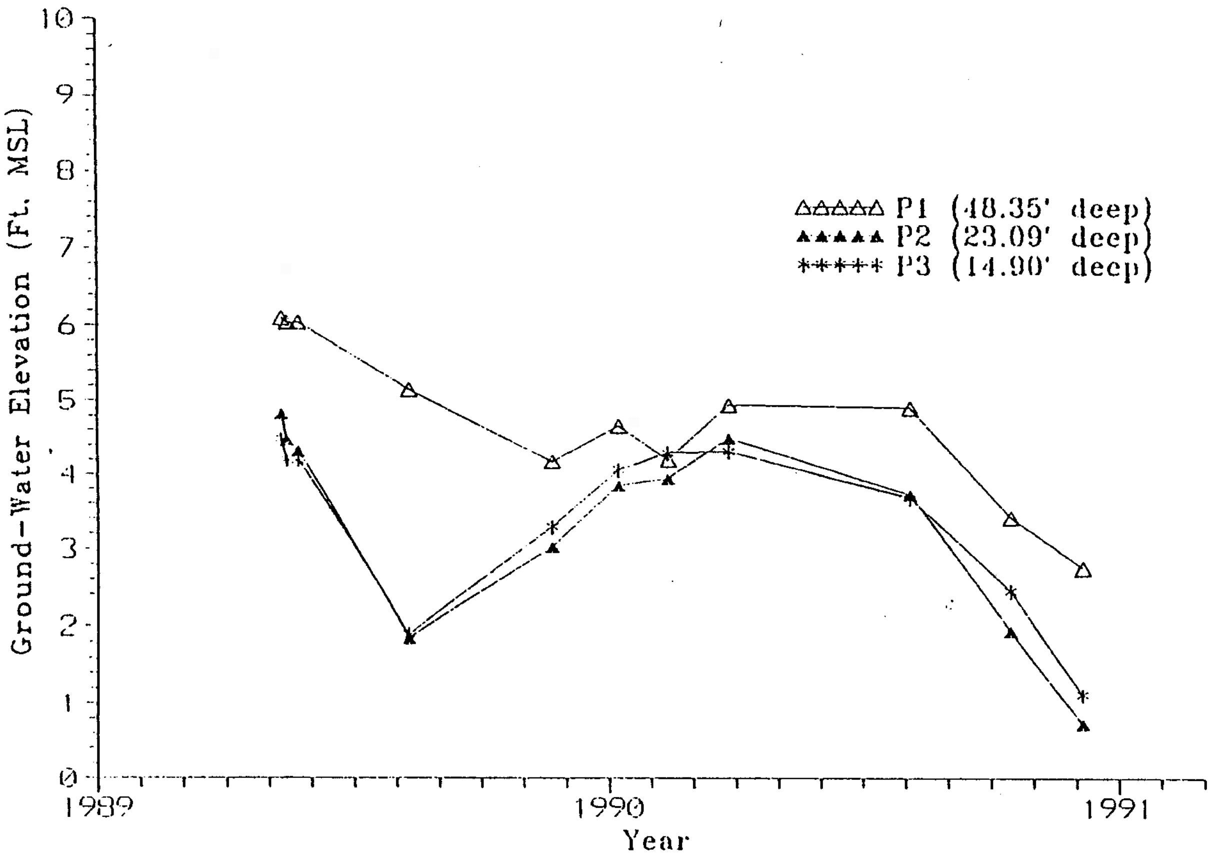

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GROUND-WATER ELEVATION HYDROGRAPH
FOR PIEZOMETERS
HALF MOON BAY AIRPORT/PILLAR PINT MARSH
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FIGURE
3.8

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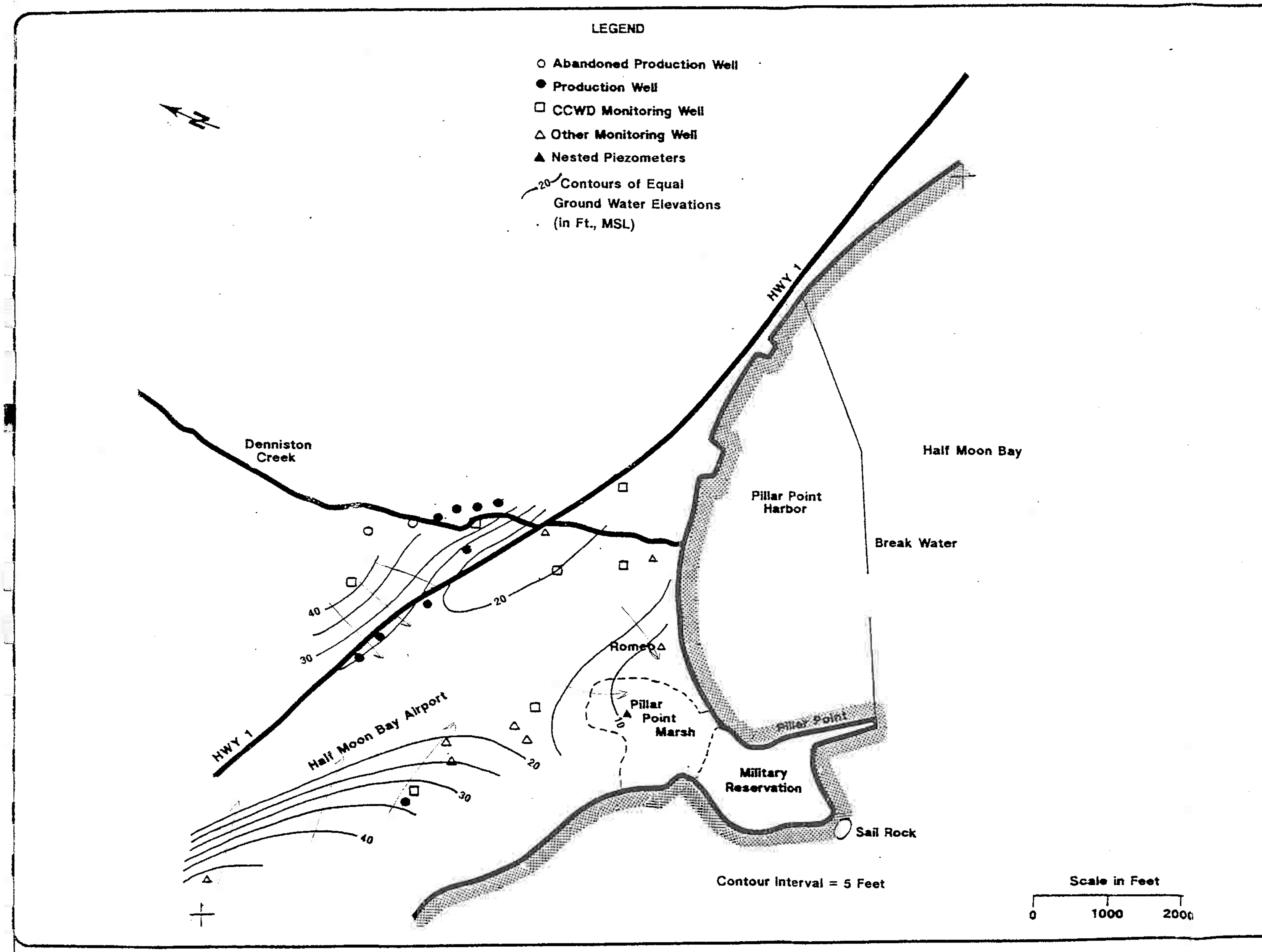

FIGURE 3.9

CONTOURS OF EQUAL GROUND-WATER ELEVATIONS, MAY 1987
HALF MOON BAY AIRPORT/PILLAR POINT MARSH

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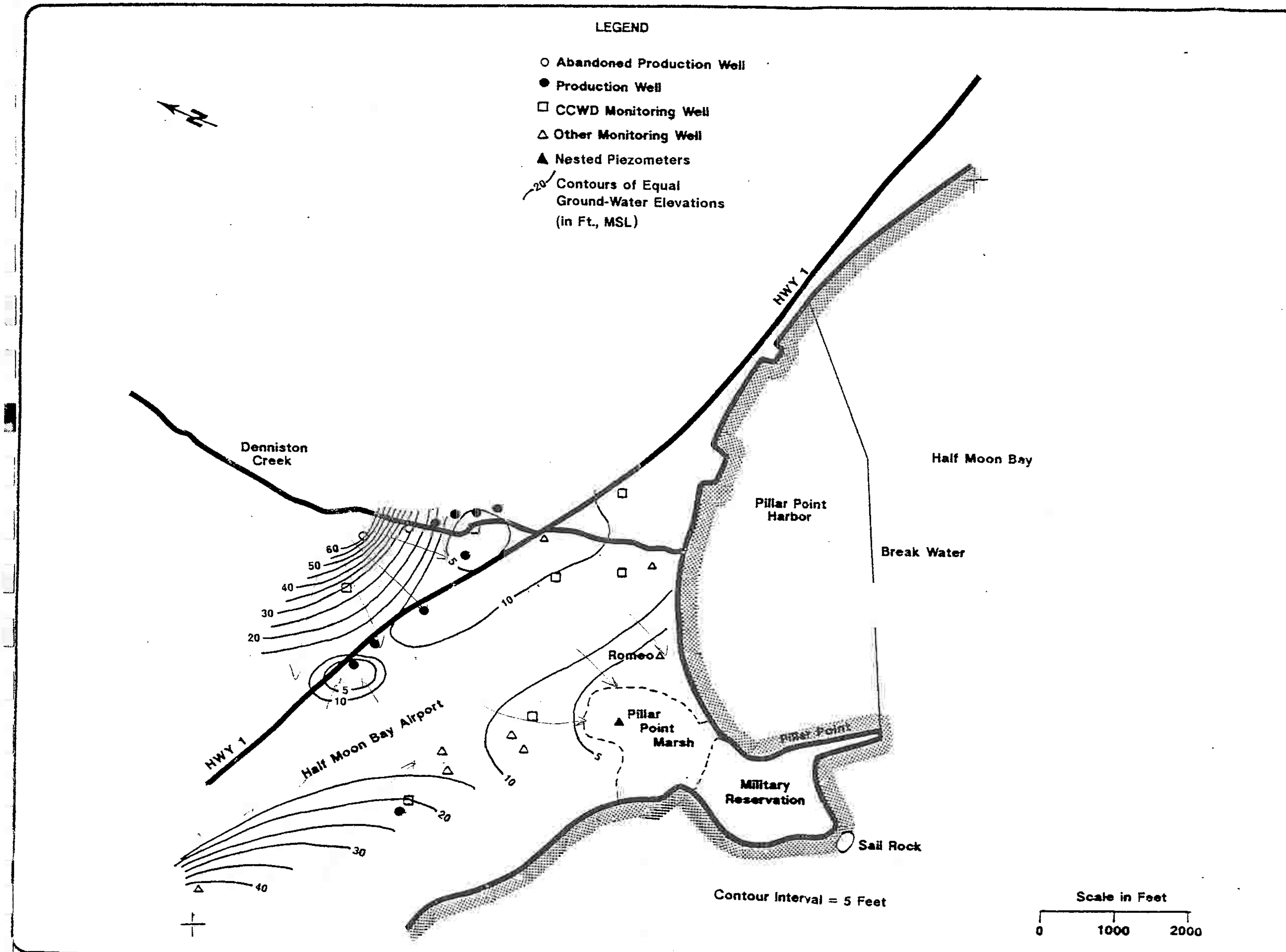

FIGURE 3.10

CONTOURS OF EQUAL GROUND-WATER ELEVATIONS, MARCH 1990
HALF MOON BAY AIRPORT/PILLAR POINT MARSH

PHASE II PILLAR POINT GROUND-WATER STUDY
CITIZENS UTILITIES COMPANY/COASTSIDE COUNTY WATER DISTRICT

87-1-074
SEPT 1991

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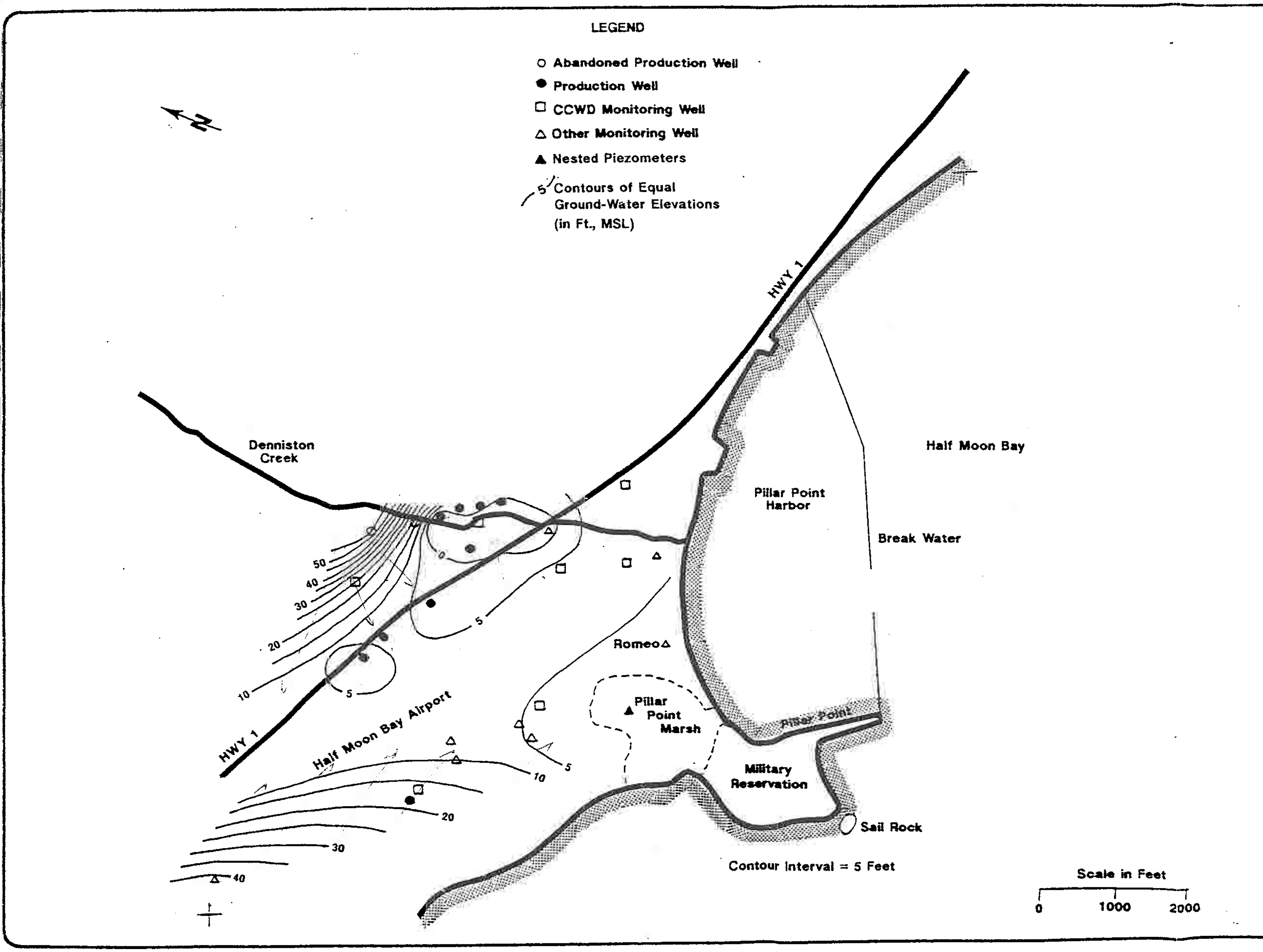

FIGURE 3.11

CONTOURS OF EQUAL GROUND-WATER ELEVATIONS, DECEMBER 1990
HALF MOON BAY AIRPORT/PILLAR POINT MARSH

PHASE II PILLAR POINT GROUND-WATER STUDY
CITIZENS UTILITIES COMPANY/COASTSIDE COUNTY WATER DISTRICT

87-1-074
SEPT 1991

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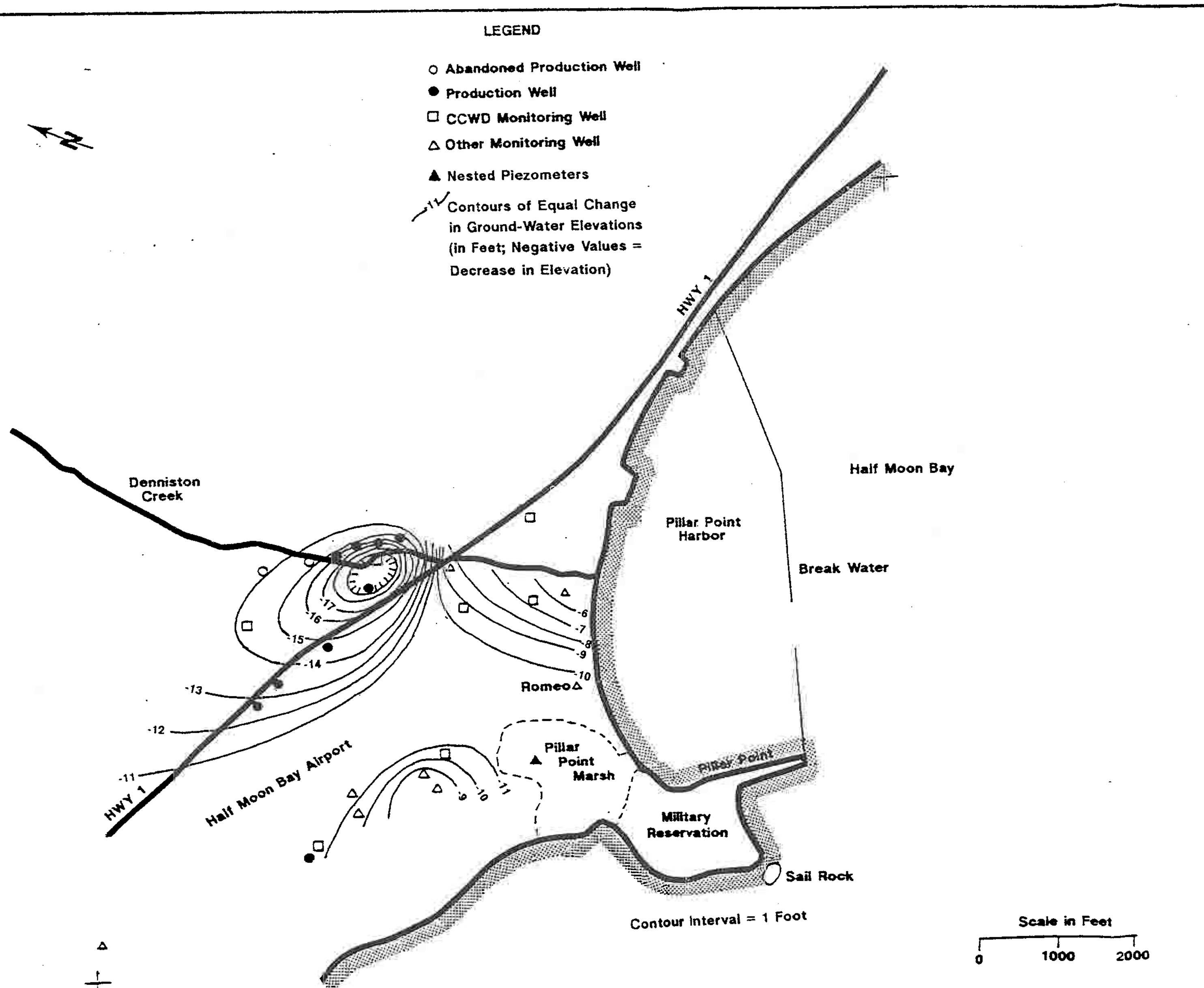

FIGURE 3.12

CONTOURS OF EQUAL CHANGE IN GROUND-WATER ELEVATIONS, SPRING 1987 TO 1990
HALF MOON BAY AIRPORT/PILLAR POINT MARSH

PHASE II PILLAR POINT GROUND-WATER STUDY
CITIZENS UTILITIES COMPANY/COASTSIDE COUNTY WATER DISTRICT

87-1-074
SEPT 1991

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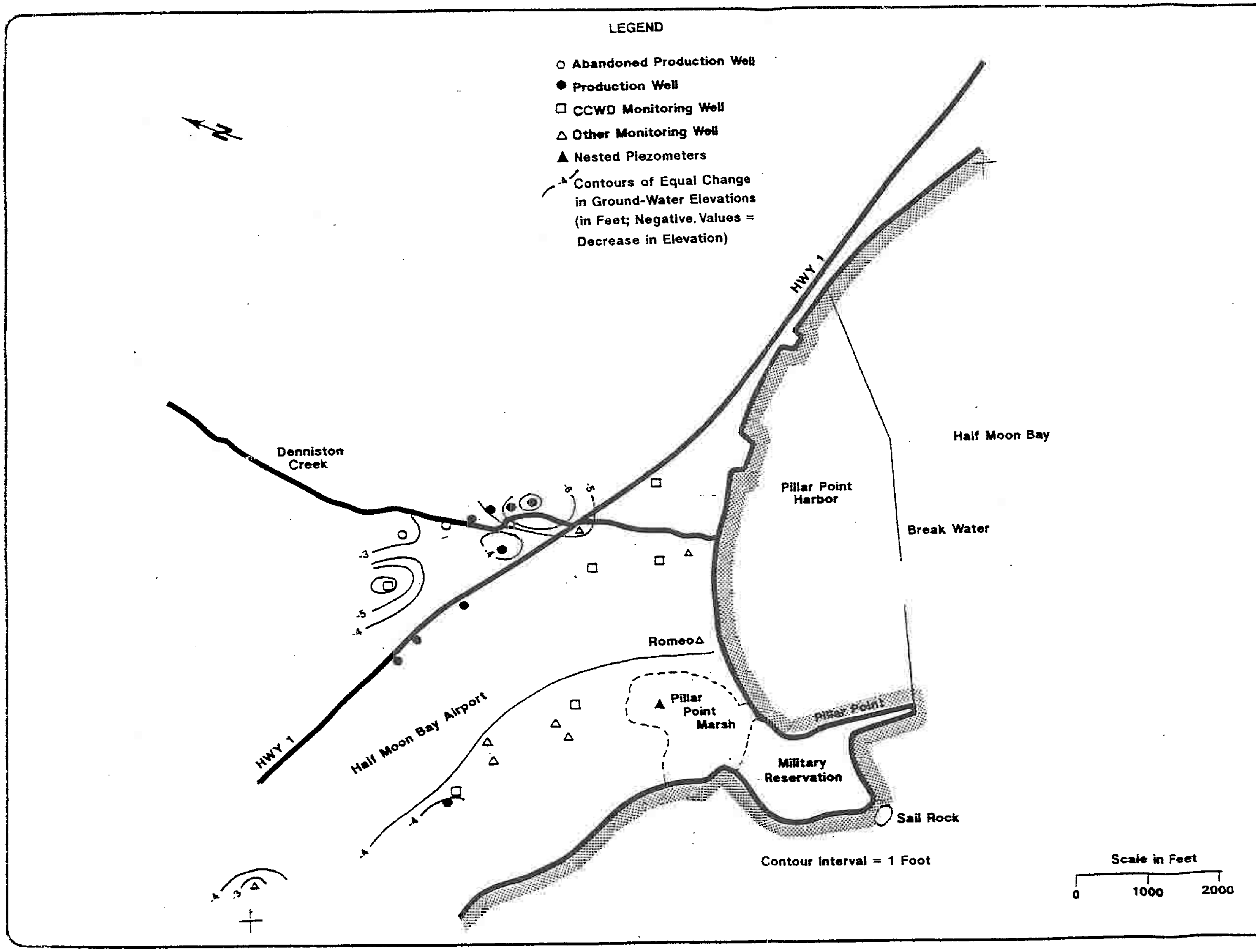

FIGURE 3.13

CONTOURS OF EQUAL CHANGE IN GROUND-WATER ELEVATIONS, MARCH TO DECEMBER 1990
HALF MOON BAY AIRPORT/PILLAR POINT MARSH

PHASE II PILLAR POINT GROUND-WATER STUDY
CITIZENS UTILITIES COMPANY/COASTSIDE COUNTY WATER DISTRICT

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Table 3.5
HISTORICAL GROUND-WATER QUALITY
Half Moon Bay Airport/Pillar Point Marsh
Selected Indicator Parameters

Well/Piezometer	Date	Specific Conductance (umhos/cm)	Chloride (mg/l)
W1	9/7/89	570	89
	12/12/89	530	72
	6/19/90	520	78
W2	9/7/89	590	92
	12/12/89	610	35
	6/19/90	560	75
W3	6/15/89	600	58
	12/12/89	610	98
	6/19/90	520	75
W4	6/15/89	480	50
	12/12/89	610	96
	6/19/90	440	56
W5	9/7/89	500	52
	12/12/89	510	63
	6/19/90	480	51
W9	6/15/89	980	170
	12/12/89	840	140
	6/19/90	820	140
CUCC SOUTH	7/3/53	410	60
	5/16/73	490	64
	12/20/76	466	65.5
	5/11/78	488	75
	5/18/79	540	78
	10/26/81	314	75

Table 3.5 (cont.)
HISTORICAL GROUND WATER QUALITY
Half Moon Bay Airport/Pillar Point Marsh
Selected Indicator Parameters

Well/Piezometer	Date	Specific Conductance (umhos/cm)	Chloride (mg/l)
	6/4/84	560	68
	5/4/87	370	76
	3/21/89	500	72
	9/7/90	478	71
CUCC NORTH	5/16/73	590	91
	6/10/76	688	116
	5/11/78	667	124
	10/26/81	580	124
	6/4/84	710	120
	5/4/87	650	110
	3/21/89	600	95
	9/7/90	582	85
5S/6W-11E1	8/15/74	622	84
	6/30/76	684	110
	8/17/78	688	110
	8/5/81	684	117
	8/4/83	693	116
	9/4/85	705	113
	9/29/87	712	108
	9/13/89	552	89
	7/25/91	562	
P1	3/21/91	600	91
P2	3/21/91	780	110
P3	3/21/91	1210	159

IV. HYDROGEOLOGIC CONDITIONS

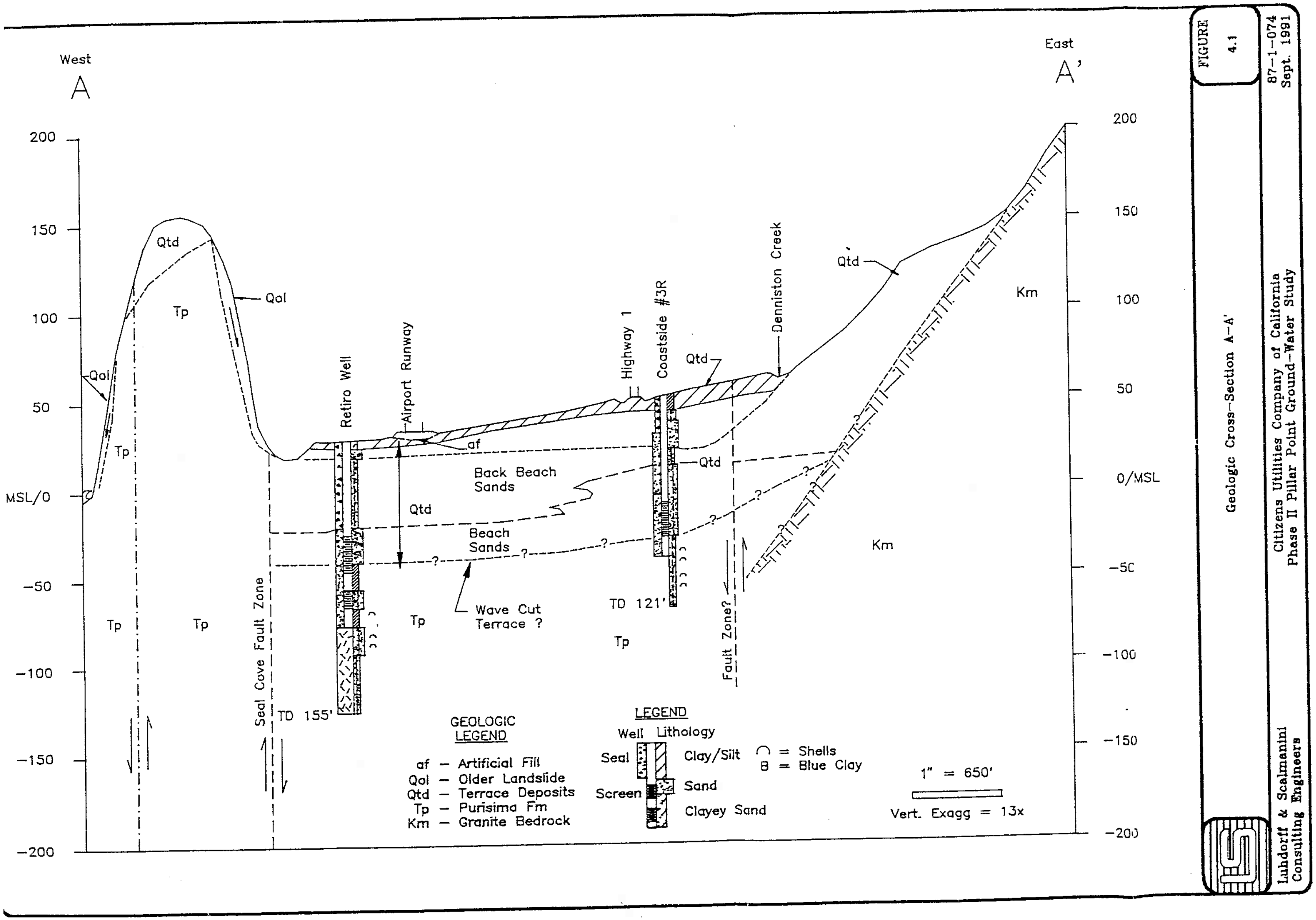
4.1 Regional Geology

The regional geology of the study area is of the Salinian block west of the San Andreas fault zone. Bedrock geology consists of the Cretaceous granitic intrusive igneous rocks of Montara Mountain to the east. Along the Pacific shore line Tertiary marine sedimentary rocks unconformably overlie the bedrock or are in fault contact with the granitic rocks. Quaternary marine-terrace deposits and alluvium overlie the older rock types (Pampeyan, 1981).

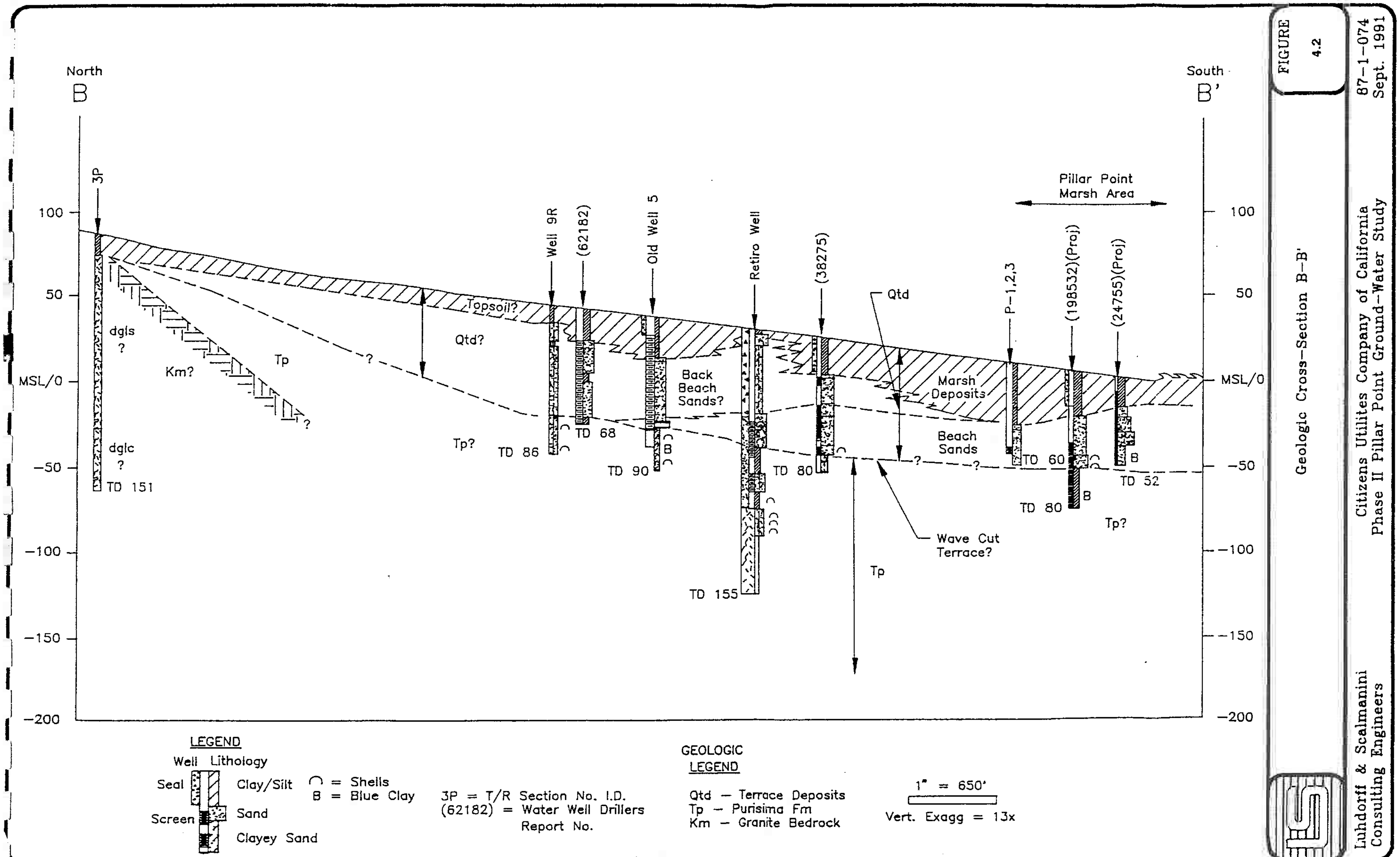
4.2 Local Geologic Conditions

The local geology is shown by two geologic cross-sections (Figures 4.1 and 4.2) located on Figure 4.3. East of Highway 1 thin marine-terrace deposits and alluvium overlie the granitic bedrock. The western limit of this area is poorly known but may be defined by largely concealed faults. Along the coast west of the Seal Cove Fault, the uplifted Pliocene Purisima Formation consists of marine-deposited silty sandstones, siltstones, and mudstones. On top of this uplifted zone are thin marine-terrace deposits.

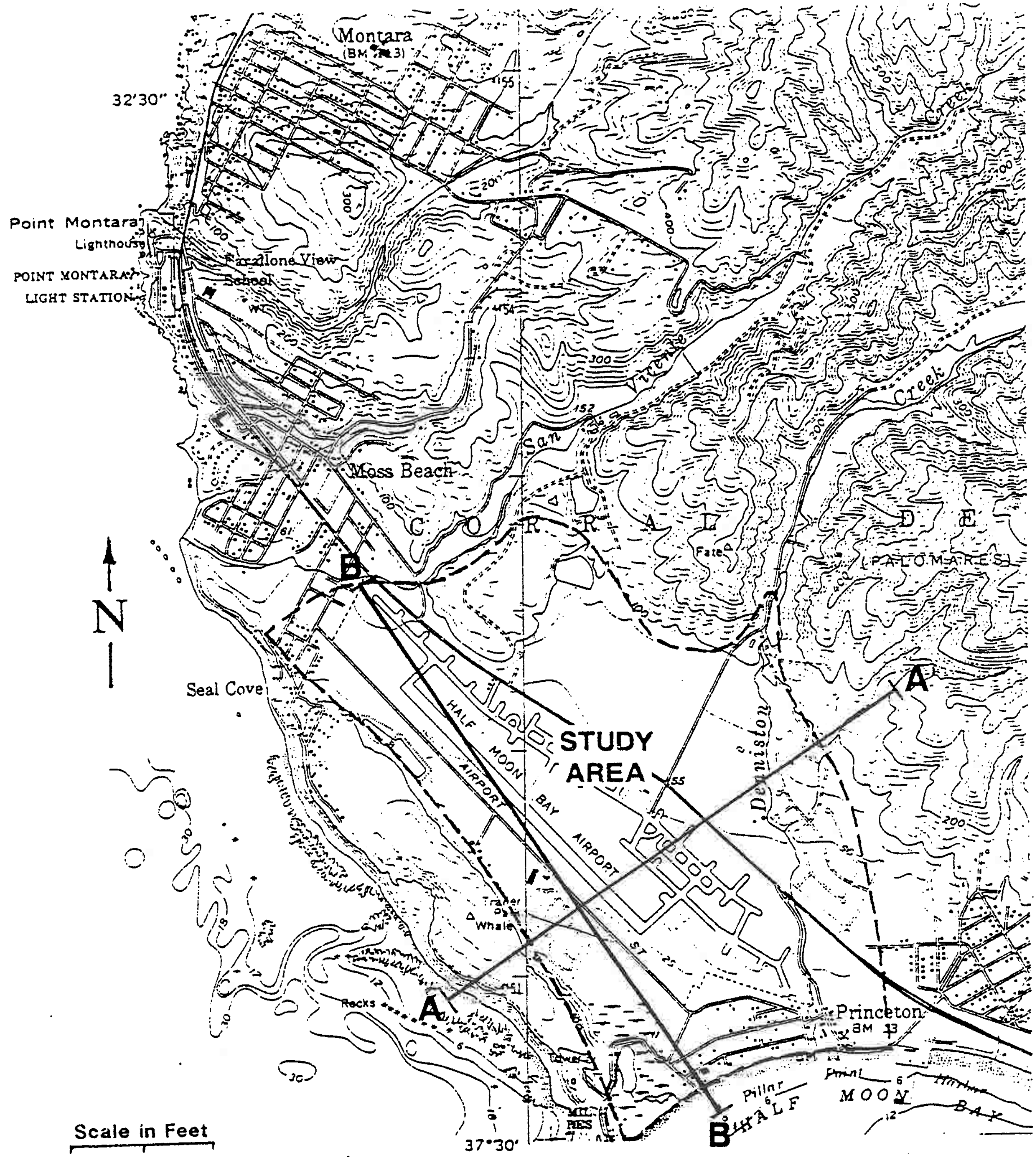
Beneath the Denniston and San Vicente Creeks valley area, borehole information indicates a thin sequence of Quaternary marine-terrace deposits exists, probably overlain by undifferentiated younger alluvium and possibly beach and marsh deposits (Figures 4.1 and 4.2). These units are about 70 feet thick and consist of unconsolidated sands to silty sands with a thin upper zone of topsoil and marsh clays near Half Moon Bay. Below the marine-terrace deposits, boreholes have encountered Purisima Formation consisting of weakly-



West
A
East
A'
200
150
100
50
MSL/0
0/MSL
-50
-100
-150
-200
Qtd
Qol
Tp
Km
Retiro Well
Airport Runway
Highway 1
Coastside #3R
Denniston Creek
af
Back Beach Sands
Beach Sands
Wave Cut Terrace ?
Seal Cove Fault Zone
Fault Zone?
TD 155'
TD 121'
GEOLOGIC LEGEND
af – Artificial Fill
Qol – Older Landslide
Qtd – Terrace Deposits
Tp – Purisima Fm
Km – Granite Bedrock
LEGEND
Well Lithology
Seal
Screen
Clay/Silt
Sand
Clayey Sand
= Shells
B = Blue Clay
1" = 650'
Vert. Exagg = 13x
FIGURE 4.1
87-1-074
Sept. 1991
Geologic Cross-Section A-A'
Citizens Utilities Company of California
Phase II Pillar Point Ground-Water Study
Luhdorff & Scalmanini
Consulting Engineers



North
B
South
B'
3P
Well 9R
(62182)
Old Well 5
Retiro Well
(38275)
P-1,2,3
(198532)(Proj)
(24755)(Proj)
Pillar Point
Marsh Area
Topsoil?
Qtd?
Qtd
dgls
?
Km?
Tp
?
dglc
?
Tp?
Back
Beach
Sands?
Marsh
Deposits
Beach
Sands
Wave Cut
Terrace?
Tp
Tp?
B
TD 151
TD 86
TD 68
TD 90
TD 155
TD 80
TD 60
TD 80
TD 52
100
50
MSL/0
−50
−100
−150
−200
LEGEND
Well Lithology
Seal
Screen
Clay/Silt
Sand
Clayey Sand
⌒ = Shells
B = Blue Clay
3P = T/R Section No. I.D.
(62182) = Water Well Drillers
Report No.
GEOLOGIC
LEGEND
Qtd — Terrace Deposits
Tp — Purisima Fm
Km — Granite Bedrock
1" = 650'
Vert. Exagg = 13x
Geologic Cross-Section B-B'
FIGURE
4.2
87-1-074
Sept. 1991
Citizens Utilities Company of California
Phase II Pillar Point Ground-Water Study
Luhdorff & Scalmanini
Consulting Engineers



NOTE: ADAPTED FROM USGS 7.5 MINUTE SERIES MONTARA MOUNTAIN QUADRANGLE

GEOLOGIC CROSS-SECTION LOCATION MAP
HALF MOON BAY AIRPORT/PILLAR POINT MARSH

FIGURE 4.3

Luhdorff & Scalmanini Consulting Engineers

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CITIZENS UTILITIES COMPANY/COASTSIDE COUNTY WATER DISTRICT

87-1-074
SEPT 1991

consolidated silty sandstones, siltstones and mudstones. These deposits are generally darker bluish gray in color and contain abundant fossils. Most water wells are completed within the marine-terrace deposits with some wells completed in the uppermost sandier units of the Purisima Formation.

4.3 Hydrologic Conditions

4.3.1 Surface Water Hydrology

A comprehensive surface-water hydrologic study was not part of the scope of work for the ground-water basin evaluation. However, some limited surface-flow observations were made to better understand surface-flow versus ground-water recharge relationships. Denniston Creek is the largest stream entering the basin. This stream is perennial upstream of the ground-water basin, but because of surface-water diversions upstream, Denniston Creek is now ephemeral as it crosses the basin. There are other small ephemeral watersheds draining the bedrock terrain northeast of the basin, and there is probably some runoff from the Seal Cove Fault escarpment to the southwest. In addition, surface water is diverted from San Vicente Creek, stored in a small reservoir on the north edge of the basin, and used to irrigate the area northeast of Highway 1 and west of Denniston Creek.

4.3.1.1 Stream Gauging

On March 16, 1989, surface-water flow measurements were made on Denniston Creek and three small tributaries. Also, surface flows were measured or observed in the drain entering the airport from the north and drainage from the airport at Airport Street. Flows were measured at eight stations as shown in Figure 3.1, and the results of these measurements are shown on Table 3.1.

4.3.1.2 Infiltration Potential

As can be seen from these measurements, surface flow into the basin on this date was sw only, –

approximately 6,235 gpm or more while outflow was nil. These data indicate a recharge rate of about 29 acre-feet per day or more when these surface flows are available. The data further indicate that more than half of the recharge along Denniston Creek occurs downstream of Highway 1 near Princeton perhaps due to flatter gradients and a more permeable stream bed. Although Denniston Creek was dry at Princeton, on the date of stream measurements, a large steelhead trout was observed at Station 1 indicating there had been substantial flow to the ocean some time that winter. It is apparent that Denniston Creek and its small tributaries have the potential to provide over 2,000 acre-feet of recharge to the basin during the winter and early spring when flows and ground-water storage space are available.

Runoff from other drainages to the northeast and southwest would add to the recharge potential. Further, diversion of surface water from San Vicente Creek for irrigation probably provides a significant but an unknown amount of recharge. This diverted water is stored in a reservoir on the north edge of the basin, which probably provides some recharge from seepage losses. Further, on two occasions, over-irrigation of brussels sprout fields was observed as evidenced by standing tailwater at the lower end of the field.

The drainage ditch that enters the airport from the north may collect excess irrigation water, overflow, and seepage from the irrigation reservoir, as well as storm runoff. During March 16, 1989, this inflow to the airport area apparently was all infiltrating as there was no discharge from the airport at Airport Street. On other occasions, flows from the airport drain to Pillar Point Marsh have been observed but not measured. It is suspected that most of the fresh-water ponding in the marsh results ~~from drainage from the airport along with~~ local runoff. Ground water also discharges to the marsh as evidenced by upward gradients in monitoring wells. However, ground-water discharges are probably only large enough to maintain soil moisture during the summer and fall.

4.3.2 Ground-Water Conditions

Ground-water levels in the basin have continued declining since the Phase I Report of 1987, apparently due to the current drought. Ground-water elevations on May 1987 ranged from 9.45 feet MSL along portions of the Half Moon Bay coastline to 48.62 feet MSL in the Coastside North well at the northern basin edge (Table 3.3, Figure 3.9). By the spring of 1990, ground-water elevations ranged from 1.76 feet MSL in production well W5 to 44.01 feet MSL in the Coastside North well (Figure 3.10).

It is apparent from Figure 3.12 that ground-water elevations declined from 20 to 30 feet in a pumping depression that has formed around the production wells along Denniston Creek. However, declines in the remainder of the basin are on the order of 6 to 10 feet. Elevations in the piezometers in Pillar Point Marsh and the wells along the coastline were from 3.5 to 10 feet MSL, and the water levels in the piezometers indicate a continued upward vertical gradient (Figure 3.8). Thus, a localized water-level decline between 1987 and 1990 is due to the pumping depression around the Denniston Creek production wells, while declines along the coastline have been comparatively small. The data indicate that ground water continued to maintain a gradient toward the Marsh and Half Moon Bay.

Ground-water levels declined further from March to December 1990. By December, ground-water elevations dropped to slightly below sea level in the pumping depression and to 41.40 feet MSL in the Coastside North well (Figure 3.11). However, elevations remained above sea level along the coastline and in the Marsh. The elevation declines were approximately 7 feet in the pumping depression and less than 4 feet along the coastline during this period (Figure 3.13). Further, the upward vertical gradient in the Marsh was still present. It is apparent that the ground-water gradient was still toward the Marsh and Half Moon Bay in December despite the current drought and pumping depression.

It is important to note that the basin has a demonstrated ability to recharge following periods of drought. As shown in Figure 3.4, ground-water levels dropped significantly from

1976 through 1978 during three consecutive years of below-average rainfall. However, the levels recovered by 1979 with increased precipitation following this drought period. Thus, water levels in the basin should increase when precipitation returns to normal amounts.

The declines in ground-water levels appear to be due to the current drought. The basin has received below-average amounts of precipitation for four consecutive years (1987 through 1990). At the same time, ground-water pumpage in the basin declined in 1989 and 1990 to below 1986 amounts (Figure 3.3). Further, flow in Denniston Creek into the basin has been very low to non-existent (Table 3.1) during the current drought. Thus, recharge to the basin and discharges from the basin have been below normal amounts, which indicates that water-level declines are due to the current drought and not over-pumping of production wells.

4.3.3 Aquifer Characteristics

The Half Moon Bay Airport/Pillar Point Marsh Basin contains an alluvial aquifer consisting of a 70-foot thickness of unconsolidated sands and silty sands overlying weakly-consolidated silty sandstones, siltstones, and mudstones of the Purisima Formation. Most water wells are completed in the upper unconsolidated deposits with some wells completed in the uppermost sandier units of the Purisima Formation. Ground water flows generally in a southerly direction, and an upward vertical gradient is present in the Marsh area.

Values for the aquifer transmissivity and storativity were estimated from well pumping tests performed by ESA in April 1989 and by LSCE in December 1990. The tests were constant rate pumping tests with 8 hour to 24 hour durations. The aquifer transmissivity estimates ranged from 600 to 825 ft^2/day and averaged 700 ft^2/day. Storativity estimates ranged from 0.00021 to 0.0075 with an average of 0.001.

4.3.4 Ground-Water Budget

A ground-water budget is an accounting of the inflow to and outflow from the aquifer system, and changes in the volume of ground water in storage. If inflow is less than outflow (a situation that occurred during the study period), storage is depleted as evidenced by decreasing ground-water levels.

Key to the development of a ground-water budget is a qualitative description of inflow and outflow components. For this analysis, the inflow components include deep percolation of precipitation in the study area and subsurface inflow from the Denniston Creek area, which includes recharge from Denniston Creek itself. Outflow components include ground-water pumping and subsurface outflow to Pillar Point Harbor and Pillar Point Marsh. By assuming that subsurface outflow to the marsh is a component of the budget, the need to estimate evapotranspiration of ground water in the marsh is eliminated. Since the study period covers 1987 to 1990, and water levels were observed to decline during this period, the decline in storage is also an important consideration.

Estimates of the components of the ground-water budget were developed using data collected during the study. Ground-water level data from May 14, 1987 and December 13, 1990 were used to develop a total storage depletion estimate of 246 acre-feet for the entire period. This estimate is based on taking the difference between the ground-water elevations on these two dates in discrete 20 acre cells and multiplying the result by an estimated storativity of 0.001. The 246 acre-foot value translates into a rate of storage decline of 69 acre-feet per year over the study period.

Inflow to the study area, which includes recharge from Denniston Creek, and outflow from the study area, which includes outflow to Pillar Point Harbor and Pillar Point Marsh, were estimated using a slightly modified version of Darcy's Law:

$$Q = TiW$$

Where:

Q = flow (ft^3/day;)
T = aquifer transmissivity (ft^2/day)
i = hydraulic gradient (ft/ft)
W = width of flow field (ft)

Based on the results of well tests discussed above, a value of aquifer transmissivity of 700 ft^2/day was used for both inflow and outflow calculations. The inflow gradient was estimated to be 0.0214 and the outflow gradient was estimated to be 0.0077 from the ground-water contour maps. Width of the inflow and outflow areas were estimated to be 3,000 feet each. These parameters yielded an estimated inflow of 377 acre-feet per year and an outflow estimate of 136 acre-feet per year.

Pumping from 1987 to 1990, as depicted in Table 3.2, averaged 411 acre-feet per year. Adding an assumed 25 acre-feet per year of private pumping results in an estimated pumping of 436 acre-feet per year from 1987 to 1990.

Deep percolation of precipitation was assumed to be the residual in the budget and, as such, can be estimated by assuming that the sum of the pumping and subsurface outflows are in balance with the sum of storage change, subsurface inflow, and deep percolation of precipitation. This approach yields an estimate of 126 acre-feet per year, which represents 8.68 percent of the total rainfall in the area during the 1987 to 1990 period. The 8.68 percent falls within the generally accepted range of 5 to 10 percent that is often used to estimate deep percolation of precipitation.

The ground-water budget for the 1987 to 1990 period is summarized in Table 4.1.

This ground-water budget represents conditions over a relatively short time period during a drought. By making certain assumptions, a long-term ground-water budget for average conditions can be developed.

Since the precipitation during the 1987 to 1990 period averaged 19.83 inches, and 1950 to 1990 precipitation averaged 25.99 inches, and assuming that 8.68 percent of this precipitation infiltrates and recharges the ground-water basin, it can be estimated that the average deep percolation of precipitation would be 165 acre-feet per year, a 31 percent increase over the 1987 to 1990 value. If it is further assumed that average subsurface inflow and outflow are

31 percent higher than the 1987 to 1990 values, and that no storage change occurs, an average ground-water budget can be calculated (Alternative 1, Table 4.2), with ground-water pumping as the residual.

The assumption that ground-water outflow would increase may be inconsistent with the goal of maximizing basin yield without causing impacts to the marsh. If the current level of outflow (136 acre-feet per year) is sufficient over the long-term to maintain the marsh (a speculative assumption that needs to be verified with ongoing monitoring), a different "safe-yield" of the basin can be calculated (Alternative 2, Table 4.2).

These two alternative ground-water budgets are presented in Table 4.2 and suggest that average annual pumping in the area could increase between 45 and 87 acre-feet per year as compared to the 1987 to 1990 average. Continued semi-annual monitoring of ground-water levels throughout the basin would be necessary to verify these estimates as pumping increases.

TABLE 4.1
SUMMARY OF GROUND-WATER BUDGET (1987-1990)
ALL VALUES IN ACRE-FEET PER YEAR

INFLOW	
Subsurface Inflow (includes recharge from Denniston Creek)	377
Deep Percolation of Precipitation	126
Total Inflow	~~478~~ 503
OUTFLOW	
Pumping	436
Subsurface Outflow (to Pillar Point Harbor and Pillar Point Marsh)	136
Total Outflow	572
STORAGE CHANGE	-69

TABLE 4.2
ESTIMATED AVERAGE GROUND-WATER BUDGETS
TWO ALTERNATIVE SCENARIOS
ALL VALUES IN ACRE-FEET PER YEAR

	ALT 1	ALT 2
INFLOW		
Subsurface Inflow (includes recharge from Denniston Creek)	494	494
Deep Percolation of Precipitation	165	165
Total Inflow	659	659
OUTFLOW		
Pumping	481	523
Subsurface Outflow (to Pillar Point Harbor and Pillar Point Marsh)	178	136
Total Outflow	659	659
STORAGE CHANGE	0	0
Δ pump.	45	87
	37 gpm	55 gpm

411 GPM / 1438

V. BIOLOGICAL ASSESSMENT

As part of the overall study, biological monitoring of the Pillar Point Marsh was conducted by Questa Engineering of Point Richmond, California. The complete report of the biological monitoring is presented in Appendix II, and a summary is presented in this section.

The wetland plant communities of the Pillar Point Marsh area can be considered a particularly valuable wildlife habitat because of the great number of wetland types present, forming a rich and diverse mosaic of food, cover, and nesting areas within a relatively small area. The wetland is also important as it provides habitat to a number of sensitive, endangered and protected species.

A reduction in the ground-water inflow to the marsh could conceivably dry up the outer or higher portions of the marsh and salinize the brackish or fresh-water portions of the marsh area, either by allowing greater shallow zone salt water intrusion, or by reducing the important winter salt flushing flows.

Significant changes in soil moisture and salinity or soil pH could result in immediate effects on the vegetation, including lowered productivity and stunted growth. Subtle changes in the extent and seasonal duration of wet or saturated conditions and a slight annual but progressive increase in root zone salinity would be expected to cause gradual changes in species composition and boundary movement of communities.

Monitoring efforts in the marsh included soil moisture, root-zone salinity, and visual monitoring of plant stress over three transects with 22 individual monitoring points. Since the monitoring period covered from December 1989 to April 1991, it was recognized that any subtle changes could not be observed, but data collected as part of this effort could be used in future monitoring efforts and with previously collected data to develop an overall assessment of the condition of the marsh.

Although the monitoring was done during the fifth year of a drought, no significant premature or unseasonal plant stress was observed in the wetland plant communities. All plants flowered and set seed at appropriate times. No unusual stunting, leaf tip burning, or premature dieback was observed. Observations of note included the continued advancement of the swamp smartweed and, to a much lesser extent, nettle into the freshwater emergent marsh, and the advancement of the invasive weedy species from the transition zone into the seasonal wetland areas. These observations were made as early as 1977, and it is unclear whether the changes are due to previous agricultural disturbances, are artifacts of drought, or less likely, are a result of ground-water pumping.

The observations that an upward ground-water gradient still exists in the marsh, and that soil moisture levels remained elevated at levels sufficient to support seasonal hydric plants at all wetland observation points, and general observations related to plant health and vigor suggest that significant impacts to the marsh attributable to the current level of pumping, even during the drought, have not occurred.

VI. GROUND-WATER BASIN YIELD AND MANAGEMENT

The current study of ground-water conditions in the Half Moon Bay Airport area suggests that the continuing drought and ground-water pumping have lowered ground-water levels in the area and have depleted ground-water storage. In addition, the ground-water data indicate that subsurface outflow to Pillar Point Marsh and Pillar Point Harbor continued, but likely at lower rates than under non-drought conditions. These observations, and other findings presented in this report, suggest that ground-water pumping could be increased above current levels without causing impacts to the marsh or causing sea-water intrusion. The management of the increased pumping, however, should be done with attention to the location of the increased pumping, the continuation of collecting ground-water level data on a semi-annual basis, and the development of contingency plans to manage pumping during drought conditions.

The low transmissivity values of the aquifer, and the associated low production rates of wells in the area, suggest that well placement be an important management consideration. The current network of wells has not caused a depression of water levels to the extent that subsurface outflow to the harbor or marsh was eliminated during the study period, only reduced. Since maintenance of subsurface outflow to the marsh and harbor is critical to basin management, increased pumping in the immediate vicinity of the marsh or harbor, even within the limits estimated through water budget analysis, could cause undesirable impacts. On the other hand, average pumping away from the marsh could be increased at least 45 acre-feet per year, and possibly up to 87 acre-feet per year, without causing impacts.

The continued collection and analysis of ground-water level data is critical to sound management of the basin. As stated earlier, the amount of "safe" pumping is given as a range since the precise amount of outflow necessary to maintain the marsh and prevent sea-water intrusion is unknown. As pumping is increased, the monitoring data will provide information relative to horizontal gradients in the major portions of the basin and vertical gradients in the marsh. Pumping should be managed such that outflow is maintained to the harbor and marsh areas, and upward gradients are maintained in the marsh.

The final management consideration involves the development of contingency plans during a drought. The estimates of "safe" pumping are based on estimated long-term average hydrologic conditions. If pumping was increased to these levels, and a drought of the current magnitude were to recur, it is possible that the monitoring data would indicate that either outflow to the marsh would be reduced to an undesirable level, or vertical gradients in the marsh would be reversed. In this scenario, pumping reductions would be warranted until drought conditions ended.

VII. REFERENCES

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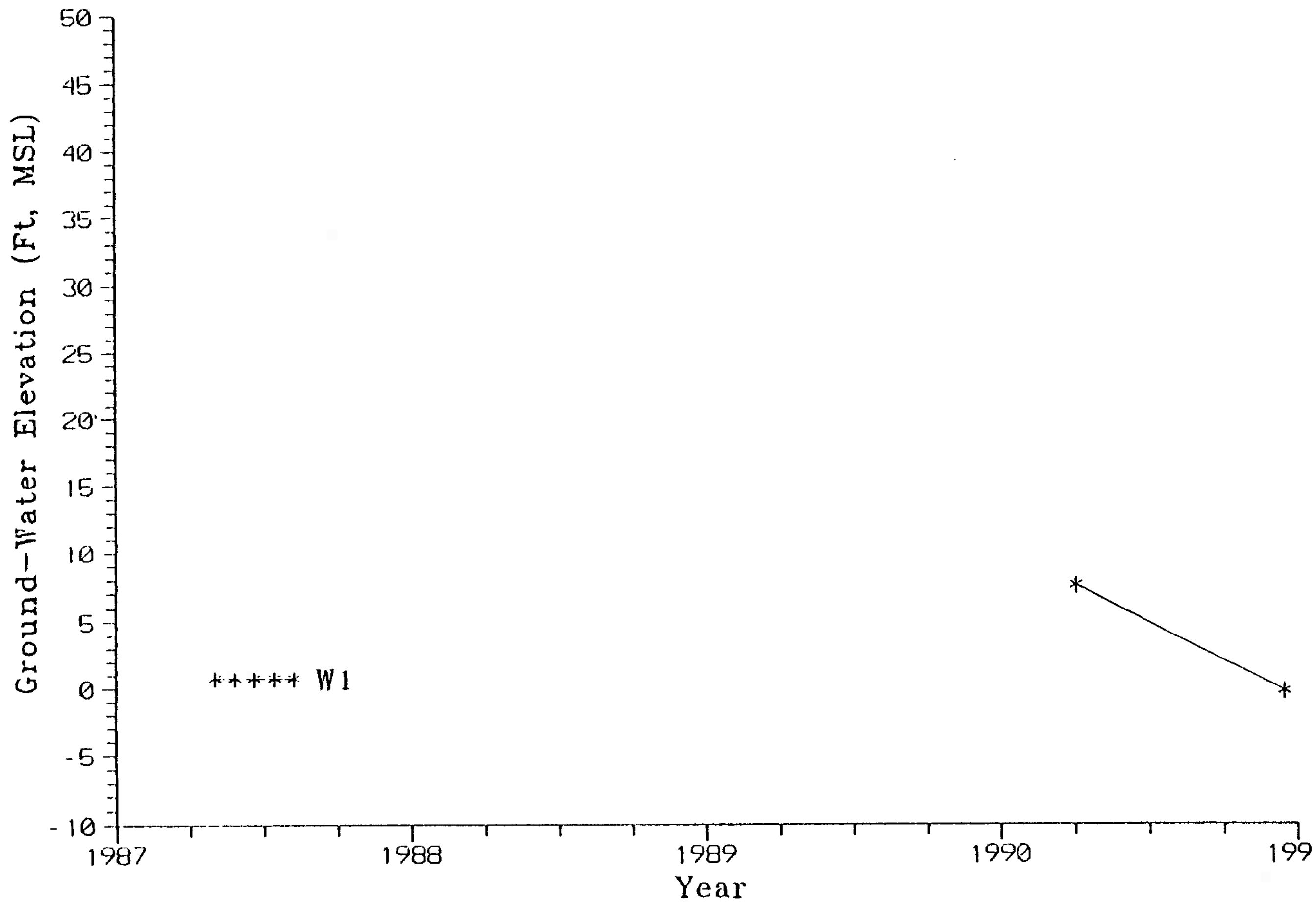
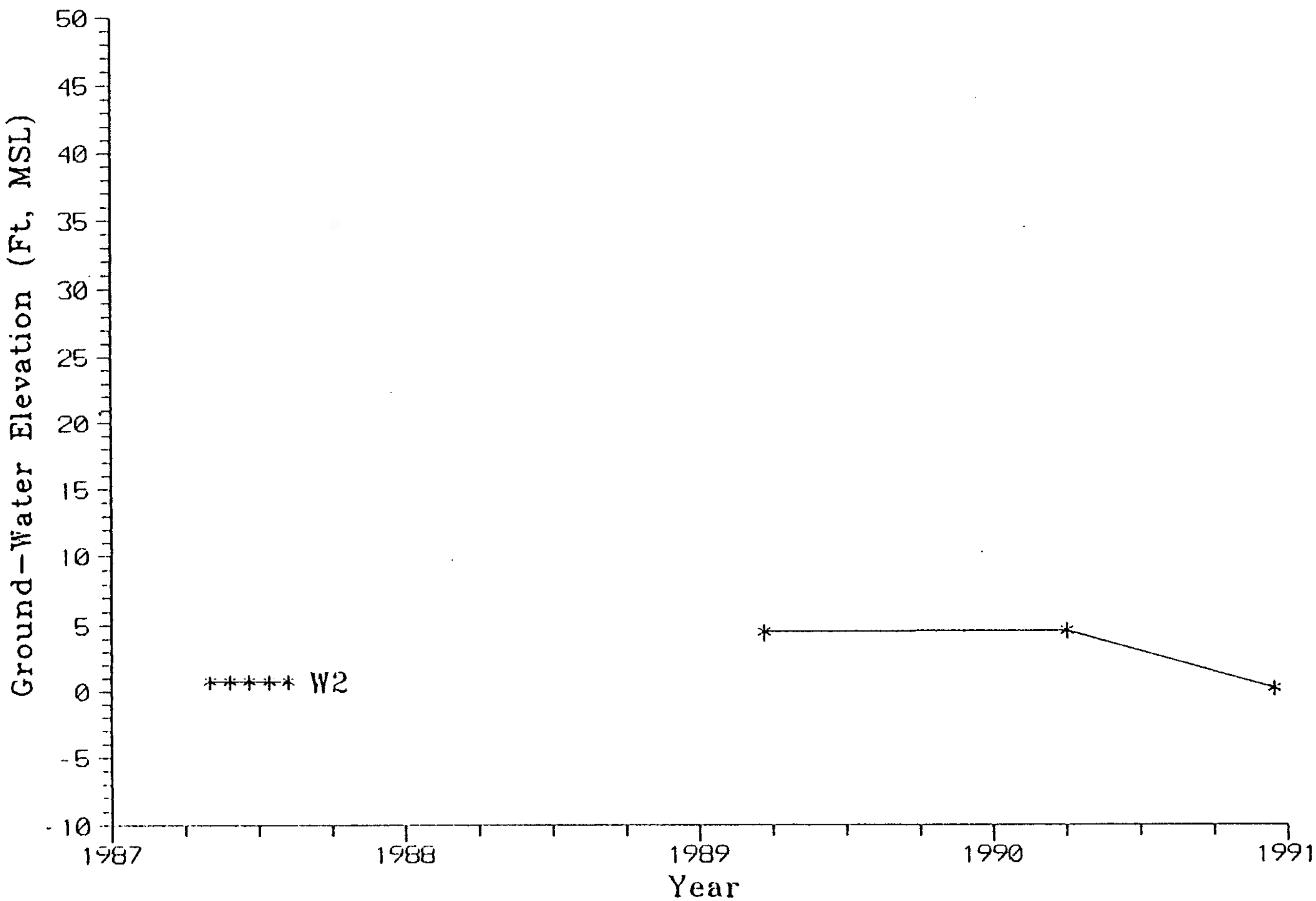
APPENDIX I

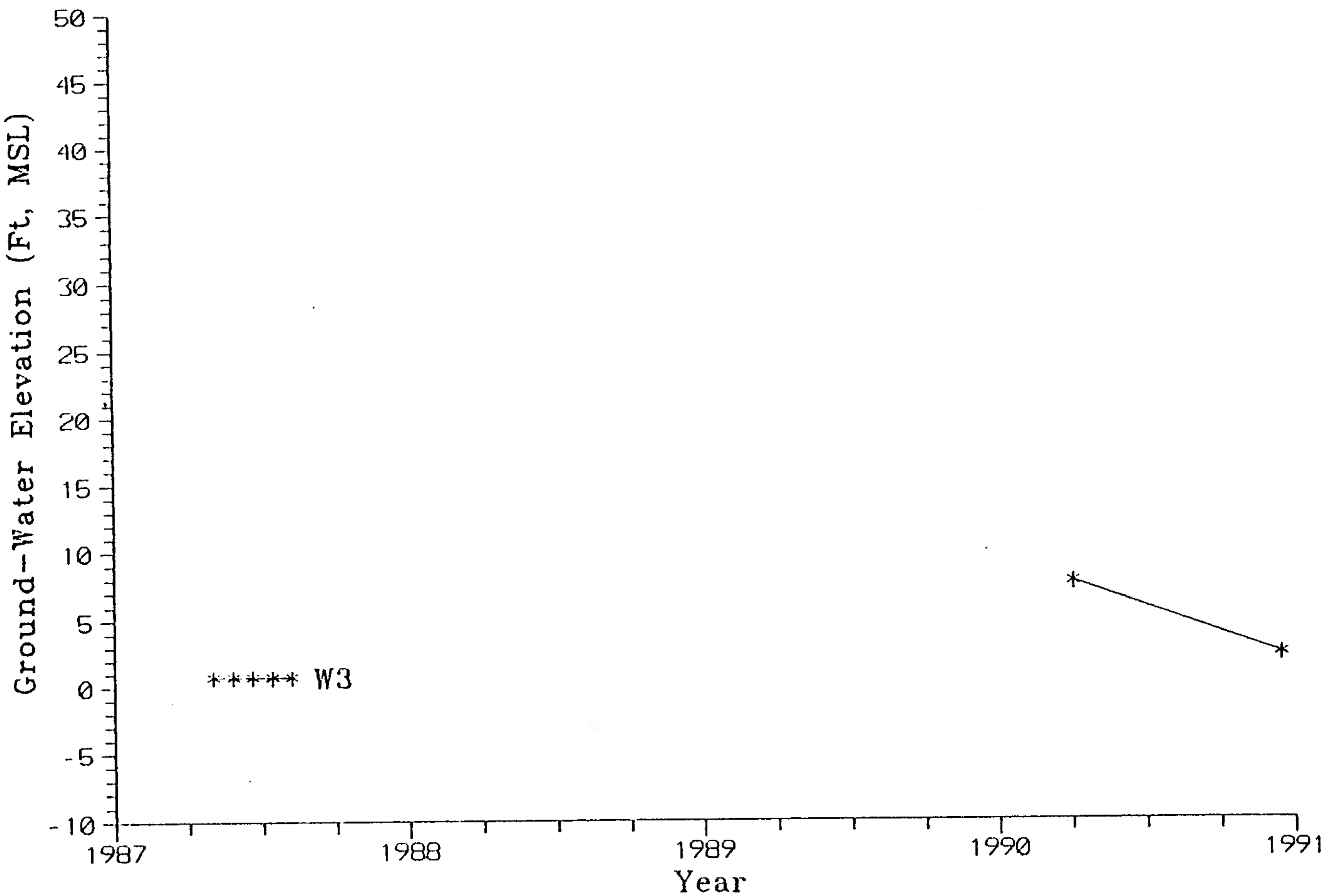
Ground-Water Hydrographs



50
45
40
35
30
25
20
15
10
5
0
-5
-10
Ground-Water Elevation (Ft, MSL)
***** W1
1987
1988
1989
1990
1991
Year



50
45
40
35
30
25
20
15
10
5
0
-5
-10
Ground-Water Elevation (Ft, MSL)
***** W2
1987
1988
1989
1990
1991
Year



Ground-Water Elevation (Ft, MSL)
50
45
40
35
30
25
20
15
10
5
0
-5
-10
1987
1988
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1991
Year
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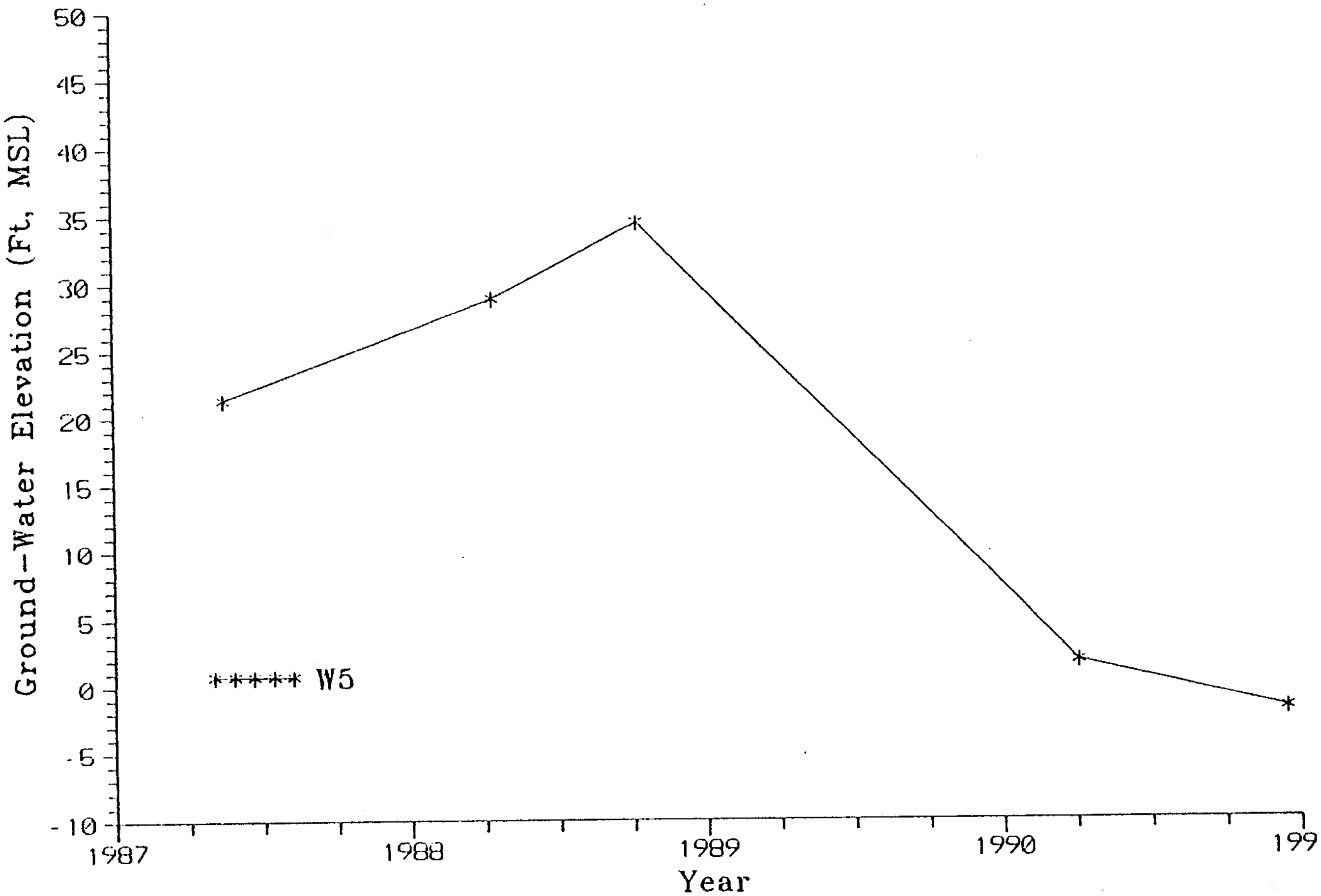
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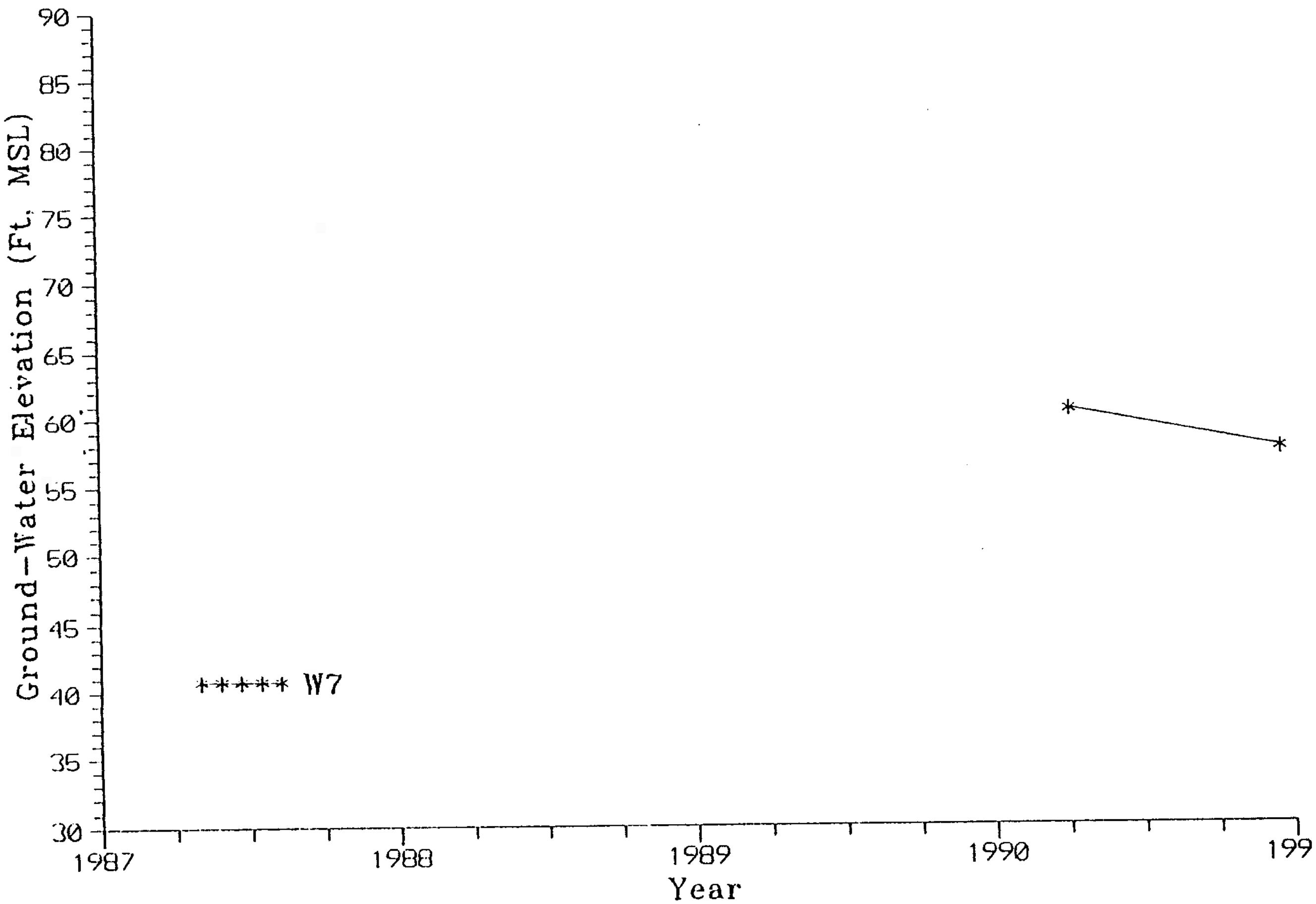
1991
Year
***** W5



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1989
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1991
Year
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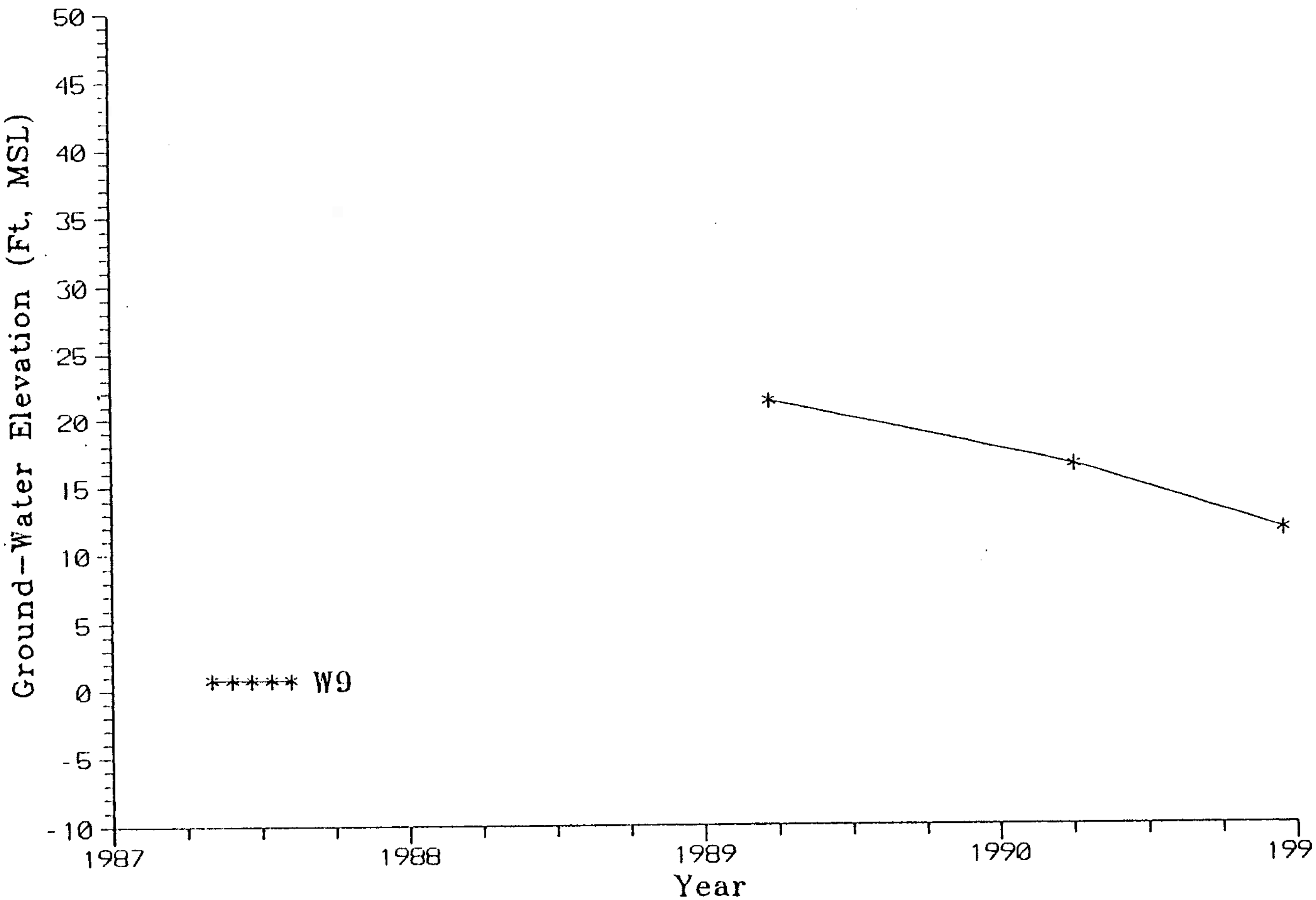

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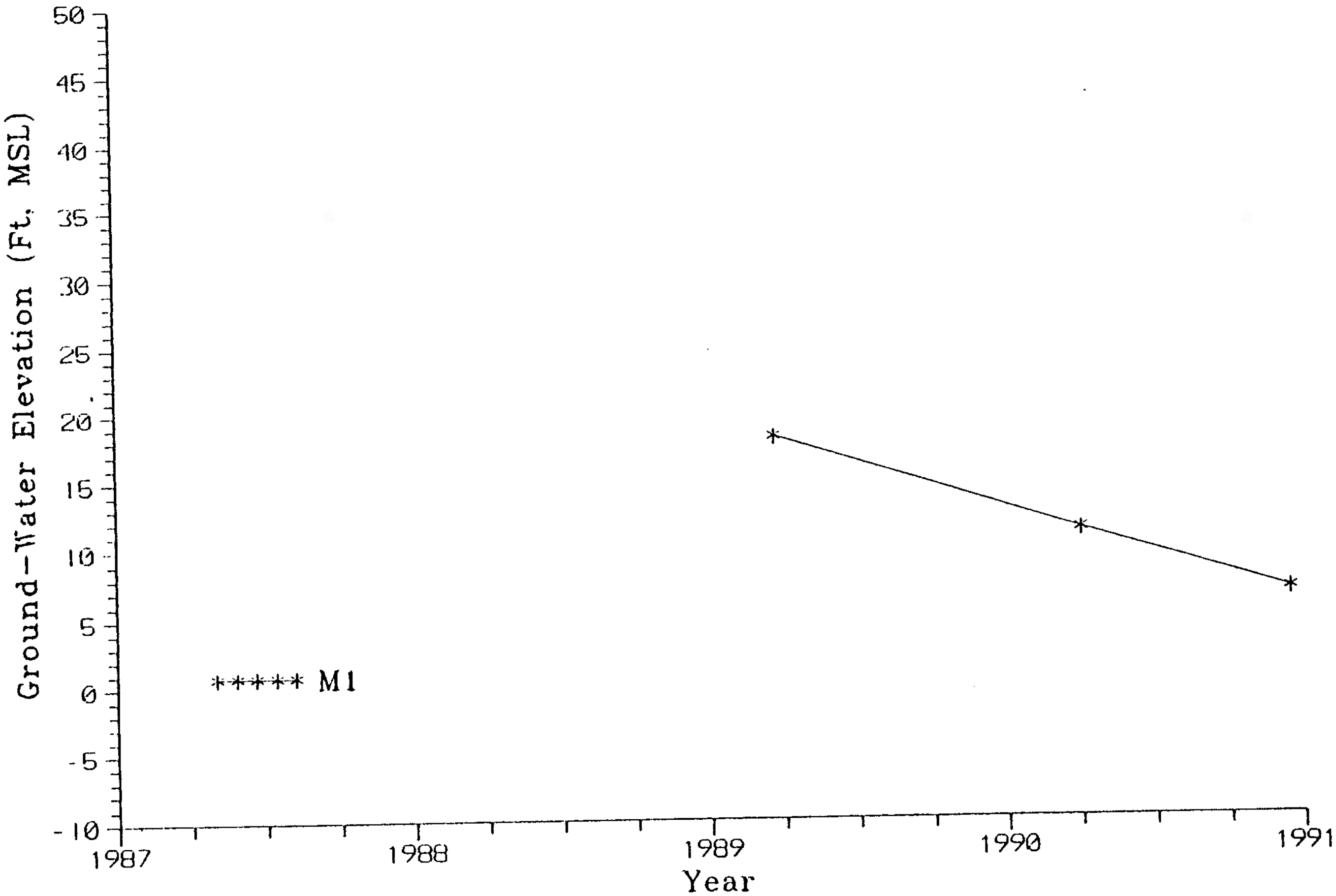
Year



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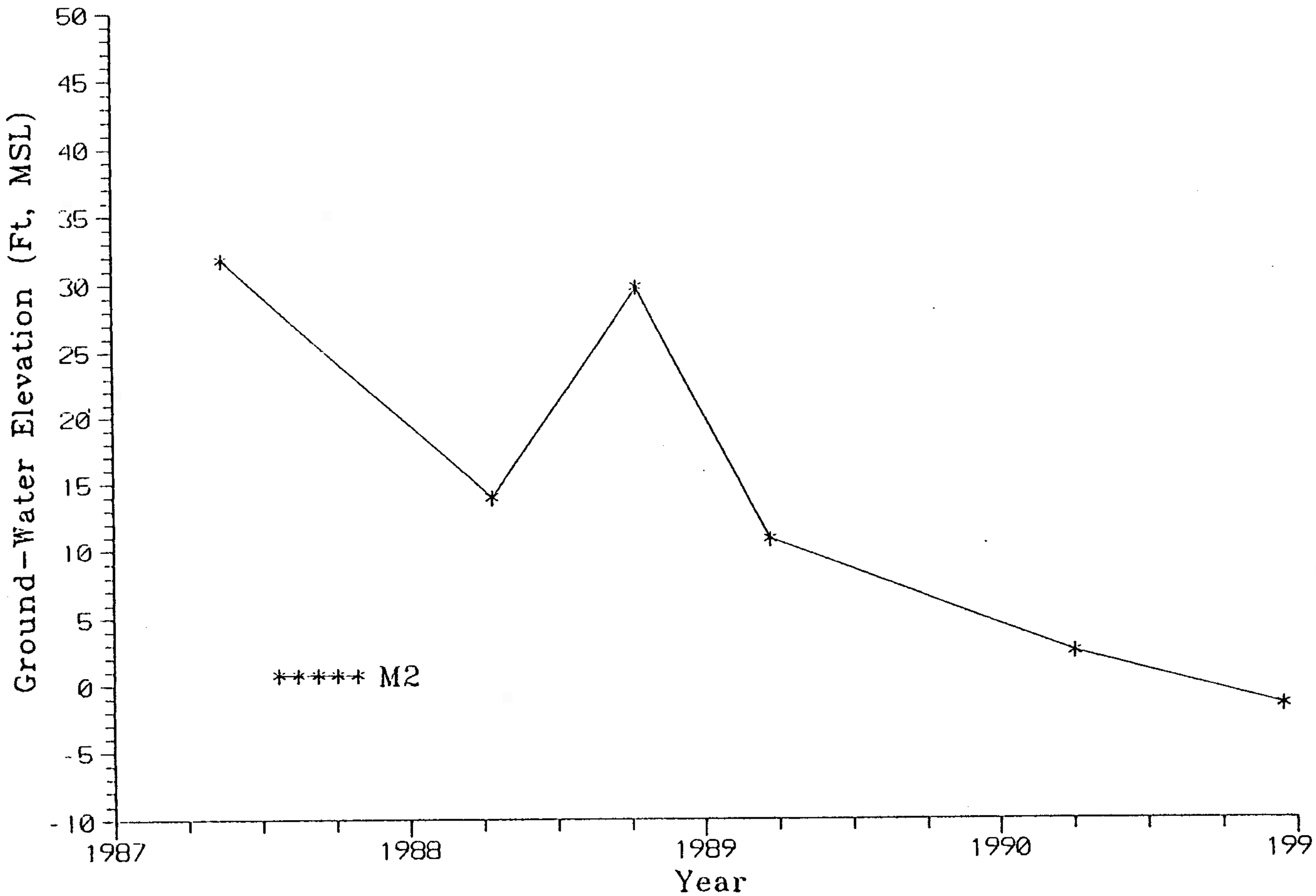
Year



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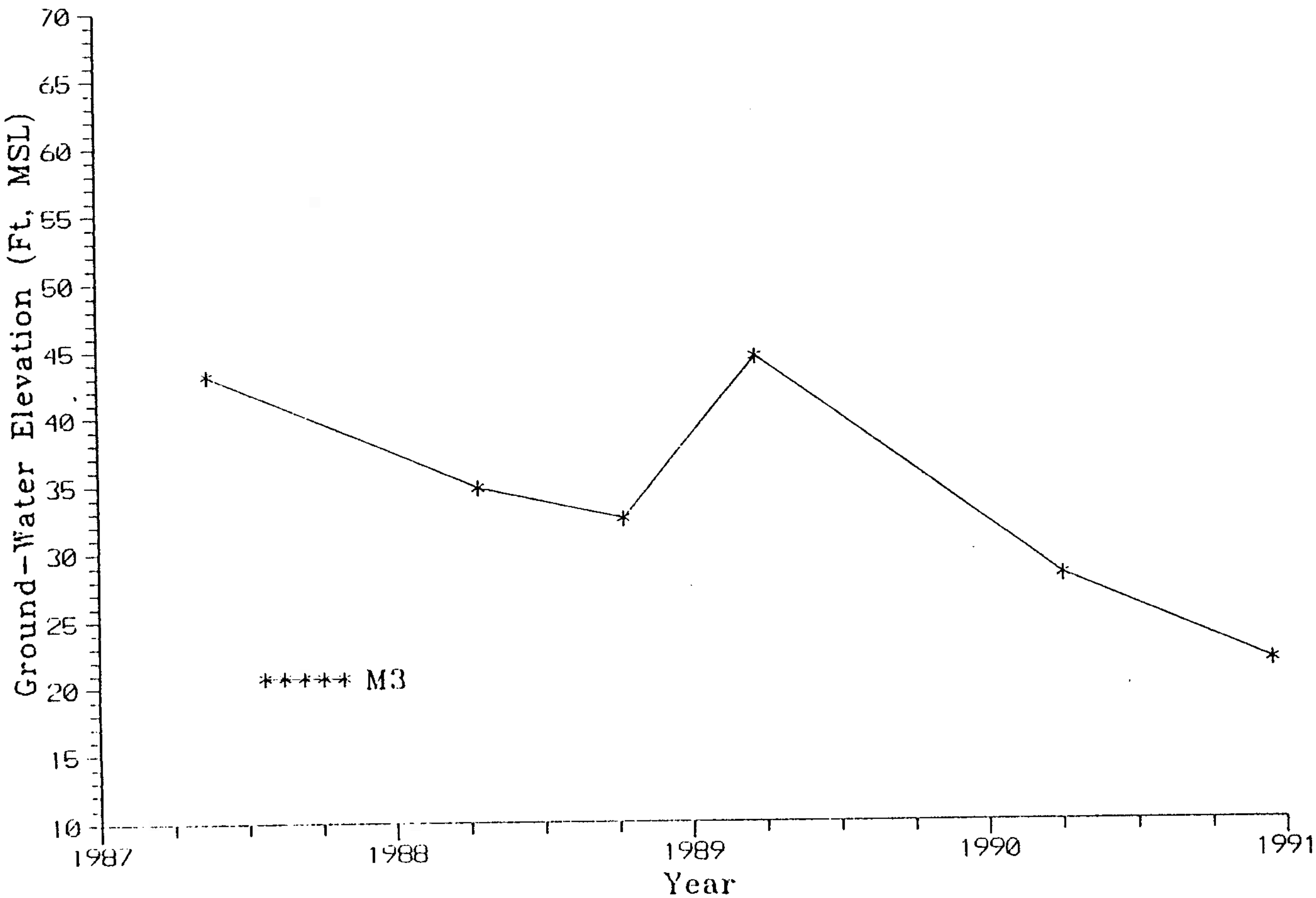
1991
Year



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1987
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1989
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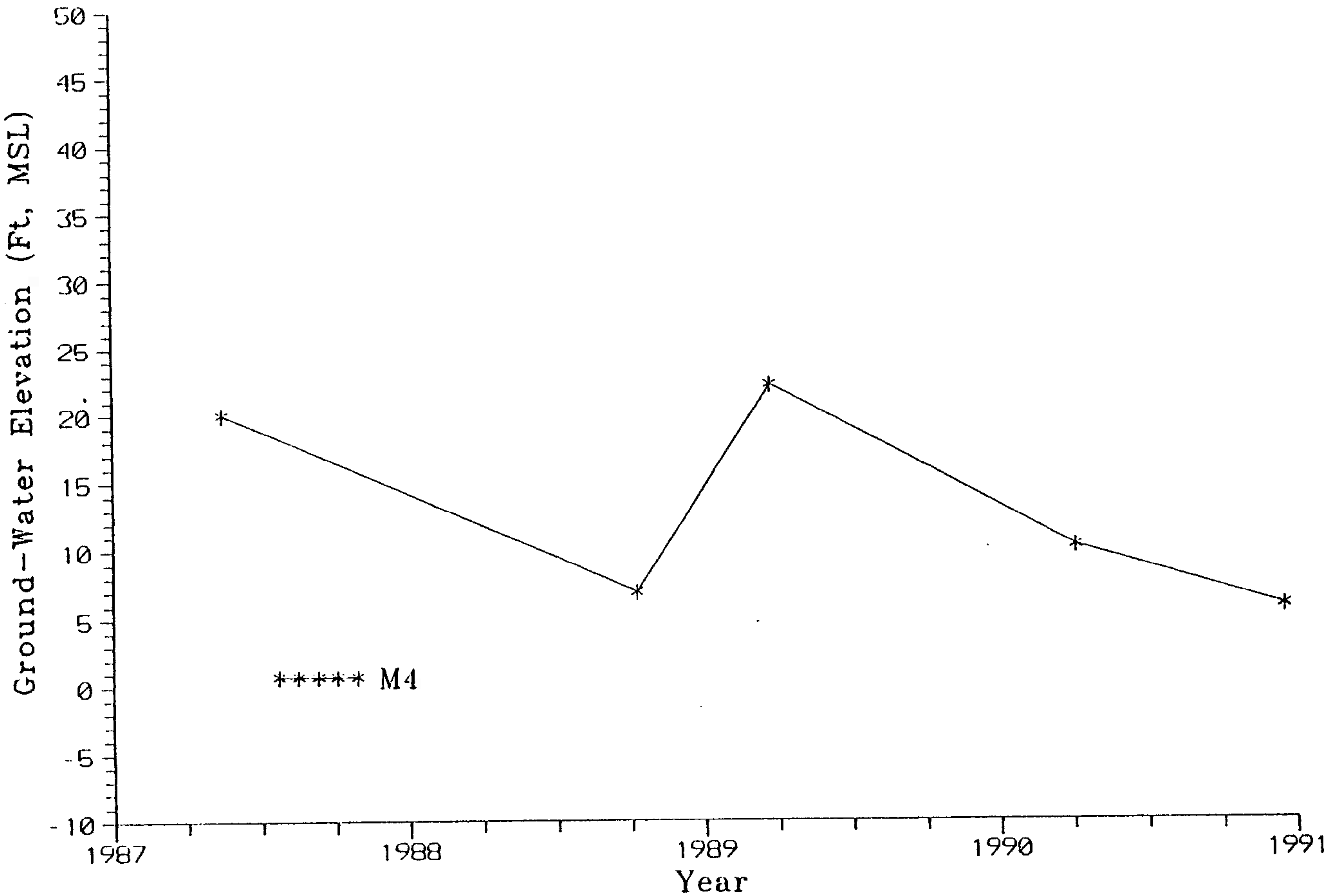
1991
Year



Ground-Water Elevation (Ft, MSL)
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1987
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1989
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1991
Year
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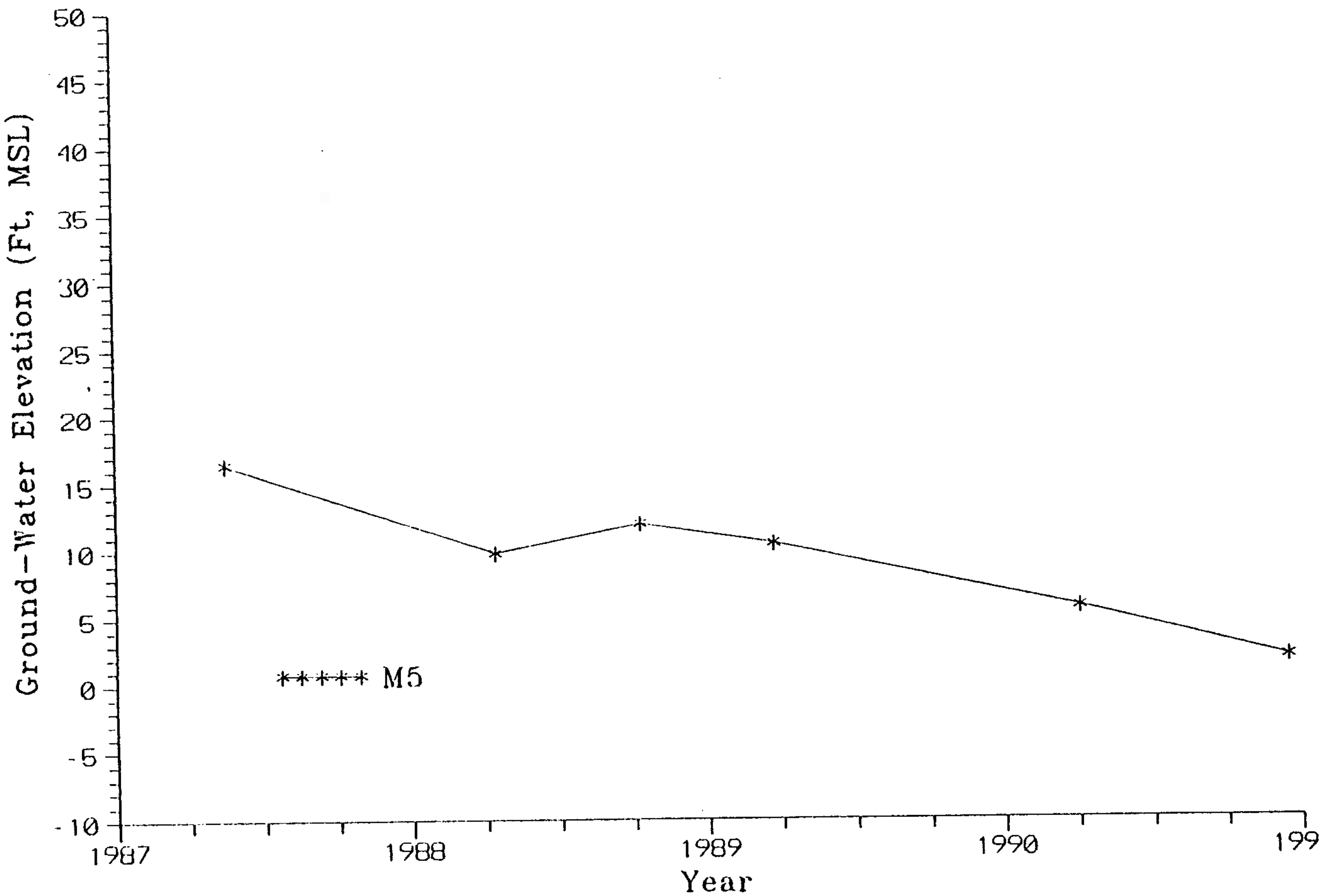

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1987
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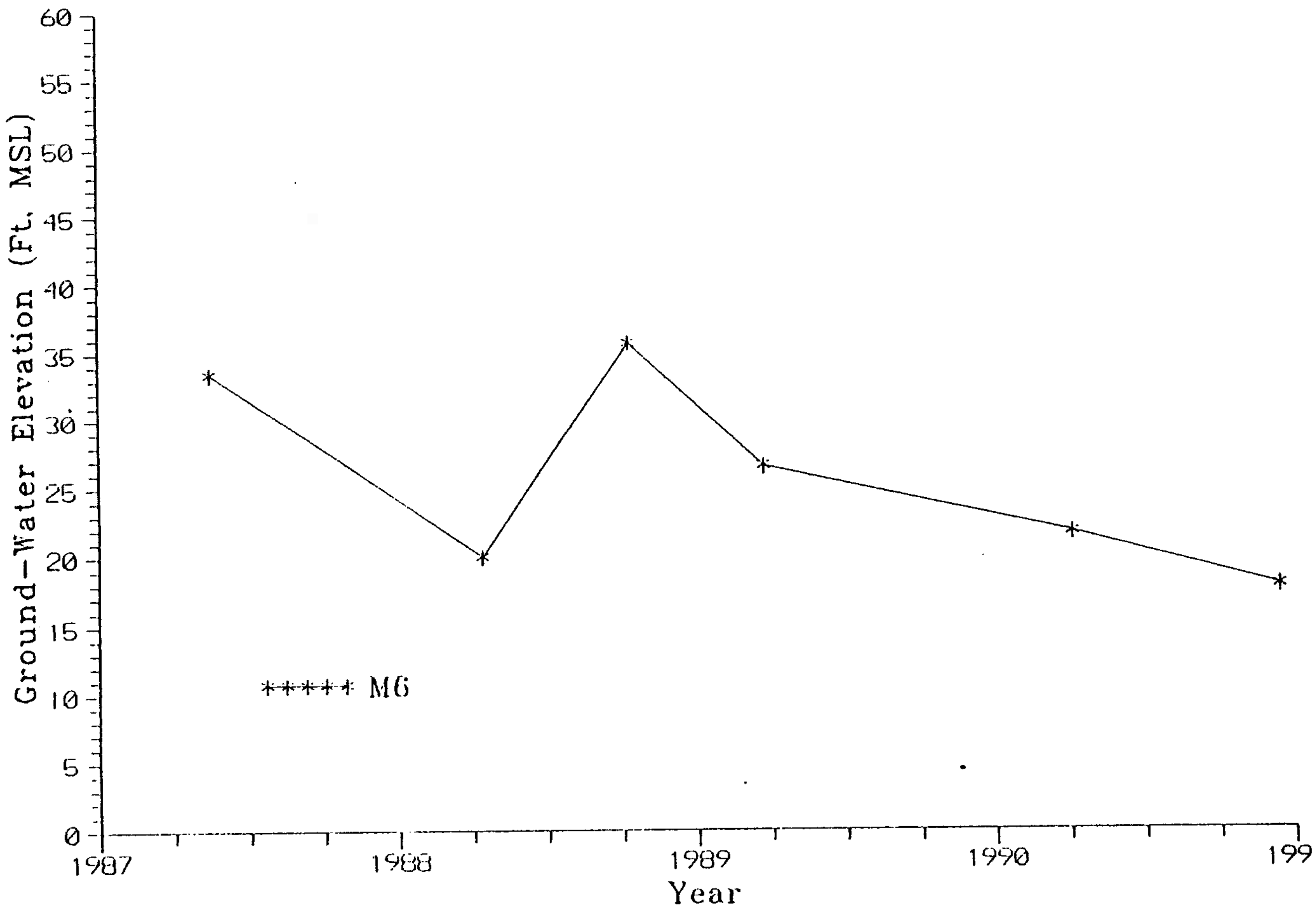
1991
Year



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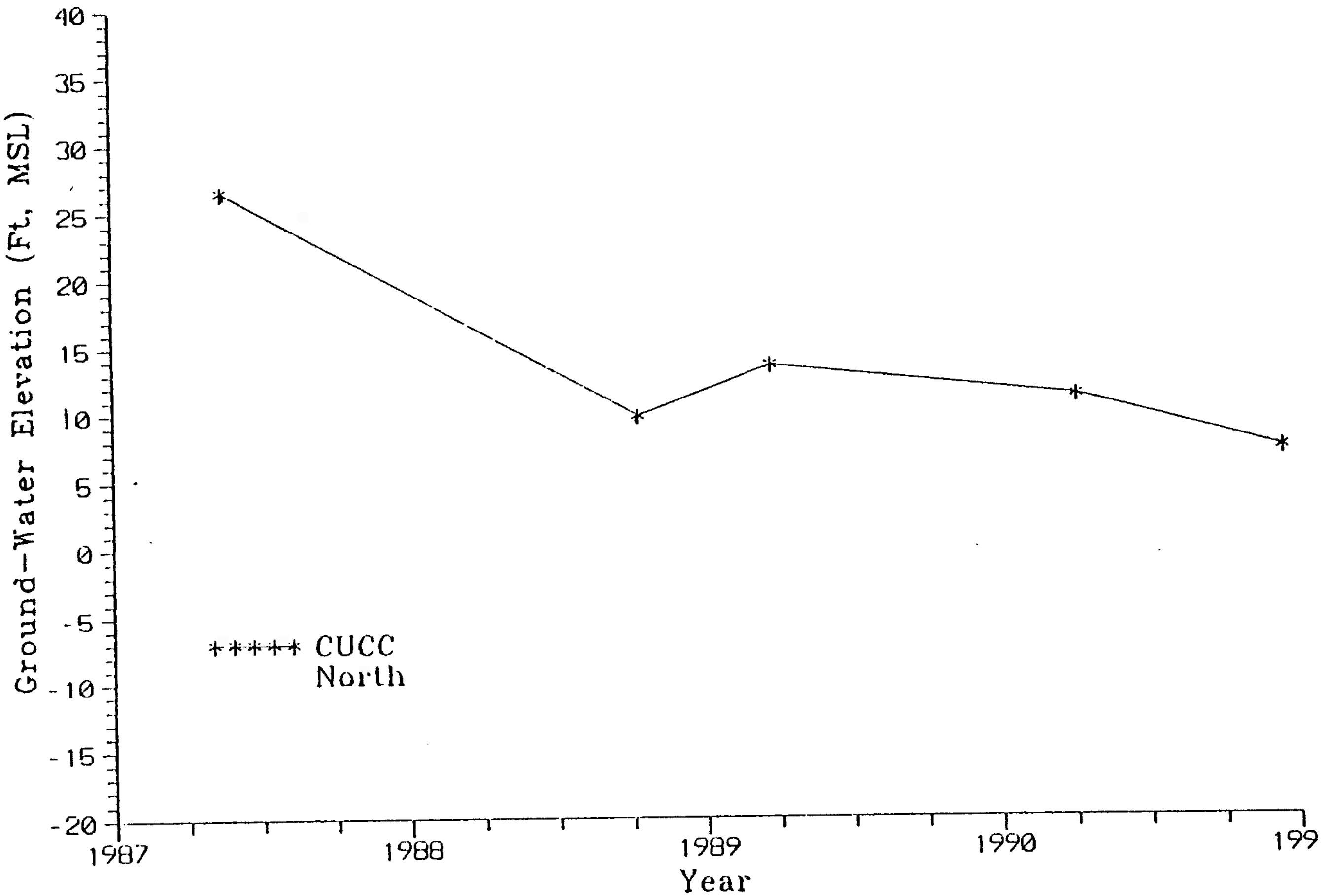
1989
1990
1991
Year



Ground-Water Elevation (Ft, MSL)
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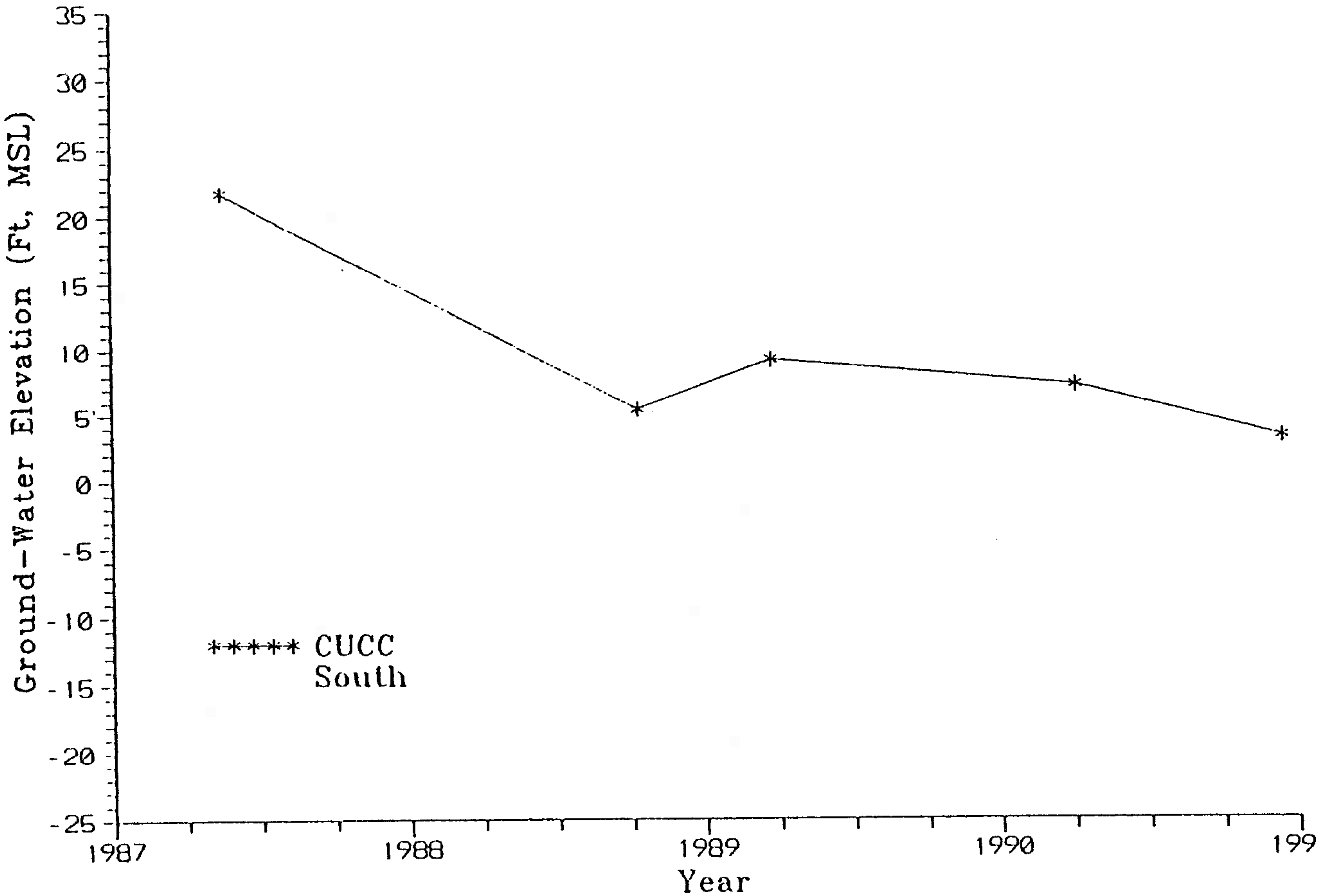
Year
***** CUCC North



Ground-Water Elevation (Ft, MSL)
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1987
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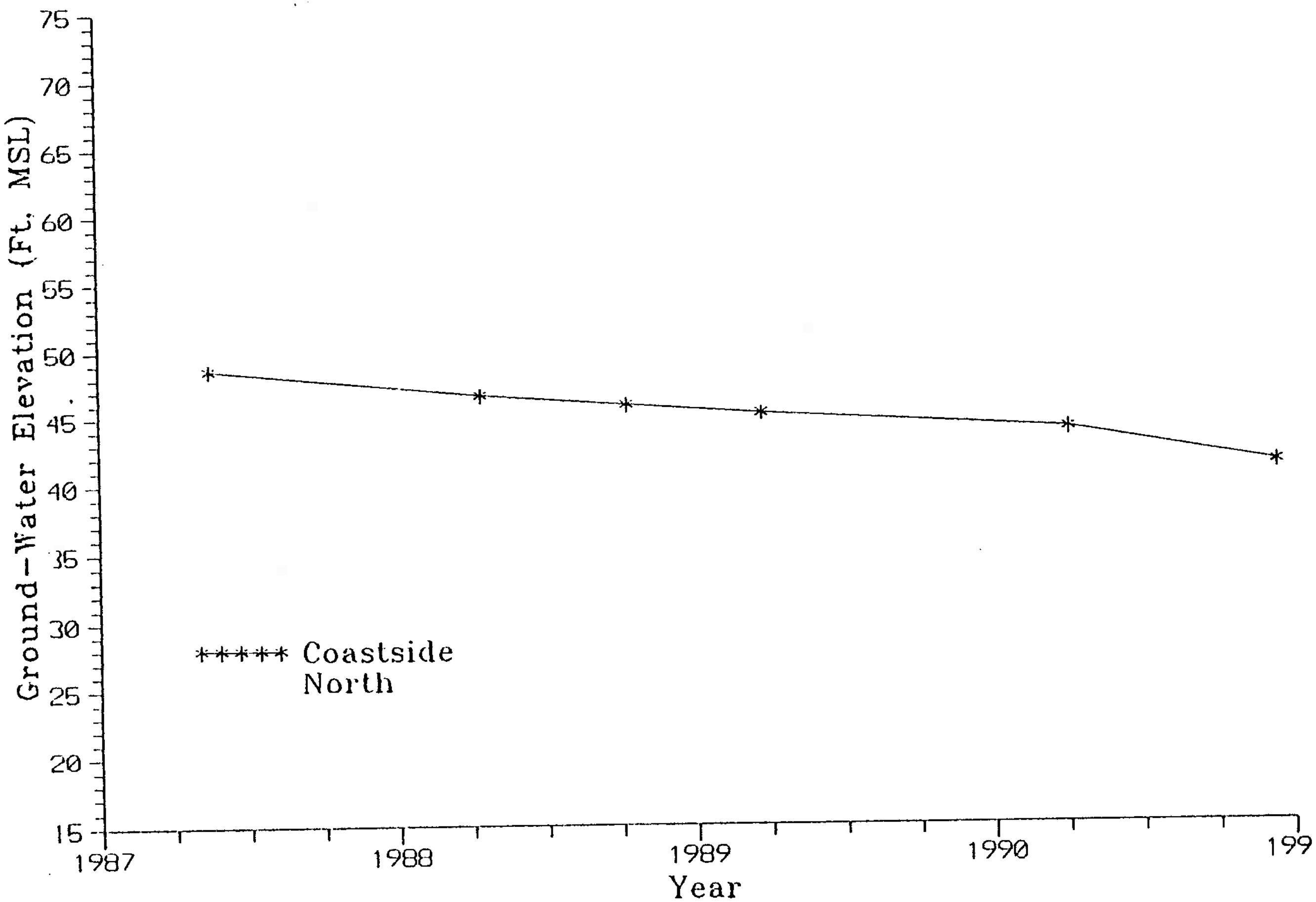
Year
***** CUCC
South



Ground-Water Elevation (Ft. MSL)
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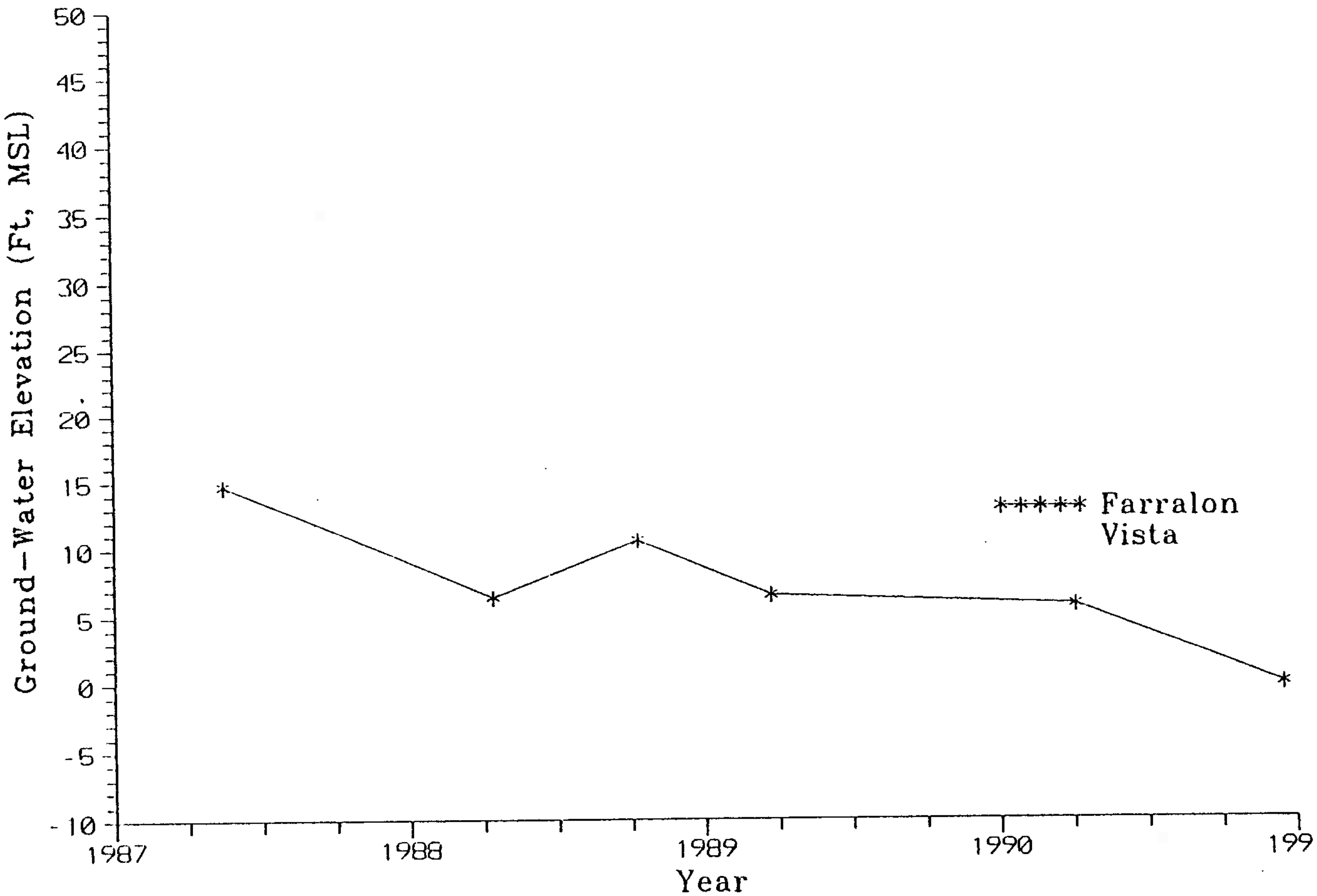
1987
1988
1989
1990
1991
Year



Ground-Water Elevation (Ft, MSL)
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1987
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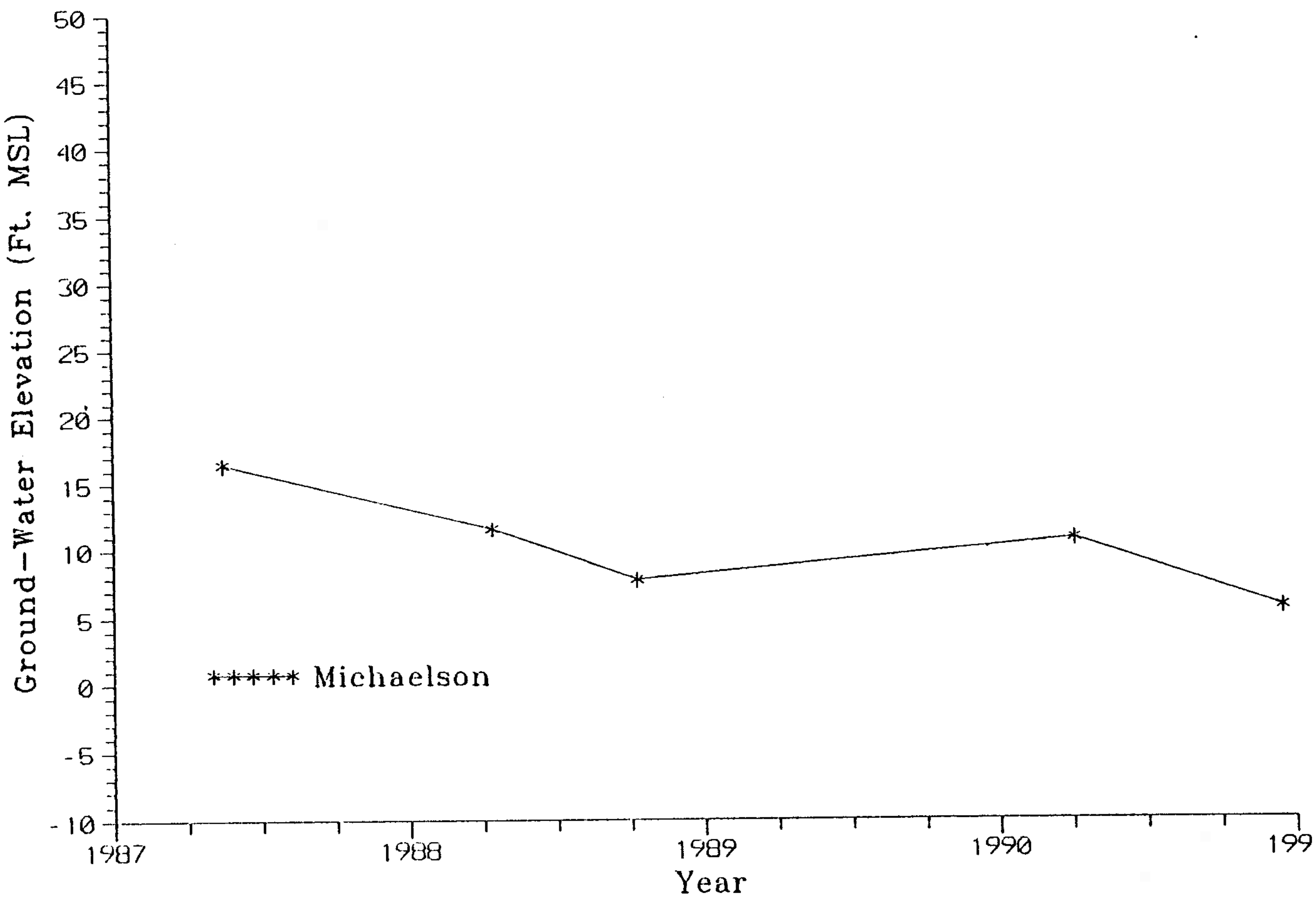
1991
Year
***** Farralon Vista



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Ground-Water Elevation (Ft. MSL)
***** Michaelson
1987
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1991
Year

Ground-Water Elevation (Ft. MSL)
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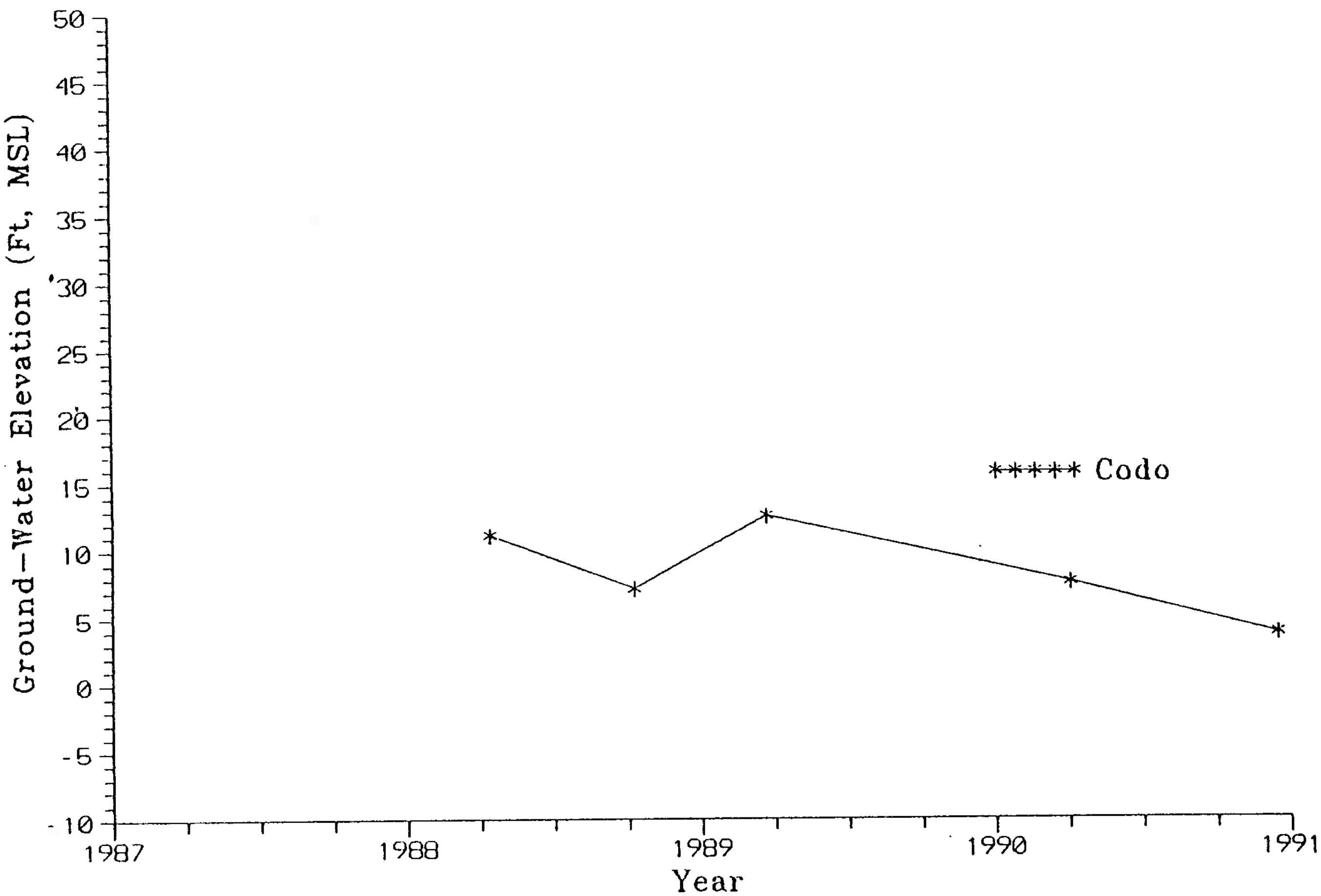
Year
***** Baranca



Ground-Water Elevation (Ft, MSL)
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1987
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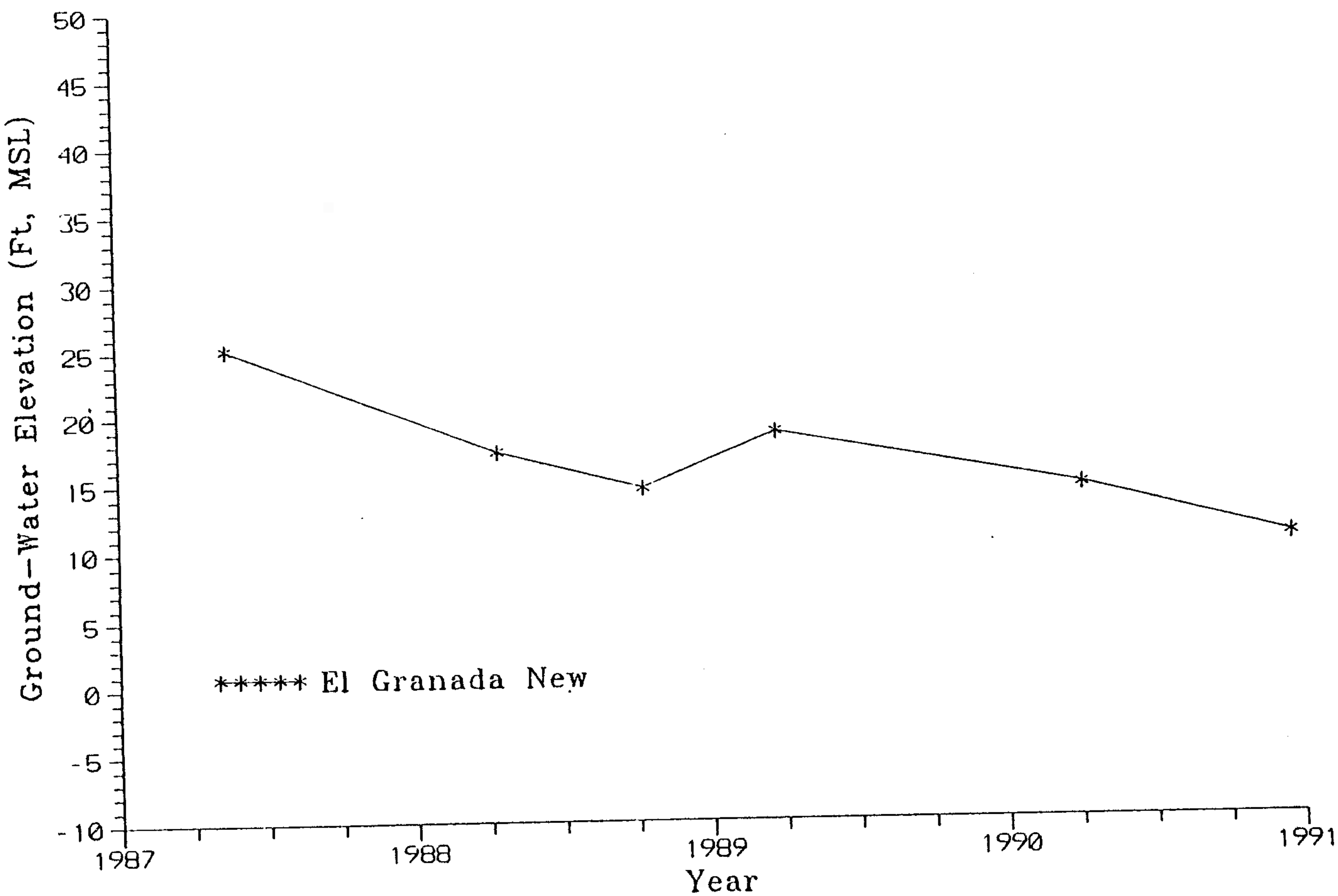

Ground-Water Elevation (Ft, MSL)
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1987
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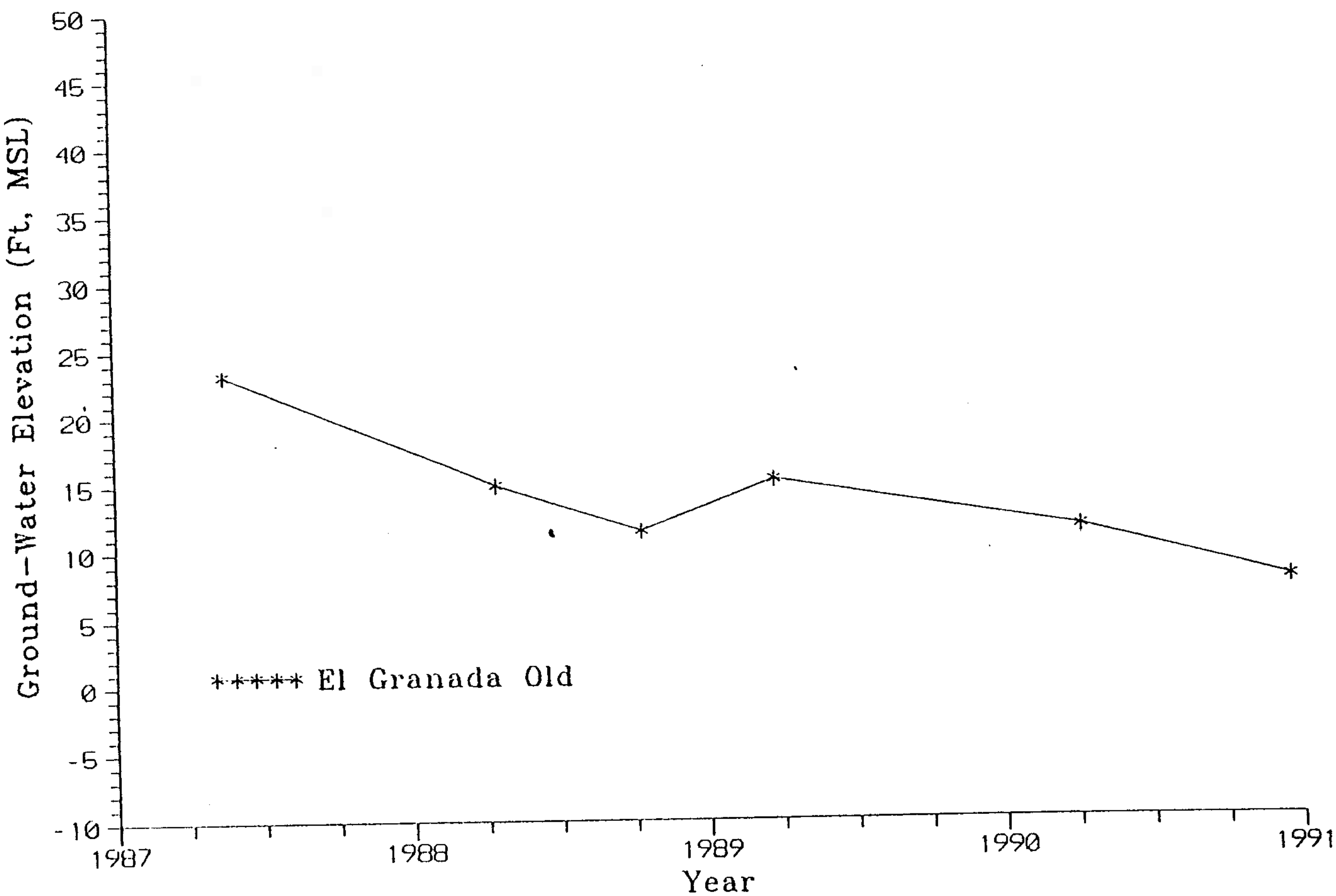
1991
Year
***** El Granada New



Ground-Water Elevation (Ft, MSL)
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1987
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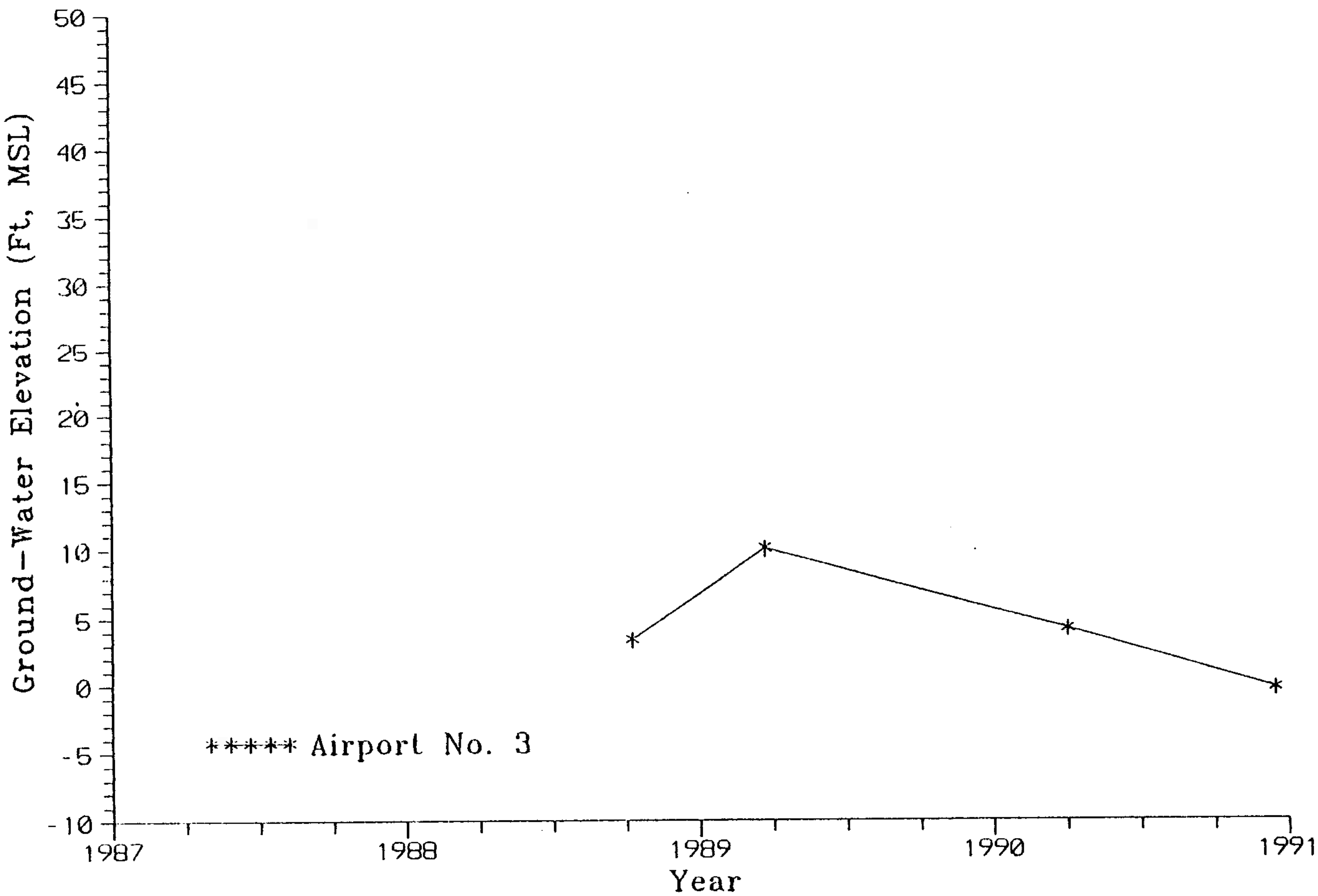
Year
***** El Granada Old



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-10
Ground-Water Elevation (Ft, MSL)
***** Airport No. 3
1987
1988
1989
1990
1991
Year

APPENDIX II

Biological Monitoring Report
Pillar Point Marsh

DRAFT

REPORT ON BIOLOGICAL MONITORING
PILLAR POINT MARSH,
HALF MOON BAY, CALIFORNIA

Presented To

Coastside County Water District
766 Main Street
Half Moon Bay, California 94019

Project 90029

Prepared By

QUESTA ENGINEERING CORPORATION
P.O. Box 356
Point Richmond, California 94807

May 1991

SCOPE AND OBJECTIVES

This report presents the results of 1 $_{1/3}$ years of monitoring soil moisture and root-zone salinity and reaction, and observing for signs of plant stress in the Pillar Point Marsh, located near Princeton, Half Moon Bay, California. Concern has been expressed that municipal development of the local groundwater resource may adversely impact the marsh, either by removing a significant volume of the total subsurface flow into the wetland, or by removing an important part of the freshwater inflow.

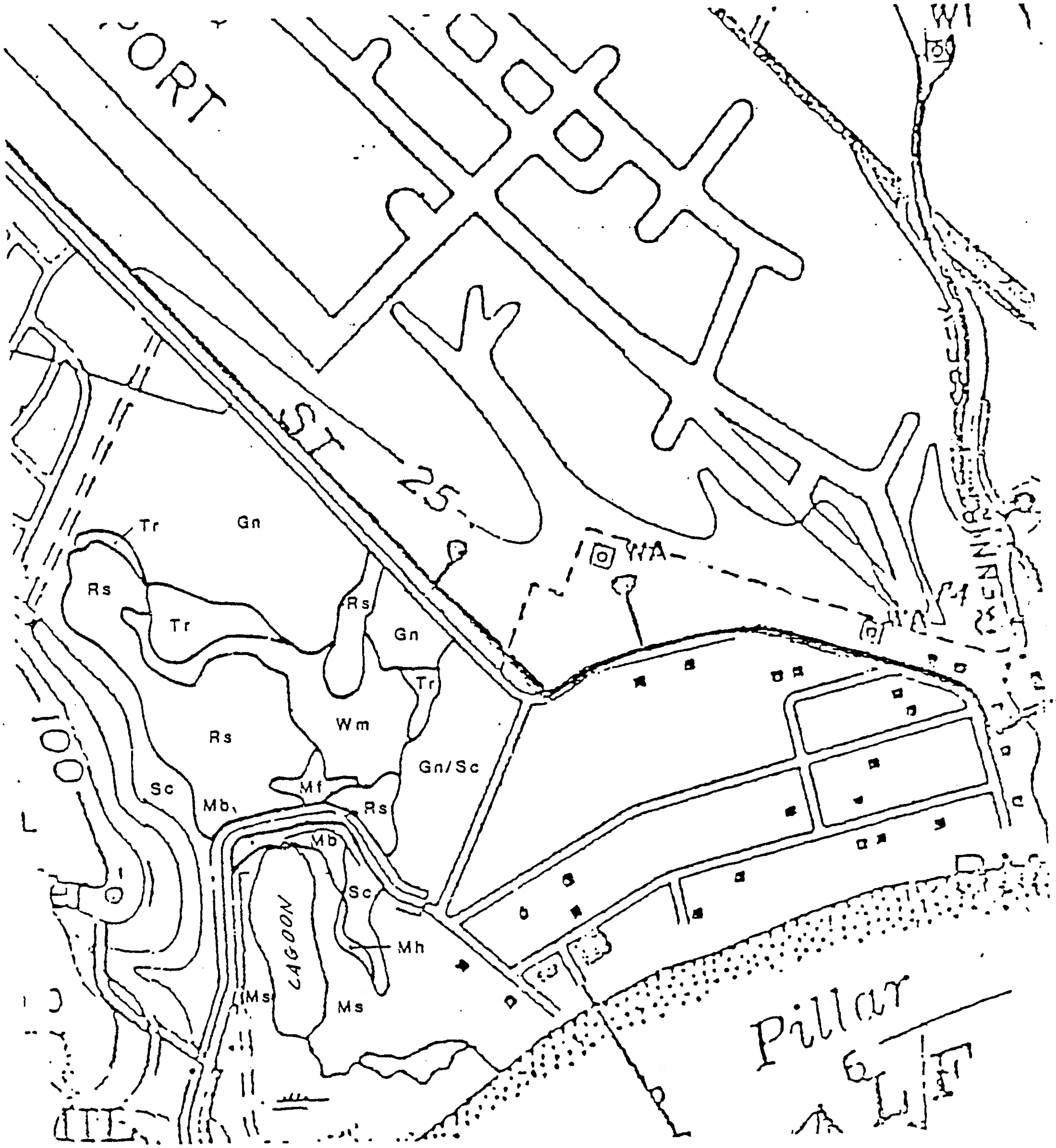
A reduction in the groundwater inflow could conceivably dry up at least the outer or higher portions of the marsh, particularly the seasonally wet areas, shortening the saturated or wet soil conditions period. A reduction in freshwater inflow could also conceivably salinize the brackish or freshwater portions of the marsh area, either by allowing greater shallow zone salt water intrusion, or by reducing the important winter salt flushing flows. Depending on magnitude, both potential effects on soil moisture and root zone salinity would have the tendency to change the productivity and species composition of the plant communities, and may cause plant community boundaries to expand or shrink in response to these changing environmental conditions. Significant changes in soil moisture and salinity or soil pH could produce immediate effects on the vegetation, including lowered productivity and stunted growth, or in the extreme, death of sensitive or intolerant species and replacement by less desirable species.

Subtle, non-dramatic changes in the extent and seasonal duration of wet or saturated soil conditions, and a slight annual but progressive increase in root zone salinity would likely not be apparent over the short term. In the absence of other factors or environmental disturbances, the species composition and boundary movement of such marginally impacted plant communities (as defined by dominant species) would be expected to change gradually over a period of years and would not be detected by a single years worth of biological monitoring. More tolerant, weedy species, already a concern in the marsh, could invade and displace the more desirable native wetland plants in a slow progression over time.

The wetland plant communities of the Pillar Point Marsh area can be considered to be a particularly valuable wildlife habitat because of the great number of wetland types present, forming a rich and diverse mosaic of food, cover, and nesting areas within a relatively small overall area. The wetland is also important as it provides habitat to a number of sensitive, endangered and protected species, including the San Francisco garter snake. The wetland communities and their dominant plants include the following (see Figure 1).

1. Salt marsh (Ms) - (pickleweed zone)
2. High salt marsh (Mh) - (jaumea-salt grass-frankenia zone)
3. Brackish marsh (Mb) - (saltrush - silverweed zone)
4. Freshwater emergent marsh (Mf) - (bulrush-cat-tail zone)
5. Riparian thicket (Rs) - (dense areas of willows)
6. Seasonal wetlands (Wm) - (swamp smartweed; silverweed; and sedge-rush)
7. Transition zone (Tr) - (generally weedy areas; bristly oxtongue, bull thistle, horse-tail)
8. Coastal scrub (Cs) - (coyote bush, annual grasses and weeds)
9. Grassland (Gr) - (oatgrass, ryegrass, brome)

If more subtle changes were to occur with respect to salinity and soil moisture, one years worth of plant community monitoring by measuring species composition and relative abundance in each of the above plant communities on a bi-monthly basis would likely not define early the potential on-set of serious long-term wetland sustainability problems. More significant, and more dramatic changes in soil moisture and root-zone salinity, however, may have more immediate effects on the productivity and vigor of plant communities, for instance by causing germination problems, failure to regenerate after severe frost damage, early die-back, or failure to produce flowers and seeds. Only in the most



LEGEND

Ms Salt marsh
Mh High marsh
Mb Brackish marsh
Mf Freshwater emergent marsh
Wm Seasonally wet meadow
Tr Transition zone
Sc Coastal scrub
Gn Grassland
Sc/Gn Mixed coastal scrub and grassland

90029

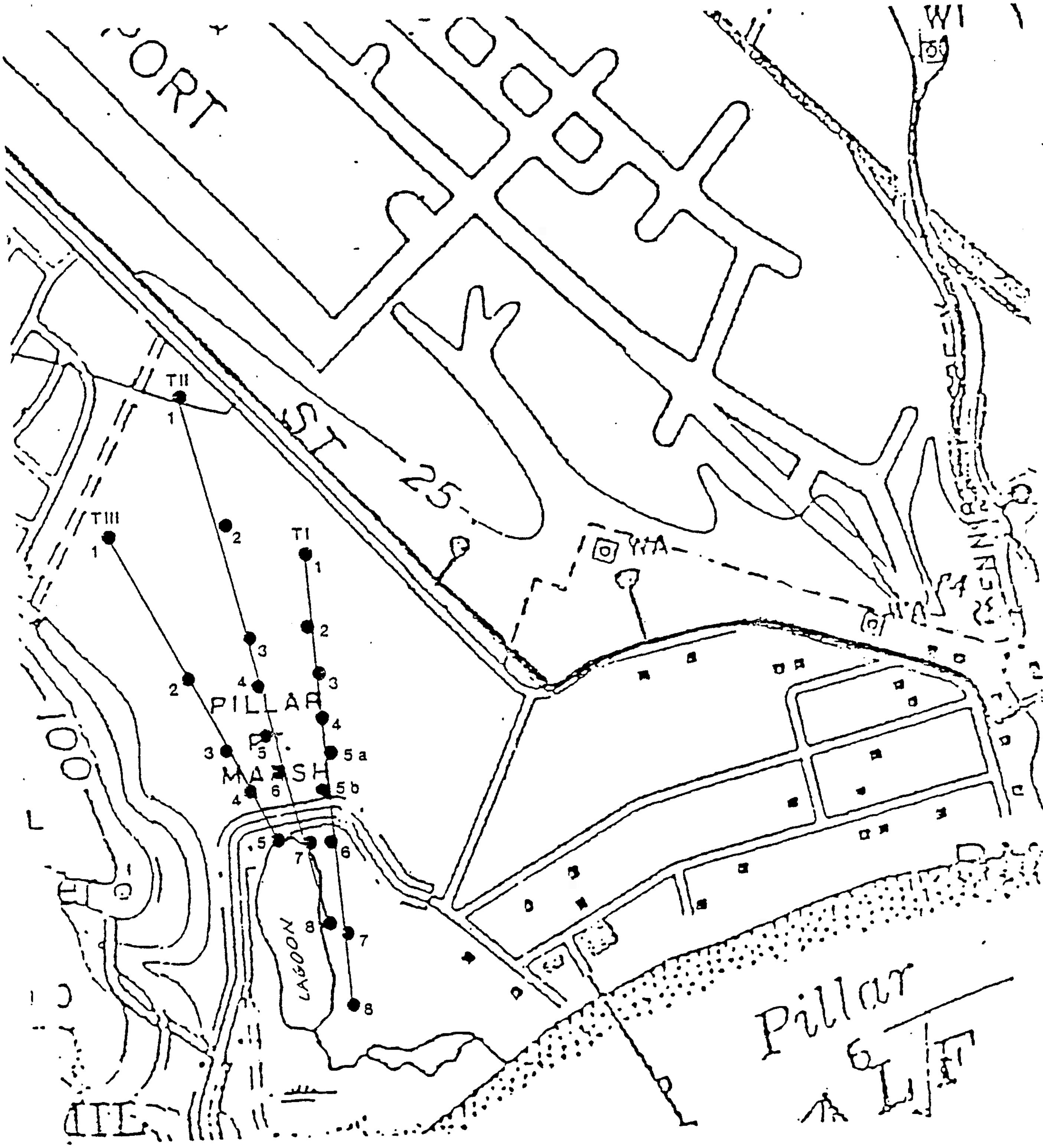
Questa Engineering Corp. Point Richmond, Calif.	PILLAR POINT MARSH PLANT COMMUNITIES	Fig. 1

extreme cases, (sudden early drying of a wetland soil or severe saline shock), would death of wetland plants be expected.

It was felt that the monitoring of soil moisture, root-zone salinity and reaction, and the visual appearance of plant stress would provide enough of an early warning system so that management actions could be immediately taken if serious impacts on the wetlands from groundwater development were beginning to be observed. At the same time, data would begin to be developed to judge future, longer term impacts such as might occur from gradual salt build-up or the drying of the peripheral seasonally wet areas. (Long-term changes, for instance, could include the displacement of the brackish marsh by salt marsh species, and the freshwater marsh by brackish species.) This data can then be used in conjunction with earlier biological inventory work including that completed by Gankin (1976), Flint (1977,78), WESCO and Ulrich (1982), and Patterson (1987) to note trends and conditions apparent only over the long term and resultant from more subtle changes in soil moisture and salinity.

METHODS

Three soil-vegetation transect lines were established through the upland and wetland plant communities of the Pillar Point marsh area, as shown in Figure 2. Some 22 observation points are included. This soil moisture, salinity and pH data is included in Appendix 1. The transects were laid out in consultation with the San Mateo County Planning Department so as to traverse all of the major plant communities, providing a means to compare soil moisture levels and apparent plant stress among the communities. The grassland and coastal scrub types were included as comparative or control points. In the initial site visit of December 1989, soil samples were obtained and soil moisture, soil-pH, and soil-salinity levels on 1:1 soil-water extracts were determined in the laboratory. This was to re-establish a long-term baseline, against which future years soil samples might be judged. Some comparison with earlier soil salinity determinations made by Flint (1976) and Ulrich and WESCO Laboratories (1982) was also thought to be possible.



9002

Questa Engineering Corp. Point Richmond, Calif.	PILLAR POINT MARSH TRANSECT LOCATIONS AND SAMPLING POINTS	Fig. 2

Initially, soil moisture levels were determined with a Soil Moisture Equipment Corporation (SMEC) soil-tensiometer, and soil-water samples were obtained with a SMEL porous-cup suction lysimeter. This proved to be a time consuming and costly procedure, and after several of the instruments were broken, lost, or removed by visitors to the marsh, a second, less time consuming, but equally effective approach was adapted. Soil moisture levels were determined using a direct reading 2.5' Aquaterr 100 moisture meter probe. This instrument was developed to assist farmers in judging soil moisture levels for irrigation scheduling, and after calibration, reads out directly in soil moisture content on a scale from 0 to 100. Since this resistivity type meter is somewhat affected by the salt content of soils, the instrument was separately calibrated to 100 for the saturated salt-marsh, brackish, and freshwater marsh wetland soils. The soil moisture readings from the moisture meter probe were then correlated with soil tensiometer readings (0 to 100 centibars scale) to determine soil moisture levels when plants might be under moisture stress, and when permanent wilting point (p.w.p.) occurs. Generally saturated soils have soil tensiometer readings less than 1 centibar, very moist soils to 5 centibars, moist soils 10 - 15 centibars, damp soils 20 - 30 centibars and dry soils above 80 centibars. Wetland plants are likely stressed at levels above 30 centibars, equivalent to about 65 - 70 on the moisture probe. Permanent wilting point (pwp) and death would occur above this, or at moisture probe values less than 55 - 60 for most wetland plants. Upland plants can generally withstand moisture stresses much higher than this.

Soil moisture content at 10- and 18-inch depths were determined monthly at the 22 specified sampling locations along the 3 transects. In some cases a shallow hole was first dug in the soil with a tile spade or 3" mud auger to allow advancement of the moisture probe. It was not possible to occupy the exact site at each subsequent sampling period as the prior disturbance would have affected soil moisture content. Sampling points were also distributed over an area at successive visits so as not to overlay impact the sensitive plant communities. This may have introduced some inadvertent variability into the data set. All soils were replaced in the excavations and backfilled upon completion of the readings.

In addition to the soil-moisture determinations, a sample of root-zone soil water was obtained for selective stations using either the porous cup suction lysimeter, or where free water occurred, a 1" dia. x 12" stainless steel bailer. Soil-water pH and electrical conductivity readings were obtained in the field using an Omega Scientific PHH-49D combined pH-salinity meter. The electrical conductivity readings are expressed as mmhos/cm x 1000. This instrument has a built-in cup with internal probes that allow readings on as little as 5 ml. of sample. In many instances by summer or late fall the soils were too dry to allow sampling soil moisture with the suction cup lysimeter during the same day visit to the marsh.

In addition to the soil-moisture and salinity-reactivity determinations, observations were made at each sampling site with respect to the relative abundance, vigor or stress of the dominant plants. In particular, wilting stress, salt burns on leaf tips, early browning, stunting or pre-mature die-back was of interest, along with notes on general growth, flowering, and seed set.

RESULTS AND DISCUSSION

Although the Pillar Point Marsh monitoring took place during the fifth year of a severe drought, no significant pre-mature or unseasonal plant stress was observed in the wetland plant communities. All plants flowered and set seed at appropriate times. No unusual stunting, leaf tip burning, or pre-mature dieback was observed. Although no specifically planned or routine monitoring or observations of the marsh wildlife were conducted, there we no affects on the habitat observed that would adversely impact the wildlife. The most potentially troublesome finding was the continued advancement of the swamp smartweed and, to a much less extent, nettle, into the freshwater emergent marsh, and the advancement of the invasive weedy species, including bristly oxtongue and bull thistle, from the transition zone into the seasonal wetland areas. These concerns were raised by Flint as early as 1977 and Patterson in 1986. Since moisture levels appeared to remain satisfactory in these communities, it is not known whether this advancement is a result of the previous agricultural disturbances, which allowed the initiation of the weed population, is an artifact of the drought, or, less likely, a result of groundwater withdrawal. Soil moisture levels remained elevated at a level thought capable of supporting seasonal hydric plants throughout their growing periods at all wetland observation points. The soil moisture observation points for the wetland plant communities were consistently much higher than the adjacent upland plant communities, which served as control points. The facultative and facultative wet plants, including rye-grass and brome, which were common to the seasonal wetland, transition zone, and grassland areas, were observed to dry first in the grasslands and then transition zone, following a moisture gradient.

Root zone pH valves were monitored along with salinity, measured as specific conductance. The pH values remained remarkably stable throughout the monitoring period for all sites and were well within the tolerance levels of the wetland plants. Because of this, pH levels will not be discussed further.

Root zone salinity values increased in nearly all sites from a low (less saline) level associated with the late December 1989 sampling period to a high (more saline) nearly a year later in late fall, before the advent of the unusually light winter rains. Some large fluctuations were observed in the saltmarsh and brackish marsh which were not seasonal, but likely associated with the occasional very high tides that flood the marsh. Salinity levels returned to approximately similar conditions of the previous 1990 spring by late April 1991, after the receipt of the heavy March 1991 rains.

As discussed by Flint (1977) the normal tidal cycle at Pillar Point has been altered and dampened by the construction of the breakwater in the early 1970's. Wave heights have been reduced, and a sand bar has accreted along the bayshore, restricting tidal action. Salinity levels measured were well within the tolerance range of the respective salt marsh, brackish, and freshwater marsh plants resident to these communities. Evaporative concentrations of salts in the brackish marsh were noted in late summer and early fall. However, field evidence indicated much variability in salinity readings over a short local area. Salinity levels in the freshwater marsh did not change appreciably over the year, and were within a range of natural fluctuation that would be expected, associated with changes in rainfall, or sampling and analysis error. However, slight, progressive, but over the long term significant increases in root zone salinity may not be noticeable or detectable after only one year of monitoring. Also, any possible increase in salinity or reaction cannot be separated from normal fluctuations associated with the drought.

The following paragraphs discuss the monitoring results with respect to each of the plant communities of the Pillar Point marsh area.

Salt Marsh (Ms)

The salt marsh plant community appeared unaffected, as would be expected over the short-term. This pickleweed community receives the majority of its moisture from tidal flooding, so the moisture supply is virtually unaffected by either drought or groundwater development. Data points TI-8, TII-7, 8 are representative of this community. TI-8 and TII-8 are in the lower, more saline portion of the marsh, but salinity levels (to 29.5 mmlos) are well within the known tolerances of pickleweed. Salinities in this more distinctly tidally influenced area of the marsh fluctuate less than for TII-7. This upper-marsh area, just below the road, is more brackish in character, probably reflecting both the surface fresh-water flow through the culvert, and any up-welling of shallow groundwater. Fluctuations in salinity are likely also associated with the occasional high tide flushing of the wetland system.

Brackish Marsh (Mb)

Immediately above these last two points, just below the road, is a small brackishwater marsh community, consisting of saltrush, silverweed, and minor slough sedge with some cat-tails and tules areas. Immediately below the road, near the culvert, narrow leaf cat-tail and California bulrush predominate, (TIII-5) while along the east side of the wetland, above the pickleweed and jaumea, saltrush and silverweed predominate (TI-6).

This community appeared healthy and non-stressed during all site visits, and it appears to remain largely unchanged in location and composition from that reported by Flint (1977) and Patterson (1987). Salt levels ranged from 3.5 to 4.8 mmhos for the upper cat-tail-tule area, and from 6.4 to 10.5 for the saltrush-silverweed area. Salinity levels fluctuated widely in this community, as it receives both the occasional high tide and freshwater outflow, but remained within the tolerance of the dominant plants. The bulrush-cat-tail portion remained permanently saturated at 10", while the higher saltrush-silverweed portion dried to a damp condition at 10", but remained saturated at 18".

A diminished freshwater outflow could endanger the narrow brackish community where it occurs immediately below the hook in the road, but there were no short-term visual indications of stress such as early die-back before seed-set, or failure to re-generate after the unusually severe winter of 1990-91 frost. If this community were severely salt stressed over the long-term, it would likely be displaced by such species as alkali bulrush, cord grass, pickleweed, or jaumea, depending on elevation, salinity level, and associated duration of tidal inundation and ponding.

Freshwater Emergent Marsh (Mf)

No signs of vegetative stress were observed in the bulrush - cat-tail community. This community was ponded and saturated during the late winter and early spring of 1990, but had dried to a still very visibly moist condition at 10" by late summer. The emergent marsh was again ponded briefly in December 1990 and more extensively from the March 1991 rains. The soil was still at or very nearly saturated at 18" in the fall of 1990 in the lower (TII-5b) sampling point, but only damp at TII-5a. TII-5a is higher, near the.boundary of the seasonal wetland, and is a mixture of swamp smartweed and California bulrush. TII-5b is lower and ponded for a prolonged period. Bulrush, cat-tail, and water parsley are dominant in the lower part. Salinities were well within the tolerance range of these freshwater emergent plants and ranged from 0.6 to 1.4 mmhos. Moisture or salt stress of the bulrush or cat-tails could lead to die-back prior to setting seeds in these plants, but this was not observed. The tules and cat-tails developed into the typically very dense, almost impenetrable stand by late spring, with heights of the tules to 7-8'. Fall senescence was similar in this community to other bulrush - cat-tail communities in the region. Since these plants were already dormant and had died back to ground level by the time the late December 1990 freeze occurred, little damage was apparently done, and the plants responded vigorously after the March 1991 rains.

An increased dryness or less prolonged ponding of this community could lead to invasion and displacement by either the surrounding willows or by the invasive swamp smartweed or coast nettle. This could not be readily discerned by the current monitoring, although it appears that the swamp smartweed is aggressively invading the edges of the community as is present in significant amounts mixed in with the bulrush. Flint (1977) also noted this concern in his report, along with coast nettle invasion indicating a historic trend. Flints' map possibly indicates a somewhat greater distribution of emergent marsh than occurs presently, but a more thorough study of sequential aerial photography would be needed to more accurately assess this. Flint also expressed great concern over the threat of advancement by coast nettle. Although nettle was observed near the higher sampling point (TII-5a) it was not dominant, and it was present in only very low amounts in the lower, more ponded sampling point (TII-5b). Indeed any change could be more a long-term trend resultant from the altered surface water runoff patterns in the area, and further complicated by the persistent drought, than an impact of groundwater development.

An increase in salinity would likely favor a shift from California bulrush, to the more salt tolerant alkali bulrush, but no alkalai bulrush plants were observed, and salinity levels remained low, in the range of tolerance of California bulrush and common cat-tail.

Riparian Thicket(Rs)

The willow thickets or riparian woodland areas also appeared healthy and vigorous throughout the monitoring period. No evidence of wilting, browning or tip burning, or pre-mature leaf drop was noted for any of the willow thicket monitoring points. A dense nearly impenetrable thicket had developed by late spring, precluding continued access to point TIII-3.

As indicated by the results for sample points TII-5 and 6, and TIII-4, the soils remained very moist at 10" throughout the monitoring period, and saturated or near-saturated at the 18-inch depth except for a time in the late summer and early fall. Moisture levels appeared adequate to support the willows as moisture levels were always well above p.w.p. Salt levels climbed somewhat between the winter stormwater runoff flushing period, and the summer period, presumably after some advancement by subsurface seawater, and concentration by evapotranspiration. However, observed salinity levels were well within the salt tolerances of arroyo willow. As would be expected, both a salinity and moisture gradient was observed, with the soils closer to the road more continuously saturated and slightly more saline (1.4 vs .60 mmhos). The upper willow area, near the trailer park dried to a damp condition by late fall. This willow area apparently receives a large part of its moisture supply from surface runoff, including from the adjacent mobile home park, and would not be expected to be impacted by groundwater withdrawal.

The willow community is essentially a monotype in this area, with few other plants growing under the dense, shaded, canopy; except at the edges and openings. Based on a visual comparison with Flint's (1977) and Patterson's (1987) mapping, it appears that the community boundary is relatively stable, and at least within the limits of this method of observation, have not expanded or shrunk appreciably.

Coastal Scrub (Cs)

Sample point TI-7, is representative of the coastal scrub community. This community is dominated by coyote bush, and includes such other upland or wetland transition zone plants as gum plant, salt bush, blackberry, and wire grass. In many areas the coastal scrub is weedy and contains mustard, bullthistle, and other weeds. The coyote bush community occurs on elevated ground peripheral to the pickleweed marsh areas. The plants in this community are tolerant of saline soils, the occasional extreme tidal flooding, and poor subsoil drainage. Like the grassland type, the monitoring of this area serves as a control point to evaluate the adjacent salt marsh. Low soil moisture, (below permanent wilting point) occurred in this community in August, somewhat latter than the grassland area, but much before the weedy or transition zone wetland areas.

There is a possibility that the coyote bush community and in particular australian salt bush could move down slope from their current slightly higher, better drained ground to invade the upper peripheral brackish marsh zone where it occurs just below the road, if this lower area dried appreciably. It could displace the silverweed, saltrush, jaumea, and frankenia, which occurs there, if a diminished freshwater outflow occurs in this zone. There were no short-term visual indications of this occurring, such as dieback of these plants. The frankenia plants apparently were severely impacted by the late December 1990 severe freeze, and are coming back only slowly from this condition.

Transition Zone and Seasonal Wetland (Tr-Wm)

The transition from the grassland area to the seasonal wetland is not abrupt, but is marked by a break in slope with an elevation drop of 2- to 3-feet. Much of this area, which was referred to as the flood overflow area by Flint (1977) and the transitional zone by Patterson (1987), is very weedy. The weed population consists of plants that compete well in saturated to moist soils and invade disturbed sites. This area was disced in 1989, prior to initiation of monitoring, and probably annually before that. Vegetation observed during the monitoring included prickly oxtongue, bullthistle, coast nettle, giant horsetail, silverweed, plantain, and swamp smartweed (TII-4, TIII-2). Prickly tongue and bullthistle dominated, and formed a dense impenetrable thicket by mid-summer, when the stalks had grown to 4- to 5-feet and dried. However, in some areas wild berries are more dominant, as near TI-4. Sedge and wire grass predominated at sample point TI-3.

The weedy population of the transition zone or seasonal wetland appears to have developed in response to past agricultural practices, including discing, which favors the development of these fast growing invaders of disturbed wet areas at the expense of the higher valve native wetland plants. This zone, unlike the adjacent willow thickets, was saturated to very moist during the spring and early summer, but had dried to (p.w.p.) permanent wilting point by late summer.

The main concern with the weedy community is fear that it would expand into and invade or displace the willows or emergent bullrush marsh. This could occur in the willows only if moisture levels drop very significantly, or severe salt shock occurs as the willow thicket is now well established, presumably with a deep rooting system that taps into the shallow groundwater. The dense canopy also would shade out the weeds. Based on limited observations, it appears that swamp smartweed and coast nettle are invading the emergent marsh in the less prolonged period of inundation zone at the outer edges. This may be a historic trend noted by Flint (1977) and since the elevation and duration of ponding is more likely associated with surface runoff, the possible invasion may be more associated with the drought than groundwater development. There appears to be an opportunity and management need to control the invasive weeds and restore this area to more valuable wetland plants.

Grassland (Gn)

Monitoring of the ruderal grassland areas served primarily to form a basis of comparison for the seasonal fluctuation of soil moisture between the upland and wetland areas. As would be expected, soil moisture levels in the grassland plant community did not reach the same degree of saturation as the wetland areas. The grassland soils also dried significantly by mid-summer, with the corresponding browning and drying of the annual species. A distinct soil moisture gradient was noted southward from the corner of the property towards the main willow woodland area. Moisture levels remained consistently higher in TII-3, and TI-2 near the margin of the grassland, with a corresponding increase in the percentage composition of perennial rye grass (a facultative species) and a longer green period (delayed browning) compared to the species in the areas further north (TI-1; TII-1, 2). It should be noted that the vegetation map prepared by Flint (1977) indicated that the grassland area was previously dominated by coyote bush which was presumably removed by discing by the property owner prior to the 1987 survey by Patterson.

CONCLUSIONS AND RECOMMENDATIONS

No significant short-term impacts on the Pillar Point marsh vegetation or wildlife habitat were observed during the first approximately 1 1/3 years of monitoring. No prematurely stressed vegetation was observed. Soil moisture levels and root zone salinity and reactivity were all within the perceived tolerances and requirements of the wetland plant communities during their growing and flowering periods.

Medium term or long term effects on the marsh from groundwater development cannot be accurately determined from a single years monitoring. Significant mid-to-long term effects might include the gradual die-back of the willow thickets and replacement or invasion of the willows and California bulrush communities by more salt or moisture tolerant weedy plants currently on the periphery of these communities, such as the swamp smartweed, coast nettle and blackberries. The willows could also displace the freshwater emergent marsh if seasonal ponding were greatly diminished.

The moisture and salinity monitoring did not reveal any trends that would lead to increased speculation or concern regarding the displacement of the high value brackish or freshwater wetland plants by more salt tolerant or weedy species. However, long-term, very gradual changes in late season soil moisture and salinity conditions could not be discerned from 1 1/3 years of data, and in fact if any occurred, they could not be separated from any effects of the drought.

Continued monthly or bi-monthly monitoring of soil moisture, salinity, and vegetation stress does not appear to be necessary. This could be replaced by a monitoring period to include June, and September this next year which would include the expected major fluctuations in water levels and salinity associated with the seasons. Since soil samples were collected at the start of this monitoring program and some historic soil salinity data is available from Flint (1977) and Ulrich (1982), it would also be valuable to collect soil samples periodically (bi-annually) to evaluate long-term trends.

Sampling in December 1991, 2 years after the initial monitoring, and some 15 years after Flints (1987) work would be appropriate.

Changes in plant community structure and species composition (if any were to occur) are also more reasonably expected to change over the long-term. A bi-annual field monitoring program (every other year) would be sufficient. Flints transects, established in 1977, and those by WESCO in 1982 for the lower marsh should be re-visited in June 1992 to discern any long-term trends in the marsh. The field work could be supplemented by low altitude color aerial photography including infrared photography, to discern stress in vegetation and gross changes in community structures and boundaries. It would be best to use the same flight lines and altitudes for the aerial photography as were utilized by Patterson (1986, 1" = 400' photos). The focus should be on the stability of the willow thickets, brackish and freshwater marsh communities and the spread of swamp smartweed, coast nettle and other weedy invaders into these communities.

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Ulrich, R., 1982. Wetland Soil Survey of the Pillar Point Marsh. Unpublished consultant's report prepared for San Mateo County Planning Department.

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PILLAR POINT MARSH

SOIL FIELD MONITORING DATA

DATE: March 27, 1990

Transect #	Plant Community	Moisture 10"	Moisture 18"	E.C. mmhos/cm	pH
TI-1	Gn	75	-	-	-
TI-2	Gn	75	-	-	-
TI-3	Wm	90	95	-	-
TI-4	Wm	95	95	.65	7.1
TI-5a	Mf	95	100	.65	7.1
TI-5b	Mf	100	100	1.4	7.2
TI-6	Mb	100	100	9.50	7.0
TI-7	Sc	85	90	-	-
TI-8	Ms	100	100	28.5	7.1
TII-1	Gn	75	-	-	-
TII-2	Gn	75	-	-	-
TII-3	Gn	80	-	-	-
TII-4	Wm	95	95	.85	7.1
TII-5	Rs	100	100	.70	7.2
TII-6	Rs	100	100	1.2	7.0
TII-7	Ms	100	100	9.5	7.1
TII-8	Ms	100	100	16.5	7.1
TIII-1	Rs	90	95	-	-
TIII-2	Tr	90	90	-	-
TIII-3	Rs	95	95	-	-
TIII-4	Rs	100	100	1.6	7.0
TIII-5	Mb	100	100	4.2	7.1

PILLAR POINT MARSH

SOIL FIELD MONITORING DATA

DATE: April 25, 1991

Transect #	Plant Community	Moisture 10"	Moisture 18"	E.C. mmhos/cm	pH
TI-1	Gn	75	85	-	-
TI-2	Gn	75	85	-	-
TI-3	Wm	90	95	-	-
TI-4	Wm	95	100	.70	7.2
TI-5a	Mf	100	100	.65	7.1
TI-5b	Mf	100	100	.70	7.1
TI-6	Mb	100	100	8.50	6.9
TI-7	Sc	80	90	-	-
TI-8	Ms	100	100	29.5	7.0
TII-1	Gn	70	85	-	-
TII-2	Gn	75	85	-	-
TII-3	Gn	75	90	-	-
TII-4	Wm	95	95	1.1	7.0
TII-5	Rs	100	100	.65	7.0
TII-6	Rs	100	100	1.1	7.1
TII-7	Ms	100	100	8.5	7.2
TII-8	Ms	100	100	18.5	7.2
TIII-1	Rs	95	95	-	-
TIII-2	Tr	90	95	-	-
TIII-3	Rs	95	100	-	-
TIII-4	Rs	100	100	1.4	6.9
TIII-5	Mb	100	100	3.5	7.0

PILLAR POINT MARSH

SOIL FIELD MONITORING DATA

DATE: May 7, 1990

Transect #	Plant Community	Moisture 10"	Moisture 18"	E.C. mmhos/cm	pH
TI-1	Gn	65	-	-	-
TI-2	Gn	65	-	-	-
TI-3	Wm	75	90	-	-
TI-4	Wm	90	95	.60	7.2
TI-5a	Mf	100	100	.60	7.1
TI-5b	Mf	100	100	1.2	7.2
TI-6	Mb	100	100	10.5	7.0
TI-7	Sc	85	90	-	-
TI-8	Ms	100	100	22.5	7.2
TII-1	Gn	65	-	-	-
TII-2	Gn	65	-	-	-
TII-3	Gn	70	-	-	-
TII-4	Wm	90	100	.95	7.2
TII-5	Rs	95	100	.70	7.1
TII-6	Rs	100	100	1.1	7.1
TII-7	Ms	100	100	9.0	7.1
TII-8	Ms	100	100	18.5	7.0
TIII-1	Rs	90	95	-	-
TIII-2	Tr	85	95	-	-
TIII-3	Rs	90	95	-	-
TIII-4	Rs	95	100	1.6	7.1
TIII-5	Mb	100	100	3.5	7.2

PILLAR POINT MARSH

SOIL FIELD MONITORING DATA

DATE: June 14, 1990

Transect #	Plant Community	Moisture 10"	Moisture 18"	E.C. mmhos/cm	pH
TI-1	Gn	60	-	-	-
TI-2	Gn	65	-	-	-
TI-3	Wm	75	85	-	-
TI-4	Wm	90	100	.65	7.2
TI-5a	Mf	95	100	.60	7.1
TI-5b	Mf	100	100	1.4	7.2
TI-6	Mb	100	100	8.5	7.1
TI-7	Sc	80	90	-	-
TI-8	Ms	100	100	26.5	7.1
TII-1	Gn	60	-	-	-
TII-2	Gn	55	-	-	-
TII-3	Gn	60	-	-	-
TII-4	Wm	95	100	.90	7.1
TII-5	Rs	95	100	1.3	7.2
TII-6	Rs	95	100	1.6	7.2
TII-7	Ms	100	100	6.8	7.1
TII-8	Ms	100	100	16.4	7.2
TIII-1	Rs	90	95	-	-
TIII-2	Tr	80	95	-	-
TIII-3	Rs	90	100	-	-
TIII-4	Rs	95	100	1.7	7.1
TIII-5	Mb	100	100	4.2	7.2

PILLAR POINT MARSH

SOIL FIELD MONITORING DATA

DATE: July 13, 1990

Transect #	Plant Community	Moisture 10"	Moisture 18"	E.C. mmhos/cm	pH
TI-1	Gn	45	-	-	-
TI-2	Gn	40	-	-	-
TI-3	Wm	75	85	-	-
TI-4	Wm	80	85	-	-
TI-5a	Mf	85	90	-	-
TI-5b	Mf	95	100	1.6	7.2
TI-6	Mb	100	100	7.8	7.1
TI-7	Sc	65	80	-	-
TI-8	Ms	100	100	32.0	7.2
TII-1	Gn	35	-	-	-
TII-2	Gn	50	-	-	-
TII-3	Gn	45	-	-	-
TII-4	Wm	85	90		
TII-5	Rs	90	95	1.6	7.2
TII-6	Rs	90	95	1.8	7.2
TII-7	Ms	100	100	8.6	7.2
TII-8	Ms	100	100	18.4	7.1
TIII-1	Rs	80	90	-	-
TIII-2	Tr	65	85	-	-
TIII-3	Rs	-	-	-	-
TIII-4	Rs	95	100	2.2	7.1
TIII-5	Mb	95	100	4.0	7.1

PILLAR POINT MARSH

SOIL FIELD MONITORING DATA

DATE: August 21, 1990

Transect #	Plant Community	Moisture 10"	Moisture 18"	E.C. mmhos/cm	pH
TI-1	Gn	35	-	-	-
TI-2	Gn	35	-	-	-
TI-3	Wm	65	-	-	-
TI-4	Wm	70	80	-	-
TI-5a	Mf	80	85	-	-
TI-5b	Mf	95	100	1.7	7.1
TI-6	Mb	95	100	9.8	7.1
TI-7	Sc	60	70	-	-
TI-8	Ms	100	100	29.5	7.2
TII-1	Gn	35	-	-	-
TII-2	Gn	35	-	-	-
TII-3	Gn	40	-	-	-
TII-4	Wm	80	85	-	-
TII-5	Rs	90	95	1.7	7.1
TII-6	Rs	90	95	1.8	7.2
TII-7	Ms	100	100	8.2	7.2
TII-8	Ms	95	100	23.5	7.1
TIII-1	Rs	80	85	-	-
TIII-2	Tr	60	-	-	-
TIII-3	Rs	-	-	-	-
TIII-4	Rs	95	95	2.1	7.1
TIII-5	Mb	95	100	3.8	7.2

PILLAR POINT MARSH

SOIL FIELD MONITORING DATA

DATE: September 14, 1990

Transect #	Plant Community	Moisture 10"	Moisture 18"	E.C. mmhos/cm	pH
TI-1	Gn	15	-	-	-
TI-2	Gn	15	-	-	-
TI-3	Wm	60	80	-	-
TI-4	Wm	70	80	-	-
TI-5a	Mf	75	80	-	-
TI-5b	Mf	90	95	.75	7.1
TI-6	Mb	95	100	12.4	7.2
TI-7	Sc	50	65	-	-
TI-8	Ms	100	100	26.5	7.2
TII-1	Gn	15	-	-	-
TII-2	Gn	15	-	-	-
TII-3	Gn	10	-	-	-
TII-4	Wm	80	90	-	-
TII-5	Rs	85	95	1.6	7.2
TII-6	Rs	85	95	1.9	7.1
TII-7	Ms	95	100	8.6	7.2
TII-8	Ms	100	100	26.4	7.2
TIII-1	Rs	75	85	-	-
TIII-2	Tr	60	80	-	-
TIII-3	Rs	-	-	-	-
TIII-4	Rs	80	90	2.2	7.1
TIII-5	Mb	95	100	4.8	7.2

PILLAR POINT MARSH

SOIL FIELD MONITORING DATA

DATE: October 19, 1990

Transect #	Plant Community	Moisture 10"	18"	E.C. mmhos/cm	pH
TI-1	Gn	0	-	-	-
TI-2	Gn	15	-	-	-
TI-3	Wm	45	-	-	-
TI-4	Wm	60	-	-	-
TI-5a	Mf	60	-	-	-
TI-5b	Mf	70	-	.65	7.1
TI-6	Mb	90	95	9.5	7.2
TI-7	Sc	35	-	-	-
TI-8	Ms	100	100	29.4	7.2
TII-1	Gn	15	-	-	-
TII-2	Gn	15	-	-	-
TII-3	Gn	10	-	-	-
TII-4	Wm	80	85	-	-
TII-5	Rs	85	90	1.5	7.1
TII-6	Rs	85	95	1.6	7.2
TII-7	Ms	95	100	-	-
TII-8	Ms	100	100	7.6	7.2
TIII-1	Rs	70	85	-	-
TIII-2	Tr	60	80	-	-
TIII-3	Rs	-	-	-	-
TIII-4	Rs	80	85	-	-
TIII-5	Mb	95	100	4.5	7.1

PILLAR POINT MARSH

SOIL FIELD MONITORING DATA

DATE: December 1, 1990

Transect #	Plant Community	Moisture 10"	Moisture 18"	E.C. mmhos/cm	pH
TI-1	Gn	65	35	-	-
TI-2	Gn	50	35	-	-
TI-3	Wm	70	65	-	-
TI-4	Wm	75	70	-	-
TI-5a	Mf	75	80	-	-
TI-5b	Mf	80	90	.70	7.2
TI-6	Mb	85	95	8.6	7.0
TI-7	Sc	70	75	-	-
TI-8	Ms	100	100	31.5	7.1
TII-1	Gn	60	30	-	-
TII-2	Gn	55	35	-	-
TII-3	Gn	65	70	-	-
TII-4	Wm	65	75	-	-
TII-5	Rs	85	90	1.6	7.1
TII-6	Rs	90	90	1.8	6.9
TII-7	Ms	95	100	6.8	7.1
TII-8	Ms	100	100	24.5	7.2
TIII-1	Rs	85	85	-	-
TIII-2	Tr	85	90	-	-
TIII-3	Rs	95	95	-	-
TIII-4	Rs	100	100	1.6	7.0
TIII-5	Mb	95	100	4.6	7.1

PILLAR POINT MARSH

SOIL FIELD MONITORING DATA

DATE: December , 1989

Transect #	Plant Community	Moisture 10"	E.C. mmhos/cm	pH
TI-1	Gn	Moist 75 -	-	-
TI-2	Gn	Moist 75 -	-	-
TI-3	Wm	Sub-Sat 90 -	-	-
TI-4	Wm	Sub-Sat 90 -	-	-
TI-5a	Mf	Sat 100 -	.60	7.2
TI-6	Mb	Sat 100 -	6.4	7.1
TI-7	Sc	Sub-Sat 90 -	-	-
TI-8	Ms	Sat 100 -	29.5	7.1
TII-1	Gn	Moist 75 -	-	-
TII-2	Gn	Moist 75 -	-	-
TII-3	Gn	Moist 75 -	-	-
TII-4	Wm	Sub-Sat 90 -	-	-
TII-5	Rs	Sat 100 -	.8	7.0
TII-6	Rs	Sat 100 -	1.2	7.2
TII-7	Ms	Sat 100 -	7.0	6.9

TII-8	Ms	Sat 100 -	21.4	7.1
TIII-1	Rs	Sat 100 -	-	-
TIII-2	Tr	Sub-Sat 90 -	-	-
TIII-3	Rs	Sat 100 -	-	-
TIII-4	Rs	Sat 100 -	1.6	7.2
TIII-5	Mb	Sat 100 -	3.8	7.1