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Half Moon Bay Airport/ Pillar Point Marsh Ground-Water Basin

Phase I Study Report

Performed for:

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Half Moon Bay, California 94019

and

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HALF MOON BAY AIRPORT/PILLAR POINT MARSH
GROUND-WATER BASIN
PHASE I STUDY REPORT

Table of Contents

List of Figures

A. EXECUTIVE SUMMARY

Available data indicate that ground-water yield is in excess of the current pumpage of approximately 400 acre-feet per year (a.f.y.) from the Half Moon Bay Airport/Pillar Point Marsh Ground-Water Basin (also called the Denniston Creek Sub-Basin). Steadily increasing pumpage over the last 10 years has not impaired winter/spring hydraulic gradients to the marsh or to the bay. During years of normal or above normal rainfall, recharge has restored ground water in storage to levels equal to those measured in 1974.

The purpose of the Phase I Study was to evaluate existing data pertaining to determination of the yield of the basin, and to make recommendations for work necessary during a Phase II Study to adequately determine the yield. The following data which relate to the yield of the basin have been identified during the Phase I Study:

- Precipitation data are available since 1939, but there are essentially no pertinent ground-water data available until about 1975. Since then, there are sufficient data on which to judge the response of the ground-water basin to increasing pumpage and other factors.

- Diversions of surface water from Denniston Creek have continued over the past ten years at varying annual rates between 300 and 900 acre/feet. Beyond those documented flow rates, there are no available records of flow in any reaches of Denniston Creek. Consequently, the amount of ground-water recharge from that stream remains unknown.

- Approximately 90 wells with logs have been identified in and adjacent to the Airport/Pillar Point Basin. Noteworthy among them are several CCWD production and monitoring wells, located throughout the basin, and two CUCC production wells located on the airport. These wells provide the majority of key data and are responsible for essentially all the pumpage in the basin. There is no agricultural pumpage in the basin, and minimal private domestic pumpage.

- Ground-water levels in the basin have remained essentially constant near the Half Moon Bay coastline over the past twelve years. In the central part of the basin, monitoring wells have identified seasonal water-level fluctuations over the same time period, but there are no apparent long term changes in water levels or ground-water storage.

- Ground-water quality throughout the basin has remained essentially unchanged over the past twenty-five years.

B. INTRODUCTION

1. Purpose and Scope

The Phase I Study was performed for Coastside County Water District (CCWD) and Citizen Utilities Company of California (CUCC) jointly by Earth Sciences Associates (ESA) and Luhdorff and Scalmanini, Consulting Engineers (LSCE). 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 prior to the development of two new production wells by CUCC at the Half Moon Bay Airport by the California Coastal Commission (Permit No. CDP 85-59, Condition No. 7). Since both utilities have an important interest in the ground-water resources of the Half Moon Bay Airport/Pillar Point Marsh Ground-Water Basin (the Denniston Creek Sub-Basin), the costs of this study were shared equally by the two agencies.[1]

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. This term 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." This requires definition of the best development and management practices to optimize use of ground water, while protecting the water supply to the Pillar Point Marsh and protecting 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 protection against loss of part of the usable aquifer system through overdraft and resultant sea-water intrusion. These goals are not incompatible. Maintenance of the fresh water portion of the marsh provides some degree of protection against sea-water intrusion, and limiting or preventing significant sea-water intrusion assures a more reliable, 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:

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[1]CCWD's participation was also required by a condition in a Coastal Act permit issued to it in 1984 (CDP 84-68).

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

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.

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 on Figure 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 near the northwest end of the airport. The basin is bordered on the east by the community of El Granada, and on the northeast by the base of the mountains. 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.

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 for CCWD, dated April 4, 1974. This report presents a good description of geologic conditions 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 a.f.y. and the basin was "in balance", i.e., ground-water storage was not changing. Based on those conditions, additional ground-water development of 400 a.f.y. 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 a.f.y. value, along with a monitoring program that appears 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/year (a.f.y.) 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 imported 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 a.f.y., is substantially higher than the nearest recorded values (1976), when pumpage was about 250 a.f. Finally, the 1974 report may have over-estimated subsurface inflow, storage, and outflow as discussed herein.

C. AVAILABLE DATA

1. Periods for Which Data are Available

Ground-water study periods are normally based on representative periods of precipitation for which appropriate ground-water data are available and which include relatively dry conditions before the beginning and end of the study period (to minimize differences in the amount of water in the unsaturated zone above the water table), and which also include wet and dry periods which can illustrate responses of the basin to those conditions.

In the Pillar Point area, the study period is being dictated by the limited availability of historical ground-water data. Specifically, there is just one well in the basin, located south of the airport at the El Granada Mobile Home Park, with a long term (1953 to present) water-level record. Additionally, the two CUCC wells at the airport have continuous water-level records since 1975, with just one earlier water-level measurement in the North Airport well in 1962; and CCWD has several monitoring wells with records from 1975.

Two previous studies of the area, one of the ground-water basin and one of Pillar Point Marsh, were completed in 1974 and 1978, respectively, and provide some historical ground water information for those times.

Although there are sufficient precipitation records (dating from 1939, part of which are included in Figure 2), the lack of ground-water data is a limiting factor in evaluating basin yield and other characteristics. It appears that ground-water conditions will have to be analyzed over the past 10 years to 12 years, with limited reference to long-term historical conditions.

2. Hydrogeologic Setting

As indicated previously, the geologic conditions of the Half Moon Bay Airport/Pillar Point Marsh Ground-Water Basin are well documented in the Lowney-Kaldveer report (1974), and will only be briefly summarized herein. The basin occupies a structural trough (a down-dropped area between two faults) which has been filled with sediments transported from the adjacent hills. The alluvial fill overlying bedrock varies in thickness from about 50 feet to a maximum of about 150 feet, based on test hole logs presented in the 1974 report and recent test holes and production well boreholes. The alluvial materials consist of sandy clay, clayey and silty sand, and relatively clean coarse to fine sand. The upper 50 to 70 percent of the alluvial section contains more silts and clays, and less clean sand. It is unknown whether the ground-water flow through these materials responds as a confined or water table system. Based on reported geologic conditions, it appears that either water table or some degree of semi-confinement or "leaky aquifer" responses can be expected.

Generally, the sediments thin and become finer grained toward Half Moon Bay to the south. This has forced some ground-water discharge to the surface (along with surface runoff) resulting in marshy conditions at the extreme southwestern corner of the basin (Pillar Point Marsh). In summary, the generally silty to clayey nature of the sands, along with their limited extent and thickness, limits the ability of these alluvial fill materials to transmit and store ground water.

3. Surface Water

There is no gaging station on Denniston Creek which 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 diversions from the creek are maintained by CCWD, which has diverted between 300 and 900 acre-feet per year for water supply since 1975, as shown on Figure 3.

The one previous ground-water report for the area (Lowney-Kaldveer, 1974), included values for stream flow into and out of the basin. However, both are estimated values, unverified by actual measurements. The amount of ground-water recharge from the stream was estimated in the Lowney-Kaldveer report to be equal to 20 percent of the assumed inflow.

At present (for this Phase I Study), surface flows and recharge to the ground-water basin from precipitation and stream flow can still only be estimated. Future analyses during the Phase II Study will include surface water measurements in Denniston Creek, as required by Permit CDP 85-59 Condition 7(a).

4. Well Data

Approximately 90 well logs within and adjacent to the study area have been obtained and reviewed in order to determine their potential for use in water-level and water quality determinations (Figure 4). Most of the wells with logs, however, are located outside the study area. A fairly large number of recently constructed domestic wells are located in the El Granada area, a separate ground-water "basin" located east of the southern portion of this basin.

Noteworthy among wells within the study area are:

1. Two wells owned and operated by Citizens Utilities Company of California (CUCC) on the airport property; these wells have records of water-levels, capacity, yield and quality.

2. Several wells owned and operated by Coastside County Water District (CCWD) throughout the basin, the majority of which are production and monitoring wells on and adjacent to Denniston Creek.

Comments relevant to wells within and adjacent to the basin are the following:

1. There is a general lack of wells near the northwestern end of the airport near San Vicente Creek.

2. There are no agricultural wells within the basin.

3. 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.

5. 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 400 acre-feet per year in 1986, an average annual increase of about 15 acre-feet per year (Table 1 and Figure 5). As noted above, there is no agricultural pumpage in the study area; and individual domestic pumpage is very small, probably no greater than 20 to 25 acre-feet per year. In summary, total pumpage from this basin has now reached approximately 50 percent of what it was thought to be in 1974, when the basin was found to be "in balance" and capable of supporting at least 400 acre-feet of additional pumpage.

6. 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 10 wells have been monitored for various periods of time. 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 2, along with historic precipitation data. Since about December, 1975,

Table 1

GROUND-WATER PRODUCTION
Half Moon Bay Airport/Pillar Point Marsh

Year	CCWD (Acre-Feet)	CUCC (Acre-Feet)	Total Production CUCC & CCWD (Acre-Feet)
1976	171.6	82.2	253.8
1977	194.3	60.2	245.5
1978	114.8	167.3	282.1
1979	135.3	169.9	305.2
1980	81.0	232.3	313.3
1981	172.2	147.7	319.9
1982	191.8	187.4	379.2
1983	98.5	223.3	321.8
1984	151.9	211	362.9
1985	122.4	232.2	354.6
1986	186.6	218.8	405.4

CCWD has conducted bi-monthly water-level measurements in up to seven monitoring wells. Hydrographs of these wells are presented on Figure 5. In addition, water-levels in the two CUCC production wells have been regularly monitored since 1975.

Water-level data are very important, since they show direct responses to seasonal recharge and discharge, along with pumpage. Generally, the hydrographs do not indicate downward water-level trends over the periods of record that would indicate overdraft conditions. 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.

The important point is that water-levels within this basin have recovered seasonally, except during temporary periods of drought.

7. Ground-Water Quality

There is a relatively long history of water quality data for the basin. Table 2 summarizes selected ground-water quality indicator parameters, chloride and specific conductance, for wells in the study area which have been monitored by DWR and CUCC. As indicated in Table 2, chloride concentrations in the study area range from about 60 to 124 mg/l, while specific conductance values range from 314 to 710 uhmos/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. There has been no apparent change in the quality of the ground-water produced from the basin.

Review of the general mineral data for the wells listed in Table 2 indicate the sodium-calcium bicarbonate water has shown little change over the 25 year period for which data are available.

Table 2

HISTORIC GROUND-WATER QUALITY
Half Moon Bay Airport/Pillar Point Marsh
Selected Indicator Parameters

Well	Date	Specific Conductance (umhos/cm)	Chloride (mg/l)
5S/6W-10H1	7/23/53	505	65
5S/6W-10	7/03/53	597	108
5S/6W-10J1	3/29/55	607	107
5S/6W-11 (CUCC South Airport)	7/03/53	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
	6/04/84	560	68
5S/6W-11 (CUCC North Airport)	5/16/73	590	91
	6/10/76	688	116
	5/11/78	667	124
	10/26/81	580	124
	6/04/84	710	120
5S/6W-11E1	8/15/74	622	84
	6/30/76	684	110
	8/17/78	688	110
	8/05/81	684	117
	8/04/83	693	116
	9/04/85	705	113
5S/6W-11Q1	4/15/55	597	82
	10/01/53	621	93
5S/6W-14D1	6/18/75	638	105
	7/22/77	635	111

D. GROUND-WATER FLOW AND STORAGE

1. Aquifer Characteristics

Specific capacity (well pumping rate in gallons per minute per foot of drawdown) data are available for 17 wells within the basin. Estimates of transmissivity (the capacity of an aquifer to transmit water, in gallons per day per foot of aquifer width) made from these data range from 120 gpd/ft to 15,000 gpd/ft, with a mean of about 3,800 gpd/ft. As can be seen, a very wide range of values is represented. The average value should be conservative (on the low side) since it includes well losses.

A single multiple-well pumping test was performed and reported in the Lowney-Kaldveer report (1974). The pumping well was not identified but was probably CCWD Well No. 3 along Denniston Creek. This test was poorly conducted for some reason, because only 3 time-drawdown measurements were made in the first 100 minutes after pumping began. The data indicate an apparent response to a nearby barrier (a boundary effect), which was not discussed or considered in the analyses of the test data. This boundary effect may reflect the unnamed fault shown on some maps in close proximity to the pumping and observation wells which may act as a semi-permeable barrier. The estimated transmissivity from drawdown and recovery data of 15,000 gpd/ft may not be far off for the test location. However, use of this relatively high transmissivity value throughout the basin (as was assumed in the Lowney-Kaldveer report) is probably not valid, judging by the wide range of transmissivities estimated from specific capacity data, as discussed above.

Other, recent pumped well tests have yielded transmissivities of approximately 2000 gpd/ft in the vicinity of Denniston Creek near Princeton and less than 1000 gpd/ft in the El Granada Mobile Home Park near the Seal Cove Fault.

In summary, an average transmissivity for the basin is unknown and is probably not applicable. There appears to be a wide variation between the alluvium in and adjacent to the creeks and other parts of the basin. Recommendations are presented in Section F of this report to determine transmissivities more precisely during the Phase II Study, by performing pumping tests for selected existing wells. These data are very important to developing a more accurate estimate of basin yield.

Specific yield (the amount of water that will drain from a unit volume of soil by gravity, expressed as a percent) was estimated in the 1974 report to range from 3 to 25 percent. The total ground-water storage capacity for the basin was estimated to be 6430 acre-feet, and the upper 2/3 of the alluvial fill was estimated to contain the <u>usable storage</u>. These may be reasonable values, but the <u>usable storage</u> may be less than 2/3 of the total as previously estimated. The reason is that use of 2/3 of total storage capacity might cause general water-level declines below sea level in some areas. Useable storage must be better defined in Phase II.

A very approximate example storativity can be estimated from well hydrographs shown on Figure 5 for CCWD wells. These hydrographs roughly suggest seasonal changes in storage of up to about 10-15 feet. If this seasonal water-level change is assumed to occur over the entire basin area of 700 acres, and is attributed only to pumpage of about 400 acre-feet plus an assumed 100 a.f. of natural consumptive use, then the specific yield is 5 to 7 percent. Using this approach, a better estimate of usable storage can be obtained in Phase II by developing late-fall water-level contours from measurements, and then developing contours of seasonal water-level changes. By factoring in consumptive use by phreatophytes and total pumpage for 1987, a reasonable storativity can be estimated.

Adjusting the specific yield to 7 percent (which is probably very conservative), and assuming only the upper 1/3 of total storage is usable, results in approximately 1300 acre-feet of usable ground-water storage, which is more than 3 times present pumpage. This amount of seasonal storage change would still permit discharge to the marsh, and would not result in sea-water intrusion, if pumpage is reasonably distributed in the middle to upper part of the basin. It must be clearly understood that the above estimates are only examples of what might be the case and usable storage must be examined more closely with more definitive data.

2. Ground-Water Recharge, Including Subsurface Inflow and Outflow

The amount of ground-water recharge to the basin is unknown at present. Recharge varies with precipitation and stream flow, and usually increases to some degree with additional pumpage. At a minimum, recharge equals present pumpage (400 a.f.) plus ground-water discharge through the marsh, subsurface outflow, and consumptive use by phreatophytes.

The Pillar Point Marsh is obviously a ground-water discharge area. However, the amount of ground water discharged to the marsh is entirely unknown. The marsh also receives seepage and surface runoff from the hillside to the west, and surface runoff from the northwest along the Seal Cove Fault, including seepage from a small reservoir along this fault. Also, perhaps the most significant source of water is surface drainage from the airport, which drains to the marsh through a collection and discharge system.

Consumptive use by phreatophytes obviously exists, especially in the marsh and along Denniston Creek, but has not been adequately evaluated, and is consequently unknown.

Subsurface inflow from the San Vicente Basin to the north certainly exists. However, the amount is dependent on aquifer transmissivity and hydraulic gradients. As described earlier, the transmissivity throughout the basin apparently varies by a factor of 7 to 8, and thus subsurface inflow may range from about 50 to 350 a.f.y. The same is true for subsurface outflow from the basin, which may range from about 150 to 1200 a.f.y., depending on the transmissivity.

Another element of recharge not previously considered, is subsurface inflow from the bedrock (Montara Granite) to the northeast. While the transmissivity of this rock unit is very low (100 to 1000 gpd/ft), the large cross-sectional area and relatively steep gradients permit significant amounts of subsurface inflow to the basin. This source could amount to 100 a.f.y. or more.

As indicated previously, there is presently no ground-water pumpage for irrigation within the basin. The presently irrigated area of about 400 to 500 acres is supplied by water imported from surface flow in San Vicente Creek. For the Brussels Sprout crop grown on this acreage, about 2 a.f. of water per acre per year is applied, which is equivalent to 800 to 1000 a.f.y. This water is stored in 3 small reservoirs, and applied by sprinkler irrigation. This operation undoubtedly results in some additional recharge to this basin; however, the amount is unknown. The important point, however, is that irrigation does not compete for the available ground-water supply within this basin, but instead adds to the supply of ground water available to some degree--however small or large.

E. GROUND-WATER YIELD

Ground-water yield of the Half Moon Bay Airport/Pillar Point Marsh Basin can presently be only roughly estimated because of the uncertainties cited in previous sections of this report. At a minimum, however, the data clearly indicate that the yield is at least equal to present pumpage (400 a.f.y.) plus subsurface outflow. This would amount to a minimum of 550 a.f.y. plus the existing flow of water to the marsh and the bay. If the subsurface outflow is as high as reported in the 1974 report, the yield could be as high as 1500 to 2000 a.f.y. Based on the example usable storage values estimated herein, the yield could approach 1300 a.f.y. Yield of the basin could be increased by inducing more recharge from Denniston Creek, if possible.

Despite steadily increasing pumpage over the last 10 years, the basin has remained essentially unchanged. Total pumpage is not yet equal to the maximum sustainable yield. Ground-water levels appear to be dictated by the elevation of the outflow point, i.e., mean sea level in the Bay, as is commonly the case in coastal basins. There has clearly been sufficient recharge to the basin to satisfy increasing pumpage without decreasing ground-water storage. If decreases in storage had occurred, they would be reflected by decreasing ground-water levels, which have not occurred over the long term. This is well illustrated by overlaying the March, 1974 and May, 1987 water-level contours, as shown on Figure 6. The slight differences in these contours (a maximum of about 5 feet in water-levels) occur only in the inland areas, removed from the coast and the marsh, and are probably due to the fact that the measurements made in 1987 were made about 2 months later than those in 1974, and after a relatively dry winter. Other differences in the shape of the water-level contours are due to the use of a different set of wells for the 1974 and 1987 measurements.

In summary, based on available data, the basin appears capable of supporting additional ground-water pumpage without significant, if any, impact on ground-water levels, storage, and subsurface flows to Pillar Point Marsh and the Bay. Detailed analyses to determine basin yield more accurately will be part of the Phase II Study; but to date pumpage and water-level responses indicate that the maximum sustained yield of the basin has not yet been reached. This, in turn, suggests that additional pumpage can proceed without harming Pillar Point Marsh, provided that it is carefully staged and monitored. Drilling and test pumping of the two additional wells presently proposed by CUCC would be very beneficial to quantifying conditions in the basin by providing better data on aquifer characteristics, as well as water-level responses to additional pumpage. The drilling and test pumping of the two new wells would be an interim stage until the more definitive Phase II Study described in Section F of this report is completed later this year. If increased pumpage during this test period is shown to impact Pillar Point Marsh, a condition for mitigating the impact could be a requirement for diversion of enough of the pumpage by pipeline to the marsh to maintain current water flows into the marsh.

F. PHASE II INVESTIGATIONAL PROGRAM

The yield of the aquifer system in the Half Moon Bay/Pillar Point Marsh area is of interest and concern since it has been generally accepted that pumpage in excess of a safe or sustained yield would result in seawater intrusion and degradation of the marsh. The previous ground-water investigation (1974) included a value of aquifer yield based on an inventory of hydrologic components, although it was not noted to be a "safe," "sustained," or "perennial" yield, the most commonly used terms when expressing values of ground-water pumping which might be considered as a limiting value. As a result of collecting and analyzing available ground-water data in the first phase, it is apparent that the second phase of the ground-water basin study should be completed as originally expected to determine the yield of the basin, although the available data illustrate that the basin's yield has not yet been reached, despite increased pumpage over the past ten years. One key consideration relative to the second phase is the methodology to employ in the determination of basin yield, given the availability of historical data and the ability to add to that data base with ongoing activities.

There are several methods commonly utilized by ground-water hydrologists to determine the sustained or perennial yield (the term "safe yield" is less commonly used in practice because of the "unsafe" implications of exceeding its value) of an aquifer system or ground-water basin. These methods can be divided into two general categories: conduit methods and reservoir methods. The former analyzes a basin as a "conduit" through which flow takes place and from which extractions (pumpage) are made from that flow. The latter method analyzes a basin as a "reservoir" which contains water in storage and which exhibits changes in storage in response to changes in extractions (pumpage) and other factors.

Conduit methods include:

- The transmissivity method, primarily applicable to confined aquifers, where flow to a well field or area of pumping within an aquifer can be calculated using aquifer characteristics, ground-water levels, and aquifer geometry.

- The trough method, based on the movement of water-levels in relation to rates of pumpage, to maintain ground-water outflow by avoiding the establishment of a pumping trough.

Reservoir methods include:

- Comparison of annual draft and annual change of ground-water levels, where perennial or sustained yield is the draft which produces no change of average water-levels.

- Comparison of annual draft and annual change of storage, a refinement of the previous method, where annual volumetric changes of storage are more accurate and indicative than average water-levels.

- Comparison of average draft and zero cyclic change of water-levels, where perennial or sustained yield over a long term is the average value of draft which results in no net change in water-levels.

- Comparison of average draft and zero cyclic change of storage, a refinement of the previous method, where changes of storage are used to account for variations in location of pumping and not just water levels over a period of no net change in water-levels.

- An inventory of all components of surface and subsurface flows, generally accepted as the most complete approach to determine aquifer yield, capable of being adapted to changing hydrologic or land use conditions.

For this small basin, with limited available data and no prospect of developing certain key long term data, i.e., stream infiltration and deep percolation of precipitation, and with no significant change in ground-water levels as pumpage has increased, the reservoir methods should not be utilized for management and determination of yield.

The concept of ground water management most applicable to the Half Moon Bay/Pillar Point area should be based on active monitoring and analysis of basin reaction to pumping in order to maintain ground-water outflow and avoid the establishment of a pumping trough which could affect the marsh and ground-water quality (the conduit-trough method). Management should not be reduced to simple management by the numbers, i.e., defining basin yield as an absolute number and limited pumpage to that value. Rather, it should be recognized that there are widely different pumping patterns in different locations, that basin reaction to that pumping will vary accordingly, and that aquifer characteristics limit the rates of ground-water movement either toward or from the vicinity of Pillar Point Marsh and Half Moon Bay. Although the potential for water-level lowering and resultant seawater intrusion is present in any coastal basin, the low transmissivity of the aquifer system precludes the possibility of sudden, significant changes. Accordingly, management actions should be based on continued monitoring and interpretation of basin reaction to existing pumping plus staged additional development; and plans for ground-water development should continually evolve as part of those management actions.

As a result of the findings in Phase I, the monitoring and analysis in Phase II should include a continuation of current water-level and water quality monitoring plus the following specific components.

1. Multiple well pumping tests should be performed to determine aquifer transmissivities and storage coefficients using existing CCWD production and monitoring wells, plus the two new CUCC wells, operated on a temporary basis to permit evaluation of their actual impacts on the aquifer. Pumping tests would be considered for one or all of CCWD wells No. 2, No. 3 and No. 5, with Monitoring Well No. 2 as an observation well. CCWD Well No. 9 should be pump tested, using Monitoring Well No. 6 as an observation well. Consideration should also be given to the construction and testing of a well near the northwestern end of the airport and San Vicente Creek to determine aquifer characteristics in that locale and to provide at least one water-level measurement point in the upgradient (inflow from San Vicente Creek) area of the basin.

2. Continuous water-level recorders should be installed in the observation wells one to two days prior to performance of the pumping tests in order to determine if there are responses to barometric and tidal changes. Also, temporary recorders should be installed in Monitoring Wells No. 5 and No. 7 for one to two days in order to determine if confined conditions exist near the coast and marsh.

3. Water-level measurements should be made on existing wells to develop Fall 1987 water-level contours. Contours of changes in water-levels would be constructed based on the differences between the Spring and Fall 1987 measurements and storage changes estimated.

4. A field survey of phreatophytes along Denniston Creek should be made by a team including a hydrogeologist and a biologist to estimate consumptive use within the basin. The same team should establish a monitoring program to evaluate ground-water conditions in Pillar Point Marsh. As part of that effort, consideration should be given to construction and operation of one additional dedicated monitoring well site in or immediately adjacent to the Pillar Point Marsh. To investigate the precise inflow of water to the marsh, a

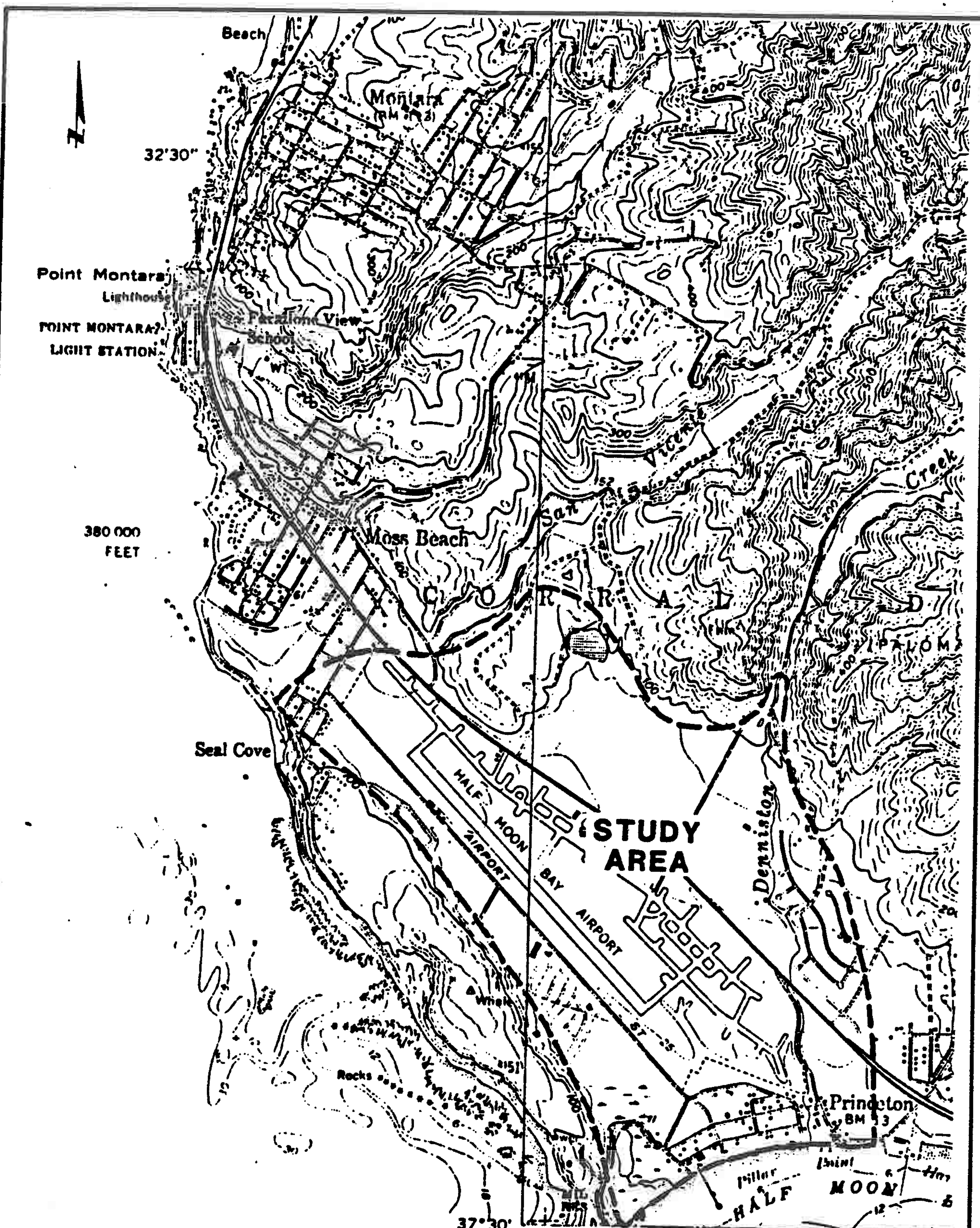
multiple completion monitoring well at the selected site should be considered to determine local vertical gradients for flow, if present, as well as any quality variations with depth.

5. Denniston Creek should be surveyed to locate good sites for stream gaging to better define stream losses to infiltration. Periodic observations, which should not be extrapolated to other times of the year or to other years, could be made to identify whether or not permanent stream gaging is warranted.

The results of the pump testing, measurements, and surveys described above would be evaluated and analyzed, and the conclusions reached presented in a report, along with the data. An investigation with this scope would result in the best possible management of basin ground-water yield. As noted above, ground-water management and evaluation of basin yield should be ongoing efforts based on monitoring and interpretation of basin reaction to current plus future additional pumping. However, to complete the current study, Phase II should continue through a complete hydrologic cycle, one year, and be documented at that time. Ongoing monitoring and updated management decisions should then be documented as appropriate in the future.

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 on Figure 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 near the northeast 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.



EARTH SCIENCES ASSOCIATES LUHDORFF AND SCALMANINI		
HALF MOON BAY AIRPORT/PILLAR POINT GROUND-WATER BASIN – PHASE I STUDY **STUDY AREA**		
Checked by ______ Date ____ Approved by ______ Date ____	Project No. 3272	Figure No. 1

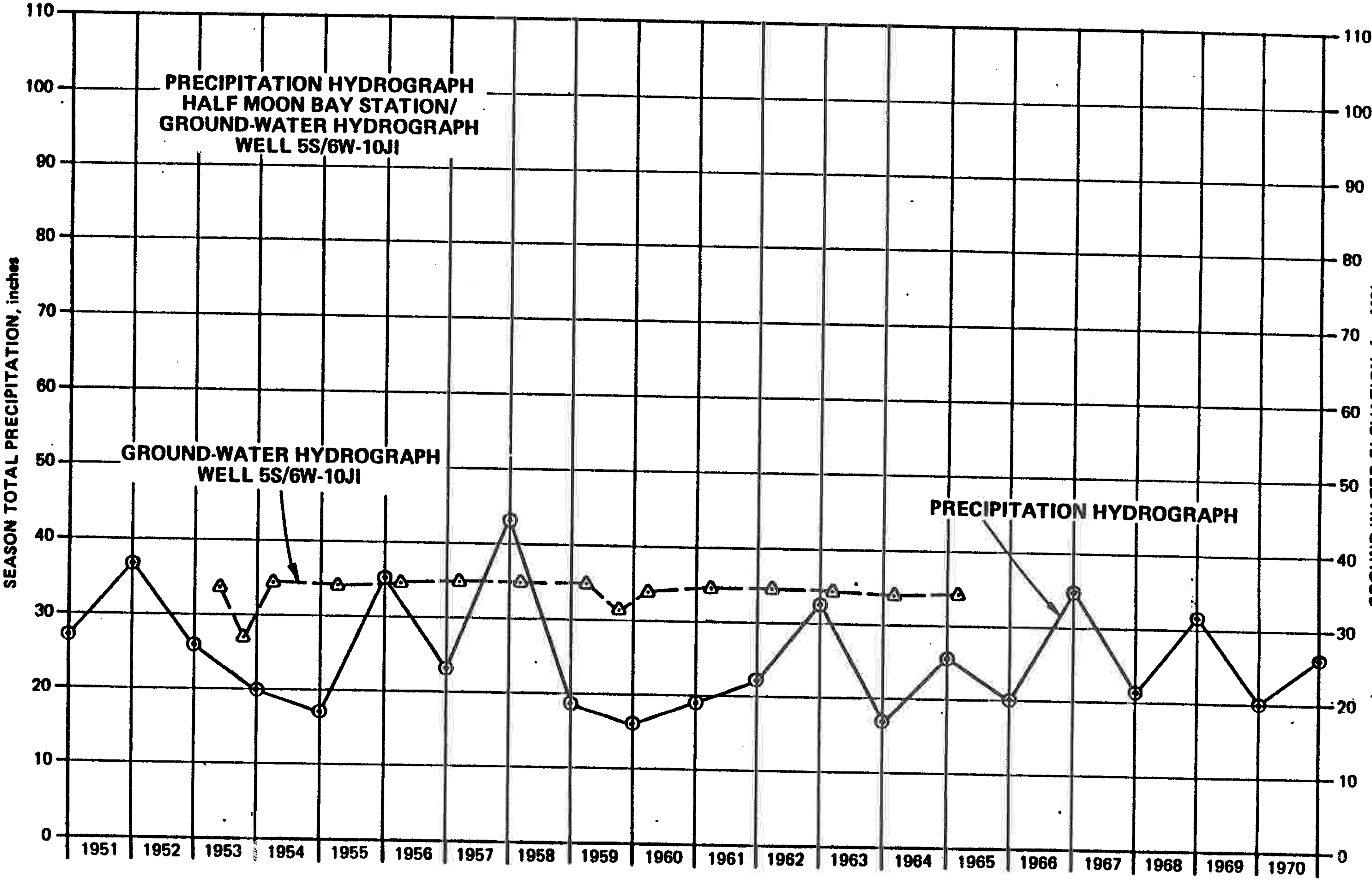

PRECIPITATION HYDROGRAPH
HALF MOON BAY STATION/
GROUND-WATER HYDROGRAPH
WELL 5S/6W-10JI
GROUND-WATER HYDROGRAPH
WELL 5S/6W-10JI
PRECIPITATION HYDROGRAPH
SEASON TOTAL PRECIPITATION, inches
GROUND-WATER ELEVATION, ft. - MSL
0
10
20
30
40
50
60
70
80
90
100
110
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970

Figure 2

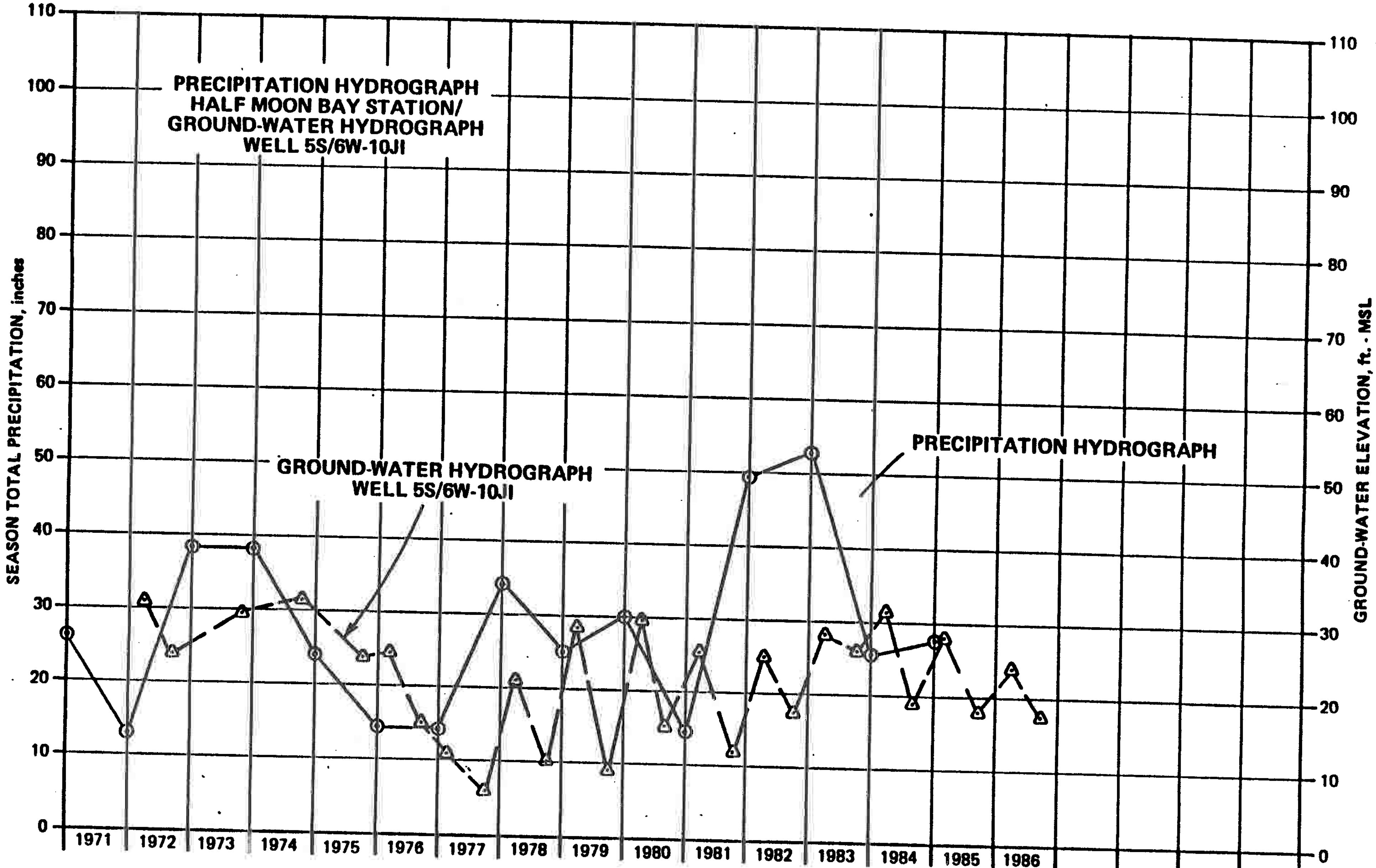


Figure 2 (cont.)

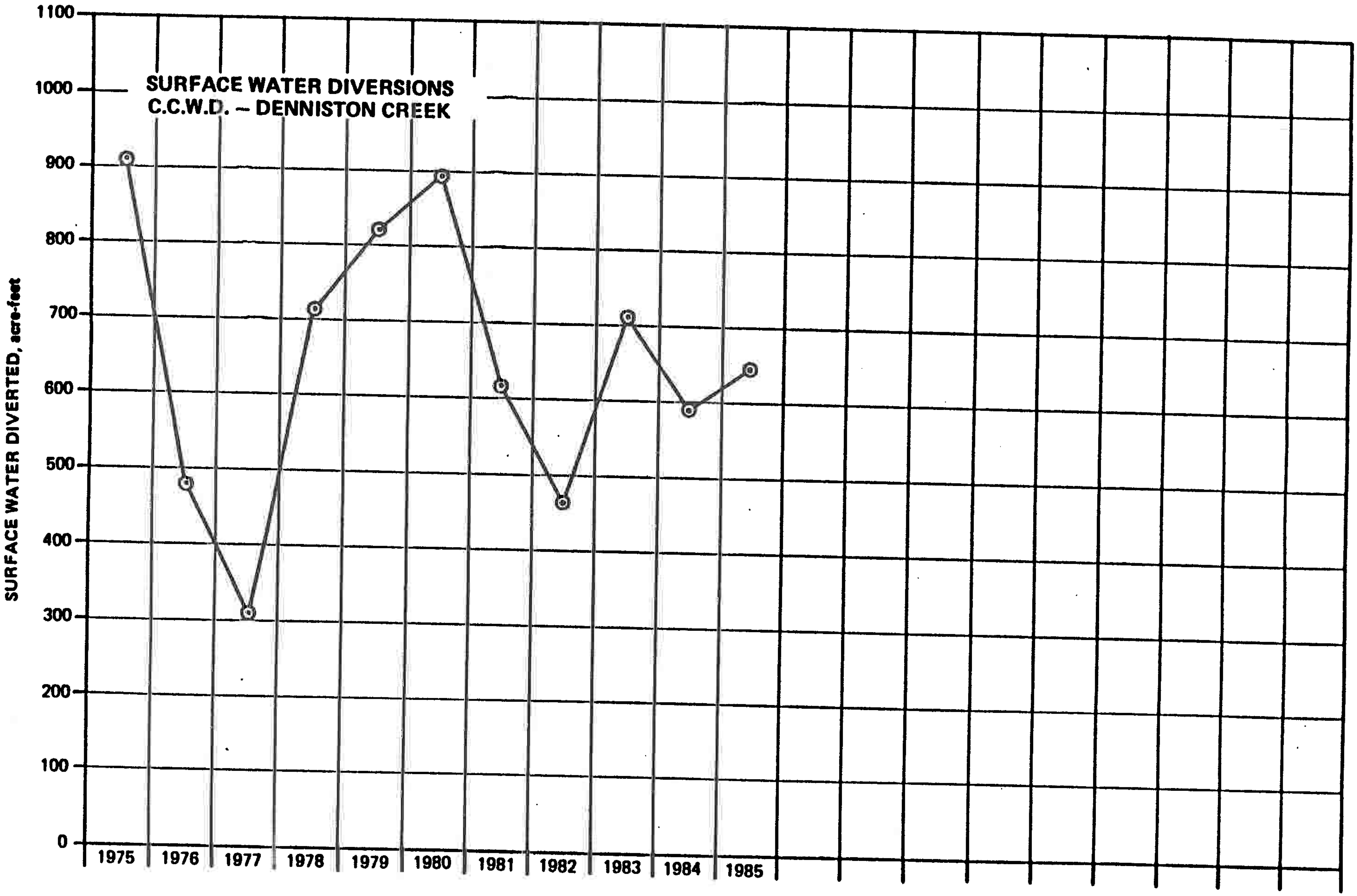
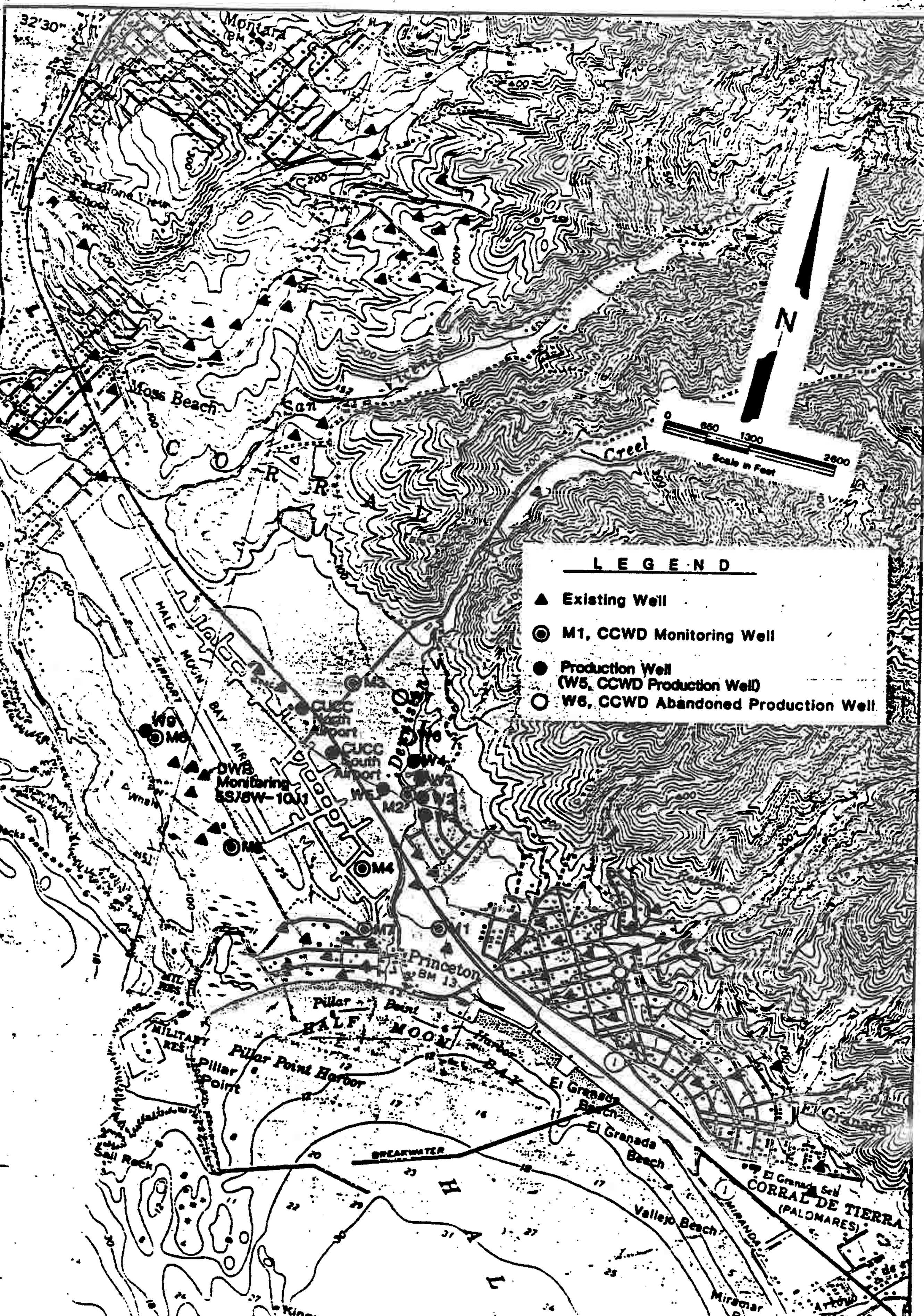

SURFACE WATER DIVERSIONS
C.C.W.D. – DENNISTON CREEK
SURFACE WATER DIVERTED, acre-feet
1100
1000
900
800
700
600
500
400
300
200
100
0
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985

Figure 3



WELL LOCATION MAP

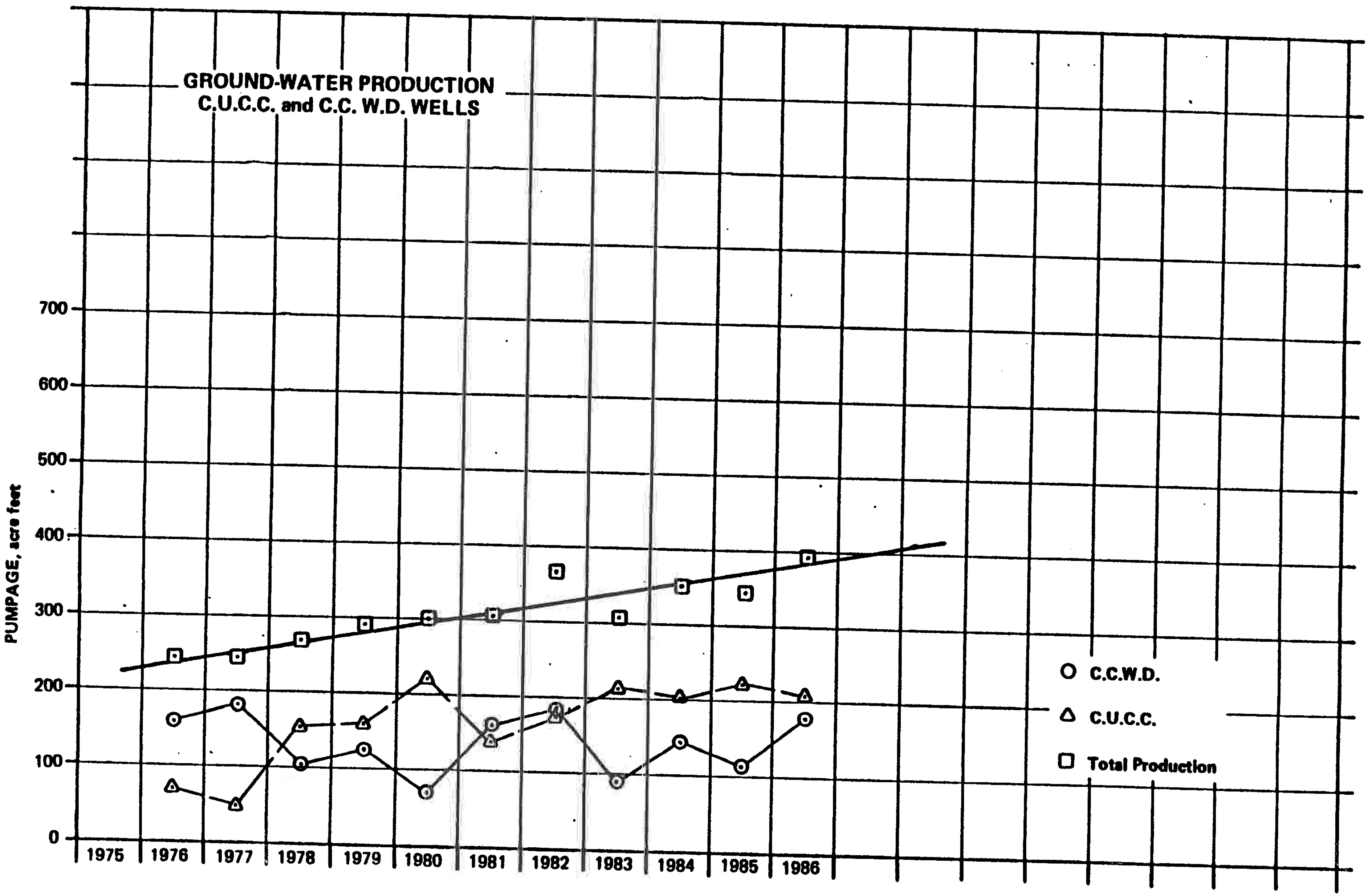

GROUND-WATER PRODUCTION
C.U.C.C. and C.C. W.D. WELLS
PUMPAGE, acre feet
0
100
200
300
400
500
600
700
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
C.C.W.D.
C.U.C.C.
Total Production

Figure 5

CCWD MONITORING
WELL HYDROGRAPHS

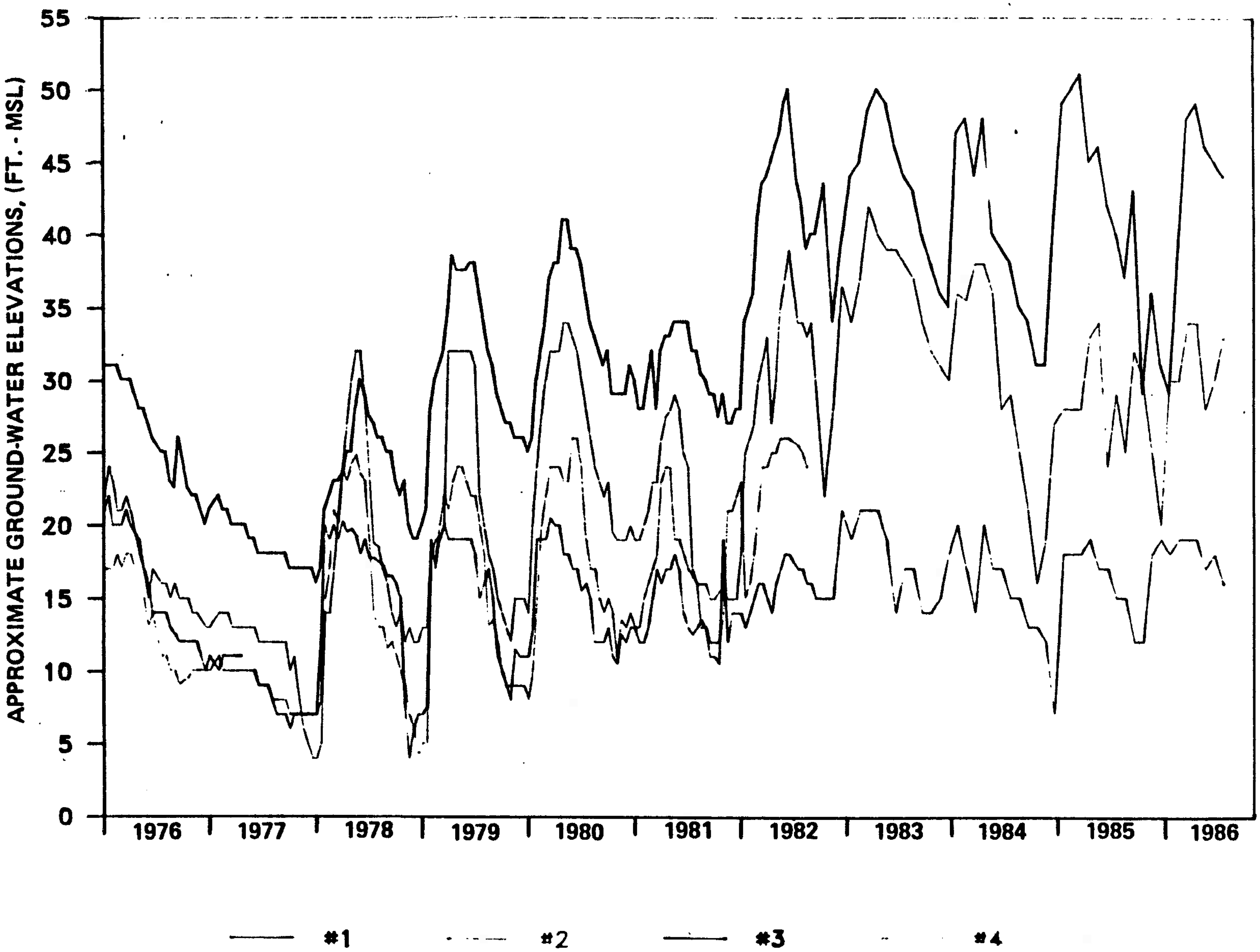


Figure 6

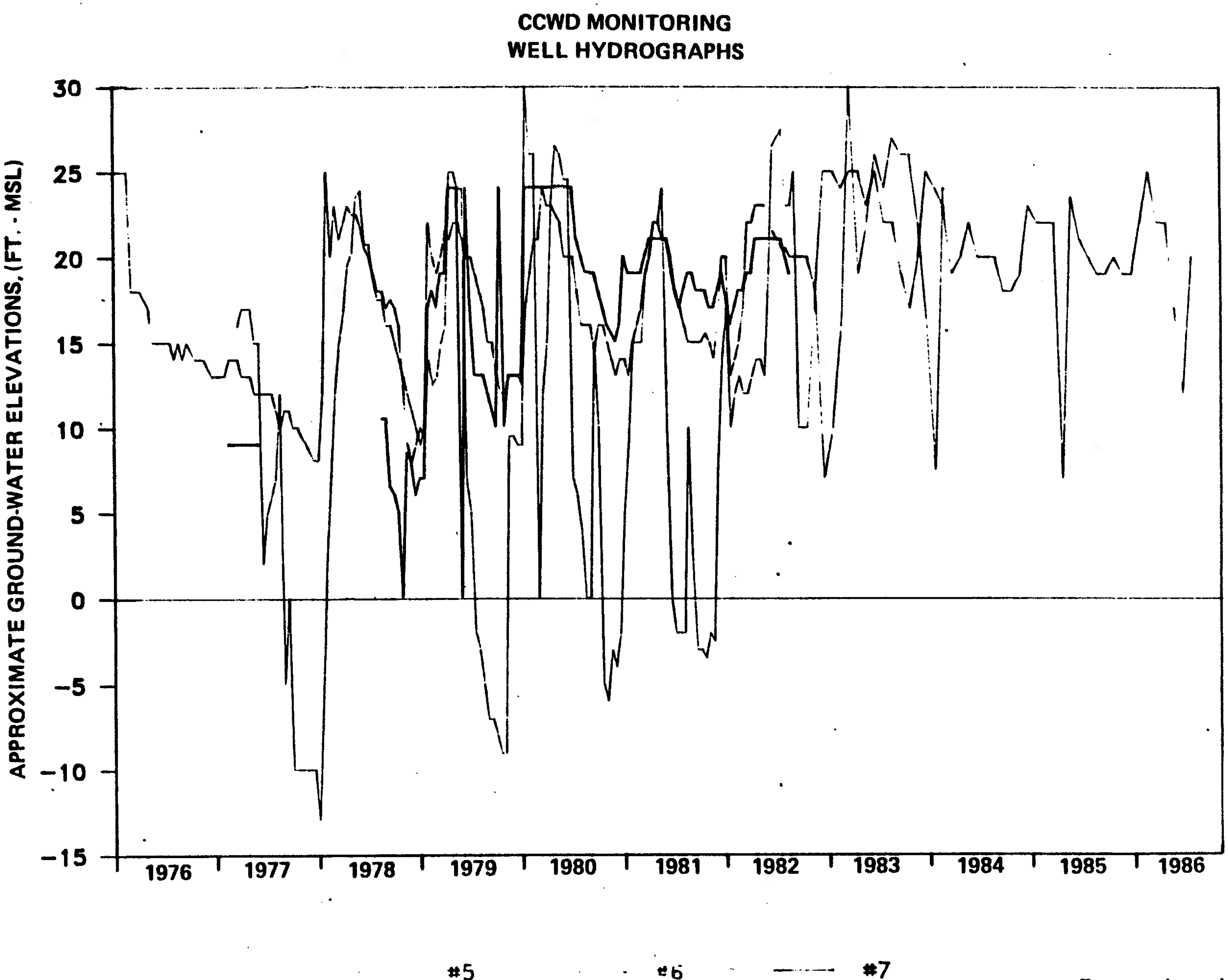
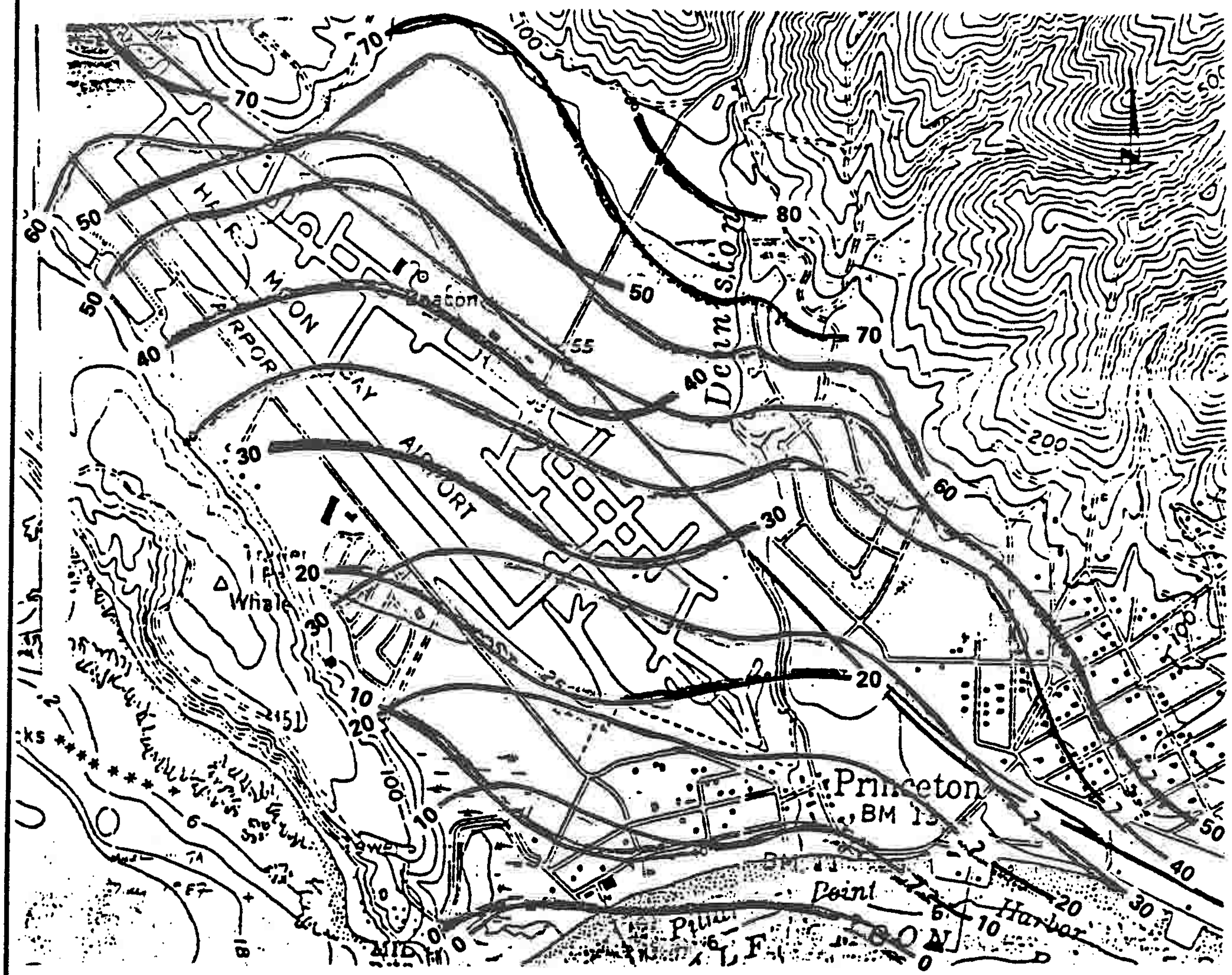


Figure 6 (cont.)



60 Contours of Equal Ground-Water Elevation (March, 1974) from Lowney-Kaldveer Associates, 1974.

60 Contours of Equal Ground-Water Elevation (May, 1987).

EARTH SCIENCES ASSOCIATES LUHDORFF AND SCALMANINI				
HALF MOON BAY AIRPORT/PILLAR POINT GROUND-WATER BASIN – PHASE I STUDY **GROUND-WATER CONTOURS – 1974 & 1987**				
Checked by	Date		Project No.	Figure No.
Approved by	Date		3272	7