Oxnard Plain, Looking North from Port Hueneme — Spence Air Photos

February 24, 1959. The Santa Clara River may be seen traversing the plain in the distance. The western segment of the area in which the investigation centered is in the foreground.

State of California

THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 63-1

Sea-Water Intrusion
OXNARD PLAIN OF VENTURA COUNTY

OCTOBER 1965

HUGO FISHER	EDMUND G. BROWN	WILLIAM E. WARNE
Administrator	*Governor*	*Director*
The Resources Agency	State of California	Department of Water Resources

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AUTHORIZATION

The Legislature in recognition of the need for the study and reporting of water quality problems enacted legislation in 1949 which has been codified in Section 229, Chapter 2, Division 1, of the California Water Code. Section 229 is quoted as follows:

> "229. The department, either independently or in cooperation with any person or any county, state, federal or other agency, to the extent that funds are allocated therefor, shall investigate conditions of the quality of all waters within the State, including saline waters, coastal and inland, as related to all sources of pollution of whatever nature and shall report thereon to the Legislature and to the appropriate regional water pollution control board annually, and may recommend any steps which might be taken to improve or protect the quality of such waters.".

ACKNOWLEDGMENT

Valuable assistance and data used in this investigation were contributed by agencies of the Federal Government and of the State of California, by counties, cities, public districts, companies, and individuals. This cooperation is gratefully acknowledged.

Special mention is made of the helpful cooperation of the following:

- City of Oxnard, Department of Water
- City of Port Hueneme
- Ocean View Municipal Water District
- Oxnard Beach County Water District
- United States Geological Survey, Ground Water Branch, Long Beach
- United States Naval Air Station, Point Mugu
- United States Naval Construction Battalion Center, Port Hueneme
- United Water Conservation District
- Ventura County, Department of Public Works, Property and Water Resources Divisions

E OF CALIFORNIA—RESOURCES AGENCY

WILLIAM E. WARNE, *Director*

PARTMENT OF WATER RESOURCES

BOX 388

AMENTO

August 10, 1965

Honorable Edmund G. Brown, Governor
and Members of the Legislature of
the State of California

Gentlemen:

I am pleased to transmit to you Bulletin No. 63-1 of the Department of Water Resources, entitled "Sea-Water Intrusion: Oxnard Plain of Ventura County". The investigation was conducted under authority of Section 229 of the Water Code which provides in part that the Department of Water Resources "... shall investigate conditions of quality of all waters within the State ....".

This report discusses the configuration of the several water-bearing zones under the coastal portion of the Oxnard Plain, together with an interpretation of the susceptibility of each zone to sea-water intrusion. As part of the investigation, the Department of Water Resources drilled 10 test holes to delineate the water-bearing zones and constructed 11 wells to monitor mineral quality changes and water level fluctuations. The data gathered and the conclusions reached in this study will be utilized in formulating plans and design criteria for the solution of the sea-water intrusion problems. The information contained in this report is currently being utilized by studies under authority of the Porter-Dolwig Ground Water Protection Law, the next progressive step in solving the sea-water intrusion problem.

Sincerely yours,

William E. Warne
Director

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

EDMUND G. BROWN, Governor
HUGO FISHER, Administrator, The Resources Agency
WILLIAM E. WARNE, Director, Department of Water Resources
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CHAPTER I. INTRODUCTION

Ground water produced from the several aquifers beneath the Oxnard Plain of Ventura County has provided the principal water supply for irrigation and urban uses over much of the plain. Since the development of irrigated agriculture early in the present century, the production of ground water increased so that the safe yield of the aquifers was exceeded during the dry periods of 1919-34 and 1946 to the present. During the dry periods the water level elevations were lowered below sea level and a trough was formed in the piezometric surface inland from the coast. The depression of water levels below sea level caused a reversal of the normal seaward flow of ground water along the coast. Under these conditions, aquifers that are hydraulically connected with the ocean are invaded by sea water at the ocean floor outcrop.

Prior to this investigation, the configuration of the several aquifers and aquicludes was not clearly understood. Also, the distribution of existing wells did not provide an adequate network of monitoring points for sea-water intrusion and water level change. The investigation reported here was undertaken to obtain this needed basic information.

Objectives and Conduct of Investigation

The objectives of this investigation were to determine the extent and rate of sea-water intrusion and to make these data available to other programs as one of the key factors in the development of plans for the protection and optimum planned operation of coastal ground water basins.

The first step taken to obtain the needed basic data was to conduct a detailed field canvass of existing wells. Three hundred sixty well sites were visited, the waters were sampled where additional analyses were needed, and depth to water measured when possible. In addition, all well data and logs obtainable were accumulated. Geologic sections were prepared from available logs and the water-bearing zones were grouped and identified as aquifers. Wells with known perforation intervals were identified by the producing aquifer. Water level pressure elevations and water quality were plotted by the identified aquifer. It was then possible to recognize the existence or absence of sea-water intrusion in each aquifer and the threat of sea-water intrusion due to a favorable or unfavorable direction of slope on the water table pressure surface. After considering all available data it was recognized that a full understanding of the seriousness of the intrusion threat could not be reached with the existing information.

The drilling program was designed to add needed geologic data so that the water-bearing zones could be delimited in greater detail in the immediate area of the coastline. The well construction program was designed to provide water level and, more particularly, early warning water quality data in areas not covered by existing wells immediately adjacent to the coastline. The drilling and well construction were done in two separate phases during the springs of 1960 and 1962. The information gained from the exploratory program was used in the final preparation of the geologic sections, water level, and isochlor plates, and in the geologic, hydrologic, and water quality interpretations. The findings of this investigation are presented in the following chapters of this report.

Area of Investigation

The Coastal Plain of Ventura County is a flat alluviated area located generally between the mouths of the Santa Clara River and Calleguas Creek in the center of the coastal reach of Ventura County. It is bounded on the northwest by the foothills of Sulphur Mountain, on the southeast by the Santa Monica Mountains, and inland by South Mountain and the Camarillo Hills. To the southwest is the Pacific Ocean, containing the relatively shallow Santa Barbara marine basin to the west and the deeper Santa Monica marine basin (with Hueneme and Mugu submarine canyons) to the south.

The coastal plain extends for 18 miles along the ocean, has an average depth inland of 9 miles, and extends over an area of approximately 85,000 acres. The portion of the coastal plain extending south from the Santa Clara River to near Revolon Slough and centering on the City of Oxnard is known as the Oxnard Plain. The Pleasant Valley portion of the coastal plain is a part of the Calleguas Creek drainage area and centers around the community of Camarillo. The gradient of the land surface near the City of Oxnard averages about 15 feet per mile. The surface of the coastal plain has a mean elevation of about 50 feet although portions of it located to the south and north of the Santa Clara River extend up to about 150 feet and 300 feet elevation, respectively.

The mean seasonal precipitation for the Coastal Plain of Ventura County averages about 14 inches. The mean seasonal natural runoff of the Santa Clara River and Calleguas Creek at their mouths is estimated to be about 216,400 acre-feet and 15,200 acre-feet, respectively.

The entire coastal plain, except for stream courses and dune and marsh areas, has, at one time or another, been used for agriculture.

Residential, commercial, industrial, and military development is slowly replacing agriculture. At present about 50 percent of the coastal plain is in agriculture; notably lemon orchards and truck crops. The present population of the City of Oxnard is about 61,000 persons. The City of Port Hueneme, located on the coast south of Oxnard, has a present population of about 19,000. Military installations include the naval base at Port Hueneme and naval air station at Point Mugu and the air force base at Oxnard.

Based on the geologic and hydrologic characteristics of the water-bearing sediments found beneath the coastal plain, four ground water basins or subbasins have previously been delimited. These basin units are named Mound, Oxnard Plain Pressure Area, Oxnard Forebay (Montalvo), and Pleasant Valley. Sea-water intrusion, under maximum adverse conditions, could invade and damage all four basins. As of the spring of 1965, the sea-water intrusion problem area has been limited to a 3-1/2-mile wide coastal strip of the Oxnard Plain Pressure Area extending between the community of Oxnard Beach and Point Mugu. This is the area covered in detail in this report and is shown on Plate 1, "Area of Investigation".

Related Investigations and Reports

The Department of Water Resources has been monitoring and reporting on the advance of sea-water intrusion under the Oxnard Plain since 1952. The problem was first reported in the Water Quality Investigation Report Number 14, "Ground Water Quality Monitoring Program in California", for the years 1953 and 1954. For the years subsequent to 1954, the status of the problem has been reported in the Bulletin No. 66 series of reports entitled, "Quality of Ground Water in California".

Three important military installations are on the Oxnard Plain --the naval base at Port Hueneme, naval air station at Point Mugu, and air force base at Oxnard.

U. S. Naval Air Station at Point Mugu   Official U. S. Navy Photograph

Commencing with the year 1957, the status of sea-water intrusion has also been reported annually in the Bulletin 39 series of reports entitled, "Water Supply Conditions in Southern California".

Appendix A, "Selected References", lists known reports contributing useful information on the geology, hydrology, and water quality of the Oxnard Plain. Reports providing information of greater application to the sea-water intrusion investigation are Bulletin 46 and 46a of the Division of Water Resources, "Ventura County Investigation", 1933; Bulletin 12 of the California State Water Resources Board, "Ventura County Investigation", October 1953; "A Plan for Ground Water Management", prepared for United Water Conservation District by John F. Mann, Jr., September 1959; and U. S. Geological Survey Water-Supply Paper 1619-S, "Geology and Ground Water Appraisal of the Naval Air Missile Test Center Area, Point Mugu, California", 1963.

History of Sea-Water Intrusion

The water problems of Ventura County were studied during the drought period of the early 1930's and the findings are published in Division of Water Resources Bulletin No. 46, "Ventura County Investigation", 1933. With respect to the adequacy of the natural water supply of the coastal plain, Bulletin No. 46 reads:

> "There is thought to be a small long-time shortage in the coastal plain with present draft, and if there had been the same acreage irrigated in Santa Clara River Valley and the plain during the past forty years as there is today, and if the pumping draft per acre had been the same as during the period of investigation, the water table in the plain would now be considerably below sea level."

During the dry years of the early 1930's, water level elevations were lowered to as much as 5 feet below sea level in parts of the coastal plain. Wells 1S/21W-8H1 and 1N/22W-28D1, located opposite the heads of the Mugu and Hueneme submarine canyons, respectively, yielded water that indicated active sea-water intrusion. The entrance of sea water into well 1S/21W-8H1, located on the beach bar enclosing Mugu Lagoon, could have occurred through other causes than aquifer intrusion. The chloride ion content in water from well 1N/22W-28D1 decreased from 2,269 parts per million (ppm) in 1931 to 87 ppm in 1933. The water levels recovered slightly during this period which may have provided enough hydraulic head to push back the intrusion. The monitoring of the mineral quality of the water from these two wells was discontinued in 1933 and the wells have since been destroyed. Wells 1S/21W-8H1 and 1N/22W-28D1 were the only sampled wells that showed evidence of possible sea-water intrusion during the early 1930's.

During the wet period from 1937 to 1945, water levels in the Oxnard aquifer recovered and remained above sea level. The water levels started to decline again after 1945, the start of the current drought. By 1949 the elevations were lowered to 30 feet below sea level in some portions of the plain. A well defined pumping trough developed about 3 miles inland from the coast which resulted essentially in a permanent landward water level gradient.

Active sea-water intrusion near Port Hueneme was first recorded in 1950. By 1952 the water produced from wells 1N/22W-20R2, -29A2, and -29C1, located opposite the head of the Hueneme submarine canyon, exceeded 250 ppm, the recommended chloride ion concentration for most uses.

In the Point Mugu area, wells 1S/21W-5H1 and -5H3 were constructed in 1949 by perforating a well casing in both the Oxnard and

Oxnard Plain, Looking South from Port Hueneme

Spence Air Photos

Upper photo: October 5, 1937
Lower photo: December 8, 1953

Mugu aquifers, placing a packer and seal between the aquifers, and providing for the separate air-lift pumping of each aquifer. The water produced, presumably from both aquifers, increased progressively from around 300 ppm chloride ion concentration when drilled to greater than 8,000 ppm in 1954. However, recognition of actual sea-water intrusion in either the Oxnard or Mugu aquifers was uncertain because of possible deterioration of the pumping mechanism. Definite evidence of active sea-water intrusion in the Point Mugu area became apparent about 1958.

The progress of the front is shown on Plate 2, "Areal Progress of Sea-Water Intrusion in Oxnard Aquifer", and Plate 3, "Decline of Ground Water Levels in Wells Versus Increase in Area Underlain by Sea-Water Intrusion -- Oxnard Aquifer".

By the summer of 1963, a total of 44 water wells, 42 near Port Hueneme and 2 near Point Mugu, were seriously affected by sea-water intrusion. While a few of these wells are still used occasionally, the dissolved minerals are so high that the water cannot be used for irrigation or cooking. The water in about 12 additional wells is degraded by sea water but the produced waters are still usable. The lost wells include: the Coast Guard lighthouse well, four of the seven U. S. Naval Construction Battalion Center wells at Port Hueneme, all five of the City of Port Hueneme wells drilled prior to 1962, both original wells of the Silver Strand Mutual Water Company, one of the City of Oxnard wells, and one of the U. S. Naval Air Station wells at Point Mugu. In addition, many irrigation and domestic wells have been lost. The loss of existing wells necessitates drilling new wells into deeper aquifers or further inland or obtaining another supply. The 44 wells lost to date are listed in Table 1.

TABLE 1

ACTIVE WELLS REMOVED FROM USE
DUE TO SEA-WATER INTRUSION

Well number	Owner	Year removed from use	Former use	Aquifer
		POINT MUGU AREA		
1N/21W-28N1	Rancho Guadalasca	1962	Irrigation, domestic	Oxnard
-32G1	USNAS-Point Mugu	1960	Military	Oxnard, Mugu
		PORT HUENEME AREA		
1N/22W-16D2	USNCBC-Port Hueneme	1963	Military	Oxnard
E1	USNCBC-Port Hueneme	1961	Military	Oxnard
Q1	City of Port Hueneme	1962	Irrigation well acquired by City	Oxnard
-19H1	Silver Strand Mutual Water Company	1954	Municipal	Oxnard
-20B1	USNCBC-Port Hueneme	1963	Military	Mugu
E1	Silver Strand Mutual Water Company	1954	Municipal	Oxnard
R1	USNCBC-Port Hueneme	1951	Military	Oxnard
-21B1	City of Port Hueneme	1963	Municipal	Mugu
B2	City of Port Hueneme	1961	Municipal	Mugu
G1	D. R. Light	1963	Domestic	Oxnard
J1	C. Clayberg	1959	Domestic	Oxnard
J2	C. Clayberg	1960	Irrigation	Oxnard
J3	City of Oxnard	1958	Municipal	Oxnard
J4	G. E. Burns	1959	Domestic	Oxnard
L1	City of Port Hueneme	1954	Municipal	Oxnard
L2	City of Port Hueneme	1954	Municipal	Oxnard, Mugu
R1	Homer Barr	1957	Irrigation, domestic	Oxnard
-22L1	Nakashima Nursery	1961	Irrigation	Oxnard
L3	Oriental Gardens	1962	Irrigation, domestic	Oxnard

ACTIVE WELLS REMOVED FROM USE
DUE TO SEA-WATER INTRUSION
(continued)

Well number	Owner	Year removed from use	Former use	Aquifer
1N/22W-22M1	(Not known)	1963	Irrigation	Oxnard
1N/22W-21M2	Prentice	1961	Irrigation	Oxnard
M3	Prentice	1961	Domestic	Oxnard
M5	Hartman Ranch Co.	1962	Irrigation	Oxnard
M7	Wilcox	1960	Irrigation, domestic	Oxnard
M8	Nakamura Farms	1962	Irrigation	Oxnard
M9	Julie Garcia	1961	Domestic	Oxnard
N1	Ventura Co. Inv. Co.	1959	Irrigation	Oxnard
N2	E. N. Buttel	1960	Irrigation	Oxnard
N3	D. Louis Ranch	1962	Domestic	Oxnard
N4	Jim Arimura	1961	Irrigation, domestic	Oxnard
N6	S. Okamoto	1962	Irrigation, domestic	Oxnard
N10	D. Louis Ranch	1962	Domestic	Oxnard
-22P1	R. D. Vestal	1963	Domestic	Oxnard
P2	Cypress Mutual Water Company	1963	Municipal	Oxnard
Q3	Cypress Mutual Water Company	1963	Municipal	Mugu
-27B1	E. Johnson	1961	Irrigation	Oxnard
B2	E. Johnson	1961	Domestic	Oxnard
-28A2	Roy E. Lawn	1959	Irrigation, domestic	Oxnard
B1	A. M. Barnard	1958	Irrigation	Oxnard
C1	Ventura Tool Company	Early 1950's	Industrial	Oxnard
-29A2	City of Port Hueneme	1951	Municipal	Oxnard
C1	U. S. Coast Guard	1951	Domestic	Oxnard

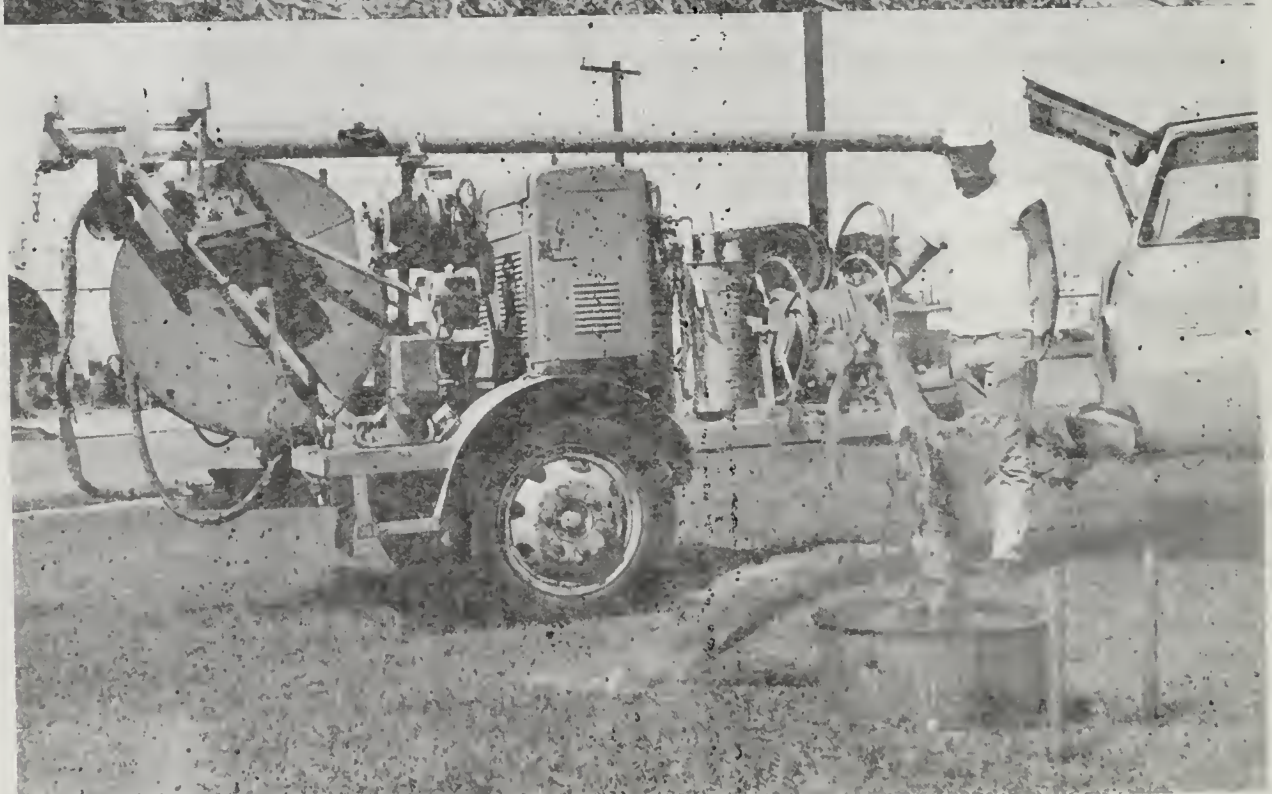
CHAPTER II. DRILLING AND SAMPLING PROGRAM

The detailed investigation of sea-water intrusion of the Oxnard Plain began in the fall of 1959. During November and December of 1959, a detailed well canvass was made to find suitable data collection wells and to obtain logs and well perforation data. During the field canvass, 360 well sites were visited. No surface evidence remained of 60 wells of record. Of the 360 sites, 250 wells were in active use and 50 wells were inactive. Locations of well and exploratory hole sites are shown on Plate 4, "Well Location Map".

Before this investigation, the Department semiannually sampled 15 active wells in the area of investigation. For this investigation, 20 more wells were sampled biannually. In addition, since the fall of 1959, 23 wells without pumps have been sampled with the Department-owned mobile pump units. A submersible pump is used to obtain samples from wells 4 inches in diameter and larger. Two-inch diameter wells are sampled with an air lift.

Water levels are measured in a network of wells spaced throughout the coastal plain by the Water Resources Division of the Ventura County Department of Public Works. The measurements are made at intervals ranging from several times a year to monthly, depending on location. Wells drilled by the Department of Water Resources for the sea-water intrusion investigation have been included in the measuring program.

All the data obtained during the preliminary investigation were evaluated during the winter months of 1959-60.



Well Sampling Equipment

Above: a submersible pump was used for sampling part of the wells in the study area. The well here being sampled is 1N/22W-27R2. In the foreground is well 1N/22W-27R1.
Below: some of the well sampling in the study area was done with an air lift pump, as is being used here with well 1N/22W-29A4.

Acquirement of Existing Wells

A network of data collection wells was necessary for continuing appraisal of the sea-water intrusion problems. Many of the existing wells are at strategic sites and are perforated only within one aquifer. As advancing sea-water intrusion removes existing wells from active production, disuse and destruction of the wells follow.

Preserving an existing well by pulling the pump and affixing a secure cap is less expensive than is constructing a new well. To be able to preserve these old wells, an agreement, or permit, was executed between the well owners and this Department providing for continued use of wells. No funds are paid to the well owner for use of his well, and in turn, he can cancel the permit by providing 90 days' advance notice. Subsequently, one permit was cancelled at the owner's request and another was invalidated by transfer of the property ownership.

The wells were adapted by private contractors to data collection needs at state expense and under this Department's supervision. Observation wells acquired and adapted by the Department are listed in Table 2.

Acquirement of Drilling Sites

The sites selected for drilling exploratory holes were located on private, city, and U. S. Naval reservation lands. The drilling sites are listed in Table 3 by site number. It also gives the name of the owner of the land.

The right-of-way for the sites on the naval reservation were negotiated by the Department's field personnel. The Ventura County Department of Public Works, Property Division, provided professional assistance in negotiating drilling site right-of-way. The legal instrument

TABLE 2

WELLS ACQUIRED FOR DATA COLLECTION USE

Well number	Aquifer	Owner	Contract work under supervision of the Department of Water Resources
1N/22W-19H1	Oxnard	Silver Strand Mutual Water Company	Provided watertight cap
-20E1	Oxnard	Silver Strand Mutual Water Company	Provided watertight cap
-21L1	Oxnard	City of Port Hueneme	Removed pump, sealed lower perforation interval, provided cap
-21L2	Oxnard	City of Port Hueneme	Sealed upper perforation interval, provided cap
-26M1	Oxnard	A. M. Barnard	Removed pump, provided cap
-28R1	Oxnard	A. M. Barnard	Removed pump, provided cap
-28C1	Oxnard	Ventura Tool Company	Removed pump, provided cap

was a right-of-entry "permit". No consideration was paid for use of the site, and the owner could cancel the permit by giving 90 days' advance written notice.

The cost for outright purchase of drilling sites would have been prohibitive. The owners of large parcels of land do not wish to encumber the future potential value of their land by the separation of small fragments.

Once the test hole has been completed and logged, the exploratory geological values have been achieved. It is anticipated that the

TABLE 3

SITES ACQUIRED FOR TEST DRILLING
AND WELL CONSTRUCTION

Site number	Land owner
1a 1b	A. E. Pecht, A. B. Furrer, and A. F. Furrer
2	Hailwood, Inc.
3	USNCBC - Port Hueneme
4	USNCBC - Port Hueneme
5	City of Oxnard
6	Rancho Guadalasca
7	USNAS - Point Mugu
8	USNAS - Point Mugu
9 9a	USNAS - Point Mugu
11	City of Port Hueneme

observation wells constructed on government land will be preserved indefinitely, but some of the observation wells constructed on private land will be destroyed when the land is developed.

To date, all site permits are still in force and the constructed wells are being actively used for data collection.

Drilling and Well Construction Program - 1960

The 1960 exploratory drilling and well construction program was designed to provide needed data collection wells and information on the Oxnard, Mugu, Hueneme, and Fox Canyon water-bearing zones in the vicinity of Port Hueneme. At the time that this drilling program was designed, the known active sea-water intrusion was limited to the Port Hueneme area. The reason for selection of each site follows.

Site 1 - Determine the nature of the geology through the total depth of water-bearing zones at a point located near the coast and opposite an area of offshore storage. Provide observation wells in suitable water-bearing zones.

Site 2 - Same need as stated for Site 1.

Site 3 - Determine the relationship between the water-bearing zones classified as Oxnard and Mugu aquifers and determine the nature of the separating clay member. Provide an observation well to monitor sea-water intrusion in the Mugu aquifer.

Site 4 - Determine the relationship between the water-bearing zones classified as Oxnard and Mugu aquifers and determine the nature of the separating clay member. Provide an observation well to monitor sea-water intrusion in the Oxnard aquifer.

Site 5 - Same need as stated for Site 1.

The drilling extended from March 22 to June 30, 1960, with a Department-owned and operated Failing 1500 rotary drilling rig. At each site a 6-1/4-inch diameter pilot hole was drilled, the cuttings were logged, and the hole was electric-logged. After the aquifer to be monitored was determined, the diameter of the pilot hole was increased to 14 inches to the necessary depth. A 6-5/8-inch steel casing was installed and the perforated interval gravel-packed. Grout seals were placed in the annulus between the casing and the drilled hole at appropriate points. The well was developed by air-lift pumping.

Drilling and Well Construction Program - 1962

About the time that the 1960 drilling and well construction program was completed, an actively advancing sea-water intrusion front was recognized in the Point Mugu area. The 1962 drilling and well construction program was designed to provide data in the Point Mugu area and other areas needing additional data. The drilling sites were numbered 6 through 15. The reason for selection of each site is stated following the site number.

Site 6 - Provide an observation well to monitor sea-water intrusion in the Mugu aquifer.

Site 7 - Provide an observation well to monitor sea-water intrusion in the Oxnard aquifer.

Site 8 - Provide an observation well to monitor sea-water intrusion in the Mugu aquifer.

Site 9 - Determine the nature of the geology through the total depth of water-bearing zones at a point located near the head of the Mugu submarine canyon. Provide observation wells in suitable water-bearing zones.

Site 10 - Provide an observation well to monitor sea-water intrusion in the Mugu aquifer. However, because of a delay in obtaining right-of-way entry and because of a lack of funds, this site was not drilled.

Site 11 - Determine the nature of the geology through the total depth of water-bearing zones at a point located near the coast and near the head of the Hueneme submarine canyon. Provide an observation well to monitor sea-water intrusion in the Fox Canyon aquifer.

Site 12 - Provide an observation well to monitor sea-water intrusion in the Oxnard aquifer in an area where there are no existing wells. This well was not constructed because of a lack of funds.

Sites 13, 14, and 15 - Provide three nests of piezometers of four wells each, at depths of 30, 60, 110, and 130 feet, to monitor downward movement of semiperched waters. A local water quality problem existed in the underlying Oxnard aquifer in this area. The piezometers were not installed because of difficulty in obtaining right-of-way entry and because of a lack of funds.

The data on the 1960 and 1962 drilling and well construction are tabulated in Table 4. Locations of the drilling sites are shown on Plate 5, "Areal Geology", and discussed further in the next chapter.

The drilling was done from January 20 to June 30, 1962. Keener Exploration Drilling Company performed the job with a light rotary drilling rig. The procedure used in drilling the pilot holes and constructing the wells was the same as that used during the 1960 drilling program. To save casing cost, 2-inch plastic casing was used to construct wells intended only for sampling and water level measurements. Six-inch steel casing was installed where transmissibility determinations were needed.

TABLE 4

TEST HOLE AND WELL CONSTRUCTION DATA

Site number	Well numbers	Test hole depth, in feet	Casing depth, in feet	Casing diameter, in inches	Perforations, in feet	Aquifers	Completion date
1a	1N/22W-27R2	1,008	1,000	6-5/8	725-755 860-890 935-990	Fox Canyon, Grimes Canyon	5-27-60
1b	R1	Separate hole	266	6-5/8	125-192 203-213	Oxnard	5-27-60
2	1N/22W-35B1	1,000	Pilot hole backfilled and sealed				6- 8-60
3	1N/22W-20N2	465	330	6-5/8	253-306	Mugu	4- 2-60
4	1N/22W-17M3	330	250	6-5/8	195-230	Oxnard	4-15-60
5	1N/22W-27B4	800	755	6-5/8	495-565 580-630 700-745	Fox Canyon	6-29-60
6	1N/21W-32A2	487	487	2	300-450	Mugu, Fox Canyon	5-10-62
7	1N/21W-32L1	300	300	6	130-235	Oxnard	2-12-62
8	1N/21W-32Q1	526	526	6	275-375	Mugu	3- 9-62
9	1S/21W- 8L1	586	502	2	445-565	Grimes Canyon	5- 1-62
9a	1S/21W- 8L2	Separate hole	290	2	170-270	Oxnard	5- 1-62
11	1N/22W-29A4	1,002	927	2	637-917	Fox Canyon	6-30-62

CHAPTER III. GEOLOGY

One of the primary purposes of the sea-water intrusion investigation of the Oxnard Plain was to determine the geologic conditions close to the coastline. Most of the geologic units described in this report and shown on Plate 5, extend farther inland than the sea-water intrusion area of study. This chapter deals with the geology within the coastal portion of the Oxnard Plain. Information regarding the remaining portion of the basin may be obtained from numerous published reports listed in Appendix A.

Relationships between the various geologic units and their contained aquifers were ascertained by constructing geologic sections, as shown on Plates 6, 7, and 8, "Geologic Sections". The configuration of the three principal aquifers are shown on Plates 9, 10, and 11, "Lines of Equal Elevation on the Top and Base of the Oxnard Aquifer", "Lines of Equal Elevation on the Base of the Mugu Aquifer", and "Lines of Equal Elevation on the top of the Fox Canyon Aquifer". Particular attention was given to areas of possible hydraulic continuity among aquifers because these relationships could show future patterns of intrusion in the basin.

The vertical sequence of fresh water-bearing materials, their age, maximum thickness, and generalized lithology are featured on Plate 12, "Generalized Stratigraphic Column of Water-Bearing Formations -- Coastal Oxnard Plain".

Geologic Setting

The east boundary and bottom of the Oxnard Plain Basin is formed by essentially nonwater-bearing Tertiary sediment-

(A stratigraphic sequence of lower Pleistocene marine- and land-deposited sands, gravels, and interbedded silts and clays with a maximum thickness of more than 2,000 feet overlies the older nonwater-bearing materials.) From bottom to top, the Grimes Canyon aquifer, the important Fox Canyon aquifer, and the lenticular beds referred to in this report as the Hueneme aquifer, are all part of lower Pleistocene deposits.

After deposition of the thick lower Pleistocene deposits, strong earth movements folded and tilted the beds and, over a broad area, erosion occurred. Upper Pleistocene sand, gravel, silt, and clay, having a thickness of over 200 feet in the Oxnard Plain, were laid down on this eroded surface. The Mugu water-bearing zone is included in the upper Pleistocene.

Moderate earth movements and a period of erosion preceded the deposition of Recent materials. The present surface of the Oxnard Plain is a broad floodplain which has been formed by meandering streams and backfilled lagoons. During Recent geologic time, Calleguas Creek and the Santa Clara River deposited alluvial material to the plain. Windblown sands and back-bay deposits and other shallow marine sediments were also deposited along the oceanfront. The Oxnard aquifer, the overlying "clay cap", and the semiperched zone were deposited during Recent time.

Although lower Pleistocene and, to a lesser extent, upper Pleistocene deposits have been tilted and folded by earth pressures, no principal faults are known within the coastal Oxnard Plain described in this report. All the aquifers may extend to outcrop offshore and be in hydraulic continuity with the ocean.

Stratigraphy

In this discussion of the stratigraphy of the area, the youngest water-bearing deposits are given first. Thus, this section starts with the semiperched and Oxnard aquifers of Recent age, then discusses the Mugu aquifer of upper Pleistocene, and concludes with the lower Pleistocene Hueneme, Fox Canyon, and Grimes Canyon aquifers.

Recent Deposits

Recent deposits in the coastal plain consist of river-deposited sands and gravels, interbedded with silt and clay. The semiperched aquifer is located immediately below the surface soil. Poor quality return irrigation waters are contained in this zone, thus posing a potential threat to the quality of waters in deeper aquifers. Beneath the semiperched zone is the "clay cap", which confines the underlying Oxnard aquifer.

Semiperched Aquifer and Clay Cap. The semiperched aquifer is the uppermost water-bearing zone in the Oxnard Plain Pressure Area. It is immediately below the soil horizon at an average depth of 20 to 50 feet. The semiperched aquifer is made up of fine to medium sands and gravels.

The clay member underlying the semiperched aquifer is relatively impermeable over most of the pressure area. However, as has been shown, a significant amount of poor quality water in the semiperched beds may find its way down into the Oxnard aquifer through the clay cap. The clay cap is usually treated as a uniform impermeable body of clay confining the Oxnard zone. Actually, in detail, the cap is quite variable, both horizontally and vertically. Many sand lenses are present within the cap, and the fine sediments include both silt and clay. In some areas, "holes" in the cap may be important conduits to downward flow. Sand lenses within the clay cap may yield water to sustain low production wells; however, we have no record of producing wells perforated in this zone.

Oxnard Aquifer. The Oxnard aquifer occurs beneath the entire Oxnard Plain Pressure Area. Well logs indicate that the aquifer sometimes divides into an upper and lower zone. Occasionally, three permeable zones are distinguishable. Each permeable zone is separated from others by lenticular clay and silt beds. Wells penetrate the top of the Oxnard aquifer at elevations varying from 60 to 200 feet. The base occurs at a more predictable elevation that usually varies between 200 and 270 feet.

Drill logs indicate that materials comprising the Oxnard aquifer are fine to coarse sand and gravel ranging in size from 1/4 to 6 inches in diameter. The clay, silty clay, and silt lenses interbedded within the aquifer appear to form localized aquicludes, which do not affect the piezometric head, but control vertical and horizontal movement of the contained water. The effects of the lenticular aquicludes are particularly noticeable in the vicinity of Point Mugu and Port Hueneme, where the extent of sea-water intrusion into the upper and lower Oxnard aquifer varies significantly within short distances.

Until the late 1940's, historic ground water levels in the aquifer along the coastal portion of the Oxnard Plain were well above sea level. This condition indicates that the Oxnard aquifer is a pressure system wherein piezometric levels are established by a confining aquiclude and landward hydraulic conditions and not by the base level of the Pacific Ocean at the coastline. The confining aquiclude, generally identified as the "clay cap", as determined from well logs and cuttings, is an overlying zone of clay and sandy clay varying in thickness from 10 to 100 feet.

In the vicinity of Mugu Lagoon, a predominance of well log information shows that Oxnard aquifer is not overlain by a continuous aquiclude. Drill cuttings from the test hole at Site 9 contained only small amounts of fine-grained materials to more than 400 feet. This suggests not only continuity between the Oxnard and Mugu aquifers, but also direct contact of ocean and lagoonal waters and the Oxnard water-bearing strata. Test holes in the vicinity, drilled and logged by other agencies, tend to substantiate that the area immediately surrounding and underlying Mugu Lagoon is open to direct sea-water intrusion from the surface.

The Oxnard aquifer crops out in the walls of the Mugu and Hueneme submarine canyons, close to the shoreline. Plate 13, "Projection of Oxnard and Mugu Aquifers to Probable Offshore Outcrop", shows the extent of the offshore outcrop as extrapolated from the known landward limits of the aquifer to their intersection with the submarine shelf and canyons.

Upper Pleistocene Deposits and Mugu Aquifer

The upper Pleistocene deposits consist of land and gravel and interbedded silt and clay, having a maximum total thickness of 260 feet. The sands and gravels have producible water throughout much of the study area and have been named the Mugu aquifer.

The Mugu aquifer is separated from the overlying Oxnard aquifer by another aquiclude which ranges in thickness from 10 to nearly 100 feet. However, in the test hole at Site 9 in the southeast corner of the basin, the two aquifers appear to be merged, as shown by Section C-C' on Plate 7.

The top of the Mugu water-bearing zone is relatively flat and occurs between elevations of 200 and 300 feet below sea level.

Material composing the Mugu aquifer is fine to coarse sand and gravel with thin interbedded zones of clayey silt. The aquifer varies in thickness from a maximum of 205 feet in the test hole at Site 11 at Port Hueneme to less than 30 feet in well 1N/22W-21J3. An almost continuous sand and gravel zone extending from elevation 270 to 475 feet below sea level was encountered in the test hole at Site 11. This is the thickest and deepest occurrence of the Mugu aquifer in the area of investigation. Beneath Point Mugu and Port Hueneme, the elevation of the base of the Mugu water-bearing zone varies from 410 to 470 feet below sea level. North of Port Hueneme, well logs indicate the aquifer commonly extends to an elevation of 360 feet below sea level.

There are only a few, unreliable records of water production from the Mugu zone, and wells that penetrate the aquifer are usually also perforated in other zones. It is likely that the Mugu aquifer crops out in the Hueneme and Mugu submarine canyons within about 0.6 mile of the coastline.

Lower Pleistocene Deposits

The lower Pleistocene deposits in the area of investigation consist of the San Pedro formation and the upper members of the Santa Barbara formation. Three distinct permeable zones can be described in the lower Pleistocene: The Hueneme, Fox Canyon, and Grimes Canyon aquifers.

Hueneme Aquifer. Only limited attention has been given to the Hueneme aquifer to date. This zone of water-bearing sediments is uppermost lower Pleistocene and is separated conformably from the Fox Canyon beds by a continuous aquiclude of clay and silty clay. The Hueneme aquifer consists of irregularly interbedded sand, silt and clay, and some gravel. The areal extent of the Hueneme zone is limited eastward from Port Hueneme along a line trending slightly north of east, as shown on Plate 5. The same unconformity at the base of the upper Pleistocene that limits the Fox Canyon aquifer, also cuts off the Hueneme permeable beds. The Hueneme zone apparently continues seaward and northward of Port Hueneme. Well log interpretations indicate that the Hueneme zone is about 450 feet thick at its deepest point, about 3 miles northwest of Port Hueneme. Hydraulic continuity within the Hueneme zone may be maintained through tortuous and circuitous paths produced by interfingering permeable lenses, or some lenses may be completely isolated.

Available data reveal that only a few wells produce from the Hueneme zone. Because of its lenticularity and limited areal extent, it is the least exploited ground water source beneath the Oxnard Plain.

The clay bed that separates Hueneme beds from the overlying Mugu aquifer is thin or may even be absent near Port Hueneme, and some hydraulic continuity between the Mugu and part of the Hueneme zone is possible. If any continuity exists between the Oxnard and the Mugu zones, a potential threat of sea-water intrusion also exists to the Hueneme zone. In addition, offshore outcrops of the Hueneme zone probably exist, and intrusion is possible from this source.

Fox Canyon Aquifer. The Fox Canyon aquifer is a portion of the lower Pleistocene San Pedro formation. Second only to the Oxnard aquifer, the Fox Canyon is the most widely distributed and exploited water-bearing zone beneath the Oxnard Plain.

Structural activity during middle Pleistocene time warped the San Pedro formation into a broad, approximately east-west trending syncline, plunging seaward. Consequently, the depth where the top of the Fox Canyon is penetrated by wells increases from about 340 feet near Point Mugu to approximately 960 feet two miles northwest of Port Hueneme at the syncline axis. To the northwest, the top of the aquifer again rises toward the surface along the northern flank of the syncline.

Across the southeastern part of the plain in the Mugu area, the Fox Canyon permeable zones are eroded off at the base of the overlying upper Pleistocene beds by an important unconformity, as shown on Section C-C' of Plate 7. Northwest of Point Mugu, progressively younger beds of the lower Pleistocene are similarily affected by this same unconformity. In the Mugu area, the Fox Canyon aquifer thins eastward to zero thickness. A small area of poor hydraulic continuity may exist between portions of the Fox Canyon aquifer and the overlying Mugu aquifer beneath the naval reservation, as shown on Plate 11 and Section F-F' of Plate 8.

If the Mugu aquifer is hydraulically continuous with the stratigraphically higher Oxnard zone, there is a potential threat of sea-water intrusion to the Fox Canyon aquifer from above.

Material composing the Fox Canyon aquifer in the area of investigation is predominantly fine to medium sand. Only a few thin stringers of gravel are noted in well logs. The aquifer is interbedded with clay, silt, and sandy clay lenses. Because of the depth of the aquifer only a few wells have been drilled into it near the coast. In delimiting the top of the aquifer, as illustrated on Plate 11, it was, therefore, necessary to rely heavily on oil well electric logs. No attempt was made to determine the actual thickness or depth of the aquifer.

The offshore extent of the Fox Canyon aquifer is difficult to determine because of structural deformation and probable faulting. In addition, the sediments become progressively finer seaward as suggested by the variance in grain size and difference in well production of the aquifer at the forebay and near the coastline. Apparently, the offshore outcrop of the Fox Canyon aquifer in the Port Hueneme area is not within 1.5 miles of the shoreline. Nevertheless, sea-water intrusion in the Fox Canyon aquifer from the offshore outcrop is a potential threat.

The extent of the Fox Canyon aquifer in the Mugu area, as shown on Plate 11, is a departure from previous thinking. According to this new interpretation, no offshore outcrop of the Fox Canyon exists near Point Mugu, as depicted on Sections A-A' and C-C' of Plate 7. The aquifer is both eroded and is pinched out in a southerly direction along a bedrock high trending parallel to the coastline. Some drilling data substantiate the presence of such a bedrock high, and the existence of such a high is reasonable when the trend of the Santa Monica Mountains toward the ocean is considered.

Grimes Canyon Aquifer. The Santa Barbara formation largely consists of clays, but the uppermost member is composed of sands and gravels. These sands and gravels which are water-bearing are named the Grimes Canyon aquifer. This aquifer presumably underlies the entire Oxnard Plain, but is not an important producing zone, except in the eastern portion of the area. The top of the Grimes Canyon zone occurs at depths greater than 1,500 feet in the basin center, but rises to about 500 feet in the northeasternmost portion. There probably is hydraulic continuity between the Grimes Canyon and the overlying Fox Canyon beds over much of the area.

CHAPTER IV. GROUND WATER HYDROLOGY

The effective forebay, or area of recharge, for all the producing aquifers underlying the Oxnard Plain is located in the Oxnard Forebay along the Santa Clara River. Because of the common forebay area, pressure levels in the aquifers exhibit similar fluctuations, both during the winter recharge season and the summer pumping season.

The reduction of the piezometric surface to below sea level in a pressure aquifer can produce either of two possible conditions. In the case where no hydraulic continuity exists between the aquifer and ocean water, the water levels would be lowered into the aquifer and the aquifer would be depleted. But in the case where the aquifer crops out on the ocean floor with no constrictions impeding hydraulic continuity, sea water would advance into the ocean end of the aquifer. The saline inflow would equal the difference between extractions and fresh water recharge until pressure levels dropped below the top of the confined aquifer, at which time change in storage would occur. Under pressure conditions, a trough parallel to the coastline forms in the piezometric surface, with the hydraulic gradient sloping toward the low point of the trough from both the forebay and offshore outcrop.

The ground water hydrology of each aquifer is discussed separately in sequence from top to bottom, starting with the semiperched aquifer.

Semiperched Aquifer

A clay cap, or aquiclude, separates the semiperched aquifer from the Oxnard aquifer. The clay cap is sufficiently impermeable to cause a pressure condition to exist in the Oxnard aquifer during periods of above sea level water level elevations. The waters in the semiperched aquifer are of poor mineral quality and pose a threat to the waters in the underlying production aquifers. While historic artesian conditions indicate that the permeability of the clay cap is, on the average, very low, the known lenticularity of the cap leads one to suspect that there are local areas of higher permeability, or holes, through the cap. Under historical water level conditions, any movement through the clay cap would be in an upward direction. Conversely, under present conditions, with the depth to the piezometric surface located about 50 feet below the ground surface in wells in the area of investigation, the hydraulic gradient is downward. Investigators attempting to balance the inflow, or recharge values, for the Oxnard aquifer with the amounts of extraction have concluded that the otherwise unaccounted for inflow is deep percolation from the semiperched aquifer.

Available evidence indicates that the unconfined water table in the semiperched aquifer exists above sea level throughout nearly all the coastal plain. The area just landward of the beach dunes in some locations is flooded by ocean wave wash. These ocean waters could move down into the semiperched aquifer and become part of deep percolation to lower zones. As yet there is no mineral quality evidence to indicate that this has occurred.

Oxnard Aquifer

Under the natural conditions that existed prior to drilling of water wells, part of the surface waters of the Santa Clara River flowing across the forebay area would percolate down to the water table, move oceanward through the conduit of the Oxnard aquifer, and discharge into the ocean water at the outcrops in the submarine canyons and on the ocean

Cabinet housing liquid level recording gage for well 1N/22W-22H2. The gage produces a continuous record of water level changes.

floor. Early residents report the upwelling of fresh water in the ocean at considerable distances from the shore. Also, it has been reported that the artesian pressure in a 4-inch well drilled to a depth of less than 100 feet was great enough to supply the water needs throughout a two-story house. The unrestricted flow from artesian wells was said to have created fresh water ponds back of the beach dunes along the coast. The artesian flow of wells throughout the pressure area diminished after the mid-1920's as the water levels dropped during this dry period. During and following the wet period of the early 1940's, artesian flow again occurred at wells in the coastal area of the plain. Pump bases frequently had to be secured watertight to the well pedestal to prevent a nuisance flow of escaping water.

During the years of deficient rainfall from 1919 to 1935, the water levels in the Oxnard aquifer dropped to a low of 5 feet below sea level in the 1930's. While the water levels recovered to above sea level during the period of above average rainfall, extending from 1936 to 1945, the levels did not fully recover to the pre-1919 elevations. Following the beginning of the period of rainfall deficiency starting in 1946, the water levels declined to a minimum elevation of 55 feet below sea level in parts of the pressure area. During the 1950's and continuing to the present time, the entire annual fluctuation of 30 feet has, in general, occurred at elevations below sea level, as shown on Plate 3.

During past wet periods, water level elevations throughout the Oxnard aquifer were above sea level, with elevations ranging from a maximum along the Santa Clara River at the upper end of the forebay to a minimum in the area farthest from the forebay, near Point Mugu Naval

Reservation. It was this area that experienced the first below sea level elevations during the drought.

When water levels are below sea level, a trough in the piezometric surface is formed. The trough in 1963 was centered about 2-1/2 miles inland from the ocean near the Santa Clara River with the distance increasing southeastward to about 3-1/2 miles near Point Mugu. During the summer, water level gradients become the steepest. During the summer of 1961, the water levels were at a record low of minus 25 feet west of Oxnard and sloped to minus 55 feet north of Point Mugu. In the summer of 1962, the water levels in the trough sloped from minus 15 feet just west of Oxnard to minus 35 feet north of Point Mugu, as illustrated on Plate 14, "Lines of Equal Elevation of Ground Water in Wells in the Oxnard Aquifer, Summer 1962 and Spring 1963". The period of water level recovery from the summer of 1962 to the spring of 1963 is also presented on Plate 14.

Mugu Aquifer

Because of the common forebay area of the Mugu and Oxnard aquifers, it can be assumed that long-term water level changes in the Mugu aquifer show corresponding changes to those in the Oxnard aquifer. As yet, there is no positive evidence substantiating the suspected hydraulic continuity between the Mugu aquifer and the ocean, although the projected outcrop area in the Hueneme and Mugu submarine canyons suggests hydraulic continuity exists. Only when sea-water intrusion in the Mugu aquifer actually occurs will the existence of hydraulic continuity with the ocean be substantiated.

Only 10 of the wells in the study area for which perforation data are available are perforated solely in the Mugu aquifer. In addition, about twice that number of wells are perforated in both the Mugu aquifer and a higher or lower aquifer.

During the summer of 1962, the water levels in the Mugu aquifer sloped from 7 feet below sea level at Port Hueneme to 60 feet below sea level in the Point Mugu area, as shown on Plate 15, "Lines of Equal Elevation of Ground Water in Wells in the Mugu Aquifer, Summer 1962 and Spring 1963". The available data indicate that the water levels in the Mugu aquifer in the summer of 1962 were about 9 feet above the levels of the Oxnard aquifer in the Port Hueneme area but were about 30 feet below the levels of the Oxnard aquifer in the Point Mugu area. The water level recovery in the Mugu aquifer between the summer of 1962 and the spring of 1963 is also presented on Plate 15. The available water level data show that the piezometric surface of the Mugu aquifer is below sea level throughout the coastal portion of the Oxnard Plain, and if hydraulic continuity exists with the ocean, the resulting landward hydraulic gradient is causing sea-water intrusion in the offshore area of the aquifer.

Hueneme Aquifer

Because of the common forebay area shared by the Hueneme aquifer and overlying aquifers, it can be assumed that long-term water level changes in the Hueneme aquifer show corresponding changes to those in the Oxnard aquifer. Only one of the wells in the study area for which perforation data are available is perforated solely in the Hueneme aquifer. This well is 1N/22W-19A1. In addition, wells 1N/22W-4F4, -17B1, and -21B3 are perforated in both the Hueneme and Fox Canyon aquifers. These wells are located in the Port Hueneme area. The water level elevations in well 1N/22W-19A1 was 11 feet below sea level in the summer of 1962 and recovered

3 feet by the spring of 1963. The pressure level was 5 feet higher in the Hueneme aquifer than in the Oxnard aquifer in the summer of 1962. A plate showing lines of equal water level elevation in the Hueneme aquifer could not be prepared because of lack of data. The available water level data show that the piezometric surface in the Hueneme aquifer is below sea level in the Port Hueneme area.

Information pertaining to the offshore areal extent, the existence of ocean floor outcrops, and offshore permeability and transmissibility in the Hueneme aquifer are not available. If hydraulic continuity exists with the ocean, the resulting landward hydraulic gradient is causing sea-water intrusion in the offshore area of the aquifer.

Fox Canyon Aquifer

The Fox Canyon aquifer is continuous across both the Oxnard Plain Pressure Area and the Pleasant Valley Basin and receives recharge from the Santa Clara River at the Oxnard Forebay and from Calleguas Creek. In the Oxnard Plain, only four wells in the study area, for which perforation data are available, are perforated solely in the Fox Canyon aquifer. In addition, 19 wells are perforated in both the Fox Canyon and one or more additional aquifers. In Pleasant Valley, most of the active wells produce water from the Fox Canyon aquifer.

Water level changes within the two separate recharge areas to the Fox Canyon aquifer are controlled by the local extraction-recharge relationship. Under the Oxnard Plain and the southwestern end of Pleasant Valley, the long-term ground water level changes parallel the changes occurring in the Oxnard aquifer. In the summer of 1962, the piezometric surface throughout the Fox Canyon aquifer was below sea level, with the elevations sloping from 20 feet below sea level at Port Hueneme to 75 feet below sea level in Pleasant Valley, as shown on Plate 16, "Lines of Equal Elevation of Ground Water in Wells in the Fox Canyon Aquifer, Summer 1962 and Spring 1963". These elevations are 5 feet lower than the levels in the Oxnard aquifer in the Port Hueneme area and about 30 feet lower than the levels in the Oxnard aquifer in the Point Mugu area. Water level recovery in the Fox Canyon aquifer between the summer of 1962 and the spring of 1963 is also presented on Plate 16. Available water level data indicate that the piezometric surface in the Fox Canyon aquifer is well below sea level throughout much of the Oxnard Plain.

Information pertaining to the offshore areal extent, the existence of ocean floor outcrops, and offshore permeability and transmissibility in the Fox Canyon aquifer are not available and any conclusions pertaining thereto are highly speculative. If hydraulic continuity exists between the Fox Canyon aquifer and the ocean, the resulting landward hydraulic gradient is causing active sea-water intrusion in the offshore area of the aquifer.

Grimes Canyon Aquifer

Two wells in the Point Mugu area, 1N/21W-32A1 and 1S/21W-8L1, are perforated solely in the Grimes Canyon aquifer. It is reported that several wells in adjacent Pleasant Valley are also perforated in the Grimes Canyon aquifer. In addition, nine wells in the Oxnard Plain are perforated in both the Grimes Canyon and one or more additional aquifers. The Grimes Canyon aquifer dips to such great depth under the Port Hueneme area that water wells have not penetrated it and, therefore, no information exists concerning its water-bearing characteristics.

The piezometric surface sloped from 55 feet below sea level at well 1S/21W-8L1 to 71 feet below sea level at well 1N/21W-32A1 during the fall of 1963, as depicted on Plate 17, "Lines of Equal Elevation of Ground Water in Wells in the Grimes Canyon Aquifer, Fall 1963". With the piezometric surface below sea level, if hydraulic continuity exists between the aquifer and the ocean, sea-water intrusion is now occurring in the offshore area.

CHAPTER V. WATER QUALITY

The aquifers underlying the Oxnard Plain consist of a largely unused semiperched aquifer, containing waters of inferior mineral quality, and five underlying aquifers, which readily yield water of marginal to suitable quality to wells. The water in the four uppermost producing aquifers are similar in character and in concentrations of the dissolved minerals because of a common forebay area. The mineral character is calcium-sodium sulfate. In the lowermost aquifer, the Grimes Canyon, the character of the water is sodium bicarbonate-chloride.

The waters in the semiperched aquifer originate partly as excess irrigation water produced from the underlying aquifers. Therefore, the semiperched waters resemble the underlying waters in character, although the concentration of the dissolved mineral consistuents ranges up to eight times greater than the concentration found in the applied waters.

Ground waters extracted from the producing aquifers of the Oxnard Plain are used throughout the area for irrigation, domestic, and industrial purposes. The water is suitable for most crops, although the concentration of boron present may adversely affect some of the boron sensitive crops. From the domestic, municipal, and industrial standpoint, the water is of marginal quality because of excessive dissolved solids, high sulfate content, and hardness.

Semiperched Aquifer

The cation character of semiperched waters is generally calcium-sodium in the lower concentration waters, but changes to sodium in the higher concentration waters. The anion character is predominately sulfate,

TABLE 5

ANALYSES OF GROUND WATER FROM SELECTED WELLS AND DRAINAGE DITCHES IN SEMIPERCHED AQUIFER

State well number	Date sampled	Temperature when sampled °F	pH	EC x 10^6 at 25° C	Constituents in parts per million / equivalents per million: Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	Parts per million: F	B	SiO_2	Total dissolved solids	Total hardness	Percent Na
Wells																			
1N/21W-19R2	1-18-62	--	7.4	8177	231 / 11.53	236 / 19.43	1632 / 70.99	11 / 0.28	0 / 0	570 / 9.34	3530 / 73.54	672 / 18.95	15 / 0.24	1.9	10.0	42	6838	1548	69
1N/22W- 8L2	8-18-59	--	7.8	7520	394 / 19.70	339 / 27.86	1240 / 53.90	-- / --	-- / --	461 / 7.56	4035 / 84.13	231 / 6.52	49 / 0.79	--	7.1	--	6749*	2379	53
-16L1	5-15-58	--	7.6	1564	138 / 6.92	39 / 3.18	125 / 5.44	-- / --	-- / --	245 / 4.02	446 / 9.30	86 / 2.43	-- / --	--	0.66	--	957*	505	35
Drainage Ditches																			
1N/21W-30B	2-14-61	65	7.7	3888	412 / 20.56	136 / 11.18	422 / 18.36	13 / 0.33	0 / 0	344 / 5.64	1505 / 31.35	403 / 11.36	79 / 1.27	2.4	1.8	34	3434	1587	36
1N/22W- 7J	1-14-53	--	8.0	3774	371 / 18.5	186 / 15.3	350 / 15.2	6.6 / 0.17	0 / 0	405 / 6.64	1875 / 39.1	145 / 4.09	23 / 0.368	--	2.48	--	3628*	1690	31
1N/22W-21B	10-11-60	70	7.7	2260	311 / 15.50	78 / 6.40	134 / 5.82	1.6 / 0.04	0 / 0	363 / 5.95	870 / 18.12	106 / 3.00	33 / 0.54	1.7	0.43	27	1827	1095	21

*Total dissolved solids determined by summation.

reflecting the anion character in the applied irrigation water. The chlorides in the semiperched waters range from near native concentration (50 parts per million) up to 700 ppm, and the sulfates parallel this increase, ranging from near native concentration (400 ppm) up to 5,000 ppm. The total dissolved solids range from near native concentration (950 ppm) up to 7,000 ppm. Base exchange apparently occurs because the sodium concentration generally exceeds the calcium concentration by a significant amount when the total dissolved solids exceed 1,500 ppm. The cation character of the applied irrigation water is generally calcium-sodium.

There is no known domestic use of the semiperched waters and little irrigation use, except where the semiperched waters drain into ditches, and are diverted by pumping. The concentration of dissolved minerals in the semiperched water in all but isolated cases exceeds criteria for domestic and municipal uses. Also, the semiperched waters are generally injurious to unsatisfactory for irrigation uses. Analyses of typical semiperched waters are presented in Table 5.

The downward movement of the semiperched waters, either by percolation through the clay caps or through faulty wells, could degrade the underlying producing zones to unusable concentrations.

The sulfate anion character of the semiperched water readily distinguishes it from sea water, which has a chloride anion character.

Oxnard Aquifer

Most production wells in the Oxnard Plain are perforated in the Oxnard aquifer.

Table 6 shows analyses of representative wells producing both fresh and intruded water from this aquifer. The fresh water produced from

TABLE 6

ANALYSES OF GROUND WATER FROM
SELECTED WELLS IN OXNARD AQUIFER

State well number	Date sampled	Temperature when sampled °F	pH	EC x 10^6 at 25° C	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B	SiO_2	Total dissolved solids	Total hardness	Percent Na
					Constituents in parts per million / equivalents per million									Parts per million					
1N/21W-28N1	12- 6-61	69	7.3	2625	248 / 12.38	102 / 8.38	162 / 7.05	9.6 / 0.25	0 / 0	293 / 4.80	341 / 7.11	563 / 15.88	8.0 / 0.13	0.51	0.56	44	1980	1041	25
-31A1	1- 4-52	--	8.4	1220	124 / 6.19	39 / 3.21	95 / 4.13	3.5 / 0.09	0 / 0	270 / 4.42	352 / 7.33	65 / 1.83	2.0 / 0.03	0.2	0.60	37	851	470	30
	6-18-63	--	8.0	1100	120 / 6.02	34 / 2.75	89 / 3.87	4.0 / 0.10	0 / 0	268 / 4.40	341 / 7.11	36 / 1.00	1.2 / 0.02	0.4	0.65	22	852	438	30
-32L1	2-12-62	--	8.2	1120	118 / 5.89	32 / 2.60	90 / 3.90	3.8 / 0.10	0 / 0	252 / 4.14	341 / 7.11	47 / 1.32	1.8 / 0.03	0.4	0.55	33	816	425	31
1N/22W- 8K3	10-25-55	64	7.6	1220	128 / 6.39	41 / 3.36	97 / 4.22	4.6 / 0.12	0 / 0	255 / 4.18	403 / 8.39	37 / 1.04	1.7 / 0.03	0.8	0.77	35	875	488	30
	11-20-62	68	8.4	1060	122 / 6.08	41 / 4.39	83 / 3.60	5.0 / 0.13	9 / 0.30	261 / 4.28	397 / 8.26	43 / 1.20	1.0 / 0.01	0.8	0.74	25	956	523	25
-16E1	11-20-59	--	7.3	1234	125 / 6.27	36 / 3.04	90 / 3.90	3.9 / 0.10	0 / 0	248 / 4.07	403 / 8.41	45 / 1.27	2 / 0.03	0.60	0.55	32	910	466	29
	10- 9-62	--	7.2	7000	842 / 42.00	257 / 21.10	425 / 18.47	19 / 0.50	0 / 0	222 / 3.64	616 / 12.83	2358 / 66.50	0 / 0	0.4	0.77	23	5550	3155	22
-16Q1	12- 3-61	--	7.5	1380	132 / 6.60	57 / 4.70	95 / 4.13	4.0 / 0.10	0 / 0	195 / 3.20	360 / 7.50	183 / 5.15	0 / 0	0.4	0.60	10	1194	565	27
	10-10-62	65	7.1	5100	645 / 32.20	230 / 18.85	230 / 10.00	11 / 0.29	0 / 0	174 / 2.85	517 / 10.77	1652 / 46.60	0 / 0	0.2	0.74	22	4334	2552	16
-20E1	7- 9-54	--	7.8	1242	115 / 5.75	37 / 3.05	84 / 3.65	3.9 / 0.10	0 / 0	226 / 3.7	348 / 7.24	51 / 1.45	2.9 / 0.047	0.8	0.63	--	793	440	29
	8-16-63	68	7.0	21000	1303 / 65.00	508 / 41.75	3300 / 143.5	30 / 0.77	0 / 0	169 / 2.76	1178 / 24.52	7757 / 218.75	0 / 0	0.1	1.24	18	16580	5337	57
-21J4	5- 8-59	--	7.8	2085	245 / 12.25	74 / 6.11	123 / 5.36	6.6 / 0.17	0 / 0	203 / 3.33	353 / 7.35	499 / 14.08	0 / 0	0.57	0.76	27	1482	918	22
	6-11-63	--	7.2	17500	1954 / 97.50	711 / 58.50	1263 / 54.91	21 / 0.54	0 / 0	82 / 1.35	640 / 13.33	6915 / 195.00	0 / 0	0.2	0.57	7.0	14530	7806	26

ANALYSES OF GROUND WATER FROM
SELECTED WELLS IN OXNARD AQUIFER
(continued)

State well number	Date sampled	Temperature when sampled °F	pH	EC x 10^6 at 25° C	Constituents in parts per million / equivalents per million: Ca	Mg	Na	K	CO_3	NCO_3	SO_4	Cl	NO_3	Parts per million: F	B	SiO_2	Total dissolved solids	Total hardness	Percent Na
1N/22W-27R1	10-11-62	66	7.9	1040	104 / 5.20	35 / 2.86	82 / 3.55	4.6 / 0.12	0 / 0	250 / 4.10	312 / 6.50	44 / 1.22	0 / 0	0.6	0.67	28	814	403	30
-28H2	11-20-62	--	8.2	900	60 / 3.00	33 / 2.67	90 / 3.90	1.9 / 0.05	0 / 0	139 / 2.29	288 / 6.01	55 / 1.55	0 / 0	0.4	0.52	12	662	284	40
-29C1	9- 2-52	--	7.2	3817	425 / 21.2	139 / 11.4	165 / 7.18	8.5 / 0.218	0 / 0	195 / 3.20	325 / 6.78	1070 / 30.2	0 / 0	0.8	0.48	--	3020*	1630	18
-35G1	11-30-62	--	8.2	780	58 / 2.92	28 / 2.25	75 / 3.25	3.5 / 0.09	0 / 0	336 / 5.50	93 / 1.94	41 / 1.15	0 / 0	0.6	0.68	13	484	259	38
-36K1	9-30-52	--	7.68	--	123 / 6.15	38 / 3.12	87 / 3.78	-- / --	-- / --	276 / 4.53	319 / 6.65	58 / 1.64	-- / --	0.60	0.56	--	763*	464	29
	5- 9-62	64	8.3	1650	162 / 8.10	50 / 4.12	127 / 5.50	5.7 / 0.15	2.1 / 0.07	240 / 3.93	324 / 6.75	259 / 7.31	2.8 / 0.04	0.4	0.70	31	1092	611	35
-36K3	4- 5-61	69	7.2	10400	733 / 36.60	305 / 25.10	1210 / 52.50	21 / 0.56	0 / 0	265 / 4.35	712 / 14.82	3386 / 95.50	0 / 0	0.2	0.92	26	7514	3085	22
1S/21W- 8L2	6- 5-63	66	7.3	26000	932 / 46.50	827 / 68.00	5750 / 250.00	35 / 0.90	0 / 0	235 / 3.85	1626 / 33.86	11569 / 326.25	0 / 0	0.1	1.46	26	24620	5125	69

*Total dissolved solids determined by summation.

the Oxnard aquifer throughout the Oxnard Plain in 1963 had total dissolved solids ranging from 700 to 1,400 ppm, sulfates ranging from 360 to 600 ppm, and chlorides ranging from 35 to 100 ppm. The waters with the highest concentrations are found in the forebay and the lowest concentrations are found just landward of the sea-water intrusion front near the coast. The superior quality water probably constitutes the native Oxnard Plain waters before development and use and reuse of ground waters occurred extensively on the plain. Under present landward hydraulic gradient conditions, some of these waters are returning from the area of offshore storage. Many decades may have lapsed since these waters entered the aquifer at the forebay.

Due to the high concentration of the chloride ion in sea water, any resulting mixture of sea water and native water results in a prominent increase in the chloride ion content. The change in chlorides in well waters in a sea-water intrusion area is the best indication of the movement of the sea-water front. As the water in a well becomes intruded, the daily or weekly variations in chloride ion concentration indicate wide fluctuations in the degree of mixing. In some instances after the first sign of intrusion is noted, the water may revert to native quality for several months before further deterioration is apparent. During the drought, well water in the Oxnard aquifer was usually degraded beyond use for domestic, industrial, or irrigation purposes within two years after intrusion was first detected in the well. Waters with concentrations exceeding 500 ppm chloride ion are marginal for all uses.

The native ground waters in the coastal portion of the Oxnard Plain contain an average of 125 ppm of calcium and 90 ppm of sodium. With the mixing of proportionately larger percentages of sea water, sodium should become the prominent cation. The relationship between calcium and sodium in waters of the Oxnard aquifer with increasing intrusion is shown on Figure 1, which is bound at the back of the report. As more sea water is added, the calcium increases faster than the sodium. This relationship holds until the water mixture contains about 5,000 ppm chloride, when sodium begins to exceed calcium in amount. This phenomenon is attributed to the base-exchange capacity of materials within the aquifer. Sodium is absorbed and calcium is released. With the continued advance of the sea-water intrusion front into materials having exchangeable calcium, the calcium would presumably replace all the sodium. With enough flushing, the water seaward of the front should become pure sea water. While as yet neither of these two conditions has been observed in the Oxnard aquifer, it is expected that they will occur with continued intrusion. It is interesting to note that the ocean water-Oxnard aquifer water mixture apparently favors an increase in calcium initially, while the Oxnard aquifer-semiperched water mixture favors the increase in sodium.

A presently unexplained anomaly occurs in the area of Arnold Road where well 1N/22W-35G1, drilled in April 1960, has water with a bicarbonate anion character. This is unique in that nearly all native waters beneath the Oxnard Plain are of sulfate character.

Another anomaly occurs southwest of Hueneme and Arnold Roads, where ground waters underlying an apparently isolated area of approximately 200 acres slowly increased in sodium, chloride, and total dissolved solids. Well 1N/22W-26M1, located in the center of this area, increased in chlorides from 116 ppm in 1952 to 539 ppm in 1959, with the anion character changing from sulfate to chloride. As far as is known, the only available contaminants in this area are sea water and the degraded semiperched waters. Recently drilled wells seaward of this area produced waters of native quality, indicating that this apparently was a local problem, separated from the area of recognized sea-water intrusion. The wells seaward of this problem area are 1N/22W-27R1, drilled by the Department, and -35C1 and -35G1. The semiperched waters are return irrigation waters and generally have very high sulfate ion concentrations. Should these waters find their way downward into the Oxnard aquifer, the anion character should remain sulfate. An explanation for this anomaly is degradation by sea water. Yet the existence of higher than native quality concentrations of dissolved minerals in the sample taken in 1952 of waters from well 1N/22W-26M1 indicates that this problem probably started before sea-water intrusion became evident at Port Hueneme. In addition to the increase in chlorides, these waters are spreading landward in the direction of the slope of the piezometric surface. During 1962, this formerly isolated problem area was linked with the Port Hueneme area of sea-water intrusion, because a rapid increase in chlorides occurred in the waters produced from wells located in the intervening area.

The intrusion perimeter, progressively enlarging each year, invaded the Oxnard aquifer a distance of 1 mile by 1955 and in excess of 2 miles by 1963, as shown on Plate 2. The rate of advance of sea-water intrusion in the Port Hueneme area has been determined to be about 1,000 feet per year. Establishing a rate in the Point Mugu area is much more difficult, but appears to be considerably slower, probably because of poor hydraulic continuity in the offshore area.

As was pointed out earlier, definite evidence of sea-water intrusion in the Point Mugu area appeared by 1958. By 1963, the mineral quality of water in eight wells had been affected by sea-water intrusion. The analyzed mineral content in the affected wells fluctuates erratically with occasional samples returning to native quality. While the affected area can be approximately delimited, and analyses indicate an increasing proportion of sea water in many samples, it has not been possible to establish a consistent rate of landward advance of sea-water intrusion. Many wells in the Point Mugu area are perforated in several aquifers. Varying amounts of water contributed to the well due to changes in head may partially account for the erratic fluctuations in mineral quality.

Degraded water due to sea-water intrusion can move downward from the Oxnard aquifer into presently nondegraded aquifers through wells which are perforated in several aquifers, gravel packed, or have defective casings, or through natural breaks in the confining beds.

Along the intervening portion of the coast, intrusion has not become evident. However, intrusion probably is occurring in the area of offshore storage, as illustrated on Plate 13. The area along the coast where the Oxnard aquifer had been intruded with waters with a concentration of chloride of 100 ppm or more was approximately 8,600 acres in the spring of 1963.

Mugu Aquifer

The water produced from wells perforated in the Mugu aquifer is generally calcium-sodium sulfate in character. The concentrations of total dissolved solids found in these waters range from 696 to 933 ppm,

TABLE 7

ANALYSES OF GROUND WATER FROM
SELECTED WELLS IN MUGU AQUIFER

State well number	Date sampled	Temperature when sampled °F	pH	EC x 10^6 at 25° C	Constituents in parts per million / equivalents per million									Parts per million					Percent Na
					Ca	Mg	Na	K	CO_3	NCO_3	SO_4	Cl	NO_3	F	B	SiO_2	Total dissolved solids	Total hardness	
1N/21W-20P1	3-21-62	68	7.7	1241	136/6.80	43/3.50	92/4.00	3.5/0.09	0/0	305/5.00	353/7.34	57/1.60	12/0.19	0.8	0.33	31	916	515	28
-32Q1	8- 1-63	--	8.0	1000	51/2.55	44/3.58	115/5.00	3.3/0.08	0/0	281/4.60	248/5.17	80/1.25	0/0	0.2	0.39	30	696	306	45
1N/22W-20B1	6-28-62	--	7.6	1125	116/5.82	36/2.97	83/3.61	5.5/0.14	0/0	254/4.16	341/7.11	46/1.31	0/0	0.6	0.70	28	794	440	29
-20N2	11-29-61	65	7.9	1188	139/6.94	29/2.38	83/3.61	4.4/0.11	0/0	249/4.08	352/7.33	53/1.49	0.5/0.01	0.81	0.66	39	845	469	28
-26Q1	5- 4-62	68	7.8	1180	113/5.66	41/3.43	94/4.10	6.8/0.17	0/0	316/4.19	387/8.06	41/1.16	5.4/0.09	0.4	0.55	34	868	455	31

TABLE 8

ANALYSES OF GROUND WATER FROM
SELECTED WELLS IN HUENEME AQUIFER

State well number	Date sampled	Temperature when sampled °F	pH	EC x 10^6 at 25° C	Constituents parts per million / equivalents per million									Parts per million					Percent Na
					Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B	SiO_2	Total dissolved solids	Total hardness	
1N/22W-19A1	12-11-59	--	8.0	1157	129/6.44	32/2.66	79/3.44	4.3/0.11	0/0	242/3.96	362/7.55	37/1.04	0.5/0.008	0.5	0.63	30	845	455	27
	5- 3-62	67	8.1	1075	109/5.43	34/2.84	86/3.73	4.8/0.12	0/0	209/3.43	366/7.63	42/1.19	0/0	0.5	0.57	29	832	414	31

sulfates range from 248 to 404 ppm, and chlorides range from 40 to 80 ppm. Representative analyses are presented in Table 7.

No conclusive evidence of sea-water intrusion in the Mugu aquifer has been found yet. Observation well 1N/22W-20N2, drilled in the west jetty area of Port Hueneme harbor by this Department, is intended to provide early evidence of intrusion beneath the land area in this aquifer.

Hueneme Aquifer

The water produced from wells perforated in the Hueneme aquifer is calcium-sodium sulfate in character. The concentrations of total dissolved solids, sulfates, and chlorides found in these waters range from 776 to 1,043 ppm, 325 to 452 ppm, 39 to 78 ppm, respectively. Representative analyses are presented in Table 8.

There is no evidence of sea-water intrusion beneath the land area in the Hueneme aquifer.

Fox Canyon Aquifer

Wells perforated in the Fox Canyon aquifer are localized in the Port Hueneme and Point Mugu areas. The waters produced from wells perforated in the Fox Canyon aquifer are calcium-sodium sulfate in character. An exception is the cation character of the water from well 1N/22W-29A4, which is calcium, according to the classification system. This deviation is not significant in that it results from only a minor percentage change of the cation constituents. The concentrations of total dissolved solids, sulfates, and chlorides found in these waters range from 640 to 1,040 ppm, 326 to 469 ppm, 40 to 71 ppm, respectively. Representative analyses are presented in Table 9.

TABLE 9

ANALYSES OF GROUND WATER FROM
SELECTED WELLS IN FOX CANYON AQUIFER

State well number	Date sampled	Temperature when sampled °F	pH	EC x 10^6 at 25° C	Constituents in parts per million / equivalents per million									Parts per million					Per-cent Na
					Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B	SiO_2	Total dissolved solids	Total hardness	
1N/21W-32K1	12- 6-62	--	7.4	1362	137/6.84	46/3.78	110/4.79	4.6/0.12	0/0	251/4.12	469/9.77	55/1.55	4.2/0.07	0.76	0.60	33	1040	529	31
1N/22W-20E2	5-15-62	--	7.7	1223	133/6.66	33/2.68	97/4.22	--/--	--/--	251/4.12	383/7.98	43/1.21	--/--	0.4	0.41	--	899	465	31
-29A4	10-10-62	66	8.1	1110	140/6.98	32/2.57	94/4.10	8.0/0.21	0/0	253/4.15	413/8.61	45/1.24	4.0/0.07	0.2	0.47	26	938	477	30

TABLE 10

ANALYSES OF GROUND WATER FROM
SELECTED WELLS IN GRIMES CANYON AQUIFER

State well number	Date sampled	Temperature when sampled °F	pH	EC x 10^6 at 25° C	Constituents in parts per million / equivalents per million									Parts per million					Per-cent Na
					Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B	SiO_2	Total dissolved solids	Total hardness	
1N/21W-32A1	11-19-63	--	7.5	1430	54/2.68	65/5.37	198/8.60	6.3/0.16	0/0	300/4.92	319/6.65	188/5.30	0/0	0.2	0.63	38	1066	402	51
1S/21W- 8L1	6- 5-63	68	7.8	1210	49/2.45	31/2.56	175/7.60	6.5/0.17	0/0	290/4.75	152/3.17	167/4.71	0/0	0.2	0.57	32	770	250	60

There is no evidence of sea-water intrusion in the Fox Canyon aquifer.

Grimes Canyon Aquifer

The two wells perforated solely in the Grimes Canyon aquifer are located in the Point Mugu area. The character of the water produced from the Grimes Canyon aquifer is generally sodium bicarbonate-chloride. deviating from the typical calcium-sodium sulfate character of water of the Oxnard Plain. The concentrations of total dissolved solids, sulfates, and chlorides found in these waters range from 770 to 1,110 ppm, 152 to 336 ppm, 167 to 190 ppm, respectively. Representative analyses are presented in Table 10. The concentration of sulfate is less than that normally found in typical Oxnard Plain waters within the producing aquifers and the chloride concentration is four times that normally found. There is no evidence of sea-water intrusion in the Grimes Canyon aquifer.

Pleasant Valley Ground Water Basin Influences

The native ground waters in Pleasant Valley Ground Water Basin are similar in character to the Oxnard Plain waters, but the concentrations of dissolved minerals, notably chlorides and total dissolved solids, are distinguishably higher.

Water from wells located on either side of the boundary between Pleasant Valley Ground Water Basin and the Oxnard Plain Pressure Area reflect commingling of waters from the separate forebays. The mineral analyses of water from many of these wells indicate a considerable fluctuation in character and quality during the past years.

CHAPTER VI. SUMMARY OF FINDINGS AND CONCLUSIONS

In this investigation, the following findings were made and conclusions drawn.

Findings

The findings made in this study may be summarized as:

1. The usable water-bearing zones underlying the Oxnard Coastal Plain were found to be five in number. In Bulletin No. 12, "Ventura County Investigation", the Oxnard, Fox Canyon, and Grimes Canyon aquifers were identified, but intermediate aquifers were not named. As a result of the present study, aquifers are named in descending order as the Oxnard, Mugu, Hueneme, Fox Canyon, and Grimes Canyon aquifers.

2. Sea-water intrusion is advancing into the Oxnard aquifer at a rate of about 1,000 feet per year at Port Hueneme and at a slower rate at Point Mugu. At both locations the front has moved inland about 2 miles, but the advance at Point Mugu has been less consistent than that at Port Hueneme. By 1963, almost 8,600 acres of land was underlain by saline water with chloride ion concentrations of 100 parts per million or more, and 44 wells had been rendered useless because of saline degradation.

3. Some evidence of saline degradation was found in the Mugu aquifer, but the route of entry has not been determined.

4. No evidence of sea-water intrusion has been found in the three underlying aquifers: the Hueneme, Fox Canyon, and Grimes Canyon.

Conclusions

From the findings of this study, the following conclusions may be drawn:

1. If the present rate of sea-water intrusion into the Oxnard aquifer continues in the Port Hueneme area, the intrusion front will in five years have advanced well into the area now occupied by the pumping trough. Continuing its advance at the present rate the front will in about the year 1990 have reached the El Rio Spreading Grounds in the Oxnard Forebay, which are about 7 miles inland. However, the rate of intrusion may be accelerated because of the exhaustion of stored water in the aquifer. The portion of the aquifer underlying the Oxnard Plain presently receives recharge from its offshore portions as well as from the forebay. But as the fresh water in the offshore portions is exhausted, the total annual recharge of usable water will diminish substantially. If the pumping is not also reduced proportionately, the movement of the intrusion front will accelerate so that it will reach the forebay well before 1990.

2. Because of the near shore outcroppings of the Mugu aquifer and the landward hydraulic gradient of the water level pressure surface, saline intrusion is probably occurring in that aquifer.

3. If piezometric levels remain below sea level in the deeper aquifers, and if hydraulic continuity exists between the ocean and the offshore extension of the aquifers, the Hueneme, Fox Canyon, and Grimes Canyon water-bearing zones will eventually experience the encroachment of ocean waters.

4. It will be necessary to continually monitor all aquifers for sea-water intrusion.

5. Degraded water due to sea-water intrusion can move downward from the Oxnard aquifer into presently nondegraded aquifers through wells

which are perforated in several aquifers, gravel packed, or have defective casings, or through natural breaks in the confining beds.

APPENDIX A

SELECTED REFERENCES

APPENDIX A

SELECTED REFERENCES

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APPENDIX B

WELL LOGS

APPENDIX B

WELL LOG B-1

Drilling Site No. 1a — State Well No. 1N/22W-27R2

Location: 5,200 feet south of Hueneme Road;
4,000 feet west of Arnold Road

Drilling Method: Rotary — Depth: 1,008 feet

Diameter: 6-1/4 inches

Date Electric Logged: 4-20-64 — Ground Surface Elevation: 5 feet

Depth in feet	Material
0- 10	Clay: Brown, medium sandy, silty clay with a few shell fragments.
10- 38	Sand: Medium to very coarse sand and granules, with fine gravel lenses, wood and shell fragments.
38- 51	Sand: Medium to very coarse sand and fine gravel, with shell fragments and thin interbeds of gray clay.
51- 58	Silt and Clay: Medium to coarse sandy silt and gray clay with wood and thin shell fragments.
58- 78	Silt: Organic, clayey silt with wood and abundant shell fragments.
78-100	Clay: Dark gray, medium to coarse sandy, silty clay with shell fragments.
100-106	Sand: Medium to very coarse sand.
106-126	Clay: Medium to very coarse sandy, gray clay with embedded granules and a few shell fragments.
126-133	Sand and Clay: Medium to coarse sand and gray clay.
133-143	Sand: Fine to coarse sand with wood fragments.
143-158	Sand and Gravel: Medium to very coarse sand 1/4 inch gravel, with wood fragments and thin interbeds of black organic silt and clay.
158-164	Sand: Fine to very coarse sand and granules.
164-199	Sand and Gravel: Medium to very coarse sand, granules and 1/4 inch to 1 inch angular gravel and wood fragments.
199-208	Clay and Gravel: Largely clay with medium to coarse sand and 1/2 inch rounded to subangular gravel.
208-212	Sand and Gravel: Sand and gravel with some clay and abundant wood fragments.

WELL LOG B-1
(continued)

Depth in feet	Material
212-224	Clay: Clay with sand and 1/2 inch subangular to subrounded gravel.
224-253	Sand and Gravel: Fine to very coarse sand, granules and subangular to subrounded gravel. Shell horizon at 243.
253-300	Clay and Sand: Gray clay and sand with some gravel and shell fragments.
300-308	Clay: Gray sandy clay with granules and shell fragments.
308-321	Sand: Gray, fine to very coarse sand, shell fragments and some clay.
321-326	Silt: Sandy silt.
326-355	Sand: Fine to very coarse sand, interbedded clay and 10 percent 1/4 inch gravel.
355-364	Sand: Fine to medium silty sand.
364-381	Sand: Fine to coarse sand with some clay and gravel.
381-411	Clay: Gray, fine to coarse sandy clay.
411-424	Sand: Gray, fine to coarse sand with clay and shell fragments.
424-431	Sand: Gray, fine to coarse sand with some clay.
431-443	Sand: Green, very coarse sand to granule with some interbedded clay and shell fragments.
443-452	Sand and Gravel: Medium to very coarse sand, granules and 1/4 inch gravel with shell fragments.
452-468	Clay: Dark gray very coarse sandy clay with embedded gravel and shell fragments.
468-492	Clay: Gray, fine to very coarse sandy clay with embedded gravel and shell fragments.
492-500	Sand: Medium to very coarse sand with shell fragments.
500-538	Sand: Medium to very coarse sand and 50 percent granules with fragments.
538-542	Clay: Gray, fine to very coarse sandy clay with shell fragments.
542-558	Sand: Fine to very coarse sand and granules with shell fragments and a few thin clay stringers.
558-659	Sand and Clay: Fine to very coarse sand to granules and interbeds of gray, medium sandy clay with shell fragments.
659-682	Clay: Sandy clay.
682-727	Sand and Clay: Fine to very coarse sand with scattered pebbles and gray to brown clay with black vegetable fiber.

WELL LOG B-1
(continued)

Depth in feet	Material
727-729	Clay: Gray, sandy gravelly clay.
729-738	Sand: Gray, fine to very coarse sand with gray clay.
738-748	Sand and Silt: Very fine sand and silt with 5 percent granules.
748-838	Clay: Soft, fine to very coarse sandy clay with abundant shell fragments.
838-855	Clay: As above except reduced sand content.
855-874	Sand: Fine to coarse sand with clay and abundant shell fragments. Predominantly fine sand.
874-880	Sand: Fine to very coarse sand with clay and some shell fragments.
880-886	Clay: Gray, medium to coarse sandy clay.
886-887	Gravel: Predominantly 1/8 inch gravel with 2 inch to 3 inch pebbles.
887-888	Sand: Fine to coarse sand with clay.
888-908	Clay: Fine to coarse sandy clay with scattered pebbles
908-940	Clay: Gray, fine to very coarse sandy clay with shell fragments.
940-998	Sand: Fine to coarse sand with thin gray clay stringers, 10-20 percent granules and shell fragments.
998-1008	Clay: Gray, medium sandy clay with 30 percent small gastropods.

WELL LOG B-2

Drilling Site No. 2 | State Well No. 1N/22W-35B1

Location: 6,000 feet south of Hueneme Road:
70 feet east of Arnold Road

Drilling Method: Rotary | Depth: 1,000 feet

Diameter: 6-1/4 inches

Date Electric Logged: 6-4-60 | Ground Surface Elevation: 9 feet

Depth in feet	Material
0- 8	Soil: Clay, silt and sand.
8- 19	Sand: Gray-green, medium to coarse sand.
19- 21	Clay: Soft, olive-gray clay.
21- 50	Sand: Green, coarse sand with gravel, shells and streaks of soft clay.
50- 60	Sand: Fine to coarse sand with gravel. Abundant shells.
60- 80	Sand and Clay: Fine sand and clay with gravel.
80- 90	Clay: Blue clay, abundant shells and some sand and gravel.
90-183	Clay: Blue clay with shells.
183-210	Gravel: Gravel with fine to coarse sand and some clay.
210-220	Sand: Sand with granules and 1/4-1/2 inch gravel.
220-247	Sand: Medium to very coarse sand and granules with thin clay stringers and shell fragments.
247-262	Sand and Clay: Fine to medium sand and granules. Some gray, fine sandy clay and shell fragments.
262-278	Silt and Clay: Gray-green, fine sandy silt and silty clay with shell fragments.
278-302	Clay: Gray, fine to medium sandy, silty clay with shells.
302-308	Sand: Medium to very coarse sand and granules.
308-316	Clay: Gray, coarse sandy clay.
316-331	Sand and Clay: Medium to very coarse sand and gray, sandy clay.
331-353	Sand: Medium to very coarse sand granules and some gravel with clay interbeds.
353-363	Clay: Gray, very firm, medium sandy, silty clay with shells.
363-368	Clay: Gray, very coarse sandy clay.
368-376	Sand: Medium to very coarse sand and granules with some gravel.

WELL LOG B-2
(continued)

Depth in feet	Material
376-390	Clay: Gray, hard, very coarse, sandy clay.
390-392	Clay: Brown, sandy clay with some sand.
392-403	Silt: Blue-green silt and very fine sand.
403-431	Sand: Medium to very coarse sand with granules. Some gravel, silt, clay and wood fragments.
431-453	Sand and Gravel: Medium to very coarse sand with granules and 1/4 inch gravel. Some wood fragments.
453-470	Clay: Gray, soft, very coarse sandy silty clay with granules.
470-493	Clay: Soft, fine to medium sandy, silty, clay with shell fragments.
493-512	Clay: Dark gray, medium sandy, silty clay with organic silty stringers and shells.
512-550	Clay: Light gray, medium sandy, silty clay with granules and shell fragments.
550-578	Silt and Clay: Gray, medium to coarse sandy, silty clay and black, clayey silt.
578-660	Silt and Clay: Medium sandy, silty clay and shell fragments.
660-722	Clay: Blue-gray, medium to coarse sandy, silty clay with some granules.
722-762	Clay: Gray, medium to coarse sandy, silty, clay.
762-767	Clay: Soft, brown, medium, sandy clay.
767-773	Clay: Dark gray and brown, medium coarse sandy, silty clay.
773-792	Clay: Dark gray and reddish-brown, medium to coarse sandy, silty clay.
792-808	Clay: Hard, gray, medium to very coarse sandy, clay.
808-816	Clay and Sand: Hard, gray, medium sandy clay and medium to very coarse sand.
816-834	Sand: Medium to very coarse sand, granules and some clay.
834-846	Sand: Fine to very coarse sand, with granules, shells, and some clay.
846-861	Clay and Sand: Gray, fine to coarse sandy clay with shells.
861-893	Sand and Silt: Silt and fine to coarse sand and granules with clay and shells.
893-900	Sand: Medium to very coarse sand, granules and 1/4 inch gravel.
900-926	Sand: Gray, medium to coarse sand with granules and a few clay stringers.
926-936	Sand and Clay: Medium to coarse sand and brown and gray fine sandy clay.
936-947	Dark gray, medium sandy clay with shells.
947-979	Sand and Clay: Medium to coarse sand and medium to coarse sandy clay interbeds with shells.
979-1000	Clay: Dark gray, fine to coarse sandy, silty clay with shells.

WELL LOG B-3

Drilling Site No. 3 — State Well No. 1N/22W-20N2

Location: 50 feet northeast of Ocean Drive
75 feet southeast of Sawtelle Avenue

Drilling Method: Rotary — Depth: 465 feet

Diameter: 6-1/4 inches

Date Electric Logged: 3-29-60 — Ground Surface Elevation: 5 feet

Depth in feet	Material
0- 8	Sand: Fine beach sand
8- 28	Clay and Sand: Interbedded brown clay with wood fragments, broken shells and fine to coarse sand.
28- 32	Gravel: Coarse sand and gravel with some clay, wood, and shell fragments.
32- 38	Sand: Fine sand, with some coarse sand, clay and wood fragments.
38- 52	Clay: Brown clay with sand, gravel and wood fragments.
52- 72	Gravel: Well rounded to subangular 1/4 inch to 1 inch gravel with brown clay and shells. Gravel consists of shale, chert, chalcedony, volcanics and greenstone.
72- 85	Clay: Blue-gray to black clay with some gravel and wood. Gravel lense at 78 feet.
85-100	Sand: Medium to coarse, angular sand with clay lenses.
100-120	Sand and Clay: Medium to very coarse sand and granules and dark gray, organic, silty clay.
120-125	Sand and Clay: As above, with 10-15 percent wood and peat seams.
125-130	Sand and Gravel: Medium to very coarse sand, granules and 1/4 inch to 1/2 inch gravel.
130-143	Sand and Gravel: As above, with brown and gray, hard, silty clay seams.
143-156	Clay: Dark gray, medium to very coarse sandy, silty clay with a few shell fragments.
156-160	Sand and Gravel: Medium to very coarse sand and 1/4 inch to 1/2 inch gravel. Clay 10 percent.
160-170	Sand and Gravel: As above except no clay.
170-175	Sand and Gravel: Medium to very coarse sand, granules and 1/4 inch gravel.

WELL LOG B-3
(continued)

175-185	Sand and Gravel: Coarse to very coarse sand, granules and 50 percent 1/4 inch to 1/2 inch gravel. Hard drilling.
185-210	Clay: Brown and gray medium to coarse sandy clay with embedded gravel.
210-225	Sand and Gravel: Coarse to very coarse sand, granules and 1/4 inch to 1/2 inch gravel.
225-245	Clay: Predominantly blue gray clay with some sand and 1/4 inch gravel.
245-255	Clay and Gravel: Gray to black clay and 1/2 inch gravel below 253 feet. Occasional thin beds of peat.
255-265	Gravel and Sand: Subangular 1/2 inch gravel and medium to coarse sand with occasional gray clay lenses. One inch gravel at 257 feet.
265-275	Sand and Gravel: Compacted 1/2 inch gravel amd medium to coarse sand. Clay lenses at 271 feet.
275-300	Sand and Gravel: Medium to coarse sand and lenses of compacted gravel. Prominent gravel bed at 281 feet.
300-305	Sand and Gravel: Coarse sand and 1/2 inch gravel.
305-325	Clay and Gravel: Gray, brown and black clay and 1/4 inch gravel with fine to medium sand, wood and small shells.
325-341	Clay: Blue-gray, sandy clay with granules, 10 percent gravel, prolific shells, wood.
341-345	Clay and Gravel: Sandy clay and granule to fine gravel.
345-355	Sand: Medium, clayey sand with gravel. Abundant shells and wood. Rock types are dark, blue-green shale and chalcedony.
355-375	Gravel: Blue-gray, subrounded, 1/4 inch to 1/2 inch, silty gravel with wood, shells and fine to medium sand.
375-385	Sand: Fine to medium sand with 1/4 inch to 1/2 inch gravel, wood and shells.
385-395	Sand: Fine to medium sand with clay and gravel.
395-405	Clay and Sand: Fine to medium sand and gray clay with wood and shell fragments.
405-415	Clay: Dark gray, medium to very coarse, sandy clay with wood and shell fragments.
415-424	Clay: Dark gray, medium to very coarse, sandy clay with embedded granules, wood and shell fragments.
424-432	Sand: Medium to very coarse sand and granules.
432-445	Clay: Dark gray clay with 20 to 30 percent medium to very coarse sand and granules. Shell fragments.

WELL LOG B-3
(continued)

445-463	Clay:	As above with 10 percent medium to very coarse sand and granules.
463-465	Clay:	Dark gray, soft, silty clay with 10 percent medium to coarse sand and a few shell fragments.

WELL LOG B-4

Drilling Site No. 4 State Well No. 1N/22W-17M3

Location: 2,350 feet west of Patterson Road;
150 feet north of 23rd Road

Drilling Method: Rotary Depth: 330 feet

Diameter: 6-1/4 inches

Date Electric Logged: 4-5-60 Ground Surface Elevation: 9 feet

Depth in feet	Material
0- 2	Silt: Reddish brown, sandy silt.
2- 10	Sand: Light brown, fine to coarse sand with some carbonaceous matter.
10- 24	Sand: Light gray, fine to coarse sand.
24- 32	Clay: Dark gray clay with some sand and gravel.
32- 44	Sand: Light gray, fine to coarse sand with some granule.
44- 58	Clay: Dark gray, sticky clay with some coarse sand and granule.
58- 78	Clay: Dark gray silty clay with some very thin lenses of fine to coarse sand.
78- 96	Gravel: Gravel with some fine to coarse sand and a few thin lenses of dark gray clay. Boulder from 81 feet to 82 feet.
96-100	Sand and Clay: Medium to very coarse sand and gray clay with wood fragments.
100-106	Sand and Gravel: Medium to very coarse sand and 1/4 inch to 1/2 inch gravel.
106-110	Sand: Medium to very coarse, silty sand and granule.
110-125	Clay: Gray, medium to coarse sandy clay with a few wood fragments.
125-145	Clay: As above with less than 10 percent sand.
145-172	Clay: Dark gray medium to coarse sandy clay with a few wood fragments.
172-194	Clay: Yellow and tan, medium to coarse sandy clay.
194-200	Sand: Medium to coarse sand with some clay.
200-206	Sand and Gravel: Light brown, coarse sand and gravel to 1/2 inch.
206-217	Sand and Gravel: Light brown, coarse sand and gravel to 3/4 inches in diameter. Some dark red clay.
217-230	Sand and Gravel: Light brown, fine to coarse sand and gravel to 3/4 inch.

WELL LOG B-4
(continued)

Depth in feet	Material
230-234	Sand and Gravel: Light brown, fine to coarse sand and gravel to 1/2 inch.
234-236	Clay: Dark gray, fine to medium sandy clay.
236-238	Clay: Dark gray clay with lenses of sand and 1/4 inch gravel.
238-240	Sand: Light brown, medium to coarse sand.
240-242	Clay: Dark gray clay with fine to medium sand.
242-282	Clay: Dark gray, sticky clay with thin stringers of medium to coarse sand and some granule.
282-284	Sand: Medium to coarse sand with some granule.
284-298	Clay: Dark gray, sticky clay with some medium to coarse sand.
298-322	Sand and Gravel: Coarse sand and gravel to 1/2 inch.
322-330	Sand: Fine to medium sand with granule and dark gray clay with shells.

WELL LOG B-5

Drilling Site No. 5 State Well No. 1N/22W-27B4

Location: 1,300 feet south of Hueneme Road;
4,450 feet east of Perkins Road

Drilling Method: Rotary Depth: 800 feet

Diameter: 6-1/4 inches

Date Electric Logged: 6-10-60 Ground Surface Elevation: 13 feet

Depth in feet	Material
0- 5	Sand: Medium to coarse, clayey sand.
5- 27	Clay: Brown, medium to coarse sandy, silty clay.
27- 39	Clay: Soft, gray, very fine sandy, silty, clay.
39- 47	Clay: Green, medium to very coarse sandy clay.
47- 66	Sand and Clay: Interbedded gray, medium to coarse sand and brown, medium sandy clay with a few shell fragments.
66- 79	Clay: Brown and gray, medium to very coarse sandy clay with a few shell fragments.
79-123	Clay: Dark gray fine, sandy, organic, silty clay.
123-131	Sand: Medium to coarse sand with gray clay stringers.
131-225	Sand and Gravel: Medium to very coarse sand granule and 1/4 inch gravel to cobbles, hard drilling. Few clay stringers.
225-230	Clay: Blue-gray, medium to very coarse sandy clay.
230-243	Sand and Gravel: Medium to very coarse sand, granule and 1/4 inch to 1/2 inch gravel with some clay.
243-249	Clay: Gray, very fine to very coarse sandy clay with some granule and abundant shells.
249-261	Sand and Clay: Gray, fine sandy clay and interbedded gray medium to very coarse sand. Few medium to very coarse shell fragments.
261-272	Sand: Fine to very coarse sand and granule with some 1/4 inch gravel. Clay stringers at 268 feet.
272-279	Sand: Medium to very coarse sand with 10 percent gravel. Shell fragments.
279-289	Sand: Medium to very coarse sand with 20 percent clay. Shell fragments.
289-302	Clay: Gray, medium to very coarse sandy clay with wood and shell fragments.

WELL LOG B-5
(continued)

Depth in feet	Material
302-326	Clay: Dark gray, medium sandy, organic clay with abundant shells.
326-402	Silt and Clay: Dark gray, medium to coarse sandy, organic silt and clay. Shell fragments.
402-408	Sand: Fine to very coarse sand and granule with shell fragments and 10 percent clay.
408-434	Clay and Sand: Gray, silty clay and interbedded fine to very coarse sand with shell fragments.
434-473	Sand: Fine to very coarse sand and 10 percent granule with wood and shell fragments.
473-507	Clay: Gray, very coarse sandy organic clay with shell fragments and interbeds of coarse sand.
507-634	Sand: Gray, fine to coarse sand with thin interbeds of gray, fine, sandy clay.
634-693	Clay: Gray, medium to very coarse sandy clay with wood and shell fragments.
693-700	Sand: Fine to very coarse sand with some clay and abundant shells.
700-783	Sand: Gray, medium to very coarse sand and a few shells.
783-790	Sand: Fine to very coarse sand with some gray clay and silt.
790-800	Sand: Fine to very coarse sand and granule with wood and shell fragments.

WELL LOG B-6

Drilling Site No. 6 State Well No. 1N/21W-32A2

Location: 100 feet northeast of Highway 1 Freeway;
500 feet southeast of Wood Road Overcrossing

Drilling Method: Rotary Depth: 487 feet

Diameter: 6-1/4 inches

Date Electric Logged: 4-7-62 Ground Surface Elevation: 12 feet

Depth in feet	Material
0- 19	Silt and Sand: Brown silt and very fine sand.
19- 38	Clay: Blue clay.
38- 47	Clay: Silty clay and abundant shell fragments.
47- 54	Peat and Silt:
54- 73	Clay: Silty clay, shell fragments and some sand.
73-133	Sand: Fine to medium sand.
133-148	Fines: Fine sand, silt and clay.
148-163	Sand and Silt: Fine to medium sand and silt with abundant shell fragments.
163-168	Sand and Silt: Fine sand and silt with some clay.
168-174	Sand: Fine sand.
174-210	Sand and Clay: Silty fine sand and clay.
210-238	Sand and Silt: Fine sand and silt with some clay.
238-260	Sand: Fine sand.
260-293	Sand and Silt: Very hard fine sand and silt.
293-306	Clay: Brown silty clay.
306-330	Clay: Blue silty clay.
330-361	Clay: Fine, blue, silty to sandy clay.
361-395	Sand and Silt: Fine to medium sand and silt with some clay.
395-405	Sand and Silt: Fine to medium sand and silt.
405-440	Fines: Fine sand, silt and clay.
440-460	Sand: Fine sand
460-479	Fines: Fine sand, silt and clay.
479-487	Volcanic Sand: Fine to coarse basaltic sand.

WELL LOG B-7

Drilling Site No. 7 State Well No. 1N/21W-32L1

Location: 50 feet north of East-West Casper Road;
0.2 miles northwest of "E" Street

Drilling Method: Rotary Depth: 300 feet

Diameter: 6-1/4 inches

Date Electric Logged: 1-29-62 Ground Surface Elevation: 8 feet

Depth in feet	Material
0- 11	Fines: Brown, fine sand, silt and clay.
11- 19	Sand and Silt: Fine sand and silt.
19- 23	Clay: Blue clay with shells.
23- 29	Clay: Silty blue and brown clay.
29- 42	Sand: Fine to medium sand with a few shells.
42- 48	Sand: Medium to coarse sand.
48- 66	Sand: Fine sand. Abundant Scutella, thin shelled pelycepod and wood fragments.
66- 84	Silt: Fine sandy silt with clay stringers.
84- 89	Sand: Brown to gray clayey sand with shell fragments.
89- 96	Clay: Gray and brown, silty clay with abundant wood fragments.
96-109	Silt: Blue, fine sandy silt and some clay.
109-118	Sand: Fine to medium sand.
118-121	Sand and Silt: Fine sand and silt, compact.
121-131	Silt: Gray and brown, clayey silt.
131-150	Sand: Fine to coarse sand.
150-163	Sand and Clay: Coarse sand, brown clay and shell fragments.
163-168	Sand: Fine to medium sand.
168-188	Sand and Gravel: Coarse sand and gravel.
188-207	Sand and Silt: Brown, fine sand and silt with a little clay.
207-244	Sand: Fine to medium sand with some silt.
244-276	Clay: Gray, silty clay with fine sand.
276-281	Silt: Blue silt.
281-286	Silt: Clayey silt.
286-300	Sand: Fine to medium sand.

WELL LOG B-8

Drilling Site No. 8 State Well No. 1N/21W-32Q1

Location: 190 feet northwest of 10th Street;
600 feet southwest of 9th Street

Drilling Method: Rotary Depth: 526 feet

Diameter: 6-1/4 inches

Date Electric Logged: 2-20-62 Ground Surface Elevation: 7 feet

Depth in feet	Material
0- 5	Fill: Silt and clay.
5- 13	Clay: Gray-blue plastic clay
13- 16	Peat:
16- 22	Clay: Blue-gray clay.
22- 32	Clay: Gray, silty clay with many shell fragments.
32- 36	Clay: Dark gray, firm clay.
36- 89	Sand: Fine to medium sand and abundant shells. Few silt and clay stringers and wood fragments.
89- 92	Clay: Light brown, sandy clay.
92- 95	Sand: Fine to medium sand.
95-102	Clay: Gray, silty clay.
102-106	Sand and Silt: Blue, medium sand and silt.
106-121	Sand and Silt: Fine to coarse sand and silt.
121-126	Sand: Silty fine sand.
126-153	Sand and Silt: Brown, clayey silt and sand.
153-157	Sand: Fine to coarse sand with some gravel.
157-169	Sand: Clayey, fine to medium sand.
169-175	Sand: Silty fine sand.
175-183	Sand: Fine to medium sand.
183-228	Sand and Gravel: Fine to coarse sand and gravel.
228-243	Sand: Fine silty sand.
243-258	Silt and Sand: Dark gray, clayey silt and fine sand.
258-262	Sand: Silty fine sand.
262-279	Sand: Gray, clayey and silty fine sand.
279-319	Sand: Fine silty sand with little clay.
319-334	Sand: Fine to medium sand with little silt.
334-378	Sand: Medium to coarse sand.
378-406	Sand: Clayey and silty fine sand.
406-422	Sand: Medium to coarse sand.
422-434	Sand: Fine sand.
434-446	Sand: Fine to medium sand with silt and clay.
446-477	Sand: Fine to medium sand with a little silt.
477-481	Sand: Medium to coarse sand.
481-521	Fines: Fine sand, silt and clay.
521-526	Volcanic Sand: Medium to coarse, basaltic sand.

WELL LOG B-9

Drilling Site No. 9 State Well No. 1S/21W-8L1

Location: 132 feet south of 20th Street;
1,000 feet west of Laguna Road produced

Drilling Method: Rotary Depth: 586 feet

Diameter: 6-1/4 inches

Date Electric Logged: 3-21-62 Ground Surface Elevation: 4 feet

Depth in feet	Material
0- 18	Sand: Fine to coarse sand with shell fragments.
18- 33	Sand and Gravel: Sand and gravel with a few thick shells.
33- 68	Sand: Fine to medium sand, abundant shells and wood fragments.
68- 87	Sand and Silt: Very fine sand and silt with shell fragments.
87-103	Sand and Gravel: Sand, gravel and abundant shells.
103-143	Sand: Fine to coarse sand with some silt and clay stringers.
143-168	Fines: Fine sand, silt and blue clay.
168-233	Sand: Fine to coarse sand with scattered gravel.
233-249	Sand and Silt: Fine sand and silt, with some coarse sand.
249-359	Sand and Silt: Very fine to medium sand and silt. Shells abundant to 280 feet.
359-408	Sand and Gravel: Medium to coarse sand and gravel.
408-460	Fines: Fine sand, silt and clay.
460-520	Sand and Silt: Very fine sand, silt and abundant shells.
520-584	Sand and Gravel: Fine to coarse sand and gravel.
584-586	Basalt: Dark blue and black basalt.

WELL LOG B-10

Drilling Site No. 11 State Well No. 1N/22W-29A4

Location: 20 feet east of San Pedro Street;
50 feet north of Main Street

Drilling Method: Rotary Depth: 1,002 feet

Diameter: 6-1/4 inches

Date Electric Logged Ground Surface Elevation: 8 feet

Depth in feet	Material
0- 7	Sand and Silt: Fine sand and silt.
7- 23	Sand: Medium to coarse sand with some gravel.
23- 31	Sand: Fine to medium sand with clay.
31- 40	Sand: Fine to medium sand with gravel.
40- 43	Clay: Firm sandy clay.
43- 51	Sand: Fine sand with clay and silt.
51- 74	Sand: Fine to medium sand with clay stringers.
74- 82	Clay: Blue, silty clay.
82-105	Sand: Fine to medium sand.
105-121	Clay: Sandy, silty clay with some gravel.
121-124	Sand and Gravel: Fine to coarse sand and gravel.
124-140	Clay: Sandy, silty clay.
140-153	Sand: Fine to medium sand.
153-222	Sand and Gravel: Sand and gravel.
222-232	Sand: Clayey, fine to medium sand.
232-244	Sand and Gravel: Sand and gravel.
244-252	Clay: Sandy clay.
252-271	Sand: Fine to medium sand.
271-276	Clay: Sandy clay.
276-483	Sand and Gravel: Fine to coarse sand and gravel.
483-510	Silt and Clay: Silt and clay with fine to coarse sand.
510-755	Clay: Gray-blue clay with silt stringers.
755-771	Sand and Clay: Fine to coarse sand and clay.
771-803	Sand and Gravel: Fine to coarse sand and gravel
803-808	Clay: Sandy clay.
808-813	Gravel:
813-858	Sand: Sand, gravel and clay.
858-870	Sand and Gravel: Fine to coarse sand and gravel.
870-910	Clay: Gray, sandy clay.
910-921	Sand: Fine to coarse sand with some gravel.
921-980	Clay: Sandy clay.
980-1002	Clay: Gray clay.

APPENDIX C

ELECTRIC LOGS

LANE-WELLS COMPANY | **ELGEN** *Electrolog*

COMPANY: CALIFORNIA STATE DEPT. OF WATER RESOURCES

WELL: DRILLING SITE 1A

FIELD: OXNARD PLAIN

LOCATION: 5200 FT. S. OF HUENEME RD. 4000 FEET W. OF ARNOLD RD.

COUNTY: VENTURA

STATE: CALIFORNIA

OTHER SURVEYS

WELL LOCATION

Elevation KB:
DF:
GL: 5'

FILE NO

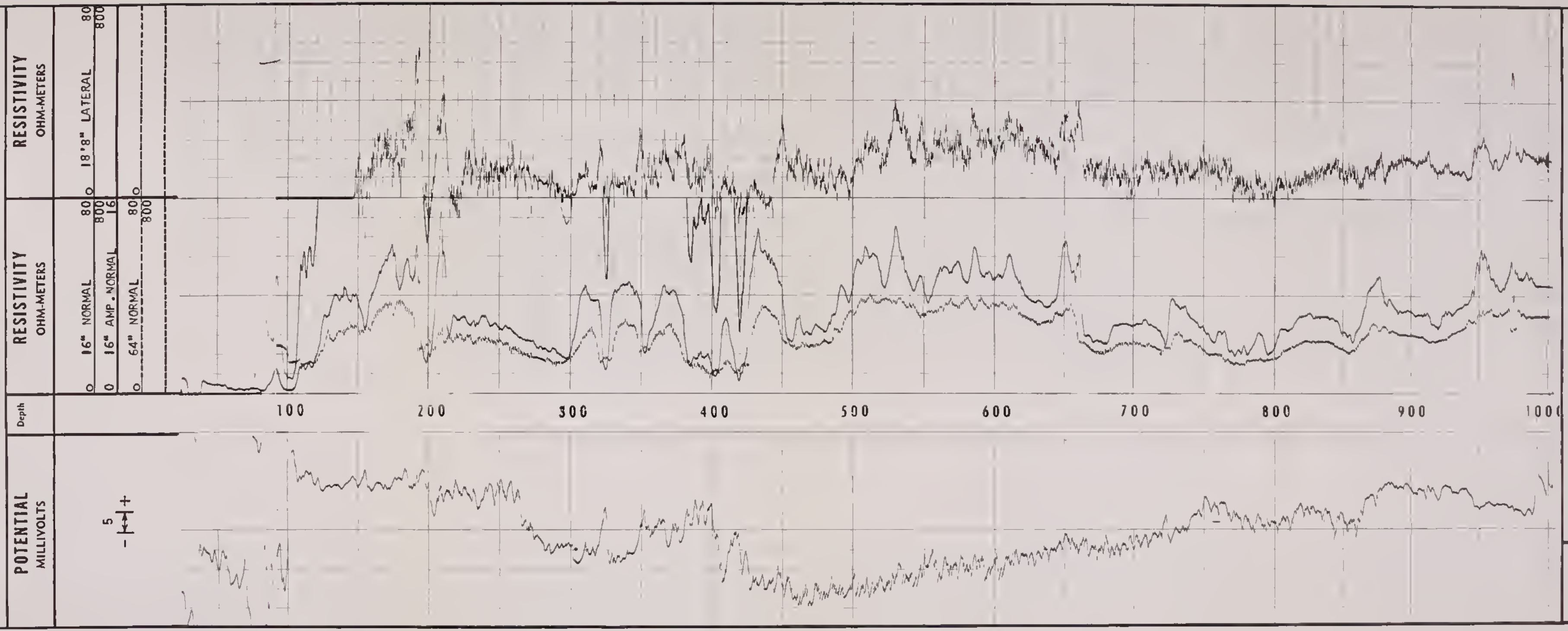
MEASUREMENTS TAKEN FROM GROUND LEVEL

Run No.	1	2	3	4	5
First reading	992				
Last reading	100				
Feet measured	892				
Casing, Lane-Wells	N.R.				
Casing, Driller	N.R.				
Bottom, Lane-Wells	993				
Bottom, Driller	1006				
Max temp. °F	80				
Mud characteristics	@ 66 °F	@ °F	@ °F	@ °F	@ °F
Resistivity	7.2				
Resist. BHT	6.0				
Nature	CLAY				
Density	N.R.				
Viscosity	N.R.				
Water Loss-cc 30 min.	N.R.				
Mud Ph.	N.R.				
Bit size	6-1/4				
Spacings:					
Short normal	16"				
Long normal	64"				
Lateral	18'8"				
Rig time	1 HR				
Recorded by	BROOKS				
Witnessed by	WIEBE				
Date	4-20-60				

REMARKS OR OTHER DATA

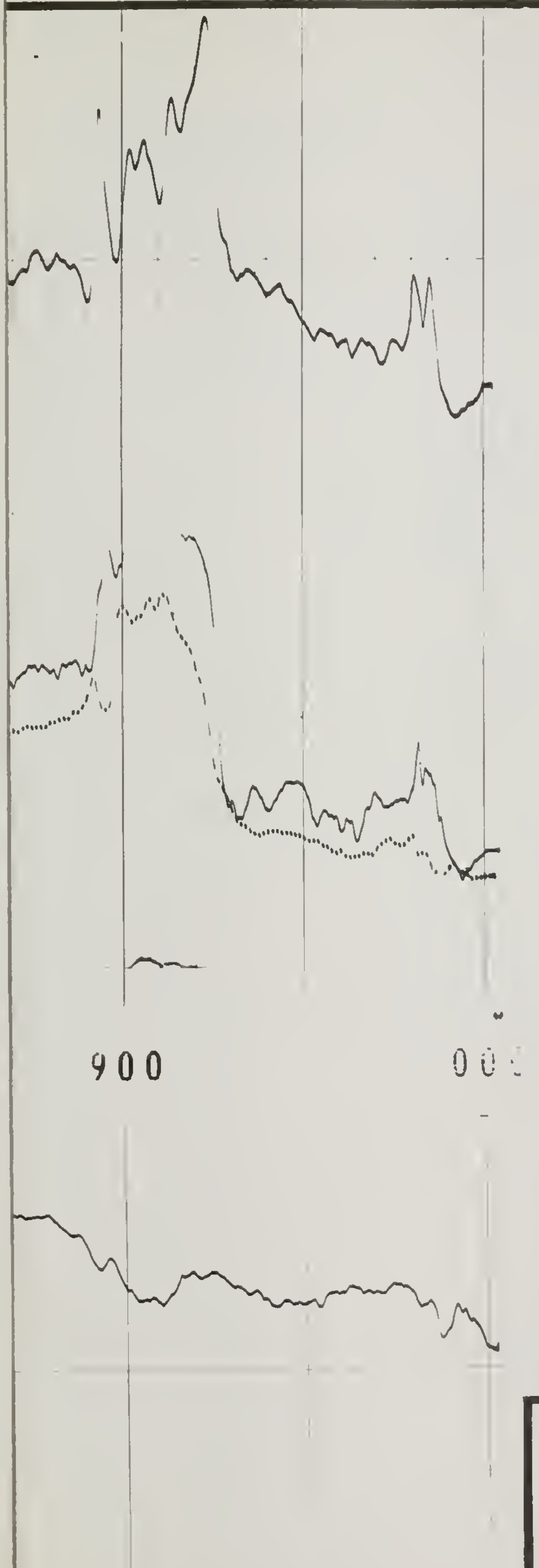
FILE NO.

CS-30-5508



ELECTRIC LOG
DRILLING SITE 1A
(1N/22W – 27R2)

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965



ELECTRIC LOG
DRILLING SITE 2
(IN/22W – 35 BI)

LANE-WELLS COMPANY ELGEN Electrolog

COMPANY CALIFORNIA STATE DEPT OF WATER RESOURCES

WELL ORILLING SITE 2

FIELD OXNARD PLAIN

LOCATION 6000 FT. S. OF HUENEME ROAD; 70 FT. E OF ARNOLD RD.

COUNTY VENTURA

STATE CALIFORNIA

COUNTY / FIELD / WELL / COMPANY

OTHER SURVEYS

WELL LOCATION

Elevation KB

DF

GL 9'

FILE NO

MEASUREMENTS TAKEN FROM GROUND LEVEL

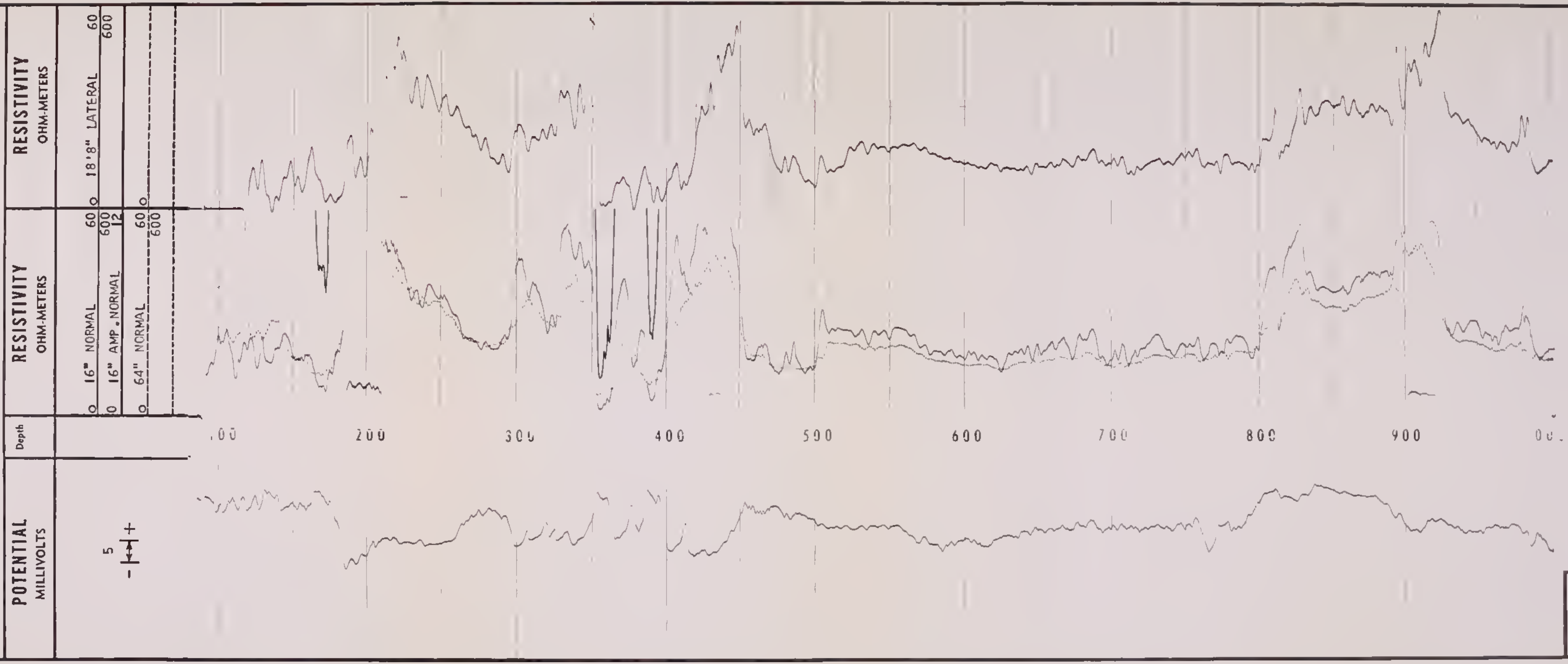
Run No.	1	2	3	4	5
First reading	1000				
Last reading	100				
Feet measured	900				
Casing, Lane-Wells	48				
Casing, Driller	48				
Bottom, Lane-Wells	1001				
Bottom, Driller	1001				
Max. temp. °F	80				
Mud characteristics	@ 70 °F	@ °F	@ °F	@ °F	@ °F
Resistivity	7.0				
Resist. BHT	6.4				
Nature	CLAY				
Density	N.R.				
Viscosity	N.R.				
Water Loss-cc 30 min.	N.R.				
Mud Ph.	N.R.				
Bit size	6-1/4				
Spacings:					
Short normal	16"				
Long normal	64"				
Lateral	18'8"				
Rig time	30 MIN				
Recorded by	BROCKS				
Witnessed by	WIEBE				
Date	6-4-60				

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965

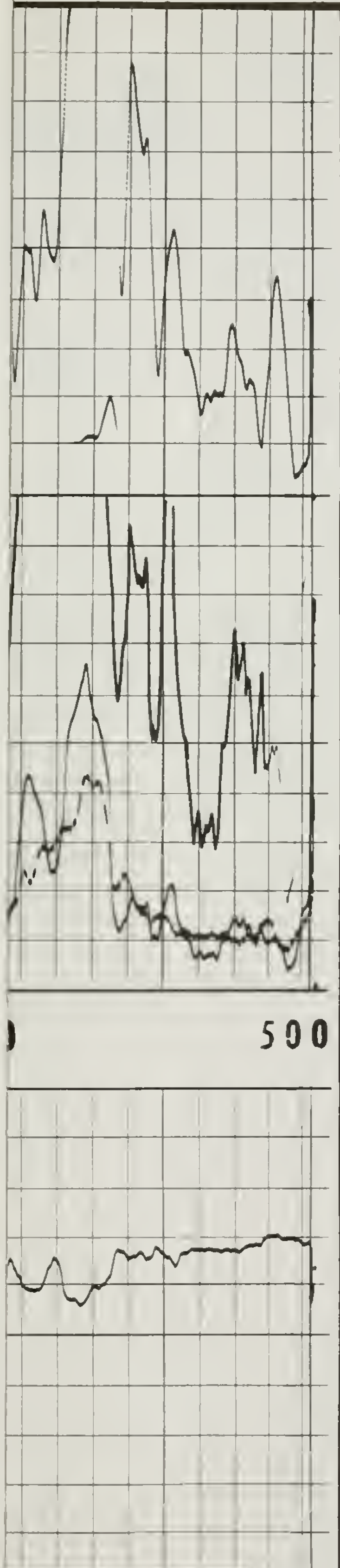
FILE NO.

REMARKS OR OTHER DATA

CS-30-5508



ELECTRIC LOG
DRILLING SITE 2
(1N/22W-35 B1)



ELECTRIC LOG
DRILLING SITE 3
(IN/22W– 20N2)

LANE-WELLS COMPANY — ELGEN Electrolog

COMPANY	CALIFORNIA STATE DEPT. OF WATER RESOURCES
WELL	DRILLING SITE 3
FIELD	OXNARD PLAIN
LOCATION	50 FT. N.E. OF OCEAN DRIVE; 75 FT. S.E. OF SAWTELLE AVE.
COUNTY	VENTURA
STATE	CALIFORNIA

COUNTY / FIELD / WELL / COMPANY

OTHER SURVEYS

WELL LOCATION

Elevation KB. ____ DF. ____ GL. 5'

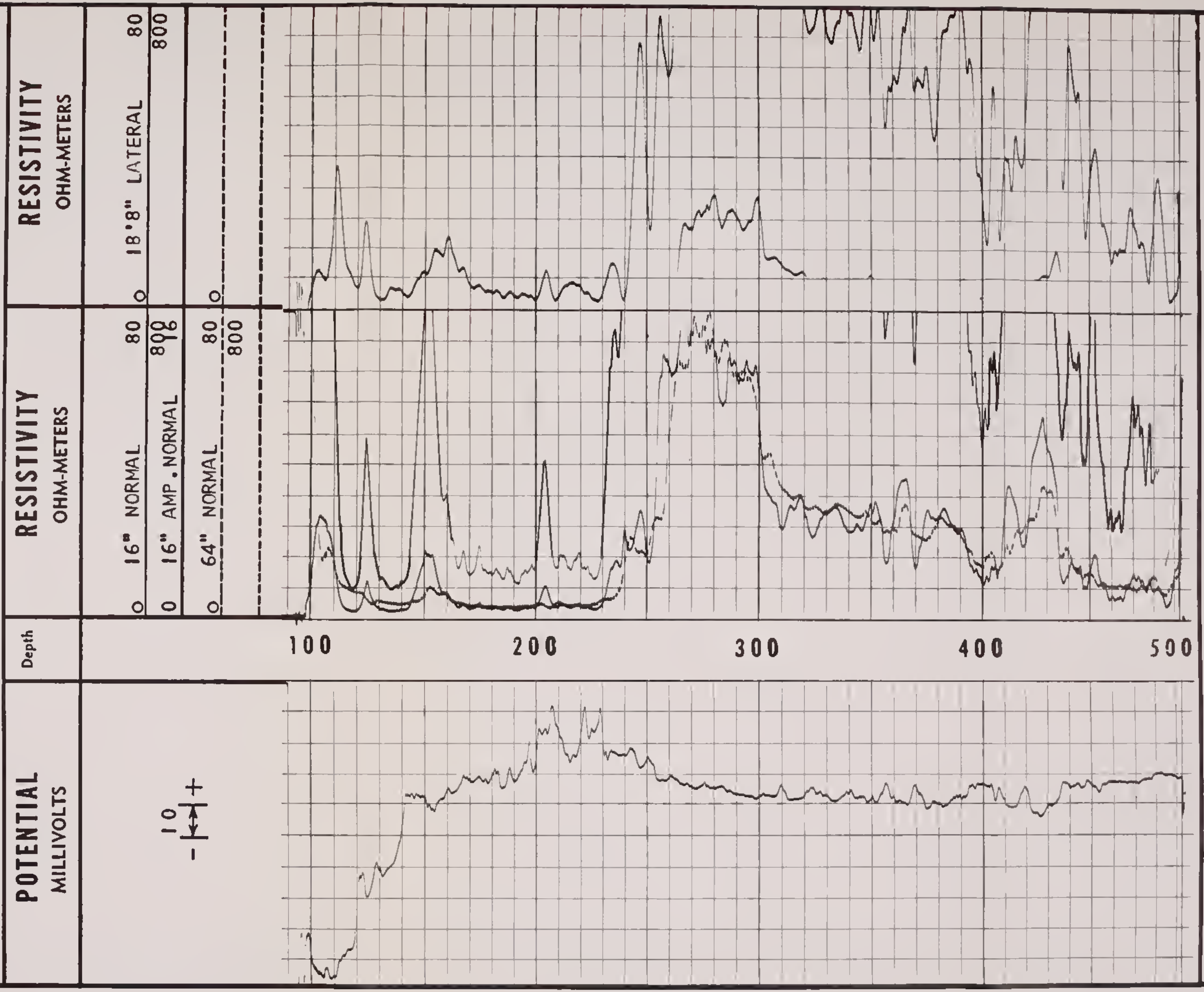
FILE NO. ____

MEASUREMENTS TAKEN FROM GROUND LEVEL

Run No.	1	2	3	4	5
First reading	497				
Last reading	100				
Feet measured	397				
Casing, Lane-Wells	N.R.				
Casing, Driller	N.R.				
Bottom, Lane-Wells	498				
Bottom, Driller	500				
Max. temp. °F	75				
Mud characteristics	@ 70 °F	@ °F	@ °F	@ °F	@ °F
Resistivity	5.8				
Resist. BHT	5.6				
Nature	CLAY				
Density	N.R.				
Viscosity	N.R.				
Water Loss-cc 30 min.	N.R.				
Mud Ph.	N.R.				
Bit size	6-1/8				
Spacings:					
Short normal	16"				
Long normal	64"				
Lateral	18'8"				
Rig time	30 MIN				
Recorded by	BROOKS				
Witnessed by	WEIBE				
Date	3-29-60				

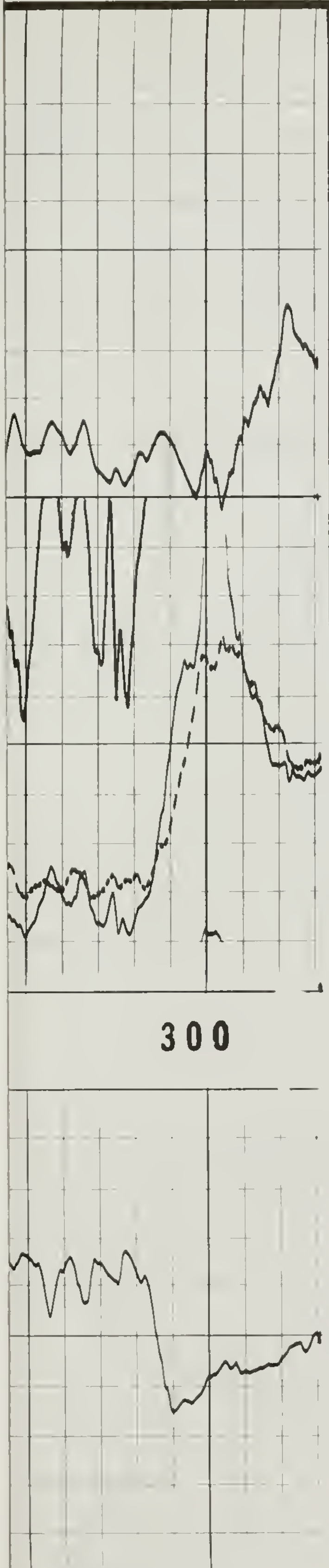
FILE NO. ____

REMARKS OR OTHER DATA



ELECTRIC LOG
DRILLING SITE 3
(1N/22W- 20N2)

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965



ELECTRIC LOG
DRILLING SITE 4
(IN/22W — 17M3)

LANE WELLS COMPANY

ELGEN Electrolog

COMPANY CALIFORNIA STATE DEPT. OF WATER RESOURCES

WELL DRILLING SITE 4

FIELD OXNARD PLAIN

LOCATION 2350 FT. W. OF PATTERSON ROAD; 150 FT. N. OF 23RD. ROAD

COUNTY VENTURA

STATE CALIFORNIA

COUNTY / FIELD / WELL / COMPANY

OTHER SURVEYS

WELL LOCATION

Elevation KB
DF
GL 9'

FILE NO.

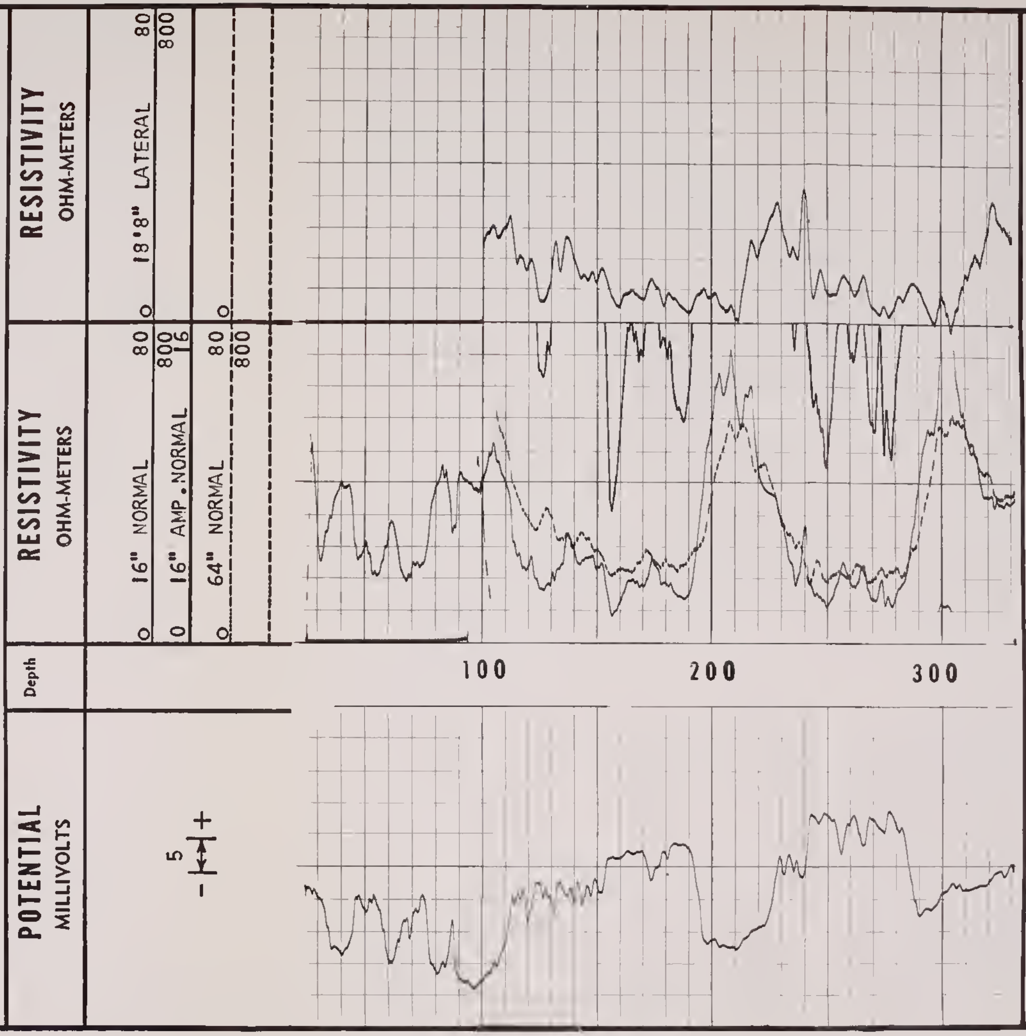
MEASUREMENTS TAKEN FROM GROUND LEVEL

Run No.	1	2	3	4	5
First reading	330				
Last reading	25				
Feet measured	305				
Casing, Lane-Wells	N.R.				
Casing, Driller	N.R.				
Bottom, Lane-Wells	331				
Bottom, Driller	330				
Max. temp. °F	72				
Mud characteristics	@ 72 °F	@ °F	@ °F	@ °F	@ °F
Resistivity	6.8				
Resist. BHT	6.8				
Nature	CLAY				
Density	N.R.				
Viscosity	N.R.				
Water Loss-cc 30 min.	N.R.				
Mud Ph.	N.R.				
Bit size	6-1/4"				
Spacings:					
Short normal	16"				
Long normal	64"				
Lateral	18'8"				
Rig time	45 MIN				
Recorded by	BROOKS				
Witnessed by	WIEBE				
Date	4-5-60				

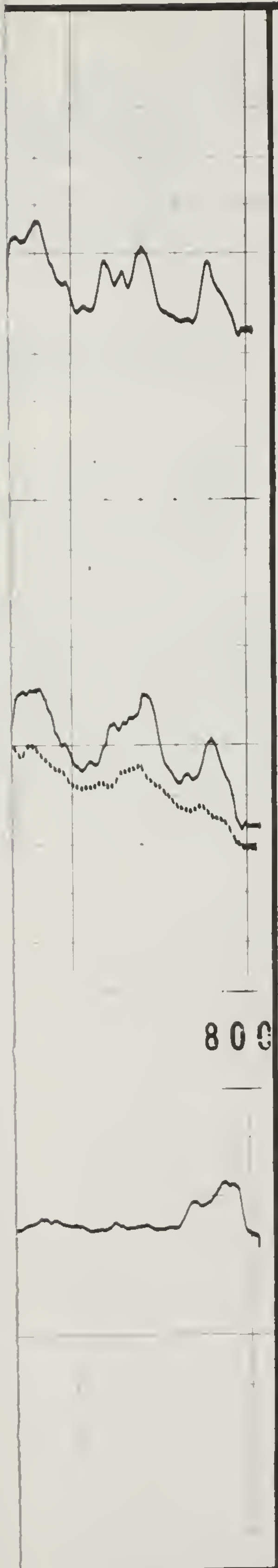
FILE NO.

REMARKS OR OTHER DATA

CS-30-5508



ELECTRIC LOG
DRILLING SITE 4
(1N/22W — 17M3)



ELECTRIC LOG
DRILLING SITE 5
(IN/22W – 27B4)

LANE-WELLS COMPANY | **ELGEN** *Electrolog*

COMPANY	CALIFORNIA STATE DEPT. OF WATER RESOURCES
WELL	DRILLING SITE 5
FIELD	OXNARD PLAIN
LOCATION	1300 FT. S. OF HUENEME ROAD, 4450 FT. E. OF PERKINS ROAD
COUNTY	VENTURA
STATE	CALIFORNIA

OTHER SURVEYS

WELL LOCATION

Elevation KB.

DF.

GL. 13'

FILE NO

COUNTY / FIELD / WELL / COMPANY

MEASUREMENTS TAKEN FROM GROUND LEVEL

Run No.	1	2	3	4	5
First reading	800				
Last reading	16				
Feet measured	784				
Casing, Lane-Wells	N.R.				
Casing, Driller	N.R.				
Bottom, Lane-Wells	800				
Bottom, Driller	800				
Max. temp. °F	81				
Mud characteristics	@ 69 °F	@ °F	@ °F	@ °F	@ °F
Resistivity	5.2				
Resist. BHT	N.R.				
Nature	NAT.				
Density	N.R.				
Viscosity	N.R.				
Water Loss-cc 30 min.	N.R.				
Mud Ph.	N.R.				
Bit size	6-1/4				
Spacings:					
Short normal	16"				
Long normal	64"				
Lateral	18'8"				
Rig time	20 MIN				
Recorded by	HUMEFLDT				
Witnessed by	WIEBE				
Date	6-10-60				

FILE NO.

REMARKS OR OTHER DATA

CS-30-5508

ELECTRIC LOG
DRILLING SITE 5
(1N/22W – 27B4)

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965

SCHLUMBERGER ELECTRICAL LOG

SCHLUMBERGER WELL SURVEYING CORPORATION
Houston, Texas

COMPANY	CALIFORNIA STATE DEPT. OF WATER RESOURCES
WELL	DRILLING SITE 6
FIELD	OXNARD PLAIN
LOCATION	100 FT. N.E. OF H/W. 1 FREEWAY; 500 FT. S.E. OF WOOD ROAD OVER-CROSSING
COUNTY	VENTURA
STATE	CALIFORNIA

COUNTY / FIELD or LOCATION / WELL / COMPANY

Other Surveys: NONE

Location of Well: N.A.

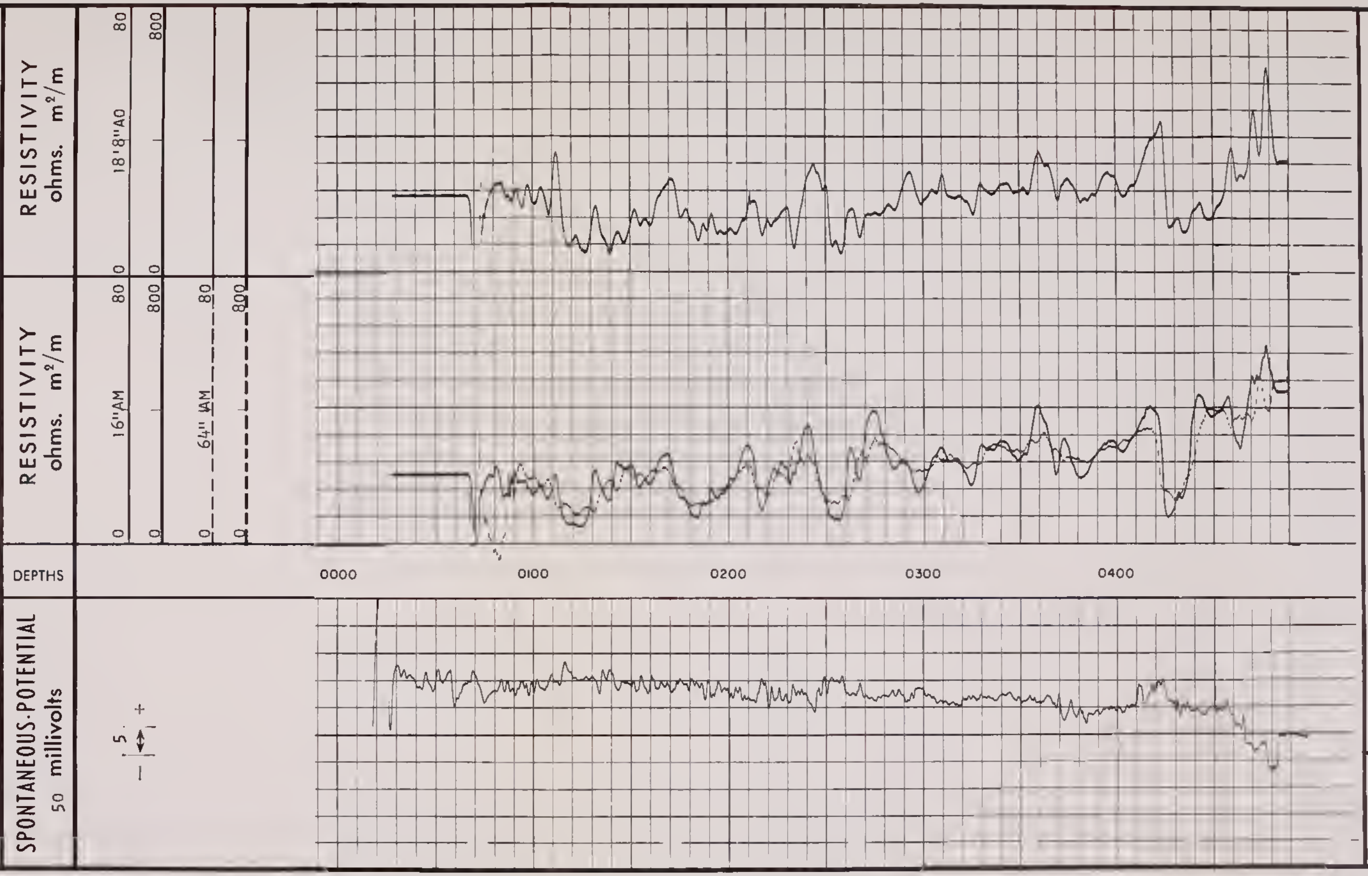
Elevation: D.F.: ___ K.B.: ___ or G.L.: 12'

FILING No.

RUN No.	ONE				
Date	4-7-62				
First Reading	482				
Last Reading	76				
Feet Measured	406				
Csg. Schlum.	27				
Csg. Driller	25				
Depth Reached	484				
Bottom Driller	487				
Depth Datum	G.L.				
Mud Nat.	CLAY				
Dens. / Visc.	9.5 / 40				
Mud Resist.	10 @ 71 °F	@ °F	@ °F	@ °F	@ °F
" Res. BHT	8.9 @ 80 °F	@ °F	@ °F	@ °F	@ °F
Rmf	- @ - °F	@ °F	@ °F	@ °F	@ °F
Rmc	- @ - °F	@ °F	@ °F	@ °F	@ °F
" pH	7 @ 71 °F	@ °F	@ °F	@ °F	@ °F
" Wtr. Loss	N/A CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	6¾"				
Spcgs.—AM	16"				
AM	64"				
AO	18'8"				
Opr. Rig Time	1½ HRS				
Truck No.	1594-VT				
Recorded By	HALL				
Witness	SCHLIGA				

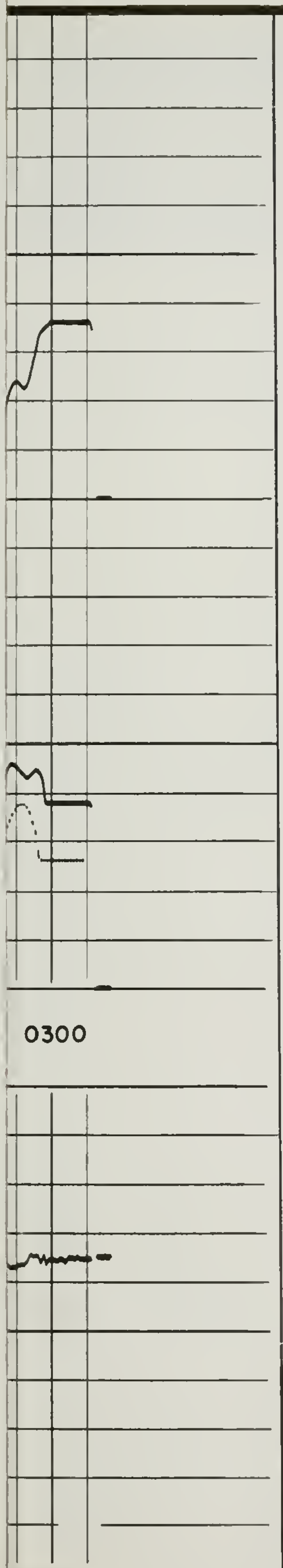
FOLD HERE

REMARKS



ELECTRIC LOG
DRILLING SITE 6
(1N/21W — 32A2)

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965



ELECTRIC LOG
DRILLING SITE 7
(1N/21W — 21L1)

SCHLUMBERGER ELECTRICAL LOG

SCHLUMBERGER WELL SURVEYING CORPORATION
Houston, Texas

COMPANY CALIFORNIA STATE DEPT. OF WATER RESOURCES

WELL DRILLING SITE 8

FIELD OXNARD PLAIN

LOCATION 190 FT. NW OF 10TH STREET; 600 FT. SW. OF 9TH. STREET

COUNTY VENTURA

STATE CALIFORNIA

Other Surveys: NONE

Location of Well: N.A.

Elevation: D.F.: K.B.: or G.L.: 7'

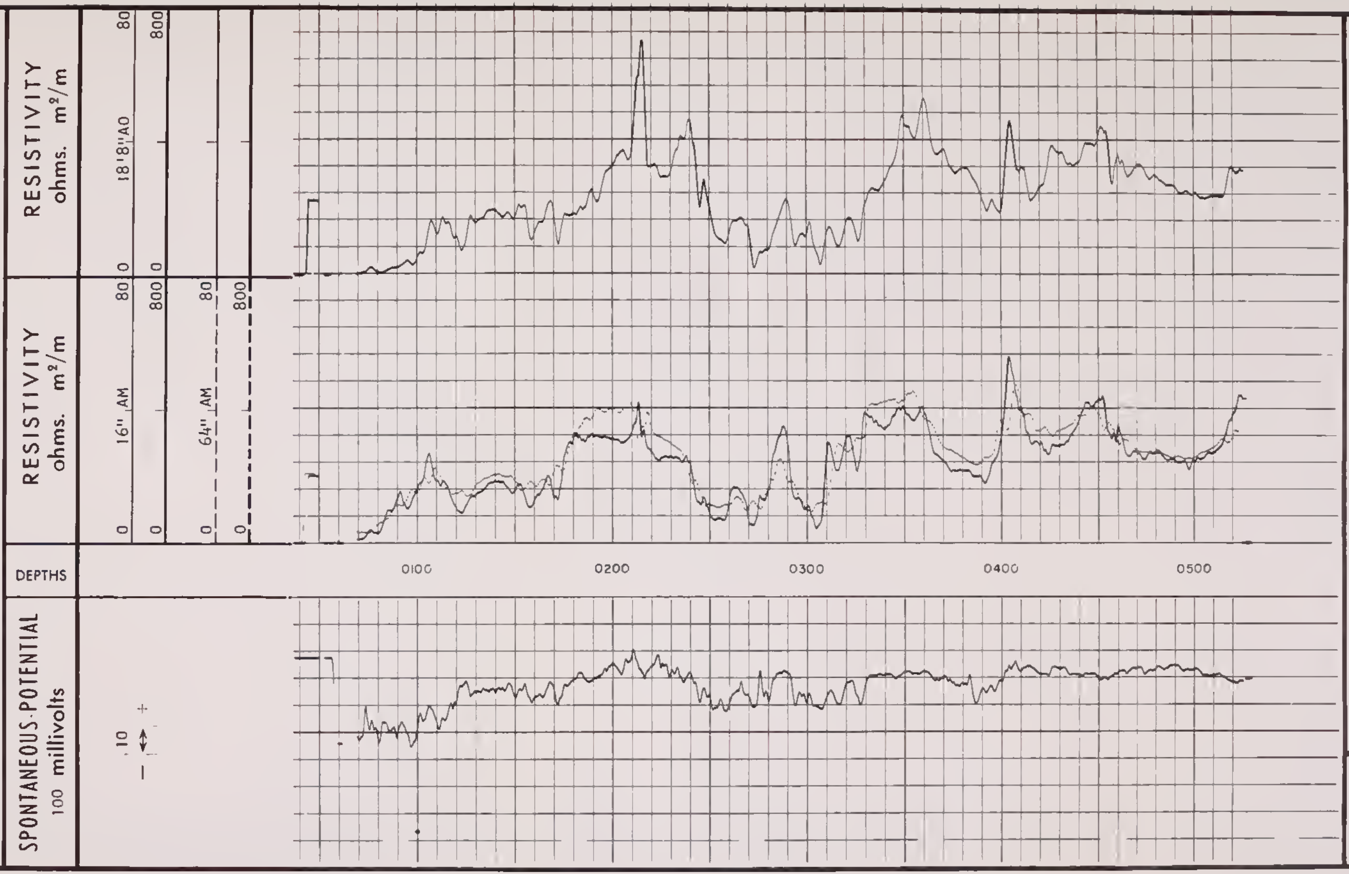
FILING No.

COUNTY / FIELD or LOCATION / WELL / COMPANY

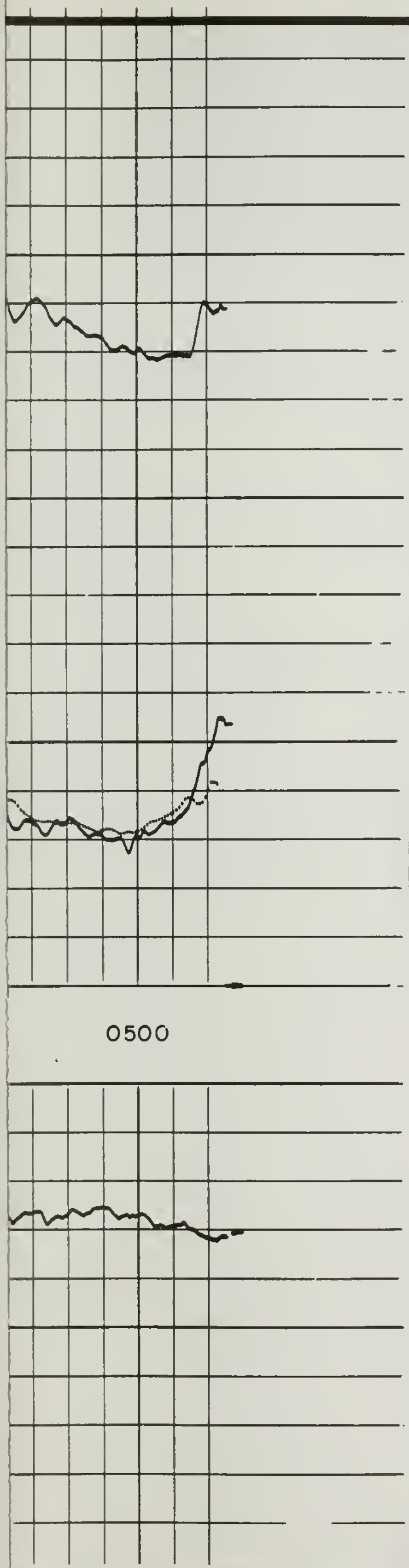
RUN No.	ONE				
Date	2-20-62				
First Reading	524				
Last Reading	70				
Feet Measured	454				
Csg. Schlum.	-				
Csg. Driller	-				
Depth Reached	526				
Bottom Driller	525				
Depth Datum	GROUND				
Mud Nat.	CLAY				
Dens. Visc.	NA NA				
Mud Resist.	4.6 @ 60 °F	@ °F	@ °F	@ °F	@ °F
" Res. BHT	4.2 @ 66 °F	@ °F	@ °F	@ °F	@ °F
Rmf	NA @ 66 °F	@ °F	@ °F	@ °F	@ °F
Rmc	NA @ 66 °F	@ °F	@ °F	@ °F	@ °F
" pH	8 @ 60 °F	@ °F	@ °F	@ °F	@ °F
" Wtr. Loss	NA CC 30 min.	CC 30 min	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	6"				
Spcgs.—AM	16"				
AM	64"				
AO	18'8"				
Opr. Rig Time	1/2 HR.				
Truck No.	1585 VT				
Recorded By	MILAM				
Witness	SCHELIGA				

FOLD HERE

REMARKS



ELECTRIC LOG
DRILLING SITE 8
(1N/21W — 3201)



ELECTRIC LOG
DRILLING SITE 8
(IN/21W — 32Q1)

SCHLUMBERGER ELECTRICAL LOG

SCHLUMBERGER WELL SURVEYING CORPORATION
Houston, Texas

COMPANY CALIFORNIA STATE DEPT. OF WATER RESOURCES

WELL DRILLING SITE 9

FIELD OXNARD PLAIN

LOCATION 132 FT. S. OF 20TH. STREET; 1000 FT. W. OF LAGUNA ROAD PRODUCED

COUNTY VENTURA

STATE CALIFORNIA

COUNTY / FIELD or LOCATION / WELL / COMPANY

Other Surveys
NONE

Location of Well
NA

Elevation: D.F.:
K.B.:
or G.L.: 4'

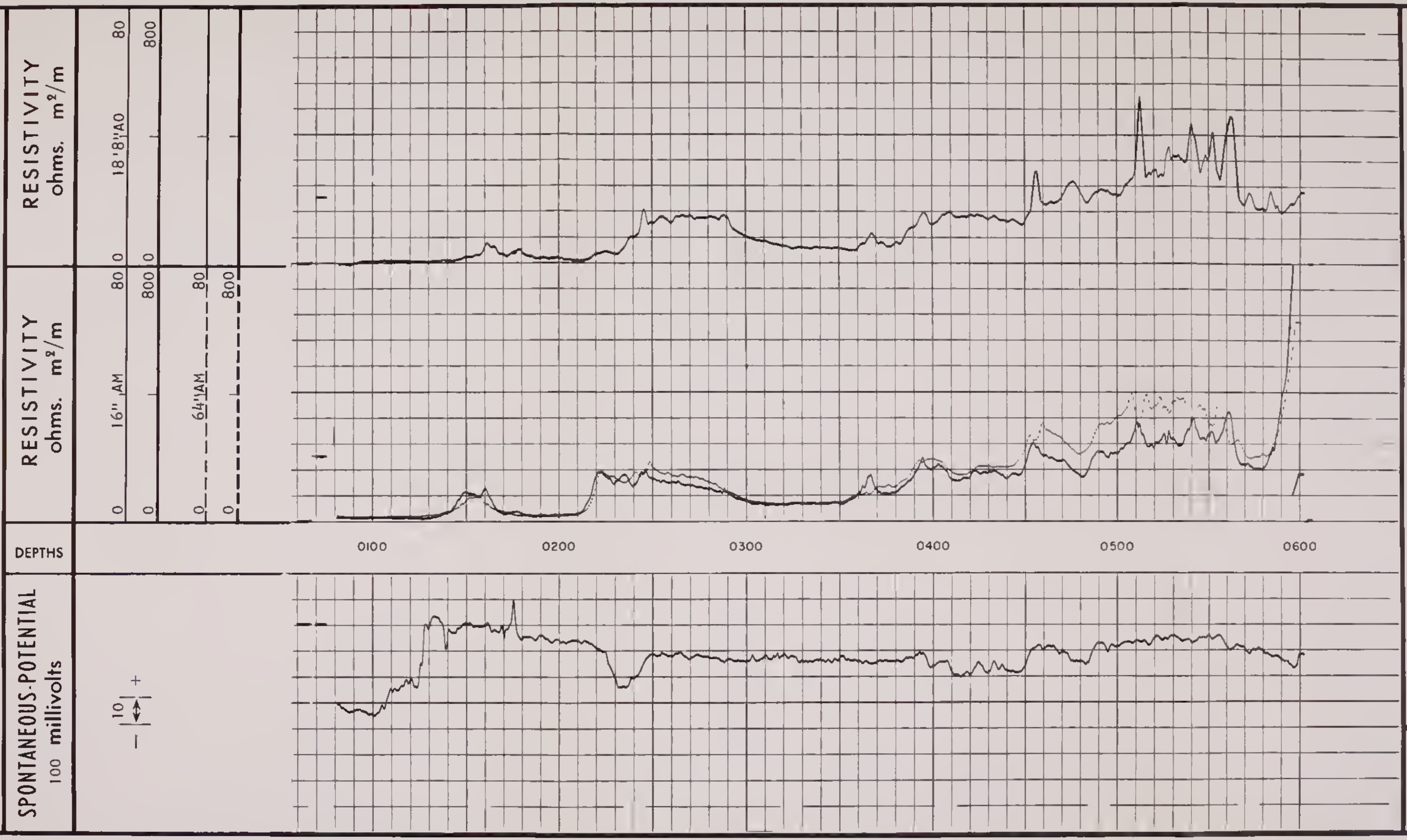
FILING No.

RUN No.	ONE				
Date	3-21-62				
First Reading	600				
Last Reading	80				
Feet Measured	520				
Csg. Schlum.	75				
Csg. Driller	75				
Depth Reached	602				
Bottom Driller	601				
Depth Datum	G.L.				
Mud Nat.	CLAY				
Dens. / Visc.	NA / NA				
Mud Resist.	3.2 @ 62°F	@ °F	@ °F	@ °F	@ °F
" Res. BHT	3.0 @ 65°F	@ °F	@ °F	@ °F	@ °F
Rmf -C	2.7 @ 65°F	@ °F	@ °F	@ °F	@ °F
Rmc -C	2.5 @ 65°F	@ °F	@ °F	@ °F	@ °F
" pH	8 @ 62°F	@ °F	@ °F	@ °F	@ °F
" Wtr. Loss	NA CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	6"				
Spcgs.—AM	16"				
AM	64"				
AO	18'8"				
Opr. Rig Time	½ HR.				
Truck No.	1585VT.				
Recorded By	MILAM				
Witness	SCHELIGA				

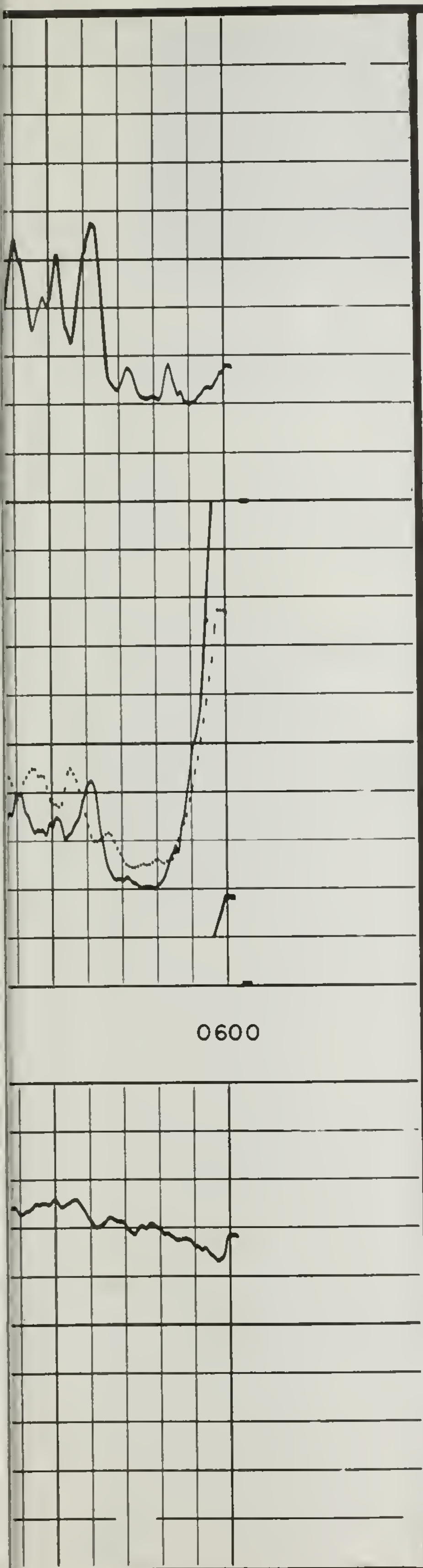
DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965

FOLD HERE

REMARKS



ELECTRIC LOG
DRILLING SITE 9
(1S./21W.– 8L1)



ELECTRIC LOG
DRILLING SITE 9
(1S./21W.– 8L1)

SCHLUMBERGER

ELECTRICAL LOG

COMPANY CALIFORNIA STATE DEPT. OF WATER RESOURCES

WELL ORILLING SITE II

FIELD OXNARD PLAIN

LOCATION 20 FT. E OF SAN PEDRO STREET; 50 FT. N. OF MAIN STREET

COUNTY VENTURA

STATE CALIFORNIA

Other Surveys: NONE

Location of Well

Elevation: D.F.: K.B.: or G.L.: 8

FILING No.

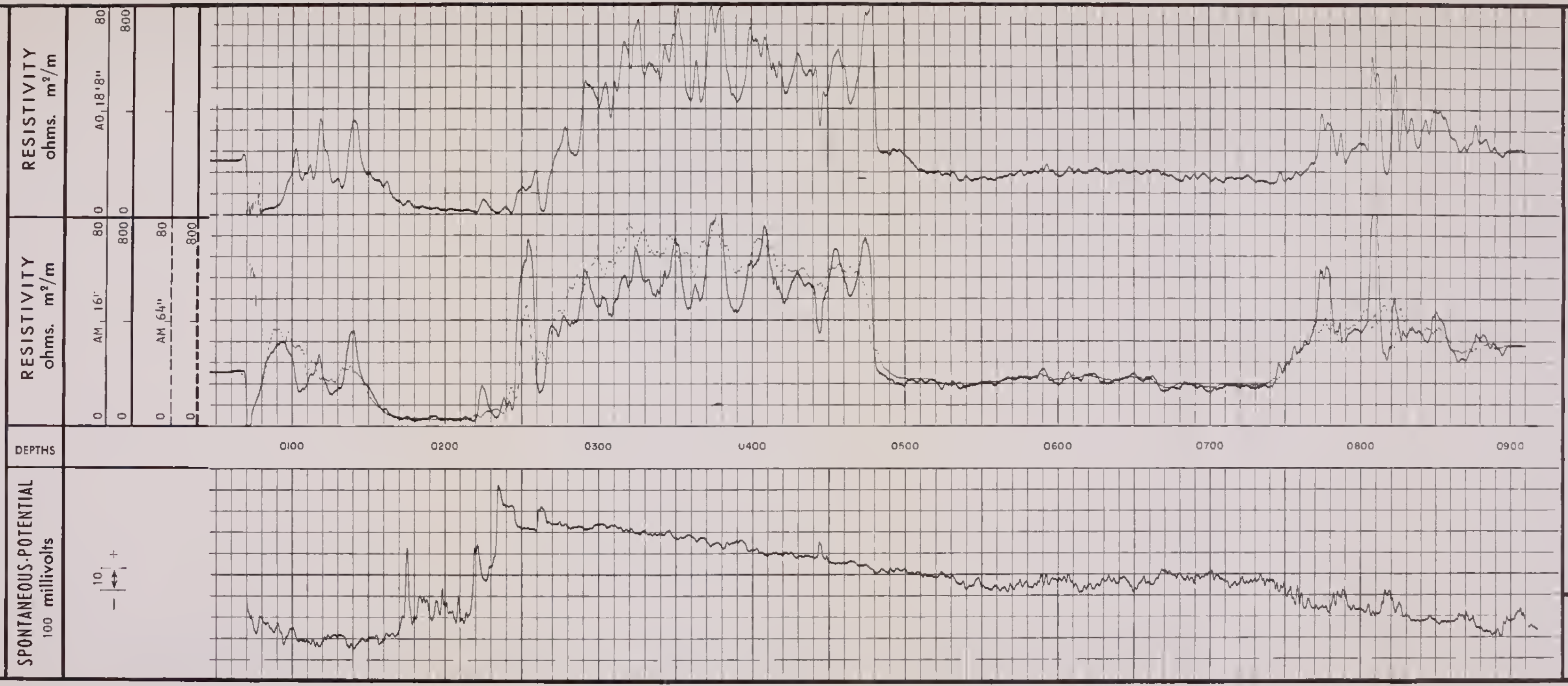
COUNTY / FIELD or LOCATION / WELL / COMPANY

FOLD HERE

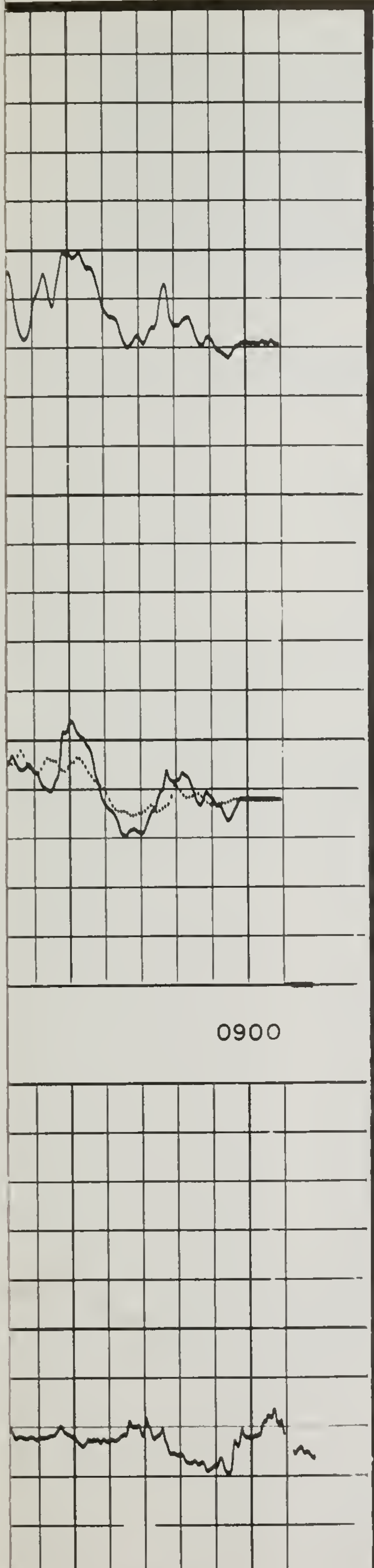
RUN No.	ONE				
Date	5-28-62				
First Reading	898				
Last Reading	75				
Feet Measured	823				
Csg. Schlum.	-				
Csg. Driller	42				
Depth Reached	900				
Bottom Driller	1002				
Depth Datum	G.L.				
Mud Nat.	CLAY				
Dens. / Visc.	12 / 50				
Mud Resist.	8.0 @ 69 °F	@ °F	@ °F	@ °F	@ °F
" Res. BHT	6.2 @ 90 °F	@ °F	@ °F	@ °F	@ °F
Rmf	- @ - °F	@ °F	@ °F	@ °F	@ °F
Rmc	- @ - °F	@ °F	@ °F	@ °F	@ °F
" pH	9 @ - °F	@ °F	@ °F	@ °F	@ °F
" Wtr. Loss	CC 30 min.	CC 30 min	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	7 3/8				
Spcgs.—AM	16"				
A M	64"				
AO	18'8"				
Opr. Rig Time	[illegible]				
Truck No.	[illegible]				
Recorded By	THOMAS				
Witness	SCHILGA				

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965

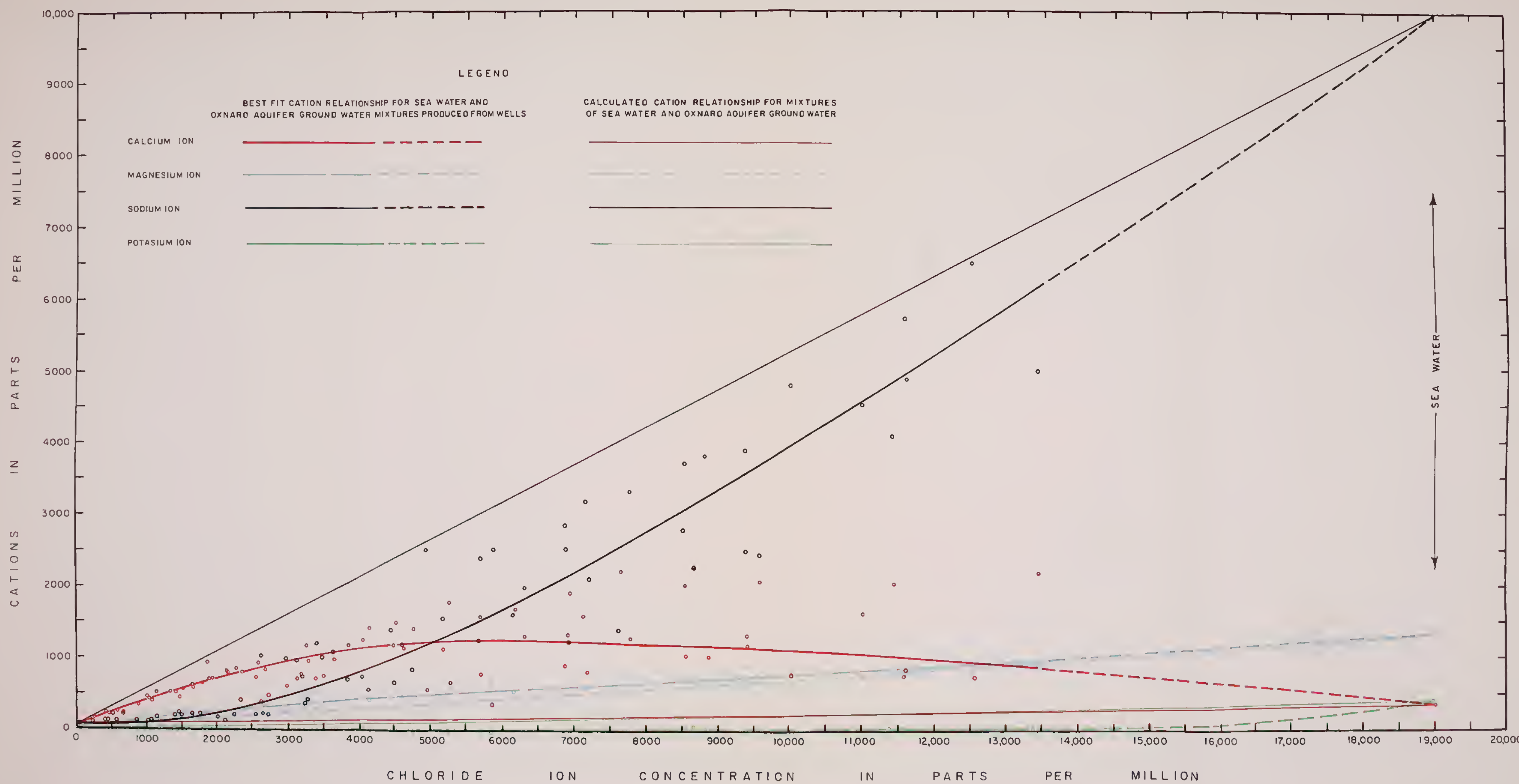
REMARKS



ELECTRIC LOG
ORILLING SITE II
(1N/22W – 29A4)



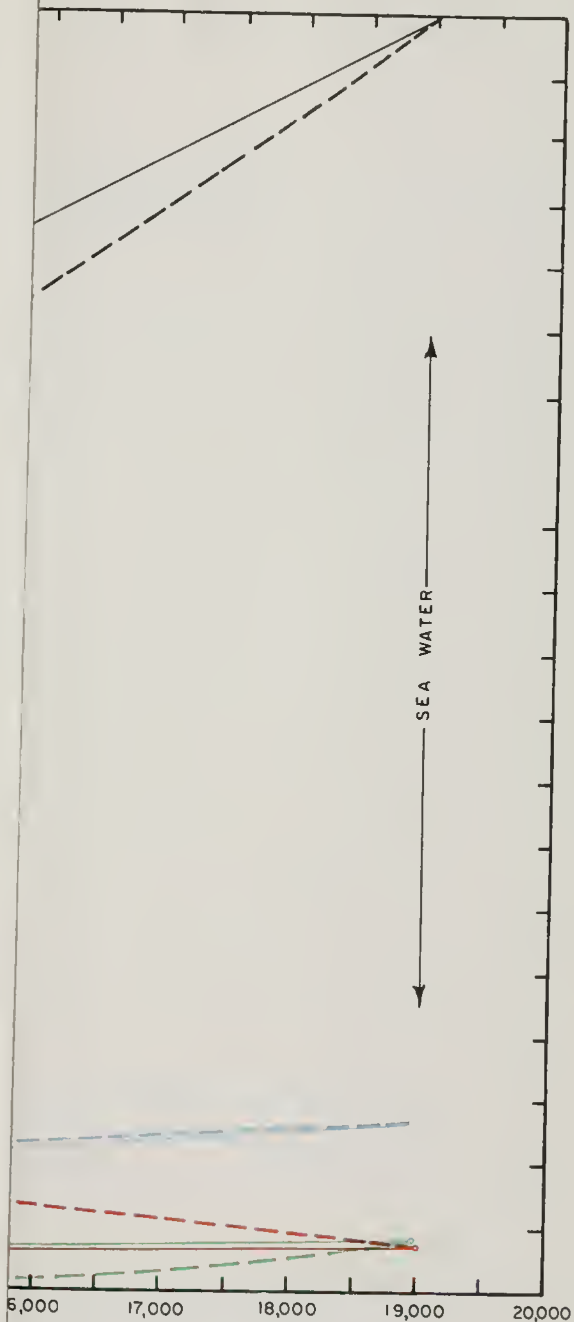
ELECTRIC LOG
DRILLING SITE 11
(1N/22W – 29A4)



OBSERVED BASE—EXCHANGE CHARACTERISTICS OF INTRUDED OXNARD AQUIFER WATERS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965

FIGURE 1



WATERS

PLATE I

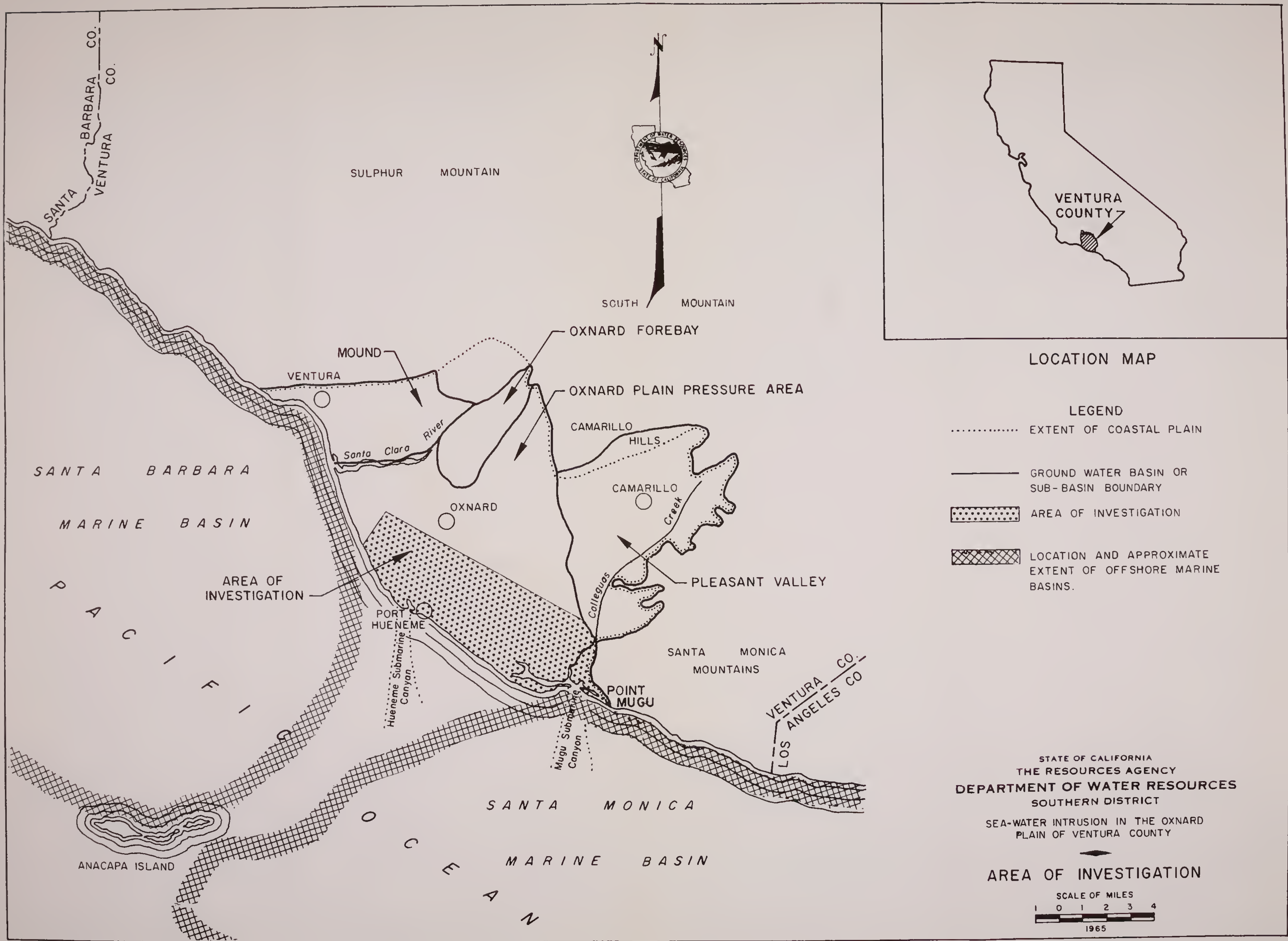

SANTA BARBARA CO.
VENTURA CO.
SULPHUR MOUNTAIN
SOUTH MOUNTAIN
OXNARD FOREBAY
MOUND
VENTURA
OXNARD PLAIN PRESSURE AREA
Santa Clara River
CAMARILLO HILLS
CAMARILLO
Creek
OXNARD
SANTA BARBARA MARINE BASIN
AREA OF INVESTIGATION
Calleguas
PLEASANT VALLEY
PORT HUENEME
Hueneme Submarine Canyan
SANTA MONICA MOUNTAINS
POINT MUGU
Mugu Submarine Canyon
VENTURA CO.
LOS ANGELES CO
PACIFIC OCEAN
SANTA MONICA MARINE BASIN
ANACAPA ISLAND
VENTURA COUNTY
LOCATION MAP
LEGEND
EXTENT OF COASTAL PLAIN
GROUND WATER BASIN OR SUB-BASIN BOUNDARY
AREA OF INVESTIGATION
LOCATION AND APPROXIMATE EXTENT OF OFFSHORE MARINE BASINS.
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
AREA OF INVESTIGATION
SCALE OF MILES
1 0 1 2 3 4
1965

PLATE I

LOCATION MAP

LEGEND

EXTENT OF COASTAL PLAIN

GROUND WATER BASIN OR SUB-BASIN BOUNDARY

AREA OF INVESTIGATION

LOCATION AND APPROXIMATE EXTENT OF OFFSHORE MARINE BASINS.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
PARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

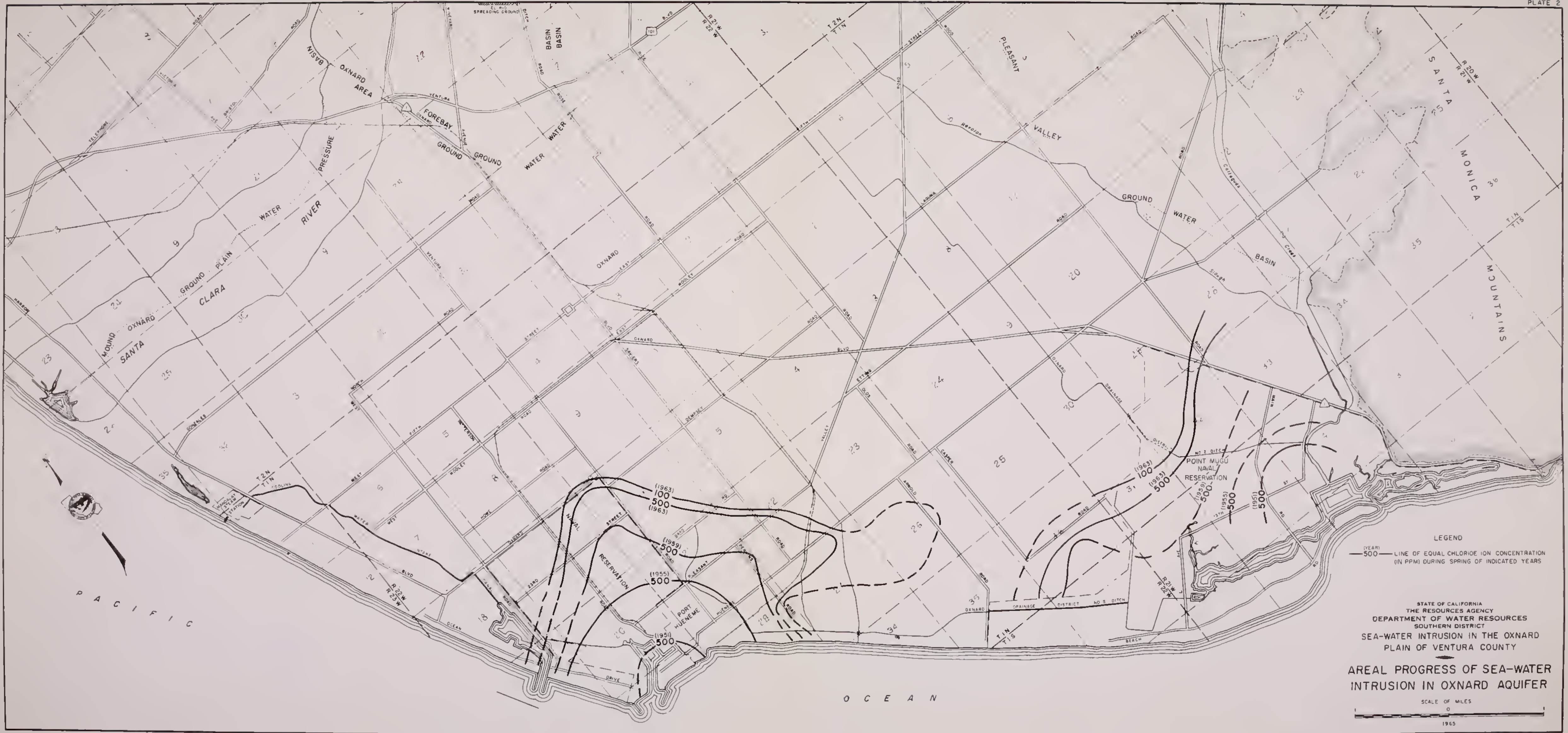
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

AREA OF INVESTIGATION

SCALE OF MILES

1 0 1 2 3 4

1965

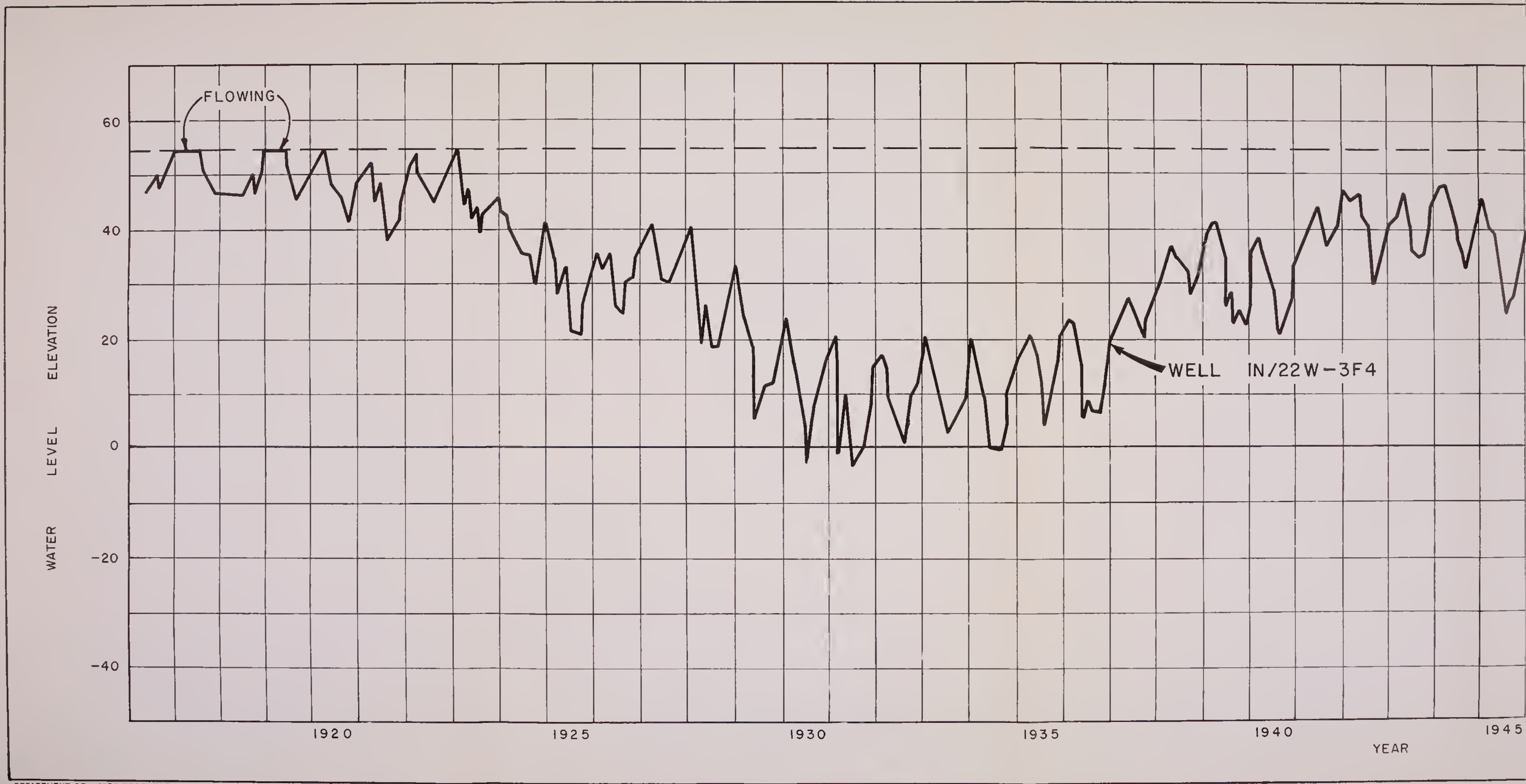


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

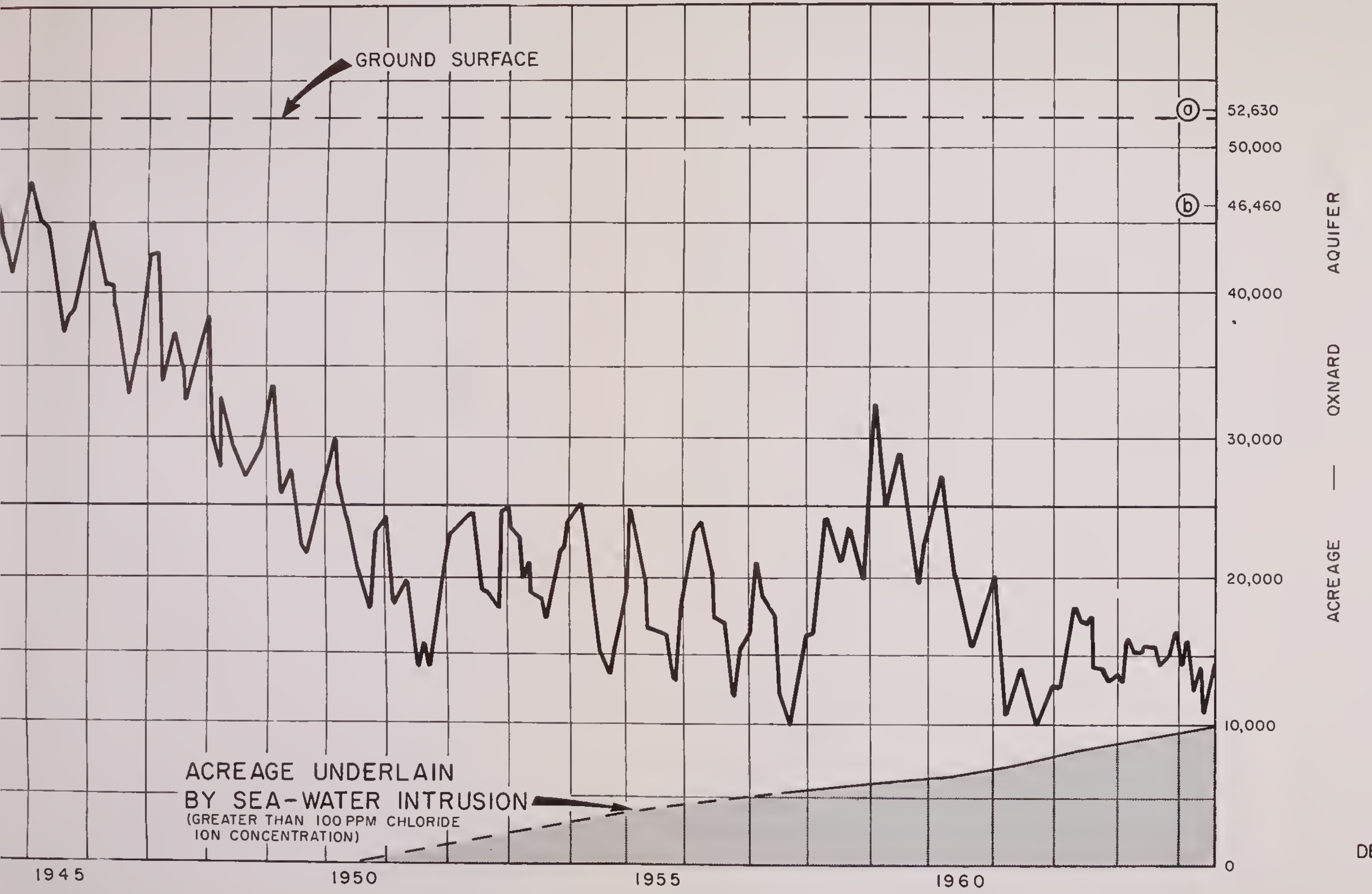
AREAL PROGRESS OF SEA-WATER INTRUSION IN OXNARD AQUIFER

SCALE OF MILES

1965



DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965



NOTE:

ⓐ TOTAL ACREAGE OXNARD PLAIN PRESSURE AREA AND OXNARD FOREBAY GROUND WATER BASINS

ⓑ ACREAGE OXNARD PLAIN PRESSURE AREA GROUND WATER BASIN

DECLINE OF GROUND WATER LEVELS IN WELLS VERSUS INCREASE IN AREA UNDERLAIN BY SEA-WATER INTRUSION-OXNARD AQUIFER

ACREAGE — OXNARD AQUIFER

NOTE:

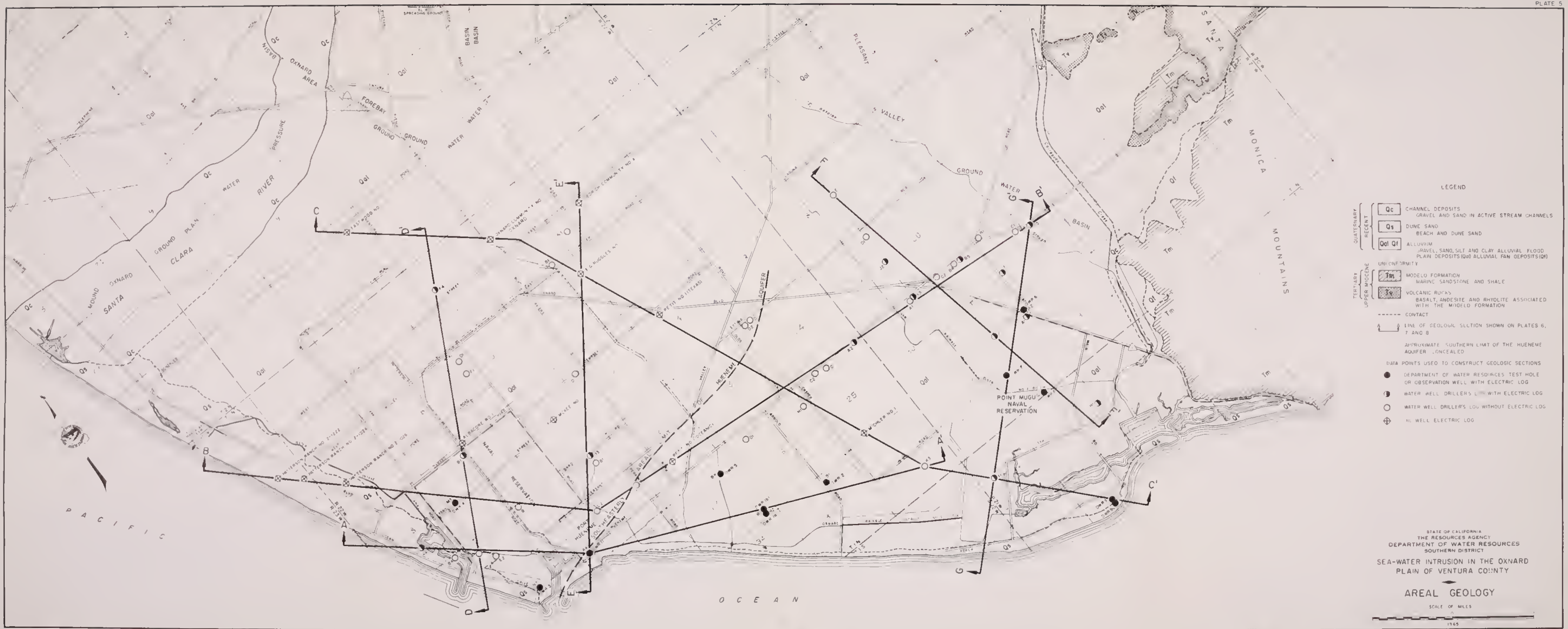
(a) TOTAL ACREAGE OXNARD PLAIN PRESSURE AREA AND OXNARD FOREBAY GROUND WATER BASINS

(b) ACREAGE OXNARD PLAIN PRESSURE AREA GROUND WATER BASIN

DECLINE OF GROUND WATER LEVELS IN WELLS VERSUS INCREASE IN AREA UNDERLAIN BY SEA-WATER INTRUSION—OXNARD AQUIFER


LEGEND
WELL AND EXPLORATORY HOLE SITES
ACTIVE PRODUCTION WELLS REMOVED FROM USE DUE TO SEA-WATER INTRUSION
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
WELL LOCATION MAP
SCALE OF MILES
0
1965
PACIFIC
OCEAN
OXNARD FOREBAY GROUND WATER BASIN
OXNARD PLAIN PRESSURE GROUND WATER BASIN
SANTA CLARA RIVER
MOUND
OXNARD
PLEASANT VALLEY GROUND WATER BASIN
SANTA MONICA MOUNTAINS
POINT MUGU NAVAL RESERVATION
NAVAL RESERVATION
PORT HUENEME
EL RIO SPREADING GROUNDS
OXNARD DRAINAGE DISTRICT NO 3 DITCH


SANTA MONICA MOUNTAINS
R 20 W
R 21 W
T 1 N
T 1 S
BASIN
Calleguas Creek
Slough
MUGU
O 2 DITCH
MAIN
ST
13TH
RD
LEGEND
WELL AND EXPLORATORY HOLE SITES
ACTIVE PRODUCTION WELLS REMOVED FROM USE DUE TO SEA-WATER INTRUSION
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
WELL LOCATION MAP
SCALE OF MILES
0
1
1965


LEGEND
QUATERNARY
RECENT
Qc CHANNEL DEPOSITS
GRAVEL AND SAND IN ACTIVE STREAM CHANNELS
Qs DUNE SAND
BEACH AND DUNE SAND
Qal Qf ALLUVIUM
GRAVEL, SAND, SILT AND CLAY ALLUVIAL FLOOD PLAIN DEPOSITS (Qal) ALLUVIAL FAN DEPOSITS (Qf)
UNCONFORMITY
TERTIARY
UPPER MIOCENE
Tm MODELO FORMATION
MARINE SANDSTONE AND SHALE
Tv VOLCANIC ROCKS
BASALT, ANDESITE AND RHYOLITE ASSOCIATED WITH THE MODELO FORMATION
CONTACT
LINE OF GEOLOGIC SECTION SHOWN ON PLATES 6, 7 AND 8
APPROXIMATE SOUTHERN LIMIT OF THE HUENEME AQUIFER CONCEALED
DATA POINTS USED TO CONSTRUCT GEOLOGIC SECTIONS
DEPARTMENT OF WATER RESOURCES TEST HOLE OR OBSERVATION WELL WITH ELECTRIC LOG
WATER WELL DRILLERS LOG WITH ELECTRIC LOG
WATER WELL DRILLER'S LOG WITHOUT ELECTRIC LOG
OIL WELL ELECTRIC LOG
OXNARD PLAIN
SANTA CLARA RIVER
PRESSURE
FOREBAY
PLEASANT VALLEY
SANTA MONICA MOUNTAINS
HUENEME AQUIFER
POINT MUGU NAVAL RESERVATION
PACIFIC
OCEAN
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
AREAL GEOLOGY
SCALE OF MILES
1965

LEGEND

QUATERNARY — RECENT

- **Qc** CHANNEL DEPOSITS
  GRAVEL AND SAND IN ACTIVE STREAM CHANNELS
- **Qs** DUNE SAND
  BEACH AND DUNE SAND
- **Qal Qf** ALLUVIUM
  GRAVEL, SAND, SILT AND CLAY. ALLUVIAL FLOOD PLAIN DEPOSITS (Qal) ALLUVIAL FAN DEPOSITS (Qf)

UNCONFORMITY

TERTIARY — UPPER MIOCENE

- **Tm** MODELO FORMATION
  MARINE SANDSTONE AND SHALE
- **Tv** VOLCANIC ROCKS
  BASALT, ANDESITE AND RHYOLITE ASSOCIATED WITH THE MODELO FORMATION

------ CONTACT

A — A' LINE OF GEOLOGIC SECTION SHOWN ON PLATES 6, 7 AND 8.

.... APPROXIMATE SOUTHERN LIMIT OF THE HUENEME AQUIFER. CONCEALED

DATA POINTS USED TO CONSTRUCT GEOLOGIC SECTIONS

- ● DEPARTMENT OF WATER RESOURCES TEST HOLE OR OBSERVATION WELL WITH ELECTRIC LOG
- ◐ WATER WELL DRILLER'S LOG WITH ELECTRIC LOG
- ○ WATER WELL DRILLER'S LOG WITHOUT ELECTRIC LOG
- ⊕ OIL WELL ELECTRIC LOG

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

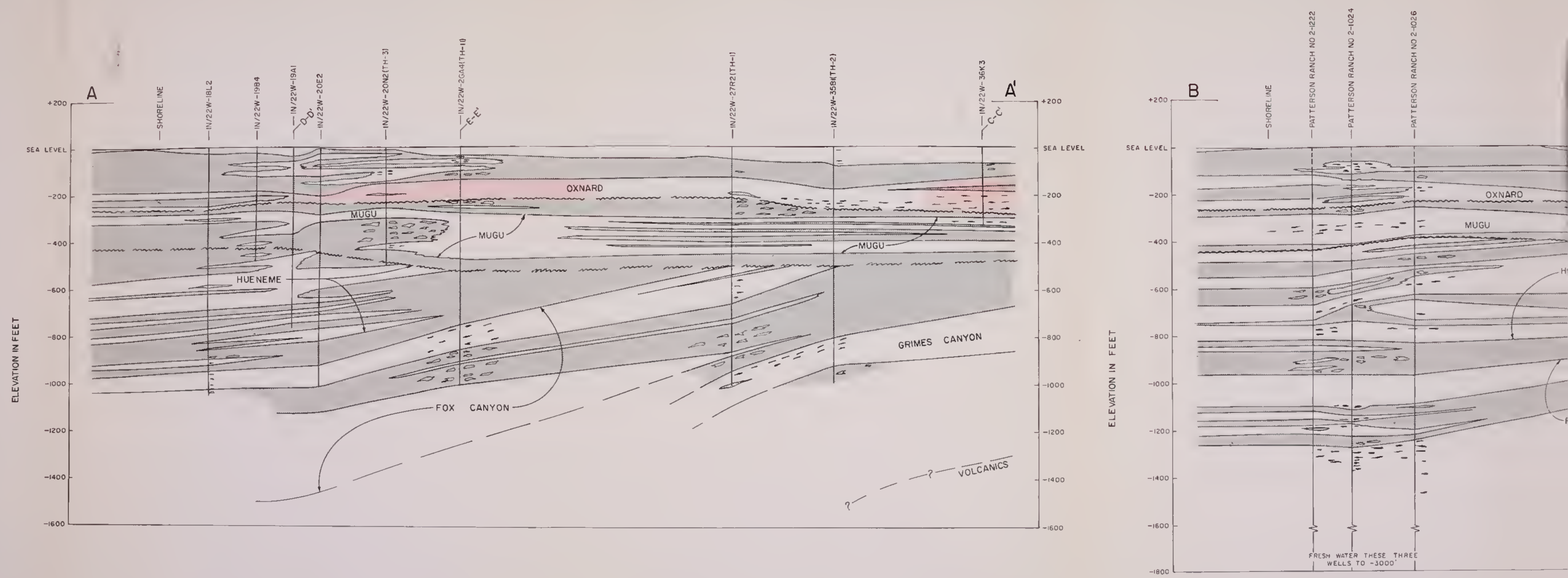
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

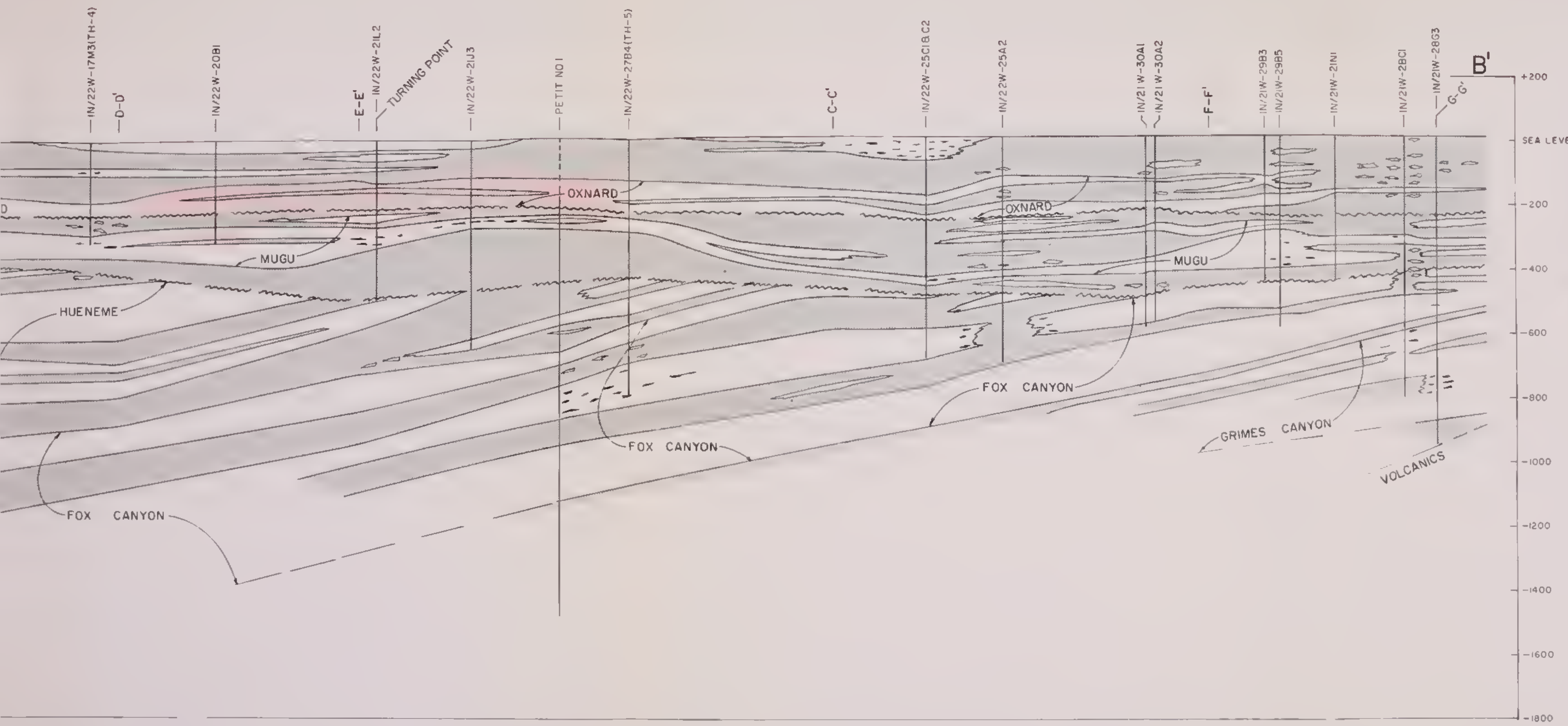
AREAL GEOLOGY

SCALE OF MILES

1 0 1

1965


A
A'
B
SHORELINE
1N/22W-18L2
1N/22W-19B4
1N/22W-19A1
D-D'
1N/22W-20E2
1N/22W-20N2(TH-3)
1N/22W-26A4(TH-1)
E-E'
1N/22W-27R2(TH-1)
1N/22W-35B(TH-2)
1N/22W-36K3
C-C'
PATTERSON RANCH NO 2-1222
PATTERSON RANCH NO 2-1024
PATTERSON RANCH NO 2-1026
+200
SEA LEVEL
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
ELEVATION IN FEET
OXNARD
MUGU
HUENEME
FOX CANYON
GRIMES CANYON
VOLCANICS
FRESH WATER THESE THREE WELLS TO -3000'



LEGEND

AQUIFER
COARSE GRAINED MATERIALS COMPRISED OF SAND AND GRAVEL

MODERATELY PERMEABLE MATERIALS COMPRISED OF CLAYEY AND SILTY SAND AND GRAVEL, OR SAND AND GRAVEL CONTAINING CLAY AND SILT LENSES

SLIGHTLY PERMEABLE MATERIALS COMPRISED OF SANDY AND GRAVELLY CLAY AND SILT, OR CLAY AND SILT CONTAINING SAND AND GRAVEL LENSES

AQUICLUDE
FINE GRAINED MATERIALS COMPRISED OF SILT AND CLAY

AQUIFER
DEGRADED BY SEA-WATER INTRUSION AND CONTAINING MORE THAN 100 PPM CHLORIDE

UNCONFORMITY

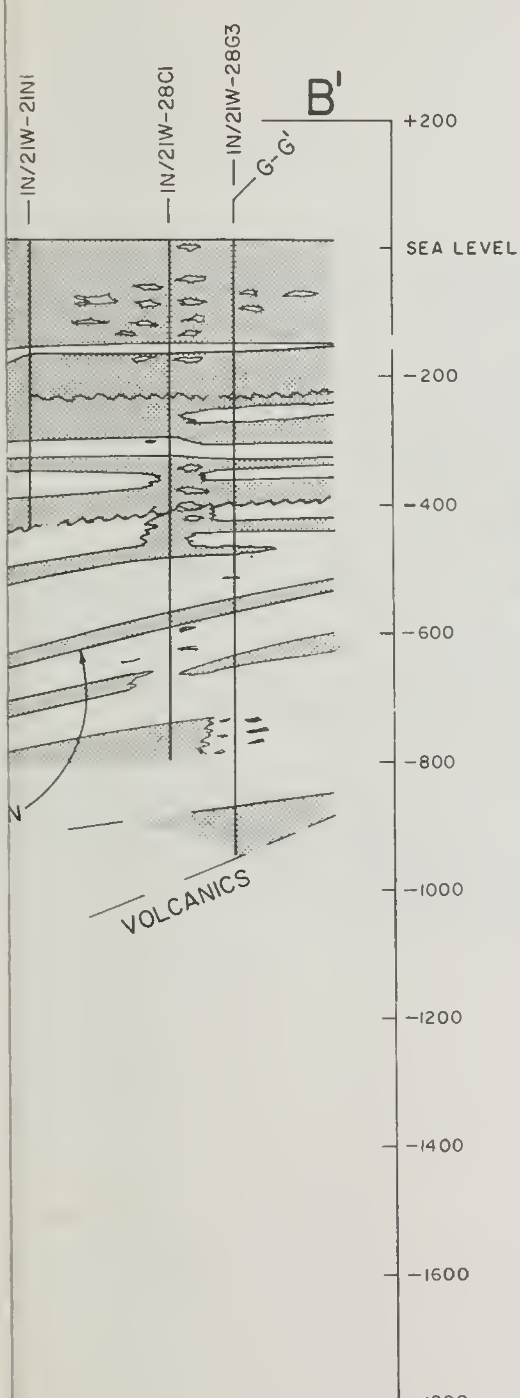
NOTE LOCATION OF GEOLOGIC SECTIONS SHOWN ON PLATE 5

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

GEOLOGIC SECTIONS A-A' AND B-B'

HORIZONTAL SCALE OF FEET
2000 1000 0 4000



LEGEND

AQUIFER
COARSE GRAINED MATERIALS COMPRISED OF SAND AND GRAVEL

MODERATELY PERMEABLE MATERIALS COMPRISED OF CLAYEY AND SILTY SAND AND GRAVEL, OR SAND AND GRAVEL CONTAINING CLAY AND SILT LENSES

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FINE GRAINED MATERIALS COMPRISED OF SILT AND CLAY

AQUIFER
DEGRADED BY SEA-WATER INTRUSION AND CONTAINING MORE THAN 100 PPM CHLORIDE

UNCONFORMITY

NOTE LOCATION OF GEOLOGIC SECTIONS SHOWN ON PLATE 5

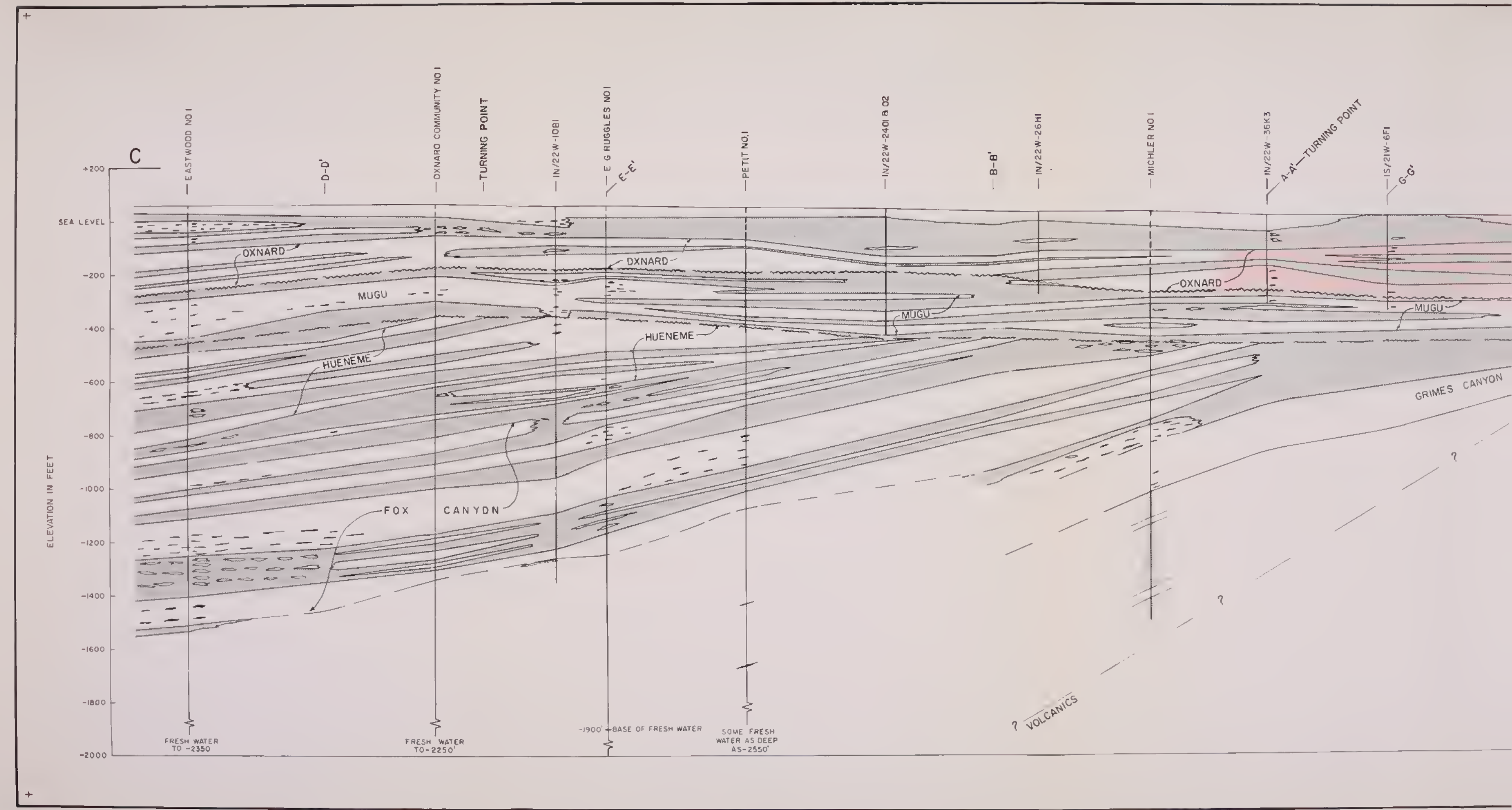
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

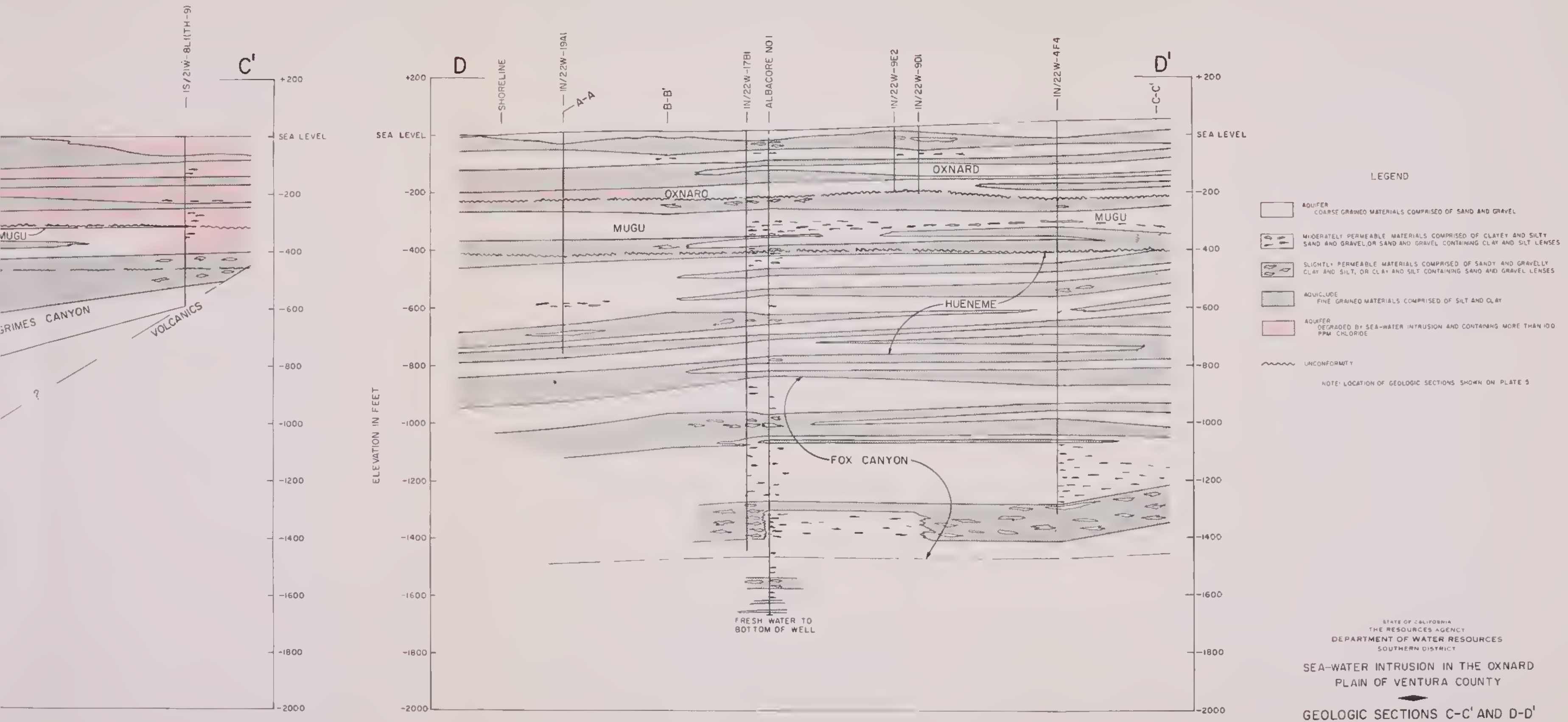
GEOLOGIC SECTIONS A-A' AND B-B'

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1965



C
ELEVATION IN FEET
+200
SEA LEVEL
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-2000
EASTWOOD NO 1
D-D'
OXNARD COMMUNITY NO 1
TURNING POINT
1N/22W-10B1
E G RUGGLES NO 1
E-E'
PETIT NO.1
1N/22W-24D1 & D2
B-B'
1N/22W-26H1
MICHLER NO 1
1N/22W-36K3
A-A'—TURNING POINT
1S/21W-6F1
G-G'
OXNARD
MUGU
HUENEME
FOX CANYON
GRIMES CANYON
VOLCANICS
FRESH WATER TO -2350
FRESH WATER TO-2250'
-1900' BASE OF FRESH WATER
SOME FRESH WATER AS DEEP AS-2550'

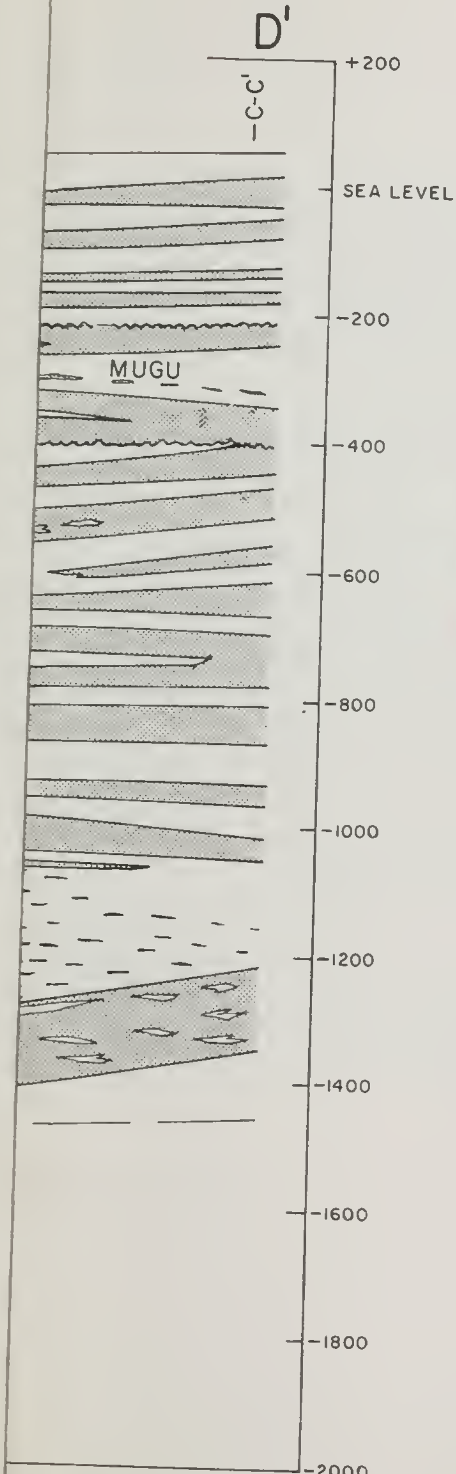


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

GEOLOGIC SECTIONS C-C' AND D-D'

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000



LEGEND

AQUIFER
COARSE GRAINED MATERIALS COMPRISED OF SAND AND GRAVEL

MODERATELY PERMEABLE MATERIALS COMPRISED OF CLAYEY AND SILTY SAND AND GRAVEL, OR SAND AND GRAVEL CONTAINING CLAY AND SILT LENSES

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AQUICLUDE
FINE GRAINED MATERIALS COMPRISED OF SILT AND CLAY

AQUIFER
DEGRADED BY SEA-WATER INTRUSION AND CONTAINING MORE THAN 100 PPM CHLORIDE

UNCONFORMITY

NOTE: LOCATION OF GEOLOGIC SECTIONS SHOWN ON PLATE 5

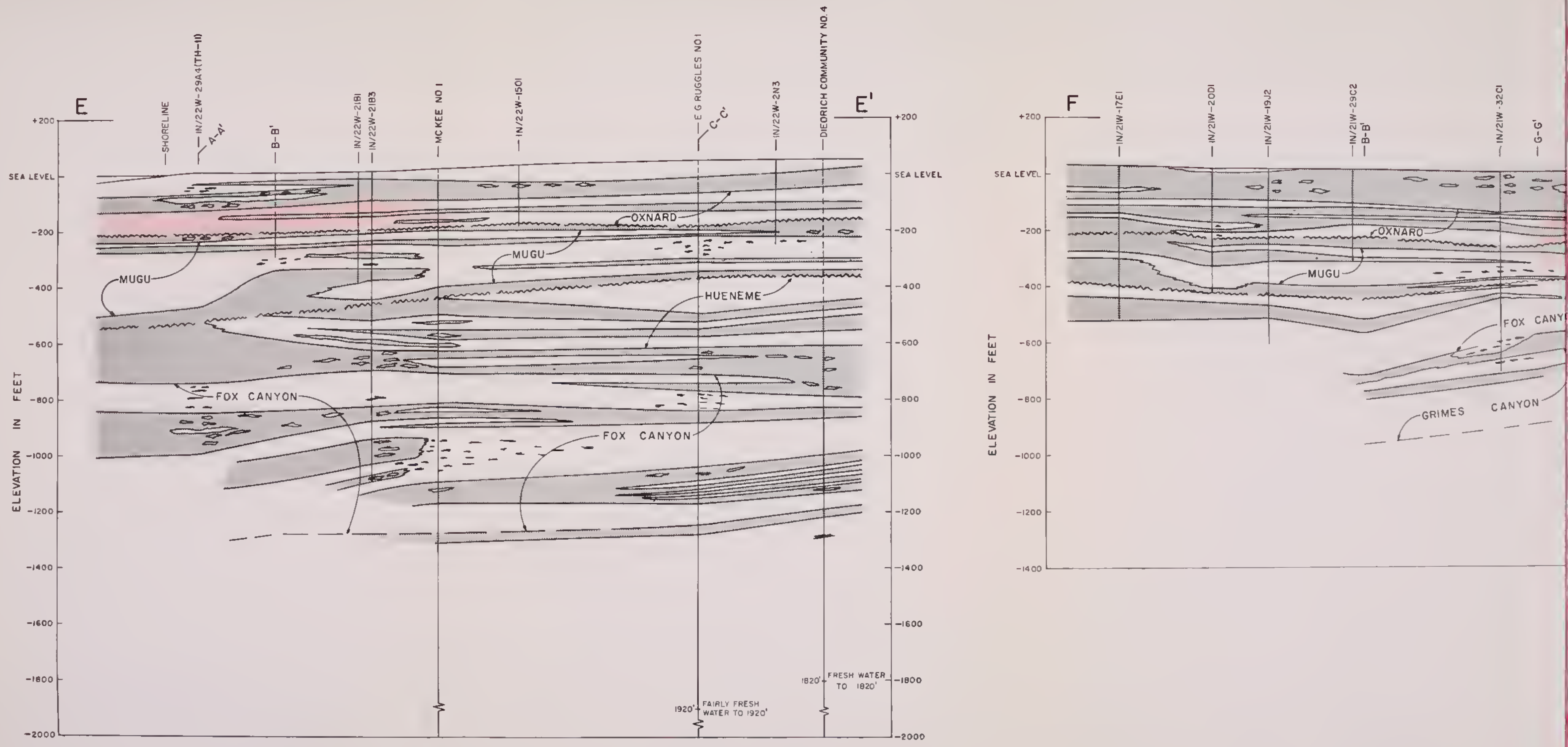
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

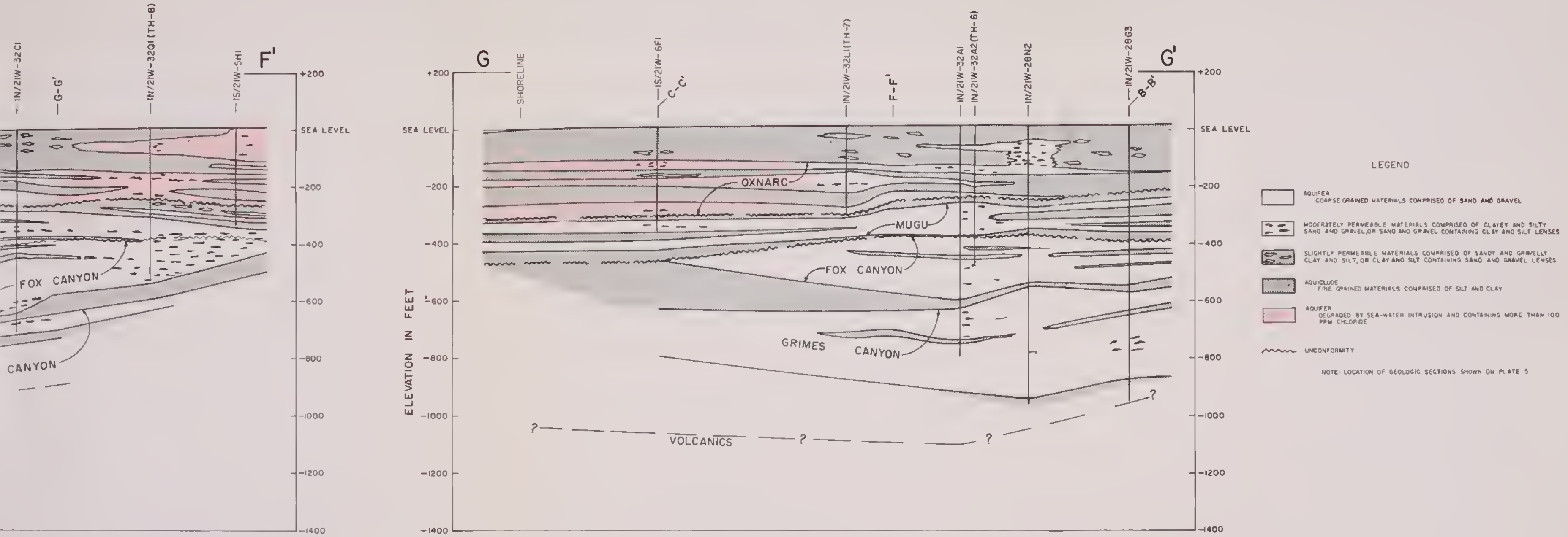
GEOLOGIC SECTIONS C-C' AND D-D'

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1965



E
E'
F
SHORELINE
IN/22W-29A4(TH-11)
A-A'
B-B'
IN/22W-21B1
IN/22W-21B3
MCKEE NO 1
IN/22W-15D1
E G RUGGLES NO 1
C-C'
IN/22W-2N3
DIEDRICH COMMUNITY NO.4
IN/21W-17E1
IN/21W-20D1
IN/21W-19J2
IN/21W-29C2
B-B'
IN/21W-32C1
G-G'
+200
SEA LEVEL
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-2000
ELEVATION IN FEET
OXNARD
MUGU
MUGU
HUENEME
FOX CANYON
FOX CANYON
GRIMES CANYON
1920'
FAIRLY FRESH WATER TO 1920'
1820'
FRESH WATER TO 1820'

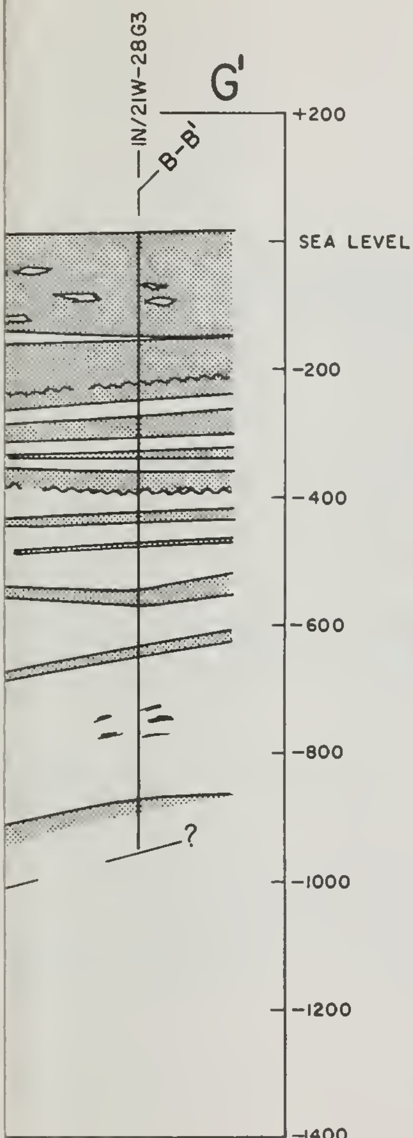


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

GEOLOGIC SECTIONS E-E', F-F' AND G-G'

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000



LEGEND

AQUIFER
COARSE GRAINED MATERIALS COMPRISED OF SAND AND GRAVEL

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AQUICLUDE
FINE GRAINED MATERIALS COMPRISED OF SILT AND CLAY

AQUIFER
DEGRADED BY SEA-WATER INTRUSION AND CONTAINING MORE THAN 100 PPM CHLORIDE

UNCONFORMITY

NOTE: LOCATION OF GEOLOGIC SECTIONS SHOWN ON PLATE 5

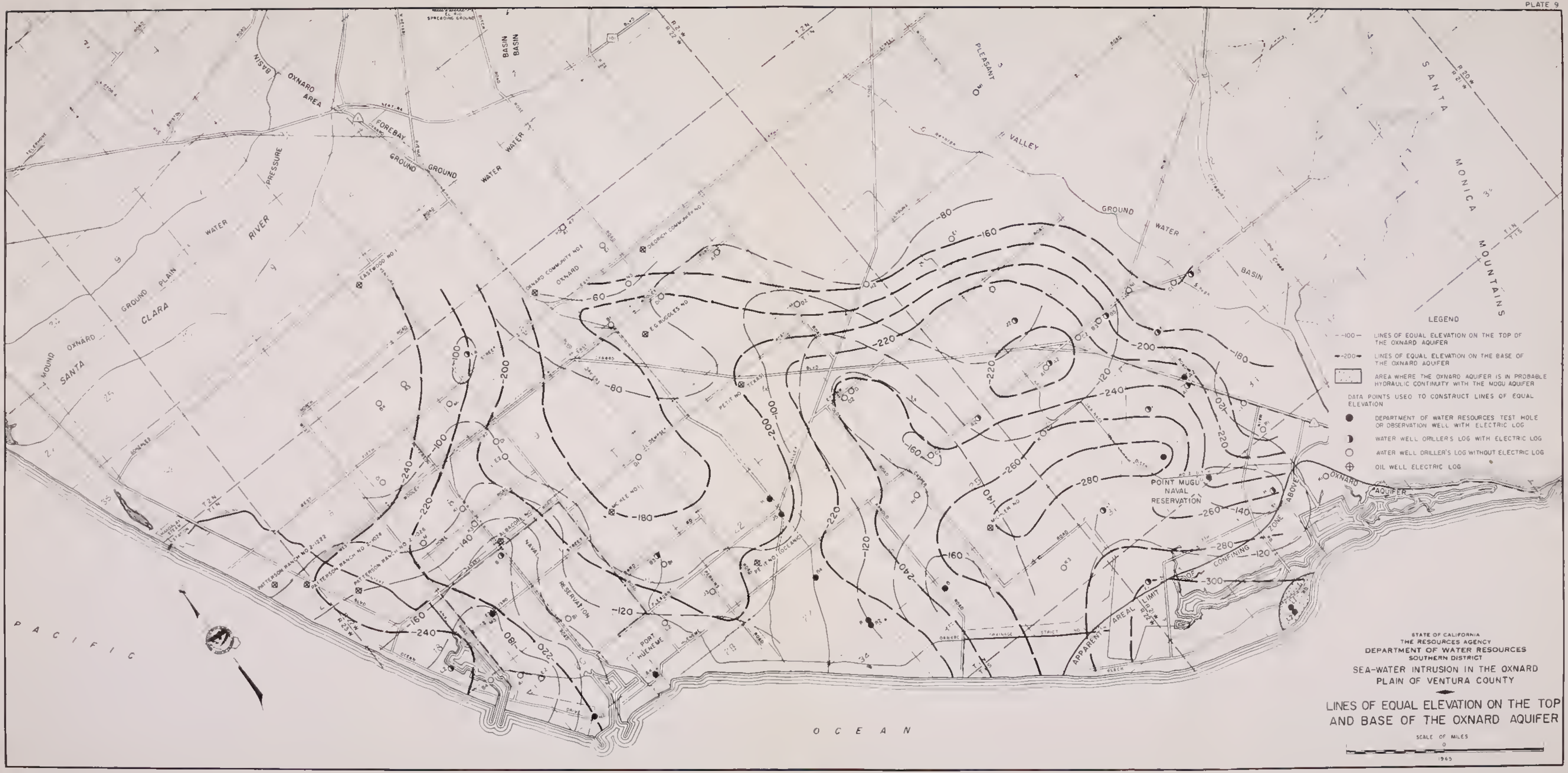
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

GEOLOGIC SECTIONS E-E', F-F' AND G-G'

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1965



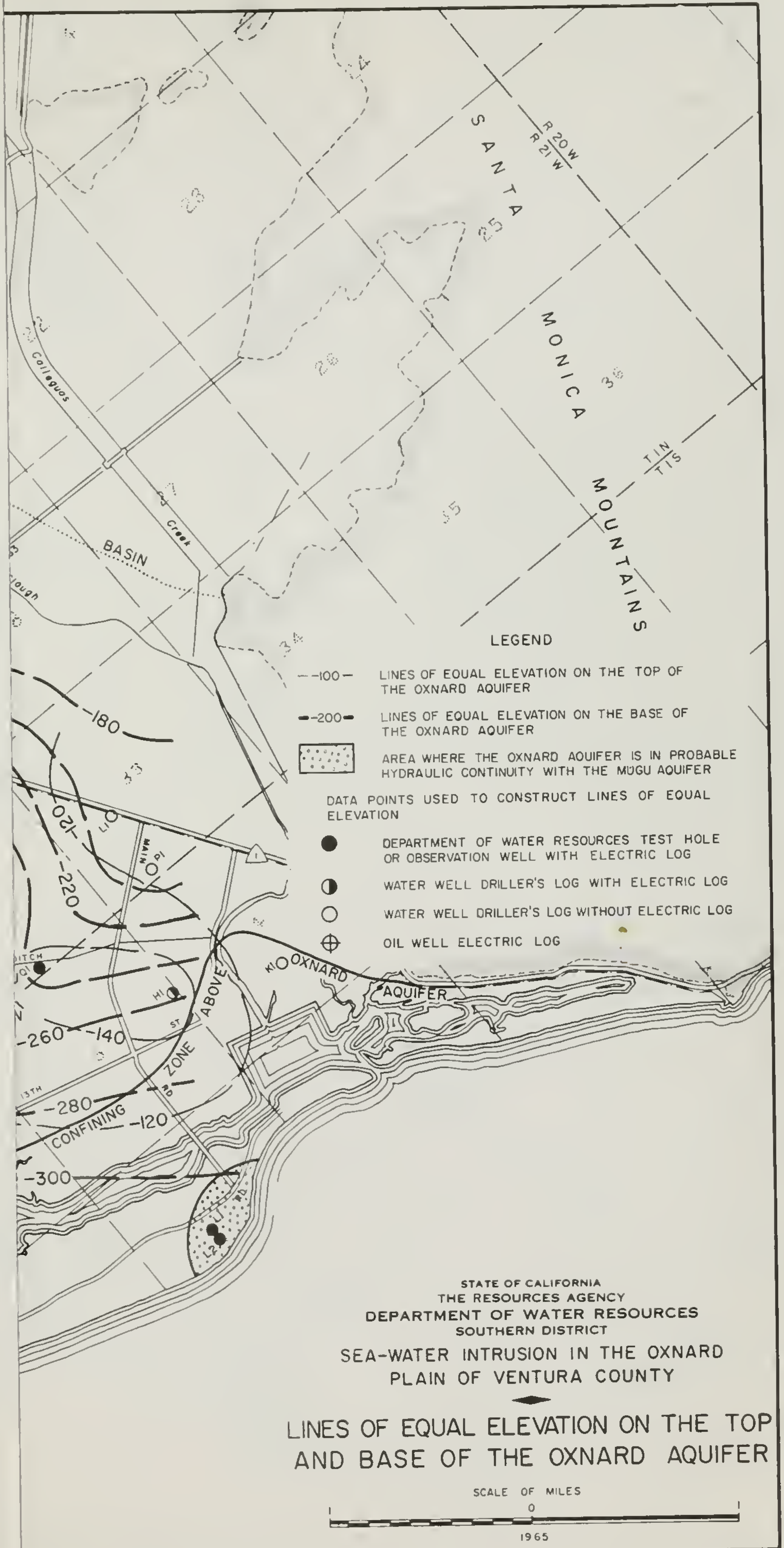
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

LINES OF EQUAL ELEVATION ON THE TOP AND BASE OF THE OXNARD AQUIFER

SCALE OF MILES

1965



LEGEND

--100-- LINES OF EQUAL ELEVATION ON THE TOP OF THE OXNARD AQUIFER

-200- LINES OF EQUAL ELEVATION ON THE BASE OF THE OXNARD AQUIFER

AREA WHERE THE OXNARD AQUIFER IS IN PROBABLE HYDRAULIC CONTINUITY WITH THE MUGU AQUIFER

DATA POINTS USED TO CONSTRUCT LINES OF EQUAL ELEVATION

● DEPARTMENT OF WATER RESOURCES TEST HOLE OR OBSERVATION WELL WITH ELECTRIC LOG

◑ WATER WELL DRILLER'S LOG WITH ELECTRIC LOG

○ WATER WELL DRILLER'S LOG WITHOUT ELECTRIC LOG

⊕ OIL WELL ELECTRIC LOG

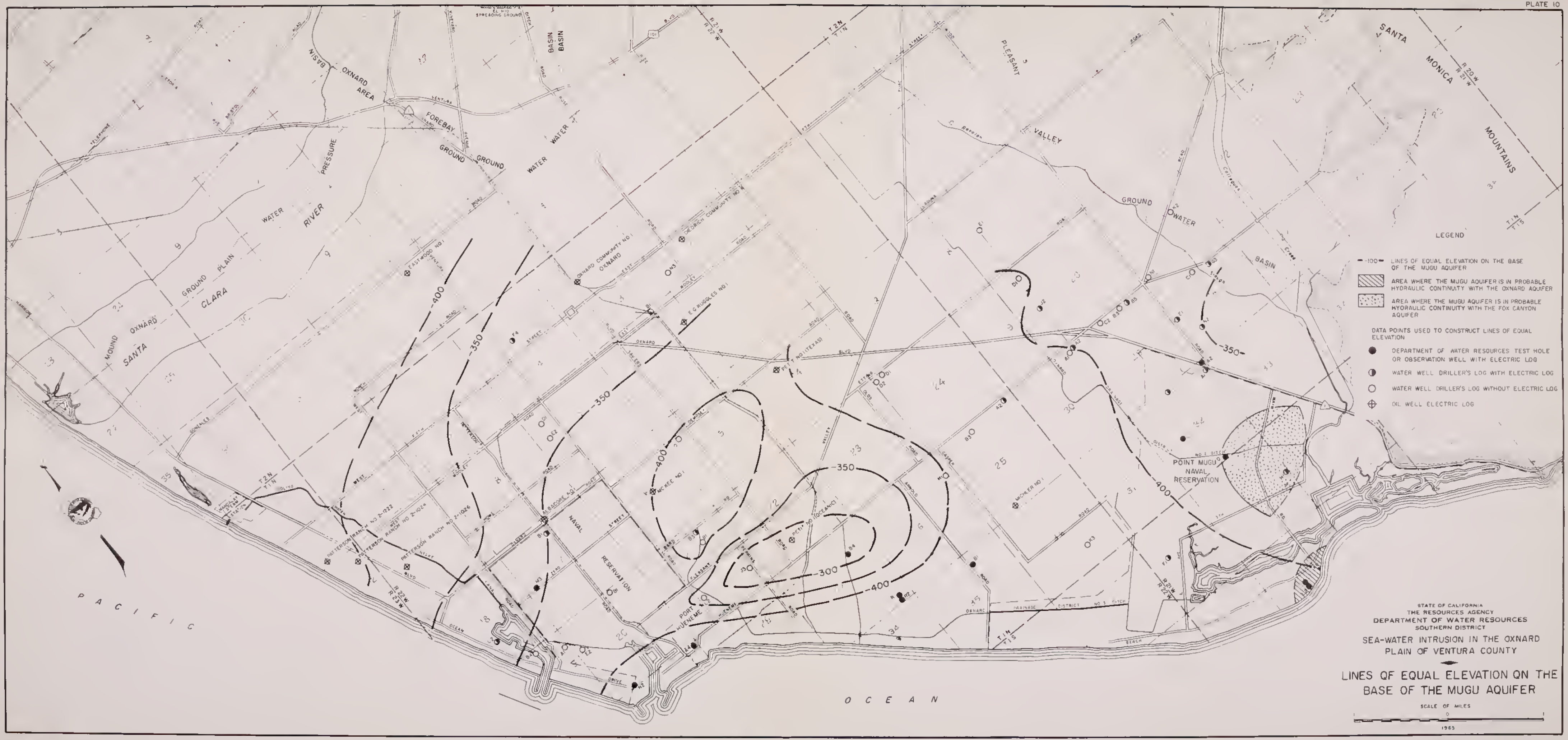
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

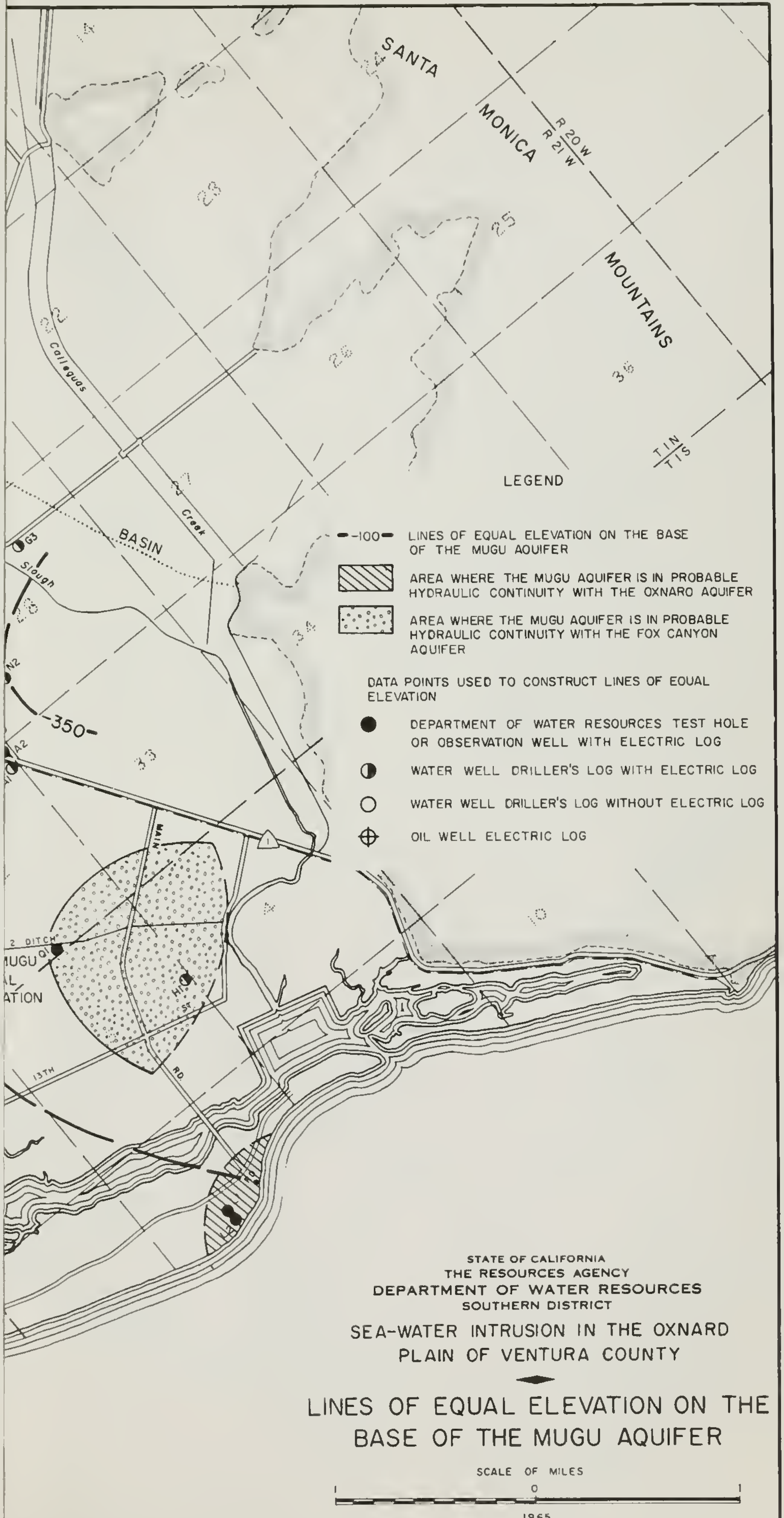
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

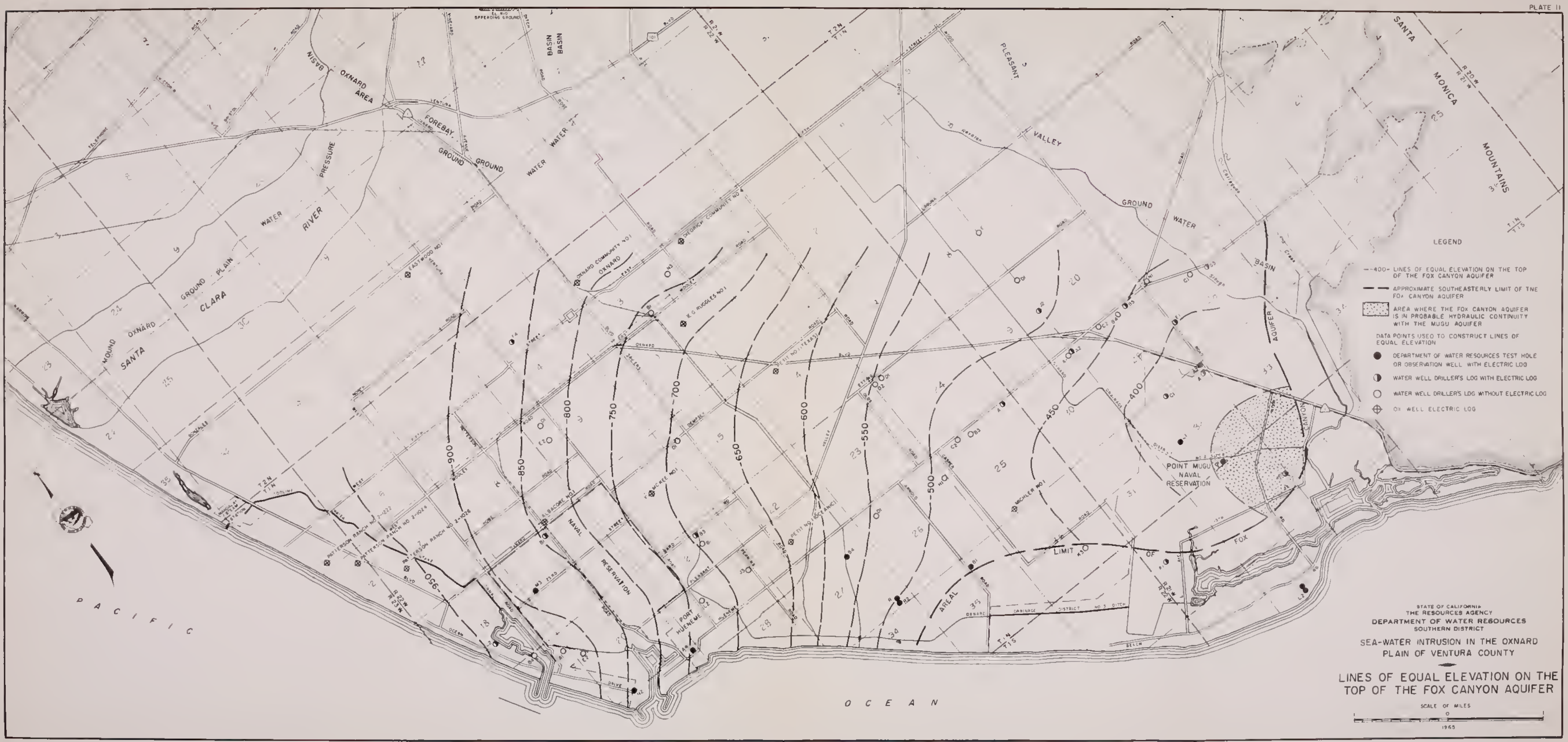
LINES OF EQUAL ELEVATION ON THE TOP AND BASE OF THE OXNARD AQUIFER

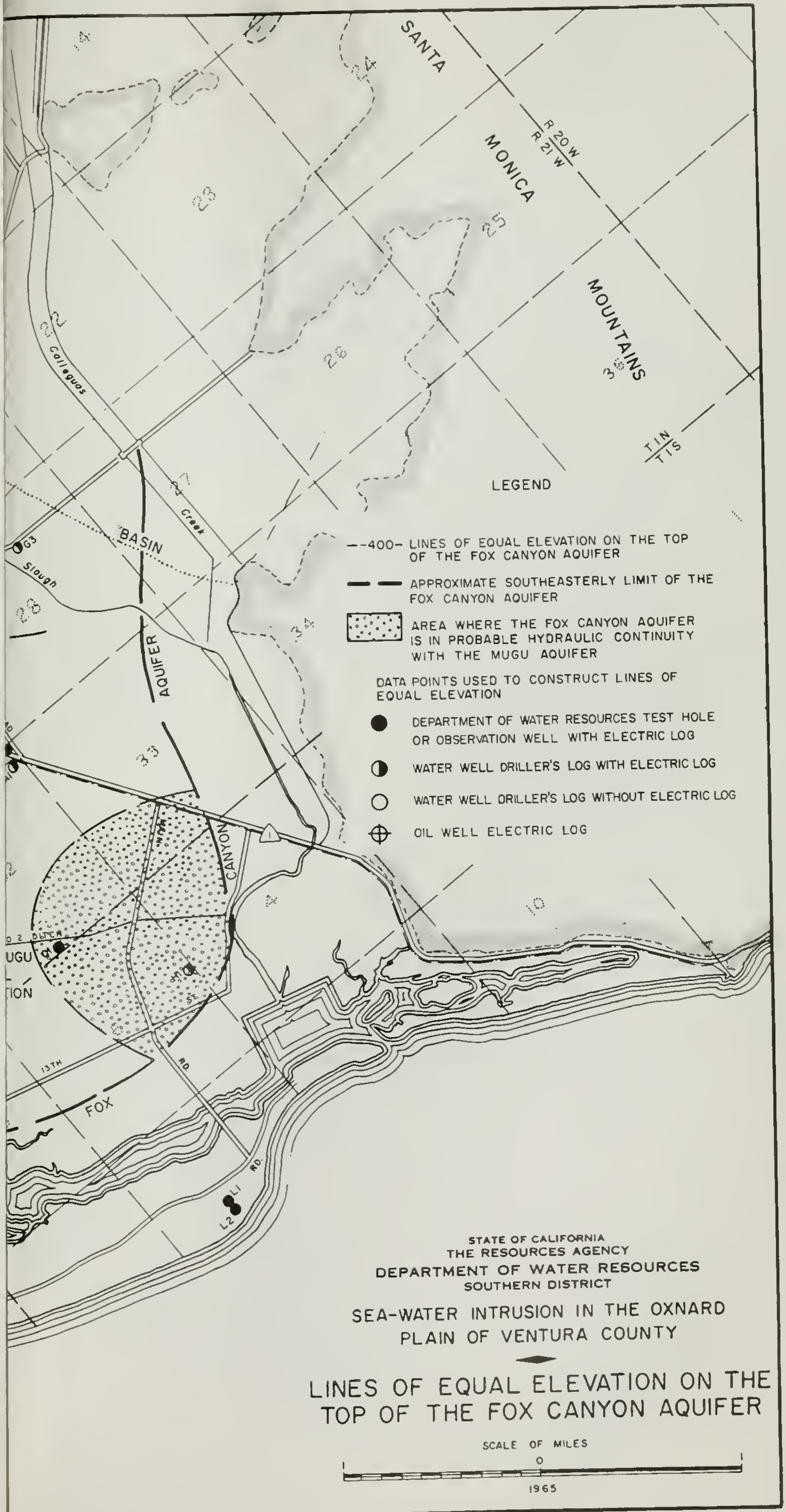
SCALE OF MILES
0 1

1965


LEGEND
-100 LINES OF EQUAL ELEVATION ON THE BASE OF THE MUGU AQUIFER
AREA WHERE THE MUGU AQUIFER IS IN PROBABLE HYDRAULIC CONTINUITY WITH THE OXNARD AQUIFER
AREA WHERE THE MUGU AQUIFER IS IN PROBABLE HYDRAULIC CONTINUITY WITH THE FOX CANYON AQUIFER
DATA POINTS USED TO CONSTRUCT LINES OF EQUAL ELEVATION
DEPARTMENT OF WATER RESOURCES TEST HOLE OR OBSERVATION WELL WITH ELECTRIC LOG
WATER WELL DRILLER'S LOG WITH ELECTRIC LOG
WATER WELL DRILLER'S LOG WITHOUT ELECTRIC LOG
OIL WELL ELECTRIC LOG
SANTA MONICA MOUNTAINS
PLEASANT VALLEY GROUND WATER BASIN
OXNARD PLAIN GROUND WATER BASIN
SANTA CLARA RIVER
OXNARD FOREBAY GROUND WATER BASIN
PRESSURE
MOUND
POINT MUGU NAVAL RESERVATION
PORT HUENEME
NAVAL RESERVATION
OXNARD
PACIFIC OCEAN
-400
-350
-300
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
LINES OF EQUAL ELEVATION ON THE BASE OF THE MUGU AQUIFER
SCALE OF MILES
1 0 1
1965


SANTA
MONICA
MOUNTAINS
R 20 W
R 21 W
T 1 N
T 1 S
Calleguas
Creek
BASIN
Slough
-350-
MAIN
DITCH
MUGU
ATION
HI
ST
13TH
RD
LEGEND
-100 LINES OF EQUAL ELEVATION ON THE BASE OF THE MUGU AQUIFER
AREA WHERE THE MUGU AQUIFER IS IN PROBABLE HYDRAULIC CONTINUITY WITH THE OXNARD AQUIFER
AREA WHERE THE MUGU AQUIFER IS IN PROBABLE HYDRAULIC CONTINUITY WITH THE FOX CANYON AQUIFER
DATA POINTS USED TO CONSTRUCT LINES OF EQUAL ELEVATION
DEPARTMENT OF WATER RESOURCES TEST HOLE OR OBSERVATION WELL WITH ELECTRIC LOG
WATER WELL DRILLER'S LOG WITH ELECTRIC LOG
WATER WELL DRILLER'S LOG WITHOUT ELECTRIC LOG
OIL WELL ELECTRIC LOG
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
LINES OF EQUAL ELEVATION ON THE BASE OF THE MUGU AQUIFER
SCALE OF MILES
1 0 1
1965


LEGEND
—400— LINES OF EQUAL ELEVATION ON THE TOP OF THE FOX CANYON AQUIFER
APPROXIMATE SOUTHEASTERLY LIMIT OF THE FOX CANYON AQUIFER
AREA WHERE THE FOX CANYON AQUIFER IS IN PROBABLE HYDRAULIC CONTINUITY WITH THE MUGU AQUIFER
DATA POINTS USED TO CONSTRUCT LINES OF EQUAL ELEVATION
DEPARTMENT OF WATER RESOURCES TEST HOLE OR OBSERVATION WELL WITH ELECTRIC LOG
WATER WELL DRILLER'S LOG WITH ELECTRIC LOG
WATER WELL DRILLER'S LOG WITHOUT ELECTRIC LOG
OIL WELL ELECTRIC LOG
PACIFIC
OCEAN
SANTA MONICA MOUNTAINS
PLEASANT VALLEY GROUND WATER BASIN
OXNARD FOREBAY GROUND WATER BASIN
SANTA CLARA RIVER
OXNARD PLAIN GROUND WATER PRESSURE AREA
MOUND
PORT HUENEME
NAVAL RESERVATION
POINT MUGU NAVAL RESERVATION
AREAL LIMIT OF FOX AQUIFER
-950-
-900-
-850-
-800-
-750-
-700-
-650-
-600-
-550-
-500-
-450-
-400-
OXNARD
EL RIO SPREADING GROUNDS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
LINES OF EQUAL ELEVATION ON THE TOP OF THE FOX CANYON AQUIFER
SCALE OF MILES
1965



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

LINES OF EQUAL ELEVATION ON THE TOP OF THE FOX CANYON AQUIFER

1965

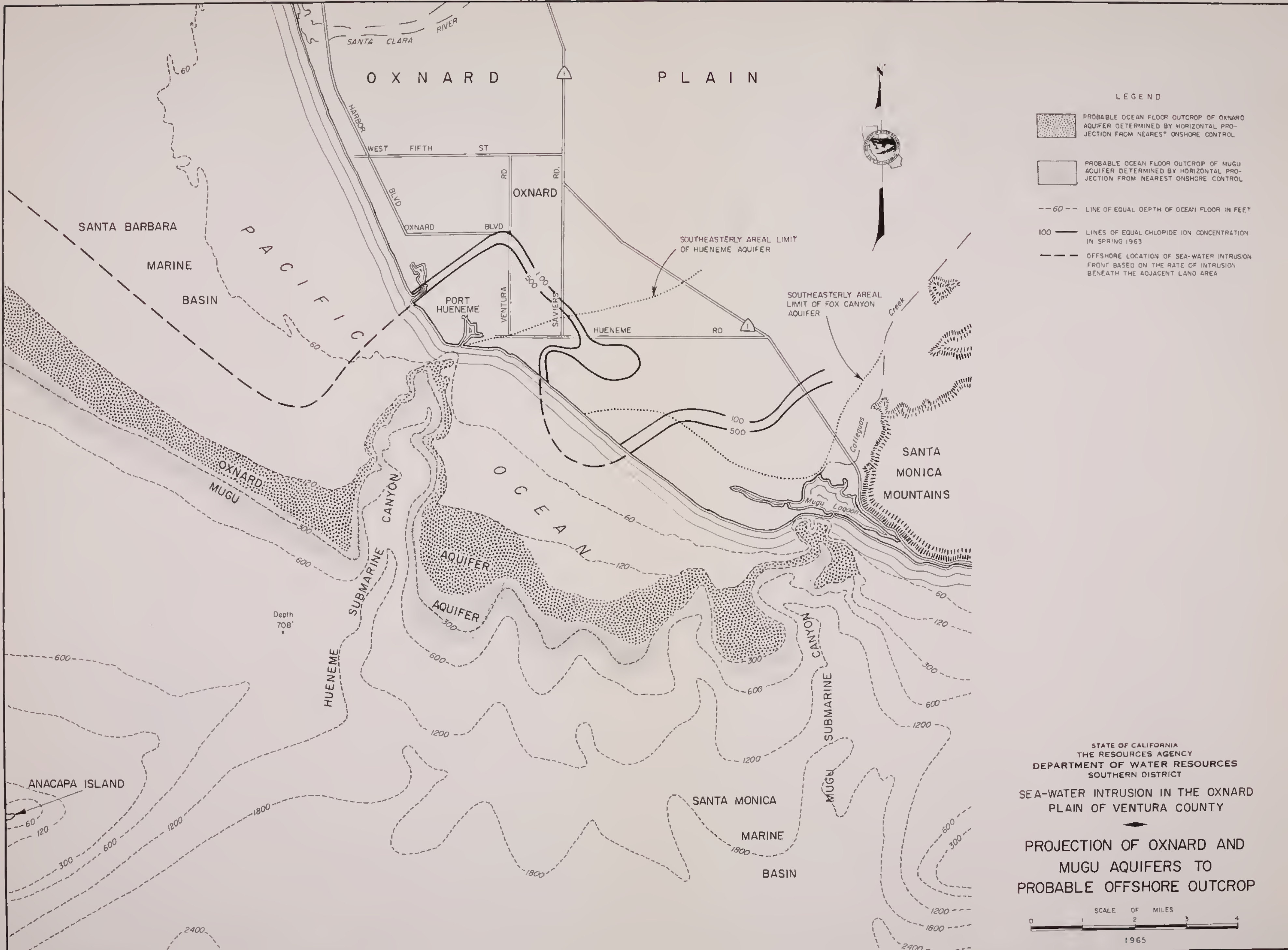
AGE	FORMATION	AQUIFER AND AQUICLUDE	MAXIMUM THICKNESS (FEET)	GENERALIZED LITHOLOGY AND GROUND WATER CHARACTERISTICS
RECENT	CHANNEL DEPOSITS DUNE SAND ALLUVIUM	SEMIPERCHED AQUIFER	160	FINE TO MEDIUM SAND AND GRAVEL. UNDEVELOPED BY WELLS. ACTIVE DEGRADATION BY BRACKISH RETURN IRRIGATION WATER.
	ALLUVIAL FLOOD PLAIN DEPOSITS	"CLAY CAP"	160	SILT AND CLAY WITH LENTICULAR FINE TO MEDIUM SAND INTERBEDS. RELATIVELY IMPERMEABLE. CONFINING MATERIAL ABOVE OXNARD AQUIFER.
		OXNARD AQUIFER	225	FINE TO COARSE SAND, FINE TO COARSE GRAVEL RANGING TO SIX INCHES IN DIAMETER. LOCALLY SEPARATED INTO TWO OR THREE ZONES BY SILT AND CLAY INTERBEDS. HIGHLY PERMEABLE. DEVELOPED BY NUMEROUS WELLS. PRINCIPAL AQUIFER BENEATH OXNARD PLAIN. ACTIVE DEGRADATION BY SALINE INTRUSION.
	DISCONFORMITY			
UPPER PLEISTOCENE	UPPER PLEISTOCENE ALLUVIAL FLOOD PLAIN DEPOSITS	AQUICLUDE	130	SILT AND CLAY. RELATIVELY IMPERMEABLE.
		MUGU AQUIFER	240	FINE TO COARSE SAND AND FINE GRAVEL. INTERBEDDED SILT AND CLAY. MODERATE TO HIGH PERMEABILITY. LOCALLY DEVELOPED BY WELLS. POSSIBLE DEGRADATION BY SALINE INTRUSION.
		AQUICLUDE	190	SILT AND CLAY. RELATIVELY IMPERMEABLE.
	UNCONFORMITY			
LOWER PLEISTOCENE	SAN PEDRO FORMATION	HUENEME AQUIFER	380	IRREGULARLY INTERBEDDED FINE TO COARSE SAND, SILT AND CLAY, NOT PRESENT SOUTH OF HUENEME ROAD. LOW TO MODERATE PERMEABILITY. DEVELOPED BY FEW WELLS. POTENTIALLY SUBJECT TO SALINE INTRUSION.
		AQUICLUDE	220	SILT AND CLAY. RELATIVELY IMPERMEABLE.
		FOX CANYON AQUIFER	580	FINE TO MEDIUM SAND AND THIN GRAVEL STRINGERS. INTERBEDDED SILT AND CLAY. MODERATE TO HIGH PERMEABILITY. DEVELOPED BY DEEP WELLS. PRINCIPAL LOWER PLEISTOCENE AQUIFER. POTENTIALLY SUBJECT TO SALINE INTRUSION.
		AQUICLUDE	40	SILT AND CLAY. RELATIVELY IMPERMEABLE.
	SANTA BARBARA FORMATION	GRIMES CANYON AQUIFER	1530	FINE TO COARSE SAND AND GRAVEL. UPPERMOST MEMBER OF THE FINE GRAINED SANTA BARBARA FORMATION. MODERATE TO HIGH PERMEABILITY. DEVELOPED BY FEW DEEP WELLS.

GENERALIZED STRATIGRAPHIC COLUMN OF WATER BEARING FORMATIONS—COASTAL OXNARD PLAIN

DEPARTMENT OF WATER RESOURCES 1965

ERALIZED LITHOLOGY AND GROUND WATER CHARACTERISTICS
M SAND AND GRAVEL. UNDEVELOPED BY WELLS. ACTIVE Y BRACKISH RETURN IRRIGATION WATER.
WITH LENTICULAR FINE TO MEDIUM SAND INTERBEDS. RELATIVELY CONFINING MATERIAL ABOVE OXNARD AQUIFER.
SE SAND, FINE TO COARSE GRAVEL RANGING TO SIX INCHES OCALLY SEPARATED INTO TWO OR THREE ZONES BY SILT AND CLAY GHLY PERMEABLE. DEVELOPED BY NUMEROUS WELLS. PRINCIPAL AQUIFER RD PLAIN. ACTIVE DEGRADATION BY SALINE INTRUSION.
RELATIVELY IMPERMEABLE.
E SAND AND FINE GRAVEL. INTERBEDDED SILT AND CLAY. MODERATE ABILITY. LOCALLY DEVELOPED BY WELLS. POSSIBLE DEGRADATION RUSION.
RELATIVELY IMPERMEABLE.
ITERBEDDED FINE TO COARSE SAND, SILT AND CLAY, NOT PRESENT NEME ROAD. LOW TO MODERATE PERMEABILITY. DEVELOPED BY FEW ALLY SUBJECT TO SALINE INTRUSION.
RELATIVELY IMPERMEABLE.
IM SAND AND THIN GRAVEL STRINGERS. INTERBEDDED SILT AND CLAY. HIGH PERMEABILITY. DEVELOPED BY DEEP WELLS. PRINCIPAL LOWER AQUIFER. POTENTIALLY SUBJECT TO SALINE INTRUSION.
RELATIVELY IMPERMEABLE.
SE SAND AND GRAVEL. UPPERMOST MEMBER OF THE FINE GRAINED A FORMATION. MODERATE TO HIGH PERMEABILITY. DEVELOPED BY LS.

HIC COLUMN OF
OASTAL OXNARD PLAIN


OXNARD PLAIN
SANTA CLARA RIVER
LEGEND
PROBABLE OCEAN FLOOR OUTCROP OF OXNARD AQUIFER DETERMINED BY HORIZONTAL PROJECTION FROM NEAREST ONSHORE CONTROL
PROBABLE OCEAN FLOOR OUTCROP OF MUGU AQUIFER DETERMINED BY HORIZONTAL PROJECTION FROM NEAREST ONSHORE CONTROL
60 LINE OF EQUAL DEPTH OF OCEAN FLOOR IN FEET
100 LINES OF EQUAL CHLORIDE ION CONCENTRATION IN SPRING 1963
OFFSHORE LOCATION OF SEA-WATER INTRUSION FRONT BASED ON THE RATE OF INTRUSION BENEATH THE ADJACENT LAND AREA
HARBOR BLVD
WEST FIFTH ST
OXNARD
OXNARD BLVD
VENTURA RD
SAVIERS RD.
HUENEME RD
PORT HUENEME
SOUTHEASTERLY AREAL LIMIT OF HUENEME AQUIFER
SOUTHEASTERLY AREAL LIMIT OF FOX CANYON AQUIFER
Calleguas Creek
Mugu Lagoon
SANTA MONICA MOUNTAINS
SANTA BARBARA MARINE BASIN
PACIFIC OCEAN
OXNARD
MUGU
HUENEME SUBMARINE CANYON
AQUIFER
AQUIFER
MUGU SUBMARINE CANYON
Depth 708'
SANTA MONICA MARINE BASIN
ANACAPA ISLAND
60
120
300
600
1200
1800
2400
100
500
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
PROJECTION OF OXNARD AND MUGU AQUIFERS TO PROBABLE OFFSHORE OUTCROP
SCALE OF MILES
0 1 2 3 4
1965

LEGEND

PROBABLE OCEAN FLOOR OUTCROP OF OXNARD AQUIFER DETERMINED BY HORIZONTAL PROJECTION FROM NEAREST ONSHORE CONTROL

PROBABLE OCEAN FLOOR OUTCROP OF MUGU AQUIFER DETERMINED BY HORIZONTAL PROJECTION FROM NEAREST ONSHORE CONTROL

--60-- LINE OF EQUAL DEPTH OF OCEAN FLOOR IN FEET

100 —— LINES OF EQUAL CHLORIDE ION CONCENTRATION IN SPRING 1963

— — — OFFSHORE LOCATION OF SEA-WATER INTRUSION FRONT BASED ON THE RATE OF INTRUSION BENEATH THE ADJACENT LAND AREA

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

PROJECTION OF OXNARD AND MUGU AQUIFERS TO PROBABLE OFFSHORE OUTCROP

SCALE OF MILES

0 1 2 3 4

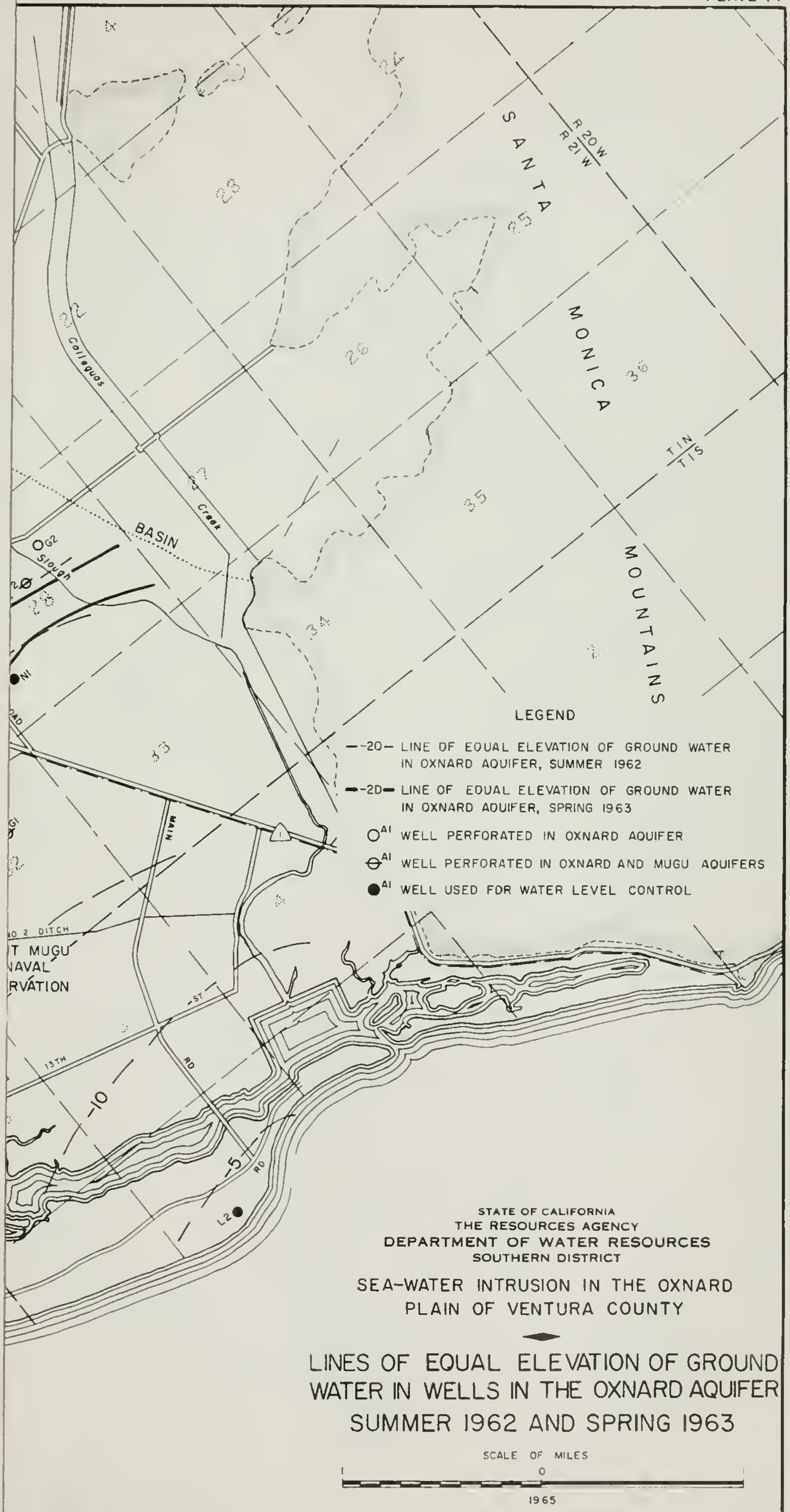
1965

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS IN THE OXNARD AQUIFER SUMMER 1962 AND SPRING 1963

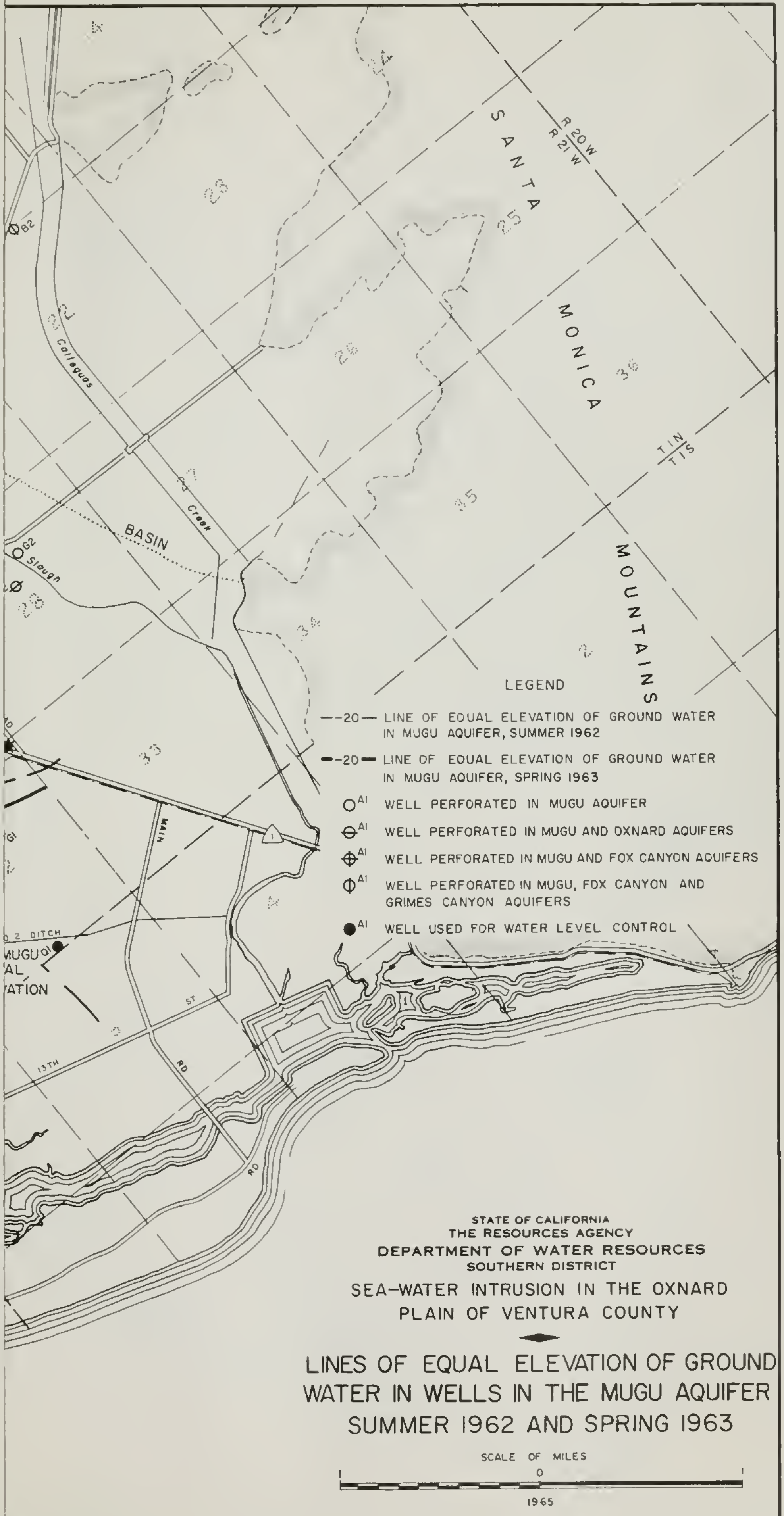
PLATE 14


SANTA MONICA MOUNTAINS
R 20 W
R 21 W
T 1 N
T 1 S
Calleguas Creek
BASIN
Slough
MAIN
NO 2 DITCH
PT MUGU NAVAL RESERVATION
13TH
ST
RD
-10
-5
-20
G2
N1
G1
L2
LEGEND
—-20— LINE OF EQUAL ELEVATION OF GROUND WATER IN OXNARD AQUIFER, SUMMER 1962
▬-20▬ LINE OF EQUAL ELEVATION OF GROUND WATER IN OXNARD AQUIFER, SPRING 1963
O A1 WELL PERFORATED IN OXNARD AQUIFER
⊖ A1 WELL PERFORATED IN OXNARD AND MUGU AQUIFERS
● A1 WELL USED FOR WATER LEVEL CONTROL
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS IN THE OXNARD AQUIFER SUMMER 1962 AND SPRING 1963
SCALE OF MILES
0
1965

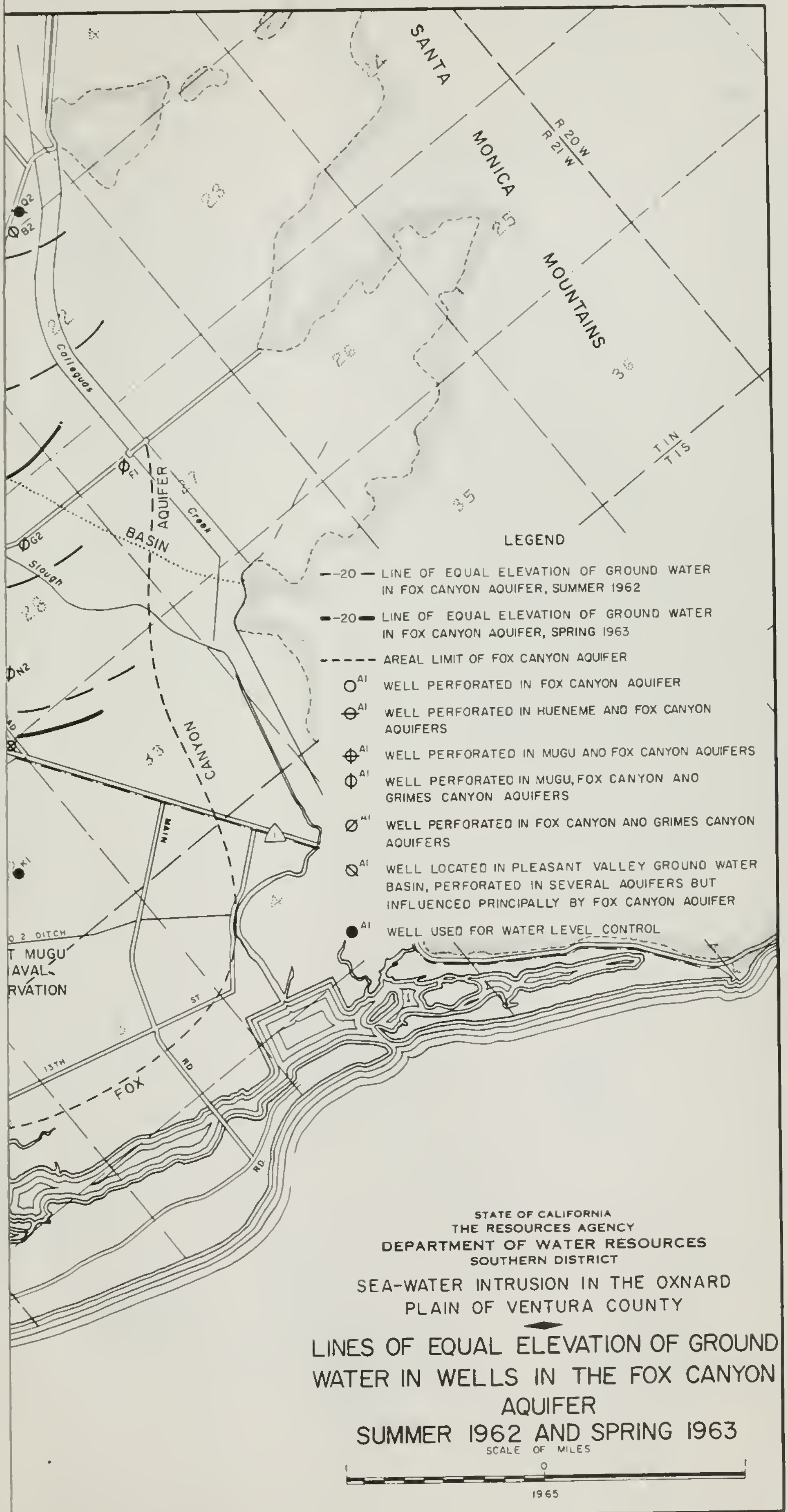
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS IN THE MUGU AQUIFER SUMMER 1962 AND SPRING 1963


SANTA
MONICA
MOUNTAINS
R 20 W
R 21 W
T 1 N
T 1 S
BASIN
Calleguas
Creek
Slough
MAIN
ST
13TH
RD
RD
2 DITCH
MUGU
AL
ATION
23
25
26
35
36
27
28
34
33
2
LEGEND
—20— LINE OF EQUAL ELEVATION OF GROUND WATER IN MUGU AQUIFER, SUMMER 1962
—20— LINE OF EQUAL ELEVATION OF GROUND WATER IN MUGU AQUIFER, SPRING 1963
A1 WELL PERFORATED IN MUGU AQUIFER
A1 WELL PERFORATED IN MUGU AND OXNARD AQUIFERS
A1 WELL PERFORATED IN MUGU AND FOX CANYON AQUIFERS
A1 WELL PERFORATED IN MUGU, FOX CANYON AND GRIMES CANYON AQUIFERS
A1 WELL USED FOR WATER LEVEL CONTROL
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS IN THE MUGU AQUIFER SUMMER 1962 AND SPRING 1963
SCALE OF MILES
1 0 1
1965


LEGEND
LINE OF EQUAL ELEVATION OF GROUND WATER IN FOX CANYON AQUIFER, SUMMER 1962
LINE OF EQUAL ELEVATION OF GROUND WATER IN FOX CANYON AQUIFER, SPRING 1963
AREAL LIMIT OF FOX CANYON AQUIFER
WELL PERFORATED IN FOX CANYON AQUIFER
WELL PERFORATED IN HUENEME AND FOX CANYON AQUIFERS
WELL PERFORATED IN MUGU AND FOX CANYON AQUIFERS
WELL PERFORATED IN MUGU, FOX CANYON AND GRIMES CANYON AQUIFERS
WELL PERFORATED IN FOX CANYON AND GRIMES CANYON AQUIFERS
WELL LOCATED IN PLEASANT VALLEY GROUND WATER BASIN, PERFORATED IN SEVERAL AQUIFERS BUT INFLUENCED PRINCIPALLY BY FOX CANYON AQUIFER
WELL USED FOR WATER LEVEL CONTROL
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS IN THE FOX CANYON AQUIFER
SUMMER 1962 AND SPRING 1963
SCALE OF MILES
1965
SANTA MONICA MOUNTAINS
PLEASANT VALLEY GROUND WATER BASIN
OXNARD FOREBAY GROUND WATER BASIN
OXNARD PLAIN PRESSURE GROUND WATER BASIN
SANTA CLARA RIVER
MOUND
NAVAL RESERVATION
PORT HUENEME
POINT MUGU NAVAL RESERVATION
AREAL LIMIT OF FOX CANYON AQUIFER
OXNARD
PACIFIC OCEAN
EL RIO SPREADING GROUND
T2N
T1N
T1S
R22W
R23W
R21W
R20W



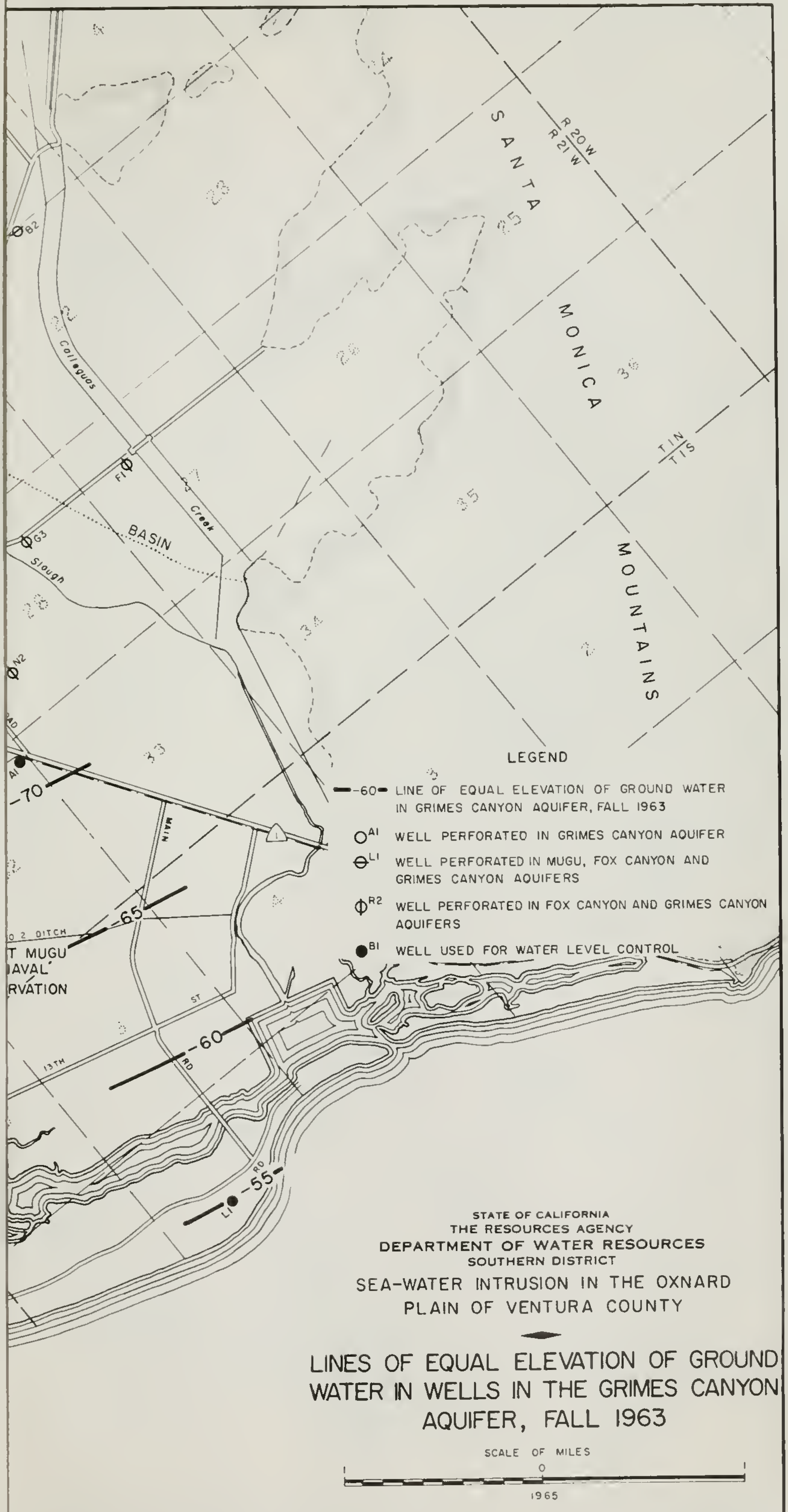
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY

LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS IN THE FOX CANYON AQUIFER
SUMMER 1962 AND SPRING 1963

PLATE 17


LEGEND
-60- LINE OF EQUAL ELEVATION OF GROUND WATER IN GRIMES CANYON AQUIFER, FALL 1963
WELL PERFORATED IN GRIMES CANYON AQUIFER
WELL PERFORATED IN MUGU, FOX CANYON AND GRIMES CANYON AQUIFERS
WELL PERFORATED IN FOX CANYON AND GRIMES CANYON AQUIFERS
WELL USED FOR WATER LEVEL CONTROL
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS IN THE GRIMES CANYON AQUIFER, FALL 1963
SCALE OF MILES
1965
PACIFIC
OCEAN
OXNARD FOREBAY GROUND WATER BASIN
OXNARD PLAIN PRESSURE GROUND WATER BASIN
PLEASANT VALLEY GROUND WATER BASIN
SANTA CLARA RIVER
MOUND
SANTA MONICA MOUNTAINS
POINT MUGU NAVAL RESERVATION
NAVAL RESERVATION
PORT HUENEME
OXNARD
-70
-65
-60
-55
T2N
T1N
T1S
R22W
R23W
R21W
R20W



SANTA MONICA MOUNTAINS
R 20 W
R 21 W
T 1 N
T 1 S
Calleguas Creek
BASIN
Slough
MAIN
ST
13TH
RD
2 DITCH
T MUGU
IAVAL
RVATION
-70
-65
-60
-55
LEGEND
-60 LINE OF EQUAL ELEVATION OF GROUND WATER IN GRIMES CANYON AQUIFER, FALL 1963
A1 WELL PERFORATED IN GRIMES CANYON AQUIFER
L1 WELL PERFORATED IN MUGU, FOX CANYON AND GRIMES CANYON AQUIFERS
R2 WELL PERFORATED IN FOX CANYON AND GRIMES CANYON AQUIFERS
B1 WELL USED FOR WATER LEVEL CONTROL
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SEA-WATER INTRUSION IN THE OXNARD PLAIN OF VENTURA COUNTY
LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS IN THE GRIMES CANYON AQUIFER, FALL 1963
SCALE OF MILES
0
1965