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COMPILATION OF TECHNICAL INFORMATION RECORDS FOR THE
VENTURA COUNTY COOPERATIVE INVESTIGATION

-Prepared by-

VENTURA COUNTY PUBLIC WORKS AGENCY

Flood Control and Drainage Department

As Part of Its Contribution

VOLUME I

July 1975

FOREWORD

During the Cooperative Water Resources Management Investigation of Ventura County, numerous Technical Information Records were prepared presenting detailed technical data as each phase of study was completed. Review was limited to consideration of technical aspects by the writer's immediate supervisors. Hence, they are preliminary.

These data are extremely valuable to those who conduct water resources investigations. The Technical Information Records were, therefore, compiled to be distributed to the members of the Technical Coordinating Committee for the investigation so that they may make full and early use of the data developed.

The compilation of the Technical Information Records was divided into two volumes. Volume I contains geologic studies and Volume II contains hydrologic, operational, and economic studies.

The data are too detailed for wide dissemination. Thus, they will not be included in Bulletin No. 104-8 that summarizes the results of the investigation. Finalized data will be kept in the DWR files.

Jack J. Coe
Jack J. Coe, Chief
Southern District

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VENTURA COUNTY DEPARTMENT OF PUBLIC WORKS
FLOOD CONTROL DISTRICT

VENTURA COUNTY WATER RESOURCES MANAGEMENT STUDY
GEOLOGIC FORMATIONS, STRUCTURES AND HISTORY
IN THE SANTA CLARA-CALLEGUAS AREA

By

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This Technical Information Record was prepared to document pertinent information as it was developed during the Ventura County Water Resources Management Investigation.

January 1975

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INTRODUCTION

The purpose of this study was to supply updated geologic and geohydrologic information for mathematical modeling studies of water quantity and quality in the Santa Clara-Calleguas area of Ventura County.

This report includes: 1) a brief description of the composition and general water-bearing characteristics of geologic formations; 2) a discussion of the effects of various geologic structures upon the occurrence and movement of ground water; and 3) a description of the history of major geologic events.

During this portion of the investigation, information developed in numerous previous studies was reviewed. The area of investigation has been intensively mapped and studied primarily because of the large quantities of oil and gas available here. In addition, numerous water resources studies have previously been conducted by State and local agencies. As a result, this portion of the investigation was largely restricted to a review of available literature.

The geologic map selected for use in this study is from Bulletin 12, "Ventura County Investigation". It has been modified to reflect additional knowledge accumulated since its original publication.

GEOLOGIC FORMATIONS

Geologic formations within the study area consist of sedimentary and volcanic rocks ranging from upper Cretaceous to Recent in age. Geologic units and their role in the geohydrology are briefly described in ascending order of geologic age.

The distribution and areal extent of formations and their stratigraphic relationship are shown on geologic maps (Plates 1 and 2) and stratigraphic column (Figure 1), respectively.

CRETACEOUS SYSTEM

Upper Cretaceous marine formations are exposed in the Simi Hills and Santa Susana Mountains where they reach a maximum thickness of 5,500 feet. They are composed mostly of fine- to coarse-grained arkosic sandstone which is brown to tan, medium-bedded to massive, locally cross-bedded and locally calcareous and well-indurated. Contained within the sandstone are one-inch to twenty-foot thick interbeds of gray to black marine siltstone, claystone and shale, with local pebble conglomerate lenses. Areas which are composed predominantly of sandstone form characteristic homoclinal strike ridges with very steep, step like, anti-dip slopes and moderately inclined dip slopes. This rugged distinctive cuesta topography is most impressive in the Simi Hills. Outcrops are blocky where well developed joint sets are present.

The fine-grained section in Bell Canyon and the poorly indurated sandstone member in the Thousand Oaks area erode to gentle slopes with occasional steep gullies.

Upper Cretaceous rocks are generally nonwater-bearing. However, in the hills south and east of the Simi Valley, water wells obtain domestic and limited irrigation supplies of good quality water from the massive, poorly cemented and fractured sandstones.

PALEOCENE-EOCENE SERIES

Several formations are included in this series. The Santa Susana-Martinez formation of Paleocene to middle and lower Eocene age is exposed in the Simi Hills and consists of up to 3,500 feet of lightly colored sandstone, some interbedded shale and a massive basal conglomerate.

The upper and lower Llajas formations are exposed in the Simi Hills and are of middle Eocene age. The lower Llajas formation consists of about 2,000 to 3,000 feet of olive drab and blue shale with minor interbedded sandstone, and a basal conglomerate. The upper Llajas formation consists of about 2,000 feet of brown to gray micaceous sandstone, siltstone, with some conglomerate.

Shales of the Paleocene-Eocene series are generally well indurated and the sandstones are fairly well cemented. The entire series generally forms rugged topography with thin sandy soils. Sandstone beds form particularly massive outcrops and very rugged topography. Rocks of this series are highly fractured, faulted and folded.

OLIGOCENE SERIES

In most of the study area the Oligocene series is called the Sespe formation; however, in the eastern Santa Clara River drainage area, it has been named the Vasquez formation. The Sespe formation varies in thickness from 1,200 to 7,300 feet and ranges in age from upper Eocene to lower Miocene. The Vasquez formation is of Oligocene and lower Miocene age and is up to 9,000 feet thick with about 4,000 feet of interbedded basaltic flows near its base.

The Oligocene series consists of continental lenticular interbedded conglomerates, sandstones and shales. The sandstones are poorly to well cemented and generally buff to gray in color. The conglomerates generally contain granitic, metamorphic, sandstone, and chert pebbles and cobbles in a matrix of sandstone or siltstone. The siltstones and shales are generally micaceous and red, maroon, blue, or gray in color. The formations generally weather into red sandy clay soils, which characterize outcrop areas of the series. Resistant units, particularly in the eastern portion of the County, form steep rugged slopes, whereas fine-grained and poorly indurated units are recognized by moderately subdued topography with many hundreds of feet of local relief.

The Oligocene series is locally water-bearing. Sandstones in the Simi Valley area usually yield from 10 to 100 gallons per minute to wells. One well in the sandstones northwest of Simi Valley yields up to 700 gallons per minute. Wells deeper than 400 or 500 feet generally obtain brackish water unsuitable for irrigation.

MIOCENE SERIES

The Miocene series consists of marine formations and volcanic rocks.

MARINE FORMATIONS

Sediments deposited under marine conditions include the Vaqueros, Rincon, Topanga, Modelo, and Santa Margarita formations.

The Vaqueros formation of lower Miocene age consists of 100 to 1,800 feet of gray to brown marine sandstone and shale. In the southwestern part of the Santa Monica Mountains this formation consists of black calcareous shale with minor sandstone beds. It is included with the Topanga formation on the geologic map in this report because of extreme geologic complexity. The Vaqueros formation forms prominent ledges, ridge caps and steep rugged slopes with tens to hundreds of feet of local relief.

The Rincon formation consists of over 2,000 feet of dark gray to brown concretionary shale and is exposed only north of the Santa Clara River.

The Topanga formation is mapped only in the Santa Monica Mountain area. It is possible that it is the equivalent of the Vaqueros formation. This formation is mostly black or gray shale in the area southwest of Boney Mountain. It is composed of sandstone, conglomerate and brown shale in the Conejo Valley area, and grades into sandstone and conglomerate in the easternmost portion of the area shown on the geologic map (Plate 2). The

Topanga formation is closely associated with volcanic rocks. Sediments of the Topanga formation have an aggregate thickness of 6,000 to 9,000 feet, while the intercalated volcanic rocks have a maximum aggregate thickness of about 13,000 feet. The Topanga formation is unconformably overlain by the Modelo sandstone and shale. The Topanga formation forms valleys and rounded hills with very steep rugged slopes tens to hundreds of feet in local relief.

The Modelo formation is of variable lithology, but has been subdivided into sandstone and shale by Kew (1924). This subdivision was followed during preparation of Plates 1 and 2. The thickness of the Modelo formation reaches 6,500 feet. The sandstones of the formation are generally light gray to tan, fine to medium grained, and contain interbedded clayey shales, and conglomerates. The shales of the Modelo formation generally consist of laminated diatomaceous and cherty and clayey shales with minor interbedded sandstones and conglomerates. Ridges and peaks are developed where the sandstones outcrop. Shale and siltstone commonly form hills with rolling crests and moderately steep to gentle slopes. Areas underlain by dense siliceous shale develop numerous resistant ridges and steep-sided canyons with substantial amounts of local relief.

The Santa Margarita formation includes up to 2,000 feet of tan, silty, diatomaceous shales and sandstones of uppermost Miocene age exposed in the Simi Hills and Santa Susana Mountains. In the Tierra Rejada area, this formation consists of 300 to 1,000 feet of conglomerate and sandstone with rounded pebbles and sand

grains composed mainly of dark volcanic rocks, interbedded with bentonitic clay, silt and tuff. The Santa Margarita formation locally contains marine fossils. These volcanic sandstones and conglomerates constitute the principal aquifer system in the Tierra Rejada Basin.

VOLCANIC ROCKS

Volcanic rocks, mostly of Miocene age and closely associated with the Topanga formation occur in the Santa Monica Mountains. These are collectively named the Conejo Volcanics and consist of up to 13,000 feet of pyroclastic rocks and basaltic flows. The pyroclastic rocks include agglomerates, mud flows and rhyolitic rocks. Fossiliferous marine shales, sandstones and conglomerates are interbedded with volcanic flows from place to place. Andesitic and basaltic dikes, sills and plugs intrude volcanic agglomerates and flows and the associated Topanga sediments. The volcanic rocks are highly faulted and fractured and moderately folded. They generally form rugged terrain with steep, rough slopes, and V-shaped canyons which exhibit hundreds to thousands of feet of local relief.

Most of the Miocene marine formations are essentially nonwater-bearing. However, Miocene marine formations and volcanic rocks in the Santa Monica Mountains constitute important water-bearing formations for domestic, stock and limited irrigation uses. The yield of water from wells ranges from zero to several hundred gallons per minute. Ground water derived

from the Santa Margarita formation and volcanic rocks is generally of magnesium-calcium bicarbonate character and of acceptable quality for most beneficial uses.

PLIOCENE SERIES

Formations of Pliocene age include the Pico and Saugus. The Pico formation consists of marine gray sandstone, blue gray shale and lenticular conglomerate. These materials weather to a dull brown silty clay soil. Landslides are common where these formations are prominent. The Pico formation is generally conformable with underlying and overlying formations in the study area except in the Las Posas Valley. It varies in thickness from 12,000 feet in the Ventura area to zero in the eastern part of Las Posas Valley. In the Ventura area, the Modelo, Pico and Santa Barbara formations are conformable and interfinger.

The contact between the Pico and Saugus formations in the Saugus-Castaic area of Los Angeles County transgresses time so that the lower part of the Saugus formation near the town of Saugus is the age equivalent of the upper portion of the Pico formation to the west. The Saugus formation consists of up to 2,500 feet of non-marine brown sand, slightly cemented gravel and gray or tan clay.

The Pico formation generally forms rounded, subdued topography with locally steep cliffs and landslide topography. The Pico formation is generally nonwater-bearing or yields highly saline water to wells. Some water wells in the Los Angeles County

portion of the Santa Clara River drainage area obtain water from the permeable sands and gravels of the Saugus formation.

Surface water from Pliocene formations is generally a sodium sulfate type with a total dissolved solids concentration of from 400 to over 2,000 milligrams per liter.

LOWER PLEISTOCENE SERIES

The Santa Barbara and San Pedro formations of the lower Pleistocene series form some of the most important water-bearing units in Ventura County.

SANTA BARBARA FORMATION

The Santa Barbara formation was deposited during upper Pliocene and lower Pleistocene time. The thickness and lithology of the formation varies considerably from place to place from about 4,000 feet of mudstone, shale, and minor sandstone near the City of Ventura to about 800 feet of sand and minor clay in the southern portion of the Oxnard Plain. Most of the clays and shales are blue in color when fresh, and contain plant remains and foraminiferal fauna. The slightly cemented buff colored gravels and sands on Oak Ridge referred to in Bulletin 12 as the Grimes Canyon member of the Santa Barbara formation extend southwestward under much of the Las Posas Valley and into Pleasant Valley where they become mostly fine to medium sand. The foraminifera found in the Santa Barbara formation in the Hall Canyon area indicate deposition at depths ranging from 125 to 900 feet below sea level, while the lithology of the Grimes Canyon member near Grimes Canyon indicates beach or littoral conditions of deposition. The lithology and fossils indicate that the present area

of the Santa Clara River Valley was under quite deep water during deposition of sediments which form the Santa Barbara formation. At this time, a fluctuating shoreline extended from near the Santa Monica Mountains through Moorpark and eastward through the Tapo Canyon area resulting in deposition of coarse grained materials at these locations. The northerly extension of the ancient shoreline is now concealed by structure or destroyed by erosion.

The Santa Barbara formation generally forms low rounded hills; however, locally, steep-sided canyons and gullies with tens to hundreds of feet of relief are found.

The Santa Barbara formation is of low permeability or contains water of poor quality in the Santa Clara River area and most of the Oxnard Plain Basin. In the Las Posas area and most of Pleasant Valley, the Grimes Canyon member contains fresh water of good quality. Exceptions include localized areas where water in basal sands or gravels does not have adequate circulation.

SAN PEDRO FORMATION

The San Pedro formation is of lower Pleistocene age and was deposited under marine and continental environments. North of the Santa Clara River it interfingers with the Santa Barbara formation, while south of the Santa Clara River it generally overlies the Santa Barbara formation unconformably. In the Oxnard Plain-Pleasant Valley areas available oil well logs indicate a conformable contact. The San Pedro formation

consists of up to 4,000 feet of marine and continental clays, silts, sands and gravels. North of the Santa Clara River the San Pedro formation consists of extremely lenticular beds with many scour and fill structures. The base of the formation in this area contains abundant marine fossils, but from near the middle of the formation to the top, marine fossils are rare except near the City of Ventura. The Fox Canyon member is a prominent sand and gravel zone of about 300 feet in thickness containing marine fossils. The Fox Canyon member is found at or near the base of the San Pedro formation and can be traced on the surface and in well logs throughout most of the Las Posas, Pleasant Valley and Oxnard Plain Basins. During the deposition of the San Pedro formation, the Oxnard Plain was mostly submerged to depths of about 125 feet and was filled by deposition from the ancient Santa Clara River. At the same time, the Santa Clara River Valley was subsiding at a rapid rate, resulting in a thickness of lower Pleistocene sediments which is now greater here than anywhere else in Ventura County. As the basin filled with sediments the shoreline moved westward, and some of the San Pedro formation is, therefore, of continental origin. Nearly all of the lower San Pedro formation in the Las Posas and Oxnard Plain areas was deposited in shallow water, probably partially in lagoons.

On the Oxnard Plain, lenticular layers of silt, sand and gravel in the upper part of San Pedro formation are known as the Hueneme aquifer. The Hueneme aquifer is present over

the northerly portion of the Oxnard Plain and in parts of Pleasant Valley. On the Oxnard Plain all of this unit has been removed by erosion generally south of Etting and Hueneme Roads. The total thickness of the Hueneme zone ranges from zero to about 1,150 feet at the deepest point of the Las Posas syncline.

The San Pedro formation forms rounded hills and local steep-sided canyons with tens to hundreds of feet of relief.

The San Pedro formation yields water to wells in the Santa Clara River Valley, Las Posas Valley, Oxnard Plain and Pleasant Valley. As far as is now known, all water in the San Pedro gravels and sands is of acceptable quality except that below about 4,000 feet in the Santa Clara River area, where some electric logs indicate that the water may be brackish and in the South Las Posas Basin in the vicinity of Arroyo Simi near Moorpark.

Surface water runoff from the San Pedro formation is generally of fair to good quality.

UPPER PLEISTOCENE SERIES

Sediments of upper Pleistocene age include clays, silts, sands and gravels younger than the San Pedro formation. In general, they are undisturbed or gently folded in contrast to the underlying folded San Pedro and older formations. Along Foothill Road in Ventura, terrace deposits and conglomerates of upper Pleistocene age rest on the San Pedro formation with angular unconformity. These deposits consist of fluvial silty sands, gravels and boulders which are gently tilted and attain a thickness of 300 feet or less.

In the Mound basin, the thickness ranges from 400 feet in the east to about 700 feet along the coast. These beds have

been downfolded gently along an older synclinal axis. There is a pronounced two-fold division of these deposits: (1) an upper tight clayey zone 200 to 400 feet thick, and (2) a lower sand and gravel zone which is from 100 to 300 feet thick. The basal coarse zone reaches a maximum thickness just north of the Santa Clara River. These coarse basal materials represent a distinct phase of deposition by the Santa Clara River which was apparently very widespread. On the Oxnard Plain the Mugu aquifer represents part of the same deposition (J. F. Mann, Jr., 1959). In the coastal area of the Oxnard Plain, this upper Pleistocene unit consists of marine blue clay, silt, sand and gravel, and is unconformably separated from the overlying Recent alluvium and the underlying San Pedro formation. Quaternary terrace deposits in the Las Posas Valley and Camarillo Hills may be age correlative to other upper Pleistocene units. These deposits are generally unconsolidated and poorly sorted silts, sands, gravels and boulders. The upper Pleistocene sediments in the Santa Clara River Valley are not differentiated from the Recent alluvial sediments.

On the Oxnard Plain, the basal pervious upper Pleistocene member or Mugu aquifer yields water of good quality to wells. The Mugu aquifer is usually separated from the overlying Oxnard aquifer by an aquiclude, ranging in thickness from 10 to about 100 feet. Exceptions are found in the Oxnard Plain Forebay and unconfined portions near Point Mugu where these aquifers merge. The terrace deposits in Las Posas are generally above the ground water table and do not supply water to wells; however, these outcrops may be areas of ground water replenishment to upper Pleistocene aquifers.

RECENT SERIES

The Recent sediments consist of clay, silt, sand and gravel of fluvial origin in most of the study area. In the coastal area they consist primarily of deltaic and lagoonal deposits and dune sand. On the Oxnard Plain, Recent sediments unconformably overlie upper Pleistocene deposits. Here their thickness varies from less than 200 feet to about 300 feet. The lower part consists of highly pervious coarse sands and gravels intercalated with clay layers and is named the Oxnard aquifer. Overlying the Oxnard aquifer are low permeability materials consisting mainly of clay and silt which are collectively called the "clay cap". The thickness of the "clay cap" ranges from zero feet in the Forebays to more than 160 feet in other parts of the coastal plain. From ground surface to depths of about 80 feet lenticular layers of sand and gravel are present. These are referred to as the "semiperched" and/or "perched zones". In the Santa Clara River Valley, undifferentiated fluvial sediments consisting of clay, silt, sand and gravel of Recent and upper Pleistocene age unconformably overlie the San Pedro and older formations. The thickness ranges from zero to 700 feet.

Recent alluvium and fan deposits also occur along streams and valleys in the rest of the study area. Their aggregate thickness ranges from a few feet to about 200 feet.

GEOLOGIC STRUCTURES

Ventura County is located in two geomorphic provinces of distinct structural characteristics. The portion of the County north of the Santa Ynez fault is in the Southern Coast Range Province, and structural features have a general northwest-southeast trend. The portion south of this fault is included in the Transverse Range Province which is characterized by east-west structural trends. Although surface runoff is contributed by the Southern Coast Range Province, the area of geologic studies lies entirely within the Transverse Range Geomorphic Province.

Geologic structures discussed in this section are primarily those structural features which affect the occurrence and movement of ground water in the study area. These consist of faults and folds which have affected water-bearing materials because of relatively Recent activity. Described geologic structures are shown on Plates 1 and 2.

FAULTS

Some faults are known to have a barrier effect on ground water movement on the basis of water level differential across faults. Other faults act as avenues of escape for deep-seated waters as indicated by the poor or unusual quality of ground water or the occurrence of springs near fault zones.

Although faults in the area have a general east-west trend, individual faults and zones vary considerably in direction along their strike. Major faults are briefly described in order as they occur from north to south.

SAN CAYETANO FAULT ZONE

The San Cayetano fault zone is located north of the Santa Clara River and has a general east-west trend which can be traced from Ojai Valley to near the Los Angeles-Ventura County line. The fault is a north-dipping thrust with a known low dip of about 20 degrees near Fillmore, increasing to about 60 degrees north of Santa Paula. The fault actually consists of two or more branches. Nonwater-bearing formations have been thrust over the San Pedro formation along the San Cayetano fault northeast of Fillmore. North of Santa Paula, Eocene sediments have been thrust over Pliocene sediments. Maximum dip-slip displacement has been postulated to reach 20,000 feet.

OAK RIDGE FAULT

This major fault extends along the south edge of the Santa Clara River Valley from the ocean west of Montalvo to a point about two miles southeast of Piru where it turns southward into Oak Ridge and may be cut off by the Santa Susana fault. The Oak Ridge fault has been penetrated by several oil wells in the Saticoy Oil Field and water wells in the east part of the City of Ventura. Here it has been found that the fault dips

southward about 60 to 70 degrees. The fault is a left-lateral and reverse fault, therefore, the south side of the fault has been thrust over the north side. Geologically Recent movement is probable along portions of the trace.

McGRATH FAULT

The McGrath fault is a branch of the Oak Ridge fault and is a left-lateral reverse fault with a dip to the south of about 70 degrees. The fault is located about two miles south of the Oak Ridge fault along the coast and is related in origin to the Montalvo anticline.

COUNTRY CLUB FAULT

This fault was originally inferred by geohydrologists to account for hydrologic discontinuity and water level discrepancy in wells near Saticoy. It is a steeply south dipping reverse fault with an appreciable left-lateral displacement. The Country Club fault may be displaced by the Ventura Foothills fault. The fault acts as a barrier to the flow of ground water with a water level differential across it of up to 100 feet.

VENTURA FOOTHILLS FAULT

The Ventura Foothills fault (Quick, 1973) is thought to be a northerly dipping reverse fault, the trace of which is postulated to be along the south edge of the Ventura Hills. It has been reported that this fault has a northerly dip of approximately 60 degrees and has a stratigraphic separation of approximately 800 feet at the base of the San Pedro (Las Posas) formation.

The presence of this fault is indicated by uplifted, and faulted marine terraces, subsurface records from oil and water wells and presence of an oil seep near its suspected location.

SANTA ROSA-SIMI FAULT SYSTEM

This extensive system consists of several branches and extensions. Within Simi Valley, the south side of this fault system has been generally down dropped relative to the north. However, along east and west extensions of the fault, the relative movement is reverse with the south side being uplifted. This suggests that the fault is a hinge or scissor type fault. The 1971 San Fernando earthquake is believed to be related to movement of an easterly extension of this system. It is, therefore, considered to be active.

SPRINGVILLE FAULT ZONE

This zone is located on the south side of the Camarillo Hills and consists of two or more parallel faults which may be dislocated in En echelon type pattern. The fault zone dips steeply to the north, with the north block generally uplifted relative to the south block. The fault zone has displaced the San Pedro and underlying formations. The reduction of permeability caused by movement has created a barrier effect with water level differentials of up to 60 feet. This impedes the movement of ground water from the Camarillo Hills to the Pleasant Valley Basin. It has not been proven that the Springville Fault Zone affects the movement of water in the Oxnard aquifer on the Oxnard Plain.

CAMARILLO FAULT

The Camarillo fault is located along the south side of a low hill in the City of Camarillo. Sediments on the north side have been uplifted relative to those on the south. The fault displaces the San Pedro formation and probably some of the alluvium near the City of Camarillo. A discontinuity of ground water levels in the lower aquifer system is apparent across the fault. In addition, observations indicate that local drawdown of pumping wells does not extend across the fault. Water levels in lenticular alluvial aquifers appear to be higher on the north side of this fault, suggesting that it may act as a barrier to the southerly movement of ground water in the alluvium. Based on the above information, the Camarillo fault is considered to act as a barrier to the subsurface movement of ground water and may have undergone geologically Recent movement.

BAILEY FAULT ZONE

The Bailey fault zone is a northeast-southwest trending zone which occurs along the northerly edge of the Santa Monica Mountains from Santa Rosa Valley to and beyond the coastline. Subsurface data indicates distinct vertical displacement along the fault. Based upon the steep gradient of water levels in the deeper zone and slight differences in quality, especially chloride ion concentration across the fault, it is thought to act as a definite barrier to ground water movement.

SYCAMORE CANYON FAULT

The Sycamore Canyon fault and other associated faults in the Santa Monica Mountains are about 15 miles long and as far as can be determined have had mostly a vertical component of movement.

FOLDS

Folds in the study area consist of anticlines and synclines mostly trending in an east-west direction. There are four prominent anticlinal structures including the Topa Topa Mountains, Oak Ridge-South Mountain, Las Posas-Camarillo Hills, and Simi Hills-Santa Monica Mountains. Synclinal basins and grabens occur between these anticlines and form the principal ground water basins of Ventura County. Folds control physical features and the extent of water-bearing materials. They also affect ground water hydrology to various degrees. The major structural basins are the: Santa Clara River syncline, Oxnard Plain Basin, Las Posas Basin and Pleasant Valley Basin.

SANTA CLARA VALLEY

The Santa Clara River syncline extends from the Pacific Coast up the Santa Clara River into Los Angeles County. The origin of this syncline is closely related to north-south compressional forces during the Cenozoic era. The water-bearing San Pedro formation has been folded in the Santa Clara River syncline, resulting in a water-bearing section up to 9,600 feet deep near Fillmore.

This may be the deepest occurrence of fresh water in the world.

North of the Santa Clara River Valley the San Pedro formation is exposed in the hills extending from the ocean to a location near Fillmore. Here where permeable beds are exposed it may receive recharge by rainfall penetration and stream percolation. The south flank of the syncline is mostly in contact with older nonwater-bearing formations across the Oak Ridge Thrust fault. It is partially covered by Recent alluvial sediments along the Santa Clara River enabling recharge by stream percolation.

The Mound Basin is the southwest extension of the Santa Clara River syncline and lies roughly between the Pacific Ocean, Foothill Road, the Country Club fault and the Santa Clara River. The basin is not a simple syncline but rather a series of uplifted, complexly faulted and eroded blocks. Based upon additional well data, the geologic interpretation of the area was revised by Quick (1973).

OXNARD PLAIN

Within the Oxnard Plain, lower Pleistocene and older formations are folded predominantly in a northeast-southwest direction and are unconformably overlain by upper Pleistocene and Recent sediments.

The Las Posas syncline is located in the northwest part of the Oxnard Plain with an axis which trends from the junction of West Fifth Street and Harbor Boulevard northeastward through El Rio and into the Las Posas Valley. The Montalvo anticline occurs near the Santa Clara River in conjunction with the McGrath fault. Another unnamed syncline occurs in the southeast part of the Oxnard Plain trending northeastward from the

coastal area between Port Hueneme and Point Mugu to an area south of Camarillo. A dome structure appears in the eastern Port Hueneme area near the junction of Hueneme Road and Arnold Road. Due to this folding and erosional unconformity, the Hueneme, Fox Canyon and Grimes Canyon aquifers of lower Pleistocene age are absent or of limited thickness here. Hydraulic continuity between the Upper and Lower Aquifer Systems is expected in several areas including the Oxnard Plain Forebay (Montalvo Basin) and the vicinity of the Point Mugu Naval Reservation (Mugu Forebay).

LAS POSAS VALLEY

In the Las Posas Valley there are three major synclinal and two anticlinal structures. The Las Posas syncline is the largest syncline with an axis trending in an east-northeasterly direction, crossing Los Angeles Avenue near Price Road. On the north side of this syncline are the Long Canyon anticline and Long Canyon syncline, and on the south side of it are the Moorpark anticline and Moorpark syncline. Folds in the Las Posas Valley strongly affect the occurrence, movement and quality of water in principal aquifer zones. The aquifers are exposed in certain areas where they are recharged with surface waters and deeply buried in other areas. Along the south flank of South Mountain and in Happy Camp Canyon water-bearing zones of the Lower Aquifer System are extensively exposed allowing replenishment by runoff and precipitation.

PLEASANT VALLEY

In the north half of Pleasant Valley, north of Camarillo, the Lower Aquifer System is folded and faulted. In addition, surface recharge and subsurface inflow are limited by several fault barriers and a thick clay cap, resulting in a continually expanding pumping trough within the Lower System in the basin. In the south half of the Pleasant Valley Basin a synclinal structure is bounded by the Camarillo fault on the north and the Bailey fault to the southeast.

GEOLOGIC HISTORY

The study area lies within the Ventura Basin which belongs to the Transverse Range Geomorphic Province. This province is characterized by east-west trending structural features in contrast to the dominant northwest-southeast structural trend of California. The Ventura basin lies between the Santa Ynez and Topa Topa Mountains on the north and the Santa Monica Mountains and Channel Islands to the south. It contains several intra-basin chains of hills and mountains that are generally anticlinal. They rise from 880 feet above sea level in the Camarillo Hills to as much as 3,700 feet above sea level in the Santa Susana Mountains.

Between these mountains and highlands occur synclinal lowlands such as the Ojai, Santa Clara, Las Posas and Pleasant Valley Basins. The westerly ends of South Mountain and the Camarillo Hills terminate into the flat, alluviated Oxnard Plain which is the most extensive and complex synclinal lowland in the basin. The western half of the basin is occupied by the Santa Barbara Channel, an epicontinental area.

Geologic history prior to Tertiary time is obscure because Pre-Tertiary rocks are not extensively exposed in the area. During most of Tertiary time the Ventura basin was a broad east-west trending downfolded belt with gentle uplift occurring to the north and south. The axis or deepest portion of the basin shifted during Tertiary time.

In Eocene time, the axis was located in the northern portion of the County. Since Eocene time, much of the northern portion of the County has been uplifted and eroded as the axis moved southward.

In Oligocene time, the axis appears to have been along the central part of the County. Later in Miocene time, the major axis was in the Santa Monica Mountains and Channel Islands area where a great thickness of volcanic rocks and marine sediments accumulated.

During Pliocene and Pleistocene time the major axis moved to near the central part of the County. Since this last major shift, the axis has migrated slowly southward so that at the present time the deepest part of the Ventura basin is coincident with the axis of the Santa Clara River syncline. Early and middle Pliocene time was characterized by a narrowing and deepening of the Santa Clara River Valley where nearly continuous deposition of marine clastic sediments occurred. The source of sediments was primarily the northern mountains which were being rapidly uplifted, folded and eroded. A maximum of 14,000 feet of Pliocene, plus 3,500 feet to 5,000 feet of conformably overlying mostly marine, lower Pleistocene sand, gravel, clay and mudstone filled the rapidly subsiding basin which was 10 to 15 miles wide and 60 to 75 miles long. This is one of the thickest known Pliocene-Pleistocene sections in the world.

The Oxnard Plain-Las Posas basins were partially separated from the Santa Clara River basin by the Oak Ridge uplift and also covered by the late Pliocene-early Pleistocene sea.

Thick marine sediments of the Pico, Santa Barbara and San Pedro formations were deposited almost continuously in the subsiding area of the Oxnard Plain, but unconformably along marginal areas.

In about mid-Pleistocene time, the basin filling ceased and the main Coast Range Orogeny began. The effects of the orogeny were widespread and included intense folding and uplift in all of the older Transverse Range. Great thrust and steep reverse faults with maximum displacements of 10,000 to more than 15,000 feet were developed in the Ventura Basin and along its margin. Some marine terraces were raised to elevations of more than 2,000 feet above the sea. The marginal Santa Ynez-Topa Topa Mountains, Santa Monica Mountains and the intra-basin highs were strongly accentuated and severely folded and faulted. In the study area, numerous steep to gently dipping normal and reverse faults and folds were developed in echelon-like trends as a result of intensive north-south compressive forces.

The middle Pleistocene Orogeny was followed by the last major glacial age. During this period, sea level dropped several hundred feet and the folded and faulted lands were eroded into more rounded hills and mountains. At the end of the major glacial period, the sea level rose and the coastal basin and parts of the inland valleys were backfilled with shallow, marine and non-marine clastic sediments of upper Pleistocene age. These materials were deposited unconformably on the eroded surface of lower Pleistocene and older formations.

After deposition of upper Pleistocene formations, sea level fluctuated and caused changes in the base level of erosion.

During this period, the Santa Clara River flowed through the Oxnard Plain, shifted its course continually and eroded parts of the upper Pleistocene formations. Thus, the Recent stream laden and deltaic sediments were deposited unconformably on upper Pleistocene and older formations.

Regional uplift of several hundred feet, accompanied by subdued folding and considerable faulting, has continued essentially to the present time, but probably at a slower pace. Continued structural activity is indicated by the slightly warped Mugu aquifer of upper Pleistocene age, tilted or warped coastal and stream terraces (Putnum, 1942), and even by folded alluvium (Jenning and Troxel, 1954). The elevations of terraces in the Ventura basin represent a mixture of the effects of eustatic sea level changes and tectonic uplift during the last one million years (Palmer L., 1967).

REFERENCES CITED

- Bailey, Thomas L., "Late Pleistocene Coast Range Orogenesis in Southern California". Geological Society of America Bulletin, Volume 54, October 1943.
- and Jahns, Richard H., "Geology of the Transverse Range Province, Southern California". California Division of Mines, Bulletin #170, 1954.
- California Department of Water Resources, "Seawater Intrusion Oxnard Plain of Ventura County", Bulletin #63-1, October 1965.
- California Division of Mines and Geology, "Geology and Mineral Resources Study of Southern Ventura County, California". Preliminary Report 14, 1973.
- California Water Resources Board, "Ventura County Investigation". Bulletin #12, Volumes 1 and 2, October 1953.
- Eckhart, R. A. and Leach, J. S., "Geologic Map of the Ventura District". Scale 1:62,500, unpublished, December 1954.
- Jenning, C. W., and Troxel, B. W., "Ventura Basin". Geologic Guide #2. California Division of Mines, Bulletin #170, 1954.
- Mann, John F., Jr., and Associates, "A Plan for Ground Water Management for United Water Conservation District", September 1959.
- Palmer, L. A., "Marine Terrace Deformation in Pacific Coastal United States". The Eleventh Pacific Science Congress Symposium #19, 1967.
- Quick, George L., "Preliminary Microzonation for Surface Faulting in the Ventura, California Area". Geology, Seismicity and Environmental Impact. Association of Engineering Geologists Special Publication, October 1973.

VENTURA COUNTY DEPARTMENT OF PUBLIC WORKS
FLOOD CONTROL DISTRICT

VENTURA COUNTY WATER RESOURCES MANAGEMENT STUDY
AQUIFER DELINEATION IN THE OXNARD-
CALLEGUAS AREA, VENTURA COUNTY

By
JOHN M. TURNER - HYDROLOGIST

This Technical Information Record was prepared to document pertinent information as it was developed during the Ventura County Water Resources Management Investigation.

January 1975

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INTRODUCTION

The purpose of this Technical Information Record (T.I.R.) is to document findings of geohydrologic studies conducted to define the vertical and areal extent of water-bearing units within ground water basins of the Oxnard-Calleguas area of Ventura County. Important ground water basins within the study area include the: Oxnard Plain Pressure, Oxnard Plain Forebay, Pleasant Valley, North and South Las Posas and Santa Rosa Valley Basins and the Mugu unconfined area. A major portion of this report describes the Oxnard Plain, an area of complex, but related multiple aquifer zones. During the initial stages of the investigation, all previous studies of the area pertaining to ground water resources were reviewed. A list containing reports utilized during the study appears at the end of this report as "References Cited".

Data to determine the extent and configuration of important aquifer zones was obtained, primarily from existing subsurface records of wells drilled for water, oil and gas. The principal and most reliable sources of subsurface data were electrical logs of water and petroleum wells. These records are invaluable since they constitute a physical record of formations penetrated adjacent to the borehole. The availability of these records allows qualitative determination of subsurface lithology

and water quality. Fortunately, these records are numerous in the Oxnard-Calleguas area due to the progressive design techniques employed by some water well drilling contractors and extensive subsurface exploration by petroleum companies. More than 200 such records were obtained within the area of investigation, the majority of which penetrate or approach the base of the ground water reservoir.

The greatest number of subsurface records are lithologic logs of materials penetrated at the time of drilling. Within the study area greater than 1,000 of these records were inspected, many of which were selected to supplement electrical log data.

During this study, a series of maps and Geologic Sections depicting various parameters were prepared. Maps depict the vertical and areal boundaries of aquifer zones and thickness of water-bearing materials within these zones. The Geologic Sections provide a visual description of subsurface relationships which occur from ground surface to the base of the ground water reservoir. Location of these sections and basin boundaries are shown in Plate 6. The discussion which follows contains material considered pertinent to modeling studies and selection of an operational plan for water resources management. A more detailed discussion of geologic aspects is contained in the Geology report.

OXNARD PLAIN FOREBAY BASIN (MONTALVO BASIN)

The Oxnard Plain Forebay Basin encompasses an area of approximately 9.5 square miles and constitutes the principal area

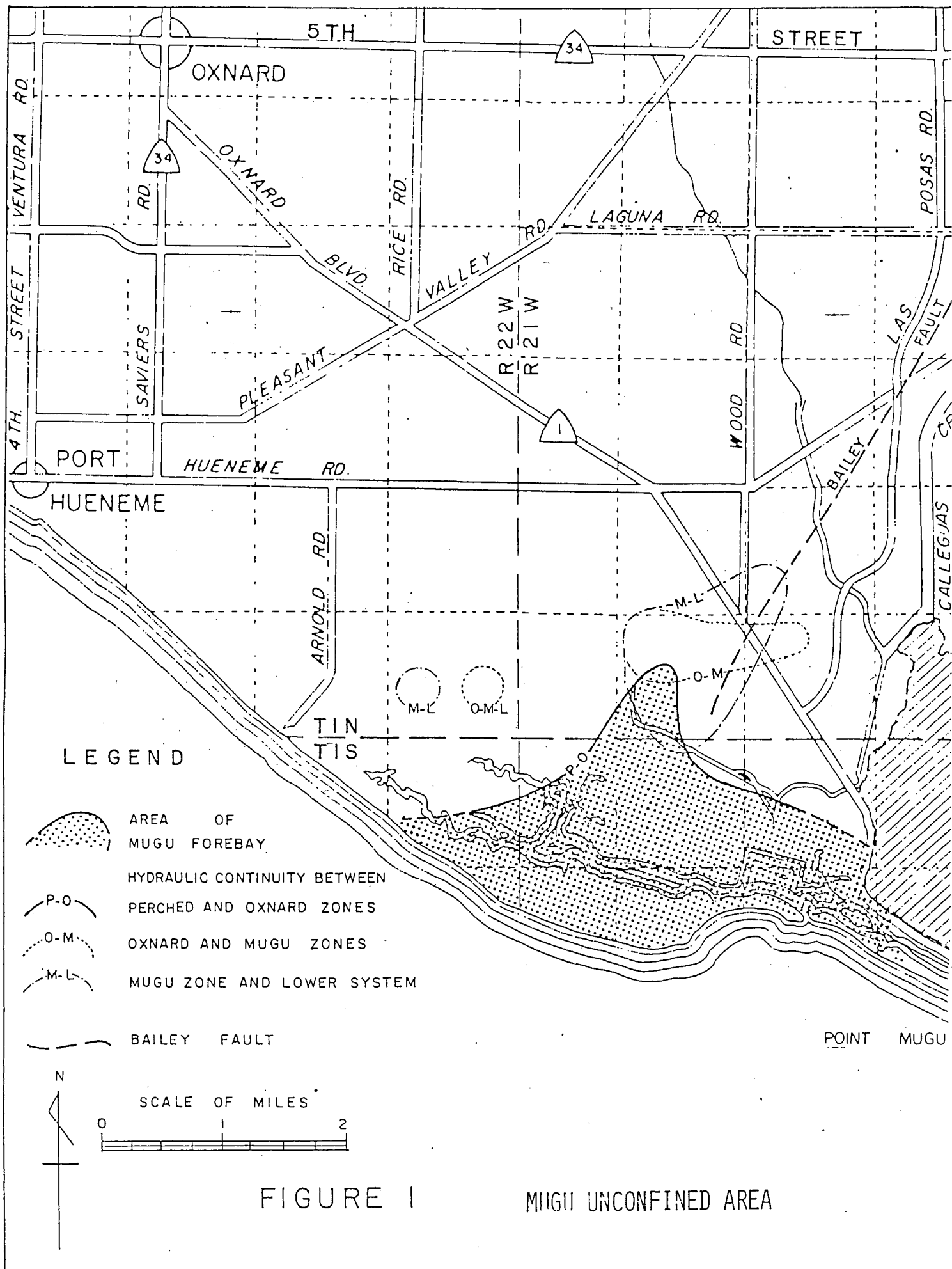
of ground water recharge within the Oxnard Plain. The areal extent of the Oxnard Plain Forebay Basin is shown in Plate 1. The principal criteria used for delineation of the extent of this basin was lack of a low permeability confining member from ground surface to the top of the initial major aquifer zone. The northwest boundary of the basin is generally contiguous with the north bank of the present Santa Clara River channel. Northwest of this boundary numerous subsurface records indicate a predominance of low permeability materials and an absence of the Oxnard aquifer zone. The northerly limit of the Oxnard Plain Forebay Basin coincides with the location of the McGrath fault, a branch of the Oak Ridge fault zone. Remaining boundaries are coincident with a thickening of the "clay cap" which effectively confines the Oxnard aquifer zone over most of the Oxnard Plain. Within the boundaries of the Oxnard Plain Forebay Basin, artificial and natural ground water recharge is a source of replenishment to the Upper and Lower Aquifer Systems.

Geologic Section C-C' indicates the generalized subsurface relationships from ground surface to the effective base of the ground water reservoir within the Oxnard Plain Forebay Basin. Within this basin the Oxnard aquifer zone consists almost entirely of permeable sand and gravel. Although the underlying Mugu aquifer contains a significantly greater percentage of low permeability material than the Oxnard zone, the lenticular nature of these materials allows relatively unimpeded replenishment to the entire Mugu aquifer.

A smaller area within the basin was delineated through which ground water recharge occurs to the Hueneme and Fox Canyon aquifer zones of the Lower Aquifer System (Plate 1). These zones were upwarped and partially eroded prior to deposition of the Mugu aquifer, resulting in hydraulic communication to water-bearing sands and gravels of the Lower Aquifer System. The relationship between Lower Aquifer System materials and overlying deposits are shown in Geologic Sections B-B' and C-C'.

MUGU UNCONFINED AREA

This unconfined area is located at the extreme southerly portion of the Oxnard Plain and encompasses an area of approximately 4 square miles. It is bounded by nonwater-bearing rocks of the Santa Monica Mountains to the east, a thickening of the confining clay cap to the north and west and the Pacific Ocean on the south. It is characterized by absence or minimum thickness of the confining clay cap normally present above the Oxnard aquifer zone. Approximate boundaries are shown in Figure 1. Boundaries of this basin are tentative because of inadequate subsurface information and, therefore, they should be modified as additional data becomes available. This unconfined area is similar to the Oxnard Plain Forebay, since both are characterized by lack of a significant clay cap confining the Oxnard aquifer zone. Sea-water intrusion now occurs in the Oxnard aquifer zone throughout the entire Mugu Forebay. Aquifer Section A-A' indicates the general stratigraphic relationships of a portion of the Mugu Forebay Basin.



Available data indicates that the Mugu aquifer is effectively separated from the overlying Oxnard aquifer zone by a low permeability layer over all but the extreme northerly portion of the Mugu Forebay. Figure 1 indicates this relationship and also areas of hydraulic continuity of other zones within and in the vicinity of the Mugu Forebay. Hydraulic continuity between the Oxnard aquifer zone and the Mugu aquifer within and adjacent to the Mugu Forebay assumes an east-west elongated configuration which covers an area of about 0.5 square miles. About one mile west of here, the log and water quality data from well 1N/22W-36K4, which is sealed from ground surface to a depth of 380 feet, indicate hydraulic continuity and sea-water intrusion into the Mugu and possibly Lower Aquifer System.

Extensive hydraulic continuity between the Mugu aquifer and the Fox Canyon aquifer zone is believed to occur in a one-square-mile area extending northerly from the Mugu Forebay. Within this area wells 1N/21W-28N2 and 32A1, both completed only in the Lower Aquifer System, indicate relatively high chloride concentration of 306 and 193 milligrams per liter, respectively. It is possible that sea water is migrating downward in the gravel pack from the Mugu aquifer in well 1N/21W-28N2 because the seal to 250 feet is above the base of the Mugu aquifer. Downward leakance through the gravel pack of well 1N/21W-32A1 is not possible because the well is sealed to a depth of 460 feet, which is considerably below the base of the Mugu zone. Smaller areas of hydraulic continuity between the Mugu aquifer and Lower Aquifer System are believed to exist about one mile west of the Mugu Forebay.

Active sea-water intrusion combined with hydraulic continuity and downward hydraulic gradient, which exist within and adjacent to the Mugu Forebay, poses a serious threat to all major aquifer zones of the Oxnard Plain Basin.

OXNARD PLAIN PRESSURE BASIN

The bases for delineating the extent of the Oxnard Plain Basin are the areal limits of the Oxnard aquifer zone and the Mugu aquifer. This basin differs from the Oxnard Forebay Basin and Mugu Forebay in that it contains a "clay cap" over the Oxnard aquifer zone.

The Oxnard Plain Basin encompasses an area of approximately 75.2 square miles and is bounded by the Mound and Oxnard Forebay Basins to the north, the North Las Posas and Pleasant Valley Basins to the east, and the Mugu Forebay and nonwater-bearing rocks of the Santa Monica Mountains to the south. Although the Oxnard aquifer zone extends offshore, the westerly basin boundary is arbitrarily assigned at the coastline because this study was confined to the onshore area. The offshore extent and configuration of various aquifer zones is contained in a report being prepared by the United States Geological Survey in Menlo Park, California. The Oxnard Plain Basin is a relatively flat alluviated area which ranges in elevation from sea level to approximately 100 feet. It is underlain by numerous important aquifer zones, which, in the center of the basin beneath El Rio, extend to depths of greater than 2,100 feet below sea level (Plate 5).

During early stages of the investigation, it was determined that major water-bearing zones beneath the Oxnard Plain could be grouped into three major units on the basis of differing piezometric levels, water quality and geologic structure. These are: 1) the semiperched aquifer and clay cap; 2) the Upper Aquifer System; and 3) the Lower Aquifer System.

SEMIPERCHED AQUIFER AND CLAY CAP

The semiperched aquifer and clay cap consist of all materials above the Oxnard aquifer zone within the Oxnard Plain Basin. The semiperched aquifer extends from the base of developed soil horizons to an average depth of approximately 75 feet over most of the Oxnard Plain Basin. This aquifer consists primarily of geologically Recent stream-deposited sands and gravels, with minor silt and clay interbeds. Permeable sand and gravel deposits are continuous in a direction generally parallel to the present course of the Santa Clara River and lenticular in a perpendicular direction as indicated on Geologic Sections A-A' and C-C'. Historically, there have been very few water wells completed within this zone because of limited well yield and poor water quality caused by agricultural return water and evapotranspiration. Recent studies in an area north of Channel Islands Harbor indicate local occurrence of ground water of acceptable quality for most beneficial uses (mineral concentration 850 to 950 milligrams per liter) within lower permeable portions of this zone. The occurrence of acceptable quality water within this portion of the zone is believed to reflect the

local effectiveness of aquicludes and aquitards within and above permeable portions of the semiperched zone. These materials prevent substantial downward migration of degraded applied and surface water under present extraction conditions. The depth to water within this zone is normally only several feet below ground surface.

Highest water levels are found in heavily irrigated areas where, without tile drains, water level rises high enough to adversely affect the growth of plantings. The maximum depth to water in this zone is approximately 10 feet. This occurs in the fall of dry years in nonirrigated areas where the depth to water is controlled by limits of evaporation from the water table.

The "clay cap" underlies the semiperched aquifer zone and extends to the top of the Oxnard aquifer zone. Plate 1 indicates that the clay cap extends to greater than 180 feet below sea level at two locations near the ocean. The clay cap consists of Recent silty clay, silt and clay with lenses of sand and silt. In results of earlier water resources studies, it was theorized that the clay cap contains areas where downward leakage occurs to the Oxnard aquifer zone. A recent cooperative investigation between the Department of Water Resources and the University of California indicated that the clay cap is an aquitard through which significant quantities of water can migrate vertically under conditions of differential head.

Because of generally poor water quality and limited quantity of recoverable storage within the semiperched aquifer zone

it is recommended that materials overlying the Oxnard aquifer zone not be modeled as an aquifer system during the current investigation. Because leakage within this zone affects underlying zones, it is recommended that results of the aquitard study, published in Department of Water Resources Bulletin 63-4, be utilized during development and verification of the mathematical ground water basin model.

UPPER AQUIFER SYSTEM

The Upper Aquifer System delineated within the Oxnard Plain Basin consists of the Oxnard aquifer zone and the Mugu aquifer. These two water-bearing units were combined primarily on the basis of similar subsurface structure although under natural conditions water levels and water quality were probably more similar than they are today. The structure of the Upper Aquifer System is more planar than the Lower System because these materials are younger and have not been subjected to as much folding as the deeper lower Pleistocene water-bearing materials (Geologic Sections A-A', B-B' and C-C'). Because of their relatively young age, they have also not been subjected to displacement by fault movement to as great an extent.

The base of the Mugu aquifer constitutes the base of the Upper Aquifer System. The nature of the unconformity between the base of the Mugu aquifer and the top of the Lower Aquifer System is very significant with regard to sea-water intrusion, and, at this time, is not thoroughly understood in all areas.

Prior to deposition of the Mugu aquifer, sea level dropped considerably causing extensive erosion of previously deposited materials on the Oxnard Plain.

The major source of erosive force during this period was the Santa Clara River which meandered over the entire Plain. Of secondary importance was the erosive energy provided by Calleguas Creek and numerous small tributary drainages. The result of this extensive period of erosion was surface exposure of numerous previously folded underlying water-bearing zones. Following this period, sea level rose inundating most or all of the Oxnard Plain. During this time, deposition of the Mugu aquifer occurred upon the previously developed unconformity in a shallow marine inland sea. The result of the sequence of erosion is extensive hydraulic continuity between the Mugu aquifer zone and important aquifer zones of the Lower Aquifer System. Recent overdraft of the Oxnard and Mugu aquifer zones has resulted in serious inland sea-water intrusion at Port Hueneme and Point Mugu. At Port Hueneme sea-water intrusion is known to occur only in the Oxnard aquifer zone where the most recent information indicates an onshore affected area of approximately 8 square miles. A far more serious condition is found at Point Mugu where the Oxnard and Mugu aquifer zones are both intruded. Here onshore intrusion of the Oxnard zone now covers an area greater than 9 square miles. The areal extent of sea-water intrusion in the Mugu aquifer is at this time undetermined. Active intrusion into exposed suballuvial materials of the Lower Aquifer System is also indicated in Sections 28 and 32 adjacent to the Mugu unconfined area.

The thickness of permeable materials in the Upper Aquifer System was contoured and is shown in Plate 3. Maximum thickness is reached in the area of the Las Posas syncline while minimum thickness generally occurs at the easterly boundary of the basin.

OXNARD AQUIFER ZONE

The Oxnard aquifer zone is the initial important water-bearing unit penetrated by water wells on the Oxnard Plain. Historically, this zone was considered to be the most important because shallow wells completed in this zone were capable of producing large quantities of acceptable quality water. Pollution of this zone by sea-water intrusion and leakage of poor quality perched waters has degraded the quality of this zone and caused many deeper wells to be drilled. In previous studies the areal extent of this zone was utilized to delineate the boundary of the Oxnard Plain Basin. During the present investigation, the maximum extent of both the Oxnard zone and the Mugu aquifer was utilized since both constitute the Upper Aquifer System which will be modeled as one unit. Combining these zones resulted in a minor easterly extension of the Oxnard Plain Basin boundary in the Pleasant Valley (Camarillo) area as shown in Plate 1.

The Oxnard aquifer zone is a laterally continuous layer of nonmarine gravel and cobbles ranging from 1/4 to 6 inches in diameter and coarse to fine sand. Interbedded within this zone are clay, silty clay and silt lenses that form localized aquicludes which restrict vertical movement of water within the zone and affect lateral movement as evidenced by differential sea-water

intrusion near the ocean. In some areas water-bearing materials are segregated into two or three zones as indicated in Plates 7 and 9. Because of this feature, the term Oxnard aquifer used in previous investigations has been revised to Oxnard aquifer zone.

The top of the Oxnard zone is an irregular surface ranging from greater than 20 feet above sea level east of Saticoy-El Rio to greater than 180 feet below sea level northwest of Port Hueneme (Plate 1). The irregularity of the top of this zone results primarily from differential erosion and sedimentation of the Santa Clara River rather than structural warping. An exception is found in the northwest Oxnard Plain near the ocean where the top of this zone appears to have been upwarped and/or faulted. South of this location near 5th Street, downwarping, probably related to the Las Posas syncline, is apparent. The base of the Oxnard aquifer zone occurs as a more regular surface, ranging from an elevation of sea level just east of the Saticoy Spreading Grounds to greater than 300 feet below sea level near Point Mugu. It is less irregular because it was deposited upon a relatively smooth erosional unconformity. The base of this zone was previously contoured and published in Department of Water Resources Bulletin 74-9, "Water Well Standards, Ventura County", and is recommended for use during the current investigation. In the northwest Oxnard Plain, the base of this zone exhibits the same structural features as the top. In addition, land surface subsidence in the vicinity of Point Mugu Naval Air Station is indicated. In the northern half of the Oxnard Plain the base of this zone has the appearance of a large alluvial fan.

MUGU AQUIFER

Between the base of the Oxnard zone and the top of the Lower Aquifer System is the Mugu aquifer of upper Pleistocene age.

Historically, few wells produced from this zone because adequate water supplies were available from the overlying Oxnard aquifer zone. Within the past 25 years, numerous multiple zone wells have been completed within this unit and more than 10 have been completed only within the Mugu aquifer.

The Mugu aquifer consists of sand and gravel with interbedded silt and clay with a maximum aggregate thickness of about 270 feet. Of this, a maximum thickness slightly greater than 200 feet consists of permeable sands and gravels.

The Mugu aquifer is an almost continuous layer of water-bearing materials deposited directly upon the erosional unconformity developed on the San Pedro formation and older underlying rocks. The basal portion of this unit generally consists of coarse materials deposited under very shallow marine or nonmarine conditions and is in hydraulic continuity with underlying zones over much of the Oxnard Plain. Later as sea level continued to rise, deposition of finer sands and gravels occurred, especially near the present shoreline. Generally, materials become finer grained toward the ocean and more coarse grained in the easterly Oxnard Plain. In the easterly Oxnard Plain much of the Mugu aquifer is believed to be of continental origin.

The top of the Mugu aquifer is in most areas overlain by a low permeability clay cap which varies from 10 to 100 feet in thickness. Exceptions are found near the Santa Clara River,

at Port Hueneme and in the Oxnard Plain and Mugu Forebays where well data indicates that water-bearing portions of the Mugu aquifer merge with the Oxnard zone.

Over most of the Oxnard Plain the top of the Mugu aquifer is relatively flat and slopes toward the ocean. The greatest irregularities of this surface are thought to be depositional rather than structural. Mild downwarping of this surface is indicated in the vicinity of the Las Posas syncline, while greater upwarping is indicated near the Santa Clara River. A contour map depicting the top of this zone was not prepared during this study because the Oxnard aquifer zone and Mugu aquifer are to be modeled as one unit.

The base of the Mugu aquifer is a more irregular surface, which ranges in elevation from less than 50 feet below sea level near the tip of South Mountain to almost 500 feet below sea level 3 miles north of Port Hueneme (Plate 2). This greater irregularity is caused by more intensive folding and sporadic nonmarine deposition. The area of greatest downwarping is coincident with the northeast-southwest trending Las Posas syncline which enters the Oxnard Plain from the Las Posas Valley and extends across the basin into the ocean. Upwarped areas include the nose and westerly extension of the Camarillo Hills and the northerly portion of the basin paralleling the present course of the Santa Clara River.

Features due primarily to deposition of fine materials are found just east of Port Hueneme.

LOWER AQUIFER SYSTEM

The Lower Aquifer System consists of the Hueneme, Fox Canyon and Grimes Canyon aquifer zones all of lower Pleistocene age. Collectively, they constitute the most valuable water-bearing zones in the Oxnard Plain Basin.

HUENEME AQUIFER ZONE

The Hueneme aquifer zone constitutes the upper portion of the San Pedro formation on the Oxnard Plain and is the uppermost unit of the Lower Aquifer System. It consists of up to 1,150 feet of sediments in the deepest portion of the basin. Previous investigators have not realized the thickness or areal extent of this unit because of insufficient deep subsurface data. The recent trend of completing deeper wells and additional data provided by petroleum companies has resulted in a more thorough understanding of the configuration and extent of this unit. Many wells penetrating deeper zones have been completed within this zone.

The Hueneme aquifer zone is composed of interbedded sand, silt and clay and minor gravel and is more lenticular than underlying zones. The somewhat lenticular nature of this unit is indicative of deposition under nonmarine conditions; however, the lack of extensive quantities of gravel would seem to indicate at least partial marine deposition, however, this has not been verified by paleontological data.

The Hueneme aquifer zone has been subjected to considerable folding, faulting and erosion since deposition, as indicated on Geologic Sections A-A' and C-C'. This activity has largely affected the areal distribution and occurrence of this unit on the Oxnard Plain. North of the Oxnard Plain this unit cannot be readily correlated. East of the Oxnard Plain, in the Las Posas Valley, water-bearing portions are extremely lenticular or absent and as a result wells do not produce much water from this zone. In Pleasant Valley some water is produced; however, most is extracted from deeper zones.

Much of the Hueneme zone has been removed by erosion of upwarped areas since deposition. On the south Oxnard Plain all of this unit has apparently been removed generally south of Hueneme and Etting Roads. In the north Oxnard Plain, just south of the Santa Clara River, much of it has also been removed by erosion since deposition due to upwarping and possibly faulting followed by erosion.

The map depicting contours on top of the Lower Aquifer System (Plate 4) has a very similar configuration to that on the base of the Upper Aquifer System over much of the Oxnard Plain. Exceptions are found within the southerly portion of the Oxnard Plain Basin where numerous irregularities occur between the two surfaces. The two most prominent features occur between Port Hueneme and Mugu Lagoon where two deep depressions ranging from 400 to 550 feet are apparent. These occur in areas where coarse water-bearing materials of the Hueneme aquifer zone are very thin or absent. This condition is also prevalent here in deeper zones

indicating a lagoonal or embayment environment of deposition for a considerable period of geologic time.

The most significant feature produced by the unconformity developed upon the Hueneme aquifer zone followed by deposition of coarse materials is extensive hydraulic continuity between this zone and the Mugu aquifer. Fortunately, onshore sea-water intrusion in the Mugu zone has occurred only near Point Mugu where the Hueneme zone is absent. Apparent lack of hydraulic continuity in much of the intruded area makes this unit increasingly important as a source of future water supply to the Oxnard Plain.

FOX CANYON AQUIFER ZONE

The Fox Canyon aquifer zone is the basal unit of the San Pedro formation. Paleontological evidence indicates that it is of lower Pleistocene age and was deposited in a shallow water marine environment over the entire Oxnard Plain Basin. Where paleontological data are available, the top and base of this zone is readily recognized by its characteristic fossil assemblage. Marine deposition resulted in a more or less uniform series of layers which can be correlated by use of electric logs over almost the entire Oxnard Plain. In recent years the Fox Canyon zone has been exploited more as a source of water supply, especially in coastal areas where shallow zones have been intruded by sea water.

On the Oxnard Plain permeable portions of the Fox Canyon aquifer zone consist primarily of fine to medium sand with stringers of gravel. Lower permeability clay, silt and sandy clay interbeds constitute about 20 percent of this zone. Water-bearing materials

become finer toward the present coastline because they were deposited farther from the ancient shoreline. The Fox Canyon aquifer zone is present throughout almost the entire Oxnard Plain. An exception is found at the tip of South Mountain where subsurface records indicate that nonwater-bearing portions of the Santa Barbara formation are penetrated beneath the Mugu aquifer. The lack of the Fox Canyon zone in this area may be attributed to upwarping and subsequent removal by erosion of the Santa Clara River as shown in Geologic Section C-C'. Another area where this zone is thought to be lacking is in the south coastal area. Here limited subsurface information indicates that an approximate one-mile band along the ocean extends from about 0.5 mile north of Arnold Road southerly to and beyond the Bailey fault where it changes trend to a northeasterly direction for about four miles and terminates against the Bailey fault zone about 0.5 mile west of Round Mountain. The apparent lack of occurrence in this area is attributed primarily to uplift and erosion in middle Pleistocene time prior to deposition of overlying zones.

The Fox Canyon aquifer zone constitutes the effective base of fresh water in north and westerly portions of the basin where the Grimes Canyon aquifer zone is absent. The most prominent structural features here are the Las Posas syncline and the Montalvo anticline which have warped this zone into its present east-west trending configuration.

Basal members of this zone may be correlated over almost the entire Oxnard Plain by use of electric logs. A key horizon is the basal sand or gravel of quite uniform thickness. Another key horizon lies above this marker zone and is separated from it

by a low permeability layer of variable thickness. This marker horizon is up to several hundred feet thick and exhibits almost identical resistivity responses on electric logs over much of the Oxnard Plain. Because of its greater thickness, wide distribution and ease of correlation on electric logs, it is considered to be the "main aquifer" of the Fox Canyon zone. In the southerly portion of the basin, correlation of the Fox Canyon zone becomes more difficult because of removal by erosion and presence of the Grimes Canyon zone.

The top of the Fox Canyon aquifer zone is more difficult to determine by correlating electric logs. Unlike the two basal aquifers, layers lying above cannot be correlated as readily over large areas. Along the coast these two members are overlain by one additional member, 100 to 150 feet thick, which constitutes the top of the zone. Inland, the clay layer separating this member from the main underlying zone disappears and they become one unit.

Generally, in cross section, the top of the Fox Canyon zone assumes a configuration similar to, but somewhat less warped than the base. A map depicting the top of this zone was not prepared because the overlying Hueneme zone is to be modeled as a part of the same system.

GRIMES CANYON AQUIFER ZONE

Throughout most of the Oxnard Plain Basin the Santa Barbara formation consists of bluish clays and shales deposited in an offshore marine environment. Low permeability and lack of flushing since deposition cause these materials to be placed in the nonwater-bearing category.

The Grimes Canyon aquifer zone is the uppermost member of the Santa Barbara formation. On the Oxnard Plain, it is composed primarily of sand with only minor amounts of gravel deposited in a near-shore marine environment. It is present only in the southerly and easterly portions of the Oxnard Plain where it underlies about 35 percent of the total basin area. Approximate northerly and westerly limits are shown in Plate 5. From this location the Grimes Canyon aquifer zone extends southeasterly to and beyond the Bailey fault zone and easterly into the Pleasant Valley Basin. Here it is the basal water-bearing unit and generally overlies nonwater-bearing portions of the Santa Barbara formation.

Lack of the permeable Grimes Canyon aquifer zone in the north Oxnard Plain is attributed primarily to a facies change caused by relatively deep water deposition of fine-grained materials seaward of the defined limits of this zone.

The offshore limits of this zone in the south Oxnard Plain are unknown. Here, preliminary results of the United States Geological Survey-State Department of Water Resources cooperative offshore sparker survey do not indicate subsea stratigraphic units correlative with the onshore occurrence of the Grimes Canyon aquifer zone. This may indicate an offshore facies change to fine-grained materials like that which occurs on the north Oxnard Plain. If this is the case, offshore intrusion of sea water into this zone is not a threat. However, if permeable portions of this zone are exposed in the Mugu or Hueneme submarine canyons or the steeply sloping sea floor between them, then sea-water intrusion is actively moving landward because of long-time water level conditions below sea level.

Limited water quality data indicate that some basal portions of the Grimes Canyon aquifer zone contain brackish water. The primary areas where this is thought to occur are downwarped portions of the basin having inadequate circulation. Subsurface data indicates that the Grimes Canyon aquifer zone is in hydraulic continuity with the overlying Fox Canyon aquifer zone over most of the area where they occur together on the Oxnard Plain. Most of the water wells which produce from this zone are also perforated in the Fox Canyon aquifer zone.

PLEASANT VALLEY BASIN

The Pleasant Valley Basin is differentiated from the Oxnard Plain Basin by a lack of the Oxnard and Mugu aquifer zones. It is separated from the Las Posas Basins and the Santa Rosa Basin by faulting and folding.

The Pleasant Valley Basin covers an area of approximately 41.6 square miles and has a drainage area of almost 57 square miles. The basin ranges in elevation from about 20 feet near its southerly boundary to greater than 800 feet in the Camarillo Hills.

The geology of the Pleasant Valley Basin is very complex and not thoroughly understood. The area is characterized by intense folding and faulting and rapid facies changes in upper water-bearing zones.

Water-bearing units within the Pleasant Valley Basin include Recent and upper Pleistocene alluvium and the lower Pleistocene San Pedro and Santa Barbara formations. Water-bearing zones within

the San Pedro formation consist of an upper series probably equivalent to the Hueneme aquifer zone of the Oxnard Plain and the underlying Fox Canyon aquifer zone. The Santa Barbara formation contains the Grimes Canyon aquifer zone which is the basal water-bearing unit within the Pleasant Valley Basin.

These formations are underlain by the Pico and Santa Margarita formations, Modelo shale and volcanics of Miocene age which are considered to be nonwater-bearing. The volcanic rocks are exposed along the southeast edge of the basin in the Santa Monica Mountains.

The following is a more complete description of water-bearing units in the Pleasant Valley Basin with emphasis upon their application to modeling studies.

RECENT AND UPPER PLEISTOCENE ALLUVIUM

Recent and upper Pleistocene alluvium of variable thickness occurs in all low-lying areas of the Pleasant Valley Basin. These materials consist of yellow and blue clay and gray sand and gravel which generally reach a thickness of 300 to 400 feet. Throughout most of the westerly Pleasant Valley Basin these materials are very lenticular and do not constitute a large, reliable source of water. The lenticular nature of these deposits is such that extensive hydraulic continuity with equivalent zones (Oxnard aquifer zone and Mugu aquifer) is very unlikely. The large quantity of low permeability materials indicates that these

deposits are confined or semi-confined throughout most of the basin. One area where unconfined conditions are strongly expected is the area 1/2 to 1 mile southwest of Somis in the vicinity of Calleguas Creek where subsurface data indicates the presence of highly permeable materials to considerable depths.

There are two areas in the Pleasant Valley Basin where water supplies derived from Recent and upper Pleistocene materials have been utilized. One area lies north of the Camarillo fault and southeast of the Camarillo Hills, while the other area lies generally southeast of the Camarillo fault in the Calleguas Creek portion of the basin. Wells in these areas have exhibited yields ranging from less than 100 to 1,000 gallons per minute with the average yield being about 400 gallons per minute.

Geologic Section B-B' indicates subsurface relationships across a portion of the Pleasant Valley Basin. Between the Springville and Camarillo fault zones, Recent and upper Pleistocene deposits (water-bearing alluvium) are extremely lenticular in the westerly portion of the basin, while on the southeast side of the Camarillo fault water-bearing materials are less lenticular up to the Bailey fault zone. The higher quantity of permeable material here is probably caused by downfaulting of this block during sedimentation by Calleguas and Conejo Creeks. Southeast of the Bailey fault the lenticular nature of water-bearing materials is again apparent. The large percentage of low permeability materials here probably reflects a lack of coarse-grained deposition by major water courses because of relative uplift during the depositional cycle. Much of the Recent and upper Pleistocene materials

present here are thought to be fines produced by weathering and erosion of volcanic rocks in the Santa Monica Mountains. The quality of water derived from these materials is generally inferior to that extracted from deeper zones. The poor quality combined with sporadic and doubtful sustained yield make these deposits quantitatively unimportant for modeling purposes.

SAN PEDRO FORMATION (FOX CANYON AQUIFER ZONE)

The San Pedro formation underlies all of the Pleasant Valley Basin except that area southeast of the Bailey fault zone. It is exposed in the Camarillo and Las Posas Hills where it has been uplifted by anticlinal forces and fault movement. The upper portion of the San Pedro formation consists of sand, clay and gravel equivalent to the Hueneme aquifer zone found on the Oxnard Plain. It differs from the Hueneme zone in that it is more lenticular in nature and contains a large percentage of low permeability layers. The occurrence of permeable zones seems to closely coincide with occurrences of permeable zones in Recent and upper Pleistocene deposits. The upper San Pedro formation is not found on the southeast side of the Bailey fault.

The Fox Canyon aquifer zone is the major water-bearing unit within the Pleasant Valley Basin. It is in hydraulic continuity with the Oxnard Plain Basin and present in all water-bearing areas of the basin, except southeast of the Bailey fault. It consists of, more or less, continuous layers of marine gravels, sands and clays which are confined in most areas and range from

about 100 feet in thickness near the Santa Rosa Valley to about 400 feet thick in the deepest portions of the basin. Average thickness is about 300 feet. This zone has been affected by extensive faulting and folding since lower Pleistocene deposition. This structural activity has resulted in displacement of the zone in numerous areas, which has had a great influence upon the occurrence and movement of ground water in the Pleasant Valley Basin. In the Camarillo and Las Posas Hills the Fox Canyon aquifer zone has been upwarped and eroded to an extent which has exposed portions of it at ground surface. Upwarping combined with fault movement have resulted in dewatering portions lying near anticlinal axes. Geologic Section B-B' indicates a vertical displacement of the Fox Canyon zone across the Springville fault in excess of 250 feet. This has caused a "barrier effect" which significantly reduces ground water underflow from the Las Posas Basin on the north and east into the Pleasant Valley Basin. It is suspected that the Springville fault extends easterly creating a barrier effect between the Camarillo and Las Posas Hills. However, well log data are insufficient to accurately delineate this extension.

The Camarillo fault has also displaced Fox Canyon and younger sediments resulting in a "barrier effect" to subsurface flow in this zone. The vertical component of movement approaches 150 feet in Geologic Section B-B' with the northerly block elevated relative to the southerly block. Between the Camarillo and Bailey faults the Fox Canyon aquifer zone and other water-bearing units have been downfaulted and folded into a synclinal graben. This

structural activity has resulted in the lowering of equivalent rock units relative to those on either side. Vertical relative movement has been greatest along the Bailey fault zone where the Fox Canyon and other lower Pleistocene aquifer zones are in fault contact with Miocene volcanic rocks of the Santa Monica Mountains.

Some wells penetrating the Fox Canyon aquifer zone yield greater than 2,000 gallons per minute; however, the average yield is in the vicinity of 1,000 gallons per minute. The quality of water derived from this zone is generally acceptable for most beneficial uses. The large storage capacity, yield and generally acceptable quality of water derived from the Fox Canyon aquifer zone indicate its importance in modeling studies. The generally confined nature of the San Pedro formation combined with its equivalence and hydraulic continuity with deposits on the Oxnard Plain indicate that it should be modeled as a portion of the Lower Aquifer System.

GRIMES CANYON AQUIFER ZONE

This zone is present throughout much of the Pleasant Valley Basin and, where present, constitutes the basal water-bearing unit. The Grimes Canyon aquifer zone constitutes the uppermost member of the Santa Barbara formation and in this area consists primarily of rusty brown sand with some gravel and clay. Over most of its area of occurrence, well logs indicate hydraulic continuity with the overlying Fox Canyon zone. Like the Fox Canyon

zone, the Grimes Canyon aquifer zone has been intensely faulted and folded since deposition resulting in changes in transmissive capability probably similar to those of the Fox Canyon zone.

Where present, the thickness of the Grimes Canyon aquifer zone is believed to vary from less than 50 feet to more than 500 feet.

Surface and subsurface geologic data indicates that the Grimes Canyon aquifer zone is generally absent beneath the south flank of the Camarillo Hills and beneath the Las Posas Hills.

The yield of the Grimes Canyon zone is not adequately defined since water wells completed within this zone are also completed in the overlying Fox Canyon or shallower San Pedro zones. Inspection of well logs, however, indicates a large quantity of permeable materials which should produce substantial quantities of water.

Water produced from basal portions of this zone in synclinal areas are generally somewhat brackish indicating inadequate circulation or flushing of stored water.

Because of extensive hydraulic continuity with the overlying Fox Canyon zone, suspected substantial yield and generally acceptable quality of water, the Grimes Canyon aquifer zone should be modeled as a part of the Lower Aquifer System.

NORTH LAS POSAS BASIN

Previously the areas north and east of the Pleasant Valley Basin were delineated as the East and West Las Posas Basins on the basis of a north-south surface water drainage divide located

about 1.5 miles west of Somis. The presence of this drainage divide is thought to be quite arbitrary with regard to the occurrence, movement or quality of ground water and, therefore, a new subdivision of this area is proposed. For data storage and retrieval purposes use of the previous designations may be necessary.

The North Las Posas Basin is differentiated from the Oxnard Plain Basin because of a lack of the Upper Aquifer System at or near the basin boundary and from the Pleasant Valley Basin by distinct structural barriers. The delineation of the subdivision between the North and South Las Posas Basins is based primarily upon structural features and distinct water quality differences.

The North Las Posas Basin covers an area of about 58 square miles and has a drainage area of some 73 square miles. It is bounded on the north by nonwater-bearing rocks of the South Mountain Oak Ridge area which extends from the Oxnard Plain Forebay Basin to and beyond Happy Camp Canyon. It is bounded on the west by the Oxnard Plain Basin and on the south by the Pleasant Valley and South Las Posas Basins. The drainage divide of the Camarillo Hills approximates an anticlinal axis and provides the boundary separating this basin from the Pleasant Valley Basin. The boundary between the North and South Las Posas Basins is formed by the anticlinal structure of the Moorpark hills and distinct water quality differences between these hills and the Camarillo Hills. The easterly boundary is formed by the nonwater-bearing rocks east of Happy Camp Canyon Wash.

The elevation of the drainage area ranges from less than 200 feet at the boundary of the Oxnard Plain to more than 2,800 feet on Oak Ridge.

The North Las Posas Basin is an east-west trending structure which has been highly folded as shown in Geologic Section D-D'. It is very unusual to see folding this intense in lower Pleistocene sediments and is indicative of relatively recent intense structural activity. In addition to intense folding, the North Las Posas Basin has been tilted so that water-bearing materials now plunge toward the Oxnard Plain.

Water-bearing materials include Recent and upper Pleistocene alluvium and terrace deposits, the Epworth Gravels and Fox Canyon aquifer zone of the San Pedro formation and the Grimes Canyon zone of the Santa Barbara formation. Nonwater-bearing formations which underlie these units include the Sespe, Vaqueros, Modelo and Pico formations.

RECENT AND UPPER PLEISTOCENE ALLUVIUM AND TERRACE DEPOSITS

Within the North Las Posas Basin these deposits consist primarily of relatively thin stream channel, valley filling and terrace materials. Stream channel and terrace deposits generally consist of sand and silt with some gravel and clay while valley-filling materials are usually of lower permeability with clay and silt predominating. Their aggregate thickness ranges from 0 to about 200 feet. Historically, several low-yield water wells have been completed within these materials.

One part of the basin where more extensive water supplies have been obtained is the Fairview area. The Fairview area is an east-west trending subbasin located in the northeast portion of the basin. Here Recent and upper Pleistocene deposits consist of sands and gravels with minor clays. These materials are unconfined

and are believed to reach depths of 200 to 400 feet. The thickness of these materials is difficult to determine because of the difficulty in distinguishing these deposits from the underlying Epworth Gravels of the San Pedro formation. Historically, numerous wells have been completed within this zone and have extracted excellent quality water for various beneficial uses. Mining of ground water from these materials has resulted in a severe lowering of water levels throughout the subbasin, necessitating abandonment of most wells. Prior to lowering of water levels, average well yield was about 500 gallons per minute.

Because of low-sustained yield, poor water quality or severe dewatered conditions, Recent and upper Pleistocene materials are considered unimportant in modeling studies.

SAN PEDRO FORMATION (EPWORTH GRAVELS AND FOX CANYON AQUIFER ZONE)

The San Pedro formation is the major water-bearing unit within the North Las Posas Basin. It reaches a maximum thickness of about 2,000 feet north of the Camarillo Hills and underlies almost the entire water-bearing portion of the basin. It is absent only in the northeast portion of the basin where the Grimes Canyon aquifer zone is the principal water-bearing unit.

EPWORTH GRAVELS

The Epworth Gravels are the major water-bearing unit within the upper portion of the San Pedro formation.

Throughout most of basin portions of the San Pedro formation which lie above the Fox Canyon aquifer zone consist of blue,

yellow and red clays, silty clays and silts of low permeability. These materials compose an aggregate thickness which exceeds 1,000 feet in some areas and effectively confines water-bearing zones which lie beneath.

The Epworth Gravels are exposed north of the Fairview subbasin and at its easterly terminus. From their westerly extension adjacent to Long Canyon, they extend eastward for a distance of about five miles and then trend southerly to a point approximately two miles north of Moorpark. The Epworth Gravels occur near the top of the San Pedro formation and are composed of about 200 feet of gravel, gravelly clay and silt which grades southward and westward into silt and clay materials. The limited extent of these deposits may indicate that they are remnants of an alluvial fan which has been folded and eroded resulting in its present outcrop configuration. Well logs indicate that they underlie an area totaling about 6 square miles and are probably in hydraulic continuity with Recent and upper Pleistocene deposits in the Fairview subbasin. The average yield of wells completed within this zone has been about 300 gallons per minute of excellent quality water. However, continuously declining water levels, limited area of extent and lack of hydraulic continuity with deeper zones make this unit unimportant in modeling studies.

FOX CANYON AQUIFER ZONE

The Fox Canyon aquifer zone is the most important source of ground water supply in the North Las Posas Basin. It consists of 100 to about 600 feet of continuous white or gray sand and

gravel with minor silt and clay lenses and interbeds. Although the Fox Canyon aquifer zone extends over almost the entire North Las Posas Basin, well data indicates that it is thickest in the central portion of the basin where coarse sands are present.

Along the South Mountain-Oak Ridge exposure it is of variable thickness and consists of gravel and sand which grades into fine sand near Happy Camp Canyon where it pinches out. It was first named the Fox Canyon aquifer because of its excellent surface exposure in Fox Canyon which is located approximately one mile west of Bradley Road. This zone is exposed almost continuously along the south flank of the South Mountain-Oak Ridge area from the Oxnard Plain to Happy Camp Canyon Wash, a distance of some 15 miles.

Along its outcrop trend it is not exposed in canyons because it is buried by shallow Recent alluvium. Paleontological evidence indicates that this zone was deposited under shallow water marine conditions. Where exposed, this zone is easily differentiated from the Grimes Canyon aquifer zone because of a distinct color difference. In the subsurface, delineation of the contact between these zones is very difficult.

From its area of exposure on South Mountain, the Fox Canyon zone dips to the south where it is down and upfolded by synclinal and anticlinal structures. Geologic Section D-D' indicates the degree of folding between South Mountain and the South Las Posas Basin. Here this unit has been folded by the Long Canyon syncline and anticline and the Las Posas syncline. In the eastern

part of the basin, it has been folded by the Epworth syncline beneath the Fairview Basin and the Moorpark anticline in the hills above Moorpark.

In synclinal areas of the basin, the Fox Canyon aquifer zone lies at great depths. In the area of the Las Posas syncline, north of the Camarillo Hills, the top of this zone is reached at depths exceeding 1,000 feet below ground surface and as a result the deepest water wells in the county are completed here. Some wells in this basin are greater than 1,800 feet deep; however, the average depth is about 1,300 feet.

In the northwest portion of the basin near Aggen Road, subsurface records and pumping tests indicate thinning of the zone resulting in reduced pumping capacity. In the Happy Camp Canyon surface geologic mapping indicates that the zone is entirely absent.

The quality of water derived from the Fox Canyon aquifer zone is excellent in the eastern half of the basin with a total dissolved solids concentration averaging about 275 milligrams per liter. In the western portion of the basin, it is of acceptable quality with an average mineral concentration of about 750 milligrams per liter.

Wells completed within the Fox Canyon aquifer zone have variable yield; however, the average yield is about 900 to 1,000 gallons per minute. Excessive extraction of ground water from this zone causes water levels to decline about 4.5 feet per year;

however, extensive permeable outcrops of this zone provide excellent areas for artificial replenishment if and when water becomes available for spreading.

The extensive nature of this unit combined with good to excellent water quality makes it an important computer modeling unit. Because it is almost entirely confined and equivalent to deeper zones on the Oxnard Plain, it should be modeled as a portion of the Lower Aquifer System. Near outcrop areas and under parts of the Camarillo Hills this zone is dewatered beneath the confining layer and should be treated as an unconfined system in the model.

GRIMES CANYON AQUIFER ZONE

The Grimes Canyon aquifer zone is present throughout much of the North Las Posas Basin where it constitutes the base of water-bearing materials. It is the upper member of the Santa Barbara formation which consists of up to 2,000 feet of clay, silt, sand and gravel. Along South Mountain, west of Bradley Road, surface exposures of this formation consist of low permeability clay or silt. Subsurface data also indicates nonwater-bearing materials below the Fox Canyon zone under the Camarillo Hills. Based upon this data and the lack of occurrence in the north Oxnard Plain, the Grimes Canyon zone is thought to be absent or of only limited extent west of Bradley Road.

East of Bradley Road outcrops of permeable sand and gravel materials become more and more prominent until in Happy Camp Canyon they make up almost the entire Santa Barbara formation. Here

extensive exposures are estimated to have a vertical thickness of about 1,000 feet. The Grimes Canyon aquifer zone is overlain by the Fox Canyon zone. At some outcrops and in some basin areas, a clay member separates this member from the Fox Canyon zone; however, other exposures and well logs indicate that they are in direct contact. Geologic Section D-D' indicates that a clay member separating the two is present throughout much of the central portion of the basin. East of the Long Canyon area the two zones are believed to be primarily in hydraulic continuity. The quality of water extracted from this zone is believed to be quite similar to that obtained from the Fox Canyon zone. Exceptions are found in some synclinal areas where the total dissolved solids concentration sometimes exceeds 1,200 milligrams per liter. Projection of water levels into the area near Happy Camp Canyon indicates that permeable materials may be almost thoroughly dewatered here. The large available storage, exposure of permeable materials and hydraulic continuity with the Fox Canyon aquifer zone indicate that this area would be ideal for use as an artificial replenishment facility.

The Grimes Canyon aquifer zone should be modeled as a portion of the Lower Aquifer System because of its stratigraphic position, expected vertical hydraulic continuity with the Fox Canyon zone and generally good water quality. In and near aquifer outcrop areas this zone is dewatered and should be treated as an unconfined system.

SOUTH LAS POSAS BASIN

The South Las Posas Basin has an area of about 19.4 square miles and a total drainage area of about 39.1 square miles. It is located in the southeasterly portion of the study area and is delineated from other basins because of water quality differences and structural barriers. Its northerly boundary coincides with the axis of the Moorpark anticline and distinct water quality differences between this basin and the North Las Posas Basin. It is bounded on the south by the Las Posas Hills and on the east by the Simi Basin and nonwater-bearing rocks of the Simi Hills. The Pleasant Valley Basin forms the westerly boundary in an area near the possible extension of the Springville fault.

The North Las Posas Basin is an east-west trending basin formed by downfolding of the Moorpark syncline in the vicinity of Arroyo Simi and uplift by the Moorpark anticline to the north and Las Posas anticline and Santa Rosa fault to the south.

Water-bearing units include Recent and upper Pleistocene alluvium and the San Pedro formation. The Grimes Canyon aquifer zone is not believed to be present in the South Las Posas Basin.

Nonwater-bearing rocks include low permeability portions of the Santa Barbara formation, the Pico and Sespe formations and some Miocene volcanic rocks.

RECENT AND UPPER PLEISTOCENE ALLUVIUM

Recent and upper Pleistocene alluvium fills channels tributary to Arroyo Las Posas. In these channels it is usually less than 100 feet thick and consists of sand and silt with some clay and gravel. The most extensive alluviated area lies beneath

and adjacent to Arroyo Las Posas where these deposits reach a depth of greater than 200 feet in a band which extends the entire length of the basin. Here these materials consist of sand, gravel and clay with some silt. In their area of occurrence, these deposits are unconfined and receive replenishment from stream percolation and precipitation. Wells have been completed within this zone primarily in the Arroyo Las Posas area and yield an average of 400 gallons per minute. Other tributary areas are generally only partially saturated or entirely dewatered.

The alluvial materials in the Arroyo Las Posas area contain water of unacceptable quality for domestic uses and marginal quality for many agricultural uses. Average mineral concentration is about 1,850 milligrams per liter. The poor quality of water here is attributed to poor quality runoff and rising water derived from the Simi basin and perhaps contribution of saline water from adjacent and underlying nonwater-bearing rocks.

Although water quality is quite poor, the quantity of water is significant and saturated materials in the vicinity of Arroyo Las Posas should be modeled as an unconfined system.

SAN PEDRO FORMATION (FOX CANYON AQUIFER ZONE)

The San Pedro formation is present throughout the entire South Las Posas Basin. It has been upfolded in the Moorpark and Las Posas Hills where it is partially exposed.

UPPER SAN PEDRO FORMATION

Within the South Las Posas Basin the upper San Pedro formation has variable lithology. Throughout most of the basin it consists primarily of low permeability clay and silt materials with included sand and gravel lenses which effectively confine the Fox Canyon aquifer zone. However, in the vicinity of Moorpark and westerly from there, a distance of some four miles adjacent to Arroyo Las Posas, subsurface records indicate hydraulic continuity between ground surface and the Fox Canyon aquifer zone indicating the presence of extensive permeable materials in the upper San Pedro formation.

Here the upper San Pedro formation should be modeled as an unconfined water-bearing unit. In other portions of the basin, it should be considered a confining member overlying the Fox Canyon aquifer zone.

FOX CANYON AQUIFER ZONE

This zone is present throughout most of the South Las Posas Basin where it constitutes the effective base of the ground water reservoir. It is exposed only along the north flank of the Las Posas Hills where it provides some replenishment from rainfall and limited runoff.

The Fox Canyon aquifer zone consists primarily of sand and gravel layers with clay and silt lenses. It is not believed to be present in extreme eastern portions of the basin. From its first easterly occurrence, it gradually thickens to a maximum of

about 400 feet in the western portion of the basin. Average thickness throughout its area of occurrence is about 200 feet.

Throughout the basin the Fox Canyon aquifer zone contains variable quality water. The quality of water extracted is largely determined by the location of wells with relation to geologic structure. In anticlinal areas ground water generally has a mineral concentration of less than 1,000 milligrams per liter while that which occurs in the area of the Las Posas syncline is poor in the vicinity of Moorpark with an average mineral concentration of 1,800 to 2,000 milligrams per liter. The poor quality of water which is present here is believed to be the result of hydraulic continuity with overlying and adjacent materials. Throughout most of the South Las Posas Basin, the Fox Canyon aquifer zone is confined and should be modeled in that manner. Exceptions are noted beneath the outcrop area of the Las Posas Hills, dewatered portions of the Moorpark Hills and in the unconfined area beneath Arroyo Las Posas near Moorpark where free-water table conditions are believed to predominate.

SANTA ROSA BASIN

With a water-bearing area of 6.3 square miles and a drainage area of only 12.8 square miles the Santa Rosa Basin is the smallest in the study area. Although it is of small size and limited storage capacity, it is one of the most complex basins because of intense structural activity. The Santa Rosa Basin is

bordered on the south and east by volcanic rocks of the Santa Monica Mountains, on the north by the Las Posas Hills and on the west by the Pleasant Valley Basin. The westerly boundary is somewhat arbitrary and may have to be altered in the future.

The Santa Rosa Basin ranges in elevation from about 200 feet at its westerly terminus to about 600 feet at the northerly limits of the San Pedro formation. The maximum elevation of the drainage area reaches about 1,200 feet above sea level in the Santa Monica Mountains.

Major water-bearing units within the Santa Rosa Basin include Recent alluvium and Quaternary terrace deposits and the San Pedro and Santa Margarita formations. Nonwater-bearing formations include the Santa Barbara, Topanga and Sespe formations and Tertiary volcanic rocks.

The Santa Rosa Basin is an east-west trending downfolded and faulted area as indicated in Geologic Section D-D'. Major folds include the Santa Rosa syncline and the Las Posas anticline. Major faults include the Santa Rosa and Bailey fault zones which have undergone considerable displacement since deposition of water-bearing materials. The Santa Rosa fault zone is part of an extensive system which extends through the Simi Valley and into Los Angeles County. Where present in water-bearing materials, it probably forms an effective barrier to north-south subsurface flow. The Bailey fault zone provides a substantial barrier to east-west underflow

of ground water. Water level data indicates that water levels are about 100 feet higher on the east side of the fault than on the west. These structural features combined with large amounts of uplift in the Santa Monica Mountains have resulted in complex geohydrologic conditions which are not thoroughly understood at this time.

The quality of water extracted on the northwest side of the Bailey fault zone is generally good with total dissolved solids ranging from about 500 to almost 800 milligrams per liter. On the southeast side of the Bailey fault zone, water quality is more variable. Here, beneath low-lying portions of the valley, the total dissolved solids concentration ranges from about 800 to 1,100 milligrams per liter and nitrate concentration ranges from 10 to 200 milligrams per liter. Along the northerly slopes of the valley much lower salinity and nitrate concentrations are generally found.

RECENT ALLUVIUM AND QUATERNARY TERRACE DEPOSITS

Recent alluvium consists of stream deposited gravel, sand, silt and clay which occurs along and adjacent to Conejo Creek and Arroyo Santa Rosa. These deposits are unconfined and reach a maximum thickness of 150 feet or less in the main portion of the Santa Rosa Valley. East of the Bailey fault zone these deposits are more porous sands and gravels while west of it they are more clayey.

Quaternary terrace deposits consist of boulders, gravels, sands, and clays which are exposed along the south slopes of the Las Posas Hills and extend to the valley floor. They are also present as eroded remnants beneath Recent alluvial deposits. These deposits have a wide range of thickness; however, their maximum thickness is believed to be no greater than 250 feet. The greatest thickness of these materials occurs on the northwest side of the easterly Bailey fault branch. Alluvium and terrace materials should be modeled as an unconfined aquifer system.

SAN PEDRO FORMATION (FOX CANYON AQUIFER ZONE)

The San Pedro formation is exposed along the south flank of the Las Posas Hills for almost the entire length of the Santa Rosa Basin. East of the Bailey fault zone the San Pedro formation is not believed to contain the basal Fox Canyon member. Here it is composed of lenticular beds of sand, gravel, silt and clay which are probably semi-confined. West of the Bailey fault well logs indicate presence of the Fox Canyon aquifer zone which is composed of sand and gravel layers about 100 feet thick. Above this zone the presence of low permeability materials indicates confined conditions except on the Las Posas Hills where the Fox Canyon aquifer zone may be near ground surface. This zone is the basal water-bearing unit on the west side of the easterly Bailey fault branch.

SANTA MARGARITA FORMATION

The Santa Margarita formation of upper Miocene age was derived from erosion and deposition of the Conejo volcanics. It

is exposed in the eastern portion of the Santa Rosa Valley where it consists of volcanic conglomerate, sandstone and tuff. It varies in thickness from 300 to 1,000 feet; however, the base of water-bearing portions of this unit is about 550 feet below ground surface. It is the basal water-bearing unit east of the Bailey fault zone and water level information indicates similar water levels as those in overlying alluvial and terrace deposits. This unit should, therefore, be modeled as an unconfined system.

REFERENCES CITED

- California Department of Public Works, Division of Water Resources. "Ventura County Investigation." Bulletin No. 46-Report. Bulletin No. 46A-Basic Data. 1933.
- California Department of Water Resources. "Sea-Water Intrusion Oxnard Plain of Ventura County." Bulletin No. 63-1. October, 1965.
- California Department of Water Resources. "Oxnard Basin Experimental Extraction Type Barrier." Bulletin No. 147-6. September, 1970.
- , and University of California, Berkeley. "Aquitards in the Coastal Ground Water Basin of Oxnard Plain, Ventura County." Bulletin No. 63-4. September, 1971.
- California Water Resources Board. "Ventura County Investigation." Bulletin No. 12. Volumes I and II. October, 1953.
- Geotechnical Consultants, Inc. "Hydrogeologic Investigation Proposed Marina Development near Oxnard, California." April, 1969.
- Mann, John F., Jr. "Overdraft on the Deep Aquifer in Pleasant Valley and Possibilities of Recharge by Spreading." Report to Board of Directors, United Water Conservation District. July 3, 1952.
- . "Supplement to a Plan for Ground Water Management-United Water Conservation District." February, 1968.
- Mann, John F., Jr., and Associates. "A Plan for Ground Water Management-United Water Conservation District." September, 1959.
- Ventura County Public Works Agency, Flood Control District. "Las Posas Area Ground Water Quality and Quantity Investigation." August, 1971.
- . "Moorpark Planning Area-Ground Water Hydrology." February, 1972.
- . Ventura County Resources Plan; Surface and Ground Water Resources. January, 1973.
- . "Revolon-Beardsley Project Environmental Study-Geohydrology." April, 1974.
- . "Preliminary Geohydrology Study; Santa Rosa Valley." September, 1974.
- . "1974 Seawater Intrusion Study; Oxnard Plain of Ventura County." January, 1975.

VENTURA COUNTY DEPARTMENT OF PUBLIC WORKS
FLOOD CONTROL DISTRICT

VENTURA COUNTY WATER RESOURCES MANAGEMENT STUDY
EFFECTIVE BASE OF FRESH WATER RESERVOIR
IN THE OXNARD-CALLEGUAS AREA

By

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This Technical Information Record was prepared to document pertinent information as it was developed during the Ventura County Water Resources Management Investigation.

January 1975

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INTRODUCTION

The objective of this portion of the investigation was to establish the effective base of fresh water in the Oxnard-Calleguas area to determine the depth at which the quality or quantity of water recovered is insufficient to justify deeper drilling and development of water wells.

During this study, hundreds of electric logs and lithologic logs from oil and water wells were inspected. Of these, about 200 electric logs and 120 lithologic logs were selected for compilation of subsurface geology, structure and extent of aquifers to delineate the effective base of the fresh water reservoir in the Oxnard-Calleguas portion of the study area.

Depths to the base were converted to elevations above or below sea level (USGS Datum) and plotted on Plate 1, which also indicates major structural barriers and boundaries of water-bearing rocks.

CRITERIA USED

Quantity and quality of water recoverable from a well are two primary factors from which the base is determined.

WATER QUANTITY: The quantity of water a well is capable of producing depends upon the permeability of the saturated portion of the aquifer penetrated. The water-bearing capability of the aquifer was estimated on the basis of interpretation of electric logs, supplemented with lithologic logs and well pump-test data. The Quaternary geology of the Oxnard-Calleguas area is complex due to its particular sedimentary and tectonic history. Here fresh water is generally stored in and produced from Recent and upper Pleistocene alluvium, and the Oxnard, Mugu, Hueneme, Fox Canyon and Grimes Canyon aquifer zones. The effective base was determined primarily from the areal and vertical extent of these zones. Although many wells in this area are capable of producing greater than 2,000 gallons per minute (gpm), the effective base of fresh water was delineated upon the basis of those units consistently yielding greater than 100 gpm of acceptable quality water. Within the Oxnard-Calleguas area, the Fox Canyon or Grimes Canyon aquifer zones of lower Pleistocene age generally constitute the basal water-bearing units. Exceptions to this condition are found in two or possibly three areas. At the base of the Santa Monica Mountains some wells produce relatively large quantities of water from highly fractured Tertiary volcanic rocks. Because of sporadic yield and generally poor water quality, they were considered to be nonwater-bearing. In addition, electric logs indicate that the upper part of Pico formation around El Rio may store fresh water; however, it was not considered in the effective base, because of its great depth,

lack of producing water wells, and unknown water quality. Aquifers in the Oxnard Plain Basin extend offshore under the Santa Barbara Channel, but the offshore reservoir was not considered during this study due to a lack of available data.

WATER QUALITY: Water extracted from wells in the area has a wide range of mineral quality, varying from less than 150 milligrams per liter (mg/l) of total dissolved solids (TDS) concentration in a portion of the Calleguas area to more than 10,000 mg/l in areas where the Oxnard and Mugu aquifer zones have been intruded by seawater along the coast. Current State Department of Health Standards define 1,000 mg/l TDS as being the upper limit of mineral concentration for domestic use; however, ground water of quality having more than 1,000 mg/l TDS concentration has been used for most beneficial purposes in Ventura County. It is difficult to determine the extent of the ground water body by quality in three dimensions because of inadequate data at the structural base of water-bearing materials; however, wells completed to the base of the Fox Canyon and Grimes Canyon aquifer zones generally yield water of acceptable quality and thus these zones were selected as marker horizons for determination of the effective base of fresh water. Exceptions are found in some synclinal areas where connate water has not been flushed since deposition. Because the effective base almost always conforms to stratigraphic units, the resulting contour map reflects structural conditions of these units over most of the study area. Another anomaly is found near the

coast where shallow zones have been intruded by seawater. Since this condition is considered transient and reversible and because these zones are underlain by deeper zones which are not intruded and can be produced separately, the deeper zones were utilized to delineate the effective base in these areas.

GENERAL CONFIGURATION OF THE EFFECTIVE BASE

Ground water basins of the Oxnard-Calleguas area are bordered by nonwater-bearing Tertiary formations of the Santa Monica Mountains to the southeast and Big Mountain to the east. The northerly boundary is formed by the South Mountain structural high and the Oak Ridge-McGrath fault zones. To the west water-bearing units extend to varying distances offshore. The offshore configuration and extent of aquifer zones were determined by means of an extensive sparker survey conducted by the United States Geological Survey and will be described in a report being prepared by them.

The effective base of fresh water within the Oxnard-Calleguas area ranges from greater than 1,000 feet above sea level near Happy Camp Canyon to greater than 2,100 feet below sea level in the north-central Oxnard Plain. Extensive folding and faulting indicated by contours on the effective base are indicative of intense structural activity within the study

area since lower Pleistocene deposition of basal water-bearing units. In many areas contours indicating structural highs are reflected by surface hills. As an example, the Las Posas and Pleasant Valley Basins are separated by intrabasin structural highs: the Camarillo and Las Posas Hills.

OXNARD PLAIN GROUND WATER BASIN - Fresh water is stored in and extracted from Recent and Pleistocene aquifers which include the Oxnard, Mugu, Hueneme, Fox Canyon and Grimes Canyon aquifer zones. The Recent Oxnard aquifer and the upper Pleistocene Mugu aquifer zones lie generally flat on the older formations and form the effective base only at the base of South Mountain and along most of the base of the Santa Monica Mountains south of the Bailey fault.

The lower Pleistocene aquifer zones are folded along north east-trending axes principally due to the mid-Pleistocene Orogeny. The uppermost lower Pleistocene aquifer zone is the Hueneme zone which is not present generally south of Pleasant Valley Road because of folding and erosion prior to deposition of the Upper Aquifer System. This zone does not form the effective base because it is underlain by the Fox Canyon aquifer zone wherever it occurs. The Fox Canyon aquifer zone forms the effective base over the northerly two thirds of the Oxnard Plain Basin. Southeast of here the Grimes Canyon aquifer zone lies beneath the Fox Canyon zone and forms the effective base

except in the area southeast of the Bailey fault. The extent of the Grimes Canyon zone is believed to be limited by a facies change, causing reduced permeability in a northerly direction.

The configuration of the effective base of fresh water is relatively uncomplicated on the Oxnard Plain. Synclinal and basin structures on the effective base appear in two areas. The most significant synclinal area occurs between the North Las Posas Basin and the ocean. Within this area a basin beneath the El Rio area causes the effective base to exceed 2,100 feet below sea level. A second, less accentuated synclinal structure is apparent in the southeast Oxnard Plain where a maximum depression in excess of 1,300 feet below sea level occurs. This structure extends roughly from Highway 101 in the northeast to Hueneme Road at the southwest termination of the structure. A structural high appears in the area of the intersection of Hueneme and Arnold Roads where nonwater-bearing Miocene volcanic rocks were penetrated by an exploratory oil well. Here the elevation of effective base is 1,000 feet below sea level.

Faults which affect the configuration of the effective base of fresh water on the Oxnard Plain include the McGrath and Bailey zones. The McGrath fault occurring in the vicinity of the Santa Clara River has a northeast-southwest trend and has, along with the Montalvo anticline, caused the effective base of fresh water to occur at shallower depths on the south side. The differential elevation of the effective base is greater than 900 feet near the ocean.

The Bailey fault occurs beneath the south Oxnard Plain and generally parallels the termination of the Santa Monica Mountains. Water-bearing materials on the southeast side of the fault have been uplifted about 50 feet near the ocean to about 200 feet where it passes the eastern margin of the Oxnard Plain Basin.

Data from numerous wells indicates that displacement generally increases in an easterly direction with maximum displacement occurring in the Pleasant Valley Basin.

PLEASANT VALLEY BASIN - Within the Pleasant Valley Basin ground water is stored and extracted primarily from the Fox Canyon and Grimes Canyon aquifer zones of the Lower Aquifer System. Above these zones water-bearing materials become lenticular, reflecting a predominance of deposition of fine-grained materials. The basal water-bearing unit within most of the basin is the Grimes Canyon aquifer zone, the uppermost unit of the Santa Barbara formation. Exceptions to this condition are found in three portions of the Pleasant Valley basin. One area is the south side of the Bailey fault zone where the Lower Aquifer System is absent and the effective base is formed by upper Pleistocene and Recent alluvium. Another area lies generally north of the Springville fault zone in the Camarillo Hills where available data indicates that the Fox Canyon aquifer zone constitutes the effective base. Another area where the Fox Canyon aquifer zone

constitutes the effective base is in the Las Posas Hills where it directly overlies the Sespe formation and Miocene volcanic rocks.

Four major fault zones significantly affect the occurrence of the effective base of fresh water in the Pleasant Valley Basin. These are, from north to south, the Springville, Santa Rosa, Camarillo and Bailey fault zones, all believed to be branches structurally related to the Santa Rosa fault zone. Maximum vertical displacement of the effective base adjacent to the Springville fault approaches 600 feet, the north side being elevated relative to the south side. Maximum displacement on the Santa Rosa fault zone is approximately 200 feet with the north side also elevated relative to the south. The Camarillo fault apparently has minimum vertical displacement, while the Bailey fault exhibits a vertical displacement of about 600 feet with the south side of the fault indicating upward displacement relative to the north.

Interspaced between major fault zones are up and downfolded areas. Upfolded areas include the Camarillo and Las Posas Hills, while significant downfolded areas are found on both sides of the Camarillo fault.

The overall effect of these structural features is an irregular westerly plunging surface with abrupt changes in elevation at major fault zones. The elevation of the effective base exceeds sea level at the base of the Santa Monica Mountains and in the

Las Posas Hills while it extends to depths of greater than 1300 feet below sea level in the west-central portion of the basin.

NORTH LAS POSAS BASIN - The North Las Posas Basin, extending from Happy Camp Canyon to the Oxnard Plain Basin, is bounded by the nonwater-bearing rocks of South Mountain on the north and by the Pleasant Valley and South Las Posas Basins at its southerly terminus. The effective base of fresh water in all areas consists of either the Fox Canyon or Grimes Canyon aquifer zones. In the western portion of the basin the Fox Canyon aquifer zone constitutes the effective base because the Grimes Canyon unit is not present. In the eastern portion of the basin, the Grimes Canyon aquifer zone is the dominant basal water-bearing zone. Although subsurface data are inadequate to accurately delineate this boundary, surface exposures on South Mountain combined with numerous deep exploratory petroleum well records indicate the above general relationship.

Folding and tilting is the dominant structural feature which has formed the configuration of the effective base in the North Las Posas Basin. Extensive folding since lower Pleistocene deposition has produced an elongated series of southwesterly trending synclines and anticlines indicative of intense structural activity. The major synclinal feature is the Las Posas syncline which enters the basin from the Oxnard Plain and extends in a northwesterly direction through the entire basin. Major upwarped features include the Camarillo and Moorpark anticlines, the axes of which approximate the southerly

basin boundary. Other major known structures affecting the effective base of fresh water are the Long Canyon syncline and anticline which occur north of the Las Posas syncline in the western portion of the basin.

In the northeasterly portion of the basin between Happy Camp Canyon and Balcom Canyon Road the effective base of fresh water is depicted as a simple north synclinal limb due to lack of adequate subsurface control. This interpretation is based largely upon the surface attitude of exposed rock units and should be considered tentative and subject to modification as additional data become available. Another area where the effective base of fresh water should be considered tentative is that area north of La Loma Road where recent data indicates poor quality water and low yield from test wells penetrating the Fox Canyon aquifer zone. This anomaly may be the result of a barrier effect causing inadequate circulation in this area. The topographic linearity of features in the vicinity of La Loma Road is suggestive of fault movement; however, additional data is needed prior to altering the configuration of the effective base of fresh water here.

Within the North Las Posas Basin the elevation of the effective base is closely related to topography. Topographic highs generally indicate minimum depths, while topographic lows indicate maximum depths to the effective base. The elevation of the effective base varies from well over 2000 feet above

sea level where outcrops of the Grimes Canyon aquifer zone occur in Happy Camp Canyon to depths of greater than 1,600 feet below sea level north of the Camarillo Hills.

SOUTH LAS POSAS BASIN - The South Las Posas Basin extends from the west end of the Simi Basin to the hills above Moorpark and Camarillo on the north, the Las Posas Hills on the south and the Pleasant Valley Basin to the west. The effective base of fresh water generally conforms to the base of the Fox Canyon aquifer zone. In areas where this zone is absent, the effective base conforms to the base of alluvial deposits. The Grimes Canyon aquifer zone is not believed to be present to a significant degree within this basin.

Folding has been the dominant structural factor determining variations in the effective base of fresh water. Dominant folds within this basin include the Moorpark syncline and anticline.

Just south of the topographic boundary of the South Las Posas Basin is the Santa Rosa fault zone, a zone which has significantly elevated rocks in the Las Posas Hills. Just south of the drainage divide of the Las Posas Hills, the Topanga and Sespe formations are exposed, indicating significant uplift of these bedrock units. Immediately north of these units and overlying them unconformably

are extensive exposures of the Fox Canyon aquifer zone which constitutes the effective base of fresh water in the Las Posas Hills.

Contours on the effective base of fresh water in the South Las Posas Basin have a west-southwest trend and display a smoother more regular surface than is found throughout most of the study area.

Elevations of the effective base reach a maximum of greater than 700 feet above sea level where elevated by the Santa Rosa fault zone in the Las Posas Hills. Another structural high occurs along the Moorpark anticline where the elevation on the base of the Fox Canyon aquifer zone exceeds 200 feet above sea level. Other areas where the effective base approaches or exceeds 600 feet above sea level include the Happy Camp Canyon stream channel area and Arroyo Simi near the Simi Basin where alluvial materials constitute the effective base. The maximum depth and thickness of the effective base occurs beneath Arroyo Simi at Moorpark where the Moorpark syncline has downwarped water-bearing materials to greater than 400 feet below sea level.

SANTA ROSA BASIN - The Santa Rosa Basin is the smallest ground water basin within the Oxnard-Calleguas area in terms of areal extent and storage capacity. It is bounded on the north by the drainage divide of the Las Posas Hills and on the south and east by the nonwater-bearing rocks of the Santa Monica Mountains and Simi Hills, respectively. The westerly boundary is a surface

drainage divide which separates this basin from the Pleasant Valley Basin (Plate 1). Recent preliminary studies by the Ventura County Flood Control District indicate structural barriers which may result in future alteration of the westerly basin boundary after more data are collected and evaluated. The Santa Rosa Basin is an east-west synclinal basin thought to have been extensively affected by faulting.

The Santa Rosa fault zone forms the boundary between water-bearing rocks in the basin proper and the nonwater-bearing Topanga and Sespe formations to the north. Within the basin several fault branches affect the elevation and formations which constitute the effective base. The Bailey fault zone consists of two or possibly three northeasterly trending branches in the Santa Rosa Basin. In each case the easterly side of the zone has been uplifted relative to the westerly side. East of the easterly branch the effective base is formed by Recent and upper Pleistocene alluvium and the Tertiary Santa Margarita formation. This is the only basin within the Oxnard-Calleguas area where rocks older than lower Pleistocene constitute the effective base of water-bearing materials. Here the effective base of fresh water varies from greater than 400 feet above sea level along the northerly flank of the basin to greater than 300 feet below sea level in the middle of the basin. West of the fault zone the Fox Canyon aquifer zone constitutes the effective base which varies in elevation from greater than 200 feet above sea level just

01.
south of the Santa Rosa fault to almost 600 feet below sea level at the structural center of the basin. Vertical offset of the effective base approaches 300 feet which is much less than the stratigraphic separation.

Near the western edge of the basin one or possibly two branches of the Bailey fault offset the effective base which consists of the Fox Canyon or upper San Pedro aquifer zones and Recent and upper Pleistocene alluvium. Here maximum vertical offset exceeds 200 feet.

REFERENCES CITED

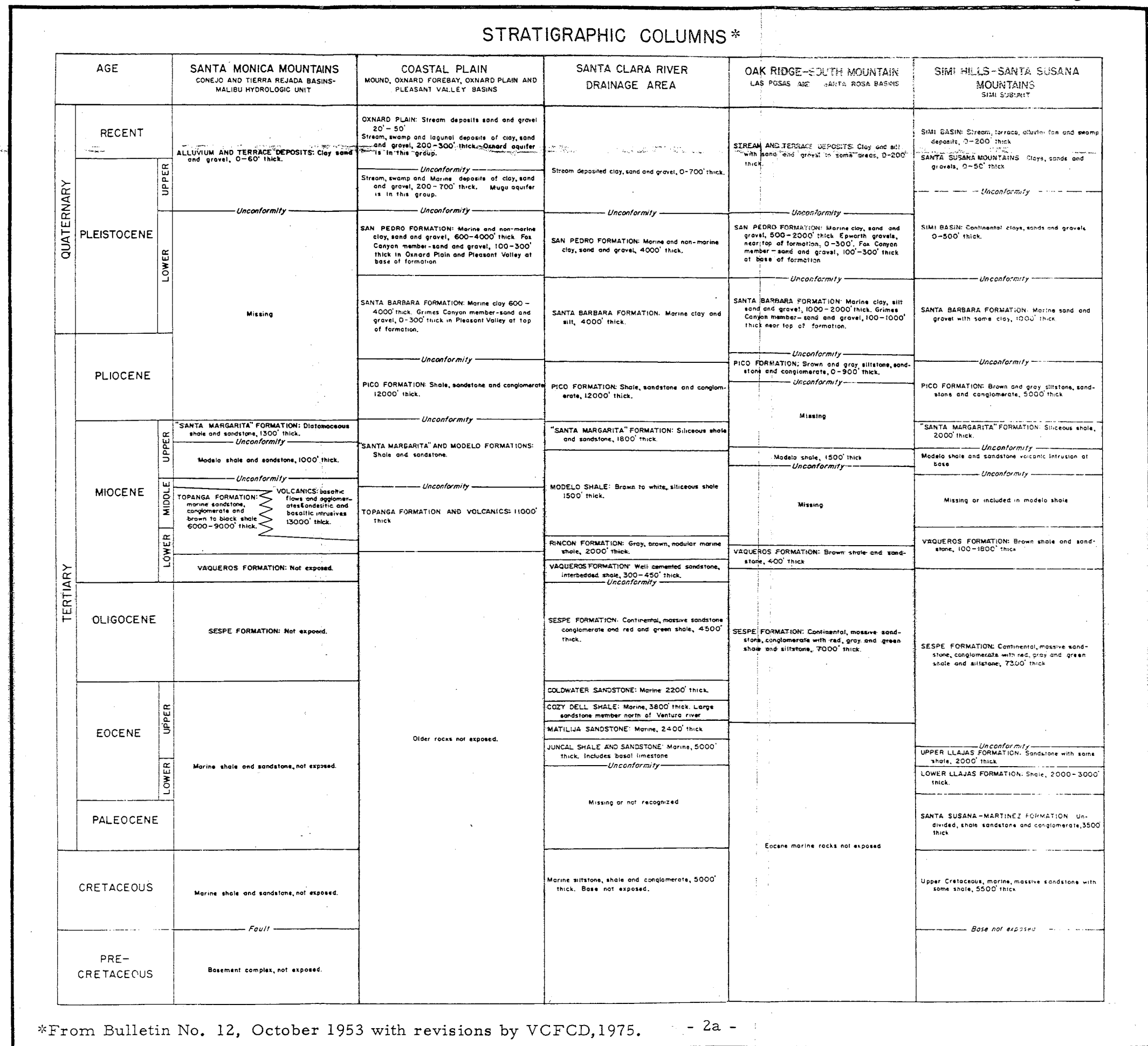
California Department of Water Resources. "Sea-Water Intrusion
Oxnard Plain of Ventura County." Bulletin #63-1.
October 1965.

California Water Resources Board. "Ventura County Investigation."
Bulletin #12. Volumes 1 and 2. October 1953.

Mann, John F., Jr., and Associates. "A Plan for Ground Water
Management, for United Water Conservation District."
September 1959.

----- "Supplement to A Plan for Ground Water Management, for
United Water Conservation District." February 1968.

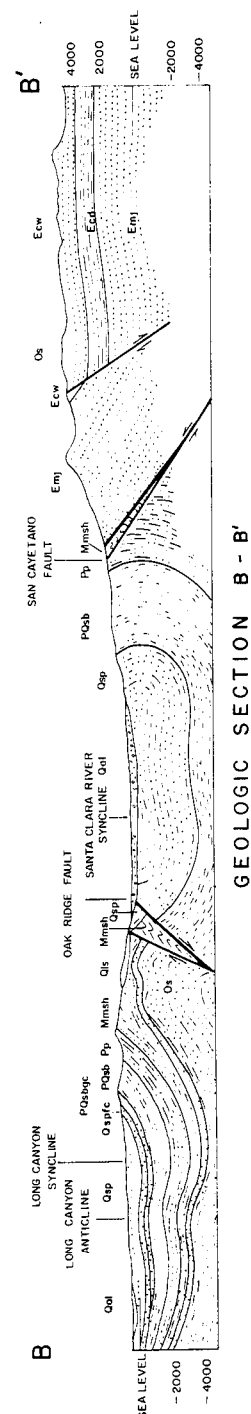
Figure 1



*From Bulletin No. 12, October 1953 with revisions by VCFCD, 1975.



GEOLOGIC SECTION A-A'-A"



GEOLOGIC SECTION B - B'

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

WATER RESOURCES MANAGEMENT
VENTURA COUNTY

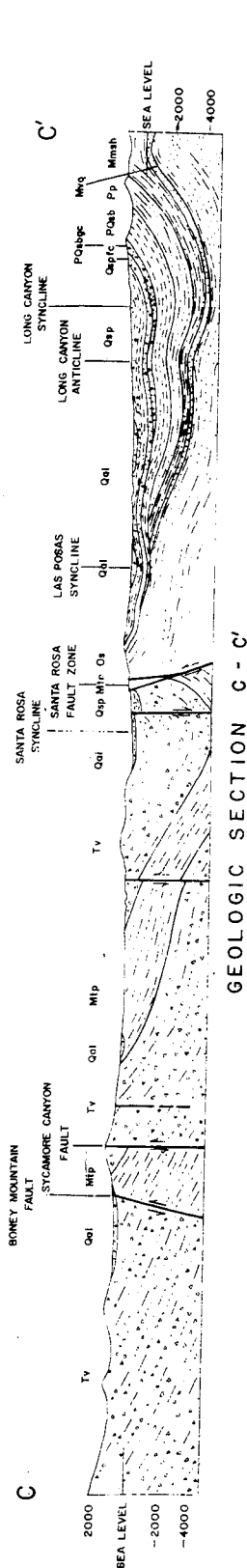
AREAL GEOLOGY

1975

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GEOLOGIC SECTION C-C'

LEGEND

QUATERNARY	RECENT	Qal	Alluvium (Sand, Gravel and clay) Water-bearing.
		Qs	Dune sand.
UPPER PLEISTOCENE		Qls	Landslide
		Qtr	Terrace deposits and older alluvium. Marine and continental gravel, sand and clay. Water-bearing.
		Qsp	San Pedro formation. Marine and continental sand, gravel, silt and clay. Generally water-bearing.
		Qspg	Edworth gravels. Water-bearing member of the San Pedro formation.
		Qspfc	Fox Canyon member of the San Pedro formation. Marine sand & gravel. Water-bearing.
LOWER PLEISTOCENE		PQab	Santa Barbara formation. Marine silt, clay, sand and gravel. Generally nonwater bearing.
		PQsb	Grimes Canyon member of the Santa Barbara formation. Marine sand & gravel. Water-bearing.
		Pp	Pico formation. Marine siltstone, sandstone, conglomerate and shale. Nonwater-bearing.
PLIOCENE		Msm	"Santa Margarita" formation. Marine shale, sandstone and conglomerate. Locally water-bearing.
		Mmsh	Modelo shale. Marine. Locally water-bearing.
MIOCENE		Mms	Modelo sandstone. Marine. Locally water-bearing.
		Mrc	Rincon formation. Marine shale. Nonwater-bearing.
Eocene		Mfp	Topanga formation. Marine sandstone, conglomerate, shale and associated volcanics. Locally water-bearing.
		Mvq	Vaqueros formation. Marine sandstone and shale. Nonwater-bearing.
OLIGOCENE		Cs	Sespe formation. Continental sandstone, conglomerate and shale. Locally water-bearing.
		Ecw	Coldwater sandstone. Marine. Generally nonwater-bearing.
Eocene		Ecd	Cozy Dell shale. Marine. Nonwater-bearing.
		Emj	Matilija sandstone. Marine. Nonwater-bearing.
Eocene		Ejc	Juncal formation. Marine sandstone and shale. Nonwater-bearing.
		Eul	Upper Lajas formation. Marine sandstone, some shale. Locally water-bearing.
Eocene		Eli	Lower Lajas formation. Marine shale. Generally nonwater-bearing.
		Esm	Santa Susana-Martinez formation. Marine sandstone, conglomerate and shale. Locally water-bearing.
PALEOCENE		Ku	Undifferentiated formations of Cretaceous Age. Marine sandstone, some conglomerate and shale. Locally water-bearing.
		Tv	Volcanics. Basaltic flows and agglomerates with some interbedded sediments. Basaltic and andesitic intrusions. Locally water-bearing.
CRETACEOUS			

—+—	CONTACT
—+—	ANTICLINE
—+—	SYNCLINE
—+—	FAULT
—+—	DIP AND STRIKE
—+—	OVERTURNED BED
—+—	VERTICAL BED
—+—	HORIZONTAL BED

Dashed where concealed or poorly exposed.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
WATER RESOURCES MANAGEMENT

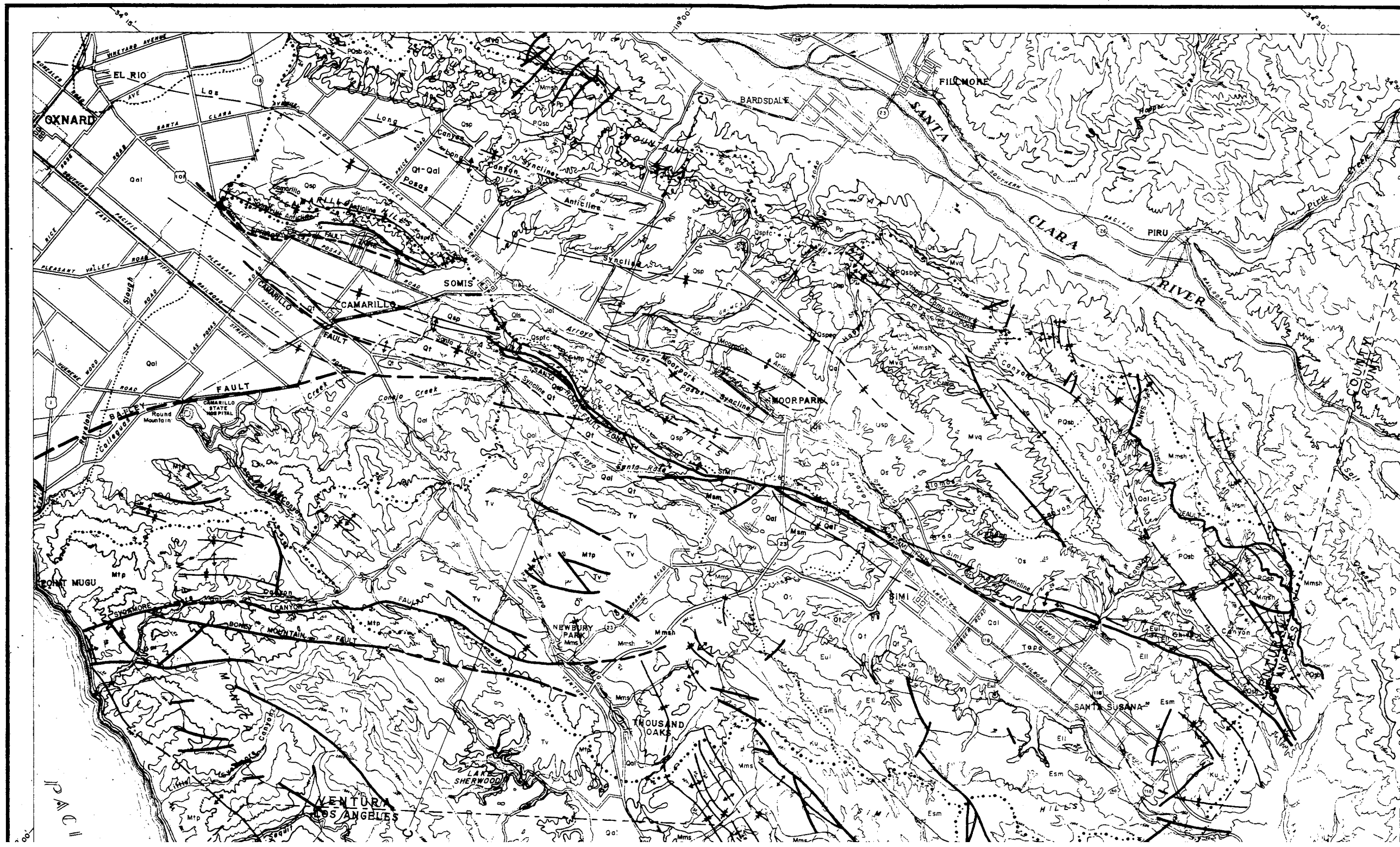
VENTURA COUNTY
AREAL GEOLOGY

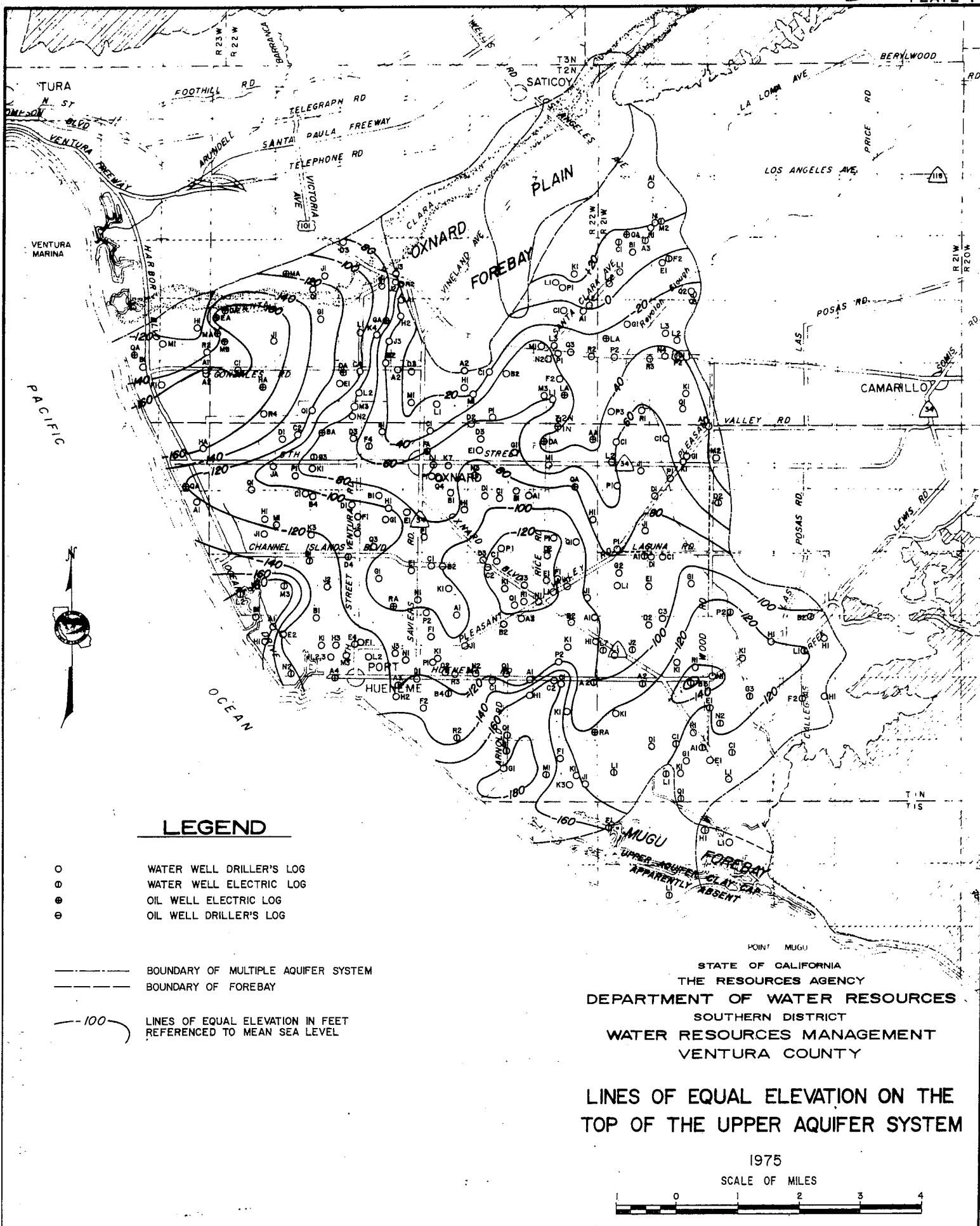
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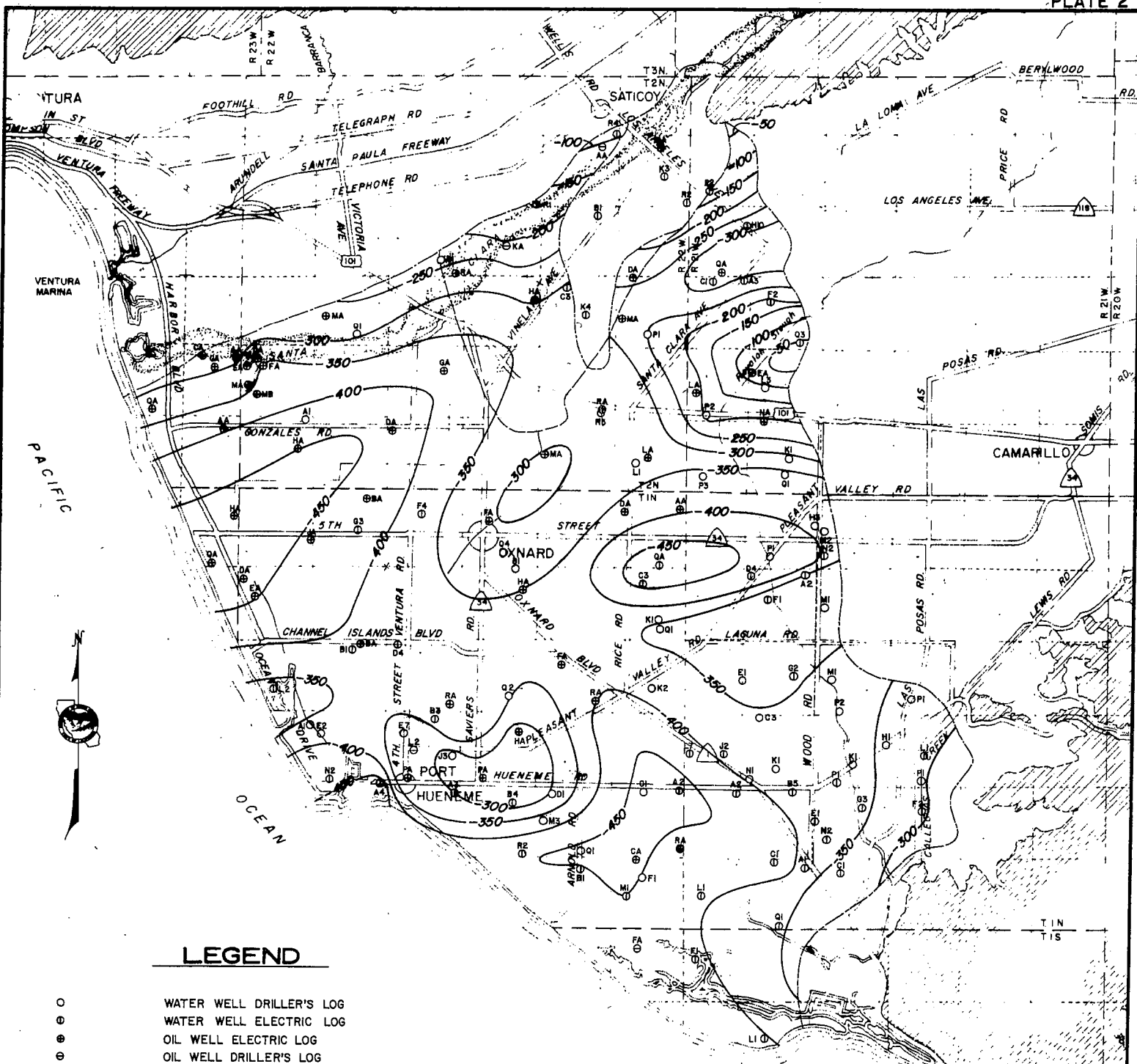
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From BULLETIN NO. 12, October 1953
with revisions by VCFCD, 1975







LEGEND

- WATER WELL DRILLER'S LOG
- ⊙ WATER WELL ELECTRIC LOG
- ⊗ OIL WELL ELECTRIC LOG
- ⊕ OIL WELL DRILLER'S LOG

- BOUNDARY OF MULTIPLE AQUIFER SYSTEM
- BOUNDARY OF FOREBAY

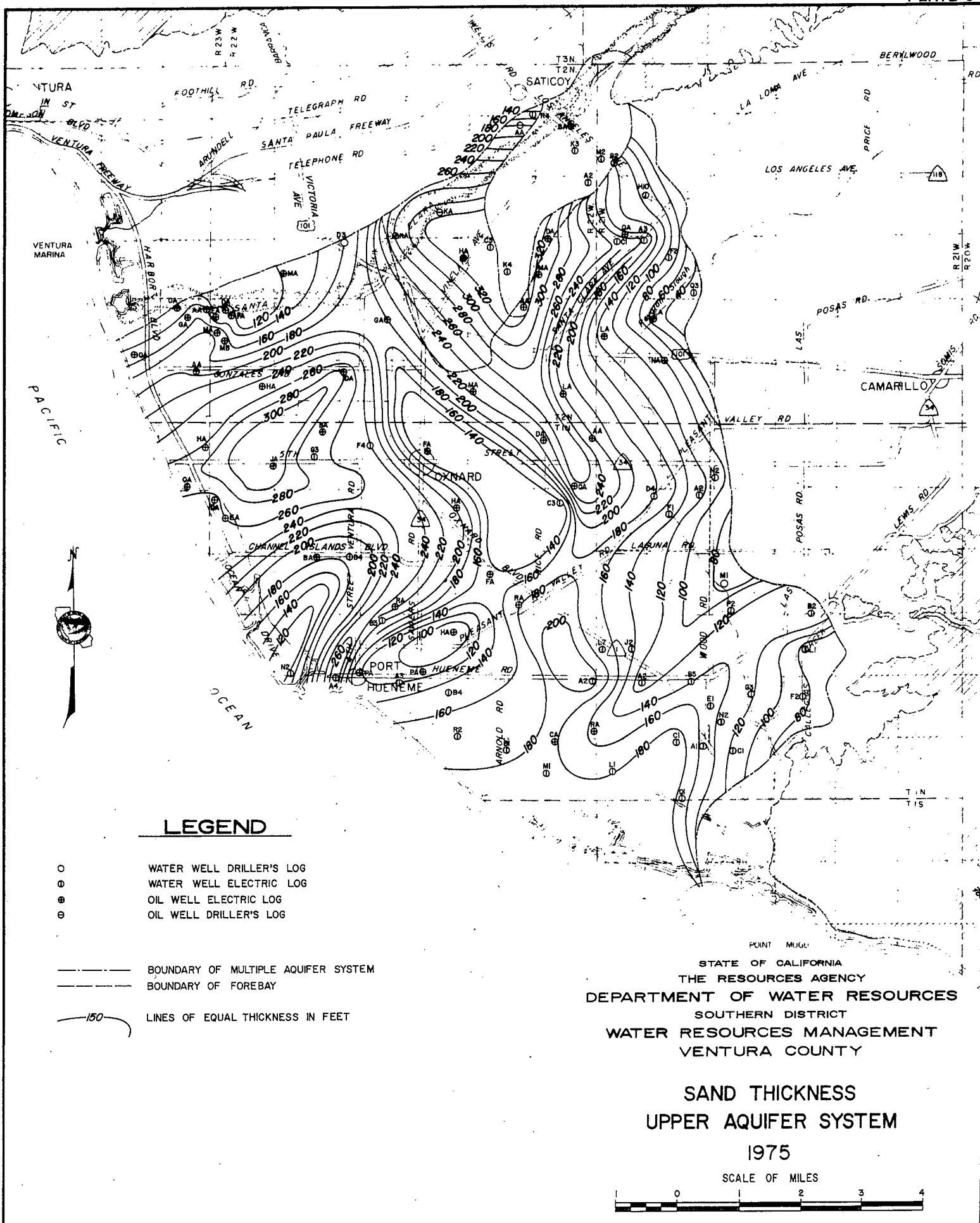
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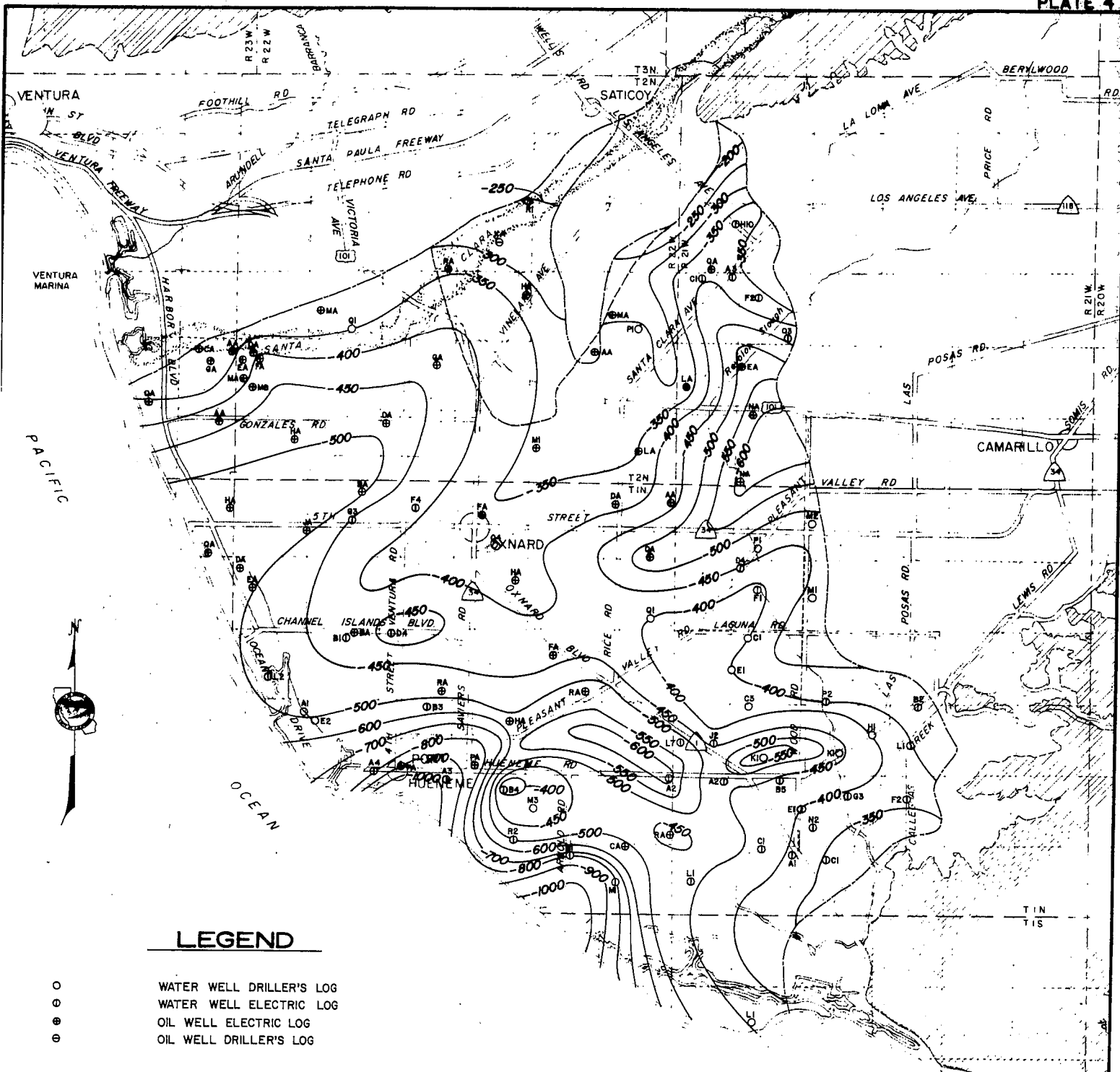
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DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
WATER RESOURCES MANAGEMENT
VENTURA COUNTY

LINES OF EQUAL ELEVATION ON THE
BASE OF THE UPPER AQUIFER SYSTEM
1975

SCALE OF MILES







LEGEND

- WATER WELL DRILLER'S LOG
- ⊙ WATER WELL ELECTRIC LOG
- ⊕ OIL WELL ELECTRIC LOG
- ⊕ OIL WELL DRILLER'S LOG

- BOUNDARY OF MULTIPLE AQUIFER SYSTEM
- BOUNDARY OF FOREBAY

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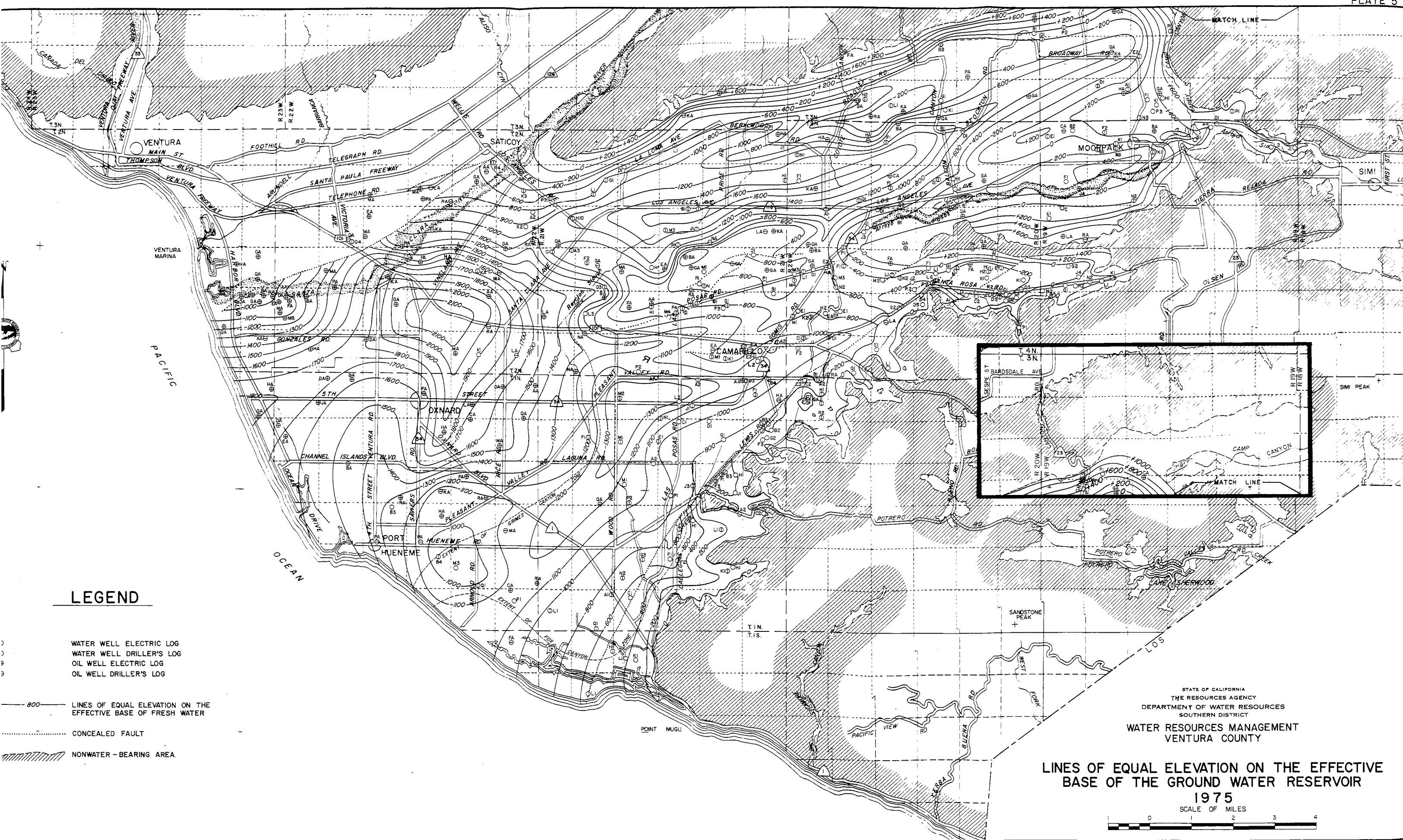
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SOUTHERN DISTRICT
WATER RESOURCES MANAGEMENT
VENTURA COUNTY

LINES OF EQUAL ELEVATION ON THE
TOP OF THE LOWER AQUIFER SYSTEM

1975

SCALE OF MILES





LEGEND

- WATER WELL ELECTRIC LOG
- WATER WELL DRILLER'S LOG
- OIL WELL ELECTRIC LOG
- OIL WELL DRILLER'S LOG

800 ——— LINES OF EQUAL ELEVATION ON THE EFFECTIVE BASE OF FRESH WATER

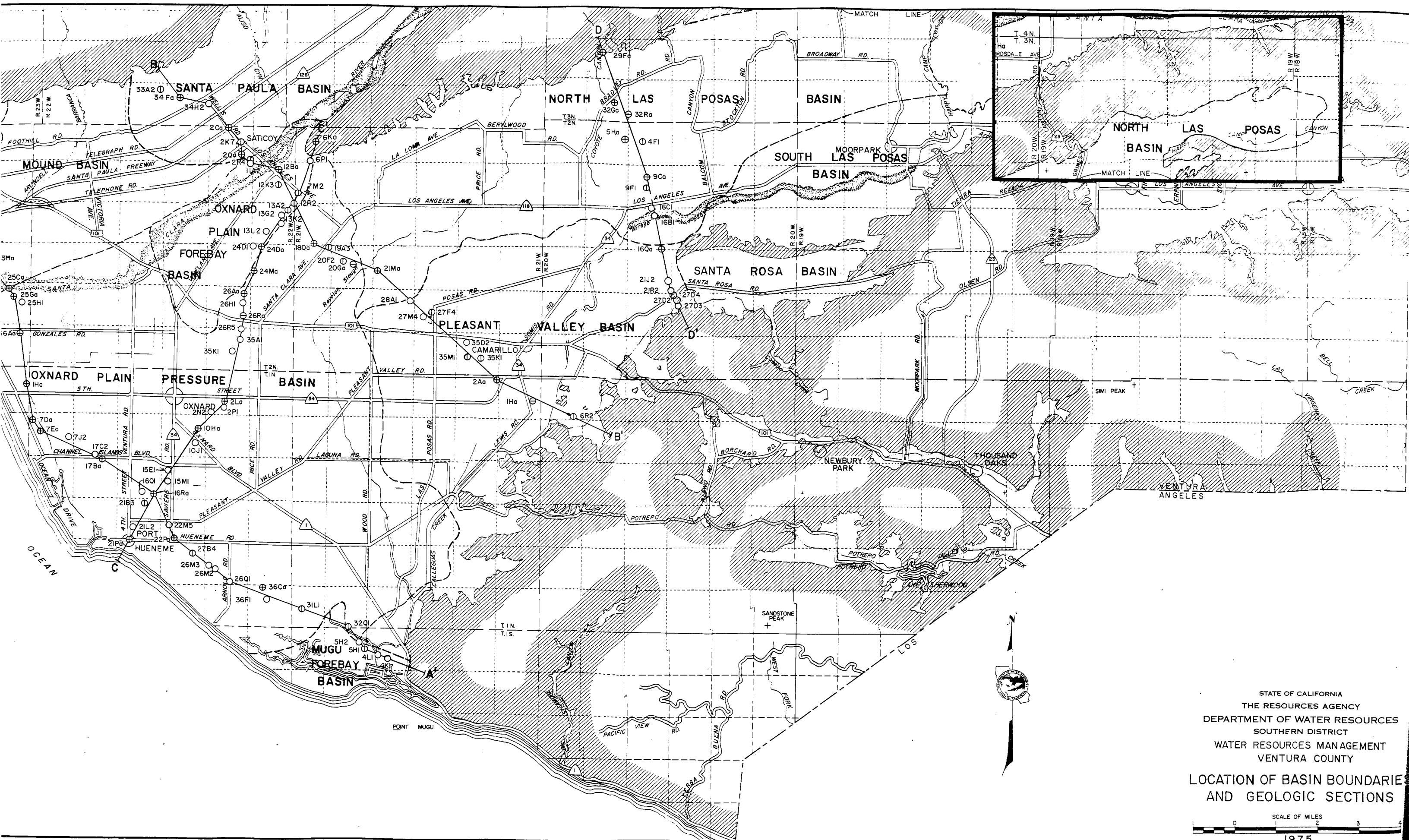
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NONWATER-BEARING AREA

LINES OF EQUAL ELEVATION ON THE EFFECTIVE
BASE OF THE GROUND WATER RESERVOIR
1975

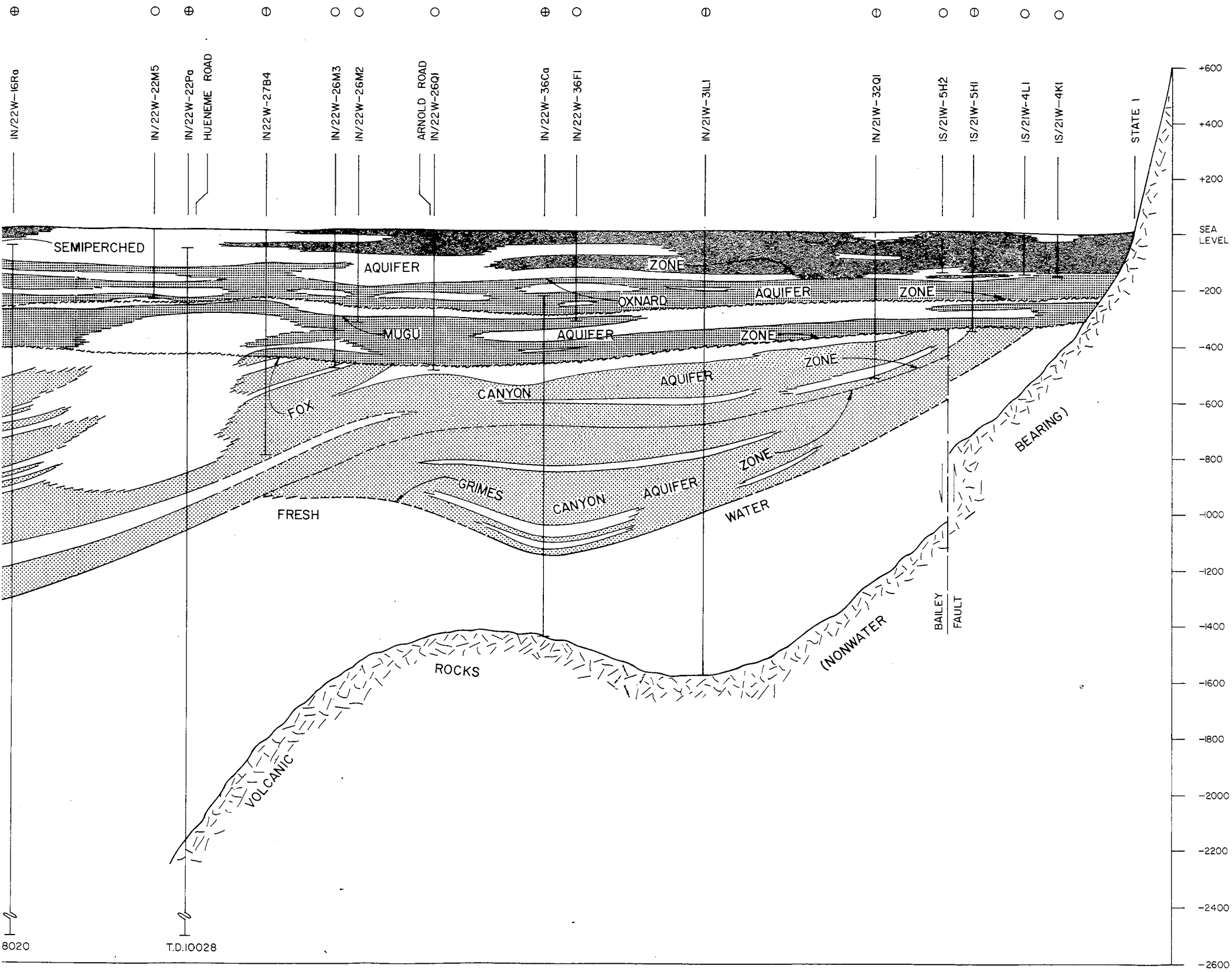
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SOUTHERN DISTRICT
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VENTURA COUNTY



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WATER RESOURCES MANAGEMENT
VENTURA COUNTY
LOCATION OF BASIN BOUNDARIES
AND GEOLOGIC SECTIONS

SCALE OF MILES
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1975

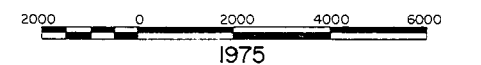


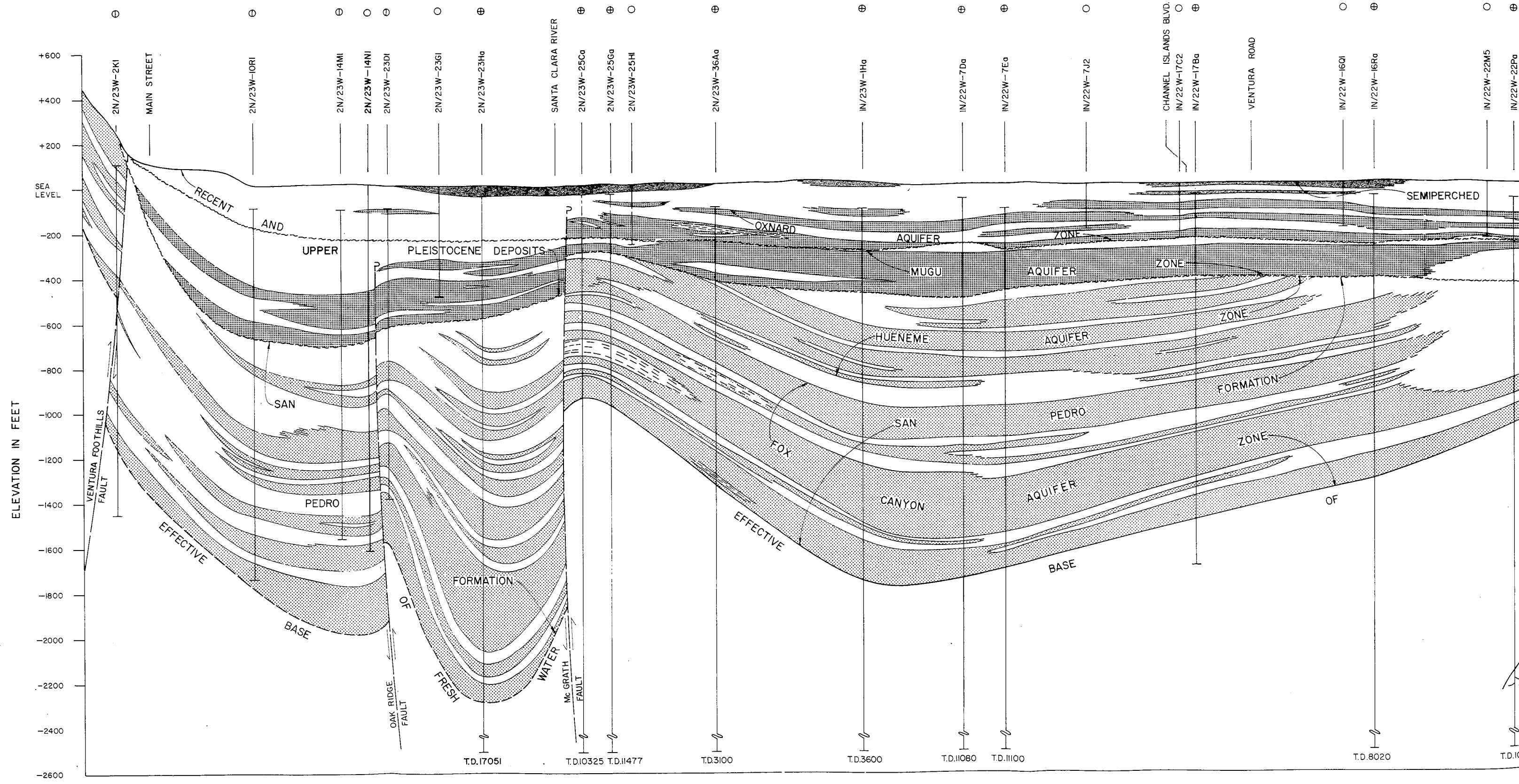
LEGEND

- SEMIPERCHED AQUIFER ZONE
 - UPPER AQUIFER SYSTEM;
OXNARD AND MUGU AQUIFER ZONE
 - LOWER AQUIFER SYSTEM;
HUENE, FOX CANYON AND GRIMES CANYON AQUIFER ZONES
 - SEMIPERMEABLE MATERIALS
 - AQUICLUDE—MATERIALS OF LOW PERMEABILITY
 - VOLCANIC ROCKS—NONWATER-BEARING
 - UNCONFORMITY
 - FAULT—ARROWS INDICATE RELATIVE MOVEMENT
 - WATER WELL ELECTRIC LOG
 - WATER WELL DRILLERS LOG
 - OIL WELL ELECTRIC LOG
- NOTE: LOCATION OF AQUIFER SECTIONS SHOWN ON PLATE 6

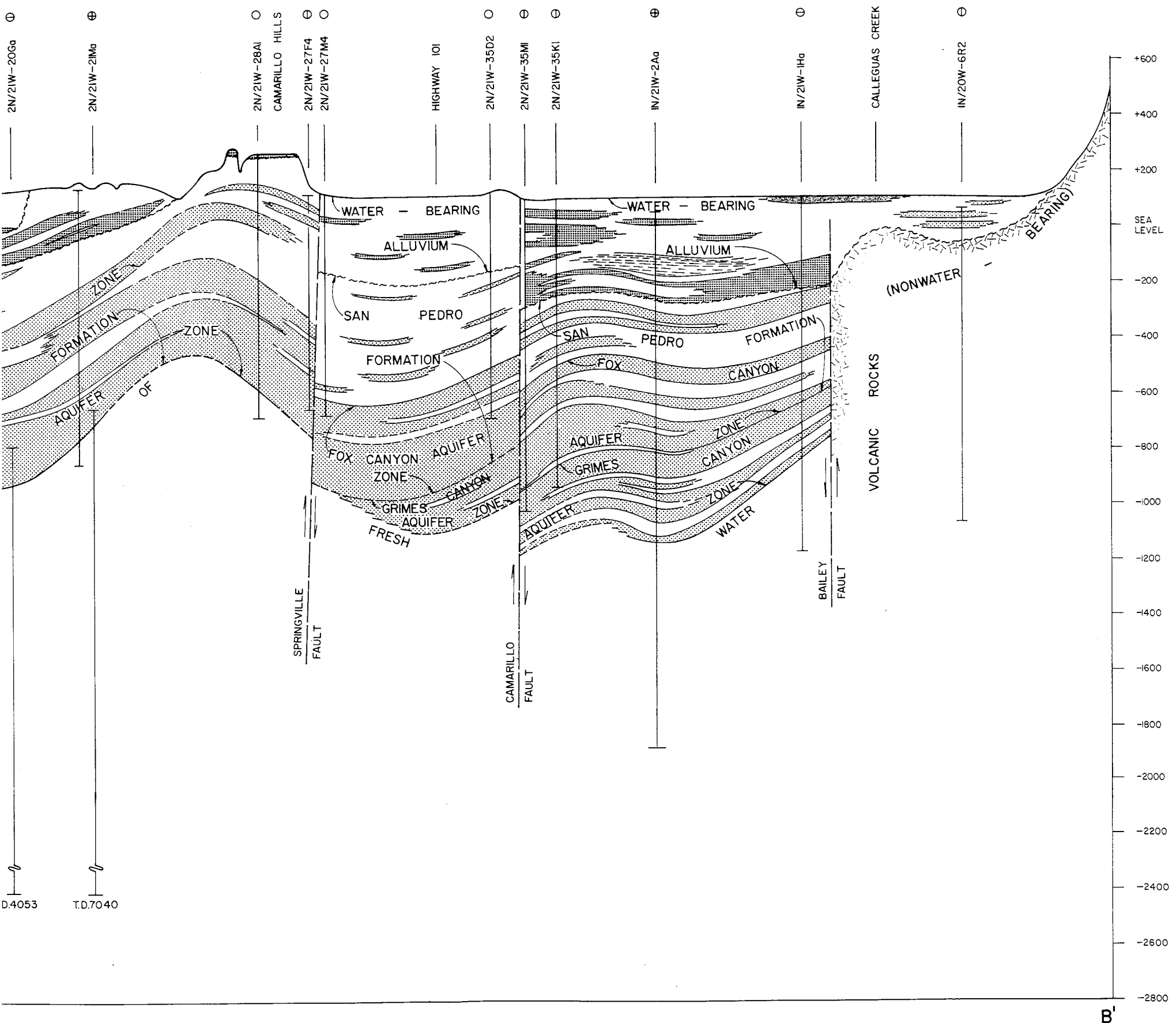
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
WATER RESOURCES MANAGEMENT
VENTURA COUNTY

GEOLOGIC SECTION A-A'





A



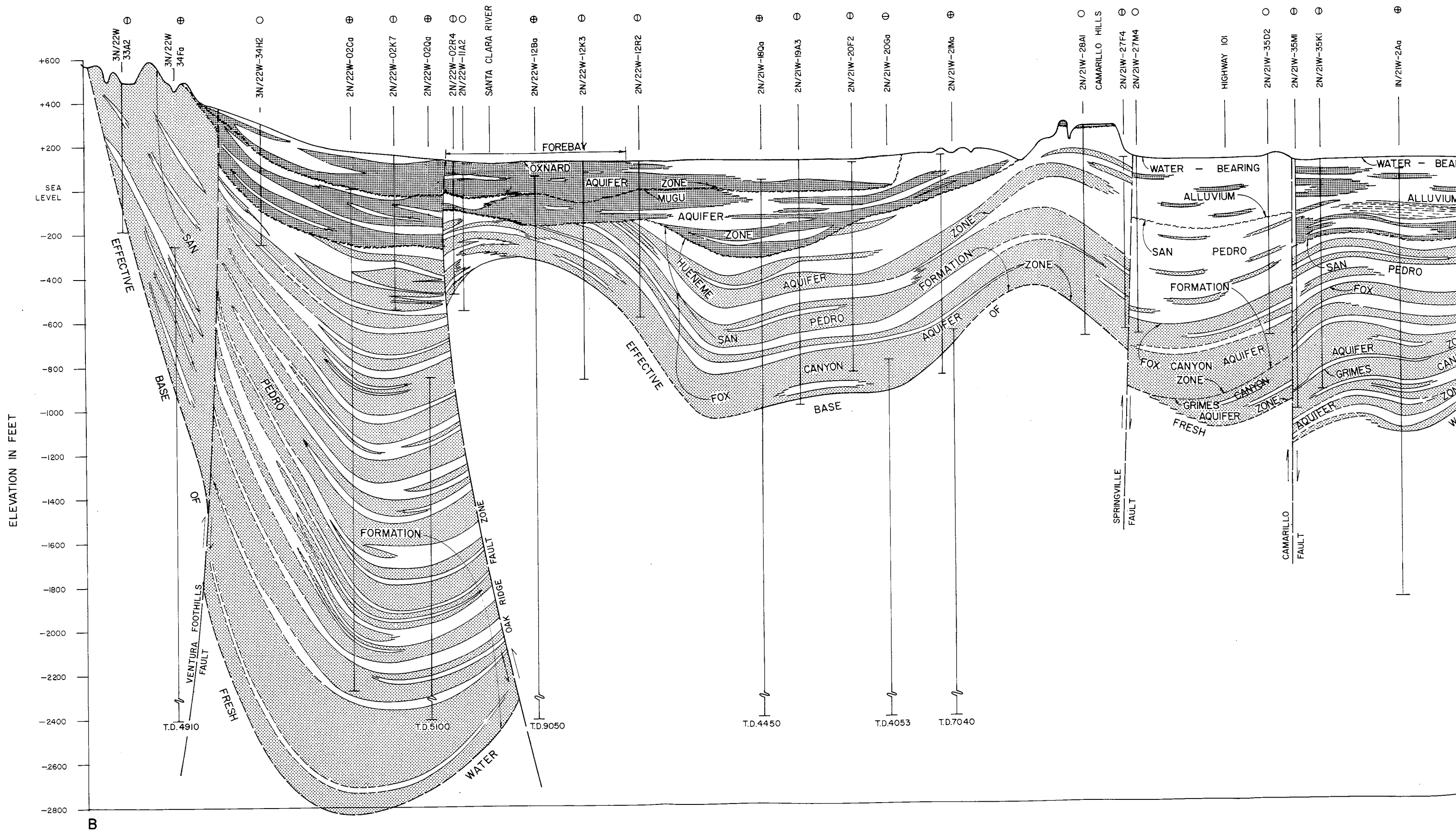
- LEGEND**
- LENSES OF WATER BEARING ALLUVIUM
 - UPPER AQUIFER SYSTEM; OXNARD AND MUGU AQUIFER ZONES
 - LOWER AQUIFER SYSTEM; HUENEME, FOX CANYON, AND GRIMES CANYON AQUIFER ZONES
 - SEMI-PERMEABLE MATERIALS
 - AQUICLUDE—MATERIALS OF LOW PERMEABILITY
 - VOLCANIC ROCKS—NONWATER-BEARING
 - UNCONFORMITY
 - FAULT—ARROWS INDICATE RELATIVE MOVEMENT
 - ⊙ WATER WELL ELECTRIC LOG
 - WATER WELL DRILLERS LOG
 - ⊕ OIL WELL ELECTRIC LOG
 - ⊗ OIL WELL DRILLERS LOG
 - NOTE: LOCATION OF AQUIFER SECTIONS SHOWN ON PLATE 6

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

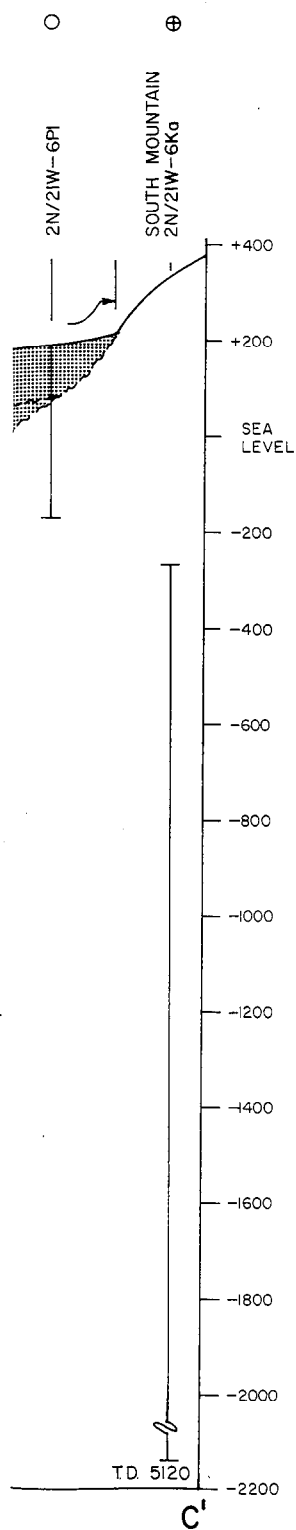
WATER RESOURCES MANAGEMENT
VENTURA COUNTY

GEOLOGIC SECTION B-B'

2000 0 2000 4000 6000
1975



B



LEGEND

-  SEMIPERCHED AQUIFER ZONE
-  UPPER AQUIFER SYSTEM;
OXNARD AND MUGU AQUIFER ZONES
-  LOWER AQUIFER SYSTEM;
PRIMARILY HUENEME AND FOX CANYON AQUIFER ZONES
-  SEMIPERMEABLE MATERIALS
-  AQUICLUDE; MATERIALS OF LOW PERMEABILITY
-  UNCONFORMITY
-  WATER WELL ELECTRIC LOG
-  WATER WELL DRILLERS LOG
-  OIL WELL ELECTRIC LOG
-  OIL WELL DRILLERS LOG

NOTE: LOCATION OF AQUIFER SECTIONS SHOWN ON PLATE 6

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

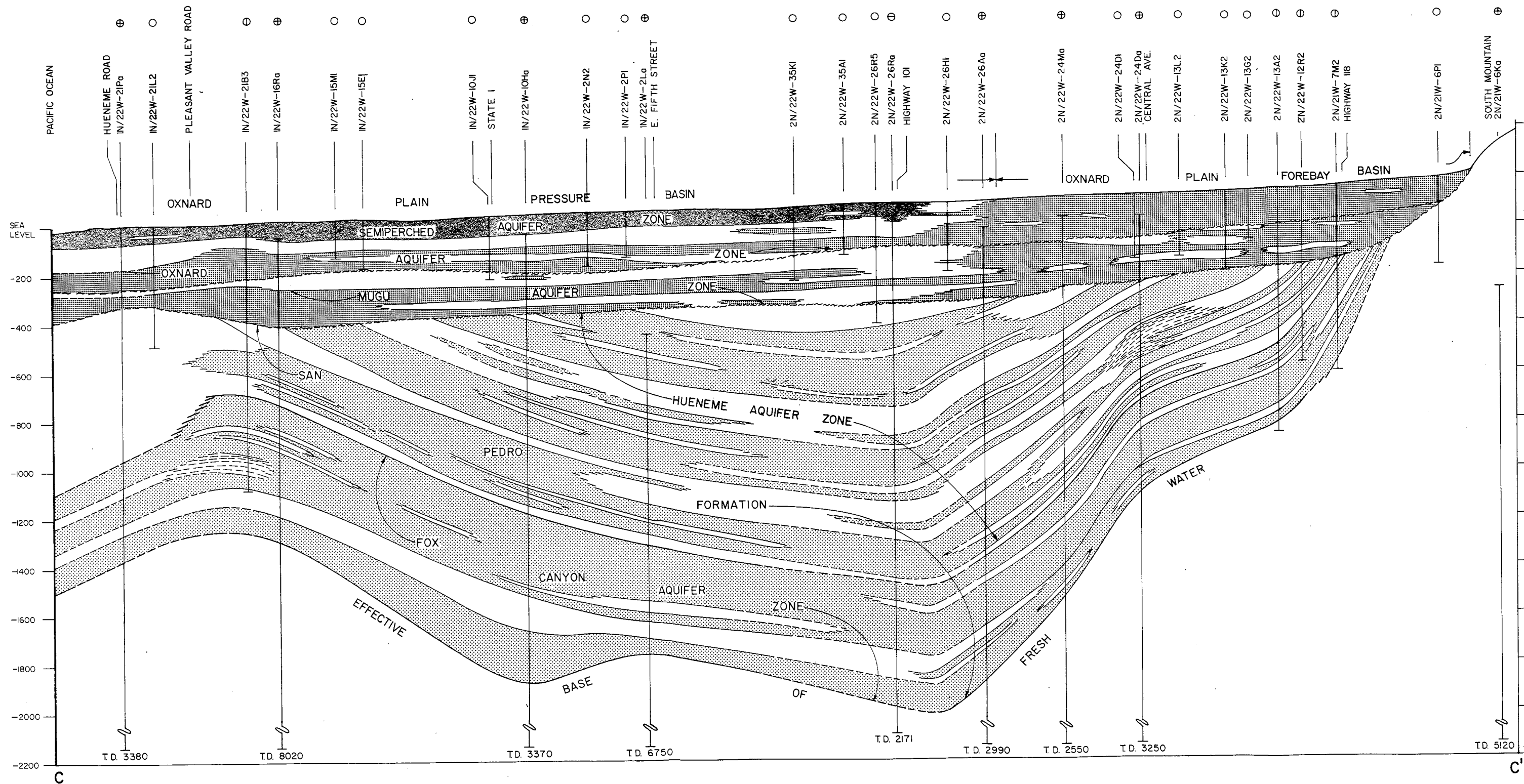
WATER RESOURCES MANAGEMENT
VENTURA COUNTY

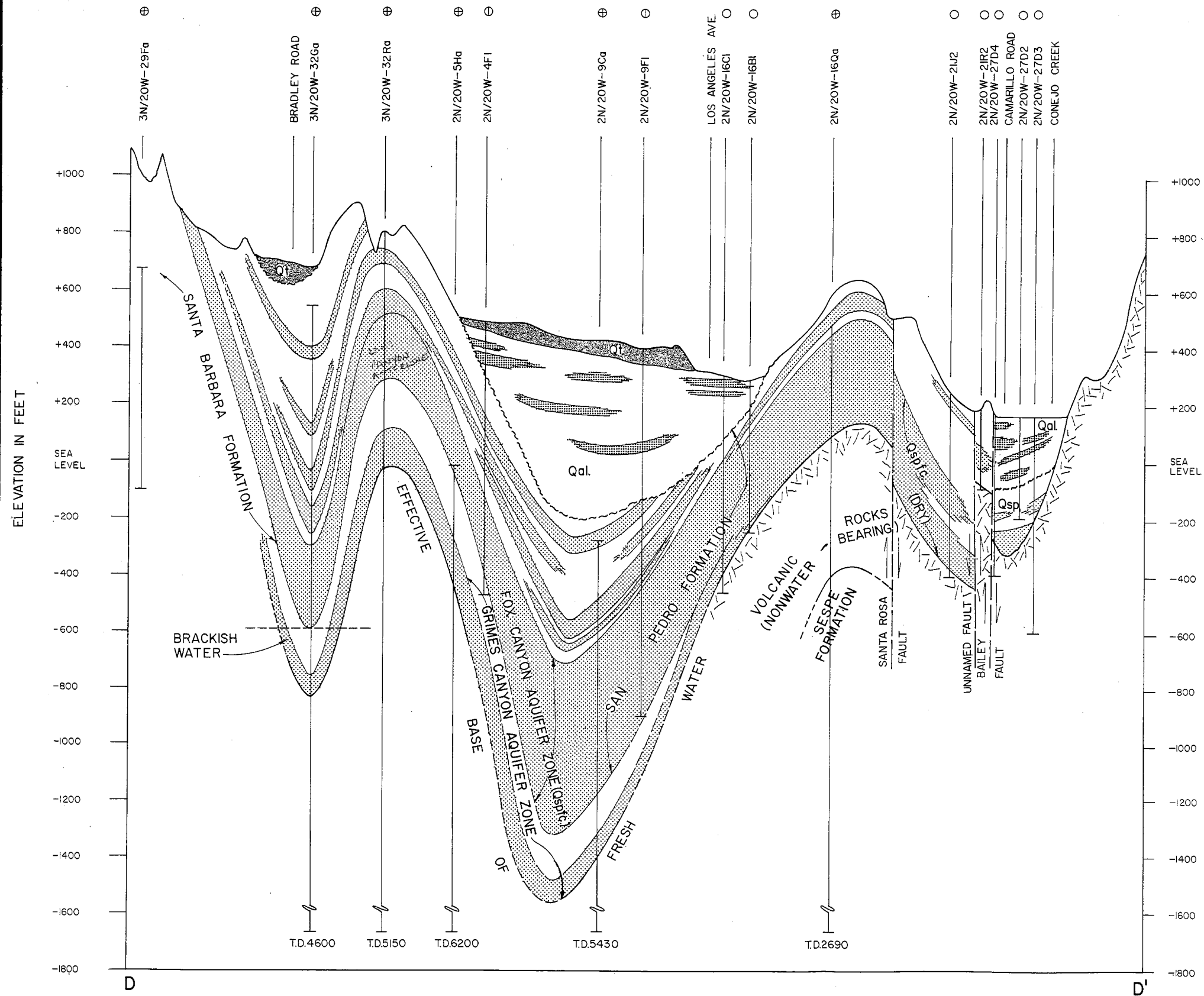
GEOLOGIC SECTION C-C'

2000 0 2000 4000 6000

1975

ELEVATION IN FEET





LEGEND

- UNSATURATED PERMEABLE TERRACE DEPOSITS, Q_t.
 - LENSES OF WATER-BEARING ALLUVIUM, Q_{al}.
 - LOWER AQUIFER SYSTEM; PRIMARILY FOX CANYON AND GRIMES CANYON AQUIFER ZONES
 - AQUICLUDE-MATERIALS OF LOW PERMEABILITY
 - VOLCANIC ROCKS—NONWATER-BEARING
 - UNCONFORMITY
 - FAULT—ARROWS INDICATE RELATIVE MOVEMENT
 - WATER WELL ELECTRIC LOG
 - WATER WELL DRILLERS LOG
 - OIL WELL ELECTRIC LOG
 - OIL WELL DRILLERS LOG
- NOTE: LOCATION OF AQUIFER SECTIONS SHOWN ON PLATE 6

STATE OF CALIFORNIA
 THE RESOURCES AGENCY
 DEPARTMENT OF WATER RESOURCES
 SOUTHERN DISTRICT
 WATER RESOURCES MANAGEMENT
 VENTURA COUNTY

GEOLOGIC SECTION D-D'

