

A PLAN FOR GROUND WATER MANAGEMENT

UNITED WATER CONSERVATION DISTRICT

JOHN F. MANN, JR. & ASSOCIATES
CONSULTING GROUNDWATER GEOLOGISTS
LA HABRA, CALIFORNIA

DR. JOHN F. MANN, JR.

DR. JOHN F. MANN, JR., who with his staff conducted the extensive research into ground water resources of the District and prepared the report titled, "A PLAN FOR GROUND WATER MANAGEMENT", is eminently qualified for this assignment.

The report represents almost two years of intensive research and is the most comprehensive study of water resources and ground water hydrology in the District to date.

A consulting geologist specializing in problems of underground water, Dr. Mann is widely recognized as one of the leading authorities in his field. He is a graduate of the Colorado School of Mines. His graduate work was taken at the University of Southern California where he won his Master of Science Degree and later his Ph.D.

Dr. Mann has completed numerous important assignments including a study of the marine geology of Bikini Atoll prior to the Bikini bomb tests there. He also conducted research and field experimentation on resistive methods with the Illinois State Geological Survey in the Division of Ground Water Geology and Geophysical Exploration.

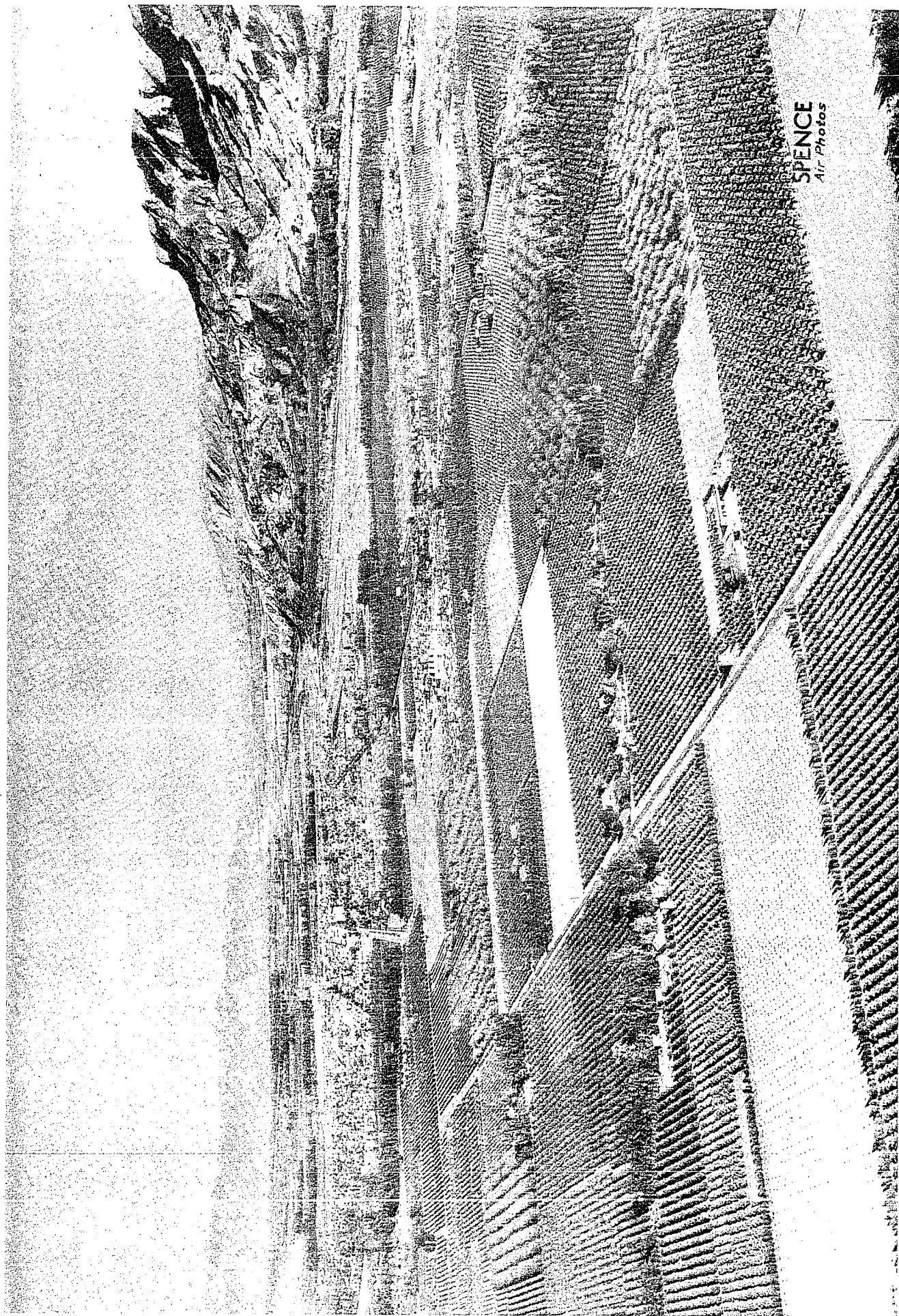
He has served as Associate Professor of Geology and acting department head at the University of Southern California.

A Fellow of the Geological Society of America, Dr. Mann is also Vice-President of the National Water Well Association and a member of the American Geological Union, where he has served on the Ground Water Research Committee since 1955. He was listed in American Men of Science in 1956.

Dr. Mann is the author of many publications dealing with ground water which are recognized as authoritative treatises on the subject.

His experience with the conditions and problems of the Santa Clara Valley and the Oxnard Plain dates from 1948 when he assisted with the U. S. Geological Survey of the Oxnard Plain.

The Board of Directors and staff of United Water Conservation District feel that the District and the people of the area are most fortunate to have had the services of such a well qualified authority as Dr. Mann to conduct this study and prepare this report.



SPENCE
Air Photos

JOHN F. MANN, JR. AND ASSOCIATES
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945 REPOSADO DRIVE
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TELEPHONE
OWEN 7-9604

SEPTEMBER 1, 1959

BOARD OF DIRECTORS
UNITED WATER CONSERVATION DISTRICT
333 WEST HARVARD STREET
SANTA PAULA, CALIFORNIA

DEAR SIRs:

ATTACHED IS MY REPORT ON THE GROUND WATER RESOURCES OF THE DISTRICT AS AUTHORIZED BY OUR LETTER AGREEMENT DATED OCTOBER 29, 1957 WHICH WAS APPROVED AND ACCEPTED DECEMBER 10, 1957.

IN THIS REPORT I HAVE PRESENTED A DETAILED DESCRIPTION OF THE GROUND WATER HYDROLOGY, AND WATER QUALITY PROBLEMS OF THE DISTRICT. USING THIS COMPREHENSIVE FACTUAL BACKGROUND A PLAN IS PROPOSED FOR THE EFFECTIVE UTILIZATION OF THE DISTRICT'S GROUND WATER RESOURCES.

I WOULD LIKE TO ACKNOWLEDGE ESPECIALLY THE EXCELLENT COOPERATION OF MR. PRICE, MR. WILDE AND THE STAFF OF THE DISTRICT IN THE PREPARATION OF THIS REPORT AND THE MANY COURTESIES RENDERED TO ME AND TO MY RESIDENT GEOLOGIST, BURT A. BABCOCK.

VERY TRULY YOURS,

John F. Mann, Jr.
JOHN F. MANN, JR.

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OF VENTURA COUNTY, CALIFORNIA

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ACKNOWLEDGEMENTS

FOR DATA, SUGGESTIONS AND COURTESIES RENDERED,
APPRECIATION IS EXPRESSED TO THE FOLLOWING:

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NAVAL AIR MISSILE TEST CENTER, POINT MUGU

CITY OF VENTURA WATER DEPARTMENT

VENTURA COUNTY DEPARTMENT OF PUBLIC WORKS, WATER
RESOURCES DIVISION

VENTURA COUNTY WATER WORKS DISTRICT No. 5

SUMMARY

1. THE WATER RESOURCES OF THE UNITED WATER CONSERVATION DISTRICT ARE ADEQUATE TO SUPPLY ALL OF THE DISTRICT'S NEEDS UNTIL FEATHER RIVER WATER IS MADE AVAILABLE.
2. FOR MAXIMUM FLEXIBILITY IN THE OPERATION OF THE PROPOSED PLAN, IT IS RECOMMENDED THAT EVERY EFFORT BE MADE TO HAVE THE IMPORTED SUPPLEMENTAL SUPPLIES DELIVERED FOR STORAGE BEHIND SANTA FELICIA DAM.
3. THE MAJOR GROUND WATER PROBLEMS OF THE DISTRICT ARE THE FOLLOWING:
 - (A) EXISTING AND FUTURE OVERDRAFTS ON THE COASTAL PLAIN;
 - (B) ADVERSE SALT BALANCE IN THE FILLMORE AND SANTA PAULA BASINS AND, TO A LESSER EXTENT, IN THE PIRU BASIN;
 - (C) HIGH WATER TABLES AT THE LOWER ENDS OF THE UPSTREAM BASINS.
4. THE PROPOSED PLAN OF GROUND WATER MANAGEMENT INCORPORATES THE FOLLOWING FEATURES:
 - (A) A MAIN PIPELINE DOWN THE SANTA CLARA RIVER VALLEY FROM SANTA FELICIA DAM TO THE MONTALVO BASIN;
 - (B) A SURFACE STORAGE RESERVOIR ON SESPE CREEK FOR THE DEVELOPMENT OF ADDITIONAL ECONOMICAL SAFE YIELD;
 - (C) SALT-BALANCE PUMPING IN THE LOWER ENDS OF THE FILLMORE AND SANTA PAULA BASINS AND EXPORT THROUGH THE MAIN PIPELINE;
 - (D) USING BYPASSED RESERVOIR RELEASES AND SALT-BALANCE PUMPING AS A MEANS OF CONTROLLING HIGH WATER TABLES;
 - (E) DIRECT DELIVERY OF HIGH QUALITY RESERVOIR RELEASES FOR RELIEF OF LOCAL QUALITY PROBLEMS IN THE UPSTREAM BASINS;
 - (F) DELIVERY OF SALT-BALANCE WATER TO MONTALVO BASIN FOR SPREADING OR DIRECT DELIVERIES; QUALITY UPGRADING IF NECESSARY WITH RESERVOIR RELEASES;
 - (G) EXPANSION OF DISTRIBUTION FACILITIES ON THE OXNARD PLAIN;
 - (H) REDUCING PUMPING DRAFT ON THE OXNARD AQUIFER BY SUPPLYING COASTAL DEMANDS FROM UPSTREAM SOURCES AND SHALLOW PUMPAGE IN MONTALVO BASIN; SUPPLEMENTING THIS SUPPLY WITH MODEST WITHDRAWAL FROM EXTENSIVE FRESH-WATER RESERVES IN THE FOX CANYON AQUIFER IN MONTALVO BASIN.

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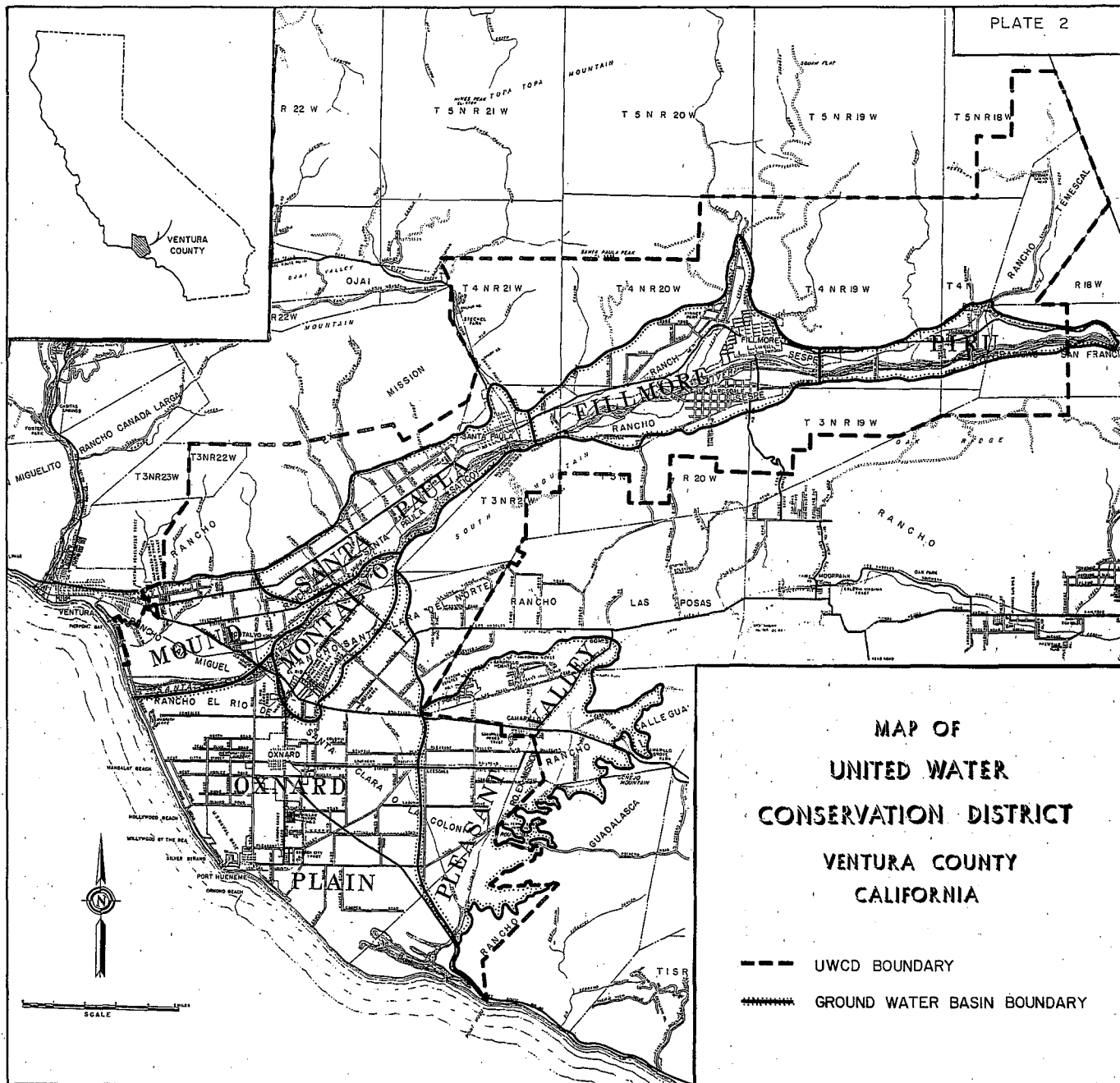
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MAP OF
UNITED WATER
CONSERVATION DISTRICT
VENTURA COUNTY
CALIFORNIA

--- UWCD BOUNDARY
~~~~~ GROUND WATER BASIN BOUNDARY

## CHAPTER I

### INTRODUCTION

#### THE UNITED WATER CONSERVATION DISTRICT

THE UNITED WATER CONSERVATION DISTRICT IS ENTIRELY WITHIN VENTURA COUNTY AND INCLUDES (1) THE VALLEY OF THE SANTA CLARA RIVER ALMOST TO THE LOS ANGELES COUNTY LINE, AND (2) ESSENTIALLY ALL OF THE COASTAL PLAIN (PLATE 2). THE DISTRICT WAS ORGANIZED IN DECEMBER 1950 UNDER THE WATER CONSERVATION DISTRICT ACT OF 1931, STATE OF CALIFORNIA, AS AMENDED. IT SUCCEEDED AN EARLIER DISTRICT, THE SANTA CLARA WATER CONSERVATION DISTRICT, WHICH HAD BEEN SET UP IN DECEMBER 1927. THE EARLIER DISTRICT OPERATED SPREADING GROUNDS AT SATICOY, SANTA PAULA, AND PIRU AND ENGAGED IN OTHER EXPERIMENTAL SPREADING ACTIVITIES. DURING THE 25 YEARS OF EXISTENCE UNDER THE ABLE GUIDANCE OF ITS ENGINEER, V. M. FREEMAN, MORE THAN 400,000 ACRE- FEET OF WATER WERE RECHARGED TO THE UNDERGROUND--WATER THAT WOULD OTHERWISE HAVE WASTED TO THE OCEAN. THE SANTA CLARA DISTRICT ALSO COLLECTED A LARGE AMOUNT OF HYDROLOGIC DATA, ESPECIALLY WITH REGARD TO AREAS OF SEA-WATER INTRUSION.

THE ACTIVITIES OF THE SANTA CLARA DISTRICT WERE FINANCED BY TAX ASSESSMENTS ON FARM LANDS (AND THEIR IMPROVEMENTS) WITHIN ITS BOUNDARIES. AS THE AREA DEVELOPED, IT BECAME APPARENT THAT THE WATER PROBLEMS COULD NOT BE SOLVED WITH A DISTRICT OF SUCH LIMITED POWERS. FOR EXAMPLE, THE DISTRICT COULD NOT ISSUE BONDS FOR THE CONSTRUCTION OF STORAGE WORKS. FURTHERMORE, THE METHOD OF TAXATION WAS NOT REALISTIC; WHEREAS THE CONSERVATION MEASURES BENEFITED BOTH URBAN AND FARM AREAS, ONLY THE FARM LANDS WERE TAXED. BECAUSE OF THESE DEFICIENCIES, THE UNITED WATER CONSERVATION DISTRICT WAS FORMED. THE SANTA CLARA DISTRICT PASSED OUT OF EXISTENCE IN 1953 BY AN ACT OF THE STATE LEGISLATURE.

SHORTLY AFTER IT WAS ORGANIZED, DETAILED STUDIES OF THE UNITED DISTRICT'S WATER PROBLEMS WERE COMMENCED UNDER THE DIRECTION OF JULIAN HINDS, GENERAL MANAGER AND CHIEF ENGINEER, AND A REPORT WAS COMPLETED IN THE FALL OF 1952 RECOMMENDING THAT TOPATOPA DAM, SANTA FELICIA DAM, AND DIVERSION AND CONSERVATION WORKS DOWNSTREAM ON THE SANTA CLARA RIVER BE CONSTRUCTED AT A COST OF \$18,500,000. IN THE ELECTION OF DECEMBER 16, 1952, THE BOND PROPOSAL FAILED TO PASS. A SECOND REPORT IN SEPTEMBER 1953

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RECOMMENDED SANTA FELICIA DAM AND LOWER RIVER FACILITIES, TO COST \$10,939,000. THE LATTER PROPOSAL FOR A BOND ISSUE WAS PASSED IN THE ELECTION OF OCTOBER 17, 1953, AND CONSTRUCTION WAS COMPLETED DURING 1955.

IN 1957, UNITED'S APPLICATION FOR A PERMIT TO STORE WATER AT THE TOPATOPA SITE WAS PROTESTED BY THE CALLEGUAS MUNICIPAL WATER DISTRICT, WHICH ALSO WANTED TO BUILD A DAM AT THIS SITE AND CONVEY THE WATER OUT OF THE WATERSHED FOR USE ON LANDS IN EASTERN VENTURA COUNTY. IN DECISION D-884 DATED JANUARY 17, 1958 THE STATE WATER RIGHTS BOARD GRANTED THE PERMIT FOR STORAGE AT THE TOPATOPA SITE TO THE CALLEGUAS MUNICIPAL WATER DISTRICT. UNITED IS CURRENTLY APPEALING THE DECISION UNDER A WRIT OF MANDAMUS.

#### PREVIOUS MAJOR INVESTIGATIONS

DETAILED WATER RESOURCE STUDIES IN VENTURA COUNTY STARTED IN 1927. IN AUGUST OF THAT YEAR FIELD WORK WAS STARTED BY THE STATE DIVISION OF WATER RESOURCES LEADING IN 1933 TO THE PUBLICATION OF BULLETIN 46 (REFERENCE 10, SEE BIBLIOGRAPHY). FOLLOWING THE COMPLETION OF BULLETIN 46, THE COLLECTION OF BASIC HYDROLOGIC DATA WAS FORTUNATELY CONTINUED BY THE NEWLY FORMED VENTURA COUNTY WATER SURVEY. THESE VOLUMINOUS, CONTINUOUS RECORDS OF THE VENTURA COUNTY WATER SURVEY HAVE PROVED OF INVALUABLE HELP IN ALL SUBSEQUENT STUDIES.

THERE WERE NO COMPREHENSIVE WATER RESOURCE STUDIES OF THE SANTA CLARA RIVER SYSTEM DURING THE LATE THIRTIES OR EARLY FORTIES. WITH THE ONSET OF DROUGHT, HOWEVER, AND THE RENEWED POSSIBILITY OF SEA-WATER INTRUSION, CAME INCREASED CONCERN OVER WATER SUPPLIES. HAROLD CONKLING, CONSULTING ENGINEER, WAS RETAINED BY THE SANTA CLARA WATER CONSERVATION DISTRICT, AND THE REPORT ON THIS INVESTIGATION WAS COMPLETED IN 1947 (REFERENCE 25). HE WAS LATER RETAINED BY THE VENTURA COUNTY FLOOD CONTROL DISTRICT; THE SECOND REPORT WAS COMPLETED IN 1949 (REF. 26). COMPREHENSIVE HYDROLOGIC STUDIES WERE MADE BY THE STAFF OF THE UNITED WATER CONSERVATION DISTRICT DURING 1951-53 UNDER THE DIRECTION OF JULIAN HINDS, THEN GENERAL MANAGER AND CHIEF ENGINEER OF THE DISTRICT. THESE STUDIES WERE SUMMARIZED IN WHAT WILL BE CALLED HEREIN THE WILDE-LONG REPORT (REF. 68). DURING THE SAME PERIOD THE STATE DIVISION OF WATER RESOURCES WAS PREPARING BULLETIN 12, WHICH WAS COMPLETED IN OCTOBER 1953 AND REVISED

IN APRIL 1956 (REF. 23). REVISIONS AND UPDATING OF UNITED'S INVENTORY METHODS WERE MADE PRIMARILY BY RAY Y. KAWANO, AND THE REPORT DATED APRIL 1956 WILL BE REFERRED TO HEREIN AS THE KAWANO REPORT (REF. 43).

THE OXNARD PLAIN PORTION OF THE DISTRICT, ESPECIALLY, WAS STUDIED BY THE U. S. BUREAU OF RECLAMATION STARTING IN 1954, RESULTING IN A RECONNAISSANCE REPORT DATED JUNE 1955 (REF. 4). A MORE DETAILED STUDY FOLLOWED, LEADING TO A PROPOSED REPORT DATED MAY 1958 (REF. 5). THE LATTER REPORT WAS RELEASED FOR OFFICIAL REVIEW ONLY, AND HAS NOT YET BEEN APPROVED.

#### OBJECTIVES OF PRESENT INVESTIGATION

THE PRESENT INVESTIGATION FOLLOWS A NUMBER OF EXCELLENT, DETAILED STUDIES, ALL OF WHICH DEPENDED, TO A LARGE EXTENT, UPON THE SAME BASIC DATA. UNDER THESE CONDITIONS, CLAIMS TO ORIGINALITY ARE NECESSARILY LIMITED. THE OVERALL OBJECTIVE--GROUND WATER MANAGEMENT--IS PERHAPS DIFFERENT. SPECIFICALLY, THE PRESENT STUDY HAS INVOLVED THE FOLLOWING:

- (1) A REFINEMENT OF THE GROUND WATER GEOLOGY OF THE DISTRICT, IN ORDER TO ANALYZE THE INFLUENCE OF THE GEOLOGIC COM-  
PLEXITIES ON GROUND WATER MANAGEMENT;
- (2) A RE-CALCULATION OF THE DISTRICT'S GROUND WATER INVENTORIES ON THE BASIS OF THE REFINED GEOLOGIC FRAMEWORK;
- (3) A DETAILED STUDY OF GROUND WATER QUALITY TO SPELL OUT THE INFLUENCE OF POOR QUALITY WATERS ON CONTINUED GROUND WATER DEVELOPMENT;
- (4) A DESCRIPTION OF THE CURRENT STATUS OF SEA-WATER INTRUSION, AND THE DEVELOPMENT OF A GENERAL PLAN FOR COMBATING IT.

#### GENERAL DESCRIPTION OF DISTRICT

##### TOPOGRAPHY AND DRAINAGE

THE SANTA CLARA RIVER RISES IN LOS ANGELES COUNTY FAR TO THE EAST OF THE DISTRICT AND FLOWS WESTERLY TO THE PACIFIC OCEAN. THE DRAINAGE AREA ABOVE ITS MOUTH, WHICH IS ABOUT THREE MILES SOUTH OF THE CITY OF VENTURA, IS 1605 SQUARE MILES. ELEVATIONS WITHIN THE DRAINAGE BASIN RANGE UP TO 8826 FEET AT MOUNT PINOS. ALMOST 90 PER CENT OF THE ENTIRE DRAINAGE BASIN IS RUGGED TOPOGRAPHY; THE REMAINDER IS OCCUPIED BY THE VALLEY FLOOR AND THE COASTAL PLAIN. FROM EAST OF THE DISTRICT EASTERN BOUNDARY, WESTERLY TO SATICOY, THE SANTA CLARA RIVER FLOWS IN A FAIRLY BROAD, BUT

DEEP TROUGH. SOUTH OF THIS TROUGH IS THE STEEP FRONT OF THE SOUTH MOUNTAIN-OAK RIDGE UPLIFT, RISING IN PLACES MORE THAN 2000 FEET ABOVE THE VALLEY FLOOR. THE NORTH SLOPES OF THE TROUGH ARE GENERALLY MUCH LESS PRECIPITOUS, ALTHOUGH THE ELEVATIONS ATTAINED ARE CONSIDERABLY GREATER. ALMOST ALL OF THE RUNOFF, AND ALL THE MAJOR TRIBUTARIES COME FROM THE NORTH SIDE. THIS ASYMMETRY OF DRAINAGE HAS EXERTED A MARKED CONTROL ON THE DEVELOPMENT OF THE TROUGH. THE ALLUVIAL FAN DEPOSITS DEBOUCHING FROM THE NORTH SIDE HAVE PERSISTENTLY PUSHED THE SANTA CLARA RIVER TOWARD THE SOUTH SIDE OF THE TROUGH. ONCE CLEAR OF THE END OF SOUTH MOUNTAIN AT SATICOY, THE SANTA CLARA RIVER HAS BEEN FREE TO SWING OVER THE ENTIRE OXNARD PLAIN. ON THE NORTH, THE SWING HAS BEEN LIMITED BY THE SOUTH-SLOPING ALLUVIAL FANS DERIVED FROM THE HILLS TO THE NORTH; ON THE EAST, THE SWING HAS BEEN LIMITED BY THE CAMARILLO HILLS AND THE HARD ROCKS OF THE SANTA MONICA MOUNTAINS AT POINT MUGU. THE OXNARD PLAIN IS CONSIDERED TO COINCIDE WITH THESE BROAD ALLUVIAL FAN DEPOSITS OF THE SANTA CLARA RIVER.

#### GEOLOGY

THE GEOLOGIC FEATURES OF THE DISTRICT HAVE EXERTED A STRONG POSITIVE CONTROL ON THE TOPOGRAPHY. THE YOUNG, SOFT ROCKS UNDERLIE THE TOPOGRAPHICALLY LOW AREAS; THE OLDER, HARDER ROCKS STAND UP IN BOLD RELIEF. ALMOST WITHOUT EXCEPTION, THE AGRICULTURAL AREAS OF THE DISTRICT ARE ON ALLUVIAL MATERIALS WHICH IN TURN OVERLIE THE SAN PEDRO FORMATION. ONE MILLION OR SO YEARS AGO, DURING A TIME REFERRED TO AS THE LOWER PLEISTOCENE, THE SAN PEDRO FORMATION WAS DEPOSITED, PARTLY IN THE OCEAN, AS A SHEET COVERING THE ENTIRE DISTRICT AND FOR SOME DISTANCE BEYOND. THESE GRAVELS, SANDS, AND CLAYS WERE ACCUMULATED TO A MAXIMUM THICKNESS OF PERHAPS 7000 TO 8000 FEET. DURING MIDDLE PLEISTOCENE TIME, THE SAN PEDRO FORMATION WAS UPLIFTED, FOLDED, AND FAULTED ON A TREMENDOUS SCALE. FROM THE HIGH AREAS THE SAN PEDRO FORMATION WAS COMPLETELY REMOVED BY EROSION. STREAMS SOUGHT OUT THE DOWNFAULTED AND DOWNFOLDED STRIPS OF SOFT ROCK AND CONTINUE TO FLOW IN THESE STRIPS TODAY. SUCH A STRIP OF SOFT ROCK IS OCCUPIED BY THE SANTA CLARA RIVER. EXCEPT IN THE EXTREME EASTERN FEW MILES OF THE DISTRICT, THE RIVER OVERLIES A FAULTED AND SYNCLINALLY FOLDED STRIP OF RELATIVELY SOFT SAN PEDRO FORMATION. EVEN THE LOW AREA OF THE COASTAL PLAIN IS TO A LARGE EXTENT CONTROLLED BY THE DISTRIBUTION OF THE SAN PEDRO FORMATION.

THE GEOLOGIC FORMATIONS OCCURRING WITHIN THE DISTRICT ARE GIVEN ON TABLE 1-1. DETAILED DISCUSSIONS OF IMPORTANT AQUIFERS ARE INCLUDED IN THE DISCUSSIONS OF THE INDIVIDUAL GROUND WATER BASINS. FOR A MORE COMPLETE TREATMENT OF THE GENERAL GEOLOGY THE READER IS REFERRED TO THE EXCELLENT MATERIAL PRESENTED IN CALIFORNIA STATE WATER RESOURCES BOARD BULLETIN 12 (REF. 23).

#### GROUND WATER BASINS

THE UPSTREAM GROUND WATER BASINS ARE FROM EAST TO WEST: PIRU, FILLMORE, AND SANTA PAULA (PLATE 2). THESE ARE ESSENTIALLY THE SAME GROUND WATER BASINS AS ORIGINALLY DELINEATED IN 1933 IN CALIFORNIA DIVISION OF WATER RESOURCES BULLETIN 46 (REF. 10). ON THE COASTAL PLAIN, HOWEVER, INCREASING INFORMATION SINCE 1933 HAS REQUIRED CONSIDERABLE MODIFICATION OF THE BULLETIN 46 BOUNDARIES. IN THE PRESENT REPORT THE BASIN BOUNDARIES ON THE COASTAL PLAIN ARE MUCH THE SAME AS THOSE GIVEN IN CALIFORNIA STATE WATER RESOURCES BOARD BULLETIN 12 (REF. 23). THE ALLUVIAL FAN OF THE SANTA CLARA RIVER MAY BE DIVIDED INTO TWO PARTS: (1) A NORTHERLY AREA WHERE FREE WATER TABLE CONDITIONS EXIST, CALLED THE OXNARD FOREDAY BASIN IN BULLETIN 12, AND THE MONTALVO BASIN IN DISTRICT REPORTS; (2) THE OXNARD PLAIN BASIN WHERE GROUND WATER IS UNDER PRESSURE. NORTH OF THE SANTA CLARA RIVER IS THE MOUND BASIN, WHERE THERE ARE NO IMPORTANT SHALLOW AQUIFERS, AND IRRIGATION WELLS MUST PENETRATE TO THE DEEPER CONFINED AQUIFERS AT THE BASE OF THE UPPER PLEISTOCENE OR IN THE SAN PEDRO FORMATION. EAST OF THE INFLUENCE OF THE SANTA CLARA RIVER THERE ARE SIMILARLY NO IMPORTANT SHALLOW AQUIFERS AND THE USUAL DRILLING OBJECTIVE IS THE FOX CANYON AQUIFER AT THE BASE OF THE SAN PEDRO FORMATION OR THE GRIMES CANYON AQUIFER AT THE TOP OF THE SANTA BARBARA FORMATION. THIS EASTERN AREA OF THE DISTRICT INCLUDES MOST OF PLEASANT VALLEY, AND PARTS OF THE CAMARILLO HILLS AND THE WEST LAS POSAS AREA (PLATE 17).

#### GENERAL GROUND WATER HYDROLOGY

SURFACE FLOWS ENTER THE UPPERMOST (PIRU) BASIN ALONG THE SANTA CLARA RIVER AND PIRU CREEK THROUGH ROCKY CANYONS WITH LITTLE ALLUVIAL FILL. RECHARGE TO PIRU BASIN IS LARGELY FROM PERCOLATION OF THESE SURFACE FLOWS. LESSER AMOUNTS OF RECHARGE TO THE PIRU BASIN, AS WELL

TABLE I-1  
GEOLOGIC FORMATIONS OF THE  
UNITED WATER CONSERVATION DISTRICT

| <u>AGE</u>           | <u>NAME</u>               | <u>AQUIFER DESCRIPTION AND LOCATION</u>                                                                                                          |
|----------------------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| RECENT               | RECENT ALLUVIUM           | SANDY SEMI-PERCHED ZONE OF OXNARD PLAIN.<br>MAIN ALLUVIUM OF UPSTREAM BASINS.                                                                    |
| UPPER<br>PLEISTOCENE | CLAY CAP                  | SILTY CLAYS AND SANDS BENEATH OXNARD PLAIN.                                                                                                      |
|                      | OXNARD AQUIFER            | COARSE GRAVELS AND SANDS--MAIN SHALLOW AQUIFER BENEATH OXNARD PLAIN.                                                                             |
|                      | TERRACE DEPOSITS          | CLAYS, SOME SANDS AND GRAVELS IN UP-STREAM BASINS AND MOUND BASIN.                                                                               |
|                      | BASAL GRAVELS             | GRAVELS WITH INTERBEDDED CLAYS JUST BE-NEATH OXNARD AQUIFER, AND IN MOUND AND SANTA PAULA BASINS.                                                |
|                      | MUGU AQUIFER              | LOCAL SAND AND GRAVEL LAYER IN THE MUGU AREA. PROBABLY A LOCAL PHASE OF BASAL GRAVELS.                                                           |
| LOWER<br>PLEISTOCENE | UPPER SAN PEDRO           | LENTICULAR GRAVELS OF THE COASTAL PLAIN. ABOVE FOX CANYON AQUIFER.                                                                               |
|                      | SAN PEDRO FORMATION       | INTERBEDDED SANDS, GRAVELS, AND CLAYS IN UPSTREAM BASINS AND IN MOUND BASIN.                                                                     |
|                      | FOX CANYON AQUIFER        | GRAVELS AND SANDS WITH CLAY LAYERS. NEAR BASE OF SAN PEDRO FORMATION BENEATH OXNARD PLAIN, PLEASANT VALLEY, CAMARILLO HILLS, AND WEST LAS POSAS. |
|                      | GRIMES CANYON AQUIFER     | LOCAL SANDS AND GRAVELS NEAR TOP OF SANTA BARBARA FORMATION IN PLEASANT VALLEY, CAMARILLO HILLS, AND WEST LAS POSAS.                             |
| UPPER<br>PLIOCENE    | SANTA BARBARA FORMATION   | NONWATER BEARING.                                                                                                                                |
| PLIOCENE             | PICO FORMATION            | NONWATER-BEARING.                                                                                                                                |
| MIOCENE              | MODELO FORMATION          | NONWATER-BEARING.                                                                                                                                |
|                      | SANTA MARGARITA FORMATION | NONWATER-BEARING.                                                                                                                                |
|                      | TOPANGA FORMATION         | SMALL QUANTITIES OF WATER IN VOLCANIC ROCKS.                                                                                                     |
|                      | VAQUEROS FORMATION        | NONWATER-BEARING.                                                                                                                                |
| Eocene               | SESPE FORMATION           | VERY SMALL QUANTITIES OF WATER                                                                                                                   |

AS TO THE FILLMORE, SANTA PAULA, AND MONTALVO BASINS, ARE DERIVED FROM DEEP PENETRATION OF RAINFALL. GROUND WATERS LEAVING THE PIRU BASIN FLOW WESTERLY INTO FILLMORE BASIN, PARTLY AS UNDERFLOW, AND EXCEPT AT THE END OF VERY DRY PERIODS, PARTLY AS RISING WATER. RECHARGE TO THE FILLMORE BASIN ALSO RESULTS FROM PERCOLATION OF FLOOD FLOWS OF THE SANTA CLARA RIVER AND OF SESPE CREEK. THROUGHOUT MOST OF ITS LENGTH, SESPE CREEK FLOWS THROUGH A ROCK CHANNEL, AND THERE IS LITTLE PERCOLATION OF THE FLOWS UNTIL THE WATERS REACH THE FILLMORE BASIN. GROUND WATERS LEAVE THE FILLMORE BASIN AS UNDERFLOW AND AS RISING WATER. THIS RISING WATER IS PERENNIAL, THOUGH FALLING TO VERY LOW FLOWS NEAR THE END OF PROLONGED DRY PERIODS. UNDERFLOW FROM FILLMORE BASIN, AND PERCOLATION OF RISING WATERS, SANTA CLARA RIVER FLOOD FLOWS, AND SANTA PAULA CREEK FLOOD FLOWS CONSTITUTE THE SOURCES OF RECHARGE TO THE SANTA PAULA BASIN.

UNDERFLOW AND PERCOLATION OF RISING WATER FROM SANTA PAULA BASIN ARE IMPORTANT CONTRIBUTORS TO MONTALVO BASIN. MORE IMPORTANT, THOUGH, IS THE PERCOLATION OF FLOOD FLOWS ALONG THE SANTA CLARA RIVER. BEYOND MONTALVO BRIDGE THERE IS LITTLE FURTHER PERCOLATION, AND THE FLOOD FLOWS REMAINING ARE WASTED TO THE OCEAN.

UNDERFLOW OUT OF MONTALVO BASIN GOES IN THREE DIRECTIONS: (1) INTO THE OXNARD AQUIFER BENEATH THE OXNARD PLAIN; (2) INTO THE FOX CANYON AQUIFER BENEATH THE OXNARD PLAIN; AND (3) INTO THE MOUND BASIN. ADDITIONAL RECHARGE TO THE FOX CANYON AQUIFER BENEATH THE DISTRICT OCCURS AS UNDERFLOW FROM THE EAST AND WEST LAS POSAS AREAS. UNDER NATURAL CONDITIONS GROUND WATER FLOW WAS PREDOMINANTLY SEAWARD. HEAVY OVERPUMPING HAS RESULTED IN LOCAL FLOW FROM THE OCEAN TOWARD THE CENTERS OF PUMPING.

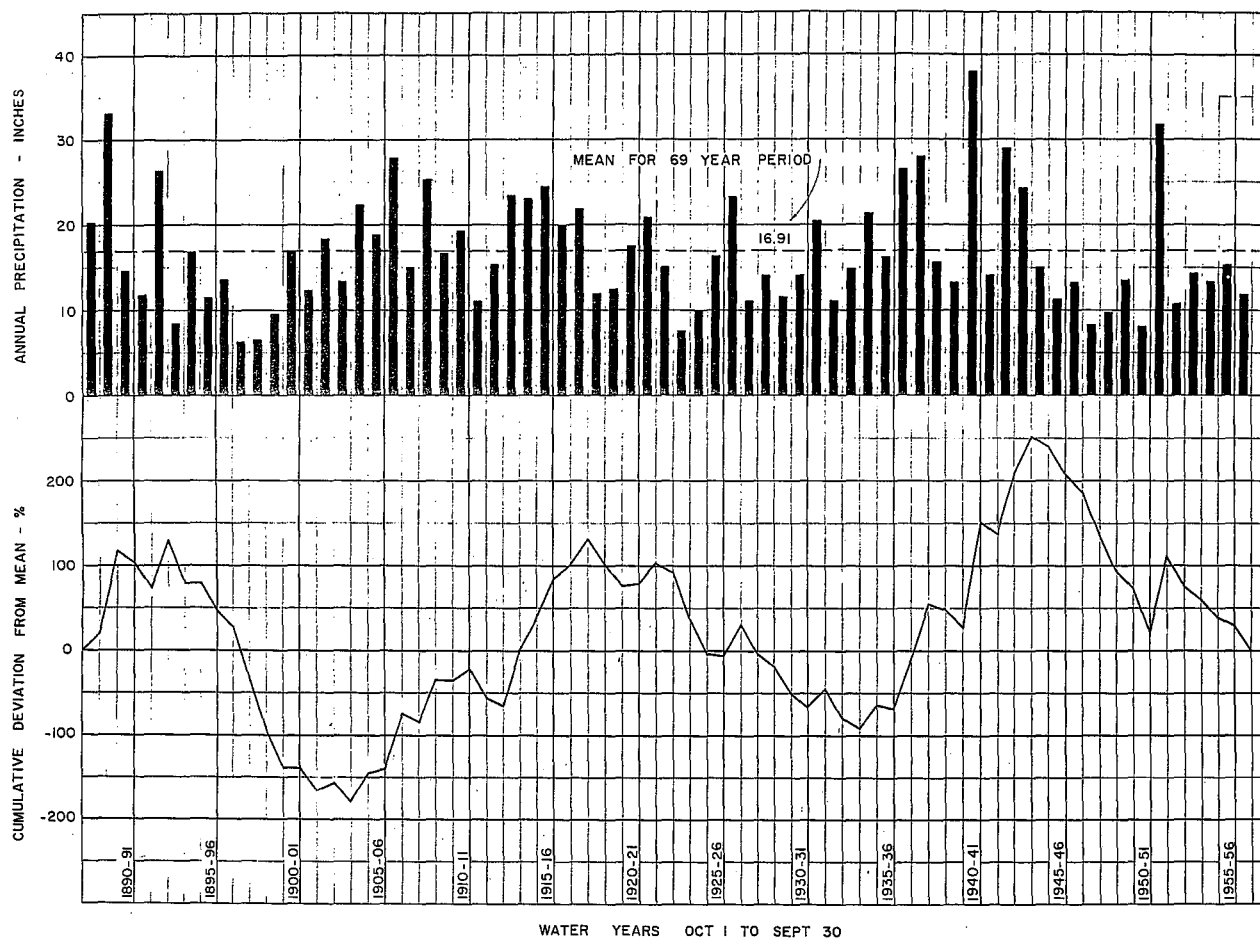
SOILS

A SOIL SURVEY OF THE ENTIRE DISTRICT AREA EXCEPT THE PIRU BASIN WAS MADE DURING 1901 BY THE BUREAU OF SOILS, U. S. DEPARTMENT OF AGRICULTURE (REF. 6). A MORE DETAILED SURVEY OF ALL OF THE DISTRICT'S AGRICULTURAL LANDS WAS MADE BY THE BUREAU OF SOILS IN 1917 AND PUBLISHED IN 1920 (REF. 7). MOST OF THE AGRICULTURAL AREAS ARE ON (1) RECENT ALLUVIAL SOILS DERIVED FROM SEDIMENTS THAT HAVE NOT UNDERGONE MATERIAL CHANGES OR INTERNAL MODIFICATIONS SINCE THEIR DEPOSITION, AND WHICH ARE STILL IN PROCESS OF FORMATION, AND (2) OLD VALLEY-FILLING AND COASTAL

PLAIN SOILS, CONSISTING OF ELEVATED AND WEATHERED UNCONSOLIDATED WATER-LAID DEPOSITS. EACH OF THESE GROUPS REPRESENTS A NUMBER OF SOIL SERIES, AND EACH SERIES IS REPRESENTED BY ONE OR MORE SOIL TYPES. MOST OF THE SOILS ARE FAIRLY PERMEABLE AND DRAIN EASILY. SOIL PROBLEMS IN THE DISTRICT ARE NOT SERIOUS. PRIOR TO AGRICULTURAL DEVELOPMENT MUCH OF THE OXNARD PLAIN HAD ALKALINE SOILS DUE TO HIGH WATER-TABLE CONDITIONS. AFTER THE INSTALLATION OF TILE DRAINS, AND LEACHING, THE SOILS WERE EXTREMELY PRODUCTIVE. BECAUSE OF HIGH PERMEABILITY SALTS DO NOT ACCUMULATE IN THE SOILS BUT ARE CARRIED DOWNWARD. THE MAINTENANCE OF GOOD PERMEABILITY IS ESPECIALLY FAVORED BY LOW SODIUM WATERS THROUGHOUT THE DISTRICT.

#### CLIMATE

THE CLIMATE OF THE DISTRICT IS QUITE MILD. AVERAGE ANNUAL TEMPERATURES RANGE FROM ABOUT 69°F NEAR THE COAST TO PERHAPS 61°F INLAND. ON THE COASTAL PLAIN THE MAXIMUM TEMPERATURE IS ABOUT 100°F AND THE MINIMUM ONLY SLIGHTLY BELOW FREEZING. FROSTS ON THE COASTAL PLAIN ARE UNCOMMON. INLAND, MAXIMUM TEMPERATURES ARE HIGHER, MINIMUM TEMPERATURES ARE LOWER, AND FROSTS ARE MUCH MORE OF A PROBLEM. LIKE THE REST OF COASTAL SOUTHERN CALIFORNIA, THE CLIMATE IS OF THE MEDITERRANEAN TYPE WITH A LONG DRY SUMMER AND A SHORT, COMPARATIVELY WET WINTER. ALMOST ALL OF THE PRECIPITATION OCCURS IN THE DECEMBER-TO-MARCH PERIOD. EVEN DURING THE WET SEASON, SKIES ARE CLEAR AND HUMIDITY LOW A VERY LARGE PERCENTAGE OF THE TIME. MOST OF THE RAIN COMES DURING STORMS LASTING FOR A DAY TO A FEW DAYS, WITH RELATIVELY LONG CLEAR PERIODS BETWEEN STORMS. THE AMOUNT OF RAINFALL FROM YEAR TO YEAR IS HIGHLY VARIABLE, AND DURING THE 85 YEARS OR SO THAT RAINFALL MEASUREMENTS HAVE BEEN MADE, THERE HAVE BEEN PRONOUNCED PERIODS OF DRY YEARS FOLLOWED BY PERIODS OF WET YEARS. EXTREMELY WET YEARS MAY OCCUR DURING THE DRY PERIODS, AND EXTREMELY DRY YEARS DURING THE WET PERIODS. NO RYTHMICAL OR FIXED CYCLICAL FLUCTUATIONS CAN BE RECOGNIZED. IN WATER RESOURCE STUDIES, A SUFFICIENTLY LONG PERIOD MUST BE TAKEN TO ASSURE THAT CONDITIONS STUDIED ARE FAIRLY REPRESENTATIVE OF AVERAGE LONG-TERM CONDITIONS. RAINFALL AT SANTA PAULA SINCE 1888 IS GIVEN ON PLATE 3.



RECORD OBTAINED FROM:

SOUTHERN PACIFIC COMPANY 1888-89 TO 1896-97  
 BLANCHARD INVESTMENT COMPANY 1896-97 TO 1944-45  
 VENTURA COUNTY AGRICULTURAL OFFICE 1944-45 TO 1956-57

## RAINFALL AT SANTA PAULA

1888-89 TO 1956-57

## COLLECTION OF DATA

THE UNITED WATER CONSERVATION DISTRICT HAS BEEN AN ACTIVE OIL-PRODUCING AREA FOR MANY DECADES. BECAUSE OF THIS ECONOMIC IMPETUS THE SURFACE GEOLOGY HAS BEEN MAPPED AND RE-MAPPED MANY TIMES. THE DETAILS OF THE SURFACE GEOLOGY WERE COMPILED FOR BULLETIN 46 (REF. 10) AND IN A MUCH MORE REFINED WAY FOR BULLETIN 12 (REF. 23). AS AN ADEQUATE DEPICTION OF THE SURFACE GEOLOGY WAS ALREADY AVAILABLE, IT WAS NOT THE INTENTION OF THE PRESENT INVESTIGATION TO REFINES THE MAPPING. THE LIMITED GEOLOGIC FIELD WORK UNDERTAKEN WAS CONFINED TO THOSE GEOLOGIC FEATURES PERTINENT TO THE GROUND WATER HYDROLOGY OF THE BASINS, AND TO DETAILS OF THE EXPOSED AQUIFERS.

THE FOCUS OF THE GEOLOGIC PHASE OF THE PRESENT INVESTIGATION WAS ON SUBSURFACE DETAILS. MUCH SUBSURFACE DATA HAD BEEN COLLECTED DURING THE BULLETIN 46 AND BULLETIN 12 STUDIES. ALL AVAILABLE WELL LOGS WERE OBTAINED FROM THE STATE DEPARTMENT OF WATER RESOURCES, VENTURA COUNTY DIVISION OF WATER RESOURCES, AND THE U. S. GEOLOGICAL SURVEY GROUND WATER BRANCH. FROM THE STATE DIVISION OF OIL AND GAS, MAPS WERE OBTAINED SHOWING THE LOCATIONS OF ALL OIL WELLS AND WILDCAT WELLS WITHIN THE DISTRICT. MOST OF THE MAJOR OIL COMPANIES OPERATING WITHIN THE DISTRICT WERE CONTACTED FOR INFORMATION, USUALLY ELECTRIC LOGS. THEY WERE VERY COOPERATIVE AND RELEASED MANY ELECTRIC LOGS, USUALLY JUST THE UPPER PART OF THE LOG, TO THE BASE OF FRESH WATER. MOST OF THE DEEP WELLS DRILLED BY THE MIDWAY DRILLING COMPANY OF OXNARD DURING THE LAST FIVE YEARS HAD ELECTRIC LOGS AVAILABLE, AND THESE WERE OBTAINED. AN ESPECIALLY GOOD SOURCE OF CABLE-TOOL DRILLER'S LOGS WAS LEONARD ANDERSON OF EL RIO.

WATER LEVELS OF NUMEROUS WELLS THROUGHOUT THE DISTRICT HAVE BEEN MEASURED BY THE VENTURA COUNTY WATER SURVEY (NOW WATER RESOURCES DIVISION, DEPARTMENT OF PUBLIC WORKS) SINCE THE BULLETIN 46 STUDIES. THESE EXTENSIVE AND CONTINUOUS WATER-LEVEL MEASUREMENTS, WHICH ARE KEPT PLOTTED UP-TO-DATE, ARE THE SOURCE OF THE HYDROGRAPHS USED IN THE PRESENT REPORT. NUMEROUS WATER-LEVEL MEASUREMENTS WERE MADE DURING 1951-53 BY THE STATE DIVISION OF WATER RESOURCES IN THE COURSE OF THE BULLETIN 12 INVESTIGATION. SOME EXCELLENT WATER-LEVEL RECORDS ARE AVAILABLE IN THE FILES OF THE SANTA CLARA WATER CONSERVATION DISTRICT. SOME OF THE WELLS

ARE MEASURED ON A MONTHLY BASIS, SOME WEEKLY, AND SOME HAD WATER-STAGE RECORDERS FOR LONG PERIODS OF TIME. UNITED HAS CONTINUED, IN PART, THE SANTA CLARA DISTRICT PROGRAM. WEEKLY MEASUREMENTS OF WATER LEVELS ARE MADE BY DASE PERSONNEL FOR THE WELLS OF BOTH THE MUGU AND HUENEME NAVAL BASES. MANY OTHER MEASUREMENTS, ESPECIALLY FOR WELLS IN THE COASTAL AREA, ARE AVAILABLE AT THE LONG BEACH OFFICE OF THE U. S. GEOLOGICAL SURVEY, GROUND WATER BRANCH.

THE FIRST COMPILATION OF WATER QUALITY DATA FOR THE DISTRICT WAS THAT WHICH APPEARED IN STATE DIVISION OF WATER RESOURCES BULLETIN 46A (REF. 11) THE APPENDICES TO BULLETIN 46. BETWEEN THE TIME OF THE BULLETIN 46 WATER SAMPLING PROGRAM AND THAT STARTED IN 1951 DURING THE BULLETIN 12 INVESTIGATION, WATER QUALITY DATA ARE RATHER SPARSE. HOWEVER, MANY SAMPLES WERE TAKEN ALONG THE COAST IN THE AREA OF POTENTIAL SEA-WATER INTRUSION DURING THE LATE FORTIES BY THE SANTA CLARA WATER CONSERVATION DISTRICT, AND BY THE U. S. GEOLOGICAL SURVEY (REF. 56). FROM 1951 TO THE PRESENT TIME, THE WATER SAMPLING PROGRAM HAS BEEN MUCH MORE SYSTEMATIC. PERIODIC SAMPLING OF BOTH SURFACE WATERS AND WELL WATERS IS CURRENTLY BEING UNDERTAKEN BY THE STATE DEPARTMENT OF WATER RESOURCES, VENTURA COUNTY WATER RESOURCES DIVISION, AND BY THE UNITED WATER CONSERVATION DISTRICT. MOST OF THE EARLIER ANALYSES WERE MADE BY THE FRUIT GROWERS LABORATORY, AND MANY CAN BE FOUND IN REPORTS PREPARED BY L. T. SHARP (REFS. 32, 62, 63). ALMOST ALL OF THE SURFACE WATER AND GROUND WATER ANALYSES DATING FROM AFTER BULLETIN 46A WERE COMPILED AND RECENTLY RELEASED AS APPENDICES TO STATE DEPARTMENT OF WATER RESOURCES BULLETIN 75 (REF. 18).

#### NUMBERING SYSTEMS

CURRENTLY IN VENTURA COUNTY, TWO WELL NUMBERING SYSTEMS ARE USED. THE ORIGINAL GRID SYSTEM, DEVELOPED DURING THE BULLETIN 46 INVESTIGATION, UTILIZES BLOCKS TWO MILES ON A SIDE. THESE BLOCKS ARE NUMBERED FROM WEST TO EAST AND LETTERED FROM NORTH TO SOUTH. WITHIN EACH BLOCK (AREA FOUR SQUARE MILES) A WELL IS ASSIGNED A NUMBER AS LOCATED. THUS WELL 10-R-57 WOULD BE THE 57TH WELL ASSIGNED A NUMBER WITHIN THE 10-R BLOCK. THERE IS NO INDICATION FROM THE NUMBER AS TO THE POSITION OF THE WELL WITHIN THE FOUR-SQUARE-MILE AREA.

THE MORE RECENTLY DEVELOPED NUMBERING SYSTEM IS THAT EMPLOYED BY THE U. S. GEOLOGICAL SURVEY AND ADOPTED BY THE STATE DEPARTMENT OF WATER RESOURCES. THIS SYSTEM UTILIZES THE TOWNSHIP, RANGE AND SECTION SUDDIVISION OF THE FEDERAL LAND SURVEY. AREAS NOT ACTUALLY SURVEYED INTO SECTIONS WERE DIVIDED DURING THE BULLETIN 12 INVESTIGATION BY EXTENDING THE GRID INTO THESE AREAS. IN THIS SYSTEM, EACH SECTION IS DIVIDED INTO SIXTEEN 40-ACRE PLOTS AND LETTERED AS FOLLOWS:

|   |   |   |   |
|---|---|---|---|
| D | C | B | A |
| E | F | G | H |
| M | L | K | J |
| N | P | Q | R |

WITHIN EACH 40-ACRE PLOT THE WELLS ARE NUMBERED IN ORDER, AS LOCATED. IF A WELL IS DESIGNATED AS 3N/20W-11N1, IT IS LOCATED IN SECTION 11 OF TOWNSHIP 3 NORTH, RANGE 20 WEST. IT IS FURTHER LOCATED IN THE "N" PLOT, AND IS THE FIRST WELL TO BE LOCATED IN THAT PLOT. ALL AREAS IN THE DISTRICT ARE REFERENCED TO THE SAN BERNARDINO BASE AND MERIDIAN (S.B.B.M.). IN ASSIGNING LETTERS TO WELLS, THE NORTHEAST CORNER IS FIXED. IF A SECTION IS SMALLER THAN 640 ACRES, THE WEST AND SOUTH LETTERED PLOTS ARE REDUCED IN SIZE OR ELIMINATED. IN UNUSUALLY LARGE SECTIONS, THE WEST AND SOUTH ROWS OF LETTERED PLOTS ARE EXPANDED.

IN THE PRESENT REPORT, THE U.S.G.S.-STATE SYSTEM WILL BE USED. LOCATING A WELL IMMEDIATELY TO THE NEAREST 40 ACRES HAS BEEN FOUND TO BE A DISTINCT ADVANTAGE. FOR MANY REASONS IT IS RECOMMENDED THAT THE DISTRICT GRADUALLY SWITCH TO THE U.S.G.S.-STATE SYSTEM. THIS SYSTEM HAS BECOME STANDARD IN THE ENTIRE STATE OF CALIFORNIA AND IS USED ALSO IN MANY OTHER STATES BY STATE ORGANIZATIONS AND THE U. S. GEOLOGICAL SURVEY. THE CALIFORNIA DEPARTMENT OF WATER RESOURCES IS CURRENTLY ADAPTING THIS NUMBERING SYSTEM TO PROCESSING OF HYDROLOGIC DATA IN COMPUTING MACHINES. TO ASSIST IN CHANGING FROM VENTURA COUNTY NUMBERS TO STATE NUMBERS, THERE IS NOW AVAILABLE A PUBLISHED CROSS-INDEX (REF. 18).

## CHAPTER II

### DETAILED GROUND WATER HYDROLOGY

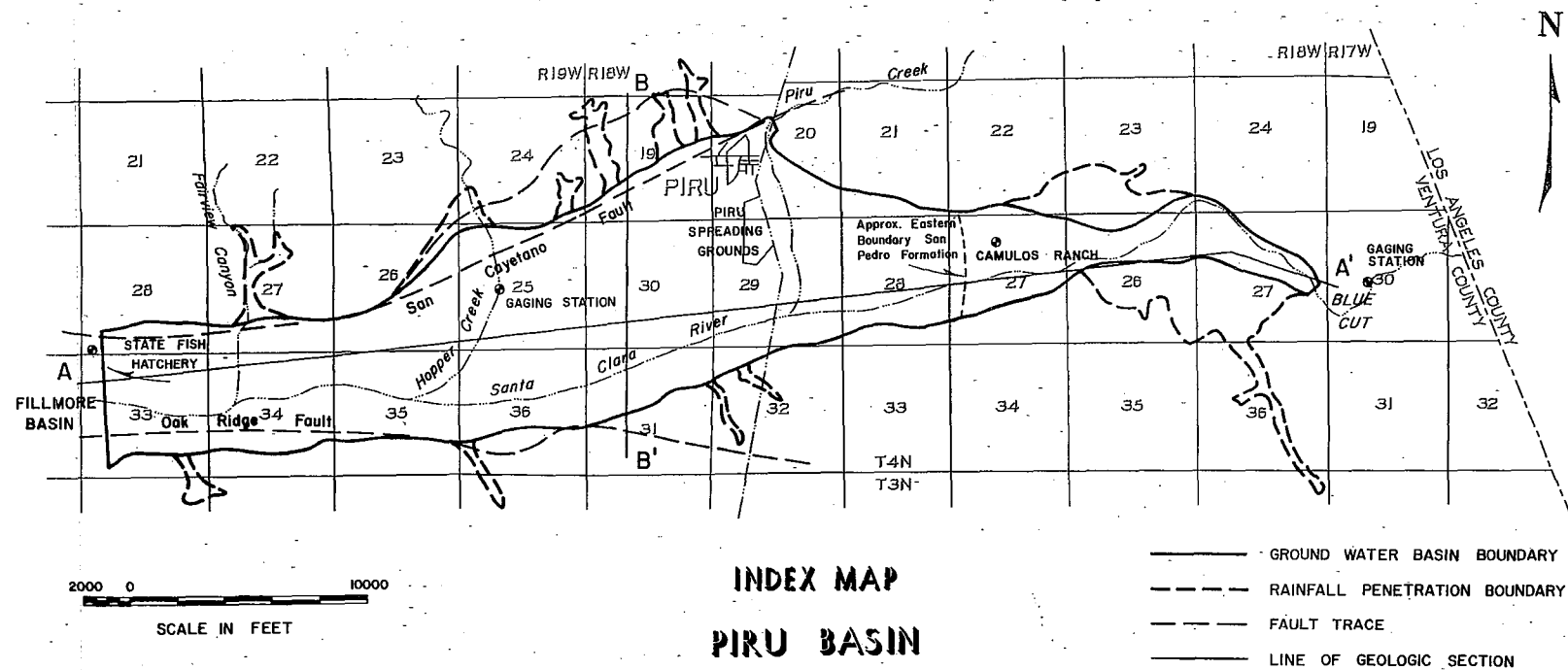
#### PIRU BASIN BOUNDARIES

THE PIRU BASIN REFERS TO THE AREA OF GROUND WATER STORAGE WHICH IS THE FARTHEST UPSTREAM OF THE MAJOR AGRICULTURAL AREAS OF THE UNITED WATER CONSERVATION DISTRICT. THE BOUNDARIES ARE AS GIVEN IN PLATE 4. THE EASTERN BOUNDARY IS PLACED 0.7 STREAM MILES BELOW THE VENTURA COUNTY GAGING STATION AT BLUE CUT, AT A PLACE WHERE THE ALLUVIUM IS THIN AND UNDERLAIN BY NONWATER-BEARING ROCKS. THE WESTERN BOUNDARY MUST BE SELECTED ON A SOMEWHAT ARBITRARY BASIS, ABOUT WHERE THE VALLEY REACHES A MINIMUM WIDTH. IN THE VICINITY OF THIS BOUNDARY IS A REACH OF PERIODIC RISING WATER. THE ALLUVIAL MATERIALS HERE ARE NOT NOTICEABLY THINNER THAN ELSEWHERE, AND THEY ARE UNDERLAIN BY PERMEABLE FRESH-WATER-BEARING ZONES TO DEPTHS OF THOUSANDS OF FEET. THE REMAINDER OF THE BOUNDARY OF THE BASIN DELINEATES THE AREA OF MORE OR LESS PERMANENT GROUND WATER STORAGE, AND CLOSELY APPROXIMATES THE AREA WHICH HAS BEEN COVERED BY THE ALLUVIAL DEPOSITS OF PIRU CREEK AND THE SANTA CLARA RIVER. INCLUDED WITHIN THE PIRU BASIN ARE THE TERRACES ALONG THE SOUTH SIDE OF THE RIVER IN SECTIONS 29, 31, AND 32, T4N, R18W, ALTHOUGH THE AQUIFERS BENEATH THESE TERRACES ARE AT TIMES NOT IN FREE HYDROLOGIC CONTINUITY WITH THE MAIN ALLUVIAL WATERS. AS SO DEFINED, THE PIRU BASIN COVERS AN AREA OF 7025 ACRES. FOR PURPOSES OF COMPUTING RAINFALL PENETRATION, A SOMEWHAT LARGER AREA OF 8285 ACRES IS USED (PLATE 4). WITHIN THE ADDITIONAL, PERIPHERAL AREAS, THE PENETRATING RAIN WATER, SUPPLIED ONLY IN VERY WET YEARS, MOVES DOWNWARD, THEN Laterally AS SLOW UNDERFLOW TO FEED THE MAIN BODY OF ALLUVIUM. THE ALLUVIUM OF HOPPER CREEK CANYON, THOUGH VERY EXTENSIVE, IS SPECIFICALLY EXCLUDED HERE BECAUSE HOPPER CREEK HAS ERODED INTO HARD ROCK NEAR ITS MOUTH, AND SUCH RAINFALL AS MAY PENETRATE IS CONSIDERED TO ENTER THE GROUND WATER BASIN AS SURFACE FLOW.

#### GROUND WATER GEOLOGY

##### GENERAL GEOLOGY

BROADLY SPEAKING, THE PIRU BASIN IS A REACH OF THE EXTENSIVE



THE MOUTH OF FAIRVIEW CANYON RESTRICTS THE RIVER SOMEWHAT, BUT THERE SEEMS LITTLE DOUBT THAT THE RIVER NEAR THE WESTERN BASIN BOUNDARY HAS IN THE PAST REACHED CLOSE TO THE NORTH WALL.

THE RECENT ALLUVIUM DEPOSITED BY THE SANTA CLARA RIVER IS PRIMARILY COARSE SAND AND GRAVEL. ELSEWHERE IN THE PIRU BASIN THE RECENT ALLUVIUM CONTAINS LAYERS OF MUCH LOWER PERMEABILITY. THESE FINER-GRAINED LAYERS, INCLUDING SOME CLAYS, PROBABLY REPRESENT ANCIENT INTER-STREAM OR INTER-FAN AREAS. IN MANY PLACES NORTH OF THE PRESENT CHANNEL OF THE SANTA CLARA RIVER, THESE CLAYS HAVE CAUSED A PERCHED CONDITION, AND THE PERCHED WATERS ARE TYPICALLY OF INFERIOR CHEMICAL QUALITY. THOUGH THEY APPEAR IN MANY PLACES, THE SHALLOW CLAY LAYERS ARE NOT CONTINUOUS, AND THE PERCHED WATERS ARE ABLE TO FLOW Laterally, AND IN AREAS OF GREATER PERMEABILITY MOVE DOWNWARD TO THE MAIN BODY OF GROUND WATER.

EXCEPT AT THE LOWER, WESTERN END OF THE PIRU BASIN, THE RECENT ALLUVIUM BECOMES DEWATERED DURING A PROLONGED PERIOD OF DRY YEARS. AS A RESULT OF THIS DRAINING, SOME SHALLOW WELLS HAVE GONE DRY. FORTUNATELY, HOWEVER, THE RECENT ALLUVIUM ALMOST EVERYWHERE IN THE PIRU BASIN IS UNDERLAIN BY DEEPER AQUIFERS, AND WATER CAN BE OBTAINED AT SOMEWHAT GREATER DEPTHS.

THE DEPOSITS OF OLDER ALLUVIUM INCLUDE THOSE LAID DOWN BY THE SANTA CLARA RIVER AND TRIBUTARIES DURING AN EPISODE DISTINCTLY PRIOR TO THAT OF THE RECENT ALLUVIUM. THE OLDER ALLUVIUM FILLS BURIED CHANNELS DEEPER THAN THOSE OCCUPIED BY THE RECENT ALLUVIUM AND IS PRESENT AS TERRACE DEPOSITS RISING ABOVE THE PRESENT STREAM CHANNELS. FLANKING THE SANTA CLARA RIVER ON BOTH SIDES JUST WEST OF BLUE CUT ARE TERRACE MATERIALS DEPOSITED DURING OLDER ALLUVIAL TIME. SIMILAR HIGH-LEVEL DEPOSITS FORM A PROMINENT BENCH ALONG THE SOUTH SIDE OF THE PIRU BASIN IN SECTIONS 29, 31, AND 32, T4N, R18W. THROUGHOUT MOST OF THE REMAINDER OF THE BASIN THE OLDER ALLUVIUM OCCURS AS A LAYER OF VARIABLE THICKNESS DENEATH THE RECENT ALLUVIUM. ON THE CAMULOS RANCH, IN SECTION 27, T4N, R18W, THE OLDER ALLUVIUM HAS A THICKNESS OF ABOUT 80 FEET. AT THE STATE FISH HATCHERY, RECENT ALLUVIUM LIES DIRECTLY ON THE SAN PEDRO FORMATION, AND OLDER ALLUVIUM IS ABSENT. HOWEVER, IN THE BURIED ALLUVIUM-FILLED CHANNEL SOUTH OF THE STATE FISH HATCHERY, THE BOTTOM 40 FEET OF FILL IS ASSIGNED TO THE OLDER ALLUVIUM. THE UPPER PART OF THIS ALLUVIAL FILL, WHICH

BLANKETS THE ENTIRE WIDTH OF THE BASIN AT THE BASIN BOUNDARY, IS CONSIDERED RECENT ALLUVIUM. ALTHOUGH THE ABSENCE OF OLDER ALLUVIUM AT THE STATE FISH HATCHERY MAY BE DUE TO NON-DEPOSITION, A MORE LIKELY EXPLANATION IS THAT THE OLDER ALLUVIUM WAS DEPOSITED, THEN LATER REMOVED BY EROSION. IN THE CENTRAL PART OF THE BASIN, SOUTH AND WEST OF THE TOWN OF PIRU, THE OLDER ALLUVIUM THICKNESS IS BETWEEN 30 AND 50 FEET.

AS COMPARED WITH THE RECENT ALLUVIUM, THE OLDER ALLUVIUM IS CHARACTERIZED BY MORE LAYERS OF CLAY, ESPECIALLY YELLOW TO BROWN IN COLOR. DURING OLDER ALLUVIAL TIME IT IS SUGGESTED THAT THE INFLUENCE OF THE THROUGH-FLOWING RIVER WAS LESS IMPORTANT THAN NOW, AND THE DEPOSITS FROM THE SIDE TRIBUTARIES WERE MORE EXTENSIVELY DEVELOPED.

OLDER ALLUVIUM OVERLIES TRUNCATED LAYERS OF THE SAN PEDRO FORMATION EVERYWHERE IN THE PIRU BASIN EXCEPT AT THE EASTERN END, WHERE IT OVERLIES THE NONWATER-BEARING PICO FORMATION.

DURING PROLONGED DROUGHTS THE OLDER ALLUVIUM BECOMES COMPLETELY DEWATERED IN THE AREA SOUTH AND WEST OF THE TOWN OF PIRU. JUST WEST OF BLUE CUT, DURING DROUGHT PERIODS, STATIC WATER TABLES DROP TO WITHIN THE OLDER ALLUVIAL GRAVELS, BUT THERE HAS BEEN NO EVIDENCE OF COMPLETE DEWATERING. NEAR THE WESTERN END OF THE BASIN, WHERE WATER LEVELS ARE PERSISTENTLY HIGH, THE OLDER ALLUVIUM SHOWS ONLY SLIGHT DEWATERING, EVEN AT THE END OF A PROLONGED DROUGHT PERIOD.

THERE ARE FEW WELLS WHICH RELY UPON OLDER ALLUVIUM AS AN EXCLUSIVE SOURCE OF SUPPLY. MOST WELLS PENETRATING THE OLDER ALLUVIUM ARE PERFORATED ALSO IN THE SATURATED OVERLYING RECENT ALLUVIUM OR IN THE UNDERLYING SAN PEDRO FORMATION. EXCEPTIONS ARE THE WELLS IN SECTION 27, T4N, R18W, WHERE THE PICO FORMATION UNDERLIES THE OLDER ALLUVIUM. HERE DURING DROUGHT PERIODS ONLY THE LOWER PART OF THE OLDER ALLUVIUM IS SATURATED, AND THIS IS THE ONLY SOURCE OF SUPPLY TO WELLS.

#### SAN PEDRO AQUIFERS

AS USED IN THIS REPORT, THE TERM "SAN PEDRO AQUIFERS" REFERS TO THE PERMEABLE SANDS AND GRAVELS IN THE HIGHLY FOLDED LOWER PLEISTOCENE MATERIALS WHICH OVERLIE THE PLIOCENE PICO FORMATION OR THE SANTA BARBARA FORMATION. NEAR THE BASE OF THE FORMATION IS A GROUP OF MARINE LAYERS SOMETIMES CALLED THE LAS POSAS FORMATION. BENEATH THE PIRU BASIN, THESE BASAL MARINE LAYERS HAVE A THICKNESS OF ABOUT 1000 FEET. THE THICKER

OVERLYING SEQUENCE OF LAYERS, COMMONLY CALLED THE SAUGUS FORMATION, IS OF CONTINENTAL DEPOSITION. IN THE ELECTRIC LOG OF ONE OIL WELL, LAYERS OF APPARENT SAN PEDRO LITHOLOGY CONTAINING RELATIVELY FRESH WATER EXTEND TO A DEPTH OF 8800 FEET. THIS UNUSUALLY GREAT INFERRED THICKNESS MIGHT BE EXPLAINED BY STEEPLY DIPPING BEDS, BY REPETITION OF STRATA DUE TO FAULTING, OR BY PRE-SAN PEDRO LAYERS NOT PREVIOUSLY RECORDED.

ALTHOUGH THE SAN PEDRO AQUIFERS UNDERLIE MOST OF THE PIRU BASIN, THEY ARE NOWHERE IN THIS BASIN EXPOSED AT THE SURFACE. THESE AQUIFERS ARE PRESENT IN WELL 4N/18W-28C1 BUT IN NO WATER WELLS FARTHER EAST. THE APPROXIMATE EASTERN LIMIT OF THE SAN PEDRO FORMATION BENEATH THE BLANKETING ALLUVIUM IS SHOWN ON PLATE 4. THE EASTERN PART OF THE PIRU BASIN, HOWEVER, IS VERY COMPLEX GEOLOGICALLY, AND CONCEIVABLY THE LIMIT COULD BE SOMEWHAT FARTHER EAST. AS INDICATED BY ELECTRIC LOG DATA, THE SAN PEDRO FORMATION AT DEPTH EXTENDS BOTH NORTH AND SOUTH BEYOND THE BOUNDARIES OF THE PIRU BASIN BENEATH THE SAN CAYETANO AND OAK RIDGE FAULTS (SECTION B-B', PLATE 5). AN EAST-WEST CROSS-SECTION ALONG THE MAJOR SYNCLINE BENEATH THE PIRU BASIN IS SHOWN IN SECTION A-A' OF PLATE 5. FROM THE APPROXIMATE EASTERN LIMIT, THE BASE OF THE SAN PEDRO FORMATION PLUNGES STEEPLY TO A PROBABLE DEPTH OF 8800 FEET IN THE NW 1/4, SECTION 30, T4N, R18W. TO THE WEST THE BASE REMAINS AT GREAT DEPTH, ALTHOUGH THERE IS PROBABLY A GENTLE ARCH IN THE WESTERN PART OF THE BASIN, AND A LOW WESTERLY PLUNGE AT THE BASIN BOUNDARY.

IN THE CENTRAL PART OF THE PIRU BASIN, THE SAN PEDRO FORMATION IS PREDOMINANTLY SAND AND GRAVEL WITH LOCAL THIN LAYERS OF CLAY. THESE PERMEABLE LAYERS EXTEND FAR DEEPER THAN PRESENT-DAY ECONOMICAL DRILLING DEPTHS. TOWARD THE WESTERN BOUNDARY, THICK CLAYS ARE INTERBEDDED WITH THE GRAVELLY AQUIFERS, AND ARTESIAN CONDITIONS ARE PRODUCED.

WATER WELLS TAP NUMEROUS SAN PEDRO AQUIFERS OVER MOST OF THE PIRU BASIN. TOTAL DEPTHS RANGE FROM 300 TO 650 FEET, AND WELL YIELDS ARE AS HIGH AS 3000 GALLONS PER MINUTE. SPECIFIC CAPACITIES GENERALLY EXCEED 100, AND IN ONE WELL THE SPECIFIC CAPACITY IS 200 GALLONS PER MINUTE PER FOOT OF DRAWDOWN. NOT ALL PARTS OF THE SAN PEDRO FORMATION YIELD WATER PROLIFICALLY. IN SOME ZONES THERE ARE THICK CLAYS AND IN OTHERS THE USUALLY PERMEABLE SANDS AND GRAVELS ARE WELL CEMENTED.

## SOURCES OF RECHARGE

THE PIRU BASIN IS RECHARGED MAINLY BY PERCOLATION OF SURFACE FLOWS ALONG THE CHANNELS OF THE SANTA CLARA RIVER, PIRU CREEK, HOPPER CREEK, AND SMALLER TRIBUTARIES. THE PERCOLATION OF THE PIRU CREEK FLOWS IS AUGMENTED BY DIVERSIONS INTO THE PIRU SPREADING GROUNDS. DURING YEARS OF HEAVY RAINFALL, SOIL MOISTURE DEFICIENCIES ARE EXCEEDED AND LARGE VOLUMES OF WATER ARE RECHARGED THROUGH RAINFALL PENETRATION. ON SOME OF THE SANDIER SOILS IRRIGATION WATER IS APPLIED VERY LIBERALLY AND THE EXCESS IS RETURNED TO UNDERGROUND STORAGE. UNDERFLOW INTO THE BASIN IS NOT LARGE, BUT A SMALL STEADY FLOW ENTERS THROUGH THE THIN ALLUVIUM AT BLUE CUT AND AT THE NARROWS NEAR THE TOWN OF PIRU. STILL SMALLER, INTERMITTENT UNDERFLOWS SEEP THROUGH THE SMALL TRIBUTARY ALLUVIUM AND FROM TERRACE DEPOSITS. LEAKAGE FROM THE TERTIARY ROCKS DIRECTLY INTO THE MAIN ALLUVIUM IS CONSIDERED TO BE INSIGNIFICANT.

## BASIN OUTFLOW

A LARGE AMOUNT OF UNDERFLOW LEAVES THE PIRU BASIN NEAR THE STATE FISH HATCHERY MOVING THROUGH BOTH THE ALLUVIUM AND THE SAN PEDRO AQUIFERS. BECAUSE OF THE SLIGHT DECREASE IN WIDTH OF THE VALLEY, BOTH THE ALLUVIAL AQUIFERS AND THE SAN PEDRO AQUIFERS SHOW A HORIZONTAL CONSTRICTION. IN THE WETTER PERIODS THE UNDERGROUND TRANSMISSIBILITY IS INSUFFICIENT TO HANDLE THE OUTFLOW AND THE EXCESS LEAVES AS RISING WATER. IN PROLONGED DROUGHT PERIODS THE UPPER PART OF THE ALLUVIAL CROSS-SECTION IS DEWATERED.

## MOVEMENTS OF UNDERGROUND WATER

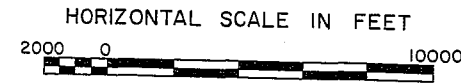
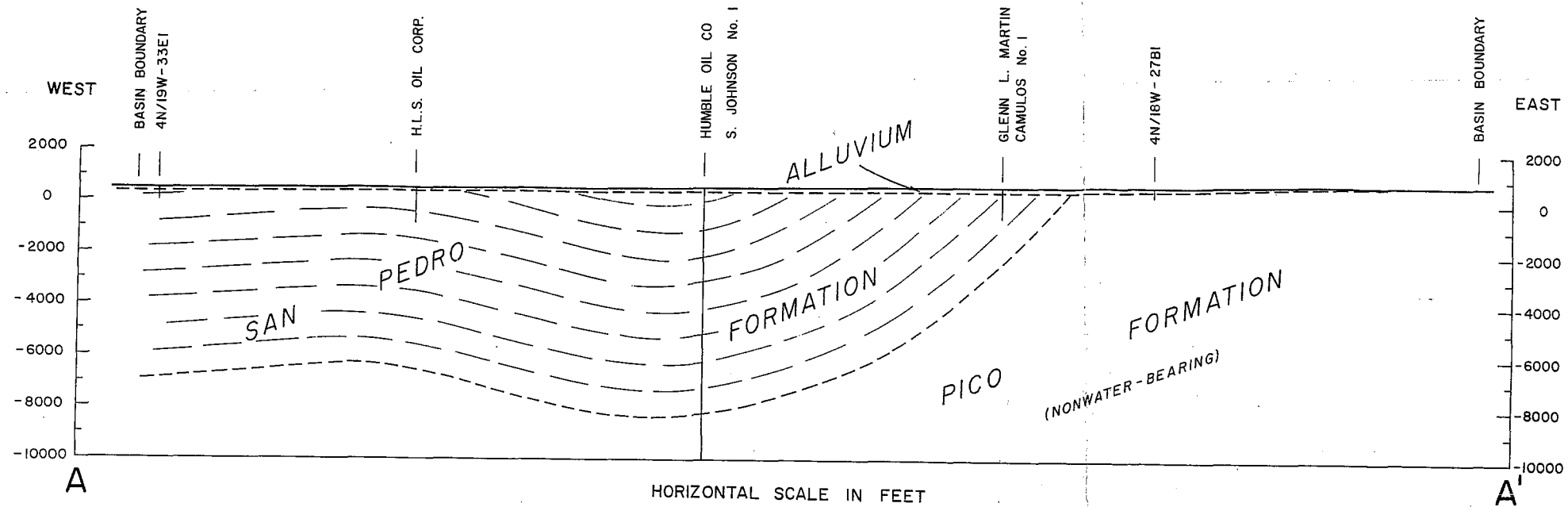
THE PIRU BASIN IS CHARACTERIZED BY THE GENERAL WESTERLY MOVEMENT OF GROUND WATER, CONFORMING TO THE SLOPE OF THE ALLUVIAL SURFACE. DURING WET YEARS, THE WATER TABLE RISES WITHIN THE BLANKETING ALLUVIAL DEPOSITS AND THE SIMPLE WESTERLY FLOW IS EVIDENT FROM THE WATER-LEVEL CONTOURS (PLATE 6A). TOWARD THE END OF A SERIES OF DRY YEARS, A LARGE AREA OF THE ALLUVIAL BLANKET BECOMES UNWATERED, AND THE WESTERLY MOVEMENT OF WATER IN THE ALLUVIAL DEPOSITS CONTINUES ONLY IN THE ALLUVIUM OF THE SANTA CLARA RIVER ALONG A STRIP AT THE SOUTHERN BORDER OF THE BASIN (PLATE 6B). TO THE NORTH, AFTER THE ALLUVIAL DEPOSITS ARE DRY, THE PUMPING PROGRESSIVELY REMOVES WATER FROM STORAGE IN THE SAN PEDRO AQUIFERS.

ALLUVIAL STRIP OF THE SANTA CLARA RIVER. THE MOUNTAINS FLANKING THIS WESTWARD-SLOPING ALLUVIAL STRIP, BOTH TO THE NORTH AND TO THE SOUTH, ARE COMPOSED OF HARD NONWATER-BEARING TERTIARY ROCKS. UNDERLYING AND COMPLETELY OBSCURED BY THE ALLUVIAL BLANKET IS A GREAT THICKNESS OF LOWER PLEISTOCENE WATER-BEARING DEPOSITS WHICH HAVE BEEN THROWN INTO A SHARP SYNCLINE WITH AN EAST-WEST AXIS. IN THE BROAD WESTERN PART OF THE PIRU BASIN THE DEEP SYNCLINE OF LOWER PLEISTOCENE FRESH-WATER-BEARING ROCKS IS ABRUPTLY TRUNCATED BOTH NORTH AND SOUTH BY THRUST FAULTS OF TREMENDOUS THROW. ON THE NORTH THE SAN CAYETANO FAULT HAS PUSHED THE TERTIARY ROCKS UP AND OVER THE LOWER PLEISTOCENE AQUIFERS. A SIMILAR SITUATION OCCURS TO THE SOUTH WHERE THE TERTIARY ROCKS OVERHANG THE SAME AQUIFERS ABOVE THE MORE NEARLY VERTICAL OAK RIDGE FAULT. THESE COMPLEX GEOLOGIC CONDITIONS ARE DEPICTED ON SECTION B-B' OF PLATE 5. IN THE NARROW EASTERN PART OF THE PIRU BASIN THE THRUST FAULTS ARE NOT CLOSE TO THE ALLUVIAL LIMITS BUT THE RESULTS OF THE STRONG NORTH-SOUTH COMPRESSION APPEAR AS OVERTURNED TERTIARY LAYERS ON BOTH FLANKS OF THE VALLEY.

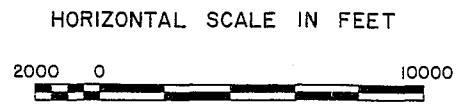
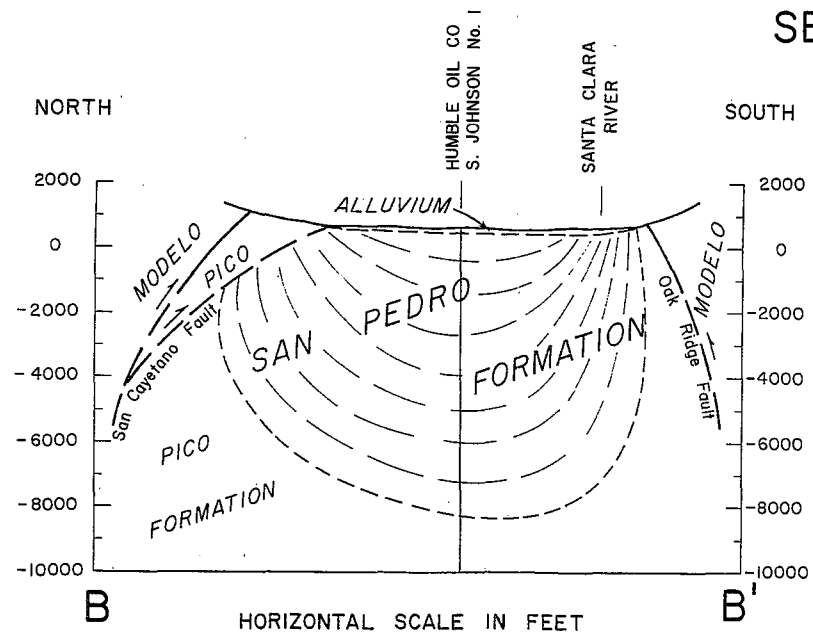
#### ALLUVIAL AQUIFERS

THE UPPERMOST ALLUVIAL LAYERS, PROBABLY OF RECENT AGE, BLANKET ALMOST THE ENTIRE PIRU BASIN. THESE SURFICIAL LAYERS INCLUDE DEPOSITS OF THE SANTA CLARA RIVER, PIRU CREEK, HOPPER CREEK, AND MINOR STREAMS COMING FROM THE NORTH. NEAR BLUE CUT, AT THE EASTERN BOUNDARY OF THE BASIN, ALLUVIAL DEPOSITS ARE PROBABLY NO MORE THAN A FEW TENS OF FEET THICK. OVER MOST OF THE REMAINDER OF THE BASIN, THE THICKNESS OF THE RECENT ALLUVIUM IS IN THE RANGE OF 60 TO 80 FEET. IT APPEARS TO BE THICKEST IN SECTION 27, T4N, R18W, WHERE THE PROBABLE BASE IS AT A DEPTH OF 80 FEET. THERE IS A GRADUAL THINNING TO THE WEST. SOUTH AND WEST OF THE TOWN OF PIRU THE AVERAGE THICKNESS IS ABOUT 70 FEET, WHEREAS AT THE WESTERN BASIN BOUNDARY SOUTH OF THE STATE FISH HATCHERY, THE THICKNESS IS ABOUT 60 FEET.

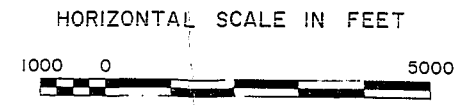
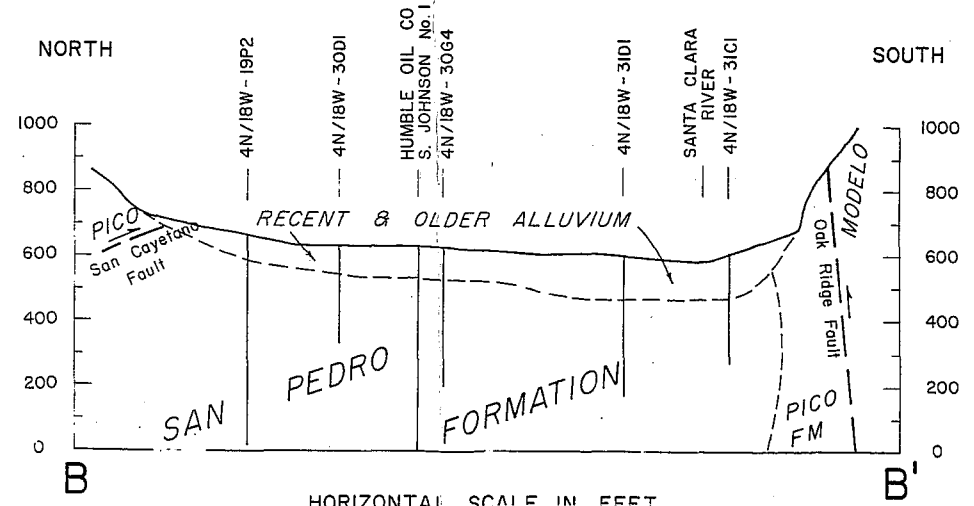
THROUGHOUT RECENT ALLUVIAL TIME THE DEPOSITS OF THE SANTA CLARA RIVER HAVE BEEN RESTRICTED TO THE SOUTHERLY PART OF THE BASIN. BECAUSE OF THE SOUTHWARD-SPREADING DEPOSITS OF PIRU CREEK AND THE FAN OF HOPPER CREEK, THE SANTA CLARA RIVER HAS NOT BEEN PERMITTED TO SWING INTO THE NORTHERN PART OF THE BASIN. WEST OF THE HOPPER CREEK FAN, HOWEVER, THE RIVER HAS BEEN LESS RESTRICTED AND HAS BEEN ABLE TO SWING MORE FREELY FROM ONE SIDE OF THE VALLEY TO THE OTHER. THE PRESENT ALLUVIAL FAN AT



SECTION A-A'



SECTION B-B'



SECTION B-B'

GEOLOGIC SECTIONS  
PIRU BASIN

11-2

PLATE 6A

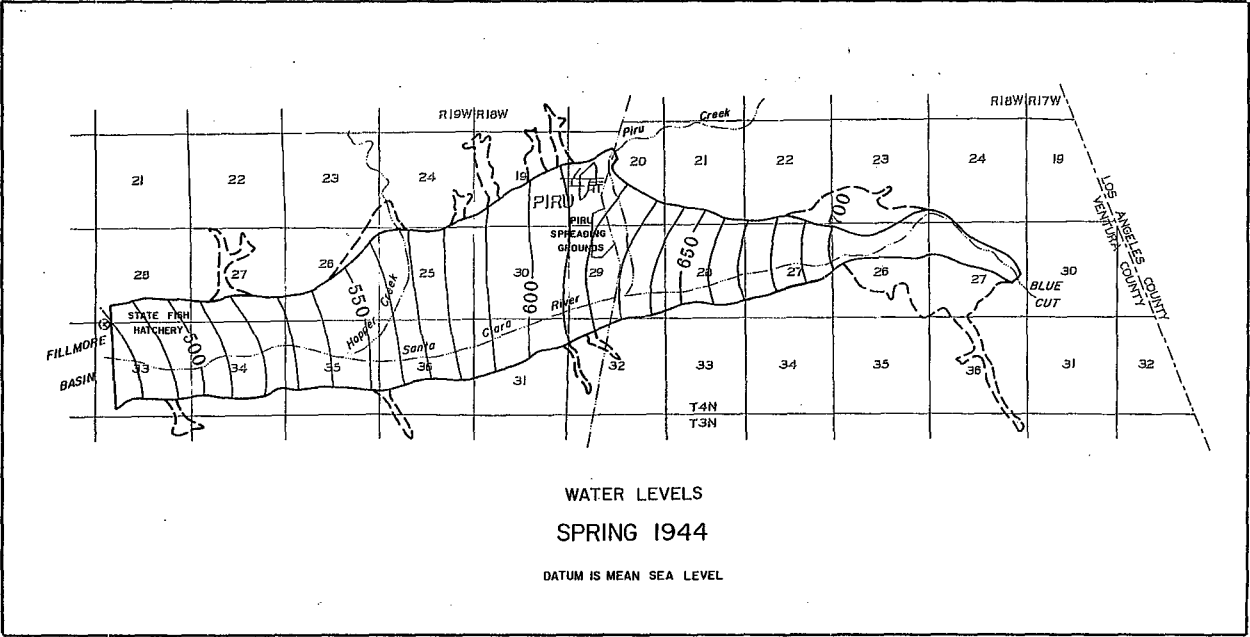


PLATE 6B

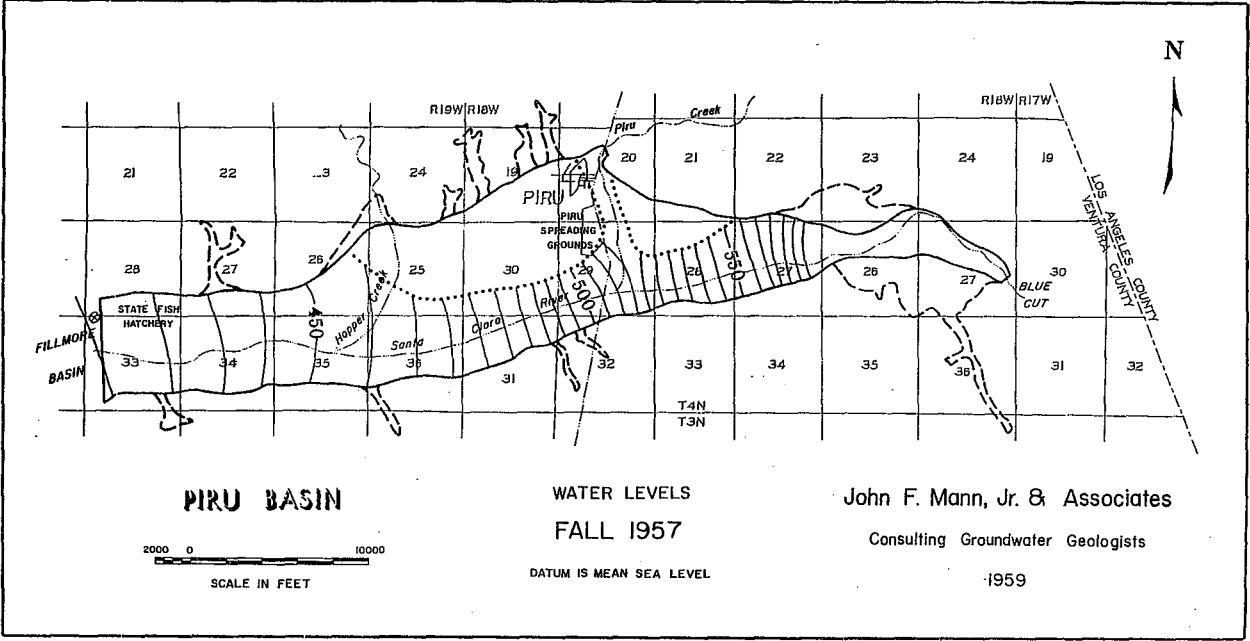
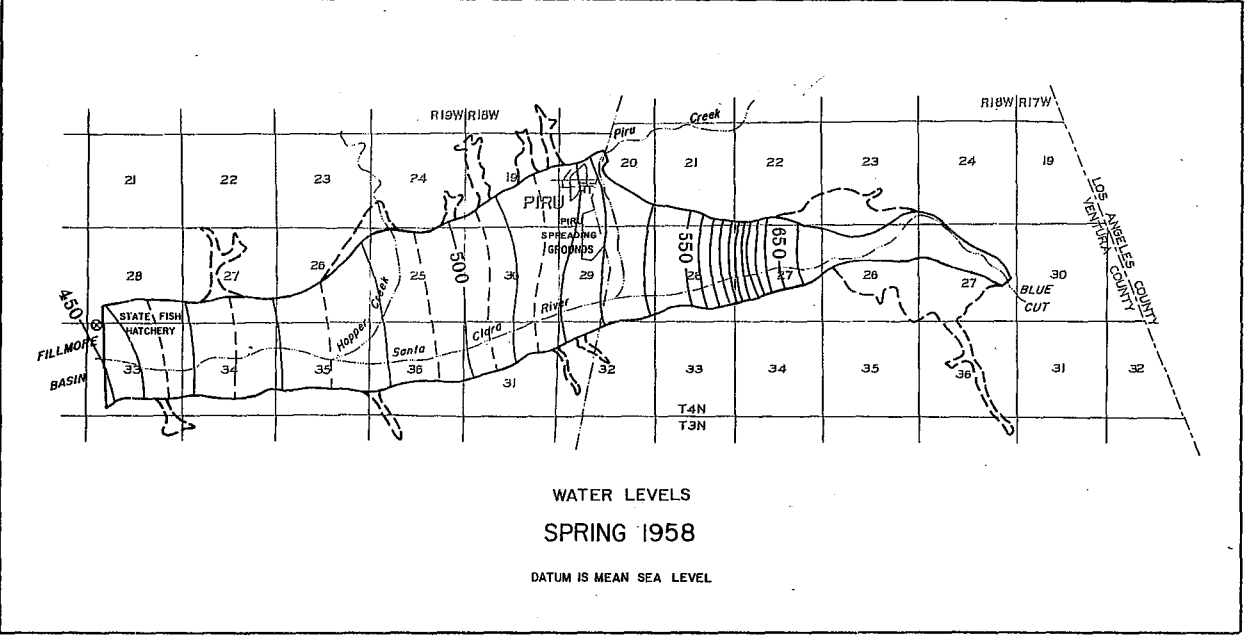


PLATE 6C



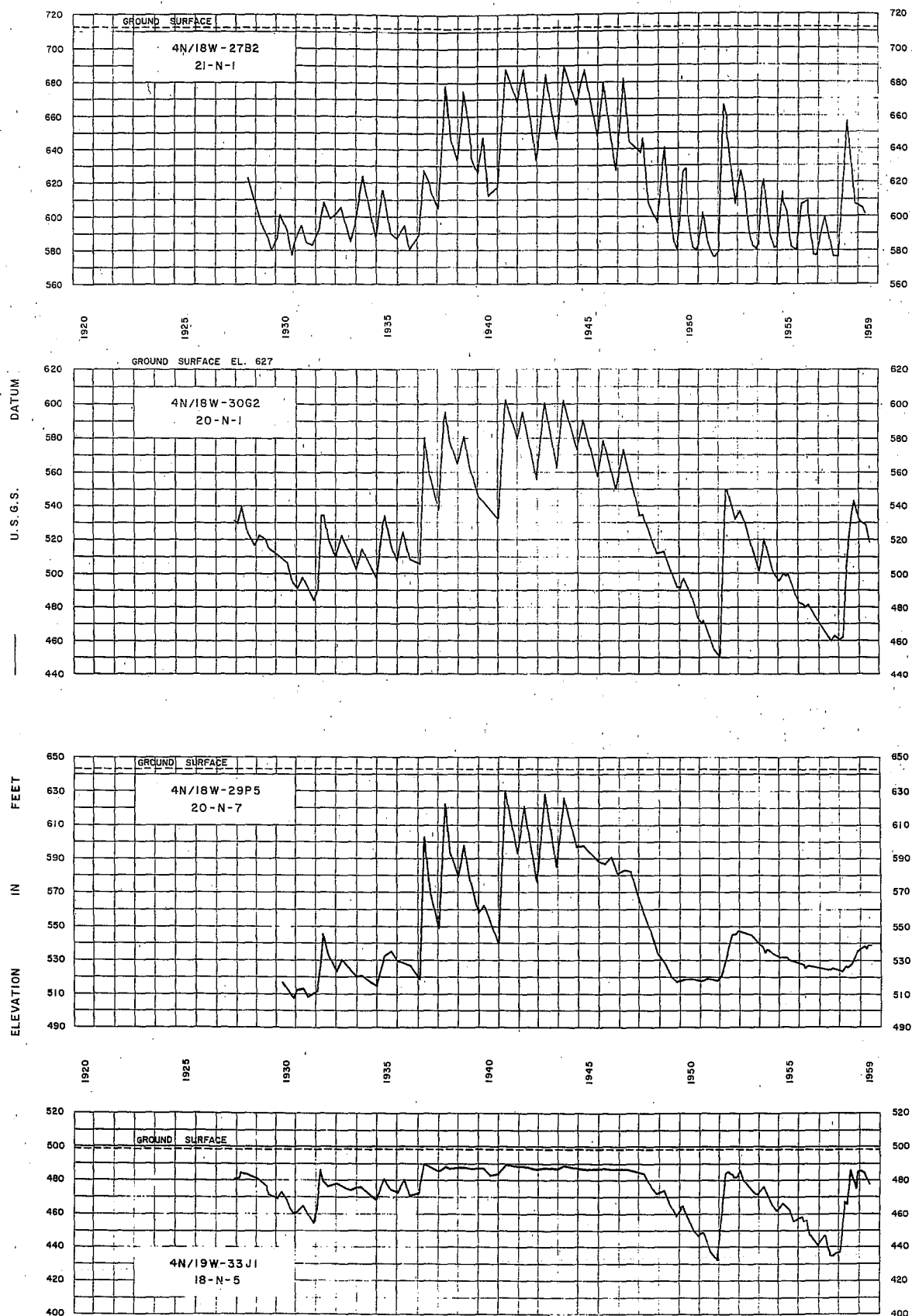
DURING THESE DRY YEARS THE SAN PEDRO AQUIFERS APPEAR TO BE ISOLATED FROM POTENTIAL ALLUVIAL RECHARGE. UNWATERING OF THE TILTED PERMEABLE ZONES IN THE SAN PEDRO FORMATION CONTINUES UNTIL A YEAR SUFFICIENTLY WET TO PRODUCE FLOW THROUGH THE OVERLYING ALLUVIAL BLANKET (PLATE 6C). FROM THE SATURATED ALLUVIAL MANTLE THE WATER QUICKLY MOVES DOWNWARD AND FILLS THE AVAILABLE STORAGE SPACE IN THE SAN PEDRO AQUIFERS.

ONCE WITHIN THE SAN PEDRO PERMEABLE ZONES THE WATER MOVES PREDOMINANTLY IN A WESTERLY DIRECTION, ALTHOUGH THERE MAY BE SOME SOUTHERLY AND NORTHERLY COMPONENTS OF FLOW AS THE WATER MOVES DOWNWARD TOWARD THE AXIS OF THE SYNCLINE. FLUSHING BY FRESH WATERS HAS APPARENTLY EXTENDED TO GREAT DEPTHS, FOR AN ELECTRIC LOG INDICATED THE PRESENCE OF LOW SALINITY WATERS 8800 FEET BELOW THE GROUND SURFACE IN LAYERS BELIEVED TO HAVE BEEN DEPOSITED IN OCEAN WATER.

OVER MANY PARTS OF THE PIRU BASIN, ESPECIALLY ALONG THE SANTA CLARA RIVER, WATER ORIGINATING FROM STREAMFLOW, RAINFALL, OR IRRIGATION RETURN MAY MOVE DOWNWARD FREELY FROM THE GROUND SURFACE TO JOIN THE MAIN WATER BODY. IN PLACES IN THE NORTHERN PART OF THE BASIN SUCH PERCOLATING WATERS ARE PERCHED ON CLAY LAYERS WITHIN THE RECENT ALLUVIUM. THESE SHALLOW WATERS ARE OFTEN OF INFERIOR QUALITY. DESPITE THIS TEMPORARY IMPEDIMENT TO DOWNWARD MOVEMENT, THE PERCHED WATERS IN TIME REACH THE MAIN GROUND WATER BODY. THE RESULT IS AN INCREASED AMOUNT OF WATER WHICH SHOULD BE CLASSIFIED "IN TRANSIT". HOWEVER, NO MODIFICATION SEEMS NECESSARY IN THE GENERAL VIEW THAT THIS IS A BASIN CHARACTERIZED BY A FREE WATER TABLE.

#### FLUCTUATIONS OF WATER LEVELS

THE HYDROGRAPH OF WELL 4N/18W-27B2 (PLATE 7) IS CONSIDERED REPRESENTATIVE OF THE EXTREME EASTERN PART OF THE PIRU BASIN WHERE RECENT AND OLDER ALLUVIUM OVERLIE NONWATER-BEARING PICO FORMATION. ALTHOUGH THE EFFECTS OF PUMPING, AND NATURAL DRAINING TOWARD THE WEST ARE SHOWN BY A SHARP DROP IN WATER LEVEL DURING EACH DRY SEASON, THERE IS A MARKED RECOVERY EACH WET SEASON DUE TO PERSISTENT UNDERFLOW THROUGH BLUE CUT AND TO PERCOLATION OF RISING WATER AND FLOOD FLOWS. FAILING RECHARGE THROUGH THE PERIODS 1947-51 AND 1952-57 IS EVIDENT, BUT THERE IS SUGGESTED ALSO A BALANCE BETWEEN RECHARGE, AND PUMPING PLUS DRAINING, FOR DEPLETION



PIRU BASIN HYDROGRAPHS

BELOW ELEVATION 580 APPEARS TO BE ACCOMPLISHED ONLY WITH DIFFICULTY UNDER EXISTING CONDITIONS OF DEVELOPMENT.

FARTHER DOWNSTREAM IS WELL 4N/18W-30G2 WHOSE WATER-LEVEL FLUCTUATIONS ARE REPRESENTATIVE OF THE AREAS WHERE THE SAN PEDRO AQUIFERS ARE PERIODICALLY UNWATERED (PLATE 7). DURING AND AFTER THE WET PERIOD OF THE EARLY FORTIES (1941-47), WATER LEVELS WERE HIGH AND THE BASAL ALLUVIAL DEPOSITS REMAINED SATURATED. DUE TO PUMPING AND NATURAL DRAINING THE ALLUVIAL DEPOSITS WERE UNWATERED. CONTINUED PUMPING DURING THE PERIOD 1947-51 UNWATERED THE UPPER PART OF THE SAN PEDRO AQUIFERS. THE SHARP DROP DURING THIS PERIOD REFLECTS LOW AVERAGE SPECIFIC YIELDS AND RELATIVELY MINOR RECHARGE. IN EARLY 1952, RECHARGING WATER MOVED THROUGH THE ALLUVIAL BLANKET, FILLED THE UNWATERED PORTIONS OF THE SAN PEDRO AQUIFERS AND PRODUCED A SHARP RISE IN WATER LEVELS. THOUGH CONSIDERABLE IN VOLUME, THIS REPLENISHMENT WAS BARELY SUFFICIENT TO REFILL THE DEPLETED STORAGE IN THE SAN PEDRO AQUIFERS. LITTLE EXTRA WAS AVAILABLE FOR KEEPING THE BASAL ALLUVIUM SATURATED, AND CONSEQUENTLY A NEW CYCLE OF SAN PEDRO UNWATERING STARTED IMMEDIATELY AND CONTINUED TO 1957. THE RECOVERY IN 1958 WAS ALMOST AS GOOD AS IN 1952.

TYPICAL OF THE WATER-LEVEL FLUCTUATIONS NEAR THE WESTERN BOUNDARY OF THE PIRU BASIN ARE THOSE SHOWN BY WELL 4N/19W-33J1 (PLATE 7). ALTHOUGH THIS HYDROGRAPH BEARS A RESEMBLANCE TO THAT OF WELL 30G2, THE DIFFERENCES ARE SIGNIFICANT. IN THE WESTERN AREA, NOT ONLY IS THE RANGE OF WATER-LEVEL FLUCTUATIONS OF SMALLER MAGNITUDE, BUT THE WATER LEVELS REMAIN HIGH IN THE ALLUVIAL DEPOSITS. THE PERSISTENTLY HIGH WATER LEVELS REFLECT THE REDUCED CROSS-SECTIONAL AREA OF PERMEABLE MATERIALS THROUGH WHICH THE UNDERFLOW MUST MOVE. DURING A PROLONGED DROUGHT PERIOD THERE IS SLOW BUT CONTINUOUS RECHARGE, PRIMARILY FROM THE ALLUVIUM OF THE SANTA CLARA RIVER NEAR THE SOUTH SIDE OF THE BASIN. THIS EXPLAINS WHY THE WATER-LEVEL LOWERING OF 1947-51 WAS LESS THAN IN THE INTERMITTENTLY RECHARGED ALLUVIAL AREAS WHERE THERE IS HEAVY PUMPING FROM THE SAN PEDRO AQUIFERS. BECAUSE OF THE STRONG UNDERFLOW COMING FROM THE SANTA CLARA RIVER ALLUVIUM IN 1952 AND 1958, THE RECOVERY WAS ESSENTIALLY COMPLETE; IN CONTRAST WITH THIS IS THE INCOMPLETE RECOVERY OF WELL 30G2 IN 1952 AND IN 1958.

THE UNUSUAL HYDROGRAPH OF WELL 4N/18W-29P5 (PLATE 7) INDICATES

A BODY OF GROUND WATER WHICH IS NOT FREELY CONNECTED WITH THE MAIN ALLUVIAL DEPOSITS. THIS WELL IS PERFORATED ONLY IN TERRACE DEPOSITS RELATED TO STREAMS ENTERING THE PIRU BASIN FROM THE SOUTH. DURING THE WET YEARS 1941-44 WATER LEVELS REMAINED HIGH, THOUGH REFLECTING HEAVY DRY SEASON PUMPING. IT IS SUGGESTED THAT DURING THESE YEARS THERE WAS GOOD LATERAL RECHARGE FROM SATURATED GRAVELS UPSLOPE TO THE SOUTH. DEPLETION COMMENCED IN 1944 AND GENERALLY HAS CONTINUED TO THE PRESENT. THE RECOVERIES IN 1952 AND IN 1958 SHOULD HAVE BEEN BETTER IF WATER HAD BEEN ABLE TO MOVE FREELY FROM THE MAIN ALLUVIUM INTO THESE TERRACE GRAVELS. RECOVERIES DURING A PERIOD OF WET YEARS SHOULD BE CONSIDERABLY BETTER.

#### STORAGE CAPACITY

THE STORAGE CAPACITY OF THE AQUIFER MATERIALS WAS CALCULATED BY APPLYING UNIT SPECIFIC YIELD VALUES TO THE LITHOLOGIES OBTAINED FROM WATER WELL LOGS. THE UNIT SPECIFIC YIELD VALUES USED ARE GIVEN IN TABLE 11-1. WITHIN GEOLOGICALLY HOMOGENEOUS CELLS, EACH INCLUDING A GROUP OF WELLS, AVERAGE SPECIFIC YIELD VALUES WERE ASSIGNED TO EACH 25-FOOT INTERVAL BELOW THE MAXIMUM WATER SURFACE, WHICH WAS ASSUMED TO HAVE OCCURRED IN THE SPRING OF 1944. THE STORAGE DEPLETION CURVE (PLATE 8) WAS CONSTRUCTED BY RELATING HISTORIC WATER-LEVEL ELEVATIONS OF WELL 4N/18W-30G2 TO THE UNWATERED STORAGE CAPACITY DERIVED FROM THE SPECIFIC YIELD STUDY. THE WATER SURFACE ELEVATION IN WELL 30G2 SHOWS A RANGE FROM A MAXIMUM OF 602 FEET IN THE SPRING OF 1944 TO A MINIMUM OF 450 FEET IN THE FALL OF 1951. ASSUMING A FULL BASIN WITH NO AVAILABLE STORAGE IN THE SPRING OF 1944, THE MAXIMUM STORAGE DEPLETION OCCURRED IN THE FALL OF 1951 AND AMOUNTED TO 113,000 ACRE-Feet.

#### FILLMORE BASIN

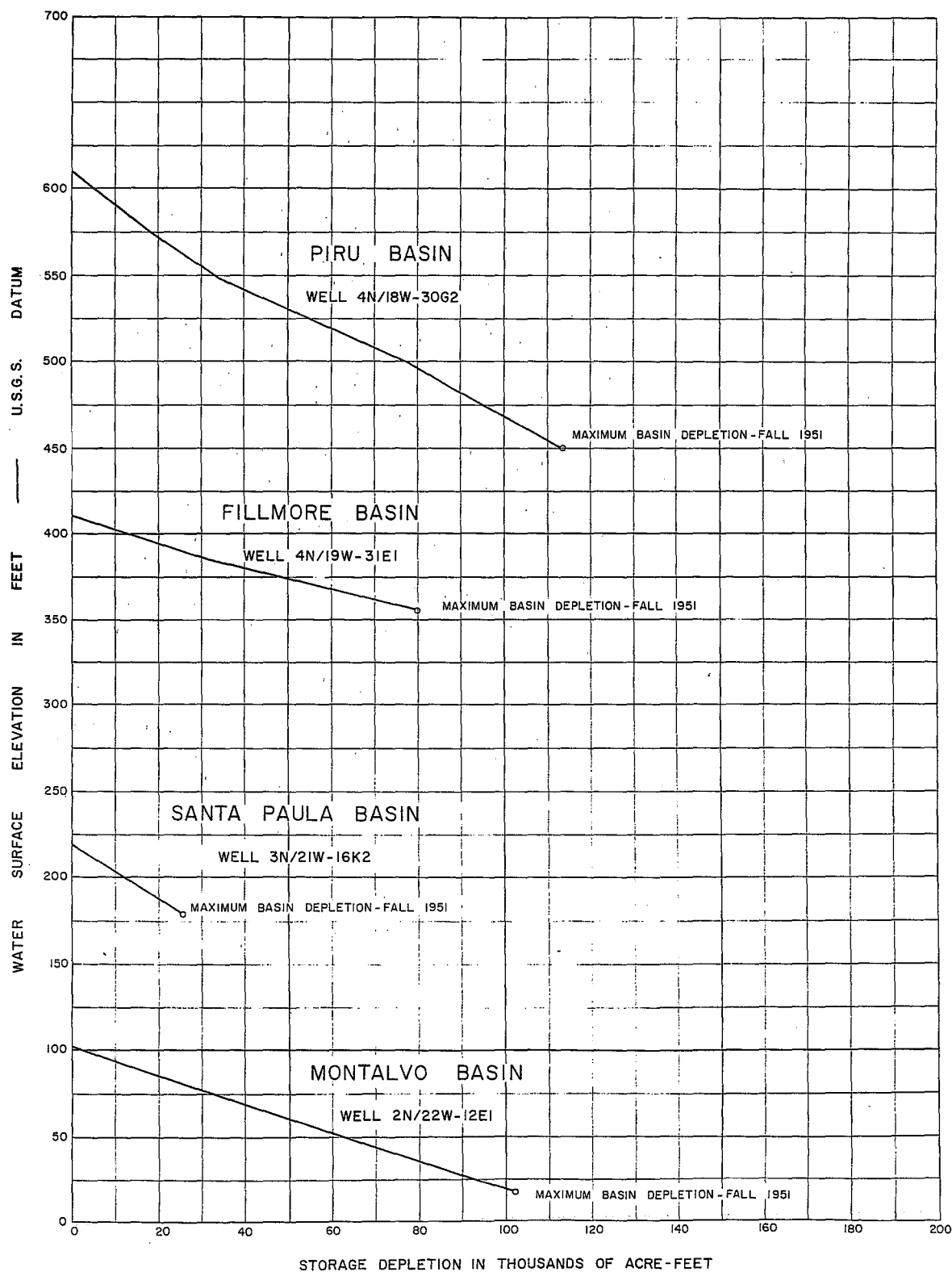
##### BOUNDARIES

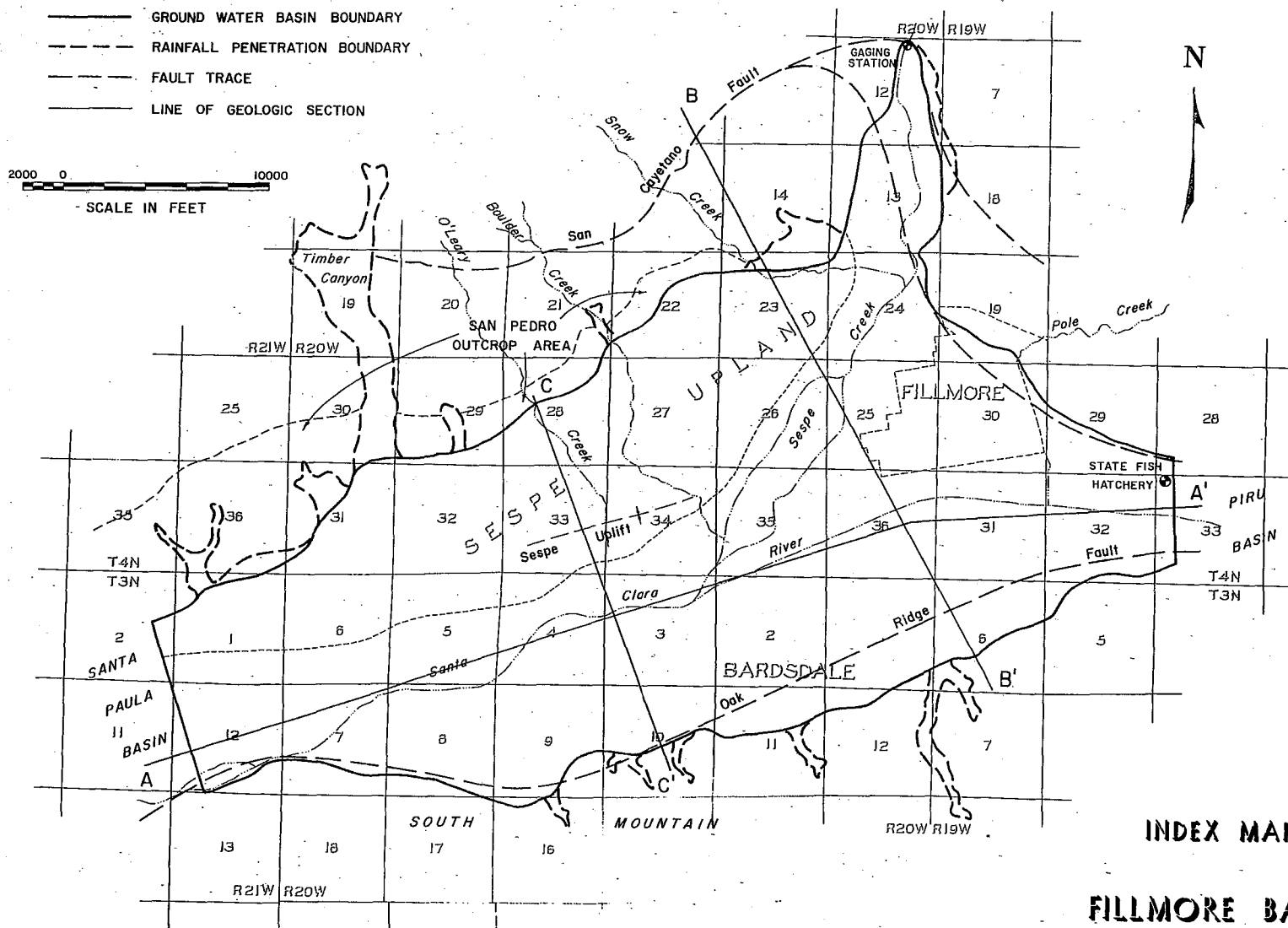
THE MIDDLE AND LARGEST UPSTREAM BASIN IN THE UNITED WATER CONSERVATION DISTRICT -- THE FILLMORE BASIN -- INCLUDES THE BROAD AREA ALONG THE SANTA CLARA RIVER EXTENDING FROM A MILE OR SO UPSTREAM FROM THE CITY OF FILLMORE DOWNSTREAM ALMOST TO THE CITY OF SANTA PAULA. THIS BROAD AGRICULTURAL AREA IS RELATED TO THE JUNCTION OF THE SANTA CLARA RIVER WITH SESPE CREEK, ITS LARGEST TRIBUTARY. THE FILLMORE BASIN IS CONSIDERED TO COINCIDE WITH THE MAJOR AREA BLANKETED BY ALLUVIAL AND TERRACE DEPOSITS (PLATE 9). THE ALLUVIUM OF THE MINOR TRIBUTARY VALLEYS,

TABLE 11-1 UNIT SPECIFIC YIELD VALUES

|                               |    |
|-------------------------------|----|
| ALLUVIUM                      | %  |
| SAND                          | 25 |
| SAND & GRAVEL                 | 21 |
| GRAVEL                        | 18 |
| BOULDERS                      | 15 |
| SANDY CLAY                    | 5  |
| SOIL, CLAY, & SILTY CLAY      | 3  |
| YELLOW CLAY                   | 3  |
| BLUE CLAY                     | 1  |
| <br>SAN PEDRO FORMATION       |    |
| SAND, INCLUDING CEMENTED SAND | 18 |
| SAND & GRAVEL                 | 16 |
| GRAVEL                        | 14 |
| GRAVEL & CLAY, CONGLOMERATE   | 7  |
| CLAY, SANDY CLAY              | 3  |

# GROUND WATER STORAGE DEPLETION





INDEX MAP

FILLMORE BASIN

WHERE GROUND WATER STORAGE IS ONLY TEMPORARY, IS NOT CONSIDERED IN THE BASIN. THE EASTERN BOUNDARY, WHICH TRENDS NORTH-SOUTH, IS PLACED AT THE TOPOGRAPHIC NARROWING AT THE STATE FISH HATCHERY. ALONG SESPE CREEK THE BOUNDARY IS TAKEN AT THE GAGING STATION, WHICH IS THE NORTHERNMOST LIMIT OF APPRECIABLE THICKNESS OF ALLUVIUM. THE WESTERN OR DOWNSTREAM BOUNDARY IS AN ARBITRARY LINE TRENDING ACROSS THE VALLEY IN AN AREA OF TOPOGRAPHIC CONSTRICTION AND PERENNIAL RISING WATER. THE REMAINDER OF THE BOUNDARY OUTLINES THE AREA OF MORE OR LESS PERMANENT GROUND WATER STORAGE. THE AREA OF THE FILLMORE BASIN IS 18,580 ACRES.

FOR PURPOSES OF COMPUTING RAINFALL PENETRATION, SOME AREAS BEYOND THE GROUND WATER BASIN ARE INCLUDED. ESPECIALLY IMPORTANT IS THE BROAD ALLUVIAL FILL OF TIMBER CREEK. FLANKING THE BASIN ON THE NORTH, BUT ONLY WEST OF SESPE CREEK, IS A LARGE EXPOSURE OF THE SAN PEDRO FORMATION (PLATE 9). THIS OUTCROP AREA OF 2080 ACRES IS NOT INCLUDED WITHIN THE RAINFALL PENETRATION ZONE, EVEN THOUGH THE SAN PEDRO FORMATION IN PLACES CONTAINS IMPORTANT AQUIFERS. THE BEDS EXPOSED CONSIST OF ONLY MINOR SANDS AND GRAVELS WHICH ARE LARGELY LENTICULAR IN NATURE AND CONTAIN MUCH CLAY. FURTHERMORE, THE BEDS EXPOSED ARE THE BASAL LAYERS OF THE FORMATION; FARTHER SOUTH WITHIN THE BASIN THESE BEDS ARE MUCH DEEPER THAN ANY EXISTING WATER WELL. IF RAIN WATER WERE TO PENETRATE INTO THESE BEDS IT WOULD NOT CIRCULATE FREELY BECAUSE THERE IS NO REMOVAL OF WATER FROM THESE BEDS, EITHER THROUGH PUMPING OR NATURAL DRAINAGE. THE ASSIGNED ZONE OF RAINFALL PENETRATION COMPRISES 19,830 ACRES.

#### GROUND WATER GEOLOGY

##### GENERAL GEOLOGY

THE FILLMORE BASIN CAN BE DIVIDED GENERALLY INTO TWO PARTS. THE LARGER PORTION, OCCUPYING THE SOUTHERN AND EASTERN PARTS OF THE BASIN, IS COVERED MAINLY BY THE LATEST SANDS AND GRAVELS OF THE TWO MAJOR STREAMS. THE SANTA CLARA RIVER ALLUVIAL DEPOSITS WITH A WESTERLY SLOPE AVERAGING 25-30 FEET PER MILE COVER THE SOUTHERNMOST STRIP OF THE BASIN. THE LATE ALLUVIAL DEPOSITS OF SESPE CREEK START AT THE NORTHEAST CORNER OF THE BASIN AND EXTEND SOUTHWESTERLY TO JOIN THE ALLUVIUM OF THE RIVER. BETWEEN THESE TWO YOUNG ALLUVIAL STRIPS IS THE ALLUVIAL FAN OF POLE CREEK, ON WHICH THE CITY OF FILLMORE IS LOCATED.

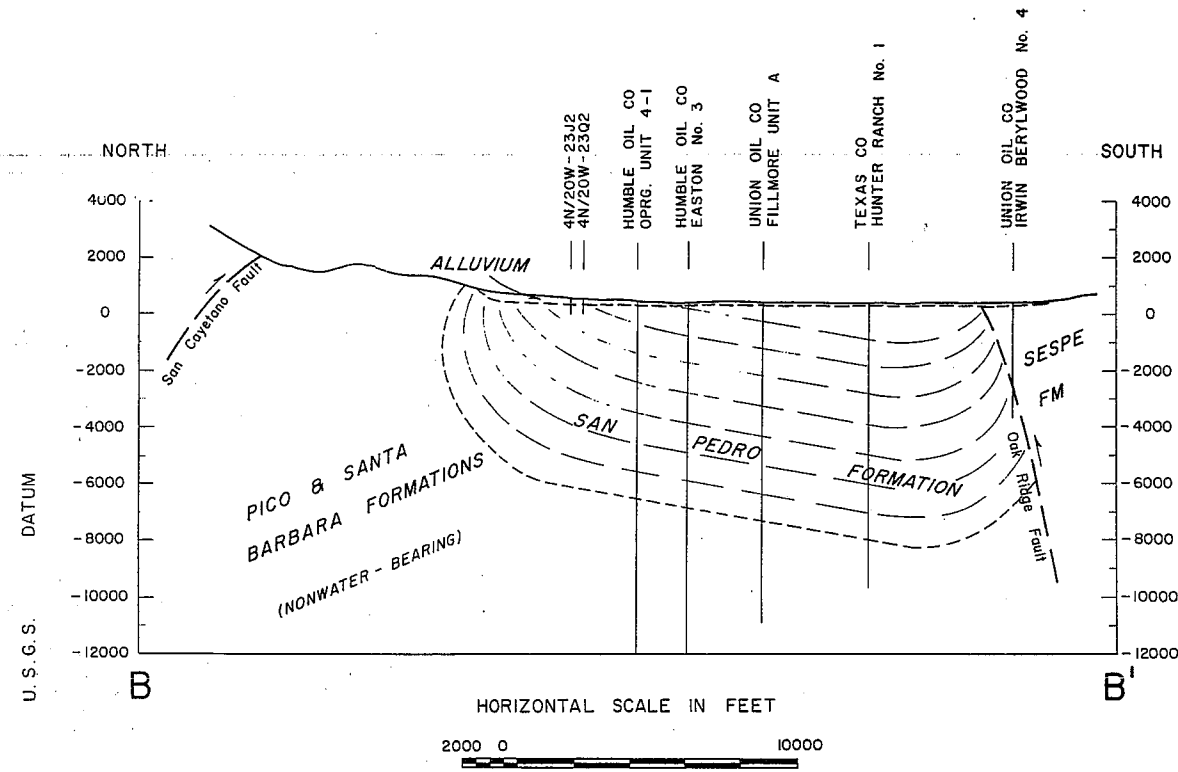
THE SMALLER NORTH-CENTRAL PORTION OF THE FILLMORE BASIN IS

DESIGNATED THE SESPE UPLAND (PLATE 9); IT LIES NORTH OF THE SANTA CLARA RIVER ALLUVIUM AND WEST OF THE SESPE CREEK ALLUVIUM. IN THE SESPE UPLAND THE SURFACE SLOPES ARE PREDOMINANTLY TO THE SOUTH AND THE SURFICIAL DEPOSITS ARE MAINLY STEEP ALLUVIAL FAN MATERIALS BROUGHT DOWN BY TRIBUTARIES WHICH RISE IN THE HILLS TO THE NORTH. ESPECIALLY CONSPICUOUS ARE THE ALLUVIAL FANS FORMED AT THE MOUTHS OF TIMBER CANYON AND BOULDER (LORD) CANYON. IN THE SOUTHERN PART OF THE SESPE UPLAND IS A PROMINENT GEOLOGIC STRUCTURE WHICH TRENDS SOUTHWESTERLY FROM SECTION 34, T4N, R20W. THIS UPLIFT OF OLDER ALLUVIUM HAS EFFECTIVELY PREVENTED BOTH SESPE CREEK AND THE SANTA CLARA RIVER FROM SWINGING NORTH AND ENCROACHING UPON THE ALLUVIAL FANS. WEST OF THE TIMBER CANYON FAN, HOWEVER, THIS UPLIFT IN VERY RECENT TIMES CEASED TO BE A BARRIER, AND THE SANTA CLARA RIVER WAS ABLE TO SWING NORTH IN SECTION 1, T3N, R21W.

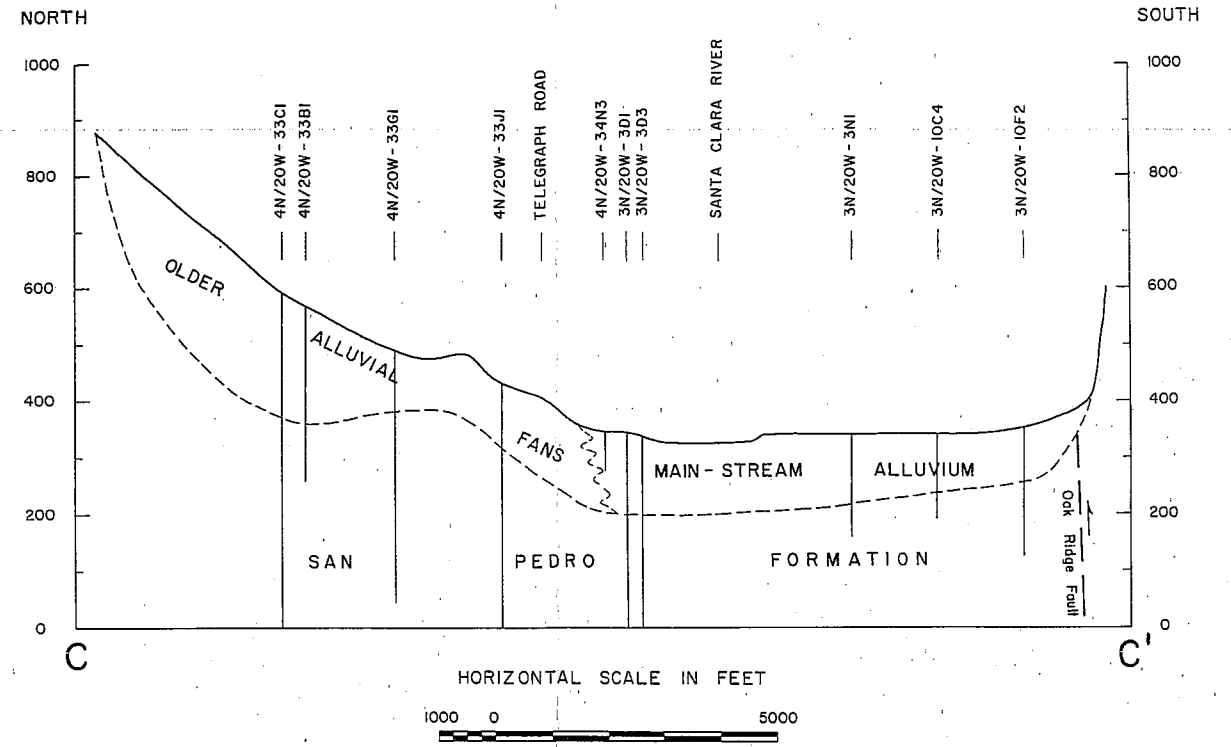
BROADLY SPEAKING THE EXISTENCE OF THE FILLMORE BASIN AS A LOW-LYING TOPOGRAPHIC AREA CAN BE EXPLAINED BY DIFFERENTIAL STREAM EROSION IN A FAULT TROUGH. THE SANTA CLARA RIVER AND SESPE CREEK ARE NOW FLOWING, AND FOR SEVERAL HUNDRED THOUSAND YEARS HAVE BEEN FLOWING, ON A SYNCLINALLY FOLDED STRIP OF SOFT SAN PEDRO SEDIMENTS. THE TERTIARY ROCKS FLANKING THE FILLMORE BASIN ON THE SOUTH ARE VERY HARD; THESE HAVE BEEN THRUST OVER THE SAN PEDRO FORMATION ALONG THE OAK RIDGE FAULT (SECTION B-B', PLATE 10). IN LATER GEOLOGIC TIME THE MAIN DRAINAGE HAS BEEN CONFINED TO THE SOUTHERN PART OF THE BASIN. THIS ASYMMETRY OF MAIN STREAM FLOW, WHICH IS EXPLAINED BY HEAVY TRIBUTARY FLOW FROM THE NORTH AND LOCAL UPLIFTS WITHIN THE BASIN, HAS EXERTED AN IMPORTANT CONTROL ON THE REGIMEN OF UNDERGROUND WATERS.

#### ALLUVIAL AQUIFERS

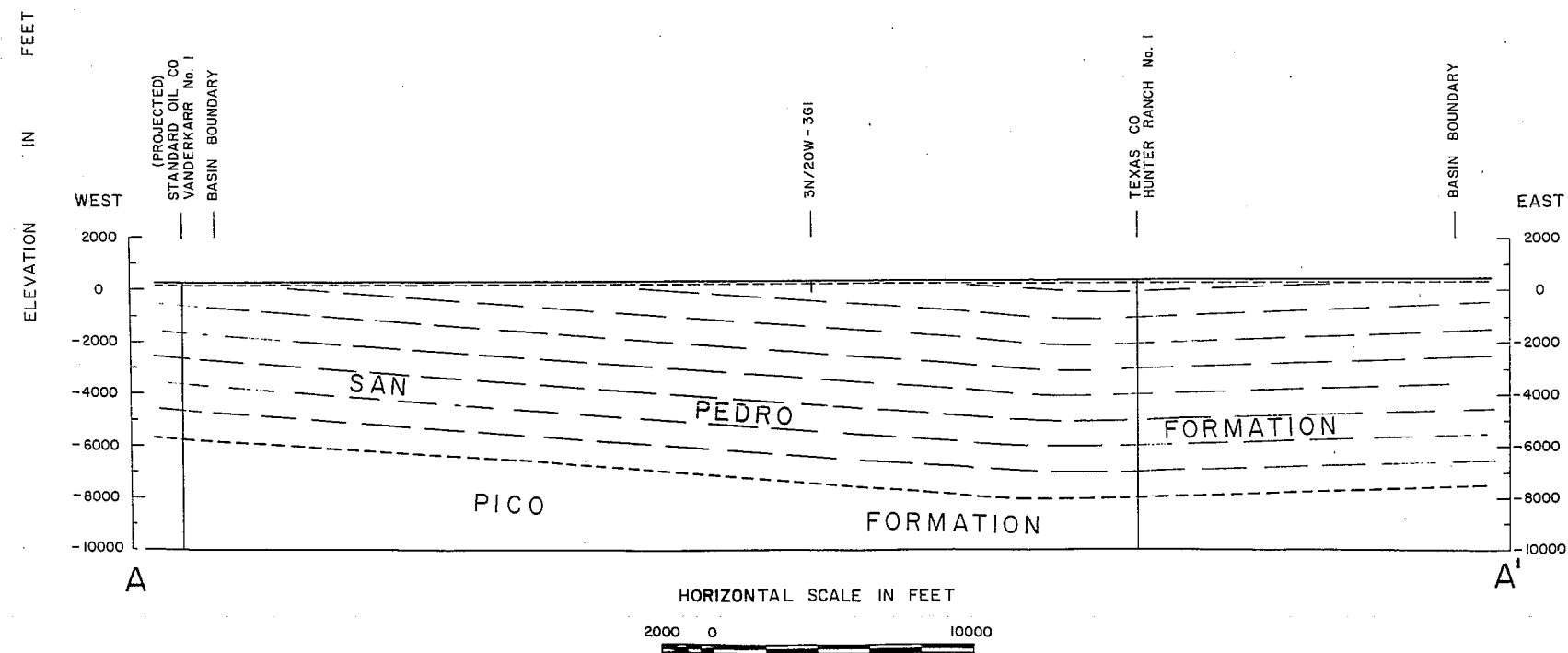
THE ALLUVIAL DEPOSITS WHICH BLANKET THE SAN PEDRO FORMATION IN THE FILLMORE BASIN ARE BEST DISCUSSED AS TWO SEPARATE UNITS: (1) THE MAIN STREAM ALLUVIUM, AND (2) THE ALLUVIAL BLANKET OF THE SESPE UPLAND. IN THE CHANNEL TO THE SOUTH OF THE STATE FISH HATCHERY, AT THE UPSTREAM BOUNDARY OF THE FILLMORE BASIN, THE RECENT SANDS AND GRAVELS OF THE SANTA CLARA RIVER EXTEND TO A DEPTH OF 60 FEET AND OLDER ALLUVIAL MATERIALS ARE FOUND BETWEEN DEPTHS OF 60 AND 100 FEET. FARTHER WEST, IN THE BARDSDALE AREA, THE TOTAL THICKNESS OF ALLUVIAL MATERIALS MAY BE AS MUCH



SECTION B-B'



SECTION C-C'



SECTION A-A'

# GEOLOGIC SECTIONS

## FILLMORE BASIN

John F. Mann, Jr. & Associates

Consulting Groundwater Geologists

11-12 1959

AS 120 FEET. STILL FARTHER WEST, AT THE DOWNSTREAM BOUNDARY OF THE BASIN, THE RECENT ALLUVIUM IS IN THE RANGE OF 60 TO 65 FEET THICK. JUST WEST OF THE CITY OF FILLMORE THE ALLUVIUM OF SESPE CREEK IS CLOSE TO 80 FEET THICK. THE MATERIALS DEPOSITED BY BOTH THE SANTA CLARA RIVER AND SESPE CREEK ARE VERY PERMEABLE, AND WATER SEEMS TO MOVE FREELY THROUGH THESE BOTH Laterally AND VERTICALLY. ALONG THE SOUTHERN BORDER OF THE BASIN THE RECENT ALLUVIUM IS INTERBEDDED WITH SIDE DEPOSITS SHED FROM SOUTH MOUNTAIN. THESE INCLUDE SOME WELL-BEDDED MATERIALS OF ALLUVIAL FAN ORIGIN CONTAINING PERMEABLE ZONES WHICH ARE NOT HYDROLOGICALLY CONNECTED WITH THE MAIN ALLUVIUM. THERE ARE PROBABLY ALSO AT DEPTH SOME ANCIENT HETEROGENEOUS LANDSLIDE MATERIALS INTERBEDDED WITH THE MAIN ALLUVIUM. SEVERAL LARGE LANDSLIDES STILL IN EVIDENCE ATTEST TO THE PROBABILITY OF SUCH ACTIVITIES IN THE PAST. THE LATERAL DEPOSITS JUST MENTIONED, AS WELL AS THE MAIN ALLUVIUM, LIE IN PART UPON AN EROSIONAL BENCH CUT INTO THE OLDER ROCKS WHICH WERE THRUST UPWARD BY THE OAK RIDGE FAULT. THE "BENCH" REFERS TO ALL THE VALLEY AREA SOUTH OF THE SUB-ALLUVIAL TRACE OF THE FAULT, AS DELINEATED ON PLATE 9. NORTH OF THE TRACE OF THE FAULT, THE ALLUVIUM IS DIRECTLY UNDERLAIN BY THE SAN PEDRO FORMATION.

THE SURFICIAL MATERIALS OF THE SESPE UPLAND ARE A COMPLEX OF TERRACE DEPOSITS, OLDER ALLUVIAL FAN DEPOSITS, AND RECENT ALLUVIAL FAN DEPOSITS RESTING UPON AN EROSIONAL SURFACE CUT ON THE SAN PEDRO FORMATION. THE OLDER ALLUVIAL DEPOSITS HAVE BEEN DISTURBED BY SOME LATE, BUT PRE-RECENT, FOLDING OR FAULTING. AN OBVIOUS RESULT OF THIS LATE DISTURBANCE IS THE STRUCTURAL RIDGE WHICH TRENDS SOUTH-WESTERLY FROM SECTION 34, T4N, R20W. A GOOD EXPOSURE OF THE TILTED LAYERS MAY BE SEEN ON THE BLUFF ALONG THE WEST LINE OF SECTION 34 A FEW HUNDRED YARDS NORTH OF TELEGRAPH ROAD. TO THE SOUTHWEST THE RIDGE WAS NOT SO HIGH AND IT HAS BEEN OVERWHELMED BY YOUNG FAN DEPOSITS SUPPLIED FROM THE NORTH. THE OLDER ALLUVIAL DEPOSITS OF THE SESPE UPLAND CONTAIN LARGE QUANTITIES OF CLAY, AND FROM WELL LOGS THE SHARP NORTHERN BOUNDARY OF THE RECENT ALLUVIUM IS EASILY TRACED WESTWARD FROM THE EAST LINE OF SECTION 34, T4N, R20W. FROM THE INFORMATION AVAILABLE, IT APPEARS THAT THE RECENT ALLUVIUM WAS BACKFILLED ALONG A SCARP CUT IN CLAYEY DEPOSITS OF OLDER ALLUVIUM (SECTION C-C', PLATE 10). IN THE SESPE UPLAND THE WELL LOGS DO NOT PERMIT A READY SEPARATION OF THE VARIOUS STAGES OF ALLUVIAL FILL, AND

THESE NECESSARILY MUST BE GROUPED TOGETHER. AS A GROUP THESE ALLUVIAL DEPOSITS REST UPON AN ERODED SURFACE, CUT ON THE SAN PEDRO FORMATION, AND WITH A STEEP SOUTHERLY SLOPE. RUNOFF FROM THE NORTH IS ABLE TO PERCOLATE DOWNWARD TO THE BASE OF THE ALLUVIAL BLANKET WHERE IT THEN FLOWS JUST ABOVE THE UNCONFORMITY. SOME OF THE VERY EARLY PUMPING WAS FROM PITS OR SHAFTS AS MUCH AS 170 FEET DEEP. IT IS SUGGESTED THAT THESE SHAFTS WERE CONTINUED UNTIL THE BASAL ALLUVIAL WATER WAS ENCOUNTERED. BECAUSE OF THE INDICATED STEEP SLOPE ON THE UNCONFORMITY, WHICH CAUSED A FREE DRAINAGE TO THE SOUTH, IT IS DOUBTFUL THAT THE WATER TABLE IN THE ALLUVIAL DEPOSITS WAS ABLE TO BUILD UP MUCH MORE THAN 10 OR 20 FEET ABOVE THE UNCONFORMITY.

#### SAN PEDRO FORMATION

THE SAN PEDRO FORMATION UNDERLIES PRACTICALLY ALL OF THE FILLMORE BASIN. THE BASIN EXISTS, IN FACT, BECAUSE THE SANTA CLARA RIVER AND SESPE CREEK WERE ABLE TO ERODE MORE QUICKLY ON THE SOFT, DOWNFAULTED SAN PEDRO SEDIMENTS THAN ON THE OLDER, HARDER ROCKS WHICH FLANK THEM. THE FILLMORE BASIN OCCUPIES A PORTION OF THE EXTENSIVE EAST-WEST SYNCLINE COMPRESSED BETWEEN TWO HUGE THRUST FAULTS. ON THE SOUTH IS THE OAK RIDGE FAULT WHOSE TRACE IS NO LONGER VISIBLE. STRONG LATERAL EROSION BY THE SANTA CLARA RIVER CAUSED A SOUTHWARD RETREAT OF THE FAULT SCARP AND THE TRACE IS NOW COVERED BY ALLUVIUM. THOUGH BURIED, THE FAULT HAS IN PLACES BEEN ACCURATELY LOCATED. THE IRWIN BERYLWOOD #4 OIL WELL IN THE SW1/4, SECTION 1, T3N, R20W REACHED THE FAULT PLANE AT A DEPTH OF 3700 FEET. THE TEXAS BASOLO #1 OIL WELL, NEAR THE SOUTHEAST CORNER OF SECTION 31, T4N, R19W ALSO PENETRATED THE FAULT PLANE -- AT A DEPTH OF 2355 FEET. IN BOTH WELLS THE DRILL PENETRATED ALLUVIUM, THEN THE SESPE FORMATION (EOCENE), AND THEN BENEATH THE HIGH-ANGLE SOUTH-DIPPING REVERSE FAULT, THE SAN PEDRO FORMATION. THE STRUCTURAL CONDITIONS ARE SHOWN ON SECTION B-B' OF PLATE 10.

THE NORTHERN THRUST FAULT -- THE SAN CAYETANO FAULT -- IS CLOSE TO THE BASIN BOUNDARY ONLY IN THE EASTERN PART OF THE BASIN, WHERE ITS STEEP SCARP APPEARS IN THE NORTHEASTERN PART OF THE CITY OF FILLMORE. SEVERAL OIL WELLS ALONG THIS SCARP WERE DRILLED INTO THE SAN PEDRO FORMATION AFTER HAVING PASSED THROUGH THE MODELO FORMATION (MIOCENE). THE FAULT TRACE HERE IS ALSO VENEERED WITH ALLUVIUM, AND IS PROBABLY VERY

CLOSE TO THE BASE OF THE SCARP. THE SAN CAYETANO FAULT IS EXPOSED AT THE SURFACE JUST WEST OF SESPE CREEK NEAR THE NORTHERN TIP OF THE BASIN, AND TO THE WEST THE FAULT OUTCROP RISES TO HIGH ELEVATIONS AND IS EXPOSED CONTINUOUSLY. FLANKING THE SESPE UPLAND ON THE NORTH IS A STRIP OF SAN PEDRO OUTCROPS. BETWEEN THOSE AND THE SAN CAYETANO FAULT ARE EAST-WEST OUTCROP BELTS OF THE SANTA BARBARA FORMATION AND THE PICO FORMATION. THE EXPOSED BASAL SAN PEDRO LAYERS, STRIKING GENERALLY PARALLEL TO THE NORTHERN BOUNDARY OF THE BASIN, SHOW SOUTHERLY DIPS OF 50 DEGREES OR LESS ALONG SANTA PAULA CREEK, BUT THE DIPS STEEPEN TOWARD THE EAST, AND IN PLACES ARE VERTICAL OR OVERTURNED.

WITHIN THE STRUCTURAL FRAMEWORK DESCRIBED, THE MAIN FEATURE OF THE SAN PEDRO FORMATION IS AN EAST-WEST SYNCLINE. A MINOR STRUCTURE -- AN UPLIFT DUE TO ANTICLINAL FOLDING, OR FAULTING -- IS REFLECTED AS THE PREVIOUSLY MENTIONED RIDGE WHICH TRENDS WESTERLY FROM THE PROMINENT HILL IN SECTION 34, T4N, R20W. THIS LAST FEATURE WAS FORMED AT A TIME MUCH LATER THAN THE MAIN FAULTING.

ALONG THE AXIS OF THE SYNCLINE IN THE FILLMORE BASIN THE BASE OF THE SAN PEDRO FORMATION IS AT GREAT DEPTH (SECTION A-A', PLATE 10). WESTERLY FROM A SLIGHT ARCH BENEATH THE STATE FISH HATCHERY THE BASE DROPS, AND NEAR THE BARSDALE BRIDGE REACHES A DEPTH OF 8430 FEET. THE ELECTRIC LOGS OF OIL WELLS NEAR THE BARSDALE BRIDGE INDICATE FAIRLY FRESH WATERS AT DEPTHS OF AS MUCH AS 7000 FEET. WESTERLY FROM THE BARSDALE BRIDGE THE BASE OF THE SAN PEDRO FORMATION CLIMBS AND AT THE LOWER BASIN BOUNDARY IS AT A DEPTH OF 5000 TO 6000 FEET.

#### SOURCES OF RECHARGE

THE FILLMORE BASIN IS RECHARGED PRIMARILY BY PERCOLATION OF THE SURFACE FLOWS IN THE SANTA CLARA RIVER AND IN SESPE CREEK. IN THE SESPE UPLAND THE RECHARGE IS FROM PERCOLATION OF THE SURFACE FLOWS COMING FROM THE NORTH, ESPECIALLY TIMBER CREEK AND BOULDER (LORD) CREEK. A SMALL PORTION OF THE PERCOLATION RECHARGE HAS ITS ORIGIN IN RUNOFF FROM SOUTH MOUNTAIN. A LARGE QUANTITY OF RECHARGE IS DERIVED FROM THE PENETRATION OF RAINFALL ON THE ALLUVIATED PORTION OF THE BASIN. PERHAPS THE MOST PERSISTENT SOURCE OF RECHARGE IS THE UNDERFLOW WHICH ENTERS THE FILLMORE BASIN FROM THE EAST, THROUGH BOTH THE ALLUVIAL DEPOSITS AND THE SAN PEDRO FORMATION. ANOTHER SIGNIFICANT INCREMENT TO GROUND WATER IS THE

EFFLUENT FROM THE CITY OF FILLMORE SEWAGE TREATMENT PLANT. THE TREATMENT PLANT IS ONLY ABOUT TWO YEARS OLD; PRIOR TO ITS CONSTRUCTION AN EQUIVALENT VOLUME OF WATER WAS CONTRIBUTED THROUGH INDIVIDUAL CESSPOOLS AND SEPTIC TANKS. LEAKAGE INTO THE ALLUVIUM FROM THE OLD ROCKS OF SOUTH MOUNTAIN IS NOT CONSIDERED SIGNIFICANT.

#### BASIN OUTFLOW

AT THE LOWER BASIN BOUNDARY, WHERE THE MAIN ALLUVIUM AND PROBABLY ALSO THE MAJOR PERMEABLE ZONES IN THE SAN PEDRO FORMATION ARE CONSTRICTED IN CROSS-SECTIONAL AREA, THERE IS A FAIRLY CONSTANT UNDERFLOW INTO THE SANTA PAULA BASIN. MORE OF THE WATER, THOUGH, IS FORCED TO THE SURFACE AND LEAVES THE GROUND WATER BASIN AS RISING WATER. UNLIKE THE INTERMITTENT RISING WATER WHICH ENTERS THE FILLMORE BASIN, THE RISING WATER WHICH LEAVES IS PERENNIAL, ALTHOUGH IN LATE 1951 THE FLOW DROPPED TO AS LOW AS 3 CUBIC FEET PER SECOND. IN THE AREA OF HIGH WATER LEVELS NEAR THE LOWER BASIN BOUNDARY, RISING WATER IS DIVERTED, AND WATER IS PUMPED FROM THE SAN PEDRO FORMATION; THESE WATERS ARE TRANSPORTED WESTERLY FOR USE IN THE SANTA PAULA BASIN.

#### MOVEMENTS OF UNDERGROUND WATER

WATER MOVES THROUGH THE ALLUVIUM OF THE SANTA CLARA RIVER FROM EAST TO WEST. IN THE ALLUVIUM OF SESPE CREEK THE WATER MOVES FROM NORTH-EAST TO SOUTHWEST AND MINGLES WITH THE WATER IN THE MAIN RIVER ALLUVIUM. BENEATH THE SESPE UPLAND GROUND WATER MOVEMENT IS PREDOMINANTLY TO THE SOUTH AND DOWNSLOPE, ALTHOUGH WEST OF FILLMORE AND NEAR THE LOWER BASIN BOUNDARY THE MOVEMENTS ARE SOUTHWESTERLY. THE TYPICAL PATTERN IS SHOWN WHEN THE BASIN IS FULL AS IN THE SPRING OF 1944, OR FOLLOWING HEAVY RECHARGE AS IN THE SPRING OF 1958 (PLATE 11).

AT TIMES OF LOW WATER LEVELS (FALL, 1957, PLATE 11), THE PATTERN IS GENERALLY SIMILAR, ALTHOUGH DIFFERING IN DETAILS. WATER FLOWS OUT OF, OR IS PUMPED OUT OF THE ALLUVIUM BENEATH SECTION 31 SOUTH OF FILLMORE FASTER THAN IT IS SUPPLIED FROM PIRU BASIN, AND A STEEP WATER-LEVEL GRADIENT SHOWS IN SECTION 32. OTHERWISE, THERE IS A FAIRLY UNIFORM SLOPE OF THE WATER TABLE IN THE MAIN RIVER ALLUVIUM. BY THE FALL OF 1957 THE WATER IN THE ALLUVIAL FAN AND TERRACE MATERIALS OF THE SESPE UPLAND HAD DRAINED AND LOCAL PUMPING HAD CAUSED DEPLETION OF SOME OF THE SAN PEDRO AQUIFERS. SUCH A DEPLETION AREA SHOWS IN THE NORTHWESTERN PART OF

PLATE IIA

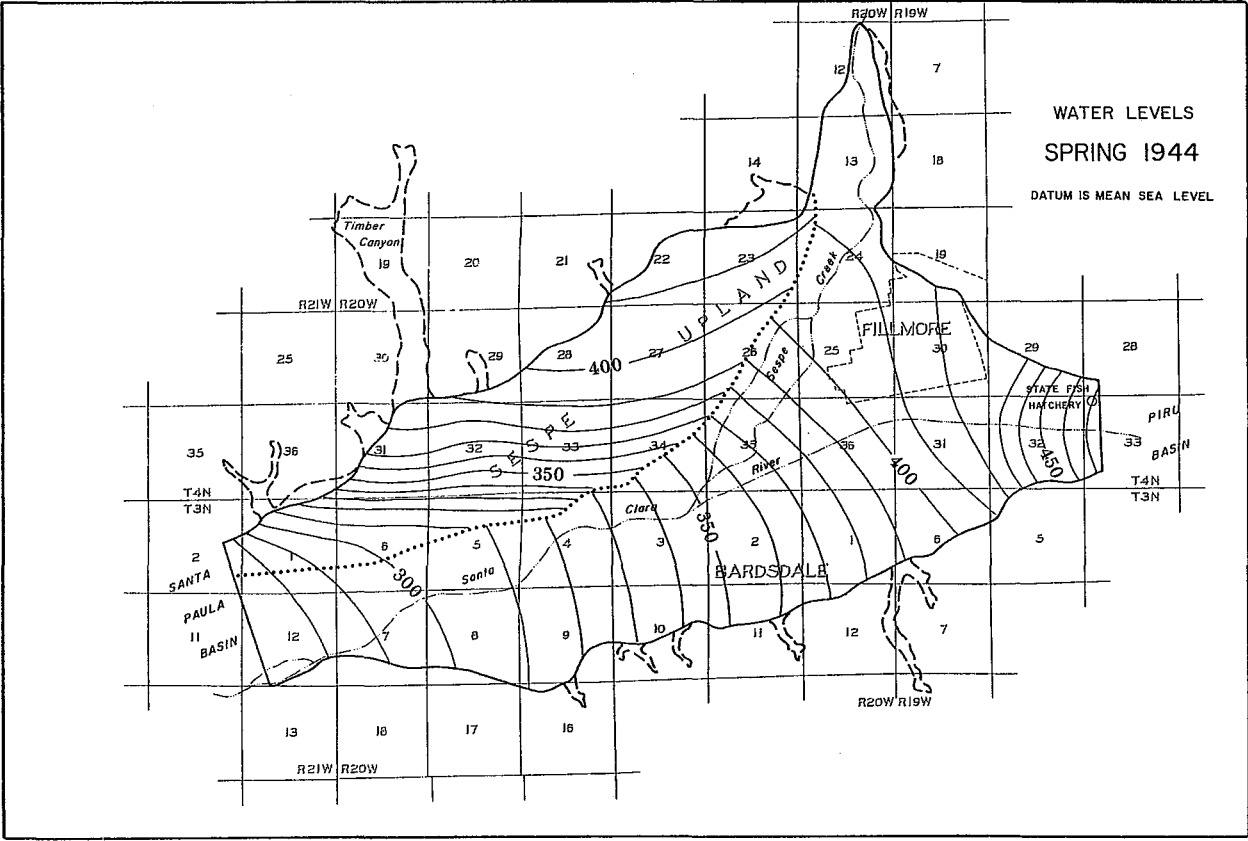


PLATE IIB

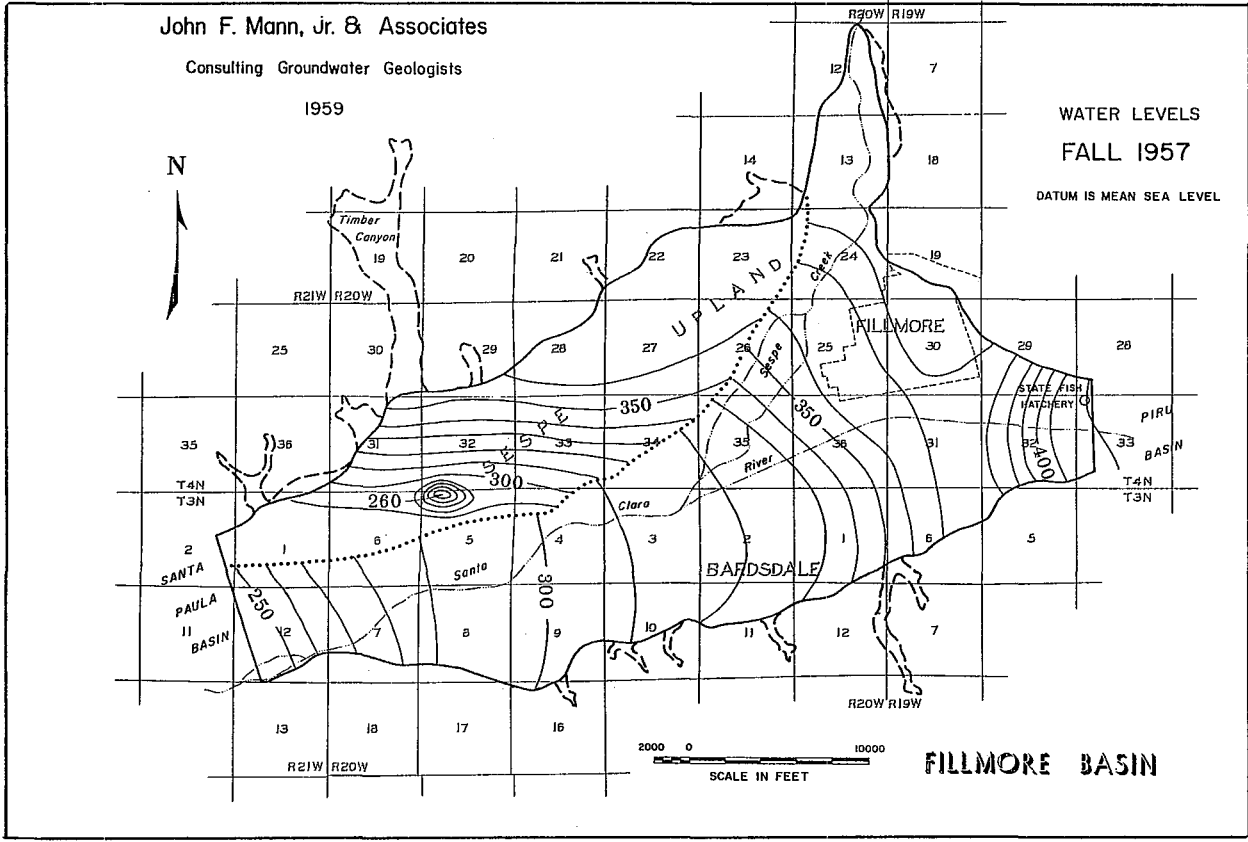
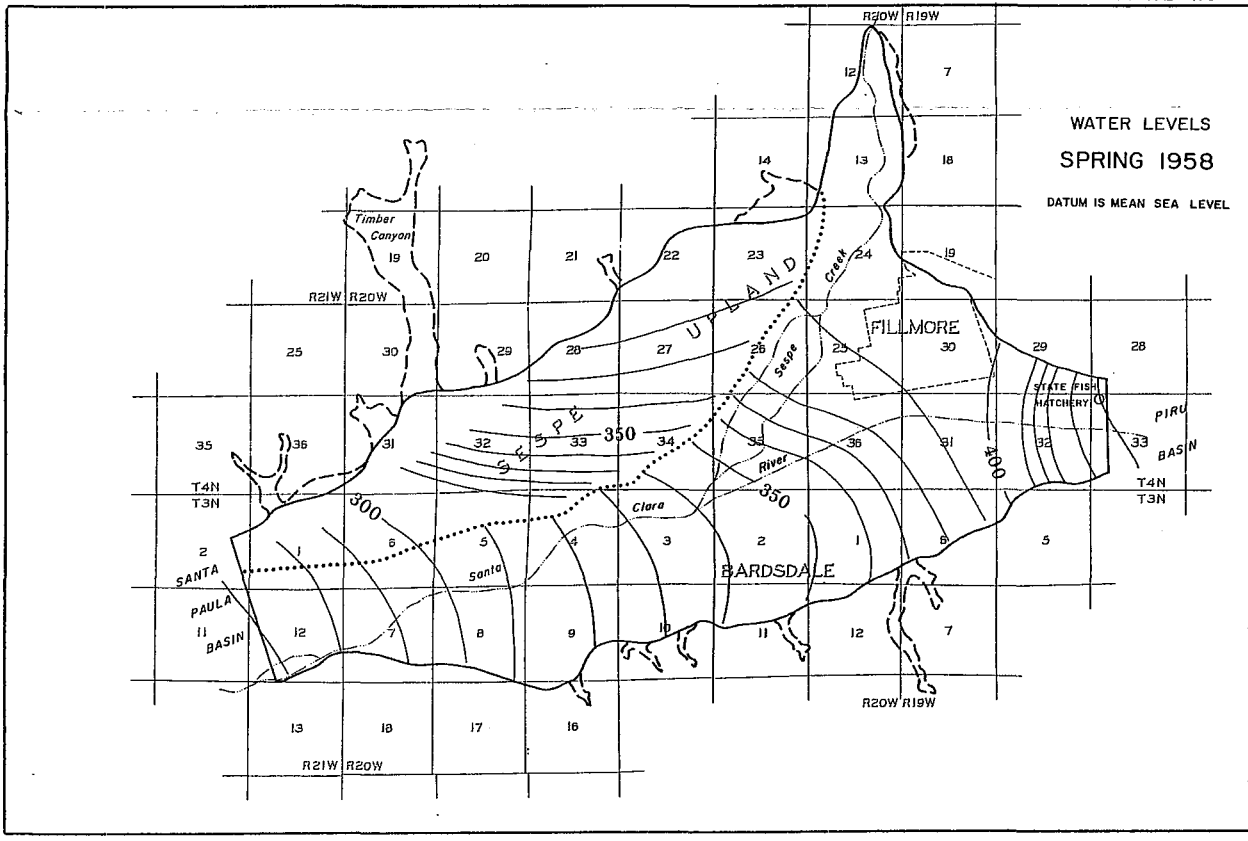


PLATE IIC



SECTION 5, T3N, R20W. DURING YEARS OF HEAVY RUNOFF THERE IS CONSIDERABLE PERCOLATION OF THE STREAMFLOW COMING FROM THE NORTH. AFTER PERCOLATING TO THE UNDERGROUND THE WATER FLOWS SOUTHERLY WITHIN THE BASAL ALLUVIAL FAN DEPOSITS. A PART OF THIS WATER PROBABLY REACHES THE MAIN RIVER ALLUVIUM. A PART ALSO DRAINS INTO THE PORTIONS OF THE TRUNCATED SOUTH-DIPPING SAN PEDRO AQUIFERS WHICH HAD BEEN DEWATERED BY PUMPING DURING THE PREVIOUS DRY YEARS. THE VOLUME DEWATERED IS SMALL AND FILLS QUICKLY AS RECHARGE OCCURS. FOLLOWING A SINGLE WET YEAR SUCH AS 1951-52 THE WATER RECHARGED TO THE ALLUVIAL FAN DEPOSITS QUICKLY DRAINS DOWNSLOPE OR INTO THE DEWATERED PORTIONS OF THE SAN PEDRO AQUIFERS; IN A YEAR OR TWO THE ALLUVIAL FAN DEPOSITS ARE AGAIN DRY.

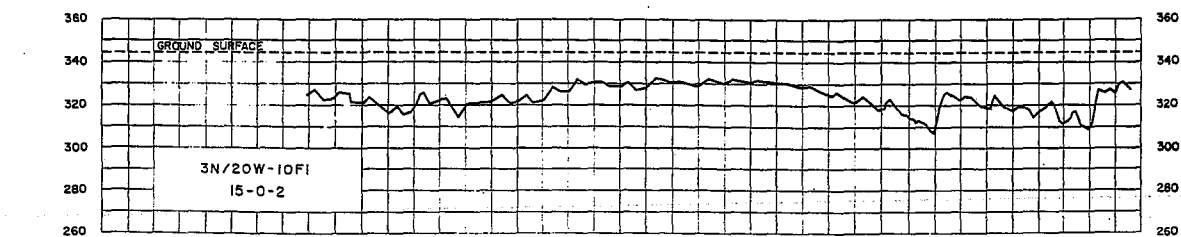
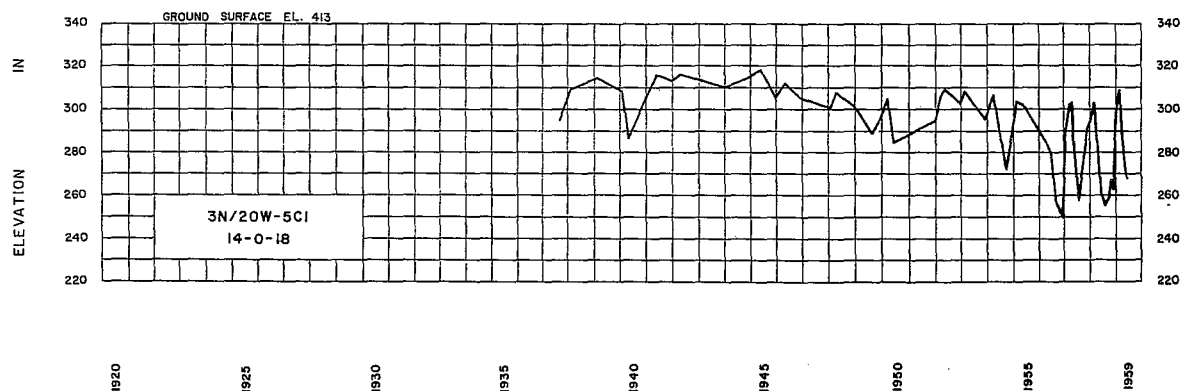
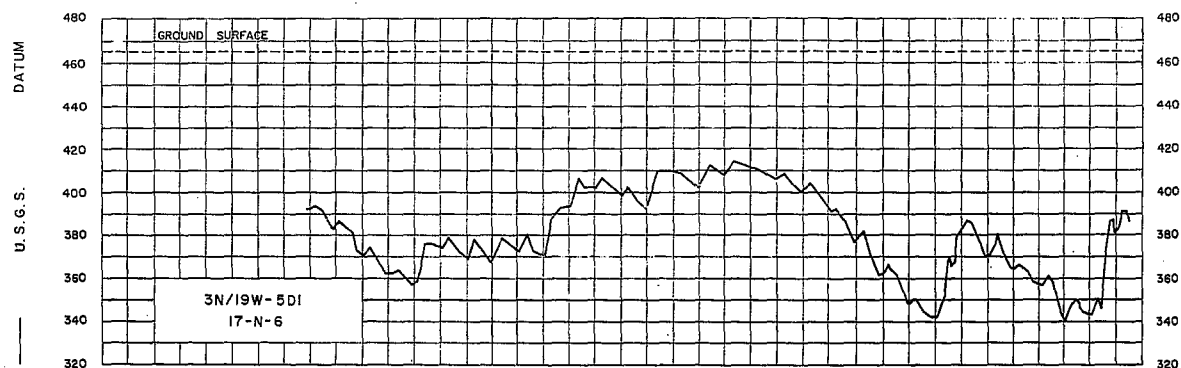
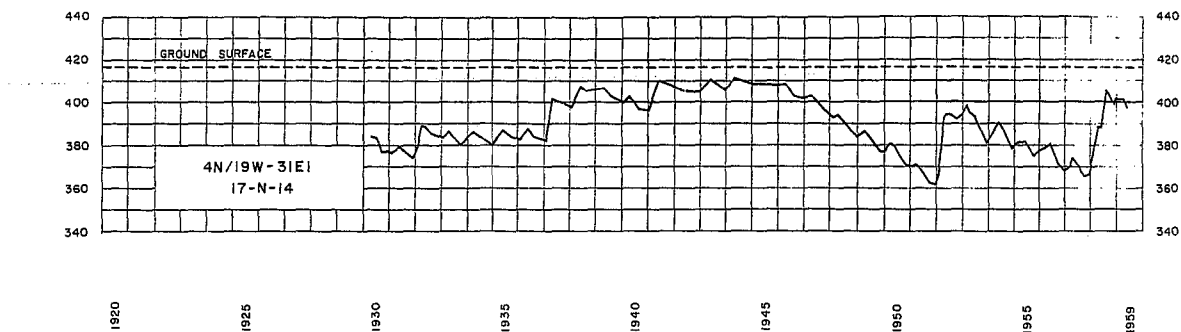
WITHIN THE SAN PEDRO FORMATION, WATER MOVEMENTS BENEATH THE SESPE UPLAND ARE SOUTHERLY IN THE DOWNDIP DIRECTION, BUT IN ADDITION THERE MUST BE SOME WESTERLY COMPONENTS OF FLOW. NEAR THE AXIS OF THE SYNCLINE, BENEATH THE MAIN RIVER ALLUVIUM, WATER MOVEMENTS IN THE PERMEABLE LAYERS IN THE UPPER PART OF THE SAN PEDRO FORMATION ARE PRIMARILY WESTERLY, AND APPEAR TO BE CONTROLLED BY THE WATER-TABLE SLOPE IN THE MAIN RIVER ALLUVIUM.

SMALL NORTHERLY FLOWS OCCUR IN THE TERRACE GRAVELS FLANKING SOUTH MOUNTAIN. THE WATER IN THE SHALLOWER PERMEABLE ZONES PROBABLY RATHER EASILY REACHES THE MAIN RIVER ALLUVIUM, BUT IN THE DEEPER PERMEABLE ZONES OF THE TERRACE DEPOSITS THE HYDROLOGIC CONTINUITY IS RESTRICTED.

#### FLUCTUATIONS OF WATER LEVELS

THE PERIODIC EFFECTS OF A SERIES OF WET YEARS ALTERNATING WITH A SERIES OF DRY YEARS ARE GRAPHICALLY DEPICTED ON THE HYDROGRAPHS OF WELLS IN THE FILLMORE BASIN. THE LOWERING OF WATER LEVELS DURING DROUGHT PERIODS HAS BEEN ONLY A FEW TENS OF FEET. IN WET PERIODS, RECOVERY IS RAPID AND FAIRLY COMPLETE.

THE HYDROGRAPHS OF WELLS 3N/20W-10F1 AND 4N/19W-31E1 ARE CHARACTERISTIC OF WATER-LEVEL FLUCTUATIONS IN THE SANTA CLARA RIVER ALLUVIUM IN THE FILLMORE BASIN. WELL 31E1 (PLATE 12) TYPIFIES THE LARGER FLUCTUATIONS OF WATER LEVELS IN THE UPSTREAM PORTION OF THE BASIN, WHERE THE MAXIMUM RANGE HAS BEEN ON THE ORDER OF 50 FEET. THE HIGHEST WATER LEVEL FOLLOWING THE HEAVY RECHARGE OF EARLY 1952 WAS NOT REACHED UNTIL EARLY IN 1953. THE SAME TYPE OF RESPONSE CAN BE NOTED IN WELLS AT THE



FILLMORE BASIN HYDROGRAPHS

LOWER END OF THE PIRU BASIN. THE ONSET OF PUMPING FROM WELLS IN THE SUMMER OF 1952 CAUSED A MINOR DEPRESSION IN WHAT WOULD OTHERWISE HAVE BEEN A SINGLE RECHARGE PEAK. THE GOOD, BUT INCOMPLETE RECOVERY IN 1952 AND 1953 INDICATES THAT A SINGLE VERY WET YEAR WILL NOT FILL THE GROUND WATER BASIN TO CAPACITY.

THE STRONG MOVEMENT OF WATER WESTERLY TOWARD THE LOWER BASIN BOUNDARY CAUSES (1) PERENNIAL RISING WATER, (2) HIGH WATER LEVELS, AND (3) SMALL FLUCTUATIONS IN WATER LEVELS. ALTHOUGH WELL 10F1 IS SEVERAL MILES ABOVE THE LOWER BASIN BOUNDARY, THE HYDROGRAPH (PLATE 12) REFLECTS THE STABILITY OF WATER LEVELS, THOUGH NOT TO THE FULL DEGREE, THAT WOULD BE EXPECTED AT THE LOWER BASIN BOUNDARY. AT WELL 10F1 THE TOTAL FLUCTUATION IS ONLY ABOUT 20 FEET; FURTHERMORE, RECOVERY IS QUICKER AND MORE NEARLY COMPLETE THAN UPSTREAM WHERE THE EFFECTS OF THE ALLUVIAL CONSTRICTION ARE NOT SHOWN.

ALONG THE SOUTH SIDE OF THE FILLMORE BASIN THE POOR RECHARGE IS REFLECTED IN THE SHARPER DROPPING OF WATER LEVELS DURING THE DROUGHT PERIODS AND THE SLOW, INCOMPLETE RECOVERY FOLLOWING A SINGLE WET YEAR. WELL 3N/19W-5D1 (PLATE 12) IS PERFORATED IN CONFINED TERRACE GRAVELS DEPOSITED FROM SOUTH MOUNTAIN STREAMS. WITH PUMPING, THESE GRAVELS ARE DRAINED DURING DROUGHT PERIODS, AND ALTHOUGH THERE IS SATURATED MAIN RIVER ALLUVIUM NEARBY, RECHARGE FROM THAT SOURCE IS SLOW OR IMPOSSIBLE AND THE PUMPING CAUSES A SHARP DROP IN THE WATER LEVELS. REPLENISHMENT IS MAINLY IN WET YEARS, AND FROM THE SOUTH.

WELLS IN THE SESPE UPLAND SHOW A VARIETY OF WATER-LEVEL RESPONSES. AS DESCRIBED ABOVE, THERE IS A GROUP OF ALLUVIAL FAN AND TERRACE DEPOSITS LYING ON A SOUTH-SLOPING SURFACE ERODED ON SOUTH-DIPPING LAYERS OF THE SAN PEDRO FORMATION. FOLLOWING WET YEARS, RECHARGE WATER MOVES DOWNWARD TO THE UNCONFORMITY AND PRODUCES A FREE WATER TABLE NEAR THE BASE OF THE ALLUVIAL DEPOSITS. FREE DOWNSLOPE DRAINAGE COUPLED WITH RECHARGE TO THE DEWATERED PORTIONS OF THE SAN PEDRO FORMATION CAUSES A NEARLY COMPLETE DEWATERING OF THE ALLUVIAL DEPOSITS. IN WELL 3N/20W-5C1 (PLATE 12) THE BASE OF THE ALLUVIAL DEPOSITS IS AT AN ELEVATION OF ABOUT 307. WHEN THE ALLUVIAL DEPOSITS HAVE BEEN DRAINED AND THE CONTINUING PUMPAGE EXTRACTS ONLY FROM CONFINED AQUIFERS IN THE SAN PEDRO FORMATION, THE WATER LEVELS DROP SHARPLY. SIMILARLY, WHEN PUMPING CEASES,

THERE IS A SHARP PRESSURE RECOVERY TO ABOUT THE BASE OF THE ALLUVIAL BLANKET, BUT NOT MUCH ABOVE THE BASE.

#### STORAGE CAPACITY

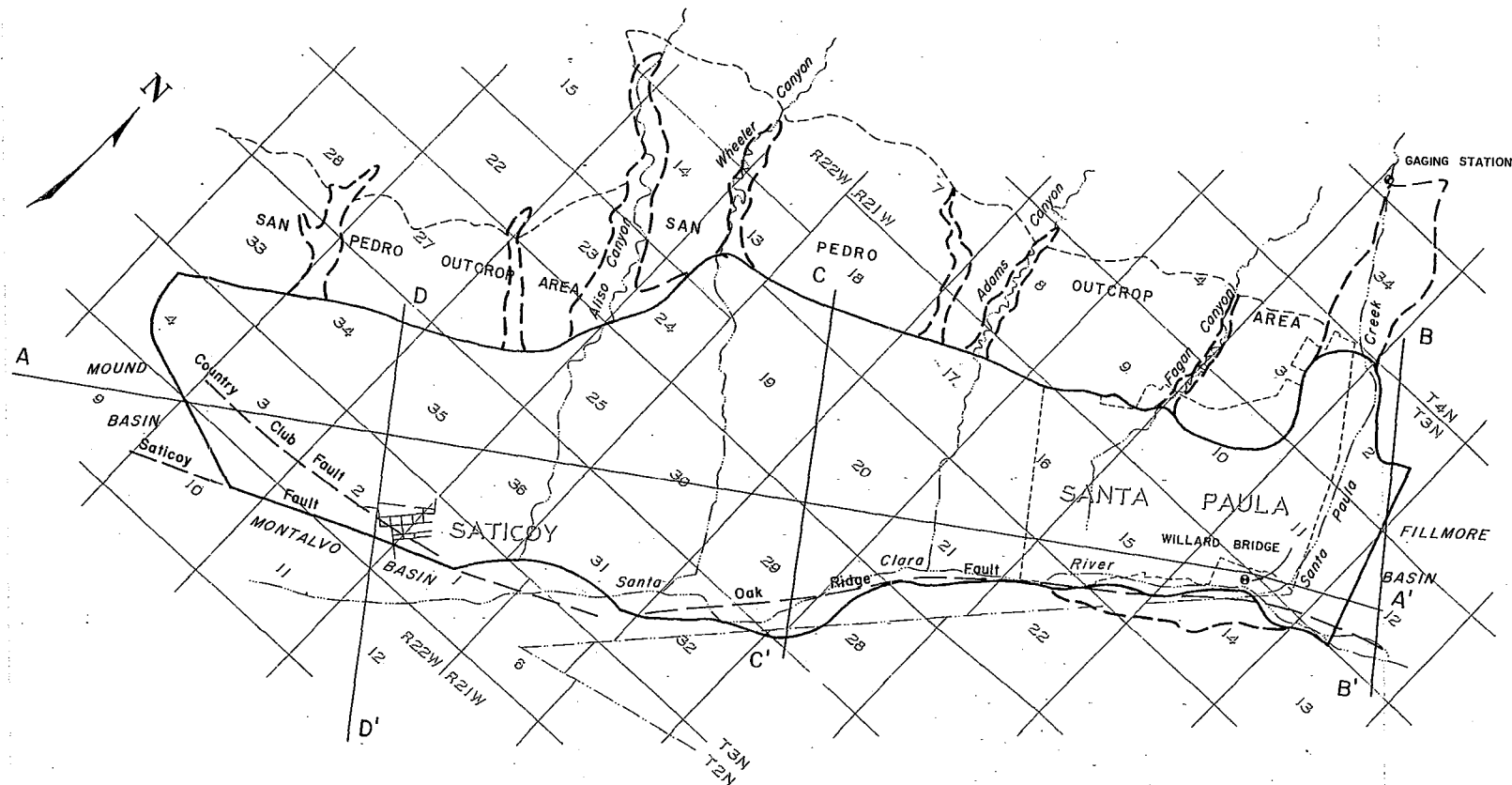
THE STORAGE CAPACITY OF THE GROUND WATER BASIN WITHIN THE ZONE OF HISTORIC WATER-TABLE FLUCTUATIONS WAS CALCULATED BY APPLYING UNIT SPECIFIC YIELD VALUES TO THE LITHOLOGIES OBTAINED FROM WATER WELL LOGS. THE UNIT SPECIFIC YIELD VALUES ARE GIVEN IN TABLE 11-1. WITHIN GEOLOGICALLY DISTINCT CELLS, EACH INCLUDING A GROUP OF WELLS, AVERAGE SPECIFIC YIELD VALUES WERE ASSIGNED TO EACH 25-FOOT INTERVAL BELOW THE HIGHEST WATER-TABLE SURFACE, WHICH OCCURRED IN THE SPRING OF 1944. THE STORAGE DEPLETION CURVE (PLATE 8) WAS CONSTRUCTED BY RELATING HISTORIC WATER-LEVEL MEASUREMENTS OF WELL 4N/19W-31E1 TO THE UNWATERED STORAGE CAPACITY DERIVED FROM THE SPECIFIC YIELD STUDY. THE WATER-SURFACE ELEVATION IN WELL 31E1 SHOWS A RANGE FROM A MAXIMUM OF 412 IN THE SPRING OF 1944 TO A MINIMUM OF 364 IN THE FALL OF 1951. MAXIMUM STORAGE DEPLETION, IN THE FALL OF 1951, WAS ABOUT 80,000 ACRE-FEET.

#### SANTA PAULA BASIN

##### BOUNDARIES

THE SANTA PAULA BASIN INCLUDES THE BROAD AREA ALONG THE SANTA CLARA RIVER EXTENDING FROM EAST OF SANTA PAULA TO THE VICINITY OF SATICOY. SANTA PAULA CREEK, A MAJOR TRIBUTARY OF THE SANTA CLARA RIVER, JOINS THE MAIN STREAM NEAR THE EASTERN BOUNDARY OF THE BASIN. SEVERAL OTHER SMALLER TRIBUTARIES FLOW INTO THE BASIN FROM THE NORTH, THE MORE IMPORTANT BEING FAGAN, ADAMS, WHEELER AND ALISO CREEKS.

THE AREA COVERED BY THE SANTA PAULA BASIN IS CONSIDERED TO COINCIDE WITH THE ALLUVIAL AND TERRACE DEPOSITS ALONG THE SANTA CLARA RIVER AS SHOWN ON PLATE 13. THE EASTERN BOUNDARY IS ARBITRARILY PLACED AT THE TOPOGRAPHIC AND HYDROLOGIC CONSTRICTION WHICH EXISTS ABOUT ONE MILE EAST OF THE CITY OF SANTA PAULA. THE BASIN IS EXTENDED UP THE VALLEY OF SANTA PAULA CREEK TO THE ALLUVIUM-COVERED GEOLOGIC CONTACT BETWEEN THE PERMEABLE SAN PEDRO FORMATION AND THE UNDERLYING, NONWATER-BEARING SANTA BARBARA FORMATION. THE ALLUVIUM OF THE MINOR TRIBUTARY VALLEYS IS CONSIDERED TO BE OUTSIDE OF THE AREA OF MORE OR LESS PERMANENT GROUND WATER STORAGE. THE WESTERN BASIN BOUNDARY CONSISTS OF THREE PARTS: (1) A REACH OF CONSTRICTED RECENT ALLUVIUM AND RISING WATER; (2) A FAULT WHICH



2000 0 10000  
SCALE IN FEET

# INDEX MAP

## SANTA PAULA BASIN

- GROUND WATER BASIN BOUNDARY
- - - - RAINFALL PENETRATION BOUNDARY
- - - - FAULT TRACE
- LINE OF GEOLOGIC SECTION

PRODUCES A SHARP BREAK IN WATER LEVELS, AND (3) A TOPOGRAPHIC DIVIDE. AS SO DEFINED, THE AREA OF THE SANTA PAULA BASIN IS 12,980 ACRES. FOR PURPOSES OF COMPUTING RAINFALL PENETRATION, A SOMEWHAT LARGER AREA OF 14,805 ACRES IS USED (PLATE 13). THE ADDITIONAL AREA CONSISTS OF NORTH-SIDE ALLUVIATED TRIBUTARY VALLEYS, AND LOW-LYING TERRACES SOUTH OF THE SANTA CLARA RIVER. RAINFALL PENETRATION IS ASSUMED TO OCCUR ONLY ON THOSE PORTIONS OF TRIBUTARY ALLUVIUM UNDERLAIN BY SAN PEDRO STRATA, WHICH CROP OUT ON THE NORTHERN FLANKS OF THE SANTA PAULA BASIN. THE SAN PEDRO OUTCROP ZONE IS EXCLUDED FROM THE RAINFALL PENETRATION AREA BECAUSE (1) THE COARSE BEDS ARE LENTICULAR AND CLAYEY; AND (2) THE LAYERS EXPOSED DIP TO THE SOUTH AND ARE DEEPER THAN THE WATER WELLS IN THE BASIN.

#### GROUND WATER GEOLOGY

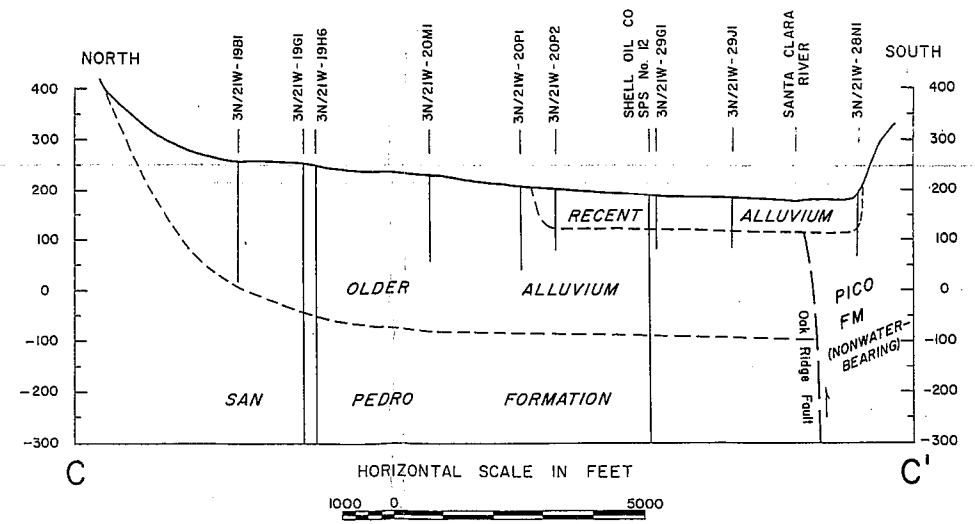
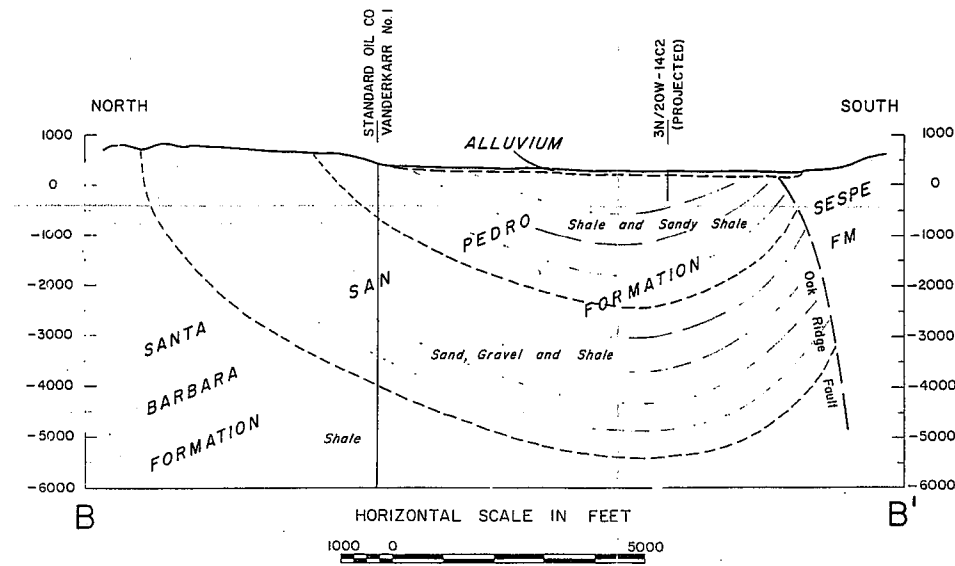
##### GENERAL GEOLOGY

THE SANTA PAULA BASIN CAN BE DIVIDED INTO TWO GENERAL AREAS. A ZONE OF RECENT ALLUVIATION FOLLOWS THE PRESENT COURSE OF THE SANTA CLARA RIVER AND IS RESTRICTED TO THE SOUTHERN PORTION OF THE BASIN. THE ALLUVIAL SANDS AND GRAVELS RANGE FROM 60-80 FEET THICK AND HAVE A WESTERLY SURFACE SLOPE OF 20-25 FEET PER MILE. THE LARGER PORTION OF THE BASIN LIES NORTH OF THE STRIP OF SANTA CLARA RIVER RECENT ALLUVIUM. THE SURFACE SLOPES ARE PREDOMINANTLY TO THE SOUTH AND THE SURFICIAL MATERIAL CONSISTS MOSTLY OF FINE-GRAINED ALLUVIAL FAN DEPOSITS CARRIED INTO THE BASIN BY THE TRIBUTARY STREAMS COMING FROM THE NORTH. THE FANS WERE DEPOSITED ON AN EROSIONAL SURFACE CUT ON THE SAN PEDRO FORMATION.

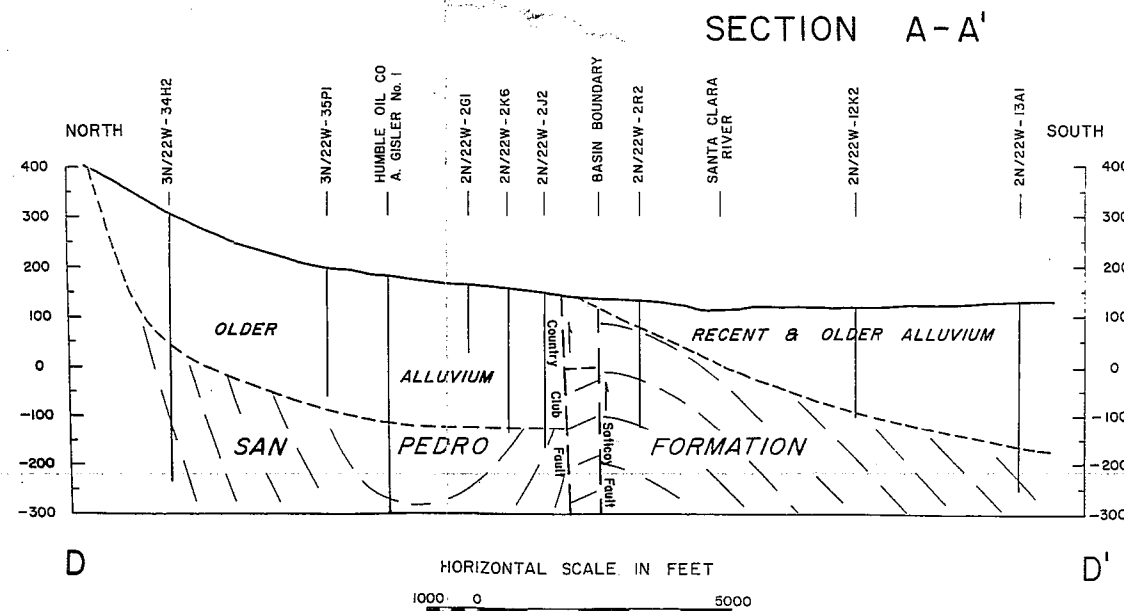
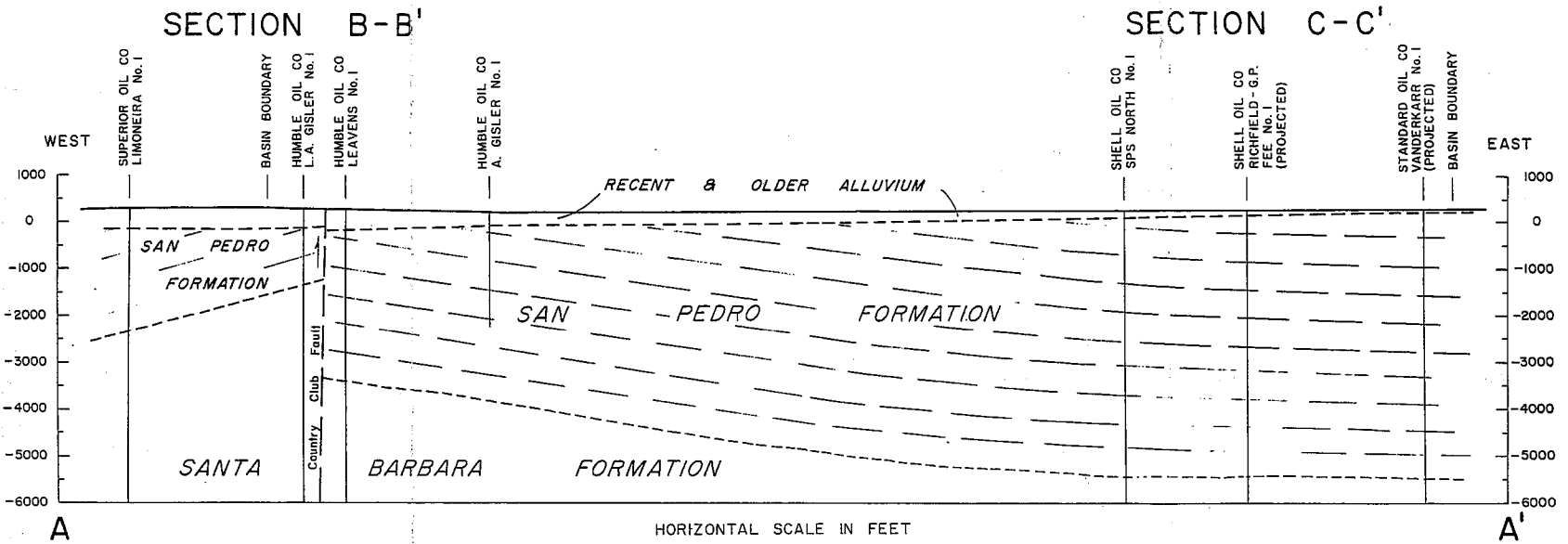
THE TOPOGRAPHICALLY LOW AREA OCCUPIED BY THE SANTA PAULA BASIN WAS DEVELOPED BY SANTA CLARA RIVER EROSION ALONG THE AXIS OF A SYNCLINALLY FOLDED BELT OF RELATIVELY SOFT SAN PEDRO SEDIMENTS. THE TERTIARY ROCKS FLANKING THE BASIN ON THE SOUTH HAVE BEEN THRUST OVER THE SAN PEDRO FORMATION ALONG THE OAK RIDGE FAULT (SECTION B-B', PLATE 14). THE ALLUVIAL BOUNDARY ALONG THE SOUTHERN EDGE OF THE BASIN CLOSELY COINCIDES WITH THE BURIED TRACE OF THE FAULT. THE SANTA BARBARA AND PICO FORMATIONS UNDERLIE THE SAN PEDRO FORMATION ON THE NORTHERN LIMB OF THE SYNCLINE.

##### ALLUVIAL AQUIFERS

THE ALLUVIAL DEPOSITS WHICH BLANKET THE SANTA PAULA BASIN ARE OF TWO TYPES: (1) THE MAIN RIVER RECENT ALLUVIUM; AND (2) THE RECENT AND OLDER ALLUVIAL FAN DEPOSITS DERIVED FROM THE NORTH. THE RELATIONSHIPS OF



ELEVATION  
IN  
FEET  
—  
U.S.G.S.  
DATUM



**GEOLOGIC SECTIONS**  
**SANTA PAULA BASIN**  
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Consulting Groundwater Geologists  
1959

THE ALLUVIAL DEPOSITS ARE SHOWN IN SECTION C-C', PLATE 14.

BENEATH THE SANTA CLARA RIVER, IN THE VICINITY OF WILLARD BRIDGE, COARSE SANDS AND GRAVELS EXTEND TO A DEPTH OF 60 TO 65 FEET. DOWNSTREAM THE RIVER DEPOSITS MAY REACH A MAXIMUM OF SLIGHTLY MORE THAN 80 FEET THICK, AND AT THE LOWER BASIN BOUNDARY RECENT ALLUVIUM IS ABOUT 75 FEET THICK.

THE ALLUVIAL MATERIAL UNDER THE NORTHERN PORTION OF THE BASIN IS A COMPLEX OF TERRACE DEPOSITS, OLDER ALLUVIAL FANS AND MINOR RECENT ALLUVIUM. THE OLDER ALLUVIAL FAN DEPOSITS CONTAIN CONSIDERABLE QUANTITIES OF CLAY IN THE UPPER PART, BUT PRIMARILY GRAVELS IN THE LOWER PART. THESE BASAL GRAVELS TRANSMIT LARGE QUANTITIES OF RECHARGE TO THE UNDERLYING SAN PEDRO AQUIFERS. THE MAXIMUM THICKNESS OF THE OLDER ALLUVIAL DEPOSITS APPROACHES 300 FEET. THE MAIN RIVER RECENT ALLUVIUM WAS APPARENTLY BACKFILLED ALONG A SCARP CUT INTO THE CLAYEY UPPER PORTION OF THE OLDER ALLUVIUM (SECTION C-C', PLATE 14).

#### SAN PEDRO FORMATION

THE SAN PEDRO FORMATION UNDERLIES THE ALLUVIUM OF THE SANTA PAULA BASIN NORTH OF THE OAK RIDGE FAULT. STRONG LATERAL EROSION BY THE SANTA CLARA RIVER HAS CAUSED A SOUTHWARD RETREAT OF THE FAULT SCARP AND THE TRACE OF THE FAULT IS NOW COVERED BY ALLUVIUM. SOUTH OF THE OAK RIDGE FAULT ARE EXPOSED TERTIARY ROCKS OF THE SESPE, VAQUEROS, MODELO, PICO, AND SANTA BARBARA FORMATIONS. THESE ROCKS ARE CONSIDERED TO BE NONWATER-BEARING, ALTHOUGH SUFFICIENT PERMEABILITY EXISTS IN THE COARSER STRATA TO ALLOW SMALL QUANTITIES OF POOR QUALITY WATER TO CIRCULATE.

THE SAN PEDRO FORMATION HAS BEEN FOLDED INTO AN EAST-WEST SYNCLINE WITH THE AXIS LYING NORTH OF THE PRESENT COURSE OF THE SANTA CLARA RIVER. THE NORTH-DIPPING OR OVERTURNED SOUTH LIMB OF THE FOLD WAS FORMED BY DRAG ALONG THE OAK RIDGE FAULT, AND THE TRUNCATED EDGES OF THE UPTURNED AQUIFERS ARE EXPOSED TO THE OVERLYING ALLUVIUM. ALONG THE AXIS OF THE SYNCLINE AT THE EASTERN BOUNDARY OF THE BASIN, SAN PEDRO SANDS AND GRAVELS REACH A MAXIMUM DEPTH OF ABOUT 6000 FEET AND ARE UNDERLAIN BY IMPERMEABLE SHALE OF THE SANTA BARBARA FORMATION. AS SHOWN IN SECTION A-A' OF PLATE 14, THE BASE OF THE SAN PEDRO FORMATION APPEARS TO RISE SLIGHTLY TOWARDS THE WEST AND IN THE VICINITY OF THE SANTA PAULA-MOUND BASIN BOUNDARY IT IS PROBABLY NO MORE THAN 4000 FEET DEEP. FLANKING THE BASIN ON THE NORTH IS A WIDE STRIP OF SAN PEDRO OUTCROPS. THE EXPOSED BASAL SAN PEDRO LAYERS,

STRIKING GENERALLY PARALLEL TO THE NORTH BOUNDARY OF THE BASIN, SHOW SOUTHERLY DIPS OF ABOUT 50 DEGREES AT THE MOUTH OF SANTA PAULA CREEK; THE DIP ANGLES BECOME LESS TO THE WEST. IN THE VICINITY OF THE SANTA PAULA-MOUND BASIN BOUNDARY SAN PEDRO STRATA HAVE 15-25 DEGREE SOUTHERLY DIPS.

A COMPLEX STRUCTURAL PATTERN OF FOLDING AND FAULTING EXISTS IN THE SOUTHWESTERN PORTION OF THE BASIN NEAR THE TOWN OF SATICOY. THESE STRUCTURES ARE RELATED TO THE OAK RIDGE FAULT. THERE IS NO EVIDENCE THAT THE RECENT ALLUVIUM OF THE SANTA CLARA RIVER HAS BEEN DISTURBED BY THIS FAULTING AND SO THE LATEST MOVEMENTS ARE BELIEVED TO HAVE TAKEN PLACE IN THE VERY LATE PLEISTOCENE. AT LEAST TWO FAULTS CAN BE RECOGNIZED, AND THERE MAY BE SEVERAL MORE. THE COUNTRY CLUB FAULT (PLATE 13) TRENDS A LITTLE SOUTH OF WEST. THE VERTICAL DISPLACEMENT SHOWN BY THE BASE OF THE SAN PEDRO FORMATION MAY BE AS MUCH AS 2000 FEET. THE FRACTURE CAN NOT BE DETECTED IN THE MOUND BASIN AND THE THROW IS ASSUMED TO DECREASE TO THE WEST. FAULT MOVEMENTS CONTINUED UNTIL THE VERY LATE PLEISTOCENE AS SUGGESTED BY SURFACE EXPOSURES WHICH CAN BE TRACED ON AERIAL PHOTOGRAPHS ACROSS THE SATICOY COUNTRY CLUB AND FOR SOME DISTANCE TO THE WEST. DISPLACEMENT OF THE BASAL UPPER PLEISTOCENE AQUIFERS HAS CAUSED A SHARP BREAK IN WATER LEVELS ACROSS THIS LINE. FLOWING WELLS AT SATICOY APPEAR TO BE RESTRICTED TO THE NORTHERN (DOWNTOWN) SIDE OF THIS FAULT. THE FAMOUS ANCIENT INDIAN SPRINGS AT SATICOY AND THE AREA OF ALKALINE SOIL SHOWN ON THE SOIL MAP (REF. 7) ARE PROBABLY RELATED TO THE SAME ARTESIAN PRESSURE. THE SATICOY FAULT (PLATE 13), TRENDING MORE TOWARD THE SOUTHWEST, IS USED AS PART OF THE BASIN BOUNDARY. ON THE SOUTH SIDE THE SANTA BARBARA AND SAN PEDRO FORMATIONS HAVE BEEN LIFTED IN PLACES TO WITHIN 100 FEET OF THE PRESENT GROUND SURFACE. THE VERTICAL DISPLACEMENT APPEARS TO DECREASE IN A WESTERLY DIRECTION ALSO. THE SATICOY FAULT IS MARKED BY A SHARP BREAK IN WATER LEVELS.

#### SOURCES OF RECHARGE

THE SANTA PAULA BASIN IS RECHARGED PRIMARILY BY STREAM PERCOLATION OF THE SURFACE FLOWS IN THE SANTA CLARA RIVER AND SANTA PAULA CREEK. A MUCH SMALLER QUANTITY IS CONTRIBUTED BY PERCOLATION OF TRIBUTARY SURFACE FLOWS COMING FROM THE NORTH. A SIZEABLE INCREMENT TO GROUND WATER STORAGE IS DERIVED FROM THE DEEP PENETRATION OF RAINFALL ON THE ALLUVIATED PORTION OF THE BASIN. UNDERFLOW THROUGH THE ALLUVIUM AND

THE SAN PEDRO FORMATION FROM FILLMORE BASIN IS A LARGE AND PERSISTENT SOURCE OF RECHARGE. ALL OF THE EFFLUENT FROM THE CITY OF SANTA PAULA SEWAGE TREATMENT PLANT IS DISCHARGED TO BASINS ADJOINING THE SANTA CLARA RIVER AND REACHES THE WATER TABLE.

#### BASIN OUTFLOW

UNDERFLOW FROM THE SANTA PAULA BASIN IS CONSIDERED TO OCCUR IN SIGNIFICANT QUANTITIES ONLY THROUGH THE RECENT ALLUVIUM ALONG THE SANTA CLARA RIVER CHANNEL INTO THE MONTALVO BASIN. STRUCTURAL BARRIERS AND MATERIALS OF LOW PERMEABILITY PRECLUDE THE POSSIBILITY OF ALL BUT MINOR UNDERFLOW WITHIN THE BASAL UPPER PLEISTOCENE OR SAN PEDRO AQUIFERS INTO THE MOUND OR MONTALVO BASINS. ADDITIONAL WATER IS FORCED TO THE SURFACE IN THE RIVER CHANNEL AND LEAVES THE BASIN AS RISING WATER.

#### MOVEMENTS OF UNDERGROUND WATER

GROUND WATER MOVES THROUGH THE ALLUVIUM OF THE SANTA CLARA RIVER FROM EAST TO WEST AS INDICATED BY THE WATER-LEVEL CONTOURS (PLATE 15). WITHIN THE BASAL UPPER PLEISTOCENE AQUIFERS AND THE UNDERLYING SAN PEDRO AQUIFERS THE MOVEMENT IS SOUTHERLY AND WESTERLY. LOCAL VARIATIONS DURING DROUGHT PERIODS, PARTICULARLY IN WELLS PERFORATED IN THE CONFINED SAN PEDRO AQUIFERS, ARE CAUSED BY HEAVY PUMPING COMBINED WITH RESTRICTED OR REDUCED RECHARGE. SANTA PAULA CREEK FAN MATERIAL IS COARSER AND RECHARGE TO THE BASAL UPPER PLEISTOCENE AQUIFERS FROM THAT STREAM CHANNEL OCCURS MORE READILY THAN IN OTHER FANS OF THE SANTA PAULA BASIN.

UNDERFLOW OUT OF SANTA PAULA BASIN MOVES FREELY ONLY THROUGH THE RECENT ALLUVIUM ALONG THE SANTA CLARA RIVER. UNDERFLOW FROM THE SANTA PAULA BASIN TO THE MONTALVO BASIN WOULD HAVE TO MOVE INTO THE UPLIFTED BLOCK SOUTH OF THE SATICOY FAULT. ALONG MOST OF THE SATICOY FAULT FROM SOUTH MOUNTAIN TO THE TOWN OF SATICOY THE UNDERFLOW FROM THE SAN PEDRO FORMATION OR THE BASAL UPPER PLEISTOCENE DEPOSITS WOULD HAVE TO MOVE INTO THE IMPERMEABLE SANTA BARBARA FORMATION. JUST AT SATICOY, THE FOX CANYON AQUIFER IS SOUTH OF THE SATICOY FAULT, BUT UNDERFLOW WOULD BE RESTRICTED BY THE KNOWN BARRIER AFFORDED BY THE FAULT. UNDERFLOW INTO THE MOUND BASIN CAN NOT BE LARGE. WELLS IN THE TRIANGLE BETWEEN THE COUNTRY CLUB AND SATICOY FAULTS SHOW RATHER FEEBLE RECHARGE. IF UNDERFLOW ACROSS THE COUNTRY CLUB FAULT IN THE BASAL UPPER PLEISTOCENE AQUIFERS IS SMALL, THEN MOVEMENTS WITHIN THE SAN PEDRO FORMATION ARE EVEN SMALLER BECAUSE OF THE

PLATE 15A

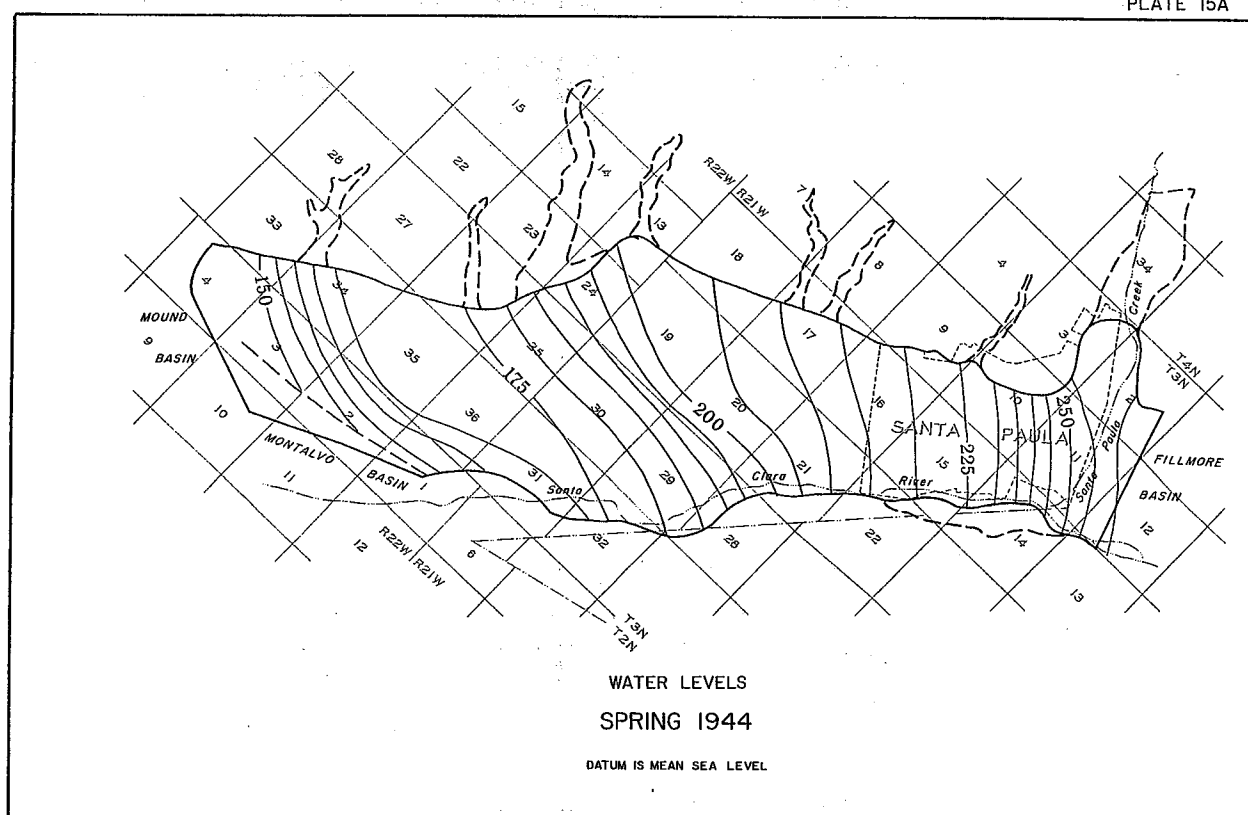


PLATE 15B

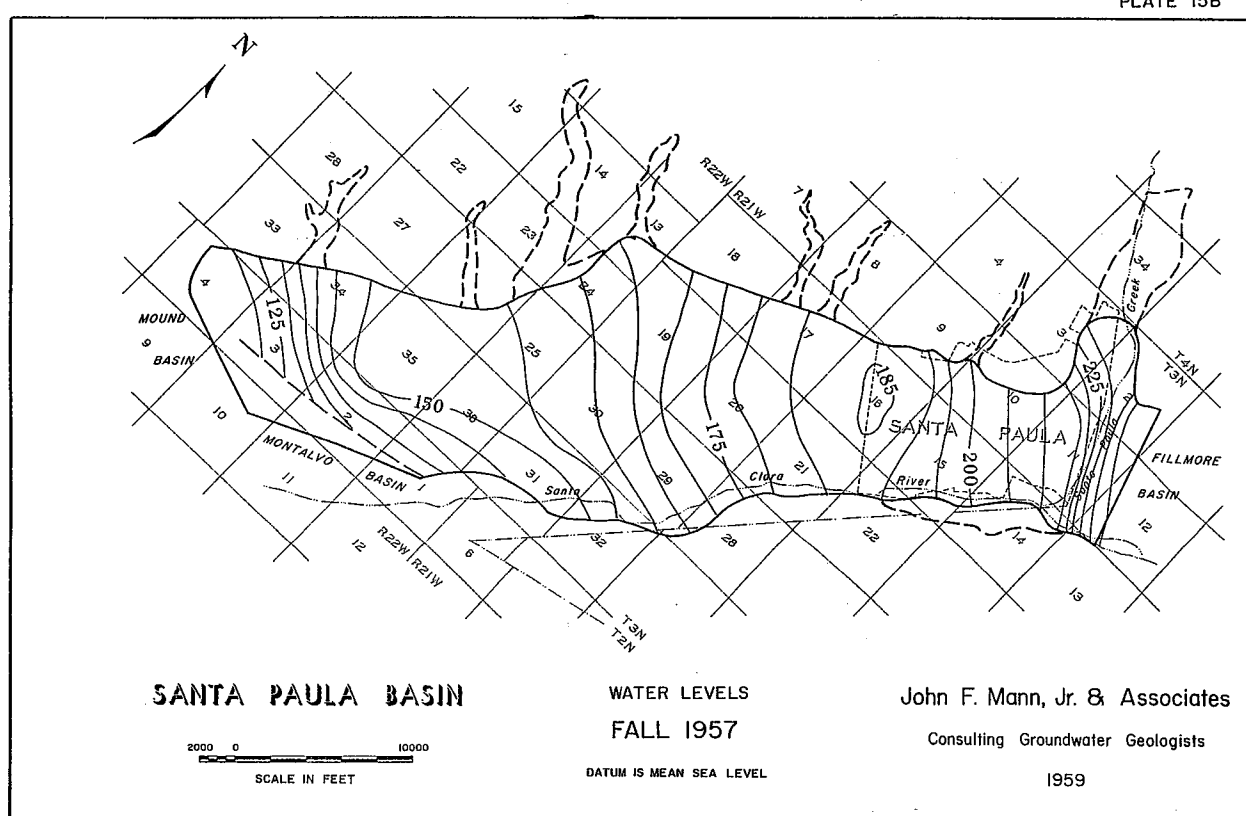
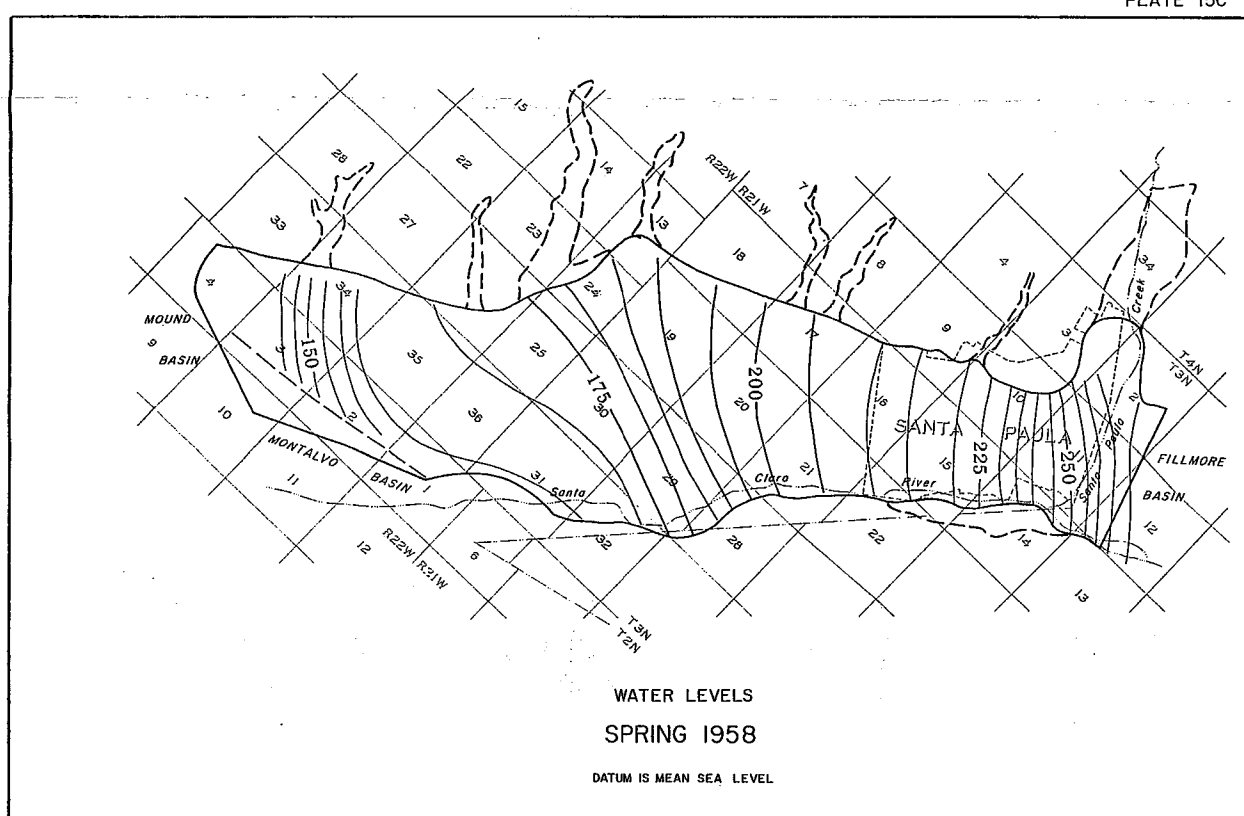


PLATE 15C



VERY LARGE DISPLACEMENTS. WESTERLY MOVEMENTS THROUGH SECTION 4, T2N, R22W ARE LIMITED BY LAYERS OF VERY LOW PERMEABILITY WHICH ARE PRESENT TO DEPTHS OF MANY HUNDREDS OF FEET BELOW THE GROUND SURFACE.

#### FLUCTUATIONS OF WATER LEVELS

WATER LEVELS IN THE SANTA PAULA BASIN SHOW ONLY A VERY SMALL RANGE OF FLUCTUATIONS. WATER-LEVEL DECLINES DURING PROLONGED DROUGHTS ARE MOSTLY ON THE ORDER OF 20-30 FEET AND RECOVERIES, EVEN IN A SINGLE WET YEAR, ARE ESSENTIALLY COMPLETE. WELLS PERFORATED IN THE BASAL UPPER PLEISTOCENE AQUIFERS OR IN IMMEDIATELY UNDERLYING SAN PEDRO AQUIFERS USUALLY INDICATE GOOD RECHARGE WHERE THEY ARE CLOSE TO THE SANTA CLARA RIVER. A HYDROGRAPH TYPICAL OF SUCH CONDITIONS IS THAT OF WELL 3N/21W-21E1 (PLATE 16).

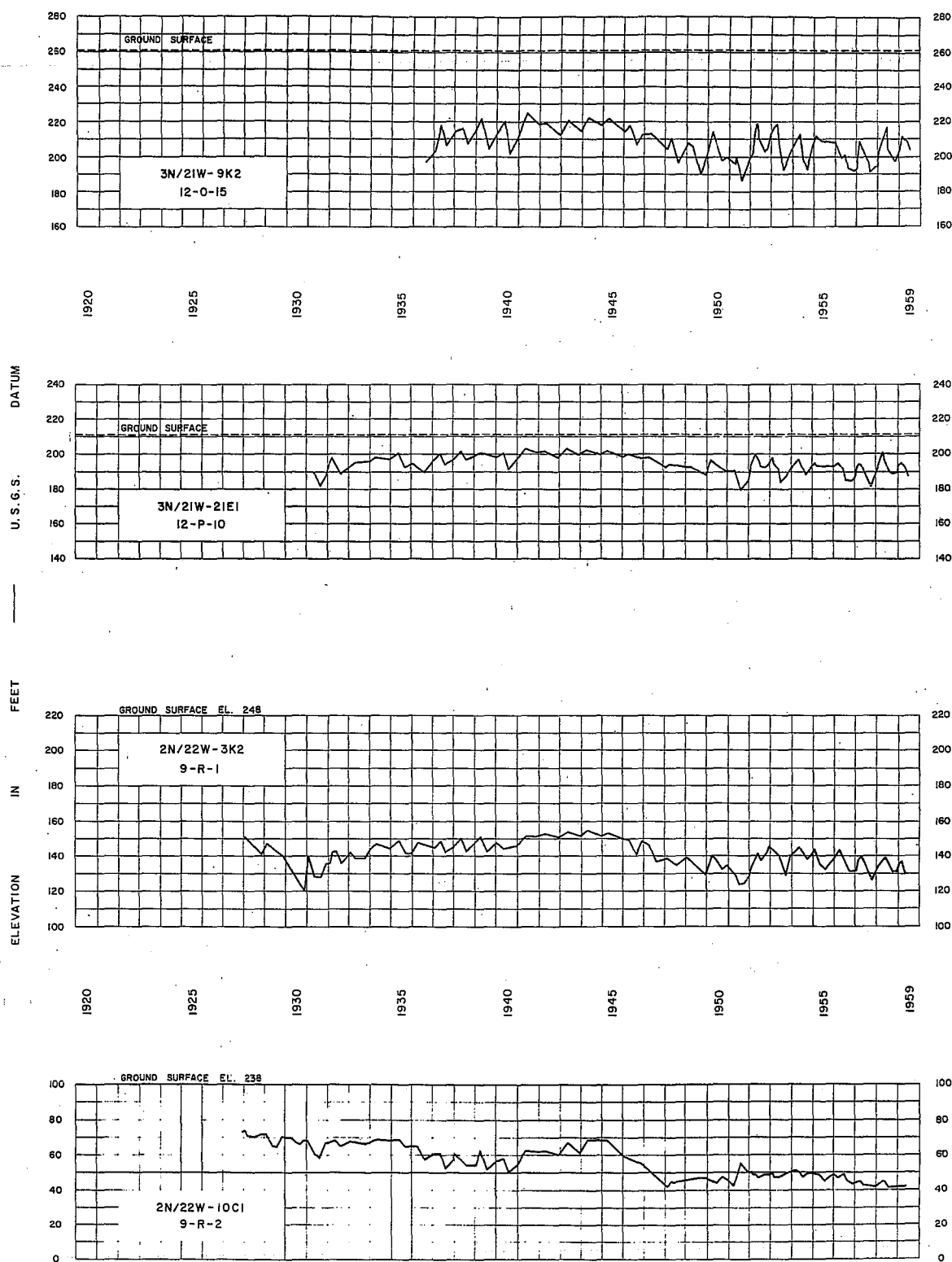
ONLY A FEW WELLS PUMP FROM THE SAN PEDRO AQUIFERS IN POSITIONS WHERE OPPORTUNITIES FOR RECHARGE FROM SATURATED OVERLYING ALLUVIUM ARE POOR. THESE WELLS SHOW THE SHARPER DECLINES AND RECOVERIES TYPICAL OF CONFINED AQUIFERS. ALSO, THERE IS A GREATER RANGE OF FLUCTUATIONS, AND RECOVERIES IN A SINGLE WET YEAR ARE SOMETHING LESS THAN COMPLETE. WELL 3N/21W-9K2 ILLUSTRATES THESE RESPONSES (PLATE 16).

NEAR THE WESTERN BOUNDARY OF THE SANTA PAULA BASIN, THE COUNTRY CLUB FAULT CAUSES SHARP DIFFERENCES IN WATER-LEVEL RESPONSES. NORTH OF THIS FAULT, AS ILLUSTRATED BY THE HYDROGRAPH OF WELL 2N/22W-3K2 (PLATE 16), WATER LEVELS ARE RELATIVELY HIGH, AND GOOD RECHARGE IS INDICATED BY GOOD RECOVERIES. FARTHER EAST AND STILL NORTH OF THE FAULT, A FEW WELLS WILL AT TIMES FLOW.

SOUTH OF THE COUNTRY CLUB FAULT, THE WATER LEVELS ARE 80 FEET OR SO LOWER. THE HYDROGRAPH OF WELL 2N/22W-10C1 (PLATE 16) SHOWS A SLOW PROGRESSIVE DECLINE OF WATER LEVELS AND PERHAPS SOME DEPLETION OF STORAGE. TO THE TOTAL DEPTH OF THIS WELL (403 FEET) THERE IS LITTLE LIKELIHOOD OF IMPORTANT WESTERLY UNDERFLOW.

#### STORAGE CAPACITY

A STORAGE DEPLETION CURVE (PLATE 8) WAS CONSTRUCTED BY RELATING HISTORIC WATER-LEVEL MEASUREMENTS OF WELL 3N/21W-16K2 TO THE UNWATERED STORAGE CAPACITY COMPUTED FROM A SPECIFIC YIELD STUDY. THE WATER-SURFACE ELEVATION IN WELL 16K2 RANGED FROM A MAXIMUM OF 218 FEET ABOVE SEA LEVEL IN THE SPRING OF 1944 TO A MINIMUM OF 183 FEET IN THE FALL



SANTA PAULA BASIN HYDROGRAPHS

OF 1951. THE MAXIMUM STORAGE DEPLETION (IN THE FALL OF 1951) WAS ABOUT 25,000 ACRE-FEET.

#### MOUND BASIN

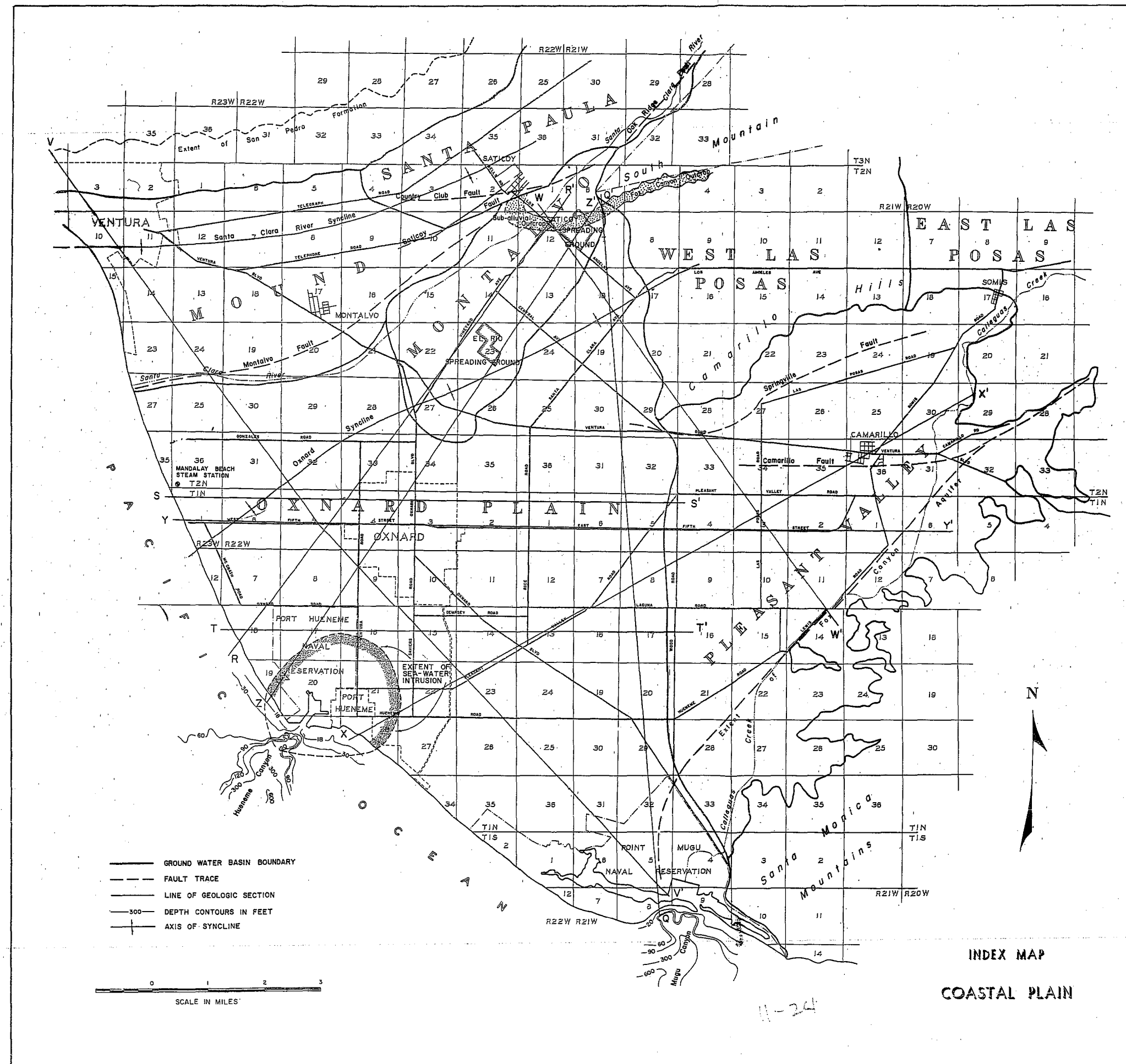
##### BOUNDARIES

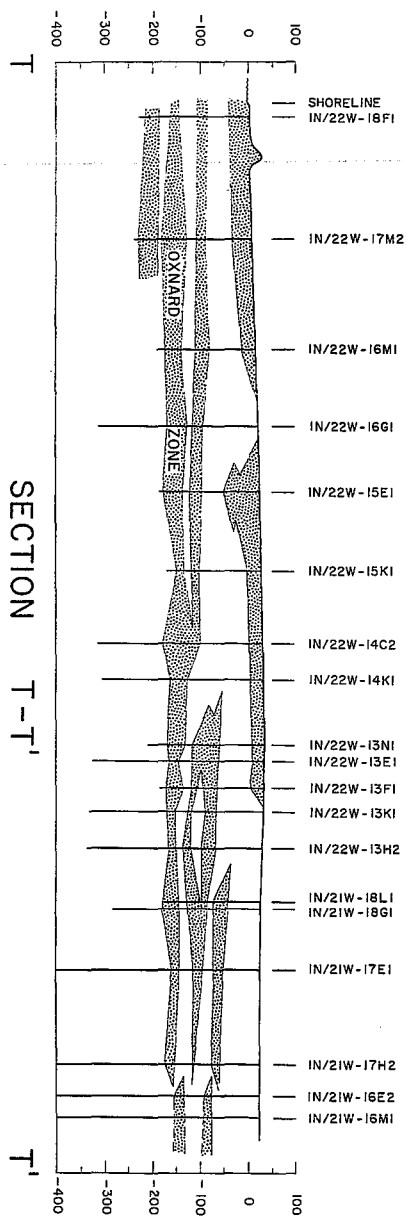
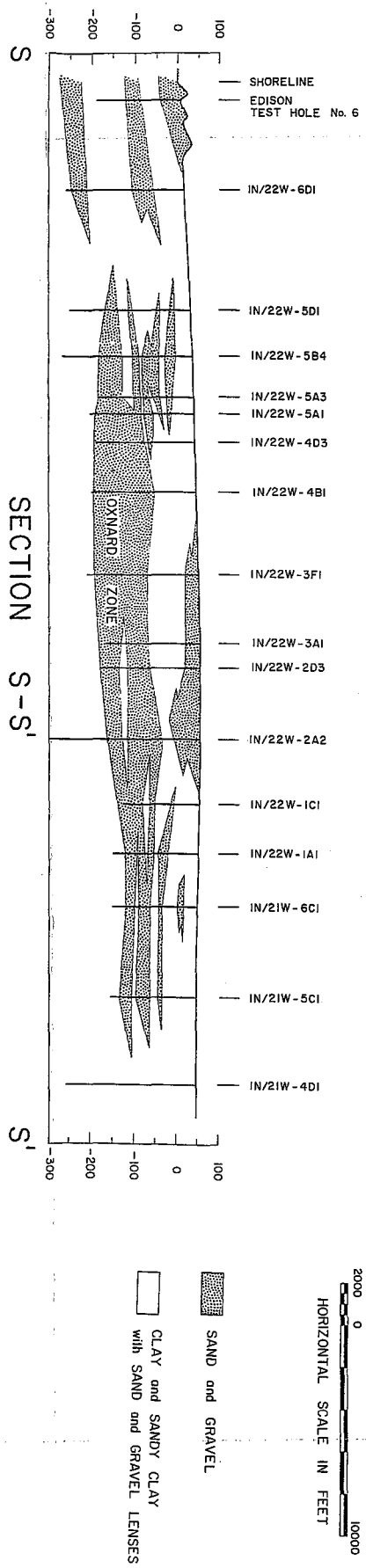
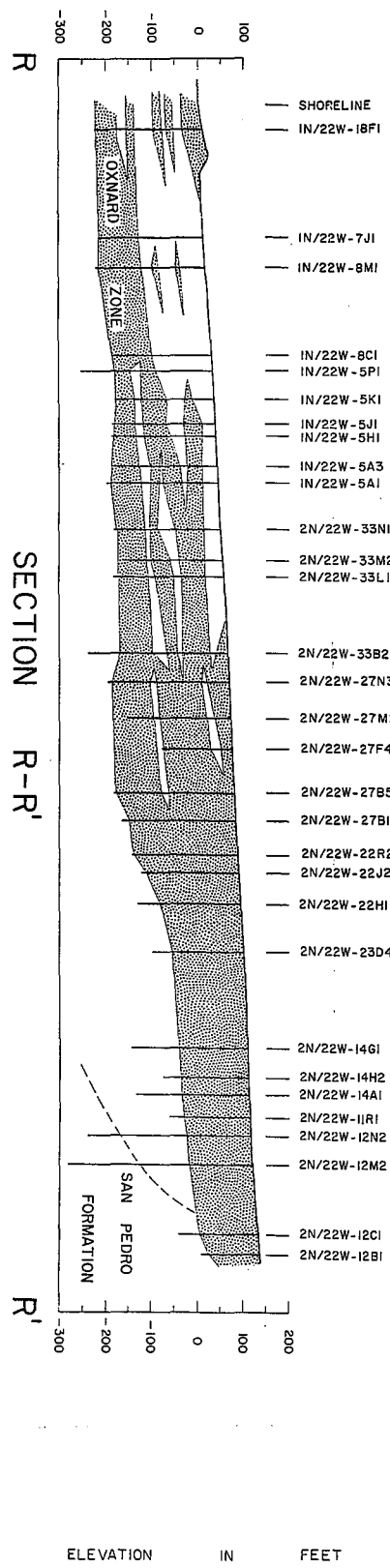
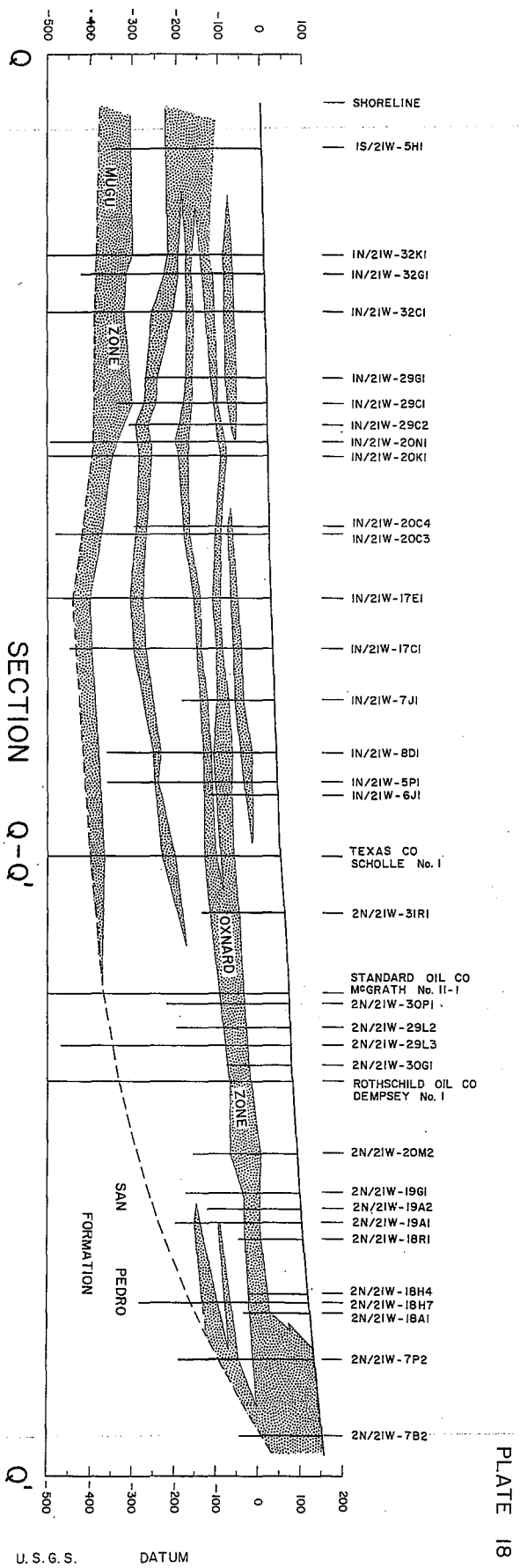
THE BOUNDARIES OF THE MOUND BASIN ARE GIVEN ON PLATE 17. THE NORTHERN BOUNDARY IS TAKEN AS THE BASE OF THE FOOTHILLS, OR THE UPSLOPE LIMIT OF THE ALLUVIAL FAN SURFACES. AS IN THE FILLMORE AND SANTA PAULA BASINS, THE OUTCROP AREAS OF THE SAN PEDRO FORMATION ARE NOT INCLUDED WITHIN THE GROUND WATER BASIN. THE EASTERN BOUNDARY IS IN PART A FAULT AND IN PART A TOPOGRAPHIC DIVIDE. THE SOUTHERN BOUNDARY IS THE APPROXIMATE NORTHERN LIMIT OF THE SANTA CLARA RIVER ALLUVIUM AND THE OXNARD AQUIFER. THE DISTRICT BOUNDARY HAS NO HYDROLOGIC SIGNIFICANCE, AND AS IN BULLETIN 12, THE WESTERN BOUNDARY OF THE MOUND BASIN IS TAKEN TO THE ALLUVIUM OF THE VENTURA RIVER.

##### GROUND WATER GEOLOGY

##### GENERAL GEOLOGY

THE MOUND BASIN CONSISTS OF A BLANKET OF CLAYEY TERRACE MATERIALS AND UNDERLYING COARSE-GRAINED ALLUVIAL AND MARINE DEPOSITS OVERLYING A SYNCLINE DEVELOPED IN THE SAN PEDRO FORMATION. THIS IS THE SAME SYNCLINE WHICH EXTENDS WESTERLY FROM THE EASTERN PART OF THE PIRU BASIN; IT CONTINUES WESTERLY BENEATH THE OCEAN FOR PROBABLY A LARGE DISTANCE. THE MAXIMUM DEPTH TO THE BASE OF THE SAN PEDRO FORMATION ALONG THE AXIS OF THE SYNCLINE IS ABOUT 4000 FEET. A LARGE THICKNESS OF THE FORMATION, INCLUDING THE BASE, CROPS OUT IN THE HILLS NORTH OF THE MOUND BASIN AND THE CITY OF VENTURA. STRIKES ARE NEARLY EAST-WEST AND DIPS ARE FAIRLY STEEP TO THE SOUTH. THE BASAL BEDS CONTINUE WESTERLY BENEATH THE ALLUVIUM OF THE VENTURA RIVER, AND APPEAR AS SMALL OUTCROPS JUST WEST OF THE VENTURA RIVER BEFORE TRENDING OUT BENEATH THE OCEAN. IN THE SOUTHERN PART OF THE MOUND BASIN THE SAN PEDRO BEDS ARE ARCHED UP ALONG THE MONTALVO FAULT (SECTION V-V', PLATE 20). MOST OF THE FOLDING AND FAULTING IS RELATED TO THE MAJOR MIDDLE PLEISTOCENE DIASTROPHISM, BUT THERE HAS BEEN APPRECIABLE FOLDING, TILTING, AND FAULTING OF THE UPPER PLEISTOCENE DEPOSITS, INDICATING THAT DIASTROPHISM HAS CONTINUED ALMOST TO THE RECENT. THE TWO UPLIFTED "MOUNDS" IN THE MOUND BASIN ARE THE RESULT OF THE VERY LATE DIASTROPHISM.





# SHALLOW

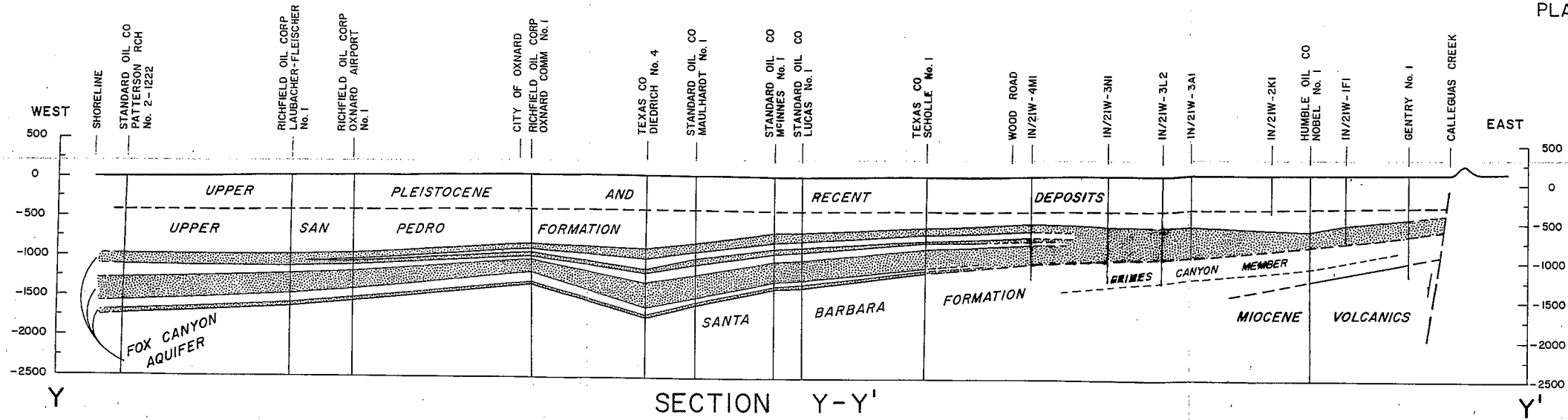
## GEOLOGIC SECTIONS

## OXNARD PLAIN

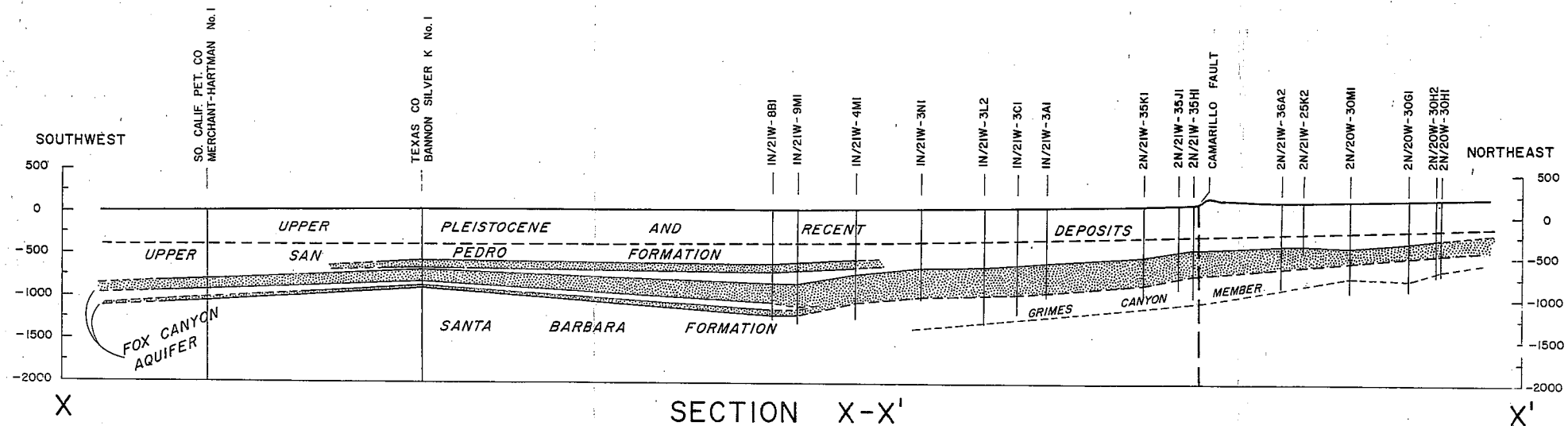
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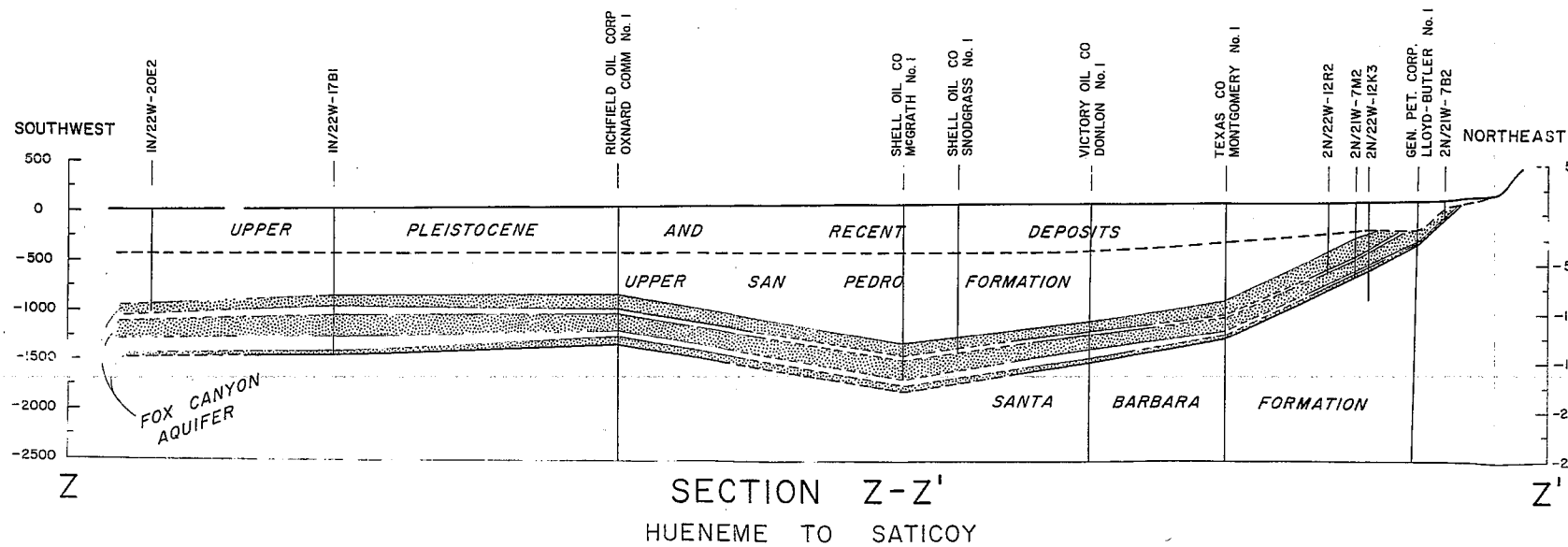
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SECTION Y-Y'  
OXNARD PLAIN-PLEASANT VALLEY  
ALONG FIFTH STREET



SECTION X-X'  
HUENEME TO CAMARILLO



SECTION Z-Z'  
HUENEME TO SATICOY

GEOLOGIC SECTIONS

FOX CANYON AQUIFER

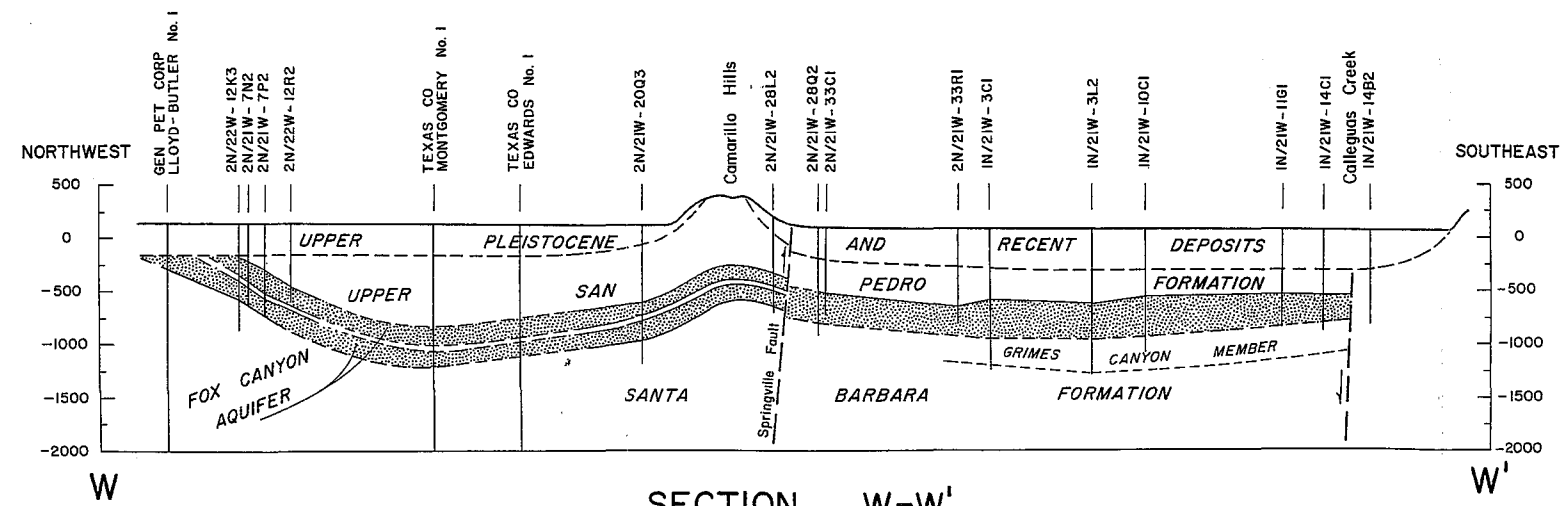
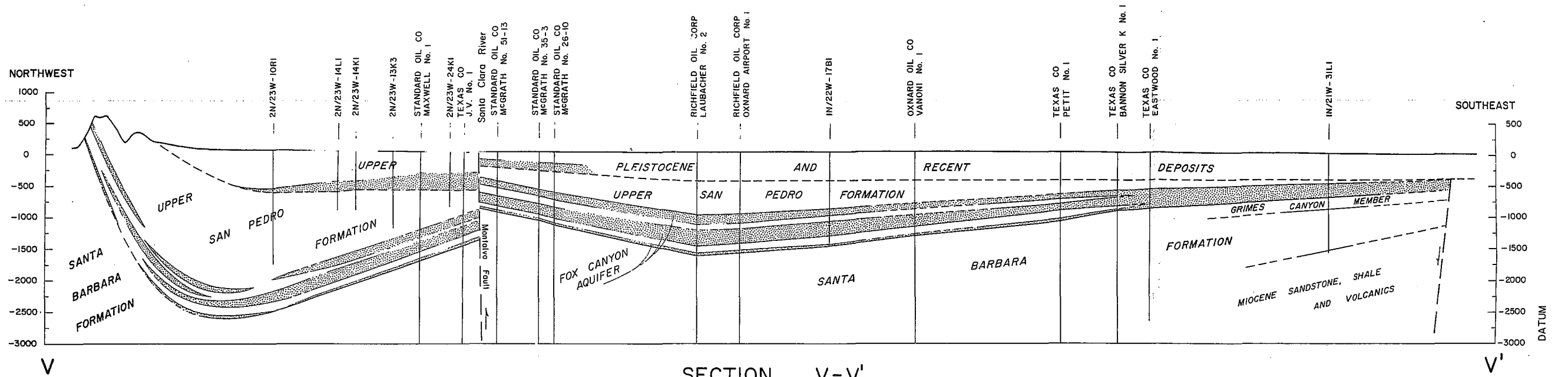
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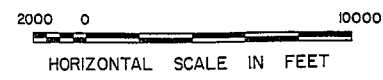
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HORIZONTAL SCALE IN FEET





**GEOLOGIC SECTIONS**  
**FOX CANYON AQUIFER**



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U-27  
Refer page U-25

TABLE III-1. WILCOX-MAGISTAD CLASSIFICATION OF IRRIGATION WATERS AS  
MODIFIED BY DONEEN (REF. 27).

| FACTOR                                     | CLASS I<br>EXCELLENT<br>TO GOOD | CLASS II<br>GOOD TO<br>INJURIOUS | CLASS III<br>INJURIOUS TO<br>UNSATISFACTORY |
|--------------------------------------------|---------------------------------|----------------------------------|---------------------------------------------|
| CONDUCTANCE<br>EC x 10 <sup>6</sup> @ 25°C | LESS THAN 1000                  | 1000-3000                        | MORE THAN 3000                              |
| BORON (PPM)                                | LESS THAN 0.5                   | 0.5-2.0                          | MORE THAN 2.0                               |
| CHLORIDE (ME/L)                            | LESS THAN 5                     | 5-10                             | MORE THAN 10                                |
| SODIUM PERCENTAGE                          | LESS THAN 60                    | 60-75                            | MORE THAN 75                                |

TABLE III-2. DONEEN'S "EFFECTIVE SALINITY" CLASSIFICATION OF  
IRRIGATION WATERS (REF. 27).

| SOIL CONDITIONS                                                                | TERMS USED | CLASS |           |      |
|--------------------------------------------------------------------------------|------------|-------|-----------|------|
|                                                                                |            | I     | II        | III  |
| LITTLE LEACHING OF THE SOIL<br>CAN BE EXPECTED DUE TO LOW<br>PERCOLATION RATES | ME/L       | <3    | 3-5       | >5   |
|                                                                                | PPM        | 165   | 165-275   | 275  |
|                                                                                | LB/AF      | 450   | 450-750   | 750  |
| SOME LEACHING, BUT RESTRICTED<br>DEEP PERCOLATION OR DRAINAGE<br>SLOW          | ME/L       | <5    | 5-10      | >10  |
|                                                                                | PPM        | 275   | 275-550   | 550  |
|                                                                                | LB/AF      | 750   | 750-1500  | 1550 |
| OPEN SOILS. DEEP PERCOLATION<br>OF WATER EASILY ACOMPLISHED                    | ME/L       | <7    | 7-15      | >15  |
|                                                                                | PPM        | 385   | 385-825   | 825  |
|                                                                                | LB/AF      | 1050  | 1050-2250 | 2250 |

NOTES: ME/L ---- MILLI-EQUIVALENTS PER LITER  
PPM ---- PARTS PER MILLION  
LB/AF ---- POUNDS PER ACRE-FOOT

TABLE 111-3 RELATIVE TOLERANCE OF PLANTS TO BORON

(LISTED IN ORDER OF INCREASING TOLERANCE)

| SENSITIVE            | SEMITOLERANT      | TOLERANT    |
|----------------------|-------------------|-------------|
| LEMON                | LIMA BEAN         | CARROT      |
| GRAPEFRUIT           | SWEET POTATO      | LETTUCE     |
| AVOCADO              | BELL PEPPER       | CABBAGE     |
| ORANGE               | PUMPKIN           | TURNIP      |
| THORNLESS BLACKBERRY | ZINNIA            | ONION       |
| APRICOT              | OAT               | BROADBEAN   |
| PEACH                | MILO              | GLADIOLUS   |
| CHERRY               | CORN              | ALFALFA     |
| PERSIMMON            | WHEAT             | GARDEN BEET |
| KADOTA FIG           | BARLEY            | MANGEL      |
| GRAPE                | OLIVE             | SUGAR BEET  |
| APPLE                | RAGGED ROBIN ROSE | DATE PALM   |
| PEAR                 | FIELD PEA         | PALM        |
| PLUM                 | RADISH            | ASPARAGUS   |
| AMERICAN ELM         | SWEETPEA          | ATHEL       |
| NAVY BEAN            | TOMATO            |             |
| JERUSALEM ARTICHOKE  | COTTON            |             |
| ENGLISH WALNUT       | POTATO            |             |
| BLACK WALNUT         | SUNFLOWER         |             |
| PECAN                |                   |             |

### UPPER PLEISTOCENE DEPOSITS

THE UPPER PLEISTOCENE DEPOSITS, WHICH OVERLIE THE SAN PEDRO FORMATION WITH MARKED ANGULAR UNCONFORMITY, RANGE IN THICKNESS FROM 400 FEET OR SO IN THE EASTERN PART OF THE MOUND BASIN TO ABOUT 700 FEET ALONG THE COAST. THERE IS A SUGGESTION THAT THESE BEDS HAVE BEEN DOWNFOLDED GENTLY ALONG THE 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, PRIMARILY SAND AND GRAVEL ZONE, FROM 100 TO 300 FEET THICK. THE BASAL COARSE ZONE IS THICKEST JUST NORTH OF THE RIVER, AND BECOMES THINNER TOWARD THE NORTH. THE COARSE BASAL MATERIALS REPRESENT A DISTINCT PHASE OF DEPOSITION BY THE SANTA CLARA RIVER, WHICH WAS APPARENTLY VERY WIDESPREAD. THE MUGU AQUIFER IN THE SOUTHEASTERN PART OF THE OXNARD PLAIN MAY REPRESENT PART OF THE SAME DEPOSITION.

IN THE EARLY DAYS OF GROUND WATER DEVELOPMENT, THE WELLS PENETRATED ONLY TO THE UPPER PLEISTOCENE AQUIFERS WHERE THESE HAD A SUBSTANTIAL THICKNESS. LATER WELLS WENT DEEPER TO TAP THE AQUIFERS IN THE UNDERLYING LAYERS OF THE SAN PEDRO FORMATION. NOW THERE ARE NUMEROUS WELLS WHICH ARE PERFORATED IN BOTH THE UPPER PLEISTOCENE AND SAN PEDRO AQUIFERS.

### SAN PEDRO FORMATION

NOT ALL OF THE AQUIFERS IN THE THICK SAN PEDRO FORMATION BENEATH THE MOUND BASIN HAVE BEEN TAPPED BY WATER WELLS. IN FACT, BECAUSE OF INADEQUATE WELL CONTROL, THE THICKNESS AND CONTINUITY OF THESE AQUIFERS IS POORLY KNOWN. THE UPPERMOST LAYERS OF THE SAN PEDRO FORMATION ARE NOT EXPOSED IN THE HILLS NORTH OF THE MOUND BASIN, BUT OCCUR ONLY IN THE SUBSURFACE NEAR THE AXIS OF THE SYNCLINE BENEATH THE UPPER PLEISTOCENE DEPOSITS. THESE UPPERMOST LAYERS ARE PRIMARILY CLAYS AND SILTS. IN THE BASAL TWO-THIRDS OF THE FORMATION, GRAVELS AND SANDS ARE MORE ABUNDANT. MOST OF THE WATER PUMPED COMES FROM AQUIFERS IN THE MIDDLE THIRD OF THE SAN PEDRO FORMATION. THE FOX CANYON AQUIFER IS INDICATED BY OIL WELL ELECTRIC LOGS NORTH OF THE MONTALVO FAULT BUT NO WATER WELLS AS YET PENETRATE DEEP ENOUGH TO REACH IT. THE TYPICAL THICK BASAL SANDS OF THE FOX CANYON AQUIFER ARE NOT PRESENT IN THE OUTCROPS NORTH OF THE MOUND BASIN. IT IS INDICATED ONLY DIAGRAMMATICALLY ON SECTION V-V', PLATE 20 THAT THE FOX CANYON AQUIFER TOWARD THE NORTH BECOMES A SERIES OF SAND AND GRAVEL LENSES. THE UPPER SAN PEDRO SHOWN ON SECTION V-V', PLATE 20

INCLUDES MANY SAND AND GRAVEL LAYERS, MANY OF WHICH APPEAR TO BE LENTICULAR.

MUCH OF THE UPPER PART OF THE SAN PEDRO FORMATION NEAR THE MONTALVO FAULT WAS REMOVED IN THE EXTENSIVE PRE-UPPER PLEISTOCENE EROSION. THIS HAS BEEN TRUE ALONG THE ENTIRE LENGTH OF THE MONTALVO FAULT WHICH TRENDS WESTERLY FROM SOUTH MOUNTAIN TO THE COAST. THE DISPLACEMENT IN THE SAN PEDRO FORMATION DECREASES WESTERLY, FROM SEVERAL THOUSAND FEET AT THE WEST END OF SOUTH MOUNTAIN TO ABOUT 500 FEET NEAR THE COAST (SECTION V-V', PLATE 20). THE DISPLACEMENT IN THE OVERLYING UPPER PLEISTOCENE DEPOSITS MAY BE AS MUCH AS 400 FEET.

WITHIN THE MOUND BASIN THE SAN PEDRO FORMATION HAS BEEN DISPLACED BY SEVERAL LARGE FAULTS. THE SATICOY FAULT, WHICH FORMS A PART OF THE EASTERN BOUNDARY OF THE BASIN, TRENDS WESTERLY AND INTO THE MOUND BASIN, AND APPARENTLY THE THROW DECREASES IN THAT DIRECTION. ANOTHER FAULT OR GROUP OF FAULTS IS ASSOCIATED WITH THE "MOUNDS" IN SECTIONS 17 AND 18, T2N, R22W.

#### SOURCES OF RECHARGE

BECAUSE OF GEOLOGIC COMPLICATIONS, THE SOURCES AND AMOUNTS OF RECHARGE TO THE MOUND BASIN ARE DIFFICULT TO DETERMINE. IN PREVIOUS STUDIES IT WAS ASSUMED THAT THERE IS A LARGE AMOUNT OF RECHARGE DERIVED AS UNDERFLOW FROM THE SANTA PAULA BASIN. THE FOLLOWING FACTS BEAR UPON THIS PROBLEM:

- (1) THERE IS NO THICK SATURATED RECENT ALLUVIUM CROSSING THE COMMON BOUNDARY;
- (2) TRANSMISSION AS UNDERFLOW MUST OCCUR THROUGH EITHER THE UPPER PLEISTOCENE DEPOSITS OR THE SAN PEDRO FORMATION;
- (3) THE UPPER PART OF THE UPPER PLEISTOCENE MATERIALS IS ALMOST ENTIRELY CLAY AND SILT; THE UNDERFLOW WOULD HAVE TO MOVE THROUGH THE PERMEABLE BASAL LAYERS;
- (4) ALONG THE SATICOY FAULT A RIDGE OF SAN PEDRO FORMATION HAS BEEN UPLIFTED ON THE SOUTH BLOCK. THE UPPER PLEISTOCENE AQUIFERS HAVE BEEN DOWNFAULTED (SECTION D-D', PLATE 14); THIS FAULT SUPPORTS A LARGE DIFFERENCE IN WATER LEVELS.
- (5) THE COUNTRY CLUB FAULT ALSO SHOWS A BREAK IN WATER LEVELS IN WELLS WHICH TAP THE UPPER PLEISTOCENE DEPOSITS. THE THROW IN THE SAN PEDRO FORMATION MAY BE AS MUCH AS 2000 FEET.

(6) THE TRIANGULAR AREA BETWEEN THE COUNTRY CLUB AND SATICOY FAULTS DOES NOT APPEAR TO HAVE MUCH RECHARGE, AS SHOWN BY THE HYDROGRAPH OF WELL 2N/22W-10C1 (PLATE 16). THE RECORDS SHOW THIS WELL TO BE PERFORATED ONLY IN THE SAN PEDRO FORMATION. THE UPPER PLEISTOCENE GRAVELS APPEAR TO HAVE BEEN POOR PRODUCERS HERE.

(7) A WELL DRILLED TO 1300 OR 1400 FEET IN THE "N" PLOT OF SECTION 4 IS REPORTED TO HAVE ENCOUNTERED LITTLE WATER.

FROM THE ABOVE LINES OF EVIDENCE IT IS SUGGESTED THAT THE UNDERFLOW FROM THE SANTA PAULA BASIN TO THE MOUND BASIN IS VERY SMALL.

THE THICK IMPERMEABLE NEAR-SURFACE CLAYS PRECLUDE ANY APPRECIABLE RAINFALL PENETRATION TO THE BASAL UPPER PLEISTOCENE AQUIFERS. MOST OF THESE AQUIFERS DO NOT CROP OUT, BUT APPEAR TO PINCH OUT IN THE SUBSURFACE SOUTH OF THE FOOTHILLS. THIS THINNING IS INDICATED ON SECTION V-V', PLATE 20. ONLY A FEW OF THE PUMPED SAN PEDRO AQUIFERS HAVE SURFACE OUTCROPS AND COULD BE REPLENISHED BY RAINFALL PENETRATION. THE AMOUNT OF THIS REPLENISHMENT IS VERY SMALL.

RECHARGE TO THE MOUND BASIN IS DERIVED LARGELY FROM THE MONTALVO BASIN AND THE OXNARD PLAIN. THE INLAND PORTION OF THE MOUND BASIN RECEIVES MOST OF ITS RECHARGE FROM THE MONTALVO BASIN. THIS SUGGESTION IS SUPPORTED BY THE PERSISTENT WESTERLY WATER-LEVEL SLOPE FROM THE MONTALVO BASIN TO THIS PORTION OF THE MOUND BASIN. THE HYDROLOGIC CONTINUITY IS BELIEVED TO BE MAINTAINED PRIMARILY THROUGH THE BASAL UPPER PLEISTOCENE AQUIFERS. THE OXNARD AQUIFER DOES NOT EXTEND INTO THE MOUND BASIN; THE SAN PEDRO FORMATION IS BADLY FAULTED. SOME IMPEDIMENT TO THE WESTERLY FLOW OF WATER IS AFFORDED BY THE EXTENSION OF THE SATICOY FAULT.

RECHARGE AS UNDERFLOW FROM THE OXNARD PLAIN TO THE MOUND BASIN MUST CROSS THE BARRIER OF THE MONTALVO FAULT. THIS FAULTING HAS NOT AFFECTED THE OXNARD AQUIFER, BUT WATER ATTEMPTING TO MOVE NORTHWARD AT THE SHALLOW LEVELS OF THE OXNARD AQUIFER WOULD HAVE TO MOVE INTO THE THICK UPPER PLEISTOCENE CLAYS OF THE MOUND BASIN. IT MAY BE CONCLUDED THAT THERE IS ESSENTIALLY NO POSSIBILITY OF WATER MOVING FROM THE OXNARD AQUIFER INTO THE MOUND BASIN. AT DEPTHS BETWEEN 300 AND 600 FEET FROM THE GROUND SURFACE THERE IS OPPORTUNITY FOR NORTHERLY UNDERFLOW BUT AT LEAST A PARTIAL RESTRICTION IS OFFERED BY THE MONTALVO FAULT. AT GREATER DEPTHS,

REPEATED FAULTING AND GREATER THROW ON THE MONTALVO FAULT WOULD MORE EFFECTIVELY HINDER UNDERFLOW. MOVEMENTS WITHIN THE SAN PEDRO FORMATION FROM THE OXNARD PLAIN TO THE MOUND BASIN ARE BELIEVED NOT TO BE IMPORTANT. THE INFERIOR QUALITY WATERS IN THE FOX CANYON AQUIFER IN SECTION 25, T2N, R23W SUGGEST POOR CIRCULATION.

#### BASIN OUTFLOW

WATER LEAVES THE MOUND BASIN PRIMARILY AS PUMPED EXTRACTIONS. DURING WET PERIODS THERE IS PROBABLY AN APPRECIABLE OUTFLOW TO THE OCEAN WITHIN THE BASAL UPPER PLEISTOCENE SANDS AND GRAVELS. IF OUTFLOW TO THE OCEAN TAKES PLACE IN THE SAN PEDRO FORMATION IT WOULD DO SO MOST EASILY FROM THE BASAL BEDS WHICH HAVE SUBMARINE OUTCROPS WEST OF THE VENTURA RIVER. BECAUSE OF THE KNOWN DEPTHS OF THE SAN PEDRO AQUIFERS AND THE KNOWN OFFSHORE CONFIGURATION, IT IS HIGHLY UNLIKELY THAT THERE WOULD BE ANY SUBMARINE SAN PEDRO OUTCROPS ALONG THE WESTERLY EXTENSION OF THE SANTA CLARA RIVER SYNCLINE. THERE IS A POSSIBILITY, HOWEVER, THAT IF HYDRAULIC GRADIENTS PERMITTED, WATER COULD MOVE UPWARD IN THE SAN PEDRO AQUIFERS, ACROSS THE UNCONFORMITY, INTO THE BASAL UPPER PLEISTOCENE GRAVELS, THEN TO THE OCEAN FLOOR. THERE IS LITTLE OPPORTUNITY FOR MOVEMENTS OUT OF THE MOUND BASIN INTO EITHER MONTALVO BASIN OR THE OXNARD PLAIN; WATER-LEVEL GRADIENTS ARE PERSISTENTLY IN THE OTHER DIRECTION.

#### WATER MOVEMENTS

UNDERGROUND WATER IN THE MOUND BASIN MOVES PREDOMINANTLY TO THE WEST OR SOUTHWEST. THE MAIN FLOW TAKES PLACE WITHIN THE BASAL UPPER PLEISTOCENE DEPOSITS FROM THE MONTALVO BASIN THROUGH THE MOUND BASIN TO THE SUBMARINE OUTCROPS. BECAUSE THE UPPER PLEISTOCENE GRAVELS BECOME THINNER TO THE NORTH, MOST OF THE WATER MUST MOVE THROUGH THE SOUTHERN PART OF THE MOUND BASIN. THESE MOVEMENTS MUST BE SOMEWHAT RETARDED BY THE FAULTING WHICH IS KNOWN TO HAVE OCCURRED IN THE VERY LATE PLEISTOCENE. NEAR THE COAST, WHEN PIEZOMETRIC LEVELS IN THE UPPER PLEISTOCENE AQUIFERS ARE DEPRESSED TO NEAR OR BELOW SEA LEVEL, THERE IS PROBABLY EASTERLY MOVEMENT FROM THE SEAWARD EXTENSIONS OF THOSE AQUIFERS.

THERE ARE SO FEW WELLS PERFORATED ONLY IN THE SAN PEDRO AQUIFERS THAT IT IS DIFFICULT TO DESCRIBE THE WATER MOVEMENTS. FAULTS OF LARGE THROW IN THE SAN PEDRO FORMATION GREATLY RESTRICT MOVEMENTS INTO THE MOUND BASIN FROM THE SANTA PAULA BASIN, THE MONTALVO BASIN, AND THE OXNARD

PLAIN. THERE HAS PROBABLY BEEN LITTLE CIRCULATION WITHIN THE SAN PEDRO FORMATION IN THE VERY LATE PLEISTOCENE AND RECENT BECAUSE OF A DEARTH OF SUBMARINE OUTCROPS AND OTHER AREAS OF ESCAPE. THE WELLS IN THE SOUTHERN COASTAL PORTION OF THE MOUND BASIN TAP SAN PEDRO AQUIFERS WHICH ARE IN HYDROLOGIC CONTINUITY WITH THE OVERLYING UPPER PLEISTOCENE AQUIFERS BECAUSE OF UNCONFORMITY TRUNCATIONS OR MULTI-ZONE WELLS.

#### FLUCTUATIONS OF WATER LEVELS

WATER-LEVEL TRENDS IN THE SAN PEDRO AQUIFERS ALONG THE COAST NEAR THE CITY OF VENTURA ARE REPRESENTED BY THE HYDROGRAPH OF WELL 2N/23W-14Q1 (PLATE 23). TWO DISTINCTIVE FEATURES OF THIS HYDROGRAPH ARE (1) A MARKED TENDENCY TO FLOW IN THE WET PERIODS, AND (2) A MARKED TENDENCY DURING DRY PERIODS TO RETURN TO SEA LEVEL AFTER HAVING BEEN PUMPED BELOW SEA LEVEL. THE HIGH HEADS DURING THE WET PERIODS ARE RELATED TO POSITIVE RECHARGE AND NOT MERELY A PRESSURE RESPONSE. IT IS DOUBTFUL THAT THE RECHARGE COULD BE EXPLAINED ENTIRELY BY RAINFALL PENETRATION ON THE OUTCROP AREAS; THE PERFORATED AQUIFER MAY NOT EVEN HAVE AN OUTCROP. THE RECHARGE MAY BE DERIVED FROM THE UPPER PLEISTOCENE AQUIFERS ABOVE THE UNCONFORMITY. THE DRY PERIOD WATER LEVELS ARE DEFINITELY RELATED TO SEA LEVEL. SINCE SUBMARINE OUTCROPS OF SAN PEDRO AQUIFERS THIS HIGH IN THE FORMATION ARE UNLIKELY, THE PRESSURE HEAD OF SEA LEVEL WOULD HAVE TO BE TRANSMITTED THROUGH THE OVERLYING UPPER PLEISTOCENE AQUIFERS.

INLAND IN THE MOUND BASIN WATER-LEVEL RESPONSES ARE QUITE DIFFERENT, AS ILLUSTRATED BY THE HYDROGRAPH OF WELL 2N/22W-9K3 (PLATE 23). THIS WELL APPEARS TO BE PERFORATED IN A SAN PEDRO AQUIFER FREELY CONNECTED WITH THE OVERLYING UPPER PLEISTOCENE. THERE WAS A GOOD RECOVERY DURING THE LATE THIRTIES AND EARLY FORTIES, AND A FAIRLY SHARP DECLINE FROM 1945 TO 1951. THE RECOVERY FROM THE 1952 WET YEAR WAS FAIRLY SLOW AND MAY NOT HAVE BEEN COMPLETED UNTIL LATE 1952 OR EARLY 1953. ALTHOUGH THERE IS A SUGGESTION OF OVERDRAFT, IT WOULD BE DIFFICULT TO SUPPORT UNTIL THE RESPONSES OF THE NEXT WET PERIOD ARE AVAILABLE.

#### MONTALVO BASIN

##### BOUNDARIES

THE MONTALVO BASIN, ALSO REFERRED TO AS THE OXNARD FOREBAY BASIN (REF. 23), COMPRISES ABOUT 6400 ACRES, AND INCLUDES THE MAIN FREE WATER-TABLE AREA OF THE OXNARD PLAIN (PLATE 17). NEAR THE NORTHEAST CORNER OF THE

BASIN THE BOUNDARY IS EXTENDED UP THE SANTA CLARA RIDER TO THE POINT WHERE THE UNITED WATER CONSERVATION DISTRICT CURRENTLY DIVERTS FOR SPREADING OPERATIONS. AT THIS POSITION THE BOUNDARY COINCIDES WITH THE OCCURENCE OF PERENNIAL RISING WATER, AND PROBABLY WITH A CONSTRICTION OF THE RECENT ALLUVIUM. THE NORTH-WESTERN BOUNDARY IS IN PART THE SATICOY FAULT AND IN PART THE BREAK BETWEEN THE RECENT ALLUVIUM AND THE CLAYEY TERRACE DEPOSITS OF THE MOUND BASIN. NEAR THE UPSTREAM LIMIT OF THE MONTALVO BASIN THE EASTERN BOUNDARY IS A SHARP LINE BETWEEN RECENT ALLUVIUM AND THE END OF SOUTH MOUNTAIN. THE REMAINDER OF THE BASIN BOUNDARY -- ON BOTH THE SOUTHEAST AND SOUTHWEST SIDES -- DOES NOT COINCIDE WITH A SHARP CHANGE OF GEOLOGIC CONDITIONS. INSTEAD, THESE LINES ARE INTENDED TO PORTRAY THE APPROXIMATE POSITION OF A GRADATIONAL CHANGE FROM WATER-TABLE CONDITIONS TO CONFINED CONDITIONS AS CLAYS BECOME MORE ABUNDANT. GEOLOGIC CROSS-SECTION R-R' ON PLATE 18 ILLUSTRATES CONDITIONS AT THE SOUTHWEST BOUNDARY, WHERE THE SO-CALLED "CLAY CAP" BEGINS. THE DESIGNATION OF THIS GRADATIONAL ZONE BY MEANS OF A LINE IS HIGHLY DESIRABLE IN COMPUTING RAINFALL PENETRATION AND IRRIGATION USE. THE BOUNDARIES AS DELINEATED ARE ESSENTIALLY THE SAME AS THOSE GIVEN IN AN EARLIER REPORT (REF. 49) AND THOSE SHOWN FOR THE OXNARD FOREBAY BASIN IN BULLETIN 12 (REF. 23).

## GROUND WATER GEOLOGY

### GENERAL GEOLOGY

THE MAIN WATER-BEARING DEPOSITS OF MONTALVO BASIN CONSIST OF COARSE ALLUVIAL MATERIALS OF RECENT AND UPPER PLEISTOCENE AGE OVERLYING WITH MARKED UNCONFORMITY A SEQUENCE OF PRE-MIDDLE PLEISTOCENE DEPOSITS. AN UNCONFORMITY OF LESSER MAGNITUDE SEPARATES THE SHALLOW GRAVELS FROM THE UPPER PLEISTOCENE LAYERS. OVER MOST OF THE AREA OF THE MONTALVO BASIN THE SAN PEDRO FORMATION IS DIRECTLY BENEATH THE MIDDLE PLEISTOCENE UNCONFORMITY. THE FOX CANYON AQUIFER, GENERALLY THE COARSE PERMEABLE BASAL LAYERS OF THE SAN PEDRO FORMATION, IS DIRECTLY UNDER THE ALLUVIAL DEPOSITS BENEATH THE SATICOY SPREADING GROUNDS (PLATE 17). THIS AREA OF CONTACT BETWEEN THE ALLUVIUM AND THE FOX CANYON AQUIFER WILL BE REFERRED TO AS THE "SUB-ALLUVIAL OUTCROP". FARTHER NORTHEAST, WHERE THE RIVER HAS ERODED THE END OF SOUTH MOUNTAIN, THE FOX CANYON AQUIFER HAS BEEN REMOVED AND THE ALLUVIAL DEPOSITS REST DIRECTLY ON THE SANTA BARBARA FORMATION, WHICH HERE IS NONWATER-BEARING.

THE CURVED SUB-ALLUVIAL OUTCROP OF THE FOX CANYON AQUIFER IS RELATED TO A WESTWARD-PLUNGING ANTICLINE WHOSE AXIAL TRACE IN GENERAL FOLLOWS THE SANTA CLARA RIVER. THE PLUNGING ANTICLINE IS TERMINATED ON THE NORTH FLANK BY THE SATICOY FAULT, PROBABLY A BRANCH OF THE OAK RIDGE FAULT. IN THE SATICOY AREA THE GEOLOGIC STRUCTURE IS PROBABLY FAR MORE COMPLICATED THAN CAN BE DESCRIBED FROM THE EXISTING DATA.

#### ALLUVIAL AQUIFERS

THE TERM "OXNARD AQUIFER" OR "OXNARD ZONE" REFERS, IN THE MONTALVO BASIN, TO THE RECENT ALLUVIUM AND THE COARSE UPPER LAYERS OF THE UPPER PLEISTOCENE DEPOSITS. THE THICKNESS OF THE OXNARD AQUIFER IN THE MONTALVO BASIN IS AS MUCH AS 150 FEET. BENEATH THE PREDOMINANTLY COARSE LAYERS CONSTITUTING THE OXNARD AQUIFER ARE ALTERNATING LAYERS OF SANDS, GRAVELS, AND CLAYS COMPRISING THE LOWER PART OF THE UPPER PLEISTOCENE DEPOSITS. SEAWARD FROM THE MONTALVO BASIN, THE OXNARD AQUIFER COMPRISES THE PERMEABLE LAYERS JUST BELOW THE CLAY CAP. IN THE NORTHEASTERN CORNER OF THE MONTALVO BASIN THERE WAS VERY LATE UPLIFT AND SOME LAYERS DEPOSITED EARLY IN THE UPPER PLEISTOCENE WERE REMOVED BY EROSION PRIOR TO THE DEPOSITION OF THE OXNARD AQUIFER. AT THE END OF SOUTH MOUNTAIN THE EROSIONAL SURFACE CUT ON THE SANTA BARBARA FORMATION APPEARS TO BE OVERLAIN DIRECTLY BY RECENT ALLUVIUM.

#### FOX CANYON AQUIFER

THE "FOX CANYON AQUIFER" REFERS TO A ZONE OF SANDS AND GRAVELS WITH INTERBEDDED CLAYS NEAR THE BASE OF THE SAN PEDRO FORMATION. THESE PERMEABLE LAYERS FORM EXTENSIVE EAST-WEST TRENDING OUTCROPS ON THE SOUTH FLANK OF SOUTH MOUNTAIN. IN MONTALVO BASIN THE WESTWARD EXTENSION OF THESE SURFACE OUTCROPS IS BURIED BY ALLUVIUM AND IS REFERRED TO AS THE "SUB-ALLUVIAL OUTCROP". FROM THE SUB-ALLUVIAL OUTCROP THE FOX CANYON AQUIFER DIPS SOUTHERLY ABOUT 8 DEGREES. THE PRESENT WELLS DRAWING FROM THE FOX CANYON AQUIFER IN MONTALVO BASIN ARE NEAR THE SUB-ALLUVIAL OUTCROP WHERE THE AQUIFER IS STILL AT A RELATIVELY SHALLOW DEPTH.

#### SOURCES OF RECHARGE

THE MAIN SOURCES OF RECHARGE TO THE MONTALVO BASIN ARE THE SURFACE FLOWS EXITING FROM SANTA PAULA BASIN. IN PART, THESE FLOWS REACH THE WATER TABLE BY NATURAL PERCOLATION IN THE REACH BETWEEN THE UPPER BASIN BOUNDARY AND MONTALVO BRIDGE. HOWEVER, LARGE AMOUNTS OF SURFACE

FLOWS ARE DIVERTED FROM THE RIVER AND ALLOWED TO PERCOLATE WITHIN THE SATICOY AND EL RIO SPREADING GROUNDS. UNDERFLOW FROM SANTA PAULA BASIN IS BELIEVED TO OCCUR ALMOST EXCLUSIVELY THROUGH THE RECENT ALLUVIUM. THE INTERDASIN TRANSFER WITHIN THE SAN PEDRO FORMATION IS CONSIDERED UNLIKELY BECAUSE THERE IS ONLY A SMALL AREA WHERE THERE MIGHT BE HYDROLOGIC CONTINUITY, AND EVEN IN THIS AREA FAULTING IS KNOWN TO RESTRICT UNDERFLOW. PENETRATING RAIN WATER IN THE MONTALVO BASIN IS ABLE TO REACH THE WATER TABLE MORE EASILY THAN OVER LARGE AREAS IN THE UPSTREAM BASINS. ALTHOUGH OCCURRING ONLY FOR SHORT PERIODS OF TIME AND UNIMPORTANT QUANTITATIVELY, ANOTHER SOURCE OF RECHARGE IS OF INTEREST. AT TIMES OF EXTREMELY LOW WATER TABLES IN THE MONTALVO BASIN, A PIEZOMETRIC SLOPE IS DEVELOPED WITHIN THE FOX CANYON AQUIFER FROM THE HIGH OUTCROP AREAS ON SOUTH MOUNTAIN TOWARD THE SUB-ALLUVIAL OUTCROP. UNDER SUCH CONDITIONS WATER MOVES WESTERLY IN THE FOX CANYON AQUIFER FROM THE WEST LAS POSAS AREA, UP THROUGH THE SUB-ALLUVIAL OUTCROP AND INTO THE OVERLYING ALLUVIAL DEPOSITS.

#### BASIN OUTFLOW

THE LARGEST PART OF THE WATER LEAVING THE MONTALVO BASIN AS UNDERFLOW MOVES SEAWARD THROUGH THE OXNARD AQUIFER. A MUCH SMALLER AMOUNT MOVES DOWNWARD FROM THE ALLUVIAL ZONES THROUGH THE SUB-ALLUVIAL OUTCROP BENEATH THE SATICOY SPREADING GROUNDS. WITHIN THE FOX CANYON AQUIFER THE WATER MOVES WESTERLY TOWARD THE OCEAN AND SOUTHERLY TOWARD THE CENTERS OF PUMPING IN PLEASANT VALLEY. ANOTHER PART OF THE UNDERFLOW MOVES INTO THE MOUND BASIN PRIMARILY THROUGH THE BASAL UPPER PLEISTOCENE GRAVELS. AT TIMES OF HIGH WATER LEVELS, SUCH AS DURING THE PERIOD 1941-1945, UNDERFLOW LEAVING MONTALVO BASIN MOVES SEAWARD ABOVE THE CLAY CAP.

THE MAXIMUM OUT UNDERFLOW DOES NOT NECESSARILY OCCUR AT TIMES OF MAXIMUM WATER-TABLE ELEVATIONS. WHEN THE MONTALVO BASIN IS FULL THE WATER-TABLE SLOPES ARE USUALLY RELATIVELY FLAT. SINCE THE RATE OF OUT UNDERFLOW IS DIRECTLY PROPORTIONAL TO WATER-TABLE SLOPE, THE FLAT SLOPES DO NOT PROMOTE RAPID UNDERFLOW. THE MAXIMUM OUT UNDERFLOW OCCURS WHEN THERE IS AN OPTIMUM COMBINATION OF STEEP WATER-TABLE SLOPE AND A LARGE SATURATED CROSS-SECTION THROUGH WHICH THE UNDERFLOW IS MOVING.

#### MOVEMENTS OF UNDERGROUND WATER

THE PREDOMINANT DIRECTION OF WATER MOVEMENT IN THE ALLUVIAL DEPOSITS OF THE MONTALVO BASIN IS FROM NORTHEAST TO SOUTHWEST. WHEN THE

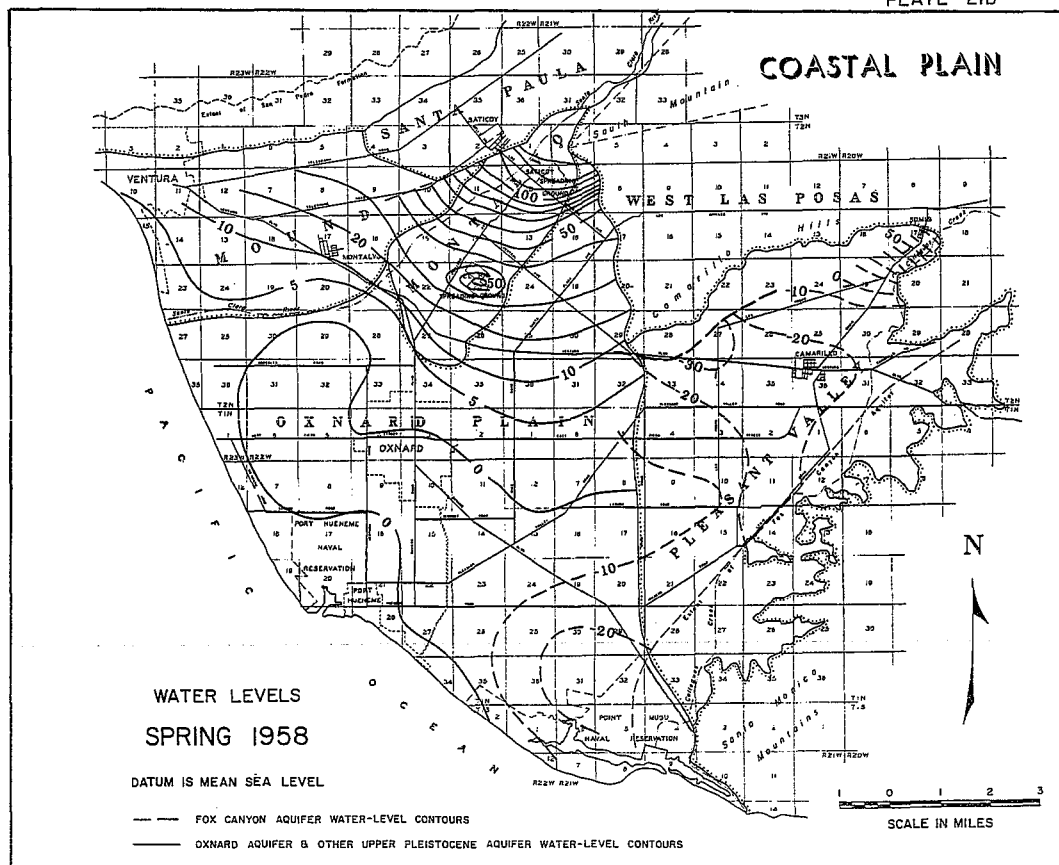
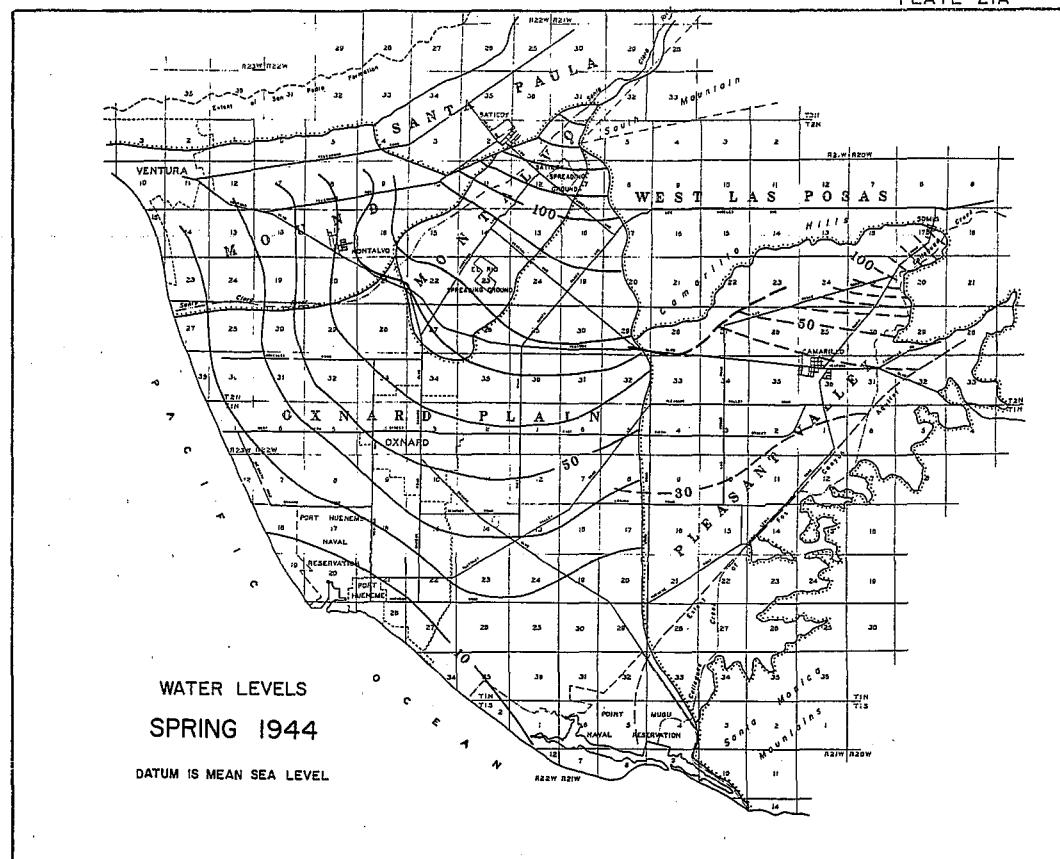
BASIN IS FULL, AS IT WAS IN THE SPRING OF 1944 (PLATE 21), THE WATER-TABLE SLOPE IS UNIFORM AND ABOUT 15 FEET PER MILE. BY WAY OF CONTRAST, NEAR THE END OF A GROUP OF DRY YEARS, WHEN THERE IS MUCH DEPLETION OF STORAGE, THE WATER-TABLE SLOPE IN THE NORTHEASTERN PART OF THE BASIN WAS ABOUT 35 FEET PER MILE (PLATE 22). THE GRADIENT FLATTENED NOTICEABLY TOWARD THE MIDDLE OF THE BASIN AND REMAINED FAIRLY UNIFORM TO THE SOUTHWESTERN BOUNDARY AT SLIGHTLY OVER 5 FEET PER MILE. EVEN AT TIMES OF MAXIMUM STORAGE DEPLETION IN THE MONTALVO BASIN, SEAWARD OUT UNDERFLOW WITHIN THE OXNARD AQUIFER CONTINUES. DESPITE THE FACT THAT WATER-LEVEL ELEVATIONS IN THE SOUTHWESTERN PART OF THE MONTALVO BASIN ARE BELOW SEA LEVEL, THE DEEP PUMPING TROUGH CLOSER TO THE OCEAN MAINTAINS A PERSISTENT SEAWARD GRADIENT OF THE WATER LEVELS.

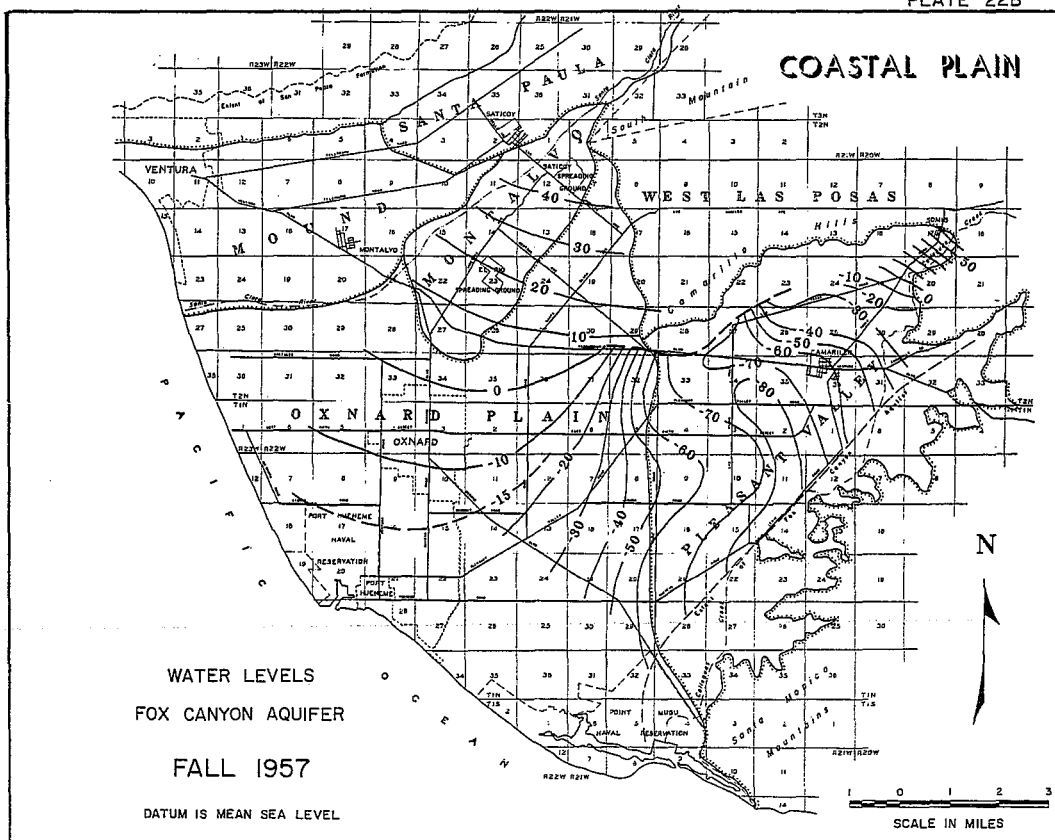
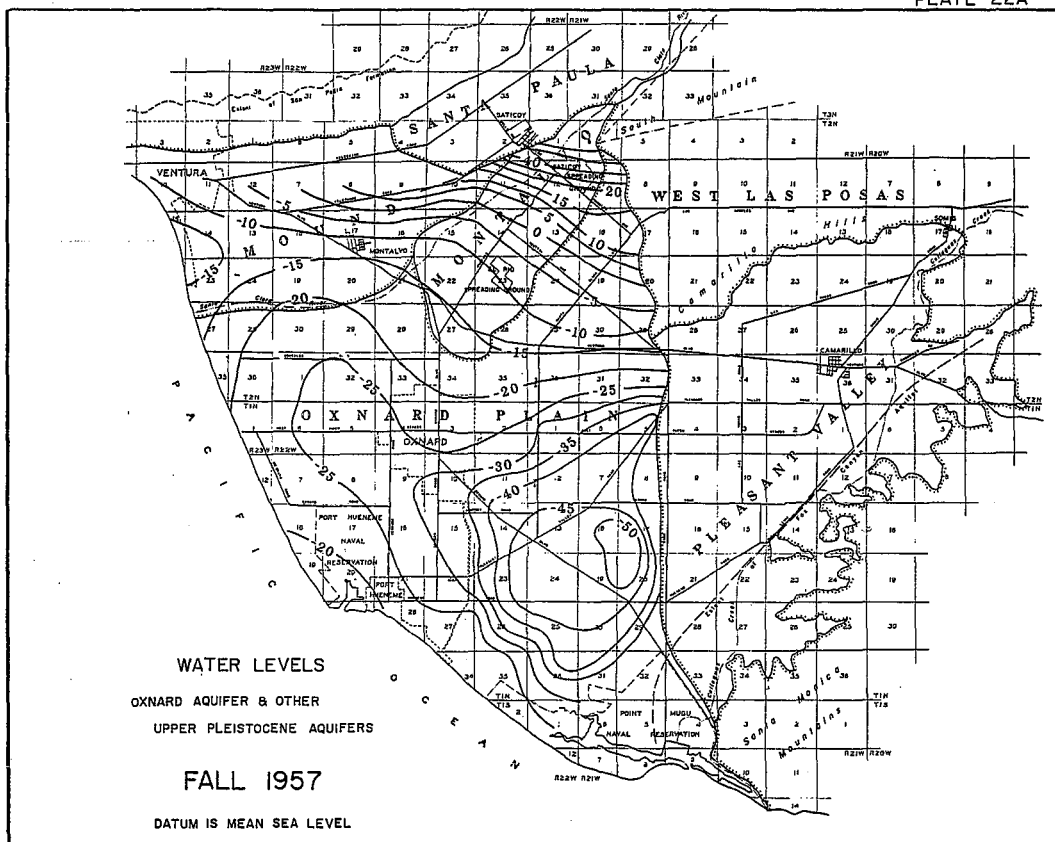
A SIGNIFICANT AMOUNT OF UNDERFLOW LEAVES THE MONTALVO BASIN AFTER PASSING THROUGH THE SUB-ALLUVIAL OUTCROP AND INTO THE FOX CANYON AQUIFER. THE FACT THAT THE FOX CANYON AQUIFER REPRESENTS A DISTINCT HYDRAULIC SYSTEM IS DEMONSTRATED BY THE PIEZOMETRIC SURFACE, WHICH ONLY 1/2 MILE FROM THE SUB-ALLUVIAL OUTCROP RISES MANY FEET ABOVE THE LOCAL WATER TABLE. MOVEMENT OF WATER WITHIN THE FOX CANYON AQUIFER IS WESTERLY TOWARD THE OCEAN AND SOUTHERLY TOWARD THE HEAVILY PUMPED AREAS IN PLEASANT VALLEY.

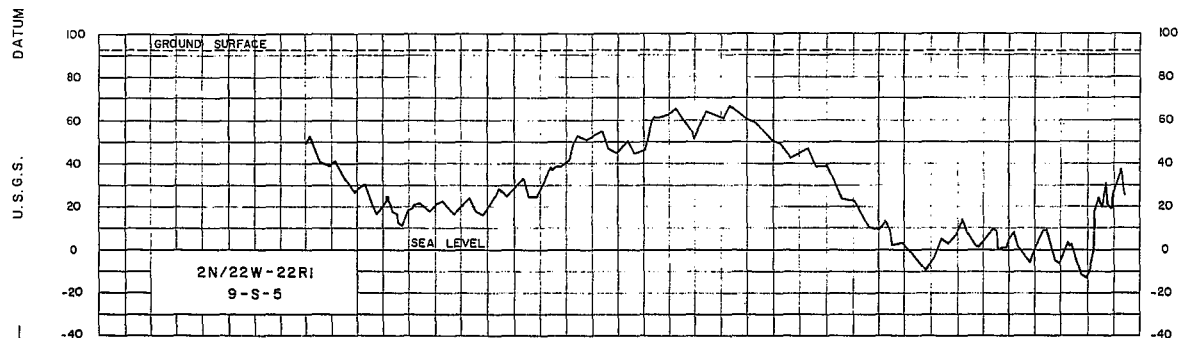
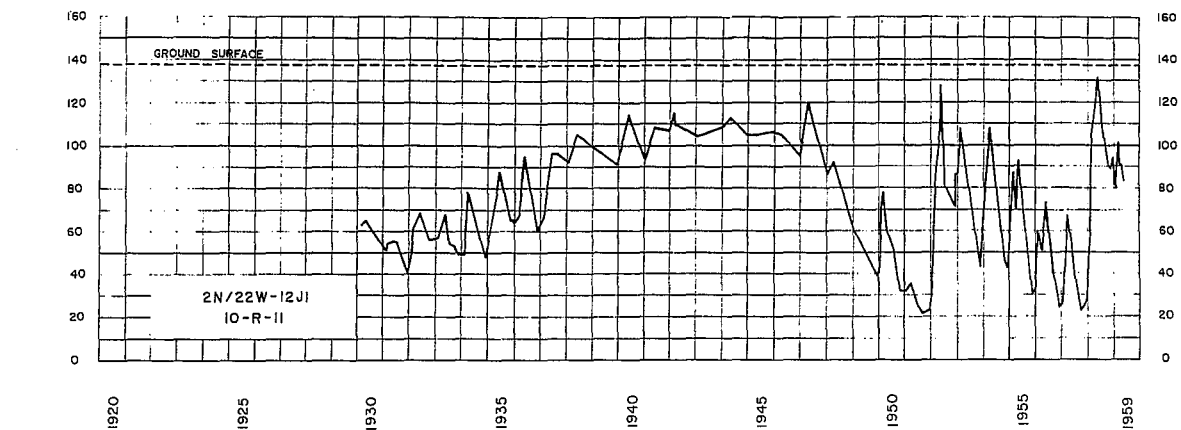
#### FLUCTUATIONS OF WATER LEVELS

THE ALLUVIUM OF THE MONTALVO BASIN CONTAINS A SINGLE, CONTINUOUS BODY OF FREE GROUND WATER. THE HYDROGRAPHS ARE MUCH THE SAME OVER THE ENTIRE BASIN, THE CHIEF DIFFERENCE USUALLY BEING ONE OF VARIABLE AMPLITUDES OF WATER-LEVEL FLUCTUATIONS. THE MAXIMUM AMPLITUDES ARE SHOWN NEAR THE SATICOY SPREADING GROUNDS, AS ON THE HYDROGRAPH OF WELL 2N/22W-12J1 (PLATE 23). THE 1957-58 RECOVERY WAS ABOUT 108 FEET. EVEN IN SOME OF THE POOR RAINFALL YEARS SUCH AS 1953-55, THE SPREADING OF SUBSTANTIAL AMOUNTS OF WATER PRODUCES GOOD ANNUAL RECOVERIES. AT THE LOCATION OF WELL 2N/21W-6P1, WHERE RELATIVELY THIN ALLUVIUM OVERLIES THE SANTA BARBARA FORMATION, IN VERY DRY YEARS THE ALLUVIUM IS DRAINED.

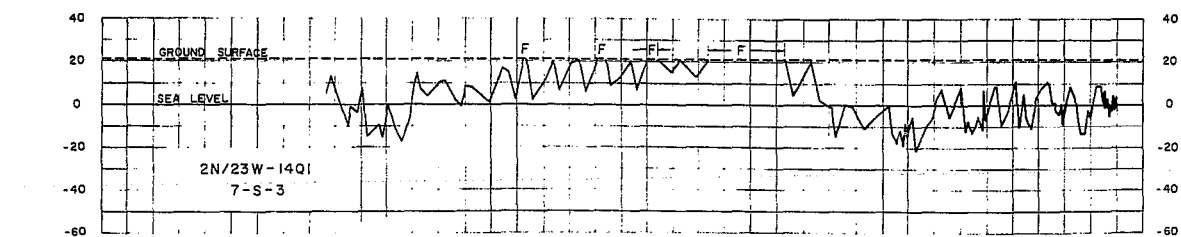
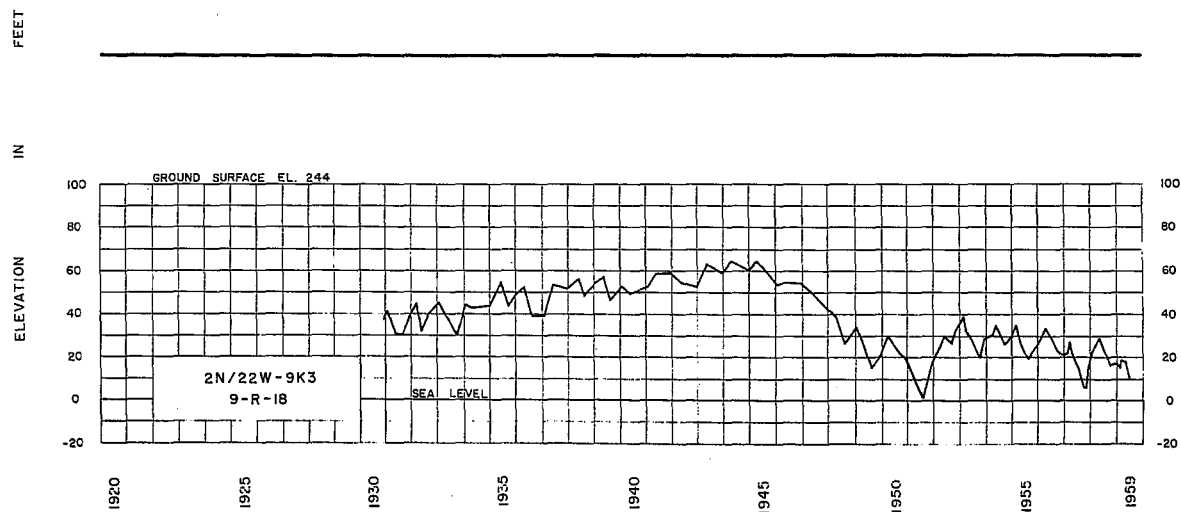
FARTHER SOUTHWEST IN THE MONTALVO BASIN THE RECHARGE EFFECTS ARE MUCH LESS NOTICEABLE THAN NEAR THE SATICOY SPREADING GROUNDS. EVEN FOLLOWING SINGLE WET YEARS THE RECOVERIES ARE SMALL. ESPECIALLY INTERESTING IS THE HYDROGRAPH OF WELL 2N/22W-22R1 (PLATE 23). IN 1952, WHEN NATURAL RECHARGE WAS LARGE, BUT BEFORE THE EL RIO SPREADING GROUNDS WERE IN







### MONTALVO BASIN HYDROGRAPHS



### MOUND BASIN HYDROGRAPHS

OPERATION, THE RECOVERY WAS ONLY 14 FEET. THE EFFECTS OF HEAVY SPREADING AT SATICOY DURING 1953 ARE SHOWN BY A 1953 PEAK HIGHER THAN IN THE 1952 WET YEAR. THE SUBSTANTIALLY BETTER RECOVERY IN 1958 REFLECTS THE FIRST LARGE-SCALE OPERATION OF THE EL RIO SPREADING GROUNDS.

A HYDROGRAPH OF WELL 2N/22W-12K3 (PLATE 25) IS AVAILABLE ONLY FOR THE PERIOD SINCE 1951. THIS WELL IS PERFORATED ONLY IN THE FOX CANYON AQUIFER AND IS LOCATED ABOUT 1/2 MILE SOUTH OF THE SUB-ALLUVIAL OUTCROP. HYDROGRAPHS ARE AVAILABLE FOR NEARBY WELLS 12K1 AND 12K2 WHICH ARE PERFORATED ONLY IN THE ALLUVIAL DEPOSITS AND SHOW RESPONSES OF THE LOCAL WATER TABLE. DURING THE SPRING WATER-LEVEL PEAKS, THE PIEZOMETRIC SURFACE IN THE FOX CANYON AQUIFER AT THIS POSITION IS USUALLY 10 OR MORE FEET HIGHER THAN THE LOCAL WATER TABLE. DURING THE HEAVY SPREADING PERIOD OF 1958, THE DIFFERENTIAL WAS SMALLER, AMOUNTING TO TWO FEET OR LESS. THE HIGH PIEZOMETRIC LEVEL IN WELL 12K3 NEED NOT BE RELATED TO A HIGH DISTANT OUTCROP AREA OF THE FOX CANYON AQUIFER. THE HIGH HEAD CAN BE RELATED TO THE WATER TABLE IN THE SHALLOW AQUIFER OVERLYING THE SUB-ALLUVIAL OUTCROP. THE PIEZOMETRIC SURFACE IN THE FOX CANYON AQUIFER HAS A FLATTER SLOPE THAN THE WATER TABLE AND RISES ABOVE IT IN A SOUTHWESTERLY DIRECTION.

#### STORAGE CAPACITY

A STORAGE-DEPLETION CURVE (PLATE 8) WAS CONSTRUCTED BY RELATING HISTORIC WATER-LEVEL MEASUREMENTS OF WELL 2N/22W-12E1 TO THE UNWATERED STORAGE CAPACITY COMPUTED FROM A SPECIFIC YIELD STUDY. THE WATER-SURFACE ELEVATION IN WELL 12E1 RANGED FROM A MAXIMUM OF 112 FEET ABOVE SEA LEVEL IN THE SPRING OF 1944 TO A MINIMUM OF 17 FEET ABOVE SEA LEVEL IN THE FALL OF 1951. THE CALCULATED MAXIMUM STORAGE DEPLETION WAS ABOUT 102,000 ACRE-FEET.

#### OXNARD PLAIN BASIN

##### BOUNDARIES

THE OXNARD PLAIN BASIN COINCIDES WITH THE PRESSURE PORTION OF THE OXNARD AQUIFER (PLATE 17). AS EXPLAINED ABOVE, THE BOUNDARY BETWEEN THE MONTALVO BASIN AND THE OXNARD PLAIN BASIN APPROXIMATES THE INLAND LIMIT OF THE CLAY CAP. THE NORTHERN BOUNDARY IS PLACED ALONG THE SANTA CLARA RIVER FOR THERE ARE NO OXNARD AQUIFER WELLS NORTH OF THE RIVER. THE EASTERLY SWING OF THE SANTA CLARA RIVER DURING THE DEPOSITION OF THE OXNARD AQUIFER WAS CONTROLLED BY SOUTH MOUNTAIN, THE WEST END OF THE

CAMARILLO HILLS, AND THE WEST END OF THE SANTA MONICA MOUNTAINS AT POINT MUGU. THE EDGE OF THE OXNARD AQUIFER BETWEEN SOUTH MOUNTAIN AND THE CAMARILLO HILLS HAS BEEN LOCATED FROM THE LOGS OF SHALLOW WELLS AND IN PLACES IS ACCENTUATED BY A TOPOGRAPHIC BREAK. THE OXNARD AQUIFER DOES NOT EXTEND INTO THE WEST LAS POSAS AREA; SHALLOWER WATER SUPPLIES ARE NOT AVAILABLE HERE AND WELLS ARE DRILLED TO THE FOX CANYON AQUIFER. SOUTH OF THE CAMARILLO HILLS THE BOUNDARY WAS DETERMINED FROM WELL-LOG STUDIES.

GROUND WATER GEOLOGY

#### GENERAL GEOLOGY

AS IT NOW EXISTS, THE OXNARD PLAIN WAS BLOCKED OUT STRUCTURALLY DURING MIDDLE PLEISTOCENE TIME. EARLIER IN LATE PLEISTOCENE TIME THE ENTIRE PLAIN AND THE SOUTHERN PART OF THE MOUND BASIN WERE COVERED BY SANTA CLARA RIVER DEPOSITS WHICH WERE SPREAD OUT ON THE EXTENSIVE EROSIONAL SURFACE THAT HAD BEEN CUT ON THE SAN PEDRO FORMATION. THESE EARLIER RIVER DEPOSITS AND THE ACCOMPANYING TERRACE MATERIALS FLANKING THE OXNARD PLAIN AND THE MOUND BASIN WERE MODERATELY FOLDED, FAULTED AND TILTED BY VERY LATE PLEISTOCENE DIASTROPHISM. THE OXNARD AQUIFER WAS LAID DOWN FOLLOWING THIS LATER DISTURBANCE AND SHOWS NO EFFECTS OF DIASTROPHISM.

#### OXNARD AQUIFER

THE OXNARD AQUIFER IS A THICK, CONTINUOUS LAYER OF COARSE, GRAVELLY DEPOSITS LAID DOWN BY THE SANTA CLARA RIVER ON THE OXNARD PLAIN. ONCE THE SANTA CLARA RIVER HAD CLEARED THE WESTERN END OF SOUTH MOUNTAIN, IT WAS FREE TO SWING OVER THE ENTIRE OXNARD PLAIN THROUGH A SECTOR EXTENDING FROM THE PRESENT COURSE OF THE SANTA CLARA RIVER TO A LINE APPROXIMATING THE POSITION OF WOOD ROAD. DURING THE EARLY STAGES OF THIS DEPOSITION, COARSE GRAVELS WERE SPREAD OVER THE ENTIRE PLAIN AREA, GENERALLY WITH THE GREATEST THICKNESS ALONG THE SATICOY-OXNARD-PORT HUENEME AXIS, AND WITH THINNING IN BOTH DIRECTIONS FROM THIS AXIS. IN THE LATER STAGES OF THE DEPOSITION THE GRAVELS WERE NOT SO WIDESPREAD, BUT WERE RESTRICTED TO WHAT IS NOW CALLED THE MONTALVO BASIN. SEAWARD FROM MONTALVO BASIN THE LATER DEPOSITS CONSIST OF MUCH SILTY AND CLAYEY MATERIAL WITH INTERDEDED SANDS AND MINOR GRAVELS. THESE LOW PERMEABILITY DEPOSITS ARE COLLECTIVELY CALLED THE "CLAY CAP". WITHIN THE MONTALVO BASIN THE OXNARD AQUIFER IS CONSIDERED TO EXTEND FROM THE GROUND SURFACE TO A DEPTH OF ABOUT 150 FEET. ALONG THE MAIN AXIS OF GRAVEL DEPOSITION THERE IS A GRADUAL THINNING

SEAWARD TO A THICKNESS OF ABOUT 100 FEET AT THE COASTLINE. THE BASE OF THE AQUIFER SLOPES ABOUT 10 FEET PER MILE, AND BENEATH PORT HUENEME IS AT A DEPTH OF ABOUT 250 FEET. IN BOTH DIRECTIONS FROM THE MAIN AXIS THE OXNARD AQUIFER SHOWS A GENERAL THINNING AND A TENDENCY TO BECOME SEVERAL COARSE ZONES SEPARATED BY CLAYS (SECTION S-S', PLATE 18). THE EXACT NORTHERN LIMIT OF THE OXNARD AQUIFER CAN NOT BE DETERMINED BECAUSE OF A LACK OF WELLS; IT MUST CORRESPOND FAIRLY CLOSELY, HOWEVER, TO THE PRESENT COURSE OF THE SANTA CLARA RIVER. THE WELL LOG CONTROL ON THE EASTERN LIMIT, IN THE VICINITY OF WOOD ROAD, IS USUALLY MUCH BETTER, ALTHOUGH IN THE MUGU AREA THE OXNARD AQUIFER IS NOT SO DISTINCTIVE. IN MUGU NAVAL BASE WELL #3 (1N/21W-31L1) THE OXNARD AQUIFER APPEARS ON THE ELECTRIC LOG AS A GRAVEL ZONE ABOUT 60 FEET THICK AND WITH ITS TOP AT A DEPTH OF ABOUT 200 FEET. ELSEWHERE BENEATH THE MUGU NAVAL BASE SANDY MATERIALS COMPRISE MOST OF THE UPPER 500 FEET AND THE OXNARD AQUIFER IS DIFFICULT TO RECOGNIZE.

#### OTHER UPPER PLEISTOCENE AQUIFERS

BETWEEN THE BASE OF THE OXNARD AQUIFER AND THE UNCONFORMITY WHICH MARKS THE TOP OF THE SAN PEDRO FORMATION IS A SECTION, PERHAPS 200 FEET THICK, OF CLAYS, SANDS, AND GRAVELS AS YET NOT EXTENSIVELY EXPLORED AND TESTED BY WATER WELLS. THE BEST AQUIFER POTENTIALS IN THESE DEPOSITS ARE IN THE SAME AREAS WHERE THE OXNARD AQUIFER YIELDS PROLIFICALLY; THUS THERE HAS BEEN NO URGENCY TO DRILL DEEPER TO TAP THESE. BENEATH THE EL RIO SPREADING GROUNDS GOOD GRAVELS WERE ENCOUNTERED IMMEDIATELY BELOW THE OXNARD AQUIFER AT DEPTHS BETWEEN 150 AND 250 FEET. AS SHOWN ON SECTION Q-Q', PLATE 18, THESE GRAVELS APPEAR TO PINCH OUT RATHER QUICKLY IN A SEAWARD DIRECTION. IN THE MUGU AREA, A WIDESPREAD GRAVEL ZONE NAMED THE MUGU AQUIFER (REF. 17) IS SHOWN ON THE ELECTRIC LOG OF MUGU NAVAL BASE WELL #3 (1N/21W-31L1) BETWEEN DEPTHS OF 350 AND 420 FEET. NORTHERLY TOWARD SATICOY THE MUGU AQUIFER BECOMES LESS PERMEABLE AND APPARENTLY IS REPLACED BY A SERIES OF ALTERNATING THIN SANDS AND CLAYS. OVER THE MUGU AREA, HOWEVER, ESPECIALLY TO THE NORTH OF THE NAVAL BASE, THERE IS EXTENSIVE PUMPING FROM THIS AQUIFER.

AT THE BASE OF THE UPPER PLEISTOCENE DEPOSITS IS A VERY IMPORTANT UNCONFORMITY DEVELOPED ON THE FOLDED AND FAULTED SAN PEDRO FORMATION. IN THE RELATIVELY FEW WELLS ON THE OXNARD PLAIN WHERE IT CAN BE LOCATED WITH CONFIDENCE, IT IS FOUND AT A DEPTH OF ABOUT 400 FEET. IN THE MORE DISTURBED

TABLE III-4. PERMISSIBLE LIMITS OF BORON FOR SEVERAL CLASSES OF IRRIGATION WATERS

| BORON CLASS | SENSITIVE CROPS | SEMITOLERANT CROPS | TOLERANT CROPS |
|-------------|-----------------|--------------------|----------------|
|             | P.P.M.          | P.P.M.             | P.P.M.         |
| 1.....      | $<0.33$         | $<0.67$            | $<1.00$        |
| 2.....      | 0.33 TO .67     | 0.67 TO 1.33       | 1.00 TO 2.00   |
| 3.....      | .67 TO 1.00     | 1.33 TO 2.00       | 2.00 TO 3.00   |
| 4.....      | 1.00 TO 1.25    | 2.00 TO 2.50       | 3.00 TO 3.75   |
| 5.....      | $>1.25$         | $>2.50$            | $>3.75$        |

AREAS SUCH AS BENEATH THE SATICOY SPREADING GROUNDS AND WESTERLY ALONG THE MONTALVO FAULT, THERE IS A STRONG ANGULAR RELATIONSHIP. OVER MOST OF THE AREA OF THE OXNARD PLAIN THE ANGULAR DISCORDANCE APPEARS TO BE SMALL. A MINOR, YOUNGER UNCONFORMITY SEPARATES THE OXNARD AQUIFER FROM THE OLDER UPPER PLEISTOCENE LAYERS. THERE IS ANGULAR DISCORDANCE IN THE MONTALVO BASIN AND THESE RELATIONSHIPS PROBABLY EXTEND WESTERLY ALONG THE MONTALVO FAULT TO THE COASTLINE.

#### CLAY CAP

THE CONFINEMENT OF THE OXNARD AQUIFER BENEATH THE OXNARD PLAIN BASIN IS CAUSED BY THE SO-CALLED "CLAY CAP", WHICH CONSISTS OF MANY SILTY AND CLAYEY LAYERS ALONG WITH INTERDEDED LENSES OF SANDS AND MINOR GRAVELS. ALTHOUGH ITS CHARACTERISTICS HAVE BEEN GENERALIZED FOR THE SAKE OF SIMPLICITY, IN DETAIL IT IS QUITE COMPLEX. SECTION Q-Q', PLATE 18 SHOWS THE RELATIVELY ABRUPT START OF THE CLAY LAYERS WHICH TYPIFIES THE SOUTHEASTERN BOUNDARY OF THE MONTALVO BASIN. AT THE SOUTHWESTERN BOUNDARY OF THE MONTALVO BASIN, THE EFFECTIVE UPSLOPE EDGE OF THE CLAY CAP IS MORE DIFFICULT TO DELINEATE (SECTION R-R', PLATE 18). STARTING WITH THE THIN CLAY LENSES NORTH OF OXNARD, THE CLAY CAP CONTAINS MORE LOW PERMEABILITY LAYERS TOWARD THE OCEAN UNTIL THE NET CLAYEY LAYER THICKNESS OVERLYING THE OXNARD AQUIFER BECOMES 100 FEET OR MORE. MOST OF THE INFORMATION ABOUT THE CLAY CAP WAS OBTAINED FROM DRILLERS' LOGS; SOME HAS BEEN OBTAINED FROM ELECTRIC LOGS OF OIL AND WATER WELLS. THE LOW PERMEABILITY MATERIALS ARE CERTAINLY NOT CAPABLE OF YIELDING APPRECIABLE SUPPLIES OF WATER TO WELLS. LESS CERTAIN IS THE EXTENT TO WHICH THE SO-CALLED "CLAYS" ARE ACTUALLY SILTS, WHICH, OVER PROLONGED PERIODS OF TIME WITH APPRECIABLE HYDRAULIC GRADIENTS, WILL PERMIT A SUBSTANTIAL AMOUNT OF WATER TO MOVE THROUGH THEM. DURING THE TEST DRILLING FOR THE NEW STEAM PLANT IN SECTION 1, T1N, R23W, NUMEROUS SAMPLES WERE TAKEN, PHYSICALLY TESTED, AND DESCRIBED IN DETAIL. THESE DESCRIPTIONS REVEAL THAT NONE OF THE LOW PERMEABILITY LAYERS ARE TRUE CLAYS. MANY OF THE LAYERS ARE DESCRIBED AS CLAYEY SILTS, AND IT IS DOUBTFUL THAT SUCH LAYERS WOULD PERMIT EXTENSIVE WATER MOVEMENTS ACROSS THE BEDDING PLANES. GENERALLY SPEAKING, THE CLAY CAP IS AN EFFECTIVE BARRIER TO VERTICAL MOVEMENTS OF WATER BETWEEN THE OXNARD AQUIFER AND THE SEMI-PERCHED ZONE. NEVERTHELESS, THE CHANCES FOR INTERCOMMUNICATION INCREASE AS THE NET THICKNESS OF THE LOW PERMEABILITY LAYERS DECREASES. IN

A FEW PLACES THIS THICKNESS MAY BE AS LITTLE AS 15 TO 20 FEET.

THE SURFICIAL DEPOSITS OF THE OXNARD PLAIN, PERHAPS THE TOP 50 FEET, CONSTITUTE THE LAYERS OF RECENT AGE. THESE AVERAGE SANDIER THAN THE CLAY CAP, AND ARE ESPECIALLY SANDY IN STRIPS WHICH APPEAR TO BE CHANNELS (SECTION S-S', PLATE 18). WITHIN THESE DEPOSITS ARE THE SHALLOW, POOR QUALITY WATERS OF THE SEMI-PERCHED ZONE.

#### SOURCES OF RECHARGE

THE ONLY SOURCE OF PERENNIAL RECHARGE TO THE OXNARD AQUIFER BENEATH THE OXNARD PLAIN WHICH IS OF REASONABLY GOOD CHEMICAL QUALITY IS THE UNDERFLOW FROM MONTALVO BASIN. AS WILL BE EXPLAINED IN DETAIL LATER, THERE IS A LARGE AMOUNT OF WATER MOVING FROM THE SEMI-PERCHED ZONE THROUGH THE CLAY CAP IN WELLS TO THE OXNARD AQUIFER. THIS RECHARGE, ESSENTIALLY IRRIGATION RETURN WATER, OCCURS ONLY IN DRY PERIODS WHEN WATER-LEVEL GRADIENTS ARE FAVORABLE, AND IS OF VERY POOR CHEMICAL QUALITY.

UNDERFLOW FROM MOUND BASIN TO THE OXNARD AQUIFER IS VIRTUALLY NONEXISTENT, FOR ALONG ITS NORTHERN LIMIT THE OXNARD AQUIFER WAS DEPOSITED AGAINST CLAYEY UPPER PLEISTOCENE TERRACE MATERIALS. FURTHERMORE, SUCH MOVEMENT WOULD BE PREVENTED BY ADVERSE WATER-LEVEL GRADIENTS. MUCH THE SAME GEOLOGIC CONDITIONS PREVAIL ALONG THE BOUNDARY OF THE OXNARD PLAIN AND THE WEST LAS POSAS AREA. FARTHER SOUTH ALONG WOOD ROAD THE OXNARD AQUIFER SHOWS SEVERAL PERMEABLE LAYERS PINCHING OUT, AND REPLACED AT THE SAME LEVEL BY THICK CONTINUOUS CLAYS (SECTION S-S', PLATE 18). WESTERLY UNDERFLOW FROM PLEASANT VALLEY INTO THE OXNARD AQUIFER IS INSIGNIFICANT. IT IS POSSIBLE THAT THE OXNARD AQUIFER IN THE MUGU AREA MAY DIRECTLY ADJUT AGAINST THE VOLCANIC ROCKS OF THE SANTA MONICA MOUNTAINS. A VERY SMALL AMOUNT OF RECHARGE MIGHT BE DERIVED FROM THIS SOURCE, BUT FROM A PRACTICAL QUANTITATIVE STANDPOINT THIS ITEM COULD BE NEGLECTED.

THE SOURCES OF RECHARGE TO THE OTHER UPPER PLEISTOCENE AQUIFERS ARE MUCH LESS CLEAR. CONTRIBUTIONS FROM THE MOUND BASIN WOULD BE PREVENTED BY ADVERSE WATER-LEVEL GRADIENTS. THERE ARE NO IMPORTANT PERMEABLE ZONES AT COMPARABLE DEPTHS IN EITHER WEST LAS POSAS OR PLEASANT VALLEY AND UNDERFLOW FROM THESE SOURCES WOULD BE SMALL. IF THERE IS SIGNIFICANT PERENNIAL RECHARGE TO THESE AQUIFERS IT IS PROBABLY DERIVED FROM THE MONTALVO BASIN. HOWEVER, THE GRAVELS BENEATH THE MONTALVO BASIN APPEAR TO BE VERY LENTICULAR (SECTION Q-Q', PLATE 18). THE MUGU AQUIFER, WHICH IS

THE LOWEST PERMEABLE ZONE ON SECTION Q-Q', PLATE 18, IS VERY CONTINUOUS IN THE MUGU AREA, BUT CAN NOT BE TRACED TO A POTENTIAL RECHARGE AREA IN THE MONTALVO BASIN. IT IS VERY OBVIOUS THAT THE DEGREE OF CONTINUITY DISPLAYED BY THESE OLDER UPPER PLEISTOCENE AQUIFERS IS MUCH LESS THAN THAT OF THE OXNARD AQUIFER.

#### HORIZONTAL MOVEMENTS OF WATER

UNDER NATURAL CONDITIONS, WATER ENTERED THE OXNARD AQUIFER AS STREAM PERCOLATION AND RAINFALL PENETRATION WITHIN THE MONTALVO BASIN, AND AS UNDERFLOW FROM SANTA PAULA BASIN. THE WATER MOVED WESTERLY AND SOUTHERLY TOWARD THE OCEAN. ESCAPE OF THIS WATER MAY HAVE TAKEN PLACE ALONG THE ENTIRE SUBMARINE OUTCROP OF THE OXNARD AQUIFER, ALTHOUGH THE SUBMARINE OUTFLOW WAS PROBABLY CONCENTRATED IN HUENEME AND MUGU SUBMARINE CANYONS. BECAUSE OF THE CONFINING CLAY CAP, HIGH ARTESIAN HEADS WERE MAINTAINED OVER MUCH OF THE OXNARD PLAIN. HEADS OF 20 FEET OR MORE ABOVE THE GROUND SURFACE HAVE BEEN REPORTED FOR THE PORT HUENEME AREA. THESE HIGH COASTAL HEADS OPERATED TO SLOW THE COASTWARD UNDERFLOW, ALTHOUGH MONTALVO BASIN PROBABLY REMAINED FULL MOST OF THE TIME, AND SHOWED HIGH LEVELS ALSO. WITH MONTALVO BASIN WATER LEVELS HIGH, SOME UNDERFLOW PROBABLY TOPPED THE CLAY CAP AND FLOWED SEAWARD IN THE SURFICIAL SANDS. THE SHALLOW GROUND WATERS WERE ABLE TO MOVE WESTERLY AND SOUTHERLY AND IN PLACES WERE ABLE TO REACH THE OCEAN. NORTH OF PORT HUENEME, AND EXTENDING TO ABOUT THE MOUTH OF THE SANTA CLARA RIVER, IS A NARROW STRIP OF SAND DUNES. UNDER NATURAL CONDITIONS, THE DEVELOPMENT OF A HIGH FREE WATER TABLE IN THESE DUNES AS A RESULT OF RAINFALL PENETRATION SERVED AS A BARRIER TO THE SEAWARD FLOW OF THE SHALLOW GROUND WATERS. THE RESULT WAS THE BACKING UP OF THE WATER ON THE INLAND SIDE OF THE DUNES. EARLY SOIL MAPS (REF. 6) SHOW PONDS AND EXTENSIVE AREAS OF ALKALI RESULTING FROM HEAVY EVAPOTRANSPIRATION BEHIND THIS WATER-TABLE RIDGE. THE PONDING EFFECT BETWEEN PORT HUENEME AND POINT MUGU MAY HAVE BEEN LESS BECAUSE OF SMALLER DUNES. ALKALI DISTRIBUTION SUGGESTS THAT THE SURFICIAL WATERS WERE ABLE TO ESCAPE TO THE OCEAN NEAR THE RIVER MOUTH AND NEAR PORT HUENEME.

IN SECTION 1, T1N, R23W, THE WATER-TABLE RIDGE STILL FORMS IN THE DUNE SANDS. IN THE SPRING OF 1958, WHEN THERE WAS ABNORMALLY HIGH RAINFALL, THE WATER TABLE IN THE DUNES HAD BUILT UP TO AN ELEVATION OF ABOUT 20 FEET ABOVE SEA LEVEL. A WATER SAMPLE FROM A VERY SHALLOW WELL IN THE DUNE SANDS

SHOWED TOTAL DISSOLVED SOLIDS OF ONLY 189 PARTS PER MILLION. IN ABOUT A YEAR THE WATER TABLE HAD DROPPED 10 FEET AND THE TOTAL DISSOLVED SOLIDS HAD RISEN TO OVER 1000 PARTS PER MILLION.

IN THE SPRING OF 1944 (PLATE 21), WATER MOVEMENTS WITHIN THE OXNARD AQUIFER WERE ESSENTIALLY THE SAME AS THOSE UNDER NATURAL CONDITIONS, ALTHOUGH THE PIEZOMETRIC SURFACE AVERAGED MORE THAN 10 FEET LOWER THAN DURING THE WET PERIOD ENDING IN THE EARLY 1920'S. FOLLOWING 1944, AS THE DROUGHT PROGRESSED AND AS PUMPING INCREASED, THE WATER LEVELS IN THE OXNARD PLAIN WERE LOWERED TO BELOW SEA LEVEL OVER ALL BUT THE MOST LANDWARD PORTIONS OF THE PLAIN. BY THE FALL OF 1957 STATIC WATER LEVELS WERE AS SHOWN ON PLATE 22. ESSENTIALLY ALL OF THE WATER LEVELS WERE BELOW SEA LEVEL; ONLY THE NORTHERN PART OF THE MONTALVO BASIN AND THE CONFINED AREA TO THE EAST SHOWED WATER LEVELS ABOVE SEA LEVEL. WATER MOVEMENTS UNDER THESE CONDITIONS ARE TOWARD THE RESIDUAL PUMPING TROUGHS. NORTH OF PORT HUENEME THE PUMPING TROUGH AXIS PARALLELS THE COASTLINE AND IS 2 TO 3 MILES INLAND. THE LOWEST STATIC WATER LEVELS ARE NORTHEAST AND EAST OF PORT HUENEME, AND THE WATER-LEVEL CONTOURS INDICATE THE MOVEMENT OF WATER FROM BENEATH THE OCEAN TOWARD THE TROUGH AXIS. THE STEEP WATER-TABLE GRADIENT NEAR WOOD ROAD DOES NOT DEMONSTRATE WATER MOVEMENT FROM PLEASANT VALLEY TOWARD THE OXNARD PLAIN; THIS IS GEOLOGICALLY IMPOSSIBLE AT SHALLOW DEPTHS. THE LOW WATER LEVELS NEAR THE EASTERN PINCHOUT OF THE OXNARD AQUIFER (WOOD ROAD) ARE EXPLAINED BY LENTICULARITY OF THE PERMEABLE ZONES.

FOLLOWING THE HEAVY RAINS OF EARLY 1958, WHICH RESULTED IN A RATHER LONG PERIOD OF NON-PUMPING, THE WATER LEVELS SHOWED A GOOD RECOVERY (PLATE 21). ALL THE AREA NORTH OF THE CITY OF OXNARD SHOWS WATER LEVELS ABOVE SEA LEVEL. PARTLY AS A RESULT OF THE SPREADING ACTIVITIES, MONTALVO BASIN WAS FILLING RAPIDLY IN THE SPRING OF 1958. THE WATER-TABLE MOUND IN SECTION 23, T2N, R22W REFLECTS THE SPREADING AT THE EL RIO GROUNDS. MOST OF THE COASTAL PORTION OF THE OXNARD PLAIN, WHICH IN THE FALL OF 1957 WAS SEAWARD OF THE TROUGH AXIS, RECOVERED BECAUSE SEA WATER MOVED INTO THE OXNARD AQUIFER. THUS, FOR COASTAL AREAS, THE "RECOVERIES" TO SEA LEVEL MUST BE VIEWED IN A CAUTIOUS WAY. AS OF THE SPRING OF 1958 THE TROUGH HAD NOT BEEN REMOVED COMPLETELY, BECAUSE NOT SUFFICIENT TIME HAD ELAPSED FOR COMPLETE RECOVERY. SMALL LANDWARD GRADIENTS STILL PERSISTED. THE ABOVE-SEA-LEVEL ELEVATIONS NEAR PORT HUENEME ARE NOT UNEXPECTED. THEORETICALLY,

IN THE OXNARD AQUIFER, SEA WATER SHOULD BALANCE FRESH WATER STANDING AT AN ELEVATION OF MORE THAN 6 FEET ABOVE SEA LEVEL.

#### MOVEMENTS FROM DEEPER AQUIFERS

IN MANY PLACES BENEATH THE OXNARD AQUIFER THERE ARE SANDS AND GRAVELS WHICH APPEAR TO BE HYDROLOGICALLY DISTINCT FROM THE OXNARD AQUIFER. HUENEME NAVAL BASE WELL #4 (1N/22W-20B1) HAS NOT BEEN INTRUDED BY SEA WATER WHEREAS A WELL FARTHER INLAND (1N/22W-17J2) ALREADY SHOWS HIGH CHLORIDES. WELL 20B1 APPEARS TO BE PERFORATED ONLY IN AN AQUIFER WHICH IS BELOW THE OXNARD AQUIFER. LACK OF SEA-WATER INTRUSION MAY BE EXPLAINED BY (1) THE SEA-WATER FRONT IN THIS AQUIFER HAS NOT YET REACHED THE POSITION OF WELL 20B1; OR (2) THE AQUIFER TAPPED IS NOT IN HYDROLOGIC COMMUNICATION WITH SEA WATER. IF THE SEA-WATER FRONT WERE ADVANCING IN THIS AQUIFER, THE WATER LEVELS IN WELL 20B1 SHOULD BE HIGHER THAN THOSE IN THE INTRUDED OXNARD AQUIFER NEARBY, WHICH IS NOT THE CASE. THE DEEPER AQUIFER THEREFORE MAY BE LENTICULAR, AND NOT EXPOSED TO THE OCEAN. THE TENDENCY HERE IS FOR WATER TO MOVE DOWNWARD FROM THE OXNARD AQUIFER INTO THE DEEPER AQUIFER.

WELL 1N/22W-23J1 SHOWS PERSISTENTLY HIGHER WATER LEVELS THAN SURROUNDING WELLS AND PROBABLY REPRESENTS CONDITIONS IN A DEEPER, HIGHER HEAD ZONE. THERE ARE NO PERFORATION DATA TO RESOLVE THIS PROBLEM. NORTH OF THE MUGU NAVAL BASE, WHERE THE FOX CANYON AQUIFER IS SHALLOW, THERE ARE SOME WELLS WHICH ARE PERFORATED IN THE OXNARD AQUIFER, THE MUGU AQUIFER, AND THE FOX CANYON AQUIFER, OR IN THESE TAKEN TWO AT A TIME. THE RESULT IS A HIGH DEGREE OF COMMUNICATION AMONG THESE AQUIFERS THROUGH THE MULTI-ZONE WELLS. IN THIS AREA, SMALL HEAD DIFFERENCES BETWEEN AQUIFERS ARE BEING ADJUSTED BY FLOWS WITHIN THE WELLS, ESPECIALLY WHEN NOT PUMPING.

#### DOWNWARD LEAKAGE FROM SEMI-PERCHED ZONES

IN A RECENT PAPER, ISHERWOOD AND PILLSBURY (REF. 39) HAVE SUGGESTED A DOWNWARD LEAKAGE FROM THE SEMI-PERCHED ZONE OF ABOUT 14,000 ACRE-Feet PER YEAR. THEIR FIELD PROGRAM INVOLVED THE INSTALLATION OF 140 PIEZOMETERS, EACH 11 FEET DEEP, ON ROUGHLY A HALF-MILE GRID. LATER, A NETWORK OF 21-FOOT PIEZOMETERS WAS INSTALLED ON ABOUT A ONE-MILE GRID. EACH OF THE 21-FOOT PIEZOMETERS WAS INSTALLED WITHIN A FOOT OR TWO OF AN 11-FOOT PIEZOMETER ALREADY IN PLACE. WATER-LEVEL ELEVATIONS WERE DETERMINED ABOUT SEMI-ANNUALLY FROM 1953 TO 1956. MANY OF THE PIEZOMETER PAIRS

SHOWED A DOWNWARD HYDRAULIC GRADIENT BETWEEN DEPTHS OF 11 AND 21 FEET. A DEEPER TEST HOLE NEAR WOOD AND LAGUNA ROADS SHOWED DOWNWARD HYDRAULIC GRADIENTS TO THE TOTAL HOLE DEPTH OF 63 FEET. THE ESTIMATE OF DOWNWARD LEAKAGE (14,000 ACRE-FeET PER YEAR) WAS BASED ON THE FOLLOWING INFORMATION AND REASONING:

- (1) THE CHANGE IN WATER LEVELS IN TWO PIEZOMETERS DURING A SUMMER PERIOD WHEN NO IRRIGATION WATER WAS APPLIED IN THE VICINITY.
- (2) THE WATER LEVELS WERE WELL BELOW THE NEIGHBORING TILE DRAINS AND SLIGHTLY ABOVE THE BOTTOM OF THE NEAREST DITCH (1/4 MILE DISTANT).
- (3) THE TWO PIEZOMETERS OBSERVED BOTH GAVE A CHANGE IN LEVEL EQUIVALENT TO 0.9 FOOT OF WATER PER YEAR. THIS 0.9-FOOT DROP REPRESENTS AN EXTRAPOLATED FIGURE DETERMINED FROM MEASUREMENTS TAKEN DURING A TWO-MONTH PERIOD.
- (4) DOWNWARD VERTICAL GRADIENTS ARE ABOUT 100 TIMES AS GREAT AS THE HORIZONTAL HYDRAULIC GRADIENTS FROM THESE TWO PIEZOMETERS TO THE NEAREST DRAIN.
- (5) IN THE OPINION OF THE AUTHORS IT IS UNLIKELY THAT THE MEAN HYDRAULIC CONDUCTIVITY IN A HORIZONTAL DIRECTION WILL BE ANY GREATER THAN IN A VERTICAL DIRECTION. THE AUTHORS SUGGEST THEIR ASSUMPTION REGARDING THE LIKELY EQUALITY OF HORIZONTAL AND VERTICAL CONDUCTIVITY MAY BE INCORRECT; BUT EVEN IF THE HORIZONTAL CONDUCTIVITY EXCEEDS THE VERTICAL BY 100 TO 1, THE HORIZONTAL GRADIENT WOULD STILL HARDLY EXCEED THE VERTICAL GRADIENT.
- (6) FROM THE ABOVE REASONING, ONLY HALF OF THE 0.9 FOOT PER YEAR, OR 0.45 FOOT PER YEAR IS ATTRIBUTED TO DOWNWARD LEAKAGE.
- (7) THE 0.45 FOOT PER YEAR FIGURE WAS APPLIED OVER AN AREA OF 32,000 ACRES TO ARRIVE AT THE ANNUAL DOWNWARD LEAKAGE OF 14,000 ACRE-FeET.

OUR REVIEW OF THE WORK OF ISHERWOOD AND PILLSBURY HAS INVOLVED THE FOLLOWING:

- (1) THE COLLECTION OF ALL THE WATER-LEVEL MEASUREMENTS MADE BY THEM;
- (2) PLOTTING ON A BASE MAP, THE MAGNITUDES AND DIRECTIONS OF HYDRAULIC GRADIENTS SHOWN BY WATER-LEVEL DIFFERENCES IN THE PIEZOMETER PAIRS;
- (3) PERSONAL DISCUSSIONS WITH ISHERWOOD AND PILLSBURY.

THERE IS NO REASON TO DOUBT THE EXISTENCE OF THE DOWNWARD HYDRAULIC GRADIENTS AND A CONCLUSION FROM THESE THAT IN THE PLACES THE SHALLOWEST WATERS ARE ACTUALLY MOVING DOWNWARD. THE FOLLOWING CONDITIONS MAY BE USED TO EXPLAIN THE DOWNWARD GRADIENTS:

- (1) APPLICATION OF WATER FROM ABOVE (PERCHING)
  - (A) IRRIGATION RETURN
  - (B) RAINFALL PENETRATION
- (2) WITHDRAWAL OF WATER FROM BELOW
  - (A) BY OUTFLOW TO THE OCEAN
  - (B) BY CLAY CAP LEAKAGE DUE TO PRESSURE REDUCTION IN THE OXNARD AQUIFER
  - (C) BY PUMPED REMOVAL FROM PERFORATED SHALLOW SANDS ABOVE THE OXNARD AQUIFER
  - (D) BY DOWNWARD LEAKAGE TO THE OXNARD AQUIFER THROUGH MULTI-PERFORATED CABLE-TOOL WELLS, GRAVEL-PACKED ROTARY WELLS, OR ABANDONED WELLS WITH DETERIORATED CASINGS.

THE ESTIMATES OF DOWNWARD LEAKAGE WERE BASED UPON DATA OBTAINED DURING A TIME WHEN APPLICATION OF WATER FROM ABOVE WAS NOT A FACTOR. OUTFLOW TO THE OCEAN FROM ZONES BELOW 21 FEET IS FAVORED BY A CONTINUOUS GRADIENT TOWARD THE COASTLINE, BUT IS HINDERED BY (A) THE WATER-TABLE RIDGE DEVELOPED IN THE COASTAL DUNES, AND (B) THE NECESSITY OF HAVING PROPORTIONALLY HIGHER HEADS AT DEPTH TO PERMIT OUTFLOW OF FRESH WATER INTO THE SALT WATER OF HIGHER SPECIFIC GRAVITY.

IF PRESSURE REDUCTION IN THE OXNARD AQUIFER GENERATED DOWNWARD LEAKAGE THROUGH THE CLAY CAP, AND THE CLAY CAP IS ASSUMED TO BE OF UNIFORM PERMEABILITY, THE MAXIMUM DOWNWARD GRADIENTS SHOULD COINCIDE WITH THE AREAS OF MAXIMUM DEPRESSION OF THE OXNARD AQUIFER PIEZOMETRIC SURFACE. THIS IS DEFINITELY NOT THE PATTERN. A MORE ACCURATE GENERALIZATION IS A CLAY CAP OF VARIABLE PERMEABILITY. UNDER THESE CONDITIONS THE MAXIMUM DOWNWARD PIEZOMETER GRADIENTS SHOULD COINCIDE WITH "HOLES" OR ROUTES OF MAXIMUM PERMEABILITY THROUGH THE CLAY CAP. A STUDY OF THE GRADIENTS OBTAINED FROM THE PIEZOMETER DATA REVEALS THE FOLLOWING:

- (1) SOME PIEZOMETER PAIRS SHOW PERSISTENT DOWNWARD GRADIENTS; SOME SHOW PERSISTENT UPWARD GRADIENTS; SOME SHOW DOWNWARD GRADIENTS AT CERTAIN TIMES, UPWARD AT OTHERS.
- (2) THERE IS NO CONSISTENT PATTERN SHOWING THAT GRADIENTS FLUCTUATE WITH THE SEASONS, OR HAVE CHANGED PROGRESSIVELY IN ONE DIRECTION WITH TIME.

(3) THREE FAIRLY PERSISTENT AREAS OF DOWNWARD GRADIENTS MAY BE RECOGNIZED:

- (a) DUE WEST OF OXNARD IN SECTION 5, T1N, R22W. THE OXNARD AQUIFER HERE IS overlain BY A NET CLAYEY THICKNESS OF AT LEAST 70 FEET.
- (b) DUE EAST OF PORT HUENEME IN ABOUT SECTION 22, T1N, R22W. MOST LOGS INDICATE A NET CLAYEY THICKNESS OF ABOUT 90 FEET OVERLYING THE OXNARD AQUIFER.
- (c) THE ENTIRE EASTERN PART OF THE COASTAL PLAIN BOTH EAST AND WEST OF WOOD ROAD. WEST OF WOOD ROAD THE OXNARD AQUIFER IS THIN AND THE CLAY CAP IS MUCH LESS SANDY THAN IN THE CENTRAL PART OF THE OXNARD PLAIN. EAST OF WOOD ROAD, IN PLEASANT VALLEY, THERE IS NO OXNARD AQUIFER. THE HIGHEST DOWNWARD GRADIENTS FOUND, IN PLEASANT VALLEY SOUTH OF CAMARILLO, WERE RECORDED FOLLOWING A RAIN, IN MARCH 1954.

THE FOLLOWING CONCLUSIONS SEEM JUSTIFIED:

- (1) THERE IS NO WIDESPREAD GENERAL LEAKAGE THROUGH THE CLAY CAP FROM THE SEMI-PERCHED ZONE INTO THE OXNARD AQUIFER.
- (2) THERE IS NO RELATIONSHIP OF MAXIMUM DOWNWARD GRADIENTS TO PLACES IN THE CLAY CAP WHERE INTERDEDED SANDS ARE THICKEST. THUS THE WATER DOES NOT APPEAR TO BE MOVING DOWNWARD THROUGH "HOLES" IN THE CLAY CAP.
- (3) MANY OF THE RECORDED DOWNWARD GRADIENTS MAY BE THE RESULT OF RAINFALL PENETRATION AND IRRIGATION RETURN, NOT NECESSARILY THE RESULT OF WITHDRAWAL FROM BELOW.

HOWEVER, THE ISHERWOOD AND PILLSBURY DATA DO DEMONSTRATE THE FOLLOWING:

- (1) SOME WATER IS MOVING DOWNWARD BELOW THE SOIL ZONES.
- (2) THIS MOVEMENT IS LOCAL, RATHER THAN GENERAL.
- (3) THE DIRECTION OF THIS MOVEMENT MAY CHANGE WITH TIME.

THE DOWNWARD MOVEMENT IS BEST EXPLAINED BY PUMPAGE FROM WELLS WITH VERY SHALLOW PERFORATIONS, OR DOWNWARD TRANSMISSION TO THE OXNARD AQUIFER THROUGH MULTI-PERFORATED WELLS, ABANDONED WELLS, OR IMPROPERLY CASED ROTARY GRAVEL-PACKED WELLS. EXCEPT IN PLEASANT VALLEY, THE DOWNWARD-MOVING WATER IS FOR THE MOST PART REACHING THE OXNARD AQUIFER. THE PRESENT DOWNWARD MOVEMENTS PROBABLY DID NOT START UNTIL THE MID-1940'S AT THE START OF THE CURRENT DROUGHT. SIMILAR DOWNWARD MOVEMENTS MAY HAVE OCCURRED DURING THE 1930'S. THIS DOWNWARD MOVEMENT TO THE OXNARD AQUIFER MUST BE VIEWED VERY SERIOUSLY BECAUSE OF THE POOR QUALITY OF THE SEMI-

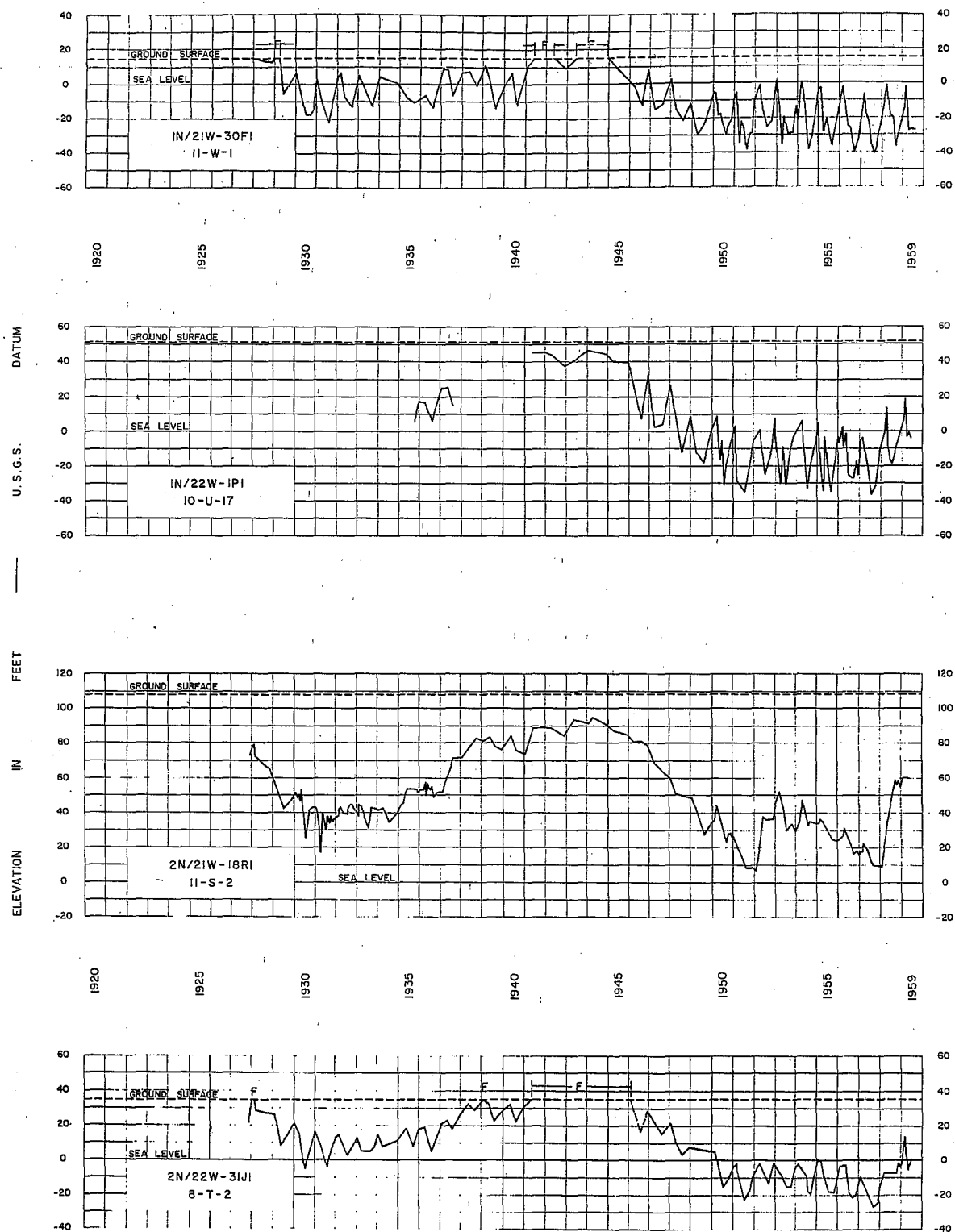
#### PERCHED WATERS.

THE METHOD USED BY ISHERWOOD AND PILLSBURY TO ESTIMATE THE DOWNWARD LEAKAGE IS VERY MUCH SUBJECT TO QUESTION. THE CHANGES IN WATER LEVELS USED WERE OBTAINED IN ONLY TWO PIEZOMETERS. THE CHANGE WAS RECORDED DURING A PERIOD OF ONLY TWO MONTHS IN THE SUMMER AND EXTRAPOLATED TO AN ANNUAL BASIS. REGARDLESS OF THE MECHANISM USED TO EXPLAIN THE DOWNWARD MOVEMENT, THE SUMMER RATE WOULD PROBABLY BE HIGHER THAN THE YEARLY AVERAGE. ALSO, THE FIGURE SELECTED APPEARS TO BE MUCH HIGHER THAN A REPRESENTATIVE AVERAGE WATER-LEVEL LOWERING FOR THE ENTIRE PIEZOMETER AREA. THE NET WATER MOVING DOWNWARD, 0.45 FOOT PER YEAR, IS EXTRAPOLATED TO AN AREA OF 32,000 ACRES, IN PLACES FAR BEYOND THE LIMITS OF THE OXNARD AQUIFER. THIS EXTRAPOLATION IS NOT SUPPORTABLE, FOR IN MANY AREAS THEIR DATA SHOW GRADIENTS WHICH ARE PERSISTENTLY UPWARD, OR AT TIMES UPWARD.

#### FLUCTUATIONS OF WATER LEVELS

WITHIN THE EXTENSIVE AND CONTINUOUS OXNARD AQUIFER, THE FLUCTUATIONS OF WATER LEVELS SHOW GRADUAL CHANGES FROM THE RECHARGE AREA OF THE MONTALVO BASIN TOWARD THE OCEAN. AS PREVIOUSLY DISCUSSED, THE HYDROGRAPHS OF WELLS IN THE MONTALVO BASIN SHOW A DEFINITE EMPTYING AND FILLING RESPONSE, CORRESPONDING TO WET AND DRY PERIODS OR YEARS. BY DEFINITION, THE OXNARD PLAIN BASIN INCLUDES THAT PORTION OF THE COASTAL PLAIN WHERE THE OXNARD AQUIFER IS CONFINED AND THUS THE HYDROGRAPHS SHOW MORE PRONOUNCED PRESSURE EFFECTS. NEAR THE MONTALVO BASIN, HOWEVER, THE HYDROGRAPHS SHOW A RESPONSE SIMILAR TO THE EMPTYING AND FILLING SEQUENCE, AS, FOR EXAMPLE, IN WELL 2N/21W-18R1 (PLATE 24). IN LATE 1951 AND AGAIN IN LATE 1957 THE TOP OF THE OXNARD AQUIFER MAY HAVE BEEN UNWATERED IN THE VICINITY OF THIS WELL.

CLOSER TO THE OCEAN AND THE PUMPING TROUGH, BUT STILL LANDWARD OF THE PUMPING TROUGH, IS WELL 1N/22W-1P1 (PLATE 24). THE HYDROGRAPH SHOWS THE SHARP ANNUAL WATER-LEVEL DEPRESSION AND RECOVERY WHICH TYPIFIES PRESSURE CONDITIONS. FOLLOWING THE WET YEARS OF THE EARLY FORTIES THERE WAS A GRADUAL DECLINE OF WATER LEVELS; SEASONAL HIGHS SHOW A RECOVERY TO ABOUT SEA LEVEL EVEN IN THE EXTREMELY DRY CONDITIONS OF LATE 1951, BUT NOT IN LATE 1957. THERE WAS UNUSUALLY GOOD RECOVERY ABOVE SEA LEVEL IN THE WET YEARS OF 1952 AND 1958, REFLECTING THE INFLUENCE OF RECHARGE FROM A LANDWARD DIRECTION.



OXNARD AQUIFER HYDROGRAPHS

CLOSER TO THE OCEAN, WITHIN AND SEAWARD FROM THE PUMPING TROUGH, WATER LEVELS SHOW A STRONG TENDENCY TO RECOVER TO SEA LEVEL, BUT LITTLE TENDENCY TO RISE ABOVE IT. ON THE HYDROGRAPHS OF WELLS 1N/21W-30F1 AND 2N/22W-31J1 (PLATE 24) THE EARLY FORTIES WERE CHARACTERIZED BY ARTESIAN FLOW, THEN A SHARP DECLINE WITH A MARKED LEVELING OF AVERAGE WATER LEVELS. SEAWARD OF THE PUMPING TROUGH AXIS, WATER MOVEMENT HAS BEEN LANDWARD FROM THE SEAWARD EXTENSIONS OF THE OXNARD AQUIFER, AND INVASION OF OCEAN WATER HAS OCCURRED NEAR PORT HUENEME. ALTHOUGH WATER LEVELS DURING THE PUMPING SEASON EACH YEAR MAY DROP SEVERAL TENS OF FEET BELOW SEA LEVEL, THERE IS RECOVERY TO ABOUT SEA LEVEL EACH YEAR DURING THE PERIODS OF LESSER PUMPING. BECAUSE OF THE SHORTNESS OF THE PERIODS OF MINOR PUMPING, IT IS DOUBTFUL THAT RECOVERY IS EVER QUITE COMPLETE.

#### STORAGE CAPACITY

A DETAILED STUDY WAS MADE OF THE STORAGE CAPACITY OF THE SHALLOWER AQUIFERS OF THE OXNARD PLAIN WHICH UNDERLIE THE CLAY CAP. DETERMINATIONS OF NET SAND THICKNESS WERE MADE FOR ALL WELLS FOR WHICH LOGS WERE AVAILABLE. IN GENERAL, THE SAND COUNTS WERE MADE TO A DEPTH OF 400 FEET, UTILIZING OIL WELL ELECTRIC LOGS FOR PREDICTING THICKNESSES OF THE DEEPER SANDS IN PLACES WHERE THE WATER WELLS DO NOT PENETRATE BEYOND THE OXNARD AQUIFER. UTILIZING THESE DATA, A SAND THICKNESS WAS ASSIGNED FOR EACH SQUARE-MILE SECTION OVER THE APPROXIMATE AREA OF 41,000 ACRES OF THE OXNARD PLAIN. THE MONTALVO BASIN WAS NOT INCLUDED IN THE STUDY. TO THE VOLUME OF MATERIAL SO CALCULATED, A SPECIFIC YIELD VALUE OF 20 PER CENT WAS ASSIGNED. THE INDICATED STORAGE VOLUME LANDWARD OF THE SHORELINE WAS 1.2 MILLION ACRE-FEET. WITHIN THE SEAWARD EXTENSIONS OF THE OXNARD AQUIFER THE STORAGE VOLUME WAS ESTIMATED AS 1.1 MILLION ACRE-FEET. SOME OF THIS SEAWARD VOLUME HAS ALREADY BEEN REPLACED BY INTRUDING SEA WATER.

#### HYDRAULIC CONTINUITY WITH THE OCEAN

THERE IS NO LONGER ANY DOUBT THAT THE OXNARD AQUIFER HAS A SUBMARINE OUTCROP IN HUENEME SUBMARINE CANYON. NOR IS THERE ANY DOUBT THAT THE HIGH CHLORIDES IN WELLS NEAR PORT HUENEME ARE THE RESULT OF OCEAN WATER HAVING MOVED INTO THAT SUBMARINE OUTCROP AND BENEATH THE LAND SURFACE IN RESPONSE TO LANDWARD GRADIENTS. SOME QUESTION MAY PERHAPS REMAIN THAT THE SEA-WATER WEDGE HAS REACHED WELL 1N/22W-17J2 BECAUSE WELL 1N/22W-20B1, ABOUT 1/2 MILE TOWARD THE COAST, SHOWS UNCONTAMINATED WATER. HOWEVER, THE

ARRIVAL OF HIGH CHLORIDE WATER AT WELL 1N/22W-17J2 IS CONSISTENT WITH THE EXPECTABLE RATE OF ADVANCE AND SHOWS CHLORIDE FLUCTUATIONS, UPON BEING PUMPED, LIKE THE KNOWN INTRUDED WELLS. WELL 1N/22W-20B1 APPEARS TO BE PERFORATED ONLY IN A ZONE DEEPER THAN THE OXNARD AQUIFER, AND ONE IN WHICH SEA WATER HAS NOT ADVANCED VERY FAR. IT IS QUITE PROBABLE THAT THE ZONE PERFORATED IN THIS WELL IS A LENS, WHICH HAS NO OUTCROP IN THE SUBMARINE CANYON. THE UNUSUALLY LOW WATER LEVELS SUPPORT THE LENS EXPLANATION. IF THERE ARE MORE CONTINUOUS AQUIFERS BELOW THE OXNARD AQUIFER, THESE ARE QUITE LIKELY EXPOSED TO OCEAN WATER IN HUENEME SUBMARINE CANYON.

BENEATH THE MUGU NAVAL BASE THE STATUS OF SEA-WATER INTRUSION IS MUCH LESS CLEAR. HIGH CHLORIDES HAVE BEEN RECORDED IN THE WATERS PUMPED FROM OBSERVATION WELL #2 (1S/21W-5H1) FOR ABOUT TEN YEARS. WATER SAMPLES ARE TAKEN FROM TWO SETS OF PERFORATIONS SEPARATED BY A PACKER AND A SEAL. ERRATIC WATER LEVELS IN THIS WELL RENDER ALL CHEMICAL DATA SUBJECT TO QUESTION. NO PRODUCING WELL ON THE MUGU NAVAL BASE HAS AS YET BEEN INTRUDED BY SEA WATER. CONSIDERING THE CONTINUITY OF BOTH THE OXNARD AQUIFER AND THE MUGU AQUIFER IT IS HIGHLY PROBABLY THAT BOTH HAVE OUTCROPS IN NEARBY MUGU SUBMARINE CANYON. AND DESPITE THE FACT THAT NO WELL AS YET CONCLUSIVELY DEMONSTRATES THE ADVANCING SEA-WATER FRONT, IT IS HIGHLY PROBABLE THAT SEA-WATER INTRUSION HAS BEEN OCCURRING FOR SEVERAL YEARS IN BOTH THE OXNARD AQUIFER AND THE MUGU AQUIFER.

AWAY FROM THE CANYONS THE PRESENCE OF SUBMARINE OUTCROPS OF THE OXNARD AQUIFER IS PROBABLE, WHEREAS FOR THE DEEPER AND MORE LENTICULAR UPPER PLEISTOCENE AQUIFERS THE PROBABILITY IS LESS.

#### FOX CANYON AQUIFER

##### PHYSICAL CHARACTERISTICS AND AREAL DISTRIBUTION

THE FOX CANYON AQUIFER COMPRISES THE PREDOMINANTLY SAND AND GRAVEL BASAL ZONES OF THE SAN PEDRO FORMATION, WHICH, ON THE BASIS OF ABUNDANT FOSSIL EVIDENCE HAVE BEEN ASSIGNED A LOWER PLEISTOCENE AGE. THE TYPES OF FOSSILS AND PHYSICAL NATURE OF THE DEPOSITS INDICATE THAT THE BASAL LAYERS OF THE SAN PEDRO FORMATION WERE DEPOSITED IN A MARINE ENVIRONMENT AND IN SHALLOW WATER. AT THE TIME OF DEPOSITION THE FOX CANYON SANDS AND GRAVELS WERE SATURATED WITH SEA WATER. AS SHOWN BY THE CONTAINED FOSSIL REMAINS, THE UPPER LAYERS OF THE SAN PEDRO FORMATION WERE DEPOSITED IN A NON-MARINE ENVIRONMENT.

THE SAN PEDRO FORMATION AND FOX CANYON AQUIFER UNDERLIE ALMOST ALL OF THE COASTAL PORTION OF THE DISTRICT. VARIATIONS IN CHARACTERISTICS FROM PLACE TO PLACE HAVE BEEN PRODUCED BY ORIGINAL DIFFERENCES IN THE MANNER OF DEPOSITION, AND BY EXTENSIVE FOLDING AND FAULTING DURING THE MIDDLE PLEISTOCENE DISTURBANCE, WITH SUBSEQUENT REMOVAL OF SOME OF THE LAYERS BY EROSION. THE MIDDLE PLEISTOCENE DISTURBANCE PRODUCED A SERIES OF EAST-WEST FOLDS AND FAULTS, SOME OF WHICH HAVE CONSIDERABLE HYDROLOGIC SIGNIFICANCE. THE NORTHERNMOST FOLD, THE SANTA CLARA RIVER SYNCLINE (PLATE 17) CAN BE TRACED FROM THE COASTLINE NEAR THE CITY OF VENTURA ALL THE WAY EAST INTO THE PIRU BASIN; IT PROBABLY ALSO EXTENDS FOR SOME DISTANCE WESTERLY BENEATH THE OCEAN. NEAR THE SANTA CLARA RIVER THE SAN PEDRO BEDS ARE ARCHED UPWARD ALONG THE MONTALVO FAULT, A COMPLEXLY FAULTED ANTICLINAL FOLD WHICH IS THE WESTWARD EXTENSION OF THE OAK RIDGE FAULT AND SOUTH MOUNTAIN UPLIFT. THE VERTICAL DISPLACEMENT ON THIS HUGE ZONE OF FRACTURING DECREASES FROM A MAGNITUDE OF SEVERAL THOUSAND FEET NEAR THE END OF SOUTH MOUNTAIN TO ABOUT 500 FEET AT THE COASTLINE. IN THE MOUND BASIN THE SURFACE EXPOSURES OF THE SAN PEDRO FORMATION DO NOT SHOW THE THICK BASAL FOX CANYON SANDS AND GRAVELS. EXCELLENT EXPOSURES OF THE FOX CANYON LAYERS ARE FOUND ON THE SOUTH FLANK OF SOUTH MOUNTAIN; THESE CONTINUE TO THE WEST BENEATH THE ALLUVIUM OF THE MONTALVO BASIN AND CURVE SHARPLY TO THE NORTH WHERE THE BEDS HAVE BEEN ARCHED ALONG THE UPTHROWN SIDE OF THE SATICOY FAULT. THIS BURIED AREA OF THE FOX CANYON AQUIFER IS VERY IMPORTANT HYDROLOGICALLY AND IS REFERRED TO AS THE "SUB-ALLUVIAL OUTCROP". WESTERLY FROM SATICOY THE FOX CANYON AQUIFER CAN BE TRACED, USING ELECTRIC LOGS OF OIL WELLS, ON BOTH SIDES OF THE MONTALVO FAULT TO THE COASTLINE. THE FOX CANYON SANDS AND GRAVELS PINCH OUT IN A NORTHERLY DIRECTION BENEATH THE SANTA CLARA RIVER SYNCLINE. FROM THE SANTA CLARA RIVER SOUTH, HOWEVER, THE FOX CANYON AQUIFER EXTENDS CONTINUOUSLY TO THE VICINITY OF THE SANTA MONICA MOUNTAINS, UNDERLYING ESSENTIALLY ALL OF THE OXNARD PLAIN, THE WEST LAS POSAS AREA, THE CAMARILLO HILLS, AND PLEASANT VALLEY.

ANOTHER IMPORTANT FOLD IS THE OXNARD SYNCLINE, EXTENDING WESTERLY FROM THE WEST LAS POSAS AREA. ALONG THE AXIS OF THIS FOLD THE BASE OF THE FOX CANYON IS IN PLACES MORE THAN 2000 FEET DEEP. FARTHER SOUTH, THE FAULTED ANTICLINE OF THE CAMARILLO HILLS APPEARS TO DIE OUT TO THE WEST. IN THE CAMARILLO HILLS, EXPOSURES OF FOX CANYON BEDS ARE RELATED

TO UPLIFTS ALONG FAULTS. THE PLEASANT VALLEY AREA SHOWS SEVERAL MINOR FOLDS AND FAULTS, BUT IS GENERALLY A WESTWARD-PLUNGING SYNCLINE. THE NORTH-WESTERN FRONT OF THE SANTA MONICA MOUNTAINS IS PROBABLY ASSOCIATED WITH A SERIES OF FAULTS, NOW LARGELY BURIED.

WATER WELLS TAPPING THE FOX CANYON AQUIFER ARE NUMEROUS IN PLEASANT VALLEY, BUT HAVE BEEN DRILLED ONLY ALONG THE EDGES OF THE OXNARD PLAIN. BECAUSE THE CENTRAL PART OF THE OXNARD PLAIN IS UNDERLAIN BY A GOOD SHALLOW AQUIFER, THERE HAS BEEN VERY LITTLE DEEP DRILLING FOR WATER. DESPITE THIS LACK OF WATER WELLS, EXCELLENT INFORMATION REGARDING THE DEPTH AND LITHOLOGY OF THE FOX CANYON AQUIFER HAS BEEN OBTAINED FROM DATA COLLECTED IN NUMEROUS OIL WELLS. ESPECIALLY VALUABLE HAVE BEEN THE ELECTRIC LOGS.

THE BASE OF THE FOX CANYON AQUIFER IS QUITE READILY DETERMINED FROM DRILLERS' RECORDS AND ELECTRIC LOGS, FOR BELOW THE BASAL GRAVEL IS USUALLY THE THICK SHALE OF THE SANTA BARBARA FORMATION. A RECOGNIZABLE CHANGE IN THE TYPES OF FOSSILS HAS BEEN DESCRIBED AS OCCURRING AT THE BASE OF THE FOX CANYON GRAVELS OR A SHORT DISTANCE BELOW THE BASE. IN THE WEST LAS POSAS AREA, BENEATH THE CAMARILLO HILLS, AND IN PARTS OF PLEASANT VALLEY, THE TOP OF THE SANTA BARBARA FORMATION SHOWS A THICK GRAVEL ZONE, REFERRED TO AS THE GRIMES CANYON MEMBER. OVER MUCH OF ITS AREA OF OCCURRENCE THE GRIMES CANYON MEMBER HAS AN EXTENSIVE HYDRAULIC CONNECTION WITH THE FOX CANYON AQUIFER.

IN CONTRAST WITH THE GENERALLY RECOGNIZED BASE OF THE FOX CANYON AQUIFER, THERE SEEMS TO HAVE BEEN NO CONSISTENT INTERPRETATION FOR THE TOP. WHEREAS THE SAND AND GRAVEL LAYERS NEAR THE BASE ARE TRACEABLE OVER AN EXTENSIVE AREA, THE HIGHER SANDS AND GRAVELS ARE LESS CONTINUOUS, APPEARING AS LENSES IN VARIOUS STRATIGRAPHIC POSITIONS. ALONG THE LINE FROM SATICOY TO PORT HUENEME (SECTION Z-Z', PLATE 19) THE ELECTRIC LOGS SHOW A CONTINUOUS BASAL GRAVEL ZONE USUALLY LESS THAN 50 FEET THICK. ABOVE THIS IS A PRONOUNCED CLAYEY LAYER 50 TO 150 FEET THICK, WITH SEVERAL THIN SANDY ZONES. ON TOP OF THE CLAYEY ZONE IS THE MAIN SANDY ZONE OF THE FOX CANYON AQUIFER, ABOUT 150 TO 250 FEET THICK. THE VARIATION IN THICKNESS IN THE MAIN SANDY ZONE IS EXPLAINED BY INTERFINGERING WITH CLAYS AT THE TOP AND AT THE BOTTOM. ABOVE THE LAYERS JUST DESCRIBED THERE IS MUCH LESS REGULARITY IN THE LAYERING. NEVERTHELESS, THERE IS USUALLY ONE OR MORE THICK (UP TO 100 FEET) SAND ZONES ABOVE THE MORE CONTINUOUS

PERMEABLE LAYERS. A TYPICAL ELECTRIC LOG OF THE FOX CANYON AQUIFER IS GIVEN IN PLATE 26.

NORTHERLY FROM THE CITY OF OXNARD THE FOX CANYON AQUIFER CAN BE TRACED, USING ELECTRIC LOGS, TO BEYOND THE SANTA CLARA RIVER. AS PREVIOUSLY NOTED, THE AQUIFER THINS AND PINCHES OUT SOUTH OF THE OUTCROPS ON THE NORTH SIDE OF THE MOUND BASIN. TOWARD THE SOUTHEAST FROM THE CITY OF OXNARD THE FOX CANYON AQUIFER THINS AND RISES (SECTION V-V', PLATE 20), APPEARING IN MUGU NAVAL BASE WELL #3 (1N/21W-31L1) AS TWO SANDY ZONES, EACH ABOUT 70 FEET THICK. TOWARD CAMARILLO THE SAN PEDRO FORMATION OVERLYING THE FOX CANYON AQUIFER BECOMES MUCH LESS SANDY; ALSO THE GRIMES CANYON MEMBER DIRECTLY UNDERLIES THE FOX CANYON AQUIFER, RESULTING IN A CONTINUOUS SAND THICKNESS OF AS MUCH AS 500 FEET.

#### VOLUME OF WATER IN STORAGE

THE VOLUME OF WATER STORED IN THE SANDS AND GRAVELS OF THE FOX CANYON AQUIFER AND UPPER SAN PEDRO FORMATION WAS CALCULATED FOR THE AREA CORRESPONDING TO THE MONTALVO, PLEASANT VALLEY, AND OXNARD PLAIN BASINS. THE MOUND BASIN WAS NOT INCLUDED IN THIS CALCULATION. ALL AVAILABLE WATER WELL LOGS AND MANY OIL WELL LOGS (ESPECIALLY ELECTRIC LOGS) WERE STUDIED. FOR EACH WELL A SAND COUNT WAS MADE, FOR THE INTERVAL FROM A DEPTH OF ABOUT 400 FEET TO THE BASE OF THE FOX CANYON AQUIFER. MANY OF THE THIN SANDS WERE NOT COUNTED. NET SAND THICKNESSES WERE DETERMINED FOR EACH WELL LOCATION, AND USING THIS CONTROL, A NET SAND THICKNESS FOR EACH SQUARE-MILE SECTION WAS ESTIMATED FOR THE ENTIRE AREA. TO THE VOLUME OF SAND CALCULATED, A SPECIFIC YIELD OF 20 PER CENT WAS ASSIGNED. THE ESTIMATED VOLUME OF WATER IN STORAGE IN THESE SANDS IS 6 MILLION ACRE-FEET. THERE IS ABUNDANT EVIDENCE THAT THESE SANDS HAVE BEEN THOROUGHLY FLUSHED WITH FRESH WATERS, AND A VERY LARGE PERCENTAGE OF THE WATER IN STORAGE IS EXPECTED TO BE OF USABLE CHEMICAL QUALITY.

LESS RELIABLE ARE THE ESTIMATES WHICH CAN BE MADE FOR THE VOLUME OF WATER IN STORAGE IN THE SEAWARD EXTENSIONS OF THE FOX CANYON AQUIFER. THERE IS A HIGH PROBABILITY THAT THE FOX CANYON AQUIFER HAS SUBMARINE OUTCROPS IN HUENEME AND MUGU SUBMARINE CANYONS AND ALONG THE OCEAN FLOOR AT COMPARABLE DEPTHS BETWEEN THE TWO CANYONS. A NET SAND THICKNESS OF 300 FEET FOR THE FOX CANYON AQUIFER AND UPPER SAN PEDRO WAS USED BETWEEN THE SHORELINE AND THE ESTIMATED POSITION OF THE SUBMARINE

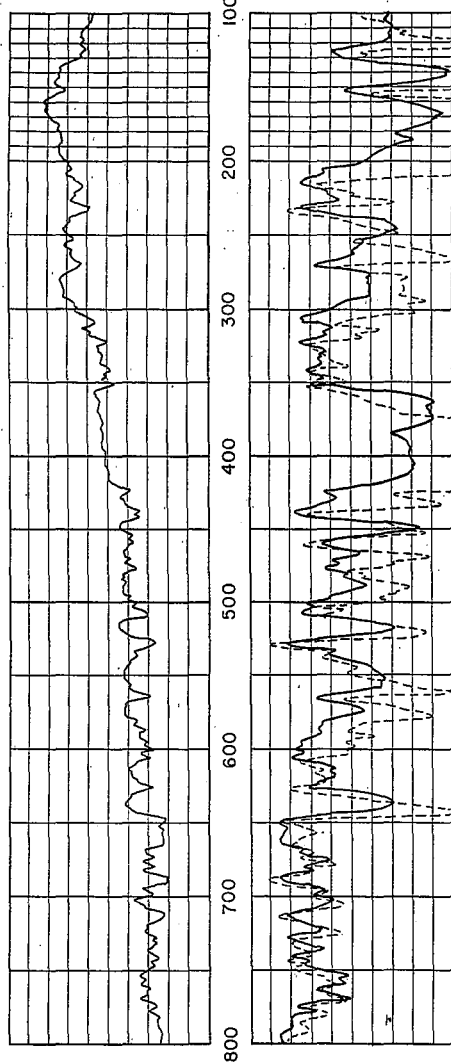
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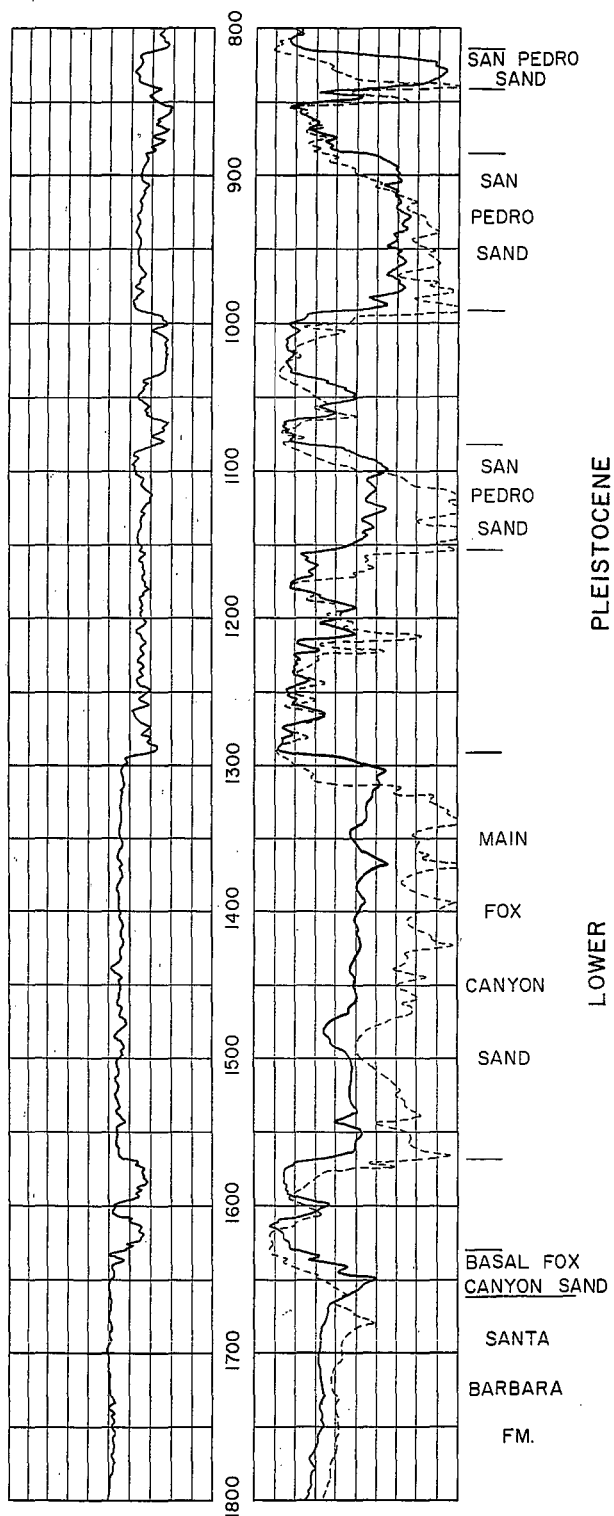
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RESISTIVITY

OHMS M<sup>2</sup>/M



OXNARD PLAIN  
ELECTRIC LOG



OUTCROP. BY ASSUMING A SPECIFIC YIELD OF 20 PER CENT, THE ESTIMATED VOLUME IN STORAGE BETWEEN THE TWO CANYONS IS 1.5 MILLION ACRE-Feet. THIS HAS BEEN AN AREA OF FREE FLUSHING AND THE WATER IS EXPECTED TO BE OF ACCEPTABLE CHEMICAL QUALITY.

THE CONDITIONS OFFSHORE NORTH OF HUENEME SUBMARINE CANYON ARE EVEN LESS CLEAR. THIS OFFSHORE AREA IS RATHER SHALLOW, AND THERE MAY BE NO SUBMARINE OUTCROPS, EXCEPT THOSE OF THE HIGHER ZONES OF THE UPPER SAN PEDRO FORMATION. THE NET SAND THICKNESS IN THIS OFFSHORE AREA WAS TAKEN AS 500 FEET, AND THE SPECIFIC YIELD AS 20 PER CENT, GIVING A STORAGE VOLUME OF 3.6 MILLION ACRE-Feet. AT THE COASTLINE, FRESH WATER HAS BEEN FLUSHED THROUGH THE ORIGINAL MARINE SANDS TO PRESENT DEPTHS OF 3000 FEET. IT IS HIGHLY PROBABLE THAT THE WATER IS FRESH WITHIN THE FOX CANYON AQUIFER IN THE OFFSHORE AREA NORTH OF HUENEME SUBMARINE CANYON. HOWEVER, THE LACK OF SUBMARINE OUTCROPS MAY HAVE RETARDED RECENT FLUSHING, AND THE CHEMICAL QUALITY OF THIS WATER MAY BE POORER THAN IN THE OFFSHORE AREA SOUTH OF HUENEME SUBMARINE CANYON.

#### SOURCES OF RECHARGE

AS POINTED OUT ABOVE, THE FOX CANYON AQUIFER IS OF MARINE ORIGIN AND WAS ORIGINALLY FILLED WITH SEA WATER. SOMETIME AFTER ITS DEPOSITION, THE FOX CANYON SANDS AND GRAVELS MUST HAVE BEEN LIFTED OUT OF THE OCEAN AND EXPOSED ON THE LAND SURFACE TO INFILTRATING FRESH WATERS. THE FRESH WATERS MOVED SLOWLY THROUGH THESE AQUIFERS AND FLUSHED OUT THE SEA WATER. DURING THIS FLUSHING THE EXITS FOR THE FLUSHED WATER WERE PROBABLY STILL BENEATH THE OCEAN. BECAUSE OF THE DEPTH AT WHICH FRESH WATER IS NOW FOUND (3000 FEET IN SECTION 1, T1N, R23W) IT SEEMS APPARENT THAT THE FRESH-WATER FLUSHING TOOK PLACE INITIALLY NOT LONG AFTER SAN PEDRO DEPOSITION, BUT BEFORE THE MAJOR MIDDLE PLEISTOCENE DIASTROPHISM WHICH HAS SO EXTENSIVELY FOLDED AND FAULTED THESE BEDS. CIRCULATION OF FRESH WATER IN THE SHALLOWER ZONES HAS PROBABLY CONTINUED TO THE PRESENT TIME. PERHAPS MORE THAN ANY OTHER EVIDENCE, THE FLUSHING OF THE FOX CANYON AQUIFER DEMONSTRATES THAT IT HAS AN EXTREME DEGREE OF HYDROLOGIC CONTINUITY. CHLORIDES, AN EXPECTABLE INDICATOR OF RESIDUAL SEA WATER, ARE ALMOST INVARIABLY THE LEAST ABUNDANT ANION.

FRESH WATERS TODAY CONTINUE TO MOVE WITHIN THE FOX CANYON AQUIFER FROM INLAND AREAS TOWARD THE COASTLINE. THE BEST PERENNIAL SOURCE

OF RECHARGE TO THE FOX CANYON AQUIFER IS THE SATURATED ALLUVIUM OF THE MONTALVO BASIN, THROUGH THE SUB-ALLUVIAL OUTCROP. AS IT IS LOCATED IN PART UNDER THE SATICOY SPREADING GROUNDS, THE SUB-ALLUVIAL OUTCROP RECEIVES A DIRECT AND IMMEDIATE BENEFIT FROM THE DISTRICT'S SPREADING OPERATIONS. BETWEEN THE END OF SOUTH MOUNTAIN AND THE WESTERN END OF THE CAMARILLO HILLS, UNDERFLOW WITHIN THE FOX CANYON AQUIFER MOVES WESTERLY FROM THE WEST LAS POSAS AREA TOWARD THE OXNARD PLAIN. THE RESPONSE OF WATER LEVELS IN THE WEST LAS POSAS AREA, HOWEVER, CLEARLY INDICATES PUMPAGE IN EXCESS OF NATURAL REPLENISHMENT, AND THIS UNDERFLOW IS EXPECTED TO DECREASE IN THE FUTURE. ANOTHER INCREMENT OF UNDERFLOW MOVES WESTERLY THROUGH THE FOX CANYON AQUIFER NEAR SOMIS AND INTO PLEASANT VALLEY. THE SOURCE OF THIS UNDERFLOW, EAST LAS POSAS BASIN, IS EXPERIENCING A SEVERE OVERDRAFT, AND THIS UNDERFLOW, TOO, WILL DIMINISH. NO OTHER SOURCE OF RECHARGE TO THE FOX CANYON AQUIFER, IN THE AREA COVERED IN THIS REPORT, IS CONSIDERED OF MUCH QUANTITATIVE IMPORTANCE.

#### MOVEMENTS OF WATER

OVER ALMOST ALL THE AREA STUDIED THE FOX CANYON AQUIFER IS CONFINED BY SEVERAL TO MANY THICK LAYERS OF LOW PERMEABILITY. BECAUSE OF OUTCROPS AT HIGH ELEVATIONS, ORIGINAL PIEZOMETRIC LEVELS WERE MUCH ABOVE SEA LEVEL AND THE WATER FOLLOWED RELATIVELY SIMPLE WESTERLY PATHS FROM THE OUTCROP AREAS TOWARD THE SUBMARINE OUTCROPS. PERSISTENT SEAWARD FLOW CONTINUED UNTIL THE MID-1940'S, DESPITE RELATIVELY HEAVY PUMPAGE IN PLEASANT VALLEY (PLATE 21). STARTING PERHAPS IN 1947 AND CERTAINLY BY 1948, THE HEAVY PUMPAGE IN PLEASANT VALLEY HAD CREATED A SEVERE OVERDRAFT AND WATER BEGAN TO MOVE WITHIN THE FOX CANYON AQUIFER FROM ITS EXTENSIONS BENEATH THE OCEAN TOWARD THE INLAND CENTERS OF PUMPING. SINCE 1948 WATER LEVELS EVERYWHERE IN PLEASANT VALLEY EXCEPT THE EASTERNMOST PORTION HAVE REMAINED BELOW SEA LEVEL. IN THE NORTHERN PART OF THE OXNARD PLAIN, WHERE THERE HAS BEEN AS YET LITTLE PUMPING FROM THE FOX CANYON AQUIFER, THE WATER LEVELS HAVE REMAINED SOMEWHAT HIGHER; SIGNIFICANT LANDWARD GRADIENTS OF THE PIEZOMETRIC SURFACE MAY NOT YET HAVE DEVELOPED.

MANY OF THE FOX CANYON WELLS IN PLEASANT VALLEY ARE LARGE-DIAMETER GRAVEL-PACKED WELLS WITH PERFORATIONS OVER EXTENSIVE VERTICAL INTERVALS. THE WELL CASING OR GRAVEL PACK MAY ALLOW FREE COMMUNICATION AMONG THE FOX CANYON AQUIFER, UPPER SAN PEDRO SANDS, AND YOUNGER ALLUVIAL

DEPOSITS. THESE WELLS MIGHT ALLOW MUCH INTER-ZONE WATER MOVEMENT, ESPECIALLY WHEN NOT PUMPING. WELLS PERFORATED ONLY IN THE FOX CANYON AQUIFER TEND TO MAINTAIN A HIGHER PIEZOMETRIC SURFACE THAN THOSE PERFORATED ALSO IN THE SHALLOW AQUIFERS. WATER PUMPED FROM THE SHALLOW AQUIFERS IS THUS REPLACED BY WATER FROM THE FOX CANYON AQUIFER, BY FLOWING UPWARD IN WELLS DURING NON-PUMPING PERIODS. INTRUDING SEA WATER MOVING INLAND IN ONE AQUIFER MIGHT TRAVEL UPWARD IN A WELL TO A DIFFERENT AQUIFER, LONG BEFORE THE SEA-WATER FRONT IN THE SECOND AQUIFER HAD REACHED THIS POSITION.

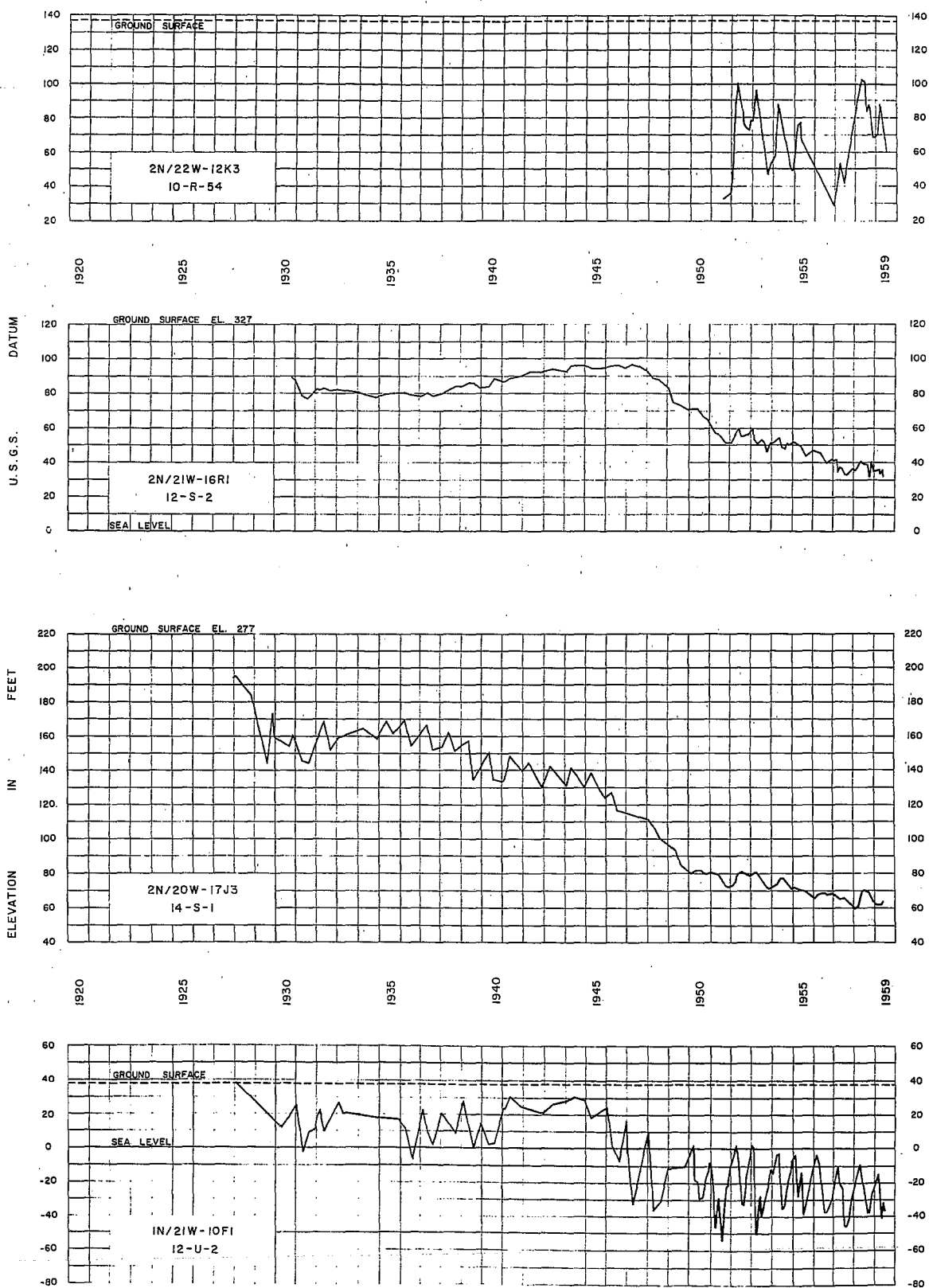
#### IMPEDIMENTS TO GROUND WATER FLOW

AS NOTED ABOVE, THE MAIN LOWER FOX CANYON SANDS AND GRAVELS HAVE A HIGH DEGREE OF CONTINUITY AND WATER MOVEMENT IS RELATIVELY UNRESTRICTED. HIGHER IN THE SAN PEDRO FORMATION THE WATER-BEARING ZONES ARE LESS CONTINUOUS AND WOULD HAVE LESS OPPORTUNITY FOR FREE RECHARGE. SIMILARLY, THEY ARE LESS SUBJECT TO SEA-WATER INTRUSION. THERE IS USUALLY VERY LIMITED INTER-CONNECTION AMONG THESE UPPER SAN PEDRO SAND LENSES. MANY, HOWEVER, HAVE BEEN INTERCONNECTED RECENTLY BY MULTI-ZONE CABLE-TOOL WELLS AND ROTARY GRAVEL-PACKED WELLS.

IN ADDITION TO RESTRICTIONS IMPOSED BY LENTICULAR DEPOSITION, UNDERGROUND FLOW IN THE FOX CANYON AND UPPER SAN PEDRO AQUIFERS IS RETARDED BY SEVERAL FAULTS. VERY LITTLE WATER IS BELIEVED TO MOVE THROUGH THE SAN PEDRO AQUIFERS ACROSS THE COUNTRY CLUB AND SATICOY FAULTS FROM THE SANTA PAULA BASIN INTO THE MOUND BASIN. A VERY EFFECTIVE BARRIER TO UNDERFLOW IS PROBABLY AFFORDED BY THE MONTALVO FAULT AND ASSOCIATED STRUCTURAL DISTURBANCES. IN THE CAMARILLO HILLS THE EFFECTIVENESS OF THE SPRINGVILLE FAULT (PLATE 17) AS A GROUND-WATER BARRIER IS AMPLY DEMONSTRATED BY A BREAK IN THE PIEZOMETRIC SURFACE OF AS MUCH AS 90 FEET. THE BARRIER EFFECT SEEMS TO DECREASE TOWARD THE WEST ALTHOUGH THERE IS NO WELL CONTROL TO CONFIRM THIS SUGGESTION. THE CAMARILLO FAULT (PLATE 17) DOES NOT APPEAR TO RESTRICT WATER MOVEMENTS WITHIN EITHER THE FOX CANYON OR UPPER SAN PEDRO AQUIFERS.

#### FLUCTUATIONS OF WATER LEVELS

WATER-LEVEL FLUCTUATIONS IN FOX CANYON WELLS SHOW A VARIETY OF RESPONSES. WELL 2N/22W-12K3 (PLATE 25), LOCATED CLOSE TO THE SUB-ALLUVIAL OUTCROP, SHOWS THE MARKED BENEFICIAL EFFECTS WITHIN THE FOX CANYON AQUIFER OF SPREADING AT THE SATICOY SPREADING GROUNDS. EXCELLENT RECOVERIES CAN



FOX CANYON HYDROGRAPHS

BE NOTED FOR 1952 AND 1953, WHEN LARGE AMOUNTS OF WATER WERE SPREAD. ESPECIALLY STRONG WAS THE RISE IN 1958, COINCIDING WITH THE DISTRICT'S BEST SPREADING YEAR. AT THIS POSITION, THE FOX CANYON PIEZOMETRIC SURFACE IN THE SPRING IS USUALLY 10 FEET OR SO ABOVE THE LOCAL WATER TABLE.

THE HYDROGRAPH OF WELL 2N/21W-16R1 (PLATE 25) ILLUSTRATES THE TREND OF FOX CANYON PRESSURE LEVELS IN WEST LAS POSAS BASIN JUST EAST OF THE OXNARD PLAIN. THE SHARP DOWNTREND, WITH LITTLE RECOVERY DURING THE WET YEARS OF 1952 AND 1958, IS INDICATIVE OF RATHER SEVERE OVERDRAFT. THERE IS LITTLE DOUBT THAT UNDERFLOW WITHIN THE FOX CANYON AQUIFER FROM WEST LAS POSAS BASIN TO BENEATH THE OXNARD PLAIN WILL CONTINUE TO DECREASE.

A SIMILAR, BUT EVEN MORE PRONOUNCED OVERDRAFT INDICATION IS SHOWN BY THE HYDROGRAPH OF WELL 2N/20W-17J3 (PLATE 25). THIS WELL IS DRILLED INTO THE FOX CANYON AQUIFER CLOSE TO THE BOUNDARY OF PLEASANT VALLEY AND EAST LAS POSAS BASIN. IN THIS FREE WATER TABLE AREA THE DECLINING WATER LEVEL IS EVIDENCE OF THE GRADUALLY DECREASING SATURATED CROSS-SECTIONAL AREA THROUGH WHICH UNDERFLOW IS BEING TRANSMITTED WESTERLY INTO PLEASANT VALLEY. THIS SOURCE OF UNDERFLOW RECHARGE IS DIMINISHING RAPIDLY.

AWAY FROM THE RECHARGE AREA, A MORE TYPICAL HYDROGRAPH OF THE FOX CANYON AQUIFER IS THAT OF WELL 1N/21W-10F1 (PLATE 25). DURING THE WET YEARS OF THE EARLY 1940'S, THERE WERE RELATIVELY FEW WELLS PUMPING FROM THE FOX CANYON AQUIFER. FOLLOWING 1945, AS THE DROUGHT PROGRESSED, MANY MORE FOX CANYON WELLS WERE DRILLED, AND THE NUMBER OF FOX CANYON WELLS ABOUT DOUBLED BETWEEN 1944 AND 1951. THE COMBINATION OF FAILING RECHARGE AND INCREASING PUMPAGE RESULTED IN STATIC PRESSURE LEVELS GOING BELOW SEA LEVEL IN 1946. IN 1948 THERE WAS AN ESPECIALLY SEVERE DROP AND THE STATIC WATER LEVELS HAVE REMAINED BELOW SEA LEVEL FOR MOST OF THE TIME SINCE THEN. THE PUMPING IS SO HEAVY THAT TRUE INLAND RECHARGE EFFECTS ARE MASKED. THE SHARP RISE IN 1951-52 IS MERELY A PRESSURE RECOVERY CAUSED BY A RELATIVELY PROLONGED PERIOD OF NON-PUMPING DURING A WET YEAR. AFTER 1953, SEASONAL HIGHS CONTINUED TO DECLINE, BUT ONLY MODERATELY. THERE IS A MARKED TENDENCY FOR PRESSURE LEVELS TO RETURN TO SEA LEVEL. THIS IS BELIEVED DUE TO THE OPERATION OF A U-TUBE EFFECT WITH SEA WATER ON THE OTHER LIMB. THE RECOVERY OF THE PRESSURE LEVEL TO SEA LEVEL (OR ACTUALLY MANY FEET ABOVE SEA LEVEL) IS A SLOW PROCESS AND WOULD OCCUR DURING A SUFFICIENTLY LONG PERIOD OF NON-PUMPING. SINCE 1953, THE PIEZOMETRIC LEVELS HAVE NOT

HAD SUFFICIENT TIME TO RECOVER TO SEA LEVEL. NOTE, HOWEVER, THAT THE LIGHTER PUMPING DURING THE RAINY WINTER OF 1958 RESULTED IN A SLIGHTLY BETTER RECOVERY IN 1958 THAN IN 1957.

THE HUENEME NAVAL BASE DEEP WELL (1N/22W-17B1) IS PERFORATED IN THE UPPER PART OF THE FOX CANYON AQUIFER, AND THIS SAND HAS BEEN TRACED TO THE SUB-ALLUVIAL OUTCROP AT THE SATICOY SPREADING GROUNDS. THE PIEZOMETRIC LEVEL IN WELL 17B1 REACHED A PEAK IN THE MIDDLE OF MARCH 1959 DURING AN UNUSUALLY DRY RAINFALL SEASON. IT IS SUGGESTED THAT THIS HIGH WATER LEVEL REFLECTS THE DECEMBER 1958 SPREADING OPERATIONS IN THE MONTALVO BASIN. IF THIS INTERPRETATION IS CORRECT, THE PRESSURE WAVE TRAVELED FROM THE SATICOY SPREADING GROUNDS TO THIS WELL, A DISTANCE OF ABOUT 8 MILES, IN THE 2½ MONTH PERIOD FROM THE END OF DECEMBER TO THE MIDDLE OF MARCH.

## CHAPTER III WATER QUALITY

### CRITERIA OF SUITABILITY

THE USABILITY OF GROUND WATER IS GENERALLY EVALUATED FROM THE RESULTS OF CHEMICAL ANALYSES OF THE MAJOR IONIC CONSTITUENTS. MINOR CONSTITUENTS SUCH AS BORON AND FLUORIDE HAVE BEEN ADDED TO STANDARD CHEMICAL ANALYSES BECAUSE THEY OCCUR IN NATURAL WATERS AND ARE UNDESIRABLE IN MINUTE QUANTITIES. IN THE EVENT OF SUSPECTED POLLUTION, THE CONCENTRATIONS OF MANY OTHER SUBSTANCES MAY BE DETERMINED. IN ADDITION TO CERTAIN SOLIDS DISSOLVED IN THE WATER, LIMITATIONS ON USABILITY MAY BE PLACED BY FACTORS OF TURBIDITY, COLOR, OR DISSOLVED GASES.

### DOMESTIC USE

CRITERIA OF ACCEPTABILITY OF WATER FOR DOMESTIC USE ARE MOST COMMONLY RELATED TO THE UNITED STATES PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS OF 1946. THESE STANDARDS WERE ORIGINALLY SET IN 1914, AND WERE REVISED IN 1942. THE 1946 VERSION REPRESENTS THE SECOND REVISION; IT IS UNDERSTOOD THAT A THIRD REVISION IS CURRENTLY BEING STUDIED. AS CONCEIVED AND REVISED, THESE STANDARDS WERE INTENDED TO APPLY ONLY TO WATERS USED BY INTERSTATE CARRIERS OR WATERS SUBJECT TO FEDERAL QUARANTINE REGULATIONS. HOWEVER, BECAUSE OF WIDESPREAD ADOPTION BY THE AMERICAN WATER WORKS ASSOCIATION AND BY MOST STATE DEPARTMENTS OF HEALTH, THESE STANDARDS NOW ARE GENERALLY APPLIED TO ALL PUBLIC WATER SUPPLIES. FOR CERTAIN CHEMICAL SUBSTANCES, THE LIMITS GIVEN ARE MANDATORY:

|                         |                      |
|-------------------------|----------------------|
| LEAD . . . . .          | 0.1 PART PER MILLION |
| FLUORIDE . . . . .      | 1.5 PPM              |
| ARSENIC . . . . .       | 0.05 PPM             |
| SELENIUM . . . . .      | 0.05 PPM             |
| HEXAVALENT CHROMIUM . . | 0.05 PPM             |

THERE APPEARS TO BE AMPLE EVIDENCE THAT CONCENTRATIONS IN EXCESS OF THESE ARE TOXIC TO HUMAN BEINGS. OF THE ABOVE CHEMICAL ELEMENTS, ONLY FLUORIDE IS OF IMPORTANCE IN THE DISTRICT, AS IT OCCURS AS A NATURAL SUBSTANCE IN ALMOST ALL OF THE WATERS. THE OTHER SUBSTANCES WOULD BE EXPECTED IN NEAR-LIMIT CONCENTRATIONS ONLY WHERE POLLUTED BY WASTES. RECENT STUDIES BY THE CALIFORNIA DEPARTMENT OF PUBLIC HEALTH HAVE INDICATED THAT A RIGID LIMIT OF 1.5 PARTS PER MILLION OF FLUORIDE MAY NOT BE WIDELY APPLICABLE TO THE

DIVERSE CLIMATES OF CALIFORNIA. WHERE AVERAGE ANNUAL TEMPERATURES ARE AS HIGH AS 60° F, THE MANDATORY LIMIT HAS BEEN REDUCED TO 1.0 PART PER MILLION. AS MOST OF THE AVERAGE ANNUAL TEMPERATURES IN THE DISTRICT WOULD RANGE FROM A LITTLE BELOW 60°F TO A LITTLE ABOVE 60°F, THE INDICATED LIMIT WOULD PROBABLY BE CLOSE TO 1.0 PART PER MILLION.

FOR LESS CRITICAL SUBSTANCES THE 1946 STANDARDS ENUMERATE NON-MANDATORY, BUT RECOMMENDED LIMITS:

|                                                  |       |                   |
|--------------------------------------------------|-------|-------------------|
| COPPER . . . . .                                 | 3.0   | PARTS PER MILLION |
| IRON AND MANGANESE TOGETHER. . . . .             | 0.3   | PPM               |
| MAGNESIUM. . . . .                               | 125   | PPM               |
| ZINC . . . . .                                   | 15    | PPM               |
| CHLORIDE . . . . .                               | 250   | PPM               |
| SULFATE. . . . .                                 | 250   | PPM               |
| PHENOLIC COMPOUNDS, IN TERMS OF PHENOL . . . . . | 0.001 | PPM               |
| TOTAL SOLIDS, DESIRABLE. . . . .                 | 500   | PPM               |
| TOTAL SOLIDS, PERMITTED. . . . .                 | 1000  | PPM               |

COPPER AND ZINC ARE RARELY REPORTED IN ORDINARY WATER ANALYSES; HOWEVER, ALL ANALYSES FOR DISTRICT WATERS INCLUDING THESE ELEMENTS SHOW VERY LOW CONCENTRATIONS, AND CONCENTRATIONS APPROACHING OR EXCEEDING THE RECOMMENDED LIMITS ARE NOT TO BE EXPECTED, UNLESS THERE IS POLLUTION BY INDUSTRIAL WASTES. IRON AND MANGANESE ARE MORE ABUNDANT IN NATURAL WATERS, AND IRON OCCASIONALLY APPEARS ON REPORTS OF CHEMICAL ANALYSES. THE RECOMMENDED 0.3 PPM IRON PLUS MANGANESE LIMIT IS BASED, NOT UPON PHYSIOLOGICAL CONSIDERATIONS, BUT UPON TASTE, AND STAINING OF PORCELAIN FIXTURES. CERTAIN AUTHORITIES REPORT THAT THE UNDESIRABLE QUALITIES ARE PRESENT AT EVEN LOWER CONCENTRATIONS. IRON PROBLEMS WITHIN THE DISTRICT ARE NOT SEVERE. SOME WELLS IN THE MOUND BASIN SHOW HIGH IRON PLUS MANGANESE. DEEPER AQUIFERS OF THE SAN PEDRO FORMATION TAPPED BY THE CITY OF VENTURA BEACH WELLS PRODUCE WATER WITH VERY HIGH IRON CONTENT AND THE CITY HAS RECENTLY COMPLETED A PLANT FOR IRON REMOVAL. WATERS APPROACHING OR EXCEEDING 0.3 PPM IRON PLUS MANGANESE ARE FOUND IN WELLS SCATTERED OVER THE OXNARD PLAIN AND PLEASANT VALLEY. ON THE OTHER HAND, THE CONCENTRATIONS IN PIRU, FILLMORE, AND SANTA PAULA BASINS ARE UNIFORMLY QUITE LOW.

MAGNESIUM IN THE DISTRICT'S WATERS IS ALMOST INVARIABLY THE LOWEST IN CONCENTRATION OF THE THREE MAJOR CATIONS. WHEN THE MAGNESIUM CONTENT IS ABOVE THE LIMIT OF 125 PPM, THE TOTAL DISSOLVED SOLIDS ARE ALSO VERY HIGH. NO DISTRICT WATERS ARE KNOWN WHERE EXCESS MAGNESIUM CONSTITUTES

THE ONLY UNDESIRABLE CHARACTERISTIC. IT APPEARS THAT MAGNESIUM CONTENT BECOMES HIGH ONLY WHEN THE WATER IS POOR FOR MANY REASONS.

IN THE NATURAL FRESH WATERS OF THE DISTRICT, CHLORIDE IS ALMOST ALWAYS THE LEAST ABUNDANT OF THE THREE MAJOR ANIONS. CHLORIDES IN EXCESS OF 250 PPM WOULD PROBABLY MEAN THAT THE NATURAL WATERS HAD BEEN DEGRADED. UNDESIRABLE TASTE, RATHER THAN HEALTH CONSIDERATIONS, HAS BEEN THE BASIS FOR THE RECOMMENDED CHLORIDE LIMIT. EXPERIMENTS IN WARMER CLIMATES HAVE SHOWN THAT CONCENTRATIONS OF 1000 PPM MAY BE TOLERABLE TO HUMAN BEINGS. FOR PERSONS SUFFERING FROM HEART AND KIDNEY DISEASES, THE TOLERANCE IS MUCH LESS THAN FOR HEALTHY PERSONS. OTHER UNDESIRABLE EFFECTS OF HIGH CHLORIDES ARE SOAP-DESTROYING POWER AND CORROSIVENESS.

HIGH SULFATES IN THE WATERS OF THE DISTRICT ARE THE RULE, RATHER THAN THE EXCEPTION. WATERS WITH LESS THAN 250 PPM OF SULFATE ARE UNCOMMON. THE RECOMMENDED LIMIT IS BASED UPON A LAXATIVE EFFECT RATHER THAN UPON TASTE OR TOXICITY. NEWCOMERS TO THE HIGH SULFATE WATER SUPPLY ARE ESPECIALLY SUSCEPTIBLE. WITHIN THE DISTRICT, PEOPLE HAVE BEEN DRINKING WATER WITH 500 TO 1000 PPM OF SULFATE FOR MANY YEARS WITHOUT DISCOMFORT. THUS THERE IS AMPLE PROOF THAT THE 250 PPM LIMIT IS UNNECESSARILY LOW. FURTHERMORE, ONLY A FEW DOMESTIC OR MUNICIPAL WATER SYSTEMS IN THE DISTRICT COULD MEET THIS REQUIREMENT.

PHENOLIC COMPOUNDS ARE COMMON ORGANIC SUBSTANCES DERIVED FROM WASTES. EVEN IN EXTREMELY LOW CONCENTRATIONS THEY IMPART A BAD TASTE TO THE WATER. THE TASTE PROBLEM IS ACCENTUATED WHEN PHENOL-BEARING WASTES ARE CHLORINATED. THE PRESENCE OF PHENOLS IN DISTRICT WATERS WOULD BE INDICATIVE OF THE INDISCRIMINATE DISPOSAL OF ORGANIC WASTES.

ALONG WITH SULFATE CONTENT, THE DISTRICT WATERS GENERALLY ARE UNABLE TO MEET THE 1946 STANDARDS WITH REGARD TO TOTAL DISSOLVED SOLIDS. FEW WATERS ARE LOWER THAN THE DESIRABLE 500 PPM AND A GREAT NUMBER ARE MORE THAN 1000 PPM. THE PERMISSIBLE LIMIT OF 1000 PPM IS ARBITRARY AND IMPRACTICAL. MCKEE (REF. 21) STATES

"MANY COMMUNITIES IN THE UNITED STATES AND OTHER COUNTRIES USE WATER CONTAINING FROM 2000 TO 4000 PPM OF DISSOLVED SOLIDS, WHEN NO BETTER WATER IS AVAILABLE. SUCH WATERS ARE NOT PALATABLE, DO NOT QUENCH THIRST, AND MAY HAVE LAXATIVE EFFECTS UPON NEW USERS. HOWEVER, NO HARMFUL PHYSIOLOGICAL EFFECTS OF A PERMANENT NATURE HAVE BEEN CALLED TO THE ATTENTION OF HEALTH AUTHORITIES."

A VERY RECENT SUMMARY REPORT BY THE STATE BOARD OF HEALTH (REF. 9) MAY BE INTERPRETED TO MEAN THAT CERTAIN OF THE RECOMMENDED LIMITS IN THE 1946 STANDARDS WILL NOT BE ADHERED TO RIGIDLY IN VENTURA COUNTY.

AN IMPORTANT OMISSION FROM THE 1946 STANDARDS IS A LIMIT FOR NITRATE CONCENTRATION. EXCESSIVE NITRATE CONTENT IS KNOWN TO CAUSE INFANT CYANOSIS (METHEMOGLOBINEMIA), AND GASTRO-INTESTINAL DISCOMFORT AMONG ADULTS. A LIMIT SUGGESTED HAS BEEN 10 PPM NITROGEN (44 PPM NITRATE). A SIGNIFICANT NUMBER OF WELLS SCATTERED THROUGHOUT THE DISTRICT SHOW NITRATE CONCENTRATIONS IN EXCESS OF THIS. WHILE THE SUGGESTED LIMIT MAY BE SOMEWHAT LOWER THAN CAN BE SUPPORTED STRONGLY, THE HIGHER NITRATE WATERS SHOULD BE AVOIDED WHERE SMALL INFANTS ARE INVOLVED.

IN ADDITION TO THE LIMITS FOR THE ABOVE DISSOLVED SUBSTANCES, THE 1946 STANDARDS INCLUDE STATEMENTS WITH REGARD TO BACTERIAL QUALITY, TURBIDITY, COLOR, TASTE, AND ODOR. OTHER RECOMMENDATIONS ARE THAT THE PH VALUE SHOULD BE LIMITED TO 10.6 AT 25°C, NORMAL CARBONATE ALKALINITY TO 120 PPM, AND THE EXCESS OF ALKALINITY OVER HARDNESS TO 35 PPM, CALCULATED AS CALCIUM CARBONATE.

#### AGRICULTURAL USE

UNLIKE THE RELATIVELY SETTLED CRITERIA OF WATER QUALITY FOR DOMESTIC USE, THERE HAVE BEEN NUMEROUS CLASSIFICATIONS OF WATER FOR AGRICULTURAL USE. BECAUSE OF VARIABILITY OF SOIL TYPE, CROPS GROWN, AND CLIMATE, IT IS DIFFICULT TO DEVISE A SINGLE CLASSIFICATION SCHEME. HOWEVER, IN ANY SUCH SCHEME, THREE CLASSES OF DELETERIOUS EFFECTS MUST BE CONSIDERED:

- (A) SALINITY (ADVERSE OSMOTIC EFFECTS)
- (B) TOXIC SUBSTANCES IN LOW CONCENTRATIONS
- (C) PROPORTIONS OF CATIONS

ITEMS (A) AND (B) RESULT IN DAMAGE TO THE PLANT ITSELF. ITEM (C) PRODUCES UNDESIRABLE PROPERTIES IN THE SOIL.

SALINITY IS COMMONLY MEASURED BY SPECIFIC ELECTRICAL CONDUCTANCE, EITHER  $K \times 10^5$  OR  $EC \times 10^6$ , A MEASURE OF THE TOTAL DISSOLVED SALTS. HOWEVER, AS DONEEN (REF. 27) HAS POINTED OUT, NOT ALL DISSOLVED SALTS IN THE IRRIGATION WATER REMAIN IN A DISSOLVED STATE IN THE SOIL SOLUTION. AS PLANTS REMOVE WATER, AND AS THE CONCENTRATION OF THE SOIL SOLUTION INCREASES, CERTAIN SALTS ARE DEPOSITED WITHIN THE SOIL, AND NO LONGER STRONGLY INFLUENCE OSMOTIC BALANCES. DONEEN THEREFORE HAS PROPOSED USING "EFFECTIVE SALINITY"

AS A MEASURE OF POTENTIAL ADVERSE OSMOTIC EFFECTS. FROM THE RESULTS OF A CHEMICAL ANALYSIS EXPRESSED IN EQUIVALENTS PER MILLION (EPM) OR MILLIEQUIVALENTS PER LITER (ME/L), PROGRESSIVELY CALCIUM CARBONATE, MAGNESIUM CARBONATE, AND CALCIUM SULFATE ARE ASSUMED TO BE DEPOSITED FROM SOLUTION. THE REMAINING EPM (OF CATIONS OR ANIONS) WHICH CAN NOT BE BOUND UP IN THESE THREE SALTS, ARE CONSIDERED TO CONSTITUTE "EFFECTIVE SALINITY". DONEEN'S CLASSIFICATION OF IRRIGATION WATERS ACCORDING TO EFFECTIVE SALINITY IS GIVEN IN TABLE III-2. AS INDICATED BY THE SOIL SURVEYS OF 1901 AND 1917, THE DISTRICT IS GENERALLY FAVORED BY GOOD, OPEN SOILS. MOST WATERS SHOULD THEN BE CLASSIFIED IN TERMS OF THE OPEN SOILS SHOWN IN TABLE III-2. THE FIGURES PRESENTED IN THIS TABLE WERE CONFIRMED BY DONEEN IN FIELD STUDIES OF CITRUS GROVES IN VENTURA COUNTY. ALTHOUGH MINOR DAMAGE SUCH AS TIP BURN IS SOMEWHAT COMMON IN VENTURA COUNTY, THE ACTUAL ONSET OF YIELD REDUCTION MAY NOT COMMENCE UNTIL THE WATER IS WELL INTO CLASS III.

WITH REGARD TO ADVERSE OSMOTIC EFFECTS, THE SALINITY OF THE IRRIGATION WATER IS LESS CRITICAL THAN THE SALINITY OF THE RESULTING SOIL SOLUTION. IN HIS VENTURA COUNTY CITRUS STUDY (REF. 27) DONEEN FOUND THAT AT FIELD CAPACITY THE AVERAGE SOIL SOLUTION WAS 2.6 TIMES THE CONCENTRATION OF THE IRRIGATION WATER. NEAR THE PERMANENT WILTING PERCENTAGE THE AVERAGE CONCENTRATION OF THE SOIL SOLUTION INCREASES TO ABOUT 5 TIMES THAT OF THE IRRIGATION WATER.

OF THE TOXIC SUBSTANCES FOUND IN DISTRICT IRRIGATION WATERS, BORON IS THE MOST CRITICAL. BORON IN MINUTE CONCENTRATIONS IS ESSENTIAL TO THE NORMAL GROWTH OF ALL PLANTS, AND BORON DEFICIENCY MAY PRODUCE VERY STRIKING SYMPTOMS. ON THE OTHER HAND, BORON-SENSITIVE PLANTS MAY SHOW ECONOMICALLY IMPORTANT INJURY WHEN IRRIGATED WITH WATER CONTAINING AS LITTLE AS 1.0 PPM. BECAUSE THERE IS A WIDE RANGE OF BORON SENSITIVITY AMONG CROP TYPES, AND THERE ARE VARYING DEGREES OF BORON INJURY, ANY CLASSIFICATION MUST REFLECT THESE VARIABLES. A LISTING OF PLANTS ACCORDING TO BORON SENSITIVITY IS GIVEN IN TABLE III-3. PERMISSIBLE LIMITS FOR BORON CONCENTRATIONS ARE GIVEN IN TABLE III-4.

CHLORIDE CONTENT IS APPARENTLY MORE CRITICAL FOR IRRIGATION USE THAN FOR DOMESTIC USE. SENSITIVITY TO INJURY DEPENDS UPON THE CROP TYPE, AND SUGGESTED LIMITS ARE GIVEN IN TABLE III-1. FRUIT GROWERS LABORATORY, SANTA PAULA, SUGGESTS 200 PPM CHLORIDE AS THE UPPER TOLERANCE LIMIT FOR

CITRUS AND WALNUTS, BUT PREFERS LESS THAN 100 PPM FOR AVOCADOS.

SODIUM PERCENTAGE IS A MEASURE OF THE EFFECT OF AN IRRIGATION WATER ON THE TILTH AND PERMEABILITY CHARACTERISTICS OF A SOIL. WITH HIGH SODIUM PERCENTAGE, SOIL CLAYS UNDERGO A CATION EXCHANGE REACTION AND BECOME DEFLOCCULATED. SODIUM PERCENTAGE IS BASED ON THE RATIO OF SODIUM (IN EPM OR ME/L) TO THE TOTAL CATIONS. THEREFORE IT IS THE PROPORTION OF SODIUM RATHER THAN THE ABSOLUTE CONCENTRATION WHICH IS MORE CRITICAL. AS POINTED OUT IN U. S. DEPARTMENT OF AGRICULTURE HANDBOOK 60 (REF. 66), THE SODIUM PERCENTAGE (SOLUBLE SODIUM PERCENTAGE - SSP) DOES NOT ACCURATELY REFLECT THE BASE EXCHANGE REACTIONS. AS THE IRRIGATION WATER BECOMES MORE CONCENTRATED IN THE SOIL SOLUTION, AND ASSUMING THAT THERE IS NO SALT PRECIPITATION OR ADSORPTION OF SALT BY ROOTS, THERE IS NO CHANGE IN RELATIVE COMPOSITION. HOWEVER, THE TENDENCY OF THE SOIL TO ADSORB SODIUM SHOWS A DEFINITE INCREASE, AND THE TENDENCY FOR WATER TO PRODUCE AN ALKALI SOIL IS MEASURED BY THE SODIUM-ADSORPTION RATIO (SAR) WHICH IS DEFINED AS FOLLOWS:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

WHERE THE CATION CONCENTRATIONS ARE EXPRESSED IN MILLI-EQUIVALENTS PER LITER OR EQUIVALENTS PER MILLION. HANDBOOK 60 INCLUDES A DIAGRAM FOR THE CLASSIFICATION OF IRRIGATION WATERS USING SAR AND CONDUCTIVITY AS VARIABLES.

MOST OF THE WATERS IN THE DISTRICT WOULD BE PLACED IN CLASS II OF TABLE III-1, ON THE BASIS OF SALINITY EXPRESSED AS CONDUCTANCE. HOWEVER, ON THE BASIS OF EFFECTIVE SALINITY, MANY WATERS WOULD BE UPGRADED TO CLASS I. ON THE BASIS OF BORON CONTENT, MOST OF THE WATERS ARE IN CLASS II (TABLE III-1). WITH REGARD TO CHLORIDES, ALMOST ALL THE WATERS ARE IN CLASS I, EXCEPT WHERE POLLUTED BY SEA WATER OR WASTES. THE MOST REDEEMING CHARACTERISTIC OF THE DISTRICT'S WATER SUPPLIES IS THE LOW SODIUM PERCENTAGE. ON THIS BASIS, VERY FEW WATERS WOULD BE LOWER THAN CLASS I. OF ALL THE CRITERIA, BORON CONTENT IS THE FACTOR WHICH HAS TO BE WATCHED THE CLOSEST.

#### INDUSTRIAL USE

THE QUALITY REQUIREMENTS OF WATER FOR INDUSTRIAL USE ARE HIGHLY

VARIABLE AMONG THE VARIOUS INDUSTRIES AND FOR DIFFERENT USES WITHIN AN INDUSTRY. IN MANY INDUSTRIES, PART OF THE WATER USED IS ALWAYS TREATED. THE CHARACTERISTICS OF THE DISTRICT'S WATER SUPPLIES WHICH MIGHT POSSIBLY CREATE LIMITATIONS ON INDUSTRIAL USE WOULD BE HARDNESS, TOTAL DISSOLVED SOLIDS, AND PERHAPS IRON AND MANGANESE. FOR MOST INDUSTRIAL PURPOSES, THE WATERS ARE USABLE, OR COULD BE TREATED TO PRODUCE A WATER WHICH IS USABLE.

#### PIRU BASIN

##### SURFACE WATERS

THE SURFACE WATERS ENTERING THE PIRU BASIN SHOW A LARGE RANGE OF TOTAL DISSOLVED SOLIDS, ALTHOUGH HAVING IN COMMON A PREDOMINANT CALCIUM SULFATE CHARACTERISTIC. ALONG THE SANTA CLARA RIVER, TOTAL DISSOLVED SOLIDS AS LOW AS 634 PPM AND BORON CONTENT AS LOW AS 0.21 PPM HAVE BEEN RECORDED FOR A FLOOD FLOW OF 1680 CUBIC FEET PER SECOND (TABLE III-5). AT EXTREMELY LOW FLOWS, TOTAL DISSOLVED SOLIDS (TDS) RISE TO 3500 PPM OR MORE, AND BORON TO MORE THAN 1.5 PPM. FOR ONLY A SMALL PERCENTAGE OF THE TIME IS BORON OVER 1.0 PPM. AS FLOW DECREASES AND CONCENTRATION RISES, SODIUM RISES AND OCCASIONALLY SHOWS MORE PPM THAN CALCIUM. PIRU CREEK IN FLOOD FLOWS SHOWS TDS AS LOW AS ABOUT 700 PPM AND BORON AS LOW AS 0.10 PPM (TABLE III-5). LOW FLOWS HAVE TDS OF AT LEAST 2500 PPM, WITH BORON OCCASIONALLY MORE THAN 2.0 PPM. ALTHOUGH DATA ARE SPARSE, FLUORIDE CONTENT DURING LOW FLOWS MAY RISE ABOVE 1.0 PPM. AS NOTED FOR THE SANTA CLARA RIVER, LOW FLOWS OF PIRU CREEK MAY SHOW A HIGHER PPM OF SODIUM THAN OF CALCIUM. PIRU CREEK IS A MORE IMPORTANT SOURCE OF BORON THAN THE SANTA CLARA RIVER, AND HAS BORON CONCENTRATIONS EXCEEDING 1.0 PPM FOR A MUCH LONGER PERCENTAGE OF THE TIME.

THE MINOR TRIBUTARIES OF THE PIRU BASIN FLOW USUALLY ONLY DURING AND AFTER HEAVY RAINS. SOME SHOW EXCELLENT QUALITY RUNOFF, BUT MOST SHOW WELL-MINERALIZED CALCIUM SULFATE WATERS. RUNOFF FROM THESE AREAS PROBABLY INCORPORATES SALTS PREVIOUSLY DEPOSITED BY EVAPORATION OR CONCENTRATED BY EVAPOTRANSPIRATION. VERY LOW FLOWS SHOW INCREASING SODIUM AND ON SOME TRIBUTARIES THIS TREND MAY REFLECT CONTRIBUTIONS FROM OIL-FIELD WASTES.

THE FLOOD FLOWS ARE OF EXCELLENT QUALITY AND CHEMICALLY SUITABLE FOR ESSENTIALLY ALL USES. THE LOW FLOWS ARE GENERALLY CLASS III IRRIGATION WATERS BECAUSE OF HIGH EFFECTIVE SALINITY AND BORON. CHLORIDE CONTENT AND SODIUM PERCENTAGE ARE PROPORTIONALLY BETTER. FLUORIDES IN

TABLE III-5  
CHEMICAL ANALYSES - PIRU BASIN

| FLOW-C.F.S.<br>WELL No.                                      | DATE     | ECx10 <sup>6</sup> | PARTS PER MILLION |     |     |                  |                 |     |                 |     |      |      | EFF.<br>SAL.<br>EPM | %NA |  |
|--------------------------------------------------------------|----------|--------------------|-------------------|-----|-----|------------------|-----------------|-----|-----------------|-----|------|------|---------------------|-----|--|
|                                                              |          |                    | CA                | Mg  | NA  | HCO <sub>3</sub> | SO <sub>4</sub> | CL  | NO <sub>3</sub> | F   | B    | TDS  |                     |     |  |
| SANTA CLARA RIVER-HIGH FLOW ENTERING BASIN                   |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |  |
| 1680                                                         | 4-7-58   | 845                | 85                | 34  | 47  | 167              | 286             | 21  | 1.3             | 0.4 | 0.21 | 634  | 4.9                 | 23  |  |
| SANTA CLARA RIVER-LOW FLOW ENTERING BASIN                    |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |  |
| 0.4                                                          | 9-3-57   | 3229               | 266               | 159 | 456 | 372              | 1638            | 232 | 1.5             | 1.0 | 1.56 | 2966 | 32.1                | 40  |  |
| PIRU CREEK-HIGH FLOW ENTERING BASIN                          |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |  |
| 1000                                                         | 3-15-52  | 975                | 106               | 54  | 29  | 132              | 403             | 11  | 9               | -   | 0.2  | 768  | 5.7                 | 11  |  |
| PIRU CREEK-LOW FLOW ENTERING BASIN                           |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |  |
| 5.0                                                          | 2-7-51   | 1880               | 173               | 81  | 170 | 342              | 726             | 70  | 1               | -   | 2.07 | 1420 | 14.2                | 32  |  |
| ALLUVIAL WATER SHOWING EFFECT OF SANTA CLARA RIVER LOW FLOWS |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |  |
| 4N/18W-27G1                                                  | 8-18-53  | 2245               | 205               | 101 | 189 | 354              | 900             | 94  | 9.9             | 0.5 | 0.8  | 1803 | 16.7                | 31  |  |
| WATER IN SAN PEDRO FORMATION SHOWING FLUORIDE DROP           |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |  |
| 4N/19W-25M2                                                  | 5-26-52  | 1145               | 108               | 41  | 80  | 226              | 369             | 31  | 4               | 2.2 | 0.9  | 852  | 6.9                 | 28  |  |
| -25M2                                                        | 8-18-53  | 1135               | 109               | 46  | 75  | 236              | 380             | 33  | 0               | 0.9 | 0.9  | 820  | 7.1                 | 26  |  |
| WATERS DEGRADED BY IRRIGATION RETURN                         |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |  |
| 4N/18W-27B1                                                  | 10-23-51 | 2020               | 322               | 152 | 311 | 392              | 1455            | 133 | 42              | 1.3 | 1.5  | 2909 | 26.2                | 32  |  |
| -29P2                                                        | 5-26-52  | 3190               | 408               | 199 | 204 | 432              | 1695            | 80  | 40              | 1.3 | 1.2  | 3386 | 25.2                | 19  |  |
| 4N/19W-25A1                                                  | 7-23-54  | 3120               | 464               | 169 | 159 | 473              | 1550            | 59  | 53              | -   | 1.4  | 2942 | 21.0                | 14  |  |
| -25C1                                                        | 10-25-51 | 2040               | 524               | 151 | 146 | 439              | 1550            | 85  | 153             | 1.0 | 1.1  | 3121 | 19.0                | 14  |  |
| -25L5                                                        | 7-23-56  | 2597               | 369               | 125 | 130 | 437              | 1135            | 53  | 120             | 0.8 | 1.2  | 2360 | 16.1                | 16  |  |
| -34C2                                                        | 10-29-51 | 2822               | 322               | 155 | 122 | 332              | 1300            | 44  | 38              | -   | 0.8  | 2279 | 18.0                | 16  |  |

PIRU CREEK LOW FLOWS MAY BE QUESTIONABLE.

## GROUND WATERS

THE GROUND WATERS OF THE PIRU BASIN RANGE IN TDS FROM ABOUT 800 PPM TO ABOUT 3000 OR SO PPM. NO GROUND WATERS IN THE PIRU BASIN WOULD QUALIFY FULLY AS CLASS I WATERS FOR IRRIGATION USE. EVEN WITH THE EXISTING OPEN SOILS AND EASY PERCOLATION, ONLY ONE WELL WATER QUALIFIES AS CLASS I ON THE BASIS OF EFFECTIVE SALINITY. ONLY A FEW WELL WATERS SHOW LESS THAN 0.5 PPM OF BORON, AND THE SAME WELLS AT OTHER TIMES PUMP WATER WHICH HAS A HIGHER BORON CONCENTRATION. MAXIMUM BORON CONCENTRATION RECORDED IS 1.5 PPM. ALL WELL WATERS WITH EFFECTIVE SALINITIES OF MORE THAN 15 ARE CONSIDERED TO HAVE BEEN DETERIORATED. THE CHEMICAL CHARACTERISTICS OF THESE DETERIORATED WATERS ARE GIVEN IN TABLE III-5. OF THE SEVEN WELL WATERS WHICH HAVE EFFECTIVE SALINITIES GREATER THAN 15, ALL BUT ONE HAVE HIGH NITRATE CONTENTS. WELL 4N/18W-27G1 SHOWS MODERATELY HIGH SULFATE AND CHLORIDE, BUT WITH LOW NITRATE. THIS WELL IS FAIRLY CLOSE TO THE RIVER AND REFLECTS THE DETERIORATING EFFECTS OF THE LOW FLOWS OF THE SANTA CLARA RIVER. RECHARGE TO THIS POSITION IS RELATIVELY GOOD. BY WAY OF CONTRAST, WELL 27B1 IS FARTHER FROM THE RIVER AND LESS EASILY RECHARGED FROM THE RIVER. THE WATER IN WELL 27B1 IS MUCH POORER THAN THE WATER IN WELL 27G1, WITH HIGHER EFFECTIVE SALINITY, VERY HIGH SULFATE, AND UNUSUALLY HIGH CHLORIDE. THE MOST STRIKING INCREASE, HOWEVER, IS IN THE NITRATE, WHICH IS BELIEVED TO BE DERIVED FROM IRRIGATION RETURN. THE DETERIORATION OF ALL BUT THE 27G1 WELL WATER IS BELIEVED DUE TO THE ENTRY OF IRRIGATION RETURN WATER. THE HIGH NITRATE CAN NOT BE DERIVED FROM SMALL TRIBUTARY RUNOFF, WHICH IS TYPICALLY LOW IN NITRATE. SIMILARLY, THE DEGRADING WATERS CAN NOT BE OIL-FIELD BRINES WHICH SHOW HIGH CHLORIDES, VERY LOW SULFATES, AND LOW NITRATES.

WITHIN THE PIRU BASIN, CHLORIDES IN THE IRRIGATION WATERS PUMPED FROM WELLS ARE ONLY A MINOR PROBLEM, IF A PROBLEM AT ALL. SIMILARLY, THE SODIUM PERCENTAGE IS USUALLY EXCELLENT FOR IRRIGATION USE. IN ADDITION TO HIGH EFFECTIVE SALINITY, HIGH BORON IS A PROBLEM, AND SOME BORON DAMAGE TO CITRUS HAS BEEN REPORTED. AVERAGE BORON CONTENT IS A LITTLE LESS THAN 1.0 PPM. WATERS PUMPED FROM A SINGLE WELL WILL SHOW A MARKED FLUCTUATION OF BORON CONTENT, ALTHOUGH NO LONG-TERM TREND CAN BE DETECTED. IT IS INTERESTING TO NOTE THAT IN THE HIGH NITRATE WELL WATERS, SHOWING

DETERIORATION BY IRRIGATION RETURN, THE BORON CONTENT IS NOT SO HIGH AS MIGHT BE EXPECTED FROM THE INCREASE IN TOTAL DISSOLVED SOLIDS. THIS PERHAPS SUGGESTS THAT SOME BORON IS BEING DETAINED TEMPORARILY IN THE SOIL.

IN USING THE PIRU BASIN WELL WATERS FOR DOMESTIC USE, THE MOST TROUBLESOME CONSTITUENT IS FLUORIDE. AVERAGE ANNUAL TEMPERATURE IS PROBABLY A LITTLE OVER 60°F, SO THE MANDATORY LIMIT WOULD PROBABLY BE SET CLOSE TO 1.0 PPM. AT LEAST 26 WELLS HAVE SO FAR SHOWN FLUORIDE CONCENTRATIONS IN EXCESS OF 1.0 PPM. THERE IS A MARKED TENDENCY FOR THE FLUORIDE CONTENT TO DECREASE WITH TIME IN CERTAIN WELLS. THIS IS ESPECIALLY TRUE OF NEW WELLS PERFORATED ONLY IN THE SAN PEDRO FORMATION (TABLE III-5). IT IS SUGGESTED THAT THE NATIVE WATERS IN SOME OF THE PERMEABLE LAYERS OF THE SAN PEDRO FORMATION HAD FLUORIDES IN EXCESS OF 2.0 PPM. THESE WERE LENTICULAR AQUIFERS WITH RESTRICTED CIRCULATION. AS THESE LENSES WERE PUMPED, THE CONTAINED WATERS CONTRIBUTED A DECREASING PROPORTION OF THE TOTAL WATER PUMPED FROM THE WELL, AND THE FLUORIDE CONTENT DROPPED. OTHER HIGH FLUORIDE WATERS, IN THE ALLUVIAL DEPOSITS, SHOW A CYCLIC FLUCTUATION, CORRESPONDING TO WET AND DRY CYCLES. IN THE ALLUVIAL WATERS, THE FLUORIDE CONTENT RISES AND FALLS WITH THE TOTAL DISSOLVED SOLIDS CONTENT. ON THE OTHER HAND, THE HIGH FLUORIDE CONTENT OF THE WATERS IN THE SAN PEDRO FORMATION IS USUALLY ASSOCIATED WITH UNUSUALLY LOW TDS.

#### FILLMORE BASIN

##### SURFACE WATERS

SANTA CLARA RIVER FLOOD FLOWS ENTERING THE FILLMORE BASIN ARE OF EXCELLENT QUALITY FOR ALL PURPOSES. THESE ARE PREDOMINANTLY CALCIUM SULFATE WATERS, WITH IMPORTANT MAGNESIUM AND DICARBONATE, BUT VERY MINOR SODIUM AND CHLORIDE (TABLE III-6). VERY LOW MINERALIZATION IS SHOWN BY SESPE CREEK FLOOD FLOWS WITH TDS OCCASIONALLY LESS THAN 200 PPM (TABLE III-6). SESPE CREEK FLOOD FLOWS ARE QUITE DIFFERENT FROM THE SANTA CLARA RIVER FLOOD FLOWS, WITH DICARBONATE SOMETIMES MORE IMPORTANT THAN SULFATE, AND MAGNESIUM LOWER THAN SODIUM. CHLORIDES ARE VERY LOW. FLOOD FLOWS LEAVING THE FILLMORE BASIN ARE A MIXTURE OF THE CONTRIBUTING SESPE CREEK AND SANTA CLARA RIVER FLOOD FLOWS WITH A CHEMICAL QUALITY REFLECTING THE PROPORTIONATE MIXTURES.

LOW FLOW SESPE CREEK WATERS, WHILE RELATIVELY LOW IN TDS, SHOW VERY HIGH BORON CONTENT AND MARGINAL FLUORIDE CONCENTRATIONS. SODIUM AND

TABLE III-6  
CHEMICAL ANALYSES - FILLMORE BASIN

| Flow-C.F.S.<br>WELL No.                                                    | DATE     | ECx10 <sup>6</sup> | PARTS PER MILLION |     |     |                  |                 |     |                 |     |      |      | EFF.<br>SAL.<br>EPM | %Na |
|----------------------------------------------------------------------------|----------|--------------------|-------------------|-----|-----|------------------|-----------------|-----|-----------------|-----|------|------|---------------------|-----|
|                                                                            |          |                    | Ca                | Mg  | Na  | HCO <sub>3</sub> | SO <sub>4</sub> | CL  | NO <sub>3</sub> | F   | B    | TDS  |                     |     |
| SANTA CLARA RIVER-HIGH FLOW ENTERING BASIN<br>10,000                       | 3-15-52  | 732                | 88                | 40  | 7   | 131              | 271             | 7   | 5               | -   | 0.0  | 528  | 3.6                 | 4   |
| SANTA CLARA RIVER-RISING WATER ENTERING BASIN<br>3                         | 1-12-53  | 1968               | 240               | 93  | 105 | 356              | 797             | 46  | 29              | -   | 0.85 | 1617 | 12.4                | 19  |
| SESPE CREEK-HIGH FLOW ENTERING BASIN<br>12,300                             | 4-3-58   | 384                | 47                | 10  | 9.0 | 106              | 94              | 5.0 | -               | 0.4 | 0.05 | 271  | 1.0                 | 11  |
| SESPE CREEK-LOW FLOW ENTERING BASIN<br>0.1                                 | 9-4-57   | 1200               | 140               | 24  | 114 | 260              | 308             | 117 | 1.5             | 1.2 | 2.4  | 874  | 6.9                 | 35  |
| ENTERING UNDERFLOW-SANTA CLARA RIVER-WET YEAR<br>4N/19W-33E1               | 8-25-52  | 1370               | 143               | 52  | 82  | 232              | 480             | 30  | 14              | 1.0 | 0.6  | 1000 | 8.0                 | 24  |
| ENTERING UNDERFLOW-SANTA CLARA RIVER-NEAR END OF DRY PERIOD<br>4N/19W-33E1 | 5-10-57  | 1500               | 142               | 65  | 86  | 279              | 516             | 30  | 21              | 0.7 | 0.6  | 1100 | 9.2                 | 23  |
| NATIVE SAN PEDRO WATER BENEATH POLE CREEK FAN<br>4N/19W-30P2               | 1-12-38  | -                  | 275               | 112 | 126 | 555              | 852             | 68  | 10              | -   | 0.5  | 2018 | 15.2                | 19  |
| -30P2                                                                      | 5-27-52  | 2275               | 272               | 108 | 118 | 464              | 835             | 72  | 19              | 2.1 | 0.6  | 1815 | 14.0                | 18  |
| -30P2                                                                      | 8-25-52  | 1996               | 236               | 71  | 127 | 544              | 591             | 80  | 9               | 0.8 | 0.4  | 1570 | 11.5                | 24  |
| DEGRADED ALLUVIAL WATER-SOUTH SIDE OF SANTA CLARA RIVER<br>3N/20W-8B1      | 5-29-52  | 2940               | 302               | 117 | 267 | 370              | 1249            | 161 | 37              | 1.0 | 1.5  | 2661 | 21.2                | 32  |
| DEGRADED ALLUVIAL WATER-NEAR WESTERN BOUNDARY OF BASIN<br>3N/21W-12D2      | 12-19-55 | 2905               | 388               | 114 | 174 | 479              | 1008            | 227 | 78              | 0.7 | 0.3  | 2425 | 17.1                | 21  |
| NATIVE SAN PEDRO WATER-SESPE UPLAND<br>4N/20W-23L1                         | 8-26-52  | 685                | 75                | 19  | 42  | 263              | 68              | 32  | 21              | 1.0 | 0.1  | 443  | 2.8                 | 26  |
| DEGRADED SAN PEDRO WATER-SESPE UPLAND<br>4N/20W-33G1                       | 3-9-45   | -                  | 293               | 68  | 166 | 301              | 999             | 39  | 49              | -   | 0.26 | 1922 | 12.8                | 26  |

CHLORIDE ARE PROPORTIONALLY HIGHER THAN IN THE FLOOD FLOWS, BUT NOT SO HIGH AS TO DETERIORATE THE WATERS FOR IRRIGATION USE. ALONG THE SANTA CLARA RIVER, THE LOW FLOWS ENTERING AND LEAVING THE FILLMORE BASIN ARE RISING WATERS. THE SPARSE CHEMICAL DATA FOR THE ENTERING RISING WATERS SUGGEST SUBSTANTIAL CONTRIBUTIONS FROM IRRIGATION RETURN WATERS (TABLE III-6). A LARGE SERIES OF ANALYSES IS AVAILABLE FOR THE RISING WATERS WHICH LEAVE THE FILLMORE BASIN. THESE ARE ALMOST INVARIABLY CLASS II IRRIGATION WATERS, WITH BORON CONCENTRATION 0.5 TO 1.0 PPM. NITRATE CONTENT IS MUCH LOWER THAN IN THE ENTERING RISING WATERS, SUGGESTING PERHAPS THAT IRRIGATION RETURN WATERS ARE BEING MORE EFFICIENTLY FLUSHED FROM THE PIRU BASIN. FLUORIDE CONTENT IN THE EXITING RISING WATERS IS OCCASIONALLY MORE THAN 1.0 PPM.

THE SMALLER TRIBUTARIES OF FILLMORE BASIN SHOW A DEFINITE INVERSE RELATIONSHIP OF TDS TO MAGNITUDE OF FLOW. CHEMICAL CHARACTERS ARE DIFFERENT IN THE VARIOUS TRIBUTARIES. HIGH FLOWS OF O'LEARY AND SNOW CREEKS ARE SODIUM SULFATE WATERS. LORD (BOULDER) CREEK DURING AND FOLLOWING GOOD RUNOFF CONTAINS CALCIUM DICARBONATE-SULFATE WATERS; DURING VERY LOW FLOWS, THE WATER IS DOMINANT SODIUM DICARBONATE, ALTHOUGH CHLORIDES ARE RELATIVELY HIGH. POLE CREEK WATERS HAVE A PERSISTENT CALCIUM SULFATE CHARACTER, AND SHOW VERY LOW CHLORIDE, NITRATE, FLUORIDE, AND BORON CONTENT.

#### GROUND WATERS

THE GROUND WATERS IN THE FILLMORE BASIN WILL BE DISCUSSED FOR FOUR AREAS: (1) MAIN STREAM ALLUVIUM; (2) POLE CREEK FAN; (3) SOUTH SIDE; AND (4) SESPE UPLAND. THE GROUND WATERS WHICH MOVE MOST RAPIDLY THROUGH THE FILLMORE BASIN ARE THOSE WHICH FOLLOW SUBSURFACE COURSES BENEATH THE PRESENT CHANNELS OF SESPE CREEK AND THE SANTA CLARA RIVER. THESE WATERS REPRESENT STREAM PERCOLATE ALONG THESE REACHES, AND ALLUVIAL UNDERFLOW FROM PIRU BASIN AS MODIFIED BY SUBSURFACE UNDERFLOW FROM THE AREAS FLANKING THESE STRIPS OF YOUNGEST ALLUVIAL DEPOSITS. ALLUVIAL UNDERFLOW ENTERING FROM THE PIRU BASIN IS REPRESENTED BY THE WATER PUMPED FROM WELL 4N/19W-33E1. THIS WATER SHOWS FAIRLY CONSTANT QUALITY FROM 1952 TO 1957 AND TYPICAL ANALYSES ARE GIVEN IN TABLE III-6.

UNDERFLOW LEAVING THE FILLMORE BASIN IS BEST REPRESENTED BY THE WATER PUMPED FROM WELL 3N/21W-12E1 (TABLE III-6). ALTHOUGH THE PERFORATIONS IN THIS WELL ARE FROM 65 TO 104 FEET, AND BELOW THE YOUNGEST ALLUVIUM,

HYDROLOGIC CONTINUITY WITH THE IMMEDIATELY OVERLYING ALLUVIUM IS BELIEVED TO BE UNRESTRICTED. THE ANALYSES FOR THIS WELL WATER SHOW (1) CONSIDERABLE VARIABILITY; (2) A DEFINITE INCREASE IN TDS SINCE 1923; (3) LOW NITRATES, SUGGESTING LITTLE CONTRIBUTION FROM IRRIGATION RETURN WATERS; (4) HIGH TDS IN 1945 AT THE END OF A SERIES OF WET YEARS, SUGGESTING SOME WET PERIOD FLUSHING OF SALTS.

THE POLE CREEK FAN AREA IS THE TRIANGULAR PATCH BETWEEN SESPE CREEK AND THE SANTA CLARA RIVER UPON WHICH IS LOCATED THE CITY OF FILLMORE. THERE IS ONLY LIMITED FLUSHING OF THE SHALLOW AQUIFERS BENEATH THIS AREA BY FLOOD PERCOLATION FROM THE TWO MAIN STREAMS. RECHARGE IS Laterally FROM THE ALLUVIAL CHANNELS AND MAY NOT EXTEND VERY FAR FROM THOSE CHANNELS. DIRECT RECHARGE TO THE AREA UNDERLYING THE CITY OF FILLMORE COMES FROM ABOVE AS (1) PERCOLATION OF POLE CREEK FLOWS; (2) RAINFALL PENETRATION; (3) IRRIGATION RETURN; (4) CESSPOOL AND SEPTIC TANK RETURN (ESPECIALLY BEFORE THE NEW MUNICIPAL SEWAGE TREATMENT PLANT WAS PLACED IN OPERATION). POORER QUALITY WELL WATERS HAVE CHEMICAL QUALITIES SUGGESTING AS SOURCES OF THE DEGRADING WATERS (1) IRRIGATION RETURN, OR (2) NATIVE WATERS OF THE SAN PEDRO FORMATION. SHALLOW PERFORATIONS ARE USUALLY AVOIDED, BUT SOME OF THE OLDER WELLS, DRILLED WHEN SHALLOW PERFORATING WAS A MORE COMMON PRACTICE, SHOW HIGH TDS. HIGHLY MINERALIZED NATIVE WATER IN THE SAN PEDRO FORMATION IS INDICATED BY THE 1938 SAMPLE FROM WELL 4N/19W-30P2 TAKEN SHORTLY AFTER DRILLING. THIS WELL IS PERFORATED ONLY IN THE SAN PEDRO FORMATION. THERE WAS A MARKED IMPROVEMENT OF THIS WATER WITH CONTINUED PUMPING (TABLE III-6). THE HIGH NITRATE AND FLUORIDE CONCENTRATIONS ARE TYPICAL OF SOME OF THE SAN PEDRO AQUIFERS. THE HIGH NITRATE CONTENT WOULD ELIMINATE THE SUGGESTION THAT THESE WATERS HAVE BEEN DEGRADED BY THE LOW FLOWS OF POLE CREEK. WEAK CHLORIDES MAY SUGGEST THAT CESSPOOL RETURN CAN NOT BE RELATED TO THE HIGH TDS. THE ANALYSIS OF 8/25/52 FOR WELL 30P2 SUGGESTS THE ENTRY OF A NEW WATER INTO THE WELL.

IN THE BROAD ALLUVIAL FLAT SOUTH OF THE SANTA CLARA RIVER, THE NORMAL ALLUVIAL WATERS HAVE BEEN DETERIORATED IN PLACES FROM SECTION 8, T3N, R20W TO SECTION 6, T3N, R19W. THE PRIMARY SOURCE OF DEGRADING WATERS IS IRRIGATION RETURN, AS SHOWN BY SHARP INCREASES IN CALCIUM, SULFATE, AND NITRATE. IN CERTAIN WELLS, FLUORIDE AND BORON ALSO BECOME HIGH. A MINOR AMOUNT OF DETERIORATION MAY BE ATTRIBUTED TO OIL-FIELD BRINES, BUT

CONSIDERING THE EARLY WIDESPREAD AND INDISCRIMINATE DISPOSAL PRACTICES IN THE BARSDALE OIL FIELD, IT IS SURPRISING THAT THE INDICATED DETERIORATION IS NOT CONSIDERABLY MORE. SOME OF THE DEGRADING WATERS MAY BE DERIVED FROM THE MOUNTAIN TO THE SOUTH BUT THIS SOURCE IS BELIEVED TO BE MINOR FOR THE FOLLOWING REASONS: (1) THERE IS NO SYSTEMATIC DECREASE IN DEGRADATION AWAY FROM THE FRONT OF THE MOUNTAIN; (2) THE INDICATED VOLUME OF DEGRADING WATERS IS FAR LARGER THAN WOULD BE EXPECTED FROM THE TIGHT OLDER ROCKS; (3) THE KNOWN CHEMICAL NATURE OF THE DEGRADING WATERS IS UNLIKE THAT EXPECTABLE FROM LEAKAGE OUT OF THE OLDER ROCKS. A TYPICAL SOUTH SIDE DEGRADED WATER IS GIVEN IN TABLE III-6.

WELLS IN THE SESPE UPLAND AREA PUMP MAINLY FROM THE SAN PEDRO FORMATION. THERE IS LITTLE MOVEMENT OF WATER FROM THE MAIN ALLUVIAL STRIPS TO THE SAN PEDRO AQUIFERS BENEATH THE SESPE UPLAND EXCEPT POSSIBLY FROM SESPE CREEK IN THE REACH NORTHWEST OF FILLMORE. IN WET YEARS, HOWEVER, THERE IS PROBABLY MOVEMENT FROM BENEATH THE SESPE UPLAND INTO THE MAIN ALLUVIUM. THE RECHARGE TO THE AQUIFERS BENEATH THE SESPE UPLAND IS THUS MAINLY FROM THE SIDE TRIBUTARIES -- TIMBER, O'LEARY, LORD (BOULDER), AND SNOW CREEKS. EXPECTABLY, THE CHEMICAL CHARACTER OF THE WATERS BENEATH THE SESPE UPLAND IS QUITE DIFFERENT FROM THOSE IN THE REST OF THE FILLMORE BASIN WHERE RECHARGE IS RELATED MORE CLOSELY TO THE MAIN STREAM ALLUVIUM. THE LEAST MINERALIZED GROUND WATERS IN THE FILLMORE BASIN, OR FOR THAT MATTER, IN THE ENTIRE DISTRICT, ARE FOUND IN SECTIONS 23 AND 26, T4N, R20W. THESE WATERS ARE OF A CALCIUM DICARBONATE CHARACTER, WITH UNUSUALLY HIGH NITRATE, AND FLUORIDE COMMONLY OVER 1.0 PPM. THOUGH EXCELLENT FOR IRRIGATION USE, THESE NATIVE SAN PEDRO WATERS MAY BE MARGINAL FOR DOMESTIC USE BECAUSE OF THE FLUORIDE AND NITRATE CONTENT. WATERS OF MUCH THE SAME TYPE, BUT USUALLY MORE MINERALIZED, EXTEND WESTERLY BENEATH THE ENTIRE SESPE UPLAND. DETERIORATION OF GROUND WATERS IN THE SESPE UPLAND APPEARS TO BE DUE TO IRRIGATION RETURN. WELL 4N/20W-33G1 IS PERFORATED ABOVE THE SAN PEDRO FORMATION AND SHOWS VERY HIGH SULFATE WATERS ENTERING THE WELL (TABLE III-6). HIGH NITRATE IN THIS AREA IS NOT NECESSARILY A CRITERION OF IRRIGATION RETURN, AS THE NATIVE SAN PEDRO WATERS MAY BE HIGH IN NITRATE ALSO. NOT ALL OF THE NUMEROUS SAN PEDRO AQUIFERS BENEATH THE SESPE UPLAND CONTAIN WATERS WITH HIGH NITRATE AND HIGH FLUORIDE. SOME WATERS SHOW LOW NITRATE; THE SAME OR DIFFERENT WATERS SHOW LOW FLUORIDE.

NEAR THE WESTERN BASIN BOUNDARY AND NORTH OF THE RIVER, THE SHALLOW WATERS, ESPECIALLY IN THE NW  $\frac{1}{4}$  OF SECTION 12, T3N, R21W HAVE BEEN DEGRADED. THESE WATERS SHOW HIGH SULFATE, HIGH NITRATE AND HIGH CHLORIDE (TABLE III-6). BOTH FLUORIDE AND BORON ARE LOW. ALTHOUGH THE DEGRADED WATERS ARE PUMPED FROM WELLS NEAR A CITRUS PACKING PLANT, THE DETERIORANT IS CHEMICALLY UNLIKE THE PLANT WASH AND RINSE WATERS. THE DEGRADING WATERS HERE, ALSO, APPEAR TO BE IRRIGATION RETURN.

#### SANTA PAULA BASIN

##### SURFACE WATERS

SANTA CLARA RIVER FLOOD FLOWS ENTERING THE SANTA PAULA BASIN USUALLY SHOW AN INVERSE RELATIONSHIP OF SALINITY TO RATE OF FLOW, BUT AT TIMES, HIGH FLOOD FLOWS SHOW HIGHLY MINERALIZED WATERS (TABLE III-7). SANTA PAULA CREEK SIMILARLY SHOWS INCREASING MINERALIZATION AS FLOW DECREASES, BUT EVEN THE LOW FLOW WATERS ARE COMPARATIVELY GOOD, WITH LOW TDS, FLUORIDE AND BORON (TABLE III-7). ONLY AT THE END OF PROLONGED DROUGHTS IS THE QUALITY POOR; THIS MAY BE EXPLAINED IN PART BY IRRIGATION RETURN UPSTREAM FROM THE SAMPLING POINT. MUCH POORER WATERS ARE ASSOCIATED WITH THE LOWER FLOWS DERIVED FROM THE CANYONS ON THE NORTH SIDE OF THE SANTA PAULA BASIN. ALL OF THESE NORTH TRIBUTARY WATERS HAVE A DOMINANT SODIUM SULFATE CHARACTER. CHLORIDE AND NITRATE MAY BE PROPORTIONALLY HIGH, AND BORON DURING LOW FLOWS MAY RISE TO MORE THAN 2.0 PPM.

##### GROUND WATERS

GROUND WATERS IN THE SANTA PAULA BASIN, WHERE NOT DEGRADED, ARE OF ACCEPTABLE BUT USUALLY NOT OF GOOD QUALITY. FOR IRRIGATION USE, BORON IS MUCH LESS A PROBLEM THAN IN THE PIRU AND FILLMORE BASINS. FOR DOMESTIC USE, HIGH TDS, SULFATE, AND HARDNESS REDUCE THE DESIRABILITY OF THE WATER BUT FLUORIDE IS ONLY A MINOR PROBLEM.

EXCEPT FOR A LIMITED NUMBER OF SHALLOW WELLS IMMEDIATELY ADJACENT TO THE SANTA CLARA RIVER, MOST GROUND WATERS ARE PUMPED FROM THE BASAL UPPER PLEISTOCENE GRAVELS AND THE MANY SAN PEDRO AQUIFERS WHICH ARE COVERED BY THE ALLUVIAL FANS DERIVED FROM THE NORTH. THE LARGEST OF THESE FANS WAS DEPOSITED BY SANTA PAULA CREEK; UPON THIS THE CITY OF SANTA PAULA IS LOCATED. BECAUSE OF THE LARGE TRIBUTARY DRAINAGE THE RECHARGE TO THIS FAN IS EXCELLENT. SEVERAL LONG SERIES OF CHEMICAL ANALYSES ARE AVAILABLE FOR WELLS IN THE NW  $\frac{1}{4}$  OF SECTION 11, T3N, R21W. THE TOTAL

TABLE 111-7  
CHEMICAL ANALYSES - SANTA PAULA BASIN

| FLOW-C.F.S.<br>WELL No.                                           | DATE     | ECx10 <sup>6</sup> | PARTS PER MILLION |     |     |                  |                 |     |                 |     |      |      | EFF.<br>SAL.<br>EPM | %NA |
|-------------------------------------------------------------------|----------|--------------------|-------------------|-----|-----|------------------|-----------------|-----|-----------------|-----|------|------|---------------------|-----|
|                                                                   |          |                    | Ca                | Mg  | Na  | HCO <sub>3</sub> | SO <sub>4</sub> | CL  | NO <sub>3</sub> | F   | B    | TDS  |                     |     |
| SANTA CLARA RIVER-HIGH FLOWS ENTERING BASIN                       |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |
| 1,500                                                             | 4-7-58   | 1745               | 182               | 62  | 138 | 253              | 691             | 66  | 5.4             | 0.7 | 0.65 | 1432 | 11.3                | 30  |
| 300                                                               | 5-5-58   | 951                | 108               | 37  | 54  | 203              | 315             | 27  | 1.5             | 0.8 | 0.56 | 705  | 5.5                 | 22  |
| SANTA CLARA RIVER-RISING WATER ENTERING BASIN                     |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |
| 20                                                                | 9-7-54   | 2115               | 226               | 86  | 185 | 337              | 874             | 97  | 4.5             | 1.0 | 0.88 | 1735 | 15.3                | 30  |
| SANTA CLARA RIVER-ALLUVIAL UNDERFLOW ENTERING BASIN               |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |
| 3N/21W-12E1                                                       | 3-3-23   | -                  | 105               | 41  | 58  | 280              | 237             | 25  | -               | -   | -    | 710  | 5.9                 | 23  |
| -12E1                                                             | 9-9-45   | -                  | 193               | 56  | 117 | 380              | 504             | 96  | 8               | -   | 0.4  | 1364 | 9.7                 | 26  |
| -12E1                                                             | 7-21-52  | 1148               | 150               | 40  | 56  | 286              | 354             | 38  | 12              | 0.6 | 0.3  | 923  | 5.8                 | 18  |
| SANTA PAULA CREEK-HIGH FLOW ENTERING BASIN                        |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |
| 1,050                                                             | 1-15-52  | 328                | 46                | 10  | 17  | 104              | 74              | 13  | 6               | 0.4 | 0.07 | 266  | 1.6                 | 20  |
| SANTA PAULA CREEK-LOW FLOWS ENTERING BASIN                        |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |
| 6                                                                 | 12-12-51 | 2700               | 309               | 98  | 213 | 283              | 1288            | 63  | 4               | 0.7 | 0.8  | 2216 | 17.3                | 28  |
| 0.4                                                               | 9-3-57   | 1175               | 92                | 33  | 118 | 281              | 265             | 85  | 1.5             | 0.6 | 0.68 | 769  | 7.8                 | 41  |
| WATER IN ALLUVIUM OF SANTA CLARA RIVER                            |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |
| 3N/21W-14C4                                                       | 7-31-56  | 1449               | 120               | 48  | 160 | 290              | 408             | 140 | 3.0             | 0.6 | 0.7  | 1125 | 11.0                | 41  |
| WELL RECHARGED BY SANTA PAULA CREEK-WET PERIOD AND DROUGHT PERIOD |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |
| 3N/21W-11E2                                                       | 6-24-44  | 1230               | 143               | 38  | 75  | 348              | 310             | 38  | 17              | -   | 0.3  | 970  | 6.4                 | 24  |
| -11E2                                                             | 8-6-51   | -                  | 175               | 46  | 89  | 338              | 413             | 63  | 24              | -   | -    | 1148 | 7.6                 | 24  |
| NATIVE WATERS IN SAN PEDRO FORMATION                              |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |
| 2N/22W-1M1                                                        | 6-25-54  | 1045               | 108               | 33  | 72  | 259              | 293             | 40  | 1.2             | 0.3 | 0.3  | 775  | 6.0                 | 28  |
| 3N/21W-9R3                                                        | 8-6-51   | -                  | 129               | 30  | 84  | 304              | 314             | 35  | -               | -   | -    | 896  | 6.1                 | 29  |
| DEGRADED WATERS PUMPED FROM WELLS TAPPING SAN PEDRO FORMATION     |          |                    |                   |     |     |                  |                 |     |                 |     |      |      |                     |     |
| 3N/21W-11J1                                                       | 3-29-51  | -                  | 295               | 118 | 233 | 365              | 1166            | 145 | 14              | -   | 1.7  | 2336 | 19.8                | 29  |
| -16H1                                                             | 8-27-52  | 4545               | 257               | 143 | 650 | 471              | 1530            | 545 | 3               | 1.0 | 2.8  | 3580 | 40.2                | 53  |
| -21B1                                                             | 8-20-57  | 2212               | 208               | 70  | 218 | 436              | 590             | 215 | 0.3             | 0.6 | 1.6  | 1670 | 15.4                | 37  |
| -28M1                                                             | 7-16-52  | 2980               | 288               | 110 | 286 | 453              | 1018            | 258 | 3               | 0.7 | 1.4  | 2505 | 21.8                | 34  |
| 3N/22W-24R1                                                       | 9-13-48  | -                  | 236               | 89  | 252 | 454              | 962             | 76  | 44              | -   | 0.8  | 2123 | 18.5                | 36  |

DISSOLVED SOLIDS ARE DISTINCTLY HIGHER DURING DROUGHT PERIODS THAN DURING WET PERIODS (TABLE III-7). AS DROUGHT PROGRESSES THERE IS USUALLY A PROPORTIONATE INCREASE IN SULFATE WITH RESPECT TO DICARDONATE. WHERE PERFORATIONS ARE DEEPER, THE WATERS PUMPED ARE CONSIDERED TO REPRESENT ESSENTIALLY NATIVE CHEMICAL CHARACTERISTICS IN THE WATERS OF THE SAN PEDRO FORMATION. THESE NATIVE WATERS SHOW A CLOSE SIMILARITY OVER MUCH OF THE SANTA PAULA BASIN, WITH DOMINANT CALCIUM, AND WITH DICARDONATE AND SULFATE NEARLY EQUAL, AS WELL AS LOW NITRATE, FLUORIDE, AND BORON (TABLE III-7). OVER MUCH OF THE BASIN THE SHALLOWEST WATERS ARE TYPICALLY POOR, AND THERE IS USUALLY A PRONOUNCED IMPROVEMENT OF QUALITY WITH DEPTH. SEVERAL CABLE-TOOL WELLS WERE SAMPLED AT VARIOUS DEPTHS DURING DRILLING, AND THE WATER ANALYSES INDICATE THE NATURE OF THE CHANGES WITH DEPTH. THE SHALLOW WATERS ARE TYPICALLY HIGH IN SULFATE AND BORON, AND PROPORTIONALLY HIGH IN SODIUM. WITH DEPTH THE WATERS IMPROVE TO THE MORE TYPICAL NATIVE SAN PEDRO WATERS. WESTERLY IN THE SANTA PAULA BASIN THE SHALLOW WATERS APPEAR TO BECOME POORER.

DETERIORATION OF GROUND WATERS IS GENERALLY RELATED TO THE ENTRY OF THE POOR QUALITY SHALLOW WATERS. THE SOURCES OF THE DEGRADING WATERS ARE: (1) IRRIGATION RETURN; (2) MUNICIPAL SEWAGE; (3) CITRUS PACKING PLANT WASTES; (4) OIL-FIELD BRINES; (5) LEAKAGE FROM THE OLDER ROCKS ON THE SOUTH SIDE.

WELLS 3N/21W-21B1, E1, F1, AND F2 HAVE BEEN DEGRADED BY THE SEWAGE TREATMENT PLANT IN THE NE  $\frac{1}{4}$  OF SECTION 21. THE EFFLUENT OFTEN EXCEEDS ONE OR MORE OF THE LIMITS SPECIFIED BY THE REGIONAL WATER POLLUTION CONTROL BOARD: CHLORIDE - 175 PPM; AND BORON - 1.5 PPM. WELL 3N/21W-16H1 MAY REPRESENT DETERIORATION FROM A CITRUS PACKING PLANT, AS SUGGESTED BY THE HIGH SODIUM CHLORIDE CONTENT OF THE WATER. MUCH OF THE MINERALIZATION IN THE SHALLOW WATERS MUST BE ATTRIBUTED TO IRRIGATION RETURN, ALTHOUGH HIGH NITRATES ARE MUCH LESS IN EVIDENCE THAN IN THE PIRU AND FILLMORE BASINS. IT HAS BEEN SUGGESTED THAT THE WATER IN WELL 3N/21W-28M1 HAS BEEN DEGRADED BY WATERS LEAKING FROM SOUTH MOUNTAIN. AN ALTERNATIVE EXPLANATION IS THAT THE SALTS ARE DERIVED FROM IRRIGATION RETURN, WITH PERHAPS SOME CONTRIBUTION BY WATERS OF SEWAGE EFFLUENT ORIGIN. THE CHEMICAL QUALITY IS CONSISTENT WITH THE ALTERNATIVE EXPLANATION. NO WELLS SUGGEST DEGRADATION BY OIL-FIELD WASTES, BY EITHER THE SODIUM CHLORIDE WATER OF THE SOUTH MOUNTAIN

FIELD, OR THE SODIUM DICARBONATE WATERS PRODUCED WITH THE OIL IN THE ADAMS AND WHEELER CANYON DRAINAGES. POOR QUALITY WATERS BENEATH THE ALLUVIAL FANS OF ALISO AND WHEELER CANYONS ARE SODIUM SULFATE WATERS LIKE THOSE WHICH APPEAR TO BE NATIVE IN THESE CANYONS. THE DEGRADING WATERS MAY BE LOW FLOWS FROM THESE CANYONS, OR BETTER QUALITY HIGH FLOW WATERS OF THE SAME CHEMICAL CHARACTER WHICH HAVE BEEN CONCENTRATED BY IRRIGATION EVAPOTRANSPIRATION.

#### MOUND BASIN

##### GROUND WATERS

WATERS PUMPED FROM THE MOUND BASIN COME FROM THE BASAL UPPER PLEISTOCENE GRAVELS OR FROM AQUIFERS IN THE UNDERLYING SAN PEDRO FORMATION. AS SUGGESTED BY THE CHEMICAL ANALYSES IN TABLE III-8, AND AS CONFIRMED BY THE GEOLOGIC RELATIONSHIPS, THESE WATERS MAY BE PART OF A COMMON HYDROLOGIC SYSTEM. FOR IRRIGATION USE, ALMOST ALL THE WATERS WOULD FALL IN CLASS III. ONLY AN OCCASIONAL WATER SHOWS AN EFFECTIVE SALINITY OF LESS THAN 7. BORON CONCENTRATION IS USUALLY LESS THAN 1.0 PPM. THE DESIRABILITY OF THESE WATERS FOR DOMESTIC USE IS LESSENED BY HIGH HARDNESS, HIGH SULFATE, HIGH TOTAL DISSOLVED SOLIDS, AND IN PLACES HIGH IRON. FLUORIDE IS EVERYWHERE LESS THAN 1.0 PPM. DEEPER DRILLING INTO THE SAN PEDRO FORMATION IN THE FUTURE MAY REVEAL THAT THE DEEPER WATERS ARE OF SOMEWHAT POORER QUALITY. DEGRADED WATERS WITHIN THE DISTRICT ARE SHOWN BY THE ANALYSES IN TABLE III-8. INCREASED MINERALIZATION IS USUALLY ACCOMPANIED BY A SHARP INCREASE IN NITRATE. AS MOST OF THE KNOWN NATIVE WATERS ARE FAIRLY LOW IN NITRATE, THE DEGRADING WATERS MIGHT BE IRRIGATION RETURN. SUCH AN EXPLANATION WOULD REQUIRE (A) VERY SHALLOW PERFORATIONS; OR (B) FAULTY WELL CONSTRUCTION EITHER IN THE WELL SAMPLED OR IN A WELL NEARBY.

THE MOUND BASIN IS AN AREA WHERE THE SAN PEDRO AQUIFERS ARE LENTICULAR AND MAY NOT BE SO THOROUGHLY FLUSHED AS BENEATH THE OXNARD PLAIN. SOME OF THE KNOWN POORER QUALITY WATERS MAY BE DERIVED FROM THESE LENSES.

#### STATUS OF SEA-WATER INTRUSION

NO WELLS IN THE MOUND BASIN HAVE YET SHOWN THE HIGH CHLORIDES OF INTRUDING OCEAN WATER, BUT SUCH INTRUSION MAY BE PHYSICALLY POSSIBLE THROUGH THE BASAL UPPER PLEISTOCENE AQUIFERS. THE CLOSEST POSSIBLE SUBMARINE OUTCROPS WOULD BE MANY MILES FROM SHORE AND THE SEA-WATER FRONT

TABLE III-8  
CHEMICAL ANALYSES - MOUND AND MONTALVO BASINS

| LOW-C.F.S.<br>WELL No.                           | DATE     | ECx10 <sup>6</sup> | Ca  | Mg  | Na  | PARTS PER MILLION |                 |     |                 |     |      |      | EFF.<br>SAL.<br>EPM | %NA |
|--------------------------------------------------|----------|--------------------|-----|-----|-----|-------------------|-----------------|-----|-----------------|-----|------|------|---------------------|-----|
|                                                  |          |                    |     |     |     | HCO <sub>3</sub>  | SO <sub>4</sub> | CL  | NO <sub>3</sub> | F   | B    | TDS  |                     |     |
| MOUND BASIN                                      |          |                    |     |     |     |                   |                 |     |                 |     |      |      |                     |     |
| NATIVE WATER IN UPPER SAN PEDRO FORMATION        |          |                    |     |     |     |                   |                 |     |                 |     |      |      |                     |     |
| 2N/23W-14L1                                      | 8-25-53  | 1650               | 162 | 43  | 157 | 405               | 480             | 74  | 5.6             | 0.3 | 0.5  | 1168 | 10.5                | 37  |
| NATIVE WATER IN BASAL UPPER PLEISTOCENE GRAVELS  |          |                    |     |     |     |                   |                 |     |                 |     |      |      |                     |     |
| 2N/22W-17N2                                      | 6-25-52  | 1453               | 139 | 40  | 135 | 242               | 494             | 81  | 3.1             | 0.4 | 0.2  | 1124 | 9.3                 | 36  |
| POORER QUALITY WELL WATERS                       |          |                    |     |     |     |                   |                 |     |                 |     |      |      |                     |     |
| 2N/22W-17L1                                      | 6-23-52  | 3090               | 354 | 100 | 284 | 306               | 1320            | 175 | 56              | 0.6 | 0.6  | 2599 | 20.6                | 32  |
| -20B1                                            | 6-29-54  | 2820               | 346 | 92  | 241 | 298               | 1095            | 191 | 163             | 0.2 | 0.6  | 2474 | 18.2                | 30  |
| 2N/23W-24K2                                      | 6-29-54  | 2210               | 255 | 79  | 162 | 288               | 828             | 142 | 85              | 0.4 | 0.6  | 1854 | 13.8                | 26  |
| -24K2                                            | 4-1-57   | -                  | 363 | 100 | 271 | 304               | 1228            | 207 | 111             | 0.5 | 0.5  | 2584 | 20.0                | 31  |
| MONTALVO BASIN                                   |          |                    |     |     |     |                   |                 |     |                 |     |      |      |                     |     |
| SANTA CLARA RIVER-HIGH FLOW ENTERING BASIN       |          |                    |     |     |     |                   |                 |     |                 |     |      |      |                     |     |
| 000                                              | 1-26-56  | 734                | 63  | 19  | 53  | 95                | 236             | 24  | 5.0             | -   | 0.20 | 508  | 3.9                 | 33  |
| SANTA CLARA RIVER-RISING WATER ENTERING BASIN    |          |                    |     |     |     |                   |                 |     |                 |     |      |      |                     |     |
| 2                                                | 8-5-52   | 1770               | 184 | 77  | 180 | 278               | 770             | 105 | 2               | -   | 0.81 | 1540 | 14.3                | 33  |
| WATERS IN OXNARD AQUIFER                         |          |                    |     |     |     |                   |                 |     |                 |     |      |      |                     |     |
| 2N/22W-11R1                                      | 11-28-52 | 1200               | 113 | 37  | 110 | 266               | 385             | 32  | 3               | 0.7 | 0.6  | 838  | 7.9                 | 35  |
| -27F1                                            | 8-27-54  | 1700               | 184 | 66  | 106 | 344               | 542             | 74  | 3.8             | 0.4 | 0.7  | 1389 | 10.2                | 24  |
| DEGRADED WATERS PUMPED FROM OXNARD AQUIFER WELLS |          |                    |     |     |     |                   |                 |     |                 |     |      |      |                     |     |
| 2N/22W-11A1                                      | 11-7-55  | 2128               | 220 | 77  | 240 | 383               | 897             | 106 | 5.0             | 0.7 | 0.8  | 1920 | 17.0                | 37  |
| -11A2                                            | 11-4-54  | 2127               | 213 | 81  | 240 | 393               | 874             | 95  | 6.9             | 0.8 | 0.7  | 1730 | 17.3                | 38  |
| -12D1                                            | 8-24-53  | 2110               | 209 | 70  | 198 | 344               | 807             | 92  | 9.9             | 0.4 | 0.5  | 1699 | 14.5                | 35  |
| -14P1                                            | 12-12-51 | 2020               | 226 | 76  | 134 | 281               | 763             | 98  | 20              | 0.5 | 0.8  | 1940 | 12.2                | 25  |
| -26F1                                            | 11-10-50 | -                  | 305 | 106 | 149 | 350               | 1097            | 80  | 5               | -   | 1.1  | 2111 | 15.7                | 21  |
| -27F2                                            | 11-3-54  | 2500               | 338 | 107 | 125 | 344               | 975             | 98  | 143             | 0.8 | 0.6  | 2060 | 14.4                | 17  |

WITHIN THE BASAL UPPER PLEISTOCENE AQUIFERS WOULD NOT REACH THE COASTLINE FOR MANY DECADES. THE BASAL LAYERS OF THE SAN PEDRO FORMATION CROP OUT ALONG THE OCEAN BOTTOM WEST OF THE VENTURA RIVER. WELL 2N/23W-5P1 HAS SHOWN INCREASING CHLORIDES FOR THE LAST FEW YEARS. WHEN THE WELL WAS DRILLED THE ELECTRIC LOG SHOWED SALINE WATERS IN THE UPPER 200 FEET. THE ALLUVIUM HERE IS KNOWN TO BE HIGH IN CHLORIDES DUE TO WASTE DISCHARGES. THE HIGH CHLORIDES IN WELL 5P1, THEN, MAY NOT REPRESENT AN EASTERLY MOVING SEA-WATER FRONT IN THE SAN PEDRO AQUIFERS. INSTEAD, THE CHLORIDE INCREASE MAY BE RELATED TO THE SHALLOW CHLORIDE WATERS LEAKING WITHIN THE WELL OR COMING THROUGH SUB-ALLUVIAL OUTCROPS OF SAN PEDRO AQUIFERS. NO WELLS IN THE DISTRICT PUMP FROM AQUIFERS WHICH COULD BE AFFECTED BY SEA-WATER INTRUSION INTO THE SUBMARINE OUTCROPS WEST OF THE VENTURA RIVER.

#### MONTALVO BASIN

##### SURFACE WATERS

THE LOW VOLUME SURFACE FLOWS ENTERING THE MONTALVO BASIN CONSIST MAINLY OF RISING WATER OUTFLOW FROM THE SANTA PAULA BASIN. THE QUALITY OF THESE LOW FLOW WATERS IS FAIR TO VERY POOR, WITH TDS RANGING UP TO MORE THAN 5000 PPM, ALTHOUGH USUALLY REMAINING BELOW 1500 PPM (TABLE III-8). THE VERY HIGH TDS WATERS MAY INCLUDE EFFLUENT FROM THE SATICOY SANITARY DISTRICT. THERE IS A TREMENDOUS IMPROVEMENT IN QUALITY DURING FLOOD FLOWS, WHEN TDS MAY DROP TO BELOW 500 PPM (TABLE III-8). IN ADDITION TO LOW TDS, THE FLOOD FLOWS ARE CHARACTERIZED BY DOMINANT CALCIUM, WITH A SODIUM PERCENTAGE OF ABOUT 25. AS THE VOLUME BECOMES LESS THE SODIUM PERCENTAGE RISES, BUT USUALLY REMAINS BELOW 50. MAGNESIUM IS ALWAYS LESS THAN SODIUM OR CALCIUM. FLOOD FLOW ANIONS SHOW SULFATE PERHAPS TWICE AS HIGH AS DICARBONATE, AND CHLORIDE QUITE LOW. AS FLOW DECREASES AND MINERALIZATION INCREASES, BOTH SULFATE AND CHLORIDE RISE SHARPLY WHEREAS THE INCREASES IN DICARBONATE ARE MORE MODERATE. BORON IS RARELY AS HIGH AS 1.0 PPM.

##### GROUND WATERS

WATERS IN THE ALLUVIAL AQUIFERS OF MONTALVO BASIN SHOW MARKED VARIATIONS OF CHEMICAL QUALITY WITH TIME. THERE IS A SUGGESTION OF AN ANNUAL FLUCTUATION OF TDS, WITH THE HIGHEST VALUES IN THE FALL AND THE LOWEST IN THE WINTER OR SPRING. THERE IS A LONGER, MORE PRONOUNCED CYCLE OVER THE WET AND DROUGHT PERIODS. ESPECIALLY NOTICEABLE WERE THE EFFECTS

OF THE SPRING 1958 RUNOFF AND THE SPREADING OPERATIONS THAT YEAR. IN 1958, THE RUNOFF WAS BY FAR THE LARGEST SINCE 1952. ANALYSES OF GROUND WATERS OVER THE ENTIRE BASIN IN THE FALL OF 1957 SHOWED A TDS RANGE FROM 1270 TO OVER 1600 PPM. IN THE SPRING AND SUMMER OF 1958 THERE WERE SHARP DROPS OF TDS TO 800 PPM OR BELOW.

ESPECIALLY INTERESTING ARE THE RESULTS OF THE 1958 OPERATIONS AT THE EL RIO SPREADING GROUNDS. THE SPREAD WATER BY ABOUT MARCH 12, 1958 HAD REDUCED THE TDS IN THE WELLS AT THE EL RIO SPREADING GROUNDS BY SEVERAL HUNDRED PPM. SPREADING CONTINUED THROUGH AUGUST WITH FURTHER IMPROVEMENT IN THE AVERAGE QUALITY. THREE MONTHS LATER, STARTING IN DECEMBER, THERE WAS ANOTHER RELEASE AT SANTA FELICIA DAM FOR SPREADING. ON DECEMBER 9, 1958, BEFORE SPREADING WAS RESUMED, THE EL RIO WELLS WERE SAMPLED. THE WELLS ON THE DOWNGRAIDENT (SOUTHWEST) SIDE OF THE SPREADING GROUNDS SHOWED TDS OF LESS THAN 1000 PPM, WHEREAS THE UPGRADIENT (NORTHEAST) WELLS SHOWED VALUES HIGHER THAN 1000 PPM. DURING THE THREE-MONTH NON-SPREADING PERIOD, THE FRONT OF MORE MINERALIZED WATER HAD MOVED INTO THE UPGRADIENT WELLS BUT HAD NOT REACHED THE DOWNGRAIDENT WELLS.

THE GROUND WATERS OF THE MONTALVO BASIN ARE CHEMICALLY MUCH THE SAME AS THE SURFACE WATERS, BUT HAVE A MUCH SMALLER RANGE OF TDS BECAUSE OF CONTINUOUS BLENDING. WHEREAS FLOOD FLOWS MAY SHOW TDS AS LOW AS 345 PPM, THE GROUND WATERS RARELY GET BELOW 800 PPM. SIMILARLY, THE HIGHLY MINERALIZED LOW SURFACE FLOWS BECOME BLENDED, BY THE TIME THESE GET UNDERGROUND, TO A MIXTURE WITH A MUCH LOWER MINERAL CONTENT. LOW SURFACE FLOWS MAY HAVE A SODIUM CONCENTRATION HIGHER THAN CALCIUM, BUT THE GROUND WATERS SHOW CALCIUM PERSISTENTLY HIGHER THAN SODIUM, ALTHOUGH AT TIMES THEY MAY BE ALMOST EQUAL. BORON IN THE GROUND WATERS IS USUALLY BETWEEN 0.5 AND 1.0 PPM, AND CHLORIDE LESS THAN 100 PPM. FLUORIDE, THOUGH AT TIMES MORE THAN 1.0 PPM, IS TYPICALLY IN THE RANGE OF 0.7 TO 0.9 PPM. SULFATE IS INVARIABLY HIGH, OCCASIONALLY AS LOW AS 300 PPM, BUT USUALLY MORE THAN 400 PPM.

IN THE WELLS OF THE ALTA MUTUAL WATER COMPANY (2N/22W-2R AND 11A) WHICH ARE PERFORATED IN THE FOX CANYON AQUIFER, THE VARIATIONS OF WATER QUALITY ARE WIDER THAN IN THE ALLUVIAL AQUIFERS. THESE VARIATIONS SHOW NO OBVIOUS RELATIONSHIP TO SURFACE RUNOFF, ALTHOUGH ONE MAY BE OBSCURED BY A LAG EFFECT, AS YET UNDETERMINED.

A LARGE SOURCE OF POOR QUALITY WATER IN THE MONTALVO BASIN IS THE OUTFLOW FROM SANTA PAULA BASIN. NEAR THE END OF A PERIOD OF DRY YEARS THE RISING WATER AND PROBABLY THE UNDERFLOW ARE APPRECIABLY MINERALIZED (TABLE III-8). POOR WATERS ARE ALSO CONTRIBUTED BY THE LOW FLOWS IN MINOR TRIBUTARIES COMING FROM THE NORTH. HIGH CALCIUM, SULFATE, AND NITRATE IN SOME OF THE DEGRADED WELL WATERS INDICATE THAT LOCAL IRRIGATION RETURN MAY BE IMPORTANT.

PART OF THE TOWN OF SATICOY IS SERVED BY THE SATICOY SANITARY DISTRICT, WHICH OPERATES A SMALL COLLECTION SYSTEM WITH ABOUT 100 CONNECTIONS. IN THE PAST, APPRECIABLE VOLUMES OF INDUSTRIAL WASTES WERE DISCHARGED TO THIS SYSTEM, ALTHOUGH IT IS UNDERSTOOD THAT THIS PRACTICE IS BEING DISCONTINUED. THE SEWAGE IS DELIVERED TO A SERIES OF SEPTIC TANKS WHICH DISCHARGE TO PERCOLATION PONDS AT THE EDGE OF THE SANTA CLARA RIVER. THE DOMESTIC WATER DELIVERED IS IN THE RANGE OF 1400 TO 1700 PPM, AND THE EFFLUENT IS USUALLY MORE THAN 2000 PPM.

#### OXNARD PLAIN BASIN

##### GROUND WATERS

PRIOR TO THE WIDESPREAD EXPLOITATION OF GROUND WATERS OF THE OXNARD PLAIN, PERCOLATION FROM THE SANTA CLARA RIVER IN MONTALVO BASIN AND RAINFALL PENETRATION, ALONG WITH UNDERFLOW FROM SANTA PAULA BASIN FED THE OXNARD AQUIFER AND THE WATER MOVED SEAWARD BENEATH THE OXNARD PLAIN AND PROBABLY ESCAPED TO THE OCEAN AS SUBMARINE SPRINGS IN HUENEME AND MUGU SUBMARINE CANYONS. WATER-LEVEL SLOPES WERE GENTLE AND OCEANWARD MOVEMENTS WERE SLOW. BECAUSE OF LIMITED TRANSMISSIBILITY IN THE OXNARD AQUIFER AND THE LOW WATER-LEVEL SLOPES, MONTALVO BASIN TENDED TO REMAIN NEARLY FULL. UNDER SUCH CONDITIONS THERE WAS MUCH REJECTED RECHARGE. THERE MAY HAVE BEEN A SLIGHT INCREASE IN MINERALIZATION OF THE UNDERGROUND WATERS AS THEY MOVED SLOWLY TOWARD THE OCEAN. THE WATER RECHARGED TO THE MONTALVO BASIN UNDER THESE NATIVE CONDITIONS WAS PROBABLY LARGELY OF VERY GOOD QUALITY. A GOOD INDICATION OF THE QUALITY OF THE ORIGINAL WATER MIGHT BE OBTAINED FROM THE CHARACTERISTICS OF THE BEST QUALITY WATER WHICH IS NOW FOUND IN THE OXNARD AQUIFER. TOTAL DISSOLVED SOLIDS WERE PROBABLY LESS THAN 700 PPM. CALCIUM WAS THE DOMINANT CATION AT ABOUT 125 PPM, AND SODIUM WAS 80 TO 90 PPM. MAGNESIUM WAS PROBABLY LESS THAN 40 PPM. SULFATE WAS THE MOST IMPORTANT ANION AT 300 OR MORE PPM, AND DICARBONATE

ONLY SLIGHTLY LESS IMPORTANT BUT WITH LESS THAN 300 PPM. IN THE PORTION OF THE OXNARD AQUIFER NEAR PLEASANT VALLEY, THE ORIGINAL DICARBONATE MAY HAVE BEEN HIGHER THAN SULFATE. CHLORIDE WAS ALWAYS MINOR AND LESS THAN 50 PPM. DESPITE THE RELATIVE ABUNDANCE OF BORON IN THE UPSTREAM BASINS, NATURAL DILUTION WAS EFFECTIVE; NATIVE BORON CONTENT IN THE OXNARD AQUIFER WAS PROBABLY NEVER AS MUCH AS 1.0 PPM.

THERE HAS BEEN APPRECIABLE DETERIORATION OF THE CHEMICAL QUALITY OF WATERS IN THE OXNARD AQUIFER SINCE THE BEGINNING OF AGRICULTURAL DEVELOPMENT OF THE OXNARD PLAIN AND THE UPSTREAM BASINS. THESE AGRICULTURAL AND ASSOCIATED DEVELOPMENTS IN THE UPSTREAM BASINS AND IN MONTALVO BASIN HAVE RESULTED IN A MORE MINERALIZED RECHARGE TO THE OXNARD AQUIFER. WHEREAS NATURAL, PRE-DEVELOPMENT WATERS IN THE MONTALVO BASIN APPEAR TO HAVE HAD LESS THAN 700 PPM TDS, AT THE PRESENT TIME FEW RECHARGING WATERS HAVE TDS LESS THAN 1000 PPM. THE DEFINITELY MORE MINERALIZED WATERS HAVE MOVED TO ABOUT THE CITY OF OXNARD, WHEREAS SEAWARD OF THE CITY OF OXNARD, MOST OF THE WATERS STILL SHOW TDS OF LESS THAN 1000 PPM. MANY WELLS TAPPING THE OXNARD AQUIFER HAVE A FLUORIDE CONTENT OF 1.0 PPM OR MORE. THE FLUORIDE CONCENTRATIONS APPEAR TO FLUCTUATE ERRATICALLY, HOWEVER. ANALYSES WITH MORE THAN 1.0 PPM FLUORIDE MADE SUBSEQUENT TO 1952 ARE MUCH LESS COMMON THAN THOSE MADE IN 1952 AND EARLIER. THIS INDICATED TREND OF IMPROVEMENT MAY NOT BE SIGNIFICANT.

UNDER NATIVE CONDITIONS, MUCH OF THE AREA OVERLYING THE "CLAY CAP" WAS CHARACTERIZED BY HIGHLY ALKALINE SOILS (REF. 7). THE CONDITIONS WERE ESPECIALLY SEVERE ALONG THE COAST WHERE THE WATER-TABLE RIDGE IN THE DUNES, ESPECIALLY NORTH OF PORT HUENEME, PREVENTED OUTFLOW OF THE SHALLOW WATERS. BEFORE THESE LANDS COULD BE FARMED THEY HAD TO BE DRAINED AND LEACHED. THERE IS NOW AN EXTENSIVE SYSTEM OF TILE DRAINS AND DITCHES OVER MOST OF THE AREA BETWEEN OXNARD AND THE COAST. THE SHALLOW WATERS ARE STILL OF VERY POOR QUALITY (TABLE III-9). AS THE MAIN INCREMENT TO THESE SHALLOW WATERS IS IRRIGATION RETURN, THE QUALITY CONTINUES TO REMAIN POOR. IMMEDIATELY FOLLOWING HEAVY RAINS, THE WATER FORMING THE GROUND WATER RIDGE IN THE COASTAL DUNES NORTH OF PORT HUENEME IS OF EXCELLENT QUALITY (TABLE III-9). THE QUALITY DETERIORATES RAPIDLY, HOWEVER.

SO LONG AS POSITIVE ARTESIAN HEADS WERE MAINTAINED IN THE COASTAL PORTIONS OF THE OXNARD AQUIFER THERE WAS NO POSSIBILITY OF DETERIORATION

TABLE III-9  
CHEMICAL ANALYSES - OXNARD PLAIN

| SAMPLING<br>POINT                                     |         |                    | PARTS PER MILLION |     |      |                  |                 |      |                 |     |      |       | EFF.        |     |
|-------------------------------------------------------|---------|--------------------|-------------------|-----|------|------------------|-----------------|------|-----------------|-----|------|-------|-------------|-----|
| WELL No.                                              | DATE    | ECX10 <sup>6</sup> | Ca                | Mg  | Na   | HCO <sub>3</sub> | SO <sub>4</sub> | CL   | NO <sub>3</sub> | F   | B    | TDS   | SAL.<br>EPM | %NA |
| TYPICAL WATERS IN OXNARD AQUIFER                      |         |                    |                   |     |      |                  |                 |      |                 |     |      |       |             |     |
| 1N/21W-5P1                                            | 6-25-52 | 1142               | 106               | 32  | 106  | 319              | 260             | 64   | 1               | 1.0 | 0.4  | 776   | 7.2         | 37  |
| 1N/22W-9Q3                                            | 4-23-58 | 1282               | 129               | 46  | 94   | 256              | 421             | 45   | 0               | 0.8 | 0.2  | 873   | 8.0         | 29  |
| 2N/22W-28J3                                           | 8-1-56  | 1418               | 159               | 56  | 104  | 293              | 492             | 57   | 22              | 0.8 | 0.8  | 1255  | 9.2         | 26  |
| OXNARD AQUIFER WATERS DEGRADED BY INTRUDING SEA WATER |         |                    |                   |     |      |                  |                 |      |                 |     |      |       |             |     |
| 1N/22W-20R1                                           | 4-16-58 | 19520              | 948               | 485 | 2887 | 253              | 1155            | 6808 | 7.4             | 0.5 | 0.9  | 13966 | 194.6       | 59  |
| 1N/22W-21L1                                           | 4-16-58 | 11925              | 1202              | 384 | 739  | 235              | 733             | 3829 | 12              | 0.8 | 0.8  | 10251 | 107.3       | 27  |
| OXNARD AQUIFER WATERS DEGRADED FROM OTHER SOURCES     |         |                    |                   |     |      |                  |                 |      |                 |     |      |       |             |     |
| 1N/22W-22Q2                                           | 8-2-56  | 3597               | 174               | 94  | 700  | 573              | 1705            | 123  | 10              | 1.2 | 2.6  | 3215  | 37.9        | 65  |
| -23N1                                                 | 1-20-49 | -                  | 278               | 70  | 172  | 347              | 814             | 144  | 23              | -   | 0.5  | 1848  | 13.2        | 28  |
| 2N/21W-32Q1                                           | 3-31-56 | 5570               | 230               | 149 | 701  | 346              | 1480            | 649  | 4.3             | 0.5 | 1.5  | 3535  | 43.0        | 56  |
| 2N/22W-26J1                                           | 7-14-52 | 2440               | 275               | 94  | 214  | 301              | 1096            | 86   | 10              | 0.7 | 0.7  | 2071  | 17.3        | 30  |
| -33A4                                                 | 8-27-54 | 2940               | 340               | 132 | 175  | 325              | 1378            | 82   | 1.2             | 0.4 | 1.2  | 2464  | 18.7        | 21  |
| WATERS OF SEMI-PERCHED ZONE                           |         |                    |                   |     |      |                  |                 |      |                 |     |      |       |             |     |
| 1N/22W-7J                                             | 1-14-53 | 3774               | 370               | 186 | 350  | 405              | 1880            | 145  | 23              | -   | 2.5  | 3628  | 30.7        | 31  |
| -18B                                                  | 8-4-52  | 5780               | 373               | 273 | 820  | 410              | 2830            | 341  | 28.5            | -   | 3.6  | 5131  | 58.2        | 46  |
| -21F                                                  | 1-14-53 | 2198               | 278               | 73  | 165  | 334              | 891             | 88   | 13.6            | -   | 1.0  | 1832  | 13.3        | 27  |
| -27C                                                  | 1-14-53 | 4149               | 306               | 188 | 620  | 337              | 2150            | 247  | 58              | -   | 2.7  | 3565  | 42.6        | 47  |
| WATER IN GROUND WATER RIDGE OF COASTAL DUNES          |         |                    |                   |     |      |                  |                 |      |                 |     |      |       |             |     |
|                                                       | 4-30-58 | 280                | 17                | 5   | 25   | 110              | 19              | 13   | -               | -   | 0.13 | 189   | 1.1         | 45  |
|                                                       | 2-18-59 | 1528               | 152               | 63  | 140  | 310              | 519             | 112  | -               | -   | 0.67 | 1296  | 11.3        | 32  |

OF CHEMICAL QUALITY IN THE OXNARD AQUIFER BY DOWNWARD MOVEMENT OF THE NEAR-SURFACE WATERS. ON THE CONTRARY, THERE MAY HAVE BEEN SOME SMALL, LOCAL UPWARD ESCAPE FROM THE OXNARD AQUIFER INTO THE SHALLOW ZONES THROUGH WELLS WITH VERY SHALLOW PERFORATIONS. WITH WIDESPREAD AND INTENSIVE PUMPING, HOWEVER, AND THE CONSEQUENT DEPRESSION BELOW SEA LEVEL OF LARGE AREAS OF THE OXNARD AQUIFER PIEZOMETRIC SURFACE, THERE WAS CREATED A CONDITION FAVORING (1) SEA-WATER INTRUSION, AND (2) DOWNWARD LEAKAGE FROM THE SHALLOW ZONES THROUGH ABANDONED OR SHALLOW-PERFORATED WELLS. THERE IS AMPLE EVIDENCE THAT WELLS HAVE BEEN DEGRADED BY INTRUDING SEA WATER (TABLE III-9). DETERIORATION OF WELL WATERS TAPPING THE OXNARD AQUIFER IS PROBABLY ALSO OCCURRING DUE TO MOVEMENTS FROM THE SEMI-PERCHED ZONE, BUT IT IS MORE DIFFICULT TO DEMONSTRATE.

#### STATUS OF SEA-WATER INTRUSION

OVER AN AREA OF ABOUT 2640 ACRES NEAR PORT HUENEME THE OXNARD AQUIFER HAS ALREADY BEEN INVADDED BY SEA WATER (PLATE 17). THE INVASION STARTED AT THE SUBMARINE OUTCROP IN HUENEME SUBMARINE CANYON, AND IN RESPONSE TO LANDWARD GRADIENTS THE SALT WATER HAS MOVED BENEATH THE LAND SURFACE. TO AVOID INTERPRETATIONS BASED ON MINOR CHANGES IN NATIVE WATERS, INVASION IS ASSUMED TO HAVE STARTED WHEN THE CHLORIDE CONTENT REACHED 100 PARTS PER MILLION. MOST OF THE NATIVE WATERS IN THE OXNARD AQUIFER SHOWED A CHLORIDE CONTENT OF 45 PPM OR LESS, AND A RISE EVEN TO 50 PPM MAY IN SOME PLACES BE AN INDICATION OF THE APPROACHING SEA-WATER WEDGE. ON TABLE III-10 ARE LISTED THE WELLS WHICH TO DATE ARE CONSIDERED TO HAVE BEEN INVADDED BY OCEAN WATER.

A SMALL PORTION OF THE OXNARD AQUIFER WAS INTRUDED BY SEA WATER DURING THE DROUGHT PERIOD OF THE EARLY 1930'S. WELL 1N/22W-28D1 SHOWED CHLORIDES OF MORE THAN 2000 PPM DURING 1931. BY MARCH 1933, HOWEVER, THE CHLORIDES WERE DOWN TO 42 PPM. WELL 1N/22W-20N1 SHOWED A SIGNIFICANTLY HIGH CHLORIDE CONTENT OF 103 PPM IN JULY 1936. BY DECEMBER 1939 THE CHLORIDES WERE DOWN TO 49 PPM. THE CHLORIDE INCREASE IN WELL 1N/22W-20E1 WHICH REACHED 100 PPM IN SEPTEMBER 1954 REPRESENTS THE RE-ADVANCE OF THE SEA-WATER WEDGE THAT HAD REACHED THE WELL EARLIER, PROBABLY IN LATE 1950. BY APRIL 1951 THE CHLORIDES HAD RISEN TO 530 PPM, BUT DECREASED TO ONLY 42 PPM IN SEPTEMBER 1952. THE RETREAT OF THE WEDGE A SHORT DISTANCE MAY BE ASSOCIATED WITH THE RECOVERY OF WATER LEVELS DURING THE WET YEAR OF

TABLE III-10. WELLS NEAR PORT HUENEME INTRUDED BY SEA WATER AS OF MAY 1959.

| STATE NUMBER | COUNTY NUMBER | MONTH WHEN CHLORIDES<br>REACHED 100 PPM |
|--------------|---------------|-----------------------------------------|
| 1N/22W-17J2  | 8-V-3         | JULY 1957                               |
| 1N/22W-19H1  | 8-V-15        | SEPTEMBER 1954                          |
| 1N/22W-20E1  | 8-V-24        | SEPTEMBER 1954                          |
| 1N/22W-20N1  | 8-V-11        | JULY 1936 AND APRIL 1948                |
| 1N/22W-20R1  | 8-V-21        | DECEMBER 1950                           |
| 1N/22W-21J1  | 9-V-28        | JANUARY 1959                            |
| 1N/22W-21J3  | 9-V-53        | MAY 1958                                |
| 1N/22W-21L1  | 9-V-15        | DECEMBER 1953                           |
| 1N/22W-21L2  | 9-V-65        | DECEMBER 1953                           |
| 1N/22W-21N1  |               | FEBRUARY 1959                           |
| 1N/22W-21Q1  | 9-V-42        |                                         |
| 1N/22W-28A2  | 9-W-20        | DECEMBER 1958                           |
| 1N/22W-28A3  | 9-W-19        |                                         |
| 1N/22W-28D1  | 9-W-2         | PRE-1931                                |
| 1N/22W-29A2  | 8-W-1         | AUGUST 1951                             |

1952, WHEN THERE WAS AN UNUSUALLY LONG PERIOD OF SUBNORMAL PUMPING. HIGH CHLORIDES ARE EVIDENT IN WELLS 1N/22W-17J2 AND 20R1 (HUENEME NAVAL BASE WELLS #12 AND #2, RESPECTIVELY). IN BETWEEN THESE TWO WELLS IS HUENEME NAVAL BASE WELL #4 (1N/22W-20B1) WHICH HAS SHOWN A PERSISTENT NATIVE CHLORIDE CONTENT (50 PPM OR LESS). IT IS HIGHLY UNLIKELY THAT THE SEA WATER ADVANCING WITHIN THE OXNARD AQUIFER WOULD HAVE BYPASSED THE POSITION OF WELL #4. LIMITED DATA SUGGEST THAT WELL #4 IS PERFORATED ONLY BELOW THE OXNARD AQUIFER, IN A ZONE (1) IN WHICH THE INVADING SEA WATER HAS NOT YET ADVANCED SO FAR INLAND, OR (2) WHICH IS LENTICULAR AND NOT IN COMMUNICATION WITH THE OCEAN. SUBNORMAL WATER LEVELS FAVOR THE LATTER SUGGESTION.

INVASION OF SEA WATER HAS PROCEEDED FROM THE OUTCROP IN HUENEME SUBMARINE CANYON LANDWARD ALONG A GRADUALLY EXPANDING ARC. AS THE RATE OF ADVANCE IS GOVERNED BY THE MAGNITUDE OF THE LANDWARD SLOPE, THE FASTEST MOVEMENT HAS BEEN NORTHEASTERLY, TOWARD THE MAIN PUMPING TROUGH. MOVEMENTS EASTERLY AND ALSO NORTHWESTERLY ACCOMPANIED THE GROWTH OF THE ARC. ACCORDING TO GHYDEN-HERZBERG PRINCIPLES, LANDWARD MOVEMENTS COULD BEGIN WHEN THE WATER LEVELS DROPPED BELOW ABOUT ELEVATION +6, ASSUMING AN AQUIFER DEPTH OF 240 FEET AND A SPECIFIC GRAVITY FOR SEA WATER OF 1.025. THUS, SEA WATER WOULD TEND TO MOVE FROM THE OUTCROP INLAND IN ALL DIRECTIONS SO LONG AS THE WATER-LEVEL ELEVATIONS WERE LESS THAN +6. AS ELEVATIONS OF THE OXNARD AQUIFER PIEZOMETRIC SURFACE HAVE BEEN MAINTAINED BELOW SEA LEVEL ALMOST CONTINUOUSLY FOR THE PAST 13 YEARS, THE SEA-WATER ADVANCE HAS BEEN FAIRLY GENERAL FROM THE FOCUS AT THE SUBMARINE OUTCROP, ALTHOUGH THE RATE OF ADVANCE HAS BEEN A MAXIMUM IN A NORTHEASTERLY DIRECTION. THE AVAILABLE DATA SUGGEST ADVANCE RATES APPROACHING 1200 FEET PER YEAR IN THE NORTHEASTERLY DIRECTION, AND PERHAPS 1000 FEET PER YEAR EASTERLY AND NORTHWESTERLY.

THE STATUS OF SEA-WATER INTRUSION BENEATH THE MUGU NAVAL BASE IS MUCH LESS CLEAR. OBSERVATION WELL #2 (1S/21W-5H1) HAS SHOWN STEADILY INCREASING CHLORIDES SINCE IT WAS INSTALLED IN 1949. THIS WELL WAS CONSTRUCTED SO THAT WATER SAMPLES COULD BE TAKEN FROM TWO DIFFERENT ZONES, WITH A PACKER AND SEAL BETWEEN THEM. THE UPPER PERFORATIONS WERE CUT BETWEEN DEPTHS OF 180 AND 190 FEET, THE LOWER BETWEEN 330 AND 340 FEET. SAMPLES FROM BOTH ZONES HAVE SHOWN VERY HIGH CHLORIDES. HOWEVER, THERE

IS REASON TO BELIEVE THAT THE PACKER AND SEAL HAVE FAILED (AS OCCURRED IN OBSERVATION WELL #1) AND IT IS UNCERTAIN WHETHER THE HIGH CHLORIDE WATER COMES FROM THE UPPER ZONE (OXNARD AQUIFER) OR THE LOWER ZONE (MUGU AQUIFER), OR BOTH. ERRATIC WATER LEVELS IN THIS WELL SUGGEST IT MAY BE PLUGGED. BECAUSE MANY OF THE WELLS INLAND FROM THE MUGU NAVAL BASE ARE PERFORATED IN BOTH SHALLOW AND DEEP ZONES, INTRUSION OF OCEAN WATER INTO ANY ZONE MUST BE CONSIDERED A THREAT TO ALL ZONES.

INCREASING SALT CONTENT IN THE WATERS OF COASTAL WELLS CAN NOT AUTOMATICALLY BE ATTRIBUTED TO INVASION OF SEA WATER INTO A PARTICULAR AQUIFER. THE POSSIBILITY OF DOWNWARD MOVEMENT OF SHALLOWER POOR QUALITY WATERS MUST ALSO BE CONSIDERED. SOURCES OF DETERIORANTS MAY BE LISTED AS FOLLOWS:

- (1) AQUIFER INTRUSION BY SEA WATER
- (2) CONNATE WATERS IN COASTAL MARINE SEDIMENTS
- (3) IRRIGATION RETURN

ITEM (1) MAY INDICATE INVASION BY SEA WATER INTO ANY AQUIFER PERFORATED IN A MULTI-ZONE WELL NEARBY, BUT CAN NOT BE TAKEN TO INDICATE THE ARRIVAL OF THE SEA-WATER FRONT IN A SPECIFIC AQUIFER. OTHER LINES OF EVIDENCE MUST BE SOUGHT TO RESOLVE THIS PROBLEM. ALTHOUGH ALL THE IMPORTANT AQUIFERS APPEAR TO HAVE BEEN THOROUGHLY FLUSHED BY FRESH WATERS, SOME LENSES OF MARINE SAND MAY NOT HAVE BEEN SO THOROUGHLY FLUSHED. UNLIKE THE INCREASING CHLORIDES WHICH TYPIFY AN ADVANCING SEA-WATER WEDGE, THESE LENSES SHOULD SHOW A REDUCTION OF CHLORIDES WITH TIME. IRRIGATION RETURN WATERS GENERALLY SHOW HIGH SULFATES AND OFTEN HIGH NITRATES, BUT NOT HIGH CHLORIDES, WHICH ARE TOXIC TO PLANTS IN SOIL SOLUTIONS AT RELATIVELY LOW CONCENTRATIONS.

THE NATURE OF AN INTRUDING SEA-WATER WEDGE IS NOW WELL KNOWN FROM THE DETAILED FIELD STUDIES CONDUCTED IN THE WEST BASIN OF LOS ANGELES COUNTY (REF. 47). IT WAS CLEARLY DEMONSTRATED THAT THE ADVANCING SEA WATER UNDER-RIDES THE FRESH WATER, AND IN THIS INSTANCE, OVER A DISTANCE OF ABOUT 4500 FEET MEASURED AT RIGHT ANGLES TO THE COASTLINE. A SIMILAR WEDGE HAS UNDOUBTEDLY FORMED WITHIN THE OXNARD AQUIFER NEAR PORT HUENEME. BECAUSE OF THIS WEDGE THE RISE IN CHLORIDES IN A WELL STARTS RATHER SLOWLY, THE CHANGE FROM 50 PPM TO 100 PPM TAKING PERHAPS 3 MONTHS OR MORE. AS THE WEDGE AT THE WELL BECOMES THICKER, THE CHLORIDES RISE MORE SHARPLY. FROM THE TIME OF THE FIRST INDICATION OF RISING CHLORIDES TO THE POINT AT WHICH

THE WATER BECOMES UNUSABLE MAY BE AS MUCH AS 6 MONTHS.

## FOX CANYON AQUIFER

### NATIVE WATERS

GENERALLY SPEAKING, NATIVE WATERS IN THE FOX CANYON AQUIFER ARE OF GOOD CHEMICAL QUALITY WHERE FLUSHING HAS BEEN THOROUGH. THESE WATERS RARELY SHOW LESS THAN 500 PPM TDS, NOR MORE THAN 1000 PPM TDS. TO THE EAST OF THE DISTRICT, IN THE EAST AND WEST LAS POSAS AREAS, THE FOX CANYON WATERS ARE LOWEST IN SALINITY. THEY APPEAR TO HAVE BECOME MORE MINERALIZED AS THEY FLOWED UNDERGROUND WESTERLY TOWARD THE OCEAN. SUPERIMPOSED ON THIS GENERAL NATIVE PATTERN ARE NUMEROUS COMPLEXITIES RESULTING FROM MULTI-ZONE WELLS TAPPING INFERIOR OVERLYING WATERS OR INFERIOR UNDERLYING WATERS, OR FROM POORLY FLUSHED SAND AND GRAVEL LENSES.

IN THE FOX CANYON AQUIFER BENEATH THE OXNARD PLAIN, CALCIUM AND SODIUM ARE USUALLY ABOUT EQUAL, ALTHOUGH EITHER MAY BE THE DOMINANT CATION (TABLE III-11). MAGNESIUM IS TYPICALLY ABOUT 30 PPM. BICARBONATE AND SULFATE ARE BOTH HIGH, AND SULFATE IS USUALLY THE HIGHER. AVERAGE TDS IS LESS THAN 800 PPM. CHLORIDE IS ALMOST ALWAYS LESS THAN 50 PPM, AND ONLY OCCASIONALLY MORE THAN 100 PPM. BORON IS ALMOST ALWAYS BELOW 0.5 PPM, AND FLUORIDE BELOW 1.0 PPM.

SOME OF THE FOX CANYON WATERS PUMPED FROM BENEATH PLEASANT VALLEY ARE MUCH THE SAME AS THOSE BENEATH THE OXNARD PLAIN; OTHERS ARE DISTINCTLY MORE MINERALIZED (TABLE III-11). THE BETTER FOX CANYON WATERS ARE OF HIGHLY ACCEPTABLE QUALITY FOR DOMESTIC AND IRRIGATION USE. THE MORE MINERALIZED WATERS, IN ADDITION TO HIGH TDS, ARE LESS DESIRABLE FOR DOMESTIC PURPOSES BECAUSE OF HIGH HARDNESS AND SULFATE CONTENT.

### SOURCES OF DEGRADING WATERS

THERE ARE SEVERAL SOURCES OF POOR QUALITY WATERS THREATENING THE CONTINUED USABILITY OF FOX CANYON WATERS, OTHER THAN SEA WATER, WHICH WILL BE TREATED IN A LATER SECTION. IT SHOULD BE STRESSED THAT WELLS DRILLED TO TAP THE FOX CANYON AQUIFER CAN NOT BE DRILLED TO INDISCRIMINATE DEPTHS AND PERFORATED IN ALL AVAILABLE PERMEABLE ZONES WITH THE EXPECTATION THAT THE WATER PUMPED WILL BE OF ACCEPTABLE CHEMICAL QUALITY. IN PLACES WELLS WHICH ARE DRILLED TOO DEEP YIELD WATERS OF INFERIOR QUALITY. ONE OR MORE WELLS IN PLEASANT VALLEY HAVE BEEN ABANDONED BECAUSE OF EXCESSIVELY DEEP PERFORATIONS AND CONSEQUENT POOR WATER. HYDROGEN SULFIDE GAS HAS BEEN

TABLE III-11  
CHEMICAL ANALYSES - FOX CANYON AQUIFER

| WELL No.                                                                  | DATE     | ECx10 <sup>6</sup> | Ca  | Mg | Na  | HCO <sub>3</sub> | SO <sub>4</sub> | CL  | NO <sub>3</sub> | F   | B   | TDS  | EFF.<br>SAL.<br>EPM | %Na |
|---------------------------------------------------------------------------|----------|--------------------|-----|----|-----|------------------|-----------------|-----|-----------------|-----|-----|------|---------------------|-----|
| NATIVE WATERS IN THE FOX CANYON AQUIFER BENEATH THE OXNARD PLAIN          |          |                    |     |    |     |                  |                 |     |                 |     |     |      |                     |     |
| 1N/21W-4M2                                                                | 8-20-52  | 1073               | 114 | 33 | 101 | 257              | 310             | 74  | 5               | 0.3 | 0.2 | 745  | 7.2                 | 34  |
| -20K1                                                                     | 6-24-52  | 1083               | 94  | 27 | 108 | 274              | 233             | 75  | 6               | 0.6 | 0.1 | 744  | 6.9                 | 40  |
| 1N/22W-17B1                                                               | 4-16-58  | 1082               | 106 | 36 | 73  | 229              | 323             | 39  | 2.4             | 0.7 | 0.3 | 775  | 6.2                 | 28  |
| -20E2                                                                     | 4-23-58  | 1201               | 140 | 30 | 91  | 262              | 380             | 43  | 1.5             | 0.3 | 0.3 | 827  | 6.5                 | 29  |
| 2N/21W-20Q3                                                               | 9-3-52   | 1120               | 94  | 34 | 122 | 280              | 325             | 55  | 7               | 0.1 | 0.9 | 816  | 8.3                 | 41  |
| NATIVE WATERS IN THE FOX CANYON AQUIFER BENEATH PLEASANT VALLEY           |          |                    |     |    |     |                  |                 |     |                 |     |     |      |                     |     |
| 1N/21W-3N1                                                                | 7-25-57  | 1266               | 96  | 36 | 128 | 281              | 296             | 96  | 0               | 0.4 | 0.4 | 831  | 8.6                 | 42  |
| -15H1                                                                     | 6-25-52  | 1938               | 175 | 56 | 184 | 338              | 522             | 173 | 5               | 0.5 | 0.6 | 1330 | 12.7                | 37  |
| 2N/20W-30H1                                                               | 9-20-52  | -                  | 94  | 66 | 246 | 369              | 352             | 257 | 1               | 0.4 | 0.5 | 1282 | 14.9                | 51  |
| 2N/21W-23R3                                                               | 11-8-57  | 1255               | 102 | 33 | 127 | 256              | 307             | 88  | 0               | 0.2 | 0.4 | 915  | 8.4                 | 40  |
| -25K2                                                                     | 11-7-57  | 2075               | 156 | 63 | 198 | 299              | 571             | 180 | 0               | 0.2 | 0.8 | 1470 | 14.0                | 40  |
| -27F4                                                                     | 6-24-52  | 1102               | 108 | 27 | 98  | 306              | 237             | 66  | 6               | 0.5 | 0.0 | 796  | 6.5                 | 36  |
| -28Q2                                                                     | 2-10-50  | -                  | 81  | 28 | 302 | 480              | 239             | 240 | -               | -   | 0.7 | 1370 | 13.2                | 68  |
| -34D2                                                                     | 8-2-56   | 909                | 74  | 24 | 85  | 264              | 183             | 50  | 2.5             | 0.4 | 0.3 | 610  | 5.1                 | 39  |
| -35K1                                                                     | 7-14-52  | 1950               | 146 | 54 | 227 | 327              | 501             | 199 | 6               | 0.3 | 0.6 | 1330 | 14.4                | 45  |
| FOX CANYON AQUIFER WATER SHOWING REMOVAL OF NATIVE SODIUM CHLORIDE WATERS |          |                    |     |    |     |                  |                 |     |                 |     |     |      |                     |     |
| 2N/21W-34D1                                                               | 2-10-50  | -                  | 81  | 28 | 302 | 480              | 239             | 240 | 0               | -   | 0.7 | 1370 | 13.1                | 68  |
| -34D1                                                                     | 7-14-52  | 932                | 65  | 33 | 92  | 283              | 190             | 53  | 5               | 0.3 | 0.3 | 626  | 5.5                 | 39  |
| DEGRADED WATERS FROM WELLS TAPPING THE FOX CANYON AQUIFER                 |          |                    |     |    |     |                  |                 |     |                 |     |     |      |                     |     |
| 1N/21W-14C1                                                               | 11-15-51 | -                  | 220 | 69 | 240 | 180              | 670             | 280 | TR              | -   | -   | 1905 | 16.1                | 39  |
| 2N/21W-35J1                                                               | 6-25-52  | 2190               | 224 | 72 | 169 | 265              | 690             | 199 | 17              | 0.6 | 0.2 | 1772 | 13.3                | 30  |

ENCOUNTERED IN THE DEEPER ZONES OVER LARGE AREAS IN PLEASANT VALLEY. MUGU NAVAL BASE WELL #3 (1N/21W-31L1) ENCOUNTERED HYDROGEN SULFIDE GAS IN SANDS OF THE SANTA BARBARA FORMATION. PLUGGING OFF THE LOWER PART OF THIS HOLE IS REPORTED TO HAVE SOLVED THIS DIFFICULTY. HYDROGEN SULFIDE WATERS WERE FOUND ALSO IN SECTIONS 27 AND 28, T2N, R21W, AND NEAR SOMIS. SMALL AMOUNTS OF THIS GAS WERE NOTICED ALSO IN HUENEME BASE WELL #21 (1N/22W-17B1). MUCH OF THE POORER QUALITY WATER, WITH HIGH TDS OR HYDROGEN SULFIDE OR BOTH APPEARS TO OCCUR IN THE UPPER PART OF THE SANTA BARBARA FORMATION (GRIMES CANYON MEMBER) ALTHOUGH IN PLACES THIS WATER MAY BE IN THE LOWER PART OF THE FOX CANYON AQUIFER. NO CLEAR-CUT GENERALIZATION CAN BE MADE AT THIS TIME.

APPRECIABLY HIGHER TDS ARE NOTED WHERE THE FOX CANYON WELLS ARE PERFORATED ALSO IN THE SHALLOWER SAN PEDRO ZONES. IN SOME OF THESE INSTANCES, THE LESS DESIRABLE WATERS ARE CLEARLY OF A SODIUM CHLORIDE CHARACTER. THE DETERIORATING SOURCES ARE PROBABLY SAND LENSES WHICH HAVE NOT BEEN THOROUGHLY FLUSHED OF THE ORIGINAL CONNATE WATERS. SEVERAL WELLS, INITIALLY SHOWING A RELATIVELY HIGH SODIUM CHLORIDE CONTENT, UPON PROLONGED PUMPING SHOWED A MARKED DROP IN SODIUM CHLORIDE CONTENT AND A MATERIAL REDUCTION OF TDS (TABLE III-11). THESE CHANGES SUGGEST THAT THE SAND LENS HAS BEEN DEPLETED OF THE POORER QUALITY WATER; THE IMPROVEMENT IN QUALITY IS EXPECTED TO BE PERMANENT.

DEGRADING WATERS WITH VERY HIGH SULFATE AND NITRATE ARE PROBABLY DERIVED FROM VERY SHALLOW SOURCES, TRACEABLE TO IRRIGATION RETURN. THE WELLS MAY BE PERFORATED EXCESSIVELY HIGH. CHANGES IN WATER QUALITY ARE HIGHLY ERRATIC. SOME OF THE SHALLOWER ZONES IN PLEASANT VALLEY ARE BEING DEPLETED RAPIDLY AND PERHAPS IN TIME THE QUALITY WILL IMPROVE BECAUSE OF THE REMOVAL OF THESE POORER WATERS.

ELECTRIC LOGS OF OIL WELLS IN AND NEAR SECTION 25, T2N, R23W INDICATE THAT THE FOX CANYON SANDS AND GRAVELS IN THIS VICINITY CONTAIN WATER OF INFERIOR CHEMICAL QUALITY. THIS AREA IS CLOSE TO THE UPLIFTED AND FAULTED AREA ASSOCIATED WITH THE MONTALVO FAULT. THE INFERIOR QUALITY MIGHT BE EXPLAINED BY (1) BYPASSING OF THIS STRUCTURALLY HIGH AREA DURING FLUSHING, OR (2) DETERIORATION BY POOR QUALITY WATERS MOVING UPWARD ALONG THE FAULT.

IF THE COMPLEXITY OF CHEMICAL RELATIONSHIPS IN PLEASANT VALLEY

IS REPRESENTATIVE, THEN FUTURE DEEP DRILLING ON THE OXNARD PLAIN MAY REVEAL FOX CANYON WATERS WHICH IN PLACES ARE NOT OF ACCEPTABLE CHEMICAL QUALITY. NEVERTHELESS, THE THOROUGHNESS OF THE FLUSHING SUGGESTS ACCEPTABLE QUALITY IN THE FOX CANYON LAYERS OVER MOST OF THIS LARGE UNTESTED AREA.

#### STATUS OF SEA-WATER INTRUSION

NO FOX CANYON WELL HAS YET BEEN ABANDONED BECAUSE OF INTRUDING SEA WATER BUT THERE SEEMS TO BE AMPLE EVIDENCE TO INDICATE THAT THE INTRUSION OF OCEAN WATER INTO THE SEAWARD EXTENSIONS OF THE FOX CANYON AQUIFER HAS ALREADY BEGUN. THIS STATEMENT IS BASED UPON THE FOLLOWING LINES OF EVIDENCE:

- (1) THE FOX CANYON AQUIFER IS A THICK, MARINE SAND. NEAR THE SHORELINE IT IS SEVERAL HUNDRED FEET THICK AND APPEARS TO EXTEND AS A DISTINCT PERMEABLE UNIT FOR A CONSIDERABLE DISTANCE BENEATH THE OCEAN.
- (2) OFF THE SOUTHERN PART OF THE OXNARD PLAIN THE OCEAN BOTTOM HAS A FAIRLY STEEP SLOPE, WHICH WOULD FAVOR THE POSSIBILITY OF A SUBMARINE OUTCROP FOR THE GENTLY DIPPING FOX CANYON AQUIFER. HUENEME AND MUGU SUBMARINE CANYONS WOULD CAUSE SUCH A SUBMARINE OUTCROP TO BE CLOSER TO THE SHORELINE THAN ELSEWHERE.
- (3) WATER LEVELS IN THE FOX CANYON AQUIFER HAVE REMAINED BELOW SEA LEVEL ALMOST CONTINUOUSLY SINCE 1948. LANDWARD GRADIENTS DEMONSTRATE THAT THERE IS A FLOW OF WATER IN THE FOX CANYON AQUIFER FROM THE SEAWARD EXTENSIONS TOWARD THE PUMPING TROUGHS IN PLEASANT VALLEY.
- (4) THIS WATER MOVES FROM THE SEAWARD EXTENSIONS OF THE FOX CANYON AQUIFER UNDER TWO POSSIBLE GEOLOGICAL CONDITIONS:
  - (A) THE AQUIFER PINCHES OUT AND THERE ARE NO SUBMARINE OUTCROPS; THE WATER IS EXTRACTED AND NO OTHER WATER REPLACES IT, OR
  - (D) THE AQUIFER HAS A SUBMARINE OUTCROP AND SEA WATER IS FREE TO MOVE INTO THE AQUIFER AND REPLACE THE WATER WHICH THE LANDWARD GRADIENTS SHOW, MUST BE MOVING OUT OF THE SEAWARD EXTENSIONS.

UNDER CONDITION (A) THERE SHOULD BE A MORE OR LESS CONTINUOUS DECLINE OF WATER LEVELS SIMILAR TO AN INLAND BASIN IN WHICH THE GROUND WATER IS BEING "MINED". UNDER CONDITION (D) THE INVASION OF HIGHER SPECIFIC

GRAVITY SEA WATER SHOULD FUNCTION TO MAINTAIN THE WATER LEVELS SOMEWHAT ABOVE SEA LEVEL. THE ACTUAL RESPONSE IS DEFINITELY THAT OF (D) (WELL 1N/21W-10F1, PLATE 25), AS WITNESS THE STRONG TENDENCY TO RESIST PROGRESSIVE DECLINE, AND TO ATTEMPT TO RETURN TO SEA LEVEL EACH NON-PUMPING SEASON.

THE MOST CRITICAL REACH FOR SEA-WATER INTRUSION INCLUDES HUENEME AND MUGU SUBMARINE CANYONS AND THE AREA IN BETWEEN. THIS REACH, UNFORTUNATELY, ADJOINS THE MOST HEAVILY PUMPED AREAS IN PLEASANT VALLEY. INTRUDING SEA WATER WILL ARRIVE AT THE COASTLINE MOST QUICKLY WHERE THE SUBMARINE OUTCROPS ARE CLOSEST TO SHORE AND WHERE THE ROUTE TO THE CENTER OF PUMPING IS THE SHORTEST. PUMPING FROM THE FOX CANYON AQUIFER IN THE VICINITY OF HUENEME SUBMARINE CANYON IS AS YET RATHER SMALL, AND INLAND MOVEMENT OF SEA WATER HAS PROBABLY NOT STARTED. DISTANCES TO THE CRITICAL WELLS FROM THE PROBABLE SUBMARINE OUTCROPS OF THE SHALLOWEST PERFORATED ZONES ARE: FOR THE HOLLYWOOD-BY-THE-SEA WELL (1N/22W-19A1) - 11,500 FEET; FOR THE SILVERSTRAND WELL (1N/22W-20E1) - 18,500 FEET.

MUGU SUBMARINE CANYON IS IN ALL PROBABILITY THE MOST CRITICAL SPOT FOR FOCUSING THE INTRUSION OF SEA WATER INTO THE FOX CANYON AQUIFER. IF A LOSS OF FRESH-WATER STORAGE OF 200,000 ACRE-Feet IS ASSUMED (WHICH IS THE ESTIMATED CULULATIVE OVERDRAFT IN PLEASANT VALLEY SINCE THE STRONG LANDWARD PIEZOMETRIC GRADIENT DEVELOPED) ON THE ORDER OF 6000 ACRES OF THE FOX CANYON AQUIFER OFFSHORE HAS ALREADY BECOME FILLED WITH SEA WATER. DISTANCES TO THE MUGU NAVAL BASE PRODUCTION WELLS FROM THE PROBABLE SUBMARINE OUTCROPS OF THE FOX CANYON AQUIFER ARE: WELL #2 (1N/21W-32G1) - 15,000 FEET; WELL #3 (1N/21W-31L1) - 15,500 FEET. THERE ARE NO OBSERVATION WELLS INTO THE FOX CANYON AQUIFER SEAWARD OF THESE PRODUCTION WELLS WHICH COULD GIVE WARNING OF THE ADVANCING SEA-WATER WEDGE.

## CHAPTER IV

### GROUND WATER INVENTORIES

THE OVERALL OBJECTIVE OF THE STUDY OF THE GROUND WATER INVENTORY WAS TO SET UP A FRAMEWORK INTO WHICH FUTURE DISTRICT STUDIES COULD BE FITTED. CONSIDERABLE WORK ON GROUND WATER INVENTORIES HAD BEEN DONE DURING 1951-53 BY WILDE AND LONG (REF. 68), AND DURING 1956-57 BY KAWANO (REF. 43). A DIFFERENT APPROACH WAS USED BY THE CALIFORNIA DIVISION OF WATER RESOURCES IN THEIR BULLETIN 12 STUDIES (REF. 23). IT WAS FELT THAT THE PURPOSES OF THE DISTRICT COULD BE SERVED BETTER BY MODIFYING THE EXTENSIVE WORK ALREADY ACCOMPLISHED BY THE DISTRICT RATHER THAN BY DEVISING A NEW INVENTORY METHOD. CONSEQUENTLY, THE EARLIER DISTRICT STUDIES HAVE BEEN VERY HEAVILY RELIED UPON. THE MODIFICATIONS MADE, TO A LARGE EXTENT, ARE BASED UPON AN IMPROVED PICTURE OF THE UNDERGROUND GEOLOGY AND HYDROLOGY.

#### BASE PERIOD

THE BASE PERIOD USED IN OUR STUDY WAS 1936-57. IN THE WILDE-LONG STUDIES DURING 1951-53, THE PERIOD 1922-1951 WAS USED, AND THIS WAS EXTENDED TO 1955 BY KAWANO DURING 1956-57. IN BULLETIN 12, THE BASE PERIOD WAS 1936-51. THE 1936-57 PERIOD HAS SEVERAL ADVANTAGES. IT APPLIES UNITED'S INVENTORY APPROACH OVER A DIFFERENT AND MORE UP-TO-DATE PERIOD. THE AVAILABILITY OF BETTER DATA WILL MORE THAN OFFSET THE POSSIBILITY THAT THE PERIOD IS LESS REPRESENTATIVE OF LONG-TERM CONDITIONS. THE 1936-51 PERIOD HAS BEEN OBJECTED TO AS BEING EXCESSIVELY WET. AN EXTENSION OF THIS TO 1957 INCORPORATES ONE WET AND FIVE DRY YEARS AND REMOVES AT LEAST A PART OF THIS OBJECTION. IN THE PIRU, FILLMORE, SANTA PAULA, AND MONTALVO BASINS, THE INVENTORIES WERE CALCULATED ON A MONTHLY BASIS FOR THE ENTIRE BASE PERIOD. ALL STUDIES WERE MADE FOR THE RUNOFF YEAR -- OCTOBER 1 THROUGH SEPTEMBER 30.

#### PRECIPITATION

PRECIPITATION ON THE FREE GROUND WATER BASINS WAS DETERMINED BY AVERAGING MONTHLY RAINFALL AT SEVERAL RAIN GAGES IN OR NEAR EACH BASIN. THE WILDE-LONG AVERAGE WEIGHTED RAINFALL FIGURES WERE USED FOR THE PERIOD 1936-51. KAWANO USED A REFINED AVERAGING METHOD FOR THE YEARS 1951-55. KAWANO'S METHOD WAS EXTENDED TO 1956-57.

## STREAM FLOWS

STREAM-GAGING RECORDS ARE AVAILABLE AT THE FOLLOWING POINTS:

SANTA CLARA RIVER AT BLUE CUT (ENTERING PIRU BASIN)

PIRU CREEK NEAR PIRU (ENTERING PIRU BASIN)

HOPPER CREEK AT HIGHWAY BRIDGE (ENTERING PIRU BASIN)

SESPE CREEK NEAR FILLMORE (ENTERING FILLMORE BASIN)

SANTA PAULA CREEK NEAR SANTA PAULA (ENTERING SANTA PAULA BASIN)

THESE RECORDS ARE PUBLISHED IN THE UNITED STATES GEOLOGICAL SURVEY WATER SUPPLY PAPERS. PRIOR TO PUBLICATION PRELIMINARY REPORTS MAY BE AVAILABLE IN THE LOS ANGELES OFFICE OF THE UNITED STATES GEOLOGICAL SURVEY. THE PUBLISHED FIGURES, ALONG WITH CORRELATIONS MADE IN THE WILDE-LONG AND KAWANO STUDIES, WERE USED IN OUR INVENTORY. FEW MEASUREMENTS ARE AVAILABLE FOR FLOOD FLOWS ALONG THE SANTA CLARA RIVER ENTERING FILLMORE, SANTA PAULA, AND MONTALVO BASINS. ESTIMATES OF ENTERING FLOOD FLOWS WERE DERIVED FROM SURFACE FLOWS IN THE BASIN JUST UPSTREAM, DEPLETED BY STREAM PERCOLATION.

## RISING WATERS

RISING WATERS HAVE BEEN MEASURED INTERMITTENTLY AT BLUE CUT ENTERING PIRU BASIN; AT THE STATE FISH HATCHERY ENTERING FILLMORE BASIN; AT THE FARMER'S DITCH DIVERSION ENTERING SANTA PAULA BASIN; AND AT THE BUTLER DITCH DIVERSION ENTERING MONTALVO BASIN. A RATHER GOOD SERIES OF MEASUREMENTS IS AVAILABLE FOR THE PERIODIC RISING WATER FLOWS AT THE STATE FISH HATCHERY. FOR MONTHS WHEN NO RISING WATER MEASUREMENTS ARE AVAILABLE, THE FLOWS WERE ESTIMATED USING LEVELS IN NEARBY WELLS AS A GUIDE. NUMEROUS LOW FLOW MEASUREMENTS HAVE BEEN MADE NEAR THE LOWER END OF FILLMORE BASIN, BUT AT VARIOUS POINTS. AT TIMES OF HEAVY RUNOFF, RISING WATER MUST BE ESTIMATED, AS THE FLOOD WATERS AND RISING WATERS CAN NOT BE SEPARATED. ESTIMATES MADE DURING THE WILDE-LONG STUDIES, ON THE BASIS OF LATER MEASUREMENTS BY THE VENTURA COUNTY WATER RESOURCES DIVISION, WERE REVISED BY KAWANO. KAWANO'S FIGURES HAVE BEEN USED IN OUR INVENTORY, ALTHOUGH IT IS BELIEVED THAT ADDITIONAL MEASUREMENTS IN THE FUTURE MAY INDICATE THAT THE ESTIMATED MAXIMA ARE TOO HIGH. SURFACE FLOW MEASUREMENTS TAKEN IN THE VICINITY OF THE LOWER BOUNDARY OF SANTA PAULA BASIN DO NOT ACCURATELY INDICATE THE VOLUME OF RISING WATER AS IT IS APPARENT THAT EVEN RELATIVELY LOW FLOWS CONSIST IN PART OF THROUGH-FLOWING SURFACE WATERS. THE ESTIMATES

USED IN THE WILDE-LONG AND KAWANO STUDIES ARE CONSIDERED EXCESSIVELY HIGH. ENTIRELY NEW RISING WATER FIGURES WERE DEVELOPED BY CARRYING RISING WATER AS AN INVENTORY RESIDUAL DURING THE 1944-51 PERIOD WHEN THE BASIN DID NOT FILL AND THERE WAS NO REJECTED RECHARGE. MONTHLY DISTRIBUTIONS WERE BASED ON RISING WATER MEASUREMENTS AND ESTIMATES AT THE FILLMORE-SANTA PAULA BASIN BOUNDARY.

#### STREAM PERCOLATION

CURVES SHOWING STREAM PERCOLATION VS. FLOWS ENTERING VARIOUS REACHES OF THE SANTA CLARA RIVER AND TRIBUTARIES WERE FIRST PREPARED FOR BULLETIN 46 (REF. 10). ON THE BASIS OF ADDITIONAL DATA, THESE CURVES WERE MODIFIED BY HAROLD CONKLING IN HIS 1949 REPORT TO THE VENTURA COUNTY BOARD OF SUPERVISORS OF FLOOD CONTROL ZONE 2 (REF. 26). THESE CURVES WERE FURTHER CHECKED AND SLIGHTLY MODIFIED DURING THE WILDE-LONG STUDIES. KAWANO IN REVIEWING THESE CURVES FELT THAT DURING THE HIGH FLOWS ESPECIALLY, THE EXISTING CURVES INDICATED EXCESSIVELY HIGH PERCOLATION RATES. ACCORDINGLY, HE ADJUSTED DOWNWARD ALL THE HIGH-FLOW PERCOLATION RATES. THE ADJUSTMENTS IN THESE CURVES MADE BY KAWANO FOR THE FILLMORE AND SANTA PAULA BASINS APPEAR QUITE REASONABLE. BUT IN THE PIRU BASIN, HOWEVER, MUCH MORE WATER PERCOLATED DURING 1952 THAN WAS INDICATED BY KAWANO'S REVISION. ADDITIONAL DATA WILL PROBABLY CONFIRM THE SUGGESTION THAT THE WILDE-LONG CURVES ARE MORE NEARLY CORRECT FOR HIGH FLOWS IN THE PIRU BASIN.

#### WATER SPREAD

TO SUPPLEMENT NATURAL STREAM PERCOLATION, WATER IS CONDUCTED FROM STREAM CHANNELS TO BASINS OR "SPREADING GROUNDS". SPREADING OPERATIONS WERE CONDUCTED BY THE SANTA CLARA WATER CONSERVATION DISTRICT FOR MANY YEARS, DIVERTING FROM PIRU CREEK IN THE PIRU BASIN, FROM SANTA PAULA CREEK IN THE SANTA PAULA BASIN, AND FROM THE SANTA CLARA RIVER TO THE SATICOY SPREADING GROUNDS IN THE MONTALVO BASIN. THE SANTA PAULA SPREADING GROUNDS, AFTER SEVERAL YEARS OF OPERATION, WERE FOUND TO BE OF LITTLE BENEFIT, AND THEIR USE WAS DISCONTINUED. THE UNITED WATER CONSERVATION DISTRICT TOOK OVER THE OPERATION OF THE PIRU AND SATICOY SPREADING GROUNDS IN DECEMBER 1952. SINCE THEN, DIVERSION FACILITIES NEAR SATICOY HAVE BEEN ENLARGED AND ADDITIONAL SPREADING GROUNDS HAVE BEEN CONSTRUCTED IN THE MONTALVO BASIN NEAR EL RIO. FROM TIME TO TIME ADDITIONAL INFILTRATION HAS BEEN ACCOMPLISHED BY DIVERTING FLOWS TO VARIOUS PARTS OF THE FLOOD PLAIN, AND

BY SCARIFYING THE BED OF THE SANTA CLARA RIVER. GOOD MEASUREMENTS ARE AVAILABLE FOR THE WATER WHICH HAS BEEN DIVERTED TO THE PERMANENT SPREADING GROUNDS.

#### IMPORTS AND EXPORTS

WATER IS IMPORTED WESTERLY THROUGH BLUE CUT AND USED ON THE CAMULOS, SHARP, AND NEWHALL RANCHES IN THE EASTERN PART OF THE PIRU BASIN. GOOD MONTHLY RECORDS ARE AVAILABLE FOR THESE IMPORTS. IN THE LOWER END OF THE PIRU BASIN, NEAR THE STATE FISH HATCHERY, THE SITUATION IS QUITE COMPLEX. THE STATE FISH HATCHERY PUMPS FROM WELLS WITHIN THE PIRU BASIN AND THE WATER IS DISCHARGED TO THE SANTA CLARA RIVER WITHIN THE FILLMORE BASIN. SOME OF THE HATCHERY EFFLUENT IS USED FOR IRRIGATION WITHIN THE FILLMORE BASIN BY THE SESPE LAND AND WATER COMPANY. MEASUREMENTS OF HATCHERY PUMPAGE AND IRRIGATION DIVERSIONS HAVE BEEN SPOTTY; THE FIGURES USED IN THE WILDE-LONG REPORT HAVE BEEN USED, AND UPDATED ON THE BASIS OF RECENT RECORDS. WATER IS ALSO PUMPED IN THIS BOUNDARY AREA BY THE LA CIENEGA WATER COMPANY AND THE SOUTHSIDE IMPROVEMENT COMPANY. THESE WATERS ARE DELIVERED TO LANDS IN BOTH THE PIRU AND FILLMORE BASINS, AND NO RECORDS ARE AVAILABLE TO DETERMINE THE DIVISION OF THESE WATERS. IN OUR INVENTORY, THE PUMPING BY LA CIENEGA WATER COMPANY AND THE SOUTHSIDE IMPROVEMENT COMPANY WAS CONSIDERED AN EXPORT FROM PIRU BASIN, ALTHOUGH A PORTION OF THIS PUMPAGE IS NOT EXPORTED TO THE UPPER PART OF THE FILLMORE BASIN.

LIKE THE LOWER END OF THE PIRU BASIN, THE LOWER END OF THE FILLMORE BASIN IS AN AREA OF HEAVY EXTRACTION AND DIVERSION. FARMER'S IRRIGATION COMPANY FORMERLY DIVERTED RISING WATER, AND NOW PUMPS FROM WELLS IN THIS AREA, AND CONVEYS THE WATER INTO THE SANTA PAULA BASIN. GOOD RECORDS ARE AVAILABLE FOR THE FARMER'S DIVERSIONS AND PUMPAGE. NO RECORDS WERE FOUND FOR DIVERSIONS ON THE SOUTH SIDE OF THE RIVER THROUGH THE TURNER DITCH; ESTIMATES OF DIVERSIONS WERE BASED ON A CROP SURVEY AND UNIT CONSUMPTIVE USE VALUES APPLIED TO THE DETERMINED ACREAGES. CONSIDERED AS AN IMPORT WERE THE MEASURED DIVERSIONS BY THE SANTA PAULA WATER WORKS AT THE GAGING STATION ON SANTA PAULA CREEK.

NEAR SATICOY, THE ALTA MUTUAL WATER COMPANY PUMPS FROM WELLS WITHIN THE MONTALVO BASIN AND PART OF THIS WATER IS USED WITHIN THE SANTA PAULA BASIN; THE REMAINDER IS DELIVERED TO THE MOUND BASIN. WATER PUMPED BY THE DEL MAR DIVISION IN THE SANTA PAULA BASIN IS TRANSPORTED WESTERLY

INTO THE MOUND BASIN.

#### SANTA CLARA RIVER UNDERFLOW

IN BOTH THE WILDE-LONG AND KAWANO STUDIES THE UNDERFLOW OUT OF THE PIRU, FILLMORE, AND SANTA PAULA BASINS WAS DETERMINED AS A RESIDUAL IN THE INVENTORY. FOR EACH OF THESE BOUNDARY AREAS WE HAVE MADE INDEPENDENT ESTIMATES OF UNDERFLOW USING THE SLOPE-AREA METHOD, WHICH EMPLOYS THE EQUATION:

$$Q = P \ I \ A$$

WHERE  $Q$  IS THE UNDERFLOW,  $P$  IS AN ESTIMATED PERMEABILITY BASED UPON A STUDY OF WELL LOGS,  $I$  IS THE WATER-TABLE SLOPE UPSTREAM FROM THE UNDERFLOW SECTION, AND  $A$  IS THE EFFECTIVE CROSS-SECTIONAL AREA OF THE ALLUVIUM AND THE SAN PEDRO FORMATION. NEAR THE STATE FISH HATCHERY, WHERE UNDERFLOW IS INTERMITTENT, UNDERFLOW RATES DECREASE AS THE SATURATED CROSS-SECTIONAL AREA DECREASES. MAXIMUM UNDERFLOW WAS FIRST ESTIMATED BY THE KIMBLE METHOD (REF. 45). BECAUSE THE AVAILABLE DATA ARE NOT WELL-SUITED TO THIS METHOD, THE RESULTS WERE NOT VERY CONCLUSIVE. THE CURVE GIVEN ON PLATE 27 WAS CONSTRUCTED BY MEANS OF THE SLOPE-AREA METHOD.

BECAUSE RISING WATER HAS NEVER FAILED AND THE SATURATED CROSS-SECTION AND WATER-TABLE SLOPES REMAIN NEARLY CONSTANT, THE UNDERFLOWS FROM THE FILLMORE AND SANTA PAULA BASINS ARE CONSIDERED TO BE CONSTANT. UNDERFLOW ESTIMATES WERE MADE BY THE SLOPE-AREA METHOD.

#### SIDE UNDERFLOW

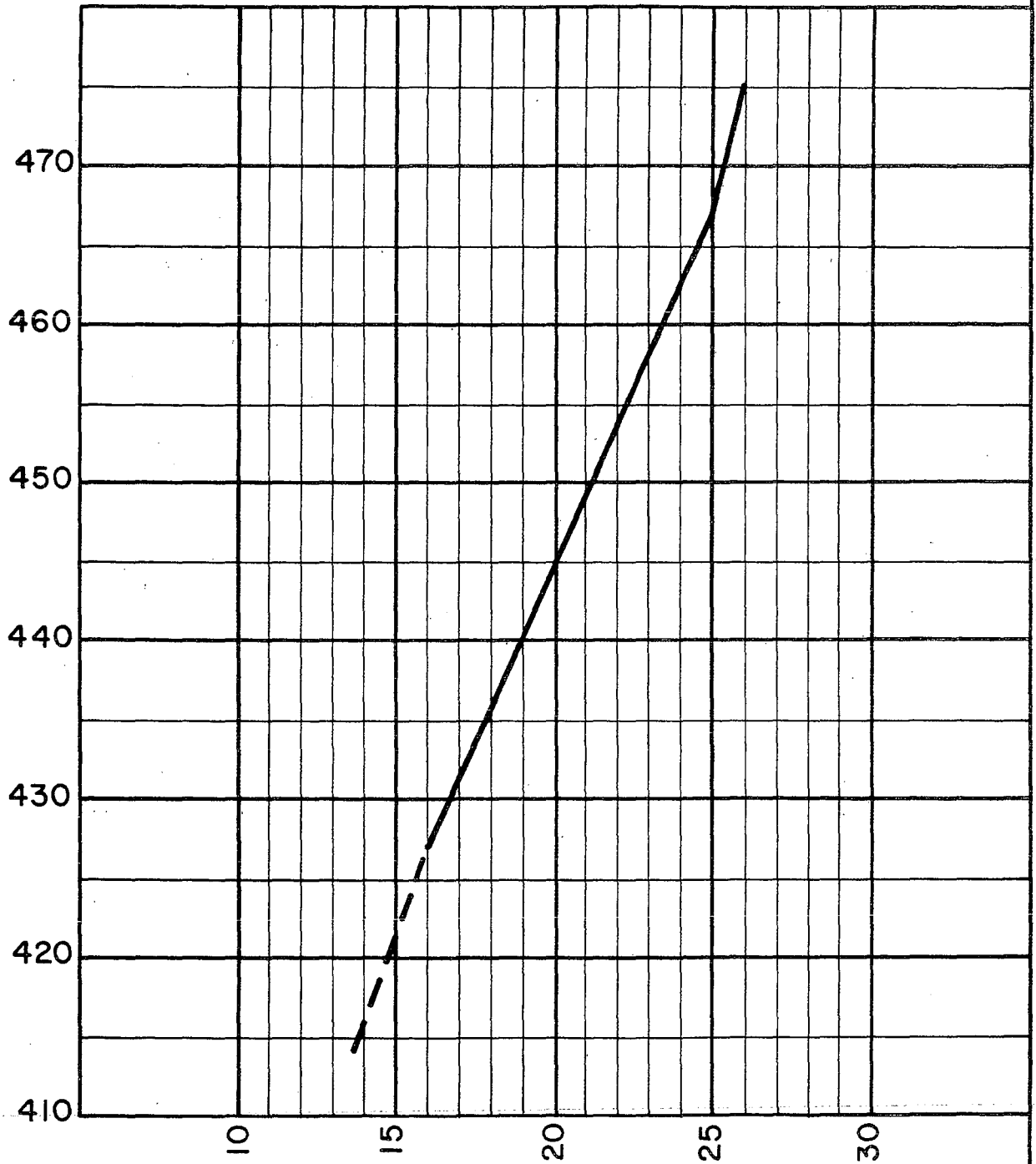
IN THE WILDE-LONG INVENTORIES, IN WHICH UNDERFLOW OUT WAS CARRIED AS A RESIDUAL, EXITING UNDERFLOWS FROM SANTA PAULA BASIN WERE LARGELY NEGATIVE. IN AN ATTEMPT TO IMPROVE THE BALANCE, KAWANO SUGGESTED SIDE UNDERFLOW WITHIN THE SAN PEDRO FORMATION IN BOTH THE SANTA PAULA AND FILLMORE BASINS. WE DO NOT BELIEVE THIS CONCEPT OF SIDE UNDERFLOW CAN BE SUPPORTED GEOLOGICALLY FOR THE FOLLOWING REASONS:

- (1) THE OUTCROPS OF THE SAN PEDRO FORMATION ARE OF LOW PERMEABILITY AND WILL NOT PERMIT ANY APPRECIABLE CONTRIBUTION FROM RAINFALL PENETRATION, OR PERCOLATION OF THE INFREQUENT RUNOFF;
- (2) THE SAN PEDRO LAYERS EXPOSED IN THE OUTCROPS ARE NEAR THE BASE OF THE FORMATION. IF WATER ENTERED THESE LAYERS IT WOULD TRAVEL DOWNWARD TO DEPTHS MUCH GREATER THAN ANY WATER WELL.

WE HAVE NOT INCLUDED AN ITEM OF SIDE UNDERFLOW IN OUR INVENTORIES.

# UNDERFLOW AT STATE FISH HATCHERY

4N/19W-33EI STATIC WATER SURFACE ELEVATION (FEET)



UNDERFLOW — CFS

## CULTURE SURVEYS

SURVEYS OF IRRIGATED LANDS WITHIN THE DISTRICT WERE MADE AS EARLY AS 1912 BY THE UNITED STATES DEPARTMENT OF AGRICULTURE. OTHER SURVEYS OF IRRIGATED ACREAGE, FOR THE YEARS 1920, 1925, AND 1930, WERE MADE IN 1930 BY THE SANTA CLARA WATER CONSERVATION DISTRICT IN COOPERATION WITH THE VENTURA COUNTY AGRICULTURAL COMMISSIONER. THE FIRST DETAILED CULTURAL SURVEY OF VENTURA COUNTY WAS MADE BY THE CALIFORNIA DIVISION OF WATER RESOURCES IN 1932 DURING THE BULLETIN 46 STUDIES. THE NEXT CULTURAL SURVEY, COVERING THE LANDS OF THE SANTA CLARA WATER CONSERVATION DISTRICT, WAS MADE BY HAROLD CONKLING IN 1947. ANOTHER CULTURAL SURVEY, IN 1949-50 AND COVERING THE ENTIRE COUNTY, WAS A PART OF THE BULLETIN 12 STUDIES OF THE CALIFORNIA DIVISION OF WATER RESOURCES. ADDITIONAL INFORMATION WAS OBTAINED BY KAWANO FOR 1955. THOUGH NOT ORIGINALLY INTENDED AS A PART OF OUR INVENTORY STUDIES, OUR MODIFICATION OF BOUNDARIES IN THE UPSTREAM BASINS NECESSITATED AN UP-TO-DATE CULTURAL PATTERN. ACCORDINGLY, A DETAILED FIELD CHECK OF LAND USE WAS MADE IN LATE 1958 AND EARLY 1959 FOR PIRU, FILLMORE, SANTA PAULA, AND MONTALVO BASINS. THE RESULTS OF THESE SURVEYS ARE GIVEN IN TABLE IV-1.

## CONSUMPTIVE USE

THE PUMPING DEMAND WITHIN A BASIN WAS DETERMINED BY APPLYING UNIT CONSUMPTIVE USE VALUES TO ACREAGES DEVOTED TO THE VARIOUS CROPS OR OTHER USES. WATER APPLIED IN EXCESS OF CONSUMPTIVE USE REQUIREMENTS IN THE FREE GROUND WATER BASINS WAS ASSUMED TO RETURN TO GROUND WATER STORAGE, OR ACTUALLY, ASSUMED NEVER TO HAVE LEFT GROUND WATER STORAGE. CONSUMPTIVE USE BY PHREATOPHYTES IS CONSIDERED PART OF THE PUMPING DEMAND. THE UNIT CONSUMPTIVE USE VALUES ARE LARGELY THOSE USED IN THE BULLETIN 12 STUDIES, AS MODIFIED IN THE WILDE-LONG AND KAWANO STUDIES. THESE VALUES WERE DEVELOPED BY THE BLANEY-CRIDDLE METHOD (REF. 3). THIS METHOD IS DESIGNED TO ALLOW COMPUTATION OF CONSUMPTIVE USE FROM CLIMATOLOGICAL DATA. IF ONLY MONTHLY TEMPERATURE RECORDS ARE AVAILABLE AND LATITUDE IS KNOWN, THE CONSUMPTIVE USE CAN BE COMPUTED FROM THE FORMULA:

$$U = K F$$

WHERE  $\underline{U}$  = CONSUMPTIVE USE OF WATER IN INCHES FOR ANY PERIOD,  $\underline{K}$  = EMPIRICAL CONSUMPTIVE/COEFFICIENT, AND  $\underline{F}$  = SUM OF MONTHLY CONSUMPTIVE USE FACTORS FOR

TABLE IV-1 1958-59 ACREAGES USED IN CALCULATING IRRIGATION AND  
PHREATOPHYTE REQUIREMENTS

| CROP OR USE       | PIRU<br>BASIN | FILLMORE<br>BASIN | SANTA PAULA<br>BASIN | MONTALVO<br>BASIN |
|-------------------|---------------|-------------------|----------------------|-------------------|
| URBAN             | 147           | 1,632             | 1,732                | 1,050             |
| ALFALFA           | 20            | 143               | 190                  | 80                |
| CITRUS & AVOCADOS | 3,990         | 9,487             | 7,815                | 1,500             |
| WALNUTS           | 72            | 178               | 742                  | 100               |
| DECIDUOUS         | 20            | 20                | 25                   | 10                |
| TRUCK             | 60            | 354               | 345                  | 360               |
| PASTURE           | 30            | 207               | 183                  | --                |
| BEANS             | --            | 359               | 739                  | 1,110             |
| PHREATOPHYTES     | 550           | 1,347             | 485                  | 310               |
| TOTALS            | 4,889         | 13,727            | 12,256               | 4,520             |

THE PERIOD (SUM OF THE PRODUCTS OF MEAN MONTHLY TEMPERATURE AND MONTHLY PER CENT OF ANNUAL DAYTIME HOURS). THE K COEFFICIENTS HAVE BEEN DETERMINED FROM SOIL MOISTURE STUDIES FOR MANY CROPS AND IN MANY AREAS. ANNUAL VALUES USED ARE GIVEN IN TABLE IV-2; MONTHLY VALUES FOR THE FREE GROUND WATER BASINS MAY BE FOUND IN TABLES 44-47 OF THE WILDE-LONG REPORT.

IN THE PRESSURE AREAS -- MOUND, OXNARD PLAIN, AND PLEASANT VALLEY -- WATER PUMPED INCLUDES THE REQUIREMENTS FOR CONSUMPTIVE USE INCREASED TO ADJUST FOR IRRIGATION EFFICIENCY. THE WATER DELIVERED MAY BE DETERMINED BY FLOW-METER RECORDS, OR STUDIES OF POWER CONSUMED IN PUMPING WATER FROM WELLS.

#### RAINFALL PENETRATION

SOME OF THE RAIN WHICH FALLS ON THE BASINS UNDERLAIN BY FREE GROUND WATER IS ABLE TO PASS THROUGH THE SOIL AND REACH THE WATER TABLE. THIS CAN HAPPEN ONLY WHEN THE SOIL HAS BEEN RESTORED TO FIELD CAPACITY AND RAIN WATER IS SUPPLIED IN EXCESS OF THE CONSUMPTIVE USE REQUIREMENTS OF THE CROP OR PLANT TYPE GROWING IN THE SOIL. THE AMOUNT OF WATER REQUIRED TO RESTORE THE SOIL TO FIELD CAPACITY IS CALLED THE "INITIAL FALL SOIL MOISTURE DEFICIENCY". THIS IS ASSUMED TO EXIST EACH YEAR ON OCTOBER 1, AT THE START OF THE RUNOFF YEAR. THE RAIN FALLING EACH MONTH IS ASSUMED TO GO FIRST TO CONSUMPTIVE USE, THEN TO SOIL MOISTURE. IF IN ANY MONTH, MORE RAIN IS AVAILABLE THAN IS NEEDED FOR CONSUMPTIVE USE AND TO RESTORE THE SOIL TO FIELD CAPACITY, THE EXCESS IS CONSIDERED TO BE RAINFALL PENETRATION. UNIT MONTHLY RAINFALL PENETRATION VALUES MULTIPLIED BY APPROPRIATE ACREAGES PRODUCES THE TOTAL MONTHLY VOLUME OF SUCH RECHARGE. DETAILED STUDIES WERE MADE BY WILDE-LONG, AND SLIGHTLY MODIFIED BY KAWANO. USING KAWANO'S MODIFICATION, WE HAVE RECALCULATED UNIT RAINFALL PENETRATION VOLUMES FOR THE ENTIRE 1936-57 BASE PERIOD. SINCE OUR STUDIES INVOLVED CONSIDERABLE REFINEMENT OF THE RAINFALL PENETRATION AREAS, THE REVISED UNIT VALUES WERE APPLIED TO DIFFERENT ACREAGES ADJUSTED TO THE 1958-59 FIELD CHECK (TABLE IV-3).

#### GROUND WATER STORAGE DEPLETION

THE WATER TABLE IN A GROUND WATER BASIN IS THE NATURAL INTEGRATOR OF ALL ITEMS OF GROUND WATER INFLOW AND OUTFLOW. IF A GROUND WATER BASIN CAN BE STUDIED OVER A REPRESENTATIVE RAINFALL PERIOD IN WHICH

TABLE IV-2 UNIT ANNUAL CONSUMPTIVE USE VALUES USED (INCHES)

| CROP OR SURFACE   | PIRU<br>BASIN | FILLMORE<br>BASIN | SANTA PAULA<br>BASIN | MONTALVO<br>BASIN |
|-------------------|---------------|-------------------|----------------------|-------------------|
| URBAN             | 8.42          | 8.42              | 8.42                 | 8.42              |
| ALFALFA           | 44.46         | 42.37             | 42.37                | 43.18             |
| CITRUS & AVOCADOS | 30.79         | 30.68             | 30.68                | 30.08             |
| WALNUTS           | 34.39         | 33.80             | 33.80                | 33.30             |
| DECIDUOUS         | 31.42         | 31.42             | 31.42                | 30.41             |
| TRUCK             | 27.87         | 27.26             | 27.26                | 26.83             |
| BEANS             | ----          | 18.00             | 18.00                | 18.00             |
| PASTURE           | 41.51         | 40.93             | 40.93                | 40.23             |
| PHREATOPHYTES     | 62.40         | 60.88             | 60.88                | 60.75             |

TABLE IV-3 1958-59 ACREAGES USED IN CALCULATING RAINFALL PENETRATION

| CROP OR SURFACE              | PIRU<br>BASIN | FILLMORE<br>BASIN | SANTA PAULA<br>BASIN | MONTALVO<br>BASIN |
|------------------------------|---------------|-------------------|----------------------|-------------------|
| URBAN                        | 147           | 1,632             | 1,732                | 1,050             |
| ALFALFA                      | 20            | 143               | 190                  | 80                |
| CITRUS                       | 3,990         | 9,487             | 6,760                | 1,500             |
| WALNUTS                      | 72            | 178               | 740                  | 100               |
| DECIDUOUS                    | 20            | 20                | 25                   | 10                |
| TRUCK                        | 60            | 354               | 345                  | 360               |
| IRRIGATED PASTURE            | 30            | 207               | 183                  | --                |
| BEANS                        | --            | 359               | 739                  | 1,110             |
| PHREATOPHYTES                | 550           | 1,347             | 485                  | 310               |
| RIVER WASH                   | 1,390         | 2,060             | 920                  | 850               |
| WATER SURFACE                | --            | 90                | --                   | --                |
| NATIVE AND NON-<br>IRRIGATED | 2,007         | 3,953             | 2,686                | 1,030             |
| TOTAL                        | 8,286         | 19,830            | 14,805               | 6,400             |

THE BASIN IS FULL AT THE BEGINNING AND END, NO CONSIDERATION NEED BE GIVEN TO NET CHANGE OF STORAGE. UNFORTUNATELY, NO SUCH PERIOD IS AS YET AVAILABLE FOR WHICH RECORDS ARE SUFFICIENTLY RELIABLE. IT IS NECESSARY, THEN, TO DETERMINE THE VOLUME OF WATER WHICH IS REMOVED WHEN THE WATER TABLE DROPS FROM ONE POSITION TO A LOWER POSITION, OR HOW MUCH WATER MUST BE ADDED TO CAUSE A CHANGE FROM A LOWER LEVEL TO A HIGHER LEVEL. ONLY A PORTION OF THE INDICATED VOLUME CHANGE IS OCCUPIED BY WATER, AND NOT ALL OF THIS CAN BE REMOVED BY PUMPING. THE PART OF THE WATER HELD TENACIOUSLY BY FORCES OF ADHESION AND COHESION IS CALLED SPECIFIC RETENTION; THE PART WHICH DRAINS FREELY IS CALLED SPECIFIC YIELD. BOTH SPECIFIC YIELD AND SPECIFIC RETENTION ARE EXPRESSED AS PERCENTAGES OF THE ENTIRE SATURATED VOLUME AND THEIR SUM IS THE POROSITY, ALSO EXPRESSED AS A PERCENTAGE. DETERMINATION OF CHANGES IN GROUND WATER STORAGE INVOLVES PRIMARILY THE APPLICATION OF APPROPRIATE SPECIFIC YIELD VALUES TO THE VOLUME DEWATERED OR FILLED. FOR THIS PURPOSE, UNIT SPECIFIC YIELD VALUES WERE USED FOR MATERIALS COMMONLY ENCOUNTERED IN DRILLING (TABLE 11-1). WITHIN EACH FREE GROUND WATER BASIN, GEOLOGICALLY HOMOGENEOUS "CELLS" WERE BLOCKED OUT, EACH INCLUDING A GROUP OF WELLS. WEIGHTED AVERAGE SPECIFIC YIELD VALUES WITHIN EACH OF THESE CELLS WERE ASSIGNED TO EACH 25-FOOT VERTICAL INTERVAL BELOW THE MAXIMUM WATER SURFACE, ASSUMED TO HAVE OCCURRED IN THE SPRING OF 1944. STORAGE DEPLETION CURVES (PLATE 8) WERE THEN CONSTRUCTED BY RELATING HISTORIC WATER-LEVEL MEASUREMENTS OF A SINGLE WELL WITHIN EACH BASIN TO THE UNWATERED STORAGE CAPACITY DERIVED FROM THE SPECIFIC YIELD STUDY.

EVERY HYDROLOGIC INVENTORY PRODUCES SOME DEGREE OF IMBALANCE, OR UNACCOUNTED-FOR WATER. THE BALANCING PROCEDURES USED HEREIN INVOLVED COMPARING A CHANGE-OF-STORAGE VALUE DETERMINED FROM THE INVENTORY WITH THE CHANGE-OF-STORAGE VALUE DETERMINED FROM PLATE 8. IN GENERAL, ALL OF THE INVENTORY ITEMS WERE INDEPENDENTLY DETERMINED, RATHER THAN ONE BEING LEFT AS A RESIDUAL. THE TWO AVAILABLE STORAGE CURVES WERE PLOTTED FOR A SERIES OF CHECK POINTS TO DETERMINE NOT ONLY THE MAGNITUDE, BUT THE TRENDS OF THE DISCREPANCIES. EXCELLENT CHECKS CAN USUALLY BE OBTAINED AS WATER LEVELS DROP OVER A PERIOD OF DRY YEARS. POOR CORRELATIONS ARE OBTAINED IN A HEAVY RAINFALL YEAR FOLLOWING A SERIES OF DRY YEARS (1952; 1958). THIS IS EXPLAINED BY THE PRESENCE OF MUCH WATER "IN TRANSIT" WHICH MAY REQUIRE MORE THAN A YEAR TO BE INCORPORATED INTO THE MAIN BODY OF GROUND WATER, AND BECOME STABLE.

## ANNUAL SUMMARIES

DETAILED MONTHLY GROUND WATER INVENTORIES WERE MADE FOR THE PIRU, FILLMORE, SANTA PAULA, AND MONTALVO BASINS. ANNUAL SUMMARIES OF THESE INVENTORIES ARE SHOWN ON PLATES 28-31. CHANGE OF STORAGE IS COMPUTED FOR THE RUNOFF YEAR (OCTOBER 1-SEPTEMBER 30), AND AVAILABLE STORAGE FIGURES ARE THOSE FOR THE END OF THE RUNOFF YEAR.

## SAFE YIELD AND OVERDRAFT

SAFE YIELD OF A GROUND WATER BASIN MAY BE DEFINED AS THE MAXIMUM PERENNIAL RATE OF EXTRACTION WHICH WILL NOT PRODUCE CERTAIN UNDESIRABLE CONDITIONS. THESE CONDITIONS MIGHT BE:

- (1) LOWERING THE WATER LEVELS SO FAR AS TO MAKE PUMPING UNECONOMICAL;
- (2) CAUSING A SERIOUS DETERIORATION OF WATER QUALITY;
- (3) INTERFERING UNREASONABLY WITH EXISTING WATER RIGHTS.

## UPSTREAM BASINS

TO DATE THE PERENNIAL EXTRACTIONS OF WATER IN THE PIRU, FILLMORE, AND SANTA PAULA BASINS HAVE NOT EXCEEDED SAFE YIELD. THESE BASINS ARE VIEWED IN THE LIGHT OF HISTORIC YIELD DURING THE BASE PERIOD 1936-57. THE HISTORIC YIELD OF THESE UPSTREAM BASINS IS CONSIDERED EQUAL TO:

- (1) THE AMOUNT OF WATER SUPPLIED TO SATISFY CONSUMPTIVE USE REQUIREMENTS FOR URBAN AND IRRIGATION PURPOSES, AND THE DRAFT ON GROUND WATER BY PHREATOPHYTES;
- (2) PLUS THE TOTAL PUMPAGE EXPORTED OR SURFACE DIVERSIONS DELIVERED TO THE NEXT BASIN DOWNSTREAM;
- (3) MINUS THE TOTAL IMPORTED WATER.

THE HISTORIC YIELDS OVER THE 1936-57 BASE PERIOD WERE AS FOLLOWS:

|                   |                           |
|-------------------|---------------------------|
| PIRU BASIN        | 12,600 ACRE-Feet PER YEAR |
| FILLMORE BASIN    | 23,100 AF/YR              |
| SANTA PAULA BASIN | <u>18,500</u> AF/YR       |
| TOTAL             | 54,200 AF/YR              |

THE SOLE LIMITATION ON HISTORIC YIELDS HAS BEEN THE AMOUNT OF WATER REQUIRED FOR CONSUMPTIVE USES IN THESE THREE BASINS AND IN

| PIRU BASIN<br>ANNUAL SUMMARY OF GROUND WATER INVENTORY (Acre-Feet) |                 |         |                 |                          |                 |                         |                       |        |                                   |                                 |                                                 |                  |                 |        |                                     |                  |                  |                         |
|--------------------------------------------------------------------|-----------------|---------|-----------------|--------------------------|-----------------|-------------------------|-----------------------|--------|-----------------------------------|---------------------------------|-------------------------------------------------|------------------|-----------------|--------|-------------------------------------|------------------|------------------|-------------------------|
|                                                                    | (1)             | (2)     | (3)             | (4)                      | (5)             | (6)                     | (7)                   | (8)    | (9)                               | (10)                            | (11)                                            | (12)             | (13)            | (14)   | (15)                                | (16)             | (17)             | (18)                    |
| YEAR                                                               | FLOOD<br>INFLOW | IMPORTS | UNDERFLOW<br>IN | TOTAL INFLOW<br>TO BASIN | UNDERFLOW<br>IN | RAINFALL<br>PENETRATION | STREAM<br>PERCOLATION | SPREAD | TOTAL TO<br>GROUND WATER<br>BASIN | NET<br>CONS. USE<br>REQUIREMENT | NET<br>EXTRACTION FROM<br>GROUND WATER<br>BASIN | UNDERFLOW<br>OUT | RISING<br>WATER | EXPORT | TOTAL FROM<br>GROUND WATER<br>BASIN | FLOOD<br>OUTFLOW | TOTAL<br>OUTFLOW | CHANGE<br>OF<br>STORAGE |
| 1936-37                                                            | 95,620          | 0       | 240             | 95,860                   | 240             | 10,290                  | 47,580                | 8,190  | 66,300                            | 6,820                           | 6,100                                           | 17,900           | 13,450          | 2,340  | 39,790                              | 48,040           | 87,830           | +26,510                 |
| 38                                                                 | 197,760         | 0       | 240             | 198,000                  | 240             | 7,470                   | 58,440                | 6,660  | 72,810                            | 8,150                           | 7,680                                           | 18,410           | 24,620          | 2,380  | 53,090                              | 139,320          | 192,410          | +19,720                 |
| 39                                                                 | 68,910          | 0       | 240             | 69,150                   | 240             | 1,870                   | 44,560                | 6,770  | 53,440                            | 8,400                           | 7,610                                           | 18,620           | 25,400          | 2,690  | 54,320                              | 24,350           | 78,670           | - 880                   |
| 40                                                                 | 27,620          | 900     | 240             | 28,760                   | 240             | 2,240                   | 18,580                | 5,110  | 26,170                            | 8,900                           | 7,160                                           | 18,700           | 13,630          | 2,650  | 42,140                              | 9,040            | 51,180           | -15,970                 |
| 41                                                                 | 317,030         | 1,400   | 240             | 318,670                  | 240             | 15,110                  | 68,270                | 5,680  | 89,300                            | 6,680                           | 4,520                                           | 18,770           | 29,510          | 2,200  | 55,000                              | 248,760          | 303,760          | +34,300                 |
| 42                                                                 | 82,600          | 1,840   | 240             | 84,680                   | 240             | 750                     | 46,690                | 0      | 47,680                            | 8,730                           | 6,060                                           | 18,800           | 37,800          | 2,790  | 65,450                              | 35,910           | 101,360          | -17,770                 |
| 43                                                                 | 192,830         | 1,800   | 240             | 194,870                  | 240             | 11,260                  | 55,810                | 3,220  | 70,530                            | 8,540                           | 5,860                                           | 18,700           | 31,300          | 2,970  | 58,830                              | 137,020          | 195,850          | +11,700                 |
| 44                                                                 | 217,440         | 1,680   | 240             | 219,360                  | 240             | 8,340                   | 61,850                | 0      | 70,430                            | 8,340                           | 5,880                                           | 18,570           | 37,470          | 2,850  | 64,770                              | 155,590          | 220,360          | + 5,660                 |
| 45                                                                 | 57,210          | 1,850   | 240             | 59,300                   | 240             | 2,250                   | 36,400                | 8,920  | 47,810                            | 7,750                           | 5,110                                           | 18,720           | 31,860          | 2,820  | 58,510                              | 20,810           | 79,320           | -10,700                 |
| 46                                                                 | 50,530          | 2,050   | 240             | 52,820                   | 240             | 1,810                   | 27,460                | 7,070  | 36,580                            | 8,480                           | 5,480                                           | 18,700           | 22,780          | 3,090  | 50,050                              | 23,070           | 73,120           | -13,470                 |
| 47                                                                 | 51,860          | 2,260   | 240             | 54,360                   | 240             | 1,970                   | 26,780                | 10,040 | 39,030                            | 9,570                           | 6,640                                           | 18,730           | 16,630          | 3,180  | 45,180                              | 25,080           | 70,260           | - 6,150                 |
| 48                                                                 | 17,490          | 2,840   | 240             | 20,570                   | 240             | 300                     | 15,240                | 1,320  | 17,100                            | 10,250                          | 6,700                                           | 18,320           | 6,160           | 2,980  | 34,160                              | 2,250            | 36,410           | -17,060                 |
| 49                                                                 | 13,250          | 3,180   | 240             | 16,670                   | 240             | 240                     | 11,640                | 1,840  | 13,960                            | 10,360                          | 6,700                                           | 16,150           | 0               | 6,180  | 29,030                              | 1,610            | 30,640           | -15,070                 |
| 50                                                                 | 11,820          | 3,840   | 240             | 15,900                   | 240             | 870                     | 9,850                 | 3,780  | 14,740                            | 9,720                           | 5,510                                           | 15,070           | 0               | 4,450  | 25,030                              | 1,970            | 27,000           | -10,290                 |
| 51                                                                 | 6,700           | 3,680   | 240             | 10,620                   | 240             | 190                     | 6,400                 | 0      | 6,830                             | 10,730                          | 6,810                                           | 13,150           | 0               | 4,620  | 24,580                              | 300              | 24,880           | -17,750                 |
| 52                                                                 | 97,710          | 3,300   | 240             | 101,250                  | 240             | 11,540                  | 47,670                | 11,800 | 71,250                            | 7,580                           | 3,740                                           | 15,690           | 2,910           | 4,380  | 26,720                              | 50,040           | 76,760           | +44,530                 |
| 53                                                                 | 16,520          | 4,020   | 240             | 20,780                   | 240             | 1,110                   | 12,660                | 6,880  | 20,890                            | 10,140                          | 5,620                                           | 18,080           | 3,990           | 6,370  | 34,060                              | 3,860            | 37,920           | -13,170                 |
| 54                                                                 | 16,900          | 4,420   | 240             | 21,560                   | 240             | 2,550                   | 12,050                | 7,920  | 22,760                            | 9,600                           | 4,860                                           | 17,340           | 0               | 6,300  | 28,500                              | 4,850            | 33,350           | - 5,740                 |
| 55                                                                 | 12,190          | 4,570   | 240             | 17,000                   | 240             | 1,420                   | 10,110                | 5,840  | 17,610                            | 7,860                           | 2,960                                           | 15,750           | 0               | 6,450  | 25,160                              | 2,080            | 27,240           | - 7,550                 |
| 56                                                                 | 11,260          | 4,720   | 240             | 16,220                   | 240             | 2,160                   | 8,890                 | 5,140  | 16,430                            | 8,880                           | 3,410                                           | 14,550           | 0               | 3,780  | 21,740                              | 2,370            | 24,110           | - 5,310                 |
| 1956-57                                                            | 15,540          | 5,840   | 240             | 21,620                   | 240             | 1,710                   | 11,620                | 1,690  | 15,260                            | 8,310                           | 1,530                                           | 12,570           | 0               | 5,670  | 19,770                              | 3,920            | 23,690           | - 4,510                 |
| AVERAGE                                                            | 75,180          | 2,580   | 240             | 78,000                   | 240             | 4,070                   | 30,410                | 5,140  | 39,860                            | 8,750                           | 5,520                                           | 17,200           | 14,170          | 3,860  | 40,750                              | 44,770           | 85,520           |                         |

FILLMORE BASIN  
ANNUAL SUMMARY OF GROUND WATER INVENTORY (Acres-Feet)

PLATE 29

|         | (1)             | (2)     | (3)             | (4)             | (5)                      | (6)             | (7)                     | (8)                   | (9)                               | (10)                            | (11)                                            | (12)             | (13)            | (14)   | (15)                                | (16)             | (17)             | (18)                    | (19)                 |
|---------|-----------------|---------|-----------------|-----------------|--------------------------|-----------------|-------------------------|-----------------------|-----------------------------------|---------------------------------|-------------------------------------------------|------------------|-----------------|--------|-------------------------------------|------------------|------------------|-------------------------|----------------------|
| YEAR    | FLOOD<br>INFLOW | IMPORTS | RISING<br>WATER | UNDERFLOW<br>IN | TOTAL INFLOW<br>TO BASIN | UNDERFLOW<br>IN | RAINFALL<br>PENETRATION | STREAM<br>PERCOLATION | TOTAL TO<br>GROUND WATER<br>BASIN | NET<br>CONS. USE<br>REQUIREMENT | NET<br>EXTRACTION FROM<br>GROUND WATER<br>BASIN | UNDERFLOW<br>OUT | RISING<br>WATER | EXPORT | TOTAL FROM<br>GROUND WATER<br>BASIN | FLOOD<br>OUTFLOW | TOTAL<br>OUTFLOW | CHANGE<br>IN<br>STORAGE | AVAILABLE<br>STORAGE |
| 1936-37 | 227,330         | 7,680   | 13,450          | 17,900          | 266,360                  | 17,900          | 21,860                  | 49,130                | 88,890                            | 20,620                          | 14,530                                          | 5,400            | 38,400          | 350    | 58,680                              | 191,650          | 250,330          | +30,210                 | 48,350               |
| 38      | 397,490         | 9,010   | 24,620          | 18,410          | 449,530                  | 18,410          | 24,550                  | 27,500                | 70,460                            | 23,470                          | 15,390                                          | 5,400            | 39,700          | 150    | 60,640                              | 394,610          | 455,250          | + 9,820                 | 18,140               |
| 39      | 66,770          | 8,980   | 25,400          | 18,620          | 119,770                  | 18,620          | 4,850                   | 39,950                | 63,420                            | 24,530                          | 16,350                                          | 5,400            | 42,500          | 220    | 64,470                              | 52,220           | 116,690          | - 1,050                 | 8,320                |
| 40      | 38,370          | 7,240   | 13,630          | 18,700          | 77,940                   | 18,700          | 4,770                   | 26,280                | 49,750                            | 26,440                          | 19,330                                          | 5,400            | 35,100          | 350    | 60,180                              | 25,720           | 85,900           | -10,430                 | 19,800               |
| 41      | 647,520         | 6,080   | 29,510          | 18,770          | 701,880                  | 18,770          | 37,880                  | 23,660                | 80,310                            | 20,890                          | 15,210                                          | 5,400            | 45,200          | 80     | 65,890                              | 653,370          | 719,260          | +14,420                 | 5,380                |
| 42      | 75,500          | 7,800   | 37,800          | 18,800          | 139,900                  | 18,800          | 3,730                   | 39,180                | 61,710                            | 25,070                          | 17,580                                          | 5,400            | 45,400          | 0      | 68,380                              | 74,120           | 142,500          | - 6,670                 | 12,050               |
| 43      | 323,530         | 8,010   | 31,300          | 18,700          | 381,540                  | 18,700          | 25,990                  | 23,110                | 67,800                            | 24,590                          | 16,850                                          | 5,400            | 44,400          | 0      | 66,650                              | 331,720          | 398,370          | + 1,150                 | 10,900               |
| 44      | 302,080         | 9,310   | 37,470          | 18,570          | 367,430                  | 18,570          | 17,070                  | 36,180                | 71,820                            | 24,460                          | 16,290                                          | 5,400            | 48,200          | 0      | 69,890                              | 303,370          | 373,260          | + 1,930                 | 8,970                |
| 45      | 73,010          | 7,790   | 31,860          | 18,720          | 131,380                  | 18,720          | 5,700                   | 38,210                | 62,630                            | 25,730                          | 18,550                                          | 5,400            | 42,900          | 0      | 66,850                              | 66,660           | 133,510          | - 4,220                 | 13,190               |
| 46      | 86,140          | 8,070   | 22,780          | 18,700          | 135,690                  | 18,700          | 3,530                   | 41,170                | 63,400                            | 26,490                          | 19,750                                          | 5,400            | 43,500          | 0      | 68,650                              | 67,750           | 136,400          | - 5,250                 | 18,440               |
| 47      | 69,310          | 7,790   | 16,630          | 18,730          | 112,460                  | 18,730          | 5,360                   | 34,700                | 58,790                            | 28,610                          | 21,450                                          | 5,400            | 36,200          | 0      | 63,050                              | 51,240           | 114,290          | - 4,260                 | 22,700               |
| 48      | 7,110           | 6,570   | 6,160           | 18,320          | 38,160                   | 18,320          | 780                     | 11,510                | 30,610                            | 29,140                          | 22,890                                          | 5,400            | 22,000          | 220    | 50,510                              | 1,760            | 52,270           | -19,900                 | 42,600               |
| 49      | 8,510           | 9,030   | 0               | 16,150          | 33,690                   | 16,150          | 610                     | 6,130                 | 22,890                            | 28,060                          | 20,540                                          | 5,400            | 16,150          | 970    | 43,060                              | 2,380            | 45,440           | -20,170                 | 62,770               |
| 50      | 17,680          | 7,420   | 0               | 15,070          | 40,170                   | 15,070          | 3,300                   | 10,200                | 28,570                            | 24,950                          | 18,690                                          | 5,400            | 12,800          | 1,260  | 38,150                              | 7,480            | 45,630           | - 9,580                 | 72,350               |
| 51      | 1,830           | 6,850   | 0               | 13,150          | 21,830                   | 13,150          | 470                     | 1,790                 | 15,410                            | 28,350                          | 22,120                                          | 5,400            | 6,030           | 1,280  | 34,830                              | 40               | 34,870           | -19,420                 | 91,770               |
| 52      | 207,190         | 8,890   | 2,910           | 15,690          | 234,680                  | 15,690          | 30,550                  | 39,120                | 85,360                            | 20,590                          | 12,790                                          | 5,400            | 23,630          | 570    | 42,390                              | 170,980          | 213,370          | +42,970                 | 48,800               |
| 53      | 22,800          | 11,770  | 3,990           | 18,080          | 56,640                   | 18,080          | 2,100                   | 16,630                | 36,810                            | 26,580                          | 16,640                                          | 5,400            | 25,950          | 770    | 48,760                              | 10,160           | 58,920           | -11,950                 | 60,750               |
| 54      | 36,370          | 9,500   | 0               | 17,340          | 63,210                   | 17,340          | 6,260                   | 15,300                | 38,900                            | 24,680                          | 15,290                                          | 5,400            | 15,200          | 1,420  | 37,310                              | 21,070           | 58,380           | + 1,590                 | 59,160               |
| 55      | 17,720          | 9,170   | 0               | 15,750          | 42,640                   | 15,750          | 3,140                   | 11,150                | 30,040                            | 23,390                          | 16,190                                          | 5,400            | 8,200           | 4,110  | 33,900                              | 6,570            | 40,470           | - 3,860                 | 63,020               |
| 56      | 32,120          | 6,490   | 0               | 14,550          | 53,160                   | 14,550          | 5,610                   | 14,120                | 34,280                            | 24,720                          | 19,060                                          | 5,400            | 9,600           | 3,750  | 37,810                              | 18,000           | 55,810           | - 3,530                 | 66,550               |
| 1956-57 | 27,160          | 8,120   | 0               | 12,570          | 47,850                   | 12,570          | 2,070                   | 13,330                | 27,970                            | 26,600                          | 20,150                                          | 5,400            | 8,850           | 5,160  | 39,560                              | 13,830           | 53,390           | -11,590                 | 78,140               |
| AVERAGE | 127,880         | 8,170   | 14,170          | 17,200          | 167,420                  | 17,200          | 10,010                  | 24,680                | 51,890                            | 25,140                          | 17,890                                          | 5,400            | 29,040          | 980    | 53,310                              | 117,370          | 170,680          |                         |                      |

SANTA PAULA BASIN  
ANNUAL SUMMARY OF GROUND WATER INVENTORY (Acre-Feet)

PLATE 30

|         | (1)             | (2)     | (3)                                | (4)             | (5)                      | (6)             | (7)                     | (8)                   | (9)                               | (10)                            | (11)                   | (12)   | (13)                                            | (14)             | (15)            | (16)                                | (17)             | (18)             | (19)                    | (20)                 |
|---------|-----------------|---------|------------------------------------|-----------------|--------------------------|-----------------|-------------------------|-----------------------|-----------------------------------|---------------------------------|------------------------|--------|-------------------------------------------------|------------------|-----------------|-------------------------------------|------------------|------------------|-------------------------|----------------------|
| YEAR    | FLOOD<br>INFLOW | IMPORTS | RISING WATER<br>LESS<br>DIVERSIONS | UNDERFLOW<br>IN | TOTAL INFLOW<br>TO BASIN | UNDERFLOW<br>IN | RAINFALL<br>PENETRATION | STREAM<br>PERCOLATION | TOTAL TO<br>GROUND WATER<br>BASIN | NET<br>CONS. USE<br>REQUIREMENT | IN-BASIN<br>DIVERSIONS | EXPORT | NET<br>EXTRACTION FROM<br>GROUND WATER<br>BASIN | UNDERFLOW<br>OUT | RISING<br>WATER | TOTAL FROM<br>GROUND WATER<br>BASIN | FLOOD<br>OUTFLOW | TOTAL<br>OUTFLOW | CHANGE<br>IN<br>STORAGE | AVAILABLE<br>STORAGE |
| 1936-37 | 232,480         | 5,020   | 38,080                             | 5,400           | 280,980                  | 5,400           | 10,920                  | 13,610                | 29,930                            | 16,150                          | 150                    | 820    | 12,260                                          | 1,800            | 12,850          | 26,910                              | 256,800          | 283,710          | + 3,020                 | 11,250               |
| 38      | 458,750         | 5,710   | 38,910                             | 5,400           | 508,770                  | 5,400           | 15,060                  | 11,900                | 32,360                            | 18,340                          | 200                    | 570    | 13,410                                          | 1,800            | 17,200          | 32,410                              | 485,560          | 517,970          | - 50                    | 8,230                |
| 39      | 60,240          | 4,920   | 41,980                             | 5,400           | 112,540                  | 5,400           | 1,940                   | 24,440                | 31,780                            | 19,070                          | 220                    | 460    | 14,880                                          | 1,800            | 16,580          | 33,260                              | 77,560           | 110,820          | - 1,480                 | 9,760                |
| 40      | 30,320          | 4,220   | 34,620                             | 5,400           | 74,560                   | 5,400           | 1,580                   | 19,880                | 26,860                            | 20,590                          | 280                    | 490    | 17,030                                          | 1,800            | 15,480          | 34,310                              | 44,780           | 79,090           | - 7,450                 | 17,210               |
| 41      | 732,110         | 5,980   | 43,530                             | 5,400           | 787,020                  | 5,400           | 25,590                  | 9,970                 | 40,960                            | 15,490                          | 190                    | 350    | 9,810                                           | 1,800            | 16,560          | 28,170                              | 765,480          | 793,650          | +12,790                 | 4,420                |
| 42      | 80,040          | 6,340   | 43,960                             | 5,400           | 135,740                  | 5,400           | 1,170                   | 20,970                | 27,540                            | 19,410                          | 280                    | 310    | 14,020                                          | 1,800            | 16,960          | 32,780                              | 102,750          | 135,530          | - 5,240                 | 9,660                |
| 43      | 387,040         | 6,110   | 42,960                             | 5,400           | 441,510                  | 5,400           | 15,510                  | 12,090                | 33,000                            | 18,400                          | 280                    | 430    | 12,790                                          | 1,800            | 17,200          | 31,790                              | 417,630          | 449,420          | + 1,210                 | 8,450                |
| 44      | 331,020         | 5,430   | 47,710                             | 5,400           | 389,560                  | 5,400           | 8,260                   | 20,620                | 34,280                            | 18,310                          | 290                    | 410    | 13,670                                          | 1,800            | 17,340          | 32,810                              | 357,820          | 390,630          | + 1,470                 | 6,980                |
| 45      | 77,900          | 5,240   | 42,490                             | 5,400           | 131,030                  | 5,400           | 1,880                   | 23,760                | 31,040                            | 20,160                          | 390                    | 460    | 15,270                                          | 1,800            | 15,360          | 32,430                              | 96,240           | 128,670          | - 1,390                 | 8,370                |
| 46      | 79,060          | 7,000   | 41,190                             | 5,400           | 132,650                  | 5,400           | 500                     | 22,530                | 28,430                            | 20,580                          | 340                    | 500    | 14,530                                          | 1,800            | 13,510          | 29,940                              | 97,330           | 127,270          | - 1,510                 | 9,880                |
| 47      | 59,490          | 8,500   | 31,730                             | 5,400           | 105,120                  | 5,400           | 2,250                   | 19,240                | 26,890                            | 21,410                          | 390                    | 710    | 13,700                                          | 1,800            | 11,050          | 26,550                              | 71,590           | 98,140           | + 340                   | 9,540                |
| 48      | 2,440           | 6,600   | 19,190                             | 5,400           | 33,630                   | 5,400           | 80                      | 12,750                | 18,230                            | 28,970                          | 480                    | 880    | 17,200                                          | 1,800            | 4,000           | 23,000                              | 8,400            | 31,400           | - 4,770                 | 14,310               |
| 49      | 3,770           | 6,940   | 13,120                             | 5,400           | 29,230                   | 5,400           | 50                      | 10,750                | 16,200                            | 18,660                          | 490                    | 870    | 14,430                                          | 1,800            | 3,340           | 19,570                              | 5,650            | 25,220           | - 3,370                 | 17,680               |
| 50      | 11,190          | 7,200   | 9,740                              | 5,400           | 33,530                   | 5,400           | 1,150                   | 10,710                | 17,260                            | 17,060                          | 440                    | 560    | 11,280                                          | 1,800            | 2,930           | 16,010                              | 9,780            | 25,790           | + 1,250                 | 16,430               |
| 51      | 390             | 5,640   | 4,310                              | 5,400           | 15,740                   | 5,400           | 40                      | 4,210                 | 9,650                             | 22,030                          | 590                    | 710    | 16,710                                          | 1,800            | 2,040           | 20,550                              | 0                | 20,550           | -10,900                 | 27,330               |
| 52      | 209,490         | 7,030   | 20,890                             | 5,400           | 242,810                  | 5,400           | 18,790                  | 19,970                | 44,160                            | 15,420                          | 370                    | 500    | 8,880                                           | 1,800            | 11,800          | 22,480                              | 210,040          | 232,520          | +21,680                 | 5,650                |
| 53      | 13,840          | 5,250   | 25,520                             | 5,400           | 50,010                   | 5,400           | 1,540                   | 17,060                | 24,000                            | 20,240                          | 540                    | 660    | 15,580                                          | 1,800            | 13,650          | 31,030                              | 21,760           | 52,790           | - 7,030                 | 12,680               |
| 54      | 26,800          | 4,790   | 14,780                             | 5,400           | 51,770                   | 5,400           | 3,930                   | 15,650                | 24,980                            | 19,050                          | 560                    | 570    | 14,440                                          | 1,800            | 12,380          | 28,620                              | 25,370           | 53,990           | - 3,640                 | 16,320               |
| 55      | 9,290           | 7,840   | 7,360                              | 5,400           | 29,890                   | 5,400           | 1,370                   | 10,330                | 17,100                            | 18,740                          | 640                    | 650    | 12,330                                          | 1,800            | 4,710           | 18,840                              | 5,680            | 24,520           | - 1,740                 | 18,060               |
| 56      | 24,190          | 7,020   | 9,200                              | 5,400           | 45,810                   | 5,400           | 3,800                   | 12,490                | 21,690                            | 18,180                          | 610                    | 560    | 11,340                                          | 1,800            | 4,430           | 17,570                              | 20,290           | 37,860           | + 4,220                 | 13,840               |
| 1956-57 | 17,920          | 8,570   | 8,370                              | 5,400           | 40,260                   | 5,400           | 2,830                   | 10,970                | 19,200                            | 19,840                          | 710                    | 740    | 11,600                                          | 1,800            | 8,780           | 22,180                              | 14,610           | 36,790           | - 2,980                 | 16,820               |
| AVERAGE | 135,610         | 6,250   | 27,600                             | 5,400           | 174,860                  | 5,400           | 5,630                   | 15,420                | 26,450                            | 19,340                          | 400                    | 580    | 13,580                                          | 1,800            | 11,340          | 26,720                              | 147,390          | 174,110          |                         |                      |

MONTALVO BASIN  
ANNUAL SUMMARY OF GROUND WATER INVENTORY (Acre-Feet)

PLATE 31

|         | (1)             | (2)             | (3)             | (4)                      | (5)             | (6)                     | (7)                   | (8)                  | (9)                               | (10)                            | (11)                    | (12)<br>NET                              | (13)             | (14)   | (15)                                | (16)             | (17)             | (18)                    | (19)                 |
|---------|-----------------|-----------------|-----------------|--------------------------|-----------------|-------------------------|-----------------------|----------------------|-----------------------------------|---------------------------------|-------------------------|------------------------------------------|------------------|--------|-------------------------------------|------------------|------------------|-------------------------|----------------------|
| YEAR    | FLOOD<br>INFLOW | RISING<br>WATER | UNDERFLOW<br>IN | TOTAL INFLOW<br>TO BASIN | UNDERFLOW<br>IN | RAINFALL<br>PENETRATION | STREAM<br>PERCOLATION | SPREADING<br>GROUNDS | TOTAL TO<br>GROUND WATER<br>BASIN | NET<br>CONS. USE<br>REQUIREMENT | IRRIGATION<br>DIVERSION | EXTRACTION FROM<br>GROUND WATER<br>BASIN | UNDERFLOW<br>OUT | EXPORT | TOTAL FROM<br>GROUND WATER<br>BASIN | FLOOD<br>OUTFLOW | TOTAL<br>OUTFLOW | CHANGE<br>IN<br>STORAGE | AVAILABLE<br>STORAGE |
| 1936-37 | 253,860         | 14,480          | 1,800           | 270,140                  | 1,800           | 4,340                   | 38,230                | 20,140               | 64,510                            | 6,170                           | 1,060                   | 5,140                                    | 24,750           | 1,320  | 31,210                              | 208,910          | 240,120          | +33,300                 | 57,000               |
| 38      | 483,030         | 16,820          | 1,800           | 501,650                  | 1,800           | 4,520                   | 39,310                | 13,650               | 59,280                            | 7,040                           | 1,060                   | 6,020                                    | 36,500           | 1,330  | 43,850                              | 445,830          | 489,680          | +15,430                 | 23,700               |
| 39      | 71,870          | 17,230          | 1,800           | 90,900                   | 1,800           | 1,210                   | 21,890                | 13,550               | 38,450                            | 7,700                           | 1,660                   | 6,040                                    | 39,600           | 1,520  | 47,160                              | 52,000           | 99,160           | - 8,710                 | 16,980               |
| 40      | 42,850          | 15,640          | 1,800           | 60,290                   | 1,800           | 750                     | 14,440                | 16,790               | 33,780                            | 8,270                           | 1,330                   | 6,940                                    | 39,600           | 1,560  | 48,100                              | 25,930           | 74,030           | -14,320                 | 31,300               |
| 41      | 764,810         | 16,940          | 1,800           | 783,550                  | 1,800           | 12,220                  | 53,680                | 400                  | 68,100                            | 6,410                           | 840                     | 5,640                                    | 36,800           | 1,140  | 43,580                              | 726,830          | 770,410          | +24,520                 | 6,780                |
| 42      | 102,750         | 16,960          | 1,800           | 121,510                  | 1,800           | 920                     | 31,470                | 0                    | 34,190                            | 8,200                           | 670                     | 7,580                                    | 31,200           | 1,730  | 40,510                              | 87,570           | 128,080          | - 6,320                 | 13,100               |
| 43      | 417,630         | 17,200          | 1,800           | 436,630                  | 1,800           | 4,570                   | 35,050                | 0                    | 41,420                            | 7,720                           | 630                     | 7,090                                    | 27,500           | 1,440  | 36,030                              | 399,150          | 435,180          | + 5,390                 | 7,710                |
| 44      | 357,820         | 17,340          | 1,800           | 376,960                  | 1,800           | 3,590                   | 27,090                | 1,960                | 34,440                            | 7,460                           | 520                     | 6,940                                    | 24,000           | 1,300  | 32,240                              | 345,590          | 377,830          | + 2,200                 | 5,510                |
| 45      | 95,180          | 15,360          | 1,800           | 112,340                  | 1,800           | 800                     | 27,580                | 4,740                | 34,920                            | 8,520                           | 240                     | 8,290                                    | 36,270           | 1,460  | 46,020                              | 77,980           | 124,000          | -11,100                 | 16,610               |
| 46      | 95,970          | 13,900          | 1,800           | 111,670                  | 1,800           | 480                     | 21,960                | 17,250               | 41,480                            | 8,480                           | 500                     | 7,980                                    | 38,300           | 1,760  | 48,040                              | 70,160           | 118,200          | - 6,560                 | 23,170               |
| 47      | 72,000          | 11,110          | 1,800           | 84,910                   | 1,800           | 1,010                   | 14,870                | 22,760               | 40,440                            | 8,990                           | 670                     | 8,320                                    | 38,040           | 1,890  | 48,250                              | 44,810           | 93,060           | - 7,810                 | 30,980               |
| 48      | 8,970           | 7,310           | 1,800           | 18,080                   | 1,800           | 100                     | 7,090                 | 7,800                | 16,790                            | 9,320                           | 550                     | 8,810                                    | 30,680           | 2,280  | 41,770                              | 840              | 42,610           | -24,980                 | 55,960               |
| 49      | 5,830           | 6,830           | 1,800           | 14,460                   | 1,800           | 60                      | 6,390                 | 5,530                | 13,780                            | 8,850                           | 750                     | 8,180                                    | 23,720           | 2,050  | 33,950                              | 0                | 33,950           | -20,170                 | 76,130               |
| 50      | 14,090          | 5,890           | 1,800           | 21,780                   | 1,800           | 710                     | 5,510                 | 9,700                | 17,720                            | 7,280                           | 350                     | 6,930                                    | 19,480           | 1,740  | 28,150                              | 4,420            | 32,570           | -10,430                 | 86,560               |
| 51      | 260             | 950             | 1,800           | 3,010                    | 1,800           | 100                     | 1,020                 | 0                    | 2,920                             | 8,250                           | 190                     | 8,120                                    | 6,480            | 2,110  | 16,710                              | 0                | 16,710           | -13,790                 | 100,350              |
| 52      | 212,880         | 10,400          | 1,800           | 225,080                  | 1,800           | 7,060                   | 27,560                | 25,370               | 61,790                            | 6,170                           | 640                     | 5,530                                    | 16,680           | 1,190  | 23,400                              | 169,710          | 193,110          | +38,390                 | 61,960               |
| 53      | 16,450          | 12,540          | 1,800           | 30,790                   | 1,800           | 700                     | 1,900                 | 21,850               | 26,250                            | 7,980                           | 2,030                   | 5,950                                    | 36,760           | 1,790  | 44,500                              | 3,210            | 47,710           | -18,250                 | 80,210               |
| 54      | 26,030          | 11,710          | 1,800           | 39,540                   | 1,800           | 2,010                   | 6,400                 | 19,760               | 29,970                            | 7,050                           | 1,630                   | 5,420                                    | 24,760           | 1,530  | 31,710                              | 9,950            | 41,660           | - 1,740                 | 81,950               |
| 55      | 10,810          | 8,300           | 1,800           | 20,910                   | 1,800           | 660                     | 3,110                 | 12,210               | 17,780                            | 6,750                           | 1,810                   | 4,940                                    | 20,440           | 1,700  | 27,080                              | 1,980            | 29,060           | - 9,300                 | 91,250               |
| 56      | 28,370          | 9,040           | 1,800           | 39,210                   | 1,800           | 2,320                   | 4,330                 | 17,160               | 25,610                            | 6,500                           | 1,730                   | 4,770                                    | 21,360           | 1,610  | 27,740                              | 14,190           | 41,930           | - 2,130                 | 93,380               |
| 1956-57 | 16,170          | 8,410           | 1,800           | 26,380                   | 1,800           | 530                     | 4,290                 | 13,080               | 19,700                            | 7,220                           | 1,600                   | 5,620                                    | 13,200           | 3,640  | 22,460                              | 5,610            | 28,070           | - 2,760                 | 96,140               |
| AVERAGE | 147,510         | 12,110          | 1,800           | 161,420                  | 1,800           | 2,320                   | 18,720                | 11,600               | 34,440                            | 7,630                           | 970                     | 6,680                                    | 27,910           | 1,720  | 36,310                              | 128,320          | 164,630          |                         |                      |

PORTIONS OF THE MOUND AND MONTALVO BASINS TO WHICH WATER IS EXPORTED. THE YIELDS OF THESE THREE BASINS COULD BE INCREASED CONSIDERABLY IF LOWER WATER TABLES COULD BE TOLERATED.

#### MONTALVO BASIN

UNDER THE CONDITIONS PREVAILING DURING THE 1936-57 BASE PERIOD, IT IS CONSIDERED THAT THE MONTALVO BASIN HAS EXPERIENCED NO OVERDRAFT, ALTHOUGH THE HISTORIC YIELD IS PROBABLY NOT MUCH BELOW THE SAFE YIELD. THE HISTORIC YIELD IS CALCULATED AS 8380 ACRE-FeET PER YEAR. THE UNDERFLOW OUT OF THE MONTALVO BASIN HAS AVERAGED ABOUT 28,000 ACRE-FeET PER YEAR OVER THE 1936-57 BASE PERIOD. THIS IS CONSIDERED TO BE THE PRIMARY SOURCE OF SAFE YIELD TO THE OXNARD AQUIFER AND TO THE MOUND BASIN. IT HAS ALSO BEEN A SOURCE OF RECHARGE TO THE FOX CANYON AQUIFER IN THE AVERAGE AMOUNT OF 2000 ACRE-FeET PER YEAR.

#### OXNARD PLAIN AND MOUND BASIN

AN ANALYSIS OF WATER SUPPLIES FOR THE OXNARD PLAIN AND MOUND BASIN WAS MADE FOR THE BASE PERIOD 1936-57. FOR THIS ANALYSIS, IT WAS FOUND ADVANTAGEOUS TO DIVIDE THE BASE PERIOD INTO TWO SUB-PERIODS--THE WET 1936-46 GROUP OF YEARS, AND THE 1946-57 PRIMARILY DRY GROUP OF YEARS. THE RESULTS OF THIS ANALYSIS ARE GIVEN IN TABLE IV-4. THE UNDERFLOW FROM MONTALVO BASIN IS DERIVED FROM THE DETAILED GROUND WATER INVENTORY (PLATE 31). LOSS OF FRESH-WATER STORAGE DUE TO SEA-WATER INTRUSION INTO THE OXNARD AQUIFER FOR THE YEARS 1946-57 HAS BEEN ESTIMATED AS 90,000 ACRE-FeET; THIS HAS RESULTED IN A LOSS OF USABLE STORAGE CAPACITY OF ABOUT 135,000 ACRE-FeET. THE REMAINING ESTIMATED LOSS OF FRESH-WATER STORAGE CAPACITY IS CONSIDERED TO HAVE TAKEN PLACE WITHIN THE UPPER PLEISTOCENE AQUIFERS SEAWARD OF THE MOUND BASIN. ONLY A VERY SMALL AMOUNT OF WATER COULD HAVE COME FROM THE COMPACTION OF CLAYS. THIS CONCLUSION WAS BASED ON THE ASSUMPTION THAT COMPACTION OF CLAYS DUE TO PRESSURE REDUCTION WITHIN THE OXNARD AQUIFER WOULD HAVE RESULTED IN SUBSIDENCE OF THE GROUND SURFACE EQUIVALENT TO A LARGE PERCENTAGE OF THE ACTUAL COMPACTION. THIS ASSUMPTION IS JUSTIFIED BY THE INCOMPETENT NATURE OF THE UPPER SEVERAL HUNDRED FEET OF SEDIMENTS BENEATH THE OXNARD PLAIN. A REVIEW OF RECORDS OF PRECISE LEVELING ACROSS THE OXNARD PLAIN REVEALS THAT NO APPRECIABLE SUBSIDENCE OCCURRED BETWEEN 1939 AND ABOUT

TABLE IV-4  
GROUND WATER INVENTORY OF OXNARD PLAIN AND  
MOUND BASINS  
(ACRE-FEET PER YEAR)

| <u>ITEM OF INCREMENT</u>                               | <u>1936-46</u> | <u>1946-57</u> |
|--------------------------------------------------------|----------------|----------------|
| UNDERFLOW FROM MONTALVO BASIN                          | 31,500         | 18,500         |
| LOSS OF FRESH-WATER STORAGE BY SEA-<br>WATER INTRUSION | 0              | 12,000         |
| DOWNFLOW FROM SEMI-PERCHED ZONE                        | 0              | 20,000         |
| REDUCTION OF OUTCROP STORAGE                           | 0              | 2,500          |
| COMPACTION OF CLAYS                                    | <u>0</u>       | <u>0</u>       |
| TOTAL                                                  | 31,500         | 53,000         |
| <br><u>ITEM OF DECREMENT</u>                           |                |                |
| PUMPAGE ON OXNARD PLAIN AND IN<br>MOUND BASIN          | 55,300         | 71,400         |
| OUTFLOW TO OCEAN                                       | 7,800          | 0              |
| UPWARD LEAKAGE TO SHALLOW ZONES                        | 500            | 0              |
| EXPORT TO WEST LAS POSAS                               | <u>700</u>     | <u>1,600</u>   |
| TOTAL                                                  | 64,300         | 73,000         |
| <br>SAFE YIELD COMPONENT OF UNACCOUNTED-<br>FOR WATER  | 32,800         | 20,000         |

1950. LATER SURVEYS MAY INDICATE THAT SOME SUBSIDENCE HAS TAKEN PLACE SUBSEQUENT TO 1950.

PUMPAGE FIGURES FOR THE OXNARD PLAIN AND THE MOUND BASIN ARE DERIVED LARGELY FROM BULLETIN 12, ADJUSTED FOR IMPORTS, AND DEEPER PUMPAGE ON THE OXNARD PLAIN. OUTFLOW TO THE OCEAN WAS BASED ON SLOPE-AREA STUDIES AND IS BELIEVED TO REPRESENT A MINIMUM. EXPORTS TO THE WEST LAS POSAS AREA ARE FROM THE DISTRICT'S RECORDS.

THE ITEM OF UNACCOUNTED-FOR WATER DURING THE 1936-46 PERIOD REPRESENTS WATER WHICH MUST HAVE BEEN SUPPLIED TO SATISFY THE ESTIMATED DEMANDS AND OUTFLOWS. THIS UNACCOUNTED-FOR WATER HAS TWO POSSIBLE EXPLANATIONS:

- (1) ESTIMATED PUMPAGES ARE TOO GREAT;
- (2) ESTIMATED INFLOWS ARE TOO SMALL.

THERE WAS NO OVERDRAFT DURING THE 1936-46 PERIOD AND IT IS ASSUMED THAT THERE WAS NO REDUCTION OF GROUND WATER STORAGE. EITHER EXPLANATION IS IN THE DIRECTION OF REDUCING AVERAGE ANNUAL OVERDRAFT. ALL OF THIS UNACCOUNTED-FOR WATER IS CONSIDERED TO BE A COMPONENT OF SAFE YIELD. DURING THE 1946-57 PERIOD, THE SAFE YIELD COMPONENT OF UNACCOUNTED-FOR WATER IS REDUCED TO 20,000 ACRE-FEET PER YEAR. TO BALANCE THE SUPPLY AND DEMAND DURING THE 1946-57 DRY PERIOD, IT IS NECESSARY TO DRAW HEAVILY FROM STORAGE AND THE SEMI-PERCHED ZONE. THE ESTIMATES FOR INTRUDED FRESH-WATER STORAGE AND LOSS OF OUTCROP STORAGE ARE BELIEVED NEAR THE MAXIMA. BASED ON CALCULATIONS OF AVAILABLE IRRIGATION RETURN WATER, THE ASSIGNED DOWNFLOW FROM THE SEMI-PERCHED ZONE IS QUITE HIGH. THIS IS A CONSERVATIVE APPROACH WHICH CURBS OVER-OPTIMISM ON AVAILABLE SAFE YIELD SUPPLY. IT IS QUITE POSSIBLE THAT THE SEMI-PERCHED DOWNFLOW IS LOWER AND THE SAFE YIELD COMPONENT OF UNACCOUNTED-FOR WATER IS HIGHER.

WITH THE ASSUMPTION THAT DURING THE 1936-46 PERIOD ALL DEMANDS AND OUTFLOWS WERE SUPPLIED FROM SAFE YIELD SOURCES, THE AVERAGE WATER SUPPLY DURING THAT PERIOD WAS 64,300 ACRE-FEET PER YEAR. FOR THE 1946-57 PERIOD THE SUPPLY IS TAKEN AS THE UNDERFLOW FROM MONTALVO BASIN PLUS THE SAFE YIELD COMPONENT OF UNACCOUNTED-FOR WATER, A TOTAL OF 38,500 ACRE-FEET PER YEAR. THE AVERAGE ANNUAL SUPPLY DURING THE ENTIRE 1936-57 PERIOD WAS 50,800 ACRE-FEET PER YEAR. THIS SUPPLY WOULD TEND

TO BE INCREASED BY THE ACTUAL AMOUNT OF WATER DERIVED FROM THE SEMI-PERCHED ZONE, EVEN THOUGH THE POOR QUALITY MAKES IT QUESTIONABLE AS A SAFE YIELD ITEM. UNDERFLOW TO THE OCEAN DURING WET PERIODS WHICH COULD NOT BE INTERCEPTED WOULD TEND TO DECREASE THE AVAILABLE SAFE YIELD SUPPLY. THE AVERAGE ANNUAL PUMPING DEMAND DURING THE 1936-57 PERIOD WAS 63,700 ACRE-FEET PER YEAR. THUS THE OVERDRAFT DURING THE ENTIRE BASE PERIOD WAS 63,700 MINUS 50,800 OR AN AVERAGE OF 12,900 ACRE-FEET PER YEAR. WITH FUTURE INCREASES OF PUMPING DEMAND, THIS OVERDRAFT WILL GROW.

#### FOX CANYON AQUIFER

THE MAIN SOURCES OF RECHARGE TO THE FOX CANYON AQUIFER ARE:

- (1) THE MONTALVO BASIN THROUGH THE SUB-ALLUVIAL OUTCROP BENEATH THE SATICOY SPREADING GROUNDS;
- (2) UNDERFLOW FROM WEST LAS POSAS BASIN;
- (3) UNDERFLOW FROM EAST LAS POSAS BASIN.

THE MONTALVO BASIN AND WEST LAS POSAS BASIN SOURCES ARE ESTIMATED AS 2000 ACRE-FEET PER YEAR EACH. THE MONTALVO BASIN SOURCE WILL BE PERENNIAL, BUT THE UNDERFLOW FROM THE OVERDRAFTED WEST LAS POSAS AREAS IS EXPECTED TO DECREASE. FROM EAST LAS POSAS BASIN, WHERE UNDERFLOW HAS BEEN ABOUT 3000 ACRE-FEET PER YEAR IN THE PAST, THERE WILL BE DECREASING RECHARGE AS OVERDRAFT INCREASES. NO OTHER SOURCES OF RECHARGE TO THE FOX CANYON AQUIFER ARE CONSIDERED AS QUANTITATIVELY SIGNIFICANT.

ALTHOUGH THERE MAY HAVE BEEN ESCAPE OF FRESH WATER TO THE OCEAN PRIOR TO 1946, THE CURRENT OVERWHELMING GROUND WATER DECREMENT IS PUMPED EXTRACTIONS. A DETAILED STUDY HAS BEEN MADE OF THE ACREAGE SERVED FROM FOX CANYON WELLS, AND METERED PUMPAGES HAVE BEEN OBTAINED, WHERE AVAILABLE. AS OF 1959 ABOUT 4900 ACRE-FEET PER YEAR REPRESENT MEASURED PUMPAGES. AN ADDITIONAL 14,600 ACRES WERE BEING IRRIGATED FROM WELLS REACHING THE FOX CANYON AQUIFER. THAT ACREAGE INCLUDES AN ADJUSTMENT FOR WATER REMOVED FROM THE SHALLOWER AQUIFERS IN THE MULTI-ZONE WELLS. ON THAT ACREAGE AN APPLICATION RATE OF 1.5 FEET PER YEAR WAS USED. THE CURRENT ANNUAL DRAFT ON THE FOX CANYON AQUIFER IS ESTIMATED TO BE 26,000 ACRE-FEET PER YEAR, FAR IN EXCESS OF THE RECHARGE.

IN CALCULATING THE OVERDRAFT ON THE FOX CANYON AQUIFER, THE FOLLOWING ASSUMPTIONS HAVE BEEN MADE:

- (1) THERE IS NO OVERDRAFT IN THE FOX CANYON AQUIFER IN THE NORTHERN PART OF THE OXNARD PLAIN;
- (2) OVERDRAFT IS RESTRICTED TO THE AREA SOUTH OF THE SPRINGVILLE FAULT, INCLUDING ALL OF PLEASANT VALLEY, AND THE MUGU AREA;
- (3) OVERDRAFT COMMENCED LONG PRIOR TO 1948 BUT LOSS OF FRESH-WATER STORAGE BY SEA-WATER INTRUSION STARTED IN 1948;
- (4) IN PLEASANT VALLEY, CURRENT RECHARGE CONSISTS OF (A) UNDERFLOW FROM EAST LAS POSAS--3000 ACRE-FeET PER YEAR; (B) UNDERFLOW FROM THE NORTH ACROSS AND AROUND THE SPRINGVILLE FAULT--3000 ACRE-FeET PER YEAR;
- (5) PUMPAGE IN THE OVERDRAFT AREA IS 25,000 ACRE-FeET PER YEAR.

CURRENT ANNUAL OVERDRAFT ON THE FOX CANYON AQUIFER AMOUNTS TO ABOUT 19,000 ACRE-FeET PER YEAR. THE AMOUNT OF FRESH-WATER STORAGE LOST TO SEA-WATER INTRUSION DURING THE 1948-59 PERIOD APPROACHES 200,000 ACRE-FeET. THIS REPRESENTS A MAXIMUM FIGURE BECAUSE THE OVERDRAFT HAS NOT AVERAGED SO MUCH AS 19,000 ACRE-FeET PER YEAR OVER THE 1948-59 PERIOD. WITH FAILING RECHARGE, AND IF THERE ARE INCREASING PUMPING DEMANDS IN THE FUTURE, THE ANNUAL OVERDRAFT WILL INCREASE.

THE TOTAL OVERDRAFT ON THE COASTAL PLAIN AND IN THE ENTIRE DISTRICT AMOUNTS TO 19,000 ACRE-FeET PER YEAR FOR THE FOX CANYON AQUIFER PLUS 12,900 ACRE-FeET PER YEAR FOR THE MOUND BASIN AND OXNARD PLAIN, FOR A TOTAL AVERAGE ANNUAL OVERDRAFT OF 31,900 ACRE-FeET PER YEAR.

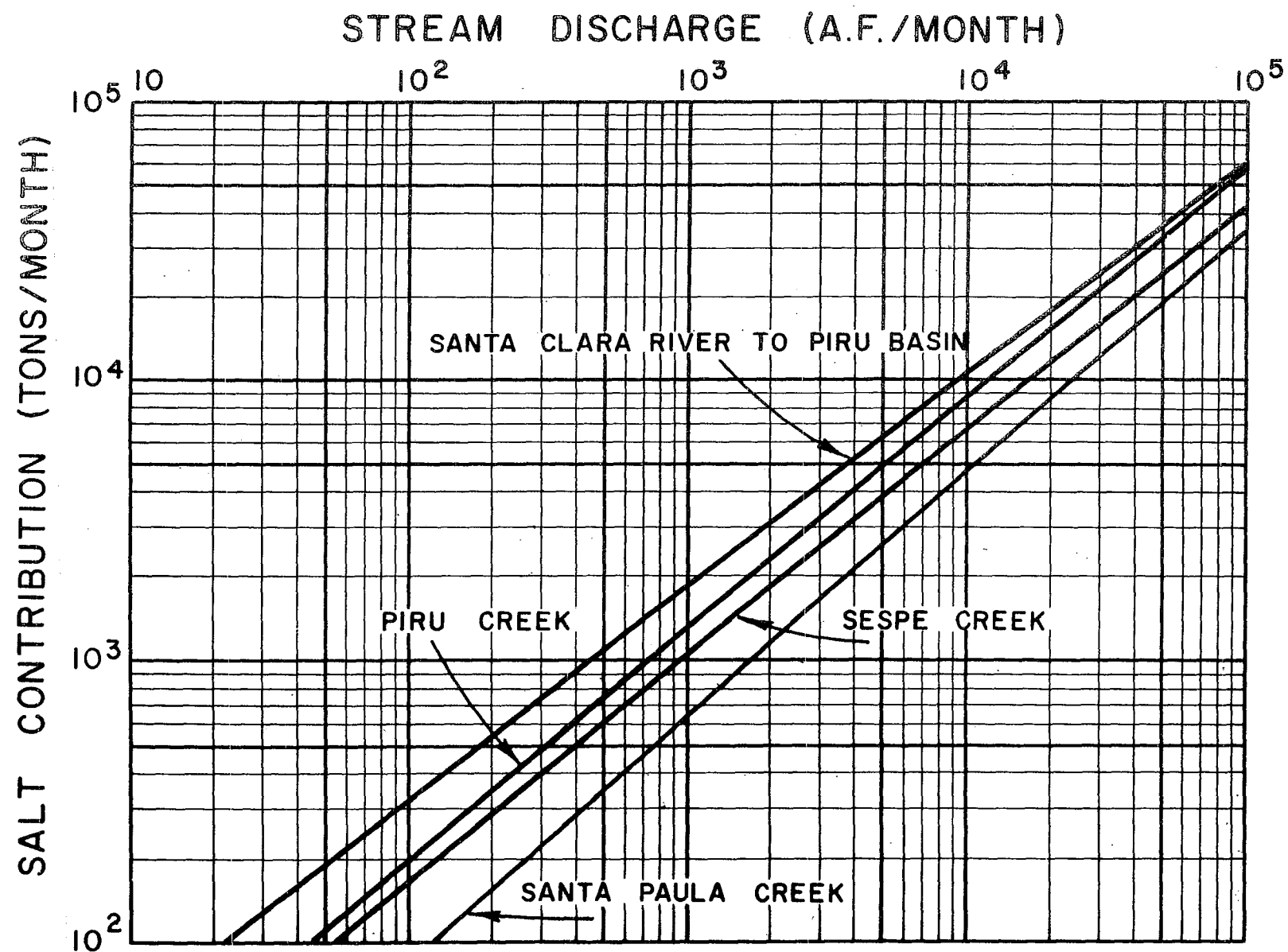
## CHAPTER V

### SALT BALANCE

#### METHODS AND PROCEDURES

ALTHOUGH NOT ORIGINALLY PLANNED AS A PART OF THIS INVESTIGATION, IT BECAME INCREASINGLY APPARENT THAT A BETTER PICTURE OF WATER QUALITY PROBLEMS WOULD BE OBTAINED IF, IN ADDITION TO THE OTHER WATER QUALITY STUDIES, A COMPLETE SALT INVENTORY WERE MADE IN THE UPSTREAM BASINS. ACCORDINGLY, DETAILED SALT-BALANCE CALCULATIONS WERE MADE FOR THE BASE PERIOD 1936-57 FOR THE PIRU, FILLMORE, AND SANTA PAULA BASINS. THIS INVOLVED ESTIMATING ALL THE SALTS WHICH ARE BROUGHT INTO EACH BASIN AND ALL THE SALTS WHICH ARE REMOVED. MOST OF THE SALTS ARE CARRIED IN SOLUTION AND IT WAS NECESSARY TO DETERMINE REPRESENTATIVE SALT CONTENTS FOR THE VARIOUS ITEMS IN THE GROUND WATER INVENTORY. USING THE CHEMICAL ANALYSES AVAILABLE FOR THE SURFACE FLOWS OF THE SANTA CLARA RIVER AT BLUE CUT, AND ENTERING FLOWS OF PIRU, SESPE, AND SANTA PAULA CREEKS, CURVES WERE DEVELOPED RELATING THE FLOW IN ACRE-FEET PER MONTH TO TONS OF SALT PER MONTH (PLATE 32). DATA WERE NOT AVAILABLE TO PREPARE SUCH CURVES FOR THE OTHER INVENTORY ITEMS, AND AVERAGE SALINITIES WERE DETERMINED FROM THE AVAILABLE SURFACE WATER AND GROUND WATER ANALYSES, MOST OF WHICH WERE RECENTLY PUBLISHED AS THE APPENDICES TO CALIFORNIA DEPARTMENT OF WATER RESOURCES BULLETIN No. 75 (REF. 18).

OIL-FIELD OPERATIONS ARE CONDUCTED IN THE TRIBUTARY DRAINAGES OF PIRU, FILLMORE, AND SANTA PAULA BASINS. ALMOST ALL OF THE OIL WELLS PRODUCE WITH THE OIL SOME HIGHLY MINERALIZED WATER. RECORDING OF BRINE PRODUCTION IS REQUIRED BY LAW, AND THESE RECORDS ARE COMPILED AND PUBLISHED ANNUALLY BY THE CALIFORNIA DIVISION OF OIL AND GAS. NUMEROUS SAMPLES OF OIL-FIELD BRINES IN THE DISTRICT WERE COLLECTED BY THE CALIFORNIA DIVISION OF WATER RESOURCES DURING THE EARLY 1950'S IN SURVEYS MADE FOR REGIONAL WATER POLLUTION CONTROL BOARD No. 4 (REFS. 12, 14). THE OIL-FIELD WATERS PRODUCED NORTH OF THE SANTA CLARA RIVER RANGE FROM THE THRESHOLD OF USABILITY TO MORE THAN 13,000 PARTS PER MILLION TOTAL DISSOLVED SOLIDS. THESE ARE MOSTLY SODIUM DICARBONATE WATERS, ALTHOUGH A FEW ARE OF A SODIUM CHLORIDE CHARACTER. SOME OF THE SOUTH-SIDE BRINES ARE MUCH MORE HIGHLY MINERALIZED, AND MANY SHOW TDS OF MORE THAN 30,000 PPM. OIL



PRODUCTION IS FROM A CONSIDERABLE VERTICAL INTERVAL, FROM FORMATIONS BOTH ABOVE AND BELOW THE OAK RIDGE FAULT. THE BRINES SHOW A VARIETY OF CHEMICAL CHARACTERS: (1) SODIUM-CALCIUM CHLORIDE; (2) SODIUM CHLORIDE; (3) SODIUM SULFATE-CHLORIDE; (4) SODIUM SULFATE; AND (5) SODIUM DICARBONATE.

THE SALTS CONTRIBUTED BY OIL-FIELD BRINES TO THE FRESH GROUND WATERS WERE ESTIMATED FOR EACH YEAR FROM 1936 TO 1957. THIS INVOLVED THE FOLLOWING:

- (1) PROPORTIONING THE BRINE PRODUCTION WITHIN EACH OIL FIELD TO THE SMALLER DRAINAGE AREAS, SO THAT THESE COULD BE FITTED INTO THE AREAS TRIBUTARY TO EACH GROUND WATER BASIN;
- (2) ESTIMATING THE VOLUMES THAT WERE NOT ALLOWED TO ENTER THE SANTA CLARA RIVER ALLUVIUM. THESE BRINES INCLUDED THOSE THAT WERE:
  - (A) PERCOLATED IN SUMPS OVERLYING PERMEABLE LAYERS WHICH DIP AWAY FROM THE RIVER;
  - (B) EVAPORATED IN SUMPS ON IMPERMEABLE MATERIALS;
  - (C) EXPORTED BY PIPELINES OR TRUCKS;
  - (D) INJECTED INTO BRINE DISPOSAL WELLS, OR USED IN A WATERFLOOD REPRESSURING SYSTEM;
- (3) TO THE VOLUMES REMAINING FROM (2), THE APPROPRIATE TONS-PER-ACRE-FOOT SALINITY FACTORS WERE APPLIED TO ARRIVE AT THE ANNUAL TONNAGE OF SALT.

CONTRIBUTIONS FROM DOMESTIC SEWAGE WERE ESTIMATED AS FOLLOWS:

- (1) POPULATIONS FOR EACH GROUND WATER BASIN WERE ESTIMATED FOR EACH YEAR OF THE 1936-57 PERIOD USING DATA AND ESTIMATES PRESENTED IN THE RECENT STUDY BY THE PLANNING RESEARCH CORPORATION (REF. 55);
- (2) SEWAGE VOLUME WAS TAKEN AS 63 GALLONS PER CAPITA PER DAY. THIS FIGURE WAS DERIVED FROM DETAILED STUDIES BY THE STATE WATER RIGHTS BOARD IN SAN FERNANDO VALLEY IN EARLY 1959. IT CORRESPONDS FAIRLY CLOSELY WITH THE PER-CAPITA FIGURE INDICATED BY THE FLOW AT THE CITY OF SANTA PAULA SEWAGE TREATMENT PLANT.
- (3) DOMESTIC USES WERE CONSIDERED TO INCREASE THE TDS OF THE DELIVERED DOMESTIC WATER BY 300 PPM. THIS IS THE MAXIMUM FIGURE GIVEN BY THE CALIFORNIA STATE WATER POLLUTION CONTROL BOARD (REF. 22). WITH ALLOWANCES MADE FOR THE DISCHARGE OF INDUSTRIAL WASTES, THE CHEMICAL ANALYSES OF THE CITY OF SANTA PAULA SEWAGE EFFLUENT INDICATE A DOMESTIC SALT PICK-UP WHICH IS WELL WITHIN THE 300 PPM.
- (4) BY APPLYING SALT PICK-UP TO PER-CAPITA FLOW FIGURES, IT WOULD APPEAR THAT THE PER-CAPITA CONTRIBUTION OF SALT TO THE GROUND WATER BASINS IN DOMESTIC SEWAGE IS A MAXIMUM OF 60 POUNDS PER YEAR, OR 0.03 TONS PER YEAR.

FOR THE SEWAGE TREATMENT PLANTS AT FILLMORE, SANTA PAULA, AND SATICOY, THE REGIONAL WATER POLLUTION CONTROL BOARD HAS PRESCRIBED THE FOLLOWING LIMITS FOR EFFLUENTS:

| <u>CONSTITUENT</u>                | <u>MAXIMUM LIMIT</u> |
|-----------------------------------|----------------------|
| TOTAL DISSOLVED SOLIDS . . . . .  | 2000 PPM             |
| CHLORIDE . . . . .                | 175 PPM              |
| BORON . . . . .                   | 1.5 PPM              |
| SODIUM EQUIVALENT RATIO . . . . . | 60%                  |

THE EFFLUENTS FROM ALL THREE PLANTS HAVE EXPERIENCED DIFFICULTIES IN MEETING ONE OR MORE OF THESE LIMITS. AT SANTA PAULA, INDUSTRIAL WASTES HAVE HERETOFORE BEEN DISCHARGED INTO THE CITY SEWER SYSTEM. A DISCONTINUANCE OF THESE DISCHARGES HAS BEEN ORDERED, WHICH SHOULD RESULT IN AN ACCEPTABLE EFFLUENT. A MORE SERIOUS INDUSTRIAL WASTE PROBLEM EXISTS IN THE SATICOY SYSTEM, BUT ONLY A MINOR ONE AT FILLMORE. BOTH SATICOY AND FILLMORE MAY CONTINUE TO EXPERIENCE DIFFICULTIES IN MEETING THE EFFLUENT STANDARDS BECAUSE THE DELIVERED DOMESTIC WATER IS SO HIGH IN TOTAL DISSOLVED SOLIDS.

INDUSTRIAL WASTES (OTHER THAN OIL-FIELD BRINES) DISCHARGED IN THE PIRU, FILLMORE, AND SANTA PAULA BASINS ARE MAINLY (1) WASH AND RINSE WATERS FROM CITRUS PACKING PLANTS, AND (2) REGENERATION BRINES FROM WATER SOFTENERS. BOTH TYPES OF WASTES HAVE BEEN THE SUBJECT OF RECENT INVESTIGATIONS BY THE REGIONAL WATER POLLUTION CONTROL BOARD (REFS. 13, 15, 20). A COMPREHENSIVE REPORT ON THE PACKING PLANT WASTES WAS AUTHORIZED BY THE WATER POLLUTION COMMITTEE OF THE VENTURA COUNTY CITRUS PACKING ASSOCIATIONS, AND PREPARED BY L. T. SHARP OF THE FRUIT GROWERS LABORATORY (REF. 32). IN THAT REPORT ARE TO BE FOUND EXCELLENT DATA ON THE FLOW VOLUME AND CHEMICAL QUALITY OF THE WASTES DISCHARGED BY ALL THE CITRUS PACKING PLANTS IN VENTURA COUNTY. MUCH HAS BEEN DONE TOWARD ALLEVIATING THIS SOURCE OF GROUND WATER POLLUTION BY (1) MODIFYING WASHING AND RINSING PROCESSES TO PRODUCE A LESS OBJECTIONABLE EFFLUENT; (2) USING UNSOFTENED WATER; AND (3) TRUCKING AWAY SALINE WASTES.

WATER SOFTENER REGENERATION BRINES ARE AN ESPECIALLY SERIOUS PROBLEM BECAUSE OF EXTREME SALINITY -- SOMETIMES REACHING MORE THAN 300,000 PPM. SUCH BRINES ARE DERIVED FROM DOMESTIC WATER SOFTENERS, AND FROM MANY INDUSTRIES WHERE A SOFTENED WATER IS REQUIRED. THE CITY OF SANTA PAULA HAS RECENTLY PASSED AN ORDINANCE PROHIBITING THE INSTALLATION

OF NEW OWNER-SERVICED WATER SOFTENERS, FROM WHICH THE REGENERATION DRINES WOULD BE DISCHARGED TO THE CITY SEWER. ANY PERSON WHO WISHES TO START USING SOFTENED WATER MUST SUBSCRIBE TO A COMMERCIAL SERVICE, WHICH WILL REGENERATE THE UNITS CENTRALLY, AND PRESUMABLY BE RESPONSIBLE FOR THE PROPER DISPOSAL OF THE DRINES.

FROM THE VERY GOOD AVAILABLE DATA, ESTIMATES OF SALT CONTRIBUTIONS BY INDUSTRIAL WASTES WERE MADE FOR THE PIRU, FILLMORE, AND SANTA PAULA BASINS.

SOME SALTS ARE IMPORTED TO THE BASINS AND SPREAD ON THE LAND AS FERTILIZER. THESE WERE ESTIMATED TO BE ON THE ORDER OF 500 POUNDS PER ACRE PER YEAR. THIS ESTIMATE COULD BE REFINED WITH A MORE DETAILED STUDY. SOME SALTS ARE BOUND UP IN AGRICULTURAL PRODUCTS AND SHIPPED FROM THE BASINS; THIS EXPORT WAS ESTIMATED TO BE 100 POUNDS PER ACRE PER YEAR. THE DETERMINATION OF SALT CONTRIBUTIONS IN WATERS LEAKING FROM THE OLDER ROCKS OF OAK RIDGE AND SOUTH MOUNTAIN IS VERY DIFFICULT TO ESTIMATE. THE ESTIMATES GIVEN, WHICH ARE BELIEVED TO REPRESENT MAXIMUM VALUES, NECESSARILY HAD TO BE BASED ON JUDGEMENT, TAKING INTO CONSIDERATION SUCH GEOLOGIC AND HYDROLOGIC FACTORS AS:

- (1) THE PROBABLE AMOUNT OF RAINFALL PENETRATION ON OUTCROPS OF THE OLDER ROCKS;
- (2) THE PERMEABILITY CHARACTERISTICS OF THESE ROCKS;
- (3) THE NUMBER AND FLOW VOLUME OF SPRINGS;
- (4) THE LACK OF CHEMICAL DETERIORATION OF GROUND WATERS DEFINITELY ASCRIBABLE TO THESE SOURCES.

## RESULTS

A SUMMARY OF THE SALT-BALANCE CALCULATIONS IS PRESENTED IN TABLE V-1. AS SALT ACCUMULATION OR REMOVAL IS A VERY SLOW PROCESS, AVERAGE FIGURES OVER A REPRESENTATIVE PERIOD ARE MORE SIGNIFICANT THAN THOSE FOR ANY SINGLE YEAR. HOWEVER, ADEQUATE ALLOWANCES SHOULD BE MADE FOR ANY TRENDS IN THE LATER YEARS OF THE PERIOD. THE SALT-BALANCE STUDIES JUSTIFY THE FOLLOWING CONCLUSIONS:

- (1) ESSENTIALLY ALL THE SALTS BROUGHT INTO THE GROUND WATER BASINS ARE TRANSPORTED BY NATURAL SURFACE FLOWS AND UNDERFLOW;
- (2) ALTHOUGH THE LOW SURFACE FLOWS MAY BE HIGHLY MINERALIZED, THE

TABLE V-1. SUMMARY OF SALT-BALANCE CALCULATIONS  
(AVERAGE TONS OF SALT PER YEAR)

| INCREMENTS                   | PIRU<br>BASIN | FILLMORE<br>BASIN | SANTA PAULA<br>BASIN |
|------------------------------|---------------|-------------------|----------------------|
| FLOOD INFLOW                 | 83,600        | 93,300            | 92,600               |
| RISING WATER INFLOW          | -----         | 21,100            | 53,800               |
| UNDERFLOW IN                 | 400           | 25,800            | 8,800                |
| IMPORTED WATER               | 3,700         | 5,800             | 1,600                |
| FERTILIZER                   | 1,000         | 2,800             | 2,600                |
| SEWAGE AND INDUSTRIAL WASTES | 50            | 250               | 600                  |
| OIL-FIELD DRINES             | 730           | 580               | 210                  |
| SOUTH SIDE LEAKAGE           | 200           | 200               | 200                  |
| TOTALS                       | 89,680        | 149,830           | 160,410              |
|                              |               |                   |                      |
| DECREMENTS                   |               |                   |                      |
| FLOOD OUTFLOW                | 39,500        | 77,500            | 122,000              |
| RISING WATER OUTFLOW         | 21,100        | 53,800            | 20,200               |
| UNDERFLOW OUT                | 25,800        | 8,800             | 3,500                |
| EXPORTED WATER               | 5,800         | 1,600             | 950                  |
| AGRICULTURAL PRODUCTS        | 210           | 560               | 510                  |
| TOTALS                       | 92,410        | 142,260           | 147,160              |

TOTAL TONNAGE OF SALT BROUGHT IN BY THESE LOW FLOWS IS VERY SMALL COMPARED TO THE TONNAGE CONTRIBUTED BY THE LESS SALINE FLOOD FLOWS;

- (3) THE MORE OBVIOUS SOURCES OF POLLUTION SUCH AS DOMESTIC AND MUNICIPAL SEWAGE, OIL-FIELD BRINES AND OTHER INDUSTRIAL WASTES CONTRIBUTE LESS THAN ONE PER CENT OF THE SALT.

IN THE PIRU BASIN, THE CALCULATIONS SUGGEST THAT MORE SALTS ARE BEING REMOVED THAN ARE BEING BROUGHT IN. HOWEVER, THE FIGURES IN TABLE V-1 MUST BE USED WITH DISCRETION, AS THE PROBABLE ACCURACY IS LESS THAN THE DIFFERENCE BETWEEN THE SUMS OF THE INCREMENTS AND DECREMENTS. THE CALCULATIONS IN TABLE V-1 REPRESENT ONLY ONE, AND NOT NECESSARILY CONCLUSIVE, APPROACH TO THE PROBLEM OF SALT BUILD-UP. ANOTHER LINE OF EVIDENCE SUGGESTS THAT THE SALT BALANCE IN THE PIRU BASIN IS ADVERSE. MANY ANALYSES WERE MADE DURING THE BULLETIN 46 STUDIES IN THE PERIOD 1928 TO 1933. ANOTHER LARGE SERIES WAS MADE DURING THE BULLETIN 12 STUDIES IN 1950 TO 1952. COMPARISONS BETWEEN THESE TWO SUITES OF ANALYSES SHOWS THAT (1) AVERAGE GROUND WATER SALINITIES HAVE INCREASED, AND (2) SALINITIES IN FOUR WELLS ANALYZED DURING BOTH PERIODS HAVE INCREASED. WHEREAS THESE SALINITY TRENDS ARE PROBABLY SIGNIFICANT, THE MAGNITUDES OF THESE CHANGES CAN NOT BE CONVERTED INTO A MEANINGFUL ANNUAL CHANGE. IN THE LIGHT OF THE TRENDS IN THE ANALYSES, IT WOULD BE DIFFICULT TO CONCLUDE THAT THE PIRU BASIN SALT BALANCE IS FAVORABLE. IT MIGHT BE SUGGESTED, THOUGH, FROM TABLE V-1, THAT THE PIRU BASIN HAS A RELATIVELY BETTER SALT BALANCE THAN EITHER THE FILLMORE OR SANTA PAULA BASINS.

THE ACTUAL DETERIORATION OF WELL WATERS IS ONLY INCIDENTALLY RELATED TO ADVERSE SALT BALANCE. A WELL WATER BECOMES POOR BECAUSE A HIGHLY MINERALIZED WATER GETS INTO THE WELL. DETERIORATION OF WELL WATERS HAS BEEN KNOWN TO OCCUR IN GROUND WATER BASINS WITH OVERALL EXCELLENT WATER QUALITY AND FAVORABLE SALT BALANCE. THUS THERE ARE TWO DISTINCT PROBLEMS TO BE CONSIDERED:

- (1) THE BROAD PROBLEM OF LONG-TERM SALT ACCUMULATION WHICH DOES NOT NECESSARILY INVOLVE WELL WATERS BECOMING UNUSABLE;
- (2) THE PROBLEM OF THE SOURCE OR SOURCES OF HIGHLY MINERALIZED WATERS WHICH CAUSE RELATIVELY RAPID DETERIORATION OF WELL WATERS.

IN TABLE V-1, THE ITEMS OF LITTLE SIGNIFICANCE FROM THE STANDPOINT OF SALT INVENTORIES MAY BE THE WORST OFFENDERS IN WELL-WATER DETERIORATION.

THE SOURCES OF THESE HIGHLY MINERALIZED WATERS IN THE FIRU, FILLMORE, AND SANTA PAULA BASINS ARE THE FOLLOWING:

- (1) AGRICULTURAL RETURN WATER
- (2) NATURAL LOW SURFACE FLOWS
- (3) MUNICIPAL SEWAGE
- (4) OIL-FIELD DRINES
- (5) INDUSTRIAL WASTES
- (6) NATURALLY SALINE GROUND WATERS

NATURALLY SALINE LOW SURFACE FLOWS HAVE DEFINITELY CAUSED SEVERE GROUND WATER DETERIORATION IN THE FIRU BASIN JUST WEST OF BLUE CUT. THE HIGH SALINITIES OF THESE LOW FLOWS MAY BE EXPLAINED BY THE SALT CONCENTRATION DUE TO EVAPOTRANSPIRATION IN THE LARGE AREA OF PHREATOPHYTES JUST UPSTREAM FROM BLUE CUT. SALINE LOW FLOWS MAY ALSO EXPLAIN THE POOR WELL WATERS NEAR THE MOUTH OF WHEELER CANYON IN THE SANTA PAULA BASIN. ELSEWHERE THE RELATIONSHIPS ARE DIFFICULT TO DEMONSTRATE CHEMICALLY. MUNICIPAL SEWAGE HAS DETERIORATED WELL WATERS IN THE SANTA PAULA BASIN, ALTHOUGH THE POLLUTANTS ARE PROBABLY TRACEABLE TO INDUSTRIAL WASTES DISCHARGED TO THE SEWERS. AN INDEPENDENT DISCHARGE OF INDUSTRIAL WASTES MAY HAVE POLLUTED ONE WELL IN THE SANTA PAULA BASIN. ALTHOUGH IN THE PAST THERE HAS BEEN INDISCRIMINATE DISCHARGE OF OIL-FIELD DRINES INTO ALL THREE BASINS, NO WELL WAS FOUND WHERE THE DETERIORATION WAS DIRECTLY ATTRIBUTABLE TO THESE WASTES.

BY FAR THE MOST ABUNDANT SOURCE OF POOR QUALITY WATER IS IRRIGATION RETURN. DONEEN (REF. 27) WORKING IN VENTURA COUNTY FOUND THAT AT FIELD CAPACITY THE AVERAGE SOIL SOLUTION HAD A SALINITY 2.6 TIMES THAT OF THE APPLIED IRRIGATION WATERS. NEAR THE PERMANENT WILTING PERCENTAGE THIS AVERAGE JUMPS TO 5 TIMES THE SALINITY OF THE IRRIGATION WATERS. THE SOURCE OF THE SALT IS APPLIED WATER AND FERTILIZERS. OF THE TWO, THE SALTS DERIVED FROM THE APPLIED WATER ARE MUCH THE GREATER. THE WORK OF KELLEY, LAURANCE, AND CHAPMAN (REF. 44) DURING THE PERIOD 1935-45 INDICATED FOR SEVERAL VENTURA COUNTY STATIONS THAT THERE WAS NO SALT ACCUMULATION IN THE SOILS. ALTHOUGH THIS MAY BE GENERALLY TRUE, THERE IS SOME EVIDENCE TO SUGGEST THAT BORON IS BEING TEMPORARILY DETAINED IN THE SOIL OF SOME AREAS OF THE DISTRICT. IF SALTS ARE NOT ACCUMULATING IN THE SOILS, THEN IN THE UPSTREAM BASINS THEY ARE BEING CARRIED DOWNWARD.

THE CHEMICAL QUALITY OF IRRIGATION RETURN WATERS IS GENERALLY POOR EVERYWHERE, AND IN THE DISTRICT SOME INDICATION OF THE CHEMICAL NATURE

OF THESE WATERS MAY BE OBTAINED FROM THE DRAIN WATERS ON THE OXNARD PLAIN (TABLE III-9). ASSUMING AN IRRIGATION EFFICIENCY OF 50 PER CENT, THEN ONE ACRE-FOOT OF APPLIED WATER IS CONCENTRATED BY EVAPOTRANSPIRATIVE PROCESSES INTO  $\frac{1}{2}$  ACRE-FOOT OF WATER WITH TWICE THE SALINITY. IN CONSIDERING THAT MOST IRRIGATION WATERS IN THE UPSTREAM BASINS HAVE TDS OF ABOUT 1000 PPM, THE RESULTING WATER WILL CONTAIN ABOUT 2000 PPM. MOST IRRIGATION RETURN WATERS WOULD PROBABLY BE MORE SALINE THAN THIS. ASSUMING 50 PER CENT IRRIGATION EFFICIENCY, THE PER-ACRE PRODUCTION OF SALINE RETURN WATERS WOULD DEPEND UPON THE CONSUMPTIVE USE OF THE CROP. HIGHER IRRIGATION EFFICIENCY WOULD PRODUCE A SMALLER VOLUME OF MORE HIGHLY MINERALIZED WATER; LOWER IRRIGATION EFFICIENCY WOULD PRODUCE A LARGER VOLUME OF RETURN WATER WITH LOWER SALINITY. A ROUGH APPROACH TO THE PROBLEM OF CALCULATING THE VOLUME OF IRRIGATION RETURN WATERS IS GIVEN IN TABLE V-2. THESE FIGURES GIVE, AT LEAST, AN ORDER-OF-MAGNITUDE INDICATION OF THE VOLUME OF THE HIGHER SALINITY WATERS INVOLVED IN IRRIGATION RETURN. UNDER THE ASSUMPTIONS USED IN TABLE V-2, ABOUT 17,000 ACRE-FEET PER YEAR OF RETURN WATER IS PRODUCED. THIS COMPARES WITH ABOUT 1100 ACRE-FEET OF SEWAGE FLOW AT THE CITIES OF FILLMORE AND SANTA PAULA IN 1958. EXPORTATION OF THIS MUNICIPAL SEWAGE (INCLUDING INDUSTRIAL WASTES OTHER THAN OIL-FIELD DRINES) WILL REMOVE ABOUT 0.5 PER CENT OF THE AVERAGE ANNUAL SALT CONTRIBUTION TO THE FILLMORE BASIN AND ABOUT 1.2 PER CENT OF THE AVERAGE ANNUAL SALT CONTRIBUTION TO THE SANTA PAULA BASIN. THIS INCREASE IN SALT EXPORT WOULD NOT BE SUFFICIENT TO INSURE A FAVORABLE SALT BALANCE. AS EVAPOTRANSPIRATIVE CONCENTRATION IS THE CHIEF PRODUCER OF SALINE WATERS, IRRIGATION RETURN WATERS WOULD HAVE TO BE EXPORTED IN LARGE VOLUME TO OVERCOME THE ADVERSE SALT BALANCE.

TABLE V-2. ESTIMATES OF VOLUMES OF IRRIGATION RETURN WATERS IN  
UPSTREAM BASINS ASSUMING 50 PER CENT OF APPLIED  
IRRIGATION WATER GOES TO CONSUMPTIVE USE.

| CROP                                              | CONS. USE              | PIRU BASIN |               | FILLMORE BASIN |               | SANTA PAULA BASIN |               |
|---------------------------------------------------|------------------------|------------|---------------|----------------|---------------|-------------------|---------------|
|                                                   | APPLIED WATER<br>FT/YR | ACRES      | 1958<br>AF/YR | ACRES          | 1958<br>AF/YR | ACRES             | 1958<br>AF/YR |
| ALFALFA                                           | 2.4                    | 20         | 24            | 143            | 172           | 190               | 228           |
| PASTURE                                           | 2.4                    | 30         | 36            | 207            | 248           | 183               | 220           |
| WALNUTS                                           | 1.6                    | 72         | 58            | 178            | 142           | 740               | 592           |
| DECIDUOUS                                         | 1.4                    | 20         | 14            | 20             | 14            | 25                | 18            |
| CITRUS & AVOCADOS                                 | 1.4                    | 3990       | 2793          | 9487           | 6641          | 6760              | 4732          |
| TRUCK                                             | 1.2                    | --         | --            | 359            | 215           | 739               | 443           |
| TOTALS                                            |                        |            | 2957          |                | 7644          |                   | 6440          |
| VOLUME OF MUNICIPAL SEWAGE<br>(ACRE-FEET IN 1958) |                        |            | ---           |                | 250           |                   | 850           |

AF/YR = ACRE-FEET PER YEAR

## CHAPTER VI

### A PLAN FOR GROUND WATER MANAGEMENT

#### INTRODUCTION

THE OBJECTIVE OF THE PLAN IS TO PROVIDE A WORKABLE SOLUTION TO THE DISTRICT'S GROUND WATER PROBLEMS. IN ADDITION, AN ATTEMPT IS MADE TO PROVIDE MAXIMUM FLEXIBILITY IN THE OPERATION OF EXISTING AND PLANNED FACILITIES. AS DISTRICT WATER SUPPLIES ARE NOT SUFFICIENT TO PROVIDE FOR ULTIMATE WATER REQUIREMENTS, FULL RECOGNITION IS GIVEN TO THE FACT THAT IMPORTED WATER WILL BE REQUIRED IN AS LITTLE AS 15 OR 20 YEARS.

THE MAJOR PROBLEMS OF THE DISTRICT ARE AS FOLLOWS:

- (1) EXISTING AND FUTURE OVERDRAFTS ON THE COASTAL PLAIN;
- (2) ADVERSE SALT BALANCE IN FILLMORE AND SANTA PAULA BASINS, AND TO A LESSER EXTENT, IN PIRU BASIN;
- (3) HIGH WATER-TABLE CONDITIONS PRODUCED OR AGGRAVATED BY STREAMBED RESERVOIR RELEASES.

#### EXISTING AND FUTURE OVERDRAFTS

A SUMMARY OF EXISTING AND FUTURE OVERDRAFTS ON THE COASTAL PLAIN IS GIVEN IN TABLE VI-1. THE SUGGESTION THAT THERE IS NO CURRENT OVERDRAFT ON THE OXNARD PLAIN MIGHT SEEM, AT FIRST, GROSSLY INCONSISTENT WITH THE UNDOUBTED INTRUSION OF SEA WATER INTO THE OXNARD AQUIFER AT PORT HUENEME. YET, ON A LONG-TERM BASIS, THIS SUGGESTION IS JUSTIFIED. THE AVERAGE OVERDRAFT IN THE OXNARD PLAIN - MOUND BASIN AREA FOR THE REPRESENTATIVE RAINFALL PERIOD 1936-57 WAS ESTIMATED TO BE 13,900 ACRE- FEET PER YEAR. WITH THE COMPLETION OF THE SANTA FELICIA DAM - LOWER RIVER SYSTEM BY THE DISTRICT IN 1955, THERE WAS MADE AVAILABLE TO THE OXNARD PLAIN AN AVERAGE ANNUAL SUPPLY OF 20,200 ACRE- FEET, WHICH MORE THAN OFFSETS THIS OVERDRAFT. THE LONG-TERM SIGNIFICANCE OF THE SEA-WATER INTRUSION HAS BEEN MASKED BY THE EFFECTS OF PROLONGED DROUGHT, WITH ACCOMPANYING HIGH PUMPING DEMAND AND SUBNORMAL RECHARGE. HOWEVER, SUCH A VIEWPOINT CAN IN NO WAY LESSEN THE SERIOUSNESS OF THE ACTUAL INTRUSION WHICH IS TAKING PLACE. AS AVERAGE ANNUAL DEMAND PROGRESSIVELY INCREASES, THERE WILL AGAIN BE OVERDRAFT, JUST AS THERE WAS PRIOR TO THE CONSTRUCTION OF THE SANTA FELICIA DAM - LOWER RIVER SYSTEM FACILITIES.

THOUGH MUCH LESS AN IMMEDIATE PROBLEM, THE LARGEST CURRENT

TABLE VI-1. OVERDRAFTS ON THE COASTAL PLAIN

| AREA                                     | AVERAGE<br>1936-57 | CURRENT           | 1970                | 1980                |
|------------------------------------------|--------------------|-------------------|---------------------|---------------------|
| OXNARD PLAIN - MOUND BASIN               | 13,900             | NONE <sup>1</sup> | 11,800 <sup>1</sup> | 15,000 <sup>1</sup> |
| FOX CANYON AQUIFER IN<br>PLEASANT VALLEY |                    | 19,000            | 16,400 <sup>2</sup> | 17,400 <sup>2</sup> |

<sup>1</sup> SANTA FELICIA DAM AND LOWER RIVER SYSTEM OPERATING AND SUPPLYING AN AVERAGE OF 20,200 ACRE-FEET PER YEAR TO MONTALVO BASIN.

<sup>2</sup> SANTA FELICIA DAM AND LOWER RIVER SYSTEM OPERATING AND SUPPLYING AN AVERAGE OF 8,300 ACRE-FEET PER YEAR TO PLEASANT VALLEY AREA.

OVERDRAFT IS ON THE FOX CANYON AQUIFER IN PLEASANT VALLEY. THIS OVERDRAFT WILL BE EASED WITHIN THE NEXT TWO YEARS WHEN THE DISTRIBUTION SYSTEM OF THE PLEASANT VALLEY COUNTY WATER DISTRICT IS BUILT. SCHEDULED DELIVERIES FROM THE MONTALVO BASIN WILL AVERAGE 8,300 ACRE-Feet PER YEAR. AFTER THIS INITIAL DECREASE, OVERDRAFT WILL AGAIN RISE.

THE EXISTING FACILITIES OF THE DISTRICT DO NOT SUPPLY ENOUGH WATER TO OFFSET COMPLETELY THE CURRENT OVERDRAFT. THERE IS AN URGENT NEED TO INCREASE SAFE YIELD BY SURFACE STORAGE ON SESPE CREEK.

#### ADVERSE SALT BALANCE

THE DETAILED SALT-BALANCE STUDY SUMMARIZED IN CHAPTER V SHOWS THAT SALTS ARE ACCUMULATING IN THE FILLMORE AND SANTA PAULA BASINS AND, TO A LESSER EXTENT, IN THE PIRU BASIN. AS POINTED OUT, THE HIGHER SALINITY WATERS ARE PRIMARILY IRRIGATION RETURN WATERS. IF LARGE QUANTITIES OF THESE WATERS COULD BE COLLECTED AND EXPORTED FROM THE BASINS, THE ADVERSE SALT-BALANCE PROBLEM COULD BE SOLVED; HOWEVER, SUCH A COLLECTION SYSTEM WOULD BE IMPOSSIBLE. THE ONLY FEASIBLE WAY TO REMOVE ADDITIONAL SALT FROM THE BASINS IS TO PUMP WATER, PREFERABLY FROM THE LOWER END OF THE BASIN, AND EXPORT IT. THE OVERALL OBJECTIVE IS TO CAUSE WATER TO CIRCULATE THROUGH THE BASINS AT A FASTER RATE. RECHARGE TO THE GROUND WATER BASINS FROM FLOOD WATERS OR STREAMBED RESERVOIR RELEASES OCCURS ONLY ALONG THE RELATIVELY NARROW STRIPS OF RECENT ALLUVIUM. AS A RESULT OF THIS STREAM PERCOLATION A GROUND WATER RIDGE IS BUILT UP BENEATH THE ALLUVIAL STRIP. UNDERGROUND FLOW IS AWAY FROM THE STREAM CHANNEL TOWARD BOTH SIDES OF THE BASIN. THE GROUND WATERS AWAY FROM THE STREAM TEND TO BE PUSHED FARTHER AWAY FROM THE STREAM. THIS RESULTS IN A BYPASSING, BUT NOT FLUSHING, OF WATERS WHICH LIKELY HAVE BEEN DETERIORATED BY IRRIGATION RETURN. ACTUALLY THESE POOR QUALITY BYPASSED WATERS ARE MOVING DOWNSTREAM, BUT VERY SLOWLY. PUMPING IN THE STREAM CHANNEL WILL INCREASE THE WATER-TABLE SLOPES AND ALLOW THESE WATERS TO MOVE OUT OF THEIR SEMI-TRAPPED POSITIONS.

THE WATER PUMPED MUST BE EXPORTED. WATER PUMPED FROM THE LOWER ENDS OF SANTA PAULA AND FILLMORE BASINS WOULD HAVE TO BE CARRIED BY PIPELINE AT LEAST AS FAR WEST AS SATICOY. IF PUMPING WERE COMMENCED SOON THE WATER WOULD BE OF ACCEPTABLE QUALITY FOR IRRIGATION PURPOSES. AS SALTS ARE CONTINUING TO ACCUMULATE, A LONG DELAY IN THE START OF THE PUMPING

WOULD MEAN THAT THE WATER PUMPED WOULD BE OF HIGHER AVERAGE SALINITY.

#### HIGH WATER-TABLE CONDITIONS

OPERATING SURFACE STORAGE ON PIRU AND SESPE CREEKS TO MAXIMIZE SPREADING DIVERSIONS AT SATICOY REQUIRES THAT THE RELEASES BE AT A HIGH RATE. IN A WET YEAR SUCH AS 1957-58 WATER LEVELS IN THE BASINS RISE SHARPLY FROM PERCOLATION OF UNCONTROLLED FLOOD FLOWS AND THERE IS RISING WATER AT THE LOWER ENDS OF THE BASINS. STREAMBED RESERVOIR RELEASES MAY AGGRAVATE THE HIGH WATER-TABLE CONDITIONS THAT NORMALLY OCCUR IN THE LOWER ENDS OF THE BASINS DURING WET YEARS. IF RELEASES COULD BE DELIVERED THROUGH THE BASINS BY PIPELINE, THESE HIGH-WATER TABLE CONDITIONS, WITH THE HELP OF THE SALT-BALANCE PUMPING, COULD BE RELIEVED CONSIDERABLY.

#### ELEMENTS OF THE PLAN

##### MAIN PIPELINE DOWN SANTA CLARA RIVER VALLEY

THIS PIPELINE WOULD PERMIT DIRECT DELIVERIES OF SANTA FELICIA WATER TO MONTALVO BASIN SPREADING GROUNDS OR TO DOMESTIC OR IRRIGATION LINES (PLATE 33). CONSIDERATION SHOULD BE GIVEN TO MAKING THIS PIPELINE OF SUFFICIENT SIZE FOR THE DELIVERY OF FEATHER RIVER WATER, IF ARRANGEMENTS CAN BE MADE FOR DELIVERY OF THIS WATER TO PIRU LAKE. THOUGH NOT ESSENTIAL TO THE OPERATION OF THE PLAN, THE DELIVERY OF FEATHER RIVER WATER TO PIRU LAKE WOULD GREATLY ENHANCE ITS FLEXIBILITY. TO PERMIT CONTROL OF HIGH WATER-TABLE CONDITIONS IN THE LOWER ENDS OF THE BASINS, RESERVOIR RELEASES COULD BE ALLOWED TO BYPASS THE BASINS IN THIS PIPELINE.

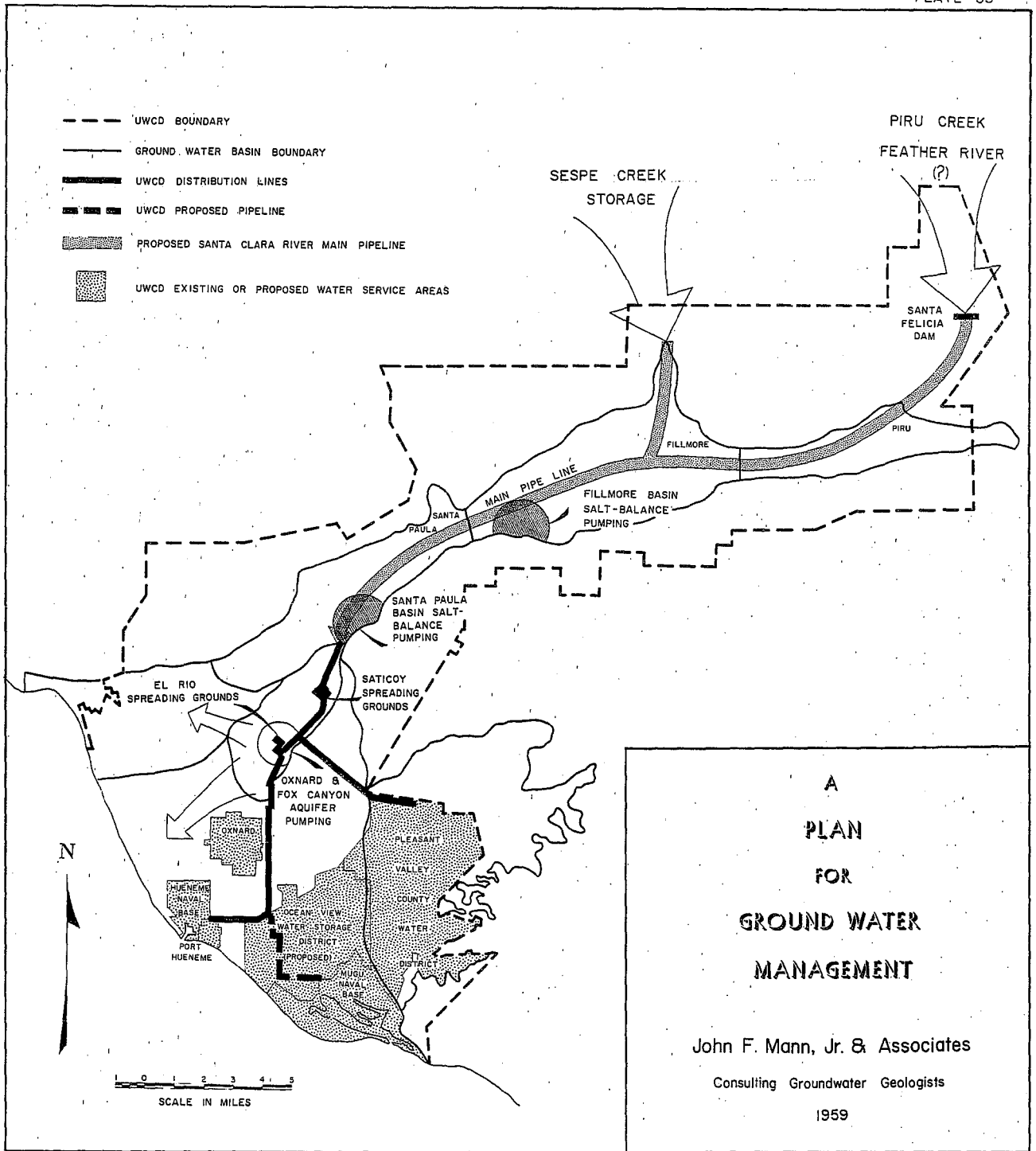
##### SURFACE STORAGE ON SESPE CREEK

THE CURRENT AND FUTURE OVERDRAFTS IN THE DISTRICT POINT UP THE NECESSITY FOR SURFACE STORAGE ON SESPE CREEK TO DEVELOP ADDITIONAL SAFE YIELD AT REASONABLE COST.

##### FEEDER FROM SESPE GORGE TO MAIN PIPELINE

RELEASES FROM SURFACE STORAGE ON SESPE CREEK COULD BE DIVERTED NEAR THE GAGING STATION AND DELIVERED THROUGH A BRANCH PIPELINE TO THE MAIN PIPELINE. THIS FEEDER WILL PERMIT FILLMORE BASIN TO BE BYPASSED WITH SESPE CREEK RELEASES, IF OPERATIONAL OBJECTIVES DEEM THIS ADVISABLE. WELLS AT LOWER END OF FILLMORE BASIN

WATER PUMPED TO IMPROVE SALT BALANCE IN THE FILLMORE BASIN COULD BE EXPORTED TO MONTALVO BASIN IN THE MAIN PIPELINE. IF PUMPING WERE COMMENCED SOON, THIS WATER WOULD BE OF ACCEPTABLE CHEMICAL QUALITY FOR



USE ON THE OXNARD PLAIN AND IN PLEASANT VALLEY, ESPECIALLY FOR IRRIGATION PURPOSES. BY BLENDING WITH WATER FROM RESERVOIR RELEASES AND THE FEATHER RIVER PROJECT A GOOD QUALITY MIXTURE COULD BE OBTAINED. WITH THE OPTION OF BYPASSING RESERVOIR RELEASES, AND WITH SALT-BALANCE PUMPING, A GOOD MEASURE OF CONTROL COULD BE OBTAINED ON HIGH WATER-TABLE PROBLEMS.

#### WELLS AT LOWER END OF SANTA PAULA BASIN

WATER PUMPED FOR SALT-BALANCE CONTROL IN THE LOWER END OF THE SANTA PAULA BASIN COULD BE DELIVERED THROUGH THE MAIN PIPELINE TO THE MONTALVO BASIN. THE OPPORTUNITIES FOR UPGRADING QUALITY BY BLENDING WITH RESERVOIR RELEASE WATER, AND FOR CONTROL OF HIGH WATER TABLES ARE ALMOST AS GOOD AS IN THE FILLMORE BASIN.

#### WELLS TO THE FOX CANYON AQUIFER

TO MAKE AVAILABLE TO THE OXNARD PLAIN A SOURCE OF SUPPLEMENTARY WATER DURING THE PRESENT PROLONGED DROUGHT PERIOD AND BEYOND IF NECESSARY, IT IS PROPOSED THAT WELLS BE DRILLED TO THE FOX CANYON AQUIFER IN THE MONTALVO BASIN. THIS WATER CAN BE TRANSPORTED TO AREAS NEAR THE COAST IN ORDER TO RELIEVE THE PUMPING DEMANDS ON THE OXNARD AQUIFER.

#### ADDITIONAL DISTRIBUTION FACILITIES ON THE COASTAL PLAIN

WATER PUMPED FROM THE OXNARD AQUIFER AT THE EL RIO SPREADING GROUNDS IS CURRENTLY BEING SUPPLIED TO THE CITIES OF OXNARD AND PORT HUENEME, AND TO THE HUENEME NAVAL BASE. A BRANCH LINE IS PLANNED, TO SERVE THE MUGU NAVAL BASE. WITHIN TWO YEARS THERE WILL BE DISTRIBUTION FACILITIES IN THE PLEASANT VALLEY COUNTY WATER DISTRICT; THIS AREA WILL BE SERVED FROM THE MONTALVO BASIN THROUGH THE AGRICULTURAL LINE BUILT BY THE DISTRICT IN 1955. THE PROPOSED OCEAN VIEW WATER STORAGE DISTRICT IS EXPECTED TO PROVIDE DISTRIBUTION FACILITIES OVER ANOTHER LARGE AREA OF THE COASTAL PLAIN. IN ADDITION TO THE CONSTRUCTED AND PROPOSED DISTRIBUTION FACILITIES, ADDITIONAL FACILITIES SHOULD BE BUILT TO SERVE THE REMAINING COASTAL AREAS.

#### GROUND WATER MANAGEMENT

##### PIRU BASIN

IN THE PIRU BASIN THERE APPEARS TO BE A RATHER SMALL ADVERSE SALT BALANCE. THE RELATIVELY GOOD SALT-BALANCE CONDITION MAY BE ATTRIBUTED TO THE FACT THAT THERE IS A LARGE OUT UNDERFLOW AND CONSIDERABLE PUMPING FOR EXPORT AT THE LOWER BASIN BOUNDARY. THERE ARE LOCAL AREAS OF WELL-

WATER DETERIORATION, AND A RATHER SEVERE QUALITY PROBLEM IN THE EASTERN PART OF THE BASIN. WATER SHOULD BE MADE AVAILABLE IN THE MAIN PIPELINE TO HELP WITH THESE LOCAL WATER QUALITY PROBLEMS. FUTURE PUMPING NEAR THE LOWER BASIN BOUNDARY TO IMPROVE SALT BALANCE MAY BE JUSTIFIED. SUCH PUMPING, COMBINED WITH BYPASSED RESERVOIR RELEASES, WOULD HELP CONTROL HIGH WATER-TABLE PROBLEMS.

#### FILLMORE BASIN

THERE IS A PRONOUNCED ADVERSE SALT BALANCE IN THE FILLMORE BASIN. ALTHOUGH WELL-WATER DETERIORATION IS RELATED PRIMARILY TO IRRIGATION RETURN WATER, EXTENSIVE AREAS OF PHREATOPHYTES CONTRIBUTE TO THE SALT ACCUMULATION PROBLEM. LOCAL WELL-WATER DETERIORATION OCCURS IN A FEW PLACES IN THE SESPE UPLAND, OVER MUCH OF THE POLE CREEK FAN, AND IN LARGE AREAS SOUTH OF THE SANTA CLARA RIVER. SALT-BALANCE PUMPING AND EXPORT THROUGH THE MAIN PIPELINE SHOULD AVERAGE AT LEAST 6000 ACRE-Feet PER YEAR. A HIGHER RATE OF PUMPING WILL PRODUCE AN ACCELERATED RATE OF IMPROVEMENT. A SERIOUS PROBLEM IS BEING EXPERIENCED BY THE CITY OF FILLMORE, BOTH IN OBTAINING DOMESTIC WATER OF GOOD QUALITY AND IN KEEPING THE EFFLUENT FROM THE NEW MUNICIPAL SEWAGE TREATMENT PLANT WITHIN THE QUALITY LIMITS SPECIFIED BY THE REGIONAL WATER POLLUTION CONTROL BOARD. GOOD QUALITY WATER FROM THE RESERVOIRS SHOULD BE MADE AVAILABLE TO THE CITY OF FILLMORE FROM THE MAIN PIPELINE AND FROM THE SESPE CREEK FEEDER. THE RESERVOIR WATER SHOULD ALSO BE MADE AVAILABLE TO ASSIST WITH THE SEVERE QUALITY PROBLEMS ON THE SOUTH SIDE OF THE RIVER. HIGH WATER-TABLE PROBLEMS AT THE LOWER END OF THE BASIN CAN BE CONTROLLED THROUGH THE BYPASSING OF RESERVOIR RELEASES COMBINED WITH THE SALT-BALANCE PUMPING.

#### SANTA PAULA BASIN

THE SALT-BALANCE CALCULATIONS INDICATE THAT SALT ACCUMULATION IN THE SANTA PAULA BASIN IS EVEN MORE SERIOUS THAN IN THE FILLMORE BASIN. SALT-BALANCE PUMPING AT THE LOWER END OF THE SANTA PAULA BASIN SHOULD AVERAGE AT LEAST 9000 ACRE-Feet PER YEAR. A HIGHER RATE OF PUMPING WOULD ACCELERATE THE IMPROVEMENT. THIS WATER COULD BE PUT INTO THE MAIN PIPELINE AND EXPORTED.

LIKE THE CITY OF FILLMORE, THE CITY OF SANTA PAULA HAS BEEN EXPERIENCING DIFFICULTIES WITH THE QUALITY OF DOMESTIC WATERS, AND IN MEETING SEWAGE EFFLUENT REQUIREMENTS. DIRECT RESERVOIR RELEASES IN THE

MAIN PIPELINE COULD BE MADE AVAILABLE TO THE CITY OF SANTA PAULA JUST ABOVE THE DELIVERY POINT OF THE FILLMORE BASIN SALT-BALANCE PUMPAGE. WATER SHOULD ALSO BE MADE AVAILABLE ALONG THE MAIN PIPELINE TO USE IN LOCAL AREAS OF WELL-WATER DETERIORATION.

#### MONTALVO BASIN

THE MONTALVO BASIN IS THE CENTER OF THE GROUND WATER MANAGEMENT PLAN. WATER DELIVERED FROM UPSTREAM THROUGH THE MAIN PIPELINE CAN BE DIRECTED TO THE SATICOY OR EL RIO SPREADING GROUNDS, OR DELIVERED THROUGH EXISTING, PROPOSED, AND RECOMMENDED MUNICIPAL AND AGRICULTURAL LINES. THE ADDITIONAL SAFE YIELD FROM SURFACE STORAGE ON SESPE CREEK, AND THE INCIDENTAL SAFE YIELD DERIVED FROM THE SALT-BALANCE PUMPING WOULD ALMOST OFFSET ANTICIPATED OVERDRAFTS UNTIL THE ARRIVAL OF FEATHER RIVER WATER. THE ADDITIONAL WATER REQUIRED COULD BE MET BY MODEST WITHDRAWALS FROM STORAGE IN THE FOX CANYON AQUIFER.

BECAUSE OF GREAT FLEXIBILITY IN BLENDING, THE WATER DELIVERED THROUGH THE MAIN PIPELINE COULD BE MAINTAINED AT A GOOD QUALITY LEVEL AT ALL TIMES. IN ADDITION TO BLENDING, "SLUG-TYPE" DELIVERIES COULD BE MADE. FOR EXAMPLE, UNBLENDED HIGH QUALITY RESERVOIR RELEASES COULD BE SPREAD AT THE EL RIO SPREADING GROUNDS DURING LOW DEMAND PERIODS THEN PUMPED OUT SEVERAL MONTHS LATER BY THE PRODUCTION WELLS ON THE SOUTHWEST SIDE OF THE SPREADING GROUNDS. THE BETTER QUALITY FOX CANYON WATERS COULD BE PUMPED FOR DIRECT DELIVERIES OR FOR BLENDING PURPOSES.

#### MOUND BASIN

THE MOUND BASIN OFFERS RELATIVELY FEW OPPORTUNITIES FOR DIRECT GROUND WATER MANAGEMENT. THERE IS A MODERATE OVERDRAFT AT THE PRESENT TIME, WITH ACCOMPANYING INTRUSION OF SEA WATER INTO THE SEAWARD EXTENSIONS OF THE BASAL UPPER PLEISTOCENE AQUIFERS. WATER QUALITY AVERAGES SOMEWHAT POORER THAN IN THE OTHER DISTRICT BASINS. AS THE CITY OF VENTURA EXPANDS INTO THE MOUND BASIN, IT IS EXPECTED THAT INCREASINGLY MORE WATER WILL BE SUPPLIED FROM CITY SOURCES AND DELIVERED TO THE NEWLY ANNEXED AREAS. BECAUSE OF THE INFERIOR QUALITY OF THE WATER IN THE CITY OF VENTURA'S DEACH WELLS, IT IS ANTICIPATED THAT THE CITY'S DRAFT ON THE MOUND BASIN WILL DECREASE IN THE NEAR FUTURE AS THE BETTER QUALITY GRAVITY WATER FROM CASITAS RESERVOIR IS MADE AVAILABLE. THE SUPPLIES FROM CASITAS RESERVOIR ARE EXPECTED TO BE ADEQUATE UNTIL AFTER 1980. THERE IS A HIGH PROBABILITY THAT THE MOUND BASIN WILL

EXPERIENCE NO SUBSTANTIAL INCREASE IN OVERDRAFT PRIOR TO 1980. IF WATER OF BETTER QUALITY WERE DESIRED IN PARTS OF THE MOUND BASIN, IT COULD BE DELIVERED FROM THE MONTALVO BASIN THROUGH EXISTING PIPELINES OR NEW DISTRIBUTION FACILITIES.

#### OXNARD AQUIFER

SEA-WATER INTRUSION INTO THE OXNARD AQUIFER NEAR PORT HUENEME IS THE MOST SERIOUS GROUND WATER PROBLEM IN THE DISTRICT. THIS IS CAUSED BY EXCESSIVE PUMPING DRAFT AND AGGRAVATED BY SUBNORMAL DROUGHT RECHARGE. IT IS ESSENTIAL THAT SEA-WATER INTRUSION INTO THE OXNARD AQUIFER BE STOPPED, AND THAT STEPS BE TAKEN TO REVERSE THE LANDWARD MOVEMENT OF THE SEA-WATER WEDGE. TO ACHIEVE SUCH AN OBJECTIVE, SEVERAL PROCEDURES HAVE BEEN CONSIDERED:

- (1) INCREASING UNDERFLOW FROM THE MONTALVO BASIN;
- (2) CREATION OF A FRESH-WATER BARRIER BY INJECTION WELLS LANDWARD FROM THE INTRUDED AREA;
- (3) REDUCING PUMPING DRAFT.

THE POSSIBILITIES OF INCREASING UNDERFLOW ARE RESTRICTED BY THE LIMITED TRANSMISSIBILITY OF THE OXNARD AQUIFER AND RECENTLY BY THE SUBNORMAL SUPPLIES OF WATER AVAILABLE FOR REPLENISHING THE MONTALVO BASIN. THE UNCOOPERATIVE CLIMATIC CYCLE HAS NOT PERMITTED THE DISTRICT TO OPERATE THE SANTA FELICIA-LOWER RIVER FACILITIES TO MAXIMUM ADVANTAGE. WITH A RETURN TO WETTER CONDITIONS, LARGE SUPPLIES WILL BE AVAILABLE FOR SPREADING IN THE MONTALVO BASIN.

THE CREATION OF A FRESH-WATER BARRIER BY A LINE OF INJECTION WELLS SIMILAR TO THOSE IN THE WEST BASIN OF THE LOS ANGELES COASTAL PLAIN HAS BEEN CONSIDERED AS A MEANS OF CURBING SEA-WATER INTRUSION AT PORT HUENEME. TO ENCIRCLE THE EXISTING SEA-WATER WEDGE WOULD REQUIRE A LINE OF INJECTION WELLS ALMOST SIX MILES LONG. CAPITAL COSTS FOR THE WEST BASIN PROJECT HAVE AMOUNTED TO \$186,000 PER MILE. THE RECHARGE LINE AT PORT HUENEME WOULD COST NEARLY \$1,000,000. IN ADDITION TO THIS WOULD BE THE COST OF WATER BROUGHT FROM INLAND AREAS FOR INJECTION. IT IS VERY DOUBTFUL THAT THE COSTS OF SUCH A PROJECT COULD BE JUSTIFIED.

THE MOST FEASIBLE MEANS OF ALLEVIATING THIS SEA-WATER INTRUSION IS BY A REDUCTION OF PUMPING IN THE COASTAL AREAS AND SUPPLYING THESE DEMANDS BY WATER BROUGHT FROM INLAND. DISTRIBUTION LINES FROM THE EL RIO

SPREADING GROUNDS ARE CURRENTLY SUPPLYING WATER TO THE CITIES OF OXNARD AND PORT HUENEME, AND TO HUENEME NAVAL BASE. ANOTHER LINE IN THE PLANNING STAGES WILL SERVE THE MUGU NAVAL BASE. JUST RECENTLY THE OCEAN VIEW WATER STORAGE DISTRICT WAS ORGANIZED; IT IS PLANNING A SERIES OF DISTRIBUTION LINES OVER A LARGE COASTAL PORTION OF THE OXNARD AQUIFER. THE REMAINING AREAS OVERLYING THE COASTAL PORTIONS OF THE OXNARD AQUIFER SHOULD BE ENCOURAGED TO FORM ORGANIZATIONS FOR THE DISTRIBUTION OF WATER DELIVERED FROM INLAND.

THE SOURCES OF INLAND WATER USED WHEN AVAILABLE ARE AS FOLLOWS:

- (1) DIVERSIONS OF RISING WATER AT SATICOY;
- (2) DIVERSIONS OF STREAMBED RELEASES FROM SANTA FELICIA DAM;
- (3) PUMPAGE FROM THE OXNARD AQUIFER IN THE MONTALVO BASIN.

BECAUSE THESE SUPPLIES MIGHT NOT ALWAYS BE AVAILABLE IN THE AMOUNTS NEEDED, IT IS RECOMMENDED THAT WELLS BE DRILLED TO THE FOX CANYON AQUIFER IN THE MONTALVO BASIN TO PROVIDE A SUPPLEMENTARY SUPPLY. WHEN RECOMMENDED UPSTREAM FACILITIES ARE BUILT, THE ADDITIONAL WATER COULD BE SUPPLIED THROUGH THE MAIN PIPELINE FROM SANTA FELICIA DAM, SESPE CREEK SURFACE STORAGE, AND THE SALT-BALANCE PUMPING.

CONSIDERATION HAS ALSO BEEN GIVEN TO THE POSSIBILITY OF MAKING UNDERGROUND STORAGE AVAILABLE IN THE SEMI-PERCHED ZONE SO THAT ADDITIONAL FLOOD WATERS COULD BE SPREAD. THIS WOULD HAVE TO BE ACCOMPLISHED BY PUMPING FROM SHALLOW WELLS. UNLESS A USE COULD BE FOUND FOR THE BRACKISH WATERS, THEY WOULD HAVE TO BE EXPORTED TO THE OCEAN. THE WATER COULD POSSIBLY BE USED IN AN EXPERIMENTAL PLANT DESIGNED TO CONVERT BRACKISH WATER TO FRESH WATER. THE AMOUNT OF WATER SUCH A PLANT COULD USE WOULD NOT EQUAL THE AMOUNT DERIVED FROM IRRIGATION RETURN (EVEN AFTER AN ALLOWANCE FOR THE DOWNWARD LEAKAGE TO THE OXNARD AQUIFER). JUSTIFYING THE COSTS OF PUMPING AND EXPORTING, AND MAINTAINING AVAILABLE STORAGE CAPACITY WOULD ALL BE DIFFICULT.

#### FOX CANYON AQUIFER

THE FOX CANYON AQUIFER IS HEAVILY PUMPED IN PLEASANT VALLEY. CURRENT OVERDRAFT IS ESTIMATED AS 19,000 ACRE-Feet PER YEAR. A PORTION OF THIS OVERDRAFT WILL SOON BE OFFSET BY DELIVERIES FROM THE MONTALVO BASIN TO THE PLEASANT VALLEY COUNTY WATER DISTRICT IN THE AVERAGE AMOUNT OF 8300 ACRE-Feet PER YEAR. ALTHOUGH ON THE OXNARD PLAIN THE PUMPING FROM

THE FOX CANYON AQUIFER HAS BEEN MINOR, THERE IS LITTLE, IF ANY, UNUSED SAFE YIELD. FURTHERMORE, UNLIKE THE OXNARD AQUIFER, THERE IS NO POSSIBILITY OF SUBSTANTIALLY INCREASING RECHARGE TO THE FOX CANYON AQUIFER. THE MANAGEMENT OF THESE TWO AQUIFERS REQUIRES COMPLETELY DIFFERENT APPROACHES. THE FOX CANYON AQUIFER IS MOST PRACTICALLY VIEWED AS A VERY LARGE RESERVE OF GROUND WATER. THE FRESH WATER IN STORAGE IN THE FOX CANYON AQUIFER BENEATH THE OXNARD PLAIN, MONTALVO BASIN, AND PLEASANT VALLEY IS ESTIMATED AS 6 MILLION ACRE-FEET. ADDITIONAL LARGE VOLUMES OF FRESH WATER ARE STORED IN THE SUBSEA EXTENSIONS. A LARGE PERCENTAGE OF THIS WATER CAN BE RECOVERED; IT IS ENTIRELY PRACTICABLE AND FEASIBLE TO DO SO. FOR MANY YEARS WATER HAS BEEN DRAWN FROM STORAGE IN THE FOX CANYON AQUIFER BY PUMPING IN PLEASANT VALLEY, AND NO FOX CANYON WELL HAS YET BEEN INTRUDED BY SEA WATER. NEVERTHELESS, IN ALL PROBABILITY SEA-WATER INVASION HAS ALREADY STARTED IN THE AQUIFER'S SUBSEA EXTENSIONS.

IT IS RECOMMENDED THAT A SMALL PORTION OF THE WATER STORED IN THE FOX CANYON AQUIFER BE PUMPED TO HELP RELIEVE THE HEAVY DRAFT ON THE OXNARD AQUIFER. TO MINIMIZE THE EFFECT OF THIS PUMPING'S CONTRIBUTION TOWARD INDUCING SEA-WATER INTRUSION, THE WELLS SHOULD BE LOCATED FAR INLAND--IN THE MONTALVO BASIN. THE QUALITY OF THIS WATER WILL BE APPRECIABLY BETTER THAN MOST WATERS IN THE OXNARD AQUIFER. BY DRAWING MODESTLY ON THESE FOX CANYON RESERVES, SUPPLEMENTAL WATER CAN BE MADE AVAILABLE FOR ALL USES ON THE COASTAL PLAIN OF THE DISTRICT UNTIL THE ARRIVAL OF FEATHER RIVER WATER.

NO RECOMMENDATION IS MADE THAT THESE RESERVES BE WITHDRAWN INDISCRIMINATELY. THIS PUMPING CAN NOT SUBSTITUTE FOR WATER FROM SAFE YIELD SOURCES. EVERY EFFORT SHOULD BE MADE TO DEVELOP ALL ECONOMICALLY FEASIBLE UPSTREAM SURFACE STORAGE. EVENTUALLY, SUPPLEMENTAL SAFE YIELD WATER WILL BE REQUIRED FROM THE FEATHER RIVER PROJECT. UNTIL THE ARRIVAL OF FEATHER RIVER WATER, AVAILABLE SAFE YIELD SUPPLIES SUPPLEMENTED BY A MODEST DRAFT ON VERY LARGE RESERVES, COULD SUPPLY ALL DISTRICT NEEDS.

## APPENDICES

### GLOSSARY

ACRE-FOOT. ONE ACRE-FOOT IS THE AMOUNT OF WATER REQUIRED TO COVER 1 ACRE 1 FOOT IN DEPTH = 43,560 CUBIC FEET = 325,851 GALLONS = 25.2083 MINER'S INCH DAYS. ONE ACRE-FOOT OF WATER WITH A TOTAL DISSOLVED SOLIDS CONCENTRATION OF 735 PARTS PER MILLION CONTAINS 1 TON OF DISSOLVED SALTS. ONE ACRE-FOOT OF OIL FIELD LIQUID = 7764 BARRELS.

ALKALINE. WATER OR SOILS WHICH CONTAIN A SUFFICIENT AMOUNT OF ALKALI SUBSTANCES (SALTS OF SODIUM, POTASSIUM, MAGNESIUM AND CALCIUM) PRESENT TO RAISE THE PH-VALUE ABOVE 7.0, OR TO BE HARMFUL TO THE GROWTH OF CROPS.

ALLUVIAL FAN. A BODY OF ALLUVIAL MATERIAL DEPOSITED BY A SWIFT TRIBUTARY STREAM FLOWING DOWN FROM A HIGH LAND ON TO A WIDE AND NEARLY LEVEL VALLEY FLOOR. THE FAN BUILDS UP RADIALY OUTWARD FROM THE POINT AT WHICH THE TRIBUTARY EMERGES.

ALLUVIUM. STREAM DEPOSITS OF COMPARATIVELY RECENT GEOLOGIC TIME.

ANTICLINE. A FOLD OR ARCH OF ROCK STRATA DIPPING IN OPPOSITE DIRECTIONS FROM AN AXIS.

AQUIFER. A GEOLOGIC FORMATION OR STRUCTURE THAT TRANSMITS WATER IN SUFFICIENT QUANTITY TO SUPPLY PUMPING WELLS OR SPRINGS.

ARTESIAN HEAD (PRESSURE). THE WATER LEVEL IN A WELL WHICH TAPS A CONFINED AQUIFER WILL EITHER STAND ABOVE THE WATER TABLE (POSITIVE ARTESIAN HEAD) OR FALL BELOW THE WATER TABLE (NEGATIVE ARTESIAN HEAD).

AXIAL TRACE. THE INTERSECTION OF THE AXIAL PLANE OF A FOLD WITH THE GROUND SURFACE.

BASE PERIOD. A PERIOD CHOSEN FOR DETAILED HYDROLOGIC ANALYSIS BECAUSE PREVAILING CONDITIONS OF WATER SUPPLY AND CLIMATE WERE APPROXIMATELY EQUIVALENT TO MEAN CONDITIONS, AND BECAUSE ADEQUATE DATA FOR SUCH HYDROLOGIC ANALYSIS WERE AVAILABLE.

CONFINED AQUIFER. AN AQUIFER WHICH IS SURROUNDED BY FORMATIONS OF LESS PERMEABLE OR IMPERMEABLE MATERIAL. WATER IS UNDER SUFFICIENT HEAD TO CAUSE IT TO RISE ABOVE THE ZONE OF SATURATION IF THE AQUIFER IS PENETRATED.

CONSUMPTIVE USE OF WATER. WATER CONSUMED AND EVAPORATED BY VEGETATIVE GROWTH, SOIL, WATER SURFACES, URBAN AND NONVEGETATIVE TYPES OF LAND USE.

CONNATE WATER. WATER ENTRAPPED IN THE INTERSTICES OF A SEDIMENTARY ROCK AT THE TIME THE ROCK WAS DEPOSITED.

CONTAMINATION. IMPAIRMENT OF THE QUALITY OF WATER BY SEWAGE OR INDUSTRIAL WASTE TO A DEGREE WHICH CREATES A HAZARD TO PUBLIC HEALTH.

CONTINENTAL DEPOSIT. SEDIMENTARY DEPOSITS LAID DOWN WITHIN A GENERAL LAND AREA AND DEPOSITED IN LAKES OR STREAMS OR BY THE WIND.

CROSS-SECTION. A PROFILE PORTRAYING AN INTERPRETATION OF A VERTICAL SECTION OF THE EARTH EXPLORED BY GEOPHYSICAL AND/OR GEOLOGICAL METHODS.

CUBIC FEET PER SECOND (SECOND FEET). ONE CUBIC FOOT PER SECOND IS EQUIVALENT TO 448.83 GALLONS PER MINUTE, 50 MINERS INCHES (SOUTHERN CALIFORNIA), 1.983471 ACRE-FeET PER DAY, OR 723.97 ACRE-FeET PER YEAR.

CUBIC FOOT. ONE CUBIC FOOT CONTAINS 7.4805 GALLONS.

DEGRADATION. IMPAIRMENT OF THE QUALITY OF WATER DUE TO CAUSES OTHER THAN DISPOSAL OF SEWAGE AND INDUSTRIAL WASTES.

DIASTROPHISM. THE PROCESSES BY WHICH THE CRUST OF THE EARTH IS DEFORMED, PRODUCING MOUNTAINS, FLEXURES AND FOLDS OF STRATA, AND FAULTS.

DIP. THE ANGLE AT WHICH A STRATUM IS INCLINED FROM THE HORIZONTAL.

DRAW. MINOR FOLDING OF STRATA ALONG THE WALLS OF A FAULT IN WHICH THE "DRAW" OF DISPLACEMENT HAS PRODUCED FLEXURES IN THE BEDS ON EITHER SIDE.

EFFECTIVE SALINITY. THE RESIDUAL EQUIVALENTS PER MILLION (OF CATIONS OR ANIONS) WHICH CANNOT BE BOUND UP IN THE SALTS OF CALCIUM CARBONATE, MAGNESIUM CARBONATE AND CALCIUM SULFATE.

EFFLUENT. SEWAGE, WATER, OR OTHER LIQUID, PARTIALLY OR COMPLETELY TREATED, OR IN ITS NATURAL STATE, FLOWING OUT OF A RESERVOIR, OR TREATMENT PLANT, OR PART THEREOF.

ELECTRIC LOG. THE LOG OF A WELL OR BORE HOLE OBTAINED BY LOWERING ELECTRODES IN THE HOLE AND MEASURING VARIOUS ELECTRICAL PROPERTIES OF THE GEOLOGICAL FORMATIONS TRAVERSED.

EVAPOTRANSPIRATION. WATER WITHDRAWN FROM THE SOIL BY EVAPORATION AND PLANT TRANSPIRATION.

FAULT. A FRACTURE OR FRACTURE ZONE ALONG WHICH THERE HAS BEEN DISPLACEMENT OF THE TWO SIDES RELATIVE TO ONE ANOTHER PARALLEL TO THE FRACTURE.

FAULT PLANE. THE SURFACE ALONG WHICH MOVEMENT HAS TAKEN PLACE.

FAULT SCARP. THE CLIFF FORMED BY A FAULT. MOST FAULT SCARPS HAVE BEEN MODIFIED BY EROSION SINCE THE FAULTING.

FAULT TRACE. THE INTERSECTION OF A FAULT AND THE EARTH'S SURFACE AS REVEALED BY DISLOCATION OF FENCES AND ROADS, BY RIDGES AND FURROWS IN THE GROUND, BY DIAGONAL RUPTURES, ETC.

FAULT TROUGH. A RELATIVELY DEPRESSED FAULT BLOCK LYING BETWEEN TWO FAULTS WITH ROUGHLY PARALLEL STRIKES.

FIELD CAPACITY. THE AMOUNT OF WATER HELD IN A SOIL BY CAPILLARY ACTION AFTER GRAVITATIONAL WATER HAS PERCOLATED DOWNWARD AND DRAINED AWAY; EXPRESSED AS THE RATIO OF THE WEIGHT OF WATER RETAINED TO THE WEIGHT OF DRY SOIL.

FREE WATER TABLE. THE SURFACE OF A BODY OF GROUND WATER NOT OVERLAIN BY IMPERVIOUS MATERIALS, AND MOVING UNDER CONTROL OF THE WATER TABLE SLOPE.

GRAVEL-PACKED WELL. ARTIFICIAL ADDITION OF GRADED GRAVEL TO A WELL TO PRODUCE A NEARLY NATURAL SCREEN BETWEEN THE FORMATION (USUALLY FINE SAND) AND THE PERFORATED CASING.

HARDNESS. A CHARACTERISTIC OF WATER, CHIEFLY DUE TO THE EXISTENCE THEREIN OF THE CARBONATES AND SULFATES OF CALCIUM, IRON AND MAGNESIUM, WHICH CAUSES "CURDLING" OF WATER WHEN SOAP IS USED, AN INCREASED CONSUMPTION OF SOAP, THE DEPOSITION OF SCALE IN BOILERS, INJURIOUS EFFECTS IN SOME INDUSTRIAL PROCESSES, AND SOMETIMES OBJECTIONABLE TASTE IN THE WATER.

HEAD. THE DISTANCE ABOVE OR BELOW THE LAND SURFACE, TO THE ELEVATION TO WHICH THE WATER IN AN ARTESIAN AQUIFER OR GROUND WATER BASIN WOULD RISE, AT A GIVEN POINT OVER THE AQUIFER OR BASIN, IF FREE TO DO SO.

HYDRAULIC CONDUCTIVITY. THE ABILITY OF A MATERIAL TO TRANSMIT WATER (SEE PERMEABILITY).

HYDRAULIC CONTINUITY. AQUIFERS, GROUND WATER BASINS, OR OTHER HYDRAULIC SYSTEMS INTERCONNECTED IN SUFFICIENT DEGREE TO ALLOW THE MOVEMENT OF GROUND WATER TO OCCUR FROM ONE TO ANOTHER OR PARTS THEREOF.

HYDRAULIC GRADIENT. A PROFILE SHOWING THE STATIC LEVEL OF WATER AT ALL POINTS ON THE PROFILE. THE WATER TABLE REGISTERS THE HYDRAULIC GRADIENTS OF FREE GROUND WATER, AND THE PIEZOMETRIC SURFACE THOSE OF CONFINED WATER.

HYDROGRAPH. A GRAPHIC PLOT OF CHANGES IN FLOW OF WATER OR IN ELEVATION OF WATER LEVEL AGAINST TIME.

IMPERMEABLE. HAVING A TEXTURE THAT DOES NOT PERMIT WATER TO MOVE THROUGH IT PERCEPTIBLY UNDER THE HEAD DIFFERENCES ORDINARILY FOUND IN SUB-SURFACE WATER.

INCOMPETENT SEDIMENTS. MATERIAL WHICH LACKS SUFFICIENT FIRMNESS AND FLEXIBILITY TO TRANSMIT PRESSURE FOR ANY DISTANCE.

INFILTRATION. THE FLOW OF A FLUID INTO A SUBSTANCE THROUGH PORES OR SMALL OPENINGS; IT CONNOTES FLOW INTO A SUBSTANCE RATHER THAN THROUGH A POROUS SUBSTANCE.

INITIAL FALL SOIL MOISTURE DEFICIENCY. THE AMOUNT OF WATER REQUIRED TO RESTORE THE SOIL TO FIELD CAPACITY AT THE START OF A RUNOFF YEAR (OCTOBER 1).

MINER'S INCH. ONE MINER'S INCH IS EQUIVALENT TO 1/50 OF A SECOND FOOT OR APPROXIMATELY 9 GALLONS PER MINUTE. (SOUTHERN CALIFORNIA UNIT)

OVERDRAFT. THE EXTRACTION OF A QUANTITY OF WATER FROM A GROUND WATER BASIN OR AQUIFER IN EXCESS OF THE SAFE YIELD, RESULTING IN A DETRIMENTAL DEPLETION OF STORAGE IN THE BASIN.

PERCHED WATER. GROUND WATER OCCURRING IN A SATURATED ZONE SEPARATED FROM THE MAIN BODY OF GROUND WATER BY UNSATURATED ROCK.

PERCOLATION. FLOW OF WATER THROUGH INTERCONNECTED OPENINGS OF SATURATED GRANULAR MATERIAL UNDER HYDRAULIC GRADIENTS COMMONLY DEVELOPED UNDER-GROUND.

PERMEABILITY. THE CAPACITY OF A WATER-BEARING MATERIAL TO TRANSMIT WATER. THE PERMEABILITY COEFFICIENT IS THE NUMBER OF GALLONS OF WATER PER DAY THAT IS CONDUCTED Laterally THROUGH EACH MILE OF WATER-BEARING BED FOR EACH FOOT OF THICKNESS OF THE BED AND FOR EACH FOOT PER MILE OF HYDRAULIC GRADIENT.

PH. HYDROGEN-ION CONCENTRATION. REPRESENTS THE WEIGHT OF HYDROGEN IONS IN GRAMS PER LITER OF SOLUTION AND IS EXPRESSED AS THE NEGATIVE LOGARITHM OF THE HYDROGEN ION CONCENTRATION.

PHREATOPHYTE. PLANTS THAT HABITUALLY SEND THEIR ROOTS TO THE CAPILLARY FRINGE AND FEED ON GROUND WATER.

PIEZOMETER. A SMALL DIAMETER PIPE OR CASING DRIVEN INTO THE GROUND FOR MEASURING PRESSURE HEAD.

PIEZOMETRIC SURFACE. THE SURFACE TO WHICH THE WATER FROM A GIVEN AQUIFER WILL RISE UNDER ITS FULL HEAD.

PLUNGE. VERTICAL ANGLE BETWEEN A HORIZONTAL PLANE AND THE MAXIMUM ELONGATION OF THE STRUCTURE.

POLLUTION. IMPAIRMENT OF THE QUALITY OF WATER BY SEWAGE OR INDUSTRIAL WASTE TO A DEGREE WHICH DOES NOT CREATE A HAZARD TO PUBLIC HEALTH, BUT WHICH ADVERSELY AND UNREASONABLY AFFECTS SUCH WATER FOR BENEFICIAL USE.

POROSITY. THE PROPERTY OF A ROCK CONTAINING INTERSTICES WITHOUT REGARD TO SIZE, SHAPE, INTERCONNECTION, OR ARRANGEMENT OF OPENINGS. IT IS EXPRESSED AS A PERCENTAGE OF TOTAL VOLUME OCCUPIED BY INTERSTICES.

PUMPING TROUGH. AN IMAGINARY SURFACE INDICATING PRESSURE RELIEF CONDITIONS IN A CONFINED AQUIFER DUE TO PUMPING.

REVERSE FAULT. A FAULT ALONG WHICH THE UPTHROWN BLOCK IS THRUST ON TOP OF THE DOWNTOWN BLOCK.

RIISING WATER. GROUND WATER FORCED TO THE GROUND SURFACE BY A SUBSURFACE BARRIER OR CONSTRICTION IN THE TRANSMITTING AQUIFER.

SAFE YIELD. MAXIMUM PERENNIAL RATE OF EXTRACTION OF AN AQUIFER OR GROUND WATER BASIN WITHOUT LOWERING THE WATER LEVELS SO FAR AS TO MAKE PUMPING UNECONOMICAL, CAUSING A SERIOUS DETERIORATION OF WATER QUALITY, OR INTERFERING UNREASONABLY WITH EXISTING WATER RIGHTS.

SALINITY. CONCENTRATION OF DISSOLVED SALTS IN A SOLUTION, USUALLY MEASURED BY SPECIFIC ELECTRICAL CONDUCTANCE.

SEA-WATER WEDGE. WEDGE-SHAPED CONFIGURATION OF THE FRESH-SALT WATER INTERFACE IN AN ADVANCING SEA-WATER FRONT. THE LOWER SPECIFIC GRAVITY OF FRESH WATER CAUSES IT TO OVERRIDE THE TOE OF THE HEAVIER INTRUDING INCREMENT OF SEA WATER.

SPECIFIC CAPACITY. THE NUMBER OF GALLONS OF WATER PRODUCED BY A PUMPING WELL PER FOOT OF DRAWDOWN.

SPECIFIC RETENTION. THE RATIO OF THE VOLUME OF WATER WHICH A ROCK OR SOIL WILL RETAIN AGAINST THE PULL OF GRAVITY TO ITS OWN VOLUME.

SPECIFIC YIELD. THE RATIO OF THE VOLUME OF WATER A SATURATED MATERIAL WILL YIELD BY GRAVITY TO ITS OWN VOLUME, AND IS COMMONLY EXPRESSED AS A PERCENTAGE. GROUND WATER STORAGE CAPACITY IS ESTIMATED AS THE PRODUCT OF THE SPECIFIC YIELD AND THE VOLUME OF MATERIAL IN THE DEPTH INTERVALS CONSIDERED.

SOIL SOLUTION. WATER IN THE SOIL ZONE INCLUDING GRAVITY WATER AND SOIL MOISTURE.

STRIKE. THE COURSE OR BEARING OF THE OUTCROP OF AN INCLINED BED OR STRUCTURE ON A LEVEL SURFACE.

SUB-ALLUVIAL OUTCROP. TRUNCATED OLDER STRATA EXPOSED BY EROSION AND LATER BURIED BY DEPOSITS OF ALLUVIUM.

SUBMARINE CANYON. AN ELONGATED, STEEP-WALLED CANYON RUNNING ACROSS OR PARTIALLY ACROSS THE OFF-SHORE SHELF, THE BOTTOM OF WHICH GRADES CONTINUALLY SEAWARD.

SUBMARINE OUTCROP. THE INTERSECTION OF A STRATUM WITH THE OCEAN FLOOR.

SYNCLINE. A FOLD IN ROCKS IN WHICH THE BEDS DIP INWARD FROM BOTH SIDES TOWARD THE AXIS.

THROW. THE VERTICAL COMPONENT OF DISPLACEMENT IN A FAULT.

THRUST FAULT. A REVERSE FAULT THAT IS CHARACTERIZED BY A LOW ANGLE OF INCLINATION WITH REFERENCE TO A HORIZONTAL PLANE.

TRANSMISSIBILITY. AN EXPRESSION OF HYDRAULIC PERMEABILITY OF A MATERIAL. EXPRESSED AS THE RATE OF FLOW, IN GALLONS PER DAY, THROUGH EACH VERTICAL STRIP OF THE AQUIFER 1 FOOT WIDE HAVING A HEIGHT EQUAL TO THE THICKNESS OF THE AQUIFER AND UNDER A UNIT HYDRAULIC GRADIENT.

UNCONFORMITY. A SURFACE OF EROSION THAT SEPARATES YOUNGER DEPOSITS FROM OLDER ROCKS.

WATER-LEVEL CONTOUR. A LINE OF EQUAL ELEVATION ON THE WATER-TABLE SURFACE.

WATER-TABLE RIDGE. A MOUND-SHAPED OR RIDGE-SHAPED ADDITION TO THE GROUND WATER BODY BUILT UP BY INFLUENT SEEPAGE.

WATER YEAR (RUNOFF YEAR). A 12-MONTH PERIOD BEGINNING OCTOBER 1 AND ENDING SEPTEMBER 30 OF THE FOLLOWING YEAR.

## BIBLIOGRAPHY

1. AGUIRRE, ET. AL. VS. FISH AND GAME COMMISSION OF THE STATE OF CALIFORNIA, ET. AL. - 1956 - APPELLANTS' OPENING BRIEF: 106 PP.
2. BAILEY, THOMAS L. - OCTOBER 1948 - UNDERGROUND WATER SUPPLY FOR THE POINT MUGU NAVAL BASE, VENTURA COUNTY, CALIFORNIA: REPORT TO NAVAL AIR MISSILE TEST CENTER, POINT MUGU, 8 PP.
3. BLANEY, H. F. AND CRIDDLE, W. D. - 1950 - DETERMINING WATER REQUIREMENTS IN IRRIGATED AREAS FROM CLIMATOLOGICAL AND IRRIGATION DATA; U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE; SCS-TP-96.
4. BUREAU OF RECLAMATION, UNITED STATES DEPARTMENT OF INTERIOR - 1955 - CALLEGUAS BASIN, CALIFORNIA: MEMORANDUM REPORT, 126 PP.
5. BUREAU OF RECLAMATION, UNITED STATES DEPARTMENT OF INTERIOR - 1958 - CALLEGUAS PROJECT, CALIFORNIA.
6. BUREAU OF SOILS, U. S. DEPARTMENT OF AGRICULTURE - 1901 - SOIL SURVEY OF THE VENTURA AREA, CALIFORNIA; REPORT OF FIELD OPERATIONS OF THE BUREAU OF SOILS FOR 1901, PP. 521-557.
7. BUREAU OF SOILS, UNITED STATES DEPARTMENT OF AGRICULTURE - 1920 - SOIL SURVEY OF THE VENTURA AREA, CALIFORNIA; 87 PP.
8. CAL ENGINEERS - MAY 1958 - VENTURA COUNTY WASTE DISPOSAL STUDY; REPORT TO VENTURA COUNTY DEPARTMENT OF PUBLIC WORKS, 109 PP.
9. CALIFORNIA STATE DEPARTMENT OF PUBLIC HEALTH - 1959 - SUMMARY REPORT ON VENTURA COUNTY WATER QUALITY STANDARDS STUDY; PRESENTED TO STATE BOARD OF PUBLIC HEALTH, IN LOS ANGELES; JULY 10, 1959.
10. CALIFORNIA DEPARTMENT OF PUBLIC WORKS, DIVISION OF WATER RESOURCES - 1933 - VENTURA COUNTY INVESTIGATION: BULLETIN 46.
11. CALIFORNIA DEPARTMENT OF PUBLIC WORKS, DIVISION OF WATER RESOURCES - 1933 - BASIC DATA, VENTURA COUNTY INVESTIGATION; BULLETIN 46A.
12. CALIFORNIA DEPARTMENT OF PUBLIC WORKS, DIVISION OF WATER RESOURCES - MAY 1952 - VENTURA COUNTY OIL WASTE INVESTIGATION: FIRST PROGRESS REPORT TO LOS ANGELES REGIONAL WATER POLLUTION CONTROL BOARD (NO. 4).
13. CALIFORNIA DEPARTMENT OF PUBLIC WORKS, DIVISION OF WATER RESOURCES - JULY 1953 - WASTE DISCHARGE NO. 2 BY THE CULLIGAN WATER SERVICE, EL RIO, VENTURA COUNTY, CALIFORNIA; REPORT TO REGIONAL WATER POLLUTION CONTROL BOARD (NO. 4).
14. CALIFORNIA DEPARTMENT OF PUBLIC WORKS, DIVISION OF WATER RESOURCES - JUNE 1954 - VENTURA COUNTY OIL WASTE INVESTIGATION: REPORT PREPARED FOR CALIFORNIA STATE REGIONAL WATER POLLUTION CONTROL BOARD (NO. 4), 89 PP. AND APPENDICES.

15. CALIFORNIA DEPARTMENT OF PUBLIC WORKS, DIVISION OF WATER RESOURCES - MAY 1955 - INVESTIGATION OF WASTE DISCHARGES FROM WATER SOFTENING UNITS, LOS ANGELES REGION: REPORT TO LOS ANGELES REGIONAL WATER POLLUTION CONTROL BOARD (NO. 4).
16. CALIFORNIA DEPARTMENT OF WATER RESOURCES - NOVEMBER 1958 - VIEWS AND RECOMMENDATIONS OF THE STATE OF CALIFORNIA ON A REPORT ON THE PLEASANT VALLEY PROJECT, CALIFORNIA 12 PP.
17. CALIFORNIA DEPARTMENT OF WATER RESOURCES - NOVEMBER 1958 - SEA-WATER INTRUSION IN CALIFORNIA; BULLETIN 63.
18. CALIFORNIA DEPARTMENT OF WATER RESOURCES - FEBRUARY 1959 - WATER QUALITY AND WATER QUALITY PROBLEMS, VENTURA COUNTY: BULLETIN 75, 2 Vols.
19. CALIFORNIA STATE REGIONAL WATER POLLUTION CONTROL BOARD (NO. 4) - SEPTEMBER 1952 - SUMMARY OF ACTIONS TAKEN ON FIRST PROGRESS REPORT ON VENTURA COUNTY OIL WASTE INVESTIGATION: EXECUTIVE OFFICER'S REPORT TO REGIONAL WATER POLLUTION CONTROL BOARD.
20. CALIFORNIA STATE REGIONAL WATER POLLUTION CONTROL BOARD (NO. 4) - MARCH 1959 - SECOND PROGRESS REPORT ON POSSIBLE GROUND WATER POLLUTION FROM THE CITRUS PACKING PLANTS IN VENTURA COUNTY, CALIFORNIA, 28 PP.
21. CALIFORNIA STATE WATER POLLUTION CONTROL BOARD - 1952 - WATER QUALITY CRITERIA: PUBLICATION NO. 3, 512 PP.
22. CALIFORNIA STATE WATER POLLUTION CONTROL BOARD - 1954 - WASTE WATER RECLAMATION AND UTILIZATION: PUBLICATION NO. 9.
23. CALIFORNIA STATE WATER RESOURCES BOARD - 1953 - VENTURA COUNTY INVESTIGATION: BULLETIN 12.
24. CALIFORNIA STATE WATER RIGHTS BOARD - 1958 - TRANSCRIPT OF HEARINGS AND DECISION NO. D-884 WITH REGARD TO APPLICATIONS 12092, 15145 OF UNITED WATER CONSERVATION DISTRICT AND APPLICATIONS 13417, 13417A, AND 13418 OF CALLEGUAS MUNICIPAL WATER DISTRICT.
25. CONKLING, HAROLD - 1947 - WATER SUPPLY OF SANTA CLARA WATER CONSERVATION DISTRICT, VENTURA COUNTY. REPORT TO SANTA CLARA WATER CONSERVATION DISTRICT.
26. CONKLING, HAROLD - 1949 - DEVELOPMENT OF A SUPPLEMENTAL WATER SUPPLY FOR ZONE 2: REPORT TO BOARD OF SUPERVISORS, VENTURA COUNTY, FLOOD CONTROL DISTRICT.
27. DONEEN, L. D. - 1959 - EVALUATING THE QUALITY OF IRRIGATION WATERS IN VENTURA COUNTY; APPENDIX F OF CALIFORNIA DEPARTMENT OF WATER RESOURCES BULLETIN NO. 75.
28. CROWELL, J. C. - JANUARY 1952 - SUBMARINE CANYONS BORDERING CENTRAL AND SOUTHERN CALIFORNIA: JOURNAL OF GEOLOGY, Vol. 60, No. 1, PP. 58-83.
29. FREEMAN, V. M. - 1935 - REPORT ON PROPOSED SESPE HOT SPRINGS PROJECT; PREPARED FOR CONSERVATION COMMITTEE, VENTURA COUNTY FARM BUREAU. DATED SEPTEMBER 16, 1935.

30. FREEMAN, V. M. - 1936 - WATER SPREADING AS PRACTICED BY THE SANTA CLARA WATER CONSERVATION DISTRICT, VENTURA COUNTY, CALIFORNIA: TRANSACTIONS AMERICAN GEOPHYSICAL UNION, 17TH ANNUAL MEETING, PART II, PP. 465-471.
31. FREEMAN, V. M. - 1949 - PRELIMINARY REPORT ON COST OF RECLAIMING WATER FROM THE OXNARD DOMESTIC SEWER SYSTEM: REPORT TO SANTA CLARA WATER CONSERVATION DISTRICT DATED SEPTEMBER 7, 1949.
32. FRUIT GROWERS LABORATORY, INC. - JUNE 1953 - PACKING PLANT WASTES AS THREATENING POLLUTANTS OF MAIN BASIN WATERS: REPORT TO WATER POLLUTION COMMITTEE OF THE VENTURA COUNTY CITRUS PACKING ASSOCIATIONS, 251 PP.
33. GREGOR, H. F. - 1952 - THE SOUTHERN CALIFORNIA WATER PROBLEM IN THE OXNARD AREA: GEOGRAPHICAL REVIEW, Vol. 42, No. 1, PP. 16-36.
34. HEM, JOHN D. - 1959 - STUDY AND INTERPRETATION OF THE CHEMICAL CHARACTERISTICS OF NATURAL WATER: U. S. GEOLOGICAL SURVEY WATER SUPPLY PAPER 1473, 269 PP.
35. HINDS, JULIAN - 1953 - INVESTIGATIONS, PLANS AND ESTIMATES FOR A SUPPLEMENTAL WATER SUPPLY FOR AGRICULTURAL, MUNICIPAL AND INDUSTRIAL USES IN THE SANTA CLARA RIVER VALLEY AND VICINITY: UNITED WATER CONSERVATION DISTRICT REPORT.
36. HINDS, JULIAN - SEPTEMBER 1953 - REPORT OF INVESTIGATION AND RECOMMENDATIONS FOR ACQUISITION AND CONSTRUCTION OF A WATER CONSERVATION SYSTEM: REPORT TO BOARD OF DIRECTORS, UNITED WATER CONSERVATION DISTRICT.
37. INMAN, D. L. - JULY 1950 - SUBMARINE TOPOGRAPHY AND SEDIMENTATION IN THE VICINITY OF MUGU SUBMARINE CANYON, CALIFORNIA: U. S. ARMY CORPS OF ENGINEERS, BEACH EROSION BOARD, TECHNICAL MEMORANDUM NO. 19.
38. INMAN, D. L. - 1950 - REPORT ON BEACH STUDY IN THE VICINITY OF MUGU LAGOON, CALIFORNIA: U. S. ARMY CORPS OF ENGINEERS, TECHNICAL MEMORANDUM NO. 14, 47 PP.
39. ISHERWOOD, J. D. AND PILLSBURY, A. F. - 1958 - SHALLOW GROUND WATER AND TILE DRAINAGE IN THE OXNARD PLAIN: TRANSACTIONS AMERICAN GEOPHYSICAL UNION, Vol. 39, No. 6, PP. 1101-1110. DISCUSSION BY MAX BOOKMAN AND R. G. THOMAS, AND REPLY BY AUTHORS IN JOURNAL OF GEOPHYSICAL RESEARCH, Vol. 64, No. 7, JULY, 1959, PP. 857-860.
40. JAMISON, R. H. - 1942 - CHANGE IN GROUND-WATER ELEVATION IN VARIOUS PUMPING AREAS, VENTURA COUNTY, CALIFORNIA, 1928-1941: TRANSACTIONS AMERICAN GEOPHYSICAL UNION, PP. 129-148.
41. KAPLOW, E. J. - 1948 - OXNARD OIL FIELD: CALIFORNIA STATE DIVISION OF OIL AND GAS, SUMMARY OF OPERATIONS, Vol. 33, No. 2, PP. 16-20.
42. KAWANO, RAY Y. - JULY 1957 - CELERITY OF THE MOUND WAVE: RESEARCH PAPER, 12 PP.
43. KAWANO, R. Y. AND PARSONS, J. K. - 1956 - SUPPLEMENT NO. 1 TO THE 1951-53 REPORT ON HYDROLOGIC INVESTIGATIONS OF THE WATER RESOURCES OF THE UNITED WATER CONSERVATION DISTRICT DATED APRIL 27, 1956.

44. KELLY, W. P., LAURANCE, B. M. AND CHAPMAN, H. D. - JANUARY 1949 - SOIL SALINITY IN RELATION TO IRRIGATION: HILGARDIA-CALIFORNIA AGRICULTURAL EXPERIMENT STATION, Vol. 18, No. 18.
45. KIMBLE, J. C. - 1936 - UNDERFLOW AT WHITTIER NARROWS, SAN GABRIEL RIVER VALLEY, LOS ANGELES COUNTY, CALIFORNIA: TRANSACTIONS AMERICAN GEOPHYSICAL UNION, PP. 521-525.
46. LONG, N. S. - 1953 - HYDROLOGIC EFFECTS OF PUMPING THE OXNARD CITY WATER SUPPLY FROM SANTA PAULA BASIN: REPORT TO CHIEF ENGINEER, UNITED WATER CONSERVATION DISTRICT.
47. LOS ANGELES COUNTY FLOOD CONTROL DISTRICT - MARCH 1957 - INVESTIGATIONAL WORK FOR PREVENTION AND CONTROL OF SEA WATER INTRUSION, WEST COAST BASIN EXPERIMENTAL PROJECT, LOS ANGELES COUNTY; APPENDIX B TO CALIFORNIA DEPARTMENT OF WATER RESOURCES BULLETIN 63.
48. LUDWIG BROTHERS - 1949 - SANITARY ENGINEERING FEATURES OF RECLAIMING WATER FROM DOMESTIC SEWAGE IN THE MONTALVO BASIN; REPORT TO SANTA CLARA WATER CONSERVATION DISTRICT DATED AUGUST 6, 1949.
49. MANN, JOHN F., JR. - 1952 - OVERDRAFT ON THE DEEP AQUIFER IN PLEASANT VALLEY AND POSSIBILITIES OF RECHARGE BY SPREADING: REPORT TO BOARD OF DIRECTORS, UNITED WATER CONSERVATION DISTRICT.
50. MANN, JOHN F., JR. - JANUARY 1954 - LOCATION OF NEW SPREADING GROUNDS IN THE MONTALVO BASIN: REPORT TO BOARD OF DIRECTORS, UNITED WATER CONSERVATION DISTRICT, 9 PP.
51. MANN, JOHN F., JR. AND ASSOCIATES - MAY 1958 - OUTLINE OF GROUND WATER HYDROLOGY, PLEASANT VALLEY COUNTY WATER DISTRICT: REPORT TO GENERAL MANAGER AND CHIEF ENGINEER, PLEASANT VALLEY COUNTY WATER DISTRICT.
52. OLIVER, GRAYDON - JULY 1948 - WATER INVESTIGATION INCIDENTAL TO WATER WELLS DRILLED BY CITY OF VENTURA IN PIERPONT BAY AREA: REPORT TO SANTA CLARA WATER CONSERVATION DISTRICT, 31 PP.
53. OLIVER, GRAYDON - NOVEMBER 1949 - WATER INVESTIGATION INCIDENTAL TO WATER WELL DRILLED BY UNITED STATES NAVY IN POINT MUGU AREA: REPORT TO SANTA CLARA WATER CONSERVATION DISTRICT, 39 PP.
54. OXNARD PLANNING COMMISSION - 1952 - MASTER PLAN FOR THE CITY OF OXNARD, REVISED.
55. PLANNING RESEARCH CORPORATION - SEPTEMBER 1957 - POPULATION STUDY AND FORECAST, COUNTY OF VENTURA, CALIFORNIA: REPORT PREPARED FOR VENTURA COUNTY BOARD OF SUPERVISORS, 190 PP.
56. POLAND, J. F., GARRETT, A. A., AND MANN, J. F. - AUGUST 1948 - PROGRESS REPORT ON WATER SUPPLY FOR THE POINT MUGU NAVAL BASE, VENTURA COUNTY, CALIFORNIA: U. S. GEOLOGICAL SURVEY REPORT PREPARED FOR BUREAU OF YARDS & DOCKS, DEPARTMENT OF THE NAVY.
57. PRICE, WM. P., JR. - 1956 - SEA WATER INTRUSION INTO THE OXNARD AQUIFER IN THE VICINITY OF PORT HUENEME, CALIFORNIA; REPORT BY UNITED WATER CONSERVATION DISTRICT TO COMMANDING OFFICER, U. S. NAVAL CONSTRUCTION BATTALION CENTER, PORT HUENEME. DATED NOVEMBER 14, 1956.

58. PRICE, WM. P., JR. AND ASSOCIATES - 1958 - FEASIBILITY REPORT, PLEASANT VALLEY PROJECT, CALIFORNIA: PREPARED FOR PLEASANT VALLEY COUNTY WATER DISTRICT.
59. QUINTON ENGINEERS, LTD. - JUNE 1959 - LAND USE AND VALUATION SURVEY OF CALLEGUAS, LAS VIRGENES, OXNARD PLAIN AND SOUTH VENTURA LANDS, 62 PP.
60. SCHIFF, LEONARD - MAY 1954 - SUITABILITY AND CHARACTERISTICS OF THE PROPOSED EL RIO SPREADING GROUND, VENTURA COUNTY, CALIFORNIA: U. S. DEPARTMENT OF AGRICULTURE, SOIL AND WATER CONSERVATION RESEARCH BRANCH.
61. SCHIFF, LEONARD - 1958 - MAINTENANCE-EL RIO SPREADING GROUNDS; REPORT TO UNITED WATER CONSERVATION DISTRICT. DATED JUNE 23, 1958.
62. SHARP, L. T. - 1956 - SANTA CLARA WATERSHED WATER QUALITY; REPORT BY FRUIT GROWERS LABORATORY TO UNITED WATER CONSERVATION DISTRICT. DATED DECEMBER 12, 1956.
63. SHARP, L. T. - MAY 1957 - WATER QUALITY IN THE UNITED WATER CONSERVATION DISTRICT AND POTENTIAL IMPROVEMENT OF QUALITY BY DAM STORAGE OF STORM WATERS.
64. SOIL CONSERVATION SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE - 1953 - GROUND WATER REPLENISHMENT BY PENETRATION OF RAINFALL, IRRIGATION AND WATER SPREADING IN ZONE 3: REPORT TO BOARD OF SUPERVISORS, VENTURA COUNTY FLOOD CONTROL DISTRICT.
65. TROXELL, HAROLD C. - 1957 - WATER RESOURCES OF SOUTHERN CALIFORNIA WITH SPECIAL REFERENCE TO THE DROUGHT OF 1944-51: U. S. GEOLOGICAL SURVEY, WATER SUPPLY PAPER 1366, PP. 92-103.
66. UNITED STATES SALINITY LABORATORY, UNITED STATES DEPARTMENT OF AGRICULTURE - 1954 - DIAGNOSIS AND IMPROVEMENT OF ALKALINE SOILS: AGRICULTURE HANDBOOK NO. 60, 160 PP.
67. WILCOX, L. V. AND MAGISTAD, O. C. - 1943 - INTERPRETATION OF IRRIGATION WATERS AND THE RELATIVE TOLERANCE OF CROP PLANTS; MIMEOGRAPHED BY U. S. REGIONAL SALINITY LABORATORY.
68. WILDE, G. I. AND LONG, N. S. - 1953 - HYDROLOGIC INVESTIGATION OF THE WATER RESOURCES OF THE UNITED WATER CONSERVATION DISTRICT.
69. WRIGHT, WILLIAM T. - APRIL 1948 - DRAINAGE SURVEY, VICINITY OF THE CITY OF OXNARD, CALIFORNIA: REPORT TO BOARD OF SUPERVISORS, VENTURA COUNTY FLOOD CONTROL DISTRICT, 46 PP.