STATE OF CALIFORNIA
GOODWIN J. KNIGHT
GOVERNOR

PUBLICATION OF
STATE WATER RESOURCES BOARD

Bulletin No. 12

VENTURA COUNTY INVESTIGATION

Volume I
TEXT

October, 1953
Revised April, 1956

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

Page

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

Page

CHAPTER V. SUMMARY OF CONCLUSIONS, AND RECOMMENDATIONS

APPENDIXES

(Appendixes are bound at end of Volume II)

TABLES

TABLES
(Continued)

TABLES
(Continued)

TABLES
(Continued)

TABLES
(Continued)

TABLES
(Continued)

TABLES
(Continued)

PLATES

(Plates 1-42 are bound at end of Volume II)

PLATES
(Continued)

PLATES
(Continued)

EARL WARREN
GOVERNOR

STATE OF CALIFORNIA

STATE WATER RESOURCES BOARD

PUBLIC WORKS BUILDING
SACRAMENTO 5, CALIFORNIA

October 1, 1953

ADDRESS ALL COMMUNICATIONS TO THE SECRETARY

Honorable Earl Warren, Governor, and
Members of the Legislature of the
State of California

Gentlemen:

I have the honor to transmit herewith Bulletin No. 12 of the State Water Resources Board, entitled "Ventura County Investigation", as authorized by Chapter 1514, Statutes of 1945, as amended.

The Ventura County Investigation was conducted and Bulletin No. 12 was prepared by the Division of Water Resources of the Department of Public Works, under the direction of the State Water Resources Board. Funds to meet the cost of the investigation and report were provided as follows: State of California (State Water Resources Board), $30,000; County of Ventura, $30,000. Information and data developed in the current state-wide investigation with state funds were used in connection with this investigation.

Bulletin No. 12 contains an inventory of the underground and surface water resources of Ventura County, estimates of present and probable ultimate water utilization, estimates of present and probable ultimate supplemental water requirements, preliminary plans and cost estimates for local water development works, and for works for importing water from sources outside the County.

Very truly yours,

C. A. Griffith
Chairman

ACKNOWLEDGMENT

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

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

Board of Supervisors, County of Ventura
Ventura County Flood Control District
Ventura County Water Survey
Los Angeles County Flood Control District
United Water Conservation District
Santa Clara Water Conservation District
Metropolitan Water District of Southern California
California State Division of Highways
California State Department of Fish and Game
United States Geological Survey
United States Soil Conservation Service
United States Navy Department
Harold Conkling, Consulting Engineer
John Mann, Consulting Geologist
Southern California Edison Company
American Pipe and Construction Company
Fruit Growers Laboratory, Inc.

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CHAPTER I. INTRODUCTION

In common with many other portions of southern California, Ventura County has recently experienced an increase in water utilization during a period of severe drought, and as a result is confronted with the necessity of developing additional water supplies to meet its expanding needs. Water resources problems of Ventura County are manifested in perennial lowering of ground water levels, sea-water intrusion to pumped aquifers, degradation of ground water quality, and general diminution of surface and ground water supplies during periods of drought to quantities inadequate to satisfy requirements. The initial alleviation of these problems will involve further regulation of the erratic local water supply, so that waste conserved during wet periods can be made available for beneficial use during periods of drought. Final solution of water problems of Ventura County will lie in importation of water supplies from outside sources.

Authorization for Investigation

In consideration of the critical water supply situation in Ventura County, the Board of Supervisors of the Ventura County Flood Control District presented a resolution to the State Water Resources Board, dated October 24, 1950, requesting a comprehensive investigation of the water resources of the County. The State Water Resources Board referred the request to the State Engineer for preliminary examination and report on the need for such an investigation and an estimate of its scope, duration, and cost.

The State Water Resources Board on April 6, 1951, approved a recommendation by the State Engineer, based on findings of the preliminary examination, for a two-year cooperative investigation, and authorized negotiation of an agreement with the Ventura County Flood Control District. The agreement, between the State Water Resources Board, the County of Ventura, and the State Department of Public Works acting through the agency of the State Engineer, was executed on April 15, 1951. It provided that the work "shall consist of (1) a complete review of reports of prior investigations concerning the water resources of Ventura County; (2) field investigations and office studies to determine (a) the location, occurrence, and condition of water resources of the County, both surface and underground, (b) present water utilization including its nature, extent, and a survey of water service agencies, (c) ultimate water requirements, (d) preliminary general plans and estimates of cost for development and utilization of local water resources of the County to the maximum practicable extent, (e) required supplemental water supply from outside sources, (f) possible outside sources for required supplemental supply, including preliminary plans for importation and estimates of costs; and (3) the formulation of a report thereon."

This agreement authorized provision of funds to defray costs of the investigation for one year. A supplemental agreement executed by the same parties on May 1, 1952, authorized funds to complete the investigation and report.

Funds to meet the costs of the investigation and report to the extent of $60,000 were provided on a matching basis, $30,000 from the County of Ventura and $30,000 from the State Water Resources Board. Of the funds made available under the agreement, not more than $10,000 were to be expended on exploration work and surveys at dam and reservoir sites. Additional funds have been expended in investigation of Ventura County by the State Water Resources Board in connection with the current State-Wide Water Resources Investigation, and by the State Division of Water Resources for studies of quality of water pursuant to sections 229 and 230, Division 1 of the California Water Code, certain results of which have been used in connection with the Ventura County Investigation.

Copies of the two agreements between the State Water Resources Board, the County of Ventura, and the Department of Public Works are included in Appendix A.

Related Investigations and Reports

Review was made of reports of prior investigations dealing with various phases of water resources problems of Ventura County, extending back to and including Division of Water Resources Bulletin No. 46, "Ventura County Investigation, 1933". Investigational reports prior to 1933 were not reviewed, as any pertinent data contained therein were evaluated and utilized in the preparation of Bulletin No. 46.

Pursuant to a request by the Board of Supervisors of the Ventura County Flood Control District on July 27, 1951, there was submitted to that Board in November, 1951, a report entitled "Review of 'Report on Casitas Dam and Reservoir' by Board of Consultants, May 1, 1951".

On November 28, 1951, the Board of Supervisors of the Ventura County Flood Control District requested a review of a report, prepared by the staff of the District, on a plan of distributing water from the proposed Casitas Reservoir. In accordance with this request, a report entitled "Review of 'Memorandum on Distribution of Water Stored in Casitas Reservoir and Matilija Reservoir to Lands and Users in the Year 1975, November 1951'" was prepared and submitted to the District on June 30, 1952.

In addition, the following listed published and unpublished reports were reviewed during the investigation, and certain information and data presented therein were used in the preparation of this bulletin.

"Ventura County Investigation", Bulletin No. 46, Division of Water Resources, California State Department of Public Works. 1933.

"Ventura County Investigation, Basic Data for the Period 1927 to 1932, Inclusive", Bulletin No. 46-A, Division of Water Resources, California State Department of Public Works.

"Future Water Supply for Ventura, California", J. B. Lippincott. May, 1934.

"Report on Survey of Ventura River, California, for Flood Control", War Department, United States Engineer Office. October 15, 1940.

"Change in Ground Water Elevation in Various Pumping Areas, Ventura County, California, 1928 to 1941", Richard H. Jamison. Transaction of 1942 of the American Geophysical Union.

"Survey Flood Control, Calleguas Creek, California", War Department, United States Engineer Office. December 23, 1942.

"Soil and Water Conservation Research Needs in the Simi Valley and Adjacent Areas, Ventura County, California", United States Department of Agriculture, Soil Conservation Service, Office of Research. February, 1944.

"Report on Survey of Santa Clara River, California, for Flood Control", War Department, United States Engineer Office. December 20, 1945.

"Flood Control and Water Conservation, Ventura County Flood Control District, Zone One", Donald R. Warren Company. 1945.

"Flood Control and Water Conservation, Ventura County Flood Control District, Zone Two", Donald R. Warren Company. 1945.

"Flood Control and Water Conservation, Ventura County Flood Control District, Zone Three", Donald R. Warren Company. 1945.

"Flood Control and Water Conservation, Ventura County Flood Control District, Zone Four", Donald R. Warren Company. 1946.

"Water Supply of Santa Clara Water Conservation District", Harold Conkling. November 19, 1947.

"Water Supply, Newhall Ranch", Harold Conkling. January, 1948.

"Safe Yield - Matilija Reservoir", Harold Conkling. May, 1948.

"Development of a Supplemental Water Supply for Zone 2, Ventura County Flood Control District", Harold Conkling. September, 1949.

"Demand on Casitas Reservoir and Safe Yield", Harold Conkling. April, 1950.

"Hydrology of Zone 3, Ventura County Flood Control District", Harold Conkling. June, 1950.

"Exportation of Water from Piru Creek to Zone No. 3", Richard H. Jamison. August, 1951.

"Water Resources of California", Bulletin No. 1, California State Water Resources Board. 1951.

"Overdraft on the Deep Aquifer in Pleasant Valley and Possibilities of Recharge by Spreading", John F. Mann, Jr. July 3, 1952.

"Report of Investigation and Recommendations for Acquisition and Construction of a Water Conservation System", United Water Conservation District of Ventura County, California. October, 1952.

"Ground Water Replenishment by Penetration of Rainfall, Irrigation and Water Spreading in Zone 3, Ventura County Flood Control District, California", United States Department of Agriculture, Soil Conservation Service, Research Branch. April, 1953.

The Division of Water Resources is presently conducting surveys and studies for the State-Wide Water Resources Investigation, authorized by Chapter 1514, Statutes of 1945, as amended. This investigation, under direction of the State Water Resources Board, has as its objective the formulation of The California Water Plan for full conservation, control, and utilization of the

State's water resources to meet present and future water needs for all beneficial purposes and uses in all parts of the State, insofar as practicable. As a result of this investigation, the State Water Resources Board in May, 1951, published "Report on Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of the California Water Plan". Included as an integral feature of these projects is a diversion conduit to deliver supplemental water to Ventura County. These projects were authorized and adopted by the 1951 Legislature in Chapter 1441, Statutes of 1951. Under this authorization, provision was made for the construction of works, operation, and maintenance thereof by the Water Project Authority of the State of California. Financing the construction of works was provided for in the authorizing act through the issuance and sale of revenue bonds and through receipt of contributions from other sources. The Division of Water Resources, since 1951, has been continuing investigations, studies, and surveys preparatory to construction of works, through budgetary appropriation by the Legislature.

Cooperation With Other Agencies

In addition to cooperation extended to the Division of Water Resources in obtaining and utilizing basic data and information as acknowledged hereinbefore, certain phases of the investigation were conducted under programs of mutual cooperation with other agencies then engaged in analyzing water resources problems in various portions of Ventura County. These cooperative programs resulted in prevention of duplication of effort, and permitted a more detailed analysis to be made of the affected areas.

An agreement, entitled "Memorandum of Understanding with Reference to Water Resources Investigation of Ventura County", was entered into on April 23, 1951, by the Division of Water Resources, United Water Conservation District, and Ventura County Flood Control District. The objective of this agreement was to coordinate the work of the three agencies involved in the investigation of the water problems of the Santa Clara River Valley. Copies of the memorandum of understanding, and supplements thereto entered into by the same agencies on October 1, 1952, and November, 1952, are included in Appendix A.

In order to provide certain necessary basic data relating to dam and reservoir sites on tributaries of the Santa Clara River, prior to commencement of field work by the Division of Water Resources on July 1, 1951, a service agreement was entered into between the Ventura County Flood Control District and the Division of Water Resources on April 24, 1951, wherein the District was to procure and provide the Division with these data and be reimbursed therefor by the Division in an amount not to exceed $1,500. The terms of this agreement were executed, and the District was subsequently reimbursed in the amount of $1,500.

During the course of the investigation, a cooperative hydrographic program was carried on by the Ventura County Water Survey, United Water Conservation District, Santa Clara Water Conservation District, United States Geological Survey, and Division of Water Resources. This program included measurements of flood flow and rising water at selected points on various watercourses throughout the County, together with maintenance of stream gaging stations.

The United States Department of Agriculture, Soil Conservation Service, Research Branch, under terms of a cooperative agreement with the Ventura County Flood Control District, entered into on November 1, 1950, conducted a study of ground water replenishment by penetration of rainfall, irrigation, and water spreading in Ventura County Flood Control District, Zone 3. The Division of Water Resources extended cooperation to the Soil Conservation Service by supplying basic hydrologic data and results of a geological investigation of the area under consideration, including the location and extent of ground water aquifers and of substrata which might impede or prevent the downward movement of waters spread on the ground surface. The results of the Soil Conservation Service study are contained in a report entitled "Ground Water Replenishment by Penetration of Rainfall, Irrigation, and Water Spreading in Zone 3, Ventura County Flood Control District, California, April, 1953". Certain data contained in this report were utilized in the Ventura County Investigation.

Scope of Investigation and Report

It has been stated that under provisions of the authorizing agreements the general objectives of the Ventura County Investigation included analysis of the quality, replenishment, and utilization of the underground water supplies of the County, and the preparation of preliminary general plans and estimates of cost for development and utilization of local water resources of the County to the maximum practicable extent. Achievement of these objectives necessitated a comprehensive investigation, the scope of which included full consideration of surface as well as ground water supplies, and the evaluation of present and probable ultimate water utilization and supplemental water requirements. Field work in the investigational area and office studies, as authorized by the initial and supplemental cooperative agreements, commenced on July 1, 1951, and continued into 1953.

In the course of the field investigation, available precipitation and stream flow records were collected and compiled for the purpose of evaluating water supplies of the County. Four stream gaging stations equipped with automatic water stage recorders were installed and maintained to supplement hydrographic data available from 15 gaging stations maintained by the Ventura County Water Survey and the United States Geological Survey. These stations were on Tapo Creek at Walnut Road in Simi Valley, Calleguas Creek at Camarillo State Hospital Bridge, and on Calleguas Creek at Highway 101 (later moved to Conejo Creek immediately above its confluence with Calleguas Creek). A station established in 1951 on San Antonio Creek, immediately below the point of outflow from Ojai Valley, was destroyed during the storm of January 15, 1952, and was not replaced. In addition, 40 stations equipped with staff gages or datum reference points were established and maintained for varying periods of time on many minor watercourses throughout the County. Frequent stream flow discharge measurements were made not only at all gaging stations, but also throughout selected reaches of major streams for the purpose of determining percolation rates therein. Periodic measurements were also made along the Santa Clara River at points of rising water.

Investigation was made of geologic features of ground water basins of the County, including storage capacity and the occurrence and movement of ground waters therein. In this connection, 1,534 water well logs and 138 oil well logs were collected and analyzed. The report on the geologic investigation is included as Appendix B.

The attempt was made to locate in the field all operating and nonoperating water wells in the County. Monthly measurements of ground water levels at 974 selected wells, made by the Ventura County Water Survey since 1949, together with seasonal measurements available from 1933, were utilized to determine the effects of draft on and replenishment of the ground water basins. Supplemental measurements were made by the Division of Water Resources at wells in certain critical areas in the fall of 1951 and in the spring of 1952. A continuous record of ground water level fluctuations in the Santa Clara River Valley and in the Oxnard Plain-Pleasant Valley area was available from about 25 water stage recorders, maintained for many years by the Santa Clara Water Conservation District. The Division of Water Resources supplemented these records by maintaining water stage recorders, for varying periods of time, at 27 nonoperating water wells in selected areas.

The nature and extent of present land use was determined from a survey conducted in the developed areas of Ventura County during 1949 and 1950 in connection with the aforementioned State-Wide Water Resources Investigation. A field check of the results of this survey was made in 1951 as a part of the Ventura County Investigation. The results of the land use surveys were used in conjunction with water use data to determine present water requirements.

As an aid in estimating future water requirements, a land classification survey was conducted in 1952, wherein all lands not then urbanized were classified with regard to their suitability for irrigated agriculture. In addition, lands not considered susceptible to irrigation were surveyed in the field to ascertain their potential for urban and suburban developments.

Current irrigation practices in the County were studied in order to determine unit application of water to important crops on lands of various soil types, and the influence of climatic factors thereon. Water use data collected from mutual water companies and certain large ranches included records of pump discharge, acreages served, crops irrigated, and amounts of water applied. Estimates of total ground water extractions from confined aquifers of the Santa Clara River coastal plain and adjacent areas were made for each of the seasons from 1944-45 through 1951-52. These estimates were based upon records of power consumption and pump test results supplied by the Southern California Edison Company.

Studies were made of the mineral quality of surface and ground waters, in order to evaluate their suitability for beneficial use and to determine the cause of any degradation thereof. In this connection, 1,080 partial and 542 complete mineral analyses were made of ground waters, and 156 partial and 234 complete analyses were made of surface waters. In addition, in excess of 600 complete analyses of surface and ground water supplies, dating back to 1927, obtained from Fruit Growers Laboratory Inc., Santa Clara Water Conservation District, Ventura County Farm Advisor, and Division of Water Resources Bulletin No. 46, were studied. A detailed report on the quality of surface and ground water supplies of Ventura County is scheduled for publication by the Division of Water Resources in the latter part of 1953.

Detailed hydrologic studies were made for each of the principal stream systems of the County. These studies included determination of present developed safe yield of surface and ground water supplies, present and probable future supplemental water requirements, present waste to the ocean of surface and ground waters, and of the portion of this waste susceptible to conservation both by surface and underground reservoirs.

The development of possible plans for additional conservation of local water supplies included field examination of feasible dam sites, together with a geologic investigation thereof. Preliminary designs and estimates of cost were prepared for several heights of dam at many of the sites, and of conveyance and distribution systems, and appurtenant works.

Preliminary plans and estimates of cost were also prepared of works for furnishing supplemental water from the proposed Southern California Diversion Conduit of the Feather River Project and from the Colorado River supply of the Metropolitan Water District of Southern California. Consideration was given to the financial and organizational aspects attendant on the development of local and imported water supplies.

Results of the Ventura County Investigation are presented in this report in the four ensuing chapters. Chapter II, "Water Supply", contains evaluations of precipitation, surface and subsurface inflow and outflow, and imports of water. It also includes results of investigation and study of underground hydrology, and sets forth estimates of present developed safe yield of surface and ground water supplies. Data regarding the mineral quality of surface and ground water supplies are presented therein. Chapter III, "Water Utilization and Requirements", includes data and estimates of present and probable ultimate land use and water requirements, and contains estimates of present and probable ultimate supplemental water requirements. It also includes available data on demands for water with respect to rates, times, and places of delivery. Chapter IV, "Plans for Water Supply Development", describes preliminary plans for conservation and utilization of local water supplies, including operation and yield studies, design considerations and criteria, and estimates of cost for the construction of works. Similar consideration is given to the development of imported water supplies. Chapter V, "Summary of Conclusions, and Recommendations", includes a brief summary of conclusions drawn from the first four chapters and recommendations resulting therefrom.

Area Under Investigation

The area under investigation comprises all lands within the boundaries of Ventura County, with the exception of Anacapa and San Nicolas Islands. Ensuing discussions of the County refer to the mainland area only. In addition, proper analysis of the available water supply necessitated investigation of that portion of the drainage area of the Santa Clara River lying within Los Angeles County.

Ventura County is situated in the South Coastal Area of California, and adjoins Santa Barbara County on the west, Los Angeles County on the east and south, and Kern County on the north. It is bounded on the southwest by the Pacific Ocean, with its coastal frontage extending northwesterly about 40 miles from the Los Angeles county line to Santa Barbara County. Ventura County has an average north and south dimension of about 50 miles, and an average width in an east and west direction of about 40 miles. The mainland portion has an area of 1,857 square miles. The location of the County is shown on Plate 1, "Location of Ventura County".

Drainage Basins

Ventura County is characterized by rugged mountainous terrain covering the northerly portion of its area, with most present developments concentrated in the alluvial valleys and lower rolling topography found in the southerly portion. The mountainous area is comprised of the Santa Ynez, Topatopa, and Piru Mountains, which are segments of the Transverse Range of the coastal ranges of California, as are the Santa Monica Mountains found in the southeasterly portion of the County. Numerous ridges in the foregoing mountains extend to elevations in excess of 6,000 feet, attaining a maximum elevation of 8,826 feet at Mt. Pinos at the northerly county boundary.

The County is drained by four principal stream systems, namely Ventura

River, Santa Clara River, Calleguas Creek, and Cuyama River. With exception of the Cuyama River, these streams discharge into the ocean along the coastal front forming the southwesterly county boundary. Minor areas in the westerly, northerly, and southeasterly portions of the County drain into Santa Barbara, Kern, and Los Angeles Counties, respectively. Furthermore, in several instances, small areas of the foregoing counties are drained by streams which are otherwise entirely within Ventura County. The headwaters of the Cuyama River rise in the northwesterly portion of the County and thence drain north and west to discharge into the ocean through the Santa Maria River. In addition to the foregoing principal streams, there are many minor watercourses and drainage systems, the largest being Malibu Creek, which drains the southerly portion of the County.

The drainage area of the Ventura River comprises 226 square miles, of which 194 square miles are designated mountains and foothills, and 32 square miles valley and mesa lands. Elevations in the drainage area vary from a maximum of 6,003 feet above sea level at Monte Arido in the northwesterly extremity of the watershed, to sea level at the mouth of the river. The mean seasonal natural runoff of the Ventura River at its mouth has been estimated to be about 67,800 acre-feet. Present developments are concentrated in the small alluvial valleys and adjacent hills south and east of the confluence of Matilija and North Fork Matilija Creeks, which are the principal tributaries of the Ventura River.

The Santa Clara River drains an area above its mouth of 1,605 square miles, of which 1,455 square miles are designated mountains and foothills, and 150 square miles valley and mesa lands. The river flows generally in a southwesterly direction from its headwaters in Los Angeles County, at elevations in excess of 5,000 feet, to the Pacific Ocean near Oxnard. Its principal tributaries are Sespe Creek with a drainage area of about 254 square miles above the gage near Fillmore, and Piru Creek with a drainage area of about 432 miles above the gage near Piru, both of which flow easterly and then southerly to join the main stream near the towns of Fillmore and Piru, respectively. Another important tributary, Santa Paula Creek, drains an area of 40 square miles southwesterly of the Sespe Creek watershed and, flowing generally south, has its confluence with the Santa Clara River at the town of Santa Paula. Urban and agricultural developments are found along the Santa Clara River bottomlands and on the broad coastal plain at its mouth. The drainage areas of Sespe, Piru, and Santa Paula Creeks are comprised primarily of national forest lands, wherein few developments prevail. The mean seasonal natural runoff of the Santa Clara River at its mouth is estimated to be about 216,400 acre-feet.

The headwaters of Calleguas Creek and its principal tributary, Conejo Creek, originate in the Santa Susana and Santa Monica Mountains at elevations in excess of 3,000 feet. The drainage area, poorly defined in the lower reaches of the stream, comprises about 331 square miles. Oak Ridge, a relatively narrow elongated range of hills extending in a east-west direction, separates the Calleguas Creek watershed from that of the Santa Clara River on the north. The watershed is defined by the Santa Susana Mountains on the east and by the Santa Monica Mountains on the south. The system drains generally in a southwesterly direction, and discharges into the ocean through Mugu Lagoon about seven and one-half miles southeasterly of Port Hueneme. The drainage area is characterized by a more moderate relief than that of the Ventura and Santa Clara River watersheds, with most of the area lying below 1,000 feet in elevation. Present urban and agricultural developments occur in the relatively small alluvial valleys and adjacent hills throughout the area, and on the coastal plain across which Calleguas Creek flows in its lowermost reaches. The mean seasonal natural runoff of Calleguas Creek is estimated to be about 15,200 acre-feet.

The southerly slopes of the Santa Monica Mountains within Ventura County are drained by Las Virgenes and Triunfo Creeks, tributaries of Malibu Creek, together with several minor streams discharging directly into the ocean. Runoff from these streams is small and developments within their drainage areas are of a minor nature.

Climate

The Mediterranean type of climate typical of the South Coastal Area prevails in Ventura County, with proximity to the ocean providing a moderating effect on climatic conditions throughout the developed area. A long, dry, warm summer season is followed by a shorter wet winter period accompanied by cooler temperatures. In excess of 80 per cent of the mean seasonal precipitation occurs during the months of December through March. Precipitation occurs generally in the form of rainfall, except in the mountainous regions where there is some snowfall in most years. Fog is prevalent along the coast during portions of each year. Temperature extremes generally increase with elevation and distance from the coast. The growing season, or lapse of time between killing frosts, is long, and generally decreases with elevation and distance from the coast. Since killing frosts on the coastal plain of the Santa Clara River Valley are extremely rare, portions of this area are producing as many as three crops per year.

Certain pertinent climatological data for three selected stations in Ventura County are shown in the following tabulation:

Station	Elevation, in feet	Recorded temperature, in degrees F.			Mean seasonal precipitation, in inches of depth	Average number of days between killing frosts
		Maximum	Minimum	Average		
Ojai	750	119	13	61	18.76	232
Oxnard	51	99	29	59	14.47	332
Santa Paula	275	105	27	--	17.50	277

Geology

Ventura County lies within the Transverse Ranges Geomorphic Province of California. Formations present include igneous and metamorphic rocks of pre-Cretaceous age, marine and continental sediments of Cretaceous to Recent age, and volcanic rocks of Tertiary age. With exception of the Recent stream deposits, all formations are to some extent deformed. In general, the structures, including fold axes and faults, trend in an east-west direction.

Ground water occurs to some extent in all of the foregoing formations. The principal aquifers are composed of continental and marine sediments of Recent and Pleistocene age. In certain areas, wells are supplied from fractured volcanic rocks of the Tertiary system, or from fissures in crystalline or consolidated rocks of pre-Quaternary age. The fractured rocks generally yield little water. However, in some localities this source constitutes the entire water supply. A detailed geologic report is included as Appendix B.

Soils

Soils of Ventura County vary markedly as to type, composition, depth, and other physical and chemical properties, in accordance with origin of the parent material, nature of deposition, and age and degree of development since the time of deposition. In general, the soils can be divided into three broad groups: (1) residual soils, which have been developed in place from the disintegration and weathering of consolidated rocks, both of sedimentary and basic igneous origin; (2) old valley filling and coastal plain soils, which are derived from elevated, unconsolidated water-laid deposits which have undergone marked changes since their deposition; and (3) recent alluvial soils, which are derived from sediments that have undergone little or no change or internal modification since their deposition. These soils have their origin in a variety of materials, including shale, sandstone, conglomerate, basic igneous rocks, and old valley filling deposits.

Residual soils are identified with hill and mountainous areas. Soil textures vary from medium to heavy; and soil depth, although variable, is generally shallow, containing inclusions of rock outcrop throughout most of the areal extent of the group. Drainage is generally good. Moisture retention is adequate except where the underlying bedrock is near the surface. Residual soils comprise a relatively small area, occupying the rolling hills and ridges at the perimeter of the interior valleys.

Soils of the old valley filling and coastal plain groups have a varied topography, occurring both on hill and rolling lands and on smooth and eroded marine or stream terraces. They also occur on sloping remnants of old alluvial fans that have either been elevated since time of deposition, or have been left in their present position through the cutting of deeper stream channels or valleys through them. The soils are usually intermediate in elevation between the residual and recent alluvial groups. They have medium texture with friable surface composition, and are well suited to irrigated agriculture. Subsoils are somewhat more compact and heavier in texture, with local tendencies toward hardpan. Surface drainage is generally good, but subsurface drainage is in some cases retarded by the heavy compact nature of the subsoil. No indication of the accumulation of harmful salts in the soil solution has been noted as a result of this condition. In portions of the County, particularly along the northern and eastern sides of Ojai Valley, this group contains considerable rock outcropping.

Topography identified with the recent alluvial soils is smooth and gently sloping. This group covers nearly the entire coastal plain of the Santa Clara River Valley, and also occurs as river and creek bottom deposits along the Santa Clara River and its tributaries. These soils comprise the numerous alluvial fans found at the mouths of tributary creeks throughout the County. Depth of soil is generally good, with textures grading from light to very heavy. The soils of the group have the common characteristic of stratification in the subsoil. On all alluvial fans, both surface and internal drainage is good. However, in some of the lower valleys where the soils are quite heavy, drainage is poor, as in the southerly portion of the coastal plain and extending northerly therefrom toward Camarillo. An extensive drainage system has been constructed in this area to alleviate this problem. In portions of the coastal plain, where drainage works have not been constructed, there are heavy concentrations of soluble salts in the soil solution.

Recent alluvial soils comprise the largest area in the County presently developed to either irrigated agriculture or developments of an urban nature.

Present Development

The establishment of Mission San Buenaventura in 1782 by Franciscan Father Junipero Serra marked the beginning of the development of Ventura County. After California became a state in 1850, and until legislative action in 1872, the area now included within Ventura County was part of Santa Barbara County.

Early-day activities were of an agricultural nature and devoted to the sustenance of the mission settlement. Water supplies for the mission were obtained by diversion from the Ventura River. Portions of the original aqueduct and receiving reservoir, used for domestic and minor irrigation purposes, are still intact. In common with other portions of Spanish California, Ventura County, in the early 19th century, was divided into several large land grants, known as ranchos. The principal activity of the "rancheros" was the raising of cattle, sheep, horses, and mules on extensive pasture lands. After the acquisition of California by the United States and the accompanying decline of the ranchos, extensive plantings were made of wheat, barley, corn, and other dry-farmed crops.

During the decade from 1880 to 1890, the economy of Ventura County experienced a marked change with the introduction of large-scale irrigation in areas where water supplies were readily available. The original plantings of citrus and walnuts were made about this time in Ojai Valley and along the Santa Clara River. These crops, particularly the former, have continued to have great commercial importance to the present day. Beans were introduced to the Oxnard Plain just prior to the turn of the century. The subsequent rapid expansion of this crop has resulted in the designation of the Oxnard Plain as the "bean basket of the world".

Originally, irrigation was accomplished through diversion of surface waters. However, increased water utilization, coupled with protracted periods of drought wherein flow in Ventura County streams diminished to negligible proportions during the summer and fall, caused irrigators to turn to utilization of supplies available in underlying ground water basins. At first centrifugal pumps were employed, but later declining water levels necessitated the installation of deep-well turbine pumps throughout most of the irrigated areas.

At the present time the Santa Clara River Valley, the coastal plain, and portions of the Ventura River and Calleguas Creek drainage areas are extensively developed to irrigated agriculture. However, irrigation developments in many parts of the County have been impeded through lack of firm water supplies. Land use surveys conducted in Ventura County during 1949-50 indicated that there were, at that time, in excess of 109,000 net acres of irrigated land. Leading crops were citrus with about 43,000 acres, beans with about 33,000 acres, and walnuts with slightly less than 18,000 acres. The value of crops produced in Ventura County in 1950 was in excess of $50,000,000, as compared to a reported value of about $20,000,000 in 1940.

At the present time and for many years past, the oil industry has been a leading producer of revenue. Large areas are presently devoted to oil fields and appurtenant developments. Numerous active oil seeps in various portions of the County attracted oil prospectors as early as the middle of the 19th century.

Other principal industries in Ventura County, excluding those allied with the production of oil, are citrus packing and vegetable processing. The American Crystal Sugar Company's sugar beet processing plant in Oxnard is the largest of the latter. Sand and gravel works supply local demands for aggregates. Concrete pipe, used in irrigation distribution and drainage systems, is manufactured locally. The United States Navy maintains a large advanced base depot at Port Hueneme, as well as an air missile test center at Point Mugu. A United States Air Force base is located near Camarillo. Electrical energy is brought into the County by the Southern California Edison Company.

The 1950 Federal census reported the population of Ventura County to be 114,647. From 1940 to 1950, the population increased by 44,962, or by about 65 per cent of the reported 1940 total of 69,685. The City of Oxnard, which in 1940 ranked third in population of incorporated cities in the County, was first in 1950 with a population of 21,567. The population of other incorporated cities in 1950, in order of their magnitude, was: Ventura, 16,534; Santa Paula, 11,049; Fillmore, 3,884; Port Hueneme, 3,024; and Ojai, 2,519.

Ventura County is well served with rail, air, and highway transportation facilities. The coast route of the Southern Pacific Railroad passes through the County, as do U. S. Highways 101 and 399 and several state highways. Local products are exported by sea from Port Hueneme. In addition, offshore loading of oil tankers is effected by means of submarine pipe lines constructed from the oil fields in the vicinity of the City of Ventura.

Recreational facilities are available in county parks, beaches, and in the Los Padres National Forest. Ojai Valley is a noted southern California resort area.

The assessed valuation of Ventura County in the fiscal year 1952-53, as reported by the County Auditor, was $283,230,490. Ventura County is among the top quarter of counties in California from the standpoint of assessed valuation.

Water service is provided through individual effort, by municipal and other public agencies, and by many private agencies. In addition, many public districts have been formed to deal with the problems of water supply, flood control, drainage, and land reclamation. The activities of these districts, their powers, and purposes are described in Appendix D. The boundaries of the Ventura County Flood Control District, the Santa Clara Water Conservation District, the United Water Conservation District, the Ventura Municipal Water District, and the Simi Valley Water Conservation District are delineated on Plate 2, entitled "Major Water Districts, 1953".

Hydrologic Units

In order to facilitate analysis of present and probable future water supply problems of Ventura County, the southerly portion thereof has been divided into four hydrologic units. These units, the boundaries of which are shown on Plate 3, "Hydrologic Units", have been designated "Ventura", "Santa Clara River", "Calleguas-Conejo", and "Malibu".

Boundaries of the hydrologic units were defined after giving consideration to those factors of water supply and utilization, topography, and geology, which affect hydrologic analysis, and in order to include those lands having correlative water problems. In general, each unit extends to definite political or topographic boundaries. It will be noted on Plate 3 that the northerly limits of the Ventura and Santa Clara River Units conform generally to the boundary of the Los Padres National Forest, except in those instances where contiguous bodies of irrigable land encroach onto the federal reservation. The complex nature of the Ventura, Santa Clara River, and Calleguas-Conejo Units necessitated further division thereof into subunits, the boundaries of which are also shown on Plate 3. Table 1 presents the total area of each of the hydrologic units and subunits.

TABLE 1

AREAS OF HYDROLOGIC UNITS AND SUBUNITS

Name	Acres
Ventura	
Upper Ojai	9,670
Ojai	10,800
Upper Ventura River	25,990
Lower Ventura River	31,170
Rincon	15,390
Subtotal	93,020
Santa Clara River	
Eastern	2,800
Piru	47,310
Fillmore	45,450
Santa Paula	52,040
Mound	17,490
Oxnard Forebay	6,170
Oxnard Plain	46,460
Pleasant Valley	36,010
Subtotal	253,730
Calleguas-Conejo	
Simi	50,010
East Las Posas	52,480
West Las Posas	14,160
Conejo	28,930
Tierra Rejada	4,390
Santa Rosa	8,030
Subtotal	158,000
Malibu	52,670
TOTAL	557,420

There are certain other relatively small areas of Ventura County which, although largely undeveloped, are by virtue of their soils and topography susceptible to future irrigation development. These areas are located primarily in the northerly portion, in the upper reaches of Piru Creek and the Cuyama River. In addition, certain lands included within the Los Padres National Forest, other than those included within the aforementioned hydrologic units, either presently use small amounts of water or are considered to have a small potential water requirement.

CHAPTER II. WATER SUPPLY

The principal sources of water supply of Ventura County are direct precipitation and runoff from tributary drainage areas. A small import of Santa Clara River water from Los Angeles County, together with relatively minor quantities of water released from the Los Angeles Aqueduct in the upper reaches of the Santa Clara River watershed have contributed to the supply. So far as was determined during the investigation, there is no record of export of water from Ventura County. The water supply of the County is considered and evaluated in this chapter under the general headings: "Precipitation", "Runoff", "Underground Hydrology", "Quality of Water", and "Safe Yield of Presently Developed Water Supply". The following terms are used as defined in connection with the discussion of water supply in this report:

Annual - This refers to the 12-month period from January 1st of a given year through December 31st of the same year, sometimes termed the "calendar year".

Seasonal - This refers to any 12-month period other than the calendar year.

Precipitation Season - The 12-month period from July 1st of a given year through June 30th of the following year.

Runoff Season - The 12-month period from October 1st of a given year through September 30th of the following year.

Investigational Seasons - The two runoff seasons of 1951-52 and 1952-53, during which most of the field work of the Ventura County Investigation was performed.

Mean Period - A period chosen to represent conditions of water supply and climate over a long series of years.

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.

Mean - This is used in reference to arithmetical averages relating to mean periods.

Average - This is used in reference to arithmetical averages relating to periods other than mean periods.

In studies for the current State-Wide Water Resources Investigation, it was determined that the 50 years from 1897-98 to 1946-47, inclusive, constituted the most satisfactory period for estimating mean seasonal precipitation generally throughout California. Similarly, the 53-year period from 1894-95 to 1946-47, inclusive, was selected for determining mean seasonal runoff. In studies for the Ventura County Investigation, conditions during these periods were considered representative of mean conditions of water supply and climate.

Studies were made to select a base period for hydrologic analysis of Ventura County during which conditions of water supply and climate would approximate mean conditions, and for which adequate data on water supply, water utilization, and ground water conditions would be available. It was determined that the 15-year period from 1936-37 through 1950-51 was the most satisfactory in this respect. The average seasonal water supply during this chosen base period so closely approached that of the mean period throughout the County that its magnitude was considered to be equivalent to that of the mean period. Furthermore, the base period exemplifies the historic cyclic nature of the water supply of Ventura County. It includes a series of eight years from 1936-37 through 1943-44 wherein the average seasonal water supply substantially exceeded that of the mean period, followed by a series of seven years wherein the average seasonal water supply was considerably less than that of the mean period. Accordingly, these periods are hereinafter referred to as the "wet period" and "drought period", respectively.

Water resources problems of Ventura County stem in part from the erratic and apparently cyclic occurrence of its water supply. The relationship between water supply and utilization during drought periods establishes the magnitude of these problems. Since 1894 there have been three major drought periods, namely: 1894-95 through 1903-04; 1922-23 through 1935-36; and 1944-45 through 1950-51. Water supply data are almost entirely estimated for the earliest of these periods, and partially so for the period from 1922-23 through 1935-36. Fairly reliable data are available throughout the County for the drought period included in the chosen base period. Although for study purposes, this latter period has been adopted as representative of drought conditions in Ventura County, it has been concluded that in some portions of the County, the period from 1922-23 through 1935-36 was of somewhat greater severity in regard to accumulated deficiency in water supply. The results of certain studies presented later in this bulletin should be qualified accordingly.

Precipitation

Ventura County receives a substantial portion of its precipitation from storms originating in both the West and Northwest Pacific and in the Southwest Pacific, almost entirely during winter months. Precipitation, comprising the largest item of the County's water supply, is consumed or disposed of in various ways: evaporation from plant and ground surfaces soon after the occurrence of rain; through accretion to the depleted soil moisture of the soil mantle, which source subsequently furnishes water to meet consumptive requirements of vegetal cover; through deep percolation to ground water in absorptive areas; and through surface runoff.

Precipitation Stations and Records

During the investigational seasons there were 57 precipitation stations in operation in Ventura County. Five of these stations were equipped with continuous recorders, and the remainder with non-recording type gages which were usually read daily. In addition, there have been some 50 precipitation stations in operation in Ventura County for varying lengths of time, which are now inactive. The longest record is that of the station at Ventura, which extends back to 1873. The stations are numerous and well distributed over the southerly portion of the County, but in the northerly and less accessible mountainous regions few stations have been established and the precipitation pattern therein is less susceptible to reliable determination.

Locations of the precipitation stations within and adjacent to Ventura County are shown on Plate 4, "Lines of Equal Mean Seasonal precipitation". Map reference numbers correspond to those presented in State Water Resources Board Bulletin No. 1, "Water Resources of California". For those stations not appearing in Bulletin No. 1, numbers were assigned consecutively after the last number presented in that bulletin. Thirty-nine active precipitation stations in Ventura County having unbroken records of 15 years or longer as of 1950-51 are listed in Table 2, together with the map reference number, elevation, period and source of record, mean, maximum, and minimum seasonal depth of precipitation for each.

TABLE 2

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT SELECTED STATIONS IN VENTURA COUNTY

Map reference number	Station	Elevation, in feet	Period of record	Source of record	Estimated mean seasonal precipitation, in inches of depth	Maximum and minimum seasonal precipitation: Season	Maximum and minimum seasonal precipitation: Inches of depth
3-83	Ozena	3,700	1904-05 1951-52	USWB	13.40	1940-41 1948-49	32.60 4.64
4-60	Aggen Ranch	375	1903-04 1951-52	Private	15.00	1940-41 1947-48	32.48 6.21
4-31	Bardsdale	400	1932-33 1951-52	Private	17.45	1940-41 1947-48	39.58 8.65
4-53	Borgstroms Ranch	200	1921-22 1951-52	Private	14.82	1940-41 1923-24	35.40 6.14
4-39	Camulos Ranch Headquarters	730	1928-29 1951-52	Private	14.25	1940-41 1947-48	36.30 7.78
4-22	Canada Larga	800	1934-35 1951-52	Private	17.90	1940-41 1947-48	43.62 8.83
4-16	Casitas Ranch	400	1924-25 1951-52	Private	23.81	1940-41 1947-48	48.02 10.90
4-65	Conejo Ranch	650	1913-14 1951-52	Private	15.38	1940-41 1947-48	33.82 6.03

TABLE 2 (continued)

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT
SELECTED STATIONS IN VENTURA COUNTY

Map reference number	Station	Elevation, in feet	Period of record	Source of record	Estimated mean seasonal precipitation, in inches of depth	Maximum and minimum seasonal precipitation	
						Season	Inches of depth
4-54	Del Mar Ranch	300	1924-25 1951-52	Private	16.82	1940-41 1947-48	41.75 7.40
4-23	Dennisons	1,250	1883-84 1951-52	Private	21.92	1883-84 1950-51	60.02 6.62
4-63	Epworth	800	1927-28 1951-52	Private	16.40	1940-41 1947-48	34.36 6.90
4-33	Fillmore (Citrus Association)	500	1925-26 1951-52	Private	18.60	1940-41 1947-48	38.68 8.82
4-24	Krotona	830	1928-29 1951-52	Private	19.97	1940-41 1947-48	45.17 9.49
4-36	Levens and Goodenough Ranch	550	1931-32 1951-52	Private	17.00	1940-41 1947-48	38.43 8.07
4-58	Limoneira Ranch	335	1904-05 1951-52	Private	16.66	1940-41 1923-24	38.51 7.13
4-18	Matilija Canyon	950	1902-03 1951-52	Private	24.76	1913-14 1918-19	50.75 6.88

TABLE 2 (continued)

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT SELECTED STATIONS IN VENTURA COUNTY

Map reference number	Station	Elevation, in feet	Period of record	Source of record	Estimated mean seasonal precipitation, in inches of depth	Maximum and minimum seasonal precipitation	
						Season	Inches of depth
4-64	Moorpark	500	1916-17 1951-52	Private	14.12	1940-41 1923-24	30.99 5.55
4-40	Newhall Ranch	750	1912-13 1951-52	Private	17.33	1940-41 1947-48	37.12 7.84
4-601	Ojai, Mallory	750	1891-92 1951-52	Private	18.76	1940-41 1893-94	42.10 6.96
4-21	Ojai	800	1905-06 1951-52	Private	23.4	1940-41 1923-24	45.18 7.30
4-56	Oxnard	51	1898-99 1951-52	USWB	14.47	1940-41 1923-24	38.17 5.83
4-29	Pine Tree Ranch	400	1931-32 1951-52	Private	17.33	1940-41 1950-51	38.73 8.61
4-38	Piru (Citrus Association)	650	1926-27 1951-52	Private	17.93	1940-41 1947-48	38.47 8.05
4-191	Port Hueneme Lighthouse	10	1891-92 1951-52	Private	13.79*	1940-41 1897-98	32.99 3.93

TABLE 2 (continued)

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT
SELECTED STATIONS IN VENTURA COUNTY

Map reference number	Station	Elevation, in feet	Period of record	Source of record	Estimated mean seasonal precipitation, in inches of depth	Maximum and minimum seasonal precipitation	
						Season	inches of depth
4-26	Rancho La Cuesta	900	1930-31 1951-52	Private	21.93	1940-41 1950-51	45.44 9.14
4-17	Rancho Matilija	650	1925-26 1951-52	Private	21.85	1940-41 1947-48	44.51 8.96
4-30	Rancho Sespe	430	1906-07 1951-52	Private	18.67	1940-41 1923-24	38.60 8.80
4-27	Santa Paula	275	1897-98 1951-52	BI Co.	17.50	1940-41 1897-98	38.11 5.91
4-28	Santa Paula	290	1931-32 1951-52	CFA	16.48	1940-41 1950-51	35.54 8.41
4-62	Santa Rosa Valley No. 1	375	1929-30 1950-51	Private	12.47	1940-41 1947-48	29.12 4.79
4-0402	Saticoy (Culbertson Lemon Association)	150	1936-37 1951-52	Private	14.6	1940-41 1947-48	35.34 6.37
4-15	Selby Ranch	750	1921-22 1951-52	Private	21.86	1940-41 1924-25	51.20 8.00

TABLE 2 (continued)

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT SELECTED STATIONS IN VENTURA COUNTY

Map reference number	Station	Elevation, in feet	Period of record	Source of record	Estimated mean seasonal precipitation, in inches of depth	Maximum and minimum seasonal precipitation: Season	Maximum and minimum seasonal precipitation: inches of depth
4-68	Simi Valley	1,200	1931-32 1951-52	Private	18.52	1940-41 1947-48	40.46 7.64
4-61	Snyder Ranch	300	1892-93 1951-52	Private	14.28*	1940-41 1897-98	32.83 4.26
4-59	Springville Ranch	60	1902-03 1951-52	ACS Co.	13.52	1940-41 1947-48	33.41 5.50
4-66	Tapo Mutual Water Company	1,080	1923-24 1951-52	TMW Co.	15.02	1940-41 1923-24	34.83 6.45
4-600	Thacher School	1,360	1906-07 1950-51	Private	22.0	1940-41 1923-24	52.75 7.31
4-5	Upper Sespe Creek	4,000	1927-28 1951-52	Private	25.34	1940-41 1950-51	60.63 9.12
4-52	Ventura	50	1873-74 1951-52	USWB	15.59	1940-41 1876-77	36.71 5.22

ACS Co. American Crystal Sugar Company
BI Co. Blanchard Investment Company
* Recorded

CFA Ventura County Farm Advisor
TMW Co. Tapo Mutual Water Company
USWB United States Weather Bureau

Precipitation Characteristics

Precipitation in Ventura County occurs primarily as rainfall, although light snowfall is not uncommon in the higher mountainous areas in the northerly portion of the County. Depth of precipitation generally increases from west to east in the southerly developed areas of the County, but decreases in this direction toward the north. Mean seasonal depth of precipitation varies from a maximum of about 32 inches in the Topatopa Mountains to a minimum of about 12 inches in the vicinity of Point Mugu. Storms moving in from the West and Northwest Pacific are first intercepted by the mountains defining the watersheds of Ventura River, Santa Paula Creek, and Sespe Creek; and it is in the higher elevations of these watersheds that depth of precipitation is the greatest in the County. The Piru Creek watershed and that of the Santa Clara River above the Los Angeles County line receive less precipitation, since many of the more productive storms have been dissipated prior to reaching these areas. The light mean seasonal depth of precipitation in the Calleguas Creek drainage area, varying from about 12 to 18 inches, results from the relatively low elevation of the watershed and its position beyond the path of the principal storms.

Plate 4 depicts the variation in mean seasonal depth of precipitation over the County and in tributary watersheds. In certain instances, the preparation of Plate 4 required extension of incomplete or broken records through correlation with stations having long-term records.

Table 3 presents recorded and estimated seasonal depth of precipitation at five selected stations in various portions of the

County, together with the "precipitation index" for each of the seasons shown. The term "precipitation index" refers to the ratio of the average depth of precipitation during a given period or season to the mean seasonal depth, expressed as a percentage.

TABLE 3

RECORDED AND ESTIMATED SEASONAL PRECIPITATION AND
PRECIPITATION INDICES AT SELECTED STATIONS IN VENTURA COUNTY

Season	Ventura, 4-52		Ojai, Mallory, 4-601		Santa Paula, 4-27		Oxnard, 4-56		Wolf Ranch (Simi Valley), 4-67	
	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth
1873-1874	96	15.02	--	--	--	--	--	--	--	--
1874-1875	98	15.24	--	--	--	--	--	--	--	--
76	135	21.00	--	--	--	--	--	--	--	--
77	33	5.22	--	--	--	--	--	--	--	--
78	130	20.22	--	--	--	--	--	--	--	--
79	82	12.79	--	--	--	--	--	--	--	--
1879-1880	142	22.06	--	--	--	--	--	--	--	--
81	89	13.91	--	--	--	--	--	--	--	--
82	77	11.98	--	--	--	--	--	--	--	--
83	74	11.51	--	--	--	--	--	--	--	--
84	232	36.13	--	--	--	--	--	--	--	--
1884-1885	61	9.46	--	--	--	--	--	--	--	--
86	130	20.22	--	--	--	--	--	--	--	--
87	95	14.75	--	--	--	--	--	--	--	--
88	130	20.31	--	--	--	--	--	--	--	--
89	108	16.85	--	--	--	--	--	--	--	--
1889-1890	171	26.65	--	--	--	--	--	--	--	--
91	98	15.39	--	--	--	--	--	--	--	--
92	71	11.10	95	17.82	--	--	--	--	--	--
93	151	23.49	154	28.82	--	--	--	--	--	--

TABLE 3 (continued)

RECORDED AND ESTIMATED SEASONAL PRECIPITATION AND PRECIPITATION INDICES AT SELECTED STATIONS IN VENTURA COUNTY

Season	Ventura, 4-52		Ojai, Mallory, 4-601		Santa Paula, 4-27		Oxnard, 4-56		Wolf Ranch (Simi Valley), 4-67	
	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth
1893-1894	41	6.39	37	6.96	--	--	--	--	--	--
1894-1895	97	15.13	107	19.99	--	--	--	--	--	--
96	63	9.90	66	12.33	--	--	--	--	--	--
97	102	15.89	104	19.59	--	--	--	--	--	--
98	38	5.94	105	19.61	34	5.91	28	4.12*	33	4.5*
99	59	9.13	47	8.80	42	7.40	79	11.57	43	6.0*
1899-1900	61	9.48	57	10.73	55	9.57	68	9.87	69	9.5*
01	90	14.05	98	18.34	92	16.09	90	13.01	91	12.5*
02	81	12.69	72	13.60	75	13.09	87	12.53	76	10.5*
03	104	16.26	86	16.21	105	18.40	117	16.91	105	14.5*
04	68	10.64	65	12.14	66	11.54	50	7.28	65	9.0*
1904-1905	156	24.30	155	29.07	139	24.26	126	18.27	138	19.0*
06	123	19.23	109	20.42	102	17.93	121	17.48	101	14.0*
07	149	23.25*	176	33.02	159	27.83	139	20.10	159	22.0*
08	111	17.31	94	17.67	83	14.58	109	15.79	83	11.5*
09	184	28.73	138	25.81	148	25.90	146	21.11	149	20.5*
1909-1910	102	15.93	91	17.02	80	13.94	90	13.08	76	10.5*
11	149	23.23	157	29.49	126	22.00	124	17.99	127	17.5*
12	88	13.73	64	12.08	64	11.14	69	10.05	62	8.5*
13	104	16.28	78	14.65	85	14.91	83	12.08	83	11.5*

TABLE 3 (continued)

RECORDED AND ESTIMATED SEASONAL PRECIPITATION AND PRECIPITATION INDICES AT SELECTED STATIONS IN VENTURA COUNTY

Season	Ventura, 4-52		Ojai, Mallory, 4-601		Santa Paula, 4-27		Oxnard, 4-56		Wolf Ranch (Simi Valley), 4-67	
	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth
1913-1914	171	26.71	183	34.42	166	28.98	128	18.51	150	20.67
1914-1915	137	21.40	114	21.46	132	23.12	133	19.23	138	19.02
16	117	18.19	128	23.98	132	23.05	115	16.62	97	13.33
17	124	19.29	118	22.15*	122	21.38	109	15.76	109	15.04
18	135	21.12	120	22.45	113	19.84	94	13.58	113	15.57
19	59	9.09	72	13.55*	71	12.41	70	10.10	73	10.11
1919-1920	63	9.82	79	14.76	81	14.24	64	9.33	85	11.75
21	87	13.51	76	14.34	99	17.28	72	10.47	68	9.34
22	123	19.21	108	20.20	121	21.10	103	14.96	127	17.53
23	85	13.31	84	15.83	85	14.93	73	10.57	62	8.53
24	44	6.85	37	6.99	44	7.71	40	5.83	39	5.36
1924-1925	59	9.03	58	10.88	57	10.01	62	8.96	66	9.15
26	99	15.52	101	19.02	94	16.41	114	16.54	133	18.37
27	108	16.79	127	23.78	133	23.32	111	16.09	118	16.28
28	76	11.83	70	13.14	64	11.15	73	10.54	87	12.05
29	63	9.85	68	12.69	77	13.48	71	10.32	75	10.34
1929-1930	67	10.56	65	12.12	70	12.26	76	11.03	76	10.53
31	81	12.76	76	14.34	80	14.00	82	11.86	93	12.80
32	118	18.32	131	24.54	118	20.60	114	16.46	115	15.91
33	56	8.73	56	10.43	64	11.21	77	11.10	83	11.50

TABLE 3 (continued)

RECORDED AND ESTIMATED SEASONAL PRECIPITATION AND
PRECIPITATION INDICES AT SELECTED STATIONS IN VENTURA COUNTY

Season	Ventura, 4-52		Ojai, Mallory, 4-601		Santa Paula, 4-27		Oxnard, 4-56		Wolf Ranch (Simi Valley), 4-67	
	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth
1933-1934	76	11.77	71	13.24	85	14.95	71	10.21	74	10.28
1934-1935	113	17.59	103	19.25	121	21.22	130	18.75	125	17.24
36	88	13.66	101	19.09	95	16.57	75	10.82	79	10.88
37	149	23.23	140	26.33	151	26.49	156	22.56	167	23.09
38	133	20.67	163	30.64	153	26.73	135	19.59	135	18.57
39	89	13.94	68	12.80	82	14.34	92	13.29	82	11.35
1939-1940	76	11.88	84	15.69	85	14.88	107	15.42	110	15.28
41	235	36.71	224	42.10	218	38.11	264	38.17	255	35.18
42	82	12.77	86	16.25	81	14.19	86	12.43	80	11.05
43	128	19.88	128	24.06	166	29.06	140	20.28	162	22.38
44	116	18.02	117	22.03	139	24.37	156	22.56	155	21.42
1944-1945	78	12.13	93	17.52	92	16.04	74	10.66	89	12.22
46	56	8.67	79	14.79	74	12.99	68	9.87	93	12.84
47	58	8.98	78	14.56	82	14.33	83	12.09	94	12.98
48	36	5.55	43	8.11	51	8.89*	42	6.13	45	6.17
49	38	5.85	56	10.47	51	8.91*	52	7.48	52	7.11
1949-1950	63	9.94	80	14.98	75	13.07	78	11.41	75	10.36
51	45	7.09	52	9.79	47	8.14	56	8.12	66	9.08*
52	153	23.78	164	30.75	196	34.30	173	25.07	197	27.17*

TABEL 3 (continued)

RECORDED AND ESTIMATED SEASONAL PRECIPITATION AND
PRECIPITATION INDICES AT SELECTED STATIONS IN VENTURA COUNTY

Season	Ventura, 4-52		Ojai, Mallory, 4-601		Santa Paula, 4-27		Oxnard, 4-56		Wolf Ranch (Simi Valley), 4-67	
	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth	Index	In inches of depth
Average for 15-year base period, 1936-37 through 1950-51	92	14.35	99	18.67	103	18.04	106	15.34	111	15.27
Mean for 50-year period, 1897-98 through 1946-47	100	15.59	100	18.76	100	17.50	100	14.47	100	13.80
Average for period of record	99	15.50	98	18.34	99	17.25	98	14.26	104	14.30

* Estimated.

Precipitation in Ventura County exhibits extreme monthly and seasonal variation, but generally with a proportionate consistency throughout the County in any given season. Seasonal depth of precipitation at Ojai has varied from a minimum of 37 per cent of the mean in 1893-94, when 6.96 inches were recorded, to a maximum of 224 per cent of the mean in 1940-41, when 42.10 inches were recorded. Similar extremes occurred at other long-term stations throughout the County. The erratic seasonal occurrence of precipitation in Ventura County is depicted graphically on Plate 5, entitled "Recorded Seasonal Precipitation at Ojai, 1891-92 through 1951-52". The apparent cyclic nature of the occurrence of precipitation at this station is shown on Plate 6, entitled "Accumulated Departure from Mean Seasonal Precipitation at Ojai, 1891-92 through 1951-52".

About 80 per cent of the seasonal precipitation in Ventura County occurs during the four-month period from December through March. It is not unusual, however, for one or more of these months to be extremely dry in a given season. The mean monthly distribution of precipitation at Santa Paula, which may be considered generally representative of the County in this respect, is presented in Table 4.

TABLE 4

MEAN MONTHLY DISTRIBUTION OF
PRECIPITATION AT SANTA PAULA

Month	Precipitation		Month	Precipitation	
	In inches of depth	In per cent of seasonal total		In inches of depth	In per cent of seasonal total
July	0.01	0.1	January	3.86	22.0
August	0.03	0.2	February	4.07	23.2
September	0.31	1.8	March	3.04	17.4
October	0.62	3.5	April	0.98	5.6
November	1.23	7.0	May	0.38	2.2
December	2.94	16.8	June	0.03	0.2
			TOTALS	17.50	100.0

Quantity of Precipitation

In certain of the absorptive areas of Ventura County, wherein precipitation constitutes a direct source of ground water replenishment, it was necessary to evaluate the total quantity of precipitation for the purpose of required hydrologic analysis. These absorptive areas included the Piru, Fillmore, Santa Paula, and Oxnard Forebay ground water basins, of the Santa Clara River Unit, and the Simi Basin of the Calleguas-Conejo Unit. The mean seasonal quantity of precipitation on these areas was estimated by plotting recorded or estimated mean seasonal depth of precipitation at stations in or near the basins on a suitable base map. Lines of equal mean seasonal precipitation, or isohyets, were then drawn, as shown on Plate 4.

By planimetering the areas between these isohyets, the weighted mean seasonal depth and total quantity of precipitation were estimated. In order to determine seasonal depth and quantity of precipitation during the base period, the estimates for the mean period were adjusted on the basis of recorded precipitation at key stations within or near each of the basins. The results of these estimates are listed in the following tabulation:

Ground water basin	Estimated mean seasonal precipitation, in acre-feet	Estimated average seasonal precipitation during base period in acre-feet
Piru	9,400	9,600
Fillmore	26,300	25,800
Santa Paula	18,800	18,500
Oxnard Forebay	8,700	8,400
Simi	12,400	13,300

Runoff

The watersheds within and tributary to Ventura County vary markedly in their production of runoff, depending on their areal extent and other physical characteristics, and on the depth of precipitation. Unit runoff is the greatest from the watersheds of the Ventura River, Santa Paula Creek, and Sespe Creek, with lower values from the watersheds of Piru Creek and Santa Clara River above the Ventura County line. Runoff from the Calleguas Creek system is of relatively minor magnitude. Tributary runoff is disposed of through percolation to ground water storage in absorptive stream channels and artificial spreading grounds, evaporation, consumptive use of native vegetation, diversions to meet requirements of irrigated agriculture and urban entities, and discharge to the ocean.

Stream Gaging Stations and Records

Long-term records of runoff from streams within or tributary to Ventura County are not available. The longest unbroken records of stream flow in the County are for Matilija Creek at Matilija and Santa Paula Creek near Santa Paula, which are continuous from 1927 to the present time. Broken records extending back to 1911 are available for Ventura River near Ventura, Piru Creek near Piru, and for Sespe Creek, where stations have been maintained at three locations. Continuous records of runoff during the base period are available for Matilija Creek at Matilija, North Fork of Matilija Creek at Matilija, Coyote Creek near Ventura, Ventura River near Ventura, Santa Clara River near Saugus, Piru Creek near Piru, Sespe Creek near Fillmore, Santa Paula Creek near Santa Paula, Arroyo Simi near Simi, and Arroyo Las Posas near Moorpark. In general, records of runoff from minor streams throughout the County are nonexistent, except for those instances where such records were obtained during the present investigation and the investigation for Division of Water Resources Bulletin No. 46.

Locations of stream gaging stations pertinent to the evaluation of the water supply of Ventura County, including the five established in connection with the Ventura County Investigation, are shown on Plate 7 entitled "Stream Gaging and Water Sampling Stations". In general, map reference numbers shown on Plate 7 are those presented in State Water Resources Board Bulletin No. 1, "Water Resources of

California". However, for stations not reported in Bulletin No. 1, arbitrary numbers have been assigned, prefixed by an appropriate County designation; i.e., V.C., Ventura County or L.A., Los Angeles County. Table 5 presents a list of the stations shown on Plate 7, together with map reference numbers, drainage areas, periods and sources of records. Records for the five stations established and maintained by the Division of Water Resources during the investigational seasons, and for San Antonio Creek near Mouth, Santa Clara River near Montalvo, Arroyo Simi near Simi, and Arroyo Las Posas near Moorpark, established and maintained by the Ventura County Water Survey, are available in the files of the Division of Water Resources. The Los Angeles County Flood Control District publishes the records for Santa Clara River ½ mile west of County line, Santa Clara River above Lang Railroad Station, Placerita Creek at Ridge Route Highway, and Castaic Creek at State Highway 126. The United States Geological Survey publishes the records for all remaining stations listed in Table 5.

TABLE 5

STREAM GAGING STATIONS IN OR NEAR VENTURA COUNTY

Map reference number	Stream	Station	Drainage area, in square miles	Period of record	Source of record
4- 1	Matilija Creek	At Matilija	55	1927-53	USGS
4- 2	North Fork Matilija Creek	At Matilija	15.5	1928-32 1933-53	USGS
4- 3	Coyote Creek	Near Ventura	41	1927-32 1933-53	USGS
4- 4	Ventura River	Near Ventura	187	1911-14 1929-53	USGS
4- 5	Santa Clara River	Near Saugus	410	1929-53	USGS
4- 6	Piru Creek	Near Piru	432	1911-13 1927-53	USGS
4- 7	Hopper Creek	Near Piru	23	1930-32 1933-36 1937-53	USGS
4- 8	Sespe Creek	At Bradfield's Camp	208	1915-27	USGS
4- 9	Sespe Creek	At Sespe	257	1911-13 1927-34	USGS
4-10	Sespe Creek	Near Fillmore	254	1934-53	USGS
4-11	Santa Paula Creek	Near Santa Paula	40	1912-13 1927-53	USGS
4-12	Santa Clara River	Near Montalvo	1,596	1927-32 1947-53	VCWS
4-14	Malibu Creek	At Crater Camp, near Calabasas	103	1931-53	USGS
VC- 1	Matilija Creek	Above Matilija Reservoir	51	1948-53	USGS
VC- 2	San Antonio Creek	Near Mouth	51	1949-53	VCWS
VC- 3	San Antonio Creek	Near Ojai	34	1927-32 1951-52	DWR

TABLE 5 (Continued)

STREAM GAGING STATIONS IN OR NEAR VENTURA COUNTY

Map reference number	Stream	Station	Drainage area, in square miles	Period of record	Source of record
VC- 4	Santa Clara River	½ mile west of County line	644	1948-53	LACFCD
VC- 5	Sespe Creek	Near Wheeler Springs	50	1948-53	USGS
VC- 6	Tapo Creek	Near Santa Susana	17	1951-53	DWR
VC- 7	Arroyo Simi	Near Simi	75	1933-53	VCWS
VC- 8	Arroyo Las Posas	Near Moorpark	118	1933-52	VCWS
VC- 9	Calleguas Creek	Near Camarillo	169	1928-31 1951-53	DWR
VC-10	Conejo Creek	Near Camarillo	70	1927-31 1951-53	DWR
VC-11	Calleguas Creek	At Camarillo State Hospital	251	1951-53	DWR
LA- 1	Santa Clara River	Above Lang Railroad Station	157	1949-53	LACFCD
LA- 2	Placerita Creek	At Ridge Route Highway	41	1947-53	LACFCD
LA- 3	Castaic Creek	At State Highway 126	203	1945-53	LACFCD

USGS United States Geological Survey
VCWS Ventura County Water Survey
LACFCD Los Angeles County Flood Control District
DWR Division of Water Resources

Runoff Characteristics

Runoff from streams in Ventura County is derived primarily from rainfall, and as a result exhibits similar monthly and seasonal variations. Absence of snowpack in tributary watersheds causes all streams to diminish rapidly in flow at the conclusion of the winter precipitation season, although some summer flow is maintained by springs in the upper reaches of the more productive watersheds. Following a severe storm, discharge in the larger streams has been known to increase in a few hours time from practically no flow to a rate of thousands of cubic feet per second. Seasonal natural runoff in the principal streams of the County has varied from a maximum in excess of 400 per cent of the mean to a minimum of less than five per cent of the mean. Seasonal vagaries in the runoff of Ventura County streams are represented graphically on Plate 8, entitled "Estimated Seasonal Natural Runoff of Sespe Creek Near Fillmore". The apparent cyclic nature of the occurrence of runoff at this station is shown on Plate 9, entitled "Accumulated Departure from Mean Seasonal Natural Runoff of Sespe Creek near Fillmore". The monthly variation in seasonal runoff is shown in Table 6.

TABLE 6

ESTIMATED AVERAGE MONTHLY DISTRIBUTION
OF NATURAL RUNOFF OF
SESPE CREEK NEAR FILLMORE,
1936-37 THROUGH 1950-51

Month	Runoff, in acre-feet	Per cent of seasonal total
October	790	0.8
November	1,830	1.9
December	7,120	7.5
January	9,480	10.0
February	24,510	25.9
March	32,280	34.1
April	10,930	11.5
May	3,760	4.0
June	1,820	1.9
July	960	1.0
August	640	0.7
September	700	0.7
TOTALS	94,800	100.0

Quantity of Runoff

As described previously, long-term records of runoff in Ventura County streams are not available. The natural runoff for each season of the mean period was estimated in State Water Resources Board Bulletin No. 1 for Ventura River near Ventura, Piru Creek near Piru, Sespe Creek near Sespe, Santa Paula Creek near Santa Paula, Santa Clara River at County Line, and Malibu Creek at Crater Camp near Calabasas. Table 7 presents the natural runoff of three representative streams in the County for each season of the base period, together with the seasonal "runoff index" for each of the streams. The term "runoff index" refers to the ratio of the amount of runoff during a given season or period to the mean seasonal amount, and is expressed as a percentage.

TABLE 7

ESTIMATED SEASONAL NATURAL RUNOFF OF SELECTED STREAMS OF VENTURA COUNTY, 1936-37 THROUGH 1950-51

Season	Matilija Creek at Matilija		Piru Creek near Piru		Sespe Creek near Sespe	
	Runoff index	Runoff, in acre-feet	Runoff index	Runoff, in acre-feet	Runoff index	Runoff, in acre-feet
1936-37	182	51,200	130	69,700	182	171,000
1937-38	288	81,200	240	129,000	255	239,000
1938-39	47	13,200	71	38,200	49	46,200
1939-40	31	8,700	36	19,400	35	32,500
1940-41	444	125,300	421	226,000	400	376,000
1941-42	46	13,000	60	32,200	45	42,200
1942-43	212	59,700	190	102,000	182	171,000
1943-44	133	37,600	233	125,000	152	143,000
1944-45	51	14,400	64	34,400	58	54,400
1945-46	64	18,100	60	32,300	69	64,400
1946-47	34	9,500	53	28,400	48	45,300
1947-48	9	2,400	12	6,600	9	8,100
1948-49	9	2,600	11	6,000	10	9,100
1949-50	13	3,600	14	7,300	18	16,900
1950-51	5	1,300	4	2,400	4	3,500
Average for 15-year base period, 1936-37 through 1950-51	105	29,500	107	57,300	101	94,800
Average for wet period, 1936-37 through 1943-44	173	48,700	173	92,700	163	152,600
Average for drought period, 1944-45 through 1950-51	26	7,400	31	16,800	31	28,800
Mean for 53-year period, 1894-95 through 1946-47	100	28,200	100	53,700	100	93,900

The actual quantity of surface runoff during the base period was evaluated from records at thirteen key stream gaging stations. Where records were not continuous over the base period, estimates for the missing seasons were made by correlation with nearby stations. Unmeasured runoff was estimated by correlation with runoff at a key station or from rainfall-runoff relationships. Table 8 presents measured and estimated seasonal runoff for the base period at the thirteen key stations.

TABLE 8

MEASURED AND ESTIMATED SEASONAL RUNOFF AT KEY STREAM GAGING STATIONS
IN OR NEAR VENTURA COUNTY
1936-37 THROUGH 1950-51

(In acre-feet)

Season	Station and map reference number						
	Matilija Creek at Matilija, 4-1	North Fork Matilija Creek at Matilija, 4-2	Coyote Creek near Ventura, 4-3	Ventura River near Ventura, 4-4	Arroyo Simi near Simi, VC-7	Arroyo Las Posas near Moorpark, VC-8	Malibu Creek at Crater Camp near Calabasas, 4-14
1936-37	51,230	13,590	22,280	108,100	546	1,010	23,940
1937-38	81,160	22,920	26,560	190,100	1,580	4,130	34,100
1938-39	13,200	2,740	3,000	18,960	31	24	4,630
1939-40	8,660	2,250	2,430	10,940	7	8	6,100
1940-41	125,280	31,290	50,890	256,300	7,150	9,350	73,220
1941-42	12,950	4,300	3,630	22,210	0	0	1,820
1942-43	59,660	15,970	28,910	136,500	2,950	3,080	47,600
1943-44	37,620	9,870	15,190	74,770	4,170	4,460	30,170
1944-45	14,350	4,820	7,270	30,080	36	42	4,240
1945-46	18,130	5,150	3,600	23,340	54	48	3,800
1946-47	9,540	3,000	2,830	11,400	277	381	3,820
1947-48	2,200	760	50	50	0	1	180
1948-49	2,700	1,150	140	160	0	0	90
1949-50	3,100	1,630	1,470	2,660	0	0	480
1950-51	1,540	590	100	0	0	0	60
Average for base period, 1936-37 through 1950-51	29,420	8,000	11,220	59,040	1,120	1,500	15,620
Average for wet period, 1936-37 through 1943-44	46,720	12,870	19,110	102,240	2,050	2,760	27,700
Average for drought period, 1944-45 through 1950-51	7,370	2,440	2,210	9,670	52	67	1,810

TABLE 6 (Continued)

MEASURED AND ESTIMATED SEASONAL RUNOFF AT KEY STREAM GAGING STATIONS
IN OR NEAR VENTURA COUNTY
1936-37 THROUGH 1950-51

(In acre-feet)

Season	Station and map reference number					
	Santa Clara River near Saugus, 4-5	Santa Clara River ½ mile west of County Line VC-4	Piru Creek near Piru, 4-6	Hopper Creek near Piru, 4-7	Sespe Creek near Fillmore, 4-10	Santa Paula Creek near Santa Paula, 4-11
1936-37	4,850	20,420	69,670	7,700	165,800	31,910
1937-38	26,900	56,290	128,700	14,770	232,300	44,320
1938-39	10,180	26,800	38,210	1,450	39,890	8,460
1939-40	1,570	14,010	19,420	800	27,920	5,300
1940-41	41,320	79,900	226,300	15,400	371,700	57,680
1941-42	23,400	43,670	32,190	1,340	37,230	6,890
1942-43	47,170	74,110	101,900	12,010	165,500	39,740
1943-44	49,770	86,110	125,200	5,610	136,700	22,430
1944-45	11,050	25,360	34,380	1,610	49,370	12,180
1945-46	6,440	19,880	32,330	2,040	59,480	11,190
1946-47	11,150	24,580	28,380	1,990	40,730	7,310
1947-48	2,270	11,980	6,630	260	4,380	1,720
1948-49	1,300	8,800	6,020	380	6,230	1,960
1949-50	890	6,710	7,270	1,020	13,920	3,490
1950-51	220	4,280	2,410	140	1,290	990
Average for base period, 1936-37 through 1950-51	15,900	33,530	57,270	4,430	90,160	17,040
Average for wet period, 1936-37 through 1943-44	25,640	50,160	92,700	7,380	147,130	27,090
Average for drought period, 1944-45 through 1950-51	4,760	14,510	16,770	1,060	25,060	5,550

Historically, foreign water has entered the Santa Clara River drainage area through release from the Los Angeles Aqueduct or as a result of spill from the Bouquet Canyon terminal reservoir on the aqueduct. Harold Conkling, Consulting Engineer, in his report entitled "Development of a Supplemental Water Supply for Zone 2, Ventura County Flood Control District, September, 1949", estimated the monthly accretions to the Santa Clara River system from this source for the period from 1925-26 through 1947-48. Estimated amounts for the calendar years 1948 through 1951 were obtained from the United Water Conservation District. These estimates indicate that a total of about 60,900 acre-feet of water from the Los Angeles Aqueduct was discharged into the Santa Clara River during the base period. The amounts varied from zero in several seasons to a maximum of about 20,000 acre-feet in 1938-39. Although this release contributed to the historical water supply of Ventura County, adequate data were not available to determine the quantitative effect thereof. Studies did indicate that in most years a substantial portion of the release percolated in the Santa Clara River channel above the Ventura County line. Furthermore, in certain years when releases were made during periods of flood flow, aqueduct water comingled with local waters and passed through Ventura County to the ocean. Although the percolation of aqueduct water above the County line undoubtedly has affected the rising water at the upper limit of the Piru ground water basin, this influence has been estimated to be of small magnitude and has not been considered in this bulletin.

Imported Water

Imported water comprises a relatively minor item in the water supply of Ventura County. Since 1940, Santa Clara River water has been imported by the Newhall Land and Farming Company from a well field in Los Angeles County near Castaic Junction for use in the Piru ground water basin. About 1,300 acres of land on both sides of the river between the County line and the town of Piru are served by the import. The following tabulation presents the seasonal amount of this import for the period from 1939-40 through 1950-51:

Season	Acre-feet	Season	Acre-feet
1939-40	900	1945-46	2,053
1940-41	1,400	1946-47	2,261
1941-42	1,842	1947-48	2,837
1942-43	1,801	1948-49	3,182
1943-44	1,682	1949-50	3,840
1944-45	1,851	1950-51	3,680

Underground Hydrology

Regulation and reregulation of the water supplies of Ventura County is accomplished almost entirely through storage in underlying ground water reservoirs. [illegible]le ground water supplies are found in the valleys and some hill areas in the southerly portion of the County, occurring principally in alluvium and unconsolidated sediments, and to a lesser extent in consolidated and fractured rocks of sedimentary and volcanic origin. These underground reservoirs are replenished by percolation of surface waters, both in natural channels and in spreading grounds constructed for this purpose, by deep penetration of precipitation and the unconsumed portion of applied irrigation water, and by subsurface inflow from adjacent ground water basins. Disposal of ground water supplies is effected by pumped extractions, by effluent discharge and consumptive use of native vegetation in areas of high ground water, and by subsurface outflow.

In connection with the discussion of underground hydrology in this bulletin, the following terms are used as defined:

Key Well--A well chosen for study because it indicates specified ground water characteristics that are considered representative of a given ground water basin or aquifer, or a portion thereof.

Free Ground Water--This generally refers to a body of ground water not overlain by impervious materials, and moving under control of the water table slope. In areas of free ground water, the ground water basin provides storage to regulate available water supplies. Changes in ground water storage are indicated by changes in ground water levels.

Confined Ground Water--A body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with overlying water, and moving under pressure caused by the difference in head between intake and discharge areas of the confined water body.

Specific Yield--This term, when used in connection with ground water, refers to 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.

Specific Capacity--The number of gallons per minute produced by a pumping well per foot of drawdown.

Drawdown--The lowering of the water level in a well caused by pumping, measured in feet.

Results of investigation of the 17 major ground water basins which have been identified in Ventura County are discussed in this section. In addition to the 17 major basins, there are several other ground water basins in the County which, because of their relatively small storage capacity and minor present utilization, have not been given detailed consideration in this bulletin. Plate 11, entitled "Ground Water Basins", shows the location of each of the 17 basins, and of selected key wells employed in analyzing the basin characteristics. The wells are numbered by the system utilized by the United States Geological Survey, according to the township, range, and section subdivision of the Federal land survey. In the portions of Ventura County not so subdivided, the township, range, and section lines have been projected. Under the system, each section is divided into 40-acre plots, which are lettered as follows:

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

Wells are numbered within each of these 40-acre plots according to the order in which they are located. For example, a well having a number 3N/21W-20M1 would be found in Township 3 North, Range 21 West, and in Section 20. It would be further identified as the first well located in the 40-acre plot lettered M. All well numbers in Ventura County refer to the San Bernardino Base Line and Meridian.

The 17 major ground water basins of Ventura County vary considerably in economic importance, depending on their usable storage capacity, areal extent, seasonal recharge, and the ease with which ground water is yielded to pumping wells. The present studies of underground hydrology included investigation of the geologic characteristics of each of the basins, together with quantitative analysis of replenishment and disposal of ground waters therein.

The geologic investigation included collection and analysis of prior geologic reports and maps, supplemented by discussion with geologists familiar with various portions of the County. Drillers logs for 1,534 water wells and 138 oil wells were collected and analyzed. These data, together with additional information obtained by field surveys, were utilized in preparing Plate 10, entitled "Areal Geology", Plates 12-A, 12-B, and 12-C, entitled "Geologic Sections", and Plate 13, entitled "Diagrammatic Sketch of Oxnard Plain and Oxnard Forebay Basins". The locations of the geologic sections are shown on Plate 11.

Aquifers of significance in ground water pumping were identified from well data, and are shown on the geologic sections. Boundaries of ground water basins were established from geologic evidence, and from analysis of the occurrence and movement of ground water as depicted on the representative ground water contour maps listed in the following tabulation:

Plate Number	Title
14-A, B, C.	Lines of Equal Elevation of Ground Water, Fall of 1936.
15-A, B, C.	Lines of Equal Elevation of Ground Water, Spring of 1944.
16-A, B, C.	Lines of Equal Elevation of Ground Water, Fall of 1951.
17-A, B, C.	Lines of Equal Depth to Ground Water, Fall of 1951.
18-A, B, C.	Lines of Equal Change in Ground Water Elevation, Fall of 1936 to Fall of 1951.
19-A, B, C.	Lines of Equal Change in Ground Water Elevation, Spring of 1944 to Fall of 1951.

Estimates were made of specific yield of the water-bearing formations and of storage capacity of the ground water basins. Methods and procedures utilized in preparing these estimates are described in Appendix B. From these data, and from information on fluctuations of the level of water in wells, changes in ground water storage occurring in ground water basins during selected periods of hydrologic significance were estimated. Plate 20, entitled "Fluctuation of Water Levels at Key Wells", presents hydrographs of ground water elevation at 18 key wells in 14 of the 17 major ground water basins. Plate 21, entitled "Relationship Between Water Levels at Key Wells and Ground Water Storage Depletion", shows graphically the relationship between ground water storage depletion and the elevation of the ground water surface at key wells in Ojai, Piru, Fillmore, Santa Paula, Oxnard Forebay, and Simi Basins. Water level measurements utilized in preparing all plates relating to the occurence and movement of ground water and fluctuations of ground water levels, were obtained from the Ventura County Water Survey.

The effects of draft on and replenishment of the ground water basins were analyzed for the base period, from 1936-37 through 1950-51, in an attempt to ascertain how and to what extent the basins could be utilized to regulate available water supplies to meet present and probable future water requirements of Ventura County. These studies included analysis of data on precipitation, surface runoff, and records of diversions of surface flow from principal streams in the County. Estimates were made of consumptive use of water and of ground water extractions as described in Chapter III. Recharge of ground water basins from stream channel percolation was estimated from data appearing in Division of Water Resources Bulletin No. 46, modified and supplemented in accordance with more recent information including measurements made during the investigation. Where adequate data were available, subsurface inflow to and outflow from the ground water basins were estimated by means of either the "rising water" or "slope-area" methods, or both, descriptions of which are included in Appendix B.

The ensuing discussion presents pertinent data and the results of studies for each of the 17 major ground water basins. As will be noted, the degree of detail to which these studies were conducted varied among the basins, depending on the relative importance of the basin and the availability of basic hydrologic data.

Ventura Hydrologic Unit

Four major ground water basins have been identified in the Ventura Hydrologic Unit. These basins, designated Upper Ojai, Ojai, Upper Ventura River, and Lower Ventura River, comprise a total surface area of about 15,650 acres. The remaining lands of the unit are principally underlain by formations of low permeability which do not yield water readily to wells. Table 9 summarizes certain physical characteristics of the four ground water basins.

TABLE 9

SUMMARY OF SELECTED GROUND WATER BASIN CHARACTERISTICS
IN VENTURA HYDROLOGIC UNIT

Basin	Area, in acres	Estimated average specific yield*, in per cent	Water-bearing formations	Principal aquifers	Estimated depth from ground surface to base of aquifers, in feet	Estimated thickness of aquifers, in feet	Condition of occurrence of ground water	Estimated average yield of irrigation wells, in gallons per minute
Upper Ojai	1,950	8	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-300	0-300	Unconfined	50
Ojai	6,040	5.5	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-700	0-700	Essentially unconfined; locally semi-confined	400
Upper Ventura River	4,990	8	Recent and Pleistocene alluvium	Sand and gravel beds	0-100	0-100	Unconfined	600
Lower Ventura River	2,670	8	Recent and Pleistocene alluvium	Sand and gravel beds	0-100	0-100	Unconfined	---

* In zone of historic water level change.

Upper Ojai Basin. Upper Ojai Basin, with a surface area of about 1,950 acres, lies in the northeasterly portion of the Ventura Hydrologic Unit, at elevations varying between 1,200 and 1,600 feet above sea level. Surface waters in the basin drain both to the west through Lion Canyon into San Antonio Creek, and to the east via Sisar Creek to Santa Paula Creek.

Water-bearing materials in Upper Ojai Basin consist of Recent and Pleistocene gravels, sands, and clays, and to a lesser extent weathered consolidated sediments of Tertiary age. The average thickness of the water-bearing materials has been estimated to approximate 60 feet, attaining an estimated maximum depth of about 300 feet near Sisar Creek. In general, ground water in the basin is unconfined, with a direction of movement conforming to the surface slope, as shown on Plate 16-A. The basin is replenished by deep penetration of precipitation, by percolation of surface water in minor watercourses, and by percolation of the unconsumed portion of water applied for irrigation and other uses. Ground water effluent appears in springs at both the easterly and westerly extremities of the basin.

Ground water in Upper Ojai Basin is presently utilized to meet relatively minor domestic and irrigation requirements. Wells yield between 10 and 200 gallons per minute, with an estimated average yield of about 50 gallons per minute. No quantitative estimates were made of the storage capacity of the basin, nor of historic change in ground water storage therein. It is considered probable, however, that the basin is presently utilized to about the maximum practicable extent.

Ojai Basin. Ojai Basin, with a surface area of about 6,040 acres, lies in the northerly portion of the Ventura Hydrologic Unit and to the northwest of Upper Ojai Basin, at elevations varying from about 700 to more than 1,200 feet above sea level. Surface waters in the basin drain southwesterly in San Antonio Creek to the Ventura River.

Water-bearing materials in Ojai Basin consist of Recent and Pleistocene alluvium, which is flanked and underlain by consolidated sediments of Tertiary age that yield minor amounts of water. The alluvium is estimated to extend to a depth of at least 700 feet near the center of the basin. Geologic sections E-E' and F-F' on Plate 12-A depict the configuration of the base of the alluvium.

Ground waters throughout the basin are essentially unconfined, although lenses of clay result in localized confinement of portions of the ground water body. During periods of high ground water levels, flowing wells have been reported in the southwesterly portion of the basin. The direction of normal ground water movement is west and south, with convergence toward the point of outflow of San Antonio Creek, as shown on Plates 14-A and 15-A. However, during drought periods the direction of movement in the southwesterly portion is reversed, as shown on Plate 16-A. Wells supplying requirements of the basin are reported to yield from 100 to 600 gallons per minute, with specific capacities varying from 3 to 20.

Sources of replenishment to ground water in Ojai Basin are percolation of surface waters on the alluvial cones at the mouths of Horn and Senor Canyons, in the channel of San Antonio Creek, and other minor watercourses, deep penetration of precipitation, and percolation of the unconsumed portion of water applied for irrigation and other uses. In addition, in 1952, an estimated 3,270 acre-feet of water were delivered to Ojai Basin from Matilija Reservoir. This water was largely spread and percolated at grounds constructed by the Ventura County Flood Control District in the north-central portion of the basin, although minor quantities of the import were sold directly to a few users. Ground water disposal from Ojai Basin is effected by pumped extractions to meet beneficial consumptive uses of overlying irrigated and urban lands, by consumptive use of phreatophytes, and by effluent discharge into San Antonio Creek.

Because of its relatively small storage capacity as related to ground water replenishment and disposal, Ojai Basin is quickly recharged during wet periods, and conversely is rapidly depleted during periods of drought. Seasonal and cyclic fluctuations of the ground water surface at key well number 4N/22W-5L1 are shown on Plate 20. Pumping lifts exhibit wide variation from wet to drought periods. In the fall of 1951, some users in the basin were pumping against heads in excess of 300 feet.

Lack of adequate hydrologic data precluded the evaluation of all items comprising water supply and disposal in Ojai Basin. Studies were made of the effects of draft on and replenishment of the ground water body during the drought period. In the spring of 1944, Ojai Basin was essentially full, and effluent discharge was occurring at its westerly extremity. From the spring of 1944 to the fall of 1951, disposal of ground water exceeded recharge, and ground water storage in the basin was substantially dewatered. Estimated ground water storage depletion during the seven-year drought period amounted to about 28,000 acre-feet. Total consumptive use of water on overlying lands, including that of precipitation, was estimated to have been about 71,000 acre-feet. Consumptive use of applied water during this period was estimated to have been about 28,200 acre-feet. The net retention of direct precipitation on the ground water basin, and of tributary surface inflow during the period was determined as a differential in solution of the equation of hydrologic equilibrium, and was estimated to have been about 43,000 acre-feet. The hydrologic equation states in effect that the sum of the items comprising the water supply of a given hydrologic unit or area must be equal to the sum of the items of water disposal plus or minus the change in ground water storage.

As shown by sections E-E' and F-F' on Plate 12-A, Ojai Basin has a concave configuration, with the depth of alluvium considerably greater in the center than at the peripheral margin. By the fall of 1947, water levels had so lowered that some wells near the margin had gone dry. Because of this historic limitation in its utility, it was estimated that the usable storage capacity of Ojai Basin, under present pattern of pumping, is equal to the computed total decrement in storage from the spring of 1944 to the fall of 1947, or about 10,900 acre-feet. Total storage capacity of the basin was estimated to be in the order of 70,000 acre-feet. The relationship between unwatered ground water storage in Ojai Basin and elevation of the ground water surface at key well number 4N/22W-5L1 is shown on Plate 21.

Upper Ventura River Basin. Upper Ventura River Basin essentially comprises the alluvial filled Ventura River Valley above the diversion weir of the City of Ventura at Foster Park. The basin has a surface area of about 4,990 acres, ranging in elevation from 200 to more than 800 feet above sea level. Surface waters drain south toward Foster Park.

Water-bearing materials in Upper Ventura River Basin consist of deposits of gravels, sands, and clays of Recent and Pleistocene age.

These deposits are flanked and underlain by consolidated sediments of Tertiary age, which form the bottom and sides of the basin. Section E-E' on Plate 12-A shows the general structure and shape of the basin. For study purposes, Upper Ventura River Basin was taken to comprise only the area underlain by alluvium. Geologic examination during the course of the investigation indicated that depth of the alluvium varies from about 60 feet northwest of Meiners Oaks, to about 80 feet at Foster Park. Maximum depths of over 100 feet occur at various points between Meiners Oaks and Foster Park.

Ground water occurs primarily in the alluvial deposits of Upper Ventura River Basin, and is unconfined. However, minor quantities of water are yielded to irrigation and domestic wells drilled into the Tertiary formations. In general, direction of ground water movement conforms with the slope of the Ventura River bed, as shown on Plates 14-A, 15-A, and 16-A. It was estimated that the total storage capacity of the basin is in the order of 10,000 acre-feet. Although it was not possible to evaluate the usable storage capacity of the basin, it is believed to comprise a relatively small portion of the estimated total capacity. The greatest number of wells in the basin are used for domestic and minor irrigation developments. A few large irrigation wells yield an average of about 600 gallons per minute, with specific capacities varying from 10 to 200.

Percolation of flow in the Ventura River channel is the primary source of recharge to Upper Ventura River Basin, with percolation of direct rainfall, of the unconsumed portion of water applied for irrigation and other uses, and of subsurface inflow from the flanking Tertiary formations comprising secondary sources of supply. Since 1948, discharge in Matilija Creek and percolation therefrom has been affected by operation of Matilija Reservoir. Ground water in the basin is disposed of by pumped extractions to meet beneficial consumptive uses on overlying and adjacent lands, including extractions by the City of Ventura at its well field upstream from the diversion weir at Foster Park, by consumptive use of phreatophytes, and by effluent discharge and subsurface outflow at Foster Park. The subsurface flow at the east end of the diversion weir at Foster Park was estimated to average less than 100 acre-feet per season.

The limited storage capacity of Upper Ventura River Basin provides only short-term retention to surface runoff, and furnishes but little carry-over storage during a period of drought. The relatively steep slope of the basin results in rapid drainage south toward Foster Park. Ground water levels in the basin respond quickly to changes in the rate of surface flow in the Ventura River.

Percolation of water originating in Matilija and North Fork of Matilija Creeks in the Ventura River channel was estimated from percolation diagrams presented in the report entitled "Safe Yield - Matilija Reservoir, May, 1948" by Harold Conkling, Consulting Engineer. Surface flow in these two streams and percolation to ground water from them meet the greater portion of the water requirements of lands overlying and adjacent to Ventura River Basin and the City of Ventura. Examination of water level measurements available from the Ventura County Water Survey, together with analysis of inflow to the basin from Matilija Creek and the North Fork of Matilija Creek, and surface outflow from the basin as measured at the gaging station on Ventura River near Ventura, indicated that during the drought period the basin was substantially full until the spring of 1947, and that percolation to the basin was adequate to satisfy demands of ground water users, including the pumping requirements of the City of Ventura. At the same time, surface discharge was sufficient to meet requirements of surface-supplied lands upstream from Meiners Oaks, and to meet the remainder of the City's requirements. Subsequent to the spring of 1947, however, use of water from the basin exceeded seasonal recharge, and water levels progressively dropped until the fall of 1951, when the basin was substantially dewatered. Recharge during the wet season of 1951-52 essentially filled the basin.

It has been stated that relatively high rates of surface flow prevailed in Ventura River Basin in most months during the wet period and during the portion of the drought period from 1944-45 to the spring of 1947. Also, requirements for water by overlying and adjacent users of ground water supplies, and by riparian surface diverters including the City of Ventura, were satisfied during this time of ample surface flow. For these reasons, no attempt was made to quantitatively evaluate recharge to and disposal of ground water supplies in Upper Ventura River Basin prior to the spring of 1947.

From the spring of 1947 through the season of 1950-51, the average seasonal percolation in Upper Ventura River Basin was estimated to have been about 3,100 acre-feet. Present use of water by overlying and riparian users, including the City of Ventura, was estimated to be about 7,700 acre-feet per season. During a wet period, such as that which occurred from 1936-37 through 1943-44, it was estimated that requirements of these users would be satisfied. During a drought period, such as from 1944-45 through 1950-51, it was estimated that, without impairment by operation of Matilija Reservoir, about 4,900 acre-feet of water per season on the average would be available to the users. Under these circumstances, about 3,300 acre-feet per season would have been available during the period from the spring of 1947 through the season 1950-51. This estimate does not include usable supplies available in ground storage in Upper Ventura River Basin at the beginning of the period, which, as stated previously, were estimated to be of small magnitude.

The estimated seasonal runoff of the Ventura River at the gaging station, Ventura River near Ventura, that would have occurred during the base period with the present pattern of land use and prevailing water requirements, and with Matilija Reservoir in operation, is shown in Table 10.

TABLE 10

ESTIMATED SEASONAL RUNOFF OF VENTURA RIVER
NEAR VENTURA DURING BASE PERIOD,
WITH PRESENT PATTERN OF LAND USE
AND WITH MATILIJA RESERVOIR IN OPERATION

Season	Acre-feet
1936-37	97,900
1937-38	186,600
1938-39	17,300
1939-40	8,900
1940-41	253,300
1941-42	19,100
1942-43	134,000
1943-44	72,500
1944-45	28,200
1945-46	21,600
1946-47	9,800
1947-48	0
1948-49	0
1949-50	2,400
1950-51	0
Average for base period, 1936-37 through 1950-51	56,800
Average for wet period, 1936-37 through 1943-44	98,700
Average for drought period, 1944-45 through 1950-51	8,800

Lower Ventura River Basin. Lower Ventura River Basin essentially comprises gravels, sands, and clays of Recent and Pleistocene alluvium in the Ventura River bottom lands between Foster Park and the ocean. The basin has a surface area of about 2,670 acres, varying in elevation from 200 feet above sea level to sea level. Surface waters drain south in the Ventura River channel to the ocean.

Depth of the alluvium in Lower Ventura River Basin varies from about 80 feet at Foster Park to in excess of 100 feet near the mouth of the Ventura River. The alluvium is flanked and underlain by consolidated sediments, most of which are of Tertiary age. Under natural conditions, this basin was undifferentiated from the Upper Ventura River Basin, but it has been treated separately herein because of the impedance to ground water movement effected by the artificial subsurface barrier at Foster Park.

Near the mouth of the river, the alluvium of Lower Ventura River Basin is underlain by water-bearing deposits of the San Pedro formation. It is believed that there is little if any hydraulic connection between the two formations. It is indicated that the San Pedro formation is recharged by percolation of tributary runoff and direct precipitation on its outcrop area in the hills northeasterly of the City of Ventura. The San Pedro formation is considered to be contained within Mound Basin, most of which is included within the Santa Clara River Hydrologic Unit. Thus, near the mouth of the Ventura River, Lower Ventura River Basin overlaps Mound Basin, with free hydraulic connection between the two severed by impermeable clays which confine the ground water in the latter basin.

Ground water in Lower Ventura River Basin is of such inferior mineral quality that the basin is not presently utilized. Lands requiring water service overlying the basin are either served by the City of Ventura or pump ground water from the underlying San Pedro formation. At the present time, an estimated 600 acre-feet of water per season are so extracted on the average. Of this amount, about 100 acre-feet per season are exported for domestic and industrial use in the Rincon Subunit, northwest of the Ventura River.

Santa Clara River Hydrologic Unit

From the economic standpoint, the seven major ground water basins identified in the Santa Clara River Hydrologic Unit are the most important in Ventura County. These basins, designated Piru, Fillmore, Santa Paula, Oxnard Forebay, Mound, Oxnard Plain, and Pleasant Valley, comprise a total surface area of about 125,700 acres, varying in elevation from sea level at the mouth of the Santa Clara River to about 800 feet above sea level in the river channel at the easterly county line. Utilization of water extracted from ground water storage in the Santa Clara River Hydrologic Unit meets over 90 per cent of the requirement of an estimated present net irrigated area of about 83,000 acres, as well as the entire requirement of the communities of Oxnard, Port Hueneme, Fillmore, Piru, Saticoy, and other smaller urbanized areas. A small portion of Eastern Basin, a large ground water basin which lies primarily in Los Angeles County, is included within Ventura County immediately east of Piru Basin. However, because of the relatively small areal extent of Eastern Basin within Ventura County, detailed analysis and discussion thereof has not been included in this bulletin.

The Piru, Fillmore, Santa Paula, and Mound Basins overlie the Santa Clara River syncline, which is a deformation in the San Pedro and older formations, and is of considerable significance to the hydrology of the basins. Ground water occurring in the Piru, Fillmore, Santa Paula, and Oxnard Forebay Basins is unconfined, whereas that occurring in the pumped aquifers of the Mound, Oxnard Plain, and Pleasant Valley Basins is under pressure caused by confining clay beds of low permeability. The unconfined ground water basins are replenished by percolation of flow in the Santa Clara River and its tributaries, percolation of direct precipitation, artificial spreading and percolation of surface waters, and by percolation of the unconsumed residuum of water applied for irrigation and other uses. The pumped pressure aquifers in the Mound, Oxnard Plain, and Pleasant Valley Basins are largely supplied by subsurface flow from areas of free ground water. Ground water in the seven major basins of the Santa Clara River Hydrologic Unit is disposed of by effluent discharge to lower basins, by pumped extractions to meet beneficial consumptive uses, by consumptive use of phreatophytes in areas of high ground water, and by subsurface flow to lower basins and to the ocean.

The effects of draft on and replenishment of ground water basins in the Santa Clara River Hydrologic Unit were analyzed as they would be with the present pattern of land use and under conditions of water supply and climate that occurred during the base period. The general method of analysis employed in these studies involved evaluation of the several items of water supply and disposal, and solution of the equation of hydrologic equilibrium to determine changes in ground water storage. Estimates of tributary surface inflow were made by correlation with measured flow at key gaging stations, records for which were presented earlier in this chapter. Estimates of the quantity of precipitation falling on absorptive areas have also been presented in this chapter. The nature and extent of land use within and adjacent to each of the basins were determined from the results of land use surveys conducted during 1949-50. Consumptive use of water and estimates of ground water extractions were determined as described in Chapter III. Records of surface diversion to irrigated and urban lands were obtained from various sources, and employed as required in the analyses. Stream channel percolation was estimated from diagrams presented in Division of Water Resources Bulletin No. 46, as modified by the United Water Conservation District in light of more recent percolation measurements. Additional percolation measurements made during the investigation confirmed the validity of the modified diagrams. Subsurface inflow to and outflow from each of the unconfined ground water basins were estimated by the rising water method, and the reasonableness of the results was checked by use of the slope-area method. Both methods are described in detail in Appendix B. Inflow from and outflow to the ocean along the coastal front of Oxnard Plain Basin were estimated from parameters established from records of piezometric levels, and from estimates of ground water extractions.

Table 11 summarizes certain physical characteristics of the seven major ground water basins in the Santa Clara River Hydrologic Unit.

TABLE 11

SUMMARY OF SELECTED GROUND WATER BASIN CHARACTERISTICS
IN SANTA CLARA RIVER HYDROLOGIC UNIT

Basin	Area, in acres	Estimated weighted average specific yield*, in per cent	Water-bearing formations	Principal aquifers	Estimated depth from ground surface to base of aquifers, in feet	Estimated thickness of aquifers, in feet	Condition of occurrence of ground water	Estimated average yield of irrigation wells, in gallons per minute
Piru	6,520	16.7	Recent and Pleistocene alluvium	Sand and gravel beds	0-200	0-200	Unconfined	800
			San Pedro		1,000+	800+	Unconfined	800
Fillmore	16,870	12.2	Recent and Pleistocene alluvium	Sand and gravel beds	0-250	0-250	Unconfined	700
			San Pedro		1,000+	750+	Unconfined	700
Santa Paula	13,520	10.0	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-200	0-200	Essentially unconfined	700
			San Pedro		1,000+	800+	Essentially unconfined	700
Mound	12,300	---	San Pedro	Lenses of permeable sediments near top	1,500+	1,000+	Confined	700

TABLE 11 (Continued)

SUMMARY OF SELECTED GROUND WATER BASIN CHARACTERISTICS
IN SANTA CLARA RIVER HYDROLOGIC UNIT

Basin	Area, in acres	Estimated weighted average specific yield*, in per cent	Water-bearing formations	Principal aquifers	Estimated depth from ground surface to base of aquifers, in feet	Estimated thickness of aquifers, in feet	Condition of occurrence of ground water	Estimated average yield of irrigation wells, in gallons per minute
Oxnard Forebay	6,170	16.5	Recent and Pleistocene alluvium	Most of formation	100-250	100-250	Unconfined	1,100
Oxnard Plain	46,460	---	Recent alluvium	Semi-perched water-bearing zone	0-50	0-50	Unconfined	---
			Upper Pleistocene alluvium	Oxnard aquifer	180-250	75-200	Confined	900
			San Pedro	Fox Canyon	600-1,900	100-300	Confined	900
Pleasant Valley	23,850	---	Recent and Pleistocene alluvium	Permeable lenses not connected with Oxnard aquifer	0-400	---	Essentially confined	400
			San Pedro	Fox Canyon	400-1,500	100-300	Confined	1,000

* In zone of historic water level change.

Piru Basin. Piru Basin is the uppermost and most easterly of the four unconfined ground water basins in the Santa Clara River Hydrologic Unit. The surface area is about 6,520 acres, and surface elevations in the Santa Clara River channel range from about 800 feet above sea level at the eastern extremity of the basin to about 470 feet at the western extremity. Surface waters drain westerly in the river channel and southwesterly in Piru Creek, a principal tributary.

Water-bearing formations in Piru Basin include Recent and Upper Pleistocene alluvium, underlain by the older San Pedro formation. The alluvium attains depths of 85 to 200 feet. From analyses of oil well logs, the San Pedro formation is estimated to extend to depths as great as 4,000 feet, although the maximum depth of the aquifers presently utilized is about 1,000 feet. As shown on geologic section J-J' on Plate 12-A, the San Pedro formation does not outcrop in Piru Basin. Also shown on section J-J' are the San Cayetano and Oak Ridge faults, which separate the San Pedro formation from flanking nonwater-bearing Tertiary formations.

Ground waters found in Piru Basin are unconfined. As shown on Plates 14-B, 15-B, and 16-B, ground water generally moves to the west in the direction of the surface slope. The water table slope flattens toward the westerly extremity of the basin, where the cross sectional area of the San Pedro formation is reduced by warping of the Santa Clara River syncline. Historically, this constriction has resulted in effluent discharge from the ground water body. The westerly boundary of Piru Basin was arbitrarily drawn at the estimated section of maximum rising water, but could have been drawn equally as well a short distance to the east or west of the assumed line. Most wells in the basin have been drilled to the San Pedro formation, and yield from 600 to 2,000 gallons per minute, with an estimated average yield of about 800 gallons per minute. Specific capacity of wells averages about 70. The estimated weighted average specific yield of water-bearing materials in the basin, in the range of depth between the highest and lowest historic water levels, is approximately 17 per cent.

Ground water storage in Piru Basin is replenished by natural percolation of Piru Creek, Hopper Creek, and Santa Clara River water, and by spreading and percolation of Piru Creek water at grounds constructed by the Santa Clara Water Conservation District near the town of Piru, which are now operated by the United Water Conservation District. Percolation of direct precipitation, and of the unconsumed portion of water applied for irrigation and other uses, including water imported from Eastern Basin, also replenishes the ground water of Piru Basin. Ground water is disposed of by pumped extractions to meet beneficial consumptive uses on overlying and adjacent lands, by exportation to Fillmore Basin, by consumptive use of phreatophytes, by effluent discharge, and by subsurface outflow.

Records of measurements of ground water levels in Piru Basin are available since the late 1920's. Seasonal and cyclic fluctuations of the ground water surface at key well number 4N/19W-25L4 are shown on Plate 20. As depicted by this hydrograph, ground water levels in the basin respond rapidly in accordance with the relative wetness of a given season. The ground water surface at this well had a recorded maximum elevation of about 572 feet in the spring of 1944, and a minimum elevation of about 448 feet in the fall of 1951. Substantial recharge to the ground water body during the wet season of 1951-52 resulted in a sharp rise in the ground water surface at this well, to an elevation of about 536 feet. Ground water storage depletion in Piru Basin at the beginning of the base period, in the fall of 1936, was estimated to have been about 51,000 acre-feet, while estimated storage depletion in the fall of 1951 was about 94,300 acre-feet. It was further estimated that the basin was essentially full in the spring of 1945. The relationship between elevation of the ground water surface at well number 4N/19W-25L4 and ground water storage depletion in Piru Basin is shown on Plate 21.

By the summer of 1936, following a dry period, nearly all wells pumping from the alluvium on the south side of Piru Basin had gone dry. As a result, overlying users drilled wells nearer the river and into the San Pedro formation, where adequate water supplies were obtained. From examination of geologic section J-J' on Plate 12-A, it appears that these overlying users could have drilled much deeper wells at the original sites and intercepted the water-bearing San Pedro formation. For these reasons, it is believed that the utility of Piru Basin is limited by factors of economic pumping lift and mean seasonal recharge, rather than by storage capacity or configuration of the basin.

Analysis was made of water supply and disposal in Piru Basin during the base period to determine changes in ground water storage, assuming that the present pattern of land use prevailed over this period. Although the method of analysis generally described earlier in this chapter was utilized, the evaluations of certain of the items of water supply and disposal warrant further description. Unmeasured flood flow in the Santa Clara River from Los Angeles County was estimated by correlation with recorded flow at the gaging station on the Santa Clara River near Saugus, maintained by the Los Angeles County Flood Control District. Effluent discharge from Eastern Basin to Piru Basin was estimated from data appearing in the report entitled "Development of a Supplemental Water Supply for Zone 2, Ventura County Flood Control District, September 1949", by Harold Conkling, Consulting Engineer, and in biennial reports on hydrologic data prepared by the Los Angeles County Flood Control District. Minor tributary surface inflow was estimated by correlation with recorded flow of Hopper Creek. Percolation of surface inflow to the ground water basin was estimated from records of diversion to the spreading grounds near Piru, and from percolation diagrams indicating losses in Piru and Hopper Creeks and the Santa Clara River channel, for various rates of discharge. Exports from the basin were taken from the records of the Sespe Land and Water Company, Southside Improvement Company, and the State Fish Hatchery. As the latter entity did not export water prior to 1948, the probable exportation that would have been made over the base period was estimated by extending the exports of record. Effluent discharge from the basin was estimated from the determined correlation between measured rates of discharge and slopes of the ground water surface. Flood flow leaving the basin was taken as the difference between total surface inflow and percolation in the stream channels and in the spreading grounds near Piru.

The hydrologic studies were conducted on a monthly basis over the base period, commencing with an assumed basin storage depletion in the fall of 1936 of 94,300 acre-feet, which was the estimated actual depletion in the fall of 1951. It was found that under conditions of the study, the basin would have first filled in February, 1938, and would have remained essentially full, with the exception of the seasons of 1938-39 and 1939-40, until the spring of 1945. From that time until the fall of 1951, disposal of water in the basin would have exceeded recharge, and basin storage would have again been depleted in the amount of 94,300 acre-feet by the fall of 1951. Since this storage depletion is equal to that which actually prevailed in the fall of 1951, it is indicated that subsequent to the last filling of the basin in the spring of 1945, conditions assumed for the study were equivalent to actual historical conditions.

A seasonal summary of the foregoing hydrologic analysis of Piru Basin is presented in Table 12.

TABLE 12

ESTIMATED SEASONAL STORAGE DEPLETION IN PIRU BASIN DURING BASE PERIOD, WITH PRESENT PATTERN OF LAND USE

(IN ACRE-FEET)

Season	Items of Water Supply				Items of Water Disposal							Change in Ground Water Storage	Ground Water Storage Depletion at End of Season
								Consumptive Use					
	Surface Inflow	Import	Precipitation	Subtotal	Surface Outflow	Subsurface Outflow	Export	Of Applied Water	Of Precipitation on Basin*	Total	Subtotal		
1935-36													94,300
1936-37	109,500	0	13,800	123,300	40,900	17,600	5,400	6,600	8,200	14,800	78,700	44,600	49,700
1937-38	222,200	0	13,000	235,200	157,700	21,600	5,400	7,300	7,300	14,600	199,300	35,900	13,800
1938-39	68,700	0	8,300	77,000	40,400	21,600	5,700	6,800	7,300	14,100	81,800	- 4,800	18,600
1939-40	35,500	900	8,000	44,400	18,200	21,600	5,700	7,100	7,100	14,200	59,700	-15,300	33,900
1940-41	345,100	1,400	20,200	366,700	299,000	21,600	5,200	6,100	8,900	15,000	340,800	25,900	8,000
1941-42	79,200	1,800	6,900	87,900	57,200	21,600	5,800	6,500	7,200	13,700	98,300	-10,400	18,400
1942-43	206,400	1,800	15,600	223,800	178,900	21,600	6,000	7,200	7,500	14,700	221,200	2,600	15,800
1943-44	225,400	1,700	13,600	240,700	192,600	21,600	5,900	7,400	7,300	14,700	234,800	5,900	9,900
1944-45	63,800	1,900	8,200	73,900	38,700	21,600	5,900	7,400	7,200	14,600	80,800	- 6,900	16,800
1945-46	57,400	2,000	7,900	67,300	32,300	21,600	6,100	7,300	6,900	14,200	74,200	- 6,900	23,700
1946-47	58,100	2,300	7,900	68,300	29,700	21,600	6,200	8,400	6,400	14,800	72,300	- 4,000	27,700
1947-48	19,300	2,800	4,300	26,400	5,000	21,600	6,000	7,800	5,600	13,400	46,000	-19,600	47,300
1948-49	15,700	3,200	4,500	23,400	1,100	21,300	5,600	7,500	5,800	13,300	41,300	-17,900	65,200
1949-50	16,600	3,800	6,500	26,900	1,500	18,000	4,900	7,400	7,000	14,400	38,800	-11,900	77,100
1950-51	7,100	3,700	4,400	15,200	300	13,800	5,000	7,600	5,700	13,300	32,400	-17,200	94,300
Average for base period, 1936-37 through 1950-51	102,000	1,800	9,600	113,400	72,900	20,600	5,700	7,200	7,000	14,200	113,400		
Average for wet period, 1936-37 through 1943-44	161,500	1,000	12,400	174,900	123,100	21,100	5,600	6,900	7,600	14,500	164,300		
Average for drought period, 1944-45 through 1950-51	34,000	2,800	6,200	43,000	15,500	19,900	5,700	7,600	6,400	14,000	55,100		

* Includes total consumptive use of phreatophytes.

Fillmore Basin. Fillmore Basin is situated westerly of and downstream from Piru Basin. The surface area is about 16,870 acres, and surface elevations in the Santa Clara River channel vary from about 470 feet above sea level at the easterly extremity of the basin to about 280 feet at its westerly limit near the City of Santa Paula. Surface waters drain westerly in the river channel, and southwesterly in Sespe Creek, a principal tributary.

Water-bearing formations in Fillmore Basin include Recent and Pleistocene alluvium having a maximum depth of about 250 feet, underlain by the older San Pedro formation, which extends to depths as great as 4,000 feet. As in Piru Basin, aquifers of the San Pedro formation are presently utilized to a maximum depth of about 1,000 feet. The Oak Ridge fault defines the southerly limit of the San Pedro formation, as shown on geologic section H-H' on Plate 12-A. With the exception of an outcrop area of about 1,600 acres near the westerly limit of Fillmore Basin, the San Pedro formation is entirely overlain by the alluvium.

Ground waters found in Fillmore Basin are unconfined except in certain relatively minor local areas. Ground water moves generally in a westerly direction in conformity with the slope of the ground surface. At the westerly boundary of the basin, the cross sectional area of the San Pedro formation is reduced by local warping of the Santa Clara River syncline. Upstream from the boundary, there is a flattening in the slope of the ground water surface and effluent discharge of ground water prevails most of the time. Near the constriction, there is a steepening of the slope of the ground water surface. Downstream from the constriction, the cross sectional area of the San Pedro formation is greater, with an accompanying decrease in the slope of the ground water surface. The westerly boundary of the Fillmore Basin was arbitrarily drawn at the section of estimated maximum rising water. Irrigation wells in Fillmore Basin yield up to 2,100 gallons per minute, with an estimated average yield of about 700 gallons per minute. Specific capacity of wells varies considerably, but probably averages on the order of 50. The estimated weighted average specific yield of water-bearing materials in the basin, in the range of depth between the highest and lowest historic water levels, is approximately 12 per cent.

Ground water storage in Fillmore Basin is replenished by percolation of surface flow in the Santa Clara River, Sespe Creek, and minor tributary streams, subsurface inflow from Piru Basin, deep penetration of direct precipitation, and percolation of the unconsumed portion of water applied for irrigation and other uses. Some contribution of minor magnitude may occur through lateral underflow of water from adjacent semi-permeable formations. Ground water in the basin is disposed of by pumped extractions to meet requirements of overlying and adjacent lands, by consumptive use of phreatophytes, and by effluent seepage and subsurface outflow into Santa Paula Basin.

During periods of drought, water levels in the central portion of Fillmore Basin exhibit a greater differential lowering than in the westerly portion where rising water usually prevails. During the recent drought period, alluvium in the central portion of the basin on both the north and south sides of the Santa Clara River was substantially dewatered. On the north side of the river, most wells drawing from the alluvium also penetrate the San Pedro formation, and yields therefrom were not seriously affected by this dewatering. However, some domestic wells drawing from the alluvium south of the Oak Ridge fault were dry during the latter years of the drought. Static depth to ground water in the fall of 1951 at key well number 4N/20W-36N2 averaged about 60 feet. The hydrograph for this well is shown on Plate 20. At this time storage depletion in the basin was an estimated 61,000 acre-feet, which was the greatest of record. The relationship between elevations of the ground water surface at well number 4N/20W-36N2 and ground water storage depletion in Fillmore Basin is shown on Plate 21. Based on available data, and for reasons similar to those cited in the case of Piru Basin, it is believed that utility of Fillmore Basin is limited by factors of economic pumping lift and mean seasonal recharge, rather than by storage capacity or configuration of the basin.

The seasonal results of the monthly hydrologic analysis of Fillmore Basin are summarized in Table 13. In this study, the items of surface inflow from Piru Basin were taken from the corresponding items of outflow in the analysis for Piru Basin presented in Table 12. Additional surface inflow to Fillmore Basin comprised measured runoff of Sespe Creek, together with measured diversions from Sespe Creek by the Fillmore Irrigation Company. Minor tributary runoff was estimated by correlation with measured flows of Hopper Creek. Import to Fillmore Basin was taken as equal to the export from Piru Basin by the State Fish Hatchery, Sespe Land and Water Company, and Southside Improvement Company. Surface outflow other than rising water was taken as the difference between total surface inflow less percolation in the basin.

The hydrologic study commenced with an assumed basin storage depletion in the fall of 1936 of 61,000 acre-feet, which was the estimated actual depletion in the fall of 1951. It was found that under conditions of the study the basin would have first filled in the spring of 1937, and would have filled each spring thereafter through 1947.

From that time until the fall of 1951, disposal of water in the basin would have exceeded recharge, and basin storage would have again been depleted in the amount of 61,000 acre-feet by the fall of 1951. Since this storage depletion is equal to that which actually prevailed in the fall of 1951, it is indicated that subsequent to the last filling of the basin in the spring of 1947, conditions assumed for the study were equivalent to actual historic conditions.

TABLE 13

ESTIMATED SEASONAL STORAGE DEPLETION IN FILLMORE BASIN DURING BASE PERIOD, WITH PRESENT PATTERN OF LAND USE

(IN ACRE-FEET)

Season	Items of Water Supply: Surface Inflow	Subsurface Inflow	Import	Precipitation	Subtotal	Items of Water Disposal: Surface Outflow	Subsurface Outflow	Export	Consumptive Use: Of Applied Water	Precipitation on Basin*	Total	Subtotal	Change in Ground Water Storage	Ground Water Storage Depletion at End of Season
1935-36														61,000
1936-37	227,600	17,600	5,400	39,500	290,100	194,000	11,200	0	13,000	22,600	35,600	240,800	49,300	11,700
1937-38	427,300	21,600	5,400	39,900	494,200	439,100	11,500	400	13,800	20,600	34,400	485,400	8,800	2,900
1938-39	89,600	21,600	5,700	22,900	139,800	94,900	11,500	100	13,400	21,700	35,100	141,600	- 1,800	4,700
1939-40	52,500	21,600	5,700	19,800	99,600	62,600	11,500	100	14,600	20,300	34,900	109,100	- 9,500	14,200
1940-41	706,500	21,600	5,200	54,200	787,500	725,600	11,500	1,400	11,800	24,400	36,200	774,700	12,800	1,400
1941-42	102,100	21,600	5,800	21,300	150,800	109,900	11,500	1,000	12,600	22,800	35,400	157,800	- 7,000	8,400
1942-43	374,300	21,600	6,000	38,000	439,900	390,900	11,500	100	14,300	21,300	35,600	438,100	1,800	6,600
1943-44	347,200	21,600	5,900	32,600	407,300	358,400	11,500	0	14,200	20,700	34,900	404,800	2,500	4,100
1944-45	96,400	21,600	5,900	21,300	145,200	100,600	11,500	2,200	14,900	20,500	35,400	149,700	- 4,500	8,600
1945-46	101,000	21,600	6,100	19,200	147,900	101,300	11,500	1,900	14,300	19,800	34,100	148,800	- 900	9,500
1946-47	79,300	21,600	6,200	20,700	127,800	81,400	11,500	4,000	16,800	18,200	35,000	131,900	- 4,100	13,600
1947-48	13,800	21,600	6,000	13,100	54,500	20,700	11,500	2,300	14,700	18,100	32,800	67,300	-12,800	26,400
1948-49	10,800	21,300	5,600	13,300	51,000	17,400	11,500	2,600	14,700	18,200	32,900	64,400	-13,400	39,800
1949-50	20,500	18,000	4,900	19,100	62,500	18,100	11,500	2,600	14,800	20,500	35,300	67,500	- 5,000	44,800
1950-51	4,100	13,800	5,000	12,200	35,100	4,900	11,300	1,200	16,100	17,800	33,900	51,300	-16,200	61,000
Average for Base Period, 1936-37 Through 1950-51	176,900	20,600	5,700	25,800	229,000	181,300	11,500	1,400	14,300	20,500	34,800	229,000		
Average For Wet Period, 1936-37 Through 1943-44	290,900	21,100	5,600	33,500	351,100	296,800	11,500	400	13,500	21,800	35,300	344,000		
Average For Drought Period, 1944-45 Through 1950-51	46,600	19,900	5,700	17,000	89,200	49,200	11,500	2,400	15,200	19,000	34,200	97,300		

* Includes total consumptive use of phreatophytes.

Santa Paula Basin. Santa Paula Basin lies between Fillmore Basin on the east and the Oxnard Forebay and Mound Basins on the west. The surface area of the basin, which for study purposes was defined by the extent of the alluvium, is about 13,520 acres. Surface elevations in the Santa Clara River channel vary from about 280 feet above sea level at the eastern extremity of the basin to about 140 feet at the westerly limit. Surface waters drain westerly in the river channel and southerly in Santa Paula Creek, a principal tributary.

Water-bearing formations in Santa Paula Basin include Recent and Pleistocene alluvium having a maximum depth of about 200 feet, underlain by the older San Pedro formation which extends to depths as great as 4,000 feet. However, aquifers of the San Pedro formation in Santa Paula Basin are presently utilized to a maximum depth of about 800 feet. The southerly boundary of Santa Paula Basin is defined by the Oak Ridge fault. The Saticoy fault, which is probably either a branch or an extension of the Oak Ridge fault, separates Santa Paula Basin and the Oxnard Forebay Basin. The boundary between Santa Paula and Mound Basins is defined by an abrupt change in slope of the ground water surface, similar to those described between Piru and Fillmore Basins and between Fillmore and Santa Paula Basins. Geologic section G-G' on Plate 12-A shows the major geologic features of the basin.

Ground water in Santa Paula Basin is generally unconfined, although a localized pressure condition does prevail in the alluvium in the westerly and northwesterly portions of the basin. Ground water generally moves in a southwesterly direction in conformity with the slope of the ground surface. Water wells in the basin draw from both the alluvium and the underlying San Pedro formation, and yield up to 1,500 gallons per minute, with a probable average yield of about 700 gallons per minute. The estimated weighted average specific yield of water-bearing materials in the basin, in the range of depth between the highest and lowest historic water levels, is approximately 10 per cent.

Ground water storage in the Santa Paula Basin is replenished by subsurface flow and effluent discharge from Fillmore Basin, by percolation of runoff in the Santa Clara River, Santa Paula Creek, and minor tributary streams, by deep penetration of direct precipitation, and by percolation of the unconsumed portion of water applied for irrigation and other uses. During the period from 1930 to 1941, inclusive, water from Santa Paula Creek was spread at grounds operated by the Santa Clara Water Conservation District near Santa Paula. This practice was abandoned in 1941, however, because of the prevailing high ground water levels. Disposal of ground water in Santa Paula Basin is effected by pumped extractions to meet requirements of irrigated and urban lands overlying and adjacent to the basin, by exportation, by consumptive use of phreatophytes, by subsurface flow and effluent discharge to Oxnard Forebay Basin, and by subsurface flow to Mound Basin.

Since the net use of ground water in Santa Paula Basin is relatively small in comparison with the magnitude of water supplies available for recharge, historical basin storage depletion has been relatively small. It was estimated that in the fall of 1951 the basin storage had been depleted about 22,600 acre-feet, which is the maximum of record. Examination of Plate 20 shows that over the period of record there was a maximum fluctuation in the water level at key well number 3N/21W-20M1 of only about 35 feet. The relationship between elevations of the ground water surface at this well and ground water storage depletion in Santa Paula Basin is shown on Plate 21.

Within Santa Paula Basin, measured historical change in ground water levels has been entirely in the alluvium. However, immediately to the north of the alluvium defining Santa Paula Basin, the San Pedro formation outcrops on the surface over an area of about 7,900 acres. Since it is indicated that there is hydraulic continuity between the alluvium and the underlying and adjacent San Pedro formation, it is probable that there has been change in ground water storage in the San Pedro formation in the area of outcrop. Lack of well log data and ground water level measurements precluded sufficient determination of physical characteristics of the San Pedro formation adjacent to Santa Paula Basin to estimate change in ground water storage.

Based on available data, and for reasons similar to those cited in the cases of Piru and Fillmore Basins, it is believed that utility of Santa Paula Basin is limited by factors of economic pumping lift and mean seasonal recharge, rather than by storage capacity or configuration of the basin.

The seasonal results of the monthly hydrologic analysis of Santa Paula Basin are summarized in Table 14. This analysis was made without regard to the undetermined change in ground water storage in the outcrop area of the San Pedro formation north of the basin. The derived values of surface outflow from Santa Paula Basin to Oxnard Forebay Basin, therefore, are in error by the amount of recharge to the San Pedro formation in the outcrop area. In the hydrologic study, items of surface and subsurface flow from Fillmore Basin were taken from the corresponding items of outflow in the analysis for Fillmore Basin presented in Table 13. Additional surface inflow to Santa Paula Basin comprised measured runoff in Santa Paula Creek at the gaging station near Santa Paula, adjusted for upstream diversion. Minor tributary surface inflow was estimated by correlation with the measured flow of Hopper Creek. It was assumed that the spreading grounds on Santa Paula Creek did not operate during the period of study. Effluent discharge across the Saticoy fault and into Oxnard Forebay Basin was estimated from the determined correlation between measured rates of discharge and slope of the ground water surface. Subsurface outflow to Oxnard Forebay Basin was estimated by means of the rising water method. As may be noted on Plates 14-B, 15-B, and 16-B, there is a sharp increase in slope of the ground water surface from Santa Paula Basin to Mound Basin. The slope from Santa Paula Basin to Mound Basin indicates subsurface flow from the former to the latter. Geologic investigation indicates that this underflow occurs in the San Pedro formation. However, the amount of the underflow was not susceptible to evaluation with the data at hand, and the values for subsurface outflow presented in Table 14 include only the underflow to Oxnard Forebay Basin. Hydrologic and geologic evidence indicates, however, that the unaccounted for subsurface flow may be in the order of 8,000 to 10,000 acre-feet per season. Records were obtained of exports of water to the Oxnard Plain Basin by the Santa Clara Water and Irrigation Company, and to Mound Basin by the Farmers Irrigation Company.

The hydrologic study commenced with an assumed basin storage depletion in the fall of 1936 of 22,600 acre-feet, which was the estimated actual depletion in the fall of 1951. It was found that under conditions of the study the basin would have first filled in January, 1937, and would have filled or nearly filled each spring thereafter through 1950. From the spring of 1950 until the fall of 1951, disposal of water on the basin would have exceeded recharge, and basin storage would have again been depleted in the amount of 22,600 acre-feet by the fall of 1951.

TABLE 14

ESTIMATED SEASONAL STORAGE DEPLETION IN SANTA PAULA BASIN DURING BASE PERIOD, WITH PRESENT PATTERN OF LAND USE

(IN ACRE-FEET)

Season	Items of water supply					Items of water disposal							Change[B] in ground water storage	Ground water[B] storage depletion at end of season
									Consumptive use					
	Surface inflow	Subsurface inflow	Import	Precipitation	Subtotal	Surface outflow	Subsurface outflow	Export	Of applied water	Of precipitation on basin[A]	Total	Subtotal		
1935-36														22,600
1936-37	246,100	11,200	0	26,900	284,200	229,900	7,200	1,900	13,900	15,700	29,600	268,600	15,600	7,000
1937-38	520,100	11,500	400	29,300	561,300	520,700	7,200	1,600	15,600	14,000	29,600	559,100	2,200	4 800
1938-39	107,400	11,500	100	16,100	135,100	97,700	7,200	2,100	15,000	14,400	29,400	136,400	- 1,300	6,100
1939-40	70,400	11,500	100	14,600	96,600	61,600	7,200	1,800	15,500	13,800	29,300	99,900	- 3,300	9,400
1940-41	822,000	11,500	1,400	43,400	878,300	832,500	7,200	1,200	13,000	17,200	30,200	871,100	7,200	2,200
1941-42	120,700	11,500	1,000	15,100	148,300	116,000	7,200	900	14,000	14,900	28,900	153,000	- 4,700	6,900
1942-43	460,900	11,500	100	30,400	502,900	463,700	7,200	1,100	15,100	14,900	30,000	502,000	1,000	5,900
1943-44	395,100	11,500	0	20,000	426,600	387,800	7,200	900	15,400	14,400	29,800	425,700	1,000	4,900
1944-45	117,000	11,500	2,200	14,900	145,600	109,200	7,200	700	16,600	13,400	30,000	147,100	- 1,500	6,400
1945-46	117,900	11,500	1,900	13,300	144,600	108,200	7,200	1,000	15,600	13,300	28,900	145,300	- 700	7,100
1946-47	94,100	11,500	4,000	14,000	123,600	86,800	7,200	1,400	17,300	12,500	29,800	125,200	- 1,600	8,700
1947-48	23,300	11,500	2,300	8,100	45,200	9,500	7,200	1,400	17,400	10,500	27,900	46,000	- 800	9,500
1948-49	20,200	11,500	2,600	9,000	43,300	8,000	7,200	1,600	17,200	11,200	28,400	45,200	- 1,900	11,400
1949-50	24,200	11,500	2,600	13,900	52,200	14,600	7,200	900	16,100	13,800	29,900	52,600	- 400	11,800
1950-51	6,300	11,300	1,200	9,100	27,900	2,000	7,200	900	17,200	11,400	28,600	38,700	-10,800	22,600
Average for Base Period, 1936-37 through 1950-51	209,700	11,500	1,400	18,500	241,100	203,200	7,200	1,300	15,700	13,700	29,400	241,100		
Average for Wet Period, 1936-37 through 1943-44	342,800	11,500	400	24,500	379,200	338,700	7,200	1,400	14,700	14,900	29,600	376,900		
Average for Drought Period, 1944-45 through 1950-51	57,600	11,500	2,400	11,700	83,200	48,300	7,200	1,100	16,800	12,300	29,100	85,700		

A Includes total consumptive use of phreatophytes.

B Alluvium only.

Mound Basin. Mound Basin is situated north of the Santa Clara River, and lies between the Pacific Ocean on the west and Santa Paula Basin on the east. It has a surface area of about 12,300 acres, varying in elevation from sea level to about 400 feet above sea level. Surface waters of the basin drain southerly to the Santa Clara River and the Pacific Ocean.

Mound Basin consists of from 100 to 500 feet of silts and clays of Recent and Pleistocene age, underlain by gravels, sands, and clays of the San Pedro formation which extends to depths of about 4,000 feet. These formations are extensively folded and faulted. The ground water presently exploited occurs in poorly defined aquifers in the San Pedro formation, and is confined therein by alluvial silts and clays of low permeability. The San Pedro formation has an outcrop area of about 4,400 acres north of the basin.

For study purposes, the areal extent of Mound Basin was taken as the area of the San Pedro formation which is overlain by alluvium. The basin extends westerly into the Ventura Hydrologic Unit, since the San Pedro formation underlies the alluvium at the mouth of the Ventura River. The southerly boundary of the basin, defined by the Santa Clara River channel, represents the southerly limit of lands served by wells deriving water from the San Pedro formation in this portion of the coastal plain. Although geologic data indicate that the San Pedro formation extends under the ocean, sufficient data were not available to determine the location of possible exposures of the pumped aquifers to the ocean, or whether such exposures actually exist. Water levels in wells near the coastal front, drawing from aquifers in the San Pedro formation, react to tidal fluctuations. This effect could result from tidal loading on the formation offshore, and is not necessarily an indication of hydraulic continuity between the aquifers and the ocean.

Ground water in Mound Basin moves under pressure, generally in a south-westerly direction, from Santa Paula Basin and from the area of outcrop of the San Pedro formation to pumping wells in the basin. Directions of movement of ground water are shown on Plates 14-B, 15-B, and 16-B. Wells in the basin yield from 300 to 1,500 gallons per minute, with an average yield of about 700 gallons per minute. Specific capacities of wells in the basin are estimated to average about 70.

Ground water in Mound Basin is replenished by subsurface inflow from Santa Paula Basin, and by subsurface flow from the outcrop area of the San Pedro formation which receives percolation of direct precipitation and stream flow in minor watercourses. Ground water in the basin is disposed of by pumped extractions to meet overlying domestic and irrigation requirements, and possibly by subsurface outflow to the ocean. Examination of ground water contour maps indicates that there may also be subsurface inflow to and outflow from Oxnard Plain Basin through the San Pedro formation, depending on the relative ground water levels in the Mound and Oxnard Plain Basins. It also appears from study of Plate 16-B, that during drought periods when piezometric levels in Mound Basin are below sea level, sea water may contribute to the seaward extensions of the pumped aquifers.

Water requirements of irrigated lands overlying Mound Basin are satisfied in part by imports of water from Oxnard Forebay Basin by the Alta Mutual Water Company, and from Santa Paula Basin by the Farmers Irrigation Company. The average seasonal amounts of these imports during the base period were about 2,100 acre-feet and 600 acre-feet, respectively.

Uncertainties regarding hydrologic and geologic characteristics precluded direct evaluation of all items of water supply of Mound Basin and disposal thereof during the base period. It is believed, however, that the primary recharge of the basin is by subsurface inflow through the San Pedro formation from Santa Paula Basin, and that the contribution from the outcrop of the San Pedro formation to the north of the basin is of secondary magnitude. The average seasonal extraction of ground water from Mound Basin during the drought period, from 1944-45 through 1950-51, was estimated to have been about 13,500 acre-feet. This includes extractions by the City of Ventura during the seasons of 1947-48, 1948-49, 1949-50, and 1950-51, of about 1,730 acre-feet, 3,240 acre-feet, 2,200 acre-feet, and 4,000 acre-feet, respectively, together with an estimated average extraction of 600 acre-feet per season from the westerly extremity of the basin.

Fluctuations of ground water levels in key well number 2N/22W-8N1 during the period from 1928 through 1952 are shown on Plate 20. It may be noted on the hydrograph that the piezometric level in this well was below sea level from the spring of 1929 to the fall of 1931, and from the spring of 1950 until the fall of 1951, and was also drawn down slightly below sea level for a short period in the spring of 1948. During the wet season of 1951-52 the piezometric level recovered to approximately 18 feet above sea level. Examination of lines of equal elevation of ground water in Mound Basin for the fall of 1951, as shown on Plate 16-B, indicates the presence of a depression in the piezometric surface near the coastal front. The center of this depression was about 16 feet below sea level. It is probable that this depression was formed as a result of heavy pumping from the beach wells of the City of Ventura, and as a result of pumping from the concentration of irrigation wells of heavy draft in this vicinity. Formation of this depression lends evidence to a conclusion that the rate of pumping draft exceeded the transmissibility of aquifers extending from Santa Paula Basin, from which subsurface flow appears to be the principal source of ground water supply for Mound Basin. It is probable that during periods when a depression in the piezometric surface prevailed, a portion of the water supply to Mound Basin was obtained from the seaward extension of the aquifers. However, it is believed that sea water intrusion to the wells in the vicinity of the depression did not occur since no increase in chloride concentration in water extracted from the wells was noted.

Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins. Confined aquifers of economic significance in both the Oxnard Plain and Pleasant Valley Basins receive a large portion of their water supply from unconfined ground water in Oxnard Forebay Basin, which in turn is principally replenished by water of the Santa Clara River. Because of the hydraulic continuity between the three basins, they are discussed together in this section. Their relative locations are shown on Plate 11. The three basins comprise a total area of about 76,480 acres, of which Oxnard Forebay Basin occupies about 6,170 acres, Oxnard Plain Basin about 46,460 acres, and Pleasant Valley Basin about 23,850 acres. Ground surface elevations vary from about 60 feet to 150 feet above sea level in Oxnard Plain Basin, and from about 15 feet to 240 feet in Pleasant Valley Basin. Surface waters course westerly and south-westerly to the ocean in the Santa Clara River, Calleguas Creek, and several minor streams and artificial drainage channels.

Water-bearing formations in the three basins consist principally of alluvium of Recent and Upper Pleistocene age, and of the underlying San Pedro formation of Lower Pleistocene age. In Oxnard Forebay Basin the aquifers primarily utilized are sands and gravels of the Recent and Upper Pleistocene alluvium. In Oxnard Plain Basin, the principal aquifer is a zone of sand and gravel lenses in the Upper Pleistocene alluvial deposits. This zone has been designated and will hereinafter be referred to as the "Oxnard aquifer". A second aquifer, the Fox Canyon member of the San Pedro formation is in contact with the base of the alluvium in Oxnard Forebay Basin, and underlies but is probably hydraulically separated from the alluvium in the Oxnard Plain and Pleasant Valley Basins. This aquifer is utilized only to a minor extent in the Oxnard Forebay and Oxnard Plain Basins, but supplies most of the water to users in Pleasant Valley Basin. In Pleasant Valley Basin, ground water is also obtained from sand and gravel lenses in Recent and Upper Pleistocene deposits which do not appear to be connected with the Oxnard aquifer, and to a minor extent from aquifers in the Santa Barbara formation underlying the Fox Canyon aquifer and from fractures and fissures in volcanic rocks along the southeasterly portion of the basin. Well log sections K-K', L-L', and M-M' on Plate 12-B show the structures and relative position of the water-bearing formations and aquifers in the three basins. Depths from ground surface to the bases of these aquifers are shown in Table 11, together with estimated thicknesses thereof.

The boundary of Oxnard Forebay Basin was taken at the Saticoy fault and the Santa Clara River on the north, and around the remainder of the basin's periphery at the limit of the area of unconfined ground water. Oxnard Plain Basin was defined by the boundaries of the Oxnard Forebay and Mound Basins on the north, by that of West Las Posas Basin in the

Calleguas-Conejo Hydrologic Unit on the northeast, and by that of Pleasant Valley Basin on the east and southeast. The basin is bounded by the ocean on the west, but the Oxnard aquifer probably extends beneath the ocean. The boundary between Oxnard Plain and the Pleasant Valley and West Las Posas Basins corresponds to the assumed limit of lands underlain by the Oxnard aquifer. The boundaries of Pleasant Valley Basin on the north, east, and south were taken as the limit of the alluvium. The northeasterly boundary was defined by topographic features.

The Oxnard aquifer of Oxnard Plain Basin is overlain by sediments of low permeability, which separate this economically important aquifer from a semi-perched ground water body of inferior mineral quality in the alluvium near the ground surface. The relatively impermeable sediments result in confinement of water in the Oxnard aquifer. Whether or not there is complete severance of hydraulic continuity between the semi-perched ground water and water in the Oxnard aquifer was not firmly established.

The portions of the Fox Canyon aquifer in both the Oxnard Plain and Pleasant Valley Basins, and aquifers of the Santa Barbara formation in Pleasant Valley Basin, are also confined by sediments of low permeability. As shown on Section K-K' on Plate 12-B, both the Oxnard and Fox Canyon aquifers appear to extend off-shore beneath the capping and relatively impermeable sediments. Absolute geologic evidence that these aquifers are exposed to the ocean is not available. However, off-shore soundings indicate the existence of two submarine canyons incised in the ocean floor, near Port Hueneme and near Point Mugu. These canyons are of sufficient depth to indicate the probability of exposure of the

Oxnard aquifer to the ocean at points as close as one-quarter mile from the coastline. Although there are not sufficient off-shore data to establish the probability of outcrop of the Fox Canyon aquifer in the submarine canyon near Port Hueneme, it appears probable that this aquifer does outcrop in the submarine canyon near Point Mugu. As described hereinafter in this chapter under "Quality of Water", the intrusion of sea water to wells pumping from the Oxnard aquifer in the vicinity of Port Hueneme has been fairly well established.

Ground water occurring in Oxnard Forebay Basin is unconfined, and it is indicated that it moves from the basin under pressure in a southwesterly direction through the Oxnard aquifer to areas of pumping draft in Oxnard Plain Basin. It is also indicated that ground water leaves Oxnard Forebay Basin under pressure and moves in a southerly direction through the Fox Canyon aquifer to Pleasant Valley Basin. The directions of movement of ground water from Oxnard Forebay Basin are shown on Plates 14-B, 15-B, and 16-B. It was observed that during the recent drought period, troughs or depressions were formed in the piezometric surfaces of the Oxnard aquifer in Oxnard Plain Basin, and of the Fox Canyon aquifer in Pleasant Valley Basin. The positions and depths of the troughs varied in accordance with pumping draft from the two aquifers, and with elevation of the ground water surface in Oxnard Forebay Basin. As a result of formation of the troughs, the direction of ground water movement on their seaward sides was reversed, as shown on Plate 16-B. Plate 13, entitled "Diagrammatic Sketch of Oxnard Forebay and Oxnard Plain Basins" shows the relative position of the peizometric surface in the Oxnard aquifer in Oxnard Plain Basin in spring of 1944 and in the fall of 1951, indicating direction of ground water movement therein under two extreme conditions.

Wells drawing from Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins yield on the average from 900 to 1,100 gallons of water per minute. However, wells drawing on the alluvium in Pleasant Valley yield an average of about 400 gallons per minute. Specific capacity of wells in Oxnard Forebay Basin averages in excess of 200, in Oxnard Plain Basin about 75, and in Pleasant Valley Basin about 40. The estimated weighted average specific yield of water-bearing materials in Oxnard Forebay Basin, in the range of depth between the highest and lowest historic water levels, is approximately 16 per cent.

Ground water storage in Oxnard Forebay Basin is replenished by natural percolation of surface flow in the Santa Clara River, and by percolation of Santa Clara River water which is diverted to the spreading grounds now operated by the United Water Conservation District near Saticoy. Ground water storage in the basin is also replenished by subsurface inflow from Santa Paula Basin, deep penetration of direct precipitation, and percolation of the unconsumed portion of water applied for irrigation and other uses. Ground water in Oxnard Forebay Basin is disposed of by pumped extractions for beneficial consumptive uses of overlying lands, by exportation, by consumptive use of phreatophytes, and by subsurface outflow to the Oxnard Plain and Pleasant Valley Basins.

As has been stated, the Oxnard aquifer of Oxnard Plain Basin is supplied principally by subsurface inflow from Oxnard Forebay Basin. To a lesser degree it receives underflow from West Las Posas Basin. During the recent drought period, when the hydraulic gradient in the Oxnard aquifer on the seaward side of the cited trough was reversed, contribution to the aquifer appears to have been obtained from the ocean. Also, there may be some exchange of water between the Oxnard and Fox Canyon aquifers in Oxnard Plain Basin, and between the Oxnard aquifer and the overlying semi-perched ground water body. Disposal of ground water in Oxnard Plain Basin is effected by pumped extractions for beneficial uses, by subsurface outflow to the ocean during periods of high peizometric level in the aquifers, and to a minor extent, by effluent discharge through uncapped wells during periods of high piezometric level.

Aquifers in Pleasant Valley Basin are supplied primarily by subsurface inflow from adjacent basins. Such contributions are received through the Fox Canyon aquifer from Oxnard Forebay Basin, and from East Las Posas and Santa Rosa Basins in the Calleguas-Conejo Hydrologic Unit. They are also received from fractured volcanic rocks on the southeast side of the basin. Some replenishment may be received as subsurface inflow from West Las Posas Basin through the Fox Canyon aquifer which crosses beneath the Camarillo Hills. As in the case of the Oxnard aquifer, with the formation of a trough in the piezometric surface in the Fox Canyon aquifer in Pleasant Valley Basin during the recent drought period, it appears that there may have been subsurface inflow through this aquifer from the ocean. Ground water found in the little-used aquifers of the alluvium in Pleasant Valley Basin appears to be replenished principally by subsurface inflow from adjacent hill areas. Disposal of ground water in Pleasant Valley Basin is effected by pumped extractions for beneficial uses, probably by subsurface outflow to the ocean during periods of high piezometric level in the aquifers, and to a minor extent by effluent discharge through uncapped wells during periods of high piezometric level.

It has been stated that during the recent drought period, with an increase in ground water extractions and a general diminution of water supplies accompanied by lowered ground water levels in Oxnard Forebay, troughs formed in the piezometric surfaces in both the Oxnard aquifer in Oxnard Plain Basin, and in the Fox Canyon aquifer in Pleasant Valley Basin.

In the Oxnard aquifer the trough first appeared in the spring of 1946, at a location about 3 miles inland from the coastline and southeast of the City of Oxnard. This trough subsequently disappeared, but reappeared during the seasons of 1947-48 and 1948-49 during times of heavy pumping draft. Subsequent to the spring of 1949 the trough persisted, with its center substantially below sea level, until the wet season of 1951-52. As ground water levels continued to lower in Oxnard Forebay, and with continuation of heavy pumping draft from the Oxnard aquifer, the trough also deepened and moved inland until in the spring of 1951 its center was from five to six miles from the coastline and about 40 feet below sea level. At that time, in excess of 27,000 acres of land were being supplied with water pumped from the seaward side of the trough, wherein conditions were conducive to the intrusion of sea water. It was estimated that during the seasons of 1949-50 and 1950-51 about 25,500 and 31,800 acre-feet of water, respectively, were extracted from Oxnard Plain Basin from the seaward side of the trough. In excess of 90 per cent of these amounts were extracted from the Oxnard aquifer, with the remainder from the underlying Fox Canyon aquifer through wells perforated in both aquifers. Since the position and depth of the trough varied considerably prior to the spring of 1950, it was not feasible to evaluate ground water extractions on the seaward side of the trough before that time.

Fluctuations of piezometric levels in the Oxnard aquifer at wells numbers 1N/22W-7D1, 1N/21W-19A1, and 1N/22W-3F4 are shown on Plate 20. A composite hydrograph of water levels at wells numbers 2N/22W-23H1, 2N/22W-23H2, and 2N/22W-23H3, representative of fluctuations in the ground water surface in Oxnard Forebay Basin, is also shown on Plate 20. It may be noted from this hydrograph that ground water levels in Oxnard Forebay Basin were below sea level for a short period in 1951. The relationship between dewatered ground water storage capacity in Oxnard Forebay Basin and elevation of the ground water surface at well number 2N/22W-23H3 is shown on Plate 21. With the present pattern of pumping, the utility of Oxnard Forebay Basin appears to be limited by its probable hydraulic continuity with the ocean through the Oxnard aquifer in Oxnard Plain Basin. In order to maintain a seaward gradient in the piezometric surface in the Oxnard aquifer with minimum pumping draft therefrom, it was estimated that ground water storage depletion in Oxnard Forebay Basin must not exceed 87,000 acre-feet. As shown on Plate 21, elevation of key well number 2N/22W-23H3 would be about 12 feet above sea level with this estimated maximum safe ground water storage depletion.

The trough in the piezometric surface of the Fox Canyon aquifer underlying Pleasant Valley first formed during the drought period in the spring of 1946. By the fall of 1946 its center was more than 10 feet below sea level. The trough disappeared during the winter of 1946-47, but again appeared in the spring of 1947, with its center approaching 20 feet below sea level in the fall of that year. After recovering during the winter of 1947-48, the trough again formed in the spring of 1948, and has persisted until 1953. The maximum depth of the center of the trough below sea level was estimated to have been about 60 feet in August of 1951. The center of the trough, as shown on

Plate 16-B, occurred about four miles southwest of the town of Camarillo. Fluctuations of the piezometric surface in the Fox Canyon aquifer at well number 1N/21W-16A1, which is near the center of the trough, are shown on Plate 20. Also shown on Plate 20 are fluctuations of the piezometric surface in the Fox Canyon aquifer at well number 2N/20W-17J3, which is in the northeasterly portion of the basin near Somis. It may be noted that since the time of first measurement in 1920, the water surface elevation at well number 2N/20W-17J3 has shown a rather persistent decline. It is believed that this is indicative of the perennial lowering of ground water levels in the Fox Canyon aquifer in East Las Posas Basin, which occurrence is described hereinafter in this section. Uncertainties regarding the exact position of the trough in the Fox Canyon aquifer in Pleasant Valley Basin, and inadequate data concerning amounts of water extracted from the several other aquifers supplying overlying lands in the basin, precluded evaluation of the magnitude of extractions from the Fox Canyon aquifer from the seaward side of the trough.

Plates 14-B, 15-B, and 16-B depict the elevation of the ground water surface in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins in the fall of 1936, in the spring of 1944, and in the fall of 1951, respectively. Plate 15-B also shows the approximate extent of the area wherein piezometric levels in the pressure aquifers were above ground surface in the spring of 1944. Delineated on Plate 16-B is the area where piezometric levels were below sea level in the fall of 1951, and underlain by a landward gradient in the piezometric surface, which condition was conducive to intrusion of sea water to the aquifers. The estimated maximum areal extent of lands in the vicinity of Port Hueneme actually underlain by sea water is also delineated on Plate 16-B.

A monthly analysis was made of water supply and disposal in the Oxnard Forebay, Oxnard Plain, and Pleasant Valley Basins during the base period, with present conditions of land use and pattern of pumping. In commencing this analysis, it was assumed that ground water storage depletion in Oxnard Forebay Basin in the fall of 1936 was equal to that in the fall of 1951, or about 109,500 acre-feet. Items of water supply to Oxnard Forebay Basin included surface and subsurface outflow from Santa Paula Basin, as shown in Table 14. In addition, a portion of the export of water from Santa Paula Basin, shown in Table 14, was delivered to Oxnard Forebay and Oxnard Plain Basins by the Santa Clara Water and Irrigating Company. An additional source of water supply to Oxnard Plain Basin consisted of underflow from West Las Posas Basin, estimated to have averaged about 600 acre-feet per season. Underflow to Pleasant Valley Basin, principally through the Fox Canyon aquifer from Santa Rosa and East and West Las Posas Basins, and to a lesser extent from fractured volcanic rocks on the southwest side of this basin, constituted an estimated average seasonal supply of about 4,100 acre-feet. Records were obtained of diversions to the Saticoy spreading grounds. Exports of water from Oxnard Forebay Basin to Mound Basin in an average seasonal amount of about 2,100 acre-feet by the Alta Mutual Water Company, and of export of water to West Las Posas Basin from Oxnard Plain Basin by the Del Norte Water Company in an average seasonal amount of about 1,100 acre-feet, were determined from records of these two companies. For purposes of analysis it was assumed that hydraulic continuity does not exist between the confined aquifers in Oxnard Plain and Pleasant Valley Basins and overlying media. Estimates of extractions of water from these confined aquifers were made for the period from 1944-45 through 1951-52. The estimated seasonal extractions that would have been made during the wet period in the Oxnard Plain and Pleasant Valley Basins, under present conditions of land use and water supply development, were taken as the average of determined extractions during the two seasons of 1944-45 and 1951-52. Subsurface outflow to the ocean through the Oxnard aquifer was estimated from parameters derived from correlation of ground water surface elevations in Oxnard Forebay Basin, and slopes of the piezometric surface and rates of flow in the Oxnard aquifer. It was estimated that with Oxnard Forebay Basin essentially full, subsurface outflow to the ocean in the aquifer would have a maximum rate of about 2,000 acre-feet per month. It was further estimated that the rate of subsurface outflow with the present pattern of pumping and with Oxnard Forebay Basin essentially full would not be materially affected until the rate of pumping draft from Oxnard Plain Basin exceeded 4,300 acre-feet per month. With lowering of ground water levels in Oxnard Forebay Basin and a rate of pumping draft from Oxnard Plain Basin in excess of 4,300 acre-feet per month, it was estimated that the rate of subsurface outflow to the ocean through the Oxnard aquifer would be reduced. The reasonableness of these estimates were substantiated by independent determinations using the slope area method.

The seasonal summary of the monthly hydrologic analysis of the three basins is presented in Table 15. It may be noted from the table that in order to effect hydrologic balance in most seasons, an item of supply designated "undifferentiated supply from other sources" is shown. For seasons prior to 1944-45, the amount of this supply was determined as a differential in solution of the equation of hydrologic equilibrium under estimated historical rather than study conditions. It was then assumed that the derived magnitude of this supply would not have been materially different under the assumed conditions of the study. For seasons subsequent to the fall of 1944, at which time Oxnard Forebay Basin was filled, both historically and under study conditions, it was assumed that changes in ground water storage in that basin would have occurred under study conditions as they did historically. The undifferentiated supply from other sources was then evaluated as a differential in solution of the equation of hydrologic equilibrium under these assumed conditions.

There are four water sources which probably contribute to the aforementioned "undifferentiated supply from other sources", but from data at hand it was not possible to evaluate the magnitude of the supply from each source: (1) Contribution to the pumped aquifers of Pleasant Valley Basin may occur from perennial change in storage in free ground water areas in adjacent hills, which ground water bodies are believed to be hydraulically connected with the aquifers in the basin. Change in ground water storage in these areas could not be evaluated because of the lack of well log and water level control. (2) During drought periods, and other times of heavy pumping draft, with attendant lowering of piezometric levels and relief in hydraulic pressure in aquifers underlying the Oxnard Plain and Pleasant Valley Basins, it is possible that clays and other relatively impermeable sediments overlying these aquifers could be compacted. Such compaction would result in release of water from the clays and sediments to the underlying aquifers. It is believed that any possible contribution to the water supply from this source is of small magnitude. (3) It was assumed that the principal pumped aquifers in the Oxnard Plain and Pleasant Valley Basins are not hydraulically connected with overlying semi-perched ground water bodies. The presence of extensive beds of clay and other materials of low permeability between the pumped aquifers and the semi-perched water bodies has been assumed to preclude supply to the pumped aquifers of water applied to the ground surface, direct precipitation, and other surface waters including the semi-perched water. It is conceivable, however, that these separating clay beds are not continuous, and that the pumped aquifers do in fact receive some recharge from overlying waters. It is possible that water supply from this source could be substantial. (4) As described previously, it was estimated that during the seasons of 1949-50 and 1950-51, water in the amounts of 25,500 acre-feet and 31,800 acre-feet, respectively, was pumped in Oxnard Plain Basin, largely from the Oxnard aquifer on the seaward side of the trough. The volume of these extractions was probably replaced by an equal volume of sea water in the seaward extension of the Oxnard aquifer. From examination of maps showing the position of ground water levels in the Fox Canyon aquifer underlying Pleasant Valley Basin, it is believed that there was similar occurrence therein. As mentioned previously, the amount of movement of water from the ocean into the seaward extension of the Fox Canyon aquifer could not be evaluated. It is probable that water supplies from the seaward extensions of the Oxnard and Fox Canyon aquifers are obtained at all times when piezometric levels in the aquifers are below sea level.

TABLE 15

ESTIMATED SEASONAL STORAGE DEPLETION IN OXNARD FOREBAY BASIN DURING BASE PERIOD,
WITH PRESENT PATTERN OF LAND USE IN OXNARD FOREBAY, OXNARD PLAIN, AND PLEASANT VALLEY BASINS

(IN ACRE-FEET)

Season	Items of water supply to basins: Surface inflow	Subsurface inflow, Oxnard Forebay and Pleasant Valley Basins	Import	Precipitation on Oxnard Forebay Basin	Undifferentiated supply from other sources	Subtotal	Items of water disposal from basins: Surface outflow	Subsurface outflow to ocean	Export	Consumptive use on Oxnard Forebay Basin	Applied water Oxnard Plain and Pleasant Valley Basins	Subtotal	Change in ground water storage in Oxnard Forebay Basin	Ground water storage depletion in Oxnard Forebay Basin at end of season
1935-36														109,500
1936-37	230,500	11,900	1,100	11,400	20,400	275,300	160,200	12,000	2,300	11,800	68,000	254,300	21,000	88,500
1937-38	520,500	11,900	1,100	11,600	11,600	556,700	435,600	21,600	2,300	11,700	68,000	539,200	17,500	71,000
1938-39	97,500	11,900	1,700	7,400	34,400	152,900	53,600	23,600	2,600	11,600	68,500	159,900	- 7,000	78,000
1939-40	61,900	11,900	1,300	6,700	46,100	127,900	27,000	23,100	2,700	11,600	68,000	132,400	- 4,500	82,500
1940-41	832,500	11,900	800	21,600	0	866,800	687,600	23,500	1,900	12,100	67,800	792,900	73,900	8,600
1941-42	116,000	11,900	700	6,900	34,500	170,000	70,800	23,800	3,300	11,500	67,100	176,500	- 6,500	15,100
1942-43	463,700	11,900	600	12,200	4,100	492,500	379,000	23,400	2,200	11,800	67,600	484,000	8,500	6,600
1943-44	387,700	11,900	500	10,900	0	411,000	299,500	23,500	2,100	11,800	67,500	404,400	6,600	0
1944-45	109,300	11,900	200	6,400	33,900	161,700	69,900	23,500	2,900	11,800	66,600	174,700	-13,000	13,000
1945-46	108,200	11,900	500	5,700	38,700	165,000	59,300	9,200	3,800	11,400	90,300	174,000	- 9,000	22,000
1946-47	86,800	11,900	700	5,900	48,800	154,100	43,900	8,800	4,100	11,700	95,600	164,100	-10,000	32,000
1947-48	9,500	11,900	600	3,700	68,300	94,000	0	3,600	5,100	10,900	97,400	117,000	-23,000	55,000
1948-49	7,900	11,900	700	4,500	76,800	101,800	0	1,000	4,400	11,200	104,200	120,800	-19,000	74,000
1949-50	14,400	11,900	400	6,800	56,600	90,100	0	0	3,600	11,800	88,700	104,100	-14,000	88,000
1950-51	2,000	11,900	200	4,400	81,000	99,500	0	0	4,700	11,200	105,100	121,000	-21,500	109,500
Average for base period, 1936-37 through 1950-51	203,200	11,900	700	8,400	37,100	261,300	152,400	14,700	3,200	11,600	79,400	261,300		
Average for wet period, 1936-37 through 1943-44	338,800	11,900	1,000	11,100	18,900	381,700	264,200	21,800	2,400	11,700	67,800	367,900		
Average for drought period, 1944-45 through 1950-51	48,300	11,900	500	5,300	57,700	123,700	24,700	6,600	4,100	11,400	92,600	139,400		

Calleguas-Conejo Hydrologic Unit

Six major ground water basins have been identified in the Calleguas-Conejo Hydrologic Unit. These basins, designated Simi, East Las Posas, West Las Posas, Conejo, Tierra Rejada, and Santa Rosa, comprise a total area of about 95,390 acres. The remaining lands of the unit are principally underlain by formations of low permeability which do not yield water readily to wells.

Ground water presently of economic importance occurs both in Recent and Pleistocene alluvial deposits, and in sediments and fractured volcanic rocks of Tertiary age. The geology of the water-bearing materials of the Calleguas-Conejo Hydrologic Unit is complex in nature, and in general there is a paucity of available geologic data. Hydrologic data are similarly inadequate in many parts of the unit. With the exception of Simi Basin, the lack of geologic and hydrologic data precluded reliable analysis of underground hydrology. Table 16 summarizes certain physical characteristics of the six major ground water basins in the Calleguas-Conejo Hydrologic Unit.

TABLE 16

SUMMARY OF SELECTED GROUND WATER BASIN CHARACTERISTICS
IN CALLEGUAS-CONEJO HYDROLOGIC UNIT

Basin	Area, in acres	Estimated weighted average specific yield*, in per cent	Water-bearing formations	Principal aquifers	Estimated depth from ground surface to base of aquifers, in feet	Estimated thickness of aquifers, in feet	Condition of occurrence of ground water	Estimated average yield of irrigation wells, in gallons per minute
Simi	10,760	8.6	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-700	0-700	Mostly unconfined, some confined	400
			Older formations	Fracture zones and permeable lenses	0-400+	---	Essentially unconfined	100
East and West Las Posas	47,820	---	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-200	0-200	Unconfined	400
			San Pedro	Epworth gravels	0-300	0-200	Essentially unconfined	300
				Fox Canyon	0-2,000	200-400	Confined except near outcrop	600
			Santa Barbara	Grimes Canyon	0-2,000	300-1,000	Confined except near outcrop	600

TABLE 16 (Continued)

SUMMARY OF SELECTED GROUND WATER BASIN CHARACTERISTICS
IN CALLEGUAS-CONEJO HYDROLOGIC UNIT

Basin	Area, in acres	Estimated weighted average specific yield*, in per cent	Water-bearing formations	Principal aquifers	Estimated depth from ground surface to base of aquifers, in feet	Estimated thickness of aquifers, in feet	Condition of occurrence of ground water	Estimated average yield of irrigation wells, in gallons per minute
Conejo	28,930	5	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-60	0-60	Unconfined	50
			Tertiary volcanics and older sedimentary rocks	Fracture zones and permeable lenses in sedimentary rocks	1,000±	---	Essentially unconfined	50
Tierra Rejada	4,390	7	Tertiary volcanics	Fractured zones	1,000+	---	Essentially unconfined	300
Santa Rosa	3,490	5	Recent and Pleistocene alluvium	Lenses of permeable sediments	0-200	0-200	Unconfined	600
			San Pedro	Fox Canyon and other permeable lenses	0-700	0-700	Confined and unconfined	600
			Volcanics	Fractured zones	1,500+	---	Confined and unconfined	600

* In zone of historic water level change.

Simi Basin. Simi Basin, situated in the northeastern portion of the Calleguas-Conejo Hydrologic Unit, has a surface area of about 10,760 acres, and ranges in elevation from about 700 to 1,100 feet above sea level. Surface runoff in the basin discharges to the west through Arroyo Simi into East Las Posas Basin. This stream is designated Arroyo Las Posas in East Las Posas Basin, and Calleguas Creek in its lower reaches.

Water-bearing materials in Simi Basin consist of alluvial gravels, sands, and clays of Recent and Pleistocene age, having a maximum depth of about 700 feet. The alluvium is underlain and bounded by older consolidated sediments, wherein ground water is found in minor amounts in fractured zones and in permeable lenses of sands and gravels. The base of the alluvium is concave in shape, deepening toward the center from the peripheral margin. Geologic cross sections Q-Q' and R-R' on Plate 12-C depict the structure and shape of the basin. Ground water in the alluvium is generally unconfined, although clay lenses, particularly in the westerly extremity of the basin, cause localized pressure conditions in the ground water body. Wells in the westerly portion of the basin have been known to flow during periods of high ground water. Normally, ground water moves in a westerly direction toward East Las Posas Basin, as shown on Plates 14-C and 15-C. However, during periods of heavy pumping draft and lowered ground water levels, the slope of the ground water surface at the westerly end of the basin is reversed, as shown on Plate 16-C.

Ground water storage in Simi Basin is replenished by percolation of direct precipitation, of the flow of minor streams, and of the unconsumed portion of water applied for irrigation and other uses, and to a limited extent by lateral subsurface inflow from the flanking consolidated formations. Water is imported to the basin by the Tapo Mutual Water

Company from a well field in Tapo Canyon. These wells pump from aquifers in the Santa Barbara formation, which formation is not hydraulically connected to the alluvium in Simi Basin, although surface waters in Tapo Canyon are tributary to the basin. Some recharge to the basin has been effected through minor spreading operations. Runkle Reservoir, with a storage capacity of 100 acre-feet, located on a minor watercourse on the south side of Simi Valley, is utilized for flood control and to regulate releases to spreading grounds downstream from the dam. In general it is believed that spreading operations in Simi Basin have not contributed significantly to ground water replenishment.

Ground water in Simi Basin is disposed of by pumped extractions for use on overlying lands and on lands adjacent to the basin, by consumptive use of phreatophytes, and by effluent discharge and subsurface outflow to East Las Posas Basin. Wells in the basin are estimated to have an average yield of about 400 gallons per minute. Wells drawing from the older formations around the perimeter of the basin, and from the Santa Barbara formation in Tapo Canyon, are estimated to yield an average of about 100 gallons per minute.

The ground water storage capacity of Simi Basin was estimated to be approximately 180,000 acre-feet. In the fall of 1951, estimated ground water storage depletion in the basin was about 31,000 acre-feet, the greatest during the period for which records of ground levels are available. Ground water levels in Simi Basin have exhibited substantial lowering since measurements were first recorded in the late 1920's. As shown by the hydrograph of the water level in key well number 2N/18W-12L3, on Plate 20, ground water levels showed a persistent decline from 1929 to

1941, when in an excessively wet season there was a substantial recovery. Water levels in the basin were then essentially stabilized until 1944-45, when a rapid decline again commenced which persisted through 1951-52. The relationship between elevation of the ground water surface at well number 2N/18W-12L3 and ground water storage depletion in Simi Basin is shown on Plate 21.

The total decrement in ground water storage during the base period was estimated to have been about 21,000 acre-feet, or an average of about 1,400 acre-feet per season. Tributary surface inflow during the period averaged an estimated 5,300 acre-feet per season, including an average import of about 1,400 acre-feet per season by the Tapo Mutual Water Company. Surface outflow, as measured at the gaging station on Arroyo Simi near Simi, averaged 1,100 acre-feet per season during the base period. Subsurface outflow to East Las Posas Basin was estimated by the slope-area method to have been about 100 acre-feet per season. Direct seasonal precipitation on the ground water basin was estimated to have averaged about 13,300 acre-feet. Average seasonal consumptive use of water on lands overlying the ground water basin, and seasonal consumptive use of water from the basin applied on water service areas adjacent to the basin was estimated to have totaled about 18,800 acre-feet. Of this amount, about 7,500 acre-feet per season represents consumptive use of applied water. It should be pointed out that, as described in Chapter III, analysis of records of application of water to principal crops grown in Simi Basin indicate that in certain portions of the basin these crops have subsisted on deficient water supplies. Had adequate applications of water been given to these crops, the foregoing estimated average seasonal consumptive use of applied water of 7,500 acre-feet would have been increased to an estimated 9,700 acre-feet.

East and West Las Posas Basins. The East and West Las Posas Basins, situated in the northerly portion of the Calleguas-Conejo Hydrologic Unit and west of Simi Basin, have a surface area of about 47,820 acres. Elevation of the basins varies from about 200 feet to more than 1,500 feet above sea level. East Las Posas Basin is drained by Arroyo Las Posas, which passes southwesterly into Pleasant Valley Basin in the vicinity of Somis. Surface runoff in West Las Posas Basin drains westerly through several minor watercourses to Oxnard Plain Basin.

Ground water in East and West Las Posas Basins occurs in Recent and Pleistocene alluvial deposits, and in the San Pedro and Santa Barbara formations. These latter two formations have been folded into east-west trending synclines and anticlines. Alluvium containing ground water in usable quantities comprises an area of about 5,100 acres on the south side of East Las Posas Basin, extending to depths of about 200 feet. Alluvial deposits elsewhere in the two basins are generally of relatively shallow depth, or so high in silt and clay content that little water is yielded to wells. Ground water in the alluvial deposits is generally unconfined.

The principal pumping aquifer in the San Pedro formation is the Fox Canyon member. The Epworth gravels, occurring near the upper limits of the San Pedro formation, comprise a secondary aquifer in this formation. Ground water in usable quantities is obtained from the Grimes Canyon member of the Santa Barbara formation, which underlies the aforementioned San Pedro formation. Sections L-L' and N-N' on Plates 12-B and 12-C show the structure and relative position of the alluvial deposits and the Fox Canyon and Grimes Canyon aquifers. Section P-P' on Plate 12-C shows the structure and relative position of the foregoing aquifers, together with the Epworth gravels. Ground water found in the Fox Canyon and Grimes Canyon aquifers is confined, except near their outcrop areas. Ground water in the Epworth gravels is generally unconfined. The Fox Canyon aquifer underlies both East and West Las Posas Basins. From analyses of limited subsurface geologic data, it is believed that the Grimes Canyon aquifer underlies much of the area of the two basins. It is also believed that the Fox Canyon and Grimes Canyon aquifers are interconnected over most of East Las Posas Basin. The alluvium and the Epworth gravels are isolated from each other, and from the Fox Canyon and Grimes Canyon aquifers, by sediments of low permeability. Ground water extractions for beneficial use are primarily from the alluvium and the Fox Canyon aquifer in East Las Posas Basin, and almost entirely from the Fox Canyon aquifer in West Las Posas Basin.

The alluvium in East Las Posas Basin is recharged primarily by percolation of flow in Arroyo Las Posas, by percolation of the unconsumed portion of water applied for irrigation and other uses, and by deep penetration of direct precipitation. The Epworth gravels and Fox Canyon and Grimes Canyon aquifers are recharged largely by deep penetration of direct precipitation on outcrop areas, and by percolation of flow in minor streams traversing these outcrops.

Ground water in the Epworth gravels and in the Fox Canyon and Grimes Canyon aquifers is disposed of through pumped extractions to meet consumptive uses of overlying lands and through consumptive use of phreatophytes. Subsurface outflow to the Oxnard Plain and Pleasant Valley Basins constitutes another item of disposal of ground water of the Fox Canyon aquifer. Ground water in the alluvium is similarly disposed of, as well as by effluent discharge near Somis, where rising water flows into Pleasant Valley Basin. A portion of the unconsumed residuum of water extracted from the Grimes Canyon and Fox Canyon aquifers returns to ground water storage in the overlying alluvium.

As mentioned previously, the alluvium presently exploited by pumping in East Las Posas Basin comprises a surface area of about 5,100 acres. The areas of outcrop of the Fox Canyon aquifer in East and West Las Posas Basins, located along the north side of both basins and the south side of East Las Posas Basin, were estimated to total about 3,320 acres. The Epworth gravels have an outcrop area of about 1,080 acres located along the northerly side of East Las Posas Basin. The Grimes Canyon aquifer outcrops on both the north and south slopes of Oak Ridge with the estimated area of outcrop being about 5,220 acres. The lack of adequate data on subsurface geology precluded evaluation of the magnitude of storage capacity available in either the alluvium or in the underlying older formations. Similarly, it was not possible to evaluate directly the items of water supply and disposal thereof in the two basins.

As shown on Plate 20, ground water levels at key well number 2N/20W-10R1, which is perforated in the Fox Canyon aquifer in East Las Posas Basin, indicate a rather persistent decline from January, 1928 when the well was first measured, until the present time. Although the rate of decline decreased during the wet period, the dry seasons from 1944-45 through 1950-51 accelerated the decline. During the 25-year period of measurement, water levels at this well were lowered approximately 230 feet. Measurements at key well number 2N/21W-16R1, also shown on Plate 20, perforated in the Fox Canyon aquifer in West Las Posas Basin, indicate that the water level lowered about 55 feet during the period from 1927 to

1953. Some recovery was noted in the water level in this well during the wet period. Subsequent to 1946-47, however, water levels rapidly declined. As shown on Plate 20, ground water levels at key well number 3N/19W-29F3, which is perforated in the Epworth gravels, persistently declined from 1929, but with a more moderate rate than indicated for the Fox Canyon aquifer. Available well measurements indicate that water levels in the alluvium are quickly drawn down during periods of drought, and that they recover rather rapidly during wet periods.

The average decrement in ground water storage in East and West Las Posas Basins during the base period was estimated from rather sparse water level and well log control to have been about 5,000 acre-feet per season. This change in storage occurred primarily in the Fox Canyon aquifer, which is believed to supply most of the water used in the two basins. During this period, seasonal consumptive use of applied water was estimated to have averaged about 16,900 acre-feet. A portion of this consumptive use was met by an import from Oxnard Forebay Basin by the Del Norte Water Company in the amount of about 1,100 acre-feet per season. Subsurface outflow from East Las Posas Basin to Pleasant Valley Basin was estimated by the slope-area method to have been about 3,000 acre-feet per season during the base period. Similarly, it was estimated that about 600 acre-feet per season were discharged to Oxnard Plain Basin as subsurface outflow from West Las Posas Basin.

Conejo Basin. Conejo Basin, situated in the south-central portion of the Calleguas-Conejo Hydrologic Unit, has a surface area of about 28,930 acres, and its boundaries conform to those of the Conejo Hydrologic Subunit. Surface elevations vary from about 300 to 2,300 feet above sea level. Surface waters drain primarily in a westerly direction in Conejo Creek and into Santa Rosa Basin.

The water bearing materials of Conejo Basin include volcanic rocks of Miocene age, and sedimentary formations ranging from Cretaceous to Recent in age. The volcanic rocks are weathered and fractured, with the degree of fracturing being greater in some areas than others. All formations except the alluvium are folded and faulted. In general, the alluvium is quite shallow, and ground water in usable quantities occurs primarily in fissures and weathered zones in the volcanic rocks. Some ground water is also found in permeable lenses of sandstones and conglomerates in the Topanga and Modelo formations of Miocene age. Ground water is essentially unconfined, and its movement conforms to the surface slope.

Ground water storage in Conejo Basin is replenished by deep penetration of direct precipitation, by percolation of flow in Conejo Creek and its tributaries, and by percolation of the unconsumed portion of water applied for irrigation and other uses. Ground water is disposed of through pumped extractions to meet requirements of overlying lands, by subsurface outflow to Santa Rosa Basin through the volcanics, by effluent discharge into Santa Rosa Basin, and by consumptive use of phreatophytes. There may also be some direct contribution to the supply of Pleasant Valley Basin by subsurface outflow from Conejo Basin through the volcanic rocks. Because of the irregular pattern of the fracture system, yield of wells in Conejo Basin varies over wide limits. Those wells penetrating large fractures or fissures have been known to yield as much as 1,000 gallons per minute. This, however, is the exception, with the general yield averaging on the order of 50 gallons per minute.

The indeterminate irregularities in the fracture systems found in the volcanic rocks precluded evaluation of total storage capacity in Conejo Basin through use of conventional methods. Furthermore, since only one well was measured sporadically in the basin over the base period, it was not possible to estimate change in ground water storage. Indications are that ground water levels in Conejo Basin recover quite rapidly during wet periods, and that the present use of ground water from the basin is being met by natural replenishment. It was estimated that seasonal consumptive use of applied water during the base period averaged about 2,600 acre-feet. Of this amount, about 2,300 acre-feet per season were utilized on irrigated lands.

Tierra Rejada Basin. Tierra Rejada Basin, situated north of Conejo Basin and east of Santa Rosa Basin, has a surface area of about 4,390 acres. The boundaries of the ground water basin are the same as those of the hydrologic subunit of the same name. Surface elevations vary from about 600 feet to 1,600 feet above sea level. Surface waters drain to the west to Santa Rosa Basin.

Ground water in Tierra Rejada Basin, as in Conejo Basin, occurs primarily in fissures and fractures of prevailing volcanic rocks of Miocene age. Small areas of the basin on the north and south sides consist of Tertiary formations in which no wells have been drilled. The volcanics extend to depths of about 2,000 feet, and are folded into a westward plunging syncline. Ground water found in the volcanic rocks is generally unconfined, and moves in a westerly direction in conformity with the surface slope. A north-south trending fault near the westerly extremity of the basin results in a differential in water levels across the fault of up to 80 feet. Wells in Tierra Rejada Basin are reported to yield an average of about 300 gallons of water per minute. However, in the periphery of the basin, difficulty has been encountered in obtaining wells of adequate yield.

Ground water storage in Tierra Rejada Basin is replenished by deep penetration of direct precipitation, by percolation of flow in minor watercourses, and by percolation of the unconsumed portion of water applied for irrigation and other uses. Disposal of ground water occurs through pumped extractions to meet consumptive use of overlying irrigation developments, and probably through subsurface outflow across the aforementioned fault to Santa Rosa Basin. About 500 acre-feet of water per season are exported to Santa Rosa Basin from a well in the extreme westerly portion of Tierra Rejada Basin. It is probable that in the past, depletion of ground water storage in the basin has occurred through effluent discharge and consumptive use of phreatophytes at its westerly extremity.

Water level measurements in Tierra Rejada Basin were initiated at the end of the year 1945 by the Ventura County Water Survey. Since that time ground water levels have shown a progressive decline, and measurements indicate that there was little recovery during the wet season of 1951-52. Water level fluctuations in the basin are illustrated by the hydrograph of well number 2N/19W-14D1, shown on Plate 20. Scattered ground water level measurements since 1930 indicate that disposal of ground water from the basin has probably exceeded replenishment thereto. There were, however, insufficient data available to reliably estimate change in ground water storage over the base period. Consumptive use of applied water in the basin during the base period was estimated to have been approximately 500 acre-feet per season.

Santa Rosa Basin. Santa Rosa Basin occupies an area of about 3,490 acres in the central portion of the Calleguas-Conejo Hydrologic Unit, and south of East Las Posas Basin. Surface elevations vary from about

200 feet to more than 400 feet above sea level. The surface drainage is to the west. Conejo Creek passes through the westerly portion of the basin and flows to a confluence with Calleguas Creek in Pleasant Valley Basin.

Santa Rosa Basin is comprised of alluvial deposits on the south side, with the San Pedro formation outcropping along the north side. Both of these formations are underlain by fractured volcanic rocks. The alluvium extends to depths of about 200 feet. The San Pedro formation consists of up to 700 feet of gravels, sands, silts, and clays, and is folded into a syncline as shown on Sections N-N' and P-P' of Plate 12-C. Ground water occurs in sands and gravels of the alluvium, and in the Fox Canyon aquifer of the San Pedro formation, which aquifer can only be traced in the western portion of the basin. Some ground water is also found in limited gravels in the silty portion of the San Pedro formation, as well as in fractures of the volcanic rocks. Ground water in the alluvium, although generally unconfined, does exhibit localized pressure conditions. Ground water in the Fox Canyon aquifer, and in other gravels of the San Pedro formation, is confined except in the outcrop areas. Ground water moves generally to the west toward Pleasant Valley Basin.

Ground water storage in the alluvium of Santa Rosa Basin is replenished by percolation of flow in Conejo Creek and its tributaries, by deep penetration of direct precipitation, by percolation of the unconsumed portion of water applied for irrigation and other uses including that of ground water extracted from the San Pedro formation, and possibly by lateral movement of ground water from volcanics in both Tierra Rejada and Conejo Basins. Ground water storage in the San Pedro formation is recharged by percolation of flow in minor watercourses, by deep penetration of direct precipitation on its outcrop area along the north side of the basin, and possibly by lateral underflow from the volcanic rocks. Ground water storage is depleted by pumped extractions to meet beneficial consumptive use on overlying lands, by effluent discharge, and by some subsurface outflow to Pleasant Valley Basin. Wells in Santa Rosa Basin are reported to yield as much as 1,200 gallons per minute, with an estimated average yield of about 600 gallons per minute.

Water level fluctuations at key well number 2N/20W-23R1, which is perforated in the alluvium, are shown on Plate 20. It may be noted that although water levels in this well showed substantial recovery during the wet period, there was a net lowering of about 20 feet during the base period. The average decrement in ground water storage in the basin during the base period was estimated to have been about 200 acre-feet per season. The estimated seasonal consumptive use of applied water during the base period was about 3,100 acre-feet. An import from Tierra Rejada Basin in the amount of about 500 acre-feet per season satisfied a portion of this consumptive use. It was estimated that during the base period there was a small subsurface outflow to Pleasant Valley Basin in an amount not in excess of 200 acre-feet per season.

Quality of Water

Surface and ground water supplies of Ventura County are generally of good mineral quality and suitable from that standpoint for irrigation and other beneficial uses. Notable exceptions are found in the waters of some minor surface streams and in the low flows of several major streams, as well as in ground waters found in some portions of the County. It has been reported that in certain areas crops have suffered injury from application of waters containing high boron concentrations. In addition it has been reported that crops in some localities have suffered from excessive soil salinity during drought periods, which is an indication that normal rainfall is a factor in keeping soil salinity within acceptable limits.

In a number of ground water basins in Ventura County, it appears that the average seasonal quantity of dissolved salts added to ground water supplies exceeds the average seasonal quantity removed. Thus an unfavorable salt balance is created which, if continued, may seriously affect the quality of ground water in the basins. Plans for water supply development to eliminate present overdrafts on ground water basins and to satisfy probable future water requirements must also provide sufficient water to maintain a satisfactory salt balance in ground water basins.

The Division of Water Resources is presently conducting a detailed County-wide investigation of water quality and water quality problems in Ventura County, in accordance with sections 229 and 230 of the Water Code. Since results of that investigation will be published in the near future, water quality data and discussion herein are limited to a general presentation of factors which affect the suitability of available water supplies for prevailing beneficial uses.

The following terms are used, as defined, in connection with the discussion of quality of water in this bulletin:

Quality of Water--Those characteristics of water affecting its suitability for beneficial uses.

Contamination--Impairment of the quality of water by sewage or industrial waste to a degree which creates a hazard to public health through poisoning or spread of disease.

Degradation--Impairment of the quality of water due to causes other than disposal of sewage and industrial wastes.

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.

Mineral Analyses--The quantitative determination of inorganic impurities or dissolved mineral constituents in water.

Complete mineral analyses reported in this bulletin include determination of calcium, magnesium, sodium and potassium, bicarbonate, carbonate, chloride, sulphate and nitrate, fluoride, boron, total dissolved solids, electrical conductance (EC x 10^6 at 25^oC), per cent sodium, and effective salinity. Partial mineral analyses include determinations of chlorides, bicarbonates, and electrical conductance. In some instances boron determination was included in the partial mineral analysis.

In general, the concentrations of principal constituents determined in a complete mineral analysis are expressed herein as "equivalents per million". Exceptions to this are boron, fluoride, and total dissolved solids. Reporting in equivalents per million was done because ions combine on an equivalent basis rather than on a weight basis, and a chemical equivalent unit of measurement provides a more convenient expression of concentration. This is particularly true when it is desired to compare the composition of waters having variable concentrations of mineral constituents. In the cases of boron, fluoride, and total dissolved solids, concentrations are reported on a weight basis of "parts per million". To convert equivalents per million, or "epm", to parts per million, or "ppm", the concentration in equivalents per million should be multiplied by the equivalent weight of the ion. Equivalent weights of the principal constituents found in water supplies are presented in the following tabulation:

Cation	Equivalent weight	Anion	Equivalent weight
Calcium	20.0	Carbonate	30.0
Magnesium	12.2	Bicarbonate	61.0
Sodium	23.0	Chloride	35.5
Potassium	39.0	Sulphate	48.0
		Nitrate	62.0

Data used to determine the quality of water in Ventura County included 273 complete and 156 partial mineral analyses of surface water, and 1,161 complete and 1,080 partial mineral analyses of ground water.

Standards of Quality for Water

The waters of Ventura County are used for irrigation, domestic, and municipal and industrial purposes. Suitability of the waters for each of these uses depends in part upon the amount and kind of dissolved minerals they contain. Water quality criteria and standards for the above named uses are discussed in the following paragraphs:

Irrigation Use. The major criteria used as a guide to judge the suitability of water for irrigation use usually comprise the following: (1) chloride concentration, (2) conductance (EC x 10^6 at 25°C), (3) boron concentration, and (4) per cent sodium.

(1) Chlorides are present in nearly all waters. They are not considered essential to plant growth, and may be especially harmful in high concentrations as they cause subnormal growing rates and burning of leaves.

(2) Conductance (EC x 10^6 at 25°C) is an indicator of the total

dissolved solids, and as such, furnishes an approximate indication of the overall mineral quality of the water. For most waters, the total dissolved solids may be approximated by multiplying the conductance by 0.7. The presence of excessive amounts of dissolved salts in irrigation water will result in reduced crop yields and burning of leaves.

(3) Boron in nature is never found in the uncombined or elemental state but occurs in the form of boric acid, or more commonly as borates. This element is essential in small amounts for the growth of many but not all plants. It is, however, extremely toxic to most plants in higher concentration. Limits of tolerance for most irrigated crops vary from 0.5 to 2.0 ppm. Citrus, particularly lemons, is sensitive to boron in concentrations exceeding 0.5 ppm.

(4) Per cent sodium reported in the analyses is the proportion of the sodium cation to the sum of all cations, and is usually obtained by dividing sodium by the sum of the amounts of calcium, magnesium, and sodium, all expressed in equivalents per million, and multiplying by 100. Water containing a high per cent sodium has an adverse effect upon the physical structure of the soil by dispersing the soil colloids and making the soil "tight", thus retarding movement of water through the soil, retarding the leaching of salts, and making the soil difficult to work. When potassium is present in water in significant amounts, its effect on soils is similar to sodium.

The following excerpts from a paper by Dr. L. D. Doneen, of the Division of Irrigation of the University of California at Davis, may assist in interpreting water analyses from the standpoint of their suitability for irrigation:

"Because of diverse climatological conditions, crops, and soils in California, it has not been possible to establish rigid limits for all conditions involved. Instead, irrigation waters are divided into three broad classes based upon work done at the University of California, and at the Rubidoux, and Regional Salinity Laboratories of the United States Department of Agriculture.

"Class 1. Excellent to Good--Regarded as safe and suitable for most plants under any condition of soil and climate.

"Class 2. Good to Injurious--Regarded as possibly harmful for certain crops under certain conditions of soil or climate, particularly in the higher ranges of this class.

"Class 3. Injurious to Unsatisfactory--Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

"Tentative standards for irrigation waters have taken into account four factors or constituents, as listed below:

Factor	Class 1 excellent to good	Class 2 good to injurious	Class 3 injurious to unsatisfactory
Conductance (EC x 10^6 at 25°C)	Less than 1,000	1,000-3,000	More than 3,000
Chloride, epm	Less than 5	5-10	More than 10
Per cent sodium	Less than 60	60-75	More than 75
Boron, ppm	Less than 0.5	0.5-2.0	More than 2.0

(End of quotation)

The values shown in the foregoing tabulation should be used as a guide only, since permissible limits vary widely with different crops, soils, and climatic conditions. Actual practice in Ventura County indicates that waters rated as class 2 and 3 by the foregoing standards particularly in regard to conductance, are successfully used to irrigate citrus. Accordingly, a new method of calculating salinity of irrigation water together with revised standards therefore has been suggested by Dr. Doneen as follows:

"This proposed standard for total salts of an irrigation water is based on the premise that the salts will accumulate in the soil due to evaporation from the soil surface and water used by the plants in transpiration. Plants usually remove only a small percentage of the total salts occurring in the irrigation water. As the soil solution becomes concentrated certain salts will precipitate. Because of the low solubility, the first to precipitate will be calcium carbonate, followed by magnesium carbonate and finally by calcium sulfate. These salts will not produce a saline soil. Other salts normally occurring in irrigation water in any significant concentration are extremely soluble and accumulate in the soil solution as salines. These salines are listed as 'effective salinity'. Therefore, calcium and magnesium carbonates and calcium sulfate should not be considered in establishing standards for total salinity as is now the practice in the use of electrical conductance, total parts per million or milliequivalents per liter concentration."

Using this method, Dr. Doneen has tentatively suggested the following criteria of effective salinity for classification of irrigation waters under three soil conditions:

Soil conditions	Class 1 excellent to good	Class 2 good to injurious	Class 3 injurious to unsatisfactory
	Effective salinity, in epm		
Little or no leaching of the soil may be expected	Less than 3	3-5	More than 5
Some leaching, but restricted. Deep percolation or drainage slow	Less than 5	5-10	More than 10
Open soils. Deep percolation of water easily accomplished	Less than 7	7-15	More than 15

Review of the soil survey of Ventura County made by the United States Department of Agriculture indicates that most of the irrigable lands in the County are classified as open soils. For this reason, criteria for soils of this condition will apply throughout this discussion unless otherwise stated.

Domestic and Municipal Use. Probably the most widely used criteria for determining the suitability of water for domestic and municipal use are the "United States Public Health Service Drinking Water Standards, 1946". The individual standards considered pertinent to the discussion presented hereinafter are shown on Table 17.

TABLE 17

UNITED STATES PUBLIC HEALTH SERVICE
DRINKING WATER STANDARDS
1946

Constituent	Should not exceed ppm
Total Solids	500 (1,000 permitted)[a]
Magnesium (Mg)	125
Chloride (Cl)	250
Sulphate (SO_4)	250
Zinc (Zn)	15
Fluoride (F)	1.5[b]

(a) Where alternate source of water unavailable.
(b) Limits for this constituent mandatory; for others recommended.

Total hardness is a significant factor in the determination of the suitability of a water for domestic and municipal use. It is caused principally by compounds of calcium and magnesium, although other substances such as iron, manganese, aluminum, barium, silica, strontium, and free hydrogen contribute to total hardness. The effect of hardness in water is primarily economic, in that its presence requires an increased use of soap, which it coagulates to form an insoluble precipitate. It also causes formation of scale which tends to reduce the efficiency of boilers and plumbing systems. With suitable treatment, however, hardness can readily be removed or reduced to acceptable limits. Water containing 100 ppm or less of hardness (as $CaCO_3$) are considered as "soft" herein; those containing 101 to 200 ppm are considered "moderately hard"; and those with more than 200 ppm are considered "very hard".

Industrial Use. The foregoing standards for domestic and municipal use are considered applicable for prevailing industries in Ventura County.

Quality of Surface Water

The mineral quality of surface water in Ventura County is extremely variable both areally and with the rate of stream flow. At times of low flow in many streams the water contains excessive mineral concentrations, particularly of boron and sulphate. Because of the variability in quality of surface water, each hydrologic unit is discussed separately herein. Representative analyses showing mineral quality of the waters in principal streams, and variations in quality with rate of flow, are presented in Table 18. The locations of surface sampling stations for which analyses are shown in Table 18 are delineated on Plate 7, entitled "Stream Gaging and Water Sampling Stations".

Ventura Hydrologic Unit. Waters of Matilija Creek, Coyote Creek, and the Ventura River above Foster Park, generally are of good quality and suitable for prevalent beneficial uses. Although at low flow stages in Matilija Creek the water contains boron concentrations as high as 6.5 ppm, water stored in Matilija Reservoir in May, 1952, showed only 0.34 ppm of boron. Below Foster Park, waters containing excessive concentrations of sulphates and boron are added to the Ventura River by tributaries, particularly by Canada Larga, even at relatively high rates of flow. As a result of these tributary inflows, water of Ventura River below Foster Park is generally considered unsuitable for domestic purposes, and of class 2 to class 3 for irrigation use.

Santa Clara River Hydrologic Unit. Water in the Santa Clara River in Ventura County is generally of good mineral quality for irrigation and other prevailing beneficial uses. However, it is seldom of excellent quality except during periods of relatively high flow. Effective salinity rarely exceeds 10 epm even during times of low flow. Mineral analyses indicate that water flowing in Santa Paula Creek is of good to excellent mineral quality even during low flow stages. Water of Sespe Creek is generally of good to excellent mineral quality for irrigation, and suitable for domestic use, for flows in excess of 60 second-feet near its mouth. For flows less than 60 second-feet, analyses indicated that water contains concentrations of boron varying from 0.7 to over 4 ppm, thus rendering it marginal to unsatisfactory for irrigation use. Mineral analyses indicate that water flowing in Hopper Creek is generally unsatisfactory for irrigation use, except during periods of flood flow. Like Sespe Creek, water flowing in Piru Creek contains high concentrations of boron at low flow stages. Based upon many analyses, it was concluded that flows must exceed 200 second-feet at the U.S.G.S. gaging station near the town of Piru before the boron concentration is reduced to values of 1.0 ppm or less. From the standpoint of its other mineral constituents, Piru Creek water is of good quality for irrigation purposes at all flow stages, although at low flow stages total solids and sulphate concentrations exceed the prescribed limits for domestic use. Waters of some of the minor tributaries of the Santa Clara River contain high concentrations of sulphate. However, their effect on the general mineral quality of the river water is considered to be negligible.

Calleguas-Conejo Hydrologic Unit. The mineral quality of surface water in this hydrologic unit varies considerably. It is generally unsuitable for irrigation or other prevailing beneficial uses during low flow stages, but during flood stages the quality is generally good. Typical examples of poor mineral quality in surface streams at low flow stages in this hydrologic unit are shown in analyses of waters from Arroyo Simi and Tapo Creek, which contained dissolved solids of 7,057 and 4,122 ppm, respectively.

Malibu Hydrologic Unit. There is a paucity of data concerning the mineral quality of surface water in the Malibu Hydrologic Unit. However, single available analyses for Big and Little Sycamore Creeks indicate that these waters are suitable for prevailing beneficial uses.

TABLE 18

SELECTED MINERAL ANALYSES OF SURFACE WATERS IN VENTURA COUNTY[A]

Stream and station number	Date of sample	Discharge, in second-feet	Conductance, (EC x 10^6 at 25°C)	Mineral constituents, in equivalents per million									Fluoride, in ppm	Boron, in ppm	Total dissolved solids, in ppm	Effective salinity in epm	Per cent sodium
				Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3					
Ventura Hydrologic Unit																	
Ventura River 42-0.7	2-25-53[B]	10[C]	2583	7.24	3.78	15.7	0.16	0	6.12	7.34	13.8	0	—	1.9	1619	19.6	59
Canada Larga 42-4.8-0.1	1-16-52[B]	300[C]	1618	9.38	5.66	6.09	0.26	0	3.72	14.55	1.92	0.30	0.1	0.4	1444	12.0	29
	8-1-52	0.5[C]	3062	8.21	13.19	18.40	0.28	0	5.36	29.20	5.94	0.09	—	1.2	2775	31.9	46
Coyote Creek 42-6.1-0.2	3-16-52	200[C]	452	2.70	1.25	0.65	——	0	2.49	1.71	0.51	0.01	—	0.1	272	1.9	14
	8-1-52[B]	3[C]	658	4.14	2.22	1.43	0.04	0	4.12	2.97	0.48	0.04	—	0.1	457	3.7	18
San Antonio Creek 42-8.1-0.2	3-15-52	Flood flow	302	1.97	0.93	0.30	----	0	1.68	1.34	0.20	0.08	—	0.2	226	1.2	9
	5-25-52	1[C]	1545	9.85	4.00	3.78	----	0	5.40	9.38	2.95	0.27	—	0.2	1195	7.8	21
Ventura River 42-10.6	5-27-52	3[C]	824	4.80	2.27	1.93	----	0	2.92	5.62	0.45	0	—	0.3	665	4.2	21
Matilija Creek 42-15.8-0.2	12-5-51	2[C]	1528	7.40	2.80	4.08	----	--	4.00	6.60	3.98	Tr.	—	2.6	924	6.9	29
	3-15-52	Flood flow	788	4.96	2.62	0.90	----	0.34	3.01	4.68	0.48	0.02	—	0.2	545	3.5	11
Santa Clara River Hydrologic Unit																	
Revolon Slough 44-2.1-1.7	1-14-53[B]	6[C]	7874	13.3	20.0	69.6	0.22	0	7.20	77.6	18.2	0.17	—	5.1	7109	89.8	68
Santa Clara River 43-4.6	8-5-52	0.5[C]	2700	12.93	7.85	14.15	0.26	0	4.44	27.20	2.91	0	—	0.6	1903	22.3	40
	1-14-53[B]	100[C]	1397	6.90	3.62	5.22	0.12	0	4.28	9.17	1.75	0.07	—	0.6	1022	9.0	33

TABLE 18 (CONTINUED)

SELECTED MINERAL ANALYSES OF SURFACE WATERS IN VENTURA COUNTY[A]

Stream and station number	Date of sample	Discharge, in second-feet	Conductance, (EC x 10^6 at 25°C)	Mineral constituents, in equivalents per million									Fluoride, in ppm	Boron, in ppm	Total dissolved solids, in ppm	Effective salinity in epm	Per cent sodium
				Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3					
Santa Paula Creek 43-15.9-0.8	1-12-53[B]	8[C]	840	4.50	1.89	2.52	0.04	0	3.56	4.21	0.90	0	---	0.1	564	4.4	38
43-15.9-4.5	3-15-52	1600[C]	402	2.62	0.77	0.68	----	0	1.85	1.98	0.25	0.01	---	0.3	282	1.4	17
Sespe Creek 43-22.3-5.4	3-30-46[D]	8000	---	1.80	0.66	0.26	----	0	1.77	0.83	0.14	0	---	0	---	0.9	10
	2- 7-51[E]	3.1	1350	5.64	2.30	5.91	0.07	0	3.44	5.95	4.51	0.01	---	4.1	848	8.3	42
Hopper Creek 43-29.7-1.0	3-15-52	4000[C]	517	4.36	1.13	0.37	----	0	1.72	3.96	0.23	0.01	---	0	411	1.5	6
	5-22-52	2.5[C]	2060	8.06	8.28	9.78	----	0	6.06	19.26	1.32	0.03	---	0.4	1850	18.1	38
Piru Creek 43-32.1-1.1	8- 4-52	5[C]	1610	6.63	5.56	6.27	0.15	0	4.34	12.60	1.70	0	---	1.6	1219	12.0	34
43-32.1-1.3	3-30-46[D]	1570	----	2.55	1.48	1.17	----	0	2.16	3.12	0.25	0	---	0.1	----	2.6	23
	11-21-46[D]	200	----	4.20	1.97	1.52	----	0	2.28	5.29	0.34	0.02	---	1.0	----	3.5	20
43-32.1-4.0	3-15-52	1000[C]	975	5.32	4.43	1.26	----	0	2.15	8.41	0.31	0.15	---	0.2	768	5.7	11
	2- 7-51[E]	5.0	1880	8.63	6.66	7.39	0.12	0	5.60	15.11	1.97	0.02	---	2.1	1420	14.2	32
Salt Creek 43-37.6-0.4	3-18-52[B]	5[C]	4854	22.8	37.8	20.8	0.35	0	5.92	73.1	1.69	0.24	---	0.7	5755	59.0	25
Santa Clara River 43-38.1	9-19-51[B]	0.7	3623	12.35	12.91	8.60	----	0	4.96	24.08	6.48	0.01	0.6	1.0	2960	21.5	25

TABLE 18 (CONTINUED)

SELECTED MINERAL ANALYSES OF SURFACE WATERS IN VENTURA COUNTY[A]

Stream and station number	Date of sample	Discharge, in second-feet	Conductance, (EC x 10^6 at 25^oC)	Mineral constituents, in equivalents per million: Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	Fluoride, in ppm	Boron, in ppm	Total dissolved solids, in ppm	Effective salinity in epm	Per cent sodium
Calleguas-Conejo Hydrologic Unit																	
Calleguas Creek 44-6.5	3- 7-52	2500	644	4.36	1.93	1.03	----	0	2.11	4.76	0.56	0.02	---	0.1	506	3.0	14
	3-15-52	130[C]	1313	9.54	3.48	2.25	----	0	3.23	11.40	0.90	0.07	---	0.3	1058	5.7	15
Conejo Creek 44-7.9-3.0	3-15-52	1500[C]	208	1.29	1.61	0.10	----	0	1.76	1.00	0.25	0	---	0	185	1.2	3
	12- 2-52	4[C]	243	0.98	0.67	0.84	0.03	0	1.64	0.30	0.39	0.18	---	0.2	214	0.9	33
Arroyo Simi 44-12.2-9.4-4.7	3-15-52	2000[C]	1649	15.51	3.83	1.22	----	0	2.45	17.32	0.65	0.04	---	0.3	1453	5.0	6
	4-16-52[B]	0.1	6757	33.88	30.58	40.20	0.64	0	8.00	71.09	23.12	0.24	---	4.1	7057	71.4	38
Tapo Creek 44-12.2-9.4-8.0-2.5	3-15-52	75[C]	2010	17.56	5.20	2.69	----	0	2.49	21.50	0.98	0.21	---	0.3	1809	7.9	11
	12-12-51	0.3	2730	25.60	6.20	3.48	----	-	2.82	29.73	2.06	0.08	1.0	0.8	4122	9.7	10

[A] Analysis by Pacific Chemical Consultants, unless otherwise noted.
[B] Analysis by division of Water Resources.
[C] Estimated.
[D] Analysis obtained from Santa Clara Water Conservation District.
[E] Analysis by U.S. Geological Survey, Water Quality Branch; unpublished records, subject to revision.

Quality of Ground Water

Mineral quality of waters in ground water basins of Ventura County is generally satisfactory for domestic, municipal, industrial, and irrigation uses. However, for domestic, municipal, and industrial uses, the ground waters are almost without exception rated as "very hard". In some areas the ground water contains concentrations of sulphates and dissolved solids which are considered excessive for domestic, municipal, and industrial uses, and in a few areas excessive boron concentrations and effective salinities render the ground water injurious or unsatisfactory for irrigation use.

In the investigation of water quality and water quality problems in Ventura County, more than 2,000 mineral analyses of ground water were studied. Table 19 shows representative analyses of ground water in each of the major ground water basins of the County, with exception of Lower Ventura River Basin. The locations of wells sampled and for which analyses are presented in Table 19 are shown on Plate 11, entitled "Ground Water Basins". Ground water quality in each of the hydrologic units is discussed separately in the ensuing paragraphs.

Ventura Hydrologic Unit. Ground water in Upper Ojai Basin contains total dissolved solids generally less than 700 ppm and effective salinities less than 6 epm. In the extreme easterly portion of the basin, toward Sisar Creek, there is a small area of poor quality ground water containing 2,000 to 3,000 ppm of dissolved solids, and boron concentrations up to 1.5 ppm.

In Ojai Basin, ground waters are generally suitable for irrigation, domestic, municipal, and industrial uses. Total dissolved solids range from about 450 to 1,100 ppm, and effective salinities are generally less than 6 epm. Comparison of mineral quality found in 1950-51 with quality reported in 1930-31 suggests an increase in total dissolved solids in ground water in Ojai Basin in the 20-year period. This increase indicates that an adverse salt balance existed during the 20-year period, but does not necessarily indicate that an adverse salt balance would exist over a period of mean water supply and climate.

In the Upper Ventura River Basin, the ground water contains dissolved solids generally less than 1,000 ppm and boron generally less than 0.5 ppm. Ground water in Lower Ventura River Basin, as previously described, is not presently utilized.

Santa Clara River Hydrologic Unit. Ground water found in the several basins in the Santa Clara River Hydrologic Unit does not exhibit a consistent pattern of water quality, varying considerably among the basins and within a given basin in accordance with the time of year, relative wetness of the season, and position of ground water levels. Higher concentrations of salts and boron are usually found in the ground waters during drought periods than during wet periods.

Ground water in Piru Basin contains total dissolved solids ranging from 800 to 3,400 ppm, with many waters exceeding 1,000 ppm. Effective salinities vary from about 6.7 to over 60 epm, although in most cases they are less than 12. Boron concentrations are generally high, exceeding 0.5 ppm in nearly all water samples analyzed, and approaching 1.0 ppm in ground water sampled near the mouth of Piru Creek. Some wells located in the extreme southerly portion of the alluvium in Piru Basin yield water with high concentrations of dissolved solids and boron, and with effective salinity unsuitable for irrigation uses. These poor quality ground waters may originate in the Tertiary formations which underlie and flank the alluvium in this area.

Ground water in Fillmore Basin is generally of class 1 to class 2 quality for irrigation use with dissolved solids averaging about 1,200 ppm and effective salinity ranging from 0.9 to 42.7 emp and averaging about 9.3 epm. Boron concentrations average about 0.7 ppm. In the northwesterly part of the basin, ground water quality is generally good, with total dissolved solids ranging from 500 to 600 ppm and with boron concentrations generally less than 0.5 ppm. Effective salinity averages less than about 5 epm. Ground water from wells in the southerly portion of the basin, in the vicinity of the Oak Ridge fault, is affected by poorer quality water emanating from tertiary formations on the south, and is generally unsuitable for irrigation use.

Ground water in Santa Paula Basin varies from class 1 to class 3 for irrigation use, with dissolved solids generally ranging from about 600 to 3,600 ppm, and effective salinity from about 4.5 to 18 emp, with a general average of the order of 12 epm. Marginal values of boron have been found in ground water throughout the basin, with concentrations varying from about 0.1 to 2.8 ppm.

Ground water pumped from the Mound Basin is of class 1 to class 2 quality for irrigation use. Some of the water is slightly in excess of the maximum standard for domestic use with regard to dissolved solids and sulphate content. Total dissolved solids generally range from about 700 to 1,300 ppm, and the effective salinity varies from about 7 to 11 epm. Boron concentrations are generally less than 0.5 ppm. As described previously, geologic investigation has indicated that the San Pedro formation, which is the principal pumped aquifer of Mound Basin, extends into the Ventura Hydrologic Unit and underlies Lower Ventura River Basin. This appears to be substantiated by a similarity between the character and quality of water derived from wells drilled in the vicinity of Ventura and ground water obtained in the remainder of the Mound Basin.

In Oxnard Forebay Basin, total dissolved solids in the ground water range from 840 to about 2,100 ppm, with the boron concentrations in the vicinity of 0.3 to 1.1 ppm. Effective salinity ranges from 7 to 15 epm.

The quality of ground water derived from the Oxnard aquifer of the Oxnard Plain Basin is comparable in mineral quality to ground water of the Mound Basin. Some of the water pumped from wells located near the Oxnard Forebay Basin shows dissolved salts higher than found in ground water from the remainder of the Oxnard Plain Basin. Water from certain wells in the vicinity of Port Hueneme has shown of recent times rapidly increasing chloride concentrations. The cause of this chloride degradation is believed to be sea water intrusion, as will be discussed in a later section. Water derived from the semi-perched ground water body of the Oxnard Plain Basin is of class 2 to class 3 quality for irrigation use and is generally unsuitable for domestic use. The dissolved solids content in the waters of the semi-perched ground water body is in excess of 1,650 ppm, while the effective salinity is greater than 11.5 epm and values exceeding 20 epm are not uncommon. Table 20 presents the results of analyses of ground water in the semi-perched ground water body in Oxnard Plain Basin, as obtained from samples taken at selected points in the drainage system in the area. The locations of the sampling stations are shown on Plate 7, entitled "Stream Gaging and Water Sampling Stations".

Ground water in Pleasant Valley Basin is derived from several aquifers of the San Pedro and Santa Barbara formations, from alluvium, and to a lesser extent, from fractured volcanic rocks along the east side of the basin. In the aquifers of the San Pedro and Santa Barbara formations, the waters are class 1 to class 2 for irrigation use with total dissolved solids in concentrations ranging from about 450 to about 1,500 ppm and boron content generally less than 0.5 ppm. While the character of the waters derived from these deposits is extremely variable, calcium is generally the most important cation. However, along the extreme easterly edge of the basin magnesium is the most prevalent cation, indicating the influence of inflow from Santa Rosa Basin and of water emanating from volcanic rocks which bound the basin on the east. Ground waters derived from the alluvium are usually of poor quality with total dissolved solids in concentrations generally in excess of 2,000 ppm and boron concentrations generally greater than 0.5 ppm. There are, however, isolated instances where waters of excellent quality are derived from the alluvial deposits.

Calleguas-Conejo Hydrologic Unit. Mineral quality of ground water in Simi Basin varies both areally and according to the geologic formation from which the water is drawn. Water pumped from the alluvium contains total dissolved solids varying from about 600 to 2,100 ppm, with boron concentrations ranging from 0.0 to 2.7 ppm. Effective salinities range from about 5 to 18 epm. Ground water in the eastern end of the basin is generally of better quality than ground water found in the western end. Water pumped from the Tertiary and Cretaceous formations varies from excellent mineral quality, with low concentrations of salts and boron, to marginal quality. Ground water derived from the Santa Barbara formation in Tapo Canyon within the Simi Hydrologic Subunit is low in dissolved salts and boron, and generally is of good quality for irrigation or domestic uses.

Ground waters in East and West Las Posas Basins are extracted from four principal aquifers, namely, Recent and Pleistocene alluvium, the Epworth gravels and Fox Canyon aquifer of the San Pedro formation, and the Grimes Canyon aquifer of the Santa Barbara formation. In general, ground water derived from the principal aquifers in the East and West Las Posas Basins contains concentrations of dissolved solids varying from about 200 ppm to 4,900 ppm, with boron concentrations ranging from 0.0 ppm to 2.4 ppm. Effective salinities vary from about 1.0 epm to in excess of 50 epm. Ground water found in the alluvium contains high concentrations of dissolved solids and boron and generally is considered unsatisfactory for irrigation and domestic use. Ground water found in the Fox Canyon aquifer is generally of excellent mineral quality with low boron concentrations and effective salinities. Ground water extracted from the Epworth gravels appears to be of excellent mineral quality. Analyses of ground water extracted from the Grimes Canyon aquifer indicate waters of class 1 to class 2 quality for irrigation use with effective salinities ranging from about 5.5 to over 8.5 epm.

Ground water in Conejo Basin obtained from the alluvium is generally marginal in quality, having dissolved solids ranging from about 1,200 ppm to 2,000 ppm. Wells drawing from volcanic rocks in this basin yield ground water with dissolved solids from about 350 ppm to about 1,100 ppm, averaging less than 650 ppm, and with generally low boron concentrations. This water is considered of good quality for both irrigation and domestic uses. Ground water obtained from the Miocene formations ranges from class 1 to class 3 for irrigation use, with total dissolved solids ranging from about 400 to 2,060 ppm and averaging 1,350 ppm. The boron content is low, with the maximum concentration for all available analyses being 0.2 ppm.

Ground water in Tierra Rejada Basin is considered suitable for prevailing beneficial uses, with total dissolved solids generally less than 600 ppm and boron concentrations ranging from 0.0 to 0.4 ppm. Effective salinities are generally less than 5 epm.

Ground water in Santa Rosa Basin varies in mineral quality in accordance with the location and formation from which it is extracted. In general, all formations presently utilized yield ground water suitable for prevailing beneficial uses. Dissolved solids are generally less than 700 ppm, with boron concentrations varying from 0.1 ppm to 0.6 ppm. Effective salinities range from about 3.5 epm to 8 epm.

TABLE 19

SELECTED MINERAL ANALYSES OF GROUND WATERS IN VENTURA COUNTY[A]

Basin and well number	Date sampled	Conductance, (EC x 10^6 at 25°C)	Mineral constituents, in equivalents per million									Fluoride, in ppm	Boron, in ppm	Total dissolved solids, in ppm	Effective salinity, in epm	Per cent sodium
			Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3					
Ventura Hydrologic Unit																
Upper Ojai																
4N/22W-10K2	8- 4-52[B]	883	4.78	1.72	3.04	0.01	0	6.22	1.90	1.46	0.04	0.5	0.1	612	3.3	32
Ojai																
4N/22W-5L1	5-17-33[C]	---	4.34	1.89	1.09	----	-	3.68	3.16	0.54	----	---	Tr.	---	3.0	15
	8- 1-52[B]	788	5.23	1.97	1.39	0.03	0	4.09	3.52	0.69	0.26	0.3	0.1	513	3.4	16
Upper Ventura River																
3N/23W-5H1	5-18-33[C]	---	7.43	3.21	2.66	----	-	5.06	6.70	1.52	----	---	0.5	---	5.9	20
	8- 1-52[B]	966	6.55	2.32	1.88	0.06	0	4.61	5.10	1.12	0.14	0.3	0.3	612	4.4	18
Santa Clara River Hydrologic Unit																
Piru																
4N/18W-19P1	11-25-24[C]	---	6.48	3.04	6.78	----	-	4.54	10.88	0.87	----	---	---	---	9.8	42
	1- 9-52[D]	1570	8.23	5.76	5.04	0.10	0	4.98	12.68	1.16	0.13	0.7	1.0	1190	10.9	26
Fillmore																
3N/20W- 6N1	10- 1-29[C]	1080	6.53	2.88	3.52	----	-	4.94	7.20	0.79	----	---	0.4	---	6.4	27
	9- 8-45[E]	----	6.90	3.63	3.43	0.02	0	4.54	7.87	1.21	0.09	---	0.6	962	6.8	25
4N/20W-23L1	8-26-52	685	3.75	1.55	1.82	0.04	0	4.32	1.41	0.90	0.34	1.0	0.1	443	2.8	26
Santa Paula																
3N/21W-11E2	5-11-29[F]	----	6.63	2.64	3.00	----	0	5.44	5.64	1.18	----	---	0.3	8796	5.6	24

TABLE 19 (CONTINUED)

SELECTED MINERAL ANALYSES OF GROUND WATERS IN VENTURA COUNTY[A]

Basin and well number	Date sampled	Conductance, (EC x 10^6 at 25°C)	Mineral constituents, in equivalents per million									Fluoride, in ppm	Boron, in ppm	Total dissolved solids, in ppm	Effective salinity, in epm	Per cent sodium
			Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3					
Mound																
2N/22W-17N2	4- 4-31[C]	1610	8.37	4.20	5.52	----	-	5.51	10.35	2.32	---	---	0.5	----	9.7	30
	9- 5-52	----	7.25	3.37	5.30	0.13	0	5.24	9.02	2.03	0.05	0.7	0.2	1060	8.8	34
2N/23W- 5P1	8- 1-52[BH]	1710	9.35	4.17	6.68	0.14	0	6.21	9.38	4.53	0.11	0.3	0.4	1354	11.0	33
Oxnard Forebay																
2N/22W-11A2	10-13-27[C]	----	7.68	3.70	5.30	----	-	5.29	10.30	1.58	---	---	---	----	9.0	32
	7-15-52[B]	1655	8.08	4.48	6.87	0.14	0	5.96	11.42	1.75	0.19	0.3	0.6	1251	11.5	35
Oxnard Plain																
1N/22W-18E1 (Oxnard)	4- 3-31[F]	1240	6.33	3.62	4.39	----	-	4.65	8.36	1.30	---	---	0.6	1004[G]	8.0	31
	9-30-52[F]	----	6.45	3.36	3.78	----	-	4.24	8.32	1.18	---	0.9	0.7	958[G]	7.1	28
1N/22W-1M1 (Oxnard)	2-21-34[E]	----	6.40	3.28	5.39	----	-	4.20	8.84	2.03	---	---	0.6	1044	8.6	36
	6- 6-52[B]	1131	6.17	3.24	4.13	----	0	4.20	8.04	1.06	0.08	1.3	0.4	940	7.4	30
Pleasant Valley																
2N/21W-25K2 (Fox Canyon)	5-18-46[E]	----	13.95	6.47	8.70	----	0	4.30	18.66	5.81	0.15	---	0.7	1926	15.2	30

TABLE 19 (CONTINUED)

SELECTED MINERAL ANALYSES OF GROUND WATERS IN VENTURA COUNTY[A]

Basin and well number	Date sampled	Conductance, (EC x 10^6 at 25°C)	Mineral constituents, in equivalents per million: Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	Fluoride, in ppm	Boron, in ppm	Total dissolved solids, in ppm	Effective salinity, in epm	Per cent sodium
Pleasant Valley 2N/21W-25K2 (Fox Canyon)	3-30-48[E]	----	6.20	2.62	3.78	---	0	3.97	5.69	2.31	0.44	---	0.3	867	6.4	30
	6-24-52[B]	1890	7.94	4.94	8.57	0.15	0	5.19	11.60	4.73	0.05	0.1	0.2	1492	13.7	40
1N/21W-11R1 (Alluvium)	6-25-52[B]	3160	13.59	10.56	12.38	---	0	6.76	18.12	11.51	0	0.2	0.8	2452	22.9	34
2N/20W-28A2 (Volcanics)	7-22-52[B]	1605	5.21	7.15	6.36	0.05	0	8.65	5.48	3.90	0.58	0.0	0.1	1097	10.1	34
Calleguas-Conejo Hydrologic Unit																
Simi																
2N/18W 8F6 (Alluvium)	10-19-51[B]	1920	13.00	8.40	9.14	----	-	5.28	20.70	4.43	0.03	0.8	1.2	2078	17.5	30
2N/18-12L7 (Alluvium)	10-18-51[B]	1275	6.08	2.92	3.17	----	-	5.13	5.08	2.14	0.08	---	Tr.	757	6.1	26
2N/18W-18F1 (Tertiary Formation)	7-29-52[B]	644	2.72	2.28	1.82	0.04	0	4.68	0.87	1.26	0.08	0.6	0.1	540	2.2	27
East and West Las Posas																
2N/19W-7C1 (Alluvium)	7-21-52[B]	2700	17.47	7.43	8.43	0.12	0	6.72	19.80	4.91	1.89	0.1	0.2	2286	16.0	26