Geology, Hydrology, and Chemical Character of Ground Waters in the Torrance-Santa Monica

Area, California
By J. F. POLAND, A. A. GARRETT, and ALLEN SINNOTT

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GEOLOGY, HYDROLOGY, AND CHEMICAL CHARACTER OF GROUND WATERS IN THE TORRANCE-SANTA

MONICA AREA, CALIFORNIA

By J. F. POLAND, A. A. GAKRETT, and ALLEN SINNOTT

ABSTRACT

The coastal plain in Los Angeles County, southern California, is divided into two distinct ground-water basins by the Newporfc-Inglewood uplift. On the northeast or inland side is the main coastal basin; on the southwest, bordering the Pacific Ocean and extending from Long Beach to Santa Monica, is the so-called west basin. The Torrance-Santa Monica area, as identified here, embraces the western part of the coastal plain and spans the entire west basin.
The west basin, which includes about 180 square miles, is an area of expanding population and of rapid industrial growth. Its water supply for domestic, indus-trial, and irrigation uses is obtained chiefly from wells. In the part of the west basin south of the Ballona escarpment the Torrance-Inglewood subarea of this report the draft on ground water has been excessive for many years; and local water levels, which were drawn down to about sea level by 1930, now are as much as 70 feet below sea level. Saline contamination has developed extensively along the coast, and the ground-water supply is threatened with ultimate deteriora-tion if the present draft is maintained.
This investigation, which covers the period from 1943 to 1947, was for the purpose of appraising the geologic conditions controlling the occurrence and circulation of ground water, the replenishment to the west basin, and the extent and sources of saline contamination and methods for its control.
The dominant geologic formations of the area are of Tertiary and Quaternary age. The Tertiary rocks, of Miocene and Pliocene age, are formed almost entirely of marine deposits and consist chiefly of shale, siltstone, and sandstone. Except in their uppermost part, they contain connate saline waters. The lower part of upper division of the Pico formation (the youngest rocks of Pliocene age) has several relatively permeable sand members which collectively average at least 200 feet in thickness. These sand members have not been tapped by water wells; however, they contain essentially fresh water and constitute a reserve supply. It would be expensive to develop this supply because the wells would have to be at least 1,500 feet deep and would require special construction to hold back the sand.
The Quaternary rocks, chiefly of Pleistocene age, contain almost all of the aquifers now tapped by water wells. Deposits of Recent age in the west basin occur only within the Dominguez and Ballona Gaps. The Pleistocene deposits, which underlie most of the Torrance-Santa Monica area, comprise three units which, in downward succession, are: (1) a capping terrace deposit and the Palos Verdes sand, which is composed of sand, silt, and gravel, commonly not more than 30 feet thick and, for the most part, above the water table; (2) the unnamed upper 1

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Pleistocene deposits consisting of silt, clay, sand, and gravel, which are as much as 400 feet thick and are of fluvial and marine origin; and (3) the San Pedro formation (composed of about half sand and gravel and half silt and clay) which is as much as 1,000 feet thick and mostly of marine origin within the west basin. The Silverado water-bearing zone and correlative aquifers in the San Pedro formation yield about 90 percent of the ground water pumped from the west basin. The thickness of this principal aquifer ranges from 50 to 700 feet; its extent within the west basin is about 120 square miles. From pumping tests its permeability has been determined as ranging from 1,000 to 2,000 gallons per day per square foot (gpd per sq ft).
The deposits of Recent age are the latest contributions to the alluvial fans of the Los Angeles and San Gabriel Rivers. They underlie the Downey plain and extend across the west basin as two tongues in Dominguez and Ballona Gaps. The upper division is fine sand and silt, but the lower division is highly permeable coarse sand and gravel, as much as 75 feet thick in Dominguez Gap.
The Newport-Inglewood uplift a regional anticlinal fold is ruptured by a series of faults, which form a discontinuous but substantial barrier to underflow from the main coastal basin to the west basin. These faults cut all rocks except those of Recent age.
Three distinct bodies of ground water occur in the area. In downward succes-sion these are: (1) a body of shallow unconfined and semiperched water of inferior quality under natural conditions, which extends to a few tens of feet below the land surface; (2) the principal body of fresh ground water, which occupies almost all the deposits of Recent and Pleistocene age and the upper part of the underlying Pliocene rocks (extending to depths as much as 2,500 feet below land surface in the west basin and 8,000 feet in the main coastal basin), which contains water of good quality; and (3) a body of saline connate water underlying the principal fresh-water body.
The principal body of fresh ground water underlies most of the Torrance-Santa Monica area and occurs beneath the greater part of the west basin. Except near Redondo Beach and north of El Segundo, where a water table exists, the aquifers of the principal water body are confined and separated from each other by substantial thicknesses of relatively impermeable silt or clay.
In the Torrance-Inglewood subarea (the part of the west basin south of the Ballona escarpment), withdrawals of ground water increased from nearly 10,000 acre-feet in 1904 to about 48,000 acre-feet per year in the thirties, and then rose to about 78,000 acre-feet in 1945, because of accelerated demands in the war years. In 1945 about half the withdrawal was used for industrial purposes.
As a result of this increase in draft, water levels noticeably declined in the early twenties and were drawn down to or below sea level throughout the subarea by 1930. A slow, irregular decline continued through 1941, when the decline was accelerated by the increased water demands of the war years. In 1946, local pressure levels in the Silverado water-bearing zone were as much as 70 feet below sea level near the inland boundary of the basin. Because of the impermeable confining beds and disproportionate draft, water levels in the several aquifers have been drawn down unequally. For example, in the Gardena area in 1946, the pressure level in the Silverado water-bearing zone was 50 feet below the semiperched water table, 20 feet below the pressure level of the "200-foot sand" and about 9 feet below that of the "400-foot gravel."
Under the early conditions of ground-water development, replenishment to the west basin occurred (1) by underflow across the Newport-Inglewood uplift,
(2) by direct infiltration of rainfall and return water from irrigation on the land surface, (3) by infiltration of local runoff, and (4) by seepage from the channel

ABSTRACT 3

of the Los Angeles River to the south and from Ballona Creek and its tributaries to the north. With the drawdown in water levels to and below sea level, water has been added to the basin in substantial quantity by landward encroachment of saline waters from the ocean and from the subsea extensions of the aquifers. Water also has been withdrawn from storage in the water-table reaches by com-paction of the water-bearing system in the confined reaches.
The replenishment to the Torrance-Inglewood subarea under native conditions is estimated to have been within the range of 30,000 to 40,000 acre-feet per year. From 1933 to 1941 the draft averaged 48,000 acre-feet per year. It is estimated that about 2,000 acre-feet per year was withdrawn from storage, about 12,000 acre-feet per year was contributed from the subsea extension of the aquifers or from the ocean, and nearly 34,000 acre-feet per year was contributed by net fresh-water replenishment from all sources.
The underflow across the Newport-Inglewood uplift varies with the differential in pressure head across the barrier faults. For the reach from the Baldwin Hills to Long Beach, the average differential is estimated to have decreased from about 40 feet in 1904 to 28 feet in 1941 and to have increased to about 36 feet in 1945 with the accelerated drawdown in the west basin. The underflow into the Torrance-Inglewood subarea in 1945 is estimated as from approximately 15,000 to 20,000 acre-feet, or about 85 percent as much as the underflow during 1904. By 1945 the underflow is believed to have constituted nearly one-half the fresh-water replenishment, and the probable excess of draft over net replenishment was at least 40,000 acre-feet in that year. A major part of this excess draft was replaced by invasion of ocean water.
In the west basin the native waters of good quality in the principal water body range in character from calcium bicarbonate to sodium bicarbonate, and their chloride content ranges from 25 to 90 ppm. For native inferior waters those in which dissolved solids are in excess of 600 ppm the chloride content is as great as 500 ppm.
The potential contaminants of the ground water in the west basin are ocean water, oil-field brines, and industrial wastes. The ocean water contains dissolved solids of about 34,000 ppm and chloride content of about 19,000 ppm. The oil-field brines are connate waters from the Tertiary rocks and range in dissolved solids about from 10,000 to 39,000 ppm. The ocean waters are in contact with the subsea extensions of the aquifers; the oil-field and industrial wastes have been discharged at the land surface and in stream channels.
In the twenties and early thirties, in response to the drawdown of the water level in the west basin, certain wells tapping the principal water body along the west coast between Santa Monica and Redondo Beach began to yield saline water. Contamination also developed near the Baldwin Hills and in Dominguez Gap about that time.
In general, the contaminated waters are not simple mixtures of the contaminant and native waters but have been so greatly modified that the nature of the con-taminant is very obscure. Such modification is caused chiefly by base exchange substitution of calcium and magnesium for sodium and by sulfate reduction. In the coastal part of Ballona Gap contamination started in the twenties and by 1931 extended beneath nearly 5,100 acres; by 1946 this contamination ex-tended to about 7,300 acres. Inland for about 1.6 miles (near Lincoln Boulevard) the contaminated waters contain more than 500 ppm of chloride. The con-taminant at this point is almost wholly ocean water. Contaminated waters extend about 3 miles inland in the Ballona Gap and range in chloride content from 100 to 500 ppm. The source of the contaminant is not definitely known, but the high sulfate content indicates that the shallow unconfined waters are a

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principal source. Adjacent to the west and north flanks of the Baldwin Hills, oil-field wastes have contaminated two areas. The contamination on the west flank is increasing but on the north flank it has receded since the thirties. Along the 11-mile coastal reach, from the Ballona escarpment (Playa del Rey) to the Palos Verdes Hills, salt water has invaded the main water-bearing zones. Contamination was first noted at Hermosa Beach about 1915 and at El Segundo in 1921. By 1931 the coastal area underlain by contaminated waters amounted to almost 5,000 acres, and the greatest inland extent was about 1.3 miles, at El Segundo. By 1946 the contaminated area had increased by about 1,700 acres. In the last 14 years the greatest advance of the front was between El Segundo and Manhattan Beach and was as much as 0.5 mile. In the reach from the Palos Verdes Hills to Hermosa Beach the average rate of advance of the front was about 90 feet per year from 1931 to 1941, and it had increased to about 140 feet per year by 1946. From Hermosa Beach to El Segundo the average rate of ad-vance in the thirties was about 115 feet a year, but it was as much as 300 to 400 feet per year by 1946. The chief source of contamination along the west coast is ocean water. Near El Segundo, part of the early contamination seems to have developed from locally discharged high-sulfate waters.
In Dominguez Gap the Gaspur water-bearing zone, of Recent age, is extensively contaminated in two principal areas. Along the coast and inland, as far as the Pacific Coast Highway (State Street), this zone is highly contaminated with ocean water. Inland from this highway to Carson Street, about 3 miles, the Gaspur zone is contaminated by waste brines from the Long Beach oil field. The Silverado water-bearing zone, which underlies the Gaspur zone but is sepa-rated from it by relatively impervious deposits several hundred feet thick, is uncontaminated as of 1947; however, it can become contaminated by downward movement of saline water through abandoned wells unless these wells are properly sealed. The contamination in the Gaspur water-bearing zone is not moving inland; it is moving slowly westward into the upper Pleistocene deposits, and ulti-mately will reach the Silverado water-bearing zone if the present water-level differentials of as much as 70 feet are maintained.
The continued inland advance of ocean water into the west basin, especially from the west coast, would result in ultimate destruction of the supply of fresh water. The water rights in the Torrance-Inglewood subarea now are being adjudicated because it is recognized that the water supply is being excessively depleted and is being replaced by salt water. In most ground-water basins bordering on the ocean, the most effective long-term program for restraining or driving back saline waters depends upon raising water levels throughout the basin to such a height that fresh-water levels at the saline front will displace salt water seaward. Such raising of water levels ordinarily does not greatly affect replenishment procedures.
However, in the Torrance-Inglewood subarea almost half the current replenish-ment is derived by underflow across the barrier features. If the restraint of ocean water should be achieved by raising water levels above sea level throughout the basin, and if water levels inland should remain at sea level, underflow across the Newport-Inglewood barrier would cease and half of the replenishment would be lost. Therefore, it seems that the amount of the natural fresh-water yield from the basin will remain substantial only if the salt water can be restrained by local control near the coast and water levels immediately coastward from the barrier can be held low enough to induce continued underflow across the barrier. Only three physical possibilities seem capable of such local control of saline waters: (1) the construction of artificial subsurface dikes or cut-off walls; (2) the development, by pumping, of a water-level trough coastward from the saline

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front; and (3) the maintenance of fresh-water head above sea level at and immedi-ately inland from the saline front. Only the maintenance of fresh-water head is considered to be an economic possibility. The fresh-water head required along the west coast would range from 3 to 13 feet above sea level. It could be attained only by artificial recharge through wells, trenches, or pits.

INTRODUCTION

LOCATION AND GENERAL FEATURES OF THE AREA

The Torrance-Santa Monica area, as identified in this report, embraces the western part of the coastal plain in Los Angeles County, in southern California. Its location is shown by figure 1 and some

Son Francisco

FIGUEB 1. Map of California showing area covered by this report and that covered by plate 1. 460508 59 2

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of its general features are shown by plate 1. It is bounded on the north by the Santa Monica Mountains, on the south by the Palos Verdes Hills, and on the west by the Pacific Ocean. It encompasses about 280 square miles, spans the entire west basin of Eckis (1934, p. 198) and extends inland beyond the axis of the Newport-Inglewood uplift. This uplift, which extends about 40 miles southeastward from Beverly Hills to Newport Beach (pi. 1), divides the coastal plain of Los Angeles County into two distinct ground-water basins. On the northeast or inland side is the main or "central" coastal basin, which includes about 500 square miles in Los Angeles and Orange Counties. As of 1948 about one-third of a million acre-feet of ground water is pumped annually to supply municipalities, diversified industries, and extensive agricultural developments from the central basin.
The ground-water basin on the southwest or coastal side of the uplift extends from Santa Monica to Long Beach and is flanked on the southwest by the Palos Verdes Hills and the Pacific Ocean. It was designated the west basin by Eckis, but in recent references by the California Division of Water Resources it has been called the west coast basin. The shorter term by Eckis is used in this report. The approximate dimensions of the west basin are 25 miles long, 7 miles wide, and 180 square miles in area. It is an area of expand-ing population and of rapid industrial growth. Two-fifths of the 180 square miles consists of a residential development with a popu-lation of at least 300,000. Irrigated farmland covers about one-fifth of the area. The city of Santa Monica is supplied with water from the Metropolitan Water District, but the water supply for domestic, industrial, and irrigation uses is obtained almost entirely from wells. In the part of the west basin south of the Ballona escarpment the draft on ground water has been excessive for many years, and local water levels, which nearly reached sea level by 1930, now (1948) are as low as 70 feet below sea level. As a result, saline contamination has developed in three areas along the coast and the ground-water supply of most of the basin is threatened with ultimate deterioration if the present draft is maintained or increased.

SCOPE OF THE INVESTIGATION AND OF THIS REPORT

Because of the critical ground-water situation in the west basin, in July 1943 an agreement for a cooperative ground-water investi-gation was made between the U. S. Geological Survey and the Los Angeles County Flood Control District. In addition to its own interest, the District also represented the joint interests of nine cities intimately concerned with the preservation of the ground-water sup-plies the cities of Inglewood, Redondo Beach, Manhattan Beach, El Segundo, Hawthorne, Culver City, Gardena, Hermosa Beach, and

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Palos Verdes Estates. All these communities obtain water wholly or partly from well fields in the west basin; several of these well fields have been affected or are threatened by saline encroachment espe-cially the wells that supply Redondo Beach, Hermosa Beach, Man-hattan Beach, and El Segundo.
The cooperative investigation of the west basin area was under-taken to appraise: (1) the geologic conditions which control the occurrence and circulation of ground water; (2) the replenishment to the west basin; and (3) the chemical character of the ground water with special reference to saline contamination.
The investigation, which began in October 1943, was under the general direction of O. E. Meinzer, chief geologist. Upon his retire-ment, A. N. Sayre served in that capacity. Until mid-1946 the proj-ect was under the supervision of district geologist A. M. Piper. A. A. Garrett and Alien Sinnott, of the field office at Long Beach, did most of the field operations under the supervision of J. F. Poland, district geologist. Garrett made the partial chemical analyses of well waters. This report is under the combined authorship of Poland, Garrett and Sinnott; the section treating the geology is largely the work of Sinnott and the section on chemical character is chiefly the work of Garrett. The hydrologic interpretations and text were prepared by Poland. The Geological Survey has made an intensive study of ground-water features in the coastal zone of 240 square miles that extends from Long Beach to Santa Monica, spans all the west basin, and extends inland for about 3 miles beyond the axis of the Newport-Inglewood uplift. The Survey also made a general study of selected ground-water features in a contiguous inland zone of 40 square miles that extends to the western boundary of the Long Beach-Santa Ana area. These two zones comprise the Torrance-Santa Monica area; the boundaries of this area and those of the Long Beach-Santa Ana area are shown on plate 1. It will be noted on plate 1 that the area imme-diately west of Long Beach (50 square miles comprising Dominguez Gap and vicinity) is common to both areas. Although the ground-water features of Dominguez Gap and vicinity were studied in the earlier investigation, the area lies within the scope of this report and is the area of the most intensive ground-water draft within the west basin.
The Geological Survey has released two reports on its work in the Torrance-Santa Monica area. A progress report (Poland, Garrett, and Sinnott, 1944) was prepared after the first year of work to outline the general ground-water conditions and to indicate the current extent of saline contamination in the critical area from Redondo Beach to El Segundo. In 1946 a factual well index was issued (Sinnott and Garrett, 1946), which for the canvassed extent of the coastal zone pre-

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sents brief tabulated descriptions of nearly all of the active or poten-tially active water wells and of those abandoned wells for which data are available (incorporated in this report as table 26). This index also summarizes the sources and scope of the available well records, chemi-cal analyses of water from wells, measurements of depth to water, and logs of wells. Wells were not canvassed bj> the Geological Survey in 62 square miles of the Torrance-Santa Monica area; however, a brief tabulated record of pertinent well data was prepared from records supplied by the California Division of Water Resources, the Los Angeles County Flood Control District, the Los Angeles Department of Water and Power, and other agencies (table 27).
The present report gives the findings and conclusions relating to the geology, hydrology, and chemical character of the ground waters in and adjacent to the west basin. Because ground-water conditions are most critical in the part of the west basin that is south of the Ballona Gap, the report treats that area in greater detail. This report was first released to the public in 1948, in duplicated form. Publication has been delayed in part by the decision to wait until the revised topographic sheets of the area became available for the base map. The last of these was supplied in 1953.
From 1940 to 1946 the Geological Survey made an intensive investi-gation of ground-water conditions within the southern part of the coastal plain from Dominguez Hill southeast to Newport Beach with special reference to saline contamination and the effectiveness of the barrier features of the Newport-Inglewood uplift to restrain inland movement of ocean water. The are i of study embraced almost all the coastal plain east of Vermont Avenue and was called the Long Beach-Santa Ana area. From that investigation four interpretive reports had been released to the public in duplicated form by 1946. 1 These reports are being published in three water-supply papers (Piper, Garrett, and others, 1953; Poland, Piper, and others, 1956; Poland, 1959). Because the Long Beach-Santa Ana area is adjacent to and, in T. 4 S., R. 13 W., overlaps the Torrance-Santa Monica area, they have many features in common. Thus, in this report, frequent reference is made to matters treated in the reports on the Long Beach-Santa Ana area.

1 Poland, J. F., Piper, A. M., and others, 1945, Geologic features in the coastal zone of the Long Beach-Santa Ana area, California, with particular respect to ground-water conditions: U. S. Geol. Survey dupli-cated report, 527 p. Poland, J. F., Sinnott, Alien, and others, 1945, Withdrawals of ground water from the Long Beach-Santa Ana area, California, 1932-41: U. S. Geol. Survey duplicated report, 112 p. Piper, A. M., Garrett, A. A., and others, 1946, Chemical character of native and contaminated ground waters in the Long Beach-Santa Ana area, California: U. S. Geol. Survey duplicated report, 356 p. Poland, J. F., and others, 1946, Hydrology of the Long Beach-Santa Ana area, California, with special reference to the water-tightness of the Newport-Inglewood structural zone: U. S. Geol. Survey duplicated report, 198 p.

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OTHER INVESTIGATIONS

The first investigation of the ground waters within the western part of the coastal plain was made by Mendenhall (1905a, 1905b) in 1903-4. At that time about 2,500 active wells within the extent of the Torrance-Santa Monica area were visited, and readings were made of depth to water, and of chemical quality as measured by electrical resistance. From 1904 to 1926 the Geological Survey continued periodic measurements of depth to water on a few selected wells. Of these, 26 were within the Torrance-Santa Monica area, but measurements for all but 3 wells were discontinued prior to 1926. Their records through 1920 have been published by the Geological Survey (Ebert, 1921, p. 13-29).
From the middle twenties to 1941 the Los Angeles Department of Water and Power made periodic measurements of depth to water in many wells within the part of the coastal plain in Los Angeles County. Of these, several hundred were within the Torrance-Santa Monica area. No interpretive reports have been published by that agency as a result of this program but the measurements have been made available for use in the preparation of this report.
Since 1929 the Los Angeles County Flood Control District has been collecting a large mass of basic data, chiefly in the form of water-level measurements, chemical analyses from wells and streams, and well logs. In its series of annual reports, that agency has published semi-annual water-level contour maps and selected hydrographs. Also, it has prepared brief reports or summary statements treating the problems of saline contamination along the coast of Los Angeles County within the west basin. The earliest of these reports is believed to be one prepared by Donald Seal (1931), in which the author pointed out the presence of saline contamination along the coast and the danger of its expansion inland. The saline encroach-ment was treated more fully by Dockweiler (1932) in a report on the so-called Nigger Slough project for flood control and conservation. The report included a plan for artificial recharge of the ground water by injection through wells. In 1935 the Flood Control District began a study of saline contamination in Ballona Gap, in connection with the construction of the new Ballona Creek flood control channel. The results of the study were issued in several progress reports and summarized in a final report by Koch (1940).
Since the late twenties the California Division of Water Resources has acted as a collecting agency and its Los Angeles office has been a depository for factual information relating to ground-water supplies, especially measurements of depth to water, chemical analyses, and well logs. Some of the measurements and chemical analyses have been made by its own staff but most of the work was done by other

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agencies, although the data were assembled by the Division. For many years the Division has been investigating the water supplies available to the ground-water basins of the Los Angeles area and it has issued several factual and interpretive reports relating in part to the west basin area (Gleason, 1932; Scofield, 1933; Eckis, 1934). In 1944 the California Division of Water Resources issued a brief state-ment on ground-water conditions in the west basin.
Since 1929, the water department of the city of Long Beach has made periodic measurements of depth to water in about a dozen wells in Dominguez Gap. Also in 1932 the water department began making periodic determinations of the chloride content of water samples usually taken once a month from 40 to 50 wells in Dominguez Gap. The measurements and analyses have been continued to date.
In connection with an appraisal of water supply and use of ground water in southern California, the Metropolitan Water District has prepared two reports concerned with ground water conditions in the southern part of the west basin (Vail, 1932; 1942).
After the cooperative investigation in the west basin was started by the Geological Survey, and partly as a result of the findings in the Survey's progress report of 1944, water users in the part of the west basin south of Ballona Gap organized a "West Basin Ground Water Conservation Group" to investigate and report on the problems con-fronting water producers and users in the area. A Ways and Means Committee of that group, appointed in March 1945, published its findings in September 1945 (Anon., September 1945).
The findings and conclusions of the Ways and Means Committee report led to the organization of the West Basin Water Association late in 1945, a nonprofit organization comprised of many of the water users in the parent group. The Water Association has released a report by Harold Conkling (1946), which appraised the possibilities of the importation of water.
Knowledge concerning the saline encroachment and the increasing overdraft upon the ground-water supplies had been widely dissem-inated by mid-1945, and in October of that year legal action was brought by three water users in the west basin for the purpose of seeking adjudication of the rights of each producer of ground water in the part of the basin south of Ballona Gap. In July 1946 the California Division of Water Resources was appointed as referee to investigate and report on physical facts pertinent to the action (Gleason, 1946). (See p. 262.)

ACKNOWLEDGMENTS

The U. S. Geological Survey has made extensive use of the data and reports summarized in the preceding section of this report. The

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basic data collected by the Los Angeles County Flood Control Dis-trict, the California Division of Water Resources, and the Los Angeles Department of Water and Power have been of immeasurable value in this investigation. Acknowledgment also is made of valuable data supplied by the cities of El Segundo, Hawthorne, Inglewood, Long Beach, and Manhattan Beach; by the Southern California Water Co., the California Water Service Co., and the Dominguez Water Corp.; by the many industrial plants that produce water from the west basin, especially the Standard Oil Co. at El Segundo for the many chemical analyses and the results of its test-pumping operations on a well tapping the upper division of the Pico formation; and the Union Oil Co. for its cooperation in making a pumping test to determine ground-water conditions in the vicinity of Bixby Slough; also, by many other agencies and individuals that cooperated fully in making their data available.
Substantial contributions on geological data appearing in this report have been made by several oil companies, especially the Stand-ard Oil Co. of California for making available an unpublished map of the surface geology of the Baldwin Hills, by G. B. Moody. With reference to stratigraphic problems, special acknowledgment for microfaunal information is due S. G. Wissler of the Union Oil Co, and M. L. Natland of the Richfield Oil Corp. Sample suites from water wells were obtained through the cooperation of the Roscoe Moss Co. by Paul Karnes and Mr. Bromwell, drillers; and also through the city of Long Beach. Cores from several wells were received from the Kalco Drilling Co. through C. C. Killingsworth; M. R. Peck furnished several logs.
Electric logs of oil wells, supplied through the courtesy of many oil companies, were utilized in correlating the deeper fresh-water zones and in determining the depth to the body of saline connate water that underlies the fresh-water body throughout the area.

NUMBERS APPLIED TO WELLS BY THE GEOLOGICAL SURVEY

In its cooperative programs on the coastal plain and elsewhere in California, the Geological Survey has designated wells by numbers that indicate the respective locations according to rectangular land surveys. For example, for well 3/14-36M3, the first part of the Geological Survey number indicates the township and range (T. 3 S., R. 14 W., San Bernardino base line and meridian), the two digits following the hyphen indicate the section (sec. 36), and the letter indicates the 40-acre subdivision of the section as shown on the accompanying diagram.

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D

E

M

N

C

F

L

P

B

G

K

Q

A

H

J

R

Within each 40-acre tract the wells are numbered serially as indi-cated by the final digit or digits of the number. Thus, well 36M3 is in the NW#SW# sec. 36 and is the third well in that tract to be listed. In the parts of the area that once were public land, the official Federal land survey is followed. Elsewhere the net is projected, but most of the land has been subdivided according to extensions of the Federal Survey so that the system can be applied readily.
This system of numbers has also been used as a convenient means of locating a feature described in the text. Thus, an area or feature within the NWtfNWtf sec. 7, T. 3 S., R. 14 W. (projected land lines), may be identified as 3/14-7D.

SUBDIVISIONS OF THE WEST BASIN WITH RESPECT TO GROUND WATER

For purposes of this report, the west basin is divided into two parts. The area extending from the Ballona escarpment (pi. 8) southeast to the Los Angeles River flood-control channel west of Long Beach forms a hydrologic unit that is believed to be essentially un-broken by barrier faults except those which bound the basin. This area, which includes some 135 square miles, or about three-quarters of the west basin, is identified in this report as the Torrance-Inglewood subarea. It is the area of the most intensive regional lowering of water level and, as late as 1945, it yielded more than 80 percent of the water withdrawn from the west basin. Also, this is the area involved in the pending suit for adjudication of water rights.
The area extending from the Ballona escarpment north to the Santa Monica Mountains, and including the Ballona Gap, is traversed by several faults which interrupt hydraulic continuity in the Pleistocene water-bearing deposits and produce conditions of localized ground-water movement. This area, about 45 square miles in extent, is identified in this report as the Culver City subarea.

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CLIMATE

The climate of the Torrance-Santa Monica area is mild and is

characterized by a wet and a dry season. The average annual rainfall is 12 to 16 inches throughout the area. About 95 percent of the rain-fall occurs in the 7 months from October through April, principally from storms originating in the north Pacific area and moving inland from the ocean; at times, however, rain develops from storms moving northwestward from the Caribbean area and across Mexico.

The prevailing winds are from the west and northwest and carry moisture over the land from the Pacific Ocean. These winds quickly lose much of their moisture as they pass eastward across the land. Within the west basin, however, their moisture content is sufficient to substantially reduce the requirements for irrigated crops below those of the ulterior valleys.
The mean annual temperature at Santa Monica, on the coast, is about 60°F; the temperature ranges from 53° in January to 66° in August. The hottest and driest periods occur when infrequent winds sweep coastward from the interior deserts. Table 1 gives monthly and yearly averages of temperature and precipitation for Long Beach and Santa Monica at opposite ends of the area, and for Los Angeles, at the inland margin. In a recent publication, Gleason (1947, pi. 21) has included a map showing lines of equal precipitation (mean for the 53-year period) for the entire south coastal basin. The distribution and magnitude of average yearly rainfall in the west basin and the increase in rainfall inland to the San Gabriel Mountains are well

shown on that map.

TABLE 1. Monthly and yearly averages of temperature and precipitation at three climatological stations in or adjacent to the Torrance-Santa Monica area in the period ending 1946
[From publications of TJ. S. Weather Bureau]

January. _________

March _____________
April. ._-.

May. ______________

July..........................

Annual

Long Beach

Tempera-
ture (°F)
1926-46

63.7
55.4
57.6
59.9

63.1
65.9
70.2
70.6

68.5
64.4
60.2
56.1

62.1

Precipita-
tion

(inches)
1920-46

2.18
2.90
1.51
.88

.31
.08

.04

.30
.55
.71
2.74

12.20

Los Angeles

Tempera-
ture (°F)
1876-1946

54.6
55.5
57.5
59.4

62.2
66.4
70.2
71.1

69.0
65.3
60.9
66.6

62.4

Precipita-
tion

(inches)
1876-1946

3.10
3.07
2.78
1.04

.46
.08
.01
.02

. 17
.68
1.20
2.63

15.23

Santa Monica

Tempera-
ture (°F)
1889-1922

52.8
53.1
55.4
57.8

60.0
63.2
65.9
66.4

64.8
62.0
68.3
64.6

59.5

Precipita-
tion

(inches)
1884-1922

3.51
2.95
2.85
.52

.46
.02
IT.
.03

. 14
.61
1.37
2.32

14.78

»T=0.005 inch or less of rain or melted snow.

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In another report (Poland, 1959), rainfall records were tabulated for Los Angeles from 1877 to 1945, and for Long Beach from 1921 to 1945; those for Los Angeles were plotted to show cumulative departure from the yearly mean. Because the rainfall at Los Angeles has been observed since 1877 and furnishes much the longest record for any station in the vicinity of the Torrance-Santa Monica area, it is presented again in table 2. Yearly and cumulated departure from the 68-year average from 1877 to 1945 (years ending June 30) also are shown by the table.

TABLE 2. Rainfall at Los Angeles, in inches, in the years ending June 30. 1877-1946; also surplus or deficiency ( ) with respect to the 68-year average of 1877-1945 i

[From publications of U. S. Weather Bureau]

Year

1877-78............
1878-79.............
1879-80.. ....

1880-81 _______
1881-82
1882-83
1883-84
1884-85

1885-86.. ...
1886-87 _ . ...
1887-88 ....
1888-89... ..
1889-90

1890-91.. _ ....
1891-92....... .
1892-93 ..
1893-94
1894-95

1895-96... .
1896-97
1897-98.. .
1898-99
1899-1900

1900-1
1901-2
1902-3
1903-4... ....
1904-5

1905-6
1906-7 ....
1907-8.. .
1908-9 _ ....
1909-10...... . ...
1910-11. ......
1911-12...... ....

Rainfall

21.26
11.35
20.34

13.13
10.40
12.11
38.18

22.31
14.05
13.87
19.28
34.84

13.36
11.85
26.28
6.73
16.11

8.51
16.86
7.06
5.59
7.91

16.29
10.60
19.32
8.72
19.52

18.65
19.30
11 72
19.18
12.63
16.18
11.60

Surplus
or defi-

ciency

5.73
-4.18
4.81

- 2.40
- 5.13

22.65
-6.32

6.78
- 1.48
- 1.66
3.75
19.31

-2.17
-3.68
10.75
-8.80
.58

- 7.02
1 00

-8.47
, _ g g^.
- 7.62

.76
-4.95
3.79
-6.81
3.99

3.12
3.77
-3.81
3.65
-2.90
0.65
_ q no

Cumu-
lated

surplus
or defi-
ciency

5.73

6.36

3.96
- 1.17
_ A KG

18.06
11.74

18.52

1 c qo
19.13
38.44

36.27
32.59
43.34
34.54
35.12

28.10
90 4.°.

20.96
11.02
3.40

4.16 -.77
3.02
3 79
.20

3

00

3

0Q

4.03
4 68
7C

Year

1912-13. . ..
1913-14
1914-15

1915-16...
1916-17
1917-18
1918-19
1919-20

1920-21 __ -

1 Q99 9°.
1923-24
1924-25-

1925-26
1926-27
1927-28
1928-29
1929-30

1930-31 ...
1 Q01 00

1933-34
1934-35

1936-37 ..
1937-38 ...
1 Q9.SZ °.Q

1939-40.. _. .._,

1940-41
1Q41 4.9
1942-43
ICUOyM
1044 4^

1Qd.eJ.fi

Rainfall

13.42
23.65
17.05

19.92
15.26
13.86
8.58
12.52

13.65
19.66
9.59
6.67
7.94

17.56
17.76
9.77
12.66
11.52

12.53
16.95
11.88
14.55
21.66

12.07
22.41
23.43
13.07
19.21

32.76
11.18
18.17
19.22
11.59

11.65

Surplus
or defi-
ciency

-2.11
8.12
1.52

4.39 -.27
- 1.67
-6.95
-3.01

- 1.88
4.13
- 5.94
-8.86
- 7.59

2.03
2.23
- 5.76
-2.87
-4.01

- 3.00
1.42

3.65 -.98
6.13

- 3.46
6.88
7.90
- 2.46
3.68

17.23
-4.35
2.64
3.69
-3.94

- 3.88

Cumu-
lated

surplus
or defi-

ciency

- 1.36

8.28

12.67
12.40
10.73
3.78
.77

- 1.11
3.02
- 2.92
- 11.78
- 19.37

- 17.34
- 15. 11
-20. 87
-23. 74
-27. 75

- 30. 75
-29. 33
- 32. 98
- 33. 96
-27.83

-31. 29
-24. 41
- 16. 51
18. 97
- 15. 29

1.94
-2.41
.23

3.92 -.02

- 3.90

' Average for 68 seasons, to 1945,15.53 inches.

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PHYSIO GRAPH Y

GENERAL FEATURES

Most of the major landform features of the coastal plain in Los Angeles and Orange Counties were formed by deformational earth movements during late Pleistocene time. (See table 3 for geologic time classification.) This deformation affected rocks now forming the most important aquifers in the area. Younger aquifers of lesser economic importance were formed by later alluviation in erosional trenches or gaps transecting these deformed older rocks. Thus, a brief discussion of the landforms is pertinent with respect to both the geologic and hydrologic conditions in the area. For a more complete discussion of these landforms, the reader is referred to a previous report in which the physiography of the entire coastal-plain area in Los Angeles and Orange Counties has been treated in detail (Poland, Piper, and others, 1956, p. 11-36, pis. 1-2).
The coastal plain, which includes the Torrance-Santa Monica area in its western part, is in the Angeles section of the Pacific border prov-ince (Fenneman, 1931, p. 493). It is bordered by the Pacific Ocean on the west and south and by the Santa Monica Mountains, the Puente Hills, and the Santa Ana Mountains and their foothills on the north and east (pi. 1).
The dominant landform features of the coastal plain are a central lowland plain with six tongues extending to the coast, bordering high-lands and their foothills, and a succession of low hills trending north-westward which separate the main lowland plain and a lesser plain to the southwest. The succession of low hills is the land-surface ex-pression of the Newport-Inglewood uplift the inland margin of the west basin.

The Torrance-Santa Monica area includes the western part of the main lowland plain and two tongues of this plain which extend to the coast across the Newport-Inglewood uplift. Between these two tongues or gaps and coastward from the uplift is a low plain of marine origin, the Torrance plain, which is flanked on the west by a belt of dune sand fringing the coast. To the north and south are bordering highland areas, the Santa Monica Mountains and the Palos Verdes Hills, respectively.
Excepting the bordering highlands, the total relief in the Torrance-Santa Monica area is about 500 feet from a high point of 513 feet above sea level at the summit of the Baldwin Hills to sea level at Ballona Lagoon, 5 miles distant in the northwestern sector of the area. The location and extent of the landforms within the western part of the coastal plain are generalized on plate 8; details of their form are shown on the Geological Survey topographic maps of the area.

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BORDERING HIGHLANDS AND ALLUVIAL APRONS

The highland areas that border the Torrance-Santa Monica area are the eastern part of the Santa Monica Mountains on the north,, and the Palos Verdes Hills on the south.
The altitudes of the ridge crests in the eastern part of the Santa. Monica Mountains reach a maximum of nearly 1,800 feet about 3 miles north of the project boundary. The highest point in the Paloa Verdes Hills is 1,480 feet at San Pedro Hill; below this, 13 wave-cut terraces at altitudes of about 100 to 1,300 feet (Woodring, Bramlette, and Kew, 1946, p. 113-116) represent successive pauses during a long^ period of uplift, which mostly occurred in late Pleistocene time. The lowest terrace is strongly deformed and rises from about 50 feet above sea level in San Pedro to about 400 feet on the north edge of the hilla west of Hawthorne Avenue.
Adjacent to the south flank of the Santa Monica Mountains and westward from the Elysian Hills are two surfaces of alluvial aggrada-tion which have been named the Santa Monica and La Brea plains* These surfaces are considered to be of late Pleistocene age, but they have been extensively modified by the erosion of broad channels in which Recent deposits have been laid down.
These foothill surfaces of aggradation absorb some rainfall and local runoff, and consequently, they contribute to the replenishment of the ground-water supply north of the Baldwin Hills.

NEWPORT-INGLEWOOD BELT OF HILLS AND PLAINS
HELLS

The Newport-Inglewood uplift is expressed topographically as a belt of discontinuous low hills that extend from the Santa Monica Mountains southeastward into Orange County. In the Torrance-Santa Monica area this belt is cut by Ballona and Dominguez Gaps near the northwestern and southeastern boundaries.
The uplift and the related plains are underlain at shallow depth, usually less than 30 feet, by a surface of marine planation which was developed upon deformed lower Pleistocene and Tertiary strata. Initially formed in late Pleistocene time, the surface evidently was a plain of low relief. On it were deposited the upper Pleistocene marine Palos Verdes sand and a thin capping of presumed continental origin, where the thickness ranges from 5 to 20 feet. Thus, the present land-surface forms of the belt offer a fairly accurate picture of the defor-mation since late Pleistocene time. For example, they reveal certain faults that disrupt the land surface and act as subsurface barriers to water movement across the uplift.
Baldwin Hills is the boldest of the uplifts along the belt, with a relief of about 400 feet above the surface of Ballona Gap, adjacent to

PHYSIOGRAPHY 17

the north and a summit 513 feet above sea level. The Beverly Hills, about 4 miles northwest across Ballona Gap, reach an altitude about 200 feet lower than the Baldwin Hills, and have less relief. The surface of the Baldwin Hills is severely dissected by sharply incised valleys; the Beverly Hills have been moderately dissected. Extending about 8 miles southeastward from the Baldwin Hills to Dominguez Hill, the Rosecrans Hills consist of an irregular low swell about 3 miles wide. The crestal altitude decreases from about 240 feet east of Inglewood to about 100 feet on the north flank of Do-minguez Hill. The swell is of deformational origin and is asymmetric, with a steeper slope on the west which is modified by two fault es-carpments. The most pronounced escarpment is about 50 feet high and extends about 2% miles S. 25° E. from Inglewood. The second escarpment is about 1% miles long, also trends S. 25° E., and termi-nates at the north flank of Dominguez Hill.
Dominguez Hill is a simple elliptical dome 3 miles long and about 195 feet above sea level. Like the Rosecrans Hills, it has a flatter slope on the northeast flank and is deformational in origin; however, it is less modified by stream erosion. Its major axis trends N. 60° W., or about 20° west of the general trend of the belt of hills.

RELATED PLAINS

The Ocean Park plain is a comparatively undeformed westward extension of the Beverly Hills; it is immediately south of the Santa Monica plain and north of the coastal part of Ballona Gap. It consists of three subdivisions: (1) a small bench to the east, which is about 190 feet above sea level, (2) an extensive central plain, which slopes gently southward, and (3) a ridge-and-trench area which lies parallel to the coast and is ascribed to upper Pleistocene shoreline features (Hoots, 1931, p. 121).
An extensive counterpart of the Ocean Park plain is the Torrance plain, which stretches from the southwest flank of the Baldwin Hills to Wilmuigton; its surface is essentially continuous with that of the Rosecrans Hills which flank it on the northeast. This plain is inferred to extend beneath the now inactive dune belt of the El Segundo sand hills along its southwest flank. The Torrance plain is somewhat warped, especially along its inland margin. North of Gardena the warping has formed a shallow depression which has no natural external drainage, and is floored with Recent play a deposits. A more pro-nounced downwarp occurs at the southwest flank of Dominguez Hill, which is floored with Recent deposits, and represents a northwest-ward extension of the Downey plain into the Torrance plain.
Under natural conditions the Torrance plain was very poorly drained. Drainage from its northern and central parts was to the

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downwarp north of Gardena; drainage from its south-central part was to the downwarp southwest of Dominguez Hill by way of Laguna Dominguez and a small creek trending eastward from Torrance. A small area west of Wilmington drained internally to Bixby Slough. Most of this discontinuous natural drainage has been integrated artificially by the Dominguez Channel, which now receives runoff from 56 square miles upstream from its Carson Street crossing and discharges into the east basin of Los Angeles harbor and thence to San Pedro Bay.
The playa deposits flooring the two natural undrained depressions described above are fine grained and dense. Penetration of rainwater and water from surface runoff through these deposits is slow. On the other hand, water from runoff has collected in these depressions and evaporation has concentrated the total-solids content of the water that has penetrated below land surface. Thus, these downwarps are closely related to the naturally inferior quality of the shallow water in the Gardena area.
GAPS

111 the Torrance-Santa Monica area the Newport-Inglewood uplift is transected by two tongues of fluvial deposits which extend from the central lowland (Downey plain) to the coast. These tongues occupy two stream-cut erosional gaps which are known as Ballona and Domin-guez Gaps. The streams which formed these gaps maintained their courses during the late Pleistocene deformation along the Newport-Inglewood uplift and thus may be classed as antecedent. Both gaps are flanked by stream-cut bluffs, which have greatest relief across the uplift.
Ballona Gap, which is topographically most prominent between the Beverly Hills and the Baldwin Hills, is 1.2 miles wide at its narrowest point and is about 10 miles long from the east end of the Baldwin Hills to Santa Monica Bay. The lower 6-mile segment is within the west basin. Its trench was cut into the upper Pleistocene marine (Palos Verdes) surface by an ancestral westward-flowing Los Angeles River and is floored by Recent alluvial deposits to a depth of 50 feet near the coast and to about 80 feet northeast of the Baldwin Hills, which are about 9 miles upstream.
The stream-cut bluffs flanking Ballona Gap reach a maximum height of 400 feet at the north face of the Baldwin Hills. Although subse-quent deformation has altered the profile of the trench in Ballona Gap, the incising stream evidently reached a level at least 50 feet below present sea level at the coast and as much as 400 feet below the upper Pleistocene marine surface at the axis of greatest deformation along the Newport-Inglewood uplift. It is believed that the present Ballona Gap represents an inland segment of the trenching that is, the incised

PHYSIOGRAPHY 19

stream was graded to a base level substantially more than 50 feet below present sea level and possibly as much as 2 to 3 miles seaward from the present coast. It is possible that Ballona Gap was trenched at essentially the same time as Bolsa Gap in Orange County, which was graded to a base level about 70 feet below sea level, prior to diver-sion of the Santa Ana River to Santa Ana Gap (Poland, Piper, and others, 1956, p. 44-46). After the ancestral stream in Ballona Gap had incised its channel about 50 feet below present sea level at the coast, presumably during late Pleistocene recession of the seas, its course was diverted southward into Dominguez Gap and was main-tained there during the later stages of the pre-Recent gap-cutting cycle.
Dominguez Gap, which passes between Dominguez Hill and the northwestern extension of Signal Hill, is 1.6 miles wide at its narrowest point and is about 7 miles long. It was trenched mainly by an ances-tral San Gabriel River, which had a southward-flowing ancestral Los Angeles River as tributary. The highest of the stream-cut bluffs along the gap is at the east face of Dominguez Hill and is about 100 feet high.
Dominguez Gap was eroded to a depth of 150 feet or more below present sea level at the coast, and to about 250 feet below the late Pleistocene surface at the crest of the uplift. The entrenched valley extended inland across the coastal plain to Whittier Narrows, with a tributary trench reaching from Compton to the Los Angeles Narrows. The Recent epoch of aggradation started with the deposition of gravel and coarse sand to a depth of 50 to 70 feet. Subsequently, deposits of silt and fine sand about 75 feet thick were deposited on top of the permeable basal tongue. Thus the trench was backfilled to a thickness of about 150 feet with deposits of Recent age.

EL SEGUNDO SANDHILLS

A coastal belt of dunes and sandhills about 11 miles long parallels the shoreline from Ballona escarpment to the Palos Verdes Hills, and extends inland from 3 to 6 miles to overlap the Torrance plain. This belt is a conspicuous topographic feature called the El Segundo sand-hills. It may be subdivided into two distinct elements. One element is adjacent to the coast and is about half a mile wide. For the most part, it is made up of dunes with crests ranging from 85 to 185 feet above sea level. These dunes are inferred to be of Recent age. The main part of the belt is from 2 to 5 miles wide, and consists of stabilized dunes and parallel ridges and alined hills which have been generally interpreted as ancient offshore bars modified by wind and stream action since their emergence from the ocean.

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The coastal bar deposits were probably formed during a high level of the seas immediately before the latest Pleistocene withdrawal which instituted the cycle of gap cutting; hence, they are considered to be of late Pleistocene age. The dunes, on the other hand, although probably formed, in part, during the pre-Recent gap-cutting cycle, presumably were formed chiefly during the drier climatic conditions that inferen-tially accompanied deposition of the later or upper division of the Recent sediments.
DOWNEY PLAIN

The western part of the extensive central lowland, or Downey plain, forms the inland border of the Torrance-Santa Monica area. It is the surface formed by alluvial aggradation during the post-Pleistocene epoch of rising base level, and is substantially adjusted in grade to the major streams which enter the coastal plain at the several passes through the bordering mountains and foothills. The alluvial deposits in Ballona and Dominguez Gaps thus represent the coastward ex-tensions of this plain.
Within the project area, the Downey plain and its extension through Ballona Gap is underlain chiefly by the alluvial fan of the Los Angeles River; the apex of this fan is in the Los Angeles Narrows at an altitude of 275 feet. The tongue of the plain extending through Dominguez Gap is largely a part of the San Gabriel River fan, whose apex at Whittier Narrows has an altitude of 200 feet.
Near the inland narrows the alluvial material composing the Downey plain is coarser and highly permeable; these segments con-stitute important intake areas for the recharge of the principal aquifers beneath the Downey plain and the extensions into the west basin.
DRAINAGE

Within the area of investigation the largest stream is the Los Angeles River which passes southward across the Downey plain from the Los Angeles Narrows and discharges into San Pedro Bay through Dominguez Gap. Upstream from the Pacific Coast Highway at Long Beach, it has a drainage area of about 1,060 square miles; almost all the drainage area is inland from the Torrance-Santa Monica area. In 1894 its channel within Dominguez Gap had two distributaries, which branched about 4 miles north of the shore and discharged into the former Wilmington Lagoon (Mendenhall, 1905a, pis. 1 and 4). Within the past two decades, however, the river has been confined in its channel by flood-control levees and now discharges southward directly into San Pedro Bay.
The streams within the coastal plain in Los Angeles County are intermittent; they carry large flows only after heavy winter rains.

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Many times in the past flash flows in winter have been too large for the natural channels to carry and have resulted in very destructive floods.
Thirteen major floods were recorded on the Los Angeles and San Gabriel Rivers from 1811 to 1891. For an unknown length of time before 1825, the Los Angeles River flowed westward through Ballona Gap, but during the floods of that year it broke out of its course to drain southward into San Pedro Bay via Dominguez Gap. During the floods of 1862 and 1884, part of the flood waters returned tem-porarily to Ballona Gap, but since 1884 the Los Angeles River has discharged southward to San Pedro Bay (Troxell and others, 1942, p. 385-391).
The largest flood of the Los Angeles River for which records are available occurred in March 1938. The maximum discharge reached 67,000 cfs at a point a mile upstream from the Main Street bridge in Los Angeles; at Long Beach, where discharge was swelled by the flood waters of the tributary Rio Hondo, a maximum discharge of 99,000 cfs was recorded (Troxell and others, 1942, p. 12 and 246). On the other hand, during the thirties, for as much as 9 months of the year, the recorded flow of the Los Angeles River at Long Beach has been less than 10 cfs; at times in 1929, 1930, and 1934 its channel was dry.
Compton Creek drains an area of some 30 square miles north of Dominguez Hill and east of the Rosecrans Hills. In the middle nineties and for several decades thereafter, it maintained a course southward along the west margin of Dominguez Gap and discharged into San Pedro Bay through the former Wilmington Lagoon. In 1938 part of the upstream channel was paved and the creek was joined to the Los Angeles River about 5.5 miles inland from the coast and about half a mile south of Del Amo Street.
The natural unintegrated drainage pattern within the Torrance plain has been discussed elsewhere (p. 17). Most of the drainage has been integrated artificially by construction of the so-called Dominguez Channel, which discharges into San Pedro Bay.
In the northern part of the area the most important stream is Ballona Creek, whose tributaries drain the northern slopes of the Baldwin Hills, the southern slopes of the Santa Monica Mountains east of Sepulveda Boulevard, and also a large area east and northeast of the Beverly Hills. About 4 miles from the, coast, at Sawtelle Boule-vard, Ballona Creek has a tributary drainage area ^ of 111 square miles. The creek, which is now paved with concrete except for the 5-mile reach above its mouth, discharges directly into Santa Monica Bay.

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Centinela Creek, its source originally in Centinela Spring in what is now the Centinela Park well field of the city of Inglewood, drains the south flanks of the Baldwin Hills and the area southwest of the Hills. The following quotation from a report by Kew (1923, p. 157) is of interest:

Before the city of Inglewood obtained its water supply from wells at the Centinela Spring, a stream carrying one hundred and twenty-five inches of water issued from this spring, and flowed down Centinela Creek, forming these channels, which are now nearly obliterated. During wet weather it was even possible to row a boat up to the spring from Playa del Rey.

Centinela Creek flows northwestward into Ballona Gap, turns south-westward and follows a course nearly parallel to and southeast of Ballona Creek, and then discharges into the coastal marshes.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CHARACTER

GENERAL FEATURES

In the Torrance-Santa Monica area, a thick section of Tertiary and Quaternary marine and continental sediments has been deposited on a basement complex of pre-Tertiary metamorphic and igneous rocks. The pre-Tertiary rocks, which are essentially non-water-bearing beds, crop out only at the bordering highlands in the northern and southern boundaries of the area, where they have been uplifted by deformational earth movements and exposed by erosion.
The Tertiary rocks are almost entirely of marine origin and range in age from Eocene to Pliocene. They consist of sandstone, siltstone, mudstone, diatomite, and siliceous shale, and are exposed extensively in the Palos Verdes Hills and in the Santa Monica Mountains; they underlie the younger rocks in all the area between these highlands. Within the Torrance-Santa Monica area these Tertiary rocks are penetrated by many oil wells in the several oil fields and by scattered "wildcat" wells. Several of the Tertiary formations are not exposed in the area and are known only from the records of these drilled wells. Except for certain rocks of latest Pliocene age which contain essen-tially fresh water, the Tertiary rocks contain only saline waters. The Quaternary rocks contain nearly all the aquifers now tapped by water wells and are chiefly of Pleistocene age; within the west basin deposits of Recent age occur only within the two gaps. Extensive deposits of coarse gravel and sand of Pleistocene age, amounting to about half the aggregate thickness of the Quaternary rocks, occur beneath nearly the whole project area and are partly exposed on the Baldwin Hills and on the north flank of the Palos Verdes Hills. Within the west basin these coarse deposits are almost entirely of littoral or shallow marine origin. Fine-grained deposits

GEOLOGIC FORMATIONS WATER-BEARING CHARACTER 23

of sand, silt, sandy clay, and clay, about equal in aggregate thickness to the coarse deposits, commonly overlie them throughout the area. The deposits of finer grain are partly of marine and littoral origin, but to a greater extent are of lagoonal and continental original. With the exception of the tongues of Recent deposits in the two gaps, the Tertiary and Quaternary rocks have been deformed along the Newport-Inglewood uplift into a succession of anticlines and domes with intervening structural saddles cut by normal and thrust faults arranged en echelon. Flanking this uplift to the southwest and northeast are synclines, where the two systems of rocks attain their greatest thickness. Along the crest of the uplift they are as much as 12,500 feet thick; in the syncline beneath the Torrance plain they are probably as much as 15,000 feet thick; in the syncline to the northeast, beneath the Downey plain, they may exceed 20,000 feet in thickness.
Many of the lithologic and paleontologic data with which the stratigraphic treatment is concerned were obtained from the reports of geologists (Hoots, 1931; Wissler, 1943, p. 210-234; Woodring, 1946) who have carried out detailed investigations in the region; other data were obtained from S. G. Wissler, paleontologist, Union Oil Co.; and fromM. L. Natland, paleontologist, Richfield Oil Corp., in connection with stratigraphic correlations and paleontologic information derived from well samples.
The areal distribution of those stratigraphic units which crop out in the area is shown on plate 2. The general subsurface stratigraphic sequence and the structural conditions, based largely on well-log information, are shown on several geologic sections, plates 3-6. A descriptive summary of the rocks in the area, including an appraisal of the water-bearing characteristics of each formation, is presented in table 3. Plate 7 is a stratigraphic correlation chart, showing graphi-cally the relative thicknesses of the formations represented in each of the eight major oil fields in the area (pi. 18). It is in two sections, each trending nearly parallel to the Newport-Inglewood uplift. One is adjacent to the coast and includes a columnar section at the Palos Verdes Hills; the other is alined along the Newport-Inglewood uplift from the Inglewood field in the Baldwin Hills to the Dominguez field at Dominguez Hill. Except for the section concerned with the Bald-win Hills, the data for this chart have been compiled largely from information supplied by S. G. Wissler and are based almost entirely upon micropaleontologic correlations supplemented by electric-log data.

TABLE 3. Stratigraphy of the Torrance-Santa Monica area, California

Geologic age

QUATEBNARY

Recent

Pleistocene

Formation and symbol on plate 2

Alluvial, coastal, and dune deposits
(Qal, Qs)

Terrace cover and Palos Verdes sand
(Qpu); not differentiated on map
from unnamed deposits below.

Unnamed upper Pleistocene deposits
(Qpu); not differentiated on map
from Palos Verdes sand and terrace
cover above.

San Pedro formation, including
Timms Point silt and Lomita marl

members (Qsp).

Thick-

ness

(feet)

0-175

0-50

0-400(7)

0-1,000

Physical character

Beneath tbe Downey plain and its coast ward
extensions, Dominguez and Ballona Gaps,
unconsolidated silt, gravel, and sand of fluvial
origin; coarser materials predominant in lower
half of the deposit. Beneath the coastal tide-
lands, silt and clay of lagoonal and fluvial origin
overlying and enclosing tongues of fluvial sand
and gravel. Locally along the coast, accretional
beach deposits. Beneath the El Segundo sand-
hills, dune deposits, designated on pi. 2 by
symbol (Qs).

Reddish-brown sand, silt, and soil, chiefly non-
marine in origin; underlain locally by a deposit of
fossiliferous sand and gravel of marine origin,
the Palos Verdes sand; together tnese mantle
the hills and mesas of the Newport-Inglewood
uplift.

Silt, clay, and some gravel, of fluvial and marine
origin; in the central part of the west basin, the
lower portion contains an extensive body of sand,
with some gravel.

Unconsolidated to semiconsolidated gravel, sand,
silt, and clay; chiefly marine, beach, and lagoonal
deposits within tne west basin, but largely of
fluvial origin inland from the Newport-Inele-
wood uplift; the coarser materials more plentiful
in the lower two-tbirds of the deposit. At some
places, silt and clay predominate.

Ground-water conditions

Beds of gravel and coarse sand in tbe lower part of
ttie deposit contain confined water and yield
water freely to many wells, especially in tongues
extending from Whittier Narrows through
Dominguez Gap and from Los Angeles Narrows
through Ballona Gap. This water is of good
chemical quality inland, but moderately to highly
saline from the coast inland about 7 miles in

Dominguez Gap and about 6 miles in Ballona
Gap. Near the coast, tongues and beds of fine
sand, and some of fine gravel, in the upper part
of tbe deposit, contain unconfined semiperched
water that is moderately to highly saline.

Chiefly above the water table and therefore un-
saturated; sufficiently permeable to transmit
some water from rainfall to underlying materials.

Beds of gravel and sand hold confined and uncon-
fined water and supply small domestic and stock
wells and some larger irrigation wells. This
water is of good quality within the Torrance-
Inglewood subarea, except locally at shallow
depth, and along the coast from El Segundo to
Redondo Beach, where it is contaminated.
This water is of good quality inland from the
Newport-Inglewood uplift.

Beds of gravel and coarse sand, most commonly in
lower two-thirds of deposit, hold confined water
and yield copiously to many wells. This water
is of good chemical quality inland from the New-
port-Inglewood uplift, also on coastal side of
uplift in the west basin, except along and near
the coast from Santa Monica to Redondo Beach.
This formation Is tbe principal source of water
within the west basin.

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TERTIARY

JURAS-

SIC (?)

Pliocene

Miocene

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PW

Upper division

Middle division

Lower division

Repetto formation

Monterey shale, at least in part
(Puente formation of Wissler and
others) (Tu).

Franciscan(?) formation

0-1,800

0-1,240

0-470

0-4,080

0-4,500

Semiconsolidated sand, silt, clay, and some fine
gravel, chiefly of marine origin. Tongues of
fluvial(?) sand and flne gravel the gravel beds
north of the Newport-Inglewood uplift and in the
upper third of the deposit, the sand layers com-
monly in the lower two-thirds of the deposit.

Olive to dark -brown massive claystone and silt-
stone, fine to coarse gray sand; * all of marine
origin.

Fine to coarse gray sand, occasionally pebbly,
brown sandy siltstone and claystone; 1 all of
marine origin.

Fine to coarse-grained gray sandstone; sandy
micaceous siltstone; bluish-gray to dark-brown
platy shale; all of marine origin.

Greenish, grayish, or bluish serpentine, talc, or
schist.1

Beds of sand and gravel in the upper part of the
deposits contain confined water and locally
might yield freely to wells. This water is soft
and low in dissolved solids, but is dark brown and
has a temperature of about 100° F. Beds of flne
sand in the lower part of the deposits are fairly
permeable but have not been tapped by water
wells. This water is essentially fresh although
total dissolved solids content may be too high for
domestic use and for irrigation.

Largely impervious; if water-bearing, the sandy
members contain connate waters whose salinity
ranges from about half that of ocean water to
that of ocean water.

Impervious, nonwater-bearing.

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i After Wissler (1943, p. 210).

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In the following paragraphs the formations are discussed in order from youngest to oldest, thereby giving early emphasis to rocks which are of greater importance from a standpoint of ground-water resources. Those rocks of Tertiary age that contain connate saline ground waters are discussed briefly because their waters are a potential source of contamination of the fresh-water body in the younger rocks.

QUATERNARY SYSTEM

RECENT SERIES
DEFINITION AND GENERAL FEATURES

The deposits of Recent age comprise chiefly the youngest uncon-solidated materials formed during the present cycle of alluviation by streams, materials associated with shoreline features, including lagoonal, littoral, and dune deposits, also slope-wash and playa deposits of minor extent.
With respect to water-bearing character, the most important de-posits of Recent age are those of fluvial origin. They consist of sand, gravel, silt, and clay, and underlie the Downey plain and its tongues, which extend to the coast through the gaps cut in the older rocks (pi. 2). Thus, the top of the Recent deposits is the surface of the Downey plain and its extensions into the several gaps; their base is the former land surface that had been produced by deformation and trenching of the coastal plain in late Pleistocene time.
In Ballona and Dominguez Gaps and inland from the gaps, logs of many wells which have been drilled through the Recent deposits reveal that the relatively fine grained sediments in the upper few tens of feet commonly are underlain by much coarser materials chiefly coarse sand to cobble gravel, which have been deposited as tongues many miles in length. These important aquifers, which underlie Ballona and Dominguez Gaps, extend inland across the coastal plain; the textural difference between them and the overlying finer grained sediments provides a basis for separation of the Recent alluvial de-posits of the area into an upper and a lower division.
Within the coastal plain as a whole, and for almost all the deposits of Recent age except those within Ballona Gap, the report on the geology of the Long Beach-Santa Ana area has treated in considerable detail their physical character, mode of origin, and general water-bearing character (Poland, Piper, and others, 1956, p. 40-52). Accord-ingly, the treatment in the following paragraphs will summarize the character of these deposits briefly, with emphasis on the two basal aquifers of the lower division which extend across the west basin in Dominguez and Ballona Gaps, and which respectively constitute the Gaspur water-bearing zone and the "50-foot gravel."

GEOLOGIC FORMATIONS WATER-BEARING CHARACTER 27

UPPER DIVISION

Flood-plain deposits. Some of the most widely distributed deposits in the upper division of Recent age in the Torrance-Santa Monica area are the alluvial-fan and flood-plain sediments laid down at times of excessive runoff, when the streams overflowed their banks and spread widely over their alluvial fans. These sediments are largely fine sand and silt, with lesser amounts of clay and gravel. The finer sediments have been widely distributed over the coastal flood plains; the sand and gravel have been laid down chiefly on the steeper inland slopes of the alluvial fans and within the larger channels. In the present climatic period, which probably existed throughout the de-position of the upper division of the Recent series, this type of alluvia-tion has been the common pattern. However, because of the in-creased development of the coastal plain and the construction of engineering works designed to control flood runoff, in recent years the streams have overflowed their banks and deposited sediment over their natural flood plains only during the largest floods.
These deposits of the upper division are distributed beneath all the Downey plain, in the two gaps within the project area, and in local areas tributary to these gaps. Their thickness is as much as 100 feet in the central part of the Downey plain; in Dominguez Gap it ranges from 45 to nearly 80 feet; but in Ballona Gap, where the Recent series as a whole is thinner, the upper division is from 10 to 50 feet thick. In the reach between Dominguez and Ballona Gaps these sediments feather out along the inland flank of the Newport-Inglewood belt of hills. The top of these deposits is the surface of the Downey plain. Within the extent of the lower division of the Recent, the base of the upper division rests almost conformably on the top of these coarser tongues; elsewhere their base is the modified lower Pleistocene land surface.
Minor deposits. The upper division of the Recent series also con-tains minor deposits which include slope-wash, playa, lagoonal, beach, and dune deposits. With the exception of the beach deposits, these have relatively little importance from the standpoint of this investigation.
The slope-wash and playa deposits probably do not measure more than a few feet in thickness in any part of the area. The former are mainly weathered rock fragments, fine sand, and silt, developed on hill slopes; the latter have accumulated in undrained depressions in or near the Torrance plain (p. 17), and consist of silt and clay of local origin.
The lagoonal marshes, which were formerly behind the barrier beaches at the mouths of Ballona and Dominguez Gaps, have acted as sedimentation basins for some of the load carried by streams dur-

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ing intermittent floods. Thus, they have received contributions of fine sand, silt, and clay, which have become interbedded with the organic debris native to the marshes.
Recent beach deposits form narrow arcuate strips of sand and gravel, which flank Santa Monica and San Pedro Bays, fringe the coastal wavecut sea cliffs and connect across the gaps by barrier beaches. These beach deposits have been the chief source of material supplied to the coastal-dune belt.
With regard to saline contamination from the ocean, these beach deposits are of great interest because: (1) at least locally along the coast, they are believed to extend for several tens of feet below sea level; (2) probably they are in direct contact with the Silverado water-bearing zone in the vicinity of Redondo Beach and with the "50-foot gravel" and the main water-bearing zone of the San Pedro formation at the mouth of Ballona Gap; and (3) they are highly permeable. Thus, under the current conditions of landward hydraulic gradient, these beach deposits probably afford conduits for the movement of ocean water into the coastal margins of the main water-bearing zones within the west basin.
The dune deposits that underlie the El Segundo sandhills are formed almost entirely of fine- to medium-grained sand of uniform texture. They range in thickness from a featheredge to as much as 150 feet. As exposed in an excavation at Hyperion (in 2/15-10), they exhibit several stages of dune formation, with dense cemented layers now buried, which probably represent former land surfaces. These dune deposits mantle an area of about 35 square miles along the southwest flank of the Torrance plain. They are almost entirely above the zone of saturation and thus do not yield water to wells. However, they are relatively permeable and transmit substantial quantities of water from rainfall to the underlying Pleistocene rocks. Where those rocks are impermeable, doubtless a water table occurs within the dune deposits. Also, the denser layers within the dunes may develop perched water bodies of local extent.

LOWER DIVISION

The deposits of the lower division of Recent age do not crop out in the area and consequently are known only from logs of wells and from samples taken during drilling. These indicate that the lower division consists almost entirely of coarse sand and gravel, deposited in tongues. In the Torrance-Santa Monica area, the two principal tongues are the Gaspur water-bearing zone in Dominguez Gap and the "50-foot gravel" in Ballona Gap. Physical connection between these two zones is afforded by the so-called westerly arm of the Gaspur zone, which extends southward from the Los Ajigeles Narrows

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to about a mile east of Compton, where it joins the Gaspur water-bearing zone (pi. 8).
Gaspur water-bearing zone. The Gaspur water-bearing zone was deposited in early Recent time by an ancestral San Gabriel River, with minor contributions from an ancestral Los Angeles River in the reach coastward from their junction near Compton.
The Gaspur water-bearing zone has been traced for more than 20 miles across the Downey plain from Terminal Island to Whittier Narrows, as shown in an earlier report (Poland, Piper, and others, 1956, pi. 7). Doubtless it extends northward into San Gabriel Valley and southward beneath San Pedro Bay. The maximum width of 4 miles occurs just south of Downey. Within the area covered by this report it is relatively narrow, being about a mile wide at the eastern salient of Dominguez Hill, but increasing some-what in width to the north and south (pi. 8).
The thickness of the Gaspur zone ranges from 50 to 75 feet. Near the coast, its base has a gradient of about 9 feet per mile, from about 70 feet below sea level 2 miles north of Dominguez Gap to 150 feet below sea level at the coast. The gradient steepens somewhat to the northeast so that, reckoned from Whittier Narrows, where the base of the zone is 100 feet below the land surface and 90 feet above sea level, the average gradient to the coast is about 12 feet per mile. Typical deposits of the Gaspur zone are indicated by the log of well 4/13-15A11 (table 28). The zone generally is characterized by a lower part consisting of coarse clean gravel from 25 to 50 feet thick, containing cobbles as much as 6 inches in diameter, overlain by an upper part of medium to coarse sand from 20 to 50 feet thick. How-ever, there is considerable lithologic variation and this typical dis-position of the gravel and sand is best developed southward from the middle of the Downey plain. Beneath the inland part of the Downey plain both the main Gaspur zone and the westerly arm become coarser and contain more gravel and less sand; neither the gravel nor the sand lie in a characteristic stratigraphic position.
Westerly arm of the Gaspur water-bearing zone. A tributary branch of the Gaspur water-bearing zone, the deposit of an ancestral Los Angeles River, here called the "westerly arm" of the Gaspur water-bearing zone, has been traced from the Los Angeles Narrows south-ward and roughly parallel to Alameda Street for about 11 miles to its junction with the main Gaspur zone about a mile east of Compton. The thickness of this westerly arm ranges from 30 to 80 feet; its average width is about 2 miles and its gradient from the south edge of the Los Angeles Narrows to the junction with the Gaspur water-bearing zone is about 20 feet to the mile, although in the 3 miles immediately north of the junction near Compton the gradient is only about 15

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feet per mile. At the junction, the Gaspur zone and its westerly arm have a common base 140 feet below the land surface, or 70 feet below sea level. This westerly arm is somewhat coarser in com-position than the deposits of the Gaspur zone in Dominguez Gap; it is similar to the gravel found in the main tongue of the Gaspur zone from the middle of the Downey plain to Whittier Narrows. Sand and minor quantities of clay are interspersed irregularly with the gravel in this westerly arm.
"Fifty-foot gravel." In Ballona Gap, the lower division of the Recent series is represented by a relatively thin and irregular gravel body which was laid down by an ancestral Los Angeles .River. In the area of its most characteristic development, between Culver City and the coast, its base ranges from 40 to 80 feet below the land surface, but its average depth is about 50 feet below the surface. For this reason the name "50-foot gravel" has been assigned for the purposes of this report. By means of well logs it has been traced inland beyond the narrows between the Baldwin and the Beverly Hills to its junction with the westerly arm of the Gaspur water-bearing zone, south of the La Brea plain and in the vicinity of Vermont Avenue (pi. 8).
The "50-foot gravel" ranges in thickness from 10 to 40 feet and consists generally of coarse gravel and a subordinate amount of sand. Its average thickness is only about a third as great as that of the Gaspur water-bearing zone in Dominguez Gap.
Logs of wells show that the depth to the base, position, and thickness of the "50-foot gravel" are very irregular. Thus, although the over-all seaward gradient of the base of the "50-foot gravel" from north-east of the Baldwin Hills to the coast is about 8 feet per mile, that gradient has been estimated by taking an average altitude of the base from well logs that show substantial variation within short distances. Other well logs show only clay or sandy clay (silt) in the depth range where the gravel would be expected to be present. The discontinuity and irregularity in thickness and position of the "50-foot gravel" sug-gest that (1) it was deposited on an uneven base which may have contained both channels and terrace remnants, and (2) the back-filling was accomplished by a stream with insufficient transporting power to lay down a broad sheet of gravel across the full width of the gap. Also, during this backfilling stage, the tributary streams that discharged southward to Ballona Gap across the dissected Santa Monica plain may have been building debris cones along the north side of the gap. Those cones would doubtless have contained mate-rials of substantially finer grain than the coarse sediments transported by an ancestral Los Angeles River.

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As determined from well logs, west of the Baldwin Hills the trans-verse profile of the base of the "50-foot gravel" dips southeastward across Ballona Gap. The lowest part of the gravel generally is be-neath or south of the present course of Ballona Creek; the altitude of the base at that point is about 40 feet lower than on the northwest side of the gap. This feature suggests that southward tilting of the "50-foot gravel" has occurred. If such is the case, the essentially straight alinement of the Ballona escarpment west of the Baldwin Hills may in part represent a fault scarp that has been modified to some degree by stream erosion. The substantial difference in chemical character of the native waters within the San Pedro formation to the north and south of this escarpment (pi. 19) might be interpreted as supporting this inference. Hydrologic evidence gives no clue in regard to the presence of a ground-water barrier along the escarpment.

WATER-BEARING CHARACTER

Upper division. Because it is composed chiefly of materials of fine texture and low permeability, the upper division of the Recent is tapped by only a very few small domestic wells. It is sufficiently permeable, however, to absorb a moderate volume of water by infil-tration of rain, by percolation from the streams the Los Angeles River and Compton and Ballona Creeks and by deep penetration of irrigation water. Most of this water first reaches the unconfined semiperched water body and ultimately is transmitted to the coarse tongues of the lower division the Gaspur water-bearing zone and the "50-foot gravel."
Gaspur water-bearing zone. The character of the Gaspur water-bearing zone has been discussed at length in a report by Poland (1959), and will be only briefly summarized here. The Gaspur zone is highly permeable and is tapped by wells throughout its 21-mile reach from Terminal Island to Whittier Narrows. However, for its extent within the west basin from the coast inland some 6 miles to Del Amo Street the zone has been contaminated by saline waters and in most of this area its water is unfit for use. Yield data are available for five wells in this coastal area. Their yield ranges from 210 to 1,500 gpm. For four of these wells, the average specific capacity (gallons per minute per foot of drawdown) is 63. Data available from pumping tests suggest that within this reach the peimeability of the Gaspur zone ranges from 3,000 to 5,000 gpd per square foot.
"Fifty-foot gravel." During the early development of ground water in Ballona Gap, the "50-foot gravel" was tapped by several scores of wells for domestic, irrigation, and stock use. Because of the decline in water levels, this water-bearing zone has been dewatered beneath a large part of the gap. Also, its water has become contaminated

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within much of its extent coastward from the Inglewood fault. Hence, most of the wells, which currently withdraw water for irrigation or other uses, tap the underlying deposits of the San Pedro formation. Fragmentary data on yields from wells tapping the "50-foot gravel" indicate that they have ranged from less than 100 to as much as 800 gpm. No information on specific capacity is available. However, because the "50-foot gravel" is only about one-third to one-half as thick as the Gaspur water-bearing zone, the yields indicate that the permeability may be about the same.

PLEISTOCENE SERIES
GENERAL FEATURES

Deposits of Pleistocene age crop out over nearly all of the Newport-Inglewood belt of hills, over the Torrance plain and the Ocean Park plain, and locally on the flanks of the Santa Monica Mountains and the Palos Verdes Hills. They are overlain by alluvial deposits in the gaps and by beach and dune deposits along the coast, and are under-lain by Pliocene and older rocks. These Pleistocene deposits are chiefly unconsolidated and consist of interlensing beds of sand, gravel, silt, and clay. In downward succession they include a capping terrace deposit, the Palos Verdes sand, certain unnamed upper Pleistocene deposits, and the San Pedro formation of lower Pleistocene. In the area shown on plate 2 the San Pedro formation is the thickest of the Pleistocene deposits.
Along the coast, the Pleistocene rocks range in thickness from about 100 to 600 feet; in the syncline southwest of Dominguez Hill their thickness is as much as 1,200 feet. Along the crest of the Newport-Inglewood zone their thickness ranges from a feather edge at the Baldwin Hills to 700 feet at the southeast edge of Dominguez Hill. Inland beyond that zone they attain a maximum thickness of about 3,000 feet beneath the central Downey plain and become thinner northward and northeastward toward the inland hills, where they have been faulted, warped upward on anticlinal uplifts, and partly removed by erosion.

TERRACE COVER AND PALOS VERDES SAND

The Newport-Inglewood belt of hills, the Torrance and Ocean Park plains, and parts of the bordering highland areas are capped by a terrace cover of nonfossiliferous red sand and silty sand. In most of the area, this cover ranges from a few feet to about 20 feet in thickness. It owes its characteristic red color to iron oxide derived from the processes of weathering.
In the Palos Verdes Hills, according to Woodring (1946, p. 106), the thickness of the cover toward the rear of one terrace "is as much

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as 100 feet, but an exposed thickness greater than 50 feet is excep-tional." The deposits there represent "cliff talus rubble, stream fan and channel material, and rill and slope wash," and in places the re-mains of land mammals have been reported. These deposits, there-fore, are definitely continental in origin. Davis (1933, p. 1055-1056, 1058-1061, figs. 5 and 6) describes the origin and physiographic as-pects of similar deposits along the Santa Monica Mountains.
At some places, the relatively thin terrace cover over the Newport-Inglewood zone and the Torrance plain may be of flood-plain origin and may have been formed immediately after emergence of the upper Pleistocene marine surface. But elsewhere the true nonmarine cover may be absent, the red zone being merely the upper few feet of the marine Palos Verdes sand, which has been modified by weathering. Hoots (1931, p. 120-123, 130) describes alluvial deposits of late Pleistocene age which cap the dissected Santa Monica plain. "These deposits range in thickness from a few feet to at least 200 feet" and are composed of dark brown poorly sorted angular rock fragments "embedded in a soft matrix of reddish-brown clay and sand." Lo-cally they "rest directly upon a slight thickness of horizontal fossilif-erous marine upper Pleistocene deposits." Thus, although in places they are considerably thicker than the terrace cover, which occurs farther south, these deposits may in large part be stratigraphically equivalent to that cover.
At several exposures along and near the Newport-Inglewood struc-tural zone, the nonmarine terrace cover is underlain by a thin layer of fossiliferous gray sand and gravel. First described under the name "upper San Pedro series" and later called the "Palos Verdes forma-tion," this stratigraphic unit has recently been defined by Woodring (1946, p. 56) as the Palos Verdes sand; he describes its typical char-acteristics as it occurs in the Palos Verdes Hills as follows:

The Palos Verdes sand like the older marine terrace deposits, consists of a thin veneer on the terrace platform, which bevels formations ranging in age from lower Pleistocene to Miocene. Also like the older marine terrace deposits, the strata consist generally of coarse-grained sand and gravel but include silty sand and silt. Limestone cobbles are the prevailing constituent of the gravel, granitic and schist pebbles being locally abundant. The thickness of the Palos Verdes generally ranges from a few inches to 15 feet and is usually less than 10 feet. At places it consists of thin lenses, and at other places it is absent.

According to Woodring, faunal evidence indicates that the Palos Verdes sand is of late Pleistocene age. The lowest, and youngest, marine terrace of the Palos Verdes Hills on which it is deposited presumably is a correlative of the upper Pleistocene marine platform that underlies the Torrance plain and the Newport-Inglewood belt of hills at shallow depth, and which prior to deformation was of very low relief.

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Outside the Palos Verdes Hills, the Palos Verdes sand or its essen-tial stratigraphic equivalent has been identified at several localities. Among those in or near the Torrance-Santa Monica area, the following are pertinent:
1. About 6 miles west of Long Beach and 200 feet south of the intersection of Sepulveda Boulevard and Vermont Avenue, a thin lens of gray sand containing marine shells is exposed beneath red soil. On the basis of the megafossils, this sand has been identified by Woodring (personal communication, Nov. 23, 1943) as the essential equivalent of the Palos Verdes sand.
2. A trench dug on the northeast side of the Baldwin Hills about 1925, for the Los Angeles Outfall Sewer, exposed a section, which Tieje (1926, p. 502-503) described as 50 feet of massive grayish green very coarse to gravelly quartzose and loosely cemented sands. He called these the "Palos Verdes sands."
3. About 2 miles northeast of Playa del Rey, at the Ballona escarp-ment, the Palos Verdes sand has been exposed by the widening of Lincoln Boulevard where it begins to decline onto Ballona Gap. Beneath a thin soil cover, reddish-brown sand 10 feet thick is under-lain by 10 feet of clay, which in turn is underlain by 15 feet of medium to coarse brown sand. The lower 6 feet of this sand layer contains abundant shell remains. From a study of this fauna, Willett (1937, p. 379-406) has correlated the enclosing sand as the stratigraphic equivalent of the Palos Verdes sand at the Baldwin Hills locality described by Tieje and cited above. About 20 feet of light-brown sand, which is presumed to be part of the San Pedro formation of early Pleistocene age, is exposed beneath this Palos Verdes sand.
4. Just outside the area, about 2 miles northwest of the city of Santa Monica, sands of "upper San Pedro" (Palos Verdes) age are exposed in Potrero Canyon. Woodring, quoted by Hoots (1931, p. 122), believes that these sands "probably correspond to the sands of the Baldwin Hills section described by Tieje as the Palos Verdes sands."
5. The Ocean Park plain and the Beverly Hills are underlain by "soft sand, clay, gravel, and conglomerate," which are considered by Woodring (Hoots, 1931, p. 121), from faunal evidence, probably to represent "upper San Pedro" (Palos Verdes) age. Hoots reports that the only fossils found in the area were from a stream-cut bluff at the north edge of Ballona Gap, where a cut bank on the west side of Overland Avenue and about 200 feet south of the crest of the hill exposes a bed about 10 feet below land surface consisting of dark reddish-brown sandy silt and containing shells. This shell bed is overlain by brown massive silt extending to the land surface. These

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upper Pleistocene marine sediments in places underlie the Pleistocene alluvial deposits which form the Santa Monica plain.
Because the main water-bearing zones of the west basin occur at depths usually in excess of 150 feet below the land surface, the shell bed that commonly marks the base of the Palos Verdes sand is not often logged by drillers. A bed containing oyster shells at a depth of 18 feet, a foot of white sand to 19 feet, and a thin "coral" bed evidently a hard-shell bed^-was found in a well about 2 miles north of Torrance, in 3/14-34. It is presumed that these shell beds are at the base of the Palos Verdes sand, and that this formation occurs here to a depth of about 20 feet below the land surface.
For a description of the correlatives of the Palos Verdes sand as it occurs in the adjacent Long Beach-Santa Ana area to the east and southeast, the reader is referred to an earlier report (Poland, Piper, and others, 1956, p. 52-55).
A detailed account of its occurrences in the type locality, including faunal lists, is presented in the report by Woodring, Bramlette, and Kew (1946, p. 56-59) on the Palos Verdes Hills.
Along the Newport-Inglewood uplift, the terrace cover and the Palos Verdes sand are almost entirely above the water table and therefore they are unsaturated. At places beneath the Torrance plain the Palos Verdes sand is below the semiperched water table and is sufficiently permeable to yield water to shallow wells, although this water commonly is of inferior quality. Where these deposits form the land surface, they are sufficiently permeable to absorb some water from rainfall and to transmit it to underlying deposits.
Although the Palos Verdes sand has little importance as an aquifer, it is of critical importance in establishing the amount of deformation of the Pleistocene water-bearing deposits in latest Pleistocene time. Therefore, its known occurrences within the Torrance-Santa Monica area have been described in some detail in the preceding paragraphs.

UNNAMED UPPEE PLEISTOCENE DEPOSITS

DEFINITION AND EXTENT

In an earlier report by the Geological Survey (Poland, Piper, and others, 1956, p. 55-57), certain strata of late Pleistocene age found, in wells between definite or probable correlatives of the Palos Verdes sand above and the San Pedro formation below have been designated "unnamed upper Pleistocene deposits." These deposits underlie much of the Torrance-Santa Monica area and are described in fol-lowing paragraphs.
In water well 3/13-32F6, near the intersection of Victoria Street and Avalon Boulevard and low on the west flank of Dominguez

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Hill, two zones of marine shells were reported one in sand 20 to 30 feet below the land surface and the other from 238 to 260 feet. The upper shell zone is inferred to represent the Palos Verdes sand, and the lower one the megafossil zone near the top of the San Pedro formation of lower Pleistocene age; the material between these two shell zones has been assigned to the unnamed upper Pleistocene deposits.
About a mile to the east and near the intersection of Victoria Street and Central Avenue on Dominguez Hill, oil wells are reported by Wissler (1943, p. 212) to pass through: (1) nonmarine yellow and brown sand, sandy clay, and gravel to 175 feet below land surface;
(2) lagoonal deposits 40 feet thick; (3) a thin deposit of lignite; and
(4) about 300 feet of marine sand and gravel, including a megafossil zone, San Pedro in age, from 215 to 250 feet below land surface. Wissler has concluded that the top 175 feet of nonmarine sediments are of late Pleistocene age, and he assigns the lagoonal deposits and the marine sand and gravel to the San Pedro formation. It is inferred that the nonmarine beds from about 30 to 175 feet below land surface represent the unnamed upper Pleistocene deposits.
Natland examined samples collected during the drilling of well 4/13-22D1, about 3 miles south of Dominguez Hill. He reported that samples taken to a depth of 164 feet were nonfossiliferous and that samples below this depth contained fossils (Natland, M. L., written communication, 1943). From this report and other evidence, it is inferred that the upper 30 feet of deposits are of Recent age; those from 30 to 164 feet are believed to represent the unnamed upper Pleistocene deposits.
By means of peg-model studies, the unnamed upper Pleistocene deposits have been tentatively correlated over most of the southern part of the Torrance-Santa Monica area. These sediments extend at least as far north as the Ballona escarpment and southward to the Palos Verdes Hills. Between these north-south limits they extend from the coast over the crest of the Newport-Inglewood structural zone, and inland beneath the Downey plain. They have not been traced beneath Ballona Gap and to the north, although their stratigraphic equivalent may be present; apparently they are absent beneath the Baldwin Hills.

PHYSICAL CHARACTER AND THICKNESS

The unnamed upper Pleistocene deposits vary considerably in lithology, both vertically and laterally. Nevertheless, the upper half of the deposits is generally fine grained, chiefly silt, clay, and sand. The lower half is chiefly sand, containing some gravel and subordinate amounts of silt and clay. Because of its coarse texture,

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this lower stratum is a productive aquifer in much of the Torrance-Inglewood subarea. Its midposition is about 200 feet below the land surface in the area of its most typical occurrence in the broad syncline extending from Inglewood southeastward through Gardena. Hence, it has been named the "200-foot sand" for purposes of this report.
Although the "200-foot sand" is composed chief!}7 of sand, logs of wells reveal much variation in its physical character from place to place. Thus, well 3/14-23L1, about a mile north of Gardena and near the synclinal axis, is reported to have cut through 332J4 feet of clay, beneath a surface alluvial sand 1}£ feet thick, before striking an aquifer hi the San Pedro formation. Here the "200-foot sand" apparently is wholly absent. At well 3/14-22A1 (for log, see table 28), also near the axis of the syncline, the "200-foot sand" is repre-sented by an upper sandy zone, a middle clayey zone, and a lower sandy zone. Many well logs indicate that the "200-foot sand" is locally a coarse gravel, as at well 2/14-27Jl (table 28), situated on the crest of the Newport-Inglewood uplift at the north end of the Rosecrans Hills. The "200-foot sand" is also largely gravel beneath an area of about 4 square miles near the coast, at and near the city of El Segundo and the Standard Oil Co. well fields in sees. 12 and 13, T. 3 S., R. 15 W., and beneath about 7 square miles in the vicinity of Gardena near the axis of the syncline.
In general, where it occurs northwest of the Gardena area just referred to, the "200-foot sand" is coarser on the limbs of the syncline than along the axis.
In the southeastern part of the west basin, about southeast of a line from Gardena to Torrance, the "200-foot sand" usually is logged as. fine sand and is tapped by very few wells. Thus, in the area in and near Domuiguez Gap it has little importance as an aquifer.
In the area between Torrance and the northeast flank of the Palos Verdes Hills, the "200-foot sand" is largely in physical and hydraulic continuity with the thick series of coarse-grained sediments of the underlying San Pedro formation (shown in the cross sections, pi. 3 B, C). It is difficult or impossible to separate the two units in this area.
Within the part of the Torrance-Inglewood subarea where it is a productive aquifer that is, between Torrance and Inglewood and from the coast to the crest of the Newport-Inglewood uplift the "200-foot sand" underlies about 70 square miles.
The "200-foot sand" is tapped by at least 200 highly productive wells in the vicinity of Gardena. Although little information is available on drawdown, estimated yields for wells tapping this
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water-bearing zone range from about 100 to as much as 1,300 gpm. Estimated yields for 22 wells as reported by Mendenhall (1905b, p. 75-80) gave an average yield of 575 gpm. Well 3/14-26E2 is re-ported to yield 50 gpm with a 3-foot drawdown a specific capacity of 17 gpm per foot of drawdown.
The thickness of the unnamed upper Pleistocene deposits ranges widely from place to place. Table 4 shows the approximate thickness and depth of both the unnamed upper Pleistocene deposits as a whole and the "200-foot sand" for their occurrence along the synclinal axis from Inglewood southeast to Gardena (pi. 3J3), and along the west coast from El Segundo to Hermosa Beach (pi. 3(7).

TABLE 4. Range in thickness and depth (in feet) to the base of the unnamed upper Pleistocene deposits in the northern and central parts of the Torrance-Inglewood subarea

Deposits

Thickness of unnamed upper Pleistocene deposits
Depth to base below land surface.
Altitude of base below sea level. _
Thickness of "200-foot sand"._. _.- ___-______-_--_-

Along coast
(El Segundo
to Hermosa

Beach)

60-150
140-250
20-80
20-60

Along axis
of syncline
(Inglewood to
Gardena)

180-280
240-310
160-260
65-135

About 5 miles southeast along the synclinal axis from Gardena, at the intersection of Carson and Alameda Streets, the Pleistocene reaches its greatest thickness within the west basin. At this point the base of the unnamed upper Pleistocene deposits is about 350 feet below the land surface, or 325 feet below sea level (pi. 6).
Along the crest of the Newport-Inglewood uplift the unnamed deposits are thickest at Dominguez Hill and in the saddle between Dominguez Hill and the Rosecrans Hills (pi. 3A). Here the "200- foot sand" is represented by about 50 to 100 feet of sand and gravel whose base ranges from 100 to 200 feet below the land surface. Far-ther northwestward along the crest of the Rosecrans Hills, the base of the unnamed deposits is nearer the surface, owing to uplift, and the aggregate thickness averages 50 feet or less. The deposits may have been eroded to a certain extent during or after the uplift of late Pleistocene time, but it is thought that they may never have reached a greater thickness. Beyond the northwest end of the Rosecrans Hills they feather out against the Baldwin Hills uplift.
On the basis of data now available from wells and outcrops, the unnamed upper Pleistocene deposits within the west basin are in-ferred to be partly marine origin and partly of continental origin. Wissler reported that samples of deposits taken from wells on Dbmin-

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guez Hill were of nonmarine, presumably fluvial origin. In a very few wells southwest of the Newport-Inglewood uplift, fossils have been reported from these deposits (see logs for wells 4/13-15A11 and 4/14-13F1, table 28), but these have been found in the "200-foot sand" or its stratigraphic equivalent.
The upper half of the unnamed deposits in the Torrance-Inglewood subarea is fine grained and is not known to contain any fossils. Ac-cordingly, most of this upper division is inferred to be a flood-plain deposit.
Because the "200-foot sand" is of coarse texture, is widespread in extent, and is relatively uniform in character and thickness over areas as great as several square miles; and also because it contains fossils at a few places, it is inferred to have been deposited in a shallow marine or littoral environment. As already pointed out, the "200- foot sand" is thickest and best developed in the vicinity of Gardena; here it may represent a deltaic deposit laid down beyond a shoreline that fringed the southwest flank of the Newport-Inglewood uplift.

STRATIGRAPHIC RELATIONS

The stratigraphic relations between the unnamed upper Pleistocene deposits and the underlying San Pedro formation are not definitely known. The contact between these two stratigraphic units is nowhere exposed, and well logs are inadequate to supply critical evidence. However, it appears likely that the unnamed deposits are conformable on the San Pedro formation along the synclinal axis; probably they are locally unconformable along the crest of the Newport-Inglewood uplift. Throughout the extent of the 200-foot sand within the Tor-rance-Inglewood subarea, the base of this sand is presumed to represent the base of the unnamed upper Pleistocene deposits and the top of the San Pedro formation (pis. 3A, B, C, and 5).
The twelve higher terraces of the Palos Verdes Hills are, at least in part, correlatives of the unnamed upper Pleistocene deposits; this fact indicates that locally, if not regionally, deformation was occurring in the interval during which they were being deposited. Possibly this deformation is reflected in the coarse deposits assigned to the lower part of the unnamed deposits.

SAN PEDRO FORMATION
DEFINITION

For the ground-water investigation of the adjacent Long Beach-Santa Ana area, the San Pedro formation of early Pleistocene age has been defined (Poland, Piper, and others, 1956, p. 60-62) as that stratigraphic unit underlying the unnamed upper Pleistocene deposits (just described) and overlying the Pico formation of late Pliocene

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age. It has been discriminated for that area partly from outcrops but mostly by data from water and oil wells drillers' logs, electric logs, samples taken during drilling, and fauna! studies. By similar methods of correlation, the San Pedro formation has been traced over most of the Torrance-Santa Monica area.
The San Pedro formation is considered to be essentially correlative with (but much thicker and more heterogeneous) the type San Pedro sand, Timms Point silt, and Lomita marl as defined by Woodring and others (1946, p. 43-53). However, it doubtless includes some younger strata; and it may include some which are older than any exposed in the type section just cited. Owing to the heterogeneous materials of this unit, the nonlithologic designation "San Pedro formation" is preferred to "San Pedro sand." The Timms Point silt and the Lomita marl are treated as the two basal members of the formation.
As here defined, the San Pedro formation embraces all strata of early Pleistocene age. In most of the Torrance-Santa Monica area, the San Pedro formation occurs between the unnamed upper Pleistocene deposits above and the Pico formation below. However, in the northern and southern parts of the area shown on plate 2, major unconformities occur at both its top and its base so that locally it underlies the Palos Verdes sand of late Pleistocene age and rests on rocks as old as upper Miocene (p. 56).
For the stratigraphic units with which the San Pedro formation of this report is correlative the San Pedro sand, the Timms Point silt, and the Lomita marl of Woodring and others the type exposures occur low on the east flank of the Palos Verdes Hills in and near San Pedro the extreme southern part of the area shown on plate 2.
In the type area, the San Pedro sand is made up largely of stratified and crossbedded sand, but it includes some beds of fine gravel, silty sand, and silt. Its component particles are derived chiefly from some distant area of granitic rocks; however, according to Woodring, some of the gravel beds contain pebbles of limestone, siliceous shale, and schist, which are assumed to have been derived locally from the Palos Verdes Hills. In that same area, two local stratigraphic units of early Pleistocene age underlie the San Pedro sand of Woodring; in downward succession they are the Timms Point silt and the Lomita marl. The Timms Point silt of the type area is composed of brownish to yellowish sandy silt and silty sand. Its type outcrop at Timms Point has been described by Clark (1931, p. 25-42). The underlying Lomita marl consists chiefly of marl and calcareous sand.
The type locality of the Lomita marl is near Lomita quarry, about a mile southwest of Lomita. Foraminifera from the Lomita marl at the quarry have been described by Galloway and Wissler (1927).

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Woodring ranks the Timms Point silt and Lomita marl as formations. However, because they cannot now be traced as distinct units to the north of the Palos Verdes Hills, for purposes of this report they are treated as the basal members of the San Pedro formation, as was done in the report on the geology of the Long Beach-Santa Ana area. Woodring reports that in the San Pedro area the greatest exposed thickness of the San Pedro sand is about 175 feet, of the Timms Point silt about 80 feet, and of the Lomita marl about 70 feet. He estimates that these three lower Pleistocene units where concealed in that same area, have a maximum thickness of about 600 feet.

REPRESENTATIVE EXPOSED SECTIONS

For the northeast flank of the Palos Verdes Hills, Woodring (1946, p. 45-53) has described a number of exposed sections of the San Pedro sand, the Timms Point silt, and the Lomita marl. Details will not be repeated here. However, one of the best exposures of the San Pedro sand is about 2,000 feet west of Narbonne Avenue, in 4/14-35E, at the Sidebotham sand pits nos. 1 and 2. Here the Lomita marl is absent, and the San Pedro sand rests directly on the Malaga mud-stone member of the Monterey formation. The no. 1 pit exposes about 100 feet of sand and interbedded layers and lenses of gravel dipping gently northward. The sand is gray or reddish-brown and includes thin crossbedded units. Its aspect, as shown in a photograph in the recent report by Woodring and others (1946, pi. 19, p. 58), is typical of that observed in exposures in the Baldwin Hills, described beyond, and at Huntington Beach Mesa in the Long Beach-Santa Ana area. In other pits or ravines farther west, along the north border of the hills, the character of the sand and gravel of the type San Pedro sand does not differ significantly from the exposures just described; the Palos Verdes sand was found unconformably overlying the San Pedro in several of these ravines. As exposed in the several gravel pits along the north edge of the Palos Verdes Hills, the San Pedro sand appears to be highly permeable.
In addition to the exposures of the San Pedro formation just described, the only other known outcrops of this formation within the Torrance-Santa Monica area are in the Baldwin Hills and along the Ballona escarpment.
About 40 feet of the San Pedro formation is exposed in the northern part of the Baldwin Hills, in a sand pit on the east side of Moynier Lane about 250 feet southeast of well 2/14-8C1. The lower part of this section comprises about 25 feet of light-buff massive well-sorted fine granitic sand; this is overlain by about 15 feet of white medium sand, which contains pebbles as large as 1 inch in diameter near the top.

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An exposure in another sand pit, about 1,000 feet south of the locality just described but on the west side of Moynier Lane, consists of about 45 feet of silty sand, sand, and gravel. In upward sequence, it comprises: 10 feet of interbedded sand and sandy gravel, with pebbles largely of metamorphic rocks and some granite; 4 feet of coarse loose sand; a 4-inch bed of dark reddish-brown fine sandstone; 6 feet of well-sorted fine loose sand; and at the top of the exposure, 25 feet of massive fine silty sand containing a few layers of scattered pebbles as much as 3 inches in diameter.
In the middle of 2/14-18, at the west border of the Baldwin Hills, about 50 feet of the San Pedro formation is exposed in a gravel pit about 400 feet east of the junction of Overland Avenue and Playa Street. The lower 20 feet of this section consists of light-gray coarse-grained loose crossbedded sand; this is overlain by about 30 feet of light-brown medium- to coarse-grained loose sand with scattered streaks of gravel from 1 to 2 inches thick, which contains pebbles of quartz, metamorphic rocks, and granite as much as 1 inch in diameter. The upper 6 feet of this sand is weathered to a reddish-brown sandy soil.

FAUNAL DATA FBOM OUTCROPS AND WELLS

In regard to the San Pedro formation as it occurs within the Tor-rance-Santa Monica area, faunal studies have been confined to sub-surface samples except for the type outcrops in the PaJos Verdes Hills, which have been studied by Woodring and his associates (1946, p. 43-53) and by several other investigators. (For references, see Poland, Piper, and others, 1956, p. 64.)
For this report, as in the report on geology of the Long Beach-Santa Ana area the nomenclature and faunal divisions employed by S. G. Wissler (1943) are usually accepted in order to develop the most uniform correlation of Pleistocene and Pliocene strata.
During the drilling of well 4/13-15A11, near the intersection of Alameda and Carson Streets in Dominguez Gap, samples were col-lected at 10-foot intervals by Paul Karnes of the Roscoe Moss Co. These samples were examined by S. G. Wissler for faunal correlation. From foraminiferal determinations, Wissler (oral communication, January 7, 1947) reported the first good San Pedro fauna at 690 feet below the land surface and suggested from fragmentary data that the top of the San Pedro formation might be as high as 450 feet. On the basis of lithologic correlation, the top is here taken at 415 feet below the land surface, at the base of a bed of sand and gravel 65 feet thick, which is inferred to represent a coarse southeasterly correlative of the "200-foot sand" in the unnamed upper Pleistocene deposits already described. The strata from 415 feet to the total depth of 1,040 feet

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are assigned to the San Pedro formation. From logs of nearby wells, it is believed that this part of the San Pedro formation is about 800 feet thick and that its base is about 1,200 feet below land surface (pl.2).
Core samples from well 3/14-10G2, which was drilled for the city of Inglewood (well 30) about 1 mile northeast of Hawthorne, were made available by the Kalco Drilling Co. and were examined by Wissler and Natland for faunal correlation. Both men were in agreement (Wissler, S. G., oral communication, January 7, 1947; Natland, M. L., oral communication, January 9, 1947) that a fauna essentially equivalent to that associated with the Timms Point silt and the Lomita marl is present from 564 to 825 feet below the land surface at this well. Wissler inferred that the base of the San Pedro formation is just below the deepest core obtained, which was at 825 feet below the surface. The base of the Silverado water-bearing zone is 710 feet below the land surface at this well.
Samples from well 3/14-29D3 (well 11 of the city of Manhattan Beach) were also examined for faunal correlation by Wissler (oral communication). He reported that the base of the San Pedro forma-tion, placed by the Geological Survey at 431 feet below land surface, essentially agrees with the position indicated by the megafossils found in the samples.
Samples were collected at about 10-foot intervals during the drilling of a test well for the Richfield Oil Corp. about 2 miles east of El Segundo (well 3/14-8N3, Richfield Leuzinger No. 1). Wissler examined these samples and placed the base of the San Pedro forma-tion at about 790 feet below the land surface. A megafossil zone, which occurred from 180 to 240 feet below the surface is inferred to mark the top of the San Pedro formation. The base of the Silverado water-bearing zone here is about 440 feet below the land surface; and fine-grained silt and clay containing Timms Point-Lomita fauna extend some 350 feet below the base of the Silverado water-bearing
zone.

From paleontologic examination of ditch samples from oil wells drilled near the crest of Dominguez Hill, Wissler concluded that the San Pedro formation was reached from 175 to about 670 feet below land surface (1943, p. 212).
In regard to the Rosecrans Hills, Wissler based his determination on paleontologic evidence from an oil well in 3/13-19A (about half a mile west of the crest of the Newport-Inglewood uplift) Wissler (written communication) assigned the deposits from 210 to 570 feet below land surface to the San Pedro formation.
Additional data on depth and thickness of the San Pedro formation obtained from other oil fields are shown graphically on plate 7 as

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diagrammatic columnar sections. In certain fields, particularly in the Potrero oil field, the base of the San Pedro formation is estimated by Wissler to be somewhat lower than is shown by the contacts on the geologic sections (pi. 3A, C] and by the contours on the geologic map (pi. 2). In such areas, it is probable that the fine-grained deposits underlying the water-bearing zones represent a basal interval con-taining the Timms Point-Lomita fauna.
Water-bearing deposits that contain a similar faunal assemblage as much as several hundred feet thick have been deposited extensively to the north and northeast of Signal Hill in the Long Beach area (Poland, Piper, and others, 1956, p. 67).
From the evidence just presented, it is apparent that, at least locally within and near the west basin, deposits of impermeable silt and clay underlie the Silverado water-bearing zone and contain a Timms Point-Lomita fauna; therefore these deposits are a basal part of the San Pedro formation. Thus, the contours on the base of the water-bearing zones of Pleistocene age shown on plate 2 do not every-where represent the base of the San Pedro formation. However, the contours on plate 2 are believed not only to depict with fair accuracy the base of these water-bearing beds of the San Pedro formation but also, for most of the area, to represent generalized structure contours on the base of the deposits of Pleistocene age.

THICKNESS

The thickness of the San Pedro formation varies greatly within the Torrance-Santa Monica area, largely because deformation and erosion have been active since its deposition. The formation has been up-turned and beveled by erosion at the outcrop along the north border of the Palos Verdes Hills (pis. 2, and 35, (7). Along the south flank of the Santa Monica Mountains the San Pedro formation doubtless is also upturned and beveled, but there it is capped by upper Pleistocene and Recent terrace and alluvial deposits and is not exposed at the land surface. In the Baldwin Hills, the San Pedro formation is domed upward and broken by faults and is at or near the surface over more than half the total area of the hills, as shown on plates 2 and ZA. The San Pedro is folded into an anticline and faulted over the crest of the Newport-Ingle wood uplift southeast of the Baldwin Hills; it does not crop out on the Rosecrans and Dominguez Hills.
The general range in thickness of the San Pedro formation is shown on the several geologic sections. In the west basin it attains a thick-ness of about 800 feet in the synclinal trough beneath Dominguez Gap, near the intersection of Carson and Alameda Streets. It may have a greater thickness, possibly 900 feet, in the sharp syncline beneath the inner harbor in Wilmington (pi. 2). To the northwest

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its greatest thickness is in the synclinal trough extending past Ingle-wood to Ballona Gap, but it decreases gradually in thickness to about 500 feet at Gardena, to 400 feet west of Inglewood, and to 300 feet beneath Ballona Gap. Thicknesses along the crest of the uplift and along the coast are shown by geologic sections on plate 3(7. Except within the Baldwin Hills and the Palos Verdes Hills, where the forma-tion has been partly or completely removed by erosion, it is thinnest along the coast near El Segundo (about 100 feet) and along the New-port-Inglewood uplift crest beneath Ballona Gap (about 50 feet, pi. 3D).
Inland from the Newport-Inglewood uplift, its greatest thickness is in the synclinal trough that trends northwest through Huntington Park and terminates beneath Ballona Gap at the north flank of the Baldwin Hills (pi. 2). Beneath Huntington Park the thickness of the San Pedro formation may be as much as 1,500 feet (pi. 4); farther southeast toward Orange County and beyond the extent shown on plate 2, it is about 3,000 feet thick.
Contours drawn on plate 2 show the altitude of the base of the water-bearing zones of Pleistocene age. It has already been pointed out (p. 44) that for the treatment in this report the base of the San Pedro formation is assumed to be at the base of these water-bearing zones, although, from faunal evidence, locally the base of the San Pedro is somewhat lower. As shown by these contours, the approximate base of the San Pedro formation is lowest at Wilmington and at the intersection of Carson and Alameda Street about a mile south of Dominguez Hill; at these places it is about 1,200 feet below sea level. Along the crest of the Newport-Inglewood zone it rises to about 400 feet below sea level at Dominguez Hill, less than 100 feet below sea level in the middle of the Rosecrans Hills, and to 400 feet above sea level in the Baldwin Hills, where in places it intersects the land surface.

PHYSICAL CHARACTER AND WATER-BEARING PROPERTIES

General features. Study of data from well logs shows that the San Pedro formation underlies most of the Torrance-Santa Monica area south of the Santa Monica plain, except where older rocks are exposed on the Baldwin Hills and the Palos Verdes Hills. For much of the area north of Ballona Gap (beneath the Santa Monica plain) the deposits of Pleistocene age cannot be divided on the basis of data now available, and the northward limits of the San Pedro formation are not known.
As shown on the geologic sections (pis. 3-5), along the northern border of the Palos Verdes Hills from Redondo Beach to Wilmington, the San Pedro formation is composed almost entirely of sand and gravel. To the north and east, the formation contains extensive beds

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of silt and clay. Within the Torrance-Inglewood subarea, these impelmeable beds commonly are in the upper part of the formation and hence overlie and confine the Silverado water-bearing zone. Northward beneath Ballona Gap, west of the Baldwin Hills, the San Pedro formation is mostly sand with some gravel. Locally, however, it includes thick interbeds of silt.
Northeast of the Newport-Inglewood uplift, in the main coastal basin, the San Pedro formation cannot be subdivided into an upper part of clay and silt and a lower part of sand and gravel. Instead, it becomes heterogeneous in character and the water-bearing beds inter-finger irregularly with layers of silt and clay.
Along the central part of the synclinal trough, from Inglewood to and beyond Gardena, the silt and clay beds within the San Pedro formation separate the coarser water-bearing deposits into two distinct aquifers (pi. 35). The upper of these two aquifers wedges out along both limbs of this syncline. The lower can be traced beneath nearly all the area from El Segundo and Inglewood southeast to the Palos Verdes Hills and Long Beach. It is the major aquifer within the west basin and has been named the Silverado water-bearing zone. These two water-bearing zones are described in considerable detail in the following paragraphs.
"'Four-hundred-foot gravel" From study of well logs on a peg model, correlated with the position of the water level, a distinct water-bearing zone in the upper part of the San Pedro formation has been located in the synclinal trough southwest of the Newport-Inglewood uplift. This water-bearing zone is well defined from Inglewood southeast to about 3 miles beyond Gardena a total distance of about 10 miles. Where best developed, it is characteristically composed of gravel or of sand and gravel, and its base is about 400 feet below land surface along the axis of the syncline (pi. 35); accordingly, it has been designated the "400-foot gravel" for purposes of this report. Along the synclinal axis the thickness ranges from 20 to 120 feet. To the west and east of the axis it feathers out against the two limbs of the syncline. The limits of the "400-foot gravel" cannot be precisely defined because weJl logs suggest that locaUy it merges with the Silverado water-bearing zone, especially southwest of Gardena. However, the approximate extent of the "400-foot gravel" has been shown on figure 2. As shown there, it is about 10.5 miles long, about 2 miles wide, and underlies approximately 20 square miles. Beyond its southeastern limit as shown on the illustration, and extending along the synclinal trough to Dominguez Gap, a deposit of fine sand of irregular thickness is shown in logs of many wells; this deposit of fine sand possibly represents the stratigraphic extension of the "400-

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foot gravel". Doubtless the fine sand has general hydraulic con-tinuity with the "400-foot gravel."
Along the axis of the syncline (pi. 3-B) the "400-foot gravel" com-monly is overlain and underlain by impermeable layers of silt and clay from 50 to 180 feet thick and thus is physically and hydraulically separated from the "200-foot sand" above and the Silverado water-bearing zone beneath.
The "400-foot gravel" does not crop out at the land surface and so is known only from its occurrence as shown by well logs. Repre-sentative logs are given in table 28. (See logs for wells 2/14-28L1 3/13-30A2, 3/14-4N2, 10G1, and 22A1.) It is tapped by several wells of the city of Inglewood, and by three wells of the Southern California Water Co. (3/14-lOCl, 22A1, and 23L1); also by many privately owned irrigation wells.
The yield is known for only two wells that tap the "400-foot gravel." Well 3/14-lOCl has a reported yield of 500 gpm; tests show that well 3/14-23L1 yielded 600 gpm with a drawdown of 51 feet, giving a specific capacity of about 12 gpm per foot of drawdown. This water-bearing zone is less than 50 feet thick as tapped in these two wells; thus the peimeability is inferred to be relatively high, and about the same as that of the underlying Silverado water-bearing zone.
The "400-foot gravel" is entirely a confined aquifer and contains water under artesian pressure. As shown by the hydrograph for well 3/14-23L1 (fig. 5), the water level in this gravel near Gardena in 1945 was only a few feet above the pressure level in the Silverado water-bearing zone beneath. Because under native conditions recharge to the "400-foot gravel" presumably was chiefly through its marginal hydraulic contact with the Silverado water-bearing zone, the current head differential would indicate that the "400-foot gravel" now is receiving little recharge.
Silverado water-bearing zone. In an earlier report (Poland, Piper, and others, 1956, p. 69) the name "Silverado water-bearing zone" was assigned to the most extensive of the Pleistocene aquifers of the Long Beach-Santa Ana area. The informal term Silverado water-bearing zone is not to be confused with the formal term Silverado formation (of Woodring and Popenoe, 1945) of Paleocene age of the Santa Ana Mountains, Orange County. The Silverado water-bearing zone was named for its typical occurrence in well 4/13-23G2 in Silverado Park within the city of Long Beach; the log is given in table 28. At this well the Silverado water-bearing zone is represented by 478 feet of sand and gravel from 596 to 1,074 feet below land surface. From data on other wells in the vicinity, the base of the Silverado water-bearing zone at this well is considered to be about 1,100 feet below land surface, .and the full thickness to be about 500 feet (pi. 2 and fig. 2). The

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upper 300 feet of the zone is highly permeable clean sand and gravel; the lower 200 feet is chiefly coarse sand.
The Silverado water-bearing zone underlies most of the Torrance-Inglewood subarea and extends inland about 2 miles beyond the crest of the Newport-Inglewood uplift. Its known extent and thickness within the area treated in this report are shown on figure 2. As de-limited on that illustration, it underlies about 140 square miles and also extends southeastward about 6 miles beyond the east margin shown on figure 2, almost to the Orange County line as shown in an earlier report (Poland, Piper, and others, 1956, pi. 8). Its over-all extent within Los Angeles County is about 165 square miles. Figure 2 shows the known range in the thickness of the Silverado water-bearing zone by means of isopachs (lines showing equal thick-ness) based on well-log information. Thus it is to be noted that the Silverado zone attains its greatest thickness (about 700 feet) near Bixby Slough in the Wilmington district. In general it is thinnest along the northern border of its known extent about 100 feet at the coast near El Segundo, and less than 50 feet in Centinela Park in Inglewood. Except for the inordinate thickening in the synclinal fore-deep immediately north of the Palos Verdes Hills, the average thick-ness of the Silverado water-bearing zone is about 200 feet.
The range in physical character of the Silverado zone from gravel to sand and gravel, and in places to sand, is well shown on geologic sec-tions, plates 3A-C and 5. Many of the logs included in table 28 are of wells that penetrate the Silverado water-bearing zone. Among those in which the material ascribed to the Silverado is most characteristic are weUs 3/13-28A1, 3/14^N2, 3/14-22A1, 3/15-13R2, and 4/14-13F1. These logs indicate that the water-bearing parts of the zone are pre-dominatly coarse sand and gravel; the maximum pebble diameter averages % to 1 inch, and reach a maximum of 2 inches (3/15-13R2, 4/14-13F1) and 4 inches (3/14-4N2). In the Torrance-Inglewood subarea interbedded layers of impervious silt, sandy clay, or clay within the Silverado zone locally reach a few tens of feet in aggregate thickness.
In most of the area between Long Beach and Redondo Beach the Silverado water-bearing zone is essentially a uniform mass of sand and gravel, with almost no interbedded clay or silt layers. It is chiefly gravel in the vicinity of "Wilmington but becomes finer westward to Redondo Beach and Hermosa Beach, where it is largely sand. The Silverado zone is the thickest and the most productive water-bearing unit in this southern reach.
In the vicinity of Gardena and Hawthorne, where it is about 200 feet thick, the Silverado zone usually consists of about half sand and half sand and gravel, and contains few layers of silt. At Manhattan

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'/>
Present known extent of Silverado
water-bearing zone

1
s/:
Approximate inland limit of Silverado

water-bearing zone '%

N

Protect boundary
4OO

Lines of equal thickness of the
Silverado water-bearing zone, in feet

2ZZXZ.
Area underlain by the
"400-foot gravel"

R.I3W.R.I2WJ

Trace of fault, dashed where approxi-
mately located; dotted where concealed

5 Miles

Approximate location of ground-water
barrier not related to known fault

FIGURE 2. Map showing extent and thickness of the Silverado water-bearing zone witflM the Torrance-Sauta Monica area.

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Beach, as tapped by the municipal wells west of Sepulveda Boulevard in 3/15-25A, the Silverado zone is irregular, but in most wells it in-cludes one layer of sand and gravel about 50 feet thick, with a thinner layer below (pi. 4). To the north, near El Segundo, in sec. 13, T. 3 S., R. 15 W., logs of wells show that the Silverado zone is about 230 feet thick and contains from 2 to 4 layers of gravel separated by bodies of silt or clay (pi. 3(7).
The Silverado water-bearing zone is tapped by many of the wells of the city of Inglewood. It is thickest (230 feet) in well 3/14-10G1 (Inglewood well 28), northeast of Hawthorne. Near the center of Inglewood, at well 2/14-28M1 (Inglewood well 26), it is only 45 feet thick. Within the Inglewood area, however, the zone is almost entirely gravel or sand and gravel and is moderately permeable.
Few water or oil wells have been drilled in the northern part of the Torrance-Inglewood subarea (an area about 5 miles long and 2 miles wide, parallel to and just south of the Ballona escarpment). Logs are not available for this area to show if the Silverado water-bearing zone is stratigraphically and hydraulically continuous with the thick water-bearing zone of the San Pedro formation beneath Ballona Gap. How-ever, because of the general similarity in physical character and com-mon position in the lower part of the San Pedro formation, it is inferred that the water-bearing zone in the San Pedro beneath the gap is correlative to the Silverado zone to the south and that the two zones have hydraulic continuity.2
Beneath the coastal 4-mile segment of Ballona Gap, most of the San Pedro formation is composed of permeable sand and gravel (pi. 3Z>). Farther inland, beyond the Inglewood fault at the Sentney plant of the Southern California Water Co., in the NW# sec. 5, T. 2 S., R. 14 W., the San Pedro formation contains three distinct aquifers separated by impervious layers of silt or clay (2/14-5D6, table 28); the lower two aquifers probably are stratigraphic equivalents of the Silverado water-bearing zone.
Inland, beyond the crest of the Newport-Inglewood uplift, the Silverado water-bearing zone and the whole San Pedro formation interfinger into more silty and clayey types of beds. This change from coarser to finer sediments involves a transition from shallow-water marine and littoral deposits to nonmarine deposits.
' Since the present report was released to the open file (1948), the California Division of Water Resources has completed its investigation (draft of report of referee, 1952). Additional information obtained in the State's investigation confirms the stratigraphic and hydraulic continuity of the Silverado water-bearing zone in the Torrance-Inglewood subarea with the thick water-bearing zone of the San Pedro formation beneath Ballona Gap. Hence, plate 6 of the State's report shows that the Silverado water-bearing zone extends north to and underlies the Ballona Gap.

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The Geological Survey has made a laboratory examination of samples collected during the drilling of two deep wells within the west basin. Detailed descriptions of the material in these wells is presented in table 28 (3/14-29D3 and 4/13-15All). The lithologic character of the material in these wells, which has been ascribed to the Silverado water-bearing zone, may be summarized as follows: Relatively clean fine to coarse gray arkosic sand, which is moderately well sorted, with particles subangular to subrounded; and clean gravel consisting of subrounded to rounded fragments of granitic and metamorphic rocks as much as 2 inches in diameter. A variation from fine sand to coarse gravel is usually represented in beds within the zone; the gravel is predominant in the basal part.
As discussed previously (Poland, Piper, and others, 1956, p. 78-84) r the San Pedro formation is thought to have been formed by streams, which carried rock debris from an inland uplifted source across a coastal plain and deposited the material as coastal deltas. These deltas were continuously reworked by strong longshore currents. Throughout much of early San Pedro time, the shoreline maintained a position about 3 miles northeast and nearly parallel to the Newport-Inglewood uplift; that shoreline extended southeastward from the east edge of the Baldwin Hills through what is now the city of Comp-ton. The Silverado zone was deposited seaward from the shoreline, chiefly as beach and shallow marine deposits.
The Silverado water-bearing zone is by far the most important aquifer in the Torrance-Inglewood subarea. In 1945 the Silverado zone was the source of water for essentially all the withdrawals by industries; essentially all the withdrawals by the municipal well fields of Hawthorne, El Segundo, Manhattan Beach, and Torrance, and about one-third of the withdrawal by the well fields of the city of Inglewood within the west basin; nearly all the withdrawals by the larger water companies, and at least half the withdrawals by private irrigators and by the smaller water companies. Of the total with-drawal from the Torrance-Inglewood subarea in 1945 some 78,000 acre-feet about 68,000 acre-feet, or about 87 percent, was taken from the Silverado water-bearing zone (p. 110).
Wells tapping the Silverado water-bearing zone in the Torrance-Inglewood subarea range in tested capacity from a few hundred to as much as 4,000 gpm. For the area immediately west of Long Beach in T. 4 S., R. 13 W., the yield characteristics have been given in another report (Poland, 1959). Table 5 shows the yield characteristics of 39 wells that draw water solely from the Silverado zone within the Torrance-Santa Monica area (fig. 2).

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TABLE 5. Yield characteristics of 39 wells tapping the Silverado water-bearing zone in the Torrance-Santa Monica area

Well

2/14-34C1 .. ..
3/14-1B2 .. -
1F1- .
IGI..-. -
9N4. _
10G1 ______ _

13B1 ._
13J3.
19C1....... - _ -
21B2.__ ... ...
29D3- _

29G1. ____ .. _
30A2.... .
30D1.. ____ .

3/15-12B1......... .... -
13H2____ _
13J1 _________ - --
13R2.... ...
13R4 ___

13R5__ __ ....
13R6- -
25A3 ..- - _ -

4/13-16A11....
21H5 _______ -. .-
27M3
30G2. _
31E4- __ ____ ... -.

4/13-31P1 _ .-..-. .
33D1 ____ .... __ ......

4/14-1H2 _ _ - .
1H3..... ...
8C1. -_.
17N1____ ...
22D1 _ .

4/14-22D2.. .. __ ..
23N2....
35J1 . ...
36H1. __ ....

S/13-6D2. ____ . _______

Depth
(feet)

450
390
350
598
670
798

800
620
400
527
520

570
525
350

400
456
400
480
440

504
495
350

1,054
731
946
695
680

900
888

596
596
518
400
404

390
640
500
610

990

580

Water-yielding
zone or zones

Depth
range
(feet)

264-362
184-282
165-339
220-290
300-402
492-711

273-543
359-602
221-268
310-468
190-431

173-350
187-297
225-255

185-240
352-425
181-373
339-460
366-407

'284-456
275-410
222-295

765-990
440-731
266-800
216-492
230-655

675-822
669-800

475-538
418-547

1(56-510
206-394
206-404

212-390
486-640
180-500
152-610

735-842

Thick-

ness

(feet)

98
98
174
61
76
118

161
129
28
158
112

177
110
30

55
73
123
121
41

56
103
54

235
291
534
276
425

147
131

45
70
344
188
198

178
154
320
458

107

160

Yield characteristics

Yield

(gallons
per
minute)

700
508
1,240
512
1,050
600

675
700
800
433
600

1,800
1,125
905

680
1,000
850
860
560

1,000
900
615

2,000
1,450
3,000
2,900
4,000

1,650
2,500

810
1,375
1,500
640
375

215
945
1,300
1,340

1,470

1,169

Draw-
down

(feet)

70
16
12
21
50
17

30
20
50
3
25

28
55
54

54
20
32
13
16

34
50
36

14.5
5
12
28
10

28
19

29
33
13
7
6

2
13
19
15

32

25

Specific
capacity1

10
32
103
24
21
35

23
35
16
144
24

64
20
17

12.6
50
27
66
35

29
18
17

138
290
250
104
400

59
131

28
42
115
91
63

108
73
68
89

46

75

Yield
factor 3

10
33
59
40
28
30

14
27
57
91
21

36
19
56

23
69
22
55
85

52
17.5
32

59
100
47
38
94

40
100

62
60
33
48
32

61
47
21
19

43

46

1 Gallons per minute per foot of drawdown.

2 Yield factor^ Specie capacity X 100
neiaiacior Tnlckness of aquiferi in feet

NOTE. In tables 5 and 6, specific capacity (relation of drawdown to discharge) is used as the convenient scale for the water-yielding capacity of a well and for the relative transmissibnity of the water-bearing zone at the place. In addition, specific capacity has been divided by thickness of water-bearing material yielding water to the well, and the quotient so obtained has been multiplied by 100 for convenience in expression. The result has been termed the "yield factor." The yield factor here is introduced as an approximate rela-tive measure for the permeability of the water-bearing material tapped by a well. Specific capacity and yield factor both involve drawdown, which (as measured in a well) is due to two increments of head loss:
(1) that incident to movement of water toward the well through material of a certain average permeability and (2) that incident to entrance of water into the well casing. Thus, both specific capacity and yield factor depend not only on the characteristics of the water-bearin? material tapped but also on the number, size, and condition of perforations in the casing and their distribution within the water-bearing zones tapped.

GEOLOGIC FORMATIONS WATER-BEARING CHARACTER 53

The 39 wells listed in table 5 show averages as follows: Yield 1,169 gpm, drawdown 25 feet, specific capacity 75 gpm per foot of draw-down, and yield factor 46 (specific capacity X100 divided by the thick-ness of aquifer, in feet). Within the Torrance-Inglewood subarea, table 5 shows no significant difference in yield factor for wells in the several townships, which indicates that although the thickness of the Silverado zone is more than twice as great between Long Beach and Redondo Beach as in the area north of Gardena, the permeability is essentially the same throughout its known extent in the west basin. The permeability is a measure of the ability of a material to trans-mit water. It may be expressed as a field coefficient of permeability, expressed as the number of gallons of water per day that percolates through each mile of the water-bearing bed (measured at right angles to the direction of flow) for each foot of thickness of the bed and for each foot per mile of hydraulic gradient (Wenzel, 1942, p. 7).
Within the west basin the permeability of the Silverado water-bearing zone was determined from a pumping test near Bixby Slough, in sec. 31, T. 4 S., R. 13 W. This pumping test was made chiefly to determine whether a barrier to ground-water movement existed between the weUs of the Union Oil Co. (wells 4/13-31P1 and 5/13-6D2) and nearby wells at (1) the Lomita plant, city of Los Angeles, in 4/13-31E, and (2) the Palos Verdes Water Co., in 4/14-36H (pi. 2)., The conclusions with respect to a hydraulic barrier are described elsewhere (p. 139 and fig. 8). The data also afforded an opportunity ,

to determine transmissibility 3 and permeability. r' On September 28, 1946, the pumps at the Lomita plant were idle
and had been shut down for several days previously. The wells of the Union Oil Co. had been pumped continuously for several months before the test, and the wells of the Palos Verdes Water Co. had been operated intermittently. During the day, wells 4/13-31P1 and 5/13-' 6D2 (Union Oil Co.) and well 4/14-36H1 (Palos Verdes Water Co., well 1) were pumped intermittently on an alternating schedule (fig.
8) and water-level measurements were made at about 10-minute intervals from 10:00 a. m. to 9:00 p. m. at wells 4/13-31E4, 4/13-31P1, and 4/14-36H1. The fluctuation of water level in these wells is shown on figure 8. Between 12:10 and 4:10 p. m., the water level in well 31E4 recovered along a uniform curve, as a result of the shut-down of the pumps in the Union Oil Co. wells from noon to 4:00 p. m. From 4:10 to 7:10 p. m., the water level in well 31E4 declined concur-rently with pumping of the Union Oil Co. wells. The tune-drawdown. graph for .well 31E4 was utilized to compute transmissibility in ac-3 Transmissibility is expressed as the field coeffleient of permeability multiplied by the thickness of th«- saturated part of the aquifer in feet,

46050& 59 5

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cordance with a procedure described by Cooper and Jacob (1946). The transmissibility was determined by use of the equation

As

where Tis transmissibility in gpd per foot, Q is discharge of the pumped well in gallons per minute, and As is the change in drawndown in an observation well over one logarithmic cycle (drawdown plotted against time on semilogarithmic paper, with time on the logarithmic scale). During the test the average joint discharge from the Union Oil Co. wells was about 2,150 gpm and the change in drawdown in well 31E4 was about 0.97 foot during one logarithmic cycle Thus, the indicated transmissibility is about 600,000 gpd per foot. The thickness of the water-bearing deposits tapped at well 31E4 is 425 feet, indicating a permeability of about 1,400 gpd per square foot.
The transmissibility and permeability of the Silverado water-bearing zone in the reach between Wilmington and Torrance were determined from the fluctuation of pressure level in well 4/14-13F1, near Torrance, during the pumping of wells 4/13-30G1 and 4/13-30K1 (city of Los Angeles, Lomita plant wells 6 and 7), 12,000 feet to the southeast, in Wilmington. The hydrograph for well 4/14-13F1 and the draft at the Lomita plant are shown elsewhere on figure 6. A time-drawdown graph was constructed as described for the pumping test of the Union Oil Co. wells near Bixby Slough. The average joint rate of discharge from wells 4/13-30G1 and 4/13-30K1 from April 19 to May 2, 1944, was 4,340 gpm. The change in drawdown in well 4/14-13F1 was about 1.41 feet during one logarithmic cycle. Thus, utilizing the equation for obtaining transmissibility given in the preceding paragraph, the indicated transmissibility is about 813,000 gpd per foot. The average thickness of the Silverado water-bearing zone between the pumped wells and observation well 4/14-13F1 is about 400 feet, indicating a permeability of about 2,000 gpd per square foot. This test is considered to furnish a more accurate and more representative value for the permeability of the Silverado water-bearing zone between Torrance and Long Beach than the test at Bixby Slough, because the latter pumping test was made in an area where physical texture, thickness, and permeability of the Silverado water-bearing zone are believed to change between the pumped wells and the observation well whereas between Wilmington and Torrance the physical character and thickness are reasonably uniform. Also, the Silverado water-bearing zone wedges out on the flank of the Palos Verdes Hills about 4,000 feet southwest of the Union Oil Co. wells and about 10,000 feet southwest of wells 4/13-30G1 and 4/13-30K1. Thus, for the pumping test at the Union Oil Co. wells, the cone of

GEOLOGIC FORMATIONS WATER-BEARING CHARACTER 55

pressure relief must have extended rapidly to the non-water-bearing rocks, resulting in distortion during subsequent growth of the coneV On the other hand, the cone surrounding wells 4/13-30G1 and 4/13- 30K1 would reach well 4/14-13F1 about as soon as it impinged upon the non-water-bearing rocks and the distortion would have little if any effect on drawdown in well 4/14-13F1, which is about 3.4 miles, distant from the south boundary of the basin.

At the Centinela Park well field of the city of Inglewood the permea-bility of the water-bearing beds of the San Pedro formation beds essentially correlative to the Silverado water-bearing zone has been determined from the fluctuation in observation well 2/14-27D1 (city of Inglewood, well 7) during the pumping of well 2/14-22N2 (city of Inglewood, well 9). The hydrograph for well 2/14-27D1 is shown on figure 7. Utilizing the time-drawdown graph and applying the for-! mula of Cooper and Jacob (p. 54), the transmissibility has been estimated at about 55,000 gpd per foot. The saturated thickness of water-bearing beds was about 50 feet at the time of the test. Thus, the permeability here is about 1,100 gpd per square foot.
For the extent of the water-bearing zones of the San Pedro forma-tion in and near the Ballona Gap zones correlative with the Silverado1 water-bearing zone in age and physical character table 6 gives the yield characteristics of eight wells.

TABLE 6. Yield characteristics of eight wells tapping the San Pedro formation in. the vicinity of Ballona Gap

Well

2/14-4N1 _. _
7P2... ._.-... .-...---.-.
23H2_______-_ .____ -

2/15-11D2.. . ...
11E3-... .
11E5.... - ...
11F4..... ....
34K1-. --.... - ... .

Depth
(feet)

300
265
827

480
405
452
380
208

415

Water-yielding
zone or zones

Depth
range
(feet)

118-219
112-187
449-796

198-340
196-376
217-430
168-346
91-133

Thick-

ness

(feet)

66
18
136

114
169
181
176
42

113

Yield characteristics . ' '

Yield
(gallons
per min-
ute)

1,010
550
3,050

345
1,125
1,155
1,805
355

1,174

Draw-
down

(feet)

31
75
40

24
17
36
32
21

35

Specific
capac-
ity"

33
7.3
76

14
66
32
56
17

38

Yield
factor 4 i

5O

4156-

12?
39
18
, 32
40

36

1 Gallons per minute per foot of drawdown.

Specific capacityX100 * Yield factor= Thickness of aquifer, in feet'

As shown by this table, the average yield of the 8 wells is 1,174 gpm, almost identical to the average yield for the 39 wells tapping-the Silverado water-bearing zone to the south. The yield factor for the 8 Wells is 36, as compared to a factor of 46 for the 39 wells of table-
5. Thus, it is concluded that the permeability of the water-bearing;

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beds in the San Pedro in the vicinity of Ballona Gap is somewhat lower than that of the Silverado water-bearing zone, probably about three-quarters as great.

STEATIGEAPHIC RELATIONS

The rocks overlying and underlying the San Pedro formation are separated from it by unconformities. The unnamed upper Pleistocene deposits apparently were laid down after some folding of the San Pedro formation had occurred along the Newport-Inglewood uplift, and are inferred to overlie the San Pedro unconformably at places along this uplift. Subsequent to their deposition, parts of these upper Pleistocene deposits and parts of the San Pedro formation were eroded during the development of the upper Pleistocene marine (Palos Verdes) surface. Therefore, the Palos Verdes sand, which was deposited on this surface, doubtless is locally unconformable on the unnamed upper Pleistocene deposits, and in some places, as at Signal Hill and at the intersection of Lincoln Boulevard and the Ballona escarpment, it rests directly on the San Pedro formation.
The Tertiary rocks underlying the San Pedro formation are reported by Woodring (1946, p. 109, and pi. 1) to be unconformable with it wherever the relations have been clearly exposed in the Palos Verdes Hills area. Here the Pico formatign of late Pliocene age is missing and the San Pedro formation rests in part on lower Pliocene and upper Miocene rocks.
Throughout the remainder of the Torrance-Santa Monica area, with the exception of the Baldwin Hills, the contact of the San Pedro formation with the underlying Tertiary rocks is concealed. Uncon-formities are more likely to be present along the Newport-Inglewood belt than beneath the Torrance or Downey plains. Structural activity along this zone, if it took place during or after the deposition of a group of rocks, could rarely avoid causing a break in the sedimentation and would be registered as an unconformity within that group or be-tween it and the overlying younger deposits. Wissler (oral communica-tion) believes that activity along the Newport-Inglewood belt began in early upper Miocene tune, and he infers (Wissler, 1943, p. 231) that there is an unconformity between the Pico and San Pedro formations in the t)ominguez and Rosecrans fields.
The Tertiary rocks (upper division of the Pico formation) in the Baldwin Hills area are exposed at several places and are cut by the main Inglewood fault into an eastern and a western block. Driver (1943, p. 308) states that "the Pleistocene is conformably deposited over the Pliocene in the western block, but is unconformable in the eastern block."

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During excavation for a storm drain, east of Culver City and one-third of a mile north of the Baldwin Hills, in 1936, Natland 4 found that the Tertiary strata were separated by an unconformity from the overlying sands of the San Pedro formation.

TERTIARY SYSTEM
PIJOCENE SERIES
GENERAL FEATURES

In most of the area shown on plate 2, strata of Tertiary age underlie the Quaternary rocks. They crop out at the surface only in the flanks of the Santa Monica Mountains and in the Baldwin and Palos Verdea Hills. These rocks consist chiefly of marine silt and sand, containing only local lenses of gravel.
The Pliocene series is subdivided on the basis of microfauna into two formations in the Los Angeles basin the Pico above and the Repetto below. The Pico formation, although absent from the geologic column in the Palos Verdes Hills, is present throughout the remainder of the Torrance-Santa Monica area and so is underlain by the Repetto formation.
The Pico formation has been divided by stratigraphers into upper, middle, and lower divisions on the basis of distinct microfaunal assemblages (Wissler, 1943, p. 212-213). For the purposes of the present investigation, a discussion of the upper division of the Pico formation and its water-bearing characteristics is pertinent, because the relatively permeable sand members in the lower part of the upper division generally contain essentially fresh ground water. In much of the area shown on plate 2, the base of the main fresh ground-water body is approximately at the base of the lowest of these upper Pico sand members (p. 86 and pi. 8).
Because permeable sand beds in the middle and lower divisions of the Pico formation within the project area contain only connate saline water, those divisions will be treated only briefly here; they are dis-cussed in detail in many reports on the petroleum geology of the Los Angeles basin.
PICO FORMATION, UPPER DIVISION

PHYSICAL CHABACTEB AND THICKNESS

The upper division of the Pico formation consists of semiconsoli-dated sand and micaceous silt and clay of marine origin. Locally, beds of fine gravel occur in the upper part of the division, presumably also of marine origin.
The upper division of the Pico formation underlies all the area shown on plate 2 except the south flanks of the Santa Monica Mountains «Natland, M. L., unpublished data from Shell Oil Co., 1936.

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and the northern border of the Palos Verdes Hills. The only known exposures of this upper division are in the northern sector of the Baldwin Hills, where they occur as buff siltstone and buff fine silty sand or sandstone with limonitic clayey partings and limonitic con-cretions. The exposures in these hills are not differentiated on plate 2 from the rocks of lower Pliocene and Miocene age.
Hoots (1931, p. 116) reported that the upper part of the Pliocene section which is exposed about 2 miles outside the west boundary of the area, in Potrero Canyon, "is equivalent to a part of the Pico forma-tion exposed at its type locality in Pico Canyon."
Along the Newport-Inglewood structural zone and in the west basin, the upper few hundred feet of the upper division is composed chiefly of silt and clay. Beneath the Baldwin Hills, according to Wis-sler (1943, p. 213), most of the entire upper division of the Pico is silt. To the north the character of the upper division of the Pico is not known. However, in almost all of the area south and southeast of the Baldwin Hills, the lower 600 to 1,000 feet of the upper division includes several beds of fine- to medium-grained sand and sandstone and, locally, beds of fine gravel. The geologic sections, plates 3A and 4 to 6, show the general disposition of these permeable zones as revealed in a few cored wells and as inferred from electric logs. These coarser beds commonly range from 25 to as much as 100 feet in thickness, and are separated by beds of massive micaceous siltstone. Thus, about 2.5 miles southeast of Dominguez Hill, well ,4/13-17Dl reached the upper division of the Pico from 683 to 1,701 feet below land surface (Poland, Piper, and others, 1956, p. 87, 143). In this well the sand occurs in 10 layers totaling 282 feet about 28 percent of the thickness. The casing of this well was never perforated, so neither the yield of the deposits nor the chemical character of the water is known.
Well 4/13-12A2 (city of Long Beach, North Long Beach weU 6), about a mile northeast of the Newport-Inglewood uplift and a mile east of the Los Angeles River, was drilled to a depth of 1,955 feet, cutting through about half the upper division from 726 feet to the bottom. (See log, table 28.) Within this depth interval, the drillers reported nine water-bearing beds, totaling about 240 feet, or about 20 percent of the top half of the upper division of the Pico, which consist of fine sand and fine gravel with some clay.
Well 3/14-17Jl, an oil-test hole about a mile southwest of Haw-thorne cut through the entire thickness of the upper division, begin-ning at about 500 feet below land surface. The electric log indicated fresh-water-bearing sand between 1,110 and 1,320 feet. Three other beds of sand, each about 50 feet thick, were reached in this well be-tween 1,750 and 2,100 feet, but these lower sand members, near the

GEOLOGIC FORMATIONS WATER-BEARING CHARACTER 59

base of the upper division, are inferred to contain brackish water (pi. 8). A pumping test, made to determine the productivity and the quality of the water in the sand member between 1,110 and 1,320 feet, is described on page 61.
Inland from the Newport-Ingle wood uplift, in the area northeast of Dominguez Hill, the deposits of the upper division of the Pico are not tapped by water wells, so far as known. However, electric logs and samples from a few oil-test holes on the Downey plain indicate that this section of the upper division of the Pico formation is almost entirely of marine origin and of the same general character as its west basin equivalent.
Within the area shown on plate 2, the upper division of the Pico formation ranges in thickness from 1,800 feet beneath Dominguez Gap at the southeast end of the Dominguez anticline to feather edges against the uplifts of the Santa Monica Mountains and the Palos Verdes Hills. As shown on plate 7, the thickness is about 1,000 feet at Playa del Key; 1,300 feet at the El Segundo oil field, and 1,100 feet at the Torrance oil field; about 900 feet at the Inglewood oilfield, in the Baldwin Hills; about 1,200 feet southeastward along the Newport-Ingle wood uplift at the Rosecrans oil field; 775 feet at the crest of Dominguez Hill, and 1,440 feet at the northwest end of the Long Beach oil field. Inland, beyond the area shown on plate 2, the upper division probably increases in thickness to much more than 2,000 feet beneath the central Downey plain.

STRATIGRAPHIC RELATIONS

At least locally, the upper division of the Pico was deposited on a surface of unconformity. However, throughout much of the Torrance-Santa Monica area, data are insufficient to determine with assurance the stratigraphic relation of the upper division to the underlying older rocks. Furthermore, the relations of this upper division to the over-lying Pleistocene rocks are uncertain in many places.
In the Torrance-Wilmington area relations are well established and, according to Wissler (1943, p. 213), the upper division overlaps the middle division of the Pico; in the Long Beach harbor district of the Wilmington oil field it rests directly on the Repetto formation of early Pliocene age. At the north border of the Palos Verdes Hills, where the San Pedro rests locally on the Repetto and on rocks of Miocene age, the upper division of the Pico is absent.
Along the Newport-Ingle wood uplift, an unconformity between the upper division of the Pico and the San Pedro formation in the Rose-crans and Dominguez oil fields was inferred by Wissler (1943, p. 212), because of the apparent absence in these fields of the Timms Point fauna, which occurs at the Seal Beach oil field!

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Inland beyond the Newport-Inglewood uplift, beneath the Downey plain, it is likely that no unconformity exists and that sedimentation took place almost continuously from late Pliocene into Pleistocene (San Pedro) time.
WATEK-BEABING CHABACTEB

Within most of the area shown on plate 2, except beneath and north of the Baldwin Hills, the upper division of the Pico formation contains layers of semiconsolidated sand which should yield substantial quan-tities of essentially fresh water to wells of adequate construction. The productivity of these sand layers in this area can be inferred from pumping tests at two wells and from a laboratory test of permea-bility of the sand from a third well, as described beyond. Information derived largely from electric logs of oil wells and pros-pect holes suggests that, in much of the area covered in this report, the water in these sand members of the upper division of the Pico is either fresh or suitable for certain industrial uses.
The position of the top of the transition zone between fresh and saline ground water has been ascertained from the electric logs of representative oil wells and prospect holes. Contours drawn on the top of the transition zone are presented on plate 8, these contours mark the approximate position of the base of the principal fresh-water body, as defined elsewhere in this report. Although correlation between oil fields in this region is precarious because of the usually pronounced lateral variation in lithology (Wissler, 1943, p. 234), the group of sand members generally prevalent in the lower part of the upper division of the Pico can be traced from one field to another; this general lithologic correlation is supported by studies of the fora-miniferal assemblages. A comparison of the position of the top of the transition and of the base of the upper division, as determined by micropaleontologists, shows that they almost coincide in this region. Notable exceptions are at the Potrero oil field, where the top of the transition zone is as much as 400 feet above the base of the upper division of the Pico; and at the west end of the Torrance oil field, in the Redondo Beach area, where the transition to saline water is 300 feet above the base of the upper division. In these two areas, and also locally in the Wilmington oil field, one or more of the lowest sand members ascribed to the upper division contain connate saline ground
water.

With respect to specific information on water-bearing character-istics of the upper division of the Pico formation, some data are avail-able as a result of two recent attempts to construct wells that pene-trated the fresh-water sands of this formation.
One of these wells, 3/14-17Jl, about a mile southwest of Hawthorne, was initially a "wildcat" oil well drilled to a depth of 4,200 feet by the

GEOLOGIC FORMATIONS WATER-BEARING CHARACTER 61

Loren L. Hillman Co., Inc., and designated "West Hawthorne No. 1." This well was utilized by the Standard Oil Co. of California in 1946 to test the aquifers in the upper division of the Pico formation with respect to quality of the water and productivity of the sands. The electric log indicated a permeable zone containing essentially fresh water from 1,120 to 1,320 feet below the land surface. To test this zone, the hole was plugged off below a depth of 1,294 feet. A double liner with an outer-pipe diameter of 8% inches and an inner-pipe diameter of 1% inches, prepacked with gravel between the two pipes, was landed at 1,294 feet and extended into the 11%-inch casing set at 849 feet. The prepacked liner was perforated from 1,089 to 1,294 feet, opposite the permeable zone.
An initial bailing test was made on this well late in May 1946, at an estimated rate of 25 gpm for about 24 hours. After 20,000 to 30,000 gallons was bailed, the chloride concentration was about 120 ppm. The apparent static level then was about 119 feet below laud surface, or about 38 feet below sea level, and the drawdown was about 38 feet after the water became relatively clear.
Subsequently, a pump was installed and a yield test was made by the Standard Oil Co. on August 1-4, 1946. The static level before the test was 111 feet below the land surface, or 30 feet below sea level. The pump bowls were set 400 feet below the land surface. The water yielded during the test contained a large amount of fine sand as well as particles of colloidal size; it was still turbid after standing several days. The maximum yield was at a rate of about 25 gpm; but this yield is not indicative of the productivity of the zone because the liner presumably filled with sand early in the test. At the end of the test, sand filled the casing to 728 feet below the land surface, about 360 feet above the top of the perforations.
In the latter part of August 1946 the sand was removed from the casing and a bailing test was made. The maximum rate of bailing was reported to be about 50 gpm with a drawdown of 50 feet. At the end of the bailing test, when the drawdown was 38 feet, the water level recovered 35 feet in 20 minutes. Large quantities of sand were removed from the well during this bailing test. The company decided that further tests were not warranted and the well was abandoned. Chemical analyses of water collected during the pumping test and in the final bailing test were made by the Standard Oil Co. (see table 30). The quality of the water is discussed on page 183.
Although the tests made on well 3/14-17Jl were unsuccessful from the standpoint of yield, it is believed that a well constructed to exclude sand, such as a gravel-packed well of 24- to 30-inch diameter with an envelope of fine gravel or coarse sand, probably would yield several times as much water as was obtained during this test. The prepacked

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gravel liner utilized for the test was only 8% inches in outside diameter and the gravel screen was less than half an inch thick.
The other type of the two wells tapping the sand members of the upper division of the Pico on which yield-test data are available is a water well drilled by the city of Long Beach in the spring of 1946 well 4/13-12A2 (city of Long Beach, North Long Beach well 6) about 6 miles north of the business district of Long Beach. Drilled to a total depth of 1,955 feet, the well penetrated about 1,200 feet into the upper division of the Pico or about 50 percent of the total depth range of the sand zones containing fresh water in the upper division at that locality (see log, table 28). A 26-inch casing was set to a depth of about 360 feet and a 16-inch casing to 1,955 feet; the latter casing was perforated from 1,805 to 1,955 feet. The well flowed 106 gpm. The water was dark brown and had a temperature of 104° to 106°F. Sufficient methane was present to burn continuously when ignited at the open casing.
On October 7, 1947, a yield test was made on this well and the yield was estimated at 400 gpm, with a drawdown of about 60 feet from a static level about 15 feet above land surface, or 53 feet above sea level. Thus the specific capacity was about 7 gpm per foot of drawdown. Although the content of dissolved solids was moderate (see chemical analysis, table 30), the water was not considered suitable for public supply because of its high temperature and dark color. The cost of treatment to make the water suitable for use was considered too costly, and the well was abandoned.
During the drilling of the well, samples were collected by the city at each change in character of the material, and at 10-foot spacings below 1,470 feet. In the laboratory of the field office of the Geological Survey at Long Beach, permeability tests were made on samples from four of the coarser zones within the depth range of the casing perfora-tions. Coefficients of permeability for these four zones, as determined in the laboratory, are as follows: at 1,890 feet below land surface, fine to coarse sand, some fine gravel, 454 gpd per square foot; 1,900 feet fine to coarse sand, some silt, little fine gravel, 212 gpd per square foot; 1,910 feet silty sand and gravel, pebbles as large as % inch in diameter, 20 gpd per square foot; 1,940 feet silty fine to medium sand, 16 gpd per square foot.
Additional information on the permeability of the upper division of the Pico was obtained from well 3/14-8N3 (Richfield Leuzinger well 1), which was drilled by the Richfield Oil Corp. about 2 miles east of El Segundo to test the oil and gas possibilities of the Pico formation. Through the courtesy of this company, a sample of sand from a per-meable zone in the upper division of the Pico formation between 1,220 and 1,240 feet below land surface was made available to the Geological

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Survey. A laboratory test indicated a permeability of 242 gpd per square foot. A mechanical analysis of this sand gave the composition tabulated below, indicating that the size ranges from fine gravel to very fine sand, but that 34 percent is medium sand.
Percent

of dry
Mechanical composition weight
(millimeters)
Fine gravel (more than 1.00)_______________ ___ _ 2. 3
Coarse sand (1.00 to 0.5)_._____________________ 24. 6
Medium sand (0.5 to 0.25)____.___________________ 34. 0
Fine sand (0.25 to 0.125)_____________________._ 31. 1
Very fine sand (0.125 to 0.05)_.________-__________... 8. 0

Information summarized on preceding pages suggests that the pro-duction of water from the upper division of the Pico formation within or near the west basin would require wells of substantial depths, probably as much as 1,500 feet on the average. Also, the sand mem-bers of the upper division are fine grained and wells of special con-struction with a thick gravel pack or a carefully selected screen would be required to withdraw water effectively. Such wells would be much more expensive than the water wells now utilized in the area. At some places, especially along and near the crest of the Newport-Inglewood uplift, yields of as much as 1,000 gpm might be obtained locally with a drawdown of not more than 100 feet. Within most of the west basin, however, it is doubtful that yields would exceed a few hundred gallons per minute with such a drawdown.
Although yields from the upper division might be substantial along the Newport-Inglewood uplift, it is concluded that the color of the water probably would be amber to dark brown and thus the water probably would require treatment for domestic use, even though the chemical quality should prove to be satisfactory. This color is pre-sumed to be caused by organic matter in colloidal suspension. It is believed that coloring by organic matter would not be excessive within most of the west basin, but the water might be turbid, similar to the water of well 3/14-17J1, and might require treatment.
The temperature of waters withdrawn from the upper division of the Pico ranged from 90° to 110°F. Therefore, these waters probably would have to be cooled for domestic use although such temperatures might not be objectionable for some industrial uses.
For wells tapping the upper division along the Newport-Inglewood uplift but inland from the west basin boundary, the static level would be above the current water levels in the Pleistocene water-bearing zones, and at places where the altitude of land surface is low, as at well 4/13-12A2, the wells would flow.
Wells tapping the upper division of the Pico formation within the west basin probably would register initial pressure levels ranging from

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sea level to possibly as much as 40 feet below sea level. Thus, to yield substantial quantities of water even from wells of special con-struction, initial pumping levels probably would be about 100 feet or more below sea level. Because replenishment to the water-bearing beds of the upper division in the west basin is inferred to be small or negligible, pressure levels presumably would decline fairly rapidly if large quantities of water were withdrawn from the sands of the upper division.
The water-bearing beds in the upper division of the Pico within the west basin contain a large quantity of water. If the average aggregate thickness of the sand layers containing essentially fresh water is approximately 200 feet, and the area is about 120 square miles, an assumed effective porosity of 25 percent would indicate storage of about 3 to 4 million acre-feet. If replenishment is negligible, as seems likely, only a small part of this quantity could be withdrawn without lowering pumping levels far below sea level. Because exploratory and well-construction costs would be high, the water yielded from the upper division of the Pico would cost substantially more per acre-foot than the ground water now yielded by wells in the west basin. Ex-tensive development of the water in the water-bearing beds of the upper division to abate the current overdraft in the west basin does not offer a permanent solution to the water-supply problems of the basin.
PICO FORMATION, MIDDLE AND LOWER DIVISIONS

The middle and lower divisions of the Pico formation do not crop out within the area shown on plate 2. As determined from cored samples from oil-test holes, they comprise interbedded sandstone, claystone, siltstone, and shale. According to Wissler (1943, p. 214- 215), the percentage of sand in the middle Pico averages about 40 percent for the oil fields within the Torrance-Santa Monica area; on the other hand, the lower division of the Pico contains about 60 percent of sand.
Among the oil fields within the area, the combined thickness of the middle and lower divisions ranges from about 400 feet at the Torrance oil field to more than 1,700 feet at the Potrero field (pi. 7), although somewhat greater thicknesses presumably occur in the basin areas between the structurally high oil fields.
In the Torrance-WUmington area the lower division is overlapped by the middle division, the latter resting with angular discordance on the Repetto formation of early Pliocene age (Wissler, 1943, p. 215). Along the north border of the Palos Verdes Hills, the entire Pico and in many places the Repetto are overlapped by the San Pedro formation of lower Pleistocene age (Woodring and others, 1941, p. 40-41).

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Elsewhere within almost all the Torrance-Santa Monica area and south of the Santa Monica Mountains, both the middle and lower divisions of the Pico formation are present and are essentially conformable with each other and with the overlying upper division and the underlying Repetto.
Within the area shown on plate 2, the water in the sand zones of the middle and lower divisions of the Pico formation is believed to be saline. However, inland beneath the Downey plain, electric logs from scattered "wildcat" oil wells indicate that essentially fresh water is contained in the sandier zones of the middle division of the Pico.

OLDER ROCKS OF TERTIARY AGE

Underlying the Pico formation in the Torrance-Santa Monica area are sedimentary rocks of lower Pliocene (Repetto formation) and of Miocene age. Lithologic descriptions of these rocks and their known range in thickness are given in table 3. Their distribution and thick-ness in the several oil fields of the area are summarized in plate 7. They include most of the oil-producing zones of the Los Angeles basin area and thus have been treated in detail in many reports con-cerned with the production of the oil resources of this area; however, they do not contain fresh water. The reader who desires information about these older formations is referred to the selected references given in an earlier report (Poland, Piper, and others, 1956, p. 93).

PRE-TERTIARY ROCKS

The pre-Tertiary rocks that crop out within the Torrance-Santa Monica area are generally considered to be of Mesozoic age. All are non-water-bearing and are briefly described here merely to complete the stratigraphic sequence.
As shown on plate 2, the pre-Tertiary rocks crop out only locally along the south border of the Santa Monica Mountains. According to Hoots (1931, p. 88-93), they are represented by the Santa Monica slate of Triassic(?) age, a Jurassic(?) igneous intrusion of granite and granodiorite, and the upper Cretaceous Chico formation consisting of conglomerate, sandstone, and shale. The Chico formation, where it occurs in the area, was not differentiated by Hoots from the Mar-tinez formation of Paleocene age because of a dense covering of brush and unexposed structural complications.
In the Palos Verdes Hills, the pre-Tertiary rocks constitute a metamorphic complex which forms a central core, which crops out only in a limited area on the northern slope of the hills about a mile south of the southern boundary of the area mapped on plate 2. These rocks consist of quartz-sericite, quartz-talc, and quartz-glaucophane schist and altered basic igneous rocks which have been ascribed by

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Woodford (1924, p. 62) to a correlative of the Jurassic(?) Franciscan group of the Coast Ranges. However, because there are no unaltered sedimentary rocks among these schist beds, Woodford considered the alternative that they might be older than the Franciscan a possibility which also has been emphasized by Taliaferro (1943, p. 122-125).

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REGIONAL FEATURES

The thick sequence of sedimentary rocks underlying the coastal plain has been deposited in a broad synclinal depression often referred to as the Los Angeles basin. In the structurally deepest part of the basin, beneath the central part of the Downey plain, the rocks of Tertiary and Quaternary age probably are more than 20,000 feet thick. Along the north and northeast margins of the basin, and locally to the southwest at the Palos Verdes Hills, these rocks have been extensively elevated, folded, faulted, and eroded, to expose a complex of igneous and metamorphic rocks (pi. 1).
The general synclinal structure of the basin is interrupted by the composite faulted anticlinal belt that extends southeastward from the Beverly Hills to Newport Beach the Newport-Inglewood uplift. In effect, this uplift divides the coastal plain into two synclinal troughs. To the northeast, a broad syncline underlies the Downey plain and extends southeastward from the north flank of the Baldwin Hills through Huntington Park and continues into Orange County. To the southwest, a relatively narrow syncline extends from Santa Monica to Long Beach and forms the structural trough known as the west basin.
The Tertiary and Quaternary rocks dip gently inland and coast-ward from the crest of the Newport-Inglewood uplift. Along the synclinal axis within the west basin, their thickness ranges from a few thousand to as much as 13,000 feet. Here they overlie a schist base-ment complex which has been reached by many oil wells (White, 1946; also see Schoellhamer and Woodford, 1951). Southwest beyond the syncline, these rocks are warped over the Torrance-Wilmington anti-clinal structure and are flexed sharply upward into the Palos Verdes Hills. Along the north flank of the Palos Verdes Hills, a deep fault is indicated by data from oil-prospect holes, but the Pleistocene rocks at the land surface are not ruptured (Woodring, 1946, p. 110, pis. 1 and 21; Schultz, 1937, fig. 4) except in the local area southeast of Redondo Beach (pi. 2).
Within the Newport-Inglewood uplift and in the two flanking syn-clines, all rocks older than the alluvial deposits of Recent age are deformed. Also, because the rocks have been deformed recurrently

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since Miocene tune, the flexure in the Pleistocene rocks is reflected with increasing amplitude in the rocks of Pliocene and late Miocene age. As shown by the contours on the base of the water-bearing zones of Pleistocene age (pi. 2), however, much of the structural deformation has occurred since the time of early San Pedro deposition, chiefly during the so-called mid-Pleistocene revolution, which took place after deposition of the San Pedro formation.

NEWPOST-INGLEWOOD UPLIFT

GENERAL FEATURES

The Newport-Inglewood uplift is a regional anticlinal fold broken by echelon faults, and extending northwestward from the Newport Mesa to the Beverly Hills, a distance of 40 miles. Throughout its extent within Los Angeles County, it is marked at the surface by the common alinement of Signal, Dominguez, Rosecrans, Baldwin, and the Beverly Hills. The continuity of these five hills is broken by two erosional gaps Dominguez and Ballona Gaps (pi. 8). Superimposed on this regional anticlinal structure are successive closed anticlines or domes and intervening structural saddles. The domes and, to a lesser degree, the saddles are broken by discontinuous normal and reverse faults arranged in echelon, many of which do not reach the land surface.
According to Wissler, the Newport-Inglewood uplift has been a zone of structural activity since Miocene time. Stratigraphic evidence has been presented that indicates recurrent movement along the zone during later Tertiary and Quaternary time. Recent major earth-quakes the Inglewood earthquake of 1921 and the Long Beach earth-quake of 1933 and a minor earthquake in 1941, which damaged several oil wells in the Dominguez oil field, indicate that the zone is still active.

The folds and faults along the Newport-Inglewood uplift at the inland boundary of the west basin form a substantial if discontinuous barrier to water movement from the main (central) coastal basin to the west basin. For example, the crestal position of the impermeable rocks at the base of the water-bearing zones of Pleistocene age deter-mines the depth of the lip below which water cannot pass into the west basin. The depth of this lip in the reach south of the Baldwin Hills has been shown on plate 3A. Also, the discontinuous faults along the uplift have produced ground-water barriers that partly restrain the coastward movement of ground water. This restraint has been produced to a small degree by displacement of water-bearing zones but it is chiefly due to cementation, which has developed along the fault planes. Thus, both folds and faults are critical features in an appraisal of the problem of replenishment to the west basin.

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FOLDS

Four domal uplifts along the Newport-Inglewood structural zone in the Torrance-Santa Monica area are topographically expressed in order from the southeast by Dominguez, Rosecrans, Baldwin, and the Beverly Hills, respectively. Oil fields have been developed on each of these hills: the Dominguez oil field; the Rosecrans and Potrero fields (near the south and north ends) of the Rosecrans Hills, respec-tively; the Inglewood field on the Baldwin Hills; and the Beverly Hills field. Consequently, because of the studies incident to the development of each field, much information is available on their subsurface geology.
In general, the land-surface contour of the several domal folds is a moderate replica of the subsurface structure, although the initial land surface on the hills has been modified by erosion.
The structure at Dominguez Hill has been described as follows (Poland, Piper, and others, 1956, p. 96):
The most regular domal structure underlies Dominguez Hill, whose general outer form reflects the deeper structural pattern in a subdued degree. Thus, whereas the crest of Dominguez Hill is only about 150 feet above the surrounding plains, the structural relief at the base of the Pleistocene is about 400 feet. [See pi. 2.] According to Grinsfelder (1943, p. 318), mapping on successive strati-graphic horizons indicates that the effect of the tectonic forces was progressively greater at increasing depth, and that "mapping on horizons as deep as 4,000 feet reveals an elliptical anticline with a northwest-trending axis, steep flanks on the southwest, with dips of from 15° to 20°." Thus the structural development of this anticline has gone on recurrently through much of Tertiary and Quaternary time.

The Rosecrans Hills comprise an irregular low swell about 3 miles wide and 8 miles long extending from Dominguez Hill northwestward to the Baldwin Hills.
Near the south end of the hills, structure contours at a depth of about 4,000 feet reveal three small domes with a northwest alinement which constitute the Rosecrans oil field (Musser, 1925). Musser has inferred that the three domes are separated by minor faults trending northeastward. At shallow depth the inferred faults apparently are absent, and the attitude of the base of the Pleistocene water-bearing zones, about 200 feet below sea level, assumes a somewhat irregular elliptical shape. The inland and coastward dip of the base of these water-bearing zones is about 2° to 3°.
At the north end of the Rosecrans Hills, the steeper western slope has a nearly straight topographic break parallel with the long dimen-sion of the hills which marks the surface trace of the Potrero fault (see p. 72). This fault passes through the center of the structure on which the Potrero oil field is developed (Willis and Ballantyne, 1943, p. 310) an elongated dome whose long axis trends about N. 65°

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W. The top of the producing zones, at the highest part of the dome, is about 3,000 feet below the land surface. At this depth the dips average 8°, whereas at the base of the Pleistocene water-bearing zones, about 250 feet below the surface (pi. 3 A), the dips are much gentler from about 1° to 2°. Impermeable beds underlie these water-bearing zones at a depth of about 50 feet below sea level.
The most pronounced and complex uplift along the Newport-Inglewood structural zone, at the Baldwin Hills, consists of a north-westward-trending dome, whose central crest has been dropped between two fault zones (Driver, 1943, p. 308). Of these two fault zones, the easterly one is known as the Inglewood fault (pi. 2). At the depth of the upper oil zone, about 900 feet below sea level, the crest of the dome underlies the SW% sec. 8, T. 2 S., R. 14 W., which is about half a mile west of the topographic summit of the Baldwia Hills. The peripheral outward dips generally are less than 20°, except at the northwest edge of the hills, where the dip is 35° to the west (Driver, 1943, p. 308). The uplift is greatest at the northern part of the hills, where the upper division of the Pico formation crops out at the surface (pis. 2, 3^4). Within most of the Baldwin Hills area, the base of the permeable beds of Pleistocene age is above sea level; these beds are non-water-bearing.
The Beverly Hills constitute the northernmost of the domal struc-tures which mark the Newport-Inglewood uplift. It is a triangular asymmetric dome underlying the northern part of the hills and is elongated in an east-west direction (Hoots, 1931, p. 132-133 and pi. 34); the closure on this structure trapped the oil produced at the small Beverly Hills oil field in the years following 1908. The oil field is now of little importance as a producer. At the oil zone, 2,500 feet below sea level, the dips on the north flank are from 15° to 20°, and are nearly 45° on the south flank. Along the crest of the Beverly Hills, the base of the water-bearing beds of Pleistocene age is less than 200 feet below land surface and from a few feet to as much as 100 feet above sea level.
FAULTS

In the area shown on plate 2, the Newport-Inglewood structural zone is broken by four known major faults which, in order from, the southeast, are the Cherry-Hill, the Avalon-Compton, the Potrero, and the Inglewood faults. As shown on olate 2, these faults are arranged in echelon, and strike, generaUy, more northward than the trend of the zone as a whole.

CHERRY-HILL FAULT

The Cherry-Hill fault, which has a known extent of about 5 miles from the east side of Dominguez Gap to and beyond the southwest
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flank of Signal Hill, has been discussed in some detail in an earlier report (Poland, Piper, and others, 1956, p. 98). Only the northwestern part of this fault is within the area shown on plate 2.
The Cherry-Hill is a reverse fault, dipping northeast. Land-surface displacement ranges from more than 100 to 40 feet along the south-west flank of Signal Hill, diminishing northwestward. Near the east edge of sec. 24, T. 4 S., R. 13 W., at the east boundary shown on plate 2, the throw or vertical displacement is about 150 feet (Stolz, 1943, p. 321) at a depth of more than 4,000 feet in lower Pliocene rocks. Extension of the fault northwestward across Dominguez Gap (pi. 2) is based upon information obtained during drilling or prospecting for oil, and from an apparent hydraulic discontinuity in the Silverado water-bearing zone (pis. 9-12). The fault probably transects all the deposits of Pleistocene age but does not cut the deposits of Recent age.

FAULTS IN THE DOMIKGUEZ HILL AREA

So far as known, no faults are present in the surface or near-surface deposits in the Dominguez Hill area. Grinsfelder (1943, p. 318) states that the effects of faulting become evident below 4,000 feet, presumably in the Repetto formation of early Pliocene age. From subsurface studies, Bravinder (1942, p. 390) reported two sets of faults: (1) high-angle faults striking obliquely across the long axis of the dome and (2) south-dipping lower angle thrust faults striking nearly parallel to the axis. Horizontal movement is evident in the oblique set, and the throw is greatest in the Miocene rocks. Although faults are not known in the Pleistocene deposits along the crest of Dominguez Hill, water levels in wells tapping those deposits indicate a substantial hydraulic discontinuity across the axis of the Dominguez anticline, because water levels on the southwest are from 20 to 40 feet lower than those on the northeast (pis. 9-12). The position of this ground water barrier is only roughly defined by the water-level data. The inferred barrier may be caused by near-surface effects of the faulting, which is known to have occurred at depth. These near-surface effects may be shear zones characterized either by many minor faults of small displacement, or by systems of tension and compression joints with little or no offset. In either case, it is believed that cementation along openings caused by these struc-tures may have produced the ground-water barrier suggested by the differences in water levels. For a discussion of the mechanism of the formation of such cemented zones, the reader is referred to the report on the Long Beach-Santa Ana area (Poland, Piper, and others, 1956, p. 104 and 123).

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AVALON-COMPTON FAULT

The land-surface trace of the Avalon-Compton fault is 2.25 miles long and extends northward from the NW# sec. 33, T. 3 S., R. 13 W., on the north flank of Dominguez Hill, to the NW# sec. 20, T. 3 S., R. 13 W., 0.1 mile west of the intersection of Rosecrans Avenue and Avalon Boulevard. The fault passes about 500 feet east of the inter-section of Avalon Boulevard and Compton Avenue and is designated the Avalon-Compton fault in this report. The fault strikes N. 24° W.; the dip of the fault plane is not known. The trace of this fault has been taken along the topographic discontinuity shown on the Compton topographic sheet and is substantiated by hydrologic data. The average land-surface displacement is about 25 feet, with the dropped block on the southwest side. If this fault is similar to other faults along the Newport-Ingle wood uplift, the throw at depth is con-siderably greater than the vertical displacement at land surface. Well logs are not available, however, to indicate the amount of dis-placement within the Silverado water-bearing zone, or at greater depth. As shown on plate 12, in November 1945 the water levels northeast of the fault were about at sea level, whereas those across the fault to the southwest were about 30 feet below sea level. This evidence demonstrates the effectiveness of the fault as a ground water barrier.

FAULTING m THE CENTRAL PART OF THE ROSECRANS HILLS

The central 4-mile reach of the Rosecrans Hills is beyond the inferred limits of the Avalon-Compton fault to the southeast and the Potrero fault to the northwest (pi. 2). This central reach has a relatively steep southwest flank, locally scarred by stream erosion. No rupture of the land surface can be noted. The Rosecrans oil field, which is about 3 miles in length, underlies the southern half of this central reach. The producing beds of the Rosecrans oil field are broken by a general northwestward-trending main shear zone and by many transverse faults, but none of these are known to pass upward into beds younger than the Repetto formation.
Although there is no geologic evidence of faults transecting the deposits of Pleistocene age, hydraulic continuity in these deposits is substantially impeded along the approximate position of the ground-water barrier shown on plate 2. So far as known, the most extensive measurements of depth to water in wells in the vicinity of this inferred barrier were made between 1930 and 1932. In 1932, one or more nearby wells became inaccessible. Accordingly, measure-ments of depth to water in 1931 have furnished the control for the position of the barrier as plotted. A straight line drawn to connect the extremities of the Avalon-Compton and the Potrero faults was

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found to separate the higher water levels to the northeast from the lower water levels to the southwest. In November 1945, the water-level displacement across this central barrier was about 30 feet (pi. 12). The cause of this barrier is thought to be similar to the one suggested for the Dominguez Hill area; namely, cementation of shear zones, which are believed to be near-surface reflections of major faulting at depth.

POTRERO FATTIT AND ASSOCIATED HONOR FAULTS

The trace of the Potrero fault, as shown on plate 2, extends about 4 miles northwestward from the west part of sec. 2, T. 3 S., R. 14 W., to the middle of sec. 16, T. 2 S., R. 14 W., in the eastern part of the Baldwin Hills, and passes through the Centinela Park well field of the city of Inglewood. The fault is marked at the surface by an escarp-ment about 50 feet high which extends along the west flank of the Rosecrans Hills for about 2.25 miles. At a depth of 3,000 feet, this fault bisects the dome on which the Potrero oil field is developed. According to Willis and Ballantyne (1943, p. 310), at the Potrero oil field in sec. 34 the Potrero fault is a zone from 100 to 200 feet wide composed of several minor displacements. The general trend of the fault zone is N. 25° W.; the dip is about 82° to the west at depth, but lessens to about 77° at land surface. The throw at a depth of about 3,000 feet is about 270 feet, with the dropped block on the southwest; Willis states that the horizontal component of the displacement is the more important, because the axis of the dome southwest of the fault appears to have been shifted northwestward 1,200 feet relative to the axis northeast of the fault. At the base of the water-bearing zones of Pleistocene age a depth of about 300 feet below land surface, the throw is probably about 100 feet in the north half of 2/14-34 (pi. 2).
However, about a mile to the north in the Centinela Park well field of the city of Inglewood no vertical displacement across the Potrero fault is indicated by well logs. As discussed on page 139, the Potrero fault is a barrier to ground-water movement; therefore, the hori-zontal component of the displacement in these younger rocks, although presumed to be considerably less than that which is ap-parent at depth in the oil zones, must at least have been sufficient to produce fracturing and permit cementation. This barrier may be of a mechanical nature, caused by fracturing and pulverizing of the coarser material along the fault plane to form an impervious zone, or it may be a cemented zone similar to that indicated for other localities. Although it is likely that both processes have occurred, cementation is presumed to have caused the principal barrier features.

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Between the Potrero fault on the east and the Inglewood fault on th& west, in the 3.6-mile reach from Century Boulevard to Slauson Avenue, six transverse faults are shown on plate 2. The four southerly faults have been plotted about in the position indicated by Grant and Sheppard (1939, fig. 8, p. 321)^ as interpreted by W. S. W. Kew and Graham Moody, reportedly o^n topographic evidence (Driver, oral communication, January 1947). The two northerly transverse faults, in sees. 21 and 16, T. 2 S., K. 14 W., have been plotted on plate 2 as shown by Graham Moody on an unpublished geologic map of the Baldwin Hills, which was made available through the courtesy of the Standard Oil Co. of Califoraia. The three southerly faults are treated here, and the three to the north are discussed later with the Inglewood fault, which they appear to offset.
The most southerly of the inferred transverse faults, near the intersection of Crenshaw and Century Boulevards, is indicated by a land-surface displacement of 10-20 feet, and by a creek channel passing westward along this small topographic offset. No substan-tiating geologic evidence is known. However, in well 3/14-3A1, a few hundred feet north of this transverse fault and between the Potrero and Inglewood faults, the water level was about 60 feet below sea level in November 1945, which was possibly 20 feet lower than water levels in sec. 3, south of the inferred fault (pi. 12). Thus, a hydrologie discontinuity is indicated and the fault is inferred to be present chiefly on the basis of this tydrologic evidence.
The second inferred transverse fault, near the north edge of sec. 34 (Manchester Avenue) and about 1 mile long, is suggested by a land-surface displacement of about 25 feet, east of the Potrero fault, with the dropped block on the south. '. lowever, logs of wells 2/14-27P1 and 34C1, north and south of the fault suggest no displacement at the base of the Silverado water-bearing zone, 220 feet below sea level. Nevertheless, water-level measurements taken in wells 2/14-27P2 and 34C1 in November 1945 were about 60 and 75 feet below sea level, respectively, suggesting a differential in water level across the in-ferred fault of about 15 feet.
The third inferred fault, which extends westward almost across the center of sec. 27, T. 2 S., K. 14 W., is indicated by a steep northward-facing bluff and a land-surface displacement of about 50 feet, dropped to the north. Logs of water wells inc icate a displacement of the water-bearing zones of Pleistocene age, of
direction (pi. 3). Hydrologie data «,re not available to show whether a hydraulic discontinuity is present across this fault.

about 30 to 50 feet in the same

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INGLEWOOD FAULT AND ASSOCIATED MINOR FAULTS

The Inglewood fault zone, as shown on plate 2, is about 9 miles long and extends northward from the northern part of the Rosecrans Hills, across the Baldwin Hills, and beneath the Recent deposits in Ballona Gap. Topographic evidence and a hydraulic discontinuity indicate that the zone extends northward beyond the Beverly Hills. Its continuity is interrupted by many transverse faults and as shown on plate 2, it has seven distinct segments. Within the Baldwin Hills area, the fault pattern is plotted as shown on an unpublished map by Moody; 5 to simplify the structural detail, however, many minor faults are not shown.
The southern segment of the Inglewood fault extends northwest-ward for about 2 miles to the center of sec. 28, T. 2 S., R. 14 W. In section 28 it is identical with the Townsite fault of Willis (1943, p. 311-312). In the northern part of the Rosecrans Hills, from a quarter of a mile south to half a mile north of Century Boulevard, a local steepening of the land-surface profile indicates the inferred surface trace of the Inglewood fault, trending about N. 30° W. How-ever, subsurface and hydraulic evidence for this segment of the Inglewood fault is much more definitive. Logs of water wells in the central part of Inglewood indicate a vertical displacement of at least 100 feet at the base of the Pleistocene water-bearing zones, with the dropped block to the southwest (pi. 2). Also, in sec. 34, T. 2 S., R. 14 W., water levels on the northeast side of the fault were about 20 feet lower in November 1945 than levels southwest of the fault (pi. 12).
At the north end of this southern segment, in the SE}£ sec. 28, T. 2 S., R. 14 W., the trace ends abruptly against a transverse fault about a mile long, which strikes N. 60° E. along a former channel of Cen-tinela Creek. The characteristics of this fault are not well known; logs of water wells indicate a displacement of about 50 feet between wells 2/14-28M1 and 28E1 (city of Inglewood, wells 26 and 23), both of which are west of the Inglewood fault. Here the water-bearing beds are dropped to the south. These wells were drilled about 16 years after Kew (1923, p. 157) wrote that "no stratigraphic evidence is present indicating any faulting in this creek." Thus, the displacement suggested by the logs of these wells, although not con-clusively demonstrated, constitutes presumed stratigraphic evidence for the existence of this fault. No hydrologic or chemical data are available for confirmation. The trace of the fault has been drawn along the former channel of upper Centinela Creek, according to information supplied by Kew and Moody (Grant and Sheppard, »Moody, Q. B., 1935, Surface geology of the Baldwin Hills, Los Angeles Countyf Calif., Report for Standard Oil Co. of California.

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1939, p. 321, fig. 8); but because it is believed to pass north of well 2/14-28M1, the position of its western part has been shifted about 600 feet to the north.
The Inglewood fault, which at the surface is probably horizontally offset slightly to the west by the transverse fault just described, extends 4 miles northward from that fault across the Baldwin Hills. The fault is again horizontally offset, to a small extent, by two other transverse faults in the southern 1.5 miles of this stretch, and trends about N. 10° W. The northern part, about 3.5 miles long, extends over the Baldwin Hills, and trends about N. 25° W.
The fault pattern in the Baldwin Hills area shows that the Ingle-wood fault is the more easterly of two faults forming a dropped block or graben along the crest of the hills (pi. 2). It is broken along this graben by several echelon faults which trend about N. 20° E. The Inglewood fault is marked here by a westward-facing escarpment with a land-surface vertical displacement or throw of about 275 feet (Driver, 1943, p. 308 and fig. 128). Locally in the NEK sec. 17, T. 2 S., R. 14 W., at the top of the producing zones of the Inglewood oil field, the throw is about 1,000 feet down on the west side, so that that zone is about 2,000 feet below the land surface in the graben and 1,000 feet below the surface east of the fault. Surface and sub-surface data indicate that the horizontal component of the displace-ment may be five times as great as the vertical component or throw. The fault dips about 80° west at the surface, and becomes less steep with depth.
About parallel to the Inglewood fault and nearly 1,000 feet to the west, another fault forms the west side of the graben. Like the Ingle-wood fault, it trends about N. 25° W. and is broken by several echelon faults trending N. 10°-20° E.; it dips about 75° to the east. According to Driver, the throw is about 30 feet at the surface and 100 to 200 feet at a depth of about 2,000 feet. The echelon faults along the graben may have been the result of stresses which caused the large horizontal component of movement along the main Inglewood fault.
Bounding the northeast flank of the Baldwin Hills is an unnamed fault about 2 miles long, trending N. 70° W., which extends north-westward and is offset by the Inglewood fault (Driver, 1943, p. 308). The dip of the fault plane is not known, but it is reported to be a normal fault with the down thrown block on the north. Data on a few wells south of the fault at its northwest end show that water levels at this point have been maintained about 90 feet above sea level; the underground drainage from the hills evidently has been trapped in the acute dihedral angle between this fault and the Inglewood fault.

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There is substantial evidence north of the Baldwin Hills that the Inglewood fault extends across Ballona Gap with a trend of about N. 26° W. and is concealed beneath alluvial deposits of Recent age. It has already been indicated that (at the crest of the Baldwin Hills anticline) the Inglewood fault marks the eastern boundary of a graben; the strata at the fault are dropped on its west side. Also, information obtained from a study of well logs in Ballona Gap proves that the water-bearing deposits of Pleistocene age have been dropped on the east side of the fault. Therefore, movement along the Inglewood fault must have been pivotal, with a change from downward displace-ment on the west in the Baldwin Hills, through a pivot of no displace-ment, to downward displacement on the east in Ballona Gap. The dip of the fault plane in Ballona Gap is not known.
At the intersection of the Inglewood fault with section D-D' (pi. 31?), the throw is inferred to be about 200 feet. Apparently no move-ment has occurred along this fault since the beginning of Recent time because the "50-foot gravel" in Ballona Gap shows no evidence of offset.
Evidence that the Inglewood fault affords an effective barrier to ground-water movement through Ballona Gap is shown by the area of flowing wells that existed inland from the fault in 1904 (Men-denhall, 1905b, pi. 6). More recent water-level data also indicate hydraulic discontinuity. For example, in November 1945 water levels east of the fault in sees. 5 and 6, T. 2 S., R. 14 W., near the Sentney plant of the Southern California Water Co., were as much as 50 to 70 feet below water levels west of the fault (pi. 12).
The trace of the Inglewood fault tentatively has been extended across the eastern part of the Beverly Hills on the basis of an eastward-facing escarpment about 70 feet high, trending N. 25° W., and alined with the fault trace across the Baldwin Hills. If the assumption is correct that this escarpment marks the surface trace of the northward extension of the Inglewood fault, the fact that there is no displace-ment of Recent beds, and that the strata of late Pleistocene (Palos Verdes) age are displaced, dates the last movement along this fault as occurring in latest Pleistocene time.
The northern limit of the Inglewood fault is not known. However, this shear zone does not extend to the older rocks in the Santa Monica Mountains.
FAULTS IN BALLONA GAP

Two faults in Ballona Gap that are not associated with the Newport-Inglewood uplift, but which have a strong influence on ground-water circulation, are the Overland Avenue and the Charnock faults (pis. 2 and 3D). Both faults have been located by well-log and water-

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level data. They bound the east and west sides of a dropped block or graben. Both have been shown on the water-level contour maps of the Los Angeles County Flood Control District since 1938 (Bau-mann and Laverty, 1940, map 9).
The Overland Avenue fault, so named in this report because its inferred trace nearly coincides with Overland Avenue in Culver City, is about 6 miles long and trends N. 30° W. It extends from the southwestern part of the Baldwin Hills northwestward across Ballona Gap, and across the southwest lobe of the Beverly Hills (pi. 2). Logs of wells indicate that where it crosses section D-D' (pi. 3D) in sec. 12, T. 2 S., R. 15 W., the vertical displacement is about 30 feet, with the dropped block on the west.
The well logs and water-level data indicate the fault extends 1.5 miles northwest of the Beverly Hills lobe over a part of the small alluvial plain, which is tributary on the north to Ballona Gap. Also, hydrblogic evidence supported by subsurface data, indicate that the fault extended southeastward across sec. 19, T. 2S., R. 14 W. Logs of wells 2/14-19C1 and 19C2 on the west side of the fault, and well 2/14-18F2 on the east side, indicate a displacement of several tens of feet at the base of the water-bearing deposits.
Although the attitude of the Overland Avenue fault is shown to be vertical in plate 3D, the true direction and magnitude of the dip of the fault plane are not known.
For the past 15 years the water levels on the east side of the Overland Avenue fault have remained 60 to 100 feet above those on the west side; this fact indicates the effectiveness of the fault as a ground-water barrier (pis. 9-12).
The Charnock fault has been so named in this report because it passes immediately west of the Charnock well fields of the city of Santa Monica and the Southern California Water Co., in the NW& sec. 11, T. 2 S., R. 15 W. The fault trace trends about N. 35° W. (nearly parallel to the Overland Avenue fault) and extends from the north border of the El Segundo sand hills 8 across Ballona Gap and through the alluvial narrows between the Ocean Park plain and the Beverly Hills. Water levels in wells and well-log data indicate that the north end of the fault trends in a more northerly direction (about N. 5°W.).
The attitude of the Charnock fault is not known; it is shown to be vertical in plate 3.D (as was done in the case of Overland Avenue and the Inglewood faults). The trace of the fault is concealed beneath deposits of Recent age for almost its full extent on plate 2, but the The California Division of Water Resources in its investigation for the adjudication concluded from additional information that the Oharnoek fault extends south to Redondo Beach Boulevard in the vicinity of Gardena and so describe it in their report (1952, p. 93 and pi. 4).

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throw is as much as 140 feet at the base of the San Pedro formation, with the dropped block to the east.
Hydraulic discontinuity is apparent across the Charnock fault, as shown by water-level contours on plates 9-12. For example, in November 1945, water levels east of the fault were as much as 50 feet below sea level, and were about 40 feet below those on the west. The absence of land-surface displacement along the Charnock and Overland Avenue faults suggests that movement along these faults has not taken place during Eecent time. The "50-foot gravel" of Ballona Gap is not known to be cut by either of these faults and thus it is believed that they have not produced any barriers to movement of water in this aquifer. As noted earlier in this report, all observable displacement along faults of the Newport-Inglewood structural zone occurred before Recent time, although movement is still taking place at depth.
The marked hydraulic discontinuities across the Charnock and Overland Avenue faults are caused in part by displacement of the water-bearing deposits against impermeable silt and clay beds. How-ever, it is probably true that cementation within the fault zones has been responsible for much of the effectiveness of these ground-water barriers.
GROUND-WATER HYDROLOGY

REGIONAL GROUND-WATER CONDITIONS

The coastal plain in Los Angeles County is divided into two distinct ground-water basins by the Newport-Inglewood uplift, which extends from Beverly Hills southeastward to Signal Hill and beyond into Orange County. To the northeast the main (or central) coastal basin covers about 500 square miles in Los Angeles and Orange Coun-ties and currently (1948) yields about a third of a million acre-feet of ground water annually about four-fifths of the water pumped from the entire coastal plain. To the southwest of the uplift, the west basin currently (1948) yields about 90,000 acre-feet a year, or about one-fifth of the total pumpage of ground water from the coastal plain. At least three distinct bodies of ground water occur in these two basins. In downward succession they are: (1) a body of shallow unconfined and semiperched water which occurs in the upper part of the alluvial deposits of Recent age within the several gaps and inland beneath most of the Downey plain, also in the upper Pleistocene deposits beneath the Torrance plain and along the flanks of the uplift;
(2) the principal body of fresh ground water, which occurs chiefly in the lower division of the alluvial deposits of Recent age, in nearly all the deposits of Pleistocene age, and in the uppermost part of the

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underlying Pliocene rocks; and (3) a body of saline connate water underlying the principal fresh-water body throughout the area. Within the coastal plain in Los Angeles County, essentially all the water currently withdrawn from wells is pumped from the principal water body. Accordingly, in following paragraphs a brief statement is presented to outline the occurrence and circulation of ground water in this body and to furnish a general background preliminary to the detailed discussion of ground-water occurrence in the west basin treated in following sections of the report.
The sediments in the main coastal basin in Los Angeles County consist chiefly of the coalescing alluvial fans of the Los Angeles River and the San Gabriel River (including the Rio Hondo) systems (pi. 1). The alluvial fans, which were laid down in a synclinal trough, com-prise tongues and lenses of sand and gravel, interbedded with silt and clay. The lenses or tongues of gravel and coarse sand are largely the channel deposits of the major streams; the fine sand, silt, and clay are chiefly flood-plain deposits carried to the interstream areas during flood stage. Beneath most of the Downey plain the alluvial deposits are at least 1,000 feet thick, near the axis of the synclinal trough along a line through Huntington Park and Santa Ana the deposits are as much as 3,000 feet thick. Most of the alluvium was deposited in early Pleistocene time, thus forming the San Pedro formation. During most of the Pleistocene epoch, the shore of the alluvial plain in this central reach was nearly parallel to a line between Watts and Los Alamitos. Here the alluvial-fan deposits interfinger with lagoonal deposits of low water-yielding capacity. In effect, these lagoonal deposits produce a partial lithologic barrier to the free coast-ward movement of the ground water. About a mile or two farther coastward, the lagoonal deposits merge with beach and shallow marine deposits extensive, thick layers of sand and gravel that constitute the inland margin of the highly productive Silverado water-bearing zone. In the reach from the Baldwin Hills to Signal Hill, the Silverado water-bearing zone extends across the crest of the Newport-Inglewood uplift and southwest to the present coast thus underlying the greater part of the west basin.
Three highly permeable aquifers within the deposits of Recent age that overlie the Pleistocene deposits and locally extend to depths of as much as 100 to 150 feet below land surface are: (1) The Gaspur water-bearing zone, which extends from Whittier Narrows to Terminal Island; (2) the westerly arm of the Gaspur zone, which extends from the Los Angeles River Narrows to a juncture with the main Gaspur water-bearing zone at Compton; and (3) the "50-foot gravel," whose east end is in hydraulic continuity with the westerly arm of the Gaspur water-bearing zone, extends westward through Ballona Gap to the

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ocean. (See pi. 8 for extent of these water-bearing zones of Recent age within the Torrance-Santa Monica area.)
These extensively continuous and highly permeable aquifers are not typical alluvial-fan deposits. They are trains of gravel and sand laid down in valleys eroded in the Pleistocene deposits and were deposited contemporaneously with a rise in sea level. They form unbroken ground-water arteries or conduits from the intake areas to the ocean in fact, they extend inland beyond the intake areas of the coastal plain, and through the passes to the inland valleys. They range in width from 1 to 6 miles; the Gaspur water-bearing zone is at least 20 miles long.
The principal body of ground water is unconfined only within the intake areas, which extend a few miles coastward from the Whittier and Los Angeles Narrows. Most of the recharge to the principal body takes place in these areas of unconfined water, by influent seepage from the major streams, by penetration of rain and irrigation water, and by underflow from the interior basins. Also, since 1938 recharge has taken place by percolation from the spreading basins along the Rio Hondo and the San Gabriel River about 3 miles coast-ward from Whittier Narrows.
Under native conditions of circulation the ground water moved generally oceanward from the intake areas, but chiefly under con-finement. Coastward, beyond the intake areas, beds of silt and clay intervene between the successive water-bearing members and cause hydraulic discontinuity between those members. Such discon-tinuities generally are slight within the intake areas but they become more extensive toward the Newport-Inglewood uplift. Movement of water is most rapid in the coarsest materials such as the materials that constitute the Gaspur water-bearing zone of Recent age and the more permeable members of the San Pedro formation. Under the hydraulic gradients from 5 to 10 feet to a mile, which initially pre-vailed throughout much of the coastal plain, movement is compara-tively rapid in coarse deposits. However, the movement, probably is not more than a mile every few years. Although movement is much slower through materials of finer texture, it probably takes place to some extent in all but the finest grained clay. Thus, the fresh water in the principal water body occupies and moves through a succession of water-bearing members that are contained in the vertical range of the alluvial deposits of Recent age and all the deposits of Pleistocene age. To a lesser extent, fresh water may move through the upper part of the Pico formation, but movement through these deposits presumably, is very slow.
The oceanward movement in the principal fresh-water body is greatly impeded along the Newport-Inglewood uplift. There, owing

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to substantial barrier features (cemented fault zones), the impedance under native conditions was sufficiently effective to produce a belt of flowing wells (the artesian area of Mendenhall) extending inland to the intake areas and occupying nearly two-thirds of the main coastal basin (Mendenhall, 1905b, pi. 1). The hydrostatic head so developed cause very high pressure in early wells. In the famous Bouton wells 2 miles north of Signal Hill (drilled about 1895), sufficient pressure heads were reached to raise the water level in casings 80 feet above the land surface or about 150 feet above sea level. These high pressures caused substantial leakage from the deeper water-bearing zones by upward movement in fracture-zone conduits adjacent to the master faults. At several places along the uplift, perennial springs occurred at the inland side of the master faults. For example, in Ingle wood and immediately inland from the Potrero fault, a spring is reported to have discharged water perennially into the head of Centinela Creek. This spring ceased to flow about 1900. Also, in Long Beach two perennial springs have been described (Brown, 1944, p. 2), both associated with and immediately inland from the faults of the Signal Hill uplift. These springs ceased to flow after pressure levels in the main coastal basin were lowered below land surface by increasing withdrawals.
Under natural conditions of high-water level inland from the uplift, a substantial part of the replenishment to the main coastal basin in Los Angeles County passed across the uplift as underflow into the west basin. This underflow moved coastward in the confined aquifers within the west basin, chiefly in the Silverado water-bearing zone of. the Torrance-Inglewood subarea and in aquifers of correlative age to the north, but also in shallower Pleistocene ^aquifers, and in those of Recent age the Gaspur water-bearing zone of Dominguez Gap and the "50-foot gravel" of Ballona Gap. In addition to the underflow, recharge from rainfall contributed to the ground-water supply of the west basin.
The Los Angeles Eiver and Ballona Creek did not furnish recharge directly to the west basin under native conditions because they were effluent within its extent and hence functioned as channels for ground-water discharge. Most of the discharge, however, was by direct escape from the aquifers extending beneath the ocean. Such dis-charge was into Santa Monica Bay along the west coast from Santa Monica to the Palos Verdes Hills, especially southward from Redondo Beach; discharge also occurred into San Pedro Bay at the south end of Dominguez Gap, probably largely from the Gaspur water-bearing
zone.

The pressure or piezometric surfaces of all aquifers in the west basin under native conditions were below the land surface everywhere

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except (1) near the coast in Balloria Gap, and (2) locally in and near Dominguez Gap, as registered in four wells that were flowing in 1904. In Ballona Gap in 1904 the area of artesian flow as shown by Menden-hall (1905b, pi. 5) extended over about 3 square miles, chiefly in sees. 21,22,23, and 27, T. 2 S., K. 15 W. Within this area, almost the entire land surface is less than 10 feet above sea level.
The decline in water level which has occurred in the main coastal

basin within the past three decades, 'has been nearly matched by a similar decline on the coastal side of the uplift (within the west basin); therefore, the local pressure differential has remained almost equal. However, the decline along the crest of the uplift has been many tens of feet; it has dewatered a part of the water-bearing conduits and the over-all escape from the main basin to the west basin has been decreased substantially. Thus, the changes in water level that occur within the main basin are critical in determining the quantity of replenishment that may be contributed to the west basin by under-flow across the uplift.
For the main coastal basin and especially for the coastal reach from Dominguez Hill southeast to Newport Beach, the interpretive reports of the Geological Survey on the Long Beach-Santa Ana area have treated in some detail the occurrence and circulation of ground water, the increasing withdrawals, the drawdown of the water level that has developed, the nature and sources of saline contamination, and the character of the Newport-Inglewood uplift as a barrier to water movement. Other sections of this report will treat elements of somewhat similar scope within the west basin.

GROUND WATER IN THE WEST BASIN

SEMIPERCHED WATER BODY

OCCURRENCE

The semiperched and unconfined water body occurs rather widely in the west basin in deposits less than 100 feet below the land surface. It is the first water reached by wells but is utilized only locally. In Dominguez Gap it is contained within the upper 20-50 feet of the Recent deposits in layers of fine sand and silt of low permeability. In Ballona Gap it occurs in deposits of similar age and physical character, but here the semiperched body commonly does not extend more than 20 to 30 feet below the land surface. Beneath the Torrance plain, this body occurs very widely in the uppermost Pleistocene deposits. About in the south-central part of the Torrance plain, where it is tapped by nearly 100 wells, the semiperched body extends to depths of as much as 80-100 feet. Thus, here it is about twice as thick as within the two flanking gaps.

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Although this water body has frequently been referred to as perched water in local usage, in reality it is semiperched. According to Meinzer (1923, p. 40-41),
ground water is said to be perched if it is separated from an underlying body of ground water by unsaturated rock [including uiiconsolidated material]. Perched water belongs to a different zone of saturation from that occupied by the under-lying ground water. * * * Ground water may be said to be semiperched if it has greater pressure head than an underlying body of ground water, from which it is, however, not separated by any unsaturated rock. Semiperched water belongs to the same zone of saturation as the underlying water, and therefore where it occurs there is only one water table, which may be called a semiperched water table. Semiperched water, like perched water, is underlain by a negative confining bed of either permeable or impermeable type. The underlying water has subnormal head.

Nearly everywhere within its extent in the west basin, the static level of the semiperched water body is higher than the pressure head of the underlying body of fresh ground water. Also, it is generally separated from the underlying water by more or less impermeable layers of silt and clay.
The semiperched water body beneath the Torrance plain is replen-ished principally by infiltration of rain and of runoff temporarily ponded by overflow from Dominguez Channel and by infiltration of irrigation water. Under native conditions in Dominguez Gap the semiperched body discharged to the Los Angeles River. For the last three decades, however, the water table has been at a lower altitude than the channel of the Los Angeles River, and the body is replenished in part by influent seepage from the river. Stream-gaging records are not adequate to define the small quantity of river loss involved but measurements in shallow wells show a ground-water mound beneath the river channel. Also, a study of saline contamination in Dominguez Gap has suggested that since about 1930 the average contribution of saline water from the Los Angeles River passing through the semiperched body to the Gaspur water-bearing zone has been at least 90 acre-feet per year (Piper, Garrett, and others, 1953, p. 190). Thus, it is inferred that the over-all annual recharge to the semiperched body has been substantially more than 90 acre-feet per year. In Ballona Gap under native conditions the ground-water body fed the creek along nearly the full reach of the gap. Within the west basin under the current conditions of depressed water level, the semi-perched water doubtless has been and now is replenished in part by seepage from Ballona Creek. Immediately inland from the Ingle-wood fault, however, even though the pressure head in the underlying San Pedro formation has been drawn down below sea level since the early thirties (pis. 9-12), the semiperched water body is known to

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have discharged water to Ballona Creek as late as 1932, from a spring in 2/14-5M (pi. 17, loc. 5).
UTILITY

Almost everywhere within its extent, the semiperched water was greatly inferior in chemical quality to the underlying fresh water under native conditions. Locally in Dominguez Gap, its quality has dete-riorated substantially in the past two decades, either from landward movement of ocean water or by addition of industrial wastes and oil-field brines. The changes in chemical quality of the semiperched water in Dominguez Gap have been discussed at length in an earlier report (Piper, Garrett, and others, 1953, p. 173-177); the chemical quality of the semiperched water elsewhere in the west basin is discussed on page 175 of this report.
Because of the general inferior quality of the semiperched water, and because wells of large capacity cannot be obtained, little water is withdrawn from it. In Dominguez and Ballona Gaps, few wells pro-duce water from this body. However, beneath the Torrance plain in the Gardena area, the semiperched water in the uppermost Pleisto-cene deposits is tapped by about 100 wells which range in depth from 25 to 100 feet. The area of this development is south of Rosecrans Avenue and north of 190th Street, and extends eastward from Haw-thorne Avenue about 5 miles to Avalon Boulevard. From information obtained during the well canvass, it is concluded that about half of the wells, or about 50, are used chiefly for irrigation; of the remainder, some are used exclusively for domestic supply but most are used jointly for irrigation and domestic supply. Many of the wells are equipped with windmills. The yield of these wells commonly is only a few gallons per minute, and the irrigated gardens usually do not exceed half an acre in extent. Accordingly, it is estimated that the over-all draft from the 100-odd wells is about 50 acre-feet a year.

DECLINE OF WATER LEVEL

Throughout the known extent of the semiperched water body, its water table has declined 10 to 20 feet since 1904, the time of earliest record. For example, in Dominguez Gap in 1903-4 essentially under native conditions of head the water table of the semiperched body ranged from 5 to 8 feet below land surface throughout the gap, and coincided closely with the pressure level of the underlying Gaspur water-bearing zone. In 1946 the depth to the water table ranged from 15 to 25 feet; and again it was about coincident with the pressure level in the Gaspur water-bearing zone. Thus, in about 40 years the water table of the semiperched body had declined as much as 10 to 15 feet in Dominguez Gap. Because a coincident decline occurred in the pressure level of the Gaspur water-bearing zone, it is concluded

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that there is appreciable hydraulic continuity between the two water bodies. Because the pressure level in the Gaspur zone was drawn down by heavy withdrawals (especially in the twenties and early thirties), water percolated downward from the semiperched body and its level declined accordingly. This conclusion has been substantiated by study of the nature and development of saline contamination within the Dominguez Gap (Piper, Garrett, and others, 1953, p. 167-169).
In the Gardena area in 1904 the semiperched water table ranged from 10 to 25 feet below land surface about 15 to 25 feet above sea level. Since 1929 periodic measurements have been made in a few wells tapping the semiperched body in this area. (See hydrographs for wells 3/14-25E2 and 25K3, fig. 5.) The water table at or near these wells was 22 feet above sea level in 1904 (from Mendenhall); 15 feet in 1929; 12 feet in 1936; and 14 feet in 1945 (high level for each respective year). Thus, this water table has had a net decline of about 8 feet in 40 years. In 1904 the pressure levels in nearby wells tapping the "200-foot sand" and the Silverado water-bearing zone, respectively, were nearly coincident with the semiperched water table, but they have been drawn down progressively until in 1946 they were about 30 and 50 feet below the semiperched water table (fig. 5). Presumably, the 8-foot lowering of the water table in 3/14-25E has occurred in part by slow percolation from the semiperched body to the underlying aquifers. However, this change in storage in the semi-perched body has been distributed over many years, and the contain-ing deposits have a low specific yield.7 Also, some part of the lowering may represent drawdown by withdrawals from the shallow wells of the Gardena area., For these reasons, change in storage in the semi-perched body is considered to have been negligible in its relation to problems of replenishment to the principal water body.

PRINCIPAL WATER BODY OCCURRENCE

EXTENT AND THICKNESS

The principal body of fresh ground water underlies almost all the Torrance-Santa Monica area, and occurs beneath all of the west basin except the crestal part of the Baldwin Hills and certain con-taminated areas along the coast. It extends downward from the base of the semiperched water body to the top of the body of saline connate water. This fresh-water body occupies: (1) the lower division of the deposits of Recent age that is, the Gaspur water-bearing zone

7 The specific yield of a water-bearing deposit is delned as the ratio of (1) the volume of water which the saturated material will yield by gravity to (2) its own volume. This tatio Is stated as a percentage. 46050& 59 7

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and the "50-foot gravel" where these are uncontaminated; (2) the unnamed upper Pleistocene deposits, in which the principal aquifer is the "200-foot sand"; (3) the San Pedro formation of early Pleistocene age which, in the Torrance-Inglewood subarea, contains (a) an inex-tensive upper aquifer, the "400-foot gravel", and (b) the underlying thick and very extensive Silverado water-bearing zone; and (4) most of the upper division of the Pico formation of late Pliocene age, except in the Culver City area where the sand members in the upper division of the Pico either are absent or, if present, commonly contain brackish to saline waters.
The depth to the base of the principal fresh-water body has been shown on plate 8. Its over-ah" thickness is indicated generally by the contours of that map because its top is within a few tens of feet of sea level in almost all of the west basin except along the crest of the Newport-Inglewood uplift and along the flank of the Santa Monica Mountains where its top rises to as much as 200 to 300 feet above sea level.
The upper division of the Pico formation is not tapped by water wells at the present time. Hence, the thickness of the principal water body now utilized is indicated by the contours drawn on the base of the water-bearing deposits of Pleistocene age (pi. 2). In the Tor-rance-Inglewood subarea, these contours define the base of the Sil-verado water-bearing zone; in the Culver City subarea, they define the base of the essential correlative of the Silverado water-bearing zone that is, the main water-bearing zone within the San Pedro formation. As shown by that map, throughout much of the west basin the thickness ranges from 200 to 700 feet but it reaches a maxi-mum of about 1,200 feet near the intersection of Alameda and Carson Streets in Dominguez Gap, at the deepest part of the syncline. Along the crest of the Newport-Inglewood uplift the thickness of the water-bearing deposits now tapped by weUs varies widely. As shown by plate 3A, the thickress ranges from a feather edge on the crest of the Baldwin Hills to 700 feet in Dominguez Gap. Specifically, along the line of section A-A' (pi. 3.4), these water-bearing deposits are about 330 feet thick in Inglewood, thin to 250 feet at the north end of the Kosecrans Hills, thicken irregularly southeastward to about 600 feet at the south edge of the Rosecrans Hills and beneath the crest of Dominguez Hill, attain a maximum thickness of 700 feet in Dominguez Gap, and thin to about 200 feet beneath Signal Hill. Along the coast the thickness of the water-bearing deposits tapped by wells is somewhat more uniform although it increases substantiaUy from north to south (pi. 3(7). These deposits are from 200 to 250 feet thick from Santa Monica to Playa del Hey, thicken to as much as 350 feet at El Segundo, thin to 200 feet at Manhattan Beach, thicken

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to 500 feet in the Redondo Beach area, and then thin to a featheredge along the north flank of the Palos Verdes Hills. The thicknesses here cited do not include the deposits of dune and beach sand that blanket the coast from Playa del Rey to the Palos Verdes Hills and extend from a few tens of feet above sea level to altitudes as much as 244 feet. For the several water-bearing zones within the principal water body, general physical character, water-bearing character, extent, thickness, and depth below land surface have been discussed in the geologic section of this report. The quantity of water withdrawn from them is discussed on pages 99-111.

CONFINED AND WATEB-TABLE CONDITIONS

Within most of the west basin, the water-bearing zones within the principal water body are separated by substantial thicknesses of relatively impermeable silt or clay. These features have been shown on the gelologic sections previously introduced. The beds of silt or clay confine the water in the several aquifers and prevent free circula-tion from one to another. For example, between Hawthorne and Gardena, near the axis of the syncline, along the line of section B-B' (pi. 35), the "200-foot sand" is separated from the "400-foot gravel" by 50 to 100 feet of silt or clay; and a similar thickness of silt or clay separates the "400-foot gravel" from the Silverado water-bearing zone beneath.
In the Torrance-Inglewood subarea, the water in the several aquifers is almost wholly confined by impermeable deposits, except to the south of Playa del Rey and near Redondo Beach (pi. 11), where a water table occurs. Near Playa del Rey, the water table is in the main water-bearing zone of the San Pedro formation; the top of this water-bearing zone here rises as high as 30 feet above sea level and the con-fining beds feather out westward in the vicinity of Lincoln Boulevard. West of Lincoln Boulevard and south nearly to Imperial Highway, the main water-bearing zone is directly overlain by permeable beach and dune deposits. Hydrographs introduced later in this report sug-gest that rainfall passes through these overlying permeable beds directly into the main water-bearing zone (p. 124).
In the Redondo Beach area, south of 190th Street (boundary be-tween Tps. 3 and 4 S.) and west of the center of the city of Torrance, the confining beds that separate the Silverado water-bearing zone and the "200-foot sand" to the east and north are not present (pi. 5). In this area the permeable deposits of Pleistocene age rise above sea level and a water table occurs in what is inferred to be the Silverado water-bearing zone, although its upper part may represent the westward extension of the "200-foot sand."

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In the area south of Sepulveda Boulevard and east of Narbonne Avenue, water-table conditions exist in the "200-foot sand," extend eastward about to Alameda Street and beneath much of the Wilming-ton area. Here, however, the "200-foot sand" is separated from the Silverado water-bearing zone by relatively impervious deposits and from west to east the water table in the "200-foot sand" stands progressively higher than the pressure surface of the Silverado zone. Elsewhere within the Torrance-Inglewood subarea, the ground water in the Silverado water-bearing zone is wholly confined and in the "200-foot sand" it usually occurs under confined conditions. In the Culver City subarea the water in the main water-bearing zone of the San Pedro formation commonly is confined, except locally along the north edge of Ballona Gap from the Charnock fault west to the coast, in the Charnock subbasin north of the Charnock well fields, and from the Overland Avenue fault east at least to and beyond the wells in 2/15-lC (pi. 2).

SOURCE AND MOVEMENT

METHOD OP INVESTIGATION

The source of ground water commonly is indicated by the direc-tion of movement. Water generally moves from areas of recharge to areas of discharge. If the water-bearing deposits are homogene-ous, the altitude of water level in a number of wells measured within a short span of time can be utilized to construct a map showing contours on the water table or the piezometric surface. Such a map shows conditions of head from place to place. Movement is at right angles to the contours, which connect points of equal altitude on the water table or the piezometric surface. The rate of movement is proportional to the hydraulic gradient and the permeability of the deposits.
As already discussed, the water-bearing deposits in the west basin do not occur as a homogeneous permeable mass but are stratified in several fairly distinct aquifers which are separated at most places by confining layers. Initially the pressure levels in all the water-bearing zones were at about the same altitude. Through the period of use, and largely because of inequalities in draft and replenishment, differences have developed in the pressure levels of the several aquifers. At some places, the maximum differential in water level in shallow and deep aquifers in 1946 was as much as 70 feet. Thus, in order to draw contours on the piezometric surface or water table for a single aquifer, only levels for wells tapping that aquifer can be uti-lized. A water-level contour map drawn from levels in random wells tapping more than one aquifer would be misleading and inac-

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curate and could not be used to determine direction of movement, or source of water.
Within the west basin, the Silverado water-bearing zone south of the Ballona escarpment and its essential correlative to the north currently yield about 90 percent of the ground-water withdrawal, including nearly all the pumpage for industrial use and about 90 percent of the pumpage for domestic use. Thus, with respect to conditions of replenishment and saline contamination, the changes in the form and position of the piezometric surface in these composite water-bearing zones of the San Pedro formation are critical, and the changes in water level in overlying aquifers are of minor importance. Water-level contour maps showing conditions in 1903-4 and in March 1933 (pi. 9), in April 1941 (pis. 10, 11), and in November 1945 (pi. 12), have been included in this report. Each of these water-level contour maps has been drawn from water-level altitudes in wells tapping the San Pedro formation that is, the water-bearing zones most intensively utilized. Within almost all the Torrance-Inglewood subarea, the water levels utilized for the maps were those in wells tapping the Silverado water-bearing zone; in the Culver City subarea the water-level data were from wells tapping the main water-bearing zone of the San Pedro formation, the essential correlative of the Silverado water-bearing zone; and inland from the west basin, water levels were from the deeper wells tapping the Silverado or equivalent water-bearing zones of Pleistocene age.
In preparing the water-level contour maps, measurements of depth to water were utilized from all possible sources. For the maps of 1933 and 1941, measurements were made chiefly by the Los Angeles County Flood Control District and by the Los Angeles Department of Water and Power; for the map of 1945, most of the measurements were made by the Flood Control District and by the Geological Survey. All measurements made by the Geological Survey during the cooperative investigation are being published in the annual reports on water levels and artesian pressure in the United States for the years 1944, 1945, and 1946 (U. S. Geol. Survey). The scope of the measurements is discussed on page 112.
Altitudes of measuring points for most of the observation wells in the Torrance-Santa Monica area have been determined by instru-mental leveling. For the area immediately west of Long Beach, in T. 4 S., R. 13 W., altitudes for many of the wells were determined by the Geological Survey in 1941-42 through a third-order level net anchored to bench mark "tidal 8" in the Los Angeles Outer Harbor, and by additional levels with transit and stadia or with alidade and level rod, tied to the third-order net (Meinzer, Wenzel, and others, 1944, p. 87-88). In the remainder of the area, altitudes of measur-

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ing points for most of the observation wells have been determined by levels of the Los Angeles Department of Water and Power, and these were utilized wherever available. For a few wells, altitudes of measuring points have not been determined instrumentally; how-ever, these altitudes have been interpolated from topographic maps o^the Geological Survey having a 5-foot contour interval.

MOVEMENT IN THE TORRANCE-INGLEWOOD SUBAEEA

Conditions in 1903-4- Water-level contours for 1903-4 are plotted on plate 9 for the southern two-thirds of the project area essentially the Torrance-Inglewood subarea. These contours were constructed from data obtained by Mendenhall and show substantial modifica-tion from his water-level contours (Mendenhall, 1905b, pi. 5). The revision has developed for two reasons: (1) The altitude of land sur-face at the wells measured during the Mendenhall field canvass has been re-interpolated because of recent Geological Survey topographic maps with a land-surface contour interval of 5 feet; in the Torrance area especially, the topography on the later map (1934 edition) differs considerably from that shown by the survey of 1894, which was published with a land-surface contour interval of 25 feet and was the basis for the well altitudes interpolated by Mendenhall.
(2) Insofar as possible, only water levels in wells tapping the Silverado water-bearing zone have been utilized hi redrawing the water-level contours, whereas the contours of Mendenhall were generalized from all available water levels, including many levels for wells tapping shallower zones.
The reconstructed water-level contours of 1903-4 show coastward movement of ground water across the Newport-Inglewood uplift and a hydraulic discontinuity from about 40 to 50 feet across the inland boundary of the west basin along the 14-mile reach from the Baldwin Hills to Long Beach. Within the west basin movement was also generally coastward. East of Manhattan Beach the 20-foot contour bulges seaward, indicating a flattening of the hydraulic gradient and a diversion of part of the ground-water flow to the northwest and to the south. This configuration of the pressure surface suggests that the known thinning of the Silverado water-bearing zone near the coast at Manhattan Beach (fig. 2) retarded discharge of ground water to the ocean. However, in the vicinity of Manhattan Beach, the dune topography is rough and hilly; and the locations of the wells shown by Mendenhall can be plotted only approximately on the revised topo-graphic map of the Torrance quadrangle. Hence, the computed alti-tude of the water surface is subject to possible errors of several feet and the contours based on these altitudes are only approximations and are not suitable for exact interpretations.

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From Manhattan Beach northward to Playa del Key, the movement of ground water was westward; inland from Sepulveda Boulevard the coastward gradient was from 6 to 8 feet per mile. Near the coast, however, the gradient was only about 3 feet per mile.
Southward from Manhattan Beach to the Palos Verdes Hills, the movement was generally westward to the coast; from the Palos Verdes Hills to Long Beach the movement was southward. The coastward gradient in 1903-4, both westward toward Redondo Beach and southward toward San Pedro Bay, was about 4 feet per mile.
Thus, the contours of 1903-4 suggest escape of ground water beneath the ocean offshore from Redondo Beach and beneath San Pedro Bay. Although fresh-water springs were reported in San Pedro Bay, under native conditions, these are believed to have developed by escape of water from the ocean-bottom outcrop of the Gaspur water-bearing zone (Poland, Piper, and others, 1956, p. 50). However, escape from the Silverado water-bearing zone under native conditions by upward movement into San Pedro Bay cannot be substantiated by such direct evidence. The writer has heard reports of former fresh-water springs offshore from Redondo Beach but these have not been verified. If such springs did occur, they must have been fed by discharge from the Silverado zone.
From the geologic relations, it would seem that escape could have occurred with much greater facility in the vicinity of Redondo Beach than beneath San Pedro Bay (pis. 5 and 6). If the permeability of the Silverado water-bearing zone is assumed to be about 1,300 gpd per square foot (about two-thirds as great as in the area east of Torrance, as indicated by comparison of yield factors from table 5), the ocean-ward discharge in the Redondo Beach area under native conditions can be estimated by use of the equation

where Q is gallons per day; Pf is the field coefficient of permeability defined as the number of gallons of water per day that would be con-ducted through each mile width of the water-bearing bed for each foot of thickness of the bed and for each foot per mile of hydraulic gradient; /is the hydraulic gradient in feet per mile; and A is the cross-sectional area of the water-bearing material in foot-miles. The average thickness of the Silverado water-bearing zone between Her-mosa Beach and the Palos Verdes Hills is about 400 feet and the dis-

tance about 3.5 miles; thus the estimated discharge $=1,300X4X 400X3.5, or about 7.3 mgd, equivalent to about 11 cfs. The presumed gradient of 4 feet to the mile at Redondo Beach is conservative; coast-ward from the 10-foot water-level contour, a steeper gradient is

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suggested by the altitudes of water level in random wells. Because the local control is poor, however, the regional coastward gradient of about 4 feet per mile was utilized in computing the estimate for seaward escape in the Kedondo Beach area as of 1903-4. Thus, the annual discharge to the ocean between Hermosa Beach and the Palos Verdes Hills in 1904 is estimated to have been about 8,000 acre-feet per year.

North from Hermosa Beach to Playa del Key and along San Pedro Bay the data on gradient near the coast in 1903-4 are fragmentary but a rough estimate of oceanward discharge is given on page 147. Conditions in 1933. The withdrawals of ground water from the Torrance-Inglewood subarea increased from an estimated 10,000 acre-feet per year in 1904 to about 50,000 acre-feet per year in the early thirties (p. 99-100). The water-level contours for March 1933 (pi. 9) show the changes in position of the water level and in direction of movement that had developed since 1904 as a result of increasing withdrawals from the west basin and from the main coastal basin to the northeast. These changes can be summarized as follows:
1. Immediately inland from the west basin boundary, in the reach from the Baldwin Hills to Long Beach, the water levels had declined about 40 feet in the 29 years but the direction of movement was still coastward into the west basin. The local gradient had been steepened to a small degree. (See also pi. 4 showing water-level profiles for 1904 and 1930.)
2. The pressure differential across the fault boundary ranged from about 30 feet at Inglewood and Dominguez Gap to about 50 feet in the central part of the Rosecrans Hills.

3. Within the area south of Inglewood the pressure level and, locally, the water table was below sea level. Everywhere westward from the axis of the pressure trough, about two-thirds of the Torrance-Inglewood subarea, the direction of movement of the water within the Silverado zone had been reversed and was landward generally southeastward or eastward toward the area of greatest pressure lowering in Dominguez Gap.
Conditions in 194-1 and in 194£. Plate 11 shows water-level con-tours for April 1941 and plate 10 indicates the rise or fall in water level that had occurred since March 1933 (pi. 9). The general pattern of the contours is similar to that for March 1933. However, attention is directed to four features:

1. The maximum drawdown of water levels in the 8-year period occurred im-mediately inland from the west basin boundary, east of Inglewood and within the Rosecrans Hills, and was about 30 feet. This drawdown, indicating local over-draft, was noteworthy because almost everywhere else within the main coastal basin (central basin), except in the Huntington Park area, water levels were higher in 1941 than in 1933.
2. In the west basin, north of 190th Street, nearly all water levels were drawn down, but the maximum decline of 16 feet, which developed between Inglewood and Hawthorne, was only about half as great as the drawdown inland beyond the west basin boundary.

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3. South of 190th Street, water levels changed only a few feet between 1933 and 1941. In the Wilmington area, a small net rise resulted from the virtual cessation of pumping at the Wilmington and Lomita well fields of the city of Los Angeles (table 7).
4. The axis of the pressure trough moved inland as much as 3 miles between Hawthorne and Gardena, but it was almost stable from 190th Street into Do-minguez Gap. This axis marks the boundary between coastward and landward movement of ground water in the Silverado water-bearing zone.

Largely because of demands caused by industrial expansion during the war years, withdrawal of ground water from the Torrance-Ingle-wood subarea increased about 50 percent between 1941 and 1945 (table 8). The water-level contours of plate 12 indicate conditions in November 1945, essentially at the end of the period of acceleration in draft induced by the war expansion, in relation to distribution of pumping draft.
The contours represent approximate low-water levels for the year, whereas the contours for 1933 and 1941 represent the high-water levels in those years. As is shown on representative hydrographs intro-duced later in this report, the yearly fluctuation in the Silverado water-bearing zone within the west basin ranges from about a foot near the coast to as much as 30 feet in areas of heavy pumping near the inland boundary. For example, the center of the depression in the piezo-metric surface immediately north of Hawthorne was 62 feet below sea level in November 1945, but it was only 38 feet below sea level in March 1945 (pi. 13, well 3/14-4N1). Thus, although the contours for November 1945 indicate a maximum decline of more than 30 feet below the contours for April 1941 (pi. 11), much of this is due to seasonal fluctuations. The contours of November 1945 were drawn to show the lowest water levels for the Silverado water-bearing zone that had occurred in the Torrance-Inglewood subarea to the end of 1945. With respect to saline encroachment from the ocean, the average con-trolling hydraulic gradient is about halfway between the seasonal high and low levels. However, the maximum rate of landward advance of the saline front occurs at the time of autumn low water. In Novem-ber 1945, the landward gradient from the coast to the minus 20-foot contour was steepest between El Segundo and Hermosa Beach, as much as 20 feet per mile; in the vicinity of Redondo Beach it was only about a third as steep, from 5 to 6 feet per mile.
The axis of the pressure trough did not move appreciably from 1941 to 1945, even though pressure levels along that axis were drawn down locally as much as 30 feet. In November 1945, the greatest differ-ential pressure across the inland boundary of the west basin was about 60 to 70 feet. Differential pressures of this magnitude occurred east of Inglewood across the southern part of the Potrero fault, also in Dominguez Gap across the Cherry-Hill fault.

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MOVEMENT IN THE CULVER CITY SUBAREA

Summary ofgeologic features. Ballona Gap, a broad trench cut- into the Pleistocene deposits by an ancestral Los Angeles River, is floored by deposits of Kecent age to a depth of 40 to 80 feet below land sur-face. These deposits consist of an upper and a lower division. The upper division consists chiefly of clay, silt, and fine sand; it is from 10 to 40 feet thick and of low permeability. The lower division, the "50-foot gravel," is composed almost wholly of gravel, but locally contains lenses of coarse sand. Its thickness ranges from 10 to 40 feet and its average base is about 50 feet below land surface. The "50-foot gravel" blankets most of the gap (pi. 8) and furnishes a thin but permeable ground-water artery from the main coastal basin to the
ocean.

Everywhere within the gap, the "50-foot gravel" is presumed to be underlain by the San Pedro formation. Near the coast, the San Pedro largely consists of sand and gravel; but inland beyond the Inglewood fault more than half the formation is made up of layers of silt and clay, which separate and confine the layers of sand and gravel (pi. 3D). Within and adjacent to Ballona Gap, three faults divide the San Pedro formation into distinct blocks which are critical with respect to water circulation and to movement of contaminated waters. These three faults are subparallel and trend about north-northwest. So far as known, they do not transect the deposits of Recent age and presumably do not interrupt hydraulic continuity in the "50-foot gravel." (See p. 76 and 78.)
Of the three faults, the Inglewood fault, the farthest inland, passes across the gap about 6 miles from the coast and forms the inland boundary of the west basin in this area. The Sentney plant of the Southern California Water Co. (in 2/14-5D) is a short distance east of this fault and within the main coastal basin. Logs of wells at this plant show that three distinct aquifers in the San Pedro formation yield water to wells and that the three are separated by impervious
strata.
The Overland Avenue fault is about 2 miles coastward from the Inglewood fault. Between these two faults, an upthrown block of the San Pedro formation contains water-bearing beds whose thickness ranges from 50 to 100 feet. The subbasin within this block is termed the crestal subbasin.
The Charnock fault is about 1.2 miles west of the Overland Avenue fault and 3 miles from the coast. Between these two faults the San Pedro formation has been dropped and the main water-bearing zone is as much as 350 feet thick. In subsequent discussion, the subbasin within this block will be referred to as the Charnock subbasin. Coast-ward from the Charnock fault the San Pedro formation is gently

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folded and its water-bearing deposits range from 100 to 250 feet in thickness.
Logs of wells indicate that the "50-foot gravel" and the underlying water-bearing deposits of the San Pedro formation are in direct con-tact locally within each of the blocks here described, and thus, some hydraulic continuity occurs. The complex structure of the San Pedro formation makes it difficult to trace the extent of hydraulic continuity, except where logs of closely spaced wells are available. However, the hydraulic continuity is known to be most free coastward from the Charnock fault, and is very poor to absent inland from the Overland Avenue fault.
North of Ballona Gap, logs of wells show a general southerly dip of the water-bearing beds of Pleistocene age, but the sand and gravel layers are irregular in thickness and position and cannot be correlated from well to well. Only within the dropped Charnock subbasin (to the north), are the water-bearing deposits thick and extensive. The main water-bearing zone extends continuously at least 2 miles north from the gap, to the vicinity of Pico Boulevard, where its top is about 50 feet above sea level and its thickness about 250 feet. Circulation of ground water. The Culver City subarea has been defined as including the part of the west basin north of the Ballona escarpment. The ground-water contour maps of the west basin for the selected times between 1904 and 1945, inclusive, indicate that exchange of ground water between the Culver City subarea and the Torrance-Inglewood subarea that is, across the Ballona escarpment has been small. Also, in the Culver City subarea, movement has been controlled very largely by fault barriers, which appear to parti-tion the subarea into three essentially separate subbasins. Within these subbasins, movement has been chiefly in response to concentra-tions of draft at several heavily pumped well fields (pi. 12). Water-level contours for the Culver City subarea for 1903-4 were reconstructed from basic data by Mendenhall but it was impracticable to reproduce them on plate 9, because of the complexity of the hy-drologic pattern for 1933. However, a brief summary of salient features is presented. These contours indicate that in 1903-4 there was a general southward movement of ground water toward Ballona Gap from the upland area flanking the Santa Monica Mountains. In Ballona Gap the contours were drawn chiefly from water levels in shallow wells tapping the "50-foot gravel" because in 1904 very few wells had been drilled to the San Pedro formation below. Here the movement of water was southwestward and essentially parallel with the slope of the land surface. In Ballona Gap, a short distance west of the Inglewood fault, the water-level contours bulge coast-ward, indicating that water hi the "50-foot gravel" was moving coast-

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ward from the main basin into the west basin, over the top of the Inglewood fault. Throughout its 6-mile reach within the west basin Ballona Creek was an effluent stream draining water from the Recent deposits of the gap. The reach of effluent seepage extended inland at least half a mile beyond the Inglewood fault and into the area of artesian flow that still existed in 1904 in the mam coastal basin. The water-level contours for March 1933 (pi. 9), April 1941 (pi. 11), and November 1945 (pi. 12), show general similarity in direction of ground-water movement; and all show substantial change from the water-level contours of 1903-4. This change was brought about by (1) heavy draft from well fields in or adjacent to the two sub-basins, and (2) the barrier action of the three major faults, which bound those subbasins.

In the main coastal basin, immediately inland from the Inglewood fault and adjacent to Washington Boulevard, heavy withdrawals from the wells at the Sentney plant of the Southern California Water Co. in sec. 5, T. 2 S., R. 14 W., and from nearby wells of the city of Beverly Hills (Cadillac and Castle plants) had developed a substantial cone of pressure relief by the early thirties. In March 1933, the pres-sure level at the center of this cone as represented by the hydrograph for well 2/14-5D5 (pi. 14), was about 10 feet above sea level; but by April 1941 it had been drawn down as much as 60 feeet below sea level. By 1945 local draft by the city of Beverly Hills had decreased and the water level in the spring of that year at well 2/14-5D5 had re-covered substantially; but it was still 30 feet below sea level. Thus the pressure levels at these well fields have been maintained many tens of feet below sea level continuously for the past decade and water in the aquifers of the San Pedro formation has been moving into this cone of depression from the south, east, and north.
Crestal subbasin. In the crestal subbasin, between the Inglewood and Overland Avenue faults, the movement of water in the San Pedro formation has been consistently southward from the Beverly Hills through 1945. Within this subbasin pumping draft is largely from wells at the Manning plant of the Southern California Water Co. in 2/15-lC and from well 2/15-12B1 of the Metro-Goldwyn-Mayer Corp. (pi. 2). Total draft from this subbasin is believed not to have exceeded 1,600 acre-feet per year. Under native conditions and continuously through the period of withdrawal, replenishment to the San Pedro formation in the crestal subbasin apparently has been supplied almost entirely by runoff from the south flank of the Santa Monica Mountains and by rainfall from the Santa Monica plain. However, in Ballona Gap north of Washington Boulevard, the water-bearing beds of the San Pedro formation are believed to be in direct contact locally with the overlying "50-foot gravel." Hence, ground

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water passing westward across the Inglewood fault in the "50-foot gravel" may contribute some replenishment to the underlying San Pedro beds in the crestal subbasin. Within this subbasin, the position of water level in the "50-foot gravel" is not known, except at well 2/15-1P2 near the western boundary; here the water level in this aquifer has been about 30 feet lower than the pressure level of the San Pedro formation for the past 15 years. (See hydrograph for well 2/15-1P2 on fig. 4; pressure levels for San Pedro formation, pis. 9-12.) Thus, near this well, for many years the pressure differential between the two aquifers would not have permitted downward movement from the "50-foot gravel" to the San Pedro formation if hydraulic continuity exists at all, movement would have been upward. Charnock subbasin. In the Charnock subbasin, during the past two decades at least, pumping has been concentrated at the Charnock plant of the city of Santa Monica (2/15-11C), and at the Charnock plant (2/15-11D, E, F) and the Sepulveda plant (2/15-llJ) of the Southern California Water Co. The joint withdrawal from these three plants was 7,352 acre-feet in 1933, reached a maximum of 10,448 acre-feet in 1940, and was 7,258 acre-feet in 1941 and 5,005 acre-feet in 1945. The decrease hi withdrawal was caused by the gradual decrease in the rate of pumping at the Charnock plant of the city of Santa Monica following 1940 and the complete cessation of pumping by the city late in 1944.
As a result of the concentrated withdrawal at the Charnock well fields and at the nearby Sepulveda well field, the water level in the San Pedro formation has been depressed several tens of feet below sea level since the late twenties. As shown by the water-level contours for the years 1933, 1941, and 1945 (pis. 9-12), and by other data, movement of ground water throughout the subbasin has been toward this focus of withdrawal for the past two decades. To the north (nearly to Pico Boulevard), water levels have been below sea level consistently since 1933, and the steep southward gradient induced by this draft has been as much as 50 feet to the mile (pi. 11). To the south (to and beyond the Ballona escarpment), water levels have been below sea level consistently since 1933, and the average northward gradient has been as much as 25 feet per mile (pi. 11). Thus, at least since 1933, about two-thirds of the water withdrawn from these well fields has come from the north and about one-third from the south. The water-level contours for the San Pedro forma-tion indicate that very little water enters the Charnock subbasin from the east (across the Overland Avenue fault), or from the west (across the Charnock fault), even though the pressure differentials across the two faults have been as much as 110 feet and 90 feet (pi. 11).

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The "50-foot gravel" may conduct some water into the Charnock subbasin, from both the east and the west. As shown by geologic section D-D' (pi. 3D), the "50-foot gravel" is in contact (at least locally) with the water-bearing beds of the San Pedro formation within the Charnock subbasin, and presumably some downward percolation of water occurs. However, fragmentary records of water levels in shallow wells indicate that in the part of the subbasin north of Ballona Creek, the "50-foot gravel" has been essentially dewatered for the past two decades. Southward from Ballona Creek, the base of the "50-foot gravel" locally is as much as 60 feet below sea level, and this water-bearing zone still must be almost wholly saturated. Coastal area. Between the Charnock fault and the coast, the "50- foot gravel" of Ballona Gap and the underlying main water-bearing zone of the San Pedro formation are in contact at many places, as shown by logs of wells. Thus, these water-bearing zones may have fair hydraulic continuity (p. 127). The water-level contours of 1903-4 indicate a general oceanward movement of water through these deposits, with a coastward hydraulic gradient of about 10 feet per mile. North of the gap, the water-level gradient was southward, indicating some replenishment from the Santa Monica upland area. By the late twenties water levels in this coastal part of Ballona Gap had been drawn down as much as 10 to 30 feet and were from 5 to 15 feet below sea level (see pi. 9 for levels in 1933). The water-level contours of March 1933 indicate some continuing contribution from the north, but the underflow to the gap from beneath the Ocean Park and Santa Monica plains must be small because: (1) the water-bearing deposits are thin, and (2) southward movement is impeded by the ground-water barrier about at the north edge of T. 2 S., which is inferred to be a fault zone. Water levels in the gap had recovered to sea level by 1941, probably in part because of the heavy rainfall of that year but chiefly owing to a general decrease of draft for irriga-tion and cessation of pumping by the Marine plant of the city of Santa Monica in 2/15-9N; both actions were caused by saline en-croachment. However, from the early thirties to date, the water level in this coastal part of the gap has been essentially flat and move-ment of water apparently has been largely in response to local draft. Except for withdrawals from the Marine plant to which reference has been made, that draft has been moderate and widely distributed. Because water levels were below sea level from the middle twenties through the thirties, sea water has advanced inland beyond Lincoln Boulevard and about half the distance from the coast to the Charnock fault (p. 197).

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WITHDRAWAL OF GROUND WATER
HISTORY OF DEVELOPMENT

Development of ground water in the coastal plain began about 1870. As of 1904, Mendenhall (1905a, 1905b, 1905c) canvassed and described about 8,200 wells within the coastal plain, of which about 2,500 were flowing in the spring of 1904. Mendenhall estimated that in 1904, the average discharge of all flowing and pumped wells within the coas-tal plain was about 250 cfs, equivalent to a yearly withdrawal of about 180,000 acre-feet. He did not evaluate withdrawals from the west basin specifically. However, in 1904 there were 134 wells with pumping plants in the west basin, as compared to 282 wells with pumping plants in the Santa Monica and Redondo quadrangles {Mendenhall, 1905b, pis. 5 and 6). The average annual yield of all pumped and flowing wells in these two quadrangles was estimated as about 30,000 acre-feet. If the estimated yield is distributed in proportion to the number of wells with pumping plants, the with-drawals in 1904 were about 14,000 acre-feet per year for all the west basin, and about 10,000 acre-feet per year from the part of the west basin south of Ballona Gap the Torrance-Inglewood subarea of this report. Because the lands irrigated by ground water within the Santa Monica and Redondo quadrangles amounted to only 12,250 acres in 1904, MendenhalTs over-all figure of 30,000 acre-feet probably is liberal (about 2.5 acre-feet per acre); thus, the estimate of 14,000 acre-feet just derived for the west basin likewise is also believed to be liberal.
During the quarter century following the canvass by Mendenhall, the rate of withdrawal from the west basin increased several fold, owing to: (1) increased demand for water for irrigation, industrial, and domestic use, (2) lack of surface-water sources, and (3) improve-ment and widespread use of deep-well turbine pumps. Information is not available to indicate the rate at which the withdrawal increased

from 1904 to 1930. However, extensive industrial development commenced in the twenties, and water levels in wells tapping the Silverado water-bearing zone began to decline noticeably in the early to middle twenties. Also, a period of low rainfall began about 1919 (table 2), causing an increase in the use of water for irrigation. Thus, it is inferred that the over-all increase in draft was most rapid after 1919. Furthermore, the figures for electrical energy sold on the "agricultural-rate" schedule in the Redondo and Inglewood operating districts of the Southern California Edison Co. are available for the period beginning in 1923. In comparison with the amount of energy sold in 1932, as a base year (p. 104), the amount of energy sold an-nually in these two operating districts of the Edison Co. from 1923

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through 1930 was higher in all years except 1927. The average use in the 8 years was 112 percent of the use in 1932; the peak was in 1923 about 140 percent of the 1932 base. Although water levels in the west basin declined nominally in the twenties, it is believed that pump efficiencies were improved sufficiently to nearly compen-sate for the increased lift, and that the amount of electrical energy required to raise an acre-foot of water remained nearly constant. Thus, it is concluded that the draft for irrigation in the Torrance-Inglewood subarea was slightly greater from 1923 through 1930 than in 1932 and following years (table 8). Accordingly, the main increase in irrigation draft must have occurred prior to 1923.
As indicated in table 8, by 1931 the withdrawal from the Torrance-Inglewood subarea was about 53,000 acre-feet per year, which inci-cates an increase of nearly 400 percent in the 26-year period since 1904. Records of withdrawal by the larger plants since 1931 are reasonably complete, and the withdrawal for irrigation and miscel-laneous uses can be approximated with fair accuracy. Methods of evaluating this withdrawal are discussed in following pages, and estimates for the yearly over-all draft from the Torrance-Inglewood subarea beginning in 1931 are summarized in table 8.

PUMPAGE FROM MUNICIPAL WELL FIELDS

In 1945, eight cities operated municipal water systems within the Torrance-Santa Monica area. The well fields of the cities of El Segundo, Hawthorne, Manhattan Beach, Santa Monica, and Torrance are located within the west basin. The city of Santa Monica, how-ever, purchased most of its water supply from the Metropolitan Water District, beginning in 1941, and reportedly discontinued the use of its well fields entirely in 1945. The city of Inglewood operated several well fields within the west basin and one (the Centinela Park well field) that was almost entirely in the main coastal basin. The city of Los Angeles operated its Lomita and Wilmington plants, which were within the west basin, and its Manhattan, 99th Street, and Figueroa Street plants in the main coastal basin. In 1945, the city of Beverly Hills pumped all of its water from well fields outside the west basin, partly from the main coastal basin and partly from the Hollywood basin of Eckis (1934, pi. E). In addition to these eight municipal systems, Los Angeles County Water Works Districts 13 and 22 withdrew water from plants wholly within the west basin. The distribution of plants producing more than 200 acre-feet of water for public supply or for industrial use in 1945 is shown on plate 12 (also see table 10).
Pumpage records for all these systems except that of Beverly Hills were collected by the Geological Survey from officials of the water

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departments or from the city engineers. In some cases these records were extended to earlier years by utilizing estimates made by other agencies, chiefly the Metropolitan Water District (Vail, 1942, table 2). Records of pumpage by the city of Beverly Hills were obtained through the California Division of Water Resources. Available records of the

yearly pumpage by each of the eight cities are given in table 7. In this table each record is carried back as far as available data will

permit. Except as noted, records are for the calendar year. Total yearly withdrawals from the municipal and county water works district fields within the Torrance-Inglewood subarea from 1931 through 1945 are summarized in table 8,-column 2.

TABLE 7. Yearly withdrawal of ground water by municipalities in the Torrance-Santa Monica area

Year Acre-feet Year Acre-feet Year Acre-feet

Beverly Hills, 1929-45

[For year ending September 30; records obtained from California Division of Water Resources]

1929
1930-
1931 - -_
1932
1933 -- __ _ ...
1934

6,900
6,960
6,290
6,480
6,139

1935
1936
1937
1938
1939 ------ ------
1940

5,654
6,635
6,778
6,801
7,958
7,742

1941
1942
1943
1944
1945 .

2 5, 874
3 4, 977
24,703
2 5 030
2 4, 824

El Segundo, 1931-45

1931
1932
1933.. . .
1934
1935

3460
502
697
7rtfi

1937 - . _ -
1938

1940-

79ft
966
942

680 7no

1941
1942
1943

1945

808
1,027
1,098
1,269
1,156

Hawthorne, 1931-45

[Estimates by Metropolitan Water District through 1941; records from city engineer beginning in 1942]

1931 . _- ....
1932
1933
1934.
1935

410
560
500
cm

600

1936 -

1938
1939
1940

690
7An

800
cm

900

1941
1942
1943
1Q4.4.

1,120
1,900
1,980

1,852

Ingle wood, 1923-45
[Record for years 1923-28 from Los Angles County Flood Control District; for years 1931-36 from Metro-politan Water District; for years 1937-45 from city engineer]

1823
1924.
1925
1926......... ....
1927
1928 .
1929 ....
1930 ....

870
2,280
1,400
1,320
2,010
2,240

1931
1932
1933 -
1934
1935
1936
1937
1938 -.

2,170
2

CATI

2,440
2,650
9 ^Vl

2,670
2,810
3,060

1939 .- . _ - ___ .
1940
1941
1942
1943
1944
1945

3,360
3,610
3,840
4,190
4,776
4,939
5,297

Metered consumption plus 10 percent to cover estimated losses. 2 Additional water taken from Metropolitan Water District.
3 Estimate by Metropolitan Water District.

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TABLE 7. Yearly withdrawal of ground water by municipalities in the Torrance-Santa Monica area Continued

Year Acre-feet Year Acre-feet Year Acre-feet

Los Angeles, 1918-45
[Total withdrawal from Lomita and Wilmington pumping plants]

1919 ....
1920 .
1921 __ --_-. . ..
1922
1923
1924 . .-. ....
1925 __ .. __ . .....
1926
1927

4,272
4,561
5,285
5,937
7,385
6,950
6,805

7,312

1928
1929...................
1930
1931 .
1932-.. ....
1933
1934... ....
1QOK

1936 __ ....

7,892

3,207
8,615
8,073
8,434
8,000

0

1937
1938
1939
1940 .
1941... ....
1942
1943
1944......... ...
1945

0
111
48
0
105
92
651
794
2,058

Manhattan Beach, 1931-45

(Estimates by city engineer, based on rated capacity of booster pumps; rounded off by Geological Survey]

1931
1932
1933
1934
1935

550
550
600
600

1936 __ ....
1Q37
1Q3R
1939
lo^trt

650
700
750
900
QKft

1941 ... _ .. ___ ...
1942-
1943 - ___ ..
1944
1945.. _ _ ...

1,000
1,050
1,300
1,300

Santa Monica, 1931-45

1931- ___ __ -.
1932
1933
1934
1935

» 2, 496
4,288
5,117
5,727
5,812

1936
1937
1QQQ
1Q3Q

1940 __ ...

6,790
7,147
7 QSQ
8,525
8,925

1941 _______
1942
1943 ___
1944
1945 .

« 4, 469
238
33
38
19

Torrance, 1931-45

1931 __ ...
1932
1933 _
1934
1935

'800
'800
'760
'890
'875

1936 . _ ....
1937
1938
1939 _ .... _ .
1940

' 1, 070
1,115
1,350
1,328
1,376

1941
1942-......... ....
1943
1944.
1945

1,178
1,500
1,757
1,786
1,748

* For withdrawal from all well fields of the city of Los Angeles within the coastal plain from 1918 through 1944, see Poland, J. F., Sinnott, Alien, and others (report on withdrawals of ground water from the Long Beach-Santa Ana area), table 4, p. 39.
i Pumpage for April through December.
6 Water supply chiefly from Metropolitan Water District beginning In 1941.
' Records from Metropolitan Water District.

WITHDRAWAL FROM THE TORRANCE-INGLEWOCMD SUBAREA, 1931-45

METHODS OF EVALUATING WITHDRAWAL

Industrial consumption. In the southern and central parts of the Torrance-Inglewood subarea, south of El Segundo Boulevard, 20 industrial plants currently obtain their water from wells. The largest use is by petroleum refineries, of which eight are in this area. Most of the records of withdrawal of ground water by each of these industrial plants was obtained from plant representatives. Meter records were available for all plants using large quantities of water. However, estimates that were supplied for several of the smaller plants were based on well performance and hours of operation. In the central part of the west basin, between El Segundo Boulevard and the Ballona escarpment, there are a number of industrial plants,

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but, as far as known, all of these plants purchase their water from municipalities or water companies.
Pumpage by large water companies. Within the Torrance-Inglewood subarea about 25 private water companies supply water for domestic, irrigation, and industrial uses. Meter records of production are avail-able for several of the larger companies. In connection with its field canvass of wells, the Geological Survey collected meter records from the California Water Service Co., the Dominguez Water Corp., the Palos Verdes Water Co., the Palisades Del Rey Water Co., and the Southern California Water Co. In addition, the pumpage of the Moneta Water Co. has been interpolated from estimates by other agencies in 1931 and 1944. With the exception of the part of the withdrawal by the Dominguez Water Corp. that is sold to industrial plants, total draft by these six companies is given in table 8, column 4. Pumpage for irrigation and miscellaneous uses. Withdrawal of ground water by private irrigators and by many small water companies is substantial. However, neither meter records nor estimates are available for most of this use. In its appraisal of withdrawal in the Long Beach-Santa Ana area, the Geological Survey estimated pump-age for agricultural purposes by deriving yearly mean energy factors (energy expended in raising a unit quantity of water) and applying these factors to the quantity of electrical energy expended in pumping from wells. In appraising pumpage for irrigation from the west basin, however, it was found that this method was not readily applicable because: (1) three operating districts of the Southern California Edison Co. extend from the west basin into the main coastal basin,
(2) pump-efficiency tests were not sufficiently comprehensive in distribution to define satisfactory yearly energy factors, and (3) many of the smaller water companies are not supplied with energy under the agricultural-rate schedule of the Edison Co.
Because the energy-factor method could not be readily applied, the pumpage for irrigation and for miscellaneous uses in the Torrance-Inglewood subarea was estimated from figures of irrigated acreage, considered together with a plot of electrical energy purchased yearly on the agricultural-rate schedule. Specifically, in 1932 and in 1941, the California Division of Water Resources made crop surveys of the lands in the west basin. Unpublished data in the files of the Division, compiled from these surveys and from maps showing service areas of municipal systems and public utilities, have been utilized by the Geological Survey to estimate the acreage supplied from wells with meter record estimate of pumpage. For the Torrance-Inglewood subarea, it has been estimated from these data that in 1932 an area of about 13,200 acres was so supplied (about 90 percent classified by the Division as irrigated lands and about 10 percent classified as

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domestic and industrial areas). Water use on the 13,200 acres in 1932, a year of nearly average rainfall (table 2), is estimated to have been about 13,200 acre-feet, an average use of 1 acre-foot per acre. This figure agrees with estimates made by the Los Angeles County Flood Control District from a field survey in 1931 (Dockweiler, 1932, pi. 11), which indicated that private irrigation and miscellaneous plants in the part of the Torrance-Inglewood subarea west of Vermont Avenue pumped about 9,200 acre-feet in that year. That figure did not include withdrawal from similar plants east of Vermont Avenue, but it is estimated that these plants pumped about 4,000 acre-feet in 1932.

Furthermore, from the crop survey of the California Division of Water Resources made in 1941, it has been estimated that the lands in the Torrance-Inglewood subarea supplied with water from wells for which neither meter records nor estimates are available was about 16,000 acres in that year. About three-quarters of this area or about the same acreage as in 1932 was classified by the Division as irrigated lands and about one-quarter of the area was classified as domestic and industrial sections. Thus, it is apparent that an increase of about 3,000 acres in lands used for domestic and industrial development supplied with water by noncanvassed withdrawals had occurred since 1932. Data are not available to indicate the rate at

which this increase in domestic use took place. Therefore, it is assumed to have been uniform, or about 330 acres per year, and to have required a duty of 1 acre-foot per acre.
To obtain yearly figures for the unmetered irrigation and domestic uses through 1941, it has been assumed that the annual sales of elec-trical energy under the agricultural-rate classification in the Redondo and Inglewood operating districts of the Southern California Edison Co. furnish an approximate index of water pumped for agricultural use from 1931 through 1941. In that 11-year period the average de-cline of water level within the Torrance-Inglewood subarea was about 4 feet for the Silverado water-bearing zone, the principal aquifer. The small increase in lift may have been more than offset by improvement in pumping-plant efficiencies. The year 1932, with an estimated with-drawal of 13,200 acre-feet for unmetered agricultural and domestic uses, has been taken as the base year. Thus, for 1931 and the years 1933 through 1941, estimates of withdrawal for unmetered irrigation use in each year have been obtained by multiplying 13,200 by the percentage of electrical energy used in that year in comparison to the 1932 base use. To the figure so obtained has been added the estimated increase in uncanvassed domestic use, prorated as described above. The sum of these two elements has been entered in table 8, column 6.

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For the war years 1942-45, agricultural withdrawals decreased sub-stantially but domestic expansion was greatly accelerated, and a con-siderable part of this increased domestic use of water was met by the smaller water companies. Data are not available to indicate the pro-portionate changes in area. Therefore, water used for irrigation and for miscellaneous purposes in these 4 years is assumed to have been constant at about 13,000 acre-feet per year.
The estimates entered in table 8 for yearly withdrawals by private irrigators and for miscellaneous use are only approximate. However, these figures constitute less than one-quarter of the total pumpage from the Torrance-Inglewood subarea. Extensive work would have been required to derive a more accurate estimate. In 1948 the Cali-fornia Division of Water Resources began a detailed study of the quantity of ground water drawn from each of the wells or well fields of this subarea, in connection with the pending adjudication of water rights. Accordingly, duplication of work, which the Division must carry out for legal reasons, was not believed to be warranted.

ESTIMATE OF TOTAL PUMPAGE

Table 8 and figure 3 summarize the yearly withdrawal from the Torrance-Inglewood subarea for the 15 years from 1931 through 1945. The estimated over-all draft from this area decreased from 52,600 acre-feet in 1931 to 44,500 acre-feet in 1937, rose to 52,700 acre-feet in 1942, and then increased sharply during the war years to about 78,000 acre-feet in 1945. As shown by the table, most of this expan-sion was caused by increased industrial demand. Withdrawals for

Municipalities, large water companies, and ind

1930 1932 1934 1936 1938 1940 1942 1944 1946

FIGURE 3. Estimated withdrawals of ground water from the Torrance-Inglewood subarea, 1931-45.

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industrial use were nearly constant at 14,000 acre-feet per year from 1931 through 1938, or about 30 percent of the total use; and increased to 19,640 acre-feet in 1942; and to 37,420 acre-feet in 1945, or about 48 percent of the total use. Most of the increase in industrial use of water during the war years was due to the expanded requirements of the oil refineries; in 1945, these refineries accounted for about 88 percent of the industrial demand.

TABLE 8. Estimated yearly withdrawal of ground water from the Torrance-Inglewood subarea, 1 in acre-feet, 1931-45

Year

1931
1932.... .... _ ....
1933
1934..
1935. _____ ....

1936...-... ....
1937 ....
1938
1939
1940 ___ ....

1941. ____ ....
1942. __ . __ ....
1943
1944...... _ ....
1945

Municipal
systems 2

12,720
in Afif\
in Qftrt

12, 830
12, 030

5,300
5,580
6,250
6,020
6,670

7,010
8,660
10,640
12,000
1 Q OOfl

Industries >

14,720
14, 710

13, 340
13, 510

14,520
14, 830
13, 670
16, 470
17, 380

18,520
19,640
24, 740
33,680
37,420

Large water
companies

11,210
10,690
10,200
10,230
10,250

10,940
9,830
10, 250
11, 220
11,280

11,200
11,360
12, 770
13, 020
14, 770

Subtotal

38,650
37,860
36,200
36,400
35,790

30,760
30,240
30, 170
33, 710
35,330

36, 730
39,660
48,150
58,700
65,410

Irrigation
and mis-
cellaneous

13,900
13,200
13, 000
14,400
12,100

14,600
14,300
16,000
14,900
15,200

13,600
« 13, 000
» 13, 000
» 13, 000
6 13, 000

Total *

52,600
51,100
49,200
50,800
47,900

45,400
44,500
46,200
48,600
50,500

50,800
52,700
61,200
71,700
78,400

1 For purposes of this report, the part of the west basin south of the Ballona escarpment is called the Torrance-Inglewood subaraa.
2 Includes water pumped by County Water Works Districts 13 and 22.
> Includes water sold to industrial plants by the Dominguez Water Corp.
«Rounded off to three figures.
»Flat estimate only.

The municipal systems accounted for nearly 25 percent of the total draft in 1931 and about 17 percent in 1945. The decrease in use by municipal systems from about 12,000 acre-feet in 1935 to 5,300 acre-feet in 1936 was a result of cessation of withdrawal at the Lomita

and Wilmington well fields of the city of Los Angeles, these fields had withdrawn about 8,000 acre-feet per year in the early thirties. Since 1936 the yield from these two well fields has been small.

WITHDRAWAL FROM THE CULVER CITY SUBAREA

Withdrawal of ground water from the Culver City subarea (the part of the west basin north of the Ballona escarpment) has not been appraised in detail. The field canvass of wells was carried only from 1 to 2 miles north of Ballona Gap and collection of records of pumpage from privately owned wells was not attempted for any part of the

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Culver City subarea. However, the most heavily pumped well fields have been those of the city of Santa Monica and those of the Southern California Water Co. Table 9 gives the draft from the Culver City subarea by these two agencies yearly from 1931 through 1945.

TABLE 9. Withdrawal of ground water, in acre-feet, from the Culver City subarea by the city of Santa Monica and by the Southern California Water Co., 1931-45 [Sum of pumpage from the Marine, Charnock, and Arcadia plants of the city of Santa Monica, and from the Pacific, Charnock, Sepulveda, and Manning plants of the Southern California Water Co.]

Year

1931...... ....
1932 __ _____ .....
1933 . ...
1934 _____ ....
1935......... ____ ...

Acre-feet

7,111
8,066
8,607
9,238
9,312

Year

1936 .-_ ..
1937 . _ ....
1938.... _ ....
1939 .... _ ..
1940 ....

Acre-feet

10, 461
10, 956
11, 773
12, 567
12,933

Year

1941 ....
1942 ..... _ ... _ ..
1943 - . . ___ -
1944 _______ ....
1945 ....

Acre-feet

8,705
4,405
5,622
6,125
6,106

In addition to the withdrawal from the principal well fields, shown in table 9, water from private plants was used to irrigate about 3,300 acres of land in 1932 and about 3,000 acres in 1941 (unpublished data from California Division of Water Kesources), chiefly along the south edge of Ballona Gap and in sees. 2 and 3, T. 2. S., R. 15 W. (pi. 2). These irrigated areas were supplied almost exclusively from private wells, although possibly as much as 200 acres of this land have been irrigated with water pumped directly from Ballona Creek (C. E. Bollinger, Los Angeles County Flood Control District, oral communication). About two-thirds of the over-all acreage is planted in garden and field crops and one-third is in irrigated grass. The quantity of ground water pumped to irrigate these lands probably is about 4,000 acre-feet a year.
The privately owned wells yielding water for irrigation in the Culver City subarea in 1945 (excluding the area north of the north boundary of T. 2 S.) were distributed as follows: in the coastal area, 30 wells; in the Charnock subbasin, 24 wells; in the crestal subbasin, 2 wells. If the annual well yields are assumed to be proportional to the distribution, the estimated draft for irrigation (4,000 acre-feet) would be about 2,100 acre-feet from the coastal area, 1,700 acre-feet from the Charnock subarea, and 200 acre-feet from the crestal sub-basin. Actually, because yields of wells in the Charnock subbasin are larger than those of wells nearer the coast and because slightly more than half of the irrigated acreage is supplied by water pumped from the Charnock subbasin, it is inferred that the division of draft as of 1945 was about 1,800 acre-feet from the coastal area, 2,000 acre-feet from the Charnock subbasin, and 200 acre-feet from the crestal subbasin.
The larger part of the withdrawal from the Charnock subbasin has been for public supply and has been obtained from the Charnock

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well field of the city of Santa Monica and the Charnock well field of the Southern California Water Co.; both fields are in the NW}£ sec. 11, T. 2 S., R. 15 W. (pi. 2). The yearly withdrawal records from these two well fields for the 15 years are graphed on plate 14. The Sepulveda plant of the Southern California Water Co. (well 2/15-1U) also is in this subbasin. The over-all draft from the Char-nock subbasin from these three well fields, and from the private irrigation wells previously discussed, is estimated to have been approximately 9,000 acre-feet in 1931, 10,000 acre-feet in 1935, 12,500 acre-feet in 1940 (the peak year), and 7,000 acre-feet in 1945. In the crestal subbasin, perennial draft has been chiefly by: (1) the Manning plant of the Southern California Water Co. from well 2/15-1C, beginning in the middle twenties; (2) the Metro-Goldwyn-Mayer Corp., from wells 2/15-12B1 and 2/14-7P1, beginning in 1932; (3) the LAC Chemical Co., from well 2/14-6H1, beginning in 1942; and (4) the Holy Cross Cemetery from well 2/14-18Q1, and irrigation wells 2/14-18F1 and F2. The over-all draft from this subbasin did not exceed a few hundred acre-feet per year until the middle thirties; it was about 1,100 acre-feet in 1935 and in 1940, and had increased to about 1,600 acre-feet in 1945.
For the Culver City subarea as a whole, it is estimated that the withdrawal in 1931 was about 13,000 acre-feet. Withdrawal increased to about 20,000 acre-feet in 1940, the peak year of pumpage by the city of Santa Monica. In that year withdrawal was approximately two-fifths as large as it was in the Torrance-Inglewood subarea to the south. In 1945, when draft by the city of Santa Monica had ceased, the withdrawal had decreased to about 12,000 acre-feet per year, or only about one-sixth of that in the Torrance-Inglewood subarea. The over-all use of water in the Culver City subarea is many times greater than the ground-water draft. Current importa-tions (1948) consist chiefly of surface water from the Los Angeles municipal supply, the Colorado River and ground water from the Sentney plant of the Southern California Water Co.

WITHDRAWAL INLAND FROM THE WEST BASIN

About 90 square miles of the Torrance-Santa Monica area is inland from the west basin and almost entirely within the main coastal basin. The over-all withdrawal of ground water from the 90 square miles was not evaluated in this investigation.
Except for the area within the city of Beverly Hills, nearly all of the territory north of Imperial Highway is within the city of Los Angeles and is supplied chiefly by water from the Los Angeles munic-ipal system. Most of the Los Angeles municipal supply to the coastal

GROUND-WATER HYDROLOGY 109

plain is imported from the Owens Valley or from the San Fernando Valley, but in this inland area the city currently obtains a minor auxiliary supply of ground water from its Manhattan and 99th Street plants. Some of the area north of Imperial Highway is served by the Sentney, South Los Angeles, and Normandie systems of the Southern California Water Co. The distribution and magnitude of draft from the larger well fields for public supply, as of 1945, are shown on plate 12.
Inland from the west basin, the position and slope of the pressure level are critical with respect to the rate of replenishment by under-flow across the west basin boundary. Both the position and slope of the pressure level between Slauson and Rosecrans Avenues are believed to be affected to a major extent by the very heavy withdrawal in the Huntington Park area, a short distance to the east of the east boundary of the Torrance-Santa Monica area. However, the position and slope of the pressure level are affected also by the intensity of local with-drawal. Thus, it is of interest to note that the combined withdrawal from the pumping plants of the city of Los Angeles and of the Southern California Water Co., between Slauson and Rosecrans Avenues, was 4,030 acre-feet in 1931, 3,130 acre-feet in 1938, and 6,440 acre-feet in 1945.

DISTRIBUTION OF DRAFT AS OF 1945

By 1945 most of the withdrawal of ground water from the Torrance-Santa Monica area was concentrated at a number of intensively pumped well fields operated almost entirely for public supply or indus-trial use. To show the nature of this concentration and its effect on the water levels in the Silverado water-bearing zone and in the cor-relative aquifers within the San Pedro formation beyond the extent of the Silverado, the magnitude of draft at such plants within the coastal zone of the Torrance-Santa Monica area has been indicated on plate 12 by means of circles whose areas are proportional to the draft. The centers of these circles are plotted at the centers of pumping. For closely grouped wells, the circle commonly encom-passes the entire well field; for groups of widely scattered wells which supply a single system, such as the South Los Angeles system of the Southern California Water Co., the circle is plotted approximately at the geographic center of pumping. The circles so plotted on plate 12 are numbered and table 10 identifies the agency withdrawing the water; numbers in this table correspond with those of the plate.
As shown on plate 12, the area of most intensive draft in 1945 was between Dominguez Hill and State Street, approximately along Alameda Street.

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TABLE 10. Agencies withdrawing ground water from the coastal zone of the Torrance-Santa Monica area in 1945 for public supply or industrial use

[Numbers identify location and magnitude of draft as indicated on plate 12; well fields withdrawing less than 200 acre-feet not listed]

Number on

plate 12

1..... ... .
2a. . _ ... ..

2b-.._ - ....
2c_._ ... .
2d_ ....
2e ....
2H
3a_ _ ......

3b
3c ....
4a _ .

4b.._ ...

5b...... _ ....
6a ....
6b...... ....
6e .
7 .
8.. ....
«-....__ _ ....
10. .

Agency

City of Beverly Hills.

Number on
plate 12

11. _ .... __ .
12.. ....
13a._ _ ....
13b... ___ ...
14a. ____ ...

14b ____ .
15.. __ ....
16. _
17..
18.
1Q
20.... _____ .
21 _ . _ .
22 _ . _ ...

23..
24 ....
9*n

25b.... .....
26
27........ .....
28... ___ ....
9Q

Agency

City of Torrance.
Columbia Steel Co.

County Water Works District 13. Palos Verdes Water Co.

Union Oil Co.

Shell Oil Co., Inc.:

Tidewater Associated Oil Co.

PRINCIPAL SOURCES OP GROUND WATER

SOURCES IN THE TORRAISTCE-INGILEWOOD SUBAREA

In the Torrance-Inglewood subarea, the principal sources of the ground water, in order of increasing age, are: (1) the Gaspur water-bearing zone in the deposits of Kecent age (in Dominguez Gap); (2) the "200-foot sand" in the unnamed upper Pleistocene deposits;
(3) the "400-foot gravel" in the upper part of the San Pedro formation of Pleistocene age; and (4) the Silverado water-bearing zone in the middle and lower parts of the San Pedro formation. In relation to draft, the Silverado water-bearing zone is of primary importance, and the "200-foot sand," the "400-foot gravel," and the Gaspur water-bearing zone are of secondary importance, and probably in the order listed.

In 1945, the Silverado water-bearing zone was the source of water for: (1) all withdrawals by industries, with the exception of one small plant; (2) essentially all withdrawals from the municipal well fields of Hawthorne, El Segundo, Manhattan Beach, and Torrance, and about one-third of the withdrawal from the well fields of the city of Inglewood within the west basin; (3) all withdrawals by County Water Works Districts 13 and 22; (4) all withdrawals by the California Water Service Co., the Dominguez Water Corp., and the Palos Verdes Water Co., and about 90 percent of the withdrawal by the Lennox, Lawndale, and Gardena systems of the Southern California Water Co.; and (5) at least half of the withdrawals by private irrigators and the

GROUND-WATER HYDROLOGY 111

smaller water companies. Of the total withdrawal from the Torrance-Inglewood subarea in 1945 approximately 78,000 acre-feet about 68,000 acre-feet or 87 percent was taken from the Silverado water-bearing zone.
Of the remaining 13 percent approximately 10,000 acre-feet about 8 percent was drawn from the "200-foot sand" and associated aquifers in the unnamed upper Pleistocene deposits, about 3 percent from the "400-foot gravel," and about 2 percent from the Gaspur water-bearing zone in Dominguez Gap.

SOURCES IN THE CULVER CITY SUBAREA

In the Culver City subarea the two principal sources of ground water, in order of increasing age, are (1) the "50-foot gravel" in the deposits of Recent age (in Ballona Gap); and (2) the main water-bearing zone of the San Pedro formation of Pleistocene age believed to be the essential correlative of the Silverado water-bearing zone to the south. The main water-bearing zone of the San Pedro forma-tion underlies all of Ballona Gap within the west basin and, at least in the Charnock subbasin, extends northward nearly 2 miles beyond the north edge of the Gap, or about to Pico Boulevard. No uniform water-bearing zone seems to exist north of Pico Boulevard. As shown by well logs, the aquifers are thin and discontinuous; as might be expected for alluvial deposits laid down by streams trans-porting debris from the Santa Monica Mountains.
The main water-bearing zone in the San Pedro formation has been the source of supply for: (1) almost all of the water pumped from the three well fields of the city of Santa Monica; (2) all of the with-drawal from the four well fields of the Southern California Water Co.;
(3) nearly all of the withdrawal used for irrigation in the area north of Washington Boulevard, south of Pico Boulevard, and east of Centinela Avenue (pi. 2); and probably more than half of the water pumped for irrigation along the south side of the Ballona Gap. Thus, of the total withdrawal in the Culver City subarea in 1945 some 12,000 acre-feet it is estimated that about 90 percent was drawn from the main water-bearing zone and associated aquifers within the San Pedro formation; most of the remaining 10 percent was drawn from the "50-foot gravel" in the deposits of Recent age in Ballona Gap.

SOURCES INLAND FROM THE WEST BASIN

As explained on page 108, the withdrawal from the 90 square miles of the Torrance-Santa Monica area inland from the west basin was not evaluated as a whole. However, all of the larger pumping plants draw water almost entirely from deposits of Pleistocene age and from aquifers within the San Pedro formation. These same

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aquifers supply a substantial part of the replenishment to the west basin across the crest of the Newport-Inglewood uplift.

WATER-LEVEL FLUCTUATIONS
SCOPE AND UTILITY OF THE RECORDS

In 1903-4 Mendenhall made single measurements of depth to water or of artesian pressure head in several thousand wells on the coastal plain. To extend these data, water-level measurements were made in 41 representative wells at irregular intervals during the next two decades by the Geological Survey. Twenty-six of these wells were within the coastal and inland zones of the present investigation. The records through 1920 have been published by the Geological Survey (Ebert, 1921, p. 13-29); records for three wells for the years 1921-26 have been published by the California Division of Water Resources (Gleason, 1932, p. 62, 77, 104).
In connection with its investigation of water resources of the San Gabriel Valley, the Division of Water Rights in the California Depart-ment of Public Works, in cooperation with Los Angeles County and the city of Pasadena, measured depths to ground water periodically from 1923 until 1928 (Conkling, 1927, 1929, p. 171-200). This program superseded the earlier program of the Geological Survey but included only a few wells in the Torrance-Santa Monica area, all of which were in the territory east of Main Street that is, in the vicinity of Compton and of Dominguez Gap.
The program of water-level measurements by the California Divi-sion of Water Rights was accompanied or followed by continuing programs of several agencies, which together extended over all the area of the present cooperative investigation. The two principal programs of periodic water-level measurement in the Torrance-Santa Monica area have been that of the Los Angeles Department of Water and Power, beginning in 1923 and terminating in 1941; and that of the Los Angeles County Flood Control District, beginning in 1928 and continuing to date. These programs have been supplemented by those of many other agencies, especially the following: The San Gabriel Valley Protective Association, beginning in 1928; the city of Pasadena, from 1928 to 1933; the city of Long Beach, beginning in 1929; the city of Beverly Hills, beginning in 1930; the Southern California Water Co., beginning about in 1929; and the California Water Service Co., beginning about in 1933. Periodic measurements have also been made by several other municipalities and water companies, by several industrial plants, and by a few individuals. Nearly all the water-level records by the agencies listed above have been deposited with the Division of Water Resources in the Cali-

GROUND-WATER HYDROLOGY 113

fornia Department of Public Works and are available to the public. Representative records from selected observation wells have been published (Gleason, 1932).
Beginning in 1943, single measurements of depth to water were made by the Geological Survey in several scores of wells in connection with the field canvass of water wells in the Torrance-Santa Monica area. Measurements were continued semiannually until December 1945 in about 60 of these wells. Measurements were made at weekly or biweekly intervals from 1944 to November 1946 in 20 other wells. Water-level recorders were also operated on six wells for periods of a month to 2 years. All the periodic water-level measurements made by the Geological Survey have been published in water-supply papers (see p. 89). Table 11 shows the scope of water-level data available from all agencies, including data taken by the Geological Survey for the coastal zone of the Torrance-Santa Monica area.

TABLE 11. Scope of water-level records available from wells in the coastal zone of the Torrance-Santa Monica area, as of July 1946

Type of record

Nonperiodic and miscellaneous measurements. __ __

Total ___ _____ ____________

Number of wells measured

Active

111
125
16
4

256

Discon-
tinued

140
350
4
27

521

Total

266
251
475
20
31

1,043

These records of depth to water in wells are of inestimable value for the interpretation of the past and present hydrologic conditions, and they reveal the changes in pressure level or water table that have developed as a result of increasing draft. Hydrographs plotted from periodic measurements in single wells show the nature of fluctuations and changes in head within the tapped aquifers. Thus, hydrographs for wells tapping separate aquifers at one place reveal the degree or the lack of hydraulic continuity between those aquifers. Water-level contour maps drawn from data for one or more aquifers known to be hydraulically continuous present the water-level conditions at selected times; discontinuities in the water-level contours define basin bound-aries or barrier features. Also, the regional changes in water level shown by comparing maps for separate times can be utilized to obtain estimates of change in storage if the specific yield or storage coefficient is known.

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Hydrographs for wells in the Torrance-Santa Monica area show several types of fluctuations, related chiefly to recharge and discharge. Specifically these fluctuations are caused by: (1) recharge from streams,
(2) recharge by penetration of rainfall, (3) recharge by underflow, (4) discharge by pumping, and (5) tidal oscillations. Typical fluctuations are illustrated and discussed in following pages.
The water-level contour maps previously introduced (pis. 9-12) show four positions of the water level and directions of water move-ment in the aquifers of principal draft between 1904 and 1945. Hydrographs for 59 selected wells in the Torrance-Santa Monica area are presented on figures 4 and 5 and plates 13 and 14. The locations of the wells are shown on plate 11; the tapped zones are identified on the individual hydrographs and by symbols on plate 11. Pertinent hydrologic data are given in table 12.

FLUCTUATIONS IN THE TORRANCE-INGLBWOOD SUBAREA

Selected hydrographs assembled on figures 4 and 5 and plates 13 and 14, illustrate the rate of change in pressure head in the several aquifers in the Torrance-Inglewood subarea. Most of the hydro-graphs concern wells that tap the Silverado water-bearing zone, which supplied about 87 percent of the draft in 1945. Other hydrographs are presented, however, to compare pressure heads in overlying aquifers with that in the Silverado water-bearing zone. These paired hydrographs are of particular interest for three reasons: (1) they furnish proof that the aquifers have substantial hydraulic separation;
(2) they indicate the effect of and furnish a clue to the magnitude of draft from each of the aquifers; and (3) they show the differentials in pressure head that have been developed between the several aquifers in the period of most intensive use and are of considerable interest in connection with possible downward migration of contamination, either now or in the future, and with the feasibility of artificial recharge.

DIFFERENCE IK HEAD DEVELOPED BETWEEN THE SEVERAL AQUIFERS VICINITY OP DOMINGUEZ GAP

The Gaspur water-bearing zone of Recent age in Dominguez Gap occurs from about 60 to 140 feet below the land surface and is sepa-rated from the underlying Silverado water-bearing zone of Pleistocene age by several hundred feet of silt and fine sand of low permeability (pi. 6). On figure 5(7, the composite hydrograph for wells 4/13-14Kl and 4/13-14L1 represents the pressure level in the Gaspur water-bearing zone from 1924 through 1946, and the hydrograph for wells 4/13-21H3 and 4/13-23G2 represents the pressure head in the Silver-ado water-bearing zone for the same period. Data from the Menden-hall well canvass of 1904 indicate that pressure levels in the two

A. WELLS IN WEST BASIN

ALTITUDE ABOVEOR BELO

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2/M-wH

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&CENTINELA SPRING CEASED TO FLOW
IN 1900. ALTITUDE 140 FEET

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BY SURFACE WA

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TER ENTERING WELL

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MEASUREMENTS >-
~-t-DISCONTINUEP

2/14- 36 Bl T^
ERADO WATER-BEARING Z

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B

1904 1906 1908 1910 1912 1914 1916 1913 19.20 1922 1924 1926 I92B 1930 1932 1934 1936 I93B 1940 1942 1944 1946 B. WELLS INLAND FROM WEST BASIN

FIGUBE 4. Hydrographs of longest record for wells in and near the west basin.

FEET IN LEVEL, SEA BELOW OR ABOVE ALTITUDE

Sf O § So O

' 'JLDOIOHdAH VOMOK V3HV

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TABLE 12. Wells in or near the west basin for which hydrographs are plotted on figures 4 and 5 and plates 13 and 14

Well

USGS

2/14-3H1 ...

3Q1-

5D5 _

5D9.

18F1..---

27D1

27F1, 2, 3.

32C1 -

34C1

36B1.....

36H1.

36K1

2/15-1P2......

11E3

11F4......

16F1.....

22B4-

23F1.. ...

24C1

34H1

34K1. .

Loca-
tion i

2667

2626D

2627

2609A

2619A

1352

1363

1324

1364

1404

1404B

2598
2597B

2578P

2578C

1240

1261A

1271M

1291

1264C

1264

Owner's name
and well

Artesian Land
and Water Co.

City of Los
Angeles.
Southern Cali-
fornia Water
Co.:
Sentney
plant, well
5.

Sentney
plant, well
9.
Shell Oil Co.,
Inc.

Mrs. J. D.
Machado.
Lewis A. Crank ...

City of Ingle-
wood, well 7.
Inglewood Park
Cemetery
Assn., wells 7,
2,11.
Formerly by
Bowler.
Inglewood
Country Club.
Southern Cali-
fornia Water
Co., Man-
chester Heights
plant, well 1.
Formerly by
Mrs. Bedell.

Olivita Mutual
Water Co.

Guy Beringhely ...
Formerly by
Borjorquez.
Southern Cali-
fornia Water
Co.:
Chamock
plant, well L
Chamock plant
well 4.
J. H. Evans ___

Clarence Michel..

Los Angeles
County Flood
Control Dis-
trict, test hole
1.
Mesmer City
Corp., Ltd.
Formerly by
Barnard.
Palisades del Rey
Water Co.,
welll.

Water-yielding zone or zones

Depth *
(fee©

j

6(

2<

2(

a

265

a

1<

4,

3:

1

5<

/80
\185

41

3!

56

2

4

2

2<

6

A

.

0

8

0

0

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0

,5

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)5

(0

0

)7

24

)2

50

)8

Feet
below
land
surface

152-257

23-54

90-312

135-266

264-362

1'

196-376

168-346

63-205

170-395

130-250

91-133

Stratigraphic
correlation

(?) ....

San Pedro for-
mation.

.....do _ . ___ -

"50-foot gravel". ..

San Pedro for-
mation.

.... . do.. ....

..... do..

do. .

"200-foot sand" ...

Silverado zone...-

.....do _ ......

Unnamed upper
Pleistocene

deposits.
Silverado zone. ...

"50-foot gravel" ...

San Pedro for-
mation,
do.

"50-foot gravel" ...

San Pedro for-
mation.

Semiperched
water body.

San Pedro for-
mation.
.... . do... -

do.-

Agency supplying
principal record 3

USGS

LADWP,
LACFCD.

SCWG

SCWC

LADWP

LADWP

LADWP,
LACFCD
LACFCD, USOS

LADWP, usas

LADWP,
LACFCD
LADWP

SCWC

USGS

LADWP

/LACFCD,
X LADWP
USGS

SCWC

SCWC

LACFCD,
LADWP
LACFD,
LADWP
LACFCD

LADWP

LADWP,
LACFCD
LADWP, owner.

See footnotes at end of table, p. 119.

460508 59 9

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TABLE 12. Wells in or near the west basin for which hydrogmphs are plotted on figures 4 and 5 and plates 13 and 14 Continued

Well

USGS

3/13-7N1

8L2 '.

17Q1
18G2.....
20C1- .
28P1-

32F2..._ _
33B1

33El.-___
3/14-4N1

11M1._._

13J2.

14M1-...

21B1._

23L1

25E2.

25K3
26C3-. .

35R1

36M3

3/15-12L1.. _

12L5
12L6 _ ..

25A1_

25H2
4/13-14K1 ..
14L1_____
14P1._.__

15A8--__.

Loca-
tion i

1418

1437G

1439A
1418F
1439F

833A
853A

1346B

1377

1409A

1379

1349

770D

791

802B
781A

794

793B

1297

1297G
1297F

701A

701C
897
887F

876E

Owner's name
and well

Formerly General
Petroleum
Corp.
H. N. Edison,
formerly by
Mrs. Bushby.

Union Oil Co. ....

Gardens Syndi-
cate.

John Larronde.. __
I. W. Hellman
Estate.

Southern Cali-
fornia Water
Co., Truro
plant, well 1.
Formerly by
Johnson Ranch.
Southern Cali-
fornla Water
Co., Southern
plant, well 2.
0. T. Johnson
Ranch, well 5.
Southern Cali-
fornia Water
Co.:
Rosecrans

plant, well
1.
Compton
plant, well
1.

A.J.Walter......
C. G. Pursche,
formerly by
C. C. Jorgen-
sen.

Southern Cali-
fornia Edison
Co., Ltd.,
(Torrance sub-
station).
(W. H. Seward,
< formerly by
[Luckensmeyer.
City of El
Segundo:
WeU I.........

WellS _ .....
Well 7

City of Man-
hattan Beach:
WeU 3.... ..

Well 4........
H. E. Diekson. ...
- do.... .....

City of Long
Beach.
Dominguez
Water Corp.,
well 5.

Water-yielding zone or zones

Depth 2
(feet)

254

341
384.0
403
401.0

750
375

700
636

200

582

440

468

397

38

30
205

550

1 315
' 193.0

355

380
350

547

395.0

114.3
29.5

980

Feet
below
land
surface

119-330

183-243
284-340

272-480
318-636

236-556

332-380

334-353

470-548

236-355

207-312
222-320

204-280

239-265

86-114
25-30

744-980

Stratigraphic
correlation

Silverado(?) zone..

..... do.-......
.... . do. ...
- do. .....
..... do.

. do. _
do

- do
..... do

"200-foot sand".. .

Silveradozone. _

"400-foot gravel"..

Silverado zone. ...

"400-foot gravel"..

Semiperched
water body,
do. ... .
"200-foot sand"...

Silverado zone. ...

"200-foot sand"...

"200-foot sand"
and Silverado
zone.

do.... .
do

Silverado zone ....

.....do. ...

.. do... ......
Semiperched
water body.
Silveradozone--.-

Agency supplying
principal record 3

LADWP

LADWP, USGS

LADWP
LADWP, USGS
LADWP
USGS

LADWP, USGS
LADWP

LADWP
scwc

USGS, LACFCD

SCWC

LADWP

SCWC

SCWC

LADWP

LACFCD
USGS, LADWP

Owner, LACFCD

(LADWP,
\ LACFCD,
I USGS

LADWP

Owner.
Do.

LADWP,
LACFCD,
USGS
LADWP
JBL, DWR
LB, LACFCD
USGS

Owner.

See footnotes at end of table, p. 119.

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TABLE 12. Wells in or near the west basin for which hydrographs are plotted^on figures 4 and 5 and plates IS and 14^~-Continued

Well

USGS

21H3-
23G2..-.

29ML... .

13F1......
22D1.....

Loca-
tion i

858B
888H

320

341D

725

797
768

Owner's name
and well

Richfield Oil
Corp., well 3.
City of Long
Beach,
Silverado well
1.

City of Los
Angeles,
Wilmington
plant, well 14.
California Water
Service Co.,
station 3, well 4.
David E.
Crutcher.
Standard Oil Co.,
producing and
pipeline dept.,
welll.

Water-yielding zone or zones

Depth *
(feet)

800
1,074

68.5

888.2

440.5

697.0
404

Feet
below
land
surface

430-788
596-1,066

669-800

140-373

245-660
206-404

Stratigraphic
correlation

Silverado zone.
.....do _ ....

Unnamed upper
Pleistocene
deposits.
Silverado zone,
lower part.

Silverado zone

.....do............
.....do _ ....

Agency supplying
principal record 3

LADWP, owner.
LB

LACFCD

LADWP, USGS

LADWP, owner,
USQS
LADWP, USGS
LACFCD, USQS

1 Number assigned by California Division of Water Resources.
2 Depths below land-surface datum indicated in whole feet are reported; those to a tenth of a foot are meas-ured by Geological Survey.
s Names of agencies used in this table are identified as follows: DWR, Division of Water Resources. State of California; JBL, J. B. Lippincott; LACFCD, Los Angeles County Flood Control District; LADWP, Los Angeles Department of Water and Power; LB, city of Long Beach; SC WC, Southern California Water Water Co.; USQS, U. S. Geological Survey.

water-bearing zones were about equal and were about 20 feet above sea level in 4/13-23D. By 1924, levels for both zones had been drawn down but the level of the Silverado water-bearing zone at well 21H3 was about 20 feet below sea level and some 25 feet below

the pressure head in the Gaspur zone (fig. 5(7). The differential increased to about 40 feet by 1930, remained nearly constant to 1941, and increased to about 60 feet by 1946 (high levels for the year for hydrographs 4/13-14L1 and 4/13-23G2). This increasing differential in pressure levels for the two water-bearing zones is indicative of the lack of hydraulic continuity between them. The Gaspur zone here is highly contaminated by oil-field brine, however (p. 258 to 260), and with this pressure differential, which currently is equivalent to some 25 pounds per square inch, the contamination poses a serious threat to the pure water of the Silverado water-bearing zone. Because the two zones are separated by beds of low permeability, contaminated water is more likely to move downward through wells whose casings are either perforated or rusted through in both zones.
The history of changes in the regimen of the Gaspur water-bearing; zone both within and inland from the Dominguez Gap have been treated in some detail in another report (Poland, 1959).

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For the semiperched water table in Dominguez Gap, the hydrograph of well 4/13-14P1, from 1941 through 1946 (also plotted on fig. 5(7) shows that the position of the water table in recent years has been essentially equal to that of the pressure level in the Gaspur zone beneath.

Wells 4/13-29M1 and 33D1, in Wilmington and about 3 miles southwest of well 4/13-23G2, tap the unnamed upper Pleistocene deposits and the lower part of the Silverado zone (table 12). Hydro-graphs for these wells (fig. 5C) illustrate the trends and increasing differential between the water levels in these two aquifers at that place since 1931.
In 1904, under essentially native conditions of head, the water level in both aquifers was about 13 feet above sea level. In the upper Pleistocene deposits the water level had been drawn down to about 20 feet below sea level by 1931, was about constant into 1938, re-covered to 17 feet below sea level by 1942, and then declined to 22 feet below sea level by 1946. The pressure level for the lower part of the Silverado water-bearing zone (well 33D1) had been drawn down to 31 feet below sea level by 1932, was about constant to 1942, and then was drawn down to 47 feet below sea level by 1946. Thus, the head differential between these two aquifers increased from noth-ing in 1904 to about 11 feet in 1932, and to 25 feet in 1946 (high level for the year).
At the Wilmington well field of the city of Los Angeles, a 240-foot section of fine sand and silt separates the upper and lower parts of the Silverado water-bearing zone; this section occurs from about 460 to 700 feet below land surface. Water-level measurements for well 4/13-33E6, not plotted on figure 5, indicate that the pressure level in the upper part of the Silverado water-bearing zone was about 21 feet below sea level in 1927, 24 feet in 1930, and 32 feet in 1946 (high levels for the year). Thus, by 1946, the pressure level for the upper part of the Silverado was about 10 feet below that of the unnamed upper Pleistocene deposits and about 15 feet above that of the lower part of the Silverado water-bearing zone (well 33D1).

GARDBNA ABBA

Four distinct and separate water-bearing zones in the Gardena area are tapped by wells. These zones and their approximate depths below land surface are as follows: (1) The semiperched water body to about 80 feet; (2) the "200-foot sand" in the unnamed upper Pleistocene deposits from 140 to 260 feet; (3) the "400-foot gravel" in the upper part of the San Pedro formation, from 320 to 400 feet; and (4) the Silverado water-bearing zone in the lower part of the San Pedro formation, from 500 to 700 feet (pi. 35).

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On figure 5B, hydrographs for wells 3/14-25E2 and 25K3 show the position of the water table in the semiperched water body from 1929 through 1945; the hydrograph for well 3/14-36M3 shows the pressure level in the "200-foot sand" from 1929 through 1946; hydrographs for wells 3/14-14M1 and 23L1 show the pressure level in the "400-foot gravel" for the same period; and hydrographs for wells 3/14-35R1 and 3/14-32F2 show the pressure level of the Silverado water-bearing zone from 1924 through 1946.
The record for the "200-foot sand" is extended back to 1904 by the hydrographs for wells 3/14-11M1 and 26C3 (fig. 4A). For the "400- foot gravel," although wells 3/14-14M1 and 3/14-23L1 are a mile apart, and although the hydrograph for well 3/14-23L1 indicates a pressure head about 5 feet below that of well 3/14-14M1 early in 1941 when well 3/14-23L1 was completed and placed in service, the two hydrographs are believed to represent the changes in pressure sur-face during the period of record. In confirmation, well 3/14-10C1, which also taps the "400-foot gravel" is 2.5 miles northwest of well 23L1; in 1945 the pressure level in well 10C1 (not shown on fig. 5) was only about 2 feet above that for well 3/14-23L1 in March and identical with it in December.
For the Silverado water-bearing zone, well 3/13-32F2 is 2.6 miles east of well 3/14-35R1 and only about a mile from the east boundary of the west basin. Nevertheless, from mid-1944 to the end of 1946, frequent measurements (at least biweekly) of depth to water in each of these wells indicated essentially an identical position of water level throughout the yearly range. In fact, the pressure level of these years in well 3/14-35R1 was not plotted on figure 5B because the graph would have been confused with that for well 3/13-32F2. For earlier years also, the levels for both can be considered coequal, as is shown by the position of the random measurements in well 35R1 as related to the hydrograph for well 3/13-32F2.
For the four water-bearing zones in the Gardena area, the changes in water levels that have occurred since 1904 can be summarized as follows, utilizing high level for the year if known:
1. In 1904, Mendenhall's data show that the water levels in the several water-bearing zones were about equal but increased slightly in altitude with depth of zone. For example, the water table of the semiperched zone and the pressure surface of the "200-foot sand" were both from about 15 to 25 feet above sea level, but the pressure surface of the Silverado water-bearing zone was from 25 to 30 feet above sea level.
2. By 1920, the water level in the "200-foot sand" had been drawn down to about 10 feet above sea level (well 3/14 26C3, fig. 4A) and that of the Silverado Water-bearing zone had been drawn down to sea level (measurement by the Southern California Edison Co. in well 3/14 35R1).
3. In 1929, the water table of the semiperched body was 16 feet above sea level; and the pressure surfaces for the "200-foot sand," the "400-foot gravel," and the

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Silverado water-bearing zone were respectively 2, 5, and 18 feet below sea level (fig. 55).
4. By 1941, levels in the four zones were respectively 19 feet above sea level (25E2); 14 feet below sea level (36M3); 15 feet below sea level (14M1); and 22 feet below sea level (32F2).
5. As of 1946, levels were respectively 12 feet above sea level (extrapolated), and 18 feet, 29 feet, and 38 feet below sea level. Thus, as of 1946, and with respect to high levels for the year, the pressure level in the Silverado water-bearing zone was 50 feet below the semiperched water table, 20 feet below the pressure level of the "200-foot sand," and about 9 feet below that of the "400-foot gravel."

VICINITY OF INGLEWOOD

In the vicinity of Inglewood, the hydrographs for wells 2/14-32C1 and 3/14-4N1, shown on plate 13, indicate conditions of change in head in the "200-foot sand" (32C1) and hi the Silverado water-bearing zone (4Nl) from the early thirties through 1945. These wells are about 2 miles apart. Several hundred acre-feet of water is withdrawn each year from well 3/14-4N1, whereas well 2/14-32C1 is used solely as an observation well. Thus, then* hydrographs do not furnish an absolute comparison of static water levels at one place. However, they do indicate the increasing differential in head between the two zones in a general way.
In 1904, water levels in both the "200-foot sand" and the Silverado water-bearing zone near the sites of these wells were about 25 feet above sea level. By 1933, the head in the "200-foot sand" was at sea level and that of the Silverado was about 8 feet below sea level. The pressure heads of both aquifers declined continuously from 1933 to 1945; by 1945, the head in the "200-foot sand" at well 2/14-32C1 was about 17 feet below sea level and the head in the Silverado at well 4N1 was about 40 feet below sea level. Thus, the head differential between the two aquifers, which was zero in 1904 increased by 1945 to 23 feet (high for the year) and about 50 feet (low for the year).

FLUCTUATIONS AND CHANGE IN HEAD IN THE SILVERADO WATER-BEARING ZONE

Figure 5 and plate 13 include hydrographs for 20 wells or groups of wells in the Torrance-Inglewood subarea that tap the Silverado water-bearing zone or correlative aquifers in the San Pedro formation. These wells were selected to give a wide and representative geographic distribution (pi. 11).

AREA SOUTH OF REDONDO BEACH BOULEVARD

With regard to the southern part of the area, figure 5 shows hydro-graphs for two wells in the water-table reach between Torrance and Kedondo Beach for well 4/14-8E1, 0.9 mile from the coast, and well 4/14-22D1, 2.3 miles from the coast; also for eight wells in the confined or pressure area between Torrance and Long Beach wells 4/14-13F1,

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3/14-35R1, 3/13-33E1, 3/13-32F2, and 4/13-15A8, 21H3, 23G2, and 33D1. From west to east, these hydrographs show great differences in (1) the character and amplitude of the seasonal fluctuations, and
(2) the rate and amount of decline in pressure head.
The seasonal fluctuations have been small in the water-table area west of Torrance and have become progressively greater to the east in the confined or pressure area. For example, in water-table well 4/14- 8E1 the seasonal fluctuation has ranged from 1 to 3 feet, and since 1943, when pumping at this well ceased, the fluctuation has been about 1.5 feet per year. The graph from a water-level recorder operated on this well by the Geological Survey showed a daily fluctuation of as much as 0.1 foot, which was correlated with the tidal fluctuation at Los Angeles Outer Harbor. This correlation indicated a tidal effi-ciency of about 1.4 percent but with an 8-hour lag in registration. Well 4/14-22D1 is 2 miles farther from the coast and only about 200 feet from a pumped well. Even though the hydrograph shows the effect of the nearby pumping, the seasonal range commonly has not exceeded 4 feet.
Within the pressure area, the seasonal fluctuation has ranged from about 5 feet at well 4/14-13F1 in Torrance to as much as 20 to 25 feet at well 4/13-23G2 (city of Long Beach, Silverado well) in Do-minguez Gap. Well 4/13-23G2 is an unused observation well a mile from the nearest active well tapping the Silverado water-bearing zone (4/13-22K1, used for irrigation); also 1.2 and 1.7 miles from the well field of the Dominguez Water Corp. (in 4/13-15A), and the Richfield Oil Corp. (in 4/13-21H). Each of these well fields is a locus of heavy draft (pi. 12, plants 14b and 26). The seasonal range shown by the hydrograph for well 4/13-23G2 was only about 13 feet from 1933 to 1938 but has nearly doubled with the accelerated withdrawal during the forties.
Most of the draft in the vicinity of Dominguez Gap is caused by continuous demands of industrial plants; the draft is about as heavy in winter as in summer. Therefore, the hydrograph for well 4/13- 23G2 might be expected to show little, if any, seasonal fluctuation. However, the draft by the Dominguez Water Corp., which is the largest single draft of the area, does vary substantially from winter to summer, because part of the withdrawal is for irrigation and do-mestic use. The monthly draft by this corporation from January 1943 to June 1944, inclusive, has been plotted on figure 5(7 to show its relation to the seasonal fluctuation in pressure level in well 4/13- 23G2. The correspondence is reasonably good, although the pressure level of well 4/13-23G2 is affected by other nearby pumping; it is possibly most strongly affected by the intermittent pumping of irrigation well 4/13-22K1.

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The decline in the pressure head of the Silverado water-bearing zone in the southern part of the Torrance-Inglewood subarea has ranged from an average of about half a foot per year near Redondo Beach to as much as 2 feet per year in Dominguez Gap. At well 4/14-8E1 (in Redondo Beach), the water table has declined 10 feet from 1928 to 1946 an average yearly rate of 0.55 foot. In Domin-guez Gap, some 10 miles to the east, the decline in the pressure head from 1924 to 1946, shown by the composite hydrograph for wells 4/13-21H3-23G2, has been 46 feet, and has occurred veiy largely in two widely separate periods. From 1924 to 1927 the decline was 20 feet, or about 7 feet per year; and from 1941 into 1946, during the war period, it was 26 feet, or about 5 feet per year.

AREA BETWEEN GABDENA AND THE BALLONA ESCARPMENT

For the central part of the west basin south of the Ballona escarp-ment, plate 13 shows hydrographs for eight wells or groups of wells which tap the confined reach of the Silverado, as follows: 3/15-12L1, L6, and L5, at El Segundo; 3/15-25H2 and Al at Manhattan Beach; 3/14-21B1, 3/14-13J2, 3/13-18G2, and 3/13-20C1, all near Rose-crans Avenue; and 3/14-4N1 and 2/14-34C1 near Inglewood. Wells 2/15-34H1 and 34K1, whose hydrographs also are shown, tap the main aquifer of the San Pedro formation (believed correlative with the Silverado water-bearing zone) in the water-table reach near Playa del Rey (pi. 11).
In the confined reach of the Silverado water-bearing zone, near the coast at the municipal well field of El Segundo, hydrographs for wells 3/15-12L1, L6, and L5 suggest a seasonal fluctuation of about 2 feet if pumping effects are disregarded. Three miles inland and south of Hawthorne, the pressure level at well 3/14-21B1 varied about 10 feet per year in the middle thirties and the annual range increased to about 15 feet by the early forties. The joint discharge of wells 21B1 and 21B2 has ranged between 350 and 711 acre-feet per year since 1940. At the east margin of the west basin, the pressure level in well 3/13-18G2 fluctuated about 10 feet per year in 1945 and 1946, but the range in pumped well 3/14-13J2 has been as much as 23 feet (in 1945).
Throughout the central part of the west basin most of the water is pumped for domestic and irrigation use. Thus, the draft is heaviest late in the summer and it is lightest from December to March. The pressure levels in wells fluctuate in direct ratio to draft demands. This general seasonal fluctuation, which is greatest far within the confined reach of the Silverado water-bearing zone and near the cen-ters of heaviest pumping, may be accompanied by a seasonal com-pression of the aquifer and the confining beds developed by the re-

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duction of artesian pressure in the summer, when pumping is most intensive, and expansion of the beds caused by the gradual increase of pressure as water moves into the compressed parts of the forma-tion during winter months. Such an explanation has been suggested by Fiedler (1944, p. 244-245) for similar fluctuation in the Roswell artesian basin. The subject of compressibility of artesian aquifers has been treated in more detail by Meinzer (Meinzer and Hard, 1925, p. 73-95; Meinzer, 1928, p. 263-291).
As in the water-table area near Redondo Beach, the seasonal fluc-tuations of the water table near Playa del Rey, at wells 2/15-34H1 and 34K1, have been very small in most years the range in level has not exceeded 0.5 foot. The nearest heavy draft is at El Segundo, about 2.7 miles southeast from these wells as shown by plate 12. The only local withdrawal is from wells 2/15-34A1 and Kl (wells 3 and 1 of the Palisades del Rey Water Co.). In 1945 their joint draft was about 170 acre-feet.
The drawdown of about 1 foot in the water table at well 2/15- 34H1, which persisted from February 1935 to April 1937, was induced by a temporary increase in draft from wells of the Palisades del Rey Water Company, as follows: 89 acre-feet in 1933; 87 acre-feet in 1934; 328 acre-feet in 1935; 147 acre-feet in 1936; 102 acre-feet in 1937; and 99 acre-feet in 1938. An active but temporary drilling program in 1935 in the so-called Del Rey Hills segment of the Playa del Rey oil field received most of its water supply from the wells of this company.
The water table in well 2/15-34K1 consistently stood about 2 feet above sea level in the thirties, but from the end of 1940 to the end of 1941 the level rose from 2.6 to 3.8 feet above sea level. Rainfall was very heavy in the water year 1940-41; at Los Angeles it was about 210 percent of the 68-year average (table 2), and the greatest since 1889-90. The unique rise in water level in well 34K1 was caused by recharge from this rainfall. The peak rainfall was in Feb-ruary and March (12.42 and 8.14 inches at Los Angeles); the water-table peak was in November-December, indicating a 9-month lag in maximum rate of recharge at the water table. The water from rain-fall here must pass through about 80 feet of dune sand to reach the water table.
The average rate of downward movement of water from rainfall at well 34K1 in 1941 apparently was about 9 feet per month, only about 3 percent as rapid as the rate of 10 feet per day cited by Sopp (1929, p. 2227) for penetration through 150 feet of Recent alluvium near Pasadena, Calif. Possibly the slow rate of movement was caused by the restraining effect of two beds of clay (7 and 9 feet thick) reported in the log for this well to be present within the dune sand. It is not

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known why the water table at well 2/15-34H1, 2,900 feet northeast of well 34K1, did not show a similar response, although a rise and decline may have occurred between the May and October measure-ments of 1941.
As shown by the hydrographs of plate 13, the decline in the pressure head of the Silverado water-bearing zone in the central part of the west basin (between Gardena and the Ballona escarpment) has differed widely from place to place.
Within the confined reach, about 1.2 miles from the ocean at the main well field of El Segundo, water levels were about 3 feet below sea level in the early thirties and about 4 feet below sea level in 1941 (wells 3/15-12L1-12L6); thus, these levels declined about a foot in 10 years. From 1942 through 1946 the decline was 8 feet, or nearly 2 feet per year. Wells at the main well field of Manhattan Beach (3/15-25A1) have shown about the same character and rate of pressure decline. On the other hand, near the central synclinal axis of the west basin at well 3/14-4N1 (north of Hawthorne) the decline in pressure head was nearly uniform from 1933 to 1940 at about 2 feet per year, and then increased to more than 3 feet per year to 1946; at well 3/14-2 IB 1, south of Hawthorne, the rate of decline was about 1.3 feet per year from 1930 to 1941 and about 3 feet per year from 1941 to 1946.
In the water-table reach near Playa del Rey (wells 2/15-34H1 and Kl), water levels were essentialy stable from 1930 through 1944 but declined about 2 feet in 1945-46. Because water levels to the north, east, and south were below sea level as early as 1933 (pi. 9), the water table of the Playa del Rey area must have been maintained at or above sea level since the early thirties by recharge from rainfall. Thus, the recharge from rainfall in this area is shown to have been more than sufficient to supply the draft from the wells of the Palisades del Rey Water Co. However, in 1945 the regional cone of water-level lowering reached wells 34H1 and 34K1 and caused a steady if slow decline. It is interesting to note that the chloride concentration of water from well 34K1 has increased sharply since January 1945 (fig. 15), coincident with the decline in water level.

FLUCTUATIONS IN THE CULVER CITY SUBAKEA

As discussed previously, the part of the west basin in and north of Ballona Gap includes three semi-independent subbasins formed by the partitioning effect of the Overland Avenue and Charnock faults. Water levels in the three subbasins have fluctuated in widely differing fashion. The hydrographs of plate 14 bring out some of the most marked differences.

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Wells 2/15-16F1 and 2/15-22B4, respectively, tap the "50-foot gravel" and the San Pedro formation in the coastal area west of the Charnock fault. Hydrographs for these wells (pi. 14) indicate that spring water levels in the two aquifers were essentially equal; in the thirties, the pressure head in the San Pedro formation at well 22B4 had a greater seasonal range than did that of the "50-foot gravel" at well 16F1, but this fluctuation was induced by nearby pumping for irrigation.
In 1904, water levels were about 5 feet above sea level near well 16F1 and 8 feet above sea level near well 22B4. By 1930 the levels had been drawn down about 10 feet below sea level at both wells. Records are not available to define when this drawdown developed; but presumably, most of it occurred in the twenties, when pumping for irrigation was most intensive. By 1930, the front of saline con-tamination had passed inland beyond both wells (pi. 16), and local draft was decreasing.
The hydrographs show a slow and relatively uniform recovery of water level from 1931 to 1941 in well 16F1, and a similar but irregular recovery in well 22B4; this recovery was caused by a decrease in irrigation draft as saline encroachment became more extensive (pi. 16). In the spring of 1941 the levels rose several feet, coincident with cessation of pumping at the Marine plant of the city of Santa Monica (in 2/15-9N); in 1940 this draft had been 944 acre-feet. Also the recovery of water level in 1941 probably was partly due to the increased replenishment during the wet winter of 1940-41. At well 16F1 the recovery continued until 1944, when the level stood a foot above sea level, and the "ground-water hole" of the early thirties had completely disappeared (pis. 9-12).
Well 2/15-23F1, about 4,000 feet east of well 22B4, taps the semi-perched water body overlying the "50-foot gravel." The hydrograph (pi. 14) suggests that, the water table of the semiperched body generally stood a few feet above the water level of the underlying aquifers in the late thirties, but has been essentially coincident since 1941.
CHARNOCK SUBBASIN

Very few of the wells in the Charnock subbasin for which water-level records are available tap only the "50-foot gravel." Many small wells which formerly tapped this aquifer have gone dry and have been abandoned, such as well 2/15-1P3 (fig. 4). The hydro-graph for this well indicates that the water level in the "50-foot gravel" declined fairly uniformly from 1904 to 1911 and from 1918 to 1926; the hydrograph for well 2/15-1P2 continues the record of the decline to 1946. Both wells are close to the Overland Avenue fault

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which, however, does not interrupt hydraulic continuity within the "50-foot gravel." The hydrographs indicate that this aquifer does not have hydraulic continuity with the main aquifer of the San Pedro formation beneath, because the pressure levels of the latter aquifer have followed an entirely different trend. Hydrographs for wells 2/15-11F4 and 2/15-11E3 at the Charnock plant of the Southern California Water Co. and for well 2/15-24C1, about 2 miles southeast, illustrate the fluctuations since 1930 in the San Pedro formation (pi. 14).
In 1904 the water level in 2/15-11C was from 30 to 35 feet above sea level and in 2/15-24C it was about 16 feet above sea level. In 1925 the level at well 2/15-24C1 was 11 feet above sea level, thus indicating a decline in head of only about 5 feet since 1904.
In 1925 the city of Santa Monica completed its first well at the Charnock municipal field in 2/15-11C; about 1927 the Southern California Water Co. began taking water from its Charnock well field in 2/15-1 IE and 2/15-1 IF, and the draft became very heavy before 1930. This concentrated withdrawal from the NW# sec. 11 has been the controlling factor in the fluctuation of the pressure level in the main aquifer of the San Pedro formation throughout the Charnock subbasin since 1926. The heavy draft at these fields was supple-mented by pumping at the Sepulveda plant of the Southern California Water Co. in well 2/15-11J, which also commenced in 1926. To-gether, these withdrawals produced a cone of perennial drawdown which rapidly extended to the north and south but was terminated abruptly on the west by the Charnock fault barrier, and was limited on the east by the more distant Overland Avenue fault. A water-level contour map of the high level for 1930 (not included in this report) shows that pressure levels at the Charnock well fields then were 20 to 30 feet below sea level; in addition, the map shows that water levels had been drawn down below sea level southward about

2 miles, or to Ballona Creek (see hydrograph for well 24C1), and northward about three-quarters of a mile, or about halfway to Pico Boulevard.
The hydrographs for wells 2/15-11F4 and 11E3 illustrate the great drawdown of water level that occurred at this center of pumping from 1931 to 1940, inclusive. The combined yearly draft from the Charnock well fields by the city of Santa Monica and by the Southern California Water Co., also illustrated on plate 14, increased from 6,070 acre-feet in 1931 to 9,190 acre-feet in 1940. Withdrawal by Santa Monica decreased about one-half in 1941 and was negligible by 1942 (the total draft from the Charnock fields was 2,505 acre-feet at this time). In response to this variation in concentrated draft, the water level in well 11E3 was drawn down to 100 feet below sea level by 1940 but

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recovered about 45 feet by 1945 and became temporarily stabilized about 55 feet below sea level. It should be noted that this well is pumped and is in the midst of other pumped wells; hence the level for this well illustrated on plate 14 represents a "recovery" level observed while well 11E3 was idle but while other wells were pumped. Thus, it shows the over-all drawdown at the well field.
Water levels in other wells tapping the San Pedro formation in the Charnock subbasin have fluctuated primarily in response to the draft at the Charnock well fields. For example, well 2/15-24C1 is 2 miles southeast from the Charnock fields and has not been pumped since 1935. Its pressure-level graph is a reduced replica of the hydrographs for wells 11F4 and 11E3 and shows the same downward trend from 1930 (1925) through 1940 and a gentle recovery of about 4 feet from 1941 to 1945, inclusive.
CRESTAI SUBBASIN

The crestal subbasin occupies the narrow upthrown block between the Inglewood fault to the east and the Charnock fault to the west. In the San Pedro formation within this subbasin, movement of water is southward and the pressure levels now stand far above the drawn-down levels to the west and east.
Records of water level by Mendenhall in 1904 and periodic measure-ments beginning in 1930 show that there was no change in the pressure head of the San Pedro formation in the crestal subbasin from 1904 to 1930. For example, measurements made by the Geological Survey in well 2/15-1F1 (Ebert, 1921, well 16) between 1904 and 1910 indicate that its pressure level then was 60 to 62 feet above sea level; it was still about 62 feet above sea level in 1930, as shown by a water-level contour map for the spring of 1930 prepared as a part of the present investigation. Also, about 2 miles to the south in 2/14-7M, the pressure level was 40 feet above sea level in 1904 and in 1930. The hydrographs for wells 2/14-7M1 and 18F1 (pi. 14) show the change hi pressure head that has occurred from 1930 to 1945, nclusive. The seasonal fluctuation has been less than a foot (a icharacteristic of wells in this subbasin). Decline of head began in 1931, was very gentle until 1936, increased in 1937, and then continued until 1945 at a fairly uniform rate about 1 foot per year in well 7M1 and 2 feet per year in 18F1. Compared with the great range in water levels to the east and west, the change in pressure head in this subbasin has been suprisingly uniform and completely independent attesting to a lack of hydraulic continuity within the San Pedro formation across the Inglewood and Charnock faults. The fluctuations of water level have been in response to change in draft within the subbasin. Perennial withdrawal has been chiefly by the Southern California Water Co. at its Manning plant in 2/15-lC,

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beginning in the middle twenties; and by the Metro-Goldwyn-Mayer Corp. from wells 2/15-12B1 and 2/14-7P1, beginning in 1932. As described earlier (p. 108), the over-all draft did not exceed a few hundred acre-feet per year until the middle thirties; it was about 1,100 acre-feet in 1935 and in 1940, and about 1,600 acre-feet in 1945. Water levels in wells at the Manning plant of the Southern California Water Co. show a seasonal fluctuation of as much as 10 feet, but their long-term trend has been in agreement with that of the hydrograph for well 2/14-7M1; water levels at the Manning plant are about 25 feet higher than at well 7Ml.
Water levels in the "50-foot gravel" in the crestal subbasin have fluctuated in a different manner from those in the San Pedro formation, presumably because the "50-foot gravel" is hydraulically continuous across the barrier faults that are so effective in damming the older aquifer. Hydrographs for wells 2/15-1P2 and 1P3 (fig. 4) show the long-term decline in head in this aquifer. For the past two decades, draft from the "50-foot gravel" within the crestal subbasin has been negligible; hence the decline has been caused largely by decrease of inflow, and by continued outflow.

FLUCTUATIONS INDUCED BY PUMPING

Seasonal fluctuations related to pumping are discernible in most of the hydrographs for wells measured monthly or more frequently. Pumping draft for irrigation and other uses fluctuates not only with the season but also from day to day. Even wells supplying water to satisfy a reasonably constant industrial demand may be subject to momentary and frequent changes in rate of discharge if the system is operated with an automatic control and substantial storage facilities. These fluctuations of the water level in observation wells induced by such changes in the rate of withdrawal can be determined only by taking a continuous record of water level.
In connection with the operation of water-level recorders in wells, the Geological Survey has obtained many examples of these short-term fluctuations. Two records of particular interest are illustrated in figure 6.
Well 4/13-33D1 (city of Los Angeles, Wilmington plant, well 14) in Wilmington taps the lower part of the Silverado water-bearing zone from 669 to 800 feet below the land surface. The wells of the Texas Co. in 4/13-27M, 6,000 feet to the northeast, tap the full thickness of the Silverado water-bearing zone from 400 to 800 feet below the surface. In December 1941 well 4/13-27M4 (owner's well 6) was being pumped continuously at 850 gpm and well 27M3 (owner's well 5) was on automatic control, pumping intermittently at 3,000 gpm. Thus, the over-all discharge was at the base rate of 850

HYDROGRAPH FOR WELL 4/I3-33DI,
6,000 FEET SOUTHWEST OF TEXAS
CO. WELLS |

DRAFT AT THE TEXAS CO. REFINERY

(WELLS4/1 3-27M3 AND 2 7 M 4)

I 9
DECEMBER 1941

A

76.0

.2

.4

.6

.8

77.0

.2

.4

.6

. 8

78.0
HYDROGRAPH FOR WELL 4/l4 ~ l3Fl.
12,000 FEET NORTHWEST OF
LOMITA PLANT WELLS
DRAFT AT LOMITA PLANT,
CITY OF LOS ANGELES

(WELLS 4/I3-30GI AND 30KI)"

i i
30
1944

B

FIGURE 6. Graphs showing fluctuations of water level in wells 4/13-33D1 and 4/14-13F1 induced by pumping of distant wells. CO

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gpm with intermittent increase to 3,850 gpm (fig. 6). The plot of pressure head in well 4/13-33D1 indicates an immediate response to the pumping of well 27M3. During the time here graphed, the average length of each pumping period for well 27M3 was about 1 hour and the average drawdown in pressure level at well 33D1 induced by this pumping was about 0.08 foot. The drawdown at the pumped well was about 15 feet in 1941. The precise amount of time required for the transmission of the pressure effect through the 6,000-foot distance is not known but the graph indicates registration at well 33D1 within a very few minutes. Before the cause of the fluctuations was identified, the recorder had to be removed from the well and thus an expanded-time graph was not obtained.
Well 4/14-13F1, near Torrance, taps the full thickness of the Sil-verado water-bearing zone. The fluctuation of pressure head at this well from April 16 to May 13, 1944 is shown on figure 6 together with the combined daily draft from wells 4/13-30G1 and Kl (city of Los Angeles, Lomita plant, wells 6 and 7). The Lomita plant wells, located 12,000 feet southeast from well 4/14-13F1, also tap the Silverado. Their pumps had been idle for about 3 weeks before the beginning of pumping at 9:20 a. m. April 19. In the following 14 days (ending May 2), about 82,620,000 gallons (254 acre-feet) of water was withdrawn from the Silverado water-bearing zone through these wells, at an average discharge rate of 4,340 gpm. The hydro-graph for well 13F1 shows that the drawdown of the pressure head caused by this pumping was superimposed on a general declining trend of about 0.04 foot per day. Before, during, and after the opera-tion of the wells at the Lomita plant, the hydrograph for well 4/14- 13F1 showed a diurnal fluctuation of about 0.1 foot; its cause is not known. As nearly as can be determined from the recorder graph for well 13F1, the pressure level at this well began to decline about 30 minutes after the pumps were turned on at the Lomita plant, about 2.3 miles distant. Considering the general trend, the drawdown in pressure level induced by the continuous operation of the Lomita plant was 1.1 feet after 4 days and 1.5 feet after 10 days.
Both the rate of response and the magnitude of drawdown at well 4/14-13F1 attest to the complete confinement of the Silverado water-bearing zone between Wilmington and Torrance. If this aquifer were unconfined in that area, it is doubtful if the effect of pumping at a distance of 12,000 feet could be detected from a recorder graph. Certainly a cone of water-table depression of appreciable depth would take many weeks to extend 12,000 feet from the origin.
By plotting on semilogarithmic coordinates the drawdown at well 4/14-13F1 against the time since the pumps at the Lomita plant were started (log scale), the graphical method developed by Cooper and

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Jacob (1946, p. 526-534) can be used to determine transmissibility, permeability, and storage coefficient. As discussed on page 54, the transmissibility determined from these data is about 813,000 gpd per foot, and the indicated coefficient of permeability is about 2,000 gpd per square foot. The storage coefficient can be calculated by use of the equation:
£=2.25

where S is the storage coefficient (volume of water that a unit decline of head releases from storage in a vertical prism of the aquifer of unit cross section), T is the transmissibility, t0 is the value of time at the drawdown intercept 0, and r is the distance of the observation well from the pumped well. The storage coefficient so derived from the semilogarithmic plot for drawdown in well 4/14-13F1 is 0.0012. Figures 7 and 8 discussed in detail in the section on barrier features (p. 137 to 141) also show drawdown fluctuations induced by pump-ing of nearby wells.

HYDROLOGIC EVIDENCE RELATING TO BOUNDARIES OF THE WEST BASIN
WATER UEVEL.S ACROSS THE BARRIER FEATURES OF THE NEWPORT-ESTGIJEWOOD UPUOFT

The faults of the Newport-Inglewood uplift produce discontinuities in the pressure surfaces of the aquifers of Pleistocene age. Thus, the location of the fault barriers commonly can best be determined by constructing water-level contour maps and by relating hydraulic discontinuities to geologic or physiographic evidence of faulting. In places where the latter types of evidence are lacking or unknown, the hydraulic discontinuity may furnish the only proof of a fault barrier, and the accuracy of location then depends wholly on the water-level control. The inferred fault barrier passing southeastward along the Rosecrans Hills from the Potrero fault to the Avalon-Compton fault and the similar feature along the crest of Dominguez Hill both have been defined purely from hydrologic data as revealed on plates 9-12, and on hydrographs to be discussed.
The effectiveness of the faults as barriers to water movement can be evaluated in part from the magnitude of the hydraulic discontinu-ities across them, and by the gradients developed immediately inland and coastward. Both features are shown by the water-level contour maps. The effectiveness can be appraised also from simultaneous water-level fluctuations in two or more wells on opposite sides of such barrier features. In a recent report (Poland, 1959) such an appraisal has been made for the 22-mile reach of the Newport-Inglewood uplift from Dominguez Hill southeast to Newport Mesa.
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From that appraisal and with respect to the reach within Los Angeles County that is, from Dominguez Hill to the Orange County line near Seal Beach it has been concluded (Poland, 1959) that:
In Dominguez Gap there is no barrier to movement through the Gaspur water-bearing zone of Recent age. In the underlying Silverado zone a substantial barrier has been developed but presumably it is not wholly watertight. Along the Signal Hill uplift the barrier features form a reasonably effective barrier to water movement but available evidence suggests that they are not wholly water-tight against differential heads of several tens of feet. In Alamitos Gap, no barrier exists within the deposits of Recent age which extend to about 90 feet below land surface. However, the barrier across the underlying San Pedro formation is believed to be essentially watertight.

For the demonstration of the hydrologic evidence from which these conclusions were derived, the reader is referred to that report. In particular, attention is directed to the analysis of hydraulic conditions across the inferred extension of the Cherry-Hill fault in Dominguez Gap, (1) in the semiperched water body, (2) in the Gaspur water-bearing zone, and (3) in the Silverado water-bearing zone (Poland, 1959).
DOMINGUEZ HILL TO THE BALDWIN HILLS

To show hydraulic discontinuities across the 12-mile reach of the Newport-Inglewood uplift from Dominguez Hill northwesterly to the Baldwin Hills, selected data collected or assembled as a part of the present investigation are presented on five pairs or sets of hydrographs, as follows:

1. Across the ground-water barrier on the northwest flank of Dominguez Hill, hydrographs for well 3/13-33B1 (inland side) and well 3/13-33E1 (coastal side). (See fig. 5B.)
2. Across the south end of the Avalon-Compton fault, hydrographs for well 3/13-28P1 (inland side) and well 3/13-32F2 (coastal side). (See fig. 5£.)
3. Across the north end of the Avalon-Compton fault, hydrographs for well 3/13-17Q1 (inland side) and well 3/13-20C1 (coastal side). (See pi. 13C.)
4. Across the ground-water barrier along the central part of the Rosecrans Hills, hydrographs for wells 3/13-8L2 and 7N1 (inland side) and wells 3/13-18G2 and 3/14-13J2 (coastal side). (See pi. 13C.)
5. Across the Potrero fault east of the center of Inglewood, hydrographs for wells 2/14-27F1, 2, and 3 (inland side), and well 2/14-34C1 (coastal side). (See pi. 13D.)

All these wells tap the Silverado water-bearing zone, therefore the hydrologic data are common to this aquifer. The locations of these wells are shown on plate 11.
On the northwest flank of Dominguez Hill, wells 3/13-33B1 and 3/13-33E1 are about 2,700 feet apart (about 2,300 feet measured normal to the water-level contours). The record for well 3/13-33E1 spans only the years 1931-32. For these years seasonal fluctuation was about the same in both wells, but the pressure head in well 33E1

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consistently stood 30 feet lower than that of well 33B1. Thus, the discontinuity shown on plate 9 (March 1933) is known to be an all-year feature. With reference to plate 9, if the approach gradient (inland side) and the escape gradient (coastal side) are projected to the inferred barrier a hydraulic discontinuity of about 25 feet is obtained. Although the measurements at well 33E1 ceased in 1933, the water-level contours of November 1945 (pi. 12) suggest that the actual discontinuity at the barrier had increased in the 12 years to nearly 40 feet.
The hydrographs for wells 3/13-28P1 and 32F2 also span a joint record of about 2 years, from 1944 to 1946. Well 3/13-28P1 is about 700 feet inland from the Avalon-Compton fault, and well 3/13-32F2 is about 4,500 feet coastward. The general character and amplitude of seasonal fluctuation are similar for the two wells. The differential in pressure head, which is about 50 feet, remained about equal through-out the 2 years. Hydrographs for wells 3/13-33B1 and 32F2 furnish a 15-year comparison of the fluctuation in wells which are 6,500 feet apart and on opposite sides of the barrier. They show that the difference between the pressure heads at the two wells has increased from 50 feet in 1931 to 66 feet in 1945.
Wells 3/13-17Q1 and 3/13-20C1, at the northwest end of the Avalon-Compton fault, are only 1,500 feet apart and nearly equi-distant from the fault. The hydrographs for these wells, which extend from 1930 to 1945 (pi. 13 O), show a striking difference in amplitude of seasonal fluctuation; the average for well 17Q1 is about 19 feet and the average for 20C1 is about 6 feet. The greater range in pressure head at well 17Q1 doubtless is caused by more intensive local pumping; however, the pressure effects are not transmitted to well 20C1 because of the fault barrier. The pressure differential at these wells was greatest in the early thirties about 48 feet in February and 32 feet in August. In 1945 the differential had decreased to about 24 feet for both spring and autumn; this was due almost entirely to decline in head at well 17Q2 (successor to 17Q1 and tapping the same water-bearing beds).
On plate 13(7, the hydrographs for wells 3/13-8L2 and 7Nl inland from the ground-water barrier along the Rosecrans Hills and those for wells 3/13-18G2 and 3/14-13J2 coastward from the barrier show a striking change during the 17-year period of record. Well 3/14-13 J2 is one of the heavily pumped wells in the Gardena system of the Southern California Water Co. Well 3/13-18G2 was pumped by the Union Oil Co. until about 1942. So far as known the two inland wells have not been pumped during the period of record. From 1931 into 1937, the pressure-head differential between wells 3/13-8L2 and 18G2 decreased from 40 feet to 25 feet. In that same period

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the head difference between wells 3/13-18G2 and 3/14-13J2 was constant at about 30 feet. From 1937 into 1941, the pressure head in well 3/13-18G2 declined about 30 feet; therefore, in 1941 a pressure differential of 52 feet had developed with respect to well 3/13-8L2. It is inferred that this drawdown of head in well 18G2 was caused by accelerated draft at the Southern plant of the Southern California Water Co. in 3/14-13J. By 1945 the high level for the year in well 18G2 was only about 4 feet above that for 3/14-13J2 and 57 feet below that for well 8L2. The record here discussed is considered to furnish indisputable evidence that well 3/13-18G2 is within the west basin and that it is hydraulically separated from the wells to the northeast by a ground-water barrier.
Hydrographs for wells 2/14-27F1, 2, 3, and 2/14-34C1 compare conditions across the Potrero fault at the north edge of the Rosecrans Hills (pi. 13Z>). Although the hydrograph for well 27F1 is shown here only from 1932, earlier measurements indicate a decline of head from 50 feet above sea level in 1930. The amplitude of seasonal fluctuation in well 27F1 has ranged from 5 to 7 feet; that in well 34C1 has ranged from 10 to 35 feet. From 1930 to 1939 the pressure head at well 27F1 was drawn down 49 feet, and the head in well 34Cl declined only 29 feet. On the other hand, from. 1940 to 1945 the head in wells 27F2 and F3 (which tap the Silverado water-bearing zone also) declined only 2 feet, whereas the head in well 34C1 was drawn down 27 feet. This greatly accelerated drawdown of pressure head in well 34C1 is believed to reflect the increase in draft on the small subbasin in section 34 which was caused by the pumping of wells 34F1 and L2 (Hollywood Turf Club) beginning about 1941. For the several pairs of hydrographs here discussed, the evidence indicates a substantial ground-water barrier at each place. The information gained from an appraisal of replenishment, however, indicates that the barrier features are by no means watertight through-out their extent under the range of differential heads that have pre-vailed across them in the past (see p. 159 to 161).

BAIIONA GAP

Across the Inglewood fault in Ballona Gap, a striking hydraulic discontinuity has developed in the pressure head of the San Pedro formation through drawdown of head east of the fault by the joint draft of the Sentney plant of the Southern California Water Co. and the Castle plant of the city of Beverly Hills. Hydrographs are shown on plate 14 for wells 2/14-5D5 and 5F2 at and near the Sentney plant, respectively, inland from the fault, and for wells 2/14-7M1 and 18F1 in the crestal subbasin coastward from the fault. Although the latter two wells are more than a mile from the Inglewood fault and nearly 2

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miles from the Sentney plant, their hydrographs represent fluctuation in the crestal subbasin. The contrast in the seasonal pattern and in the long-term trend needs no verbal emphasis. It is concluded from these graphs and from the shape of the water-level contours on plates 9-12 that between the Baldwin Hills and the Beverly Hills, the Ingle-wood fault presents an essentially water-tight barrier to movement in the San Padro formation.
The water level in the "50-foot gravel" inland from the Inglewood fault was about 62 feet above sea level in 1946 (well 2/14-5D9) about 90 feet above the pressure level in the San Pedro formation beneath (well 5D5). In the crestal subbasin coastward from the fault, the water level in the "50-foot gravel" as of 1946 was known only for well 2/15-1P2 (fig. 4), and was about 12 feet above sea level. Although the suggested gradient from well 5D9 to well 1P2 in 1946 was 25 feet per mile, it is inferred that no hydraulic barrier transects the "50-foot gravel" at the Inglewood fault. It is of interest to note that the gradient between these two places was 25 feet per mile in 1904 also, although the water level was about 30 feet higher at that time.

PUMPXNQ TEST AT INGHJEWOOD WELL, FIELD

From January 3 to April 30, 1945, the Geological Survey operated a water-level recorder on well 2/14-27D1 (city of Inglewood, well 7), in the Centinela Park well field of the city of Inglewood, and 200 feet east of the Potrero fault. During the early part of the period of operation, it was noted that the water level in this well was drawn down several feet by the pumping of certain nearby wells in the Centinela Park field. With the cooperation of the Inglewood Water Department, a pumping schedule was arranged for the active wells in the Centinela Park field to determine the effectiveness of the Potrero fault as a barrier to water movement. The Inglewood Water Department kept a careful record of the pumping periods for the active wells in the field. The results of this pumping test are shown on figure 7.
As indicated by the plan of wells in the Centinela Park field (fig. 7), 9 of the 11 active wells in the field are east of the Potrero fault (in the main coastal basin) and 2 are west of the fault (in the west basin). All of the wells tap aquifers in the San Pedro formation, which is correlative with the Silverado water-bearing zone.
Figure 7 shows the drawdown in water level at well 27D1 caused by the pumping of well 22N2, 300 feet to the north. At the time, all other well pumps at the field were idle except those for wells 22P1 and 22P2, which were operated continuously through the period of record on the graph (March 5-12). The drawdown induced by pumping of well 22N2 was 3.8 feet after 46 hours of pumping. Obviously there is free hydraulic movement between these wells. As explained on page

DATUM LAND-SURFACE BELOW FEET, IN WATER, TO DEPTH

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55, this drawdown of water level in well 27D1 resulting from the pumping of well 22N2 was utilized in computing transmissibility and permeability of the water-bearing beds.
Figures 7 and 8 show the hydrograph for well 27D1 during the intermittent operation of the pumps in wells 27D2 and 27D3 (city of Inglewood, wells 10 and 14); both of these wells are west of the Potrero fault and are 325 and 725 feet, respectively, from well 27D1. For the period here graphed (6 a. m. April 25 to noon, April 27), two of the wells east of the fault 22P1 and 22P2 were operated continuously and all others were idle. Although the hydrograph for well 27DI indicates drawdown and recovery of the water level in response to pumping, the fluctuations are not related to operation of the pumps in wells 27D2 and 27D3. For example, on April 25 the pumps in these two wells were started at 11:10 and 11:05 p. m., respectively, but the recovering water level in well 27D1 was not affected in the least. Clearly, the Potrero fault is an effective ground-water barrier within the head differentials imposed by this test. The drawdown in well 27D2 at the tune of the test is not known. In November 1944 its-level was drawn down to 30.7 feet below sea level after pumping for 15 minutes, or about 26 feet below the level in well 27D1. Presumably,, the differential of April 25-27 was similar.

PUMPING TEST NEAR WTLMINGTON

In September 1946, with the cooperation of the Union Oil Co., the Palos Verdes Water Co., and the Department of Water and Power of the city of Los Angeles, the Geological Survey made a pumping test near Bixby Slough, in Wilmington. This pumping test was made chiefly to determine whether a barrier to ground-water movement existed between the wells of the Union Oil Co. (4/13-31P1 and 5/13- 6D2) and nearby wells at (1) the Lomita plant of the city of Los Angeles, in 4/13-31E, and (2) the Palos Verdes Water Co. property, in 4/14-36H. Figure 8 shows the relative locations of the wells, and graphs the results of the pumping test. All of the wells involved in the pumping test tap the Silverado water-bearing zone. Because the wells of the Union Oil Co., beginning with well 5/13-6D1 in 1922, always have yielded water of markedly different chemical quality from that yielded by the wells north of Anaheim Street (fig. 34), it had long been suspected that the Union Oil Co. wells might be sepa-rated from the west basin by a hydraulic barrier. For example, from the beginning of 1931 to the end of 1945 about 14,616 acre-feet of water was withdrawn from the Silverado water-bearing zone through the wells of the Union Oil Co. In 1931, the water yielded by well 5/13-6D1 contained about 500 ppmof chloride and 1,200 ppm of dis-solved solids; as of 1945, the water from well 5/13-6D2 contained

R.WW. R.I3W.

WELL

USGS

4/I3-3IE4

4/13- 31 PI
5/I3-6D2

4/I4-36H1

OWNER

CITY OF LOS ANGELES
LOMITA PLANT, WELL NO. 4

UNION OIL CO.
UNION OIL CO.

PALOS VERDES WATER CO.
WELL NO. 1

Si £43

PUMP
OPERATIN6

4/I3-3IPI AND 5/13-602
(COMMON PUMPING
PERIODS)

4/I4-36HI

SEPTEMBER 28, 1946

FIGUEE 8. Map of wells, and graph showing results of pumping tests to determine presence or absence of barrier features near Bixby Slough.

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about 380 ppm of chloride and about 1,000 ppm of dissolved solids. On the other hand, the water withdrawn from the wells in 4/13-3IE north of Anaheim Street, has ranged from 42 to 108 ppm of chloride and from 350 to 500 ppm of dissolved solids.
On September 28, 1946, the pumps at the Lomita plant of the city of Los Angeles were idle and had been shut down for several days. The wells of the Union Oil Co. had been pumped continuously for several months before the test, and the wells of the Palos Verdes Water Co. had been pumped intermittently during previous days. During the day, wells 4/13-31P1 and 5/13-6D2 (Union Oil Co.) and well 4/14-36H1 (Palos Verdes Water Co., well 1) were pumped intermittently on an alternating schedule (fig. 8), and water-level measurements were made by the Geological Survey at about 10- minute intervals from 10:00 a. m. to 9:00 p. m. at wells 4/13-31E4, 4/13-31P1, and 4/14-36H1. The fluctuation of water level in these wells is shown on figure 8. During the periods of pump operation as shown, the average joint discharge from the Union Oil Co. wells was about 2,150 gpm, and the discharge from well 4/14-36H1 was estimated by the operator as 1,230 gpm.
Between 12:10 and 4:10 p. m., the water level in well 31E4 recovered along a uniform curve as a result of the shutdown of the pumps in the Union Oil Co. wells from noon to 4:00 p. m. From 4:10 to 7:10 p. m.,, the water level in well 31E4 declined concurrently with pumping of the Union Oil Co. wells. There is no hydraulic barrier between the Union Oil Co. wells and well 31E4 at the Lomita plant of the city of Los Angeles. On the other hand, the recovering water levels in wells 31E4 and 31P1 did not show any response to the shutdown of the pump in well 4/14-36H1 (Palos Verdes Water Co., well 1) at 2:00p. m., nor to the starting of the pump again at 8:00 p. m. Also, the recover-ing level in well 36H1 was not affected by the starting of the pumps in wells 4/13-31P1 and 5/13-6D2 of the Union Oil Co. at 4:00 p. m. Thus, there appears to be a substantial hydraulic barrier somewhere between well 36H1 on the west and wells 4/13-31E4, 31P1, and 5/13- 6D2 on the east. The location and direction of this barrier are not known but it is inferred to be a cemented fault zone, because the Silverado water-bearing zone is known to be continuous, highly permeable, and about 700 feet thick between wells 4/13-31E4 and 4/14-36H1. If this barrier should extend northward from the Palos Verdes Hills into the west basin, it would have some effect on local circulation of ground water; but so far as known, it does not separate any of these wells from the main body of ground water in the west basin.

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REPLENISHMENT TO THE WEST BASIN SOURCES AND GENERAL iFEATTJRES
EAKLY CONDITIONS

Under the early conditions of ground-water development, replenish-ment to the water-bearing deposits of the west basin tapped by wells occurred in four ways. In probable relative order of importance they were as follows:

1. By underflow across the Newport-Ingle wood uplift (the inland boundary of the west basin) through the deposits of Recent and of Pleistocene age.
2. By direct infiltration from the land surface of (a) water from rainfall, and (b) return water from irrigation, from cesspools, and by leakage from distribution systems.
3. By infiltration of local runoff water from the hills bordering the west basin, including the Santa Monica Mountains and the Santa Monica plain to the north, the hills of the Newport-Inglewood uplift (especially the Baldwin Hills) to the northeast, and the Palos Verdes Hills to the south.
4. By seepage within the west basin from the channels of the Los Angeles River to the south, and from Ballona Creek and its tributaries to the north.

CONDITIONS DEVELOPED BY WATEE-IEVEI DECLINE

OCEAN-WATER REPLENISHMENT

During the period of ground-water use, the draft has become large and levels have been drawn down to sea level and below. As a result, in the twenties ocean water began to invade the water-bearing zones along the coast and became a source of recharge. Because of the accelerated decline of water levels in recent years this condition has become critical.

WATER RELEASED BY COMPACTION

Because of the drawdown of water level, water has been withdrawn from storage in the water-table reach, and some water has been derived by compaction of the aquifers and of the surrounding and enclosing fine-grained, relatively impervious sediments. The latter has been called "water of compaction" by Tolman (1937, p. 142-143, 470-472). The quantity so yielded doubtless has been largest in recent years and in areas of greatest drawdown of the pressure head, such as Dominguez Gap.
In certain other areas in California, large quantities of water have been derived by compaction of sediments resulting from regional drawdown of the pressure level. For example, in the Livermore Valley, Alameda County, Calif., Smith (1934; Tolman, 1937, p. 495-
498) has estimated from a careful ground-water inventory that some 15,860 acre-feet of water was supplied by compaction of the alluvial materials during a low-water-level period from 1925 to 1930 an

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average rate of about 3,200 acre-feet per year, as compared to an average yearly pumping draft of about 12,500 acre-feet. However, the amount of land-surface subsidence was not known, and the volume of compaction could not be determined.
In the Santa Clara Valley of Santa Clara County, Calif., Tolman and Poland (1940, p. 23-35) found that water of compaction, as measured by subsidence of the land surface and inferred equivalent reduction of pore space, was about 230,000 acre-feet from 1919 into 1937. Subsidence developed over an area of about 200 square miles as a result of an average water-level lowering of 100 feet in the 20 years from 1915 to 1935. The maximum subsidence, about 5.5 feet, was at San Jose. Insofar as water was derived from compaction of silt and clay bodies (aquicludes) within or enclosing the aquifers, it represented a nonreplaceable contribution to the usable ground-water supply.
In the west basin no such substantial subsidence of land surface has occurred as a result of ground-water withdrawal. In the vicinity of Terminal Island, near the crest of the Wilmington oil field, the land surface subsided as much as 7 feet between 1928 and 1947.9 This subsidence was attributed by Gilluly, Johnson, and Grant (1945, also see Gilluly and Grant, 1949) as due almost wholly to the pressure decline and resulting compaction of the oil-bearing sands of Miocene and lower Pliocene age in the Wilmington oil field (which was caused by the removal of oil and gas beginning about 1937). In a recent report, Harris and Harlow (1947, p. 1197-1218) have concluded that the subsidence resulting from the pressure decline has occurred chiefly in the shale and siltstone associated with the oil sands. The publi-cation of these two conflicting concepts on the mechanics of land subsidence emphasizes the need for careful research to resolve the relatively unexplored question of whether subsidence of the land surface associated with the withdrawal of large quantities of fluid is caused primarily by compaction of the permeable reservoir beds or of the relatively impermeable but porous silt, clay, and shale members which are interbedded with or confine the permeable beds, and which, in effect, are a part of the reservoir system.
A large range in the proportion of compaction of coarse-grained permeable deposits to that of fine-grained, relatively impermeable deposits probably will be found, as more examples of land subsidence associated with withdrawal of fluids or gases are studied in detail. The compressibility of each deposit must be in part a function of the physical character; for the fine-grained deposits the rate of com-

6 Since the present report was released to the open file (1948), the maximum subsidence in the Wilmington area has increased to 22 feet (1955).

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paction will also be a function of permeability which determines the rate at which pressure differentials can be equalized that is, the rate at which fluid can escape from the fine-grained deposits to the more permeable reservoir rocks and permit compaction of the former. Also in the vicinity of Terminal Island, a land subsidence of as much as half a foot occurred in 1941, concurrently with the dewatering for construction of the large graving dock at the Naval Operating Base on Terminal Island. A brief description of this dewatering operation, its effect on water levels in nearby wells, and the local subsidence of land surface has been given by Grant (1944, p. 149-154).
As summarized elsewhere (Poland, 1959), this dewatering at Ter-minal Island was carried out by turbine pumps in 36 gravel-envelope wells which tapped the Gaspur water-bearing zone. The dewatering was started on June 27, 1941, and reached a maximum during August, when the average rate of withdrawal was about 35,000 gpm. Pump-ing operations ceased on April 4, 1942, after the removal of about 26,000 acre-feet of water from the Gaspur zone in 9 months, or slightly more water than was pumped concurrently from this same zone by all water wells from Terminal Island to Whittier Narrows. The lowering of the piezometric level for the Gaspur water-bearing zone was as great as 35 feet in well 5/13-3L1 (Southern California Edison Co., well 4), and 15 feet in well 4/13-35M1, respectively 0.5 mile and 1.7 miles north of the center of pumping at the graving dock. The maxi-mum recorded subsidence was at bench mark 43, at the southwest corner of the Southern California Edison Co. property and 1,650 feet from the center of the graving dock. Records taken by this company indicate that subsidence of bench mark 43 was 0.495 foot relative to bench mark 18, which is about 3,500 feet from the center of the graving dock. As described by Gilluly and Grant (1949, p. 497), substantial recovery of bench-mark altitudes coincided with recovery of water level in observation wells, during the reduced pumping rates of the latter part of the dewatering operation arid immediately after cessation of pumping. The recovery of bench-mark altitudes ranged from 14 to 78 percent, with an average recovery of about 42 percent. From these facts, it was concluded by Gilluly and Grant that one-half or more of this subsidence due to the drawdown of the piezometric level of the Gaspur zone was attributable to mineral-grain rearrange-ment, and the remainder was due to elastic compression. It is of interest to note that the bench marks that underwent the largest subsidence had the smallest percentage of recovery of altitude.
At the center of the greatest drawdown of the pressure level of the Silverado zone within the west basin at Carson and Alameda Streets in Dominguez Gap the subsidence of land surface from about the

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end of 1933 to 1944-46 was 0.354 foot, according to first-order leveling by the U. S. Coast and Geodetic Survey. 10
Three miles to the south, on the right-of-way of the Southern Pacific Railroad, about 0.6 mile northeast of the Anaheim Street crossing, bench mark G 33 67 subsided 1.316 feet between 1914 and 1944-46. Of this subsidence, 0.942 foot has occurred since December 1931, and 0.528 foot since July 1941. This bench mark is within the productive limits of the Wilmington oil field and the greater part of the sub-sidence is believed to have been caused by the compaction which .accompanied the withdrawal of oil and gas from that field. Although the land surface has subsided several tenths of a foot throughout much of the southern part of the west basin, it is not Tmown how much of this subsidence is due to compaction of sediments :accompanying the decline of pressure head in the Silverado water-bearing zone. It may have been partly because of tectonic adjust-ments and partly because of pressure decline in the saline water sands at much greater depth which are hydraulically connected with the producing oil sands of the Wilmington and other oil fields. Accord-ingly, a direct estimate of subsidence due to compaction of sediments accompanying the decline of pressure head in the Silverado zone has not been attempted in this investigation. However, the quantity of water made available by such compaction of sediments has been estimated on page 151, by use of the empirical storage coefficient determined from the lowering of pressure head in well 4/14-13F1 due to the pumping of the wells at the Lomita plant of the city of Los Angeles (p. 133).
With fully effective confinement, water is yielded from storage only in proportion to the compaction of the water-bearing system (and expansion of the fluid) in response to pressure drop; therefore, it follows that in such cases the storage coefficient must be a measure of the compressibility of the system, and of the land-surface subsidence that will occur with each foot of sustained drawdown of the regional pressure level. However, in the ground-water basins of southwestern United States the water-bearing deposits consist almost entirely of valley fill (Meinzer, 1923, p. 291-303), and confining beds, although abundant, commonly are not extensive. Thus, with prolonged and sub-stantial withdrawal of water, conditions of fully effective confinement are rarely found, and most of the water commonly is withdrawn from storage in the unconfined reaches of the basins by draining of the pore spaces. Only near the coast, where relatively impermeable beds .associated with marine deposition are extensive, and in valleys such

10 Bench mark D-167 At Dolores, at the southeast corner of the intersection of Alameda and Carson Streets, on the Dominguez Water Corp. property, at the pumping-plant building, in the face of the west

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as the San Joaquin, where the deeper water wells partly tap aquifers interbedded with fine-grained lacustrine deposits, would reasonably effective confining systems be found. When considered in relation to time intervals of as much as a few years, and possibly even several tens of years, conditions of fully effective confinement presumably are encountered only in the great artesian basins in which the aquifers have been deposited in interior seas. Probably the Dakota sandstone and the overlying plastic shales form the outstanding example of such a basin (Meinzer and Hard, 1925, p. 73-96; Darton, 1896).
Within the west basin, the area of greatest overdraft and of most serious saline contamination is the Torrance-Inglewood subarea. For these reasons, this subarea now (1948) is involved in a. pending ad-judication of water rights. Thus, the following appraisals of re-plenishment concern first the magnitude of replenishment to the Torrance-Inglewood subarea and second the replenishment to the smaller subbasins in the Culver City subarea.

REPLENISHMENT TO THE TORRANCE-INGLEWOOD StJBAREA MAGNITUDE OF REPLENISHMENT IN 1903-4

The average rate of replenishment to the west basin in 1903-4 is believed to have been nearly equivalent to the natural and artificial discharge of that time. Such discharge occurred almost wholly by underflow to the ocean through the undersea extensions of the aquifers of Pleistocene and Recent age and by withdrawal through wells. The water levels were too far below the land surface to afford appreci-able opportunity for evapotranspiration losses.
For the Torrance-Inglewood subarea an estimate of the natural discharge to the ocean in 1903-4 can be made by summing up (1) the discharge from the San Pedro formation (Silverado water-bearing zone and correlative aquifers) along the west coast from Playa del Rey to the Palos Verdes Hills, and along the south coast from the Palos Verdes Hills to the Los Angeles River, and (2) the discharge from the Gaspur water-bearing zone to San Pedro Bay. For the Silverado zone, the cross section along the coast is known with reason-able accuracy (pi. 3(7), but the hydraulic gradient during 1903-4 at the coast cannot be accurately determined. Although water-level contours for the Silverado zone in 1903-4 have been recon-structed from data of Mendenhall (pi. 9 and p. 90), few of the wells in which water-level measurements were made near San Pedro Bay and from Manhattan Beach northward to Playa del Rey tapped the Silverado zone. The permeability of , the Silverado zone was de-termined from pumping tests near Torrance and near Bixby Slough, but it was not determined along the coast. Yield factors for wells near the west coast compared to yield factors for wells between Long

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Beach and Torrance (table 5) where the permeability has been de-termined as about 2,000 -gpm per square foot (p. 54) suggest a proportion of about 2 to 3, or a permeability of about 1,300 gpm per square foot for the coastal reach from Palos Verdes Hills to Playa del Rey. The following paragraphs sum up the several increments of natural discharge:

1. For the reach from the Palos Verdes Hills to Hermosa Beach, the discharge to the ocean as of 1903-4 has been estimated as about 11 cfs, or about 8,000 acre-feet a year (p. 92).
2. In the same way and only as an approximation, the discharge to the ocean between Hermosa Beach and Playa del Rey can be estimated. The length of this reach is about 7 miles, the average thickness of the aquifer is about 125 feet (pi. 3C), the permeability is estimated as about 1,300 gpd per square foot, and the average hydraulic gradient at the coast in 1903-4 was at least 2 feet per mile. Thus, the discharge of that time (north of Hermosa Beach) is estimated to have been at least 2.3 mgd about 3.5 cfs or about 2,500 acre-feet per year.
3. In regard to discharge from the Silverado water-bearing zone to San Pedro Bay, electric-log data for oil wells on Terminal Island indicate that the aquifers of the Silverado zone along that reach have an average thickness of about 250 feet. From the Los Angeles River west to the non-water-bearing rocks of the Palos Verdes Hills the width of the escape area is about 4 miles. Thus, the effec-tive cross section is about 1,000 foot-miles. The coefficient of permeability for the Silverado zone in this area is not known, but it is probably somewhat lower than that in the Torrance area, where it was determined to be about 2,000 gpd per square foot (p. 54), and near Bixby Slough where it is about 1,400 gpd per square foot. If the permeability beneath Terminal Island is assumed to be about 1,000 gpd per square foot and if the hydraulic gradient of 1903-4 is taken as 4 feet per mile (p. 91), then the ocean ward discharge through the Silverado zone beneath Terminal Island can be calculated at about 4 mgd about 6.2 cfs or approximately 4,500 acre-feet per year.
4. Underflow to San Pedro Bay from the Gaspur water-bearing zone of Recent age is estimated to have been about 2.8 cfs, or about 2,000 acre-feet per year. These figures are based on the assumption that conditions at the coast were as follows: width of water-bearing zone, 2 miles (pi. 8); thickness, 60 feet or an area of 120 foot-miles; hydraulic gradient, about 5 feet per mile (Mendenhall, 1905a, pi. 4); and an estimated permeability of 3,000 gpd per square foot (see p. 31).

In summation, the estimated yearly discharge to the ocean in 1903-4 from the aquifers beneath the Torrance-Inglewood subarea was about 21 cfs or 15,000 acre-feet from the Silverado water-bearing zone and was about 2.8 cfs or 2,000 acre-feet from the Gaspur water-bearing zone. Thus, the estimated total subsea escape was about 24 cfs or about 17,000 acre-feet per year. When this figure is added to the artificial discharge by pumping which has been estimated at about 10,000 acre-feet per year during 1903-4 (p. 99) the suggested over-all discharge was about 27,000 acre-feet per year, and the replen-ishment was comparable to that figure.

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The rainfall record for Los Angeles (table 2) indicates that the 11 years ending with 1903-4 included only 4 years of normal or slightly above normal rainfall. With respect to the 68-year average rainfall of 15.53 inches, at the end of the year 1892-93 there was a cumulated surplus of 43.34 inches of rainfall. By the end of 1903-4 there was a cumulated deficiency of 3.79 inches, indicating an 11-year deficiency 4>f 47.13 inches. The 3 years beginning with 1897-98 were the driest on record. Thus, runoff to the streams and recharge to the main coastal basin must have been continuously deficient during the 11-year period. Largely because of this deficiency, ground-water levels in the intake area near Whittier declined about 14 feet in this period and those near Anaheim declined about 40 feet (Poland, 1958). Also, the pressure level at the Bouton wells 2.5 miles north of Signal Hill and only 2 miles from the west basin boundary, declined ^bout 80 feet in the same period. The decline of pressure head in the Bouton wells was far more than the average for the main coastal basin in Los Angeles County, however. The decline of artesian pressure along the northeast flank of the Newport-Inglewood uplift ^between Compton and Manchester Boulevard is known to have averaged about 30 feet from the initial historic level to 1904 (Menden-hall, 1905b, pi. 5).
The recharge to the west basin must have been affected in two ways by this deficiency of rainfall. First, there must have been little if ;any direct penetration of rainwater from the land surface in this period; certainly there was essentially none except in the 4 wettest years. Second, the replenishment by underflow across the Newport-Inglewood uplift must have diminished substantially in the 11-year period, because the pressure levels on the inland side of the barrier faults fell about 30 feet. Draft from the Torrance-Inglewood sub- &rea was not large at that time and it appears doubtful that pressure levels in that subarea of the west basin could have declined in any such amount. Accordingly, the pressure differential across the barrier faults is inferred to have been greatly reduced by the decline in pressure level in the main basin; thus recharge to the Torrance-Inglewood subarea probably was considerably less in 1903-4 than in the eighties. It is believed that under native conditions of average rainfall the recharge to the Torrance-Inglewood subarea was 30,000 to 40,000 acre-feet per year.

MAGNITUDE OF REPLENISHMENT IN 1933-41

The replenishment to an underground basin may be estimated by measurement or calculation of the rate of inflow (intake methods) or the rate of discharge (discharge methods), or by determining changes in ground-water storage. Methods that have been applied to deter-

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mine intake and discharge from ground-water reservoirs have been summarized by Meinzer (1932, p. 99-144).
For the west basin, the direct appraisal of the several elements of replenishment would be very tedious, and estimates of rain-water penetration, irrigation return water, and underflow (subsurface recharge) are subject to substantial error unless the basic data are sufficient to furnish reasonable control over the variable factors in the respective equations. Such is not the case at the present time. However, it is understood by the writer that the California Division of Water Resources, as referee in the pending adjudication of water rights, is planning to make a careful estimate of the several elements responsible for replenishment to the basin (California Division of Water Resources 1952). 11

ESTIMATE BY RELATING PUMPAGE AND CHANGE IN STORAGE

For the purposes of this investigation, the elements of greatest interest are the over-all replenishment, the sea-water contribution, and the underflow across the Newport-Inglewood uplift. It can be assumed that, for years of average rainfall, the contribution by infil-tration of water from rainfall and runoff from the land surface will be nearly constant from year to year. The residential and industrial areas are expanding rapidly and the agricultural area is decreasing, but the joint contribution by return water from irrigation of crops and lawns probably will not change appreciably as agricultural lands become residential districts.
The average gross replenishment can be determined most simply by selecting a period of years in which the cumulated rainfall did not markedly digress from the cumulated average, and in which the position of the water level was about equal at the beginning and the end of the period that is, a period of little or no storage change. If the pumpage is known (or closely estimated) and if the storage change is estimated by the use of the specific yield and storage coefficients, the replenishment can be calculated. If there is no seaward discharge and no change in storage within the period, the gross replenishment is equal to the pumpage.
For the Torrance-Inglewood subarea of the west basin the area included in the plaintiff's complaint for adjudication of water rights 12 a relatively small amount of storage change occurred from the spring high-water level of 1933 to the spring high-water level of 1941 (pis. 9 and 11). Accordingly, this period of 8 years has been » Since this report was released to the .open file (1948), the California Division of Water Resources has completed its investigation as referee.
i* California Water Service Co. and others n. City of Comptbn and others, Action No. 506,806 in thft Superior Court for Los Angeles County, Calif., Oct. 1945.

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selected for appraisal of the average replenishment to this area before the accelerated draft and decline of water levels in the war years 1942-45.

The average yearly rainfall at Los Angeles in the years from 1933 into 1941 was greater than normal. However, 1940-41 was the only year of greatly excessive rainfall (table 2). With respect to the aver-age rainfall for the 68 years from 1877-78 through 1944-45, as shown in table 2, the average rainfall in the years 1932-33 through 1939-40 was 1.76 inches above normal, and the cumulated surplus for the 8 years was 14.04 inches. For the 9 years from 1932-33 through 1940- 41 the yearly average increased to 3.47 inches above normal, and the cumulated surplus was 31.27 inches. Thus, it might be expected that inclusion of the year 1940-41 would yield a nonrepresentative figure for storage change and replenishment. However, most of the water withdrawn from the Torrance-Inglewood subarea is taken from the Silverado water-bearing zone, which is confined by relatively imper-meable beds through most of the area. Therefore, it is doubtful that the rainwater penetration of the winter 1940-41 could have had an appreciable effect on the water levels of the Silverado zone or even on the water levels in the shallower "200-foot sand" by April 1941. Examination of the hydrographs introduced on figures 4 and 5 and plates 13 and 14 substantiates this general conclusion. Therefore, it is considered that the period selected is reasonably representative but that rainwater penetration in the 8 years was slightly above average.
The rise or fall of water level in the Silverado water-bearing zone from March 1933 (pi. 9) to April 1941 (pi. 11) is shown by lines of equal change (long dashes) on plate 10; the rise or fall for the "200-foot sand" in this 8-year period also is shown (short dashes). As discussed on pages 87-88, a water table occurs in the Silverado water-bearing zone only in the Redondo Beach area (pi. 10); another water table occurs in the correlative main water-bearing zone of the San Pedro formation in the vicinity of Playa del Rey. It will be noted from the lines of equal change on plate 10 that: (1) the storage change in the water-table reach of the Silverado zone near Redondo Beach did not exceed 5 feet; and (2) the storage change in the water-table reach of the main water-bearing zone near Playa del Rey did not exceed 6 feet. The maximum change (except for the local fall of 20 feet east of Inglewood between the Potrero and Inglewood faults) in the Tor-rance-Inglewood subarea, east of Hawthorne in the pressure area, was about 16 feet. Inland beyond the west basin boundary, the maximum fall was in excess of 30 feet.

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TABLE 13. Estimated storage change in the Torrance-Inglewood subarea, from March 1933 to April 1941, for the Silverado water-bearing zone and correlative aquifers in the San Pedro formation

Township
(S.) and
range (W.)

Area (square
miles)

Rise (+) or
fall (-)
(feet)

Change in volume

Square miles X
feet

Acre-feet

Storage change
(acre-feet of
water)

Silverado water-bearing zone, water-table area near Redondo Beach

2.91
11.94
.72
1.38
1.05
. 17

18.17

_ £
_ 3
K

+ 1
+ 3
+ 5

- 2.91
OK OO

- 3.60
+ 1.38
+ 3.15
+ .85

- 36.95

- 1,862
- 22, 925
- 2, 304
+ 883
+ 2, 016
+ 544

- 23, 648 1 -4, 730

Main aquifer, San Pedro formation, water-table area near Playa del Rey

1.42
1.11
.39
2.00

4.92

- 1
_ o

- 5
+ 1

- 1.42
- 3.33
- 1.95
+ 2.00

-4.70

-909
- 2, 131
- 1, 248
+ 1, 280

- 3, 008 1 -600

Silverado water-bearing zone, confined area

2/14
2/15
3/13
3/14
3/15
4/13
4/14

7
1
8
33.5
5
32
7.5

94

- 11.6
- 5
-4.4
+ 8.5
- 2.2
+ .8
0

- 81
- 5
- 35
-285
11
+ 25
0

- 392 -250, 880 2 -300

i Total change in volume (acre-feet) multiplied by 0.20 (specific yield).
' Storage coefficient assumed to be 0.0012 throughout the pressure area.

The storage change in the Silverado water-bearing zone was deter-mined in the following manner:
1. The working copy of plate 10, at a scale of 1:48,000 was superimposed over a map sectionized in the manner of plate 2, each main grid unit representing 1 square mile. For the two water-table areas, a grid subdivided in hundredths of a square mile was utilized to determine the part of each section falling between two lines of equal change. For the larger pressure area, the average change of water level in feet was estimated for each square mile. For each territory the area ia square miles lying between lines of equal water-level change (0-2, 2-4, and 4-6) was summed up separately. Cumulative areas so obtained were multiplied by the odd-foot value between the two boundary lines (the average change for the area between the 2- and 4-foot lines was assumed to be 3 feet), giving a volume for storage change in square miles X feet. By summing up all such volumetric elements for each area, the total volume change was obtained for that area.

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2. The specific yield for the two water-table areas was assumed to be 20 percent (in accordance with estimates made by Eckis from samples collected in the field and tested in the laboratory) (1934, pi. E). The storage coefficient of 0.0012 obtained from the drawdown of water level in well 4/14-13F1 due to pumping of the Lomita plant wells (p. 133) was applied to the main pressure area. Table 13 presents a summary of water-level changes, volumes dewatered or saturated (or of pressure-level change), and water released from storage.

The storage change has been computed for the "200-foot sand" in the same manner. Contours of the water level in this aquifer were not constructed for the beginning and end of the period of appraisal. Instead, the changes hi position of the water level in the period for individual wells were plotted on the working copy of plate 10 and the lines of equal change were drawn from these data. Table 14 sum-marizes the results of the computation. About one-fourth of the pertinent well logs show water-table conditions at current water levels in the upper Pleistocene deposits ("200-foot sand" and other deposits); therefore, the over-all specific yield was assumed to be about 5 percent.

TABLE 14. Estimated storage change in the Torrance-Inglewood subarea, from March 1933 to April 1941, for the "200-foot sand" and correlative deposits of upper Pleistocene age

Area (sq mi)

16.93
19.70
10.90
8.24

55.77

Rise (+) or fall (-)
(feet)

- 3
- 5
_ <7
- 9

Change in volume

Square miles X feet

- 50.79
-98.50
- 76.30
- 74.16

-299.75

Acre-feet

- 32, 505
-63,040
-48,830
-47,460

- 191,835

Storage change
(acre-feet of water)

1 -9, 600

»Total change in volume (acre-feet) multiplied by 0.05 (specific yield).

The estimated storage change within the Silverado zone in the 8-year period (table 13) is 5,600 acre-feet of which 5,300 acre-feet occurred in the water-table areas. The estimated storage change in the un-named upper Pleistocene deposits (table 14) is 9,600 acre-feet. Thus, the over-all withdrawal from storage in the 8 years is estimated to have been 15,200 acre-feet, or an average rate of about 2,000 acre-feet per year. Changes in storage in the shallow unconfined body and in the 400-foot gravel probably were inconsequential during this period.
The total withdrawal from the Torrance-Inglewood subarea in the 8 years from 1933 through 1940 (table 8) was 383,100 acre-feet; the average rate of withdrawal was about 47,900 acre-feet per year. There was essentially no natural discharge during this period, therefore, the gross replenishment is equal to the withdrawal less the change in

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storage that is, 383,100 less 15,200 or 367,900 acre-feet. Thus, the average yearly gross replenishment is estimated to have been about 46,000 acre-feet.
CONTBIBTJTION FROM THE OCEAN

With the extensive drawdown of water levels to and below sea level, saline waters have invaded the Torrance-Inglewood subarea along the full reach from Playa del Key to the Palos Verdes Hills. Also, along the south shore from the Palos Verdes Hills to the Los Angeles River channel, saline waters probably have moved northward beyond Terminal Island toward centers of pumping. The water in the Silverado zone beneath Teiminal Island is inferred to have been of inferior quality under native conditions (Piper, Garrett, and others, 1953, p. 197). To date, these inferior waters have not advanced sufficiently far northward to reach any actively pumped well fields. As shown by the distribution of withdrawals on plate 12, the first major well fields to receive such inferior waters presumably would be that of the Union Oil Co. in Wihnington (pi. 12, no. 23) and that of the Texas Co. (pi. 12, no. 24) at the west edge of Dominguez Gap; Regardless of the quality of the ground water in the Silverado zone beneath Terminal Island, there must have been a substantial con-tribution of water to the west basin from the subsea reach south of Terminal Island in response to the landward gradients that have existed since the early thirties. This contribution is not being replaced by water of good quality, and probably it is being followed landward by saline waters, either ocean water entering the outcrop of the Silverado zone beneath San Pedro Bay, or connate saline waters contributed from within the subsea ground-water system, or both. Ocean water advanced inland in the Gaspur water-bearing zone in the thirties (see p. 259, also pi. 16); the extent of that inland advance has been shown in an earlier report (Piper, Garrett, and others, 1953, pi. 17).
The over-all contribution from the ocean or from the seaward extensions of the water-bearing zones of the Torrance-Inglewood subarea from 1933 to 1941 is estimated in following paragraphs. The extent of encroachment of saline waters for the reach along the west coast from Playa del Rey to the Palos Verdes Hills is shown on plate 16. The contribution from the ocean can be computed if the assumption is made that the rate of advance of the saline front is a direct measure of the rate of landward inflow of salt water to the water-bearing deposits.
Prom the appraisal of the rates of saline encroachment as suggested by the advance of the saline front from 1931 to 1946 (pi. 16), and with consideration to the effective hydraulic gradients, it is concluded

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(p. 251 to 253) that the average yearly rate of advance of the saline front from Playa del Eey to El Segundo from 1931 to 1941 did not exceed 40 feet, from El Segundo to Hermosa Beach it was about 115 feet, and from Hermosa Beach to the Palos Verdes Hills it was about 90 feet. The effective porosity of the Silverado water-bearing zone and correlative water-bearing deposits along this full reach is estimated to be about 20 percent. The product of the cross-sectional area of water-bearing materials, the average yearly advance, and the effective porosity may be considered to be a measure of the contribu-tion seaward from the front.
The cross-sectional area (pi. 3(7) for the reach from Hermosa Beach to the Palos Verdes Hills is about 3.5 miles long by 400 feet thick. If the average advance of the front (pi. 16) was 90 feet per year through material with an effective porosity of 20 percent, the quantity of water required to fill the block 3.5 miles long by 400 feet thick by 90 feet wide would be about 3,100 acre-feet. In the same way, the yearly displacement for the reach from Hermosa Beach to Playa del Eey is estimated at about 2,500 acre-feet.
By this method, the average annual contribution to tbe ground water in the area coastward from the saline front in the reach from Playa del Eey to the Palos Verdes Hills for the years from 1931 to 1941 is estimated to be about 5,600 acre-feet.
By another method, the contribution along this reach can be com-puted as the product of: (1) the cross-sectional area of permeable material; (2) an estimated permeability of 1,300 gpd per square foot (p. 147); and (3) the average hydraulic gradient. For the reach from Hermosa Beach to the Palos Verdes Hills, where the average landward gradient of the thirties was about 3.5 feet per mile, the contribution so computed is 7,100 acre-feet per year. If the contribution in the reach from Hermosa Beach to El Segundo is computed assuming a perme-ability of 1,300, a cross-sectional area 4.5 miles long and 150 feet thick, and an equivalent hydraulic gradient of 3.5 feet per mile; and if the small contribution from El Segundo to Playa del Key is estimated from the rate of saline encroachment, as above, the over-all contribu-tion along the west coast is about 10,800 acre-feet per year.
If the quantities derived by these two independent methods are assumed to indicate the general limits of such a contribution along the west coast in the thirties, the suggested mean is about 8,000 acre-feet per year. Most of this contribution must have been ocean water, but it also included water that descended from the land surface to the water table, in the areas coastward from the saline front, south of Hermosa Beach and north of El Segundo. In the thirties, these two areas included about 3,000 acres, and the average annual contribution of water from the land surface in this dune-sand area may have been

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as much as 1,000 acre-feet. If these figures are correct, the ocean-water contribution is estimated to be about 7,000 acie-feet per year. For the south coast facing San Pedro Bay, the landward movement of water in the Silverado water-bearing zone in the thirties can be estimated in the same manner as the coastward discharge of 1903-4 (p. 147). It is inferred that the Silverado zone or correlative deposits crop out on the ocean floor from 8 to 9 miles southwest of Terminal Island. 13 The average depth of the piezometric level at Terminal Island from 1933 to 1941 was about 30 feet below sea level. Thus, the average inland gradient of those years is inferred to have been about 4 feet to the mile about equal to the coastward gradient of 1903-4. Therefore, the annual contribution of water moving north-ward in the Silverado zone from beneath San Pedro Bay in the thirties is estimated to have been about 4,500 acre-feet per year.
The landward movement of salt water in the Gaspur water-bearing zone is known to have underrun about 300 acres from 1931 into 1943 (Piper, Garrett, and others, 1953, pi. 17 and p. 178). The thickness of the Gaspur water-bearing zone is about 60 feet and the effective porosity is about 25 percent. The landward encroachment of the thirties thus was approximately 400 acre-feet per year.
In summation, the average yearly contribution of water to the Torrance-Inglewood subarea from 1933 to 1941 from the ocean or from the subsea extensions of the aquifers is estimated to have been about 12,000 acre-feet per year. Thus, within the limitations of the assumptions made here the average net replenishment of fresh water to the Torrance-Inglewood subarea in these years is 46,000 acre-feet less 12,000 acre-feet, or about 34,000 acre-feet per year.
UNDERFLOW ACROSS THE NEWPOET-INGLEWOOD UPLIFT

Under native conditions of high-water level, the quantity of under-flow passing across the Newport-Inglewood uplift from the main coastal basin to the Torrance-Inglewood subarea along the crestal reach from Long Beach to the Baldwin Hills varied in accordance with the differential in the water levels across the fault barriers of the uplift as the one variable (the product of permeability and cross section was a constant). At the crest of the uplift the Silverado water-bearing zone and related deposits in the San Pedro formation then were fully saturated, and the upper Pleistocene water-bearing zones were fuUy saturated, except at the crests of Dominguez Hill and the Rosecrans Hills, and high on the flank of the Baldwin Hills. In accordance with the drawdown of water level due to increased withdrawal from the main coastal basin, water levels along the crest of the uplift have declined from 100 to 150 feet below the initial levels

13 U. S. Coast and Geod. Survey hydrologic chart 5143, Los Angeles harbor and vicinity, 1936.

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and substantial dewatering of certain aquifers has occurred. For aquifers almost entirely dewatered along the crest of the uplift, the transmissibility of the saturated cross section has become the primary control on the quantity of water passing into the west basin, and the differentials at the barrier features have become secondary. For aquifers wholly dewatered along the crest, no water passes coastward beyond the crest, and the differentials along the barrier features have no meaning.
DEWATERING ALONG THE UPLIFT CHEST

Plate 15 has been prepared for the purpose of appraising the magni-tude of dewatering of the water-bearing beds along the crest of the Newport-Inglewood uplift from the Baldwin Hills to Long Beach. The position of the water-bearing beds .(pi. 15) has been generalized from plate 3.4, with slight modification between Manchester Avenue and Imperial Highway, in order to follow the land-surface and inferred subsurface crests. Plate 15B shows on an expanded scale, the pres-sure level and the local water table of the Silverado water-bearing zone and correlative aquifers along the alinement of the section for selected times from 1903-4 to 1945. A partial plot of the water levels of the eighties, inferred from data by Mendenhall, also is shown. The water-level profiles for 1904, 1933, 1941, and 1945 are taken from plates 9-12; the profile for 1930 is from a work map not included in the report. Although the water-level profiles are constructed from data for wells tapping the Silverado zone and correlative deposits, these profiles also can be used to appraise the general order of de-watering of the upper Pleistocene deposits. Part of the generalized position of the top of the Silverado zone has been plotted at the expanded scale of plate 15B in order to emphasize the extent of dewatering in this principal aquifer.
As shown by the profiles of plate 15, the upper Pleistocene water-bearing deposits (the "200-foot sand" and correlative deposits) have been extensively dewatered along the crest. On the other hand, the Silverado water-bearing zone and lower Pleistocene correlative de-posits have been partly dewatered in the 6-mile reach between the Baldwin Hills and El Segundo Boulevard, but no dewatering has occurred in the 8-mile reach from El Segundo Boulevard to Los Cerritos (Long Beach). The extent of dewatering is summarized as follows:

1. The upper Pleistocene water-bearing deposits initially were fully saturated except at the crests of the Dominguez Hill and Rosecrans Hills and high on the south flank of the Baldwin Hills. By 1945 these deposits had been entirely dewatered along all the crestal reach northwest of El Segundo Boulevard, and had been dewatered nearly to sea level along the crestal reach of Dominguez Hill. Thus, in the early forties, the only segments of these deposits still saturated were: the 3-mile reach between El Segundo Boulevard and Artesia Street, along most

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of the Avalon-Compton fault; and the 3-mile synclinal reach beneath and adjacent to Dominguez Gap. The water-bearing beds in the reach along the Avalon-Compton fault are only about 60 feet thick but they are highly permeable and are tapped by many wells; thus, these deposits are believed to transmit substantial underflow through the fault barrier. On the other hand, the water-bearing beds beneath Dominguez "Gap, which are composed almost entirely of fine sand (pi. 3.A), as much as 120 feet thick (well 4/13-2Jl), are not tapped by many wells because they are not highly permeable, and their transmissibility is less than that of the thinner aquifers northwest of Dominguez Hill.
In terms of cross-sectional area, about 50 percent of the upper Pleistocene water-bearing deposits throughout the area shown on plate 15.4 have been de-watered by the drawdown of water level from native conditions to the levels of 1945. However, the reduction in transmissibility has been much more than 50 percent, because the permeable deposits which occur northwest of well 3/13-17E1 and including those at the Centinela Park well field of the city of Inglewood, have been wholly dewatered. Utilizing the generalized data of plate 15A, the calculated cross-sectional area of the initially saturated upper Pleistocene aquifers is 4.4 million square feet and by 1945 the dewatered area totaled 2.1 million square feet.
2. The Silverado water-bearing zone and correlative aquifers in the San Pedro formation of early Pleistocene age initially were fully saturated along all of the crestal reach from Los Cerritos (Long Beach) to the Baldwin Hills. In nearly all of the 8-mile reach southeast of El Segundo Boulevard, the top of the Silverado zone is more than 100 feet below sea level, and beneath Dominguez Gap is as much as 400 feet below sea level. However, between El Segundo Boulevard and the Baldwin Hills, the top of the Silverado zone and correlative deposits is several tens of feet above sea level on a large area. Thus, because of the decline of water level to near sea level, by 1945, extensive dewatering has occurred in the deposits in the 6-mile reach northwest of El Segundo Boulevard.
In terms of cross-sectional area, about 35 percent of the' water-bearing beds of the San Pedro formation northwest of El Segundo Boulevard had been dewatered by 1945. Throughout the entire reach, only about 10 percent had been de-watered. However, in the 2-mile reach from near well 2/14-27J1 (city of Ingle-wood, well 16) southeast to the intersection of Century Boulevard and Western Avenue, the decline of water level by 1945 had dewatered about two-thirds of the thickness and only 30-50 feet of the Silverado zone remained saturated. No well data are available to determine whether the reduction in saturated cross section may have been partly compensated by a steepening of the hydraulic gradient. In any case, a drawdown of water levels to as much as 30 feet below sea level would essentially dewater the Silverado water-bearing zone in this reach and would prevent underflow to the west basin.
From the generalized data of plate 15, the calculated cross-sectional area of the Silverado water-bearing zone and correlative aquifers is 18 million square feet, of which about 12.8 million is south of El Segundo Boulevard and about 5.2 million is north; of the latter, about 2 million square feet had been dewatered by 1945. Thus, the saturated cross-sectional area of the lower Pleistocene aquifers, as compared with that of the upper Pleistocene aquifers, was about four times as great under initial conditions and about seven times as great in 1945.

CHANGE IN DIFFERENTIAL HEAD ACROSS THE BARRIER FEATURES

The average differentials in water level across the barrier features of the uplift between the Baldwin Hills and the southeast edge of

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Dominguez Gap can be calculated approximately from water-level contour maps of the Silverado water-bearing zone by estimating average differential heads across measured segments of the barrier features and totaling these differentials, which are weighted in accord with the lengths of the respective segments. In this manner, average differentials in water level have been estimated for 1904, 1933, 1941, and 1945, from the data of plates 9 to 12. Results are summarized in table 15.

TABLE 15. Average water-level differentials, in feet, across the barrier features of the Newport-Inglewood uplift between the Baldwin Hills and Long Beach, 1904-45

Year

1904_______ . __ __ .____...___._.__ __ _
1933 (March)_._.__ _ _______________ _ _
1941 (April).. . __---_.-_____-___.______
1945 (November) ____ __ _ __ __ _ __

Baldwin Hills

to El Segundo
Boulevard

(6 miles)

49
29
22
32

El Segundo
Boulevard to
Long Beach
(Smiles)

33
37
33
40

Totaled

average from
Baldwin Hills
to Long
Beach
(14 miles)

40
34
28
36

The water-level differentials have been summed up separately for the 6-mile reach northwest of El Segundo Boulevard and the 8-mile reach to the southeast. The former parallels the area of partial dewatering along the crest, and also is the one with the poorer control on water-level differentials, especially across the Potrero fault north of Century Boulevard; here, the amount of drawdown of water level in the several fault blocks between the Potrero and Inglewood faults is irregular and largely unknown.
Although the average differentials presented in table 15 are only approximate and their derivation has required a considerable amount of extrapolation, they suggest with respect to the Silverado water-bearing zone and correlative deposits that:

1. In 1904 the differential in water levels was about 50 percent greater north-west of El Segundo Boulevard than to the southeast.
2. By 1933 the differential northwest of El Segundo Boulevard had decreased about 40 percent and was less than the differential to the southeast, which had increased slightly.
3. The average differential was least in 1941 only 28 feet for the over-all 14- mile reach.
4. If the average head differential between 1933 and 1941 is assumed to be the average of those 2 years, then the head differential northwest of El Segundo Boulevard in that 8-year period (26 feet) was just about half of that in 1904, whereas southeast of El Segundo Boulevard it was slightly higher than in 1904 (35 feet). If the water transmitted across the barrier features is proportional to the differential in head, as seems reasonable, if the permeability of the water-bearing beds is considered uniform along the full reach, and if the effect of de-

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watering north of El Segttndo Boulevard is ignored, the underflow into the Tor-rance-Inglewood subarea in the period 1933-41 can be estimated to be about 86 percent as great as in 1904 (product of differential head times cross-sectional area, for each segment).
5. In the same way, the underflow into the Torrance-Inglewood subarea as of 1945 can be estimated to be about the same as in 1904. If the dewatering along the crest north of El Segundo Boulevard is considered wholly effective in propor-tionately reducing the underflow to the west basin, then, the underflow as of 1945 would have been about 90 percent as great as in 1904, with respect to the Silverado zone and correlative deposits.

Of all water-bearing deposits of Pleistocene age along the reach from the Baldwin Hills to Los Cerritos that is, the extensively de-watered upper Pleistocene deposits as well as the Silverado zone and correlative deposits of early Pleistocene age it is estimated that the underflow as of 1945 was about 85 percent as great as in 1904.

METHODS OP ESTIMATING UNDERFLOW

The underflow to the Torrance-Inglewood subarea from the main coastal basin comprises two elements, (1) the underflow in the Gaspur water-bearing zone of Recent age, which passes into the west basin through the throat of Dominguez Gap, and (2) the underflow through all the aquifers of Pleistocene age, of which the Silverado water-bearing zone and correlative aquifiers constitute the principal conduit. The Gaspur water-bearing zone is not cut by the barrier features of the uplift specifically, the Cherry-Hill fault (pi. 12) and thus no differential in water level has been developed. Accordingly, the un-derflow to the west basin through this aquifer can be estimated as the product of the permeability, the cross-sectional area, and the hydraulic gradient. The permeability has been estimated to be about 3,000 gpd per square foot (p. 31), the cross-sectional area at the throat between Dominguez Hill and Los Cerritos is about 72 foot-miles (width 1.2 miles parallel to the ground-water contours, and thickness about 60 feet), and the hydraulic gradient through the throat has been about 12 feet to the mile in recent years (pi. 11). Thus, the current underflow to the west basin through the Gaspur water-bearing zone is estimated at about 4 cfs, or about 2,900 acre-feet per year.
The quantity of underflow to the Torrance-Inglewood subarea through the deposits of Pleistocene age also could be estimated directly if: (1) the permeability of the water-bearing deposits from place to place along the crest of the uplift had been determined by means of a sufficient number of pumping tests to afford reliable control; (2) the average hydraulic gradient across the crest were known for the particu-lar instants or periods of appraisal; and (3) the amount of withdrawal between the crest of the uplift and the inland boundary of the west basin were known, so it could be subtracted from the underflow passing

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the crest. Neither the permeability nor the crestal hydraulic gradient can be evaluated with reasonable accuracy at this time. In the 3-mile reach from the top of Dominguez Hill to the Los Angeles River not a single water well taps the Silverado water-bearing zone immediately inland from the barrier faults. It is here that the greatest differential in pressure level now exists across the barrier features of the uplift. During this investigation an attempt was made, with the cooperation of the Los Angeles County Flood Control District, to utilize certain oil-test holes for obtaining data on the permeability and piezometric level of the Silverado zone within this critical reach; however, the negotiations were unsuccessful.
The importance of obtaining accurate data on the hydraulic gradient can be illustrated by the following example. If the average perme-ability along the crestal reach is assumed for the moment to be 1,000 gpd per square foot, the quantity of water transmitted across the saturated crestal section of the Silverado zone and correlative deposits in 1945 would have been about 3,400 acre-feet per year for each foot per mile of hydraulic gradient.
The quantity of underflow passing into the Torrance-Inglewood subarea through the Silverado water-bearing zone and correlative deposits could be estimated by another method. The axis of the pres-sure trough, as shown on plates 9 to 12, marks the boundary between water moving inland and water moving coastward. That axis has migrated inland in recent years because the draft from the Torrance-Inglewood subarea has increased about 50 percent while the underflow has remained roughly constant. The quantity of water withdrawn between the barrier and the axis of the pressure trough that is, within the area underlain by a coastward gradient is a measure of the replenishment by underflow. It is impossible to estimate this draft accurately at present. For example, the axis of the pressure trough as of 1945 passed through the main well field of the Dominguez Water Corp. (pi. 12, plant 14b). The proportion of water contributed to this well field from the inland side (coastward hydraulic gradient) and from the coastward side (landward hydraulic gradient) cannot be determined without constructing additional observation wells to indicate the steepness of the coastward gradient as compared to the landward gradient.
However, as plates 9 and 11 suggest, the coastward hydraulic gradient on the inland side of the trough of pressure relief is somewhat steeper than the landward gradient on the oceanward side of the cone. If, for purposes of rough calculation, it is assumed that the coastward hydraulic gradient to such pumping plants along the axis of the pres-

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sure trough was twice as great as the inland gradient in 1945, and presuming that the transmissibility of the deposits on the two sides is the same, then the contribution from the inland side would be two-thirds of the total to such well fields. On the basis of this assumption, the underflow from the main coastal basin to the Torrance-Inglewood subarea through the Silverado water-bearing zone as of 1945 is esti-mated roughly to have been about 12,000 to 16,000 acre-feet per year. If the estimated underflow through the upper Pleistocene deposits and through the Gaspur water-bearing zone is added to this, the total contribution to the Torrance-Inglewood subarea by underflow from the main coastal basin in 1945 is estimated to have been within the

range of 15,000 to 20,000 acre-feet.

FACTOBS AFFECTING CURRENT AND FUTURE REPLENISHMENT

The net replenishment to the Torrance-Inglewood subarea from 1933 to 1941 has been estimated at about 34,000 acre-feet per year (p. 148-155). Although the withdrawal as of 1945 had increased to some 78,000 acre-feet (table 8), or to about 160 percent of the average yearly draft of the thirties, the net replenishment in 1945 is believed not to have differed greatly from that of the thirties. Be-cause the average differential in the water level across the barrier features is believed to have increased by a few feet from the thirties into 1945 (p. 158), the underflow to the Torrance-Inglewood subarea probably was slightly greater in 1945 than in the thirties. Therefore, because the sum of the other elements of net replenishment is con-sidered to have been about equal in years of average rainfall, the net replenishment of the middle forties presumably has been at least equal to and probably slightly in excess of that of the thirties.
The increase in draft during the war years drew down the water levels substantially in the Torrance-Inglewood subarea and steepened the landward hydraulic gradient along the coastal reaches of the basin. The ocean-water or subsea contribution, which is estimated to have been about 12,000 acre-feet per year in the thirties, is believed to have more than doubled by the end of 1945. Additional drawdown of the water levels in the Torrance-Inglewood subarea would increase the rate of ocean-water contribution in direct proportion to the increase in landward hydraulic gradient along the coastal reach.
If a decrease in draft should occur and water levels in the Torrance-Inglewood subarea should remain about constant for the next few years, and if water levels in the main coastal basin should be drawn down appreciably below the levels of 1945, contributions by underflow from the main coastal basin, which are believed to constitute about

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half the current net replenishment to the subarea, would be reduced roughly in proportion to the decrease in average differentials across the barrier. The reduction in underflow probably would be slightly greater than the decrease in differential head because of the effect of additional dewatering along the crest of the uplift. Thus, it is to the interest of water users in the west basin that water levels inland from the barrier be maintained as high as is feasible in other words, replenishment to the Torrance-Inglewood subarea is affected beneficially by conser-vation of the water supply and increased replenishment to the ground-water reservoir throughout the coastal plain in Los Angeles County.

REPUENISHMENT TO THE CULVER CITY SUBAREA

tinder initial conditions and to date, replenishment to the Culver City subarea has been supplied very largely by infiltration of runoff from the south flank of the Santa Monica Mountains west of the Inglewood fault and from rainwater penetration beneath the Santa Monica plain and within Ballona Gap. Initially, some replenishment doubtless passed coastward across the Inglewood fault from the main coastal basin. Since the middle twenties, however, little if any water has entered the Culver City subarea from the Pleistocene deposits to the east, because water levels in those deposits consistently have stood lower on the inland side of the Inglewood fault than on the coastal side. In the "50-foot gravel," however, a coastward gradient still prevails across the Ingelwood fault and some water presumably passes into the Culver City subarea through this conduit.
In the crestal subbasin (between the Inglewood and Overland Avenue faults) withdrawal now is wholly from, the San Pedro forma-tion. The draft did not exceed a few hundred acre-feet per year until the middle thirties, when it increased to about 1,100 acre-feet per year (p. 108). Keplenishment to the San Pedro formation is believed to be almost entirely from the north. As shown by the hydro-graphs for wells 2/14-7M1 and 18F1 (pi. 14), the water level declined at a gentle rate of about 0.6 foot per year in the early thirties, but it had declined at more than double that rate since 1936. The water-level trend in these observation wells must be interpreted with caution, because a general decline of water level in the subbasin would be expected to have occurred in response to drawdown of water levels to the south (escape area), east, and west, as well as to the increased withdrawal in the subbasin itself. Nevertheless, the evidence suggests that the replenishment under present conditions is somewhat less than the draft.
Replenishment to the Charnock subbasin as of 1904 was from: (1) the north by infiltration of rainfall and runoff on the Santa Monica

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plain; (2) the east by movement of water from the crestal subbasin, probably largely through the "50-foot gravel," which is not cut by the Overland Avenue fault; and (3) by direct penetration of water from the land surface in the part of the subbasin within Ballona Gap. The concentrated withdrawal from the Charnock and Sepulveda well fields (p. 97 and pi. 12) has developed and maintained a central ground-water depression in which water levels have stood several tens of feet below sea level for the past two decades. Because of this great drawdown of water level, replenishment to the central part of the Charnock subbasin has been derived in part from the south since the late twenties. On the other hand, the general drawdown of water level within the Culver City subarea has largely dewatered the "50-foot gravel," and replenishment from the crestal subbasin to the east probably has about ceased, except for possible contributions across the Overland Avenue fault.
The draft from the Charnock subbasin is estimated to have ranged from 12,500 acre-feet in 1941 to 7,000 acre-feet in 1945. The hydro-graphs for wells 2/15-11E3 and 24C1 (pi. 14) suggest that in 1945 the replenishment was about equal to the estimated draft of 7,000 acre-feet. The water-level contours of plate 12 suggest that the hydraulic gradient from the north was then about 2^ times as steep as that,from the south, and thus assuming uniform permeability of the water-bearing material that more than two-thirds of the replen-ishment was from the north. With respect to replenishment from the south, the water-level contours of plates 9-12 suggest that some of this replenishment moves northward from south of the Ballona escarpment, possibly in part from the crestal subbasin around the south end of the Overland Avenue fault.
The coastal area apparently receives almost all its replenishment from the Santa Monica upland to the north and by direct infiltration of rainwater in Ballona Gap. Through the thirties, when water levels stood below sea level, it also received substantial recharge from the ocean. For the past two decades no replenishment has moved west-ward across the Charnock fault. In fact, with the great differential in water levels that has existed across the Charnock fault since the late twenties, some water probably has moved inland across the fault.
The draft in the coastal area in the forties is estimated to have been between 2,000 and 3,000 acre-feet per year. The hydrographs for wells 2/15-16F1 and 22B4 (pi. 14) suggest that the replenishment from all sources has been at least equal to this draft in recent years.

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CHEMICAL, CHARACTER OF NATIVE AND CONTAMINATED GROUND WATERS

GENERAL NATURE OF THE CHEMICAL PROBLEMS

Locally, in the early twenties and more widely in the early thirties, certain wells near the coast from Ballona Gap to and beyond Redondo Beach began to yield saline water, leading ultimately to abandonment of some wells in which the salinity of the water became so great that it could no longer be used.
The districts in the Torrance-Santa Monica area in which the chlo-ride content of some or all of the ground-water bodies exceeded 100 ppm in 1945-46 are shown on plate 16. These districts include several bodies containing water of native inferior quality specifically, a part of the Wilmington district, a narrow zone extending along the north flank of the Palos Verdes Hills, the Gardena area, an area be-tween Hawthorne and Inglewood, and a narrow strip along the west edge of the Baldwin Hills. They also include areas of inferior water in Dominguez Gap, along the coast from Redondo Beach to El Segundo, and in Ballona Gap, which have developed from progressive contamination during the past two decades; these are identified by diagonal ruling on plate 16.
The approximate extent of saline contamination in 1931-32 is also shown and represented by the boundaries of contaminated waters then containing more than about 100 ppm of chloride. Thus, the spread of contamination in the 14-year period is indicated by the relative position of the two boundaries.
In the Gardena area, the native waters of inferior quality occur within the shallow unconfined water body. In all the other districts underlain by water of more than 100 ppm of chloride, the inferior water is in the principal water body.
In Dominguez Gap, native waters of inferior quality occurring in the shallow unconfined body have become contaminated extensively during the past two decades. However, contamination has developed more widely in certain underlying water-bearing deposits in the principal water body specifically in the Gaspur water-bearing zone and in the unnamed upper Pleistocene deposits to depths of 150 to 200 feet below land surface. In Dominguez Gap, the extent of con-tamination as shown on plate 16 relates to conditions in the principal water body and not to those hi the shallow unconfined body. Within the west basin and outside of the districts underlain by inferior waters as indicated on plate 16, a few wells tapping the principal water body yield water containing more than 100 ppm of chloride. Although these are not identified on plate 16, several of the wells are treated in the text beyond.

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Because of the increased development of ground water in the west basin and the continuing decline in ground-water levels, local agencies that draw water from the basin or are concerned with the conservation of ground water have become increasingly alarmed by the spread of saline contamination.
Following sections of this report treat this problem of saline con-tamination by: (1) describing the chemical character and extent of waters of good quality and of inferior quality existing under native conditions; (2) describing the sources of saline contamination insofar as they can be identified; (3) determining the present extent of salt-water encroachment in the several water-bearing zones in the west basin; and (4) evaluating the possibilities for saline contamination to become more extensive hi the future.

SCOPE AND SOURCES OF ANALYTICAL DATA

In connection with the canvass of water wells within the coastal plain by Mendenhall (1905a, 1905b) in 1903-4, the approximate dis-solved-sdlids content of the water from about 2,500 wells in the Tor-rance-Sahta Monica area was computed from their electrical con-ductances. Except for these determinations, only a few analyses are available for the period prior to 1929. The bulk of chemical analyses are for well waters sampled since that time beginning chiefly in 1931-32, that is, sampling programs of the several active agencies began at about the time that local contamination problems became serious. At the present time, a large amount of analytical data has accumulated; this information includes both comprehensive analyses and those in which only one or two constituents, usually chloride or bicarbonate, have been determined. The scope of these data and the term of record by each contributing agency have been given in an earlier report (Sinnott and Garrett, 1946). In all, about 1,500 com-prehensive analyses and about 12,000 field (partial) analyses have been made available for study. The Geological Survey has drawn freely upon this information in compiling the part of this interpretive report that deals with the chemistry of native and contaminated waters in the Torrance-Santa Monica area. From these data, representative analyses have been selected (table 30) to show the character of native waters and the progressive development of contamination in critical
areas.

In addition to the large number of analyses, several interpretive reports relating to the problems of saline contamination have been made. Nearly all of these reports have been made by or for the Los Angeles County Flood Control District and chiefly discuss contamina-

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tion in Ballona Gap. Most of these have been cited earlier in this report (p. 9).
Beginning late in 1943 as a part of the field canvass, the Geological Survey sampled 427 water wells in the Torrance-Santa Monica area, subsequently 73 of these were resampled. About 46 wells in critical areas were sampled periodically to determine if any change in salinity was occurring. In addition, a number of wells were sampled re-peatedly while pumping. In all, the Geological Survey made 667 field analyses, comprising determinations of electrical conductivity, soap hardness, and chloride. These analyses are presented in table
29. Also, the Geological Survey has made 12 preliminary analyses in which electrical conductivity, soap hardness, calcium, bicarbonate, sulfate, chloride, borate, and iodide were determined; and 21 com-prehensive analyses were made. These 33 analyses are included in table 30.

Plate 17 shows the location of wells for which chemical analyses are available from all sources, and indicates by symbol the type of analysis made. This plate also shows the water-quality data of Mendenhall by means of contours which indicate the approximate content of dissolved solids in parts per million. Necessarily, some generalization has been made; however, these contours suggest the approximate quality of the ground water under native conditions. During the survey by Mendenhall the approximate dissolved-solids content of the samples from about 7,500 wells of which about 2,500 were within the Torrance-Santa Monica area was computed from determinations of their electrical conductances, corrected to 60°F. The relationship between electrical conductivity and the approximate dissolved-solids content of natural waters within the coastal plain in Los Angeles and Orange Counties has been set forth in a recent report (Piper, Garrett, and others, 1953, p. 10, 11, and pi. 3). This relationship is a simple one and in many cases obviates the need for a gravimetric determina-tion of dissolved solids.

CHARACTER AND DISTRIBUTION OF NATIVE WATERS IN THE DEPOSITS COMMONLY PENETRATED BY WATER WELLS

RANQE IN CHEMICAL CHARACTER OF WATER FROM WELJLS

Native waters tapped by wells in the Torrance-Santa Monica area vary widely in quality from excellent to markedly inferior. For purposes of this report, water is considered inferior when its dissolved-solids content is more than about 600 ppm (Piper, Garrett, and others, 1953, p. 50). In general, all the confined waters in that part of the area inland from the Newport-Inglewood uplift are of good to excel-lent quality and are suitable for all domes tic and irrigation purposes

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and for industrial use with only moderate treatment. These are chiefly calcium-bicarbonate waters; their chloride content ranges from 20 to 30 ppm and their hardness from 150 to 225 ppm. In this report, terms describing the general chemical character of a water are used in particular senses, as in the following examples: (1) Calcium bicarbonate designates a water in which calcium amounts to 50 percent or more of the bases and bicarbonate to 50 percent or more of the acids, in chemical equivalents; (2) sodium calcium bicarbonate designates a water in which sodium and calcium are first and second, respectively, in order of abundance among the bases but neither amounts to 50 percent of all the bases; and (3) sodium sulfate bicar-bonate designates a water in which sulfate and bicarbonate are first and second in order of abundance among the acids, as above. Coastward from the Newport-Inglewood uplift within the west basin, native waters of good quality range in character from calcium to sodium bicarbonate. Except locally, the chloride in confined waters here ranges about from 30 to 200 ppm, but those containing more than about 100 ppm are considered inferior because their dissolved-solids content is usually in excess of 600 ppm. Locally, the chloride content of certain presumed native confined waters is as high as 400 ppm, although it is possible that some of these have been con-taminated in recent years.
Unconfined waters on both sides of the Newport-Inglewood uplift are generally inferior but are poorest in quality on the coastal side. The chloride in these waters is as great as 2,200 ppm and dissolved solids as much as 4,000 ppm.
To show the overall range in chemical character of waters in the Torrance-Santa Monica area, chemical analyses of 375 samples from 338 wells have been plotted on figure 9. This method of plotting well waters has been used earlier to show the chemical character of water from wells in the Long Beach-Santa Ana area. The plotted positions of the analyses on the graph are dependent upon the pre-dominating chemical constituents in the water. Hence, water types can be recognized at once by inspection of the graph. Additional explanation is given on figure 9. This plate presents almost all of the analytical data available to the Geological Survey in graphic form. Included on the graph are analyses of (1) native waters of good quality,
(2) native waters of poor quality, (3) native blended waters, and (4) contaminated waters those native waters that have been modified by the addition of inferior waters from sources exterior to the initial native water body.
The native waters of diverse character can be divided in a general way into several types; each type is more or less characteristic of a

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Motive or blended waters of
both good and inferior quality

Contaminated waters

Scale indicates percentage
equivalents

KEY DIAGRAM

Area I Carbonate hardness exceeds
50 percent
2 Carbonate alkali exceeds 50 percent
3 Won carbonate hardness exceeds
50 percent
4 Noncarbonate alkali exceeds
50 percent
5 Mane of the preceding characteristics
exceeds 50 percent

FIGURE 9, Chemical character of 375 water samples from 33S wells in the Torrance-Santa Monica area,
1929-46.

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stratigraphic range. The zones of water quality associated with certain stratigraphic ranges are discussed later in this section.

ZONES OF WATER QUALITY

In the Long Beach-Santa Ana area, eight distinct vertical ranges of "water quality have been discriminated within the deposits tapped by water wells (Piper, Garrett, and others, 1953, p. 17-18). Each of these except the uppermost that occupied by the body of unconfined water coincides roughly with a particular stratigraphic zone. In general, the waters of the several ranges as delineated differ from each other in chemical character. The difference in character is striking between certain ranges and between others it is minor. Similarly, in the Torrance-Santa Monica area each zone of water quality coincides in a general way with a particular stratigraphic range. As in the Long Beach-Santa Ana area, differences in character between adjacent ranges may be small, and water of uniform character does not neces-sarily exist throughout the lateral extent of any one range. However, although the full stratigraphic sequence of the Long Beach-Santa Ana irea prevails in the Torrance-Santa Monica area, only six ranges of water quality have been discriminated. Certain of these ranges span stratigraphic intervals identical with those of their counterparts in the Long Beach-Santa Ana area to the east; others span a more inclusive stratigraphic interval.
In both the Long Beach-Santa Ana and the Torrance-Santa Monica areas the uppermost range is that occupied by the semiperched and essentially unconfined water body in the upper part of the alluvial deposits of Recent age in Dominguez and Ballona Gaps and in the topmost part of the upper Pleistocene deposits beneath the Torrance plain. Commonly, the semiperched water body in both the Recent and Pleistocene deposits is separated from the underlying principal water body by a few tens of feet of relatively impermeable layers of silt and clay.
The five ranges in the principal confined ground-water body in the Torrance-Santa Monica area have been assigned numbers identical to those used for comparable ranges in the Long Beach-Santa Ana area In downward succession, these five ranges are as follows:
Range 1. The lower division of the Recent deposits, which in-cludes the Gaspur water-bearing zone of Dominguez Gap and the "50-foot gravel" of Ballona Gap. In Dominguez Gap the Gaspur water-bearing zone is 40 to 60 feet thick and its base is about 120 feet below land surface. In Ballona Gap, the base of the "50-foot gravel" is about 50 feet below land surface, and its thickness ranges from 10 to 40 feet. Locally the "50-foot gravel" is in hydraulic continuity with underlying permeable Pleistocene deposits. The extent of the

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Gaspur water-bearing zone and the "50-foot gravel" is shown on plate 18.
Range 2. The Long Beach-Santa Ana area, the uppermost Pleisto-cene deposits beneath the Downey plain, is not differentiated from range 3 in the Torrance-Santa Monica area.
Range 8. The unnamed upper Pleistocene deposits, including the "200-foot sand" and strata correlative with or in hydraulic continuity with those deposits, ranges in thickness from a feather edge at the Baldwin and Palos Verdes Hills to as much as 300 feet along the syn-clinal trough within the west basin. The base of this range commonly is from 200 to 300 feet below land surface in the west basin.
Range 4- In the Long Beach-Santa Ana area the uppermost part of the San Pedro formation beneath the Downey plain is not dif-ferentiated in the Torrance-Santa Monica area.
Range 5. The upper part of the San Pedro formation, including the "400-foot gravel" of the area between Gardena and Inglewood, but excluding the Silverado water-bearing zone. In general, this is the stratigraphic equivalent of range 5 of the Long Beach-Santa Ana area. In the west basin, this range is thickest in the synclinal trough (as much as 200 feet); along the crest of the Newport-Inglewood upliftr although this range is present, it is substantially thinner. Along much of the coast from Redondo Beach to Santa Monica the range decreases in thickness to a feather edge or is entirely absent. Along the synclinal trough the base of this range is about 300 feet below land surface in Inglewood, about 400 feet below at Gardena, and as much as 700 feet below in Dominguez Gap, near the intersection of Alameda Boulevard and Carson Street. In Ballona Gap, just inland from the Newport-Inglewood uplift specifically, in 1/14-32M and 2/14-5D the San Pedro formation has been divided tentatively into an upper, a middle, and a lower part (fig. 14). However, the separation is intended pri-marily for local subdivision of the formation on the basis of water-bearing zones and is derived chiefly from examination of logs of wells at the Sentney plant of the Southern California Water Co. Although the upper part of the San Pedro formation here may not be correlative with any part of range 5, as here defined, it has been found most feasible to include the waters yielded from this upper part of the San Pedro formation in that range.
Range 6. The middle and lower parts of the San Pedro formation, including the Silverado water-bearing zone of the Torrance-Inglewood subarea and the main water-bearing zone in Ballona Gap coastward from the Newport-Inglewood uplift the essential correlative of the

CHEMICAL CHARACTER OF WATERS 171

Silverado zone. Within the west basin the thickness of this range is as much as 600 feet between Wilmington and Kedondo Beach, but northward from Gardena the thickness commonly does not exceed 200 feet and hi Inglewood it is as little as 50 feet. The depth of its base is shown by the contours of plate 2. In Ballona Gap, just inland from the Newport-Inglewood uplift, the aggregate thickness of the middle and lower parts is probably about 230 feet, and the top of the middle part is about 290 feet below land surface. In the Long Beach-Santa Ana area, range 6 included the lower part of the Silverado water-bearing zone; there the upper part was included in range 5. However, range 6 includes the full vertical extent of the Silverado zone. In other respects, range 6 of the two areas is essentially common. Range 7. The upper division of the Pico formation underlies nearly all the west basin. This range contains the deepest fresh waters known to occur in the area, although its waters are brackish locally north of Ballona Gap. Its vertical range has been described on pages 57-59. The depth of its base, where known, is shown on plate 8. On following pages the waters contained in the six ranges of the Torrance-Santa Monica area are described in detail; on plates 18 and 19 are plotted the wells from which native waters have been selected that are considered representative of the respective ranges tapped. For each of the waters so selected, the dissolved solids content and a "binomial symbol" are shown on the plates 18 and 19. The binomial symbol is written in the form of a decimal fraction. The first term denotes the percentage of hardness-causing constituents among the bases that is, of calcium and magnesium; the second term denotes the percentage of bicarbonate and carbonate calculated to bicar-bonate among the acids. For example, the symbol 60.75 would in-dicate a water in which the calcium and magnesium amount to 6Q percent of all the bases, in terms of chemical equivalents, and in which bicarbonate (including carbonate, if present) amounts to 75 percent of all the acids.
The complement of this binomial symbol indicates the percentage amounts of non-hardness-causing constituents or "alkalis" among the bases, and of noncarbonate acids. In the example here given, the complement is 40.25, which indicates 40 percent sodium and potassium [the "percent sodium" of Scofield (1933, p. 22-23)1 and 25 percent sulfate and chloride, in chemical equivalents.
The analyses selected as representative for native waters are listed on table 16 and are grouped according to their respective ranges.

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TABLE 16. Analyses of representative native ground waters

[See table 30 for description of sources and for analytical data in parts per million]

Well

Dissolved
solids

(parts
per
million)

Constituents (percentage equivalents)

Calcium

(Ca)

Magne-
sium

(Mg)

Sodium and po-

tassium

(Na+K)

Bicar-
bonate
(HCOs) >

Sulfate
(S04)

Chloride

(Cl)»

Waters from the unconfined shallow body [Location of sources shown on plate 18]

3/13-27B1.......................
30P1- ....
31H4.. ....
3/14-26Q2.. ___ . ____ .....
4/13-8LI........................

Minimum ,.

«954

81,125
8924

»3,907
83,609

924
3,907

34.0
4Q d
48.4

37.2 OR n

25.0
JO A

24.4
26.2
20.8
21.0
28.0

20.8
28.0

41.6
34.4
30.8
41.8
47.0

30.8
47.0

46.4
31.8
27.0
5.4
7.2

5.4
46.4

22.8
!6.6
22.6
6.4
46.2

6.4
46.2

30.8
51.6
50.4
88.2
46.6

30.8
88.2

Waters from the Caspar water-bearing zone or "50-foot gravel" in alluvial deposits of Recent age [Location of sources shown on plate 18]

2/14-5D9.. ....
3/13-36D1 ____ . __ ....
4/13-2P4 ________ . ...
15A3.... _ ....
35M3... __ . __ .. ..

Minimum. ...Jit

'747
404
8338
»449
'318

318
747

43.6
CO ft

52.4
50.2
23.2

23.2
52.6

20.2
13.6
11.4
17.0
15.6

11.4
29.2

827.2
833.8
36.2
32.8
861.2

27.2
61.2

48.0
68.6
62.0
52.8
66.2

48.0
68.6

28.4
19.6
25.6
28.6
14.4

14.4
28.6

23.6
11.8
12.4
18.6
19.4

. 11.8
23.6

Waters from unnamed upper Pleistocene deposits including the "200-foot sand" [Location of sources shown on plate 18]

2/14-29Kl....____...___._____._
32E1-... ....
3/13-20H1.............. ....
3/14-26J1 __________ . _ .
4/13-6J1- ....
4/13-19H1. _________ . __ .
19J4-.. ....

Minimum ...

' 442
8496
362
8377
«308
518
8787

308
787

46.0
37.6
51.4
44.2
51.4
46.0
34.2

34.2
51.4

20.8
24.0
19.0
20.4
14.8
17.0
19.2

14.8
24.0

833.2
838.4
29.6
35.4
33.8
37.0
46.6

29.6
46.6

57.0
59.8
60.0
54.2
63.4
39.2
30.4

30.4
63.4

11.6
13.8
28.0
8.6
24.8
14.8
5.4

5.4
28.0

31.4
26.4
12.0
37.2
11.8
46.0
64.2

11.8
64.2

Waters from the "400-foot gravel" in upper part of San Pedro formation [Location of sources shown on plate 19]

3/14-10C1.......................
15Q1......................
23L1..... . ...

Minimum ^.
Maximum t . .

8347
8359
8323

323
359

34.2
42.0
46.2

34.2
46.2

17.8
21.2
21.0

17.8
21.2

848.0
336.8
»32.8

32.8
48.0

69.8
65.0
62.0

62.0
69.8

13.6
19.6
24.6

13.6
24.6

16.6
15.4
13.4

13.4
16.6

Includes carbonate (COs) and borate (BOs), if determined. 1 Includes fluoride (P) and nitrate (NOs), if determined.
* Calculated.

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TABLE 16. Analyses of representative native ground waters Continued

[See table 30 for description of sources and for analytical data in parts per million]

Well

Dissolved
solids

(parts
per
million)

Constituents (percentage equivalents)

Calcium
(Ca)

Magne-
sium

(Mg)

Sodium and po-

tassium

(Na+K)

Bicar-
bonate
(HCOs) »

Sulfate

(SOO

Chloride

(Cl) »

Waters from the Silverado water-bearing zone, or, beyond that zone, from the middle and lower parts of the San Pedro formation

[Location of sources shown on plate 19]

2/H-4N1
5C1-.. ... ...
5D6 . ...
1402..... ....
1901.......... ... . -

2/14-22P1 . ___ . _
23H2-... ....
2/15-1C2. - ....
11C6...... ... .
11D2 _ ....

2/15-11E1 . ...
11J1 ______ . ___ . .....
14A1 . __ .
15A4.. ....
15F2 ... .

2/15-15H1 ... .
24C1 .... -
26B1......... ....
34A1 . ______ . __ . ...
34H1.

3/13-6G1 _ . .
3/14-1G1 _____ ... _____ .
3K2.. ....
4N1 ______ . ...
9N3 _____ . ...

3/14-lOGl. ....
13J3 ___ . ___ . _ . ...
21B2.. ....
30A2.... ....
35R1 ___ ... .

3/15-1H1 ....
12B1...._........ ....
13R1.. ....
24D1 ....
25A4-. __________ ...

4/13-14Q4... __ ...... __ . __ .
15A2 ___ . _______ -
21Q1... __ . _____ . __ .
22E1
30K1- ....

4/13-31E3. _____ . ...
31E4...... .. .. -
4/14-1H .. ..
5N2-. _________ . ... .
7J3 ....

4/14-8C1-. __ ... .
8E1... ________ ......
11G2-.- ... . .
16L3....... ....
17G1 ... . -

4/14-17N1. ....
23N2 ....
35E2....... ....
36H1... ....

Minimum ,,.J,.,, _ ....
Msxi"inm ,

3350
3313
473
»360
3535

8355
'371
»563
3483
8557

3546
8476
8558
»631
3620

3567
3567
8492
8474
8445

3363
3349
3335
3305
8327

3425
3319
3319
8 343
3251

»583
3484
8367
3433
3365

3236
3208
3218
221
3239

3377
3388
8252
3303
8320

3344
8327
3267
3291
8325

3427
3332
8547
3334

208
631

47.2
34.8
36.6
49.4
40.8

49.4
47.0
44.8
49.2

45.8
35.0
44.0
44.0
57.8

42.8
42.8
26.4
37.8

46 6
51.0
39.4
35.6
33.0

25.6
49.2
32.0
33.8
35.0

29.2
33.6
36.4
42 2
39.6

27.2
23.8
16.0
26.4
17.8

13.0
11.2
43 4
35.6
35.2

33.0
31.6
27.8
18.8
27.2

28.2
15.2
2g g
22 0

11.2
57-8

20.8
33.6
19.2
20.6
15.0

17.8
25.6
26.8
31.8
35.2

29.6
19.0
30.6
21.6
18.4

30.4
32.2
28.2
15.8
21.8

3.2
15.6
20.8
22.2
19.4

15.0
18.4
14.6
17 9

19.8

23 4
18.6
19 6
20.6
19 0

11.4
13.8
5.0
11.2
19.4

11.0
8.0
14.2
24.6
17.6

18.8
22.0
20.4
7.4
16.8

20.0
8.0
6.6
19 2

3.2
35.2

32.0
331.6
344.2
30.0
344.2

828.4
825.0
3 26.2
23.4
315.6

324.6
346.0
25.4
334.4
323.8

26.8
25.0
45.4
346.4
844.6

350.2
333.4
339.8
342.2
347.6

359.4
'32.4
353.4
349.0
45.2

47.4
347.8
844.0
837.2
41.4

61.4
62.4
79.0
62.4
62.8

76.0
380.8
842.4
39.8
347.2

»48.2
46.4
351.8
373.8
56.0

351.8
876.8
363.8
358.8

15.6
80.8

61.6
59.4
63.6
61.0
65.2

61.6
59.4
52.0
51.0
50.6

48.0
60.0
52.0
44.6
43.6

48.0
51.2
65.0
61.0
59.4

64.0
63.4
72.8
80.4
83.0

86.8
62.4
84.2
83.0
82.8

71.2
75.0
77.4
67.0
57.2

66.2
76.6
82.0
81.2
85.8

72.4
61.0
68.6
67.6
67.6

62.6
65.8
87.6
87.4
76.4

68.4
78.8
63.0
72.0

43.6
87.6

27.4
17.6
20.8
26.8
12.0

26.6
27.2
30.8
31.7
37.8

37.0
19.8
26.8
37.2
39.4

32.4
38.2
8.6
7.8
11.4

24 6
24.0
11.2
3.4
.2

.8
23.6
1.2

1.2

5.6
.2
.0
2.6
7.0

18.2
5.2

1.6
.4

.0
10.8
11.0
4.2
1.0

.8
1.2
.0

.0

1.8
.4
1.0
.0

.0
394

11.0
23.0
15.6
12.2
22.8

11.8
13.4
17.2
17.3
11.6

15.0
20.2
21.2
18.2
17.0

19 6
10.6
26.4
31.2
29.2

11.4
12.6
16.0
16.2
16.8

12.4
14.0
14.6
17.0
16.0

23 2
24.8
22.6
30.4
35.8

15.6
18.2
18.0
17.2
13.8

27.6
28.2
20.4
28. 2
31.4

36.6
33.0
12.4
12.fr
23.$

29.8
20.8
36.0
28.0

10.6
366-

1 Includes carbonate (COs) and borate (BOs), if determined.
* Includes fluoride (F) and nitrate (NOj), if determined.
3 Calculated.

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TABLE 16. Analyses of representative native ground waters Continued

[See table 30 for description of sources and for analytical data in parts per million]

Well

Dissolved
solids

(parts
per
million)

Constituents (percentage equivalents)

Calcium
(Ca)

Magne-
sium

(Mg)

Sodium and po-

tassium

(Na+K)

Bicar-
bonate

(HCOs) l

Sulfate

(800

Chloride

(Cl)»

Waters from undifferentiated Pleistocene deposits north of Ballona Gap

[Location of sources shown on plate 19]

1/14-19R1... __ ..... _ ....
20M1... ....
1/15-28B2 ....
32A1... __ . ___ .... _ ..

3719
3683
3569
3577

569
719

4Q 8
20.0
49.2
42.0

20.0
4.Q R

34.6
19.0
31.6
36.6

19.0
36.6

3 15. 6
361.0
19.2
21.4

15.6
61.0

56 0
67.0
53.2
42.2

42.2
67.0

21.2
4.2
26.4
44.0

4.2
44.0

22.8
28.8
20.4
13.8

13.8
28.8

Waters from upper division of Pico formation

[Location of sources shown on plate 19]

1/15-25C1........ ....
2/14-27J1 __ ....
2/15-1C5 _ . _________ . __
3/14-17J1- __ ._.
4/13-12A2...... ....

5/13-3H.. ....

Minimum

3 2, 670
31,225
' 1, 698
«481
3452

3750

452
2,670

40.2
4.2
4.0
19.4
5.2

7.6

4.0
40.2

30.2
3.0
6.2
14.6
2.0

3.4

2.0
30.2

29.6
92.8
389.8
366.0
«92. 8

389.0

29.6
92.8

13.4
90.2
38.2
77.6
79.2

6S.O

13.4
90.2

7.4
1.6

6.2
1.6

.8

.0
7.4

79.2
8.2
61.8
16.2
19.2

31.2

8.2
79.2

1 Includes carbonate (COs) and borate (BOs), if determined.
2 Includes fluoride (F) and nitrate (NOa), if determined.
3 Calculated.

CHEMICAL CHARACTER OF THE WATERS

TTNCONFINED WATERS

In general, the native unconfined waters in the Torrance-Santa Monica area are of poor quality. Only locally are they used for do-mestic or irrigation purposes. Commonly, the high salinity of the water and the low permeability of the shallow deposits discourage extensive development.

The unconfined waters in Dominguez Gap generally range from 175 to 2,200 ppm in chloride content and from 1,000 to 12,900 ppm in dissolved solids; they are chiefly sodium sulfate to sodium sulfate, chloride waters. Typically, the bicarbonate content is high, rang-ing from 250 to 1,100 ppm. It is likely that these unconfined waters have been concentrated by evaporation and, locally, by addition of saline waters at land surface, and thus they do not represent native waters. Therefore, no conclusion can be set forth here in regard to the chemical character of these waters under purely native condi-tions. Probably, however, their chloride content was usually more than 100 ppm.

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Near Gardena, about in sees. 24 to 27, T. 3 S., R. 14 W., and in sees. 29 and 30, T. 3 S., R. 13 W. (pi. 16), many domestic wells tapped the unconfined water body in 1903, as shown by the well canvass of that time. As of 1946, the body is tapped by about 100 active wells. The salinity of these unconfined waters is low enough at least locally, to be used for domestic purposes and for irrigation. Their chloride content ranges from 50 to 2,200 ppm but commonly it is from 300 to 500 ppm. An analysis of water from well 3/14-26G2 (table 30) indicates a sodium, calcium chloride water. No other com-plete analyses of the unconfined water in this area have been made, so far as known, but it is inferred that the proportion of sulfate and bicarbonate in these waters is somewhat lower than in Ballona Gap. On the basis of determinations of electrical conductivity, the dissolved solids are estimated to range from 1,000 to 4,000 ppm.
In Ballona Gap, as of 1903, many domestic and stock wells 10 to 30 feet deep tapped the shallow water body. At that time the dis-solved solids in these unconfined waters ranged from 750 to more than 2,000 ppm, but chiefly were about 1,000 ppm; all estimates were based on determinations of electrical conductivity. Locally, how-ever, the dissolved solids of these waters ranged from 1,500 to 2,300 ppm. Presumably, the water quality as determined in 1903 was es-sentially native. Because of the gradual drawdown of the water levels in Ballona Gap during the twenties and early thirties, many of these shallow wells went dry. Others were abandoned as a result of deterioration in the quality of the water. By the middle thirties none of these early shallow wells were in use. About all that is known concerning the quality of the unconfined water body in re-cent years has been obtained from 19 shallow wells bored by the Los Angeles County Flood Control District since 1936; almost all these wells were located in the reach between Lincoln and Centinela Boule-

vards. That agency has made complete analyses of water from two of these wells and partial analyses from five others. The two com-plete analyses (2/15-23Q1 and 23Q2, table 30) indicate that locally in sec. 23 the shallow unconfined waters are sodium sulfate to sodium, calcium sulfate waters. The partial analyses, which span a more ex-tensive reach, show a chloride content ranging from 170 to 300 ppm. On the other hand, samples taken in 1943-^5 from well 2/15-23M2, adjacent to the Ballona Creek channel and 13 feet deep, ranged in chloride content from 2,600 to 11,580 ppm. The channel here is within the reach of tidal water; doubtlessly, this accounts for the very high salinity of water from that well.
The chemical data for the unconfined water in Ballona Gap are so incomplete that its regional chemical character is not known, either under native conditions or in recent years. The complete analyses

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from wells 2/15-23Q1 and Q2 (table 30) are probably not of native waters but instead, they concern waters concentrated by evaporation,, by the possible addition of saline waters at land surface, or by infil-tration of ocean water. However, from knowledge of the native quality of the unconfined body in other areas, it is reasonable to ex-pect that even under native conditions the sulfate content was somewhat high.
Inland from the Newport-Inglewood zone, but proximate to it, little is known in regard to the character of the shallow waters be-cause of the dearth of chemical analyses. One well, 3/13-27B1, in 1932 yielded a sodium, calcium bicarbonate, chloride water. The chloride and dissolved-solids contents of this water were 181 and 954: ppm, respectively. The well is 8 feet deep and taps Recent deposits. The chemical character of the unconfined waters beneath the Downey plain has been discussed in an earlier report (Piper, Garrett, and others, 1953, p. 21, 26, 51).

CONFINED WATERS

WATERS IN RANGE I (GASPUR WATER-BEARING ZONE AND "50-FOOT GRAVEL")

The Gaspur water-bearing zone extends from the coast through Dominguez Gap and inland to Whittier Narrows. Only the coastal 8-mile segment is within the Torrance-Santa Monica area, however (pi. 18). Inland from the Newport-Inglewood uplift the native waters of the Gaspur zone contain about 250 to 350 ppm of dissolved solids and about 175 to 225 ppm of hardness. All are calcium bicar-bonate waters. Across the Newport-Inglewood belt and within the west basin, the native waters gain in dissolved solids about 25 to 4Q percent, so that concentrations are as much as 450 ppm, largely ow-ing to an increase in sulfate, chloride, sodium, and calcium. This increase may be due to contributions of water from the westerly "arm" of the Gaspur zone. However, at the present time much of the Gaspur zone throughout its extent in the west basin is either incipiently or definitely contaminated either from local sources or from the ocean to the extent that the native character of the water is completely obscured (pi. 16).
The "50-foot gravel" in Ballona Gap contained water ranging from 650 to 750 ppm of dissolved solids in 1903^4; this estimate is based upon determinations of electrical conductance. Locally, however, the dissolved-solids content was at least 850 ppm. Fragmentary data available suggest that ocean-water intrusion had not then occurred. In general, the water in the "50-foot gravel" initially was of substan-tially better quality than the unconfined water in the overlying shallow deposits.

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Comprehensive analyses are not available to show the chemical character of native waters in the Gap contamination of the "50-foot gravel" had started before extensive sampling of well waters was begun. The available analyses indicate that the dissolved solids have increased to about 1,000 to 1,500 ppm in recent years.
Inland from the Inglewood fault, well 2/14-5D9 (Southern California Water Co., Sentney plant, well 9) taps the full thickness of the "50-foot gravel." That well in 1940 yielded calcium, sodium bicar-bonate water containing 747 ppm of dissolved solids. In 1945 it yielded a calcium sulfate, bicarbonate water whose dissolved solids had increased to 958 ppm.
Inland from Ballona Gap, well 2/14-lMl, 80 feet deep, yielded water in 1935 containing 27 ppm of chloride, showing that at least locally the water from the "50-foot gravel" was then as low in chloride as that from deeper aquifers.

WATERS IN RANGE 3 (UNNAMED UPPER PLEISTOCENE DEPOSITS)

Within the west basin the chemical character of waters in thB unnamed upper Pleistocene deposits is known almost wholly from analyses of waters from wells tapping the "200-foot sand" or correlative extensions in the Torrance-Inglewood subarea (pi. 18). Beneath the central part of the Torrance plain south of Rosecrans Avenue, under native conditions the "200-foot sand" yielded water in which the dis-solved solids ranged about from 300 to 500 ppm and which was of the calcium, sodium bicarbonate type. Analyses made since 1929 (particularly chloride determinations by the Geological Survey for 1944-45) show that the chloride content of these native waters ranges about from 50 to 90 ppm. The upper limit here placed on their chloride content may be too low; water from two wells (3/14-22R2 and 26Q3) in 1943 contained 155 and 121 ppm of chloride, respectively (table 29), and dissolved solids were less than 600 ppm, according to determinations of electrical conductivity. However, data showing these to be native waters are lacking, and the chloride content may have been increased by local contamination. On the other hand, in sec. 26, T. 3 S., R. 14 W., the chloride content of waters taken in 1944-45 from wells tapping the unnamed upper Pleistocene deposits is as low as 22 ppm (table 29, wells 3/14-25N3, 26P1, and 26Q5). North of Rosecrans Avenue, and especially in the area between Hawthorne and Inglewood, the unnamed upper Pleistocene deposits contain water in which the dissolved solids range about from 500 to 700 ppm and the chloride from 125 to at least 250 ppm. Analyses are not available to define the character of these waters closely, chiefly because wells tapping the unaamed deposits for which an-

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alyses are available also tap the underlying San Pedro formation.. However, these waters are of native inferior character.
Southeast of Garden a, in sec. 31, T. 3 S., R. 13 W., the unnamed upper Pleistocene deposits now (1948) contain water which probably is contaminated locally. Under native conditions these deposits yielded water ranging in dissolved solids from 400 to 500 ppm (pi. 17). Analyses of water samples collected periodically by the Geological Survey in 1941-42 from wells in sec. 31 suggest that confined water in these unnamed upper Pleistocene deposits may contain somewhat more than 500 ppm of dissolved solids locally; also, they suggest an increase in salinity during that period in certain wells tapping these deposits (Piper, Garrett, and others, 1953, p. 264).
To the south, about in sec. 19, T. 4 S., R. 13 W., the unnamed upper Pleistocene deposits yield water in which the chloride content (based on water samples from 2 wells, each 180 feet deep) is about 25 ppm and the dissolved solids content is about 300 ppm. Here the water from that depth is of excellent quality and is considered free of contamina-tion. However, water from wells not more than 100 feet deep inferred to tap the upper part of the unnamed deposits is of poorer quality. In 1941-42 that water ranged from 62 to 409 ppm in chloride content and from 350 to 1,050 ppm in dissolved solids. Waters of both poor and good quality in sec. 19 are believed to be native, however.

WATERS IN RANGE 5 (UPPER PART OP THE SAN PEDRO FORMATION)

In the west basin, the character of waters from range 5 (the upper part of the San Pedro formation) is known only from data of wells tapping the "400-foot gravel" in the synclinal trough beneath the Torrance plain. Analyses are available for four wells in T. 3 S., R. 14 W., and for one well in T. 2 S., R. 14 W., all of which tap only the "400-foot gravel." Of these five analyses, three are for waters considered representative for the "400-foot gravel." These are 3/14- 10C1, analysis of August 21, 1945; 3/14-15G1, analysis of 1940; and 3/14-23L1, analysis of December 5, 1940 (table 30 and pi. 19). In these analyses the dissolved solids range from 323 to 359 ppm; from north to south, the ratio of calcium to other bases increases somewhat, with a corresponding decrease in the ratio of bicarbonate to other acid radicals. Also from north to south, chloride decreases from 38 to 28 ppm, and sulfate increases from 42 to 69 ppm. The content of 69 ppm of sulfate at well 23L1 the southernmost of the three marks that water as being different from the water in the underlying Silverado water-bearing zone, which here contains less than 34 ppm of sulfate. The other two analyses do not conform to the regional character as described. For example, well 3/14-15D1 yields a water

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definitely poorer in quality than the type water. In 1930 this well yielded a calcium, sodium chloride water in which the dissolved solids and chloride content were 576 and 198 ppm, respectively. This water has about the same amount of dissolved solids as that known to occur in the overlying unnamed upper Pleistocene deposits west of Hawthorne. Thus, analysis 3/14-15D1 probably represents a blend of waters from the "400-foot gravel" and from the unnamed deposits above.

In Ballona Gap, east of the Inglewood fault, the upper part of the San Pedro formation is tapped by several wells at the Sentney plant of the Southern California Water Co. (wells 2/14-5D5, 5D7, and 5D10); also by several public-supply wells of the city of Beverly Hills (wells 32M3 and 32K1). Chemical analyses are available for these wells. As shown on figure 14 and as discussed on pages 210-212, the character of these waters has varied between wide limits; however, as there explained, this fluctuation presumably does not represent a trend toward contamination but probably results from the blending with inferior native waters that existed in sec. 32. The waters were initially sodium bicarbonate waters; later analyses show a slight trend toward sodium, calcium bicarbonate waters. Chloride ranges generally from 62 to 173 ppm.

WATERS IN RANGE 6 (MIDDLE AND LOWER PARTS OF THE SAN PEDRO FORMATION)

Throughout its known extent in the west basin, except near the coast and locally elsewhere, the Silverado water-bearing zone of the middle and lower parts of the San Pedro formation yields native waters of excellent quality (pi. 19). These range from sodium, calcium bicarbonate to sodium bicarbonate waters.
In the southeastern part of the west basin, in and near Dominguez Gap, wells tapping the Silverado water-bearing zone yield sodium bicarbonate water, in which the dissolved solids range from 210 to 250 ppm, the hardness generally ranges from 70 to 85 ppm, and the chloride content is about 25 ppm. From east to west across Dominguez Gap, the sulfate seems to diminish; at well 4/13-14Q4 the sulfate con-tent is about 35 ppm, and at well 2lQl it is negligible. In Dominguez Gap most of the waters selected as representative of the Silverado water-bearing zone, as shown on plate 19, are from the upper or central parts of the zone. These waters are similar in hardness content to waters from wells tapping the upper part of the Silverado zone north-east of the Signal Hill uplift, where they range in hardness about from 66 to 91 ppm; those from the lower part of the Silverado zone range in hardness about from 15 to 28 ppm.
Along the northeast flank of Palos Verdes Hills in T. 4 S., K. 14 W., and in the southwest corner of T. 4 S., R. 13 W., the

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Silverado water-bearing zone contains waters markedly different from those in the same zone beneath Dominguez Gap.
These markedly different waters are essentially sodium bicarbonate waters in which the bicarbonate is as high as 389 ppm; they differ from typical Silverado waters to the north and to the northeast in that (1) their sodium content is somewhat in excess of 100 ppm and
(2) their chloride content commonly ranges from 50 to 75 ppm higher than that of the typical Silverado waters. The chloride is as high as 129 ppm (4/14-35E2) and sulfate commonly is less than 3 ppm. The high chloride content of these waters doubtless is due to blending with connate sodium chloride water occurring locally in the Silverado water-bearing zone beneath the flank of the Palos Verdes Hills (Piper, Garrett, and others, 1953, p. 57-58, and p. 230 analyses for well 5/13-6D1). This connate water is considered native, but since its inclusion with marine sediments it has been modified by the usual processes of base exchange and sulfate reduction, and, in addition, it has been diluted by land-derived waters. Analyses of water from well 5/13-6D1 are typical of this diluted connate water; the chloride and dissolved solids content are about 450 and 1,200 ppm, respectively. To the north, the effect of blending with this connate water does not extend more than about half a mile; wells 4/13-30K1 and 4/14-16L3, each about three-quarters of a mile northeast of the Palos Verdes Hills, yield water containing only 24 ppm of chloride. To the east, water from wells 4/13-31E3 and E4 shows the effect of blending with the connate water, although such blending has not been particularly deleterious; the chloride content of water from both wells in 1932 was less than 70 ppm. To the southeast, the extent of the connate water is not known, but evidence from electric logs of oil wells suggests that it may underlie the eastern part of Terminal Island.
In the west basin northwest of Dominguez Gap and extending about to Inglewood that is, through the known extent of the Silverado water-bearing zone the waters are consistently harder and higher in proportion of calcium and magnesium among the bases than those from this zone in Dominguez Gap. For example, the hardness ranges about from 100 to 275 ppm; north of Rosecrans Avenue, it is commonly more than 200 ppm. In these sodium, calcium bicarbonate waters the dissolved solids range about from 250 to 500 ppm but commonly are about 300 to 350 ppm. Across this central part of the west basin, from northeast to southwest that is, from the crest of the Newport-Inglewood uplift to the coast certain trends in chemical character are suggested by available data. These trends are as follows:

1. Near, but coastward, from the crest of the Newport-Inglewood uplift, the sulfate in the Silverado waters is at least 30 ppm. Westward, the sulfate di-

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minishes rapidly and becomes low or negligible at the axis of the syncline; in general, it remains small or negligible to the coast.
2. Near, but coastward from the crest of the Newport-Inglewood uplift, the chloride content of the Silverado waters is probably not more than 36 ppm. This chloride content is reasonably constant to within about 2 miles of the coast; under native conditions it increased to about 90 ppm at the coast.

Adjacent to the coast, from the Ballona escarpment to and beyond Redondo Beach, native water no longer occurs in the Silverado water-bearing zone; as of 1946 this coastal strip was moderately to intensely contaminated. The chemical features of this contamination, and minor lateral differences in native waters found here initially will be discussed later.
Inland for 2 miles or more from the crest of the Newport-Inglewood uplift, from Dominguez Hill on the south to near Inglewood on the north, wells tapping the Silverado water-bearing zone yield water characteristically different from that in the central part of the west basin. As shown by analyses of water from wells 3/13-6G1, 3/13-8L2, and 3/14-lGl (table 30), these are predominantly calcium bicarbonate waters; they differ chiefly in chloride and sulfate content from those waters coastward from the Newport-Inglewood uplift. In these waters, chloride is about 26 ppm and sulfate about 75 ppm. Beyond the known extent of the Silverado zone (pi. 19), waters of excellent quality occur in the middle and lower parts of the San Pedro formation correlative with it. Analyses of water from well 2/14-22P1 at Inglewood, from wells 2/14-4N1 and 5D6, north of the Baldwin Hills, and from well 2/14-14C2, east of the Baldwin Hills, are repre-sentative. These wells contain calcium bicarbonate to sodium bicarbonate waters; their range in constituents and character may be determined from table 30, plate 19, and from table 16.
In sec. 5, T. 2 S., R. 14 W., available analyses indicate that water in the lower and middle parts of the San Pedro formation is sodium bicarbonate water and possibly is of somewhat better quality than that from the upper part of the formation (fig. 14).
In the Ballona Gap, about from the Inglewood fault to the coast, native waters in the San Pedro formation range from calcium, sodium bicarbonate to calcium bicarbonate waters. They contain about 40 to 70 ppm of chloride (usually about 60 ppm), nearly 100 ppm, and locally more than 200 ppm of sulfate, and about 480 to 650 ppm of dissolved solids. Thus, compared to waters inland from the Inglewood fault, their content of dissolved solids is higher than in the waters in the middle and lower parts of the San Pedro formation to the east. Also, they differ in character from the waters in the San Pedro formation yielded to wells just south of the Ballona escarpment (pi. 19, also p. 215). Native waters from wells 2/15-1 Ul and 23P1
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in Ballona Gap were anomalous in character (as compared to the type waters in the gap) but were roughly similar to the waters south of the escarpment; this fact suggests some blending of the two types of
water.

As of 1946, in the coastal part of the gap the waters in both the San Pedro formation and the overlying "50-foot gravel" of Recent age were contaminated; the extent and degree of contamination will be discussed later.
In the area just south of the Ballona escarpment, about in sees. 26 and 34, T. 2 S., R. 15 W., analytical data suggest that the waters under native conditions generally ranged from 80 to 100 ppm of chloride, from 30 to 50 ppm of sulfate (but usually less than 40 ppm) and from 500 to 600 ppm of dissolved solids. They were sodium bicarbonate to sodium, calcium bicarbonate waters and are repre-sented by analyses of water from wells 2/15-26B1, 34Al, 34H1, and 34K1 (table 30: well 26B1, Mar. 29, 1932; well 34A1, Nov. 18, 1929; well 34H1, Jan. 8, 1930). Their chemical character is shown by figure 11, which compares them to representative waters of the San Pedro formation in Ballona Gap. (See also discussion of contamina-tion at Playa del Rey.)

"WATERS OF THE TJNDIFFERENTIATED PLEISTOCENE DEPOSITS

To the north of Ballona Gap, and particularly beyond the north limit of T. 2 S., water-bearing zones are so discontinuous that a regional stratigraphic correlation has not been made (p. 45). Here, as may be expected, the waters from these several zones range con-siderably in quality and show striking local differences in character. Nevertheless, the over-all range in character is not markedly greater than that of the waters in the San Pedro formation immediately to the south in Ballona Gap. This also is to be expected because of the presumed hydraulic continuity with those deposits. Analyses of waters from wells 1/14-19R1, 1/14-20M1, 1/15-28B2, and 32Al are believed to illustrate the range in chemical character of these waters (table 30 and pi. 19).
Typical of water from wells tapping the undifferentiated Pleistocene deposits is a nonsystematic fluctuation of dissolved solids, particularly chloride, in recurrent analyses for any given well over a period of several years. The chloride content in these waters ranges from 40 to 268 ppm and the sulfate content ranges about from 5 to 212 ppm. They range from calcium bicarbonate to sodium bicarbonate waters. Definite evidence of local contamination in these deposits cannot be proved because of the great range in proportion of individual con-stituents and because of the great range of dissolved ,solids as a whole. However, definitely inferior waters in these Pleistocene

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deposits may be derived through upward movement from the under-lying Pliocene rocks.

WATERS IN RANGE 7 (UPPER DIVISION OF PICO FORMATION)

For the Torrance-Santa Monica area, information on the chemical quality of water from the upper division of the Pico formation is-obtained from analyses of water from six widely separated wells 1/15-25C1, 2/14-27J1, 2/15-1C5, 3/14-17J1, 4/13-12A2, and 5/13-3EL (See table 30 and pi. 19.) Three of the analyses (3/14-17J1, 4/13- 12A2, and 5/13-3H) are from wells in or near the Torrance-Inglewood subarea. In these the dissolved solids range from 452 to 750 ppm, the chloride from 52 to 130 ppm, and the bicarbonate from 413 to 487 ppm. All are sodium bicarbonate waters. For the three the average percent sodium is 83. Thus, these are potable waters, although they are not desirable for irrigation because of their high percent sodium. In well 4/13-12A2 (city of Long Beach, North Long Beach well 6) the water was dark brown and the temperature was about 104 °F. Although color and temperature could have been reduced by treat-ment, the yield of the well was considered too low to make treatment economical and the well was abandoned.
Of the other three analyses, one is from a well in the eastern part of Inglewood (2/14-27J1) and the others are from wells north of Ballona Gap, which are inferred to tap the upper division of the Pico formation or correlative deposits. In these the total solids range from 1,225 to 2,663 ppm, the chloride from 66 to 1,363 ppm, and the bicarbonate from 396 to 1,266 ppm. All these waters are unfit for ordinary uses. Thus, available analytical data suggest that the waters in the upper division of the Pico formation north of Inglewood are saline and un-usable; however, south of Inglewood, locally at least, they are of a quality suitable for some uses, although they may require treatment. In the descriptions of native waters in the water-bearing zones of the Torrance-Santa Monica area of Recent and Pleistocene age, the silica content of the waters was not discussed because it does not appear to be a distinctive characteristic of any of the several ranges. The silica content of these waters was from 10 to 30 ppm, commonly less than 20 ppm. However, of the analyses of waters from the upper division of the Pico formation, four analyses indicate a considerably higher silica content, ranging from 35 to 59 ppm. Because of this greater concentration in the waters of the upper Pico, silica might be used as a diagnostic constituent in a critical study dealing with blended native waters yielded from wells tapping both the upper divi-sion of the Pico formation and the overlying water-bearing zones.

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WATEBS AT THE CENTINELA PABK WELL FIELD OF THE CITY OF INGLEWOOD

At the Centinela Park well field of the city of Inglewood, wells on opposite sides of the Potrero fault yield water with marked differences in chemical character. Elsewhere along the faults of the uplift, at least south to Dominguez Gap, differences are minor. Hydrologic information shows conclusively that the fault here is a substantial hydraulic barrier. Chemical evidence confirms the existence of that barrier. At this well field, seven wells were sampled in 1944-45 by the Geological Survey. Of the wells so sampled, five were east of (inland from) the Potrero fault and two were west of it. Inland from the fault, the chloride content of the water ranged from 25 to 56 ppm; coastward from the fault but adjacent to it, the chloride content ranged from 121 to 156 ppm. (For type analyses, see wells 2/14-22N3 and 2/14-27D3, table 30.) Inland from the fault, the waters are calcium bicarbonate in character and the dissolved-solids content is about 375 ppm. To the west, across the fault, well 2/14-27D3 also yields calcium bicarbonate water but the dissolved solids content is about

450 ppm. Although not cited here, chemical data from wells about a mile to the southwest, in sec. 28, T. 2 S., R. 14 W., suggest that the increase occurs chiefly in chloride and sulfate, with a proportionate increase in calcium and sodium. Only at well 28E1 (city of Ingle-wood well 23) is the increase in cations wholly in sodium. However, the character of water from this well probably is anomalous; transverse faulting south of the well may separate it from the others in sec. 28 for which chemical data are available.
At the Centinela field, both the "200-foot sand" and the water-bearing zones in the San Pedro formation are tapped by many of Inglewood's public-supply wells. However, water levels here are now (1948) at or below sea level and the "200-foot sand" is almost wholly dewatered; thus, in recent years the water has been withdrawn almost entirely from the San Pedro formation.

POTENTIAL CONTAMINANTS OF FRESH-WATER BODIES IN THE TORRANCE-SANTA MONICA AREA

Fresh waters in the Torrance-Santa Monica area, which have be-come contaminated, or which have received an increase in salinity, are a result of a mixture with certain waters, either moderately or ex-cessively high in total solids. These latter waters have their source either outside the fresh-water zones, with migration into those zones after discharge at or near the land surface, or by establishment of favorable gradients through permeable deposits, or both, or inside the fresh-water zones, occupying either a part of a permeable zone strati-graphically equivalent to that containing the fresh water, or a con-

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tiguous zone or zones that may be either younger or older than that containing fresh water, but requiring a suitable gradient and hydraulic continuity to advance into the fresh-water zone.

EXTERIOR CONTAMINANTS

Contaminants that initially are outside zones containing fresh water under native conditions and that require hydraulic continuity and a favorable gradient toward those zones in order to mingle with the fresh waters are: (1) ocean water, (2) industrial wastes, and (3) oil-field brines.
OCEAN WATER

As in the Long Beach-Santa Ana area, ocean water is an obvious potential contaminant in the Torrance-Santa Monica area because water-bearing zones, at places along the coast from Santa Monica to the Palos Verdes Hills and beneath San Pedro Bay, crop out on the ocean floor and are inferred to be in hydraulic continuity with the ocean; because certain areas, specifically the coastal parts of Domin-guez and Ballona Gaps, have been or are now being overrun by ocean water within the tidal range; and because the water levels near the coast widely have been drawn down below sea level.
In the coastal part of Dominguez Gap, the original tidal flats have been filled in and dikes have been constructed along both the Los Angeles River and Dominguez Channel with the result that inland movement of tidal water is restricted to those water courses; in the Los Angeles River, the extreme inland reach of oceanic water during the highest tides is 0.95 mile or to a point about a quarter of a mile south, of Anaheim Street. To the northwest in Ballona Gap, tidal marshes extend inland nearly to Lincoln Boulevard. In the old channel of Ballona Creek, the tidal range was about the same as in the adjacent marsh; in the new channel, completed early in 1938, the inland reach of tidal water is about to Inglewood Boulevard, 1 mile farther inland and about 3 miles from the coast.
To show the chemical character of ocean water, two analyses are given in table 31 a "standard" analysis and an analysis of water from San Pedro Bay. For these representative analyses, ocean water generally ranges from 34,100 to 34,500 ppm in solids, and from 18,400 to 19,000 ppm in chloride. Magnesium is about three times as abundant as calcium; however, in native ground waters, calcium is the more abundant. In ocean water, the bicarbonate content is about 140 ppm; in native ground waters, bicarbonate may be as great as 400 to 500 ppm, but normally it is about 250 to 300 ppm.

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INDUSTRIAL WASTES

Wastes discharged as a result of industrial activity become potential contaminants of fresh-water zones in the Torrance-Santa Monica area when (1) they are discharged into natural or artificial water courses that traverse that area, or (2) they are discharged at land surface in sumps and pits and are allowed to evaporate and seep away.
Four water courses traverse the Torrance-Santa Monica area. These are the Los Angeles River, Dominguez Channel, and Compton Creek, which are all in and near the Dominguez Gap, and Ballona Creek, in the Ballona Gap. The conditions of industrial-waste disposal in Dominguez Gap have been discussed at length in an earlier report (Piper, Garrett, and others, 1953, p. 80-83). Wastes discharged to the Los Angeles River inland from Dominguez Gap commonly are sodium chloride or sodium sulfate waters and in most cases are considerably less concentrated than oil-field brines. However, the analyses here cited suggest that in recent years, disposal of wastes into the Los Angeles River inland from Dominguez Gap has been carried on to a lesser degree than formerly.
Within the west basin, the chief point of disposal of waste to the Los Angeles River (in 1946) is just upstream from Wardlow Road. Here are the skimming sumps of the Oil Operators, Inc. From these sumps, oil-field brines have been discharged to the Los Angeles River at a rate that averaged 4.4 cfs from 1928 through 1943. These brines have ranged in chloride content from 9,000 to 16,000 ppm since 1932 and at times of low natural runoff the brines have made up the total flow of the river.
The Dominguez Channel is used for disposal of oil-field brines from the Dominguez and Rosecrans fields and of saline wastes from the several oil refineries in the industrial area west of Long Beach. As shown by analyses of water taken from Dominguez Channel by the Geological Survey in 1942-43, the water of the channel has ranged at least from 145 to 10,000 ppm of chloride throughout its reach southeast of Main Street to Wilmington Avenue. For at least a part of the time, the volume of wastes carried by the Dominguez Channel has been as much or more than that carried by the Los Angeles River. Inland from the west basin, Compton Creek discharges to the Los Angeles River about 5.5 miles from the coast and 0.3 mile inland from the Cherry-Hill fault. In 1942-43 from analyses by the Geological Survey, the chloride content in the lower reach of Compton Creek ranged from 62 to 132 ppm. Although the indicated concentration is low, the creek carries organic material which makes the water very turbid and foul-smelling. For approximately the same period through which the water samples were taken, the mean flow in the creek was about 10 cfs; the minimum flow was 3 cfs.

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Available chemical analyses for Ballona Creek suggest that, at least at times, the creek has received contributions of water of marked salinity. For instance, the highest chloride sample reported (4,354 ppm) was obtained in 1932 from a spring discharging from the north-west bank of Ballona Creek, 700 feet upstream from Higuera Street (in 2/14-5M). A comprehensive analysis was not made, hence the chemical nature of the saline water is not known. Most of the samples collected from the creek have contained only a few hundred parts of chloride. The lowest concentration known was for a sample taken from the creek February 11, 1936 by Dr. Carl Wilson; this sam-ple had a chloride content of 15 ppm. A series of five analyses, two by Dr. Wilson in 1936 and three by the California Division of Water Eesources in 1937-38, indicate that the streamflow then ranged in character from a sodium chloride water to a sodium, calcium bi-carbonate water. None of the comprehensive analyses suggest ad-ditions of oil-field brines during that period; fluctuations in chloride content are accompanied by a corresponding change in sulfate content. If such chloride fluctuation had resulted from addition of oil-field brine, little or no change in sulfate would have occurred. Koch (1940, p. 18) reports that a sample taken in December 1939 from a small creek flow-ing into Ballona Creek from the Baldwin Hills (sampling point in 2/14-5N, about 100 feet north of Jefferson Boulevard) contained 2,630 ppm of chloride. This creek, according to the report, carries much of the surface runoff of the Inglewood oil field. However, the extent to which the Ballona Creek has been used as a means of disposal for oil-field brines is purely conjectural in the absence of analyses of creek flow showing such discharge.
From the early thirties to 1938, extensive sections of Ballona Creek were paved with concrete. As of 1938, the channel was paved with an impervious lining from Crenshaw Boulevard for about 4 miles down-stream to LaSalle Avenue, which is about 0.75 mile upstream from the Overland Avenue fault (pi. 2). From LaSalle Avenue to the coast, about 5 miles, only the sides of the channel are paved (1946). The tidal reach now extends inland about 3.1 miles, or to Inglewood Boule-vard. Thus, since 1938, it has been only in the 2-mile reach from LaSalle Avenue to Inglewood Boulevard that the channel bottom has been open to receive influent seepage from the creek discharge. This 2-mile reach spans the Charnock subbasin and the coastward 0.75- mile segment of the crestal subbasin. It is not known whether sub-stantial seepage losses from the creek occur in this reach, but certainly a potential threat of contamination exists at such times as the creek carries water unfit for use. Coastward from Inglewood Boulevard, seepage contributions, if any, are from the saline tidal waters.

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OILFIELD BRINES

There are eight major oil fields in the Torrance-Santa Monica area the Inglewood, Potrero, Rosecrans, and Dominguez fields along the Newport-Inglewood uplift and the Playa del Ray, El Segundo, Tor-ranee, and Wilmington fields along the coast (pi. 18). u In addition, there are two minor fields Lawndale and Beverly Hills from which production is small. In all these fields most of the connate waters raised to the land surface are separated from the oil by settling or by mechanical or chemical dehydration. Analyses of the connate waters for four of these fields are given in table 31. 15 For the several oil fields, methods of brine disposal are described as completely as possible insofar as such information was made available to the Geological Survey. Yield of oil-field brines. The total amounts of brines pumped from the several oil fields in the Torrance-Santa Monica area are substantial.

Table 17 shows the quantities of these brines discharged by each oil field for the year 1940, from records published by the California Division of Oil and Gas (1940-41, p. 28, 30).

TABLE 17. Quantities of water produced from oil fields in the Torrance-Santa Monica area in 1940

[Data from publications of the California Division of Oil and Qas]

Oil field

Beverly Hills.. _ _______ ___ _ ___ _ ____ ___ __
Inglewood___ ________ ____ _ _ _ __ __.
Potrero________________ _ _ __ __ __ __ _____ Rosecrans _ __ __ _ _____ _ __ _ __ _ ____ Dominguez.. _____ _ __ ____ __ ____ _ ____

Playa del Rey____________ _ _ _______ ____ ___ ElSegundo__ _ ___ ____ _ _ _ _ ___ ____ Lawndale_____ __ _ __ _ __ _________ _ ____ Torrance.. ___ __ ____ _____ ____ _ _ ____ Wilmington _ _ ___ ______ _____ ______ ___

Fluid yield (

Annual

90, 141
3, 705, 140
337, 368
1, 556, 879
3, 291, 324

3, 833, 257
1, 179, 636
79, 730
1, 695, 170
759, 856

barrels)

Daily average

247
10, 150
924
4,265
9,017

10, 500
3,232
218
4,644
2,082

The total withdrawal of brines from these 10 fields in the Torrance-

Santa Monica area as of 1940 was about 45,000 barrels a day or about 2,200 acre-feet a year, which is about 3 percent as great as the quantity of ground water pumped from the west basin alone in that same year. Inglewood field. The Inglewood oil field covers much of the Bald-win Hills north of Inglewood. The discovery well was completed late in 1924, and 150 productive wells had been drilled by September

14 Two of the fields, Dominguez and Wilmington, are discussed at length by Piper, Qarrett and others (1953, p. 70, 78) but those discussions will be briefed here.
i* For analyses of connate waters from the Dominguez and Wilmington fields, see Piper and others (1963, table 29).

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1925. The field has been developed almost entirely by the Kettleman and Inglewood Corp., Standard Oil Co. of California, Tidewater Associated Oil Co., Shell Oil Co., and the Texas Co. As of 1946, at least two companies, the Tidewater Associated Oil Co. and the Stand-ard Oil Co. of California, ran the brines from their producing wells into settling ponds from which the overflow was piped chiefly to the city of Los Angeles Hyperion outfall sewer, which follows the north flank of Baldwin Hills and the south edge of Ballona Gap to the ocean. A part of the Standard Oil Co. waste water reportedly is discharged (1946) to Ballona Creek about half a mile upstream from Lincoln Boulevard, or well within the tidal reach. As of 1946, the Tidewater Associated Oil Co. discharged about 2,650,000 gallons of waste fluid each month. Although none of the brines from the Inglewood field are known to have been discharged to Ballona Creek above tidewater as of 1946, the analysis of the flow of a small stream from the north slope of Baldwin Hills (sampled in 1939 with a chloride content of 2,630 ppm) suggests that at least a diluted connate water was then discharged at land surface
Potrero field. The Potrero field, east of Inglewood, was discovered in 1927, and by mid-1941 about 26 wells were in production. It is reported that, in the early thirties, the brines either were diverted into unlined ditches and sumps where they drained to the southwest, or they were hauled to a dump in Centinela Creek within the city of Inglewood until a city ordinance was passed to prohibit such practice. As of 1946 most of the production has been from wells of the Basin Oil Co., and waste brines are discharged to the Los Angeles County Sanitation District sewer system.
Rosecrans field. This field occupies the west-central part of T. 3 S., R. 13 W., about 2 miles west of Compton. The chief operators in the field are the Union Oil Co. and the Barnsdall Oil Co. The Union Oil Co. carries (1946) the oil with its admixed brine from each well to a central dehydrating system. From there, the brine is pumped to a skimming pond near the intersection of Rosecrans Avenue and Main Street. This pond is used by the several companies operating in the field. The effluent from this pond reportedly is piped to a Los Angeles County sewer line. Of the total quantity so disposed, the Union Oil Co. in 1946 reportedly contributed about 57,000 barrels a month.

Dominguez field. The Dominguez oil field was discovered in 1923 and has been developed largely by the Shell Oil Co. and the Union Oil Co. Since about 1930, at least a part of the waste fluids from the oil wells in this field have been piped to the plant of the Deepwater Chemical Co. for extraction of iodine. This plant is about 0.1 mile north and 1 mile west of the intersection of Wilmington Avenue and

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Victoria Street, on the northwest flank of Dominguez Hill, The effluent from the plant is piped (1946) to an outfall on the Dominguez Channel about 0.4 mile northwest of Avalon Boulevard. When the plant is idle, the brines are piped to the Dominguez Channel through the same line.
Other means of disposal of brines formerly were employed by at least one of the operating companies (Piper, Garrett, and others, 1953, p. 70). In 1932, the Shell Oil Co. reportedly released brines into a ravine high on the southwest flank of Dominguez Hill and into the crater of a blown-out oil well near the crest of Dominguez Hill, just west of Wilmington Avenue and about 0.3 mile south of Victoria Street. It is understood that this practice was discontinued late in 1932. The quantity of brine so discharged at the land surface is not known, but if such disposal had been practiced since 1923, several hundred acre-feet of waste brine could have percolated to perme-able deposits formerly saturated with fresh water.
Playa del Rey field. This field is divided into two areas: (1) The ocean front or Venice area, along the coastal front of Ballona Gap, which was discovered in 1929; and (2) the Del Hey Hills area, almost wholly in sec. 27, T. 2 S., R. 15 W., which was discovered in 1931. In the Venice area, the brines from wells operated by the Union, Ohio, and Barnsdall Oil companies are piped to a plant operated by the Dow Chemical Co. for extraction of iodine. As of 1946, about 460,000 gpd was treated. The effluent from the plant is piped to a canal which is open to tidewater a short distance north of the plant. The brine treated by the plant constitutes almost the total water production of the field, although locally small amounts of brine may be discharged at land surface and allowed to drain away. The area occupied by this field is or has been overrun by tidal water of salinity equal to or greater than that of the connate brines.
In the Del Hey Hills part of the field, the brines are collected from the individual wells and then are piped into the city of Los Angeles Hyperion outfall sewer.
El Segundo field. The El Segundo field, which is just east of the city of El Segundo, was discovered in August 1935 and was completely developed by late 1938. Waste fluids from wells east and southeast of El Segundo are piped (1946) to a main disposal line that crosses Sepulveda Boulevard at El Segundo Boulevard. Waste fluids from active wells in a minor producing area within the city of El Segundo, south of the city's water-treatment plant at Holly Avenue and Mary-land Street, are conveyed to this line through a pipe running south on Center Street. The main disposal line runs west along El Segundo Boulevard, thence to the Standard Oil Co. refinery where, presumably, the brine is discharged to the ocean.

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Torrance field. The Torrance field is about 7.5 miles long; it reaches, nearly to the Wilmington field on the east and to within about a mile of the coast on the west. The first productive well was completed in 1922, and peak production was reached in 1924. As of mid-1941, most of the production was from the southeastern part of the field. From investigation of means of brine disposal in this field, it appears that (1946) many of the smaller companies discharge the brines from their wells to small sumps usually one for each well from which the brines evaporate or seep away. For the southeastern part of the field, brines from about 300 acres each of the Superior Oil Co. and of the Standard Oil Co. are piped to a skimming pond, about 1,500 feet east of Normandie Avenue and 0.9 mile south of Sepulveda Boulevard. From the pond, the brines are piped to the Los Angeles County sewer farm, which is between Vermont Avenue and Figueroa Street and about 0.8 mile south of Sepulveda Boulevard. In 1946, about 20,000 gpd of waste fluids were discharged to the sewer farm. Previous to about 1940, the fluids were conveyed from the skimming sump to the sewer farm by an open ditch. A large sump, just southwest of the intersection of Hawthorne Avenue and Torrance Boulevard, is reported to be used for disposal of waste fluids from wells of the Del Amo Estate Co.; from this sump, the fluids reportedly are allowed to-evaporate or seep away. Disposal methods of waste fluids from the western part of the field are not known.
Thus, in the Torrance field it is possible that at least several hundred acre-feet of saline brines have passed from the land surface into the ground-water bodies, although only in sec. 9, T. 4 S., R. 14 W., are they inferred to have reached deposits tapped by an active water well. Wilmington field. The Wilmington oil field is west of the Los Angeles River and extends inland for a distance of about a mile to 3 miles from the Cerritos Channel and the innermost basins of the Los Angeles harbor. The first well of commercial importance was drilled here late in 1936. By the early forties, more than 900 wells were in production. At least three of the principal operators pipe their brines directly to tidewater (1946). However, many operators reportedly discharge brine into sumps or at land surface. Such disposal is of no serious consequence in the eastern two-thirds of the field, because that area now is underlain at shallow depth by con-taminated waters which are no longer used. In the western third of the field, however, water wells not more than 75 feet deep yielded water of fair quality in the early forties; hence, in this western area, these brines are a potential contaminant, not only of the shallow water-bearing zones but also of the underlying Silverado water-bearing zone, by passage from the shallow zones through defective

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-well casings, or by slow downward movement through intervening deposits that are not wholly impermeable.

INTERIOR CONTAMINANTS

The native interior contaminants in the Torrance-Santa Monica area are chiefly those inferior waters that have been described earlier. These include:

1. Uneonfined and semiperched waters in the Dominguez and Ballona Gaps and beneath the Torrance plain. Locally in the gaps these contain as much as several thousand ppm of dissolved solids; their concentration probably has been increased both by contamination and by evaporation. Beneath the Torrance plain the dissolved-solids content of the uneonfined waters ranges from 1,000 to 4,000 ppm.
2. Waters in the southernmost reach of the Gaspur water-bearing zone in Dominguez Gap. Here, this water-bearing zone has been extensively invaded by exterior contaminants; it, in turn, can contaminate deeper water-bearing zones now containing water of good quality.
3. Native connate or diluted connate water confined in the San Pedro formation adjacent to or underlying the northeast and east flanks of the Palos Verdes Hills. This is sodium chloride water and locally, at least, contains 1,200 ppm of dissolved solids.

Of the three sources, the first and second are the most critical. Wells tapping underlying aquifers must pass through these two, and where the inferior shallow water has a higher head than the deeper water of good quality, downward circulation will occur if well casings are defective. Both in Dominguez Gap and beneath the Torrance plain, water levels in underlying zones are several tens of feet be-low levels in the inferior water bodies above.

CONTAMINATION OF THE NATIVE FRESH WATERS

GENERAL EXTENT OF WATER-QUALITY DEPRECIATION

As stated earlier, a few wells near the coast began to yield salty water in the late twenties. Subsequently, many of these wells were abandoned because contamination became so intense that the water could no longer be used. On plate 16 are shown the districts in the Torrance-Santa Monica area in which one or more of the ground-water bodies contained more than about 100 ppm of chloride in 1945-46. In certain of the districts, inferior waters existed under native conditions. In the Ballona and Dominguez Gaps, and along the coast from Playa del Rey to the Palos Verdes Hills, however, the extent of waters containing more than 100 ppm of chloride has re-sulted largely from saline contamination in the last 20 years, pri-marily from exterior sources. The inland advance of contamination along the coast since 1931-32 is indicated on plate 16 by the change in the position of the line showing 100 ppm of chloride.

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MODIFICATIONS IN CHEMICAL, CHARACTER OF CONTAMINATED WATERS

For both the Torrance-Santa Monica area and the Long Beach-Santa Ana area, contaminated waters are, almost without exception, not a simple blend of a native and a saline water. Instead, chemical reactions have occurred either concurrently with, or subsequent to,, blending with the contaminant to the extent that the nature of the contaminant is completely or substantially disguised. Most com-monly, these reactions involve (1) base exchange and (2) sulfate reduction.

1. For many of the contaminated waters in the Torrance-Santa Monica area, successive analyses of water from a given well during its period of active contam-ination show a definite increase in calcium along with the customary increase in chloride. Hence, these analyses might erroneously be taken as evidence to show blending with a calcium-chloride contaminant. However, no contaminant has been known to exist in the Torrance-Santa Monica area in which calcium pre-dominates as an alkali radical. Therefore, this calcium enrichment, resulting from blending with a contaminant in most cases known to predominate in sodium among the bases, must be due to a modification in the ratios of calcium, mag-nesium, and sodium to each other. This modification is known as base exchange. The fact that the base exchange process goes on extensively has become well-established. It can occur because the zeolite and glauconite minerals and certain clay-forming minerals have the property of holding the bases (calcium, mag-nesium, sodium, and potassium) loosely and in variable proportions. In the presence of a natural water, with whose chemical composition it is not in equi-librium, any of these particular minerals (and possibly some types of organic matter associated with sedimentary deposits) has the property of releasing to the water a part of the base or bases most loosely held and of absorbing from the water an equivalent amount of the base or bases for which it has a stronger bond. This process of exchanging bases goes on until an equilibrium is reached between the proportions of the several bases in the mineral and in the water, or until the exchangeable bases are exhausted in one or the other. With respect to the chemical character of the water, the effect is an increase in one or more bases and an ion-for-ion decrease in one or more of the remaining bases. Thus, if a sediment in equi-librium with a calcium bicarbonate water be subjected to contact with a water in which sodium predominates among the bases, a part of that sodium will be removed and will be replaced by calcium and to a smaller extent by magnesium in an ion-for-ion proportion. Hence, from this base-exchange phenomenon may arise the1 illusion that a calcium-rich contaminant has invaded the aquifer.
2. In both the Long Beach-Santa Ana area and the Torrance-Santa Monica area, many of the waters known to be contaminated by ocean water contain less sulfate than would result from a simple mixture of native water and the ocean' water in the proportions indicated by the total amount of chloride present. This sulfate removal probably is due to the reduction of sulfate to sulfide, either by the.action of anaerobic bacteria or by the action of organic material, with the-concurrent production of CO2 in either case, which -would increase the bicarbonate content of the water. In brines associated with petroleum, chemical analyses show the s'ulfate content to be low or zero, doubtless because the hydrocarbons have reacted with the sulfate and have resulted in the formation of hydrogen stilfide; the hydrocarbons in turn are oxidized to form carbon dioxide and water.

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For a more complete discussion of these phenomena and for a bibliography relating thereto, reference should be made to the report on chemical character of waters in the Long Beach-Santa Ana area (Piper, Garrett, and others, 1953, p. 85-91).

CONTAMINATION EST BALLONA GAP

SUMMARY OF NATIVE WATER QUALITY

The geologic conditions in Ballona Gap and the hydraulic relations between the "50-foot gravel" and the underlying San Pedro formation have been summarized on pages 94 to 98. It is inferred that the difference in chemical character between waters yielded from the "50- foot gravel" and from the San Pedro formation was not great under native conditions. Water from wells tapping the "50-foot gravel" ranged about from 650 to 750 ppm of dissolved solids, although local wells presumably tapping the "50-foot gravel" yielded water contain-ing at least 850 ppm of dissolved solids. Data concerning the chemi-cal quality of water from wells tapping the San Pedro formation are fragmentary; the dissolved solids content probably ranged about from 480 to 650 ppm, although locally it was probably nearly as great as in the "50-foot gravel." These data represent the conditions as of 1903-4 and are based on determinations of electrical conductance of, water from the wells sampled.
Chemical analyses of samples taken since about 1929 suggest that-^- at least for the period preceding that of extensive contamination wells within Ballona Gap, tapping the "50-foot gravel" or underlying zones, yielded water markedly different from that yielded by wells tapping the San Pedro formation just south of the Ballona escarp-ment. In Ballona Gap, the waters contained from 40 to 70 ppm of chloride (the higher part of the range is confined to the shallower de-posits), and nearly 100 to more than 200 ppm of sulfate. Soutli of the Ballona escarpment, particularly in sees. 26 and334, T. 2 S., R. 14 W;., native water contained 80 to about 100 ppm of chloride and usually less than 40 ppm of sulfate. Figure 10 compares the chemical charac-ter of native or only incipiently contaminated waters in Ballona Gap to those immediately south of the Ballona escarpment. The prin-ciples of the procedure in plotting chemical character of waters on a so-called trilinear diagram have been described by Piper (1945). Also, figure 9 explains the chemical character of waters in the Tor-rance-Santa Monica area relative to their plotted positions on the diagram. On figure 10 the waters from Ballona Gap and from the area south of the gap plot in two separate fields, chiefly because of the difference in ratio of calcium and magnesium to sodium, and of bicarbonate to sulfate.

CHEMICAL CHARACTER OF WATERS

No.

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2
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10
11
12
13
14
15

Well

Parts per million '

Dissolved
solids

Waters in Ballona Ga

2/15- 1C2
11C6
11D2
14AI
15A2
15A4
15F2
15H1
24C1

Waters so<

2/15-11 Jl
23P1
26B1
34A1
34H1
34K1

563
483
557
558
645
631
620
567
567

th of Ballona

476
631
492
478
445
483

Cl

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62
52
41

77 75
71
65
59
38

Gap
62
96
87
94
86
100

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150,
134
182
131
185
197
204
151
184

82
28
39
29
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so ;

TIQUEE 10. Chemical character of selected native waters to Ballona Gap compared to waters just south of the Ballona escarpment.

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However, this distinction in water character is not universal. For example, two wells in the gap, 2/15-1 Ul and 23P1, in 1930-31 yielded water somewhat similar to that from wells tapping the San Pedro for-mation immediately south of the Ballona escarpment. The water in well 2/15-23P1 may represent a blend with a northward-extending lobe of the waters occurring south of the escarpment; it is difficult, however, to see how such a blend could have reached well 11J1 with-out appearing first in wells 2/15-24C1 and 14A1 (pi. 19). Thus, the chemical evidence here presented suggests that under native condi-tions, little, if any, water moved from the gap to the deposits south of the escarpment, or vice versa. Although the type native waters selected from sees. 26 and 34, T. 2 S., R. 15 W., are sodium, calcium bicarbonate waters, the analyses of water from wells 2/15-34A1 and 34K1 (table 30) suggest that, at least part of the time, sodium bi-carbonate waters were present locally.
On the west flank of Baldwin Hills, well 2/14-18F1 in 1925 yielded water containing 182 ppm of chloride, 143 ppm of sulfate, and 823 ppm of dissolved solids. This water is probably a native blend in which waters from pre-Pleistocene deposits have moved into the San Pedro formation and are tapped by that well. The analysis repre-sents a water similar to, but less concentrated than that from well 5/14-12C1 (table 30), on the east flank of the Palos Verdes Hills; this well is believed to tap pre-Pleistocene deposits in an area presumed to be free of contamination from surface-disposed brines. Analyses of water from well 2/14-18F1 in 1932 and 1945 show definite contami-nation, in which oil-field brine doubtless has contributed most, al-though not all, of the observed salinity.
For the shallow unconfined waters hi Ballona Gap, too few analyses have been made to gain definite knowledge of their chemical character, either under native conditions or during the development of contami-nation. However, under native conditions dissolved solids commonly ranged from 800 to 1,000 ppm, but locally they are inferred to have been as high as 5,000 ppm. For water from several wells tapping the unconfined body in sees. 22, 23, and 24, T. 2 S., R. 15 W., the chloride concentration in 1930-32 was about 200 to 400 ppm not inordinately high for shallow unconfined waters near the coast. However, be-cause the unconfined waters can be expected to differ markedly with local conditions, these analyses are of little value for determining the quality of the unconfined waters elsewhere within the gap. It is con-cluded that the native unconfined waters at shallow depth in Ballona Gap generally were somewhat inferior and locally were greatly inferior to the waters in the underlying aquifers of the principal water body.

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GENERA! FEATURES AND EXTENT OF CONTAMINATION

The study of the history and progress of contamination in Ballona Gap is complex and is rendered difficult for three reasons:
1. Before 1930 only a few comprehensive analyses of Ballona Gap waters were made. Because of this dearth of analyses, some locally native water types in the gap may have been considered in this report as definitely or incipiently contami-nated.

2. Only locally in the areas of contamination has the salinity increase been sufficiently great to afford definitive knowledge of the chemical character or the source of the contaminant,
3. The directions in which contaminated waters and contaminants move within the gap are influenced locally by hydrologic barriers which transect the San Pedro formation but do not transect the "50-foot gravel" (p. 94). Therefore, the paths taken by the contaminated waters during the period of development to date (1946) have depended not only upon the hydraulic gradient and the amount of hydraulic connection between the "50-foot gravel" and the underlying water-bearing beds of the San Pedro formation, but they also depend upon the barrier partitions .within that formation.

Since 1930 many active wells have been sampled periodically. Consequently, a large number of analyses are available for study for the period 1930-46, and much can be learned regarding the chemical character and contamination of the watesrs during this period. Information is not available to indicate the tune contamination began in Ballona Gap. As of 1930-32, however, waters containing more than 100 ppm of chloride occurred within the "50-foot gravel" or the underlying water-bearing deposits of the San Pedro formation beneath about 5,100 acres, or about 8 square miles, along the coast and extending inland to the vicinity of Sepulveda Boulevard (pi. 16). In this area, the chloride concentration then ranged from 100 to about 400 ppm, and the dissolved solids commonly ranged from 800 to 2,000 ppm. The extent of contamination between the Charnock and Over-land Avenue faults as of 1930-32 is not known because analyses are not available. However, in the middle and late thirties, wells south of Ballona Creek in this block yielded water containing as much as 500 ppm of chloride (wells 2/15-13K2 and K4), and it is inferred that this area was contaminated as early as 1930-32.
At the north edge of the Baldwin Hills, and some 6 miles inland from the coast, chiefly in sec. 5, T. 2 S., R. 14 W., an area of about 250 acres was underlain by contaminated waters in 1930-32. Of six wells for which analytical data are available, the chloride content of five wells was in excess of 500 ppm and was 254 ppm in the sixth. The contamination extended northward beyond well 2/14-5F2 and south-ward beyond well 2/14-8D1. The greatest concentration was in well 5Nl (5,414 ppm of chloride). Fragmentary analytical data suggest that the waters were not contaminated between the coastal
460508 59 14

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and inland areas as of 1930-32, although native water containing more than 100 ppm of chloride existed along the west flank of the Baldwin Hills; this is shown by a chloride concentration of 182 ppm in well 2/14-18F2 in 1925.

As of 1946, nearly all of Ballona Gap coastward from the Overland Avenue fault was underlain by contaminated waters; this coastal area of contamination had extended to some 7,300 acres, or about 11.4 square miles, an increase of about 2,200 acres in 15 years (pi. 16). The movement of the saline front had been generally northward across the gap; coastward from the Charnock fault, it had advanced from 0.4 to 0.9 mile; inland between that fault and the Overland Avenue fault, it probably had advanced about 1 mile in the 15 years. As of 1946, essentially all the area coastward from Lincoln Boulevard was underlain by water with a chloride content greater than 500 ppm. At the north edge of the Baldwin Hills, in sec. 5, T. 2 S., R. 14 W., the area of contamination probably remained about constant from 1930 into 1946, although its front may have moved northward be-cause of the large withdrawals from the wells of the Southern Cali-fornia Water Co. and the city of Beverly Hills in 2/14-5C and 2/14-5D. Between the coastal area of contamination and the area north of the Baldwin Hills, a third area of contamination developed on the west flank of the Hills in the thirties and early forties. By 1946, about 200 acres east of the intersection of Overland Avenue and Jeffer-son Boulevard was underlain by water containing more than 500 ppm of chloride (pi. 16). The focus of this contamination is presumed to be in the vicinity of well 2/14-7K1, because water from this well con-tained 18,810 ppm of chloride in 1939.
In contrast to the general contamination in the gap, an area about 0.15 mile wide and 0.8 mile long, inland from the Charnock fault and south of Ballona Creek, was still uncontaminated as of 1940 accord-ing to analyses of samples from wells 2/15-24C1 and 24F3. So far as known, the main water-bearing zone in this narrow strip then con-tained less than 60 ppm of chloride; as of 1945, it probably was no more than incipiently contaminated.

CONTAMINATION NEAR THE COAST

In the coastal area of contamination, saline encroachment pre-sumably began in the twenties and abandonment of wells started about 1930. For example, two wells of the Venice Consumers Water Co. in sec. 16, T. 2 S., K. 15 W., about 1 mile from the ocean, were abandoned in 1930 because of salinity. Abandonment of wells at the Marine plant of the city of Santa Monica in 2/15-9N began about 1933, although at least one or two of the wells were used into 1941. In 1940, well 2/15-9N7 (well 5 of the city of Santa Monica) yielded

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water containing over 1,100 ppm of chloride. For the interval from 1930 to 1945, sharp increases in salinity were restricted chiefly to wells within 1.5 to 2 miles of the coast. Records of chloride analyses for selected wells are plotted on plate 20 to show the rate of salinity increase in the coastal area of contamination in Ballona Gap. Anal-yses were made chiefly by Los Angeles County Flood Control Dis-trict, California Division of Water Resources, and Los Angeles De-partment of Water and Power. In general, the chloride increase has been greatest in wells less than about 1.5 miles from the coast. Except for these badly contaminated wells, and some local wells not shown here, the graphs indicate that, for the area as a whole, salinity has not definitely increased since the middle thirties; in fact, many of the well waters have had a slight decrease in salinity in recent years. For this coastal area of contamination, chemical evidence does not sug-gest any regional quality gradient between the "50-foot gravel" and the San Pedro formation.
The information regarding the zones tapped is too meager to indi-cate whether any definite relation exists between depth of zone tapped and water quality. Tentatively it may be concluded that, at least for the coastal part of the gap, no uniform vertical gradation in; quality exists. Therefore, the two water-bearing zones are not dis-cussed separately in dealing with contamination here, but instead, they are treated as containing a single contaminated water body.

CHEMICAL FEATURES OF CONTAMINATION

In the coastal area of contamination many of the well waters have become grossly contaminated; in 1945, at least one well (2/15-22Jl) yielded water in which the dissolved-solids content was more than 4,000 ppm. To show the manner in which chemical character of the contaminated waters has changed with increase in concentration, figure 11 is plotted to show a number of the more highly contaminated waters in order of increasing concentration. Also plotted on the graph are the group of native waters from figure 10. Figure 11 shows that the points representing the contaminated waters scatter to the right and range upward. In terms of character change, departure to the right indicates an increase in the proportion of sulfate or chloride and a similar increase in the proportion of sodium. The shift up-ward and increased concentration denotes an increase in calcium and magnesium and a proportionate loss of sodium. Inferentially, the in-crease in alkaline earths at the expense of the sodium might be inter-preted to indicate that a high-calcium or high-magnesium contami-nant is present in Ballona Gap. However, neither here nor in the Long Beach-Santa Ana area has such a contaminant been found. Therefore, the increase hi alkaline earths is presumed to be due to

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'Native water* in Ballona Gap;
sse also (ig. 10

Brie* from Playa del Rev
oil fiel/

Brine from Ingjewood
oil field

Mo.

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Well

2/15 -986
26C1
9N1
26B3
14J2
16 J3
13A11
16 Jl
23F3
24L2
15N1
23N1
22C3
9N6
22B2
22F2
22J1
2301

Date

July 30, 1931
Oct. 1, 1931
V- ". 1933
Dec. 12, 1939
Dec. 12, 1939
Oct. 9, 1931
Dec. 12, 1939
Apr. 3, 1930
Oct. 9, 1931
Oct. 3, 1939
Mar. 23, 1932
Apr. 16, 1945
Oct. 9, 1931
Apr. 24,1940
Apr. 19, 1945
Apr. 16, 1945
Apr. 17, 1945
Dec. 14, 1939

Dissolved
solids,
parts per
million

653
1,254
1,385
1,419
1,442
1,468
1,596
1,724
1,885
2,038
2,181
2,300
2,409
2,415
2,470
2,510
4,007
5,182

FIGURE 11. Chemical character of native and contaminated waters in the coastal part of Ballona Gap.

base exchange, in which the sodium in the incoming contaminant is replaced nominiformly by calcium or magnesium, or both. As will be noted on figure 11, the occurrence of base exchange disguises com-pletely any possible gradation in quality "toward that of known con-taminants. As shown on the illustration it is obvious that, as salinity of the water increases, the path of the plotted points does not head toward the plots for either ocean water or a typical oil-field brine. If the degree to which base exchange has occurred could be deter-mined and a correction made in the position of the plotted points, then a trend toward one or the other of the possible contaminants might actually occur.
Although, as shown by figure 11, no consistent trend in chemical character occurs with increasing concentration, it will be noted from data presented below that from the coast to about 1.5 miles inland,

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or about to Lincoln Boulevard, chloride increase is attended by an increase in sulfate in about the proportion to be expected if ocean water were the contaminant. The progress of contamination from Lincoln Boulevard inland to near Sepulveda Boulevard indicates that the sulfate content of the contaminated waters has increased above

that which could possibly result from the addition of sulfate carried into the aquifers by ocean water alone. Hence, inferentially, the en-croachment of ocean water into Ballona Gap extends about to Lin-coln Boulevard, or nearly as far as the 500 ppm chloride contour shown on plate 16.
To show the proportionate amount of sulfate increase in the coastal strip, analyses of contaminated water from three wells have been selected (2/15-9N6, 16J1, and 26C1, all within 1.75 miles of the coast) and are compared to hypothetical mixtures of native waters with ocean water. Table 18 shows these contaminated waters and

the corresponding hypothetical mixtures, based on an equality of chloride concentration. As the table shows, only 9N6 contained an excess sulfate content (8 percent) but, because of possible analytical errors in the determination of that constituent, this small excess is not considered to be sufficient to rule out ocean water as the contam-

inant. On the other hand, analysis 26C1 showed a deficiency of 42 percent in sulfate content. In this case, however, a loss in sulfate is

TABLE 18. Contaminated water from wells 2I15-9N6, 16J1, and %6Cl, in com-parison with hypothetical mixtures of the presumed native water with ocean
water

Parts per million:
Presumed native water of well 2/15-
9N3, April 11, 1933
Well 2/15-9N6, contaminated water of
Apr. 24, 1940
Native water mixed with ocean water-Well 2/15-16J1, contaminated water of Apr. 3, 1930
Native water mixed with ocean water. Well 2/15-26C1, contaminated water
of Oct. 1, 1931
Native water mixed with ocean water-

Equivalents per million:
Well 2/15-9N6, Apr. 24, 1940
Native waters mixed with ocean water-

Well 2/15-16J1, Apr. 3, 1930 __ Native water mixed with ocean water-Well 2/15-26C1, Oct. 1, 1931 . __ Native water mixed with ocean water-

Excess (+) or deficiency ( ) of the contaminated waters with respect to native and ocean water mixtures, as follows:
Water of 2/l&-9N6__. _ . Water of 2/1S-16J1. _ .... __ .
Water of 2/16-2601. ___ - ___

Constituents

Calcium

(Ca)

76

380
95

270
87

131
81

18.97
4.75
13.48
4.36
6.54
4.06

+14.22
+9.12
+2.48

Magne-
sium

(Mg)

26

60
100

105
70

90
47

4.93
8.20
8.64
5.72
7.40
3.83

- 3.27
+2.92
+3.67

Sodium

(Na)

78

465
711

210
451

225
255

20.21
30.92
9.11
19.59
9.76
11.09

- 10.71
- 10.48
- 1.33

Bicarbon-
ate

(HCO3)

274

250
266

373
269

662
272

4.10
4.36
6.11
4.41
10.85
4.46

-.26
+1.70
+6.39

Sulfate
(S04)

161

323
299

231
238

112
192

6.72
6.22
4.81
4.95
2.33
4.00

+.50
-.14
- 1.67

Chloride
(Cl)

60

1,180
1,180

720
720

373
373

33.29
33.29
20.31
20.31
10.52
10.52

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not diagnostic, because the process of sulfate reduction is common in both native and contaminated waters it certainly could have oc-curred here. Referring again to the table, all the contaminated waters are lower in sodium and higher in the sum of calcium and magnesium than the hypothetical mixtures. This discrepancy is due to base exchange in the direction of calcium enrichment and is to be expected. Hence, its occurrence will not, in itself, invalidate the postulation of ocean-water contamination of those well waters whose analyses are examined here.
In contrast, table 19 presents the sulfate content of water from a number of wells inland from the 500 ppm chloride contour, but coastward from Sepulveda Boulevard. The sulfate content of thetee waters is compared to that which would result from mixtures of native water with ocean water, based on an equality of chloride concentration. As may be seen from the table, all the analyses cited show more sulfate in the contaminated water than could possibly have resulted from an ocean water-native water blend. The excess of sulfate, expressed as the percent of excess over that contained in the hypothetical blend, ranges from 31 to 440 ppm for waters in the confined body. Well 2/15-23Q1, tapping the unconfined body, yielded water in which the percent excess of sulfate with respect to the native confined water is 1,240 ppm. Thus, considering the change in sulfate concentration that has occurred, the shallow water could be causing part of the contamination. Hence, for the coastal part of Ballona Gap, the concentration of sulfate suggests that ocean-water contamination doubtless has occurred inland about to and possibly beyond Lincoln Boulevard. From Lincoln Boulevard to Sepulveda Boulevard, the shallow water in the unconfined body may be the principal contaminant. However, it is likely that the boundary between the ocean-water and high-sulfate-water contamination is very irregular and indefinite.
In an attempt to define the position of this boundary, and to identify the contaminant inland from Lincoln Boulevard, three other chemical characteristics of potential contaminants were considered. These characteristics are (1) bicarbonate content, (2) calcium-magnesium ratio, and (3) borate content. The study of these characteristics failed to provide a better definition of the boundary.
1. The bicarbonate content in ocean water is about 140 ppm; in the shallow unconfined waters of Ballona Gap it commonly is about 500 to 700 ppm but in one locality it is as great as 1,670 ppm; in oil-field brines from the Inglewood field according to six available analyses it ranges from 297 to about 2,000' ppm and averages 1,350 ppm. In native waters in Ballona Gap it probably ranged about from 275 to 300 ppm. Therefore, a Ballona Gap native water contaminated by ocean water alone would decrease in bicarbonate, but if the contaminant were either shallow unconfined water, or an oil-field brine, the

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TABLE 19. Sulfate content of water from selected wells in the coastal part of Ballona Gap in comparison to that resulting from a hypothetical mixture of native water l and ocean water

Well

2/15-13J3-._____._._.._.__.__..__.._.-_-._ ._.___._._
13M1............. _.._--._... ._-. ..______
14Q1-................................. ....
15N1._.____.__..___.___._._________.__........__.___ 22B2. ___ ...... _ .. _ . _ . _ ... . _ ..

2/15-22C1...... _ .... ____ . __ ...__ .__ ..... 22C3. ___ .. ______________ .. .. 23A2-..._ __-..__. __ __ ._. .... 23A3......... .... 23C1 ___ . __ ________ . __ .... ___ ...

2/15-2SF3................. .... 2301... .... 23G2.____. _.__ _ - ___._ ______.. 23H1. __ .... _ . ________ .... _ . _____ 23J2. __ .... _ .. ___ ....

2/15-23M3....... ._.__._.___._-___.____.__. .... 23Q1...._ ._ .-_ _._. ....._.___ 24L2..

Parts per million

Chloride

456
375
259
604
222

266
337
187
214
371

206
240
231
300
174

250
941
208

Sulfate
(actual)

492
295
231
492
931

835
674
532
449
483

593
607
633
730
476

583
2,234
923

Sulfate (hypo-
thetical)

208
192
177
223
173

169
188
168
172
193

170
175
174
183
166

176
167
171

Excess

(percent)

137
54
31
121
438

394
259
217
161
150

249
247
264
299
187

231
1,240
440

i Native water selected is that from well 2/15-9N3, analysis of Apr. 11,1933.

bicarbonate content of the contaminated water would increase slightly and irregularly. A study of the analyses of contaminated waters throughout the coastal part of Ballona Gap indicates that in such waters a bicarbonate content of 400 to 500 ppm is common and that, with very few exceptions, notably at the Marine plant of the city of Santa Monica, the increase in chloride is attended by an increase in bicarbonate. Well 2/15-9N6, at the Marine plant, yielded water that decreased in bicarbonate from 308 ppm in 1931 to 226 ppm in 1940. Over the same period, the chloride content increased from 81 to 930 ppm. How-ever, here the bicarbonate loss is considerably more than would result from ocean-water contamination alone. In general, the conclusion was reached that, for this coastal area of Ballona Gap, bicarbonate is useless as a criterion for deter-mination of the sources of contaminants.

2. The calcium-magnesium ratio for ocean water, computed from equivalents per million, is 0.19; for oil-field brines from the Inglewood field, it ranges from 0.28 to 1.04 and averages 0.56, according to six available analyses; for shallow, unconfined waters, it appears to be less than 1 (well 2/15-23Q1, 0.57; well 23Q2, 0.73). For presumed native waters in Ballona Gap, the ratio ranges from 1.2 to 2; hence, it would be expected that native waters rendered inferior by blending with any of the known contaminants, would show a decrease in calcium-magnesium ratio concurrent with salinity increase; of course, for only moderate contamination, the decrease would be slight. According to computations (not presented here)r such a decrease in calcium-magnesium ratio does not occur. Actually, with increase in salinity of randomly selected native waters, a considerable scatter (from 0.9 to 2.5) occurs in the value of the ratio; therefore, such a ratio could be of little value in discriminating the source of a contaminant.
In contrast, waters in Dominguez Gap that were contaminated by ocean water have a much lower calcium-magnesium ratio than waters contaminated by oil-field brines (at least, for chloride concentrations less than 1,000 ppm). There, in water contaminated from the ocean, the ratio averages about 0.6, whereas in

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waters primarily contaminated by oil-field brine, the ratio averages about 2.3 (Piper, Garrett, and others, 1953, p. 190). That is, a calcium-magnesium ratio much greater than 0.6 would seem to indicate a contaminant other than ocean water. In regard to those waters in Dominguez Gap, the base-exchange reac-tions, which usually occur with blending of native waters and saline waters and which cause much irregularity in the proportion of bases, was operative to only a small extent. On the other hand, in Ballona Gap, the great irregularity in calcium-magnesium ratios in contaminated waters doubtless results from base-exchange reactions which prevent the use of that ratio as a diagnostic charac-teristic.

3. The borate content in ocean water is about 25 ppm. In presumed native waters of Ballona Gap, the borate content commonly ranges from 0.3 to 0.8 ppm, although some of these native waters particularly those which may rep-resent a blend with waters from the flank of the Santa Monica Mountains contain as much as 1.4 ppm. Therefore, if a contaminated water with 500 ppm of chloride contains more than about 1.5 to 2 ppm of borate, it is inferred that some saline water other than ocean water has been the cause of such contamina-tion. Little is known concerning the borate content of potential contaminants in Ballona Gap; however, a sample of water from Ballona Creek, collected in 1931, contained 350 ppm of chloride and more than 5 ppm of borate. Although not in Ballona Gap, and cited for example only, a sample of water collected in 1932 from the Los Angeles River just downstream from the sumps of Oil Oper-ators', Inc., contained 14,289 ppm of chloride and 169 ppm of borate. Frag-mentary data not presented here suggest that oil-field brines in the Los Angeles basin contain several times as much borate as ocean water (Piper, Garrett, and others, 1953, p. 67 and table 8).
Information on the borate content of contaminated waters in the

coastal part of Ballona Gap shows that at least 13 wells have yielded water containing more than about 1.5 ppm of borate (for waters in which the chloride content is not appreciably more than 500 ppm). Of these 13 wells, 8 are in sec. 23, T. 2 S., R. 15 W.; all of the,wells are in that part of the coastal reach of Ballona Gap about from Lincoln Boulevard to Centinela Boulevard. For 12 of these wells, the borate content ranges from 1.6 to 3.4 ppm. The additional well, 2/15-23N1, yielded water in 1931 containing 7.6 ppm. Nearly all of these wells are farther inland than the presumed inland extent of ocean-water contamination, as determined on the basis of sulfate content. However, throughout the area in which the 13 foregoing wells are located, other wells, equally saline, contain only slightly larger amounts of borate than is presumed to have occurred in the native waters; many of these wells yield high-sulfate waters. There-fore, it is concluded that the borate content of contaminated waters inland from Lincoln Boulevard is of virtually no value in attempting to delimit the inland extent of ocean-water contamination, because no definite borate-chloride ratio seems to exist.

With respect to possible contamination from Ballona Creek, the available analyses of side inflows and creek water are listed in table 20.

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The points where the samples were taken are shown by corresponding numbers on plate 17. The table shows that waters discharged into the creek are of sufficiently great sulfate and chloride content to cause contamination of ground waters within the coastal reach inland from tidewater; that is, providing that the materials beneath and adjacent to the creek are sufficiently permeable to permit appreciable seepage from the creek. Regarding such seepage, the California Division of Water Resources (1933, p. 26) notes that, "Discharge during summer usually penetrates into creek bottom before reaching tidewater." At the time of this observation, August 1931, the flow hi the creek was estimated at 3 cfs.

TABLE 20. Chloride, bicarbonate, and sulfate content of water samples from Ballona Creek and its tributaries or points of inflow, 1931-40

[Analyses principally by Los Angeles County Flood Control District]

Num-
ber on

plate
17

1

2

3

4
5

6

7
8

9

10

11

12

13

14

Sampling point

La Cienega storm drain; west half, near West Adams Blvd., 200 feet north of Washington Blvd.

Sacatela storm drain, 50 feet upstream from out-
let of La Cienega storm drains.
Spring at west half of La Cienega storm drain . Spring, 700 feet upstream from Higuera St., dis-charging to Ballona Creek from northwest bank. Storm drain, Moynier Lane, 900 feet south of West Adams Blvd.
..... do.. ....

Creek flowing from north flank of Baldwin Hills and entering Ballona Creek about at Jefferson Blvd.

Spring, issuing from cave at north flank of Bald-win Hills, 0.37 mile south of Jefferson Blvd., in Lenawee Ave., extended.
Ballona Creek, at Duquesne St. Analyses by California Division of Water Resources.

Ballona Creek, at Lincoln Blvd. Sampling point within tidal reach in creek.

Ballona Creek. Sampling point not known. Analysis by Dr. Carl Wilson.

Date sampled

Apr. 20,1931
Mar. 1,1932

Apr. 20,1931
Mar. 1, 1932
Mar. l, 1932

Mar. 1, 1932
Mar. 1,1932
Mar. 25, 1932
Mar. 1,1932

Mar. 1,1932
Dec. 21,1939

Apr. 29,1932

Aug. 19,1931
Aug. 11,1937
Oct. 27,1937
Feb. 21,1938
Dec. 27,1939
Apr. 25,1940
Dec. 17,1935
Jan. 30,1936
Apr. 15,1936
May 11,1936
Oct. 14,1936
Jan. 19,1937
Mar. 8,1937
Nov. 27, 1939
Aug. 24,1936
Oct. 14,1936
Jan. 19,1937
May 10,1937
Nov. 27, 1939
Dec. 9, 1939
Aug. 24,1936
Jan. 19,1937
Dec. 14,1939
Jan. 30,1936

Feb. 11,1936

Constituents, parts per million

Chloride

(Cl)

86
304

160
241
227

524
4,354
4,083
468

262
2,633

311

350
240
532
265
368
489
68
185
460
446
383
388
450
441
629
321
306
287
356
306
7, 560
12,600
17,600
186

15

Bicar-
bonate
(HC03)

353
418

353
500
369

622
806
778
422

320
363

581

360
361
394
508

160

62

Sulfate

(S04)

45

100

1,880

201
218
231
225

80

17

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As discussed on page 187, the channel of Ballona Creek is paved with an impervious lining inland from La Salle Avenue; however, coastward from this avenue the bottom of the channel is unlined. The analyses (table 20) of creek water suggest that, if seepage has occurred here, the waters so introduced into the ground-water body may have caused a substantial part of the contamination. From La Salle Avenue inland, the ground-water bodies are protected from saline waters flowing within the creek channel. La Salle Avenue is 0.7 mile inland from the fault separating the Charnock and the crestal subbasins; hence, both basins are subject to possible con-tamination from the creek channel at the present time.
In regard to the sources of contamination in the coastal part of Ballona Gap, it may be concluded that inland at least as far as Lincoln Boulevard and including the abandoned Marine plant of the city of Santa Monica, ocean water has caused most if not all of the contami-nation. The presence of a landward hydraulic gradient from the early twenties to the late thirties coincides with this conclusion. The conclusion regarding an oceanic source of contamination is in general agreement with that of the Los Angeles County Flood Control District, which was the result of extensive work in Ballona Gap by that agency (Koch, 1940, p. 16).
The Los Angeles County Flood Control District also prepared the first detailed map showing contamination conditions in Ballona Gap. This map (Koch, 1940, pi. 2) shows lines of equal salinity and designates a suggested boundary between sea-water intrusion and oil-field brine pollution.
Inland about from Lincoln Boulevard to Sepulveda Boulevard, water from the shallow, unconfined body tentatively is presumed to be the chief cause of contamination, although near Lincoln Boulevard the contaminant may have been a blend of ocean water and unconfined water. Although confirmatory information is not available, it is likely that Ballona Creek has been an important factor in contami-nating the shallow water body, at least as far inland as La Salle Avenue. Nowhere in this coastal part of Ballona Gap has it been possible to identify any contamination from oil-field brines. In part, this may stem from the difficulty of applying any of the criteria that ordinarily may be used in recognition of a blend of oil-field brine with native water.

CONTAMINATION ON THE WEST FLANK OF BALDWIN HILLS

An area of contamination developed on the west flank of the Baldwin Hills in the thirties; by 1946, about 200 acres east of the intersection of Overland Avenue and Jefferson Boulevard was under-lain by water containing more than 500 ppm of chloride (pi. 16). Evidence suggesting that the contamination originates in the Baldwin

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Hills is afforded by a sample of water (collected in 1939 from well 2/14-7K1), which contained 18,810 ppm of chloride. Referring to table 31, the chloride content of brines from the Inglewood oil field, based on six analyses, ranges from 17,500 to 20,000 ppm. The depth of well 2/14-7K1 is not known, but it is high on the west flank of the Baldwin Hills and presumably taps the San Pedro forma-tion.

The location of well 7K1 is such that contamination by ocean water is physically impossible, because the base of these water-bearing deposits is more than 100 feet above sea level (pi. 2). Hence the well doubtless is contaminated by oil-field brines. It is to be ex-pected that such highly contaminated waters would percolate through the water-bearing deposits and ultimately would contaminate wells in Ballona Gap. Evidence of this fact is provided from two analyses of water from well 2/15-7P2 (table 30). In June 1945 the well yielded water containing 600 ppm of chloride; in February 1946 it yielded water containing 1,100 ppm. During that period the sulfate content increased from 152 to 156 ppm; the comparatively small increase in sulfate is consistent with brine contamination considering the small amount of sulfate present in the brines of the Inglewood field. These two analyses are plotted on figure 12. The analyses are so plotted on this graph that the vertical height of a given constituent represents the amount of that constituent in equivalents per million. The oil-field brine contamination has reached at least as far south as wells 2/14-18F1 and 18F2; to the west it presumably extends into sec. 12, but chemical evidence showing its exact extent is lacking. As shown by plate 2, the permeable sand and gravel of the San Pedro formation crop out extensively to the north, east, and south of well 2/14-7K1, and any brines discharged at the land surface can readily move down the westerly dipping beds to the Overland Avenue fault.
CONTAMINATION ON THE NORTH FLANK OF BALDWIN HILLS

About 300 acres, located chiefly in sec. 5, T. 2 S., R. 14W., was underlain by contaminated waters in 1930-32. The contamination extended northward beyond well 2/14-5F2 and southward into the Baldwin Hills beyond well 8Dl. Inferentially, this area became contaminated some years earlier than the coastal area. By 1931 several wells in 2/14-5P yielded water containing from 1,000 to 5,400 ppm of chloride. Because this contamination apparently is due to blending with oil-field brines, as will be explained, the contamination could have started at any tune after 1924, which was the year of initial development in the Inglewood oil field. Analyses from three highly contaminated wells in this area are available: analyses 2/14-5N1, March 23, 1932; 2/14-5P1, October 22, 1931; and 2/14-5P3, October 2, 1931. Their chemical character is shown on figure 12. Of the

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2/I4-5NI
MAR. 23 1932

SODIUM AND
POTASSIUM

MAGNESIUM

CALCIUM

CHLORIDE AND
NITRATE

SULFATE

BICARBONATE AND
CARBONATE

WELLS ADJACENT TO THE NORTH FLANK OF BALDWIN HILLS

_______A___________

2/I4-5PI
OCT. 22,1931
2/I4-5P3
OCT. 2,1931'

WELLS ADJACENT TO THE WEST

FLANK OF BALDWIN HILLS

FIGTJBE 12. Chemical character of contaminated waters from wells in Ballona Gap ad-jacent to the west and north flanks of Baldwin Hills.

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analyses given, only 5P3 shows an appreciable amount of sulfate; however, in relation to the concentration of dissolved solids, that sulfate content is proportionally far less than in most of the contami-nated waters toward the coast. Because the brines from the Ingle-wood field are low in sulfate ranging from 13 to 56 ppm (table 31) the low sulfate in the contaminated waters is a reasonably good indication of the source. Although well 5P1 contained 2.9 ppm and well 5P3 contained 3.5 ppm of borate, this constituent does not assist in isolating the source, because no analyses of borate in Ingle-wood brines are available.
Although it is possible that the contamination could have origi-nated from Ballona Creek, such an origin is unlikely because of the following three important factors:
1. Because of the position of the contaminated area shown on plate 16 and be-cause of the position of the more highly contaminated wells, a source to the south rather than to the north is the more logical.
2. Existing analyses of water samples from Ballona Creek upstream from the contaminated area fail to show the presence of waters sufficiently saline to cause the observed concentration in the contaminated wells.
3. Contamination from Ballona Creek would have resulted in definite impair-ment of the waters from one or more of the Sentney plant wells of the Southern California Water Co.
Hence, it is concluded that contamination here has been the result of discharge of oil-field brines from the Inglewood oil field.

Although the wells in 2/14-5P were strongly contaminated by 1931, recurrent chloride determinations from two wells, 2/14-5C1 and 5F2, plotted on figure 13, suggest that the concentration at these wells was not appreciably higher in the early forties than it was in 1931. Well 5C1, 0.2 mile east of the Sentney plant of the Southern California Water Co., taps essentially the same range as well 5D6 (Sentney plant,

FIGTJBE 13. Chloride content of waters from wells 2/14-5C1 and 2/14-5F2. Analyses chiefly by Los Angeles County Flood Control District.

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well 6), and is about at the north edge of the contamination. Well 5F2, within the area of contamination, is about 0.2 mile south of 5Cl. It is 260 feet deep and taps the upper part of the San Pedro formation. Well 5F2, although of irregular chloride content, showed an increase in salinity into 1939, then it showed a decrease. Well 501 may have-reached a peak at about the same time as 5F2; chloride determinations on 5C1 from 1941 into 1945 show a decrease in chloride into 1944,. then a leveling off at about 50 ppm. Well 5F2 yielded contaminated water containing very little sulfate and is assumed to be contaminated by oil-field brines.
To determine the current status of salinity in the area shown as contaminated in 1930-32 (pi. 16), an electrical-conductivity traverse was made on well 2/14-5P1 in July 1946. This unused well is located about 1,750 feet southeast of Ballona Creek and about 1,500 feet north of the flank of the Baldwin Hills. The measured depth was then 179 feet below land surface. The casing is perforated in gravel, 20 to 32 feet below land surface. As computed from values of specific conductance, the dissolved solids in the water within the casing, from water surface at 13 feet to 88 feet below land surface, ranged from 4,600 to 4,800 ppm. From 89 to 176 feet below land surface, the dissolved solids ranged from 7,400 to 8,000 ppm. In 1931 a sample from the well contained 2,856 ppm of dissolved solids; thus, at least at this one well, the salinity concentration has intensified appreciably during the 15-year period. Well 5Nl, 1,000 feet northwest of 5Pl, yielded water containing 8,528 ppm of dissolved solids in 1932; this well was not found in 1946, and its salinity at that time could not be determined.

WELLS AT THE SENTNEY PLANT OF THE SOUTHERN CALIFORNIA WATER CO.

In the NW}£ sec. 5, T. 2 S., R. 14 W., analyses of water from the Sentney plant wells of the Southern California Water Co. show that they yield waters with erratic fluctuations in chemical concentration; these analyses strongly suggest a blending of waters of different and distinct types. Although, as of 1946, all the active wells yielded presumably native water, distinct vertical differences in chloride concentration occur; water with the lowest chloride content is yielded from the lowest part of the water-bearing beds. Well 5C1, 0.2 mile east of the Sentney plant and perforated below 277 feet, yielded water containing 44 ppm of chloride in 1945. Well 5D6, perforated below 326 feet, yielded water containing 49 ppm of chloride in 1945. Well 5D4, for which the perforated interval is not known, yielded water containing as much as 219 ppm of chloride in 1936. The records of chloride content of water yielded from seven wells of the Sentney plant have been plotted on figure 14, together with the record of

SURFACE LAND BELOW INTERVAL.FEET PERFORATED MILLION PER CHLORIDE.PARTS

.' Ul

1-1

-3*+-

4 FORMATIO PEDRO SAN

6

01 OI 01 01
o o
* «

aaiovavHO 50

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perforations for these wells. Three conclusions may be drawn in part from the figure:
1. Well 5D6, which taps the middle and lower parts of the San Pedro formation, yielded water of the best quality, but as of 1943 the quality approached that of water yielded from the upper part of the formation.
2. Essentially no difference in chloride concentration exists between waters in the "50-foot gravel" of Recent age (well 5D9) and in the underlying upper part of the San Pedro formation. However, the former has yielded water definitely higher in sulfate than that from the San Pedro formation. Since 1944 analyses of water from well 5D9 tapping only the "50-foot gravel," have shown an increase in dissolved solids, which has been due chiefly to an increase in calcium and in sulfate.
3. For the respective zones tapped, only a comparatively small range in chloride content exists as of 1944, from about 65 to 150 ppm. For the span of the records, no definite progressive contamination is indicated, with the possible exception of well 5D4, which has not been pumped since about 1936.
The heaviest production from the Sentney plant is from the upper part of the San Pedro formation which here includes the main aquifers. Well 5F2, which is 0.4 mile southeast and was definitely contaminated in the thirties, also once yielded water from the upper part of the San Pedro formation. Because a steep cone of pressure relief has been maintained at the Sentney plant for many years (pis. 9-12 and 14) it might be expected that, at least by 1946 wells at the Sentney plant would have become contaminated from the south that is, from the same source that caused well 5F2 to become saline. The fact that these wells have not yielded definitely contaminated water suggests a hydraulic 'discontinuity between the Sentney plant and the contaminated water body to the south. However, the hydro-graphs for wells 5D5 and 5F2 plotted on plate 14, suggest that no hydraulic separation exists. Accordingly, it is concluded that the bulk of the northward-migrating contaminant was withdrawn through wells 5F2, 5C1, and possibly other wells, in the thirties and early forties, and that a small marginal interception was withdrawn through wells 5D4 and 5D7 in the middle thirties (fig. 14).
Under native conditions, inferior waters occurred in sec. 32, T. IS., R. 14 W; in 1931 wells 32M1 and M3 yielded water containing 227 and 304 ppm of chloride, respectively. It is believed that these waters have migrated in part to the Sentney plant wells and have caused some of the observed fluctuations in chloride.
From existing analyses of water from the Sentney plant wells, it is inferred that as of 1946 the active wells were not contaminated, and that the recent fluctuations in chloride are not an indication of incipient contamination, but instead, they are a result of blending with inferior waters present to the north and east.

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BATE OF ADVANCE OF THE CONTAMINATION FRONT

In Ballona Gap the greatest advance of the contamination front in the last 16 years has been in the Charnock subbasin. From 1930-32 to 1945-46 the front has advanced about 1 mile, and in 1946 it was about 0.6 mile from the Charnock well field of the Southern California Water Co. This advance is estimated at an average rate of about 350 feet per year; the direction of advance is to the northwest and is in response to the hydraulic gradient developed by withdrawals from the Charnock field. If the front continues to advance at the same average rate, it will reach the Charnock field in 8 to 10 years. However, as the front moves closer to the field, it is expected that the rate of move-1- ment will be accelerated by the steeper gradient.
As of November 1945 (pi. 12), the hydraulic gradient to the well field from the northwest was about 30 feet per mile; from the southeast, about 15 feet per mile at the saline front. Thus, if the transmissibility of the deposits to the north and to the south is equal, about two-thirds of the supply is derived from the north and one-third from the south. The water now yielded from the Charnock well field contains about 50 ppm of chloride, about 700 ppm of dissolved solids, and 400 ppm of hardness (table 30). The saline waters just south of Ballona Creek in the Charnock subbasin contain as much as 500 ppm of chloride/ 2,000 ppm of dissolved solids, and 800 ppm of hardness (table 29). If such saline waters eventually should reach the Charnock plant wells and should be withdrawn with the native waters in a proportion of 1:2, the resulting blend would contain about 200 ppm of chloride, 1,100 ppm of dissolved solids, and 500 ppm of hardness.
In the coastal area, contamination has advanced along about a 3-mile front, chiefly in sees. 14, 15, and 16, T. 2 S., K. 15 W. Part of the advance as shown on plate 16 is conjectural because of the scarcity of wells that could be used to locate the front more precisely. How-ever, for the 16-year period the greatest advance appears to be along the west boundary of sec: 14 and in sec. 15, where it was from 0.7 to 0.9 mile. This represents an average yearly rate of about 260 feet, although for most of the front the rate is probably not more than half so great.

CONTAMINATION FROM PIiAYA JXEjb REY TO REDONDO BEACH

In the coastal reach from Playaidel Rey southward to and somewhat beyond Redondo Beach essentially the 11-mile reach from the Bal-lona escarpment to the Palos Verdes Hills salt water has invaded the main waterbearing zone «,nd now extends inland from half a mile to nearly 2 miles (pi. 16). Locally, this contaminated water contains as much as 5,000 ppm of dissolved solids.

460608 59 15

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Under the native conditions of coastward ground-water movement it is believed that waters of good or fair quality existed to the coast along essentially all of the reach from Playa del Rey to Redondo Beach. As of 1904, Mendenhall (1905b) canvassed 13 wells from Manhattan Beach to Redondo Beach that were less than 0.7 mile from the coast. Of these, all except three yielded water containing less than 600 ppm of dissolved solids. Only one well, in 3/15-36H (Mendenhall 273, Redondo), yielded water containing more than 1,000 ppm of dissolved solids. North of Manhattan Beach no wells had been drilled near the coast as of 1904 except near Playa del Rey in 2/15-34E (Mendenhall 80 and 81, Redondo), 0:4 mile inland from the coast. There, the main water-bearing zone yielded water containing 710 ppm of dissolved solids as of 1904.
So far as knows, contamination within this coastal reach was first noted between 1912 and 1918 in well 4/14-6F1, at Hermosa Beach and 0.6 mile inland, from the coast (p. 244). In the reach of greatest current inland advance at El Segundo, contamination was first re-ported in 1921 in wells of the Standard Oil Co. in 3/15-13D and 14A (pi. 16). Well 3/15-14A2, about 0.6 mile inland from the coast, yielded water containing 90 ppm of chloride in 1920; this water was considered essentially native to the range tapped. Beginning in 1921, its quality deteriorated rapidly^ however (fig. 20).
From 1920 to the early thirties, withdrawal from the Torrance-Inglewood subarea of the west basin increased substantially, largely because of the construction of a number of well fields supplying new industrial plants. As has been shown, water levels, were lowered to and below sea level throughout most of the subarea. As a result of this lowering of water level, contamination of wells had occurred along most of the coastal reach from El Segundo to Redondo Beach by 1932. The inland front of contaminated waters containing more than 100 ppm of chloride as of 1930-32 is shown on plate 16. At that time the greatest inland extent of the contaminated waters was about 1.3 miles at El Segundo; the least extent was not more than half a mile,.near Century Boulevard and at Hermosa Beach. Along the full ,11-mile reach, the area then underlain by contaminated waters was, about, 5,000 acres, or nearly 8 square miles.
As of 1946, the front of waters containing more than 100 ppm of chloride, as shown on plate 16, ranged from half a mile inland near Century Boulevard to 1.7 miles at El Segundo. At Redondo Beach, the front then was 1.1 miles inland from the coast. From 1932 into 1946, the greatest advance of the saline front occurred between El Segundo and Manhattan Beach and was as much as 0.5 mile. How-ever, the average advance of encroachment between Playa del Rey and Redondo Beach in the 14 years was about 0.3 mile, and the in-

CHEMICAL CHARACTER OF WATERS 215

crease in the area underlain by contaminated water was about 1,700
acres.

The withdrawal of water along the coastal reach is largely concen-trated at five well fields or local centers of pumping. Analytical data relating to the active wells in these fields have been taken more or less continuously for many years. Thusj the rate of contamination, the chemical character of the contaminated waters, and the source or sources of contamination can be appraised best by analysis of condi-tions at these several well fields.

WELL FIELD AT PIAYA DEI REY

Just south of the Ballona escarpment in the vicinity of Playa d.el Rey, water is yielded only from the main water-bearing zone of the San Pedro formation, which here immediately underlies the dune-sand deposits and which, at least locally, is in hydraulic contact with them. At well 2/15^34A2 (Palisades del Rey Water Co. well 4) the main water-bearing zone is about 130 feet thick, and its top is about 30 feet above sea level. The log for this well is considered to be representative and is shown on plate 3(7.
The Palisades del Rey Water Co. pumps water from two fields. The field in 2/15-34K is about 0.4 mile from the ocean; there two wells have been drilled, of which one (2/15-34K1) is now active. The other field, in 2/15-34A and 2/15-27R, is about 0.9 mile from the ocean and about 0.5 mile from the escarpment; there four wells have been drilled, and one (2/15-34A1) is now active. Of the two fields, that in 2/15-34K is the older; well 2/15-34K1 (Palisades del Rey Water Co. well 1) was drilled in 1924. The first weU in field 2/15-34A (2/15-34A1) was drilled about in 1930.
Waters yielded from the two fields were chemically alike and ranged from sodium, calcium bicarbonate to sodium bicarbonate waters, although in the available analyses sodium always made up at least 44 percent of all the bases. In these waters under native conditions, the sulfate content was usually less than 40 ppm. Good series of chloride determinations are available for wells 2/15-34A1 and 34K1 and are plotted on figure 15. As shown in these chloride analyses, both wells became definitely contaminated by 1945, and well 2/15-34A1 was incipiently contaminated in the early thirties. Contamination now is much more serious at well 2/15-34K1, not only because the chloride content is neafly twice; that at well 2/15-34A1, but also because the rate of contamination increase is many times greater, as indicated by the slope of the chloride graph.
A striking difference in character change of the two waters is shown by the graph of bicarbonate in water from the two wells (fig. 15). In 1929, both wells yielded water containing over 300 ppm of bicarbonate.

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MILLION PER PARTS BICARBONATE, ot i\)
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CHEMICAL CHARACTER dF WATERS 217

By 1932, the bicarbonate in well 34K1 had decreased to about 150 ppm; well 34A1 remained about the same through the period of record. Since about 1940, well 34K1 has shown an increase in bicarbonate to almost 200 ppm. The loss in bicarbonate in water from this well is accompanied by a loss of bases, chiefly in calcium and to a minor degree in sodium. It is interesting to note that the bulk of the bicarbonate loss in well 34K1 occurred during a period of very slight chloride increase. A possible explanation of the chemical behavior of this well is that the aquifer tapped by the well was being partly recharged by local rainfall on the sand-dune area. The San Pedro formation here is known to be in local hydraulic contact with the sand-dune deposits (p. 125, pi. 13).
Because the chloride increase in water from well 34K1 has become pronounced since 1945, with no corresponding gain in bicarbonate, it is tentatively concluded that the well is now within the area con-taminated by ocean water. Furthermore, because the well is now within the area in which a regional inland gradient exists, it is expected that it soon will yield water unfit for use.

WELL FIELD OF THE CITY OF El SEGUHDO PERTINENT GEOLOGIC FEATURES

At the well fields of the city of El Segundo in sec. 12, T. 3 S., R. 15 W., two distinct water-bearing zones in the deposits of Pleistocene age are tapped by wells. Recent deposits here consist solely of sand dunes and are non-water-bearing. The upper of the two Pleistocene aquifers is the "200-foot sand" of the unnamed deposits of upper Pleistocene age; here it ranges from 30 to 40 feet in thickness. The lower aquifer is the Silverado water-bearing zone and ranges from 70 to 140 feet in thickness. At the main well field of the city of El Segundo in 3/15-12L, only the upper 30 to 40 feet of the Silverado water-bearing zone is sufficiently coarse to permit perforation of well casings; the lower part, which is as much as 100 feet thick, consists of fine sand and some silt. In the NE# sec. 12, the logs of three municipal wells indicate a much more irregular lithology. Here also, the upper 30 to 40 feet of the Silverado water-bearing zone is permeable sand and gravel; however, in two of the three wells a basal gravel is present which is sufficiently permeable to yield water. The Silverado water-bearing zone is separated from the "200-foot sand" in the upper Pleistocene deposits by an impervious clay layer which is 15 to 40 feet thick. Both aquifers here dip gently southward (pi. 3<7).

SUMMARY OF NATIVE WATER QUALITY

Inland from the coast, toward the axis of the syncline underlying the Torrance plain (pi. 2), it has been possible to distinguish between the quality of the water in the unnamed upper Pleistocene deposits

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and that of the water in the Silverado water-bearing zone beneath, because chemical analyses are available for waters from certain wells tapping the upper zone only and from other wells tapping the Silverado zone only. In sec. 12, T. 3 S., R. 15 W., however, all wells tap both zones and thus yield blends of waters from the two aquifers. Neces-sarily, therefore, a description of native conditions here will be confined to these blended waters. An analysis of water from well 3/15-12L1, sampled March 4, 1930, is selected as representative of the native water throughout the local extent of the tapped water-bearing zones. From this analysis and from others, made before contamination had become more than incipient, it is inferred that these waters ranged about from 390 to 425 ppm in dissolved solids and contained less than 100 ppm probably from 85 to 92 ppm of chloride. The early (1929-30) analyses of water from wells of this field, particularly those from well 12L1, show an interesting fluctuation in sulfate content. For example, the analysis of 12L1 for February 13, 1931, shows that sulfate is absent. Other analyses of water from 12L1 for that period show that sulfate ranged from a trace to 35 ppm.

PROGRESS OP WATER-QUALITY DEPRECIATION

Table 21 lists all the wells drilled by the city of El Segundo and gives their status in 1946. Of the ten wells listed, seven were drilled at the main field near the city's water treatment plant at Grand Avenue and Maryland Street; only two wells, 12L5 and 12L7, were active in 1946. Of the other three wells, two are about 0.4 mile northeast of the main plant, and well 12B1, the latest one drilled, is about 0.2 mile north of the first-mentioned wells. All three are now

active. Chloride analyses for wells 12L1, 12L3, and 12L6, plotted

TABLE 21. History and chloride content of public-supply wells of the city of El Segundo

Well

USGSi

3/15-12L1. ....
12L2-. ....
12L3.. . ...
12L4-.. ....
12G2-..-. - _-.. __

12Q1. .... ___ ....
12L6...... _ ... _ .
12L5. .... __ . ___ ......
12L7... __- ..._ __ ..
12B1. __ ... ____ ....

City
of El

Segundo

1
2
3
4
5

6
7
8
9
10

Date
drilled

1920
1924
1930
1938
1939

1939
1939
1942
1944
1945

Chloride content

Initial «

analysis l

100
98
104
430
113

128
157
116
151
82

Latest 8

analysis

304
123
211
430
138

86
886
245
219
86

Date
aban-
doned

1939
1937
1940

1938 (5)
(8)
1945

8«

Reason for
abandonment

Caved in.
Do.

Do. (4)

Became saline.

1 United States Geological Survey.
2 Earliest analysis available.
» Latest analysis available.
4 Abandoned at time of drilling; water too saline for use. Active in December 1946.

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on figure 16, show the development of contamination at the main field. Because of the fluctuation in chloride content for well 12L1 in 1930-31, it is thought that contamination was then incipient; by 1936 the increase in chloride content was positive. However, only in well 12L6 did salinity increase to a degree that made the water unusable. Wells 12L1 and L3 were abandoned because of mechanical difficulties; doubtless, the salinity of the water yielded by these wells would have increased appreciably above the amounts shown on the graph if pumping had been continued.
The two active wells at the main field as of 1946 (nos. 12L5 and 12L7) both yielded water containing more than 200 ppm of chloride at the end of that year. As shown by the graphs (fig. 16), the chloride content was about stable to mid-1946, and then it increased substan-tially. It is believed that if these wells are pumped almost continu-ously, within a relatively short time the chloride will increase at an accelerated rate similar to the increase shown by the graph for well 12L6 in 1944-45 (fig. 16). Both of these active wells tap the same water-bearing zones that are tapped by wells 12L1, L3, and L6 (which were abandoned earlier). As shown later (p. 224), although both water-bearing zones are about equally contaminated, the upper of the two zones may be slightly more saline. Figure 16 also shows the chloride concentration of waters from wells 12G1 and 12G2. In contrast to chloride graphs for wells at the field in 3/15-12L, the graphs for both wells in 12G show a decrease in salinity (to a greater extent in well G2 than in well Gl). Well 12G1 yields more water from a stratigraphi-cally lower part of the Silverado water-bearing zone than any other city well. The monthly combined withdrawal for the two wells also has been plotted on figure 16. It will be noted that the chloride decrease has occurred over a period when withdrawals were nearly
constant.

CHEMICAL FEATURES OP CONTAMINATION

As described earlier, at the main field of the city of El Segundo the trend of contamination is toward ever-increasing salinity and resultant abandonment of the wells; however, at the more recently developed field to the northeast in 3/15-12G, the trend since about 1941 is toward a decreasing salinity. In well 12G1 the water has almost re-turned to its native character. For all the wells of the city of El Segundo, the following description treats the manner in which con-tamination has occurred and suggests a possible source of this con-tamination. Although the analyses for any single well do not span the entire period of record, a series has been selected arbitrarily to show progressive increase in chloride content. These analyses have been plotted on a trilinear graph (fig. 17) which shows the salinity trend at the main field. Although some departure from a definite

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CHEMICAL CHARACTER OF WATERS 221

No.

a

1
2
3
4
5
6
7
8
9

Well

(3/15-12G1)
12L1
12L2
12L2
12L3
12L6
12L6
12L6
12L6
.12L6

Date

Feb. 25, 19g
Nov. 25, 1930
Sept. 11, 1930
Mar. 9, 1931
July 24, 1939
Jan. 4, 1940
Sept. 2, 1942
Apr. 24, 1943
Feb. 25, 1945
Oct. 24, 1944

Chloride,
parts per
million

92
92
104
123

157 , 181
208
220
420
520

FIQTJBE 17. Chemical character of native and progressively contaminated waters at the main well field of the city of El Segundo.

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trend occurs, in general, as contamination progresses, the water is enriched chiefly in chloride and in calcium. Inasmuch as no^known calcium-chloride contaminant is known to exist locally, it is assumed that the contaminant is a sodium-chloride saline in which base ex-change has occurred during blending with the native water.
To determine the source of contamination at this field, use is made of the chloride-bicarbonate ratios of the progressively contaminated waters for which the analyses have been plotted on figure 17. Figure 18 shows these ratios plotted against the chloride content;hypothetical

CHLORIDE -BICARBONATE RATIO(MILLIEQUIVALENTS) D ro-c01

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D

Hype

2/I5-I2G2

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O

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jthetical ratio, o

cean water ^^^

O

il -field brine /

O

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100 200 300 400 500 CHLORIDE , PARTS PER MILLION FJOUKE 18. Chloride-bicarbonate ratios of progressively contaminated waters at the main well field of the city of El Segundo.

ratios for a sea-water mixture and an oil-field brine mixture with a native water are plotted also. Sea water is strongly suggested as the source of contamination. That is, for the contaminated water con-taining 520 ppm of chloride, the C1-HCO3 ratio is 3.58; for the ocean-water and brine mixtures with native water, computed to the same chloride concentration, the ratios are 3.21 and 2.49, respectively. The points representing the actual analyses fall on a reasonably well defined curve which approaches the point representing the ocean-water mixtures more closely than that representing the oil-field brine mixture. The analysis used in computing the hypothetical mixture of brine and native waters was furnished by the Richfield Oil Corp. The water analyzed was from Richfield well El Segundo No. 2 (in 3/14-18G) and was yielded through perforations from 7,243 to 7,319 feet below

CHEMICAL CHARACTER OF WATERS 223

the land surface presumably from rocks of upper Miocene age (pi. 7). The constituents cited below were determined from a sample collected and analyzed by the Richfield Oil Corp. for the Geological Survey; quantities are reported in parts per million (except pH which is reported in percent) :
Parts per million
Chloride___._________ 9, 390

Dissolved solids____ ____24, 561

Suspended solids.________ _ 207
Water soluble organic matter

(approx.) ___________ - 5, 300

Parts per million
Silica_________________ 81

Iron and aluminum oxides _____ 3

Hydroxyl_____________ 0
Carbonate____________ 0
Bicarbonate

Sulfate__

1 In percent.

1, 946
26 PH. '7. 8

Although the trend in chloride-bicarbonate ratios suggests ocean water as the contaminant, the other possible diagnostic constituent, sulfate, is not entirely confirmed by table 22. In the table, the actual sulfate content of the progressively contaminated waters is compared with the sulfate content that would be present if sea water alone had caused the chloride increase. In most of the contaminated waters sul-

fate is shown to be present in excess; this fact suggests a source of sulfate in addition to that brought in with sea water.

TABLE 22. Comparison of actual and hypothetical sulfate content in progressively contaminated waters in the main well field of the city of El Segundo

Well

3/15-12L1.. ___ .... _ . _______
12L2-. _.-_ _. ... _ ...... _ ..
12L2. _ .... __ ....
12L3-..... . -.__-.. ..._._._
12L6... .... _ ...... 12L6. __ . ._. ____._.-___...__ 12L6.. .... 12L6- _ .- .. .. 12L6........................_......

Date of
sample

Nov. 25, 1930
Sept. 11, 1930
Mar. 9,1931
July 24,1939
Jan. 4, 1940
Sept. 2,1942
Apr. 24,1943
Feb. 25,1945
Oct. 24,1944

Chloride
(ppm)

92
104
123
157
181
208
220
420
520

Sulfate (ppm)

Actual

14
19
17
60
90
20
76
97
119

Hypo-
thetical i

14
18
23
26
30
32
60
74

Excess (+)
or defi-
ciency ( )
of sulfate
(ppm)

+5 -1
+37

+64 -10
+44
+37
+45

i Computed from a hypothetical mixture of sea water and a native water of 14 ppm sulfate, for which mixture the chloride content is identical to that of the actual contaminated water under comparison.

In regard to contamination at wells 12G1 and 12G2, the salinity increase has not yet become sufficiently intense that the source can be identified. It is inferred that the cause of contamination is the

same at the two fields. If such is the case, the chemical character of the contaminated waters would be expected to be the same in both areas. As a check on this inference, the analysis of water from well 12G2 for February 7, 1942, has been selected for comparison. This analysis represents the most saline water of record taken from this well. The chloride-bicarbonate ratio for well 12G2 plotted on figure 18 falls close to the generalized curve. The value of 74 ppm for sulfate

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is in excess of that brought in by sea water by about the same amount as in the wells in the main field (in 3/15-12L).
For the main field, the Geological Survey in 1945 conducted a series of pumping tests on well 12L6 in order to determine, if possible, which of the two water-bearing zones tapped would yield water of better quality. Figure 19 shows the electrical-conductivity values

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C §

01

Pumping test Oct. 30-31, 1945; perforations 222-248 feet below lond surface; lower set plugged off September 1945

Pumping test Sept. 5,1945;
.perforations 222-248 and
298-318 feet below lond surface

10 IS 20 25 ELAPSED PUMPING TIME, HOURS

FIGUBK 19. Character of water discharged from well 3/15-12L6 (city of El Segundo, well 7) during pumping tests of September 5 and October 30-31,1945.

obtained from two separate tests, on September 5 and October 30-31, 1945. During the test on September 5, the well yielded water through perforations from 222 to 248 feet and from 298 to 318 feet below land surface. The lower perforations were then plugged, and during the test of October 30-31 the well yielded water from only the shallower of the two water-bearing zones. The test of September 5 is believed to have been too short for the water from the well to have reached constant quality. During the pumping test of October 30-31 the water yielded initially was poorer but after 13 hours of continuous pumping it was of better quality than that yielded during the short span of the September test. The graphs are not conclusive but the results are included here as a matter of record.

WELL FIELDS OF TEE STANDARD OIL CO. AND OF THE GENERAL CHEMICAL CO. AT EL SEGUNDO

The well field of the Standard Oil Co. of California is between El Segundo Boulevard and Rosecrans Avenue and is west of Sepulveda Boulevard, in sec. 13, T. 3 S., R. 15 W. Immediately east of Sepul-veda Boulevard, in 3/14-18N, are the wells of the General Chemical Co. These two well fields are treated together here because they tap the same water-bearing zones, and conditions of contamination are common to both.

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In this area, wells tap both the "200-foot sand" of upper Pleistocene age and the Silverado water-bearing zone of the San Pedro formation (pi. 3(7). The "200-foot sand" here is about 20 feet thick, and its top is about 150 feet below the land surface and 50 feet below sea level. Commonly it is separated from the underlying Silverado water-bearing zone by 20-30 feet of impervious silt or clay.
The Silverado water-bearing zone in sec. 13 ranges in over-all thickness from about 150 feet in the northwestern part to about 250 feet in the eastern part (along Sepulveda Boulevard). This thickness includes beds of silt or clay of irregular occurrence. In general, the Silverado zone here spans three more or less distinct parts, which in downward succession are: (1) the principal water-bearing member, which is chiefly sand and gravel and about 100 feet thick; (2) an interbed of silt or clay from 20 to 50 feet thick; and (3) a basal mem-ber, which consists of alternating thin layers of sand, gravel, and silt, about 100 feet thick. The bottom of the Silverado zone is about 300 feet below sea level along Sepulveda Boulevard (pi. 2). Logs of wells in 3/15-13D and 14A, about 0.7 mile from the coast, suggest that the basal member grades westward into a layer of nearly uniform silt, and that the thickness of the upper member of the Silverado zone decreases to about 70 feet; the character of the zone here is similar to that at the main well field of Manhattan Beach, 2.4 miles southeast.

SUMMARY OP NATIVE WATER QUALITY

In the "200-foot sand," water is inferred to have been somewhat inferior under native conditions. As of 1903-4, a well in the southeast angle of the intersection of Rosecrans Avenue and Sepulveda Boule-vard (Redondo, no. 150), which tapped the "200-foot sand," yielded water containing 630 ppm of dissolved solids. This well was about 1.4 miles inland from the ocean. Because of the comparatively poor quality of water in the "200-foot sand" in this area, it has been tapped by few wells. For the well fields here discussed, only three are known to have yielded water from this zone wells 3/14-18N3 and 18N4 of the General Chemical Co. and well 3/15-13H1 of the Standard Oil Co. All other wells of these two companies tap solely the Silverado water-bearing zone; some tap the upper part, some the basal part, and some tap both.
In the Silverado water-bearing zone, under native conditions, two somewhat distinct water types existed hi sec. 13, T. 3 S., R. 15 W. In the western part of sec. 13 and in the northeastern part of sec. 14, the native water was similar to but perhaps of somewhat poorer quality than that at the city of El Segundo main well field. Both waters contained about 400 ppm of dissolved solids, were calcium, sodium bicarbonate waters and contained substantially equal quan-

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tities of chloride; however, the waters at the Standard Oil Co. field may have been somewhat higher in bicarbonate, with a corresponding increase in calcium and sodium. In the eastern part of sec. 13, where nearly all the producing wells of the company are now located, the native water was of somewhat better quality than those described above. These native waters ranged from sodium, calcium bicar-bonate to sodium bicarbonate in character and contained from 330 to 375 ppm of dissolved solids and from 50 to 60 ppm of chloride. This difference in quality in the two parts of the field is presumed to result from the deeper penetration of wells in the eastern portion of the section; these waters from the deeper part of the range penetrated agree closely in quality with those that have been yielded from the Silverado water-bearing zone to the east. With respect to sulfate content, a slight difference existed in native waters from the two parts of the field. To the west, they contained about 15 ppm; to the east, the content was probably less than 10 ppm in the upper part and was negligible in the lower part of the range penetrated.

HISTORY OF WELL DRILLING AND ABANDONMENT

Since the first two wells of the Standard Oil Co. were placed in operation in 1914, withdrawal of water from the field has been con-tinuous and has increased in quantity until, as of 1945, the 11 active wells yielded 4,780 acre-feet of water. Table 23 lists the 25 wells drilled by the company before 1946 and shows their status as of January 1946 and the chloride content of their water. For the six producing wells abandoned by 1930, the latest analysis indicated chloride in excess of 200 ppm in each; for the five wells abandoned from 1930 to 1946, only one appears to have yielded water containing more than 200 ppm of chloride at the time of abandonment. At least three of the latter group were abandoned because of mechanical difficulties or gradually diminishing yield. Although the various reports seem inconclusive, it appears that company wells 1 to 8 were abandoned because of excessive salinity. By 1922 salinity became apparent in this area, several years earlier than anywhere else along the coast. For the contaminated but still active wells along the east edge of sec. 13, the salinity increase is only slight; generally an increase in dissolved solids of not more than 25 percent has occurred.

CHEMICAL FEATURES OF CONTAMINATION

A study of the analytical data available for the wells in sec. 13, T. 3 S., R. 15 W., and also for those adjacent to the east, has dis-closed that the contaminated waters there are of two general types with respect to change in chemical character and time of such change.

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TABLE 23. History and chloride content of wells at the Standard Oil Co.,
El Segundo refinery

Well

Company

1 ____ . ___
2 . _ ..... _ ..
3 . .
4a..... -_ .._
4b................

5.... ... .
6 _ ... ____ ....
7_ _ . ...
8..... ... ...
9 ....

10...... ....
11... ___ ....
12.... ....
13 .
14 -

15... __ .
16................
17
18 .
19..... __ ......

20
21.... .
22. _ . _ . __ ...
23. _ . _
24.

USGSi

3/15-13D1.. ....
13D2 -
14A2.. . ... .
14A1.. ____ .
13E1........ ......

13F1... ___ .....
13G1- . ....
13G2.-
13F2..... ....
13R1..-

13A1... __
13J1- _ -
13H1. ....
13A2 ___ -
13H2... _ ....

13A3. -
13R2.--- __ .... .
13R3...- __ .....
3/14-19O1... . ...
3A5-13R4- __

13R5-
13J2-.. _ ....
13R6....... ......
13J3-
13A4 .. ____ ..

Date
drilled

1911
1911
1917
<1920
1920

1922
1923
1928
1929
1930

1930
1935
1937
1939
1940

1941
1941
1941
1943
1943

1944
1944
1945
1945
1945

Chloride content (parts per million)

Initial »

102
188
90

89

248
58
118
510
60

92
92
86
96
102

86
170
86
121
72

68
83
70
97
95

Date

31921
1921
1920

1921

1922
1924
1928
1929
1930

1930
1935
1937
1939
1940

1941
1941
1941
1943
1943

1944
1945
1945
1945
1946

Latest

255
950-125

2,400

664
194
620
505
60

92
202
198
224
70

160
, 104
141
112
109

75
92
68
119

Date

1921
1923

1930

1929
1942
1939
1929
1943

1940
1945
1944
1944
1946

1945
1946
1946
1946
1946

1946
1946
1946
1946

Date aban-
doned

1922
1922
1924
1920
1930

1929
1943
1939
1929
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1940

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1944

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i Unites States Geological Survey.
* Earliest analysis available.
»An analysis is available in which the chloride content is 91 ppm; date of analysis unknown. «Abandoned after construction because of insufficient thickness of water-bearing strata.
«Presumed inactive, but status not known definitely.
»Presumed active as of Jan. 1,1946.

1. In several of the earlier wells, notably 3/15-13E1, 13F1, and 14A2, con-tamination occurred at a comparatively early date and was characterized by a somewhat sudden increase of chloride and sulf ate and by an increase in dissolved, solids to more than 5,000 ppm.
2. In the wells just west of Sepulveda Boulevard, contamination has occurred to only a slight degree and is characterized by a small increase in chloride, by only a small increase in sulfate, and by a suggested concurrent but irregular decrease in bicarbonate.
These two water types will be described separately and graphs will be presented to show how contamination has occurred in each case.

For the first type, in which sulfate has increased markedly, figure 20 shows the extent to which sulfate and chloride increases are coinci-dent with the advance of contamination. To show that the sulfate content of these waters is more than that which could have been

brought in by sea water, figure 21 gives chloride and sulfate analyses plotted graphically for well 13G2, also the hypothetical content of

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I 000

800

" 600

400

200

1920 1922 1924 1926 1928 1930

FIGURE 20. Chloride and sulfate content of progressively contaminated waters from wells 3/15-13E1 and 14A2 (Standard Oil Co. wells 4b and 3).

2 $00

400

200

CHLORIDE -

«=»-

SULFATE

HYPOTHETICAL SULFATE CONTENT

(OCEAN-WATER BLEND)

300 O

200

too

19 Z9 1931 1935 1939

FIGURE 21. Chloride content and actual and hypothetical sulfate content of progressively contaminated waters from well 3/15-13G2 (Standard Oil Co. well 7).

CHEMICAL CHARACTER OF WATERS 229

sulfate in the contaminated water if sea water had been the sole contaminant. The graph for this well shows that sulfate increase began in 1933; definite chloride contamination began in 1935. As of 1939, the increase in sulfate was about five times as great as that which would have been brought in by sea water. Obviously a high-sulfate contaminant must have contributed to the deterioration of the water in these wells.
The Standard Oil Co. conducted pumping tests in 1923, 1929, and 1930, respectively, for three wells that yielded contaminated water at an early date 3/15-14A2, 13F2, and 13E1; a series of water samples was collected from each of the wells until the quality of the effluent became constant. Each well tapped the Silverado water-bearing zone. Figure 22 shows the chloride analyses plotted for the three wells. Presumably, the pump had been idle for several days prior to each test. The following facts are significant:
1. The water yielded initially from each well was highly contaminated, but the water taken in the succeeding samples improved substantially in quality.
2. For each well, the water representative of the Silverado water-bearing zone at the time of the test contained less than 350 ppm of chloride; this water was yielded only after extended pumping 8 hours for well 13E1 and about 160 hours for well 14A2.

Accordingly, it is inferred that the water causing the contamination was coming from a source outside the Silverado zone; and that, while each pump was idle, a relatively small amount of the contaminant moved through the well casing and collected within the Silverado zone immediately outside the well casing. With continued pumping, the supply of concentrated contaminant was exhausted, and the water then yielded indicated the concentration of the regional contaminant in the Silverado zone. If the more concentrated contaminant had been invading the Silverado zone directly, the water quality would have deteriorated or remained about constant during prolonged pump-^ ing, because the saline water would have been replenished as rapidly as it was withdrawn. Contamination of this nature has been en-^ countered in Santa Ana Gap and was described in an earlier report (Piper, Garrett, and others, 1953, p. 115-118).
The graph for well 14A2 in 1923 shows a regionally contaminated water containing about 120 ppm of chloride little more than the native chloride concentration of about 90 ppm. For the three wells, a local source of contamination apparently supplied a small amount of highly saline water; the water yielded after prolonged pumping re-flects the regional contamination in the Silverado zone, which con-tained less than 200 ppm of chloride in the middle twenties and 200 to 400 ppm about 1930. It is inferred that the more concentrated contaminant withdrawn through the wells during the first hours of:
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CHEMICAL CHARACTER OF WATERS 231

pumping must have entered the Silverado zone by passing down through the well casings from the overlying "200-foot sand." Because the well casings were not perforated opposite this overlying aquifer, the concentrated contaminant must have entered the casing through leaks.
As a further demonstration of the type of contamination occurring here locally, table 24 compares the contaminated water from well 3/15-13E1 with a hypothetical water formed by a mixture of ocean water and a native water to the same chloride content. The table shows that a large excess of sulfate is present in the contaminated water, also that a large excess of calcium and magnesium is present above that which could be accounted for solely by base exchange fol-lowing ocean-water contamination. The excess of calcium and mag-nesium amounts to 14.13 equivalents per million, and is nearly equal to the sulfate excess of 14.26 equivalents per million. Hence, the local contaminant was doubtless a calcium sulfate or calcium, mag-nesium sulfate water at the time of mixture with the ground water.

TABLE 24. Contaminated water from well S/15-18E1 (Standard Oil Co., well 4&) in comparison with a hypothetical mixture of a presumed native water with ocean
water

Parts per million:
Contaminated water, well 3/15-13E1;
Hypothetical mixture of ocean water
Equivalents per million:
Contaminated water, well 3/15-13E1; Hypothetical mixture of ocean water
Excess (+) or deficiency ( ) of the contaminated water with respect to

Constituents (ppm)

Calcium

(Ca)

54
400
96
2.70
19.96
4.79

+15. 17

Mag-
nesium

(Mg)

19
260
172
1.56
21.38
14.14

+7.24

Sodium

(Na)

62
1,181
1,371
2.69
51.36
59.64

-8.28

Bicar-
bonate
(HCOa)

252
230
238
4.13
. 3.77
3.90

-.13

Sulfate
(S0<)

12
1,020
335
0.25
21.23
6.97

+14.26

Chloride

(01)

91
2,400
2,400
2.57
67.70
67.70

For the wells along the eastern boundary of the Standard Oil Co. property, just west of Sepulveda Boulevard, contamination has been far less intensive, and at least three wells 3/15-13H2, J2, and R5 yielded essentially native water as of January 1946. Graphs showing the chloride content of waters from these wells have been presented on figure 23. Wells 3/15-13A1, A2, and A3 all tap essentially the entire thickness of the Silverado water-bearing zone, which here is only about 100 feet thick. The graph for well 13A1 suggests a slight but reasonably consistent increase in chloride from 1931 to 1939; those for

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100

uses
300
3/6-I3AI
I3A2
I3A3
I3A4
I3HI
I3H2
BJI
I3J2
I3J3
I3RI
BR2
I3R3
I3R5

I3A2<

1930 1932 1934 1936 1938 1940 1942 1944 1946

FIGURE 23. Chloride content of waters from selected wells of the Standard Oil Co. at El Segundo.

wells A2 and A3 indicate a sharp increase in chloride in the early forties. The greatest recorded concentration of chloride for well 13A2 268 ppm was accompanied by a sulfate content of 66 ppm; this is considerably more than that which could have been brought in with ocean water. For wells 3/15-13H1 and 13H2, the graphs show that definite contamination has occurred at well 13H1, and that well 13H2 yielded essentially native water as of January 1946. Well 13H1 taps the full range of the Silverado zone, and well H2 taps only the basal part. Thus, the contamination here is in the upper part of the Silverado zone.

Of the three wells 3/15-13 Jl, 13J2, and 13J3, well 13J1 taps the full thickness of the Silverado water-bearing zone, well 13J2 taps the middle part, and well 13J3 taps the middle and lower parts. Well 13J1 became contaminated in 1943, and the other two were incipiently contaminated in January 1946; here, also, the upper part of the Silver-

CHEMICAL CHARACTER OF WATERS 233

ado zone is the most saline. Of wells 3/15-13R1, 13R2, 13E3, and 13R5, well 13R1 taps about the middle part of the water-bearing zone, 13R2 taps only the lower part, 13R3 taps the upper part, and 13R5 taps both the middle and lower parts. The water from well 13R3 is the most saline; this fact indicates that here again the water in the upper part of the Silverado zone is markedly of poorer quality than that from the middle and lower parts. Contamination in the upper part of the zone in 13R began in late 1941, and therefore, it is roughly coincident with the onset of contamination adjacent to the north. To the east, at the property of the General Chemical Co. in 3/14- 18N, an analysis of water from well 18N3, in 1930, suggests that here, as to the west, waters contained about 60 ppm of chloride under native conditions. Of the three wells of the General Chemical Co. for which chemical analyses are available, wells 3/14-18N3 (company well 3) and 18N4 (company well 4) tap both the "200-foot sand" in the unnamed upper Pleistocene deposits and the Silverado water-bearing zone beneath. Inferentially, well 18N5 also taps both zones. Be-cause of the low chloride content of water initially yielded from 18N3 (about 60 ppm), that well probably drew most of its water from the Silverado zone and drew a comparatively minor part from the "200- foot sand."
To show the progress of contamination at the well field of the General Chemical Co., chloride determinations on waters from the three wells have been plotted on figure 24. The graph for well 18N3 indicates that contamination here reached a peak in 1940 and since then has decreased markedly; as of January 1946, water from these wells was only very slightly contaminated.
If the graphs of figure 24 are compared with those of figure 23, it Avill be noted that this contamination peak occurred not only in well 3/14-18N3, but also in wells 3/15-13A2, 13A3, and 13H1, of the Standard Oil Co.; for these latter three wells, however, the peak occurred about hi 1942, 2 years later than in well 18N3. This con-tamination seems to be superimposed on a regional trend toward increasing ground-water salinity which, as of 1945-46, was only moderate. In an attempt to discover whether this superimposed contamination showed a sulfate-chloride pattern similar to that in several of the early wells of the Standard Oil Co. (fig. 21 and p. 231), computations were made to determine, for periods of peak salinity, whether more sulfate had entered the wells than could be accounted for if sea water were the sole contaminant. The data concerning sulfate excess or deficiency for the four wells is given in table 25. The data contained therein indicate that the sulfate content during peak salinity was in excess of that to be expected from an ocean-water blend, and that the sulfate-chloride pattern was essentially

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FIGUBE 24. Chloride content of waters from wells 3/14-18N3, 18N4, and 18N5 (General Chemical Co., wells 3,4, and 5).

similar to that of the earlier contaminant in wells 3/15-13E1 and 14A2, about a mile to the west. For wells 3/15-13A2, A3, and Hi (fig. 23), the chloride peaks of 1942 had essentially disappeared as of mid-1943, and for each well the chloride concentration had returned to the projected normal increase in regional contamination. Fur-thermore, the abnormal chloride concentration began and ended within a period of 2 years in wells 13A2 and A3 and within one year in well 13H1.
For well 3/14-18N3, the chloride peak of 1940 had essentially disappeared as of 1942. However, as shown by figure 24, the chloride content of waters from the wells of the General Chemical Co. con-tinued to decrease from 1942 into 1946, this fact indicates that the regional contamination front had not yet reached this well field by the end of 1945. Also, as of 1945, the sulfate content of water from the General Chemical Co. wells was only slightly greater than normal; this indicates that the local contaminant has been almost entirely removed or dissipated.
Probably this high-sulfate contaminant is not the cause of the regional contamination, which has progressed much more gradually, and which, for the active wells near Sepulveda Boulevard, has re-sulted in a maximum concentration only slightly in excess of 200

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TABLE 25. Sulfate content of contaminated water from certain wells in sec. 18, T. 3 S., R. 14 W., and sec. IS, T. 3 S., R. 16 W., in comparison with hypothetical sulfate content resulting from mixture of a presumed native water with ocean water

Well

3A4-18N3,.... -- .--. . -
3/15-13A2...........................
13A3........ ....
13H1...........................

Analysis (parts per million)

Date

Apr. 24,1940
Jan. 23,1943
Dec. 22,1942
June 24,1942

Chloride
(Cl)

246
268
134
364

Sulfate
(S04)

43
66
13
64

Sulfate con-
tent result-

ing from
mixture
with sea
water (parts
per million)'

31
34
15
48

Excess (+)
or deficiency
(-)ofthe
contami-
nated water
with respect
to the hy-
pothetical
mixture

(percent)

+39

+94 -13
+33

i Based on a native water with presumed chloride and sulfate content of 60 and 5 ppm, respectively.

ppm of chloride in wells 3/15-13A2. As for the wells of the city of El Segundo, ocean-water intrusion is inferred to have caused the regional contamination, although the change in chemical character of the contaminated waters from the wells near Sepulveda Boulevard has not been great enough to furnish diagnostic proof of such a source. The source of the high-sulfate contaminant is not known. How-ever, from the occurrence and movement of this contaminant, as described in previous pages, it is inferred that it originated at or near land surface. If waste water containing sulfuric acid were discharged at land surface, it would be neutralized by downward percolation through the soil zone and surface deposits, and it would pick up calcium and, to a lesser degree, magnesium (p. 231). From land surface to a depth of about 140 feet, the underlying deposits are permeable dune sand or beach deposits, which rest upon the "200-foot sand" of upper Pleistocene age. Well logs indicate that a bed of silt, 10 to 30 feet thick, underlies the "200-foot sand" and separates it from the Silverado zone beneath. Thus, some of the water discharged at land surface doubtless could have seeped through the dune sand to the "200-foot sand" and could then have moved laterally on top of the subjacent silt bed. The lateral move-ment would have been in the direction of ground-water flow. Down-ward movement into the Silverado water-bearing zone would occur only where the silt bed was absent, or where it could move through defective well casings.
It is inferred that the high-sulfate contaminant, which has been described in waters from wells 3/15-13E1, 13F2, and 14A2 (p. 227), was derived by downward percolation to the "200-foot sand" and entered these wells through defective or leaky casings. It is inferred further that between the early twenties and the early forties, this high-sulfate contaminant migrated eastward about 1 mile to wells 3/15-13A2 and 13H1 (company wells 13 and 12). In 1935 the con-

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taminant reached well 13G2 (fig. 23). Apparently, the "200-foot sand" is not present at well 13G2, and thus, the high-sulfate con-taminant must have migrated into the upper part of the Silverado water-bearing zone before reaching this well. Doubtless at some place west of well 13G2 the "200-foot sand" is in direct hydraulic connection with the upper part of the Silverado zone.
Apparently, at the well field of the General Chemical Co. (3/14-18N) the bulk of contamination has entered the casings from the "200-foot sand," and the underlying Silverado water-bearing zone has been com-paratively free of contamination. For example, a series of samples taken June 2, 1943, from well 3/14-18N3, during a 24-hour period of operation after a 3-month shutdown, yielded the following quantities of chloride: At start of test, 760 ppm; after pumping 1 hour, 360 ppm; after pumping 24 hours, 148 ppm. Presumably, a relatively small amount of contaminated water migrated downward through the well casing from the "200-foot sand" to the Silverado zone and was soon removed by pumping. (For a parallel example, see discussion of pumping tests of wells 3/15-13E1 and 14A2 (p. 229).)

WELL FIELD OF THE CITY OF MANHATTAN BEACH

Of the 11 public-supply wells of the city of Manhattan Beach, 6 were drilled in a small tract near the intersection of Eighth Street and Sepulveda Boulevard in the NE# sec. 25, T. 3. S., R. 15 W. This tract, initially the only well field of the city, is 0.8 mile from the ocean and 1.3 miles south of the large well field of the Standard Oil Co. at El Segundo. With one exception, these six wells tap only the Silverado water-bearing zone, which here ranges in thickness from 30 feet (well 25H1) to 120 feet (well 25A3). That exception, weU 3/15-25H1, taps 14 additional feet of coarse sand, 240 feet below the lower assigned limit of the Silverado water-bearing zone. Well 3/15-30D1 (city well 8), which is about 400 feet east of this well field, also taps the Silverado water-bearing zone.
The "200-foot sand" in the unnamed upper Pleistocene deposits was reported to be present in only one well at the main well field no. 3/15-25H1 (city well 1) but it was not tapped by that well. About 1 mile east, logs of three additional wells drilled by the city wells 3/14-30H1, 30A2, and 29D3 (city wells 9, 10, and 11) show that there the thickness of the Silverado water-bearing zone ranges from 120 feet in well 30H1 (city well 9) to 250 feet in well 29D3 (city well 11); the "200-foot sand" there has been tapped by well 30H1 but the other two wells tap only the Silverado zone.

SUMMARY OF NATIVE WATER QUALITY

Analyses of water from wells hi the main field in 1930 indicate that the water in the Silverado water-bearing zone contained from 70 to

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80 ppm of chloride and 20 to 35 ppm of sulfate. It is inferred that this water was essentially native. This inferred native water con-tained about 250 ppm of bicarbonate and 350 ppm of dissolved solids. The chloride content of waters from six of the municipal wells has been plotted on figure 25. As shown by this figure, the chloride content of water from well 3/15-25A1 (city well 3) ranged from 76 to 120 ppm from 1929 to 1931; however, definite contamination did not develop until 1940 (in well 25H2). As of 1944, all wells hi the main field yielded water containing more than 300 ppm of chloride.
By 1946 only wells 25A2 and A3 at the main field were still being utilized; both yielded water containing about 500 ppm of chloride. The three municipal wells near Aviation Boulevard, however, 3/14 29D3, 30A2, and 30H1, as of 1946 yielded native water of excellent quality. (See table 30.)

CHEMICAL FEATURES OP CONTAMINATION

To show the general change in chemical character of the waters
at the main well field because of the progress of contamination, selected analyses have been plotted on figure 26. The graph indi-cates a trend characteristic of contaminated waters along the seaward margin of the coastal plain that is, toward an increase in chloride, or chloride and sulfate, and with the ratio of sodium to calcium plus magnesium remaining more or less constant; for high-sodium con-taminants, such as ocean water and oil-field brines, this approximately constant ratio could be explained only through ionic readjustment by base exchange. The starting point (well 3/14-30D1, analysis of Oct. 20, 1938) represents a water assumed to be essentially native. As revealed by the analytical data (table 30), the drift toward the apex of the graph has resulted almost entirely from an increase in chloride; sulfate has increased very slightly, and bicarbonate has decreased. The slight increase in sulfate renders unlikely the existence of a high-sulfate contaminant here. Thus, the two possible sources of con-tamination are oil-well brines and ocean water. The sulfate content of the progressively contaminated waters suggests that of the two sources, ocean water has been the source at this field (fig. 27). On this fig-ure both chloride-bicarbonate and chloride-sulfate ratios have been plotted against the chloride content, as determined from all available complete analyses of the contaminated waters. Also plotted on the graph are the points showing, respectively, blends of an essentially native water with ocean water, and with a typical oil-well brine. The illustration shows two pertinent features:
1. The points representing the chloride-bicarbonate ratios of the well waters fall slightly closer to the line indicating the ocean-water blend than to that of the oil-field brine blend. For waters with chloride content of more than 450 ppm,

750

500

250

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1930 1932 1934 1936 1938 1940 1942 1944

FIGUBE 25. Chloride content of waters from selected public-supply wells of the city of Manhattan Beach.

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.Ocean water,

from Torranc*
oil field

No.

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3
4
5
6
7
8
.9
10
11
12

Well

3/14-30D1
30D1
30D1
3/15-25H1
'3/14-30D1
30D1
30D1
30D1
3/15-25A1
25A1 .
3/15-25A2
25A2

Date

Oct. 20, 1938
Mar. 31, 1944
Aug.- 15, 1944
June'11, 1943
Sept., 25, 1944
Oct. 24, 1944
Oct. : 29, 1944
Feb. 5, 1946
Aug. 15, 1944'
Sept. 25,1944-
Sept.. 15, 1944'
Sept, 25, 1944

Chloride,
parts per
million

67
111
172
203
212
226
303
371
545
561
631
677

FIGURE 26. Chemical character of contaminated waters from selected public-supply wells of the city of Manhattan Beach.

MILLIEQUIVALENTS FROM RATIO. CHLORIDE-SULFATE oooN at -fc tvj

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the digression of the plotted points from the ocean-water blend represents a decrease of bicarbonate amounting to about 7 percent. For the line indicating the oil-field brine blend the loss would have to be about 13 percent. However, this evidence certainly is not diagnostic with respect to selection between the
two sources.

2. For values of chloride above 300 ppm the points representing the chloride-sulfate ratios of the well waters are alined much closer to the trend of the line indicating the ocean-water blend than to that of the oi
is, the contaminated well waters contain much more
been brought in by oil-field brines, but slightly less than the computed amount carried in by ocean water. Of the two features, the chloride-sulfate ratio pre-sents the only definite evidence of ocean-water contamination.

So far as is known from existing analytical
western part of the Torrance oil field contain
as the inferred native water at the main well
hattan Beach. Hence, waters contaminated
be expected to show no increase in sulfate
nation. The analyses of the contaminated in sulfate; however, this increase is less than simple blend of native water with ocean water, This lack of agreement possibly could be e: sulfate reduction if substantiating evidence because of the rapidity with which sulfate the difficulty of obtaining confirmatory
any given place is necessarily an inferential only does the sulfate content of these waters increase in contamination, but, as indicated
of the chloride-sulfate ratio is about parallel chloride-sulfate ratio for a simple ocean-water concluded that ocean water is the contamin; Beach well field.

VERTICAL RANGE OF CONTAMINATION

As described earlier, all wells at the main fie hattan Beach, except well 25H1, yield from Silverado water-bearing zone. Well 25H1 tas zone and a 14-foot sand, 240 feet below that and in January 1945, the Geological Survey traverses in well 3/15-25H1 to determine: (1) i existed between the waters yielded from the any vertical range in quality existed in the wa through the perforations reported to be 221 t surface opposite the Silverado zone. The datii traverses are shown on figure 28, from which the have been drawn:

-field brine blend. That sulfate than could have

data, brines from the ost as much sulfate
of the city of Man-
such a brine would
increase in contami-
do show an increase
that resulting from a as shown by figure 27. to be a result of
be found. However,
may occur and
its occurrence at
However, not
become greater with figure 27, the trend
to the hypothetical
mixture. Thus, it is
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d of the city of Man-
51, single aquifer the both the Silverado
me. In October 1944 made conductivity
any range in quality
two zones; and (2) if ,er entering the casing 240 feet below land
obtained from those
following conclusion*

Arrow outside casing
indicates perforations; 375
additional perforations
527-541 feet below land
surface. Measured depth
of well 579 feet

200

225

250

275

300

325

350

'9
s;375
ns

nd

pth

n

iX
Reported
of pump i

_c

1

Pumping level about 195 feet
^ below land surface
i -1- '

position
ntoke

*=
>

'

Traverse Oct. 27, 1944

after pumping 8 '/i hours.
Pumping rate, 275 gpm

J
-J

}

Traverse run to 475 feet below

land surface; no change in
conductivity below 400 feet

1

DO 1000 1500 2000

X*>

. / ;
Traverse January 3, '
1945 after pumping
18 Vt hours

/
Traverse January 2, 1945
offer pumping 53 minutes.

Well had been idle for 1 week previous to test

ll
_ ^

\

- '

feet below land surfac

after pump idle l'/4 hoi

/

1 2
jrs

;

/

\ Traverse Janu
V pump idle 30
\ ofter pumpinc

±
__J

ary 3, 1945;
minutes
24 hours

s

500 1000 1500 2000 500

ELECTRICAL CONDUCTIVITY (MICROMHOS AT 250 C)'

FIGURE 28. Conductivity traverses in well 3/15-25H1 (city of Manhattan Beach well 1), Oct. 27,1944, an<f Jan. 2-3,1945.

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1. The quality of the water from the deeper perforations (527-541 feet) was somewhat better than the water admitted to the pump intake. The amount of water yielded through these perfoiations was small, probably about 25 gpm.
2. Fresh water entered the well from 248 to 256 feet below land surface; there,, the conductivity decreased from about 1,500 to 700 micromhos (dissolved solids about from 900 to 400 ppm). The casing reportedly is not perforated at this depth; thus the water must have entered either through unreported perforations or through a leaking casing.
3. Saline water entered the casing from 230 to 243 feet below land surface. The concentration of this water was indeterminate,
greater than 1,850 (dissolved solids, greater than about

but the conductivity was
1,100 ppm).
4. Under nonpumping conditions, the saline water entering through the perforations 221-240 feet below land surface mo1
fresh water at 248-256 feet and at 527-541 feet. Doubtl
displaced the water in the casing, but it also invaded
zones while the pump was idle.

WELLS IN AND NEAR REDONDO BEACH

To the south of 190th Street, near the coast, the Silverado water-bearing zone and the "200-foot sand" cannot be discriminated as separate entities. From here southward to tpe Palos Verdes Hills, the materials penetrated by wells are permeable throughout nearly their entire thickness' (pi. 3(7). Beneath the dune sand, which ex-

down to displace the
ess this saline flui4 not only
these lower w(ater-bearing

tends from land surface about to sea level, the
tapped by wells is considered to be within

water-bearing material
the Silverado water-
bearing zone. Wells have penetrated this zone ttra depth as great as 400 ;feet below sea level (well4/i4^-i7El and 5N1). A comparison of drillers' logs of wells in the western part of sec. 8, T. 4 S.j R. 14 W., suggests a local division of the Silverado zone into an upper and a lower part, separated by a few tens of feet of clay. Records of water levels in well 4/14-8E1, which taps only the upper part, and in well 8Dl, which taps both the upper and lower parts, show little difference in altitude of water level in the two parts from the middle to the late thirties. Since about 1941, however, as shown by measurements at these two wells, the water level in the lower part has been slightly higher than that in the upper. Available chemical analyses suggest-some slight difference in quality of water from the two parts; also, even where the separating clayey layer is not present, the deeper water is of appreciably better quality.

SUMMARY OF NATIVE WATBB QUALITT

Water of native quality is represented by analyses of water from wells of the California Water Service Co. in sec! 31, T. 3 S., R. 14 W., and from random wells in sees. 5, 8, and 17, T. 4 S., R. 14 W. Accord-ing to these analyses, the native waters contnined 50 to 60 ppm of chloride, and about 300 to 360 ppm of dissolved solids; the sulfate content decreased from north to south. In sec, 31 the sulfate content

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of these native waters was about 40 ppm; in sec. 5, from 15 to 12 ppm; in sec. 17, from about 7 ppm to only a trace. The native waters range from sodium, calcium-bicarbonate waters in the northern part of the area to sodium bicarbonate waters in the south. For the cen-tral part of the area, the analysis of October 6, 1931 of well 4/14-5N2 (table 30) has been selected to be representative of a native water of good quality. Locally, near the coast, inferior waters existed under native conditions according to early records. For example, by 1908, about half a mile from the coast in 4/14-7J, brackish water containing noticeable quantities of hydrogen sulfide gas was reported at depths of less than 185 feet below land surface. The water below that depth was utilized from about 1905 to 1930 by several public-supply wells of the California Water Service Co. It is reported to have been of good quality until it became contaminated late in the twenties.

PROGRESS OF "WATER-QTTAMTY DEPRECIATION

The earliest known occurrence of water-quality depreciation in the Uedondo Beach area is indicated by a series of analyses from well 4/14-6F1, which was drilled in 1912 by the Southern California Edison Co. The chloride content of the water from that well was 79 ppm. By late 1918 the chloride content had increased to 462 ppm. The public-supply wells of the California Water Service Co. in 4/14-7J were abandoned prior to 1931 because of saline contamination. Also, well 4/14-17E1, which was drilled in 1929 and perforated at intervals from 253 to 400 feet below land surface, yielded water containing 404 ppm of chloride in October of that year. Thus, as of 1930, the iront of contaminated water extended inland at least 0.8 mile at Redondo Beach.

The general progress of contamination hi the Redondo, Beach area since 1930 is best shown by the chloride plots for several wells with good analytical records. These have been plotted on figure 29 and include well 4/14-5N2, which, since 1932, has an .excellent record of -chloride determinations made by the Los Angeles County Flood Con-trol District. Definite contamination hi this well, began in 1938, and it increased so rapidly that the well was abandoned in 1945. Also plotted on figure 29 are chloride determinations on waters from wells 4/14-8D1 and 8E1, which were badly contaminated when abandoned in 1942 and 1943, respectively; well 8Cl, which was incipiently con-taminated as of 1946; and well 3/14-31A1, which in mid-1947 still yielded water of .excellent quality. The trend of chloride for well 8Cl is anomalous; on the basis of trends shown by the chloride ^graphs for wells 5N2,8D1, and 8E1, it would be expected that when the chloride -content increased beyond 100 ppm, the slope of the curve would be-come much steeper and ultimately would result in the abandonment of

CHEMICAL CHARACTER OF WATERS 245

YI4-3IAI
0
500

0
2000

500

4/14-5N2

/ 4/I4-8EI
- y 4/I4-8DI
4/I4-8CI

3/14-3IAI

4/I4-5N2

1930 1932 1934 1936 1938 1940 1942 844 1946

Floras 29. Chloride content of waters from five wells In the Bedondo Beach area.

the well. However, for well 8C1, the chloride content passed beyond 100 ppm in early 1946 but subsequently returned to a lower value (94 ppm). The actual front of contamination has not yet reached well 8C1; however, during the summer of 1946 that well must have drawn water from a zone of diffusion in which a small amount of blending with the contaminant had occurred.
To the south, water from well 4/14-17E1 was of poor quality (404 ppm of chloride) in 1929. Well 4/14-17G2, half a mile inland from well 17E1 and 1.3 miles from the coast, yielded water of excellent quality in 1946. The front of contamination currently is coastward from this well (pi. 16). Still farther south, analyses of water from well 17N1 suggest that the water was incipiently but not definitely contaminated as of 1930 (the chloride content was 86 ppm). In 1944, the chloride content had increased to 122 ppm and the front of con-tamination had moved east of well 17N1.

CHEMICAL FEATURES OF CONTAMINATION

In accordance with an outstanding characteristic of contamination along the west and south coasts of the Los Angeles basin, the most obvious feature of the contamination in the Kedondo Beach area is the regular and comparatively intense increase in chloride. Particu-larly in the initial stages of contamination, chloride usually increases regularly and consistently, although one or more of the other constit-uents may fluctuate irregularly. Because an excellent series of chem-ical analyses is available covering the full span of contamination in well 4/14-5N2 (Kedondo Union High School well), and because the
460508 59 17

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water yielded from that well before abandonment became more saline than waters available from any other well nearby, the analyses have been plotted on a trilinear diagram (fig. 30) to show graphically the change in chemical character that occurred as contamination increased. Also shown for comparison are the points representing native water of excellent quality from wells 3/14-31A1 and 4/14-17G1 and the point representing contaminated water from well 4/14-17E1. The graph shows that the waters from 4/14-5N2 and 3/14-31A1 initially were similar; that the water from well 5N2 did not change materially from its initial character until some time between 1937 and 1942; and finally, that the points representing increased contamination define a trend, which suggests the addition of a calcium-chloride or calcium-sulfate saline. Actually, however, the increase in calcium is due to base exchange. On the graph, the points representing the analysis for well 17E1 and the analysis of August 7, 1942, for well 5N2 nearly coincide, thus suggesting that the two are of similar character. However, certain discrepancies exist, particularly in the relative concentrations of calcium and magnesium.
Evidence relating to the possible source of the contaminant entering well 4/14-5N2 is presented on figures 31 and 32, which shows that of the two possible contaminants ocean water and oil-well brine the former is the more likely source. The magnesium increase in the contaminated water, as shown by the pairs of dashed lines in figures 31 and 32, allowing for a moderate increase by base exchange, is more compatible with the amount in ocean water than that in oil-well brine. The amount of sulfate in the brine is not sufficient to produce the observed increase of sulfate. That increase could result from a mixture with ocean water with sulfate reduction of about 45 percent (that reaction is presumed to occur here because of the reported presence of free sulfide in some waters nearby). In addition, the bicarbonate content of the contaminated water is less than that which would be expected by the addition of brine. Thus, the evidence shown on figures 31 and 32, although not entirely excluding the possibility of oil-well brine contamination, shows that ocean water probably is the contaminant. Moreover, the contamination is more intense to the west, and its front is known to have moved from west to east. If water deterioration were from an oil-well brine specif-ically, from brines discharged at land surface in the Torrance oil field (pi. 18) a decreasing salinity from the ocean to the present front about a mile inland would be unlikely. Few, if any, active oil wells are less than a mile from the coast, and oil-field brines are not discharged within the city limits, which include the area of most in-tensive contamination.

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3/14-31Al-water of excellent quality, native, in
northern part of area
V V V V

0 4/14-17Gl-water of excellent quality, native, in
'. / southern part of area

No.

1
2
3
4
5
6
7
8
9

Date

Oct. 6, 1931
Mar. 24, 1932
May 11, 1932
Nov. 3, 1932
Sept. 2, 1937
Aug. 7, 1942
Sept. 4, 1942

Sept. 18, 1944 . Apr. 13, 1945

Parts per million

Dissolved
solids

303
299
283
301
369
628
647
2,280
3,370

Chloride

57
57
59
62
70
267
278
1,060
1,770

FIOUKE 30. Chemical character of selected native waters and the progresslvely'contaminated water from well 4/14-5N2 in the Redondo Beach area.

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CALCULATED PERCENTAGE OF NATIVE WATER 100 99 98 97 96 95 94 93 92 91 90 89

D

SODIUM AND
POTASSIUM

20

FIGUEE 31. Progressively contaminated waters from weI14/14-5N2 (Redondo Union High School well) in relation to hypothetical mixtures of native fresh water with oil-well brine (well 4/14-9D).

CHEMICAL CHARACTER OF WATERS 249

CALCULATED PERCENTAGE OF NATIVE WATER 100 99 98 97 96 95 94 93 92 91 90 89

[[SODIUM AND1S&3 CHLORIDE
POTASSIUM KX3 AND
RXH NITRATE

20

30

FIOUBE 32. Progressively contaminated waters from well 4/14-5N2 (Redondo Union High School) in relation to hypothetical mixtures of the native fresh water with ocean water.

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Regarding the possibility of contamination of fresh water by oil-well brine, such contamination is believed to have occurred at well 4/14-9K1. The chloride content of its water increased from 50 ppm in 1926, to 189 ppm in 1946, and to 216 ppm in June 1947. This well is 2.3 miles from the coast and water of good quality is inferred to be present to the west the regional front of contamination as of 1946 is shown on plate 16 as 1.2 miles west of this well. However, water levels throughout this area are below sea level, and a landward gradient has existed for many years; therefore, the possibility of ocean-water contamination cannot be excluded. Because this well seems to be the only one contaminated in an area now yielding water of good quality, a local source of contamination is presumed. The chemical data are not diagnostic of the source. It is of interest to note that a brine sump, about 1,000 feet northwest of well 4/14- 9K1, reportedly has been used as a place of disposal for many years (p. 191). The quantity of brines discharged into these sumps is not known.
RATE OF INLAND ADVANCE OF THE CONTAMINATION FRONT

For the reach from Playa del Rey to the Palos Verdes Hills, it has been shown that, as of 1946, contaminated water underlay a coastal strip ranging in width from half a mile to 1.7 miles. Throughout this reach, water levels now (1946) are below sea level, and a land-ward gradient prevails (pi. 12). There is no known physical barrier to the continued inland advance of contamination across essentially the full width of the west basin, at least to the eastward margin of the area in which landward gradients exist.
With respect to the problems of use and conservation of the ground-water body in the west basin, the rate of encroachment of saline waters is of critical concern. It has been shown that, throughout the area here treated, the ocean is the principal source of the con-taminating waters. Thus, the supply of contaminant is unlimited, and the rate of advance is dependent upon the permeability and effective porosity of the conducting aquifer chiefly the Silverado water-bearing zone and the gradient of the water level or piezometric surface within that aquifer. The rate can be estimated by use of an average permeability coefficient and effective porosity and an average water-level gradient. However, the front will advance most rapidly in the most permeable gravel layers, and in places where cones of pumping drawdown intersect the body of contaminated water and cause relatively steep landward gradients. Thus, because conditions may range widely from the average, it appears that an appraisal from empirical data is the most reliable. However, two methods of pro-cedure are possible. First, the field travel time of the saline front from one actively pumped well to another can be determined by

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periodic chemical analyses. Second, the average rate of encroach-ment can be estimated from the regional advance of the saline front as shown on plate 16. Both methods will be presented in this study; however, both are subject to qualification.
With respect to the first method for three specific localities within the coastal reach, the landward rate of saline advance is known reasonably closely from periodic analyses of the water from pairs of actively pumped wells:
1. At El Segundo, wells 3/15-13G2 and 13H1 (Standard Oil Co. wells 7 and 12, respectively) both tap the upper part of the Silverado water-bearing zone. From the chloride plots of figures 21 and 23, the initial contamination at well 13G2 was in January 1935, and at well 13H1 it was in August 1938. Thus, the saline front moved 900 feet east in 3.6 years, or at an average rate of about 250 feet a year.

2. At the main well field of the city of Manhattan Beach, contaminated water first reached wells 3/15-25A1 and 25A2 (city wells 3 and 7) in June 1942 and June 1943, respectively (fig. 25); water from well 3/14-30D1 (city well 8) first showed contamination in May 1944. Thus, it took an average time of about 1.4 years for saline water to advance 500 feet eastward from wells 25Al and A2 to well 30D1 that is, an average rate of about 350 feet a year.
3. Near Redondo Beach, contamination first became appreciable in wells 4/14- 8D1 and 8E1 of the California Water Service Co. in mid-1939. In March 1946, incipient contamination first reached well 4/14-8C1 (Dominguez Water Corp. well 12-A), some 1,350 feet eastward from wells 8D1 and 8E1. Here, it took about 6.8 years for the contamination front to move 1,350 feet, or at an average rate of about 200 feet a year.

Thus, for the three specific places along the west coast south of Play a del Rey, for which evidence is available from actively pumped wells, the average rate of landward advance of saline water between these wells has ranged from 200 to 350 feet per year. However, it must be considered that these rates of advance have been calculated for the time it took the front to-advance from one actively pumped well to another. Also, they cover different time periods, and are reckoned from unknown, but presumably unequal, gradients. There-fore, these rates are inferred to be more rapid than the regional average and cannot be considered to be representative of the rate of inland movement in the reaches where the cones of water-level depression of actively pumped wells do not intercept the saline front that is, in reaches where the flatter regional gradient prevails.
The change in position of the saline front for the 15 years from 1931 (1930-32) into 1946 (pi. 16) can be utilized to estimate the yearly rate of advance. In such an appraisal, however, two considerations which complicate the estimate should be kept in mind:
1. The positions of the saline front both in 1931 and in 1946, as shown on plate 16, are relatively uncontrolled except at or near certain pumped wells whose waters have been analyzed often enough to furnish reasonable control. In

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reaches between these wells, such as that between Redondo^Beach and Manhattan Beach, the saline front of 1946 has been drawn in a conservative position, and the front may have been several hundred feet inland from the indicated positionfat that time. Thus, rates of advance, calculated from the average change in position of the front along such a reach, furnish only rough approximations.
2. Although the hydraulic gradient has been landward along the full reach from Playa del Rey to the Palos Verdes Hills since the early thirties, the magni-tude of the gradient has ranged seasonally (from spring to autumn), from year to year, and especially from place to place, as shown by the water-level contours of plates 9-12. These changes in gradient have been discussed more fully on pages 90 to 93. The rate of movement of the saline front changes in direct proportion to these changes in hydraulic gradient.
The reach between the Palos Verdes Hills and Hermosa Beach is the one in which the change in hydraulic gradient is easiest to deter-mine, partly because the water-bearing deposits are thickest here, and the change in gradient has been relatively uniform across the reach. In the 15 years from 1931 to 1946, the saline front (pi. 16) moved inland an average distance of about 1,500 feet. The hydraulic gradient from 1931 into 1941 was reasonably uniform and ranged from about 3 feet per mile in the spring to 4 feet per mile in the autumn. Thus, the average inland gradient was about 3.5 feet per mile. From 1941 into 1946, the yearly average gradient increased from about 3.5 feet per mile to 5.5 feet per mile, and for the 5-year period it averaged about 4.5 feet to the mile. Thus, from these data, in the reach from Hermosa Beach to the Palos Verdes Hills, the rate of advance of the saline front was about 90 feet per year from 1931 into 1941, increased to about 140 feet per year by 1946, and averaged about 120 feet per year from 1941 into 1946.
For the reach from Hermosa Beach to El Segundo, the landward hydraulic gradient ranged widely from 1931 into 1946. As of 1933, it was flatter than the gradient in the area to the south (pi. 9); as of 1941, it was somewhat steeper (pi. 11); and in the autumn of 1945 it had increased to as much as 20 feet per mile locally as measured by the distance between the 10 and 20 contours (pi. 12). For this reach from Hermosa Beach to El Segundo, the saline front (pi. 16) moved inland an average distance of 2,300 feet in the 15-year period. The change in gradient has been so irregular throughout this reach that it is not considered feasible to attempt an evaluation of the average gradient for selected periods. However, from fragmentary chemical data, it is estimated that the saline front advanced about 1,150 feet from 1931 into 1941 and advanced the same distance from 1941 into 1946. Utilizing this approximation, the suggested average rate of advance was about 115 feet per year in the thirties and about 230 feet per year from 1941 into 1946. As of 1946, the rate of advance probably was as much as 300 to 400 feet per year in the areas of steepest landward gradient along this reach.

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In the reach from El Segundo to Playa del Rey, where the hydraulic gradient along the saline front has been not more than 1 to 2 feet to the mile prior to 1945, the data of plate 16 suggest that the landward advance of the saline front probably has not exceeded 30 to 40 feet per year prior to 1945. As of 1946, the hydraulic gradient had steep-ened to as much as 3 feet to the mile (pi. 13, hydrographs for wells 2/15-34H1 and Kl), and the rate of inland advance probably had increased to about 60 to 80 feet per year.

INFERIOR WATERS OF THE GARDENA AREA WATERS FROM THE UNCONFIKED BODY

As discussed earlier, in the Gardena area the shallow deposits extending to a depth of as much as 60 to 80 feet below land surface generally contain inferior unconfined waters. As shown by plate 16, the area underlain by these inferior waters extends about 17 square miles. However, to the southeast that is, to or beyond sec. 31, T. 3 S., R. 13 W. the extent of the shallow water body is indefinite. It is believed, from water-level records, that a number of wells in sec. 31, ranging in depth from 30 to 70 feet, tap unconfined water. Still farther south, specifically in sec. 19, T. 4 S., R. 13 W., it is believed that wells 70 to 90 feet deep and wells about 180 feet deep tap different parts of an essentially common zone correlative with the "200-foot sand." This belief is based mainly on hydrologic information rather than on chemical data; the water from the shallow wells is inferior in quality to water from the deeper wells.
The available chemical evidence indicates that the shallow waters

throughout the area under discussion have been inferior since at least 1903; however, the tendency toward salinity increase is too slight to be indicative of contamination. In 1903, wells shallower than about 60 feet yielded inferior water with a dissolved-solids content ranging from more than 1,000 ppm to more than 2,300 ppm. Wells 60 to 80 feet deep yielded water containing 650 to 750 ppm of dissolved solids. According to analyses of waters from the shallow wells in the Gardena area over the period 1943-45, the chloride content was usually less than 400 ppm except in sec. 26, T. 3 S., R. 14 W., where at least seven wells yield water containing more than 400 ppm; of these, well 3/14- 26G2 yielded water containing 2,150 ppm of chloride and about 3,900 ppm of dissolved solids. For sec. 31, T. 3 S., R. 13 W., wells less than 80 feet deep yielded water in which chloride ranged from 28 to 267 ppm and dissolved solids ranged about from 310 to 924 ppm; the few analyses made since 1941 suggest only a very slight increase hi salinity during that time.
Therefore, in summarizing water-quality conditions in the Gardena area with specific reference to the unconfined body, the following fea-

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tures are pertinent: (1) Unconfined water in the shallow deposits apparently was inferior under native conditions, (2) an extreme range in quality existed across the area, and (3) existing chemical data for any given well point to the tentative conclusion that, in general, the quality of water is not deteriorating.

WATERS FROM TEE UNNAMED UPPER PLEISTOCENE DEPOSITS

The native concentration of waters in the "200-foot sand" in the unnamed upper Pleistocene deposits is also determined in part from chemical data collected during the Mendenhall survey in 1903. Then, the concentration of dissolved solids in water from wells 150 to 250 feet deep hi the Gardena area ranged from about 350 to 460 ppm. However, in sec. 24, T. 3 S., R. 14 W., at least six wells yielded water considerably above that upper limit, and two of these six wells yielded water containing more than 1,800 ppm of dissolved solids. Similarly, in sec. 27, T. 3 S., R. 14 W., a well 230 feet deep yielded water containing 1,730 ppm of dissolved solids (Mendenhall 325, Redondo). In sec. 36, T. 3 S., R. 14 W., a well 250 feet deep yielded water containing only 340 ppm of dissolved solids (Mendenhall 1006r Redondo).
According to field analyses in 1943 by the Geological Survey, the "200-foot sand" in the Gardena area then yielded water ranging from 22 to 774 ppm of chloride and from 320 to 1,750 ppm of dissolved solids. The maximum value cited is that from a well only 175 feet deep which does not penetrate the full range of the "200-foot sand"; hence, that water probably is not representative of that aquifer. In general, however, the chloride content ranged from 60 to 80 ppm. In sec. 31, T. 4 S., R. 13 W., three wells tapping the "200-foot sand" or correlative deposits yielded water containing, respectively, 159, 205, and 138 ppm of chloride. For these wells, the dissolved solids, as computed from electrical conductivity, were about 640, 1,000, and 600 ppm. Here, wells tapping aquifers below the "200-foot sand" yield water containing less than about 53 ppm of chloride.
It is believed that under native conditions water yielded from most of the "200-foot sand" in the Gardena area contained from 50 to 90 ppm of chloride. Locally, however, as the foregoing discussion indi-cates, some of the waters were inferior in!903 (Mendenhall survey) and in 1943 (Geological Survey water-sampling program). On plate 16 is shown an area of some 470 acres just northeast of Gardena largely confined to sec. 19, T. 3 S., R. 13 W. in which waters from the "200-foot sand" have become contaminated in recent years. These boundaries include an area in which the chloride content of the waters yielded from the "200-foot sand" is now greater than 100

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ppm; earlier analyses are available to show that there has been a trend toward increase in chloride in recent years. The fragmentary evidence shows that, in sec. 19, chloride has increased in some wells tapping the "200-foot sand" and, as of 1943, at least five wells tapping that aquifer yielded water containing more than 100 ppm of chloride. However, because complete analyses of water from wells tapping the "200-foot sand" in this area show no more than a nominal range in chloride content, nothing can be said concerning the source or type of contamination.

A comparison of the chemical character of waters from the shallow,, unconfined body, from the "200-foot sand," and from the Silverado water-bearing zone is made on figure 33. Here are shown graphical representations of virtually all the available complete analyses of water from wells in the Gardena area. As indicated by the illustration, the water (mostly unconfined) from the shallower ranges is a calcium, sodium chloride water; that from the "200-foot sand" is a calcium, sodium bicarbonate water, and that from the Silverado water-bearing zone is a sodium, calcium bicarbonate water. The range in dissolved solids for the analyses shown is from 924 to 3,900 ppm for the shallow water body, 377 ppm for the "200-foot sand" (well 3/14-26J1), and 241 ppm for the Silverado water-bearing zone (well 3/14-35R1). Figure 33 shows that the waters from the two underlying zones are of much higher quality than that from the shallower body. Because of the higher head in the semiperched body, it is essential that wells in the Gardena area which tap underlying zones and which are to be abandoned be plugged with cement or with other impermeable ma-terial, so that the waters in the semiperched body cannot eventually circulate into and contaminate the water in the underlying zones. If the well to be abandoned is not plugged, ultimate failure of the casing, caused by corrosion by the saline waters, will allow such circulation and the resulting contamination.

CONTAMINATION IN DOMINGUEZ GAJ»

Much of the following material has been abstracted from the report on chemical characters of waters in the Long Beach-Santa Ana area (Piper, Garrett, and others, 1953, p. 167-197) and from earlier pages in this report. Because the Dominguez Gap is an integral part of the west basin, the more general features of water character and water contamination are reviewed here. No field work has been done in the Dominguez Gap since release of that earlier report, how-ever, and thus the conditions summarized here are those which existed in the gap in 1943.

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ii

EQUIVALENTS PER MILLION

3/14-26 J|
FEB.8,1946

3/14-35 Rl
FEB.8,1946

I WATER FROM THE
f"200-FOOT SAND"

[WATER FROM THE SILVERADO
f WATER-BEARING ZONE

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SUMMARY OP NATIVE-WATER OCCURRENCE AND QUALITY

In Dominguez Gap, three principal aquifers are actual or potential sources of water for wells. In downward succession from the land surface, excluding the shallow, unconfined body, these are:
1. The lower division in the alluvial deposits of Recent age, known as the Gaspur water-bearing zone. It is about 40 to 70 feet thick, its base is about 90 to 150 feet below land surface, and it is over-lain by flood-plain silt which is probably somewhat permeable. The water in this zone is only imperfectly confined; probably there is some interchange of water between it and the overlying unconfined body. The native waters in nearly the full reach of the Gaspur water-bearing zone were of the calcium bicarbonate type and contained from 350 to 600 ppm of dissolved solids, from 25 to 60 (or possibly more) ppm of chloride, and from 190 to 275 ppm of hardness. In general, each of these quantities decreased southward, or toward the coast.
2. The Silverado water-bearing zone of the San Pedro formation. This water-bearing zone is separated from the Gaspur zone by 175 to 550 feet of silt, clay, and fine sand of low permeability. It is a body of uniform gravel and coarse sand and ranges in thickness from 500 feet at well 4/13-23G2 (city of Long Beach, Silverado well 1) to as little as 180 feet between Anaheim Street and the coast (pi. 19 for extent of the Silverado water-bearing zone in the west basin and fig. 2 for thickness). Water of the Silverado zone is effectively con-fined by the overlying deposits of low permeability. The water is a typical sodium bicarbonate water; dissolved solids ordinarily range from 200 to 325 ppm and chloride ranges from 20 to 30 ppm. Hard-ness is about from 80 to 120 ppm in waters from the upper part of the zone, but it is about from 35 to 80 ppm in waters from the central and lower parts of the zone. Southwestward beyond the Dominguez Gap and toward the Palos Verdes Hills, the dissolved-solids content increases to about 400 ppm and the chloride content increases to at least 100 ppm. (See p. 180.) The increase in dissolved solids is due to blending with locally occurring connate water. The'water is of the type that is yielded from wells 5/13-6D1 and 6D2. It is a sodium chloride water in which the chloride content has ranged between 364 and 510 ppm for the period of record. These chloride analyses are shown on figure 34. The chloride analyses of water from wells 4/13- 30G1 and 31E1 also are shown for comparison. The chloride content of these has ranged between 25 and 67 ppm. These two wells show little, if any, effect of blending with the connate waters.
3. The upper division of the Pico formation of Pliocene age, which, in its lower part, includes several layers of medium- to coarse-grained sand of fair permeability. It is separated from the Silverado zone by

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PIOURE 34. Chloride content of waters from wells 5/13-6D1 and 6D2, also from wells 4/13-30G1 and 31E1, showing effect of connate water in the Silverado water-bearing zone adjacent to the Palos Verdes Hills.

impermeable beds of silt and clay, ranging in thickness from 200 to 650 feet. The permeable beds in the upper division of the Pico forma-tion contain essentially fresh water, not now tapped by wells. For the vicinity of Dominguez Gap, the quality of the water from the upper division of the Pico formation is known from analyses of water from two wells: 4/13-12A2, in the northern part of the gap, and 5/13-3H, just northeast of Terminal Island. Both wells contain sodium bicarbonate waters. The water from well 12A2 contained only 689 ppm of total solids and 58 ppm of chloride (see also p. 183); the water from 5/13-3H contained 750 ppm of total solids and 130 ppm of chloride. Except for their high sodium percentage, these waters are suited to many ordinary uses and are fairly comparable in quality to some waters currently used for irrigation and other purposes.

REVIEW OF CONTAMINATION

Of the three water-bearing zones described, gross contamination occurs solely in the uppermost the Gaspur water-bearing zone. In that zone, contamination may have begun as early as 1913 at the coast. By the middle twenties, water of depreciated quality had been drawn from many wells tapping the Gaspur zone within half a mile of the coast.
By 1931, contamination in the Gaspur zone had become intense; in addition to the coastal contamination, two other areas of contamina-tion existed farther inland: one area was along the west margin of the Gaspur zone near the intersection of Alameda and Dominguer.

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Streets, in sec. 10, T. 4 S, R. 13 W.; and the other area was along the eastern margin of the zone between 223d Street and Wardlow Road, about 4 miles inland from the coast. These areas (pi. 16) are sepa-rated from the coastal area of contamination by a reach of compar-atively fresh water in the Gaspur zone. The detailed conditions of contamination within these three areas have been shown in the ante-

cedent report (Piper, Garrett, and others, 1953, p. 178 and pi. 17). In all three depreciated areas, the contamination has been ch,aracter-ized primarily by an increase in chloride and in sodium.
For the coastal contaminated area, the source doubtless is ocean water, which presumably is in hydraulic continuity with the water body of the Gaspur zone at an offshore outcrop and which occupies dredged channels of the Long Beach harbor. Wells near the coast yield contaminated water with a comparatively low calcium-mag-nesium ratio; this fact indicates that an oceanic source is responsible for that contamination.
For the area of contamination along the west margin of the Gaspur zone near the intersection of Alameda and Dominguez Streets, evi-dence (not presented here) suggests that the focus of contamination may lie to the west in upper Pleistocene deposits which probably are in local hydraulic continuity with the Gaspur zone. This contamina-tion is believed to have been caused chiefly by downward percolation of contaminated waters from above and partly by surface discharge of oil-field brines on the southwest flank of Dominguez Hill (Piper, Garrett, and others, 1953, p. 70 and 191). Here, contaminated waters from wells contain high sulfate concentrations as well as high chloride concentrations the sulfate-chloride ratio is appreciably greater than that of ocean water. The high sulfate concentration is believed to have been derived from the overlying shallow and unconfined waters, in which the native sulfate content presumably has been augmented by the addition of industrial wastes high in sulfate.
For the area of contamination along the east margin of the Gaspur zone between 223d Street and Wardlow Road, the increase in salinity is characterized by moderate or, in some cases, slight increase in sulfate concurrent with gain in chloride. Presumably, the contam-ination here has resulted from overland discharge of waste waters from the oil operations on the Signal Hill uplift and from the dis-charge of brines to the Los Angeles River from the sumps of Oil Operators, Inc.; at times, this discharge has made up the total flow in the river. For these two inland areas, the postulation that con-tamination has entered from, or is transmitted through, overlying deposits to the Gaspur zone is based in part on three facts: (1) Because of the somewhat permeable character of the deposits overlying the Gaspur zone, they allow downward percolation; (2) south of

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Spring Street, the water in the Gaspur zone is under a lower head than the unconfined water in the shallow deposits; north of Spring Street, the water levels in the two bodies are essentially the same but the uneonfined water is more saline and has a greater density; and (3) the sulfate content of the very saline unconfined waters in sec. 10, T. 4 S., R. 13 W., is a source of high sulfate-chloride contamination in the Gaspur waters at the west edge of the zone; at the east edge of the zone, the presence of saline waters at land surface has been long established, and the effect of these on the concentration of the uncon-fined waters is well known. For example, a sample of water collected November 18, 1946, during dewatering operations for a proposed sewage pumping plant at Willow Street, just east of the Los Angeles River, contained 1,260 ppm of chloride. This site is 1.9 miles north of the farthest inland reach of tidal water in the Los Angeles River. For analyses of waters in the two areas of contamination, see Piper, Garrett, and others (1953, table 30, analyses 4/13-10G3, 14L1, 14M3, 14M8, and 14Q2).
Underlying the Gaspur zone, but separated from it by impermeable layers, the Silverado water-bearing zone has not as yet been contam-inated. However, several wells tapping the Silverado zone 4/13- 20L1, 21R1, 31E2 yield water containing somewhat more chloride than exists there normally; presumably, these wells are inadequately cased through inferior waters in the upper Pleistocene deposits which there overlie the Silverado zone. As long as these wells are pumped, lateral movement of the contaminated waters in the Silverado zone is retarded. On the flank of the Palos Verdes Hills, the water yielded from well 5/13-6D1 is decidedly inferior in quality and is presumed to be a native diluted connate water. (See p. 180, also fig. 34.) Con-tamination of the Silverado zone may eventually develop from heavy pumping of wells tapping the zone, which would thus encourage the northward and eastward movement of this inferior native water. Because it is so widely contaminated in Dominguez Gap, the Gaspur water-bearing zone is not now intensively pumped in that area. However, because the pressure level in the Silverado zone beneath is from 40 to 80 feet below the pressure level in the Gaspur zone, there is grave danger that the Silverado zone will become contaminated by downward circulation of saline water from the Gaspur zone, chiefly through abandoned wells that penetrate both zones. Therefore, in each case of abandonment of a well tapping the Silverado zone in Dominguez Gap, the casing should be plugged with cement or other impermeable material to prevent downward circulation of water from the Gaspur zone after corrosion has developed leaks in the casing.

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CONTROL OF SALINE ENCROACHMENT

NEED FOB RESTRAINT OF ENCROACHMENT

In preceding sections of this report it has been shown that saline encroachment from the ocean is the principal source of contamination in the west basin, and that contamination by industrial and oil-field wastes, although substantial, is localized chiefly in the vicinities of Dominguez Gap and the Baldwin Hills. In part, disposal of oil-field brines and industrial wastes at the land surface or in stream courses has been eliminated in recent years by the responsible agencies; also, Los Angeles County recently has passed an ordinance prohibiting disposal of wastes in such a way as to be injurious to the ground-water supplies. Doubtless this ordinance will reduce the discharge of saline or acid wastes at the land surface in the future.
The continued inland advance of ocean water at present, or accel-erated, rates would result in ultimate destruction of the ground-water basin beneath the Torrance-Inglewood subarea. It is true that, at the present rate of landward advance of the saline front, many years would elapse before saline waters from the ocean would move entirely across the basin. As salt waters were drawn across the basin by con-tinued excessive draft, however, well fields would be abandoned progressively as they were engulfed by salt water. Ultimately, the widespread encroachment would force a reduction in draft, and water levels in the basin would rise to sea level; however, the rise in water levels to sea level probably would not occur until the basin was essentially fully underrun by salt water.
If water levels on the inland side of the Newport-Inglewood barrier remained about at sea level, underflow across the barrier would diminish in proportion to the rise of water levels on the coastward side and would cease if the levels were equalized. In such circum-stances, the only continuing replenishment to the Torrance-Inglewood subarea would be by penetration of water from the land surface, which is estimated to constitute about half the current fresh-water replenishment. Except in the two water-table reaches of the Silverado zone and correlative aquifers along the west coast, replenish-ment from land surface would penetrate into the shallow water body and into the upper Pleistocene deposits. Even if water levels in these deposits ultimately should be raised many feet above sea level, it is believed that confinement of the Silverado zone is sufficiently effective to trap saline waters in the confined segments of that aquifer. Indeed, the saline waters on the coastal side of the barrier then would threaten to encroach inland beyond the barrier, and from Long Beach to the Baldwin Hills the water users of the main coastal basin would in turn be faced with the need for effective control along the
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barrier, just as the water users of Orange County face that need. Such a condition, even though it could not occur for several decades, should not be allowed to develop. It would appear that the people of the west basin will benefit from conservation of ground water and maintenance of head in the main coastal basin, and the people of the main coastal basin have a direct interest in the protection of the west basin from ultimate destruction by saline water.
The pending adjudication of water rights in the Torrance-Inglewood subarea was instituted because of recognition that the water supply was being excessively depleted and was being replaced by salt water. The California Division of Water Resources has been appointed referree to investigate physical facts involved in the action, including the amount of water that may be safely withdrawn or diverted annually from the basin, and the limitations on pumpage from the basin which would permit the recovery of ground-water levels therein to the elevation at which infiltration of salt water would cease, within any given period (Gleason, 1946). The Division is now (1948) engaged in an intensive and thorough study of the problems at issue in the adjudication. 16
In these circumstances, the following discussion of methods for control of saline encroachment is limited to (1) pointing out certain general conditions that exist with respect to the problems of control, and (2) indicating possible protective measures that it may be advisable ,to investigate more fully prior to the adjudication of the water rights.

METHODS OF CONTROL GENERAL ASPECTS

In most ground-water basins bordering on the ocean, if water levels have been drawn below sea level and ocean water has encroached

beneath the land, the most effective long-term program for restraining or driving back the saline waters depends upon raising water levels throughout the basin to a sufficient height that fresh water at the saline front will displace salt water seaward. If such levels are to be maintained, a long-term basin-wide balance of draft and replenish-ment must be attained. Such raising of water level above sea level throughout a basin ordinarily does not appreciably affect the quantity of replenishment.
In the Torrance-Inglewood subarea of the west basin, however, about half the replenishment currently (1946) is derived by underflow across the barrier features of the Newport-Inglewood uplift. The quantity of this underflow varies in proportion to the differential in water levels across those features. Thus, if restraint of ocean water

i« The California Division of Water Resources completed its intensive study for the adjudication in 1952.

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ultimately should be achieved by raising water levels above sea level throughout the basin, and if levels on the inland side of the barrier features should remain at sea level, the coastward pressure differential would be eliminated and the underflow across the barrier features would cease. Then, the only replenishment would be the result of infiltration from land surface, by natural or artificial means, or by recharging through wells. Because the ground-water supply of the main coastal basin in Los Angeles County, as estimated by Gleason (1947, p. 159) is currently overdrawn by about 12,000 acre-feet per year (21-year base period), and because draft for domestic and industrial use in that area is increasing, it appears unlikely that water levels inland from the barrier features will be far above their present position for many years to come. They may drop many feet below sea level, however, at times of prolonged drought.
Therefore, it appears that the natural ground-water yield from the Torrance-Inglewood subarea would be substantial only if salt water could be restrained by local control near the coast and if at the same time, water levels immediately coastward from the barrier features could be held sufficiently low to maintain a substantial pressure differential across those features.

CONTROL ADJACENT TO SALINE FRONTS

There appear to be only three physical possiblities for local control of the saline waters. Possibly none of these would prove economically feasible, but the methods are appraised briefly in following paragraphs. In order of probable increasing feasibility they are: (1) the con-struction of artificial subsurface dikes or cutoff walls, (2) development of a water-level trough coastward from the saline front, and (3) maintenance of fresh-water head above sea level immediately inland from the saline front. These same three possibilities have been discussed in an earlier report concerned with restraint of sea-water encroachment from Long Beach to Newport Beach (Poland, 1959).

CONSTRUCTION OF ARTIFICIAL SUBSURFACE DIKES

Movement of saline water farther inland could be wholly prevented if it were practicable to construct impermeable subsurface dikes or cutoff walls across the full cross section of the water-bearing materials at the saline fronts. Such dikes probably could be constructed by injecting some form of grout or emulsified asphalt into closely spaced wells. Along the west coast from Playa del Key to the Palos Verdes Hills, however, a dike about 12 miles in length and as much as 500 feet thick would be necessary. Presumably, at least several thousand wells would be required to accomplish such an operation. Along the 4-mile reach of the south coast between the Palos Verdes Hills and the Los Angeles River, wells as much as 1,000 feet deep would be re-

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quired. Therefore, the work required to seal both coastal reaches would be very costly and probably would be impracticable from an economic standpoint.

DEVELOPMENT OF A WATER-LEVEL TROUGH COASTWABD FROM THE SALINE FRONT

The saline front along the west coast probably could be held back by installing and pumping a line of wells seaward from the front in order to develop a water-level trough deep enough to maintain a seaward hydraulic gradient continuously along the front. Such wells should be placed as far coastward as possible, while still main-taining the seaward gradient at the saline front. It would be neces-sary for the wells to be spaced close enough to each other to intercept all inland moving salt water. Establishment of such a water-level trough would result in substantial drawdown of water levels inland from the saline front before stability would be achieved. Such a water-level trough would draw substantial amounts of fresh water from the inland side of the trough; waste of this fresh water would reduce, and possibly eliminate, the useful yield of the ground-water basin. The water discharged from the wells would be highly saline, and doubtless, it would have to be discharged coastward from the line of wells possibly piped to the ocean. If so, many miles of pipe line would be required.
For the 4-mile reach from the Palos Verdes Hills to Long Beach, the position of the saline front is not known. Thus, before a line of wells could be constructed to intercept the northward advance of saline waters from beneath San Pedro Bay, an exploratory drilling and water-testing program would be required to determine the position of the front inferred to be present in the Silverado water-bearing zone in the vicinity of Terminal Island.
Obviously, a large number of wells and pumps would be required to establish and maintain such a trough. Also, the cost of pumping waste water would be very substantial. The most serious feature, however, is the waste of fresh water, which could not be avoided in such an operation. For these reasons, it is extremely doubtful that economic justification for such a program could be established.

MAINTENANCE OF FRESH-WATER HEAD ABOVE SEA LEVEL

The most feasible method for local restraint of saline encroachment appears to be maintenance of the fresh-water head at an effective height above sea level at, and immediately inland from, the saline front. The effective height above sea level would depend upon the depth to the base of the permeable deposits. For coastal waters in contact with the ocean, the thickness of a fresh-water lens floating on salt water is a function of the height of fresh water above sea level and the specific gravity of the salt water. This is known as the

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Ghyben-Herzberg principles; it has been described and applied by Brown (1925). For ocean water with a specific gravity of 1.025, the thickness of the floating fresh-water lens would be 41 times its height above sea level that is, it would extend 40 feet below, for each foot above, sea level.
Thus, along the saline front from the Palos Verdes Hills to Hermosa Beach, where the base of the Silverado water-bearing zone is as much as 500 feet below sea level (pi. 3C), a fresh-water head about 13 feet above sea level would be required to displace ocean water to the base of the Silverado zone. Along the full reach to the Ballona escarp-ment, the depth to the base of the water-bearing beds ranges from 500 feet to less than 100 feet; therefore, locally, as little as 3 feet of fresh-water head above sea level would suffice. Along the south coast inland of Terminal Island, where the base of the Silverado zone locally is as much as 1,000 feet below the land surface, heads as much as 25 feet above sea level would be required to displace the salt water. Because the contact of the Silverado zone with the ocean is believed to be about 8 to 10 miles south of Terminal Island, encroachment of saline water under the Ghyben-Herzberg principle may be delayed considerably even under favorable geologic conditions.
To achieve an effective fresh-water head along the saline front from the Palos Verdes Hills to the Ballona escarpment, two steps would be essential: (1) Discontinue pumping draft inland from the saline front for as great a distance as practicable; (2) practice artificial recharge along and immediately inland from the front. Such recharge could be undertaken on the north flank of the Palos Verdes Hills by in-troducing water in pits or trenches excavated in sand of the San Pedro formation (Silverado zone), where it is exposed or close to the land surface (pi. 2); similar methods possibly could be used in the sand-dune areas that overlie the main water table south of Hermosa Beach and north of El Segundo. North of El Segundo, spreading from one or more trenches at the land surface might suffice to build up an effec-tive level (3 to 5 feet above sea level). In the central pressure area from Hermosa Beach to El Segundo, and probably in much of the area south of Hermosa Beach, recharge presumably would have to be obtained chiefly through wells or deep shafts.
So far as known, recharge through wells to form a fresh-water dam along the west coast for the purpose of conservation and restraint of ocean-water encroachment was first proposed by Dockweiler (1932, p. 21 and 83-86) in a report to the Los Angeles County Flood Control District. He proposed that water be diverted from the Los Angeles River at Del Amo Street through a canal to a storage reservoir, and after desilting and treatment, the water be injected into a line of 16 wells about 400 feet deep and spaced about 350 feet apart, in the Re-

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dondo Beach area so as to form a fresh-water ridge parallel to the saline front. The recharging capacity of the wells (20-inch diameter) was estimated to be about \% to 2 million gpd per well, and the con-templated salvage of water, previously wasted to the ocean, was 10,000 acre-feet per year.
Possibilities for replenishment of the basin by recharging reclaimed sewage water through wells have been discussed by Goudey (1946, p. 23-32) who has included an estimate of the cost of recharge by such means, based on the proposed introduction of 53,000 acre-feet per year of reclaimed sewage water into the ground, with a design capacity 50 percent in excess of this to provide for additional recharge as ex-traction increases.

It is not within the scope of this investigation to explore the design possibilities of a well-recharging system, either as a line of wells to produce a fresh-water ridge, or as a widely distributed system to build up water levels generally through the basin. However, it is believed advisable to point out that recharging through wells is still in the experimental stage (Meinzer, 1946). Thompson (1942) has. prepared a brief outline of principal reports on the subject prior to 1941.

So far as known to the writer, recharging through wells has not been practiced widely nor with much success in southern California. Specific examples have been described by Lane (1934) and by Mitchel-son and Muckel (1937, p. 10 and 74-75). However, recharging through wells has been extensively practiced in the midcontinent area and in the East for disposal of oil-field brines and for repressuring of oil sands by water drive. It has also been used with considerable suc-cess on Long Island, in connection with the return of cooling water to the ground; Brashears (1946) has reported that in the summer of 1944 over 200 recharge wells and several recharge pits were returning water at a combined rate of about 60 mgd.
The Silverado water-bearing zone in the Torrance-Inglewood sub-area is a thick and permeable aquifer. Yields of as much as 1,000 to 2,000 gpm with moderate drawdowns, ranging from 10 to 50 feet, are common. (See table 5.) Along the saline front from Redondo Beach northward to the Ballona escarpment, the land surface almost everywhere is more than 100 feet above sea level; therefore, recharging heads as much as two to three times as great as the average draw-downs could be applied. It seems reasonable to expect that, if clear, stable water were available for recharge, infiltration rates in excess of 1 cfs per well might be obtained for substantial periods of time. However, clogging of recharge wells can develop from several causes, such as silting, blocking of sand and gravel pores by air or other gases liberated by drop in pressure, bacterial or other plant growths, and

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chemical precipitation. Therefore, to furnish specific basic data it is suggested that, when suitable water can be obtained, experiments be made to determine how rates of recharge through wells compare with rates of pumping and whether effective recharge can be maintained for substantial periods of tune in single wells. Possibly, certain wells now abandoned (about at the saline front) could be utilized. After such information has been gained from several wells of both plain-, and gravel-packed construction a program for possible artificial re-charge through wells could be analyzed on a much firmer basis than is now (1948) possible. 17

BASEST-WIDE RAISING OF WATER LEVELS

If it is decided ultimately that restraint of saline encroachment by local control is economically impracticable, it would appear that the only other alternative for preservation of the ground-water basin is to raise water levels above sea level throughout essentially all the basin. Doubtless such a program could be accomplished over a period of time by reducing withdrawals sufficiently below replenish-ment, and possibly by supplementary artificial recharge. Obviouslyr the time required to raise levels would depend in part upon the magnitude of reduction in withdrawals and the amount of artificial recharge, if any. If water levels are raised above sea level through-out most of the basin, some continued underflow across the Newport-Inglewood barrier could be induced by a concentration of pumping operations along the coastward side of the barrier so as to draw water levels below the inland levels. Without such underflow, and without artificial recharge, the perennial yield of the basin would be only a small fraction of the present withdrawal.

i' Since release of the present report to the open file (in 1948), the Los Angeles County Flood Control District in 1950 made experiments to test the possibility of preventing or retarding saline intrusion along the coastal margins of the west coast basin. These experiments included the use of an abandoned well as in injection well, the operation of a spreading basin in the sand-dune area east of Redondo Beach, and the operation of a spreading basin and bored-pit injection wells near El Segundo (Laverty, Jordan, and van der Qoot, 1951).
As a result of the investigations, the California Legislature provided $750,000 for investigation and studyr Tith the objective of formulating plans and design criteria for the correction or prevention of sea-water in-trusion. Most of this money was used for the installation and operation of an experimental recharge lest at Manhattan Beach in the west basin, operated by the Los Angeles County Flood Control District under nontract with the State. The findings obtained from the funds appropriated by the State legislature are described in a report by the State Department of Water Resources, now (1956) in preparation. The re- «ults of the operation of a line of recharge wells at Manhattan Beach have been described briefly by Laverty and van der Qoot (1955), who have made the following conclusions (p. 907):
The investigation of the prevention and control of sea water intrusion has established that, for an area with comparable geologic and hydrologic condition to the west coast basin: (1) Prevention and control ean l>e successfully realized in a confined coastal aquifer by recharge through wells. (2) Recharge can pressurize x confined aquifer continually through a given reach, thereby reversing a preexisting landward gradient End nreventing further sea water intrusion. (3) Recharge will provide significant replenishment to the inland round water basin with only a relatively small oceanward loss of fresh water. (4) Recharge can be per- 'irmed in an aquifer previously degraded by sea water intrusion and within the physical limitations as i" stablished at the test site will not have any consequential deleterious effect on inland pumped supplies, """i fact, all evidence collected to date indicates that the degraded portion of the aquifer can be reclaimed ' T recharge through weJls.

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In the vicinity of Dominguez Gap, raising the pressure level of the Silverado water-bearing zone above sea level would be the only wholly effective procedure for protection of that aquifer from contamination now present in the Gaspur water-bearing zone. That contamination now is moving slowly southwestward into the unnamed upper Pleisto-cene deposits and, under present conditions of depressed water level beneath, ultimately it would invade the Silverado zone extensively.

WELL RECORDS

Records of the water wells in the Torrance-Santa Monica area are given in tables 26 and 27. Table 26 contains brief tabulated descriptions of essentially all the active or potentially active water wells, and of those abandoned wells for which data are available pertinent to the objectives of the investigation. All wells described in table 26 are in the coastal zone of the Torrance-Santa Monica &rea. Part of the descriptive date resulted from a field canvass of water wells by Alien Sinnott and A. A. Garrett, from October 1943 to June 1945. These data supplement antecedent information made available to the Geological Survey by many agencies, both public and private.
The field canvass of water wells in the Torrance-Santa Monica area was carried northwestward from Dominguez Gap to the vicinity of Santa Monica specifically to the north boundary of T. 2 S., plus sees. 31-33 in T. 1 S., R. 14 W., and sec. 36 in T. 1 S., R. 15 W. Thus, for the full reach of the coastal zone of the Torrance-Santa Monica area as shown on plate 2 (about 240 miles) the field canvass by the Geological Survey has covered all but 22 square miles between Santa Monica and Beverly Hills and contiguous to the Santa Monica Mountains.

Descriptions are included in table 26 for 1,843 wells in the coastal zone; about 590 of these wells were not covered by any of the data antecedent to the field canvass by the Geological Survey. Of the 1,843 wells, 474 are in the area east of Vermont Avenue and south of Artesia Street, which was canvassed during the investigation of the Long Beach-Santa Ana area.
Table 27 presents a tabulation of the data available for wells in the 40 square miles of the inland zone and in the 22 square miles of the coastal zone flanking the Santa Monica Mountains and not canvassed by the Geological Survey. None of these wells has been visited by the Geological Survey, and the data here classified have-been obtained wholly by local agencies. For these 62 square miles, the 225 wells listed in table 27 probably include about all wells for which local agencies have collected logs, chemical data, or periodic

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water-level measurements; the table also includes most of the wells-now active in that area.

Locations of all wells listed in tables 26 and 27 are shown on plate
2. In the canvassed area, all wells that could be found were located either by a pace traverse, by Brunton compass intersection, or by an odometer traverse. In a few cases, such as the well field of the city of Inglewood at Centinela Park, the weUs were located by using a planetable and telescopic alidade. Those abandoned wells which could not be found in the field canvass were located by means of the master maps of the California Division of Water Kesources. Original records of the field location and canvass are in the files of the Geologi-cal Survey.
For the 62 square miles of the Torrance-Santa Monica area not covered by the field canvass of the Geological Survey specifically, the 22 square miles of the coastal zone flanking the Santa Monica Mountains and the 40 square miles of the inland zone locations of wells were plotted directly from the master maps of the California Division of Water Kesources, the Los Angeles County Flood Control District, and the Los Angeles Department of Water and Power. The three principal systems of numbers for water wells in the area, are (1) the serial-numbering system of the California Division of Water Resources, (2) the location-numbering system established by the Los Angeles County Flood Control District which has been adopted by several other agencies, and (3) the numbering system of the Geological Survey, based on a projection of the rectangular land-survey lines (described on page 11). In addition, the Los-Angeles Department of Water and Power applied a location-num-bering system to several hundred weUs within the area in connec-tion with its former extensive program of measuring depth to water. The serial- and location-numbering systems have been described in an earlier report (Sinnott and Garrett, 1946).
In tables 26 and 27 the wells for which data have been made* avail-able to the Geological Survey by other agencies are those which are numbered in each of the three systems or carry numbers of the Los-Angeles Department of Water and Power as well as "USGS" num-bers. All wells canvassed initially by the Geological Survey, and for which there are no previous data, may be readily identified in table 26 by USGS numbers only.
Table 28 presents a lithologic description of typical water wells in the coastal zone. Field analyses of waters from wells in the coastal zone are given in table 29. Chemical analyses of native and con-taminated waters from wells in the area are presented in tables 30* and 31.

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TABI^E 26. Description of water wells in the

Type of pump: Al, air lift; O, centrifugal; J, jet-centrifugal; P, plunger; T, deep-well turbine. Power: Use of well: A, abandoned and generally destroyedj Dom,, domestic; Ind, industrial; Irr, irrigation; Obs, Analyses and measurements: 0, three or fewer "complete" chemical analyses; Or, four or more "complete" of cuttings; W, miscellaneous water-level measurements; Ws, periodic measurements at about semi-ments at about weekly intervals; Wr, water-level'recorder operated currently. Symbol followed by [Minor area at north end of coastal zone

Identification of wells

USGS Serial
No. 2

Loca-
tion
No. 2

LADWP
No. 3

Owner or user

Well data

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JH

"*"* W
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Water
zones i

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ft

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M m
OJJ

43

B

T. 1 S., B. 14 W.

1/14-31B1...

32D1.
QOT1

32K1..

32ML.

32M2-

32M3-

32M4-

32R1._

32R2._

33C1...

33C2

B-12m

B-12
B-12r

B-12s

B-12v

B-12aa

B-12t

B-12fE

B-12p

B-12q

B-120

2615

2625
2636C

2636D

2626G

26261

2626E

2626M

2636A

2636B

OAJ.R A

22-C-24

99 r1 Q1

telyou.

Water Co.

City of Beverly Hills:

Cadillac well 1 .

or 2.

2A.

Water Co.
- do .

Houser.

151

99
95

91

91

Q1

92

92

93

91

112

114

50

362
425

310

354

415

340

464

520

388

7

26
19

26-16

16

16

26-16

12

12

12

16

228

110
204
226
276
26
185
238

120
218
278

52

6
8
12
13
58
23
88

5
22
16

T. 2 S., B. 13 W.

2/13-30N1..
31B1...
31C1...
32C2___
31KL.

31K2..

32C1...
32C2

' 32C3
32C4...
32D1_.
32F1...
32F2...

32F3

32F4...
32L1...

B-51b
B-52h
~B-52i"~

B-57a

B-52f

B-57m

B-57p

B-57b
~B-57g"~

B-57h
B-57f

B-57i

B-57J
B-57e

1413
1424
~1414A"

1425A

1414

14341
1434J

1334
~i434E"~

1434F
1434D

1434G

1434H
1434C

11-A^20
ll-A-17
ll-A-18
ll-A-19

ll-A-23

ll-A-15
ll-A-16
ll-A-24

ll-A-25

Mrs. Ida E. Barrett _

.. do __ , .
..... do_
Southern California
Water Co., Broad-
way plant, well 1.
Formerly John Hayes,

Formerly Chapman. ..
Southern California
Water Co:,
Towne plant, well 2.
Formerly J. DiVasto-.
__ .do. ____ . ....
J. F. Withers .
Formerly Kmkaid.-.-
Formerly .American
States Water Serv-
ice Co.
Southern California
Water Co., Towne
plant, well 1.
H. HavUl-.-l

Hefley (formerly
Davis.)
Southern California
Water Co.:

140
132
133
133
130

133

132
130

133
134
132
127
127

127

127
123

165
395
"50676"

243

416

60
800

150
"365"""

890

900

65
170

7
16

12

10

7
14

,..-

12

7
7

......

370
384

604

636

"§§3"

......

6
13

30

8

~~"§2~

See footnotes at end of table.

WELL RECORDS 275

coastal zone of the Torrance-Santa Monica area

E, electric motor; I, internal combustion; M, manual; S, steam; W, windmill.
observation; PS, public supply.
analyses; Op, three or less "partial" analyses; Cpr, four or more "partial" analyses; L, driller's log or record annual intervals; Wm, periodic measurements at monthly or less frequent intervals; Ww, periodic measure-"d" indicates measurements discontinued.

excluded; locations of wells not verified in field]

Water zones '
Continued

Character of
material

Pumping data

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*C8 S

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ft

B
AH

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 1 S., R. 14 W.

Gravel ....
.. do.... ... ...
do.... ..
.. do....--.-...
Gravel and sand . .

__ do ....

A.. ....

Obs ....
A.. ....

Obs... ....

A.... ...

PS ....

A.- ....

Obs ....

A.

A._

A ....

A. . ...

Wsd.. ....

Cpr, L, Ws-.-_-

Or, L, Wm

Op, L, Wsd .

Or, Wm.........

Op, L, Wsd.....

Or, Wm_.. .

L

L-.- ....

L.-. ... .

Wmd. ....

W-468, well 18.

W-139, weU 585 (Santa
Monica).

LACFCD, well 2626J.

W-139, well 575 [Santa
Monica).
W-139, well 576 (Santa
Monica).
W-139, well"533 [Santa
Monica).

T. 1 S., R. 14 W.

Gravel ______
..... do........ ..

. do-...

355

720

§6.5

52

T, E

T, E

Obs....
Obs.......... .
A.. ....

PS......

A.... ... .

A. .
Obs.......... .

A... .... ..
A. .

A...
A. ..

PS... .... .

Wmd, Ws --
L, Wmd, Ws-.-
Wmd-... ....
Wmd- .....--
C, Op, Wm.

L, Wmd.. ......

Wmd._ ....
Or, L, Wm..

W... ....
Wmd. .... -.
L, Wmd.. .....
L, Wd.. ....
Wmd _ ....

C, Cp, Wd ..

Wmd.. ....
Wsd............

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TABLE 26. Description of wetter wells in the coastal

Identification of wells

usas Serial
No. «

Loca-
tion
No. *

LADWP
No. *

Owner or user

Well data

<D d
{3*

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fl 1"
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ft

Water
zones !

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44 aj

S3

*

T. 2 S., R. 13 W Continued

2/13-32N1..

32N2-.

qorii

ao/~i9

32Q3-

32R1-.

32R2-.

32R3..

B-57

B-57n

B-57k

B-570

B-57L

B-62c

B-62o

1425

1425B

1435

1435B

1435A -

1445B

1445E

ll-C-29

1.

2.

Powell.

Kirst.

City of Los Angeles,
99th Street plant:
Well 1 .. -

Well 2 .

Well 6 -

125

125

199

120

121

118

118

118

550

656

575

550

620

610

927

12

16

16

10

14

16

20

20

270
300
387
479
290
466
569
588

305
535
309
326
537

5
10
10
20
17
25
14
44

38
17
15
15
18

T. 2 S., R. 14 W.

2/14-3H1...

3K1...

3K2...

3M1...

3M2...

3Q1 .
4A1-...

4C1-...

4G1....

4M1
4N1...

5B1_.__
5B2... .

5C1 .

5C2,-._

5D1...

5D2 ...

B-15q

B-156

B-15C

B-15d

B-15
B-15f

B-12z

B-15n

B-12f
B-12bb
B-12dd
B-12a

B-12u

B-12b

B-12c

2667B

2667A

2657

2657A

2667
2656

2646

2657B

2636
2636E
2626K
2626A

2626P

2626B

2626C

22-D-10

22-O-27

OO fT V)

22-C-16

Water Co.

and Dry Cleaning.

Water Co.
.....do.... ....

..... do........

well").

City of Beverly Hills:

City of Beverly Hills,
Castle, well 1.

Southern California
Water Co.:

Sentney plant:
Welll . .....

Well2_.-..._-

123

111

112

100

103

111
99

OQ

100

118
104

83
83

82

81

88

88

200

233

307

801

661
297

1,240

125

150
300

317
430

752

333

274

269

12

7

12

12

10
12

12

12

10

26-16
18

12

26

16

18

118

182

269

385
530
201

265
296

166
193
214
149
210

29

37

8

7
25
50

20
17

22
15
51
30
47

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

277

Water zones »
Continued

. Character of
material

Pumping data

S

a s

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a
t~

1**
*M
fl

2*

9

Miscellaneous

Use of well Analyses and
measurements

Remarks'

T. 2 S., R. 13 W.

Gravel ....

.....do... ....
.....do. ....
.....do........ .....
.....do............

.....do... ....
.....do...... ....

.... .do... ....
.....do... ....

430

500

95

50.5

T, E

T, E

T, E

T

TCI

T, E

PS.. .. ..

PS

A.
A.. ... .

A.

PS .

PS

PS ..

C, Cp, L, Wsd,
Wm.

Or, Cp, L,
Wmd.

Wd.. ....
L--

Wmd..

Cr, L, Wmd....

C, L-

C, Wwd....... .

W-139, well Iil8 (Be-
dondo).

T. 2 S., R. 14 W.

Sand and gravel
shells.

Gravel and sedi-
ment
... .. do ....

Sand, gravel, and
clay.

Gravel. ....
Gravel and sand _

460508 51

1,010

> 11

31

9

T, E

T, E

T, E

T, E

A.... ....

A... ... .

A....... ......

Obs... _..
A. .....

A. _______

A.............

A...... ....
Irr... .

A ....
PS... ....

PS.... ....

A....... .

A... ... ...

C, Cp

L _ ....

L.. ... .

L ....

L, Wm.. ....
L...... ...

Wmd __ . .....

L ....

Wd _____ . ...
C, Cp, L

Wsd.....
Cr, Cp, Wm. ...

C, Cpr, L, Wsd.

C, Cp, L, Wm,
Wwd.

L........ ....

L........ ....

W-139, well 46. (Santa
Monica); W-468,
well 14.

W-139, well 4£ (Santa
Monica).
W-139, well 47 (Santa
Monica).
W-139, well 481 (Santa
Monica).

W-139, well 52 (Santa
Monica).

W-139, well 577 (Santa
Monica).

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TABLE 26. Description of water wells in the coastal

Identification of wells

USOS Serial
No. *

Loca-
tion
No. 2

LADWP
No. »

Owner or user

Well data

TJ

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Q

Water
zones t

ft
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s§

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A
6-4

T. 2 S., R. 14 W. Continued

2/14-5D3
5D4_._
5D5...

5D6 ...

5D7.__

5D8...

5D9...

5D10..

5E1 .

5E2..-

5F1-...

5F2..._

5M1...

5N1...
5P1 .
5P2..__
5P3-

5P4..._

6B1....

6H1...

7K1...

7M1.__
7M2

7P1..-
7P2 _

8O1....
BT>1

9A1 .

10F1...

10F2...
10L1...

B-12e
B-12ee
B-12n

B-12y

B-12L

B-12k

B-121

B-12d

B-12J

B-13g
B-13e

B-13c

B-13a

B-13h

B-161

2627A
2626L
2626D

2626H

2627E

2627D

2627B

2627C

2627Q
2628A

2628

2628C

2609A

2628B

2668B

22-C-17

22-C-13

22-C-12

22-C-8

22-C-9
22-C-10

22-C-5

22-D-18

22-D-5

WeU3. .....
Well 4.........
WelU.... __

Well 6.........

WeU7..... .

Well 8. .-...

Well 9... __ ..

WeU 10.... .

well 3.

well 2.

SheU Oil Co.-...-..-..

weUl.

.... .do........ ... ...

LAC Chemicals, Inc--

"Vickers 2-4."

Metro-Goldwjm-
Mayer Corp.:
Old welL_._____.__

Sunset Fields golf
course, well 3.

course.

88
88
88

88

88

88

88

88

94

92

102

95

98
105
115
123

110
99
100

93

210

67
57

53
57

165
125
100

116

112
118

279

266

810

287

425

54

290

59

152

260

178.8

69.2

417

47

190

500
26

102
265

185
25
438

572

402
417

12

30

16

12

14

12

7

12

12

10
16

12

14

12

152
172
209
326
492

158
190
225
70
160
248
342

362
23
34
121
145
154
188

15
37
65
127

20

59

68

60
108

122
175

256

220
360
386

8
25
48
16
18

24
17
37
18
64
34
13

8
5
20
11
4
4
36

16
10

36, 25 '

12

6

12

12
22

6
12

182

10
19
36

See footnotes at end of table.

WELL RECORDS

zone of tne Torrance-Santa Monica area Continued

279

Water zones i
Continued

Character of
material

Pumping data

su
-S

11,°

rawdown 8

(feet)

ft

a

£

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 28., H. 14 W. Continued

....

Sand and gravel
__ do ....
... -do... ...
Sand and gravel-
Sand, gravel, and
clay.
.. _ do ... _ r _
Sand and gravel. .
- do- _ ......
Gravel and sand..

Sand and gravel. -
Fine gravel ....
Sand and fine
gravel.
Sand and gravel- -
Sand. _ __ , _
Clay and gravel _
Sand and gravel
__ do ______
..do.-. ....
.. do ....

Gravel ______
do ..
Sand and gravel _
Gravel ______

Gravel ______

Gravel ....

do ....

Gravel ______
- do. ....

Sand and gravel..
-. do... ....

Sand, gravel, and
clay.
Gravel ______
Sand... .. ..
Gravel and sand ...

400

150

350

.

. ...

OCA

550

125

....

....

75

......

T, E

T, E

T, E

T, E

T, E

"p~w~~

....

P, W

T

Tjl

P, W

A.. _ ... _ .
A ... ...
PS... ......

PS.... ....

PS ....

PS ....

PS ....

A...- _ ..

A... ......

A-. .....

A ....

A........ _

A.-... ...
"A"" I II

A... ....
A ....
A...... ...

Tnd. _

Dom/Irr ......

Cp, L, Wd_..._

Cr, Cp, L, Wm.

Cr, Cp, L, Wm.

C, L.... ....

C, L...... .....

C, Cp, L .....

Cp, L . ....

L

L-

Cr, Cpr, L,
Wmd.
Cp, L, Wsd-.

C, Op.. ....
C, Cpr, L, W

Wmd.

L, Wmd. __ ...
W^sd.
Wmd ._.

Cp, L .....

Op..............

Cp. ......

C f^f\
O.L.I .. ... .

C t~^r\

(~*r\ £?::;:::::.-:-
Cp, Ws.. ... .

L.....-. ......

L, Wmd .._.

LACFOD, well 2627L.

LAOFOD, well 2626N.

LAOFCD, weU 2626R.

No casing in well.

W-139, well 606 (Santa
Monica) W-468,
well 15.

280 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLES 26. Description of water wells in the coastal

Identification of wells

USGS Serial No.»

Loca-
tion
No. »

LADWP No.» Owner or user

Wen data

a> "°f

- |

<

?
0>

A

X

(H

So

r

Water
zones"

3 a

o>

Q

«

»s
a
EH

T. 2 S., R. 14 W. Continued

2/14-10L2

10Q1...

J4C1...

14C2..

1 .ifio

1 ,|TJI1

15A1
IfiTtl

18D1-.

1GT71

! 18F1

1ft"P1

18Q1...
19C1

1QH9

19K1

20J2

21M1-.

21N1..

22G1..

22N1..

B-16g

B-16J

B-16C

B-16d

B 1 A
B-16a
B-16b

B-16k
B-13d
B-13b

B-34d

B

-IO*

B-34f
B-341

B-34J

B-34h

B-34g

B-421

Tl_jiOV

TJ _ 4OT

B-42p

B-42m

B-38a

2668A

2669

2679C

2679D

9fi<7O

2679A
2679B
1QQA

2679B
2619
2609B

2619A

1Q1 1

1311A

1*311 TO

1332A

1QOO

lOA-l A

1371A

1*3*71 /"*«

1371B

1352A

22-D-6

22-D-19

22-D-4

22-D-15

22-D-3
22-D-2
22-D-l
10-B-l

OO-W-T1 9

22-C-7

10-A-4

10-A-3

10-A-14

10-A-16

10-A-13

coarse.

ment Co.
..... do....... ....

..... do-.

..... do.. .....

.....do.... ...
..-.do... ... -

Formerly Lugo.... ....

..... do.....

Fox Hills Country
Club:
"Well 1

Well 2... ....

Arthur Vallon.. . .

Oil Co.

Investiaent Co.

.... . do.. --

mann.

bohm.

Nelson.

Angeles, Hyde Park
weHl.

City of Inglewood: Well 8 . - -

130

127

127

127

129
123
203
50

35

131
112
33
145

41

50

60
157

158

151

139

175
186

174

157

160

157

148

531

454

608

1,015

300 to 150
150
150
420
840
388
84

126

265.8
550

350

501

500

200
300

310

230

210
152

122

263

145

290

12

16

16

16

12
12
12
12
16
14
16

12

12
12

14

18

18

10-8
16

7

7

7

18

321

334
362
417
410
435
622
656
666
843
969

29
50
14
53
90
252

55

197

252
288
395
132
196
226
378

148
215
183
208

95
f 180
246

10

13
12
24
23
2
10
2
26
21
4

12
6
34
73
222
20

3

33

20
17
33
27
7
8
33

36
8
23
22

27
IT
39

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

281

Water zones "
Continued

Character of
material

Pumping data

ll

O

rawdown'

(feet)

n

a

h

Miscellaneous

Use of well Analyses and
measurements

Remarks'

T. 2 S., R. 14 W. Continued

- do...... ...
..... do...
-....do..... :....

Gravel _ ... .
.... . do .
..... do...... ....
Sand and gravel ...
..... do . ...
.. ...do...... ....

-....do.... ....

__ do. -.
.....do.... .... .-.

Gravel ....

clay.
Gravel and sand ...

Sand. .. _ .. ....
Sand and gravel _
__ do __ ....
..... do...... ....
.....do... ... ...

Sand and gravel ...
Gravel ....
Sand and gravel _
.. _ do ....

Gravel ....
..... do.... ......
Gravel and sand _

....

....

....

....

T, E

T, E

T, E

P, E

rp TTI

T,

v

E

T, E

T, E

T, E

PS ....

PS... ....

PS

A.... ....

PS
PS

A.. .....

Obs ...

Irr.. ....
Irr.

A.. ...

A...... ... .

A.-. ... .

A........ .....

A... ... .
A-..

A...

A...... ....

A..... ....

A..

L, Wmd, Ws...

Wmd, Ws ....

0, L, Wsd,
Wmd.

Or, L.....

O, Wmd

L.Wmd
W.... _ ....
L
L, Wmd.

L.. ....

O, L, Wmd, Ws.
Op, L.-- - ...

Op..............

O, Op, L,
Wmd Ws

C, Op, L, Wmd.

Cp.. ......

Wsd... ...

O, L..

L, Wmd. .

L.. ....

L.. ....

L. .

L.... ....

L_. ..__

Op, L...

These three wells were
Interconnected.

W-139, weU 213
(Redondo).^
W-139, weU 214
(Redondo).
W-139, well 216
(Redondo).

W-139, well 217
(Redondo).

282 GEOLOGY, HYDROLOGY, TORRANCE-8ANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

usas Serial No.»

Loca-
tion
No. »

LADWP No.' Owner or user

Well data

0)
13

~|
,_, ^

*?
«

*»8-
ft

. ID

1o^
'll

rt* '

;ft

Water
zones 1

D,
R

II
§*

ft

01

Si
A
EH

T. 2 S., R. 14 W. Continued

2/14-22N2..

22N3..

22N4

22N5..

22N6..
22P1...

22P2...

23D1._
23Q1-.

23H1..

23H2._

23H3. .
23N1..

24G1._

24H1_.

25Q1..

25Q2..

27A1-.
27B1...
27C1...

27C2...

2703

2704. .

27C5-.
2706. .
27C7-.

B-38b

B-38d

B-38e

B-38f

B-38u

B-42v

B-42w
B-46a

B-46e

B-46h
B-42n

B-60a

B-51a

B-42g
B-42f

B-42U

B-42t

B-42r

B-42S
B-42C
B-42q

1352B

1352D

1352E

1352F

1352P

1362H

1371D
1381A

1381E

1381D

13910
1372

1401

1403

1362B
1362A

1362Q

1362F

1362D

1362E
1362
1362C

ll-A-3

ll-A-21

10-B-7

10-B-8

WellO . .

Well II............

Well 12...........

Well 13

Well 20...
Well 19 . .

Well 24...

Creamery.

Manhattan plant:
Well 2 ......

Well 3A-

Well 1A

Leuzinger.

Formerly Eliza
Connelly Farrell.

King.. ... .

Inglewood Park
Cemetery 'Associa-
tion:
Well 8-

Well 10 ....

Well 9 ... .

Well 4 .

Well 5
WeU 1 .....
Well 3 ... .

142

144

145

146

165
150

161

142
137

137

137

136
152

139

143

151

152

186
191

159

157

157

157

157
158
157

297

290

282

300

325
314

400

418

588

827

599
339

251

146

125

108

110

375

350

350

302

279
501
335

18

18

18

18

18

18

12

16

20

20
12

12

12

7

8

16

14

86
97
113
173
242
105
176
246
98
122
170
239

184

246
187
188
265
216
267

293
457
505
449
488
720

90

70
100
162

90

44
176
235
188
242
252
148
214
12
136
214

9
13
36
17
23
15
20
21
17
45
25
21

23

8
26
20
27
11
23

52
18
62
30
30
76

8

14
17
11

20

96
19
43
11
4
32
22
32
76
30
22

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

283

Water zones 1
Continued

Character of
material

Pumping data

Gallons per minute Drawdown'
(feet)
o.

PM

Miscellaneous

Use of well Analyses and
measurements

Remarks f

T. 2 S., R. 14 W. Continued

Gravel ______

Gravel ______

Sand and gravel _

sand.

..... do ....

Sand and gravel ...

do....

Gravel ....

do

__ do _____ ..

... -do..... . ....
Gravel ______
do
Sand and shells ....
Sand and gravel ...

Gravel ______
Sand and gravel ...
... ..do-... ....
..... do __._.___

325

700

500

400

600

550

3,050

2,700

-. .

550

40

47

.... .

T,E

T, E

T, E

T, E

T, E
T, E

T, E

T, E

T,E

PS ....

PS ....

PS .... -

PS

. PS.. -
PS ....

PS

PS-. ...

PS ....

PS-, ...
A

Obs -

A... ....

A

A._

A...... . .
A...... ....

Irr. . ...

Irr.. ....

A. ......

A... _ ....
A. _
A ..

Cp, L, Wsd .

O,Op,L,Wsd-_

C, Cp, L, Wsd..

0, L....
C, L, Wsd. .

C, Cp, L, W .

Ws
Wsd...... .

O, L, Wmd ...

C, L, Wsd.

C, L, Wd. __ -
L-.. .

L, Wmd, Ws .

Wmd

L, Wmd _

Wmd.

C .
L--.

C, L, Wmd .

L.

L, Ws ....

L... __ .

L.... ___ .....
Wmd.. ..
TJ.. ....

W-139, well 225
(Redondo).

W-139, well 800
(Redondo); W-468,
weU2.

W-139, well 733
(Redondo); W-468,
well 3.
LACFCD, well 1372A.

W tO I-* H* I-* tO H»

8 8
" <O

tdtdWWW W W W WW

21 "*" 3 rfc
CD "» C3 ^

?: ?? ? ? ??

td *^H P*^^fl
J.J I-»H* H* bS H*

£3 £§£3

,

£?£?

td td td

h-t H* H*
C*3 O3 G3
-*J -*J -*J

g w W

8

OCOCOQO O to O OO Oi O W

ototooto to w o i--tP * *. h-

W ** W' W > ?. ^
* -" <B'~J-
>

OS O O O

fcd 'n
^

? tt

&« >* s

-J 00 00 OOO <O OOOO 00

SSSSSi

>-*ui->to
-~jooa>o

to oo o> oo oo oo

tO W »-*»-* H*
woeoeocoo

' 01 H* H* to en 03 as to i-* to
01 too w wo65i-'*-iS

dO9

!!

M
^)t*
O W
"HS

O

Altitude

(feet) «

Depth (feet) «

Diameter

(inches)

Depth to top
(feet)

Thickness
VlvClJ

HH

i

1
2.

1. H
* t

t

5
8
s
V

Well data

if «
i

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

285

Water zones 1
Continued

Character of
material

Pumping data

I-

||
0

"a

£ 2 03 s""'
it
P

a

a

h

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 2 S., R. 14 W. Continued

Sand and gravel _

-_do . . Gravel and sand. .

. do ..do............. Gravel ....

do
..... do... ....

.....do.... ....

.....do ....
__ do.... __ . ....
.....do... ....
.....do ....

do ....
.... . do ......

275
400

300

420

450

600
600

600
700

------- -------

T,E
T, E

T, E

T T?

T, E

f, E
T, E

T

Y?

T, E

....

P
T,I

Obs ... .

PS .....
PS. ......

PS...... ......

A.. ....

Obs ....
Irr._ ..... .
A ..
A.

A.. ....
to
A.
PS...... ... ...
PS
A
A ...

PS... ....
PS ....

A __ ... ...
Dom. ...
A. -
A ....
A
A..
A ....
Obs... ....
A ...
Dom. to.. ....
A. _ -
A........

Wind, ws. ......

Cpr, L, Wsd
C, Cp, L, Wsd..

C, L, Wsd

L, Wmd __ ...
L.Wsd..... ....
Ww ....

Wsd
C, L

L ....

L....... ... .
L, Ww_
C, Cp, L, Wd...
C, Cp, L.. .

L -

Wmd.. ....
C, Cp, L ...
C, Cp, L

L ....
C, Op
C, L, Wmd.....
Wmd ___ .
Wmd ____ ...
O.L.

Wmd, Ws _ ...
C. ... .

C, Cp, L, Wd
C.Wd ... ...
Wmd ....

W-139, well 175
(Redondo).

W-139, well 177
(Redondo).
W-139, well 132
(Redondo).

9?
du
coi

bd bd

W

u:

toto o MOO

II

? ^ *"* H- 1 *uq , . *2i m

H; -4M ^^i^r

coSoo

CO CO CO oo CO

O) O> O) QS C71

£ S S 2 fc

bdd

toI
X

T Q !>
to to

bd bd

8 <!

ii1

p>.«. IB.^. ht, CO CO CO CO CO tO M JO tO tO Ii

(t> 2. U E? i
" "g. & o!

i-

K \

23 a S 8 £J£5

d O

O

t-*

- i to

8

bOO

Hollywood Turf Club:
Well 2... ...

bd bd bd

bd o
1

1
CO l->

ojfg°!z!°

%*>

*

i * w 3"

CO 01 *» «. <O tO
<I to <l -4 to to

S.I 118

too oo os to 1
-8-

bd bd bd bd bd bd bd

£ ? £ *" U

Q

f ? ?

f
to en o t->

| i|| tf

1

OO & to to O to to
^ OS >U OS 00 tO -4 "J

to co i-> ik)».

ot

oo to o> oo

to coi-'coi-'
CO CO ~4 tO OS

t^ C0inot£

SQGQ
H^OO
SB

?i|

tr<

15

-^'Tf S
Altitude

(feet)

<

Depth (feet)

«

Diameter

(inches)

Depth to top
(feet)

Thickness

(feet)

S 1

§ §
a i

Well data

o".^

S

^

"-at"

287

zone of the Torranee-Santa Monica area Continued

Water zones 1
Continued

Character of
material

Pumping data

1=

ll

P "

a

03 s~'

fi

'l

2

Miscellaneous

X7se of well Analyses and
measurements

Remarks *

T. 2 S., R. 14 W. Continued

. . do...... ....

720
430

....

700

1,500
500

400

- .?.-

70

T, E
T, E

- - - - - -

T,E

T,E
T,E

T, E

T, E

PS............
PS... ....
A. ....
A... ....
A., ...
A. ...
A._ ...
A..
A.
Irr.. ....
Irr

A. ... .
A.............
PS.. ....

A.............

PS.... ....
A.

0, Op, L, Wsd__
C, C~p, L, W .
C, Cp, Wmd __
C, L, Wmd. ..
C, Wd ....
L, Wd....
Wmd. _____
C. ....
L .
Wmd
Cp, L, Wmd ....

C,L...... ...
0, Wd
Wsd ______

Wmd..

Wsd.... ...
Wsd............

W-139, well 174
(Redondo).
LACFCD, weU 1344.
W-139, weU 159
(Redondo).

W-139, well 713
(Redondo), W-468,
well 4.

T. 2 S., R. 15 W.

Sand and gravel...

..... do ....

....

Sand and gravel _

....

....

T T?

T

TTl

....

T ip

A.. .....

PS
A,.. -...
A..... ____

PS ... .

A... ..

Obs_ .
A..... ..

A..... .
A...
Irr. ....

L... .

C, Cp
Wsd.
C, L. ......
C, Cp, Wm. ....

\^Ts

Cp, Wm, Wrd..

\KTcf1

-L.. ....

Wmd ______

W-139, well 678 (Santa
Monica).

LACFOD, weU 2596B.

LACFCD, well 2596O.
LACFCD, well 2596D;
initial depth 865 ft.,
plugged at 464 feet.
W-139, well 820 (Santa
Monica); W-468,
well 16.

W-139, well 833 (Santa
Monica); W-468,
well 17.
W-139, well 693 (Santa
Monica).

IL

IS § s

Oi CnCnCnoK itto: MO9CO to

3 S g o g «

&~2i CL 2**^2«cDi.LQJ 2* S-
<< vj <<j << r^vj *<j v$ ft<<j «<

i^PIPs

xT (4 *<!< tefl

5 IO IO IO IO IOIO IO

. HtOf-itk ecio t->

Oi

§§ gi

OBOO MO O

8 £ s s s

a09
g

?!

?tf
r<
&
~3
^

0

s

Altitude

(feet) «

Depth (feet) «

Diameter

(inches)

Depth to top
, (feet)
Thickness

(feet)

I

a

Well data

* *%

to

.

I

WELL RECORDS 289

zone of the Torrance-Santa Monica area Continued

Water zones 1
Continued

Character of
material

Pumping data

a. «i
if
o

la

&
fi *

Miscellaneous

_

Use of well Analyses and
measurements

Remarks '

T. 2 S., R. 15 W. Continued

..... do __--...

Gravel ____ ...

- - - - - - - - - - -

Gravel.. ....

Gravel..

Sand and gravel _

....

500

-

T, E

T, E

P w
T, E
T, E

T,E
T, E

....

T, I

Irr.. -

A...
A... ... -
A... ... -
A.. -
A... -
A...-. .
A.. ... -

Irr.. ... .
Irr.. ....
Irr.. ....
A..
Irr.. ... .
Irr..... ....
Irr.. ....
A _
A..

A.... ..-..
A... ....
A.. ... .

A....... ...

A ....
A.....
A... . ...
A..... .....
A.....
A __ ....
A...... ....
A... ....
A _ ....
Obs. ....
A..... .... _
A ____ ...
Dom; Irr. .... .

Op, L .....

Wmd
L... ----- -
L

Op, L - ...
Wmd..
L...... ...

L-

L, Wmd..- __
L.. ....

C, L, Ws ....
L, Wmd, Wsd..

Wsd. _ -
L ___ _ ..
Wmd __
L...
Wsd.. ....
L

Wsd. ... .
L.. ....
Wmd, Wa ___
L.. ... .
L... ....
L... ....
L.. ....

L... ....

L... ....
Ws ..-..-...-...
Cpr, L, Ws .....
Werf

C, Cor, Wmd ...

OU wefl.

W-139, well 898 (Santa
Monica).

W-139, well 899 (Santa
Monica).

W-139, weU 890 (Santa
Monica).

W-13Q turall QA^ ffZa-nto,

Monica).
W-139, well 905 (Santa

Monica). W-139, well 952 (Santa,

Monica).
W-139, well 931 (Santa
Monica).

W-139, well 934 (Santa.
Monica).
W-139, well 941 (Santa
Monica).

gp eg ppp p
-

to to
gj en
S S
Q >

fcj^

OS Oi Oi

WWW WW

2-2L.2-S £L2L® o
^~*^ ^-"p* ^* " £ *;, Q

!

88

SB § g

f
<o«o«o«e

W W WW

boto totototo
CnCnCnCn^FtCn
0000 GO 00 00 35

WO W^^W

WWW

to to to
cnCnCn

to totot
CndCTiC

r& SS 1 Q B(R

Q g '

bj C»00 00

CB 0 CB CB

«5 5CO5CO O
Cn oiOi-atO to

O CMtO
IO Oi-^cnCn Oi-^

COtOtOtO
Cn en *. *.

0000 OOOOGO O 00 00 00

V-1 tO tO t

CO Oa Cn -^j O5

O cp
iqSt

S
OOQ

hppta

^CD
O Q

?lf
t*

*h0 O

-*
"a

O

8

Altitude

(feet) *

Depth (feet) «

Diameter

(inches)

Depth to top
(feet)

Thickness

(feet)

Identification of wells

Well data

4H6 coasiai
Water

zones »

WELL RECORDS

zone of. the Torrance-Santa Monica area Continued

291

Water zones '
Continued

Character of
' material

Pumping data

&.

O

te

a

Drawdoi k
(feet)
a

£

Miscellaneous

Use of well Analyses and
measurements

Eemarks '

T. 2 8., R. 15 W. Continued

.... .do ....

. .do. ....
. do

. . do... . ...

.. do ... ...

__ do __. _
..... do.. ...
do
.. do
..do...

- - do-. ,
Sand... ....

Sand
.. do ..-. .

.do.

..do. .
do

450
600
600

600

1,350

1,350

1,350

1,800
1,350

990
345

1,125

1,155

2,100
1,805

24

17

36

32

T, E

T, E

T, E

T, E

T,E
T,E
T,E
T,E

T,E
T,E

T, E

T, E

T,E

T,E
T, E

T,E
T,E

A
A-..
A

A... ...
A.. . .
Obs
A.. ...

A..

PS

PS

PS

A _ -

PS.... .
PS
PS ... ...
PS ...

PS ....
PS

A.... _ ..... .

A......

PS

A.. . ...
PS..... ....

Irr __ .....

Irr.. ... .

PS ....
PS ...

A. ..... .
PS ......
PS
A... __ .

A...... ....
A....

Obs... ..
A.

Cp, L, Wd
C, Cp, L
L, Wd.
L, Wsd. -

L-...
Or, Cpr, L, W-.
Wmd, Ws...
L... -

L . . . ..

Cp, L, W -

Cp, L, Wd

L, Wmd-.

Cp,L,Wd...
C, Op, L.. ......
Cp, L, Ws
Cpr, L, W .

Cpr.L.W... ....
Cr, Cp, L, Wm..

0,Wd... . __ ..

C,L,Wd .....

Cr, Cp, L, Wm..

C,L,Wd -
C,Cp,L ....

C,Wm.. ____

C*r\

C,Cp .
Cr, L.Wmd.. ...

Cr, Cp, L, Wsd..
Cr,Cp,L,Wm-
C,Op,L,W ..

Cp....-. ..

L,Wmd,Ws....
L.Wmd

Electrical ground.

W-139, weU 836 (Santa
Monica).

LACFCD, well 25788.

LACFCD,well2578B.

LACFCD, well 2579.
W-139, well 847 (Santa
Monica).

292 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

TJ8Q8 Serial No.s

Loca-
tion
No. *

LADWP
No. *

Owner or user

Well data

"** » Depth (fet)«

5

Water
zones i

Depth toop
(feet)

Thickness

(feet)

T. 2 S., R. 15 W. Continued

2/15-11R3-.
12B1..

12B2..
12J1
12Q1...
12Q2...
13A1

13B1...

13F1...
1301
13G2-.

13H1..

13J1...
13J2 _
13J3...
13K1..
13K2 .
13K3 .
13K4 _.
13M1__
13M2-.
13M3-.
13M4..

13P1
13P2...

13P3
13P4...
13Q1--
14A1 -
14A2-.
14A3--

14C1-.
14E1-.
14E2-.
14E2-.
14F1...
14H1-.
14J1...
14J2...
14M1..

14P1..
14P2 .
14Q1-.

14Q2--
14E1..

14R2..

15A1 ..
15 A2...
15A3
15A4...
15B1...

B-13

B-lOq

B-13z

B-lOt

B-29s

B-29e

B-34e

B-34m
B-29r

B-29q

B-29p
B-29k
B-29n

B-29m 5-29

B-29t

B-29f
B-29u

B-lOn
B-lOm
B-29g

B-lOy
B-25a
B-25f
B-25g
B-25b
B-29o
B-29i
B-29h
B-25C

B-25d

B-29b

B-29J
B-29a

B-29d

B-8h
B-8a
B-8e
B-8d

2609
2599A

2609O

2599B

1290H

1290A

1300A

1300B
1290Q
1290F

1290E
1280J
1280L
1280K
1280

1290K

1290B
1290D

2589A
2589
1280D

2579B
1270
1270D
1270E
1270A
1280N

1280E
1270B

1270C

lOOnR

1280Q
1280A

1280C

2569C
2569
2569B
2569A

23-D-5

22-C-6

23-D-l
22-C-l

9-B-2

10-A-l

9-B-7

23-D-4

9-B-13

9-B-47

9-B-10

O-R 0

9-B-8

Mayer Corp.

"FT. TTuffinaTi

opment Co.

Formerly J. D.
Machado.

M. Firsick..... ... .
- do-... ...
- do..

. do..... ... ...

Norton Co.
M. E. Gordon

Ranch

Barnes City well 2.
Utsuki. _. .

Water Co.
..do.... ....

E. S. Merrill.. _ ...

Corp.

Southern California
Water Co.:

Pacific plant:
Well 1 .
Well 2... ... ...
Well 3 ... ...
Well 4... _ ...
Formerly T. L.
Qooch.

48
77

80
67
48
51
37

37

34
34
34

33

28
28
32
30
29
29
29
30
30
30
30

25
25

24
25
24
45
44
42

57
48
47
47
47
46
33
37
42

32
26
29

31
24

26

56
55
56
57
58

276
220

520
108
152

622

94

201

167

199
200
212
214

190

89
100

300

200
210

550
300
462

168

178
111
140
37

398
111

50
120

201

165

251
200
225
335
150

14
30-10

10
12
12
10
16

16
12
12

12

12
14
10
14
12
7
12
12
12
12

8

12
10

16
8
16

14
8
12
12
12
7
8
12
12

12

10

16

12
14
10
30-16
12

134

47

29

29
47
77

' 17

134

80
25

45

74

65
72

57

103

21

12
6
87

83

291

98
86

120

120

106
78

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

293

Water zones >
Continued

Character of
material

Pumping data

00 &rj
53 a

O

If
cs 1^
t-t

Q

a

S

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 2 S., R. 15 W. Continued

Sand and gravel _

Gravel ____ ....

..... do ....
do

Sand and gravel

1,400

....

T,E

T

T,E

T, E
T,E
T,E
T,E
T,E
T,E
P,W
T,E

T,E

T,E

T,E

T, E

A1,E

....

T, E

A....
Ind...- ....

A
Obs ..
A... ....
A.... . .. ...
Irr

A....... ......

A... ..... -

Irr..-.

PS
Irr. ...... -
Irr.. -
Irr....... .....
Irr
Irr.. _

Irr
A.... ......
Obs ...
A ....

Irr..
A

A
A.. .....

A
Obs

Irr..

A

A
PS ....

PS ....

A... "X
PS . "..
A

Wmd
C,Cp,L.... .

L....... ... -

Cp, Wmd, Ws..

Wd
Wmd... ...

L.... ... .

Cp,W . .

L, Wd...... ,.

Cp, L, Ws.. ..

Cp... .... . .
C, Cpr.W...... .
Cp, Ws .
Cpr, Ws... .

C, Cpr,W.. .

Cpr, Wm... .....
L,Wsd...... .

Wd.... _
Wmd

L. ....

C, Cp, Wmd _ .
Wmd.
L,Ws .

Cp .
C, Cpr, Wmd-. .

L

Opr, Wmd.
Cp.Wsd.....
Cpr, Wsd. __ .
C, Cpr, L, Wmd.

C,Cpr,Ws.. .

Cr, Cpr, L,
Wmd.
C, Cpr,L,Ws...
Cpr, Wrd, Wmd

L,Wd.,

Wmd
C, Cp, L -
0,L.. -
Cr, Cp, L, Wm.

22-C-l probablyjwas
old well.
Oil well.

LACFCD, well 1271N.

,

LACFCD, wel!2669D.

460508 58

294 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. s

Loca-
tion
No. s

LADWP
No. s

Owner or user

Well data .

Altitude

(feet) <

Depth (feet) « <D
°1

P

Water
zones i

Depth toop
(feet)

a>

a

EH

T. 2 S., R. 15 W. Continued

2/15-15C1...

15F1...

15G1-.

15H1-

15H2-.

15N1--

15N2
1 IPI

15P2...
15P3

15P4...
15R1

16D1..
16D2-.
16F1...

16J1 _

16J2
16J3
16M1-

17B1...

17B2

17E1

17E2...

17F1...

17G1...

17G2-.
17G3--
17G4..

18A1

21A1
22A1

22B1...
22B2...
22B3

B-8

B-23f

B-23d

B-25

B-25e

B-23e

B-23m
B-24g
B-24f
B-24m

B-25h

B-5a
B-5L
"R..OO

B-23a

B-23c
B-23b
B-23k

B-3b

B-3e

B-23J

B-23I

B-23g

B-23h

B-5k
B-5e
B-5f

B-3i

B-24

B-26e
B-26k

2559

12500

1250A
1260C

1260

1260A

1250B

1250D
1251G
1251 P
1251L

1260P

OKQQP

2539J
1240

1240A

1250
1240B
1230

2529

2529A

1210A

1210

1220

1220A

25391
2539A
2539B

2519B

1251

1261B
1261P

9-B 16

9-B-17

9-B-15

oo_ri Q

Q-A 1

O_ A 9

9-B-18
9-A-3

9-B-24

Sprouse.

- - - do--..-........ .

Lachenmayer.
Washington Park
Mutual Water Co.

Dairy.

Southern California
Water Co.:

Lincoln plant:
WellS
Well4. ..

Southern California
Water Co.:

Pen Mar plant:
WeU 10..

Zanja plant:
WeU 11.....

Park Water Co.

& Smith.

Laundry.

Kinney & Co.

Water Co.

Vawter.

Formerly American
States Water
Service Co.:
WeU 8..... ...
WeU 6 .. ...
WeU 7..... - ...

Formerly H. C.
Morse.

Flood Control
District, test
hole 11.
Clarence Michel ------
do
do.. -----

42

34

35
44

40

41

25

25
25
23
25

27
27

24
25
9S

26

20
22
14

36

45

22

21

80

30

22
22
22

25

10
17

22
22
21

133
149.8
224

203

120

73
140
125

200
164
56

270

277
210
84

251

107

90

87

89

188
140
206

103

22

90.5

26

6

12

12

12

20
20
14

16

18
12
12

8

15

10

(10)

20
18
18

7

2

14

16

84

33
93

62

50

65
59

75

7

40

35

10
56
6
140
170
10

51

42

9
27

78

105

222
151

100

100

47

54

175
48
122
15
18
92

131

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

295

Water zones «
Continued

Character of
material

Pumping data

§5
w"

§a
<§

"a

a"^
P

a

PH

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 2 S., R. 15 W. Continued

Gravel-.-----.

Sand --

- do -

.. do. .... -

. do

Sand and gravel _
- -.,.do -------
Sand. ______
-_ do
Gravel and sand..

Sand and gravel

-

T, E

P, W

P, M

-

"~T~ir"
T. E

A....
Obs -

A-. _
PS ...
A.
A...

A
A...-. -. ------

Irr.. ._ .
A...

A... ....
A
Obs .....

A-.. .
A. ....
~XI- -I .
A..... -
A...... ....
A- _ ... -
A... .
A...
A.

A...
A...- ..
A...

A... .... -
A.
A-.. ...

Obs.
Irr..-. .
Irr-.

Wsd... ...

L.._
Cr, Cpr

Cpr, L, W-
Cpr, W.

Cpr..-- __ - .

Cp, L, Wd., .

C, Cp, L, Wmd.
C, Cp, L, Wsd-
C, Cpr, L, W

L...
L...
L-.. -
L..

L-.-

L..

Cp, L

L -

L, Wsd..

Cr, Cpr, L, W..
Co..

W-139, well 49
(Redondo).

LACFCD, well 1260E.

W-139, weU 27
(Redondo).

W-139, well 922
(Santa Monica).
W-139, well 17

(Redondo). W-139, well 12
(Redondo).

W-139, well 6
(Redondo).

W-139, well 947
(Santa Monica).
LACFCD, well 1261D.

296 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. »

Loca-
tion
No. »

LADWP No.» Owner or user

Well data

O

g"
*9 '<l?
< ^

<!

I

a

1
0

t. o> *"'s?
a|

*§!.

Q

Water
zones i

a

=>.§ I"

Q

m

si
a

fr

T. 2 S., R. 15 W. Continued

Z/15-22B4...

22B5
22C1...
22C2 _

22C3
22D1-.

22D2..
22D3-.

22E1...

22E2

22F1...
22F2...
22F3...
22G1.

22J1 _
22J2...

22J3...

22K1..
22L1

99P1

22R1--
23A1...
23A2...
23A3...

23A4...
23B1...

23B2-.,
23C1
23E1
23E2

23F1...
23F2
23F3...

23G1...
23G2
23H1,_

23H2..

23H3..

23J1 ...

23J2...

Sec foott

B-26a

B^24c
B-24d

B-26
B-24h

B-24i

B-24e

B-24b
B-24a
B-24k

B-27J
B-26h

B-27e

B-26J
B-24o

B-27~h
B-30o
B-30q
B-30m

B-26d
B-261
B-26b

B-26C

B-30g.

B-30i

B-30J

totes at enc

1261 A

1261K
1261D

1261
1251H

12511

1251J

1251B
1251A
1251 C

1262B
1261 C

1262

1261D
1251 R

1262A
1281J
1281K
1281 C

1271B
1271D
1271

1271A

1281

1281A

1281B

1 of table.

9-B-23

fr-B-19

9-B-20
9-B-21
9-B-22

9-B-25

9-B-29

9-B-28

9-B-26

. -..do..... ...
..._.do...... ....

Los Angeles County
Flood Control Dis-
trict, test hole 22.

Del Rey Land &
Water Co.:
WelH .... -
Well 2-... .... .
Well 2.... ... ...

Los Angeles County
Flood Control Dis-
trict, test hole 21.

Del Rey Land &
Water Co.

Formerly Del Rey
Land & Water Co.

Del Rey Land &
Water Co.

State of California... ..

Los Angeles County
Flood Control Dis-
trict, test hole 7.
Mrs. N. R. Tho mason -

Los Angeles County
Flood Control Dis-
trict:

Los Angeles County
Flood Control Dis-
trict, test hole 15.

Los Angeles County
Flood-Control Dis-
trict, test hole 13.

24

17
16
19

22
12

18
18

12

9

15
15
15
12

9
7

9

7
7

4
7
17
17
18

17
21

25
20
13
12

15
16
16

13
24
15

17

13

16

13

207

185
79

182

122
26

20

150

176
145

20.6

77.3
151

120

52

183

101
24.1

126
175

24
16
137

114

22

150

19

123

16

12

12

12

2

12

14
12

2

12
12

12

14

12
8
12
16

12

16
12
8-

2
2
14

14

2

12

63

20
63

14
32
17

-

20
80

54

26
44

53

142

16
16

12
150
105

33
57

60

9
105

70

WELL RECORDS 297

zone of the Torrance-Santa Monica area Continued

Water zones > Continued

Character of
material

Pumping data

1

ll'as
o

"a

°C'

C3

0

a p
PI

Miscellaneous

Use of well Analyses and
measurements

Remarks'

T. 2 S., R. 15 W. Continued

Sand and gravel

Gravel and sand. .
Fine sand ....

Gravel..... ....

Sand and gravel.

sand.

Gravel ....

.... .do.... ....

....

....

....

....

T, E

T, E
T, E
P, W

T, E
T, E

P.E
T, E

T, E

T, E

T, E
T, E

T, E
T, E
P, M

T, E

T, E

T,E

T. E

Irr...

Irr.... -
Stock...

A . __

A..... .....
A .. ..

A..

Obs ....

Irr
Irr.-
A...... ....
Obs. ... .

A

A...... .
Irr-.

Irr.. -
A..
Irr.. ..
Irr..... -
Obs.

A....... .... -
A..

A ... ...
Irr ..... -
Irr... ....

Obs -
A _ .. __
Irr ......

A....... ... ...
A.... ......
Irr.. ....

Obs. ....

Irr ...

A _______ .

Dom. Irr..-.--

0, Cpr, L,
Wmd, Ws.
Cpr.
C, Cpr, Wsd ....
Cpr, L, Wsd....

C, Cp... - .

L .. __
Cp...... ....

Cpr, L, Wsd

Wrd, Ws.

Cr, Cpr, Wsd...
Cr, Cpr, Wsd ...

L, Ws.....

Cr, Cpr, Wsd
C, Cpr, L, Wsd.

C, Cpr, Wd...-

Cpr, Wsd. ...

L.. -

C, Crp, W. _ ..
C, Cpr, W.. .
C,Cpr,Wrd,
Ws, Wwd.
L, Wsd...
L,Wsd..

Cpr, Wrd,Wsd-
C, Cpr, Wmd ...

Cpr, Wsd- -

L, Ws ....
L, Wsd. -
C, Cpr, L, Wsd.

C, Cpr

L, Ws..... ...

Cpr, L, W. .....

L,Wsd.. ....

C. Cnr, L. W__.

LACFCD, well
1251M.
LACFCD,welll261Q.

LACFCD,weU1281G.

LACFGD,welll282O.

Test hole.

LACFCD,weU1281H.

LACFCD, well 1271P.

LACFCD, weU 1271M.
LACFCD, well J271S.

LACFCD, weU 1271E.
LACFCD, well 1271F.

LAOFCD,weU128lM.

LACFOD,welll282M,

298 GEOLOGY, HYDROLOGY, TORRANCE-8ANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USQS Serial
No. 2

Loca-
tion
No. 2

LADWP
No. s

Owner or user

Well data

to
o

*H
iS^

4

to

a

&
P

to

af.So
p

Water
zones 1

f

&
P

<D

>W ®

A
^

T. 2]S.f R. 15 W. Continued

2/15-23J3...

23K1..
23K2..
23L1
23M1..
23M2-.
23M3-.

23N1..

23P1

23P2...

23Q1
23Q2
23Q3
23Q4
23R1...

24B1...

24C1

24C2...
24C3

24D1..
24D2_.
24D3..
24D4..
24E1

24E2
24F1...

24F2
24F3

24F4...
24Q1..

24Q2..
24L1...

24L2

24P1

24P2...

26A1

B-31d

B-26f

B-27a

B-27b

B-31f
B-31e
B-31b

B-30d

B-30

B-30e

B-30r

B-30h
B-30n

B-30b

B-30a
B-30k

B-30c
B-30f

B-31a

B-31c

1282C

1271C

1272A

1272B

1282L
1282E
1282A

1291D

1291

1291E

1281L

1291G
12811

1291B

1291A
1291H

1291C
1291F

1292A

1292

9-B-37

9-B-39

9-B-40

9-B-30

Q_T> 00
0 "R ^1

Los Angeles County
Flood Control Dis-
trict:

Jp/jQ-f- Vicilfi 17

Water Co.

do ..

_ ..do
Los Angeles County
Flood Control Dis-
trict:

.... . do. ....

Mesmer City Corp.,
Ltd.

Mesmer.

T. loki . ,. .. ..

Formerly Machado _

Flood Control Dis-
trict, test hole 3.

Flood Control Dis-
trict, test hole 12.

..... do _ .. __ ..
_ do ....

Mesmer.

Flood Control Dis-
trict, test hole 18.
Formerly Kitakata
Hog Ranch.
Los Angeles County
Flood Control Dis-
trict:
Test hole 4 _ .. .

13

12
13
12
11
12
10

9

10

10

10
11
10
10
11

23

20

18
23

18
22
20
21
17

17
16

18
18

16
20

22
15

12

15

15

9

200

18.0
50
19
15.7
13
140

151

185

11.4
24.2
139

239

196

402

209

145

122

24

14
18

79

71

97
209

200

24

131

7.8

14

2
2
2

12

14

14

2
2
14
14
16

14

16

16
14

14
18
14
14
2

15

12
16

16
16

10

8

38

62

23
47
182

34
127
170

38
137

23

37
45

38
44
200

30

29

24

78

9
81
30

21
66
225

21
69

51

4
34

43
93
6

77

96

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

Water zones '
Continued

Character of
material

Pumping data

ll

0

awdown 6

(feet)

t-<

P

a

Pn

Miscellaneous

Use of well Analyses and
measurements

Remarks *

T. 2 S., R. 15 W. Continued

clay.

. . do..... ... ..

Sand

Gravel..- _ - __

Gravel . . __

shells.
Sand and gravel ...

-.do..,.. ... -

-

- ....

T, E

P, W

T, E

T, E

T, E
T, E
T, E
T, E

T, E

T, E
T, E

T, E

-

T, E

....

Obs -
A-- -
Obs
A... ....
Obs
Obs .....

irr

Irr -

A
A
Irr
Irr- .
Irr
Irr

A.

Obs ....

Irr
A -

Irr
Irr

A.. ...
A.. ...

Irr
A-. .... -

A.

A.....
Obs

A. -- -
Irr

A... ...

A....- ... -

A...

Cpr, L, Wmd

Cpr, L, Ws..
Cp
Cpr, L, Ws ....
L, Wmd
Cpr, L, Ws...-
C, Cpr, Ws _ --

C, Cpr, L Wmd,
Ws

Wmd
fn

C, Cpr, L, Wsd.
C, L, Wmd.
Cpr, W...
C, Cpr, Wsd .

L.

C, Cpr, L,
Wmd, Wrd,
Ws

L.. .

C, Cpr, L, Wsd.
Cpr, W.. -
L, Ws.

Cp ....
L, Wsd...

Cpr, L, Wd .

L, Wmd
Cp, Wmd, Wrd,
Ws
L

Cr, Cpr, L, W..

L... ..-

L...

L, Wmd.

LACFCD, well 1272L.
LACFCD, well 1281E.
LACFCD, well 1272M.
LACFCD, weU 1271L.
LACFCD, weU1272N.

LACFCD, well 12721,
LACFCD, well 1282F.

LACFCD, well 1282B.

LACFCD, well 1281G,

LACFCD, well 1291J.

LACFCD, well 1292B.

LACFCD, well 1282K.

300 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wetts in the coasted

Identification of wells

USQS Serial
No. »

Loca-

tion No.' LADWP No.»

Owner or user

Well data

"°»

si
5

Depth (feet)»

ft"

Water
zones'

1*

Thickness

(feet)

T. 2 S., R. 15 W. Continued

2/16-26A2
26A3
26A4...
26A5
26B1...
26B2 _

26B3...
26B4

2601...

26C2...
26F1...
26F2...

27F1...

27R1..

34A1...

34A2...
34A3...
34A4...

3401...
34H1..

34K1..
34K2..

3501...

35G1-.

B-311
B-31h
B-31g
B-31

B-27C

B-27f

B-27
B-27d
B-27L

B-24J

B-271

B-28b

B-28g
B-281
B-28e

B-28f
B-28C

B-28
B-28a

B-28J

B-28d

12821
1282H
1282Q
1282

12720

1272D

1272
1273
1273A

1253

1283

1264B

1264E
1264F
1264D

1254
12640

1264
1264A

1274

1284

9-B-53
9-B-51

9-B-41

9-B-42

9-B-48
9-B-50

9-B-43

9-B-46

Q_TD_JJ

'PoQt HA!A 1

Ranch,
-....do... - -

Flood Control
District, test hole
14.

Mesmer.

lona Rancho.

Flood Control
District, test well.

Water Co.:

Well 6... - Well3__..
Well 4... -
Well 5

Exploration Co.

Formerly Barnard.
Palisades del Ray

Water Co.: Well 1. . . - Well 2.. . -
Extension Co.

Ranch.

9
9
9
10
155
9

10
10.4

8
13
13

5

1 jo

130

137
134
150

150
131

82
83

166

159

5.25

400

176
18

9AO

101.0
126

110

237

305

380
250
565

643
250

208
216

380

261

2

18

16
2

14

10
14

6

18

18
16

15tf

15H
12

16
14

18

10

29

47

0

0

0

91
95
158

_

96

104

272

233

250

42
48
18

T. 3 S., R. 13 W.

3/13-4D1...

6A1....
5A2....

5F1 ....

5F2 ....
5H1 ...

6Q1 ...

6P1 __

6R1 ...
7F1....

B-62a

B-62b
B-62]

B-58a

B-62i

B-53e

B-53f

B-58
B-53h

1445

1445A
1445D

1436

14450

1416

1416A

1426
1417

11-0-19

Water Co., Clovis
plant.

and Kirst.
Southern California
Water Co.:

Avalon plant:
Well I......

Well 2.........

Wright.
Southern California
Water Co.:

well 1.

welll.
Athens Water Co

Formerly Parker... -

115

115
116

113

113
112

138

162

132
189

575

300

475

470
300

301

315

325
179

14-12

10
9Ji

14

14
9

12

12

12

305
530

280

320
396
377

247
271
184
219

135

39
25

20

62
38
53

9
27
25
96

42

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

301

Water Bones'
Continued

Character of
material

Pumping data

fe

|f
0

^i

|1

Q

1

£

Miscellaneous

Use of well Analyses and
measurements

Remarks'

T. 2 S., R. 15 W. Continued

Sand and gravel ...

..do ..... -

Sand and gravel...

- do

....

320

335

....

- -...

21

....

T, E

C, E

T, E
P, E

T, E

A __ _
A
A -
A .... .

A .

A _ ..-.
A

A __ --. .-

A.._

A...

PS... .... -

A

A...

A
Obs.

PS ....
PS ... ...

A.._ -

Cp, L.
C, Cpr, Wsd..~

Cpr, Wsd~~
C, Cpr, L, Wsd.
Wsd_

Or, Cpr, Wmd-

C, Cpr, Wmd,
Wrd.
Cp.. ... .
Cr, Cpr, L, W..
Cpr, W .

Cpr. ...

O, W... .....

Wmd.
L, Wmd -
Cp, L, Wsd.
L.W. ~

L . _
Cr, Cpr, L,
Wmd, Ws.

Cr,Cpr/L,Wmd. C, Cp, L ..
Wmd..

Cp, Ws _

LACFCD, well 1282J.

LACFOD,weU1272K.

Oil test hole.

Do.

T. 3 S., R. 13 W. Continued

Gravel ______

..do ...__ .
. .do....

Gravel ____ - _
. . do.... ......
Gravel.. --

Sand and grave] _

560

950

720

515

-

300

-

T, E

T, E

T, E

T, E

....

T, E

PS

A... ...
A

PS ...

PS
A

PS

A..

PS
A. ... ...

C, L, Wm....-

L...

C, L, Wm __ -

L, Wmd..

L, Wmd..
L...- ...

W-139, weU 675
(Redondo).

LACFCD, well 1436A
W-139, well 615
(Redondo).

302 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. »

Loca-
tion
No. »

LADWP
No. s

Owner or user

Well data

a> dg'*

P
<

0

1

a

P

a|

C3.S

5

Water
zones i

^J I"

fl

<D

3
^

T, 3 S., R. 13 W. Continued

3A3-7G1...
7N1...

7N2...
7N3...
7P1-

8C1....

8C2

8G1...
8H1
8H2...
8H3-.
8L1-...
8L2-...

9A1....
9B1....
9B2_...
9B3... .
9B4 .
9C1.

9E1....
9F1....
9F2 .
9F3 .
9G1... _
9N1...

9N2
9N3...

QTM

16A1...

16H1..

16H2..
16H3-.
16J1...

16J2...
16J3...
16M1-.

16M2..
, 16M3..
16N1..
16P1
IfiPO

16Q1...
16R1..
17B2...
17D1..

17E1...

B-53k
B-54d

B-54k

B-54f

B-58g

B-58d

B-63a

B-58b B-63

B-68c
B-68i
B-58e

B-63d

B-63C
B-63b

D_JMo

B-64f B-64
T> £»Q

B-64m

B-691

B-69o
B-64h

B-64b
B-64d

B-69g
B-59d
B-59n

B-59a

1417A
1418

1418D

1418B

1437E

1437B

1437F
1437
1447

1437A
1437G
1437C

1457B

1457A
1457

1448

1448B
1448A

1468

1459C

1469F

1469J
1469H
1449B

- \AAf\

1459

1469E
1438
1428A

1428

11-C-ll
ll-C-10

ll-C-37

ll-C-36
ll-C-45
ll-C-17
ll-C-16

ll-C-34

U Ti *&.
ll-D-31
ll-D-32

11-D 30

11 C 15

ll-C-13
ll-C-14

11-D 24
ll-D-45

11 D 21

ll-D-19
ll-D-18

Petroleum Corp.
Sentinel Oil Co .... -

Getty Oil Co.

Wright.
Southern California
Water Co., Delmar
plant, well 1.

Stiller. -
Albert Glass, well 2...

erly Mrs. Bushby).

.. do
..... do

Wright.
Oorvro'P TVIlitp

Mildred Rangel
S.Wilson --

Corp.
Mrs.H. Saulque

Ingram.

brook Park Mutual
Water Co.

Flood Control
District.
Southern California
Water Co.:
Willowbrook
plant:
Welll ...

Well 2 -
F. L. Walton--- ...
Johnson Ranch

(formerly Woods).
do ... ..

Faulkner.
E. G. KidweU ..-

A ip \7pi t~f»h

Cr6ss6V Psrk
Mrs. Dorothy Gordon.

vorth.

192
177

175
168
168

116

120

110
108
109
108
120
128

95
95
95
95
95
96

94
93
92
92
93
98

92
93

86

83

81

82
82
79

81
79
07

93
104
105
93
96
81
80
120
125

131

575

317
405.5
350

557

549

70ft

531
350

585
254

500

310

18

90

344

408

200
250

21.5

220

250
250
243

250
60
131

250

236
196
200
219.0
241

300

14

12

12

16
12
10
12
14
5

12

12

3
2
4
4
4

13
10

4

2

W

12

12

6

8

10
8
12
6
12

(9)

190
334

150
225
390

369

270

305

185
204
180

184

174

161

230
258

100
16

25
94
159

136

62

47

15
15
46

59

45

78

25
42

See footnotes at end of table.

WELL RECORDS

zone of the Tor ranee-Santa Monica area Continued

303

Water zones 1
Continued

Character of
material

Pumping data

&
g|

,2!
o

to

a

-die

03

P

1E)

PH

Miscellaneous

Use of well Analyses and
measurements

Eemarks '

T. 3 S., R, 13 W. Continued

.do... .. ..

.-..do.. ___ .....

325

715

350

300

....

810

129

. . -

T, E

T, E

P PTTJ

T, E
T, E

T, E

P, M

P,M
T, E

T, E

T, E
~"T~~E"

T, E
T, E
T, E

T, E

T, E

PS
A.

A...- -

A.

A...

PS

A..
to-.-

PS . ...
PS. .....
A..
PS ... ...

A.._ ..

A.

Dom, Stock

Ind-

Obs

A

Obs

PS- ....
A

Obs. .... .
A...
A. __

Dom, Ind
Obs.
Irr.-. .... -

Dom, Stock...
A ....
A.... ......

A. . . .

Cp, L, Wmd.

L... - -
W..... .
L..... .

Cr,L. .

L, Wmd. - Wmd __
L... .
Wmd, Ws, Ww.

W..... .

Wmd. - W.......
Wsd.. -

Wsd.-

Op...... ....
Op....... ....
Cp.. .
Cp, L, Wmd,
Ws
Wmd, Ws -

Wmd.. -

Wm_. _ ....

L...

L, Wmd-.
Cp, L, Wmd.

W
L...

Cp....

Cp, L
Wm . . ... -

Wmd. __ ......
Cp, L, W.......
Wsd.
L....... ....

L.. ....

W-139, well 614
(Redondo).

LACFCD, well
1458A.

LACFCD, well 1469J.

W-139, well 592
(Redondo) .

W-139, well 686 (Re-
dondo).

dGO
O00

?!

!»r ?1
o

Altitude
(feet) «

Depth (feet) «

Diameter

(inches)

Depth to top
(feet)
Thickness
(feet)

M

1

a

1

1!

s?
I

!SI

i'

8

§
£

,»»»a

OO

§1 Kl

QO

O d!

Q o o:

tJ « J3 i
f!

2?OS? 3 QOO
3 S S B

i s! P1! I !

8 I
? f

rl*

I^

Gallons per
minute *

Drawdown'
(feet)

Pump

5

I »
O H
g O
E o

t»

00
o
c«

306 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TASLE 26. Description of water wells in the coastal

Identification of wells

USQS Serial
No. s

Loca-
tion
No. 2

LADWP
No. 3

Owner or user

Well data

CD

s "

~l
_,'""'

*

10

Jj
43

o>
fi

t-,
0>

s-s

»n5

P

Water
zones i

0
^^

si-
CD
P

S

ol

A

EH

T. 3 S., R. 13 W. Continued

3/13-20H2..
20H3.-
20H4..
20J1
20J2-..

20J3.-

20L1...

20L2...

20L3...
20L4
20L5...
20M1..
20N1..
20P1...

20P2...
ofipq
20R1..

21C1...
21O2...
21O3...
21C4--
21D1...

21E1...

21F1-.

21F2. .
21G1-.
21G2. .
21G3--

21H1..
21J1...
21N1-.

21P1_.
22A1...
22C1...
22O2...

22D1-.

22G1-.

22H1..

22H2..
22H3..
22H4..

22H5-.
22J1...

B-lllv
B-lHo

B-lllh

B-lllm

B-llls

B-106a

B-llle

B-lllj

B-lllp
B-llle

B-116n

B-69h
B-69e
B69f

B69d

B-116J

B-116b

B-116d
B-116C
B-116h

B-116e

840E
840B

830

830A

830B

820

840

850A

860O
850

860B

1479
1469O
1469D

1469B

870F

870O

870A
870
870D

870E

7-A-15
7-A-17
7-A-18
7-A-24
7-A-19

7-A-23

7 A <)*.

7-A-13
7

_ A _RA

7_ A _1 O

7-A-30
7-A-26

7-A-27

ll-C-5

7- A -91

7_A 99

ll-D-12

ll-D-14

ll-D-15

7-B-10

7 B 9

East Gardena Water
Co.:
Well 2 ....
WeUl....... ...
WeUl..... -

erly W. S. Martin).

ply Co.

Moore.

Darling.

Stein.

Haskin.
C. C. Copeland -

A. L. Flick

(formerly M. A.
Smith).

District (formerly
"Conklinwell").

Hanselman.

Flick.

do ~

Montague.

provements Co.

Carrien.
Francis E. Barron _ ..

Formerly Compton
Ice Co.

City of Compton:
Magnolia plant:
.Well 1
WeU4

Tire Co.

Robison ___ .-.-

106
105
105
79
103

84

90

77

87
77
77
77
51
67

66
57
72

90
100
95
95
108

100

101

97

100
89
87
90

78
80
102

97
71
74
74

76

71

69

69
69
70

67

160
174.0
335
187
68.0
280

70

85

200
200
190
151.0
253

80

280

236

157.5

75

200

200
192

192

70
206

258
160

260

310

256

350
714
257

717
220

14
16
7

16

10

8

6
8

6
8
10

6

6
12
8

14

12

7

7

12

4

12
7

7

12

12
16
12

16

125
116

165

89

170

235

667

199

70
79

17

111

90

18

33

15

See footnotes at raid of table.

WELL RECORDS

zone of the Tor ranee-Santa Monica area Continued

307

Water zones '
Continued

Character of
material

Pumping data

o>
w 53

0

awdown 6

(feet)

ft

ft

h

Miscellaneous

Use of well Analyses and
measurements

Eemarks '

T. 3 S., R. 13 W. Continued

Gravel and boul-
ders.

Gravel ______

Gravel and sand..

Coarse gravel.--

T, E
T, E

T, E

T, E

P, E
P, E
C, E

P, E

T, E
P, W

T, E
T, E
T, E
T, E
T, E

P, W

T, E
T, I
T, E

T, E
T, E

T, E
T, E^

Irr
Irr_
Obs ..
Irr-

Irr....... .....

A... ....

A.. ... .

A-. ....

A.. ....

Dom, Irr __ --
Irr-

PS.... ... . -

A. ....

A... -

Irr. -

A.. . ...

A. ... ...

Irr_
PS ......
A.. .....
A

A....... ... ...

A.. ... ..

PS ... ...
PS
A- _ ...

A.. ... .

Wind-. _ ......

Cp, Wmd____ Wmd, Ww

L, Wmd. ....
L, Wmd--... ...

Cp, Wmd.......

L_. ....

Wmd.. ....

C, Cp, Wmd.
Cp,W ......
Cp ... .
Wmd, Ws- __

Cp .... - Wmd
Cp.. ....
Cp ....
Wmd--.-.- .--

Cp... ....
Op..... ....
Op..............
Cp
L, Wmd-. ......

Cp, L, Wsd.....

Wmd... _ .

L.. ....

Cp, Wmd....

Cp, Wsd

Wsd.-..---.- ..

Cp.. .. ..

Cp.. ....
Cp, L, Wm
Wmd-

L, Wmd... .....

L...-.. . .....

L, Wmd...

C, L, Wmd.
C, L, Wmd.
Wmd.. ....

L... _ ....
i,. ....

W-139, well 551 (Re-
dondo).

W-139, well 588
(Redondo).

W-138, weU 57
(Downey).

W-138, well 64 .
(Downey).
W-138, well 522
(Downey).

308 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial No.«

Loca-

tion No.* LADWP No.» Owner or user

Well data

<a
a

s^

si
*

1

f0> fl

t-l
0

«§
fl

Water
zones i

s§
S"

Q

0>

a

H

T. 3 S., B. 13 W. Continued

3/13-22L1..

22L2
22M1..
22N1-.

22N2..
22Q1...

26B1...
26B2...

26B3...
26D1-.

26F1-.

26Q1-.

26H1..
26J1...
26J2

26L1-.
26L2-.

26M1..
26N1-.

26Q1...
26Q2...
26Q3...

26R1..
26R2-.

26R3-.
27A1...
27B1...
27B2...

27C1...

27N1

28A1 .
28B1...
28C1...
28C2...
28C3
28D1..
28D2..
28E1...
28E2...
28G1-.
28G2-.

28G3-.
28L1...

28P1...
29A1...

B-116L

B-116a
B-116p
B-116

B-116q
B-1161

B-121S
B121

B-12ib

B-121L

B-121J

B-121C

B-122

B-122m

B-122n

B-1220

B-116m
B-116k

B-117

B-lllf
B-lllr

B-lllg

B-lllq

B-llli

860A

860
860C
861

861A
871

881C
881

881A

891B

891

881B

882.....

892E

892F

892Q

871A
871B

862

851
8510

851A

851B

841

7-B-22

7-B-23
7-B-21

7-B-32

7-B-34

7-B-16

7-B-47

7-B-33

Walton.
- do..

Schildwacher.

lege.

thorne.
. .do.....

Robert W. Poe (for-
merly Dr. J. A.
Monk).

Steel Co.

land Park.

Day...... -

Edison Co., Ltd.

Flood Control Dis-
trict.

.....do... -

Water Co.
E. M. Hart..

mings.

Bert Phillips-. -

Harsh man.

Water Co.

Veatch

Mrs. N. M. Veatch.. .

Park Cemetery.

Haskins.

71

71
74
8fl

80
68

65
66

65
65

64

61

62
60
60

60
60

62
57

57
59
59

57
57

58
67
68
68

73

97

91
96
98
97
97
99
95

92
93
96

95
85

102
67

530

332
80
110

700
562

237

130
775.0

655

140

199

135

654

204

200
175

35
146
8
480

474

351
155.0

546

327

210
130
480
312
340

93.0
370

401.0
154

10

7

6

7

10
12

12

8

20

10

6
8

6

8
4

6

12

7

12

6

4

6
1J4

12

4
10

10
QU»

520

670

80

84

60

330

319

305

284
100

28

142

58

51

72

216

21

92

66
54

See footnotes at end of table.

WELL RECORDS 309

zone of the Torrance-Santa Monica area Continued

Water zones '
Continued

Character of
material

Pumping data

a.

|1

o

"a

00 >d »
o3 s""'

ft

Pi

Pk

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 3 S., B. 13 W. Continued

do _-
.. do . -

1,000

900

675

C, E

T, E

C, E

C, E
T, E

P,W

P, W
T, E

P, W

C
P, W

P, W

T, E

P, E
C, E
T, E
P, I
T, E
T, E
T, E

P, W
T, E

A..

A.
A .
A. ....

Obs_. ....

Irr_
A

A_
Obs

A.. ....

A.... ......

PS ..... _ .
Irr....... _ ._
A.............

Dom.
Irr . ...

Irr.. ......
Obs ....

Irr.. ....
A....... ......

Irr, Stock .....
A.. ......

Irr.... ....
Irr. ....
A.. ..
A. ....

PS-. - ..

Irr-.
A
A . --
Stock.........
Irr.. ....

Obs-- ____..
A.... ---

L '

L
Wmd. ....
Wmd._ _ . _ _.

Wm ____ ...
C, Cp, L, Wsd

Wsd. _____ _.
Wmd __ __

Wmd. ___ ..
L, Wmd.

L ... ..

C, L, Wmd.
Cp.... _

Cp. .....
L..-. __ . ...

Cp.. ....
W,Wm.

Cp, Wmd, Ws..

Wsd....... .....

Cp ... ...
Wsd....... ....

W ....

C......
L... ....

C, L, Wmd,
Ws.

Wmd, Ws. ...
C. .... .
Cp. ---
Cp.-- --
Cp
f1 T,

Cp
C, Cp, Wmd....
Cp, L ....

Cp, Wsd .
Cp, L. ... .

L, Wrd, Ww....
L

W-138, well 54
(Downey).

W-138, well 167
(Downey).

W-138, well 214
(Downey).

LACFCD, well 882D;
test hole.

Test hole.

W-138, well 252
(Downey).

W-139, well 580
(Redondo) .

460508 59- -21

310 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. 2

Loca-
tion
No. 2

LADWP
No. s

Owner or user

Well data

CD

o

a^

"*<« ^~^

<

1

CD
P

CD
"** to
CD CD

a §
«5

p

Water
zones i

|?
S<s

tf
p

to

CD

oS

A
^

T. 3 S., R. 13 W. Continued

3/13-29A2...

29A3...
29B1...
29B2...
29B3...

29B4-.

29B5...
29C1
29C2-..
29E1...

29E2

29E3
29E4...
29E5_._
29E6-.
29E7
29E8...
29F1___
29F2...
29F3...
29F4.._
29F5

29F6_.-
29G1..
29G2--
29G3_.
29G4-.
29N1_.
29N2__

29P1...

29P2...
29P3...

29P4.._

29P5...
30A1...

30A2...

30A3...
30A4...
30B1...

30B2...
30C1...
30C2_._
30D1..

30D2..
30D3..
30F1

30F2...

B-llln

B-lllw

B-lll
B-lllb
B-llla

B-107f

B-107h

B-106b

B-106e

B-106m

B-106w
B-lOGx
B-1061

B-106p
B-106e
B-10GL

831 C

831D

831B
831A
831

832

832A

821

821 B

8210

811E
811F
811

811B
8110
811A

7-A-28

7-A-29

7-A-34

7-A-52

7-A-32

7-A-31

7-A-9
7-A-8
7-A-10

Farm
- _do - -

T. B. Goossen__. ......

Hammond.
Rider__-.....- - .

H. W. Bach . -----
M. P. SUva- .....

E. J. BelL-- ....

A. Pratt. -----------
W. E. Smith ....

K. C. Holland---. - W. S. Condren ....

WUliam H. Meyer..
H. E. Kuck- ---

Union Oil Co., "Gar-
dena No. 1."

Dykzeul.

table Union.

Dunn.

W. J. Gcade. --.--..__

Formerly N. E.
Cowles.
B. W. Barnes_ -

66

65
64
62
70

75

67
56
55
43

44

44
45
44
45
47
45
55
47
46
48
47

47
55
50
60
60
35
38

46

45
56

52

51
41

45

45
45
40

48
48
45
42

41
40
32

35

234

172.0

183
168

208

220
300
196
70

54.5

140
198
85
65

70
215
75

72
57

55
198
111
235
70
350
553

514

536

39.0

696

225
247
210

256
250
225
201

40
116
205

40

10

6

6
12

6

5
8
8
10-6-5

8
6

4
8
8
8

4
12

7

12

14

7

7
8
10
6

10
7

6

155
176
182
196
204

454
510

359
512
593

151

166

175

17
5
3
4
1

37
41

12
73
111

11

35

30

See footnotes at end of table.

WELL RECORDS 311

zone of the Torrance-Santa Monica area Continued

Water zones «
Continued

Character of
material

Pumping data

%

aliens p

minute «

0

to

a

rawdow (feet)

P

1

PH

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 3 S., R. 13 W. Continued

..--.do. ... .

do

Sand ___ ......

Gravel ______ _ Gravel and sand _

Gravel __ __ _ .

... ..do..... ....

Gravel and sand..

T, E

Al, I
P, E
J, E
T, E

T, E
T, E
P, E
P, E

P, W

P, W
T, E
T, E
P, E
P, W
P, E
J, E
P, E
P, E
P, W
P,E

J, E
P, E
P, E
T, E
P W
T, E
T, E

T, E

T. E

T, E
T, I

T, E
J, E
T, E

P, W

Irr, PS ..

Stock.
A . . . .

Stock.

Stock.

Horn

A.............

Stock.

A. . ...

A.............
A... ....

A.. ....

Irr..-__-. -

Irr.. ....
A.............

Irr............

LT.. ....
A.............

A.............
A.............

Irr............

L.. ....

On 8S=::::::::::::

OT\

Cp.... ....

Op, L, Wmd.___

OT\
OT\

C*Y\

On
On

On Op... .... SP "

Cp..............

C*r\
C*r\

Cp..............

f^v\

OlA

C, Cp, L........

On

Cp, L...........

Wmd._ ....

C. -.-...--.-....

Wsd.. __ ......

Cp, L, Wmd....

L, Wmd........

L. ....

Wmd.. _-... .
Cp, Wmd.......
Wmd _ . ___ .
L

C, Cpr, Wsd __
Wsd..._ .....
L.. ....

CD..............

LACFCD, well 831D.

Oil-test hole.

W-139. well 545
(Redondo).

W-139, well 464
(Redondo).

W-139, well 496
(Redondo).

312 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

TJSGS Serial
No. »

Loca-

tion No.' LADWP

No. 8

Owner or user

Well data

Altitude (feet) <

Depth (feet)«

fc.
CD

P

Water
zones i

Depth toop
(feet)

Thickness

(feet)

T. 3 S., R. 13 W. Continued

3 3-30G1
30G2-.
30G3..
30G4..
30H1..

30H2..
30H3..
30J1...

30J2...
30J3_-_
30J4--
30J5...
30K1..
30K2..
30L1...
30L2...

30L3...
30L4...
30L5...
30L6...
30M1..
30M2-
30M3-.
30N1.-

30P1...
30Q1...
30Q2
30Q3.._
30Q4...
30Q5...
30R1.-
30R2--
31A1
31B1...
31B2
31B3...
31B4...
31B5...
31C1...
31C2...
31F1...
31F2...
31F3
31F4...
31H1-.
31H2-.
31H3-.
31H4..
31H5-.
31L1...
31L2...
31L3
32C1--

32C2-.
32D1-.
32F1

32F2...
32F3...
32F4...
32F5...
32F6...

B-106C

B-206y

B-107g

B-107

B-107e

B-107d

B-107C

B-107c

B-107a

B-112C

B-112a
B-112

821A

821D

822A

822

812A

812

813

813

823

833D

833B

833A
833

7-A-33

7-A-35

7-A-37

7-A-43

7-A-49

7-A-48
7-A-47

Formerly Chas.
Straumer.

M. R. Peck (formerly
Gityof Long Beach) .

George W. Shirley....

Mrs. Mabel C. Voss..
Geo. D. Arnell ....

W. A. Sehofield .

Maid Dairy Farms).

Fred CastUlo _ ......

Ethel McClain .---_

Ralph Marsh.- ___

M. Takeshita ....

... ..do-...

_ .do.-.. - ....

L. B. Chase Oil Co.,
well 1.

Ed Cost- -----------

41
41
42
43
44

41
43
37

36
35
40
36
39
33
31
31

36
36
33
32
31
31
23
27

29
33
31
30
32
30
31
34
30
26
26
26
27
26
27
27
27
27
30
30
26
26
26
26
26
31
31
31
32

35
30
33

49
43
46
42
43

175
35
300
41.1
48

175
59.0
743

148
92
75
156
200

198
198

30

55
200
39
37.1
28
195

42
80
40
100
37.8
60
550
319
200
25
700
65
300
79
250
650
159

30.0
404
30
150
152
50
140
700
50
70
275

750
550

1,500
662

10

6
5

10
8
16

7
8

8

2V£
12
6
6
6

8
6

10
12

6

2

3

12
6

3
3
2
10
6
6

8
5

12
10

10
10

34

495
520
132

132

8

530

14

10
208
12

10

22

130

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

313

Water zones >
Continued

Character of
material

Pumping data

Gallons per 'minute Drawdown' (feet)

a

|

Miscellaneous

Use of well Analyses and
measurements

Remarks'

T. 3 S., R, 13 W. Continued

Gravel ._. ..

Sand and gravel ...

Gravel and sand..

Gravel and sand..

....

Sand and gravel

125

765

__ .-_-_

50

....

____

-

T, E
P, W
P
P, W
P, M

P, E
P, W
T, E

T, E
P, W
P, E
T, E
T, E
P, E
P
T, E

P W
P,I
C, E
T I
P W I
P, W
P, W
T, E

P, W
P, W
P, W
P, E
P W
T,E
T

TP

P

TTl

E
P
P W
T, E
T, E
P W
rp TP

rp TP v

P, E
P,E
P, W
P, E
T, E
P, W
P, E
P, E

T, E
P, I

T, E

T. E

Irr, Stock. ....
Irr

Stock. _ ....

Dom, Stock ...
Dom, Stock...
Stock..
Dom, Stock ...
Dom, Irr ......
Dom, Stock _

Dom, Stock,
Irr.
LT.
LT
Dom ____ .
Irr

Dom, Irr _
Dom.. ....
Dom, Stock ...

A.............
Dom......

Dom __ ...
Dom, Irr ......

Dom ___ . ...
Dom. _ ......

Dom, Irr ......
Dom, Irr ___

Irr... ..

Irr.,.. .....

Irr.
Ind _

Obs.. ....

Obs

A.
Irr.. ... ...

Op. . ..... -
Cp, L-. ......

Cp, L...........
Op.. ....
Cp.. ... ...
Cp ... .

Cp ...

Op ....

Op. ..
Cp ....
Cp ... .
Cp. ....

Op... .....
Cp ....
Cp, L...........

Cp ... .
Cp.......
Cp, ...
Op-... ....
Cp

Op....... ....

Cpr, W-.. ...

Op. ....
Cpr ....
Cp, W.. .
Cp. ....

Op.. Cp,
Cp, W.... ..

£:::::::::::::
Op....... ....
Cp ... ...

Cp. ... .-.. .
Cp, W,... ...
Cp ....
Cp, W. ... ...

Cp, ...

L, Wm _ . _ ..

C, Wd
C.. ....

L.. ... ...

Oil.well.

314 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USG8 Serial
No. z

Loca-
tion
No. 2

LADWP
No. 3

Owner or user

Well data

s>

3"

P
<!

X

«35

a

ft<B
P

<B

a|

OSfl

fi

Water
zones *

ft

P

m

si
a
*

T. 3 S., R. 13 W. Continued

3/13-33A1...
33A2...
33B1...
33E1...

34B1...
34D1..
34D2-.

35A1...
35B1...
35B2...
35B3
35B4
35C1
35C2...
35E1...
35G1 _
35H1-.
35J1...
35J2...
35K1..
35L1...
35M1..

35N1..
36A1...
36A2...

36B1...

36B2...
36B3...

36C1

36D1..
36G1 .
36J1

36P1___
36P2

36P3...
36Q1...
36Q2...

B-117d

B-117b
B-117a

B-122J
B-122h
B-122L

B-122q
B-122e

B-122p

B-122d
B-122C
B-122b

B-123b
C-930C

B-129

B-122I

C-929C

O-929J

853A

862B
862A

893
892B
892D
882C
883C

893A

883B
883A
883

884A

902

892C

913B

903

7-B-36

7-B-37
7-A-50

7-B-45
7-B-35

7-B-42

7-B-39

7-B-40

7-B-38

6-A-26

7-B 44"

Union Oil Co
- do---
I. W. Hellman Estate.

I. W. Hellman Estate.

Morrell.

H. Y. Sasaki
.... . do.- -
..... do.- . -----

_.do---- ~

..do.. -

do.--
.. do-.- -
..do--. - --
Pacific Electric
Railway Co.

bridge, test well
(south).

Edison Co., Ltd.
. .do.- - -----

test well.

City of Long Beach:
North Long
Beach:
Woll 9

Well ET-4

City of Long Beach:
Well ET-3-

Boulevard
bridge test well,
second,
third

Extension Water
Co., Inc.

146
146
153
115

115
125
125

53
57
56
56
56
57
57
74
52

47
47
<1Q
51
49

47
57
57

56

54
56

56

56
51
52

46
44

44
50
50

250
350
375
700

500
374

100

174.0
92
140
150
595.9

130

175
154
129

350
18

260
20

200
29

30
21

15
15
190

16
12-10

16
16

12

8
8
6

10 3-1^
10-8
10-8
12-10
12-10
7

12
6

12

6
10

6
6

6

8

272
410

86
60

124

30
70

35
41

6

T. 3 S., R. 14 W.

3/14-1 A1-. -

1A2...

1B1...
1B2___

B-52d

B-52e

B-52e

1405A

1405B

1405
1405C

n

{~\ OQ

Smith.
Mrs. Drusa Wellett
Southern California
Water Co.:

Normandie plant:
Well 1
Well 2 __

158

163

198
195

97

233

220
390

m

10

12
14

210

184

17

98

See footnotes at end of table.

GO

ira P

ooo

So,

««

GO

PP-

OHI I

-1
>3 OQQ QO

VF

OO
p

p

33

OO

WW

2.

a

o
E C3

"

8-gJ ® 5

S-g>a

Gallons per
minute
Drawdown

6

(feet)

Pump

%a^

2.

I

8
ll

w 1

< 2 §*
P

O

C

P

a-

*t

dI

S"11o

9. s1

Q oo
B" £

316 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

usos Serial
No. 2

Loca-
tion
No. 2

LADWP
No. *

Owner or user

Well data

d a"*

SI
*

"S
8
a
a
®

p

a>

a|

esfl

p

Water
zones >

I

o.^

P

o

2! s

^

T. 3 S., R. 14 W. Continued

3/14-lFl.-..

lGl-__

1J1-...
1L1 .

1P1-

1O1 mi.-.

2A1...

2F1 ....

2L1..__
3A1...

3D1 ..

3F1....

3J1....

3K1...

3K2,...
3E1 ...

4N1 ...

4N2...
4N3...
4N4...
4N6

4N6...
6B1.-..

6E1....

6T1.

6Q1...
6J1-

6M1...

701...

7P9

ffTjfi

B-47J

B-53J..-
B-48c

B-48b
B-53a

B-47i
B-47e

B-47a

B-48
B-13b

n OA

T> -MJ

B-44g

Pt-44i

B-40e

B 40
T>^A*

"R_4n/1

B-36h

B-36

B-36c

B-36J

B-361

1395A

1406A
1396A

1396
1406

1385A
1395

1385

1386
1375

1365A

1366

1376B-.

1366B

1376C

1346B

1346
1346O

134AA

1336

IQfiA

1316

1307B

10-D-13

10-D-ll

10-D-12

10-D-8

10^C-12

10-O-13

10-O-10

10-O-9

10-C-7

10-C-17

Los Angeles County
Water Works
District No. 1.

Water Co., Nor-
mandie plant,
well 3.

High School.

Emil Firth.. ....

Broekley.

Formerly Wesco-
Chippewa Pump
Co.
O. T. Johnson Ranch:
Well 6 ___ ... .

Well 4--- -

Yahira.

Harvey).

(formerly C. A. Van
Nest).

Southern California
Water Co.:

Yukon plant:
Well I........

Well 2. _ ....

Truro plant:
Welll __ ....

Well 2. ......

Newell.

Development Co.

Dicksens.

field).

Bennett.

more.

Land & Improve-
ment Co.

Ranch.

228

200

180
233

218
195
189

220

204

160
146

so

83

90

74

76
81

76

73
76
75
74

76
90

88
"""77"

80
90

104

103

105

350

598

104
283

445

120

495

368

602
434

191

139.0

94.8

652

756
105

636

695
695

98i

184
500

77
1,200
200

151.0
208

245

245

301

16

14

6
12

12
12
7

12

14

12
14

10

8

6

16

12

14
6

10

12
6

18

10

8
6

12

14

14

165

220
265

191

127
185

161

230

246
223

336

366
536
560
367

318
479
477

130

174

36
25

92

318
22

98

64

136
7

56

46
14
62
38

80
157
197

70

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

317

Water zones >
Continued

Character of
material

Pumping data

a ®

3 3

|a
o

to

1^

08 ^

ft

s

PH

Miscellaneous

Use of well Analyses and
measurements

Remarks T

T. 3 S., R. 14 W. Continued

Gravel and sand..

Sand and gravel ...

fine gravel.

.....do.............
do.. .
... . -do...... ...

1,240

512

1,045

500

1,100

12

21

4

T, E

T, E

T, E

P, W

T, E

T, E

T, E

P
P, W

PS...

PS ...

A...
A

A
A.............
A _ ....

A.............

Irr..

A _______
Obs . ...

Irr.. ....

PS... ....

PS .....

PS ... ...
A.............
A.
A........ .....

A.............
A. ... .

A......... _ .
A. . .....

A ...

A.... ....

A.. ....

C, L, Wmd-

C, L, Wm. .....

Wsd . ...
L.. ....

L, W...._... ...
L.. ....
Wmd.. .

Op, L, Wmd

Op, L, Ww .....
L, W._. ....
Op, L, Wsd,
Ww.

Wmd ....

C, Op, Wmd,
Ws.

Cp, W..........

C, Cp, L, Wm

C. ....
W.......... .....

Or, L, Ws _ ....

C, L, Wm . ...
W......... ......
W........ ....
Wmd, Ws.- .

C, L.. ....
C.. ... ...

L, W....... .....
L... ....

L, Wsd. .....
W.... ... .

L, Wsd.
Wmd .....

Wmd ___ ....

W-468, well 5A.

W-139, well 700 (Re-
dondo) W-468,
well 5.

LACFCD. weH
1335-B.

318 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial No. 2

Loca-
tion
No. 2

LADWP
No. a

Owner or user

Well data

01

*sC"

£§.
1 1

*

1"~*

CU

fi

01

fl

53.1
iH s*^

fi

Water
zones i

a

2

J'S "if
01

p

01

Jy'S

EH

T. 3 S., R. 14 W. Continued

3/14-7K1...

7M1
7Q1--
7R1
8D1._.

8D2...

8E1..._

8E3...

8G1 ...

8G2...

8H1...
8K1...
8K2...

8Ll.-_-

8N1 ...

8N2 ...
8N3...

8Q1 ...
9E1...

9J1.

9N1...
9N2...

9N3...

9N4-

9Q1...

or»9

10A1

10C1

in/~1 9

10C3...

B-36d

B-37a
B-37c
B-36e

B-36n

B-36f

B-36k

B-36g

B-37f

B-36p

B-40c

B-41
B-41a

B-41e

B-41h

Tl-4.1i

R-4da

B-44e

1317

1318
1318B
1327

1327D

1327A

279

1337

1327B

1328A

1338A

1357

1348
1348A

1348E

1358C

1376

1366A

10-C-5

10-C-19

10-C-18

10-C-15
10-C-33

10-C-4

10-C-14

10-D-6

10-D-7

merly Dooley) .

Richfield Oil Co,--
Formerly Frank Ben-
nett.

well 1.

nett.

well 2.

Bohan.

Well 3-- ~

Well 4._

..-.do.. ....

do.- -

Oil Co., Leuzinger
weUl.

S. H. Phillips

- - do..--.---.

hart.
City of Hawthorne:
Well 1
Well 2... .... ..

Well 3.- .... .

Well 4.-... ....

Hawthorne.

Water Co., Korn-
blum plant, well 1.

merly Fred No-
mura).

100

139
95
95
93

89

97

96

96

87

87

82
85
88

93

106

104
93

88
78

77
65

90
96

78

80

65

69

77

64

67
66

140.0

350
125
197
191

200

169

279

1,000

296

304

300
335
333

300

425

308

300
350

430

559
679

760

670

477

600

437

4W

429

10

14
7
12
10

10

12

14

12

10
12
12

12

14

12

10

12
14

16

16

12

12

12
12

158
115
171

113

102
165
246

100
259
114
282

119
267

125
134
290

293

385

240
321
622
295
322
300
396
92
194
329

230

371
490
516
350
370
378

17
19
20

56

33
6
29

36
33
31
8

33
66

5
22
130

57

38

200
148
12
23
66
70
6
82
77
50

10

14
6
84
18
4
18

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

319

Water zones 1
Continued

Character of
material

Pumping data

S TO rj
o|
0

If

&^~^

ft

Q
S

Miscellaneous

Use of well Analyses and
measurements

Eemarks '

T. 3 S., R. 14 W. Continued

. _ do _ , ...
.....do...... _

Sand and gravel ...
Gravel and sand ...

Sand and gravel ...
Gravel and sand. .
.. ...do... ....

Sand and gravel ...
-. do.... ....
Gravel... ____
Sand and gravel-
Fine sand and

gravel.

Gravel and fine
sand.
Gravel... ___

Sand and gravel _
__ do. ....
Gravel ______
. . do._..........
Sand and gravel ...
__ do. _. ....
.....do.............
..... do............
..... do. ....
Gravel ....

Gravel... ....
Sand and gravel _
__ do... _____
__ do ____ ..
. do.... ......
__ do. _ ......
..... do ....

250
500

400

500
700
750
1,050

500

....

12

30

70
35
50

....

T, E
P

T, E

T, E
T, E

T, E

T, E

T, E

T, E
T, E
T, E
T, E

T, E

T, E

P, E

A
A........ .....
PS ......
A. .... _ .
A...... _ .

A....
PS ...
PS .....

A. ....
PS ... .
A.............
Irr. ....

A..

A........

A.. ... .
A...... ... .

PS
PS. _
PS
PS _
A... _ . ...

A............
Irr ..

PS

"X" I I

L.... . ...
L, Wmd.... ....
Cp, L, Wsd -
L, W
C, L, Wsd..

Wmd... __ ...
Cp, L, Ws-. .
Cp, L, Ws_ . -
Wmd, Ws. ......
L, W.. ... .
L ... __
Cp, L, Wmd,
Ws.

Cp ....

W .....

Cp, L, Wsd __ .
C, Cp..

C, Cp, L..
C, Cp, L........
L- _ . ...

L... ____ .
C, Cp, L, Wmd,
Ws.

L, Wmd ____

LACFCD, well 1347;

320 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identincation of wells

USGS Serial No.»

Loca-
tion
No. «

LADWP
No. *

Owner or user

Well data

Altitude (feet) <

Depth (fet)« 0> I
51

p

Water
zones i

Depth toop
(feet)

Thickness

(feet)

T. 3 S., R. 14 W. Continued

3/14-10G1..

10G2..
10K1-.

10L1...

IIA1...
11C1...

11D1..
11G1..
11G2-.
11J1...

11M1._

12B1...

12B2.,_
12B3 ..
12H1..

12H2._
12H3._
12Q1...
12Q2...

13BL-.

13C1...
13E1...
13F1...
13H1..

13J1...

13J2 ...

13J3...

13M1..
13P1...
13Q1...
13Q2...

See footr

B-44f

B-48f
B-48a

B-48g
B-48h
B-48e

B-44c

B-53i

B-53

B-53b

B-54

B-49a
B-49b
B-64b

B-54n

B-54c

B-54q

-

1367

1397A
1386A

1387
1387A
1397

1377

1407D

1407

1407A

1408

1399
1398A
1409

1409B

1409A

1409C

----- -

10-D-17-

10 D-5
10-D-10

ll-C-26
ll-C-9

10-D-l

ll-C-8

ll-C-31

totes at end of table.

City of Inglewood: Well 28.-

Well 30 _
City of Hawthorne,
well 5.
Formerly Security
Trust and Savings
Bank.

O. T. Johnson Ranch,
wellS.
G. J. Pillow .
O. T. Johnson Ranch-
. . do................
O. T. Johnson Ranch,
well 7.

Formerly Johnson
Ranch.

Jerome Dorsey) for-
merly Shell Oil
Co.).

- do...

Los Angeles County. .

.. do-...
. do.

Southern California
Water Co.:

Adelaide plant:
Welll--..-

Ballona plant:
Welll.....

B. M. Phillips.. .

General Petroleum
Co.
Southern California
Water Co.:

Southern plant:
Welll-... -
Woll 9

Well 3-..

V. E. Rasic _ . _

Mrs. Nellie Seymour-

62

62
62

60

199
115

103
152
152
155

59

195

194
194
202

199
205
140

151

130

93
51
67
88

85
82

85

49
48
49
52

798

480

400

251
407

236

701
413

200

302

183.2
270
344

322
582
332

800

564

101
224
274
500

1,000
582

620

100
80

48

18

18-14
12

8

14

7

10

4
6

16
12

16

16

5
10
8
16

12-10
16

16

10
6
6

492
546
638
676

200
233
320

188
284

172

132
164
115

250
269
720

273
285
447

210
390

236
370
408
444
500
536
359

400

498
586

35
32
16
35

51
15
24

36
81

104

30
142
183

10
126
3

4
61
96

64
110

4
10
16
6
18
20
9

52

52
16

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

321

Water zones >
Continued

Character of
material

Pumping data

&-

ll

CB

a Drawdoi te
(feet)
a

S

S

Miscellaneous

Use of well Analyses and
measurements

Remarks *

T. 3 S., R. 14 W. Continued

Sand and gravel _
Gravel and sand --
Gravel __ ...
Sand and gravel--

Sand and gravel
.. _ do. ____ ..
. __ do. ....

- do -. .....
Gravel and sand- .

. .do.... ....
Gravel ______

... -.do ....

Sand.... ....

... .. do. ... ...
- do.. ....
. -do - ...

gravel.

sandy clay.

. do. . -- -

600

675

725

700

17

30

18

20

T, E

T, E
T, E

T,E

T, E

T, E
T, E

P, E

P, E

T, E

T, E

T, E

P
P, I
T, E

T, E

T, E

P, W
P, W
P, W
P, W

PS... ...

PS ... .
Irr.. ....

A.. _____

A ... .

Irr... _ . _ ..
Obs ....
Irr............
Irr... ... ...

A.............

tod.. ....

A.............

A.............
A. ....
Stock-..

PS... ....

PS... ....

Obs ....
Irr...... .
Ind...........

A. ....
PS...... ......

PS..... .

Irr

Irr--

C, Cp, L ...

L... ....
Wsd.. ....

L, Wmd. ___ .
C, L......

Cp...... ....
Cp, Ws. ....
Cp, W._ _ .....
Cp, L, Ws .

Wsd, Wmd.-.-.

Cp, L... --

L, W .....

L, W___.
L, Wmd..
L, Wmd .... .

L, Wmd, Ws....
Cp, L ..... .

C,L...... ... ...

C, L, Wm... ...

Cp... . . ....
Cp ... ...
Cp ....
Cp-.- ... .

W-139, well 255 (Re-
dondo): W-468, well
10.

322 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. 3

Loca-
tion
No. 3

LADWP
No. a

Owner or user

Well data

Altitude *(feet)

Depth (feet)« D iameter
(inches)

Water
zones i

Depth topo
(feet)

Thickness

(feet)

T. 3 S., R. 14 W. Continued

3/14-14A1...
14B1...

I4M1-
15B1...
15D1

15F1

15G1--

15G2--
15K1-.

- 15M1._
15N1-.
15Q1

16A1-.
16A2...
16A3
16D1..
17D1-.

17H1.-

17J1

17L1

17M1..
18A1
1801...

18G1-.
18N1..

18N2-,
18N3. -

18N4..

19A1-.
19A2...
1901...

19D1..
19D2. .

19Pl-._
20J1-..
20J2-.-
20P1

20P2-.

B-49
B-49c

B-45d

B-41e

B-45

B-45a

B-41i

B-41f
B-41k
B-41m
B-41b

B-37J

B-37h

*B-vJ7d

B-37n

B-37k

B-37U

B-37g
B-370

B-37

B^89f
B-89c
B-89e

B-«9d

1398
1388

1379

1358

1368 .

TjOCQ

iqeo

1358A -iqcQT^
1358E

iqoo

1329A

1318C

1309B

1309A

1309G

1329B

1309

730A
730
731A

731

10-D-18

10-D-14

10-D-9

10-D-3
10-D-2

10-C-2

10-C-31

10-0-16

10-C-l

8-A-15

O. T. Johnson Ranch:
Welll.
Well 2-.. .... -

Well 5. ~

Formerly Cochran &
Williams.

ler.

Water Co., Cerise
plant, well 1.

field.

bins.

J. F. Bell-

weU 8.

Water Works Dis-
trict 22.

Inc., West Haw-
thorne 1.
O. T. Johnson Ranch,
well 9.

LuigiMirettL- .

Co.
Richfield Oil Co_ _-
General Chemical Co.
Welll.
Well 2--- --
Well3-__

Well 4--.. - -

well 18.

- - do---

Formerly Maggie
Weaver.
do-... - -

85
65

49
52
59

52

52

53
50

57
56
52

60
60
60
81
100

87

81

108

92
96.
102

89

150
150

110

81
82
94

125
145

140
70
65
75

76

395
277

440
410
368

410

290
74 _

87
80
35.0

150
87.0
95.0
185
421

460

1,294

506

300
125
275

197

450
80
428

350

240
175
400

75
168
159.1

229.3
600
320

158

12

12

12

6

10

5
6
' 7

7
6
12
14

11-9

14

4
5

16

16

8
7
16

7
7

8
10
12
12

6

340
239
244
265
270
276
332

308

360
381

116
296
107
270
312
424
1,089

188
320
128

183

158

i94
219
255
324
353
186

226
302

221
257

352

184

40
4
17
1
3
1
48

60

19
29

37
115
13
32
102
33
205

21
163
70

38

17

16
19
53
22
24
15

36
6

17
11

123

87

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

323

Water zones '
Continued

Character of
material

Pumping data

&

Gallons minute

a

°+>

P

1

fi

Miscellaneous

., Use of well Analyses and
measurements

Remarks T

T. 3 S., R. 14 W. Continued

do
. do - . -

' -

do .

. . do .
do

... ..do...... ... .
.. do....

__ do ___ _ _ .
. . do..... .....

and gravel.

do

do .

510

195

273

20

800

900

50.

T, E

T, E
T, E

T, E

T, E

T, E
P, I
T, E

AI, E

T, E

T, E

P, I

T, E

W

P, W

T, E
T, E

Irr._
A

Irr.._ ... .
Irr. ....
A.. ....

A..... ....

A... ....

A
A....r ....

A
A.. _.__
A.. -.... .

Obs.... ....

to. ...

PS............

Ind ....

A.. ..-.-"-.... .
A. -
Ind.... ...

Ind-.-.-. ....

A. ....
Ind... ... .

A. ....
Obs ......

A....- -----

Op, L, Ws.. .
"L. ....

Cp, L, Wmd....
Op ....
C, L, W-. ...

W..... ... .

C, L__ ....

Wsd... . . -
Wmd.. ....
W-..- ... ...

Wsd... ....
W__. ....
Ws.. ....

C, L, W--

L, Wmd..

C,L, W__ ._

C, L, Wsd. ...

Cp, L, .

L..... ....

L_.__ ... ...

L, W.... .

Cpr, Or, L, Wsd.

Cpr, Cr, L, W..

Cp ...

L, Wmd, Ws .

L, Wrd. -
Cp, W--

W......... ......

,

W-139, weU 170
(Redondo).

LACFCD, well 1368A.

water test.

324 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. »

Loca-
tion
No. «

LADWP No.* Owner or user

Well data

Altitude (feet) «

Depth (fe)«

i-
<D

"I

ft

Water
zones*

Depth toop
(feet)

0>

a

T. 3 S., R. 14 W. Continued

3A4-21B1...
21B2...
21E1...
21F1...

21M1..
21R1..
21R2..

22A1

22B1...

22B2...

22C1...
22J1

22R1-.
22R2
23J1
23J2...
23L1...

23M1..

23N1_.

23N2..

23P1

23Q1...
23R1-.

23R2..

23R3-.
23R4-.
23R6..
24A1
24A2...
24A3...
24B1...
24E1...

24F1...
24F2...
24F3...
24F4...
24G1..
24J1...

24J2 ...

24K1..
24K2..

B-41d
B-41n

B-91

B-46e

B-45e

B-46b

B-96._._

B-lOlp

B-96g

B-96b

B-96c

B-lOlf

B-idin

B-lOlb

B-lOle

B-fo'ij

B-106h

1349
1349A

740

1379A

1369B

1369A

770

790C

770D

770B

771

780

781 E

781B

781 C

?on

800B

8^-A-fo"

8-A-16

8-B-14

8-B-41
8-B-5

8-B-37

8-B-7

ft_"R 4A

7_A_4

Southern California
Water Co.:

Rosecrans plant:
Well I....
Well 2

Southern California
Water Co.:

Chicago plant:
Welll

Chadron plant:
Welll

Moneta Water Co.
do

.....do...... ....
H TT "WVifly^lor

..... do.. ....

Water Co., Comp-
ton plant, well 1.

Rogers.

"Park View High-
lands."

Summers.

Mrs. Ethel Harris.

Bell _. _.
. ....do...--. ....

W. P. Griffith......

ham.

E. W. Field. .

C.J. Knight

Griffin.

Martin.

63
62
63
$7

61
62
62

49

62

62

53
62

62
61
50
48
62

52

51

61

4.Q

45
47

46

46
46
45
56
62
61
62
52

51
51
61
61
62
62

52

51
51

468
627
194
60

438

710

236

392

557
500

485
350
203
280
397

654

751

350

171

50.0

214

250
216
200
215
40
33.0
418
355

45.9

41.7
130
48.6
268

56.6

40

12
14
10
12

12

16

12

10

14

16

16

12

12

7

4

7

6
9

12

10
4H

6
8
8
24
6

6

6

310

378

317
514
660
146
220
316
341

328

334

312
476

160

158

21

67
132
8
68
16
21
47

108

19

96
85

50

Bee footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

325

Water zones '
Continued

Character of
material

Pumping data

S- §"!

"H

te

Drawdo (feet)

I

Miscellaneous

Use of well Analyses and
measurements

Remarks'

T. 3 S., R. 14 W. Continued

sand.

433

550

1,160

600

10

3

51

T, E
T,E
P, I
W

T, E
T, E
T, E

T, E

T, E

T, E
T, E
T

T, E

P, W
P, E

P, E

P, I
T, E
T, E
P, W
P W
T, E

P, W
P, W
T, I
P, W

P, W
P. E

PS............
PS............
Irr--. ....

PS............
Irr.. ....
Irr... ... ...

PS...........

A

Irr.
A. ---.

Irr..- ....

A ....
PS .

A. .. . ...

A ....

A..... ---

A..- -- .

Irr.._ ....

Irr.. -----
Irr... ... ...
Irr ....
Irr
Irr

A

Irr.- ...
Irr
A. --

Irr
Dom__ . _ ....

C, Wm-_
C, L, Wm _
Wmd. ... .

Or, L, Wmd .
Cp ... .

Cr, L, Wm..___.

L.

I,. ....

Cp ... .
Wmd .

Cp, L, Wsd
Cp . ..
L.Wsd .
Wmd.
C, L, Wm ...

I,.. ....

L.. ....

Wmd...- ....

Wsd... -----

Cp.. ....
Wsd.. -

Cp, L, Wmd,
Ws.

Op.... ......
Cp..............

Cp ....

Cp ....

Wmd -

Cp ....

W-139, well 284 (Re
dondo); W-468, wel
0.

W-139, well 285 (Re
dondo) W-468, wel
9a.

W-139, well 461 (Re
dondo).

460508 59 22

326 GEOLOGY- HYDROLOGY. TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in .the coastal

Identification of wells

USGS Serial
No. 2

Loca-
tion
No. 2

LADWP
No. s

Owner or user

Well data

o

13
- 3^

43 "8 "*jj
<l

o>
S

.g "S
o

Q

CD
"*~* CO

O CD a| a .s
Q

Water
zones 1

a

aB~3
O>

5.48 a^
CD
P

O

fl o

2!

iaE-|

T. 3 S., R. U W. Continued

3/14-24K3__
24K4_.
24K5--
24K6..
24K7-.
24K8_.
24K9-.
24K10.
24K11.
24K12.

24K13.

24K14.

24L1...
24L2...

24M2._
24M3._
24N1.-

24N2..
24N3..
24N4-.
24N5-.
24P1
24P2...
24Q1
24Q2...
24Q3...
24Q4...

24R1-.
25A1...

2SD1..
25D2..
2SE1...
25E2'._
25E3...
25E4
25E5
25Fl-_
25P2.-
25P3
25H1..

25J1.--
25J2.._
25J3---
25K1__
25K2- _
25K3-_
25K4--
25L1...
25L2-.
25L3
2SL4

25N1_.
25N2--

25N4- .
25N5_ .

B-106g

B-106q

B-106

B-lOlm

B-lOlk

B-106U

B-106J

B-lOlc

B-101g._

B-108k

B-107n
B-107i

800A

800O

800

790B

790A

800E

801

791

791B
791A
801A

802B
802

7- A 1

8-B-2

8^B^6

7 A 9

7 A 3

8-B-12

7 A 38

8-B 13

Ward A. York.. ______

J. P. Kahr.. _-_-__-_
H. E. StovaU.. ...____
H. H. Coll... ... ...

Park Water Co.

Jantzen.

Water Co., Amestoy
plant, well 1.

.____do_._..--_-_-...___

A. S. WallLs.... _______

Water Co.
Mrs. Nellie Baldrick__
T. L. Hubbell- ....

Frank X. Price. -..._.

do

Formerly John J. Dean.

Formerly C.E.Wallin

__-_do_ ....
A. J. Walter ____., _

B. Leach. ....

J. F. O'Haver. ....

51
51
SI
51
51

51r-1

52
52
52

51

55

51
53
52
53
51
49

48
47
48
47
49
47
50
47
46
51

48
44

46
43
42
44
39
41
41
38
42
39
39

31
31
35
32
32
32
34
34
33
33
36
38
37
36
36
36
36

47
40
62
60
51
40

40
47
250

53

680

200
320
720
134.0
720
197

57
53

180
60
70
80
38

37.3
225

50

38
32.2
35.0
30
35
249
207
28

36
100

30
178
56.6
27
44
150
192

205

160

5H
6
8
6
6
7

10
12

16

8
14
16
7

7

8
5

4

6

10

8
71

6
8
8

8

8
10

4

8

12
6
8
6

8

6

6

6

60

210

11

^

165

39

17

See footnotes at end of table.

-9H)

loaovi

raopan)
'68T-AY Mi

(opnop
'68T-AY M.

(opnop
'68T-AY ^

(opnop
'68T-AV M.

do -... ....
- - do

---pniAY'l --

do

du '1 fuijvv

'do ----SAY

do ....

1
1
n

do

puiiw

1

'do pniAV

AY

- - - - - - - rj -- .

"praAY

'JO '1 uiAY

--psAY'do -

rj - - - -

do

do

- - JJI

V

- -y -
- -JJI " -

-y -

y ------

v -_ ....

- -y -----

y.. ....
- - - - -JJI

JJJ

V
JJJ

- - -JJI

JJJ

V
JJJ

JJJ

- -y ----- -

- - - - - y ....

JJJ ------

-- -JJI

- -JJI

a'i

AV'd

jj
I'd
AY'd
AY'd
a'd
a'i
AV'd

AV'd

AY'd

AY'd

d PI

AY'd
I'd

'TV a
I'i

AV'd
AY'd
I'd
I'd

a'o

dAV'd
a'd

a'i

a'x

'TV i a'x

a'i

a'i

AV'd
AY'd
AY'd
AV'd
AV'd

OS8 6S

;

J- ' £ "S 'a

Sa 9 |0 9. n s8S^i^ny pire ^uba ts

. snogn^it^w

D

S

a

a

So

p

0

|f
"I

^psmdmnj

joSSSio

pannjjnoo
J9^BAY S950Z i .

suoz /o 9i[i

IZS

328 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USOS Serial No.*

Loca-

tion No.* LADWP

No. *

Owner or user

Well data

d

g^~! «^

*

1

so,

<D

Q

h> ®*"?
a|

«a

Q

Water
zones*

I
O'-v

iid^'

Q

S

II
X) t<

T. 3 S., B. 14 W. Continued

3/14-25N6-.

25P1...

25P2...
25P3

26A1 ..
26 A2 -
26 A3....
26A4...

26BL..
26B2 -
26B3
26B4

26B5
26B6
26B7
26C1...
26O2...
2603...

26C4...

26D1..
26D2._
26D3-.

26E1
26E2

26E3
26F1
26Q1-.
26Q2-.
26H1-.

26J1-

26K1-.
26L1-.
26L2 .-.
26L3-.
26M1-
26M2-.
26N1-.
26N2-.

26P1
Oft T> 9

26P3
26Q1
26Q2...
26Q3
26Q4
26Q5-
26R1-.

26R2..
26R3-.

B-102i

B-lOli

B-101

B-lOlo

B-lOla

B-96f
B-96d
B-96e

B-lOlh
B-102f

-

~B~-97e"~

B 102k

B-102a

B-102

7Q9A

791C

781

781H

7R1 A

771D
771A
771B

781D
792

~772A~~~~

782E

782A

782

8-B-10

8-B-9

8-B-ll

8-B-36

8-B-16

....

-

Caldwell.

Mikkelson.

Stables.

E. C. Bartlett .....

man.

(formerly C. C.
Jorgensen).

. rdo.- . .

Lyon.

H. H. Blake- --------

Mrs. E. U. Knape. ...

L. F. Kurtz. ---------

L. L. Flores. ....

P.T.Martin---

son.

36

31

36
Q1

46
46
46
44

44
44
45
45

45
45
48
44
43
44

44

46
48
43

41
42

42
42
42
43
42
43
37

32
41
41
40
40
44
55
55

AK

11

50
45
43
47
41
41
31

37
35

163

192

40
170

40
40
228
183

41.3
185
60
58.4

60
80

41.0
220
205

175
188
215

260
250

470
65,8
200
67.6

134
231

100
"199""""

125
249
300
"236" "

280

204

250

261
132.5

120.0
219

7

12

4
7

6
10
4

7
4
6

12
7
6
12

2H
8
7

10

8
8

6

7
8

-

4

6

8

7
8
7

8

150

126

122
190
234

151

"137"

"lie"

129

128

139

33

10

60
40
12

80

""62"

"m"

82

104

118

See footnotes at end of table.

WELL RECOEDS

zone of the Torrance-Santa Monica area Continued

329

Water zones '
Continued

Character of
material

Pumping data

Gallons per 6minute Drawdown'
(feet)
o.

AH

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 3 S., R. 14 W. Continued

Sand and gravel... SO 3

T,E

P,E

T

P,W

P,W

P,W

P,W
P,E

P,W
P

T, E

P,W
P

Al, E
T,E

T,E
P W
T,I
P,W
P,W

T,E

C,E
P,E
T,I
T,E
T,E
T,E
T, E

T,E
T,E
T,E
P,I
T,E
T,E
A1,I
T,E
P,W

P,E
T.I

A.. ....

Stock.
Irr._ ... .
A...

A

A-.. . __ -

Irr ... ...

A.. _
Irr .

A.

A..

Dom, Irr.

Irr.- ....
Irr.-. ... -
Irr.. ....
A ___
A.

Stock.

A.

Irr- ~

Irr, Stock. ....

Dom... ....

Wmd. _ . ...

Op..

Op - ....

Op ....

L.- ...

Op, Wsd .....
Wmd-..

Cp ... ...

Wmd. __ - ...
Op ... .

Wsd - .

Op...... .....

W ..... _ .....
L, Wmd. -
L

Cp, L... ..-

Cp, W ....
Cp... .....
Cp ... ... -
C, Op -

L.- ....
C, Cp, L -

Op... .... Cp....... ....
Cp - ...

Cp...... ..... CP..- ....

Cp, Wmd«. .- op.. .....
CP ...
Cp, L..~-

Cp, L, Wsd ..
C, Cpr..

Cp. -
Cp ....

W-139, well 406 (Re-
dondo); W-468,
well?.

W-139, well 403
(Redondo).

W-139, well 433
(Redondo).

L.

W-139, well 295
(Redondo) W-468,
wellS.

W-468, well 8a.

W-139, well 327
(Redondo).

330 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wetts in the coastal

Identification of wells

USGS Serial No. 2

Loca-
tion
No. 2

LADWP
No. a

. Owner or user

Well data

0> d^ £1'

*

I

a "a

0

"5?

a| 2S

0

Water
zones i

si

0

W

0>

SI
43

^

T. 3 S., R. 14 W. Continued

3/14-27Al__.

27C1___
27D1__
27J1-..
27J2...
27J3-..
27K1..
27K2..
27K3-.
27K4..
27K5-.
27K6..
27L1...
27L2
27M1-.
27M2-.
27M3-.
27N1-.
27N2-.
27N3--

27N4-.
27N5-.
27P1
27P2
27P3
27P4._
27P5...
27P6...

27P7
27Q1...
27 Q2___
27Q3...
27Q4...
27Rl-_

27R2-.
28K1__

28Q1...
29C1...
29D1 . .
29D2-.

29D3-.

29G1-.
29M1...

29N1..
29N2..
29R1-.
30A1...

30A2
30D1..
30H1..

30M1
30P1
30R1-.

B-96f

B-91a

B-97b

B-92e

B-89b
B-89a
B-89

B-90J

B-90h
B-90

B-84d

B-«4i
B-84h

B-^5a

B^90a

771C

751

772

752A

721B
721A
721

722C

722B
722

711

701 P
711A

702

722A

8-B-1S

8-A-ll

8-A-19

(Park Department).
. . do.__. .. .

Mrs. D. V. Davis .....

H. W. Nielsen.. ...

A. A. Blain.. ...

Nellie M Pohl
H. A. Alien. . ...

Bonstell.

C. C. Eliot

A. R. Black -

White Mfg. Co -

Union Oil Co ..--

States Water
Service Co.

Beach, well 11.
California Water
Service Co.:

16. _ .

12 .

Schoellerman.

City of Manhattan
Beach:

Well 8 ... -
WellQ -

Frank Alien..

50

45
48
41
41
43
47
44
47
46
47
47
51
50
55
64
55
70
66
65

64
65
57
56

69
58
Kg

50
57
53
52
52
54

54
72

92
82
93
96

88

87
115

113
120
inQ
on

102
157
07

241
164
100

485

448

150
160
225
237
121.5
65
140
212

149
220
63
210
200

160
140

225
285
231
238
200
250
200
175

65
280

80
55
230

230

99.5
200
165
97

620

570
474

500
208
150

525
350
390

276.5
311
250

14

6

7
10
8

8
8
7

8
8

6

8
6

12
12

8
6
7
8
4

8
6

7

12

10
6
8
6

16

16
16

16
8

8

16
16
16

6

328

130

160

190
394

173
197
346
206

187
225
142
218

245

108

88

70

75
37

177
63
36
194

110
30
24
82

66

See footnotes at end of table.

WELL RECOKDS 331

zone of the Torrance-Santa Monica area Continued

Water zones J
Continued

Character of
material

Pumping data

b

-2 % a
§.a r3 a
o

Pt

t>o^ c »
£&
C3 ^

fl

a

S

Miscellaneous

Use of well Analyses and
measurements

Remarks ?

T. 3 S., R. 14 W. Continued

. . do. .... -

shells.

-. do -
- do .

.....do ....
. do .. .
Gravel and sand. -

600

1,800

1,125
905
980

25

28

55
54
26

T,E

T,E

P,E
Al, E
A1,E
T, E
P, W
P,W
P, W
P, E
P,W
P,W
P,W
P, W
T,E
T,E
T, E

P, W, E

T,E
C,E
T, E
P,W
P,I
P,I
P,W
A1,E

P,E
P, E
A1,E
P,E
P,E

T,E

P,W

T,E

T,E
T,E

T,E
P,W

T,E
T,E
T,E

T,E

ITT. ....

A

Irr
Irr.

Stock.

Stock.

A.

Irr
A. -

A...

A..
A.
PS

PS
PS

PS -
A-.. -
A
A.... -

PS
PS
PS

Irr
A
A

Wmd.- __ . _
Op...... ....
Op ... .
Cp ....
Cp,L .....
Cp ... . _
Cp ....
Cp ... ...
Cp_ ....

Cp. ....
CPL_... ....

Cp. ....
Cp... _ ... ..
Cp_

Cp ... ... -

Cp_ ....
Cp ....

Cp... ... ...
On
On

Cp_
Cp.-. ... .

Cp. ... ...

Op.. .... -
L

Wsd_

Wmd...-- _ -._

Wsd-.
Cp, L...

Cp,L._.

Cr,Cpr,L,Wm
Wsd-

C,L--. _
Cr, Cpr, L, Ws_.
Or, Cpr,L,W .

W .... -

W-139, well 325
(Redondo).

332 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26, Description of water wells in the coastal

Identification of wells

USQS Serial
No. a

Loca-
tion
No. >

LADWP
No. »

Owner or user

Well data

-d^

*°^j

Sfi
*

o> 3
'S

Q

1?
Q A

«i
Q

Water
zones i

1
"*"* a>

ss

Q

m

y>
H^R

a
EH

T. 3 S., R. 14 W. Continaed

3/14-31A1...
31A2
31A3
31A4
31A5...

31A6
31E1...
31ML_.

32A1
32FL-.
32H1..
32H2-.
32J1...

32K1-.
32R1-.

33AL-
33A2...
33A3
33A4...

33B1__
33B2.._
33C1..
33C2..
33D1_-
33EL-.

33E2...

33FL-

33F2...

33Q1..
3302..

3303..

33H1..
33H2..
33H3..
33H4._
33HS-.
33J1-...
33J2..-

33J3.-
33 J4._.
33K1..
33K2..
33K3..
33L1...

33L2
33L3...
33L4...
33L5...
33P1...

B-85d

B-85f
B-851
B-85e

B-85C B-85
B-85h

B-SOc
B-90b
B-90e

B-90g

B-90f
B-901

B-92f

B-92b

B-92a

B-92q

B-92

B-92J

B-92L

B-921

B-92m

B-92o

B-92C
B-92k
B-92n

712A

712B
712C
713

712
703
703C

732
723
733

733B

733A
733C

753

742A

742.-
742C

743
743B
743C

743E

753C

743D

753A

753D

743A
753B
743F

8-A-4

8-A-5

8-A-8

8-A-12

8-A-9

8-B-34

California Water
Service Co.:
Station 6, well 7 _

wellC.... -

California Water
Service Co.,
Station S, well 6.

California Water
Service Co.:
Station 8, well 8.

~W R Oallinger

do
W. S. Fullerton.

- - - do ....

Pacific Crest
Cemetery.

ton.
V. 0. Mott. ... .

Formerly R. O.
Hickman.

Harsh.

A. C. Hurt
... .. do ~

Co.
DonF. Willis ....

McAllister..-_-_- _ .-

Water Co.

El Nido Chapel -

95
94
QD

92
130

92

68

95
146
100
QQ
110

I'in

109

74
74
80
7ft

QC

Q^
1HR

105
82
121

107

98

100

100
82

98

77
77
80
80
80
78
71

78

84
94
Ql

93
on
01

93
110

340

510
125.9

502
260
151

449
900
197
158
413

200

250
198.8
200

207
214
272
101.4
594
228

190

233

400

250
230

174

199
230
187.8
250
300

201

218
230
191
250

160

178
216.0

12

16
10

16
6
7

16
12
8
7
12

8
8

6

12
8

8
7
10
10
IOH
6

7

10

10

10
10

7

6
10
8

12

8

10
12
10
8
8

7
10
8

183

150

190

136

140

137

152
233

122

169

154

110

100

112

173

167

157

292

282

15

309

50

63
180

98

59

79

120

74

87

28

24

See footnotes at end of table.

MM M M MMMM

B: B BB: B

off a QOQO fO

r" t-1

o: o 0
2 COS

i &

:

oo
ow

o^ e

MM

^5^9

-p-

5«
r1

PB

M MM

QOOOQ

Q

Bgr
|I
gg}

a

Gallons per
minute

Drawdown 6

Pump

d
a

1B

IB

M P-

|

^

o S"
C+ £Q 0* O

S §

T

*

I
i

I

^

r
a

334 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. «

Loca-
tion
No. «

LADWP
No. s

Owner or user

Well data

01

a

£*-'

<

«S

a

P

01

aj a>

B|
.23-

p

Water
zones i

a
o

oo-

gj

s>p

flj?
o«S

A
^

T. 3 S., R. 14 W. Continued

3/14-33P2
33P3
33Q1

33R1_-
34A1
34Bl-_.
34B2

34C1...
34D1..

34D2-.

34D3..
34D4..
34FL-
34F2
34F3
34G1-.
34H1..
34J1-..
34K1..
34K2-.

34L1...
34M1 -
34N1..
34N2..
34P1

35A1..-
35A2.-
35A3
35A4
35B1-.
35B2
35B3
35B4
35B5
35C1

35E1...
35G1..
35H1..
35H2. .
35J1. . .

35L1-.

35L2...
35L3...

35L4
35M1_.
35M2-
35M3-
35M4-
35R1-.

OftTJ-l

36B2...

36D1..

B-93a

B-97a

B-92d

B-97d

B-102c

B-102d

T»_Q7

B-103b

754

762

752

763

782C

782D

782B

783A

fyoq

pyfrq

794

8-A-18

8-B-39

8-B-32

8-B-31

8-B-30

8-B-19

8-B-23

8-B-29

7-A-39 "

casting Co.

EdSaul -

Edison Co., Ltd.

Edison Co., Ltd.

Academy.

J. J. Williams

Earl Wing..

ly R. B. Morrow).

J. T. Ems .

\Vs-lt6r Niplson

Ed Saul __ - _____

W. H. dark.
B. W. Davidson _ __
Higgins Brick & Tile
Works.

Cameron.

F. W. Link.. -

Edison Co., Ltd.
(Torrance substa-
tion) .

John Greenwood. -.

84
90
100

82
56
57
65

68
74

74

72
70
70
71

66
60
62
66
58

70
72
76
76
72

41
40
46
45
48
47
46
54
50
55

63
58
56
47

62
61

64
62

63
63
63
63
63
57

38
38

29

200
200
225

99.5
235
229

ICO

300

250

225

215
215
264.0

214

225
100
235
300
219

221
150

188
165
400
265

400

480
45
200
139.6

190.0
410

410
147.3

600

148.7 finn
193
550

77.4
315
127.0

10

10

7

7

8

10

8
12
8

10
10
10

8

7
12
7

8

8

12

16

10

6
16

8

8

155

155

125

110
184
254

470

70

35

70

68
4
126

78

See footnotes at end of table.

WELL RECORDS 335

zone of the Torrance-Santa Monica area Continued

Water zones '
Continued

Character of
material

Pumping data

su

IIis

O

<£>

a

<&*"'

Q

1

Miscellaneous

Use of well Analyses and
measurements

Kemarks '

T. 3 S., R. 14 W. Continued

_. ..do _____ .
.do_...__ .

500

600

T,E

T, E

T, E

T,E

T,E
P,E

P,E

T,E
T, E
T, E
T, E
P,W
T, E
T, E
P, W
T, E
P, E

T,E
T,E
T,E
P,E
T, E

P,I
P,I
P,W

P, W
P,I
T, E
P,E

T,E

T, E
P,M
P,W
P,M

P, W
T, E

P,E

P,I
P, E

T,I
P,W
A1.E

P

Irr- .....

Ind..... ..

Ind. ....

Irr ... ...

Irr.. ....

Stock.

A.. ....

Irr, Stock- .. -
A....... ......

Irr.

A. .

PS......... ...

PS............

A......... .

C*n

g-1-r.

Wmd. -...

Or* E^:::::::::::::
Cp.. ....

Cp. . .... .

Cp, Ws.-

Cp... ....

Cp...........

Or»

Cp.... . ...

Cp, L, Wmd

Cp....... ... .
Cp
Cp, L.
Cp ....

Cp, L.. ....
Cp....... ....

Cp........... ...
Cp.., ...
Cp

Cp... ....

L-..- . ...
Cp... ....
Cp... ....
W......... .... .-

Cp............. .
L. ....

Cp...... ....
C, L, Wmd .

Cp..............

C, Cp ....

Wsd, Ww.

L, Wmd... . .-

LACFCD, well 792B.

336 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. »

Loca-
tion
No. »

LADWP
No. a

Owner or user

Well data

Altitude
(feet) «

Depth (fet)« Diameter
(inches)

Water
zones '

f
Q^j-

P

Thickness

(feet)

T. 3 S., R. 14 W. Continued

3/14-36D2..
36D3..
36E1...

36P1 _
36G1-.
36G2-.

36J1...
36J2...
36J3...
36K1..
36K2..

36K3-.

36L1
36L2-.
36M1.-
36M2..

36M3..

36N1-.
36N2..
36Q1...

36Q2...
36R1-.
36R2

B-102g

B-106d

B-107b

B-102q
B-107k

B-102o

B-108c

793

803A

803

793A
803B

793C

793B

stnA

7_A_49

7-A-41

8^B-38

8-B-22

7-A-44

7 \ A*\

A. Corwin.

J. W. Barnett (for-
merly P. H. Carrel).

L. H. Figge

Park Association.

Ranch.

tnerly Luckens-
meyer) .

do.

Martin Ranch).

36
36
51

47
40
43

39
36
36
42
43

47

47
47

47v)
51

52
52
47

4fi
37
36

144.5
185
163

128.5
300
400

350
55.8
64
322
659

300

270

587
100.0
315

193.0
80
63.0
500
218.0
352
254
70

7

4

6

5
8

10

10

4

12

7

4
6
6

6
10

142

526

21

141

T. 3 S., R. 15 W.

3/15-1H1...

12B1...
12G1-.

12G2-.

12H1. .

12L1...

12L2

12L3

12L4_._
12L5

12L6

B-36a

B-33g

B-33h

B-36b

B-33

B-33a

B-33b

B-33J
B-33k

B-33i

1306A

1297E

1297D

1307

1297

1297A

1297B

10Q7/-1

1297G

1297P

10-C-8

9-D-15

9-D-14

9-D-3

9-D-2

9-D-l

9-D-16

Andrew Bennett

City of El Segundo:
Well 10
Welle. --

Well 5 _ _ -

Smith-. _
City of El Segundo:

Woll 1

WeU2_

WellS--

Well 4 __ ... .
WellS.-..

Well?...

110

115
113

108

140

176

174

171

183
167

174

625

400
349

394

189

355

503

370

378
380

350

12

16
16

16

8

16

16

16

16

16

84
177

185
139
205
290

129
197
318

236
285

210
230
278
218

275

207

262
222
296

48
13

55
15
16
42

24
6
5

20
70

10
14
22
36

33

31

50
26
24

See footnotes at end of table.

WELL RECORDS 337

zone of the Torrance-Santa Monica area Continued

Water zones >
Continued

Character of
material

Pumping data

§US
II

o

a

'Cf Q>

03
hi

Q

ft

AH

Miscellaneous

Use of well Analyses and
measurements

Remarks'

T. 3 S., R. 14 W. Continued

25 6 A1,I
P, W

P, W
P, E

T, E
P, E
P, M
C, E

P, W
P, E
P, W
P

P, W

P, W

T, E
T, E
P, E

Irr .

A _ . ...

A

Dom, Stock

A. ... ...

Obs

A... .....
Obs-

Op.............. OP...-.---

Cp ... ...
Op. .
Wsd- __ . ...

Wsd.. ... .
Cp
Cp.. ... ...
Cp ... .
Cp, L.- .... ..

L, Wmd

Cp
Cp
Cp
L, Wmd

Wmd, Ws, Ww-

Cp ....

f^r\

W-139, well 384 (Re-
dondo).

W-139, well 1001 (Re-
dondo); W-468, well
6.

W-139, wen 660 (Re-
dondo).

T. 3 S., B. 15 W.

... .. do..

do .
- do....- ...

gravel.

do

gravel.

Gravel ______

gravel.

sand.

clay.
_ ..do __ ... __

- - - do -- --._

540

680
1,050

950

.

900

970

54
20

11

18

33

T, E

T, E
T, E

T, E

P, W

T, E

T, E

PS
PS

PS

Obs

A.

A ...

A.. ...

A-. _
PS

A

Ws. .....

C, L.
Or, Cpr, L, Wm

Ws ... ...

Or, Cpr, Wmd--

Wmd.

C, Cpr

Cr, Cpr, L,
Wmd

338 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. 2

Loca-
tion
No. 2

LADWP
No. 3

Owner or user

Well data

CD da"*
~!

«^"'

<S

*?
8

£1

&
fi

CD

f

- ^,^-N

***~'

fi

Water
zones 1

ft o

CD
fi

oj

£1

EH

T. 3 S., R. 15 W. Continued

3/15-12L7.-

12R1-.

13A1...

13A2...

13A3

13A4...

13D1__
13D2_.

13E1
13F] _

13F2...

13G1

1QH.9

13H2..
10T1

1**T9

13J3-..

1 QT? 1

13R2-.
13R3-.

13R4-.

13R6-.

\A A 1

14A2

24D1..

B-371

B-37p

B-32
B-32a

B-33e

B-33d

B-33c

B-33f
B-37S

B-37r

B ^*>H

B-32e

1308

1308A

1288
1288A

1298B

1298A

1298

1299
1308B

1309D

1289

9-D-12

Well 9.-..- .

Edison Co., Ltd.

Standard Oil Co.:
Well 10--. -

Well 13.-.-.

Well 15--.- ....

Well 24.-.. __ ...

Welll _.
Well 2.--. .....

Well4b.. ...
Well 5..-

Well 8.--.

Well 6.-. -

Well 7...-... ...

Well 14. -.
Well 11--. .

Well 21.-..

Well 23 .

Well Q

Well 16.- .
Well 17 _ - __ -

Well 19 ______
Well 20---

Well 22 __ . ...

Well4a
'Well t

City of Manhattan
Beach:
Well 5... ____

164

QC

106

110

101

122

97
90

100

105

129

145
QC

104
107

100

143

164

153
134

133
158

149

79
116

99

380

345

450

400

450

250
251

404
497

474

530

475
600

456
400

452

466

400

480
450

440
504

495

403

390

16

16

16

16

12
12

26-16
20-12

20

16
16

16
16

16

16

16

16
16

16
16

16

26-16

16

212
278

230
292

249
286
268
318
242
302
412

159
150
168
Ifi9
185
320

355

192
242
340
408
195
230
288
370
435

216
162
198
277
352
181
222
290
366
235
282
263
380
292
376
339
212
270
366
284
426

275
378

185
307

158

23 ' 22

59
50

25
12
15
10
38
38
13

11
14
4
33
99
27

55

38
52
34
16
15
40
32
25
7

85
12
29
86
73
31
34
51
7
15
13
103
68
50
24
121
13
12
41
26
30

71
32

33
11

9£

See footnotes at end of table.

WELL RECORDS 339

zone of the Torrance-Santa Monica area Continued

Water zones 1
Continued

Character of
material

Pumping data

feD**°
£

1!
9 S
0

«o

a

&

11.
h

Q

0,

PH

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 3 S., E. 15 W. Continued

Sand and gravel .
do . .

sand.
Sand and gravel ...

do ...

Sand and gravel
- do ------

and clay.

do . ...
do..
Gravel and sand-.
. . do .
Sand and fine
gravel.

clay.
Gravel ....
.. do
Sand _____ -

- do
- do
do

clay.
Gravel and sand- -

Sand and gravel ...
Sand

__ do__ ..
- . do_- -
do_.-.
do
- do..
- do
. do..

do
- do .
.. do-... -----
- do. -_ _.
do

gravel.
Sand and gravel ...

clay streaks.

. do....

sand.

800

1,000

800

475

....

1,180

1,000
850

i,ioe

920

600

860
880

560

900

600

20

39

35

85

....-.-

26

20
32

87

14

13
28

16
34

50

20

T, E

T, E

T, E

T, E

....

....

T, E
T, E

T, E

T, E

T, E

T, E
T, E

T, E
T, E

T, E

PS

A

Ind-

Ind.-

Ind-

A
A

Ind
A...--.-. _ --

A.. __ -. _ ..

A

A.. __ _
A. __ ..

Ind-
Ind-. --

Ind"-

Ind--

Ind-

Ind
Ind.._ .

Ind--_ -_
Ind

Ind

A
A _ .. ...

Obs

C, Cpr, L- ...

W...... ....

Or, Cp, L, W

Or, Cpr, L .

Cr, Cpr, L ......

C, Cp, L

Cr, Cpr, L-
C,Cpr,L,Wrd,
Wsd

Cpr, L, W..... -

Wind-.. _ -,--

Cr, Cpr, L, W_.
Cr, Cpr, L

C, Cp, L

Cp, L -

Cr, Cpr, L, W-.

Cr, Cpr, L__._._

C, Cp, L

C, L_ ...

C, L, Wm, Wrd

LACFCD, well
1307A.

340 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial No.*

Loca-

tion No.* LADWP

No. »

Owner or user

Well data

<D

S"*

£i

i *"

"

#
S

®P

<D

a-s

. rt* '

P

Water
zones >

a o

©

q

m

0)

o«2

a
EH

T. 3 S., R. 15 W. Continued

3/15-25A1..,
25A2
25A3...

25A4

25C1

25H1-.

25H2..

36H1-.

36H2..

B-84b
B-84g
B-84f

B-84a

B-84e

B-84

B-84c

B-85b

B-85g

701A
701E
701 D

701

691

701B

701C

703A

703B

8-A-2

8-A-l

8-A-3

8-A-17

703A

WellS..-
.Well 7 -
Welle.--.

Well 2.--

Beach Co.

City of Manhattan
Beach:
Welll...

Well 4..

Beach Land and
Water Co.

145
156
156

151

88

142

152

85

40

547
350
350

339

200

579. 1
1,000

395.0

116

14
16
16

16

10

16

16

7

204
224
222
287

222

284

209

527
239

76
36
46
S

57

11

31

14
26

T. 4 S., R. 13 W.

4/13-1C1.--

1F1_

1F2....

1M1
INI ...
1P1 _
1P2_
1P3.
1P4
1O1
1Q2.--
2A1 .
2J1-
2J2.

2J3
2J4
2K1--
2N1...
2P1

2P2
2P3 .
2P4 .
2Rl-_.
3R1-.-

5J1

5LL

5QL

C-934b

B-1231
C-935k

(M)35e
C-935f

B-123f
B-123e

B-123d
B-118c

B-123c
B-123a
B-123?.
B-118h

B-113a

B-113

B-113b

904

895A
905F

905
905B

894A
894

885B
875D

8S5A
884
895
875K

834A

834

835

6-C-4

7-B-41

7-D-50

7-A-46

Extension Water
Co.

North Long Beach
well 3.

Co.

E. W. Maekie. ___ .
T. W. Bishop

do
Del Amo Estate Co _

do.--.. - .
. do -- -
do..-

Del Amo Estate Co _

-.do .

do .

Dominguez Estate
Co.:
Well2.-_

Welll-.-

Flood Control Dis-
trict, test well 3.

47

46

46

45
42
42
43
44
43
44
43
45
45.
42

44
44
44
41
37

37
37
41
41
34

13

12

11

236

467

85

43.0

400
100

162
60
400
160
927
155

168
178.4
24.5
100
118

97
145
161
85.3
392

750

751

105

12

16

S

4

8
4

4
4

12

12

14

14mm

12

4
12
14
12

12

12

6

190

380

419
49

22

29

126
368

633
688
350
587

24

59

251
74

3

88

6
8

44
26
5
164

See footnotes at end of table.

WELL RECORDS 341

zone of the Torrance-Santa Monica area Continued

Water zones i
Continued

Character of
material

Pumping data

ft-
«!
§3

O

"a

a? feS.
(H
ft Pi

Miscellaneous

Use of well Analyses and
measurements

Remarks'

T. 3 S., R. 15 W. Continued

- do.............

gravel.

gravel.

sand.

clay.

400
690
615

300

216

32
36

T, E

T, E

T, E

PS ....
PS ....
PS .....

A _ . ...

A.. _ ._

PS ....

Obs

A ____ .. ...

A...... ....

Or, Cpr, L, Ws.

Or, Cpr, L, W._

C, Cp, L, W.._.

L...... _ .

Cr, Cpr, L,
Wmd, Ws.

Cr, Cpr, L,
Wmd, Ws.

L _______ ..

W-139, well 267
(Redondo).

W-139, well 271 (Re-
dondo).

T. 4 S., R. 13 W.

.. do.... ....

.... . do. ...

Siltysand

- do... ...

T, E

T, E

T, E

P, W

C,I
P, E
T, E
P, E

P, I
T, E

T, E

T, E

P, E
T, E

P, E
T, E
T, E

T, E

Dom, PS ......

Dom, PS ...

Dom, Stock ...
A.............
PS, Irr .....
Irr... __ ....
PS....... .....
Dom, PS ...

PS ,..
Irr............
A _ ....

Stock.
Irr............
Obs
Obs... ....

Irr..... _ ....

Irr

Irr, Stock _ .
Obs... ....

A _ .... __ ..

A........ .....

Cp, L .

Cr, L, Wr, Ww.

Cp........ ... ...

Cp, W_. ....
W .... _ . ...
Cpr __ . ...
Cp ....

Cpr ....

W ....
Wmd ._.-. .
L, W-......
Cpr, L, Wmd

Cpr, Wmd- .....

Cpr, L, Wm
Cp ....
L, Wm

Cp .... .
W..... .... .
C.. ..
W. ....
Cp, L, W.

Cp, L, W.

L, Wd, Wrd..-

Cpr, L .....

W-138, well 843.

USGS test well.
LB, well E-14.

JBL, well 834.

i

. . '.-.-. !

460508 58

342 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

usas Serial
No. s

Loca-
tion
No. »

LADWP
No. s

Owner or user

Well data

Altitude (feet) «

Depth (feet)' 0)

S"S

5

Water
zones i

Depth toop
(feet)

Thickness

(feet)

T. 4 S., E. 13 W. Continued

4/13-6J1.
6J2-...
6K1___

6K2...
7E1...
8L1..-

SP1 Q"R1
9E1 .
9H1...

9R1--.
10A1..

10A2. .

10B1..

10B2_.
10C1-.
10E1..

10E2..

10F1
10G1_
10G2
10G3--
10G4__
10H1-.
10H2-.
10H3-.
10J1--

10J2...
10J3-.-
10J4...
10N1..
10R1-.
11B1..
11B2-.
11B3__
11C1-.
11D1..
11D2..
11E1..

11F1...
11H1..

11J1...

11K1..
11K2.-
11K3-.
11KS-.
11L1
11L2
11L3...
IIPI..
12A1..
12A2..

B-108a

B-108b -

B-108
B-114

B-113C
B-114a

B-118

B-118a
B-118d
B-118f

B-119a

B-llSc

B-llSg

B-119s

B-119t

B-123

B-127b

B-127m

B-1240

824

814

80S. -
836

Q KC

845

875B
875E
87SO

866

87SC

875J

876M

876N

885

896A

896D

886E

7- A->;1

7-D-47

7-D-40

7-D-36

7-D-35

7-D-48

7-D-38

Shell Oil Co., Inc... -

Shell Oil Co., Inc_- -

-.do ~

... .. do ... .
Stauffer Chemical Co.
Shell Oil Co. , Inc.

Mrs. Jeanette Jones.. .

.. do .. .
..... do ....
-.do .... __ ......
L. Machado.. ...,. ..

... ..do ....
C. H. Ellers _ . ....

. . do - ....
Dominguez Estate Co.

Edison Co., Ltd.

..... do..... ....
Dominguez Estate Co.
__ do _ . ...

City of Long Beach.. .

20
20
23

23
34
18

18
21
16
24

24
33

32

29

24
26
25

30

28
29
30
30
30
31
30
30
29

29
29
30
24
29
38
37
37
38
35
34
31
31
34
37

36

34
34
33
36
33
34
33
30
40
38

95
173.3
82

70
99.9
32.2

9.3
1,060

1,202

568
175

112

141

120
895
1,092

1,230

17.6
185
90
80
115
370

85
157

160
350

20.5
27.9
26.0
26.7
30.4
149
28.6
145
110
30.8
14

127
140
167
20.9
140
144
30.5
23.3
330
1,946

4
8
5

3
7
36

2

32-16-

12

10

10

10
16
12

18-12

1H
7
5
5
6
10

4
4

10
10

4
IJi

IJi
IJi
IJi
12
1H
12
2
1H
6

14
1H

1H
1H
6
26-16

25

93
120

717
63
907
335
795
975
12

63
70

42

123

20
24
26
25
27

30

27

60
13

50
22
17

284

128

3
10

140
3
50
105
70
45
6

17
32

115

20

2
4
1
2
1

2

5

53
7

65
7
6

See footnotes at end of table.

haoo
!C

3

'CWCW ^ ^Ht ^
fff

go

QQQQt^QQfQ Q QQQQQQQ O "O

^ooootfo
cro o crH cr

ooo

BB

BB

p-P-

ha ha ha ha ha ha ha

BBBBBBB

QQQQQQQQQ

sr

fOQ

s1 sr

s s

00 OS

p. &
I B-

^ cn

1 I

J3 03

f fcj cj
oa«Tt»wrw WO-WOQ BQ
r, s Cr, H* *3.~O O

cj f

ftH t-| cJ
triW WO3

f f

w "'i.

ooo 0

QQQ QQQ

ir!

Q
if

l!

2.

Gallons per
minute

Drawdown 6

(feet)

Pump

S
3,

1

11

Remarks' ~

OS.
O Ct>

II"r

Pumping da

CO

I

344 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. s

Loca-
tion
No. »

LADWP
No. a

Owner or user

Well data

a>
O^

. -I*"' 51
*

1

a

S1

fl

3^

a| ~<^-
fi

Water
zones'

I

&
fl

M
m
o

^ S oS
J3
&

T. 4 S., R. 13 W. Continued

4/13-12B1..

12B2.-

12C1..
12E1..

12E2.-
12F1...
12F2
12G1-.
12G2--
12H1

12H2-
12K1-.

12K2--
12K3--
12M1-
13D1..

13E1-.
13J1--
13M1..
13M2-
13N1-.

13N2-.
14A1..
14A2--
14B1..

14B2-.
14C1..

14D1-.

14D2..

14D3-.
14D4-.

14F1
14F2...
14F3
14G1-.
14H1..

14J1...
14J2...
14J3...
14K1..
14IC2-.
I4K3--

14K4-.
14K5--

14K6-.
14L1...

14L2...
14M1-
14M2-.
14M3-
14M4..

C-935g
B-129b
B-127C

C-935h

C-935n
C-935d

C-9351

C-935b
C-935C

C-905g

C-905d

C-905

C-905h
B-127d

B-127a

B-124c

B-124b

B-124a
B-119n

B-124m

B-124q

B-127

C-906e

B-127e
B-127J
B-124h

B-124g

B-124k

B-124L
B-1241

905C
906A
896B

906B

905G
915

906D

905A
904A
906

897L

897E

897A

897N
896C

896

886B

886A

8761

886
876J

887K
887G

8971

897F

897
897J
887B

887A

887F

887J
887D

6-C-l

6-C-2

6-C-3

6-C-6

7-D-27

7-D-25

Pillow _______

Virginia City. ....

Club.

..... do-....... .. ....
Virginia Country
Club.
__ .do... _______ .
..... do ....

C. S. Jones, Los Cer-
ritos Estates.

..... do ....
Dominguez Water Co.

Dominguez iEstafe Co.

..... do ....
Dominguez Water
Corp., well 14.

Corp.:
Well 11. _ -

Well 11
Well 9. ... .

__ do _ - ....
Los Angeles County ...

Fitzgerald Engineer-
ing and Construc-
tion Co., test well 3.
Oil Operators, Inc _

H. E. Dickson _ _ ..
... .. do....
Southern California
Edison Co., Ltd.

Edison Co., Ltd.
City of Long Beach ....
Southern California
Edison Co., Ltd.

N. Namura. ___ ....

40

42
38

38
77
35
37
37
54

81
91

44
45
38
60

47
106
56
30
58

58
30
30
31

31
31

30

28

29
28

30
30
24
32
32

27
28
25
29
29
31

29
30

29
29

28
27
26
26
26

130

15

138
336

35
177
27
22

674

1,010

295
350
475
358

121
295
450
35
205.0

240
500
31
230

200
193

189

161

150
1,013

130
135
22.3
187
164

600
33
26

71
130

110
49.2

20.3
114.3

140
145
83
87

4

12

6

6

12

16

14
14
12
12

6
6

4

5

6
12

12
12

12

16

12
12

12
12
W

8

6
6

5

2
6

1H
10

8
4
2
8

106
130

424

980

188

280
256

220

63
176

88

77

80

117
791

50
73
18

143

16
86

14

200

31

72

80
101

200

37
33

61

44

58

31
222

59
28
4

2

5
28

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

345

Water zones »
Continued

Character of
material

Pumping data

gl

la
O

«0

OS^*"^

* *

Miscellaneous

Use of well Analyses and
measurements

Remarks'

T. 4 S., R. 13 W.-Continned

Sand _______

Gravel _

Gravel and sand..

- do- ~

clay.

sand.

Sand and gravel

Sand..

Gravel

Sand. __ -

360 __

1,600

... . .

210~"II

P, W

P, W
P, W
T,I

T, E
T, E
T, E
T, E

T, E
P,I

C, E

T, E
T, E

T, E

T, E

""t",¥"

T

TCl

P,I

P, W
P w
T.E

A..

A_
Obs ....

A_
Obs
A. -

Dom, Irr,
Stock.
Obs
Obs

Irr...
Irr-.
Irr. .

A. ......

Obs
Obs

A. ...... -
A
A
Irr.

Dom, Irr. .....
PS, Irr

A... ....

PS ....

A... .....
PS ... . -

A

Obs. ....
Irr.. ...
A -- -

A ... ...
A...- ------
A ______ -
A _ -- . -

A __ ...
Obs -----

A... -
Obs

A... .
A... -

Irr...

L..._. ....

Wm ....

Wd ... ...

Cpr, W ....

Op, L, Wm .....

Wmd ....
L, Wr ..

L _.........
L _ ....

L _ ....

W.........

Cpr, W ....
Cpr, Wmd _....

W. ... .
L.. . ...
Cpr . __ .
Cpr, L, W -

Cpr . ...

L.. ....

Cr, L, W.. .

L...
Cr, L.......... .

C, Cpr, L-

Cpr, L. Wm ....
Op . -
Cp, L, W. ...

W.....

Cpr, W...

Cp, Wd.....
Cpr, W ..... .
Cpr, W _ ......

Cpr, Wm .....

Cpr, L-Wmd
Cr, L, Wr... -

W ..... -
L.. ....

Cp. ...
C ____ -
Cnr..-.-. -

LACFCD, well 908P
test well.

JBL, well 896-B; LB,
well E-l.
LB.wellET-1.

LB, wen ET-2.

LB, well DT-4.
JBL, weU 897A; LB,
well D-20.

LB, well DT-6.

LB, wen D-31.

LB, well D-24.
USGS test well.

LB, well DT-1.
LB, weU DT-3.
JBL, weU 897-D.
LB, well D-21.
LB, weU D-35.

USGS test well.
LB, well D-15.

LB. well D-10.

346 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

usas Serial
No. a

Loca-
tion
No. »

LADWP
No. J

Owner or user

Well data

01

ft a"

«x~'

4

^

35

&
Q

t-
01

01'

«3

Q

Water
zones i

.0 ®

01

Q

01

«l,
a
^

T. 4 S., R. 13 W. Continued

4/13-14M5-

14M6__
14M7-
14M8-
14M9-
14M10-
14N1..
14N2. .
14N3-.
14P1._-
14Q1
14Q2...

14Q3
14Q4...
14Q5-.
14Q6...

14R1-.

14R2-.

15A1
15A2..
15A3..
15A4-.
15A5-.
15A6-.
15A7-.
15A8..
15A9..
15A10-

15A11.
15B3-.
15B4__
15B5-.
1501..
15D1-.

15E1..

15E2-.
15H1..

15J1...
15K1_.

15K2-.
15K3..
15N1..

15P1
15P2...
15P3

15Q1..
15R1..
15R2-.

16A1..

16D1..
16H1..

B-124J
B-126h
B-124p
B-125e

B-124f

B-124

B-125a
B-127h
B-127g
B-127L

B-1271

B-119g
B-119L
B-119k
B-119J
B-118n
B-119f
B-119h
B-1191
B-119u

B-119m
B-119e

B-119b

B-119C
B-119d

B-119T

B-119Q

B-120a
B-120d

B-119

B-119v

887E
889G
887M
888E
887L
887

887C

888

897C
897M

897H

876C
876H
876G
876F
876R
876B
876D
876E
877B

876P
876A

876A

867B
8760

877A

877

877C

868
868C

867

867D

7-D-34

7-D-33

7-D-62

7-D-20

7-C-14

C. F. Smith ....

.. do - - -

D. S. Bell

test well 1.

do... ...

- do_ _

Ing and Construc-
tion Co., test well 2.

Dominguez Water
Corp.:
Well7A
Well 8
Well 10 - ....
Well 2, old series..
Well 6. .
Well 1..... ....

Well 4 .... - WellS
O. E. Elftman __

Corp.:

Well 15 .. _ - Well 3 ... .
Well 2 __
Well 16 - ...

Cedric Seabranch

do.....

Dominguez Estate
Co.

ucts Corp.

. . do

Co.

Co.

Cedric Seabranch..

26

27
27
27
27
26
22
25
26
26
27
28

26
27
27
27

27

21

27
28
28
28
28
28
28
28
28
29

27
27
27
27
24
21

21

21
26

24
24

24
23
20

20
20
21

22
22
22

21

14
21

129

112
100
125
98
97.0
110
14ft
128
29.5

134

54.3
900

119

200

24

161
998
158
164
1,001
1,226
1,027
980
159
230

1,054
947
1,047
975

461

117.5

360
130

76
136

140
110
925

571
183
650

150

135

200

80
147.3

10

112
12

4
8

8
1H
8
8

4

12

6

16
12
16
12
12-10-6

12
12
12

16
12
12
16

10

16

10
5

4
5-3

12
5
16

12
8
12

10
6
12

6

8
4

89
116

60
25

50

744

95

65

68
769
76
' 65
777
775
750
744
94

800
760
767
755

203
380
193
325

50

80

483

465
147

80

60

25
4

67
5

69

156

20

3

76
229
57
54
224
451
277
236
36

190
187
380
220

102
15
36
65

59

56

302

106
31

46

20

See footnotes at end of table.

WELL RECORDS 347

zone of the Torrance-Santa Monica area Continued

Water zones 1
Continued

Character of
material

Pumping data

a.

«!.is
o

a

rt "m

CS^

P

3

PH

Miscellaneous

-

Use of well Analyses and
measurements

Remarks 7

T. 4 S., R. 13 W. Continued

Gravel and sand ...
Sand and silt ......

Sand and gravel ...

Gravel and sand ...

Fine and coarse

gravel.
Coarse gravel .....

..... do ... ...
.. do ...
do
.. do ... .
..do ....
. do
..do
do -. . .

Gravel and sand _
do.
... ..do ....
- .do

Sand and gravel ...
Gravel and sand. .
Sand and gravel.. .

Sand and gravel. ..

Gravel and sand ...

210

....

2,000

1,600

1,270

1,030

430

....

14.5

4

- -.-

T, E

P, W
P, W

T, E

- -

P,M

T, E
T, E
T, E

T. E
T, E
T, E
T, E

T, E
T, E
T, E
T, E

T, E

T, E
P, W

P, W
P, W

O T V
T, E

T, E

T, E

T, E
T, E
T, E

P, W

P, W

Irr--

A
A.. . _ ....
A
A
A. ... ...
Irr -
Obs ... .

A _ ....

A.
A

A I

A.. -

A _ .-.-..

PS
PS . . .
PS
A.
PS .
PS
PS
PS ... ...
A.
A... -

PS ...
PS
PS - -
PS -

Irr

Obs -

Irr

Irr.

Irr
Ind- ~
Ind

Ind-.
A

Irr

Obs

C, Cpr, L -
W
W.

Cpr, L, W
Cp, L...

C,Cpr,L,W

Cpr, W.. -
Cr, Cpr, L, W
Cpr, Wd

Cp, L, W.

C, L .

Cr, Cpr, L
Cp, L -
Cr, L
Cr, L, W -
Cr, L
C, L, W
L...
L

C, L..
Cr, L..
Cr, L..
C, L

Cp, L. Wmd .

Cp, L

Ws.

Cp, W
C, Cp, L

C,Cp,L

Or*

Cp ... ...

Cpr, L _ ....

Ws.

Wmd. .

LB, well D-13.

LB, well D-ll.

LB, well C-10.

LB, well D-2.
USGS test well.

LB, well D-l.
LB, well D-3.
JBL, well 897-C|

JBL, well 897H.

bridge test well.

W-138, well 861.

JBL, well 867-A.

JBL, well 867-Bi

JBL, well 877-C; LB,
weUD-4.
LB, well D-37.

JBL, well 867-B.

348 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial
No. »

Loca-
tion
No. «

LADWP
No. s

Owner or user

Well data

o
rj"*

~ l
«*""'

"*

»

fi

S>
*" M

a| ^-i^--
p

Water
zones 1

S

11§*
fi

01

ol

A
^

T. 4 S., R. 13 W. Continued

4/13-16M1..
17C1...
17D1..

17E1..
17G1-.
18A1-.
18A2--
18H1-.
18J1
18J2...
18N1-.
18P1
18Q1-.

18Q2-.
18D1-.
19E1-.
19H1..
19H2..
19H3..
19H4..
18H5..
19J1...
10TO

19J3
19J4...
19R1..
20K1..

20L1

20B1..

21H1..
21H2._
21H3..
21H4..
21H5..
21H6..
21J1...
21Q1...

21R1-.
22D1..

22E1...
22E2...
22G1..
22G2
22H1..

22H2..

22J1... *n"K"i

22L1...
22L2

22Q1...
22R1..

22R2-.

23A1

B-109C

B-109g

B-109e
B-109d
B-109
B-109f

B-llOh

B-llOk

B-llOa

B-llOf

B-llOc
B-llOb

B-llOm

B-llOg

B-115a

B-115

B-115d

B-120C
B-115h
B-115g
B-115f
B-120L

B-H5e
B-115k

B-120b

B-120g

B-120f
B-1201

B-120
B-120h

826

827D

827A
827
827B
827O

818A

818B

818

828

B9OA
QOQ

829D
829C

839A

839

849

868B
858C
858B
858A
868H.

868
859A

flfiRA

878A

878

879A
879

7-C-15

7-C-6

7-C-8

7-C-7
7-C-5

7_O Q

7-C-10
0. A -.10

7-O-13

7-D-58

7-D-17

7 D 59

7-D-6

Corp.

General Petroleum
Corp.:
Well 1 . . -
Well 2 ___ .
C. F. Fiesel. __ . _ .

A. E. Smith, west well.

meyer.

Southern California
Edison Co., Ltd.

Kreyssler.
Harbor View Dairy
Co.

Richfield Oil Corp
Well 4.. ____
Well 3 _ . ___
WeU2... __ .. __
Well?...-. -
WellS. _ . __ ..
Well 1
Shell Oil Co., Inc.,
Wilmmgton:
Well 1
Well 2-.
Richfield Oil Corp.:
Well 6.... _ . __
Well 5.....
Well9..._

. . do ... .

Commission.

City of San Pedro __

Tide Water Associ-
ated Oil Co.

Watson Estate Co.

28
26
26

35
27
33
35
36
38
38
39
39

39
39
44
34
37
37
36
36
35
40
41

41
41
41
37

37

40

20
34
35
35
27
25
35

36
34

20
18

25
21
23

20
19
20
20
14

31
17

20

21

1,701

121
87
461
200

67
250
276

251
250
220
180
90
70
70
180
70
262
325

100

550

554

586

156
800
800
800
721
800
643

750
846

1,128
650
900
50
149
120

82
165
590
18.5
728

250
170

19.5

30

5
3
12

8

5

12-10

12

7
8

8-6
4

12
12

8
12

12-10

12

16
24-12
24-12
24-12

18

20-12
16

18

4
2H
12

4
8
14
2
20-12

10
6

2

6

203
212
200

238

433

173

460

114
435
430
430
430
435
428

440

410

93

133

411

107

48
38
30

117

384

126

18
116
358
356
291
365
215

330

235

30

28

317

38

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

349

Water zones '
Continued

Character of
material

Pumping data

Gallons per minute Drawdown'
(feet)
&

Miscellaneous

Use of well Analyses and
measurements

Bemarks'

T. 4 S., R. 13 W. Continued

....

Gravel and sand..

.....do. ....

Gravel and sand..

.. _ do.. __ ... ...
.....do............
..... do. ... .

Gravel ___ . ....

Sand and gravel

....

....

1,200
1,000
760
1,460
1 QSfl
1,600

1,200

....

125

....

....

....

5
6

18

....

P,W
P, W

P, W p W
T,I

T
T
P, W
A, L
P, E
P,E
P, W
P. W
P, W

T, E

P, E
P, E
Al, E

T, E

T, E

T, E
T, E
T, E
T, E
T, E

T, E

P, W
P.W
T, E

P, W
T, E
T,E

T, E

P, E
T, E

Obs ....

A

Jit....... -

A-. .
A. ... .
A.. ....

Ind..
Ind... ....

A ....

A .._.__.. ..

Dorn, Ind .....

PS... ....

Dom, Ind

A... ... .
Ind
Ind.-. ..
Ind .
Ind. ..
Ind.. ... .
Ind ....

Ind.. ....

A.............
Ind... ...

Dom, Irr ...

Dom, Irr

~Irr
Obs
Ind ... .
Ind

Dom _ ..

Obs

A

Op. ....

Wrd.
W.... __ . __ .

W. _ ....
Wd...... ....
W... ....
W.... _ ....
Cpr, W ___ ...

L, Wmd ___ .
L, Wd ....

Cp ....
C, Cpr, W... ...
Op..............

f^r\

Cp
Cp........ ..... .
Cp, L .... .
O, Cpr, Wmd

Cr, Cpr, W. .
Cp, Wmd _ ....
Cpr, L, Wd ..

C, Cpr, L, W

Cp, L, Wd

L....... ....
Cr, L ....
C, Cp, L, Wm..
O, Cp, L, Wm
C L
L........ ....
C, Cp, L.....

C, L.. ....
C, L.-

L ....
G, Cpr, L, Wm.

Cpr, Wmd. .....
Cpr, L, W. .....
Cpr, Wm _ ....

Cpr, Wm _
Cpr, L, W.
Cpr, L, Wmd

C, L......... ...

Cp. ... .
C, Cpr, L, Wd-

Wm _____ ...

Cnr. W __

LACFCD, weU 836O.
JBL, well 826.

JBL, well 818.

JBL, well 829;
LACFCD, well
829B.

JBL, well 839A.

JBL, well 858B.

LB, well C-13.
LB, well C-15.
LB, well O-16.

LB, well C-19.
LB, well C-5.
LB, well C-14.

LB, well, B-12; JBLy
well 879.
LACFCD, well 8790!
test well.
LB, well CT-23.

350 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USQS Serial
No. 2

Loca-
tion
No. *

LADWP
No. »

Owner or user

Well data

<D

fl"

w >~'

^

«

S

A
Pi

ft

tH
O>

a|

-*3

. ft

Water
zones '

a

1

43 <S S1
o

M

O> sl
«
EH

T. 4 S., R. 13 W. Continued

4/13-23B1...
23C1...
23C2...
23C3...
23D1..
23D2..
23E1...

23E2
23F1...
23F2...
23G1--
23G2--

23H1..
23J1...
23L1...
23L2...
23L3
23M1-.

23M2..
23N1..
23P1...

23P2...
23Q1..
23R1..
24E1...
24E2..-
24F1...
24F2
24Q1...
24Q2..
OJ.n.Q

24K1...
24K2...
24K3...
24L1...
24L2
24M1-.
24M2..
24N1. .
9jH*JO
24N3...
24P1...
24P2-.
24QL__
24Q2...
24Q3...
24Q4...
24Q5...
24Q6...
24Q7...
25N1...
26A1._,

26B1...
26B2-.
26C1...

26D1...
26E1...

26E2...
26F1...

B-125f 898

B-125J 888J
B-126h 888G
B-125 888A

B-125b 888B

B-125g 888F
B-125I 888H

B-125d 888D
B-126d 889D
B-126 889B
B-126e 889E

B-126b 889A
B-126g 889F
B-126a 889

C-917 390
B-126f 899

B-126C 889C

B-136L 380C

B-136m 380D

....

7-D-18
7-D-13

7-D-9

7-D-8

7-D-7

3-B-l

C. H. Barnes. ... _
R. E. Rose.. __

S. D. Wilson..........

Mrs. HU1. -. -

R. J. WhetnaU... ..

Silverado well 1.

. . do-... - . -

.... . do.-.. ... . -

M. F. Knoy ______

test well 4.

M. M. Thomas ___

Lever ___ .. __

25
24
24
24
24
21
22

20
23
22
23
25

23
21

21
20
21

21
18
19

20
19
15
24
24
23
22
19
20
20
19
21
20
22
22
21
21
21
21
21
19
20
16
16
20
19
18
18
16
12
18

18
19
18

15
15

15
16

142
77
80
84
125
63.2

160
149
24.3
54.3
1,074

100
10
135
145
115
912

115.2
106

26.5
56.9
33
26.0
38.1
25
26
31
28.3
99

25
25
27
28
28
25.0
28
54
29.4
31
27
28
20.5
18.1
25
22
31
26
16

131

60
69
84.1

85
147

99

2
2

10
12

10
12

1H 4-3
26-16

4

12
5
10

14

1M
1^
6
6
6
6
6
8-6
8-6
8-6
8-6

6
6
6
6
6
6
2
6
6
6
6
6
6
6
6
6
6

8

2
2
7

2
12

3
12

57
73.5
75

46
21

596

90

71

71
130
260
410
77

24

105

40

63
110

85
3
5

59
4

470

10

61

50
30
24
502
41

2

26

29

39
36

See footnotes at end of table.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

351

Water zones >
Continued

Character of
material

Pumping data

s.

a>

Drawdown'

(feet)

I

Miscellaneous

Use of well Analyses and
measurements

Remarks'

T. 4 S., R. 13 W. Continued

Gravel ______
..... do.. .. ..

Gravel and sand-

Sand and gravel ...

Silt and sand...

Sand _______

Sand _______

Gravel ....

Gravel _____ ..

Sand and gravel

7

....

....

....

....

....

....

P, W
P, W
P, W
T, E

T

T, E

P, W

....

....

"p"w"

P, W

P, W
P, W
P, W

P, W

O, E

A
Irr.-. .-.
Irr_ . ...
Irr. ....
Obs. .....
Obs_ ... .
A.

Obs.... ... .
A...... ....
Obs __ ... ...
Obs
Obs ...

A.... ....
A. ....
A. ....

A.,... ... .
A ......

Obs
A.._. .
A

Obs ....
Irr.. ....
A

Obs Obs ..
A.... ....
A.. .
Obs
Obs
Obs
Obs
A
A
A. -
A. ....
Obs
A.
Irr... _
Obs
Obs
A...
A
Obs
Obs
A....... ......
A
A.
A. ....
A.
A... ... .

Irr.. ....
Stock. ....
Obs

A.. ....

Irr..- .....
A. ....

L. - ....

O, Opr, L

Opr, Wmd __ .

Opr, Wd .... .

L, W....... .....
Opr, L, Wm ....

Or, L, Wr, Ww.

W........ ....
Opr .. _ .. ...
Op, Wd ...
Op, L. ..
Or, Opr, Wd -
Opr, L, Wmd ...

Opr, L, Wrd ....
Op... ...

Opr, L, Wmd
W.....I ...

Opr, W
Opr, W....
Opr, W.
Opr, W. .
Opr, W..
Opr, W......
Opr, W. _ .... .
Opr, W.... ..
Opr, W.
Cpr, W...
Opr, W..
Opr, W..
Cpr, W... ......
Opr, W..
Opr, W...... ...

Cpr, W......
Op, W ..
Cpr, W..
Cp, W
Opr.W..
Cpr, W.. ....
Cpr, W......
Cpr, W.. ....
Cpr, W .
Cpr, W.. .
Cpr, W.. ..
Cpr.-..- ......
0, Cp, L, Wd...

C, Cpr.. .
Cpr, L .
Cpr, Wmd. .....

I,.. ....

Cp,W ... .
Wd...

LB, weU O-ll.
LB, well C-8.
JBL, well 888-A; LB,
well O-9.
LB, well C-9 (new).

USGS test well.

LB, well CT-13.

JBL, well 889-B.
LB, weU O-4.

LB, well C-3.

Probably LB, well
C-l.
USGS test well.

LB, well CT-1.
LB, well CT-20.
LB, weU CT-21.
LB, well CT-18.
LB, well CT-19.
LB, weU CT-16.
LB, well CT-17,
LB, well CT-15.
LB, well CT-22.
LB, well CT-7.
LB, weU CT-14.
LB, well CT-9.
LB, well CT-10.
LB, well CT-12.
LB, weU OT-11.

LB, well CT-25.
LB, weU CT-26.
LB, well CT-8.
LB, well CT-24.
LB, weU CT-2.
LB, well CT-3.
LB, well CT-6.
LB, well CT-5.
LB, well CT-4.
LB, test well.
LB, test well.

JBL, well 899.

JBL, well 889-C; LB,
well B-6.

352 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coastal

Identification of wells

USGS Serial No.»

Loca-
tion
No. «

LADWP No.' Owner or user

Wen data

a

2»

;H~

*

I

a

ft

£

a!*£
ft

Water
zones'

$
5?

I&

A

in

Sf

s
b

T. 4 S., R. 13 W. Continued

4/13-26F2...
26O1...
2602- .
26J1...
26K1
26L1...
26P1
WDO

26P3

26P4...
26P5
26P6
26Q1...
26Q2...
26Q3..,

26Q4 .
26Q5 .
26Q6...
26Q7...
QAT>1
27J1...
27KL-.

27L1...

27L2...

27M1__
27M2-.
27M3-

27M4..
27N1

27R1..
27R2-.

28N1 .
28N2_
29A1...

29B1...
2901

KIWI

29E2...
29F1...
29M1..
9OTW9

29P1...
29R1..

[30A1...
[OflAO

[30C1...

130D1..

wno

SATPI

B-136b
TJ 1*>Ca

B-136J

C-917C

B-135d

B-135h

B-135k

B-1351
B-135J
B-135m

B-135n

B-134k

B-115n
B-115C

B-134m

B-134]
B-134

B-llOd
B-133t
B-133S
B-133]

RSQTT

....

380A QQrt
381G

W)A

370

360

360C

360A
360B
360D

360E

340 idn\

839B
839C

320A

330
320

809
310B

310A Q-jn

. . . .

3-B-3
3-B-4

3-A-10
3-A-ll

7-C-12

3-A-20

o_ A a

O_ A O1

3-A-22

3-A-3

O_ A _«>

C. Smith..............

W. I. Engvalson ___

City of Long Beach ...

C. J. Link ..

City of Long Beach ...

son.

.... . do................
R. B. Hording ....

Watson Estate Co. ...

Tidewater Asso-
ciated Oil Co.
The Texas Co.:
Well 2... _........

Well 3 ....
Well 1 .___
Well 5... ... .

Well 6 ....
Well 7. ....

Wilmington Ceme-
tery:
Well 1....... ......
Well 2... ....

E. W. Sanderson ......

Mrs. E. Schneider ....

Banning Park well.
Fletcher Oil Co.:
Well 1......... ....
Well 2
Los Angeles Co. San-
itation District 2.

Poggie Ranch:
Well 1.............

WAII *>

16
17
16
15
13
15
12
12
12

13
13
12
12
13
13

13
13
12
11
13
14
12

27

13

33
35
34

36
32

10
11

45
45
41

42
50

42
43
41
37
37
40
43

36
37
15

46

46
14

200
80
107
16.0
71
19.3
98
83.7
633

85

18.4
85
64
83

75
70

87
96
140
493

230

820

900
842
946

825
850

336
115

300
200
366

415
600

80
403
68.5

84.1
375

400

300

314

189.8
285

12
2
26-16
4
2
1J4
12
2
12

4
4
IX

2
2

2
2
2
2

12
12

20-12

14

24-12
14
20-16

16

6

8
8

14
12

2
6
15
5

8
6

4
4
8

12

12

43
17

13

87
383
200

196
371
740
412
500
266

435
498
562

200

185
200
285
207
485

194

212

28
3

3

108
110
30

9
317
20
398
306
534

390
44
288

100

9
166
74
239
115

106

102

See footnotes at end of table.

WELL EECOEDS 353

zone of the Torrance-Santa Monica area Continued

Water zones <
Continued

Character of
material

Pumping data

1-

»!,§s
0

1O£J
Fg <g S*I

f-f ft h

Miscellaneous

Use of well Analyses and
measurements

-

Remarks 7 1

T. 4 S., R. 13 W. Continued

Sand _______

Sand and gravel

clay.

.... .do... .....

Medium gravel ...

-

15

-

2,~400

3,000

2,000

....

400
400
600

....

18.4

12

0
P, E

P, W
P, W

P, W
P, W

O, E
P, W
P, W

P, W
P, W
P, W

P w
O, E

T, E

T, E

T, I
T

P. W
P, W
T, E

"T"B"

P, E
P, W

P, W
Al, E

T, E
Al
T

T, E

A.. ...

Irr.
Obs...
A...... ....
Obs

Obs... ....
Irr.._.
Irr............
Irr. ....

Irr....... .....
Irr.... ... .

A __ .... __ .

A..

A... __ .....

ind...
A..

Ind... . ... .
Ind...

A._

LT.. ......

Dom, Irr. .....

Obs.. .....
Dom, Irr ......

Dom _ ...
Dom __ .
A.. .
Obs ....

Obs ....
PS..... ...

Ind...
Ind....... ....
Ind..

Irr, Dom

Obs ....
A...... ....

Cp.............
Cpr-. ....
Opr, W ....

Cpr, L, Wm ....

Opr, Wm. ......
Cpr, L. ....

Opr- ....
Opr, L, Wm ....

Opr _____ ...
Cpr. ____ . ...

Opr ....

Cpr ______ .
Cp...... ...
Cpr, W __ . ...
Opr, Wm ....
Opr, L, Wmd ...

L.. ....

Opr, L, Wd .... .

Opr, L, W. _ ..
Opr, L, Wd
Cpr, L, Wm....

L, Wm. _ . ....
L...... ....

L _ .... _ ..
Opr, Wd. .

Op, Wm.. ......
Opr, Wmd __ .
Cp, L ....

Op, L, Wmd ....
Op, L

Cp, Wmd __ ..
Op.. ....
L, Wd... ......
C, Opr, Wm ....
W....... ....
Wmd.. .....

L.. ....

Op, L, Wmd ....

Wmd ....
L... ....

LB, well B-15.

LB, well B-18.
LB, well B-20.
LB, well B-17.
USGS test weU.

LB, well B-9.
W-138, weU 885; LB,
well B-l.
LB, well B-7.
LB, weU B-4.
USGS test well.
LB, well B-8.
LR, well B-16.
LB, well B-22.

LR, well B-21.
LB, well B-23.
LB, weU B-2.
LB, weU B-24.
LB, well B-19.
LB, weU B-13.
LB, well B-14.

W-138, well 984.
LB, well B-10.

JBL, well 320.

W-139, well 353 (Re*
dondo).

to to co
C) O Ot

2 W <© [2 H-. pi

w d>ea
Ot Oi en

ff> £><©

cowwww w 1 en cn cn en en £££ SSSSSSSSS S3
.^.^ ^._._ _-.,, , ,r , - -- -- M MMM M MM y y
Pj-'i-'toi-' [->[-> W i-> i-it;»-'»-'to oo -j p pt [&. eo f* {- io i-1

O O W W bdbd bd! bd b3b3b3cdb3 bd! bd
1 i >L >L ,L ' »L' »L iitLii. ,1' i.

h-i 1 * CO CO

g

CO 1^

to o

COCO COCOCO COCOCOCdCO CO 1 CO

toto tooooo oooooooooo ooi --3

CO M CO

p.

a P.

tg-
0 ff

t

ag. P. -

W|

r r
W! W

y TJ lr<MMMMWCl Q

S h* f-*.eotOh-U!E P

a

B S
o

WWWWW

CO CO CO CO CO

w w

W O

_ MI Jj-i ^ o w

K2 ?/-, ^! !?» ass_

62 ^' S M sisooi-'

o3S> ^ § ' SO weS".. "'

t>! ^ B

2! p =

oy cj *«

3 33 3 3|f| I ?333333
gs &B & B&MEd O

O, h* to tO to tO' CTOh-'

M * -

too uto

h-i O5O5 tO

s

(00 tO tO tO tO frOtO tO

S too Etoo

CO W
00 t *

ej

GO

OGO

Hf GO "HCD

!H
f

o

g

Altitude
(feet) «

Depth (feet) «

Diameter

(inches)

Depth to top
(feet)

Thickness
(feet)

Identification ofwells

WeD data

!!

oo

g.p.

O p

Wtel

^>

Q 0^ QQtr1

-

Qt-'QQQQQQQf1

2.
BBl

i <j P. i a.

TO 00 TO

ooo

02 020Q

O OO o- o-o-
CO CO CO

"I"

PS"

s %>

o OQ on

B L?^ "

p- IB

D.P.D.

QQQQQQQ

! i

t^r.

& §

| "*

|>CD

i »

S^E^ip M ^

Q
B

D*
m

§ §

g®

a

Gallons per
minute

Drawdown"
(feet)

Pump

S
a

%&

Analyses andmeasurements

1

- *

08-
2 g

ffo

& r

^

a

8

1

1

|

B

H
O
O.
W
O
02

CO
Cm
Cm

P pppl i p p pp ?
tdW tdWWW td W W W

^ ^o ^ ^ Je

3 1 1
5 03 c» w c

Q Q

H>

P P «*

5 S
o

W W Wt
5 PO 95?

35 O5 Cn 5i t^. rf^

o w >. P

22 22

to

2

co cococo

i i

W tdW

-1-1

a

ooS

?

2 II *
£ |S w

*-«O Ob
OO OO

* >-» H* h* >"

sosio 5*. oo

-J Cn iX <pi-> CD COO OO <O
H-> rf>. g» WCn -J^JO OO -J

SE £? Ci & *^00

cofeSSo

Kfe' *-t

'2% zt

S 3 £

v> o
Q2' OS

W!

li

>e &!|
Pi
a

09
P
m

!!

?»r

?i
o

Altitude

(feet) *

Depth (feet) »

Diameter

(inches)

Depth to top
(feet)

Thickness

(feet)

Identification ofwells

a

I*
if

H**1

CO
Ox
o>

W

&

i

P

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

357

1 Water zones '
' Continued

Character of
material

Pumping data

JL
&

|a
o

I-

OS*"*'

p

&

*

Miscellaneous

Use of well Analyses and
measurements

Remarks 7

T. 4 S., R. 14 W. Continued

Sand and gravel _

day.

.... . do. .... -
.... . do.......

...-.do.............
. do . _ ... ...
Sand... . ....

..... do. .... -

gravel.

Gravel

gravel.

gravel.

. . do

... .. do

. . do
..do... ....

..... do .... . -
. do

. do.. .
OO3TS6 SCUld 3U(1.

gravel.

gravel.

__ do _ . __

815

810

1,375

1,320
1,550

1,300

525

270

1,500

344

450

1,560

33

29

33

6
10

20

13

12

T, E
P, W

T,E

T.E

C,E
A1.E

T,E
T,E

Ind....... __

Ind.......... .

Ind...

A. __ ....

Ind... ...
Ind... ...

A. ____ ....

A. . __ ..
Obs ...

Obs...........

A. . _

A ....

A.... ... ...
A. ....

A

A
A. .... -

A..
A..
A.. _.

PS,Irr.
A. _

Obs.

Obs. . ....

A. ... .
A-. ...
Dom, Stock ...
Ind-..

PS ....
PS ....

L..... ....

L_ _ ....

L.. ....

C, L ....
C, L.. ....

L.. ....

W .. _ ......

L... .

W ....

C, Cpr, L, Wm.

Or, Cpr, L,
Wsd.
Opr, L, Wsd .

L.. ..... .

L,W ...

L.. ....

L.. ....

C, Cpr, L, Wmd,
Wrd.
L-. .
L.. ....
L.. ....

Or, Opr, L.. __

Opr, L,Wm .

C,Opr,L,Wm,
Wrd, Ww.

L .... ..
L... __ ....
W...... ... ..

C, Cpr, L ..

O,L.Ws ___ ..
C,L,Ws.. ...

460508 5$

tO fcSh-l-i

Union Oil

Joshua H
Works:
Well Well

Formerly

335

-O^ > sza ooa i-1 1- f- i i-2" taf-t-

O5 O5 <35 O5 O5 O5 O5

td bd W

i ii

O Ol Q
OOO

b-fb.) WWtri

ii<i> Cn Cn 00

*

9 0 90

OTQ.-I b^ OT

^eg-dOS^n
"c-ll^-Bgog
. I'^C^o B-5SSS .
JJH Q. *"* rt W ^T^ ' i . h-» .-*«

ip^TQB ^ »22

O
&
03" S

00 Op
000

11. Ell

nw dar

oo ^i

--i--i
COM

^j^j^j

orni Co.

- I
S

TT:

M

^!^! ^»P

8gP. &§
WN>

|g >M

B>

Mrs. Water

W W W

a 0 ^ 2^ ^g

l f

,0 Q

§

00 ooo OOCTIOJ
to to>-> toio-co

rf^OI H-» CO W I-* CO rfk t

-j 5

- -

0»->
M*.

>->cia
OI->
COOS

)-»-> to

09rf>.l-> >->
<H-iCO tO

__ ....
CO CO tO t-* t-^

^w_o o o t-t|_*H^ tO H^

i,L»L i »L i i

£ 2

ISI

II

03 £ S.

--J 1 ' C

I
1 II

S

g

H>>OQ

°l

»£

^ag*
PJ|

F

SS'"^

n.

o

R

Altitude

(feet) «

Depth (feet) «

Diameter

(inches)

Depth to top
(feet)

Thickness

(feet)

Identification ofwells

Well data

13P £0

fl> e*
*S

8

I
a

00
Cn
00

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

359

Water zones 1
Continued

Character of
material

Pumping data

b

sra ^

§3 'a 9
0

«0

a

f

O^1

a <»

*&03

tH

fi

§

(X,

Miscellaneous

Use of well Analyses and
measurements

Remarks 7

T. 4 S., R. 14 W. Continued

Sand and gravel

.. do .
..... do.....
. . do -- -

- do

sand.

gravel.

gravel.

Fine sand __

Sand and gravel--

Sand and fine
gravel.

__ do

Coarse sand, and
fine gravel.

- do

gravel.

2,500

1,675

1,650

1,200

1,100
640

375
215

17

....

24
7

6
2

T,E

T,E

P,M
T
'

T,E

T.I

P W
T,E
T,E

T,E

T, E
T.E

T, E

T,E

T.I

T,E

Ind--. _

Ind

A- . ...

Obs
A... ...
Obs

A.. _ ....

A _ ....

A.... _

A

Dom. Irr.. --
A....
Obs

Irr
A..

A...
A...... ....

PS ....

Irr.. ....

A....... ......

Obs ....
Irr.. .,.

Obs .... .

A.. _
A.
Ind...... ... -

Ind-..
A _

Cp.L.W

CP

' L

C,L,Wsd

L,Wmd,Ws-

L, Wmd, Wrd

Cp,Wmd
L,Wmd ...

L,Wsd-

L. ___ -

W

C, Cpr, L -
C,L ...
Wmd,Ws ...
Cp, Wmd ....
L.Wsd ....
C,L .... -

C,L
C--

C,Cpr,L,Wsd-

C, Cpr, L, Wml-
Cr,Cpr,L,Wmd.

Wmd.Ws ...
Cp,Wsd-.

Cp, L, Wm, Ww.
Cp, L,Wmd....

Wmd--.-.- .

C,Cp,L__.

L,Wmd ... ...
Cp,L... .
L,W ....

LAD WP Torrance well
1.

W-139, well 345 (Re-
dondo).

W-33, well 342 (Re-
dondo).

8 SSggg
- SSS

WW W W WW! W W I J, I I IliT I

! O

V ¥
ts ts

f T w o

Q^OQ WWW^OOQQ td ^&! 55 WW§^ BtflOtfi> !* §

&; fg-i &

OWCtt*- *-
nOtenM M

p
wj W'i

fi

£21 EH

tdtd

r: T
?S ?

U ^&||

°|§|go

l-4 -4 IOO>

03 Co co co toe

TV
H

MC.1

d
GO

0
GO

i^QO ^-) A

>y .t->

?if

t< *5o O

- 3

nj

§

Altitude

(feet) «

Depth (feet) «

Diameter

(inches)

Depth to top
(feet)
Thickness

(feet)

Identification ofwells

Well data

s ^s

CO

00

g
§h-l
e
s*

r

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

361

Water zones '
Continued

Character of
material

Pumping data

§1

Drawdown'

(feet)
a

S

£

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 4 3., R. 14 W. Continued

Sand and gravel-

Gravel and sand. .
..... do. ....

. _do-.. _

gravel.
Sand and gravel _

.....do.............
.....do..... .....

....

Sand and fine
gravel.
Sand and gravel ...

Sand and fine

gravel.

Sand and gravel _

Sand.. ...

Sand and gravel _

-....do-. ....
.....do.............

Sand and gravel _
.....do.......... .

000
900

945

....

....

....

800

13

....

....

....

....

T,E

T

P,I
T,E

T, B
T, E

T, E
T, E

P, E
P, E

... , ...

T, E
T, S

P, W
T, E

T, E

T, E
P. E
T,I
P, M

P, E
T, E
T, E

~"T~~E""

T, I

Irr. ....

A... ......

A...

Dr. ....
A.._

PS ...
PS ....

A. _ ....

A... .-..

PS
Obs ... .

A... ... .

A....... ......
Obs.. ......
Ind ....
Irr.. ....
Irr. ... .
Obs ....

Stock.
Irr-
Obs ....

Irr

A..... ....

A.............

A

Dom, Irr ......

Stock.
Obs ..

Obs.

A

"A"
Irr. ....

L

L.. ....

L,Wsd. .
L,W ......

L, W.. ....
L, Wmd ...
L, Wmd

L.. ....

C, Cp, L, Ws ...

Ws.

L, W...... ..... .

Cpr. ___ .....
Cp, W ......

L, Wmd, Ws ....

Cp, Wmd.. .....

Op..............

Ws .
Wrnd. ... .

Cp. .....
Cpr, W

L, Wsd ......

L, W....... .....

L, Wmd .....
Cp ....
Cp, L, Wmd __

L, Wmd, Ws. ...

L, Wmd, Ws,
Ww.
L, Wmd .
L. ....

Cp, L .

W-139, well 348 (Re
dondo).

W-139, well 351 (Re-
dondo).

362 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 26. Description of water wells in the coasted

Identification of wells

U8G8 Serial
No. »

Loca-
tion
No. »

LADWP
No. >

Owner or user

Well data

a>

w*^

"" M
~ ^

*

I

£
ft

hi

o>

_.jq
S fl
- <5

ft

Water
zones i

a

3
*" s

5§. g1
ft

m
a>
iy'S

°s
A

h

T. 4 S., R. 14 W. Continued

4/14-35D1..

35D2.-
35E1...
35E2...

35F1

35J1

35K1..

36H1._

36H2..
36J1...
36J2...

B-131

B-131a
B-131b

B-131c

B-131e

B-131d

B-133

B-133a

B-133g
B-133q

271

271A
271B

281

281B

281A

301

301A
301C
302A

2-B-8

2-B-9

3-A-7

Water Works Dis-
trict No. 13.
__ do. . __ . ...

Los Angeles County
Water Works Dis-
trict No. 13.

Water Co., Oak
Plant.

Water Co.

Palos Verdes Water
Co.:
Well 1.............

Well 1A--... ...
Well IB...........

Verdes Banch.

166

156
178
180

IfU

181

286

47

41
33
27

696

618
585
630

514

500

606

610

793
600

12
18

14

16-12

14

26-12

26-16
16
6

60

0
200

39

290

152

140
43

574

685
430

461

316

458

653
457

T. 5 S., R. 13 W.

5/13-1H1...
3D1...
3D2...
3D3...
3K1...

3K2...

3K3...
3L1....
3N1...
3P1 .
3P2
3P3....
3P4 .
3P5....
3P6
3P7....
3Q1-...
3Q2-
4Q1

6D1...
6D2...
18J1...

B-1350

B-1350
B-135f

B-135g

B-135b

B-133k
B-133w
B-1341

362

362A
373

373A

353

312A
312B
326

3-A-13

.....do.... _ .... _ ...

Edison Co., Ltd.
.....do... ....
Southern California
Edison Co., Ltd.:

Well 4
Well 10 .... __ .
Well 13 __ ...
Well 2.. __ ....
Well 5. . ...
Well 6.... ......
Well 3 _ -
Well 12. ....
Well 11
Well 15
Well 1

Terminal Island,
welll.

- ...do _ ...

Co.

40
6
6

6

7

3

25
24
3

70
116
168
118
1,200

250

151
372
150
150
35
155
159
35
150
150
151
35
470

1,016
990
582

3

16

16

18

26-12
24-16
16

147
189

140

65
85

235

600
735

33
86

14

90
74

86

299
107

1 Only those aquifers yielding water through perforated sections of the casing are listed.
2 Assigned by California Division of Water Resources.
8 Los Angeles Department of Water and Power.
4 Altitude of land-surface datum, from topographic map.
5 Depths below land-surface datum indicated in whole feet are reported; those to a tenth foot are measured by Geological Survey.
6 Commonly from test at time of well completion; in some cases, however, figure represents estimated current discharge of pump.
7 W-139, Water-Supply Paper 139; name in parentheses indicates quadrangle on which well plotted. LACFCD, Los Angeles County Flood Control District.
8 4 by 6 feet.
»3 by 3 feet.
" 5 by 10 feet.

WELL RECORDS

zone of the Torrance-Santa Monica area Continued

363

Water zones '
Continued

Character of
material

Pumping data

&

£

Sa 39

C5

to

a

f o^ a <o
*&CO

1~t

0

Miscellaneous

Use of well Analyses and
measurements

Remarks '

T. 4 S., R. 14 W. Continued

Sand and gravel ...

Sand and gravel _

Sand and Gravel

..... do. ....

- .-do..

.....do ...-. .
do....

850

1,200

1,300

1,340

1,310

19

15

T.E

T, E
T, E

T, E

T, E

T, E

T, E

PS.... .....

Ind..
PS....... ..

Ind...

PS

A. _ .. __ ..

PS...... ...

A. _ . __ ...
PS
A....

C, Cp, L, W....

Cp, L..... .
C, Cp, L, Wmd.

C, W... ....

C. L.. ..... .

L, W.........

Cr, Cp, L,
Wmd, Wrd.
Cp, L, W
Cp, Cr, L, Wm.
Wmd.... .

T. 5 S.. R. 13 W.

.....do.... ....

Gravel and sand

Sand and gravel _
do

Very fine gravel ...

Sand ____ . _ ..
..... do...... ... .

....

454
1,470

....

34
32

P, E

....

Al
T, E

Ind.-
A __ . __ ...

A... ____ ..

Obs ....
Obs __ . __ .
Obs...........
Obs _ . ...
Obs. __ . _ -
Obs .....
Obs . ._...
Obs
Obs
Obs.. ___ ...
Obs ... .
Obs._ ......
Obs ___ - ...

Ind...... ...
Ind.. . ...

L. ... .

C, Cpr, Wd

L

Cpr, W __ ..

L..... ....

L, Wmd.
L ... .
L- .....

Wmd __ . ... .
L, Wmd. .
L, Wmd.-

L... ....
L...
L........ .
Wmd ....
L, Wmd. .

C, L....
Cp, L, W

W-138, well 998.

W-138, well 882.

364 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 27. Data on wells in the inland zone of the Torrance-Santa Monica area and in the northern 22 square miles (uncanvassed) in the coastal zone

[Analyses and measurements: C, three or fewer "complete" chemical analyses; Cr, four or more "complete" analyses; Op, three or less "partial" analyses; Cpr, four or more "partial" analyses; L, driller's log olr record of cuttings; W, miscellaneous water-level measurements; Ws, periodic measurements at about semiannual intervals; Wm, periodic measurements at monthly or less frequent intervals; Ww, periodic measurements at about weekly intervals; Wr, water-level recorder operated currently. Symbol fol-lowed by "d" indicates measurements discontinued. Serial number and location number: Assigned by California Division of Water Resources]

Identification of wells

USQS Serial
No.

Location
No.

Analyses and
measurements

Depth (feet) Owner or occupant and remarks

T. 1 S., R. 13 W.

1/13-32F1
32J1.......

32J2

B-18
B-18a

B-18c

2735
2746

2746A

L
L.Wmd

L.. ....

375
499

99

LADWP, well 21-0-8.
Felipe Boliller, W-139, well 998 (Santa Monica).

T. 1 S., R. 14 W.

1/14-8P1 __

8P2

9N1.._

9Q1
10F1-.

10F2...

10H1......
10K1......
10M1.....
10M2 .....

10N1.. .
10Q1... ...
lORl. .....
10R2. .....

10R3..
10R4.. .

10R5.
11J1..-

11J2-. .....

12E1......

12E2 ...

12F1 ......

12Q1....._
13E1......

13P1......

UD1.. .

14M1.....
1501
15D1 _
15D2.. __
15D3 .
15L1 __ ..
15P1 ......
17D1 .
17E1. .... .

17N1-
18A1-. .
18Q1 ......

B-llm

B-11L

B-llk

B-llb
B-14f

B-14g

B-14x
B-14d
B-14a
B-14v

B-14

B-16i
B-14n

B-16h
B-14o

B-14k

B-14m

B-14L

B-14J

B-14i

B-17d
B-14p.

B-14q

B-14h

B-16L
B-14e
B-14c
B-14b
B-14w

B-14y
B-13r
B-llu
B-13v

B-13t

B-llf B-6L

2620A

2620

2630

2640
2660A

2660B

2670B
2660
2650A
2650B

2660

2670D
2670

2670O
2670A

2680

2690C

2690B

2690A

2690

2700
2691

2692

2671

2671A
2661
2651A
2651
2651B
2661A
2662A
2621A
2621C

2622B
2611
2611F

L....... ....

L_.... ...

L... ....

W<!

L.. _

L.. ....

L.. ....
Ws...
Wd-. ... ...
L............ .....

Wmd ___ .. .

L..

L.... ....

L

L.. .. . .

L. . ..

L.. ....

L_. _.. .__ .

L.. ....

L...... ....

L...... ....

L....... ....
L....... ....
L.. ....
C,Wm __ . ...
C,Wm __ . ...

L... ....

L.... __ ....

150

167

384

120
300

285

401
250

259

110

50

37

275

108

291

340

698

540

296

65

468
764
1,137
435
370

2,570
270
201

J. B. Schock, W-139, well 625 (Santa Monica).
A. C. Watts, W-139, well 624 (Santa Monica).
J. N. Wilson, W-139, well 617 (Santa Monica).

Miss Winstauley, W-139, well 298

(Santa Monica). W. Squire, W-139, well 297 (Santa

Monica).

Reginald H. Jones.

E. L. Baker, W-139, well 488 (Santa Monica).

Union Ice Co., LADWP well 22-B-3.

N. A. Watson, W-139, well 205 (Santa Monica).

H. Kettle, W-139, well 204 (Santa Monica).
A. C. Watts, LADWP, well 22-B-5. W. C. Fry, W-139, well 273 (Santa

Monica). W. C. Fry, W-139, well 274 (Santa

Monica).
H. K. Vickroy, W-139, well 276 (Santa Monica).
H. Devire, W-139, well 278 (Santa Monica).
Mrs. K. T. McFadden, W-139, well 279 (Santa Monica).

B. Duin. W-139, well 424 (Santa Monica).
Mrs. M. L. Frary, W-139, well 431

(Santa Monica). W. J. Fay, W-139, well 294 (Santa

Monica).
Hollywood Mineral Baths.

Sterling Laundry.
Rancho La Brea Oil Co.
(Oil well).
City of Beverly Hills.
Sherman plant, well 5a, LACFCD, well 2621D.

Qarbutt Oil Co. Vpil well).
City of Beverly Hills.
Mission Water Co.

WELL RECORDS 365

TABLE 27. Data on wells in the inland zone of the Tor ranee-Santa Monica area and in the northern 22 square miles (uncanvassed) in the coastal zone Con.

Identification of wells

TJSGS Serial
No.

Location
No.

Analyses and
measurements

Depth
(feet) Owner or occupant and remarks

T. 1 S.t R. 14 W. Continued

1/14-18H1... ...

18H2

18H3. .....
18J1 ....
18K1. .....

18K2......

18K3 ...
18K4....--
18K5...
18N1...

19D1......
19D2 ...
19D3 ___

19J1 ....
19J2.......
19J3 ....
19M1.....
19R1..-.--
19R2......
19R3-..

19R4 .
20O1- ..
20D1. .....
20M1.....
21E1......

21F1
21F2 __ .
21J1.... ...
21L1 .... ..

21L2
21P1. .....
22C1..
22E1 ...
23Q1 ......

23H1......

23H2

24B1----.
24O1 ...

24J1......
26N1 ...

27N1 ......

28O1......

29C1......
29D1... ...

29D2......
29K1 ...

30A1-. ....

30A2
30A3 ......
30A4 ...

30Q1.. ....
30G2...
30H1......

B-lln

B-6j

B-13w
B-lld
B-llr

B-llq

B-llo

B-llp
B-llbb
B-lls

B-llc
B-llaa
B-lle

B-6s
B-6u
B-6h

B-llg

B-llz B-6g
B-llcc

B-llv
B-13s

B-lli B-6i
B-13n

B-13m
B-13J
B-13k
B-13L

B-13i
B-13q
B-13p
B-13o
B-14s

B-14t

B-14U

B-17J
B-14r

B-17i
B-15L

B-15m

B-13u

B-lly
B-llx

B-llw

B-6u

B-6t
B-6v

B-llj

B-6w

B-llh

2611A

2621B

2621D
2621
2611E

2611D

2611B
2611C
2611Q
2602D

2602B
2602E
2602O

2613E
2613Q
2613D
2603
2613B
2613C

(2613F)
26131
2613A
2622A
2622
2623B
2632

2642A
2642
2653
2643A

2643
2643B
2662
2652
2683

2682

2682A

2702A
2692A

2703
2675

2655

2643C

2623A
2623

2624

2613Q

2613F
2613H ...
2614A

2614B

2614

C,L... .. ....

Wsd .. - ...

0,L ....

L ...

L....... ....
L-... ....
Cr.Ws.. .. ..
L... ..

L. -..
Gr.Ww.. ___ ...
G,L,Wmd ....

Ww ....

L-. ....
L.W. ....
L,W_..-...._._.._

L,Ww ...
L.. ... .

L... ....
L ... ...
L....... ....
L ---------

L.- ... ...
L.. ... .

L. .... L-..- -
L..

L... ....

L ... .

L.. - ... ...

L

L.. ....

Ij.. ....

L, Wsd_ ...___..--
L, Wsd...........

L, Wwd. _ ......

Wmd ....

Wsd __ . ____ .
Wsd ....
L-..- ....

C, Wsd...........
W __ ... __ ....

600

472

277
565
120

300

600
300

163

616
616
576

367
324
400
252
331
300

450
1,930
160
290
3,229

2,496
200
875
1,817

323
1,233
1 220
1,342
45

834

932

625

65

870

2,680

433
421

(809)
382

315
419
160

318
160
61

L.A.P.E.R. Co., W-139, well 629-(Santa Monica).

well 6A.
Well 7.
City of Beverly Hills.
L. T. Swall, W-139, well 643 (Santa Monica).
J. A. Swall, W-139, well 640 (Santa

Monica). W-139, well 637 (Santa Monica).

W-139, well 639 (Santa Monica). City of Beverly Hills.
Hammel & Denker, W-139, well 647 (Santa Monica).
City of Beverly Hills.
Do.

Beverly Hills Ice & Cold Storage Oo.,. LADWP, well 22-A-12.
City of Beverly Hills.
Do.
Do.

R. C. Holly.
City of Beverly Hills.
Do.
Do.

Do.

Qarbutt Oil Co. (oil well). William Niles.
City of Beverly Hills.
Tidewater Associated Oil Co. (oil well).

Do.
Do.

Tidewater Associated Oil Co. (oil well).

(Oil well).
(Oil well).

J. L. Plummer, W-139, well 458 (Santa Monica).
Qeo. Simmons, W-139, well 469 (Santa Monica).
Qeo. Simmons, W-139, well 460 (Santa Monica).

W. P. Moon and Co.; W-139, well 437 (Santa Monica).

E. Jennison, W-139, well 603 (Santa Monica).
Rosedale Cemetery Association, W-139, well 538 (Santa Monica).
Utah-California Oil Products (oil well).
City of Beverly Hills.
Do.

Do.

K. H. Whitworth, LADWP, well 22-A-9.
City of Beverly Hills, LADWP, well
22-A-6. to
Do. W
Do. *
J. H. Whitworth, W-139, well 615 (Santa Monica).
City of Beverly Hills.
LADWP, well 22-A-ll.
J. H. Whitworth.

366 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 27. Data on wells in the inland zone of the Torrance-Santa Monica area and in the northern 22 square miles (uncanvassed) in the coastal zone Con.

Identification of wells

USQS Serial
No.

Location
No.

Analyses and
measurements

Depth
(feet) Owner or occupant and remarks

T. 1 S., R. 14 W. Continued

1/14-35F1 .

35M1

35P1-
36D1.....
36M1.....

B-15g

B-15h

B-15r

B-lSj
B-15i

2685

2676

2686B
2695
2696

L._ ....

L__ ....

Ws
L__ ....
L..

235

159

281
66
125

F. W. Marshall, W-139, well 146 (Santa Monica).
Otto Wilhelm, W-139, well 147 (Santa Monica).
Kravchyk.
Henry C. Jensen.
Ferdinand Hohn, W-139, well 160 (Santa Monica).

T. 1 S., R. 15 W.

1/15-14D1___
14D2 _-
22N1......
23F1 .
24A1......
24A2. _

24M1-....
25C1... ...

2501......
25F1......
25G1.._.__

25K1......

25K2..
27N1.
27N2......

27N3 ...

28B1..
28B2 ...

28B3-.
29C1. .....
29G1.. .
30M1.....
32A1._
32A2
32A3-
32B1
32F1

32L1

32Q1......

32Q2 ...
32B1.
32R2
33B1..

33B2.

33B3. -
33B4. __ .
33B5
33D1___...
33D2 ...
33D3 ...
33D4-. ..

33G1-
33J1. _ -

33J2 __ ..

B-6a
B-6
B-6o
B-6b
B-ll
B-lla

B-6c B-6k

B-6m

B-to B-«x

B- e

B-6d

B-7b B-7i

B-7h

B-le B-la

B-lf

B-ld B-l
B-lc
B-4f
B-4z

B-4g

B-2J B-2k

B-2f

B-2e

B-2d
B-4v
B-4X
B-4t

B-4r

B-4s

B-4q
B-4p
B-4e

B-4b B-4
B-40

B-4aa B-4L

B-7q

2570
2571
2553
2573
2602
2602A

2583
2594B

2583A
2594C
2594D

2594A

2594
2555B
2555E

2555D

2544A
2544

2544B
2523
2524
2504
2535B
2535F
2535C
2525
2525A

2526C

2526B

2526A
2536B
2536C
2545D

2545B

2545C
2545A
2545
2535 A
2535D
2535
2535E

2545E
2546F

2556F

Wsd._ ....
Ws..-. ....
L.. ....
W ____ ....
W.. ....
L.. ....

Wsd _ ._. -
C, Cp, L, Wwd...

L.. ....
L.. ......_. .
Wmd_. ....

W. _ ....

Wmd, Ws---
W._ ....
L-. ....

1... ....

W., ...
C, Wmd..........

Wsd._
W.. ....
Wsd
L, Ws -
C, W_

Ws Wsd
L.... ....
L... ...

L...

L... .....

Wsd, Wmd- .
W.. ....
L-.... ....

L.. ....

L...... ....
L.. . ...
L..-.. ....
L, W..-

L--.-.--.. .....

W...... ....
L...... ... .

L.. ....

150
96
3,003
300

647

450

2,745
4,168
500

750

720

70

525

300

289
200
250

2,510
4,587

170

99

280
140
90

140

300
268
89
200

300
186

173
83

103

Carl Laemle, LACFCD, well 2560A. Harold Lloyd.
Amalgamated Oil Co. (oil well).
Los Angeles Country Club.
Continental Baking Co.
Beverly Glove Division, Calif. Con-sumers Co.

Beverly Hills Nurseries.
City of Beverly Hills, Eoxbury plant, well 1.
West Coast Oil Co. (oil well),
(oil well).
City of Beverly Hills, LADWP, well 23-B-l. Hillerest Country Club, well 1, LADWP, well 23-B-3.
well 2, LADWP, well 23-B-2.

H. K. Laird, W-139, well 726 (Santa Monica).
Pacific Land Co., W-139, well 704 (Santa Monica).

United States Government Soldiers

Home, well 11, LADWP, well 23-A-l.
Do.
Zukin.
Charles Goodwin.
Los Angeles Athletic Club.
City of Santa Monica, Arcadia plant. Do.
Do.

Union Oil Co. (oil well).
Birch and Eoyer (Santa Monica & Sawtelle Oil Co.) (oil well).
Philip J. Flynn, W-139, well 896 (Santa Monica).
Dunham, W-139, well 893 (Santa

Monica). W-139, well 892 (Santa Monica).

H. T. Maloy, LADWP, well 23-C-fl. Maloy.
Artesian Water Co., W-139, well 887 (Santa Monica).
Artesian Water Co., W-139, well 882

(Santa Monica). W-139, well 883 (Santa Monica).

W-139, well 881 (Santa Monica). W-139, well 880 (Santa Monica). City of Santa Monica, Arcadia plant. Do.
Do.
Artesian Water Co., W-139, well 874 (Santa Monica).
Giuliano.
L. P. Heldman, W-139, well 757 (Santa Monica).
J. C. Charles, W-139, well 756, (Santa Monica).

WELL RECORDS 367

TABLE 27. Data on wells in the inland zone of the Torrance-Santa Monica area and in the northern 22 square miles (uncanvassed) in the coastal zone Con.

Identification of wells

USGS Serial
No.

Location
No.

Analyses and
measurements

Depth
(feet) Owner or occupant and remarks

T. 1 S., R. 15 W. Continued

1/15-33J3 _ ...

33K1......
33K2... ...
33L1......

33N1......

33P1... ...

33Q1 .
33Q2......
33Q3
33R1 .
3401
34C2 ...
34C3
34E1.. .

34M1. _

34N1-

34N2..,.__

34P1 _

34P2

34P3 -

34P4... ...

34P5 ...

34Q1-
34R1... ...
35E1..
35K1..___ _

35K2 .
35N1

B-4m

B-4a
B-4w

B-4n

B-4U

B-4J
B-4c
B-4b
B-4d
B-7g
B-7a
B-7
B-7k

B-7n

B-7o

B-7p

B-7L

B-7m

B-7e..._

B-7t

B-7c
B-7r
B-9v
B-9f

B-9o
B-9i

2546Q

2546D
2546
2546H

2536

2536A

2546E
2546B
2546A
2546C
2555C
2555A
2555
2555G

2556C

2556D

2556E

2556A

2556B

2556

2556G

2566
2566B
2576D
2576

2576B
2576A

L.. . .. .

Wsd..-.....
Wmd... __ ......

L.. ....

L, W... ....

Wsd.. ....

Wsd.. _..
Wsd... .
L,W_ _

Wsd... ...
1^. ....

L,.. ....

L..

L,.. ....

L... .

L___ ...

L,W_

Ws

Op, Wmd.........

Wsd
L,. ....
Wmd
Ij. ....

Ws, Wrd ----- .
L...... ....

200

150
200

300

280

150
150

231
500

94

86

83

76

82

160

200

350

2,867
185
145

319

J. K. Thomas, W-139, well 763, (Santa Monica).

J. L. Edmonds.
Wm. Campbell, LADWP, well 23-C-
10.

Jasper Thomason, W-139, well 767 (Santa Monica).
H. T. Maloy, W-139, well 894 (Santa Monica).
Ogden Estate.

Do.

M. G. Le Page.
Do.

A. Wiseman, W-139, well 734 (Santa Monica).
D. Kennedy, W-139, well 747 (Santa Monica).
J. B. Mallory, W-139, well 752 (Santa Monica).
Geo. W. Lavell, W-139, well 753 (Santa Monica).
E. H. Thornbrue, W-139, well 738 (Santa Monica).
D. L. Alien, W-139, well 739 (Santa Monica).
(Ballona Water Co.) L. E. Ogden, LADWP, well 23-D-39.

LADWP, wel!23-D-40.
Ballona Water Co., LADWP, well 23-D-43.
E. D. Gill, LADWP, well 23-D-38. Amalgamated Oil Co. (oil well).
J. R. Savichi, LADWP, well 23-D-37. E. R. Taylor, W-139, well 685 (Santa Monica).
Mr. Bain, LADWP, wel!23-D-36.
C. Wicks, W-139, well 784 (Santa Monica) .

T. 2 S., R. 13 W.

3/13-5A1 ... .
5F1
5H1 .

5N1 ....
6R1 .
6R2__.,._.
6R3 ... .
6R4 ... .

7B1 .

7L1... ....
7R1 .

17L1.......
18A1.. .

18O1 ..

18P1

18Q1 .
18Q2......

B-19n

B-19g
B-19o

B-19b
B-19a
B-19f
B-19c
B-19d

B-19

B-19k
B-19i

B-55d
B-191

B-19L

B-50

2747A
2737
2747B

2728
2727
2728C
2728A
2728B

2718

2719
2729

1430
2729A

2719A

1411

L.. .

L,. ....

C.L. ....

L... ....

L,Wmd,Ws .

L
L.... ......

L
L.... ... .

L . .

C,L,Wd-.... ..

C,L,Wd-..
C,L,Wd._ ... __

275

285

408

300

151

60
171

428
64

98

536

610
530

Service Towel and Linen Supply Co.

Angelus Hospital, LADWP, well 21-C-7.
Jefferson lee Co.

Globe Ice Cream Co.

Globe Ice Cream Co., LADWP, well 21-C-2. George Zobelein, LADWP, well 21- C-l.
W. T. AustermeD.

A. H. Brocamp, W-139, well 110 (Santa Monica).
Los Angeles Railway Co.
Fred Espe, W-139, well 112 (Santa Monica) .
J. W. Sommerville, W-139, well 126 (Santa Monica).
Los Angeles Department of Water and Power, Figueroa plant, well 5.
Well 1.
Well 2.

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TABLE 27. Data on wells in the inland zone of the Torrance-Santa Monica area and in the northern 22 square miles (uncanvassed) in the coastal zone Con.

Identification of wells

USGS Serial
No.

Location
No.

Analyses and
measurements

Depth
(feet) Owner or occupant and remarks

T. 2 S., R. 13 W, Continued

2/13-18Q3

18Q4 ...
18R1
19M1,.._.
20D1......
20D2... _
20D3 _
20H1......
20H2
20J1
20K1......
20RI
29A1......
29H1......
29H2 ...
29P1......

29P2... _

B-55f
B-51
B-55
B-55e
B-55a
B-55b
B-60
B-61
B-55c
B-61a
B-61b
B-61e
B-61d
B-56a

B-56

1420
1402
1421
1421B
1421A
1431
1441
1442
1431A
1442A
1442B
1443B
1443A
1433A

1433

C,L,Wd__. _ ....

C,L,Wd._. .
L.. ....

L.. . ... ^....
L... ....

C,L.... ....
1^.. ....
L.. ....
L.. ....
L.. ....
L.. ....
L.. ....
L. ....
L.. ....

530

560
462
80
300
540

260
328
193
224
195
201
165
166
93

560

Los Angeles Department of Water and Power, Figueroa plant, well 3.
Well 4.
Southern Service Co.

Mrs. McKenzie Manning.

Do.

Goodyear Tire and Rubber Co., well 3. LADWP, weD 314.
Well 4.
Well 5.
Well 5.
Well 5.
WellS.
Well 3.

O. A. Nelson, W-139, wen 632 (Redon-do).
Los Angeles Department of Water and Power.

T. 2 S., R. 14 W.

2/14-1M1 .....

1M2
2A1.......
2C1 .
2M1......

B-15k

B-15p
B-15o
B-15a
B-15b

2697

2697A
2686A
2686
2677

Cp.L....... ......

L.. ....
L,Ws._ ....
Wsd.. ....
L.. ....

80

154
868

347

G. H. Paine, W-139, weB 193 (Santa
Monica).
G. W. Johnson Laundry.
Daniel Murphy.

Artesian Water Co., W-139, weH 37
(Santa Monica).

TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area

[Based on drillers' records except as indicated. Stratigraphic correlations by Alien Sinnott and J. F. Poland]1 1/M-19D3. Beverly Hills Ice and Cold Storage Co.

[Abont one-half mile east of Beverly Hills, altitude, 224 ft. Driller's record, with modifications based on sample descriptions by F. B. Kelsey of California Division of Water Resources. Perforations and yield not known]

Material

Deposits of Quaternary age, undivided:

Sandy clay, brown, and gravel- __ ______________________

Clay __ .... ___ . __ ... __ ...... __ ...... _ .... __ ..... ___ . _ . ...
Sand and gravel ________ _________________________

Silt, mottled gray and brown, micaceous, with slate pebbles to one-half inch in

Clay, brownish, imbedded with slate and granitic pebbles to one-half inch in

Silt, chiefly brownish, imbedded with slate pebbles and granitic sand......

Thickness

(feet)

44
6
18
4
12
4
6
24
30
14
8
1
2
2
5
28
32

8

6
8
52

Depth
(feet)

44 50'
68
72
84
88
94
118
148

162 170'
171
173
175
180
208
240

248

254
262
314

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TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

1/14-19D3. Beverly HOIS Ice and Cold Storage Co. Continued

Material Thickness

(feet)

Depth
(feet)

Deposits of Plioeene(?) age, undivided:
Silt, blue-gray, with streaks of sand_________________________.
Clay, light and dark gray, arenaceous, with some silt and imbedded with a few pebbles_____________________________________. Coarse sand and fine gravel, containing pelecypod shells___________. Fine sand, dark blue gray, containing pelecypod shells____________. Sand, packed and loose_____... __.._______________. Sandy clay____________________________________. Sand.

Silt, light and dark gray, with a few pebbles ____________ . Clay and gravel-___________-___________________ Coarse sand and gravel to 2 inches in diameter..._____________.__. Medium sand, gray, with a few pebbles, and gastropod fragments..... . Silt, gray, micaceous, with fine sand and pelecypod shells_________.. . Clay, blue-gray, arenaceous and micaceous, with a few pebbles of granite__. Sand and gravel to 4 inches in diameter, containing a few gastropod shells . Silt, bluish-gray, arenaceous and micaceous___________________. Sandy clay.____.______________________________. Sand and gravel to iyt) inches in diameter; lower portion contains boulders 8 inches in diameter _______________________________. Clay, blue, with pelecypod fragments______________________.

334

366

392
394
395
436
446
448
462
468
500
520
530

562
576

2/14-3M2. Formerly Artesian Water Co.

(In Ballona Qap north of the Baldwin Hills. Altitude 103 ft. Perforations not known. Reported flow 450 gpm in 1903]

Alluvial deposits:
Soil and clay________________.__.._________________ 22 22
"50-foot gravel":
Gravel and coarse sand____________________________.... 50 72
Unclassified:
Clay.-..........................-...-...-.. -..................-..........-. 1 73
Gravel......____.__._......___.___._.___.________.. 5 78
Clay-.-_..._......_____.__.__._.___________.__._ 14 92
Sand and streaks of clay_____._ __..____________ 18 110
Clay, hard..-._.___._______________._____.___.____. 50 160
Coarse sand_____________________________,_______ 10 170
Clay, hard, blue .-_-__________________-_ __ 56 226
Tine sand, blue__________________________________ 2 228
Clay, blue.. .._.__._. ....._._.__.. .. . _._.__ 15 243
Clay, yellow. .____._.____._____....___.__ .___... 29 272
San Pedro formation:
Coarse sand and gravel, yellow.. . ______._ __ 96 368
Gravel with coarse sand. _______________________________ 16 384
Clay, blue. . _ _...____ _____...________ __.. 4 388
Sand, black, andshells..____ ____________ 67 455
Sandy clay, hard. _.___ _-__-__.__ 16 471
Sand, fine, blue________________....______________ . 7 478
Clay-.. _.___.__.__.___ __..___ __._. 5 483
Gravel and coarse sand-.__....... . ___r...................... 35 518
Clay, hard. ________________:__ ____________ 4 522
Sand and clay ______________________________________ 18 540
Fine sand-._.________-______.____________._______ 28 568
Gravel and sand with a few streaks of clay__.________________ 12 580
Fine sand______________. ___ _. _______________ 4 584
Sandy clay_______ - ____-___... 86 670
"Cement". - - 1.5 671.5
. Gravel-. _____... __.___.._._._____..______. 2.5 674
Clay, hard__....._____.....___..__ ...._ _ 6 680
Sand, some gravel___________ ... ________..__-_-- 5 685
Clay, hard__.______._.______._-._____._______ .. 5 690
Sand...._ ____._____ __........ _.____ 6 696
Gravel___.__... . _.__ ________ 6 702
Sand..-.-....-- 42 744

Clay, hard-- _ _ _-__ _ __ _._- 16 760
Gravel and sand_____________ . _________.__ 10 770
Sand. _--.-- 31 801

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TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

2/14-5D6. Southern California Water Co., Venice-Culver City system, Sentney plant well 6

[In Ballona Gap, north of the Baldwin Hills, altitude 88 ft. Casing perforated at 326-342 ft, and
492-515 ft]

Material Thickness

(feet)

Depth
(feet)

Alluvial deposits:
Soil.......-...... ....

Sandy day _________________________. Sandy gravel to one-half inch in diameter________. San Pedro formation:

Clay, green . .______________._ Clay, blue.... ..____________________ Sand and gravel to 1 inch in diameter..._________ Clay, blue________________................. Sand and gravel to IJi inches in diameter________ Clay, blue____________-.__________. Fine sand, muddy, with some one-quarter-inch gravel.... Fine sand, muddy.. Clay, blue __________________ Sand and gravel to 2 inches in diameter; some shells_... Sand and gravel to one-half inch in diameter; some shells. Sand: some gravel to one-quarter inch in diameter.... . Sand and gravel to 1^ inches hi diameter__ __ ___ Clay, blue__._---.__.________-..-...- Sand and gravel to 1 inch hi diameter...____...... Clay, blue_________________________ Sand and gravel to 1^ inches in diameter________ Clay, very sandy.. _____________________ Silt, fossiliferous, blue___________________ Clay, blue...-..-.---.-... ...._......--..--.-. Fine gravel, muddy, to one-quarter inch in diameter..... Fine sand, muddy _________________ Sandy clay__________.______............. Clay and gravel to 2 inches in diameter___........ .. Sand and gravel to 2 inches in diameter______.... Sand, muddy__ _____________________ Unclassified:

Sandy clay___...._____._________....... Clay, blue__________________________

16
7
70
17
4
8
11
21
10
14
7
4
66
2
11
16
14
9
79
4
20
24
8
10
35

57
208

9
23
36

68
84
91
161
178
182
190
201
222
232
246
263
267
313
315
326
342
366
365
444
448
468
492
500
510
546

602
810

2/14-23H2. City of Los Angeles, Manhattan plant well 3A

[About 3 miles northeast of Inglewood, altitude 137 ft. Casing perforated at 456-480,496-520, and 725-776 ft. Yield on test 3,050 gpm with drawdown of 40 ft]

Alluvial deposits:
Soil..... ....

Clay, gray, soft.___.
Unclassified:

Clay, gray, hard ...
Sandy clay, blue, hard-
Sandy clay, blue, soft-
Sandy clay, blue, hard-
Fine sand, blue __.
Clay, blue, hard___.
Silt, blue-..-.--....--..
Sandy clay, blue... _.
Clay, blue, hard__.
Sandy clay, blue..__.
Clay, blue, hard_.--.
Clay, yellow, hard ..
Ban Pedro formation:
Coarse sand...---.--.-.

Fine gravel._____.
Coarse sand......__.
Clay and gravel. ___.
Coarse gravel____..
Fine sand.._____.
Clay, blue, hard_-.--.
Sandy clay, yellow__.
Coarse gravel__-----
Clay, blue, hard___.
Sandy clay, yellow. _.
Coarse gravel ..-._.
Fine gravel..-..__.
Sandy silt, wet____.
Coarse gravel__-.-.-.

4
26

62
73
80
86
94
149
168
201
234
240
268
278

287
292
311
316
331
346
368
395
399
435
449
460
479
488
501

WELL RECOKDS 371

TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

2/14-23H2. City of Los Angeles, Manhattan plant, well 3A Continued

Material

San Pedro formation Continued

Peat . .-..- _ - . - .- -. - ..

Unclassified:
Silty sand-.... .-.-.---------..-._----.- _ ___...__..__.._ __.___. ____._.___..__

Thickness

(feet)

2
15
6
7
16
7
9
7
5
14
2
18
12
39
14
2
44
51
25

22
9

Depth
(feet)

503
518
524
531
547
554
563
570
575
589
591
609
621
660
674
676
720
771
796

818
827

2/14-27D1. City of Ingle wood well 7

[About 1 mile northeast of Inglewood hi Centinela Park, altitude 145 ft. Casing perforated at 100-115, 135-159, 177-191, and 245-265]

Deposits of upper Pleistocene age, undivided:
Clay. _ .. __ ...---.. _-.---__--.-_------.-----.----..--_.-.... ___ . _ -.
Sand, cemented-. ______________ . _ ________________

Clay __ . . -..-.. . _ ....
Gravel. ____ . ______ . ______ . ______________________

San Pedro formation:

Clay. . - .- .. .. .-.. .

Clay-....... _-_ - ... . .-_._.__..._........___._ _ .... Sand, cemented.- __ -.. . _____ .. _____ . _____________

Silverado water-bearing zone:
Coarse gravel _____ . __ ..-..-.. ...... ____________________

Unclassified:

24
36
10
8
2
35

20
24
18
14
54

20
1

34

24
60
70
78
80
115

135
159
177
191
245

265
266

300

2/14-27J1. City of Inglewood well 16

[About 1 mile west of Inglewood, altitude 234 ft. Casing perforated at 236-283 ft. Yield about 450 gpm; drawdown not known. Driller's record with modifications based on sample descriptions by F. B. Kelsey of California Division of Water Resources]

Deposits of upper Pleistocene age, undivided:
Soil, dark-brown.____________.._________________
Fine sand and clay, yellow..________________________.
Medium sand and clay, yellow. _________________________.
Sand, yellowish-gray, and gravel to 2 inches in diameter.-..__.______. Sand and gravel to 2 inches hi diameter..___________________. Silt, light-gray, streaked with fine micaceous sand.._......_________. Clay, greenish-gray, with coarse sand and gravel to 3 inches hi diameter___. San Pedro formation:

Sandy clay. ____________________________________. Coarse gravel mixed with clay__________. _ _ _ _________. Silt, light-gray, laminated._.__________________________. Very fine sand, light-gray...__________________________... Silty clay, black, micaceous. __________________________. Fine sand, blue________. _________________________. Coarse gravel_______________ ______________________. Sand, light-gray, gravel to 4 inches hi diameter. _________________. Medium sand, gray, with calcareous clay and sand concretions, weathered schist pebbles and lignite fragments. _____________________.

4
17
18
22
53
54
61

94
100
105
131
139
143
150
157

184

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TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

2/14-27 Jl. City of Inglewood well 16 Continued

Material Thickness
(feet)

Depth
(feet)

San Pedro formation Continued

Silt, gray, micaceous, and fine sand________.________..._ . Fine to coarse sand, and gravel to 6 inches in diameter, with silt and lignite
fragments .
Unclassified:

Silt, gray, micaceous, with lignite fragments.--.__________._ .
Boulders of granite and sandstone imbedded in gray silt_____ .
Silt, gray, micaceous; shell fragments at about 575 feet -
Silt, blue-gray, micaceous..___________________... . Silt, dark-gray, micaceous____________ _________... . Silt, very hard.________________ _______...___ _ ..
Sandy clay ... .__ . .
Sand.

Fine gravel____________________ ..
Very coarse gravel, and gas._____________
Clay, fine sand, and gravel to 6 inches in diameter...

52

47

123
6
298
276
20
5
45
2
1
14
24

283

406
412
710
986
1,006
1,011
1,056
1.058
1.059
1,073
1,097

2/14-28L1. City of Inglewood well 27

fAt the north end of the business district of the city of Inglewood, altitude 131 ft. Casing perforated at 283-310, 398-414, and 424-440 ft]

Deposits of upper Pleistocene age, undivided:
Sand and clay__________________________.
"200-foot sand":

Sand and gravel to 2 inches in diameter_ ..._.......
Sandy clay__. _________________________. Sand and gravel to one-half inch in diameter....._______. Sandy clay____________________________. Gravel to 3 inches in diameter...._._____ ___._... Clay and gravel... .....__.______ _____... Sandy clay ______________________________. Clay and gravel_________________________. Fine sand, muddy; some gravel to one-fourth inch in diameter-Fine sand, muddy; some gravel.._______________. Sand and clay .__.__-____________________. Clay, sand, and gravel to three-eighths inch in diameter...__ San Pedro formation:

Blue clay_____________________________. "400-foot gravel," 279-316 feet:
Sand and gravel to one-half inch in diameter__________. Clay and gravel....___._________.. ______. Sand and gravel to 1 inch in diameter___.. ___._... Clay and gravel...________________________. Gravel, packed, to 1 inch in diameter_______________. Clay, soft, blue, and fine gravel. __...... ..._....... Silt, blue ......_._ .___._.____-_______. Sandy clay, blue.- _.. . Sandy clay and small gravel___________._______. Silverado water-bearing zone, 396-455 feet:
Fine sand and gravel to one-half inch in diameter_______. Sand and gravel to three-fourths inch in diameter_______. Sand, fine to coarse_.---.__________________. Sand and gravel to three-fourths inch in diameter.______. Silty clay, blue, and gravel to one-fourth inch in diameter...... Sandy clay, blue, and gravel to 1 inch in diameter.___..._. Sandy clay, blue___________________________. Clay and gravel..________________________. Unclassified:

Clay, hard, with a small amount of gravel _____... Gravel, cemented________________________. Clay, blue.____________________ ______.
- Clay with layers of fine sand. __________________. Clay, blue_______________________.____.

134

6
12
7
8
13
4
18
4
14
16
2
5

36

134

140
152
159
167
180
184
202
206
220
236
238
243

279

290
295
300
307
316
324
394
396

402
412
422
438
445
455
475
481

505
509
545
548
600

WELL RECORDS 373

TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

2/15-1C5. Southern California Water Co., Venice-Culver City system, Manning plant well 5 [About 1 mile north of Culver City, altitude 175 ft. Gravel envelope well, casing Initially perforated afc 672-852 ft.; subsequently plugged at 464 ft., and casing perforated at 146-321 ft. and 370-374 ft.]

Material Thickness

(feet)

Depth
(feet)

Deposits of upper Pleistocene age, undivided:
Soil . .
Coarse sand_ .... _ Clay . _ .
San Pedro formation:
Sand.... - ._.__ Fine gravel and thin clay streaks..
Fine gravel, packed_~~ ... -.. Fine gravel, packed, and fine sand streaks. Fine sand, loose_ . . __._.. Sand, hard-packed, and small gravel Unclassified:
Fine sand, hard-packed, blue.. .--.... Pico(?) formation:
Clay, sticky, blue..
Sandy clay, blue........
Clay, sticky, blue__.................... Coarse sand...

Clay, blue_
Clay, sticky, blue..
Sandy clay and coarse sand -... Clay, sticky, blue__
Sandy clay, blue.. .
Medium sand, gas showing.. Sandy clay, blue........
Sandy clay, gray .
Sandy clay, red, with small gravel.. Clay, gray....
Medium sand _
Clay, gray. . . -
Small gravel and sand
Clay, gray.
Small gravel and sand.
Sandy clay, gray, and thin streaks of sand. Sand, gray
Gravel and sand .
Medium sand

Sand, loose, and small gravel._ Sandy clay and thin streaks of sand... Fine sand, blue...... . Medium sand, blue........
Clay, sticky, gray

15
45
11
74

101

10
14
25
4
24
111
19
52
31
7
29
30
25
3
2
11
6
2
2
20
6
2
7
3
14
30
5
51

27
31

37
75
90
135
146
220

321

331
345
370
374
398
509
528
580
611
618
647
677
702
705
707
718
724
726
728
748
753
755
762
765
779
809
814
865

2/15-11D2. Southern California Water Co., Venice-Culver City system, Charnock plant well 3 About 1 mile west of Culver City, altitude 98 ft. Casing perforated at 240-276 and at 300-340 ft. Yield 345 gpm with drawdown of 24 ft.]

Alluvial deposits:
Soil and clay. . .
"60-foot gravel," 24-42 feet:
Sand and gravel. .
Sand, gravel and clay...... . . San Pedro(?) formation:
Clay........ ..... .
Sand and gravel. , .
Clay.... .... San Pedro formation:
. Sand, blue.... .
Clay........ .... Sand___. ..... .
Sand and gravel to 1 inch hi diameter.
.Sand and gravel. .
Sandy clay, black__ .
Sand, blue...... .
Clay, blue__...... .
Sand, blue._.. .
Pico(?) formation:

Clay, blue . Shak. 42

24

34
42

70
116

134
198
240
244
274
302
340
366
376

438
480

460508 58

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TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

2/15-14A3. City of Los Angeles, Barnes City well 2

[About 1 mile southwest of Culver City, altitude 42 ft. Driller's record, with modifications based on sample descriptions by F. B. Kelsey of California Division of Water Resources. Casing perforated at 210-250, and at 405-425 ft.]

Material Thickness

(feet)

Depth
(feet)

Alluvial deposits:
Silty clay, brownish. -.- - -
"50-foot gravel":
Gravel, dry........ --.- . _ - ...
Boulders........ --.-. ... - -- -- -.-.-_
San Pedro(?) formation:
Fine sand, blue, and shells -- - ..
"Sea mud" and shells_ - ..... .
Clay, blue.___.. - - -
"Sea mud" and shells__ - - - San Pedro formation:
Sand, cemented, and gravel.......... - .
Fine sand, blue__..-- - -- - ---- -...
Fine sand, gray, granitic, containing a few pebbles to H inch hi diameter _-_
Gravel____-------- - ...
Coarse sand and gravel - ...
Fine sand__ - -
Coarse sand, packed_ - ...
Coarse sand, gray, and fine gravel; coarser hi lower portion ...
Pico(?) formation:
Silt, gray, micaceous, massive...... ... - 37

24

36
42

50
62
75
130

134
190
206
232
262
308
360
425

402

2/15-17G4. Formerly American States Water Service Co. well 7

[About 2 miles southeast of Santa Monica, altitude 22 ft. Casing perforated at 40-185 ft.]

Alluvial deposits:

"50-foot gravel":

San Pedro formation:

Sand... .- . ...
Clay.........-.....-.-. .-. ... .-. ....

San Pedro (?) formation:

Clay...........

6

11
07

12
9
24
39
12

15

6

6

17
44

56
65
89
128
140
1 P\P\

188

200
206

2/15-24C1. Mesmer City Corp. Ltd. well 1

[In Ballona Gap, about 2 miles south of Culver City, altitude 20 ft. Casing perforated at 215-221, 235-254, and 344-350 ft]

Alluvial deposits:
Clay...... .... __ .
"50-foot gravel":

San Pedro(?) formation:

San Pedro formation:

Unclassified:
Clay.... . ...

29

36

15
90

30
' 42
- "8
-- 9

24
21
99
21

7

29

65

80
170

200
212
221
230
254
275
374
395

402

WELL RECORDS 375

TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

2/15-34A2. Palisades del Key Water Co. well 4

[About 1 mile east of Playa del Key, altitude 137 ft. Casing perforated at 172-212 ft]

Material Thickness

(feet)

Depth
(feet)

Dune and beach sand:
Soil...._ __
Sand, yellow. _ ________ San Pedro formation:
Gravel and sand_________ Sand, yellow...-_________ Gravel and sand______..__ Sand, yellow..__________ Sand, muddy, and light gravel.. Sand, blue____________ Gravel to !} $ inches in diameter. Sand and small gravel__...... Sand, blue, and muddy gravel_ Unclassified:

Sandy clay-____________ Sand and gravel- ._______ Clay. _ _ .

15
4
23
15
10
8
10
43

107
7
31

4
97

105
120
124
147
162
172
180
190
233

340
347
378

3/13-8G1. Clara Peopping

[About 2 miles southwest of Watts, altitude 110 ft]

Deposits of upper Pleistocene age, undivided: Soil......................._......__... Sand, cemented_______________.
Clay. .
Sandy clay _______________ . Clay_ .._ ._......._._..... Gravel ___..___________ . Clay........._.._.............._ Sandy clay _______________ . Gravel..__________________... Clay and gravel..._____ ____ . San Pedro formation:

Clay____ _______ Gravel.__________________.... Clay...................................... Gravel...__________.______... Fine silty sand, black.________.... Shells- ......
Sand and clay_______________... Clay, sticky, brown._._... __ . Silverado water-bearing zone:
Sand, green_______________.. Sand and gravel_____________... Clay, green..._ ____ ___.... Sand-._____-- :.._____.__. Sandy clay, black____________.... "Quicksand," black____________. Sand, cemented.._____________. Clay, hard, black ____ .._... .
Sand and gravel, very coarse. .
Sand, water-bearing..__.- .
Sandy clay_________._____ . Clay, hard, black._____ .... . Sand (gas) ._ . . . Clay- _.. __. __.____. Sand. .... _-. Unclassified:

Clay and sand________________. Sandy clay, streaked with sticky clay. . Fine sand__________________. "Quicksand" and some gravel_.___... Clay... _... .

27
4
3
2
3
2
46
9
16
5

58
5
30
5
40
6
7
10

11
16
3
30
56
6
19
21
40
54
13
7
35
7
26

10
148
6
2
2

41
87
96
112
117

175
180
210
215
255
261
268
278

305
308
338
394
400
419
440
480
534
547
554
589
596
622

632
780
786
788
790

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TABLE 28. Material* penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

3/13-28A1. C. H. Hazel

[About 1 mile southwest of Oompton, altitude 91 ft. Casing perforated at 457-467 and 505-525 ft]

Material Thickness

(feet)

Depth
(feet)

Deposits of upper Pleistocene age, undivided:
Soil....................................... Clay. ....___ -- _ .-_ Clay and sand___.___............... Clay.__________ .... Clay, blue, and "hardpan" ... Clay and gravel _-.................. Clay and sand............................ Sand....._______ __....... Sand and shells_.___._____..... Sandy clay .... Sand..................................... Coarse sand_______..... .... Sandy clay ..__ . Sand, cemented_____________ San Pedro formation:

Fine sand and decomposed wood...._.. Sandy clay............................... Sand and shells_._________.___ Sandy clay_______._____.... Clay, blue. _____ _.......... Bilverado water-bearing zone, 348-555 feet: Coarse sand and shells....................

Coarse sand and small gravel____.... Sand__________................. Gravel, cemented____................. Sand and small gravel. .... Sand__________ - . - Silty sand._______
Sand, gravel, and clay
Gravel, cemented......................... Sandy clay .... Clay, bine... . . Coarse sand and gravel
Clay, blue................................

15
45
54
63
69
99
114
138
147
183
201
225
258
267

273
291
324
327
348

375
399
405
420
429
441
444
468
480
495
555
558

3/13-30A2. J. P. Schlaegel

About 1 mile east of Oardena, altitude 45 ft. Casing perforated at 363-373, 528-538, 560-577, 616-628, and 660-690 ft]

Deposits of upper Pleistocene age, undivided:
Soil.... ___..................._....

Sand......................

Clay_....___ .__.
Sand
Clay......................
"Cement"__.____ .
Clay.. _--...... ._...
Fine sand.................

Clay, blue__..___...
"200-foot sand":
Fine sand.. ~......
Coarse sand...............
Sand______.____.
Gravel and clay.____..
San Pedro formation:

Clay_..________.
"400-foot gravel," 242-387 feet:
Sand__:.......___...
Sand, packed ...
Clay__................
Sand_*. __.....
Sand and clay............
Clay..... ......-......
Gravel___ __._.
Fine gravel __..
Clay......................
Coarse sand.....___....
Clay......................

19
11
15
2
31
9
I

43
16
12
6

60

28
II
21
18
23
16
8
4
9
7
125

9
17
36
47
62
64
95
104
105

148
164
176
182

242

270
281
302
320
343
359
367
371
380
387
512

WELL RECORDS 377

TABLE 28. Materials penetrated by typical water wetts in the coastal zone of the Torrance-Santa Monica area Continued

3/13-30A2. J. S. Schlaegel Continued

Material

Silverado water-bearing zone:
Sand __ . . . _ . ...

Sand _______ _______ . ...

fllo-YT

Thickness

(feet)

9
15
10
4
25
10
8
9
6
8
10
3
1
14
6
38
1
9
6

Depth
(feet)

521
536
546
550
575
585
593
602
608
616
626
629
630
644
650
688
689
698
704

3/14-4N2. Southern California Water Co., Lennoz system, Trnro plant well 2

[Altitude 73 ft. Casing perforated at 500-512, 519-576, 680-602, and 611-674 ft. Reported yield 1,100 gpmj

Deposits of upper Pleistocene age, undivided: "Hardpan"_________________._____.. ____..............
Sandy day, gray.... __ . __
Sandy clay, blue__ ....
"200-foot sand":

Sand, gravel to 2 Inches in diameter.................... .... Sandy clay, blue.... ___...... _______________........ Sand, gravel to 2 Inches in diameter..______________________ Sand, gravel to 3 Inches in diameter_______________________ Sandy clay, yellow.. __.__.._______________________ Sandy clay, yellow, with streaks of sand and gravel to 2 inches in diameter.... Sand and gravel to 2 Inches in diameter_____________________ Clay, blue__ ____________________________ Sand and gravel to one-half inch in diameter__________________ San Pedro formation:

Clay, blue__ __ ....____________________ Sand, muddy ____________________ Sandy clay, blue.... ____________________________ Sand, muddy__ ____________________________ "400-foot gravel", 320-399 feet:
Sand and gravel to 2 inches in diameter_____________________ Fine sand and gravel to one-fourth inch in diameter______________ Fine sand, muddy. ...____........................ Clay, blue_____ ___________________________ Silverado water-bearing zone:
Fine sand and gravel.. ____________________________ Fine sand and some gravel to one-fourth inch in diameter.___________ Fine sand and gravel to one-half inch in diameter________________ Fine sand and gravel to 2 Inches in diameter__________________ Sand and gravel to one-half inch In diameter........-.. ._...... .... Sand and gravel to 3 inches In diameter_____________________ Sand and gravel to 1 inch in diameter______________________ Sand and gravel to one-fourth Inch In diameter_________________ Sand and gravel to 2 Inches in diameter_____________________ Fine sand, muddy, and gravel to one-half inch in diameter___________ Sand and gravel to 2 Inches in diameter.. Sand and gravel to 4 Inches in diameter_____________________

Clay, Mue_____________________________________ Sand, gravel to one-half inch in diameter, and clay............................

Gravel to one-half inch in diameter, and sand..................................

14
73
105

119
124
131
13»
142
153:
167
1ST
197

213
236
310
320

332
342
399
477

485
493
500
512
519
570
576
580
602
611
641
674
685
692
695

378 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

Well 3/14-10G1. City of Ingle wood well 28

[About 3 miles south of Inglewood, and 1 mile east of Hawthorne, altitude 62 ft. Casing perforated at 492- 627, 646-568, 638-654, 676-680, and 703-711 ft. Yield 600 gpm with drawdown of 17 ft]

Material Thickness

(feet)

Depth
(feet)

Deposits of upper Pleistocene age, undivided: Soil

Clay, yellow
Fine sand

Clay, yellow
"200-foot sand":
Sand and blue clay
Silty sand
San Pedro formation:
Sandy clay, blue
Fine sand

Clay, blue___________________ "400-foot gravel," 362-406 feet:
Sand, cemented
Gravel to 2 inches in diameter

Clay, blue _.__.
Sand and gravel to 1 inch in diameter
Fine sand.

Sandy clay, blue
Clay, sand and gravel
Sandy clay, blue
Silverado water-bearing zone:
Sand, hard, blue
Gravel to 2 inches in diameter

Sand and gravel to 1 inch in diameter Clay, blue
Gravel to 1 inch in diameter
Gravel to 3 inches In diameter
Fine sand..
Silty sand
Clay, sand, and coarse gravel
Gravel to 5 Inches in diameter
Gravel to 2 inches in diameter

Sand with fine streaks of clay
Sand and gravel to 1 inch in diameter
Sand, with streaks of clay..
Sand and gravel to 2 inches in diameter....
Basal deposits containing Timms Point fauna:
Clajjblue................................. 87

3
94
97
172

256

292
306

367
373
378
386
406
474
475
480

492
496
527
546
557
574
578
602
638
642
654
676
680
703
711

798

> Microfaunal determinations by S. G. Wissler.

3/14-22A1. Southern California Water Co., Lawndale system, Chadron plant well 1

[About 2 miles southeast of Hawthorne, altitude 49 ft. Casing perforated at 319-382, 540-554, 622-634, 640- 646, and 660-668 ft. Reported yield 1,160 gpm; drawdown not known]

Deposits of upper Pleistocene age, undivided:
Clay.. ________.... .____..
Fine sand_________________.
Clay._._________.___........
"200-foot sand":
Fine sand. __________________. Sand with streaks of clay_________. Clay. . _ . Sand, muddy________________. San Pedro formation:
Sandy clay _________,. _______. "400-foot gravel," 317-384 feet:
Gravel to 1 inch in diameter__ ___. Sand and pea gravel_ __________ Clay..._ _-_ _ _. Clay with streaks of pea gravel.. .... Clay.......... ... .

2
14

10
36
36
8

113

29
38
38
18
58

100
114

124
160
196
204

317

316
384
422
440

WELL RECORDS 379

TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

3/14-22A1. Southern California Water Co., Lawn dale system, Chadron plant well 1 Continued

Material Thickness

(feet)

Depth
(feet)

Silverado water-bearing zone:
Sand, muddy,_________.....____.... Sand, with some pea gravel and fine gravel. ___. Sand and gravel to one-half inch hi diameter.--.-. Sand- .

Sand and gravel to three-fourths inch in diameter - Sand._....................... .-.........__. Gravel to three-fourths inch in diameter.-___... Sand with streaks of clay___________... Gravel to one-half inch in diameter._______-. Unclassified:

Clay. .- Sand.._______________ ..____..

514
540
554
622
634
640
646
660

710

3/14-29D3. City of Manhattan Beach well 11

About 2 miles east of Manhattan Beach, altitude 88 ft. Driller's record, with modifications based on lab-oratory examination of samples by Alien Sinnott of Geological Survey. Faunal examination by S. G. Wissler. Casing perforated at 221-238 and 418-433 ft. Yield on test 600 gpm with drawdown of 25 ft]

Dune and beach sand:
Soil.-

Silty sand, buff; sand grains subangular to rounded and largely of quartz; a
few granitic pebbles to three-fourths inch in diameter________.........
Deposits of upper Pleistocene age, undivided:
Clayey silt, gray, micaceous, with a few quartzite, granite, and other pebbles
to three-fourths inch in diameter-_._________.____________
Sandy silt, micaceous__-_--- -____------ _ _.. ..
Clay, with limonitic zones and dendrite along fractures_____________ Silty sand, gray buff, moderately micaceous; sand grains subangular to rounded, consisting mainly of quartz and feldspar______ ________-...... San Pedro formation:
Sandy silt, gray buff, with limonitic concretions; pelecypod fragments; in-cluded sand grains poorly sorted; a few small pebbles of quartz and meta-morphic rocks ____.... .
Silverado water-bearing zone:
Sand, gray, fairly clean, coarse, angular to subangular, feldspar and quartz, with some smaller amounts of pyroxenes, magnetite or ilmenite, garnet, chlorite, muscovite, biotite, epidote, and a trace of shell fragments. Com-position: quartz, 35 percent, feldspar, 50 percent, others, 15 percent. In places streaks of heavy minerals cemented in part with calcite and hematite.
A few pebbles up to 1 inch in diameter. Moderately well sorted..__.__ Gravel and coarse sand, gray, clean, with pebbles up to 1 inch in diameter; pebbles chiefly granitic______-________________.. ... Sand, gray, coarse, poorly sorted, angular to subangular. Composition and roundness similar to sand from 190 to 218 feet. Wood fragments from 290 to 300 feet. A few pelecypod and gastropod fragments in sample taken from 306 to 310 feet... ... Sand, gray, very fine to medium; contains a few pelecypod fragments. Ellip-soidal calcareous concretions up to 4 inches long and up to \% inches in diameter recovered at depth 335 feet_____________________~... Sandy silt, dark gray._
Fine to very fine sand, gray.-________________________.... Fine to medium sand, gray,-moderately well sorted_......____.. .. Coarse sand, gray, angular to subangular, with abundant shells of pelecypods and gastropods-.________ -___-_____-_-_.___ ... Gravel and sand, gray, clean, with abundant shells of pelecypods and gastro-pods. Pebbles chiefly granites and metamorphic rocks (quartzite), with some pegmatite and vein quartz; clay layer or layers about 1 inch thick at
418 feet___________________
Pebble gravel, with a few boulders; pebbles are of granitic rocks. Abundant gastropod shells,_________.____________________.-..... Gravel and sand; abundant gastropod shells______________.-..... Unclassified:
SDty clay, gray..__ .
Gravel, clay, and "shale"--__._.________...._____._ ... Clay, gray, with some micaceous silt-_________.________.. ...
Clayey silt, gray.-__.. . . .- _ . .

90

4

100

127
135
147

165

190

218

220

310

348
354
365
394

410

418

425
431

453
458
470

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TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

3/15-13R2. Standard Oil Co. well 16

[About 2 miles southeast of El Segundo, altitude 153 ft. Casing perforated at 368-460 ft. Yield on test 860 gpm with drawdown of 13 ft]

Material Thickness (feet)

Depth
(feet)

Dune and beach sand:
Yellow sand, loose._..___._______________ Unnamed upper Pleistocene deposits:
Clay, soft, blue_________________________ "200-foot sand":

Sand and gravel to 1 inch in diameter...__________. San Pedro formation:

Sandy clay, yellow.____________.._________ Silverado water-bearing zone:
Sand and gravel to three-fourths inch in diameter__ _. _ Sandy clay, blue.._______________________. Fine sand, blue_____________________.. Sand and gravel to 2 inches in diameter_____ _ _.__. Sandy clay..__________________________ Fine sand and gravel, blue, to three-fourths inch in diameter. Sand and gravel to 1 inch in diameter... _....___ _ Sand and some gravel to three-eighths inch in diameter Sand and gravel to 1H inches in diameter_______ .... Sand and gravel to three-fourths inch in diameter............. Sand and gravel to 2 inches in diameter_______.._.. Sand and gravel to three-fourths inch in diameter__.__. Unclassified:

Sandy clay, hard.._______________________

175

11

17

24

20
36
17
7
32
21
35
13
17
11
20
4

20

175

186

203

227

247
283
300
307
339
360
395
408
425
436
456
460

480

4/13-12A2. City of Long Beach, North Long Beach well 6

About 5 miles north of Long Beach, altitude 38 ft. Faunal examination by M. L. Natland. Casing per forated 1805-1955 ft. Well flowed 106 gpm in October 1946; temperature, fl4°-1040 F in October 1946; sufficient methane present in water to burn continuously. Yield estimated at 400 gpm with drawdown of about 60 ft]

Alluvial deposits:
Soil . . ..
Sand and gravel, water bearing.... ______
San Pedro formation:

Clay, yellow___________________ Clay, blue, hard____ ______..__ Sandy clay, blue, with some gravel.._..___ Clay, yellow....................................... Clay and gravel, tight______________. Clay, yellow, hard____________......... Sandy clay, blue, with some gravel, water bearing. Sand, packed, and gravel, water bearing_____ "Sea mud," shells, and wood fragments...__. Clay, blue, hard_________________ "Sea mud" and shells.__..__.______... Sandy clay, blue..._______________. Coarse sand, some gravel, water bearing____... "Sea mud" and shells..______________ Sandy clay, blue_________________... Sandy, clay, blue, and shells___________.... Silverado water-bearing zone, 237-466 feet:
Sand and gravel, with shells___________... Coarse sand, water-bearing___________ . Sand and gravel, loose, water bearing_____ . Fine sand and gravel, with shells________ . "Sea mud," gravel, and shells._-____... . Sand and gravel, with streaks of clay_____... Sand and gravel, clean . . _. ___ . Sand and gravel, with streaks of sandy clay__ . Clay, blue, with streaks of sandy clay......__... Clay, blue, hard______________.___ . Sandy clay, blue..._._ .. . . Coarse sand, dirty, tight_.___ __ .... Clay, blue, with streaks of sand.. _ ....

48

51
58
172
23
31
10
24

11
27

35
47
58
66
76
85
92
117
134
136
152
164
186
214
229
237

256
263
271
319
327
357
408
466
638
661
692
702
726

WELL RECORDS 381

TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

4/13-12A2. City of Long Beach, North Long Beach well 6 Continued

Material Thickness

(feet)

Depth
(feet)

Pico formation, upper division:
Sandy clay, blue....________-._._-.___... ...... Sandy clay, packed, with streaks of coarse blue sand. __ Clay, blue, sticky ___.____ . __ __ ...... Sand, packed, with streaks of blue clay.________.__.. Clay, blue_______.__----- - . .. . Clay, blue, hard___ __-__.._ __ __ _... Sandy clay, blue____ .. . -- . . . Clay, blue, hard_-__..__.-.. -- .. .- ..... Sandy clay, blue__________.__.___.__-.__ Sand and gravel, with streaks of clay, water bearing...__.. Clay, blue, sticky..._.__..-- .. .. Sandy clay, blue..__..__.__..__.... _ .. . Clay, sticky, blue, with streaks of gravel.... .... Sand and gravel--.__.._ . - . . ._.... Clay, blue, sticky_______._ __........ Sandy clay, blue, with streaks of gravel......._.........._.... Clay, blue, hard and sticky.. .__..__.-..-.___....... Sandy clay, blue, with streaks of hard sticky clay. _____, Sand, packed, with streaks of blue sandy clay; water bearing. Sandy clay, blue.-..-____.-_---___.-..- ...... Sandy clay, blue, with streaks of sticky clay. _ _... Clay, blue, sticky.__ .. . . -................. Clay, blue, hard and sticky _ --..-.-. . .... Clay, blue, hard, with streaks of blue sand__.__ _... Clay, blue, hard_______.__.__..._.._ ...... Clay, blue, hard, with thin streaks of packed sand............ Fine sand, blue, with streaks of soft clay; water bearing__.. Clay, blue_____________.____________.. Clay.... _.. _-.- ..._. .--.- .... Clay, blue, hard __ _. . . _ . . . Very fine sand, blue, mixed with clay......_ .. .. Clay, blue, with thin streaks of sand_....__._ _ . Sand, dry, very hard__________-_____........ Sand, dry, very hard, with streaks of soft blue clay_. __.. Fine sand, blue, with streaks of clay; water bearing _.... Fine sand, blue, and some fine gravel; water bearing...__.. Clay, blue _
Clay, blue, and streaks of sand; water bearing..._...__... Sand, blue, and fine gravel; watef bearing.................... Clay, blue..._.... - .... - .... Sand, blue, and clay. _T _ .... Clay, blue, very hard _ . _ . ... _.... Clay, blue_______.__..-..------ _ _ _ . Clay, blue, very hard. __._ __..__.._ _ . Clay, blue..__ ... - . _.._ .-__.-_ Clay, blue, hard __.._ .. _ _ .. . Sandy clay, blue...__._..._ _. 1 _ _ _ . Sandy clay, blue, and fine sand; water-bearing __.__.. Clay, blue.._________.__._...__ __.__.. Clay, blue, very hard ... - -.- - . . Clay, blue, with streaks of fine blue sand; water bearing...... Fine sand, blue; water bearing.. .... _..._ . Clay, blue_-___________._...__._______ Coarse sand, blue, and fine gravel; water bearing_____.. Clay, blue, hard-___.__._ _ __..... _ . Fine sand, blue, packed, with clay...__.__.__.__.. Sand, blue, clay, and some gravel- _________.... . Fine sand, blue, and clay ____________________

66
25
8
57
13
12
22
20
30
13
45
13
19
8
11
61
39
35
22
7
122
49
28
5
59
16
60
4
22
4
30
8
2
14
26
16
2
16
10
24

781
806
814
871
884
896
918
938
968
981
1,026
1,039
1,058
1,066
1,077
1,138
1,177
1,212
1,234
1,241
1,363
1,412
1,440
1,445
1,504
1,620
1,580
1,684
1,606
1,610
1,640
1,648
1,650
1,664
1,690
1,706
1,708
1,724
1,734
1,758
1,764
1,770
1,776
1,780
1,785
1,796
1,826
1,830
1,838
1,847
1,866
1,886
1,888
1,918
1,926
1,938
1,948
1,955

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TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

4/13-15A11. Dominguez Water Corporation well 15

In Dominguez Gap, altitude 27 ft. Descriptions of material by Alien Sinnott and R. C. Newcomb of the Geological Survey, based on examination of samples which were collected every 10 ft. by Paul Karnes, driller for Roscoe Moss Co. Faunal examination by S. G. Wissler. Depth interval commonly assigned on basis of interpolation between sampling points. Samples from surface to 220 ft. were taken from well 4/13-15A10 (Dominguez Water Corp. well 14), located about 200 ft. northwest of well 4/13-15A11. Casing perforated at 800-990 ft. Reported yield 2,000 gpm with drawdown of 14Ji ft.]

Material Thickness (feet)

Depth
(feet)

Alluvial deposits:
Soil. - .- .- . .._ ...._. .-... .- .- Sand....-___-.-.-_........___..................__--.--_._--.-_---_ Sandy silt, brownish gray to gray, with fine sand; grains granitic, subangular
to rounded, with some mica and very little clay material.__._._...... Gaspur water-bearing zone:
Gravel and sand, gray; fine to coarse quartzose sand, angular to subangular; cobbles to 6 inches in diameter. Greenish-gray silt and fine sand at 120
feet. Lower portion fossiliferous, with pelecypod fragments. Eighty to
90 percent of the pebbles are granitic; remainder chlorite schists, argiUites
and phyllites._____._________________._._ . ... Unnamed upper Pleistocene deposits:
Sandy silt, greenish gray, sand portion very fine to medium, angular to suban-gular; pebbles to one-half inch in diameter at 160 feet, chiefly granitic; musco-
vite and blotite abundant. A few small chalky concretions, pellets at 170
and 180 feet; limonitic stains present. Pelecypod fragments present at 170
feet. At 190 feet, ferromagnesian minerals largely altered to epidote. Quartz
and feldspar, 75 percent; dark minerals, 25 percent----------------- - ... Medium sand, olive gray, angular to subangular; largely granitic; garnet more abundant than in shallower samples..______.__._-_-... --... Silty sand, greenish gray, medium-grained, angular to subangular, and granitic; chlorite and garnet with biotite and other ferro-magnesian minerals present among darker grains; some gravel present__._-... .. . . ..---.. Medium sand, gray, angular to subangular, granitic; clean and well sorted . Sandy silt, olive green to gray, angular to subangular sand grains; with musco-vite and biotite, some garnet and chlorite; some pelecypod fragments.. - Silty sand, gray....__..____________.____...____..__ Sandy silt and silty sand, grayish green to gray, micaceous, granitic; sand grains in lower portion are very well sorted, subrounded to subangular, and consist of about 75 percent quartz; other minerals include feldspars, micas, epidote(?), garnet (?), chlorite, and ferromagnesian minerals ...... Sand, gray, buff, with a small amount of silt--.--_ - - -- - Sand, gray buff, and gravel, moderately clean, poorly sorted; smaller grains angular, larger ones subangular; pebbles to 1 inch in diameter, largely of vein rocks and dark igneous rocks...._....___------------___........... Sand and gravel, gray; sand, fine and fairly well sorted; gravel predominant to upper portion with pebbles to 1 inch in diameter, consists of basic and acidic
igneous rocks and vein rocks___--..-____~ . -
San Pedro formation:
Silty sand, gray; micaceous and predominantly silty in upper part, more sandy
in lower portion. Sand grains angular to subangular, fairly well sorted in lower portion, and granitic. Gastropod and pelecypod fragments present-.
Silt and silty sand, gray, micaceous; silt in upper portion; pelecypod fragments
in lower sandy portion-..__.________..._--___.-------..-.-. Sand, gray, coarse, very clean, fairly well sorted, angular to subangular, granitic; larger grains of metamorphic rocks in part. Epidote, garnet, magnetite or ilmenite, ferromagnesian minerals and pyrite are common among the heavy minerals. Pelecypod fragments present but rare....-..---_- .- ... Sand and gravel to three-fourths inch in diameter; pebbles consist of worn fragments of vein quartz, gneiss, granite, and chlorite schist .. .... Fine to coarse sand, gray, poorly to well sorted, silty in lower few feet, angular to subangular; arkosic (feldspars 50 percent, estimated); more abundant biotite associated with silty portion_.._-___ - - - - Silt, gray, with silty sand in lower portion; pelecypod fragments, and numerous Foraminifera.---

Fine to medium sand, gray, angular to subangular, poorly sorted; granitic, about 65 percent quartz, 25 percent feldspar, 10 percent other minerals; some silt present, and pelecypod fragments____ - ___.
Silty sand, gray, medium to coarse, with abundant pelecypod fragments. _.... Medium to coarse sand, gray, clean, fairly well sorted, angular to subangular, granitic; some silt present, and pelecypod fragments-
Sandy silt, and clay, gray buff______.....__...

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85

142

190

215

235
248

307
311

340
350

371

415

455

485

505

515

615

645

675
710

735
744

WELL EECOEDS 383

TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

4/13-15A11. Dominguez Water Corporation well 16 Continued

Material Thickness

(feet)

Depth
(feet)

Silverado water-bearing zone:
Gravel and sand, subangular to rounded, granitic; pecten fragments; pebbles to three-fourths inch in diameter; material grades fairly evenly, from pebbles
to fine sand.. _ . .. _.._________.__ _____.. Sand and gravel to 1 inch in diameter, angular to subrounded; about 30 percent feldspar, 55 percent quartz, 15 percent other minerals____________. Gravel and sand; pebbles to 1 inch in diameter__________-__.... . Gravel to 2 inches in diameter; sand nearly absent; sand up to about 10 percent in lower part_______________________________-__. Sand and gravel, slightly buff-gray in upper portion to clean gray in lower por-tion. Composition of sand averages 75-80 percent feldspars, 20-25 percent quartz, with smaller amounts of other minerals, including micas (muscovite and biotite), chlorite, epidote, garnet, pyroxenes, amphiboles, and magnetite or ilmenite.

From 15 samples, taken at 10-foot intervals from 000 to 1,040 feet, 78 pebbles were selected at random, ranging from H to 1 inch in diameter. The rock types present among these pebbles were tentatively determined as follows: Granitic rocks (including granite, granodiorite, and other rocks) . 51 Granite gneiss.. . .... . 8 Pegmatitic vein rocks and vein quartz__... . . . 9 Gabbroie rocks. _ . , . 6 Biotite and chlorite schists__________.____._ .. .. 2 Extrusive(?) igneous rocks_.._________ . . . 1 Chert(?).. .._..-... ... _ ..-..-_..- 1

20

804

824
871

891

163 1,054

4/13-23G2. City of Lone Beach, Silverado well.

In Dominguez Gap, altitude 23 ft. Driller's record, with modifications based on description of samples by J. C. Kimble of California Division of Water Resources, and by W. W. Paulsen of Geological Survey. Casing perforated at 615-900 ft. Well not used]

Alluvial deposits:
Soil and sand __.___________..._.........
Clay ..... __.___________________

Sand.__._________________________ Clay......... ... . _ . _..

Gaspur water-bearing zone:
Gravel__.__________________________ Unnamed upper Pleistocene deposits:
Clay, yellow______________________ . . Clay... Gravel and coarse sand, loose.________________ San Pedro formation:

Silty clay, gray. ____________.____.__,

fine sand___________________________, Clay, hard, blue..__ ___________________.

Fine gravel, "dirty". __.________________. Clay . ... . _._
Fine sand.___._ ___________________. Sandy clay . __. ________________. Clay.. Sand with some gravel___________________. Clay... ......-...-............... .- ...-.. Silverado water-bearing zone:
Gravel, clean and loose, with a few streaks of coarse sand_. Gravel, "muddy"__________________,____. Gravel, clean and loose___._________.______. Coarse sand, gray . _ _________. Fine gravel.__._______________________. Coarse sand__________________________. Fine gravel and sand_____________________. Coarse sand, arkosic, unweathered, loose, and well-rounded. Sand, cemented- ____________________ _.

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10

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96
42

50
60
10
6
4
22
34
96
14
20

124
10
170
50
8
40
34
34

20
65
68
78

122

142
238
280

330
390
400
406
410
432
466
562
576

720
730
900
950
958
998
1,032
1,066
1,074

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TABLE 28. Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

4/14-8D1. California Water Service Co.

[About 1 mile east of Eedondo Beach, altitude 146 ft. Driller's record, with modifications based on descrip-tion of samples by F. B. Kelsey of California Division of Water Resources. Casing perforated at 198-206 248-272,384-396, and 490-540 ft. Yield about 344 gpm; drawdown not known]

Material Thickness (feet)

Depth
(feet)

Dune and beach sand:

Sandy soil, reddish brown_._________________________. Sandy soil, light brown, and clay...._______.__._________ ..-_. Sand, granitic, light reddish brown; considerably weathered, feldspar decom-posed and kaolinized, apparently beach sand________________. Fine sand, light brown, unweathered, and containing pelecypod fragments; apparently beach sand____________________________. Fine to medium sand, light gray, with a few pebbles of granitic and dark-grained igneous rocks; pebbles moderately well-rounded and about 1)^ inches
in maximum diameter......._________________________. San Pedro formation:
Silverado water-bearing zone, 138-556 feet:
Sand, gravel and shells.. __________._____________.
Fine to medium sand, dark gray, with shell fragments...... ._ .....
Sand and gravel, dark gray, granitic; size-ranges from fine sand to pebbles
up to 1 inch, in diameter; pebbles consist of granitic and dark-grained igneous rocks; also pebbles of cherty shale. ___.___.__ __. Silt, irregularly colored yellow and blue, fine to coarse sand, gray, granitic; fragments angular and unweathered; contains a few pebbles of granitic rocks subangular, ranging in size to 2 inches in diameter......_ _. Sand and gravel, gray, granitic; gravel about 50 percent by volume and as much as 3 to 4 inches in diameter_____________________; Coarse sand, gray, granitic, with a few small subangular pebbles up to one-half inch in diameter..________________________. Coarse sand, gray, granitic, with pebbles up to 2H inches in diameter..... Silt, gray, irregular, banded, mottled light and dark. __ _ ... Sand and gravel, gray, granitic, ranging from fine sand to coarse gravel with pebbles to 6 inches in diameter; gravel 50 percent by volume._...__. Silverado water-bearing zone, 138-556 feet Continued:
Medium sand, gray, granitic, fragments angular__ . Fine sand, dark gray, containing gastropods and pelecypods, principally small forms . ________________.. __ _. Silt, bluish gray, micaceous, with locally irregular bodies of very fine light gray sand.________________________________. Sand and gravel, gray, principally granitic; sand fine to coarse with angular fragments; gravel moderately well rounded with pebbles as much as 2J6 inches in diameter_."."___________________.____.._. Fine to coarse sand, gray, granitic, with angular fragments, and a few pebbles less than 1 inch in diameter_ _________________.

Fine to medium sand, gray, with some coarse material up to one-eighth inch In diameter.. . .. _.___________.___.. ..,

162

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4
9

30

84

138

154
170

178

198

206

228
238
248

272

320

338

384

394

556

564

WELL RECORDS 385

TABLE 28.~Materials penetrated by typical water wells in the coastal zone of the Torrance-Santa Monica area Continued

4/14-13F1. David E. Crutcher. Formerly City of Los Angeles, Torrance plant, well 1

[About 1 mile southeast of Torrance, altitude 49 feet. Casing perforated at 246-260,348-36$ and 647-670 ft. Yield on test 1,660 gpm with drawdown of 66 ft]

Material Thickness Depth
(feet)

Deposits of upper Pleistocene age, undivided:
Soil... . -. .
Clay, yellow___-___________. Sandy clay, yellow, and shells____ . Sand and shells___ _________
Clay, yellow__ - _______ . "200-foot sand":
Sand and shells__.___________. Fine sand._______-.____. Cemented sand_- --______..-. Cemented shells, sand and gravel____. Fine sand.._____________. Coarse sand.__.- _...____ . Clay, blue_______.__.____... Fine sand, blue____________ __. San Pedro formation:

Clay, blue______________... Silverado water-bearing zone:
Medium gravel_-------__..__--. . Fine sand_____ ____-_. Coarse sand.__________-_... Coarse sand, fine gravel...-_--._.--. . Coarse sand__..__.-.___..._.... Cemented sand______ ____. ___. Packed sand, blue_____________. Clay, hard, blue_ ___ . Fine sand _________________. Silty sand__...._. . ....._ . Sand, some fine gravel__ ________. Coarse gravel___... ______.... Unclassified:

Silty sand ... .

4
1
4
6
9
18
33

90

12
12
76
21
27
1
111
62
24
39
27
21

42

2
44
47
69
74

84
85
89
95
104
122
165

245

257
269
345

394
505
657
581
620
647

710

4/14-28J1. Weston Ranch, well 6

[About 3 miles southwest of Torrance, altitude 165 ft. Casing perforated at 290-306, 410-415, 424-446, and 470-600 ft]

Deposits of upper Pleistocene age, undivided:
Soil _ .-
Coarse gravel___ __.___ .
Coarse gravel and clay..________...
Coarse gravel__-_________-.-. Clay, brown________________. Unclassifled:
Sand...-_____.________... Clay, blue_________________. San Pedro formation:
Silverado water-bearing zone:
Sand....__-------__.-_.__... Gravel..___ _.- .... . Sand..-_-----_...._____...... Gravel....__-_________... Sand._.__.--.---..--.____... Gravel.._______________. Sand__________..--_._._. Fine gravel_ __...____...

10
25
10
9
92

123

12
16
104
5
9
21
25
30

10
36
45
54
146

269
278

290
306
410
415
424
445
470
500

386 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 29. Field analyses of waters from wells in the coastal zone of the Torrance-Santa Monica area, 1943-46

[Analyses by TT. S. Geological Survey]

Well

2/13-31K1 ...
32F3--.
32N1
32N2 ...
2/14- 3K1
4N1 » .. .
5D5 ......
5D6...
5D7. .....
5D10..
7M ......
7P1 ...
8C1 1.....

18F2 ......
18Q1...-.
19C1 ......
19K1 .
22N2 ...

22N3 ...
22N4 ...

22N5 ...
22F2...

27D2 ..

27D3..

27J1- .....

28E1.. .

28F1. __

28L1......

28M1.. ....

32E1 ......

32F1 ......

32F2 ......

34C1
2A5- 1C1 _ ...
1C5 _ ...
2E1 _ ..
2F2- _
9L1......
11O1......
11C2-
11C3-.
11C6-
11O6......

11C7...... lies.. .
11D1......

11D2-
11E3- _ ..

11E5 ....

11F2- .

Date

Jan. 10,1945
Jan. 13,1945
Jan. 23,1945
Jan. 13,1945
June 8, 1945
Dec. 10,1945
June 14,1945
do .
. . do..
. . do ..-
Dec. 10,1945

Apr. 17,1915

Dec. 10,1945
July 8, 1944
Nov. 7,1944
June 29,1944
July 1944
Nov. 3,1944
July 1944
July 1944
Nov. 3,19443
Apr. 27,1945
Nov. 8,1945
July 1944
July 1944
Nov. 3,19442
Apr. 24,1945
July 1944
Nov. 3,1944*
Apr. 23,1945
July 1944
Nov. 3,1944
May 23,1945
Nov. 8,1945
July 1944
Nov. 6,1944
July 1944
Nov. 6,1944
July 1944
Nov. 6,1944
July 1944
Nov. 6,1944
Apr. 27,1944
Nov. 7,1944
July 1944
Nov. 3,1944
July 1944
Nov. 3,1944
June 29,1944
June 14,1945
. _ do.. _ ..

June 16,1945
_ .do.. _ ..
June 30,1945
July 1, 1945
July 2, 1945
July 4, 1945
June 28,1945
June 28,1945
June 29,1945
June 19,1945
July 3, 1945
June 28,1945
June 19,1945
June 28,1945
June 19,1945
June 28,1945
June 15.1945

Chloride

ion (Cl)
(parts per
million)

28
23

39
46
27
78
49
163
83
70
332
346
68
211
123
97
135
36
26
35
56
30
31
25
33
25
25
25
161
161
156
122
121
24
23
93
85
93
112
108
44
92
119
86
83
89
89
102
101
26
46
61
53
55
147
49
70
81
43
51
56
70
52
53
46
48
47
46
46
84

Soap
hardness
as

CaCOs

(parts per
million)

160
150
14ft
mn

260
230

165
230
280
295
425
440
220
425
315
235
275
205
160
200
255
145
165
190
210
180
145
195
515
315
320
450
275
120
150
375
330
325
245
340
195
290
305
230
280
250
215
250
215

225
260
270
285
225
340
375
425
290
325
365
390
340
415
440
270
375
315
425
345

Specific
conduct-

ance (mi-
cromhos

at 25°C)

572
544
559
654
856
666
Qft3
640
i ion

1,150
804
2,060
1,730
802
1,630
1,100
1,020
1,070
649
670
645
791
584
587
516
632
572
559
577
1,430
1,390
1,070
1,190
1,200
493
443
1,110
1,050
1,010
893
1,230
659
990
1,000
927
890
875
872
895
872

516 sdn
824
873
847

1,050
862
1,060
1,090
896
884
934
1,060
1,000
1,030
1,100
960
984
1,020
1,050
969

Tem-
pera-
ture

Remarks

iHto.

IJ^hr.
IJ^hr.

2>ihr.

IJ^hr.
24 hr.
24 hr.

IJ^hr.

Ihr.
IJ^hr.

24 hr.
2}^hr.
24 hr.

24 hr.

24 hr.

24 hr.

3H hr.
5^hr.
14 hr.
8hr.
12 hr.
12 hr.
10J* hr.

7hr.
6hr.

10 hr.

See footnotes at end of table.

WELL RECORDS 387

TABLE 29. Field analyses of waters from wells in the coastal zone of the Torrance-Santa Monica area, 1948-46 Continued

Well

2/15-11F3.. .

11J2-. _ ..
11J3._ ..
12B1- _.
13A1- -
13J2 _
13J3 .
13K1_ __
13K2-. ..
13M1......
14C1-. ...
14M1_ .
14P1. .....
15A4 _ ...
22B2
22B3. .....
22B5-- ....
22C1......
22F1 ......
22F2-. ....
22J1
22H __ ..
23A1- _.
23A2- ...
23C1......
23H1......
23J2. _ ...
23N1......
23P2- .....
24D1......
24E2- -
34A1- ....

34K1......

3/13- 5F1.. ....
6F2...
9F2 _ ...
9F3 ......
9G1_ ..
9N1 _ ...
16J1 __ ...
16M2-
16N1 ......
16R1. . .
17F1
17R1
17R2. .....
19A1. _ ..
19A3. ._
19A5 __
19B1 ......
19D2 ...
19J3 ... .
19K1......
19Q1.. .
19Q2. .-
20A2. .....
20B2 ......
20H3. _ -
20J3- ......
20L3 ...
20L4-..
20L5
20N1 ......

Date

June 19,1945
June 28,1945
June 14,1945
June 14,1945
Sept. 5,1945
July 7, 1944
Sept. 5,1945

. -...do --

May 11,1945

June 15,1945
Apr. 26,1945
May 3,1945
June 14,1945
Apr. 16,19451
.do» ... .
A^r. 17,1945

Apr. 16,1945
..... do.. ...
Apr. 17,19451
Apr. 28,1945
Apr. 16,1945

....do.i... ...
.... -do.i- . .
May 4, 1945
Apr. 16,19451
Apr. 28,1945
Apr. 16,1945
__ do.....
July 5, 1944
Aug. 25,1944
Nov. 2,1944
Apr. 13,1945
July 20,1945
Oct. 30,1945
Aug. 25,1944
Nov. 2,19442
Apr. 13,1945
July 20,1945
Oct. 30,1945

.... . do. ..
Jan. 6, 1945
- do . .
. . do.. ...

Dec. 29,1944
Dec. 28,1944
Dec. 27,1944
Dec. 28,1944
. do.. ...
Apr. 4, 1944

-....do ...
do .....
Apr. 4, 1944
June 15,1944
June 16,1944
..... do .....
... . . do .....
Dec. 3, 1943

Apr. 4, 1944

.do... .....
do
Apr. 4, 1944
June 17,1944
Apr. 4. 1944

Chloride

ion (Cl)
(parts per
million)

82
80
147
101
90
312
626
261
115
447
204
85
108
110
85
223
202
206
369
807
521
1,640
340
324
323
340
302
358
452
266
286
235
116
119
119
125
127
133
SQ
89
91
97
102
32
30
73
61
108
21
37
28
29
25
22
30
25
107
55
79
129
121
27
180
124
68
26
26
25
24
22
24
23
93

Soap
hardness
as

CaCOs

(parts per
million)

340
415
350
250
365
480
1,050
440
340
525
665
240
315
400
325
700
625
600
975
1,250
1,100
2,300
875
340
340
565
725
500
625
565
340
775
290
295
220
215
245
275
130
130
155
150
195
170
170
190
400
440
160
215
155
165
155
130
135
155
200
175
180
180
240
150
475
250
210
175
155
165
165
150
130
150
200

Specific
conduct-

ance (mi-
cromhos

at 25° C)

1,060
1,070
1,240
1,060
1,130
1,850
4,200
1,940
1,220
3,020
1,930
1,050
1,300
1,310
1,090
3,230
2,370
2,770
3,290
4,240
3,400
6,310
2,870
1,960
1,820
2,410
2,640
2,570
3,230
2,100
1,670
2,350
941
992
923
948
987
990
709
696
709
744
779
612
615
756
1,200
1,260
U7

706
609
598
559
545
536
565
804
610
676
647
856
575
1,850
1,100
725
600
571
581
555
545
539
544
930

Tem-
pera-
ture

72

70

Remarks

10 hr.

15 rain.
2hr.

SOmin.
SOmin.
14 min.

Sulflde odor.

See footnotes at end of table.

388 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 29. Field analyses of waters from wells in the coastal zone of the Torrance-Santa Monica area, 1943-46 Continued

Well

3/13-20P2.. ....
20P3 _ ...
21C1.. .
21C2.. ....
21C3-. ....
21C4. .....
21E1......
21F2. .....
21G2.. ....
21N1 ......
21P1-
22Q1......
26J1
26L1......
26M1... ...
26Q1 ......
26E1......
28B1 ......
28C3-. _ .
28D1......
28D2 ......
28E1.. ....
28E2......
28G1 ...
98O9

28G3 ...
28L1 _ ...
29A3-. ....
29B1 ......
29B2 ......
29B3.
9QT14.
29C1 ......
29C2 __ ..
29E1......
29E2. .....
29E3
29E4..

29E6. _ ..
29E7. _ ..
29E8 __ ..
90P1

29F2..

29F4-
OQT?K

29F6. _ ..
2901......
29O3 ___ .
9QXT1
29N2......
30A2......
30O1......
30F2 __ ..
30Q4......
30H1......
30H2......
30J1 -
30J2.......
3013
30J4
30J5
30K1 _
30K2...
30L2...
30L3-.
30L4-...--
SOLS......
OAT C

30M2
30M3
30N1

Date

June 17,1944
Apr. 4, 1944
Apr. 5, 1944

Apr. 6, 1944
Apr. 5, 1944
June 21,1944
Anr K 1Q44

Dec. 8, 1943
Apr. 6, 1944
Apr. 4, 1944
Dec. 21,1944
do
Apr. 3, 1944
Dec. 21,1944
do.
Dec. 8, 1943

do .....
.... -do... .....
do
..... do .....
.. do.... -
_ .do .....
.... . do.....
. do
Dec. 9, 1943
Dec. 8, 1943
Dec. 4, 1943
Dec. 9,1943
Dec. 4, 1943

..... do...
Dec. 3, 1943
Dec. 4, 1943

.... . do...
do
Dec. 3 1943
. do.
Dec. 4, 1943
.. do
do.
.....do .....

do... Dec. 3, 1943
Dec. 4, 1943

Dec. 2, 1943
do
... .. do ...

. . do - Dec. 3, 1943

. ..do. ....
do...
... .. do.. ...
.... .do. .
do .
do ..
.....do -
..... do ......
TiAf* 9 1Q4S

. -do ..
Dec. 3, 1943
Dec 2 1943
..do. ....
. do -
Dec. 3, 1943

Chloride

ion (Cl)
(parts per
million)

sn

111
24
26
t)K

24
23
21
40
21
OQ

22
35
OQ

26
35
on

9d.

368
23
Oft

Af)
21
OQ
OQ

44
24
26
97

54
70
44
83

39

200
133
OAO

QQ
171
136
74
1QS
160
134
170
183
122
Af)

24
40
f)K

66
100

215
109
25
144
185
400
127
QJ.
77
53
88
9dA

263
QO
951

83
35

Soap
hardness
as

CaCOs

(parts per
million)

330
165
145
150
130
150

370
130
120
115

195 IQS;
140
155
50
140

675
120
190
200
120
190
150
190
140
160
160
175
150
140
180
185
140
275
300
200
325
230
275
295
175
300
245
170
255
260
195
140
135
95
100
175
250
440
K1 K

270
110
250
350
600
250
200
205
185
245
325
440
OKA

475
310
130

Specific
conduct-

ance (mi-
cromnos

at 25°C)

648
851
583
604
594
575
571
1,030
1 380
507
557
502
685
cco

564
635

471
2,040

599
674
409
557
496
658
545
557
851
911
855
841
989
1,030
900
1,190
1,500
1,160
1,420
1,180
1,520
1,530
1,260
1,300
1 340
1*270
1,490
1,690
1,430
776
548
458
413
723
930
1,520
1.760
,878
471
972
1,320
2,180
931
808
774
681
1,010
1,390
1,830
771
2,090
995
625

Tem-
pera-
ture

69

Remarks

See footnotes at end of table.

WELL RECORDS 389

TABLE 29. Field analyses of waters from wells in the coastal zone of the Torrance-Santa Monica area, 194S-46 Continued

Well

3/13-30Q1
30Q2- .
30Q3
30Q4
30Q5..
30R2..
3/14-1 B2.

2F1...
3A1._ .
3J1-. ...

8D2 ...

8G1
8G2
8N1

8N2 .
9E1.___._
9N1
9N2

9N3. ..

9N4 -

10A1- . -

10C1
1001 ...

11D1
11G2.
11J1
12B1... _
12Q2.. .
13B1
13F1.. ....
13M1......
13P1...
13Q1...
13Q2- --
14A1......
14M1......
15B1 ......
17M1

18A1
18N4. .....
19A1 _ .
19C1

20J2. _ ...
20P1... ...
21R1_ ..
22C1-. __
22R1_
22R2 ...

23Q1 ...
23R2 ...
24A1 ......
24A2 ___
24B1. .....
2401... ...
24K1 ......

Date

. .do .... .
..do.... .
Dec. 2, 1943
Dec. 3, 1943
.do...
... ..do..... ...
Jan. 23,1945

June 21,1944
June 27,1944
.do...
Nov. 7,1944
Apr. 27,1944
Nov. 7,1944
Nov. 8,19452
Apr. 27,1944

Apr. 25,1944

do
May 24, 1944
June 27,1944
.... .do. .
Nov. 7,1944
Apr. 14,19451
June 27, 1944
Nov. 7,1944
Nov. 9,1945
June 24,1944
Nov. 9,1945
May 24, 1944
Aug. 25, 1944
Nov. 8,1944
July 1944

Nov. 6,1944
May 24, 1944
do
Nov. 9,1945
Oct. 10,1945
Jan. 23,1945
Jan. 24,1945
July 17,1944
__ do ....
..... do...
Nov. 15, 1943
do .
June 21,1944
May 25, 1944

do - July 6, 1944

Nov. 8,1944
May 25, 1944
Oct. 13,1943
Oct. 9, 1943
Oct. 13,1943
Aug. 11,1944
Oct. 24,1944
Oct. 30,1945
Oct. 9, 1943
..... do .
Oct. 18,1943
__ do ....
... .. do .....
do... ..
Nov. 8,1944
Oct. 14,1943
Oct. 15,1943
Nov. 15,1943
do
do ...
Feb. , 1944
Nov. 15.1943

Chloride

ion (Cl)
(parts per
million)

335
275
309
417
211
23
24

40
36
156
234
133
123
134
188
217
202
150
221
28
33
30
29
29
138
48
38
31
31
41
42
31
43

39
75
26
35
33
24
24
34
145
121
322
410
31
33
32
145
148
107
132
91
123
116
118
109
35
44
32
33
36
155
159
434
59
147
255
76
353
268

Soap
hardness
as

CaCOa

(parts per
million)

500

525
690
400
145
160

160
125
300
260
225
210
280
240
280
275
240
275
125
145
135
115
90
275
135
160
130
160
140
155
115
180

215
160
120
245
195
130
100
170
150
225
640
690
160
150
110
265
230
205
160
150
160
195
190
220
130
135
135
155
130
250
240
405
185
230
, 410
190
390
280

Specific
conduct-

ance (mi-
cromhos

at 25°C)

1,910
1,750
2,110
2,450
1,570
536
496

588
586
882
871
889
869
813
1,070
1,130
1,240
1,120
1,470
479
648

547
542
866
614
535

488
553
560
486
580

550
636
461
606
591
467
465
572
660
706
2,360
2,480
590
584
528
862
880
775
757
639
728
759
738
745
585
578
532
545
523
922
931
2,020
645
945
i onn
732
2,070
1.630

Tem-
pera-
ture

72

72
72
72

Remarks

10 min.

3min.

Sulfide odor.

30 min.
13 min.

1 min.

5 min.

See footnotes at end of table.

460508 5S

390 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 29. Field analyses of waters from wells in the coastal zone of the Torrance-Santa Monica area, 1943-46 Continued

Well

3/14-24K3. ..
24K6
24Q1
25E4_ .
25J1
25K3- ..

25L3__ .
25N2
25N3. _ ..
25N4
25P1._ _ .
25P2 _ ...
26A2 _
26B1
26B5 ___ .
26C1 _ ...
26C4
26E2. __ .
26E3 ___
26F1..
26Q1
26Q2 ___
26J1 ____
26K1.- -
26L1.. .....

26L3. .....
26M2.
26N1 _ ...
26P1..-
26P2.
26Q2
26Q3_
26Q5. -
26R1 ......

26R2. .....
26R3 __ .
27J1. _ ...
27J2. ___ .
27J3- ___
27K1 ___ .

27K2
27K3 ......

27K4.
27K5-. _ .
27L1..
27L2 ......
27M3 ...
27N1 __ ..
27N3 _ ...
27N4......
27N5..
27P2. .....
27P3 -
27P4. .....
27P5-

27P6 ___ .
27Q1 ___ .
27Q4. .....

Date

. --.-..1943
Nov. 15, 1943
Nov. 16,1943
Nov. 18,1943
Nov. 16,1943

.do...
Nov. 18, 1943
__ do ....
... ..do
Nov. 19, 1943
Nov. 16,1943
Nov. 18,1943
Nov. 17,1943
Oct. 14,1943
Nov. 18, 1943
Oct. 14,1943
Nov. 18,1943
Nov. 16, 1943
Nov. 17, 1943
Nov. 5, 1943

Nov. 17,1943"
Oct. 29,19431
Nov. 17,1943
Nov. 5,1943
Nov. 19,1943
. do
Nov. 5,1943
Nov. 4,1943
Nov. 19,1943
. . do. .
Nov. 4,1943
. do
Nov. 16,1943
Nov. 19, 1943
Nov. 2,19442
Apr. 14,1945
Nov. 9,1945
Nov. 19, 1943
do. ....
Nov. 4, 1943
Nov. 5,1943
. do
Nov. 4,1943
Nov. 15, 1944
Apr. 14,1945
Nov. 9,1945
Nov. 5, 1943
__ do ._ ,
Nov. 2,1944
Apr. 14,1945
Nov. 5, 1943
do.......
-...do .....
Nov. 17, 1943
__ .do ....
..... do... .
. do........
__ do.... _ .
.... .do..... ...
Nov. 5,1943
Nov. 6,1943
Nov. 17,1943
do
Nov. 8,1944
Apr. 14,1945
Nov. 9,1945
Nov. 17,1943
Nov. 5,1943
.....do........

Chloride

ion (Cl)
(parts per
million)

354
224
K7J.

251
50
216
51
235
263
22
25
57
280
489
685
518
1,130
265
82
146
1,020
36
2,380
50
32
31
127
127
1QQ

36
97

29
25

30
1,560
1,010
1,030
1,270
24
23
76
77
188
105
110
138
123
189
89
94
97
97
66
131
78
64
129
44
64
120
55
47
52
103
83
80
130
774
139
1.120

Soap
hardness
as

CaCOs

(parts per
million)

480

CftA

245
120
360
ion

260
300
145
160
165
275

390 77";
450
1,150
340
180
300
950
130
1 QP»A
165

150

195 IQK
240
160
130

185
190
idn
I

RflA

725
1,050
1,800
155
140
240
170
245
185
245
220
290
97ft

180
190
250

ion
ion
230
230

150
240
OAA

160
150
210
280
195
180
260
150

800

Specific
conduct-

ance (mi-
cromhos
at 25°C)

2,200
1,750
2 9sn
1,430
799

1,900
631
1,660
1,230
528

654
1,600
2,300
2,670
2,630
4,070
1,250
722
900
3,890
nv>

7,630
587
518
546
815
SI %

1,290
549
498
499
506
803
506
A QAA

3,210
3,270
3,640
USl
521
716
694
996
790
838
854
761
1,030
743
750
747
765
686
874
723
678
978
621
688
863
653
627
641
807
722
705
690
2,920
836
3.750

Tem-
pera-
ture

Remarks

Sulflde odor.

Do.
Do.

Do.

Do.
Do.

See footnotes at end of table.

WELL RECORDS 391

TABLE 29. Field analyses of waters from wells in the coastal zone of the Torrance* Santa Monica area, 1948-46 Continued

Well

3/14-29D3 ......
29G1......

29M1- ..

29N1- ....

30D1 ......

30H1-. ....

30M1... _

31A1 ......

31 A3 ......

31A4 ......

31E1 ......

82A.1......

32H1 ......
32H2 ......
32J1. ......
32R1......
33A2. .....
33A3 ......
33B1 ......
33E1 __
33E2 ......
33Q1......
33H4......
33H5 __ ..
33J1. __ ..
33J2-... ...

33K1 .
33L1 __ ..
33L4 _ ...
33P1-
33P2 __ ..
33Q1.. ,
34A1......
34B2- ._
34C1 .
34D1. _ ..
34D2 .
34D3-.....
34F2 ......
34F3 _ ...
34G1.. .
34J1-
34K2......
34L1 ...
34M1 _
34N1 __.
34N2- _

Date

1945 ....
May 29,1944
Aug. 14,1944
May 29,1944
Aug. 14,1944
May 29, 1944
Aug. 15,1944
Aug. 7,1944
Aug. 15,1944
Oct. 24,1944
Apr. 13,1945
Oct. 8, 1943
Oct. 15,1943
Aug. 15,1944
Oct. 24,1944
Apr. 13,1945
Oct. 30,1945
Oct. 22,1943
Nov. 16, 1943
Aug. 14,1944
Oct. 24,19442
Apr. 17,1945
May 29, 1944
Aug. 14,1944
May 29,1944
Aug. 14,1944
Nov. 9,1945
May 29, 1944
Aug. 14,1944
Nov. 9,1945
May 18,1944
Sept. 4,1944
Oct. 24,19442
Apr. 13,1945
July 20,1945
May 29, 1944
Aug. 14,1944
Nov. 15, 1944
Oct. 22,1943
Nov. 13,1943
Oct. 19,1943
.....do. ....
Oct. 20,1943
. . do........
.... do .....
Oct. 19,1943
.. do........
Oct. 21,1943
Oct. 20,1943
Oct. 21,1943
Oct. 20,1943
Oct. 20,1943
Oct. 9, 1945
Oct. 19,1943
.... do .
....do........
. do
Nov. 4,1943
Oct. 19,1943
Oct. 22,1943

Oct. 29,1943
Oct. 22,1943

. do -
Nov. 3,1943
do
Oct. 29,1943
- do
Nov. 3,1943
- -.do.
-..do __
do.
do

Chloride

ion (Cl)
(parts pe
million)

45
60
57
73
71
68
62
156
160
229
351
81
74
74
78
76
75
200
330
206
175
265
57
56
50
48
59
50
48
46
56
63
68
53
51
83
60
60
53
90
59
104
125
50
44
46
51
91
53
43
48
31
30
30
47
36
74
28
41
39
39
28
105
49
55
94
53
30
113
25
65
51
113
82

Soap
hardness
as

CaCOs

(parts pe
million)

110
155
165
180
180
160
155

250
160
425
170
180
180
125
120
205
230
350
290
270
325
155
160
140
130
200
140
130
200
1OK

185
115
155
185
170
190
165
idn
80
125
125
350
170

175 idn
145
180
145
<K

130
130
145
125
125
140
120
130
130
140
130
120
215
165
150
180
160
130
220
120
200
170
210
210

Specific
conduct-

ance (mi cromhos
at 25°C)

1,070
FAi

642
673
670
659
636
QrtO

930
1,090
1,490

694
694
635
675
703
i ndn

1,790
1,070
957
1,250
648
647
620
617
643
620
617
611
587
662
625
562
629
746
647
627
573
575
511
562
1 (\dft

Rd.fi
665
ceo

559
711
584
527
555
459
457
453
523
iRQ
608
475
492
523
525
450
849
631
572
698
564
483
893
451
630
571
822
741

Tem-

pera-
ture

72

72

7O

79

72

74

74

72

72

Remarks

5hr.
6hr.
5hr.
9 hr

2hr.
6hr.

8hr.

See footnotes at end of table.

392 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 29.^-Field analyses of waters from wells in the coastal zone of the Torrance-Santa Monica area, 1943-4® Continued

Well

3/14-35A1.
3SA2 _ ...
35B1......

35B3.. -
35B4..
35C1.. .
35H1.
35H2. ___

35K1

35L4...-.

35M3 .

35E1 i -
36D2......
36D3... ...

36G1...
36J2 ....
36J3
36K1 .
36L1 __ ..
36L2.. _ .
36M1.. .
36Q2 __ ..
36E1... ...
36E2... ...
3/15-1 HI......
12G1......

12G2.. ....

12L5......

12L6 ......

Date

Oct. 29,1943
Nov. 4,1943
Nov. 3,1943
Nov. 4,1943
.. do ....
Nov. 3, 1943

..do........
-_do__ ......

Nov. 3,1943

.. do........
_ .do ...

Nov. 20, 1943
Nov. 19,1943
do ...
do
Nov. 16, 1943

do _
do .....
Nov. 19, 1943
.. do .
do ...
Nov. 16, 1943

... .. do ...
July 6, 1944
Aug. 11,1944

Oct. 30,1945
Oct. 28,1943
Aug. 11,1944
Oct 24. 1944 8

Oct. 30,1945
Oct. 28,1943
Aug. 11,1944
Oct. 24,1944
Apr. 13,1945

Oct. 30,1945
A nr Q 1 Q4fl

Aug. 11,1944
Oct. 24,1944'

July 20,1945
Sept. 5,1945*

Oct. 30,19453*

Chloride

ion (Cl)
(parts per
million)

58
32
26
78
59
28
33
63
707

120
27
55
30
27
26
33
22
91

24
22
97
66
22
32
25
32
23
24
185
SB
85
84
100
179
189

163
1<M

128
146
147
161
195
282
194
406
507
355
738

886

i run

901

Soap
hardness
as

CaCOa

(parts per
million)

150

160
200
170
160

110
550

165
160
150
130
120
115
. 90
120
140
120
115
185
185
80
120
120
105
115
135
270
250
140
215

195
210
200
210
185
155
215
175
200
255

475
625
400
onn

1,450

Specific
conduct-

ance (ml-
cromhos

at 25°C)

595
504
528
692
588
504
485
566
2,500

728
516
538
537
448
442
440
507
513
469
464
793
724
400
484
469
469
398
546
1,020
984
793
798

954
1,010
910
924

775
866
826
870
1 1,020

1,840
2,100
1,570

: 3,190
3,220
3,210
3,260
3,260
3,320
3,300
3,300
3,290
3,270
3,260
3,260
, 3,260
! 4,150
, 3, 570
' ' 3,640
3. 610

Tem-
pera-
ture

71

70

70
70
71

71
71

70
70

Remarks

Time elapsed after pumping: 15 gal from well.

8hr.

8hr.

8hr.

2# hr.
2 hr.
15 min.
4hr.

0.
1 min.
3 min.
8 min.
18 min.
33 min.
1 hr 3 min.
1 hr 33 min.
2 hr 18 min.
2 hr 48 min.
3 hr 48 min.
4 hr 48 min.
5 hr 48 min.
0.
1 min.
3 min.
5 min.

See footnotes at end of table.

WELL RECORDS 393

TABLE 2Q.-^Field analyses of waters from wells in the coastal zone of the Torrance-Santa Monica area, 1943-46 Continued

Well

3/I5-12L6......

12L7......

13A2......

13A3......

13A4......
13H1......
13H2......

13J1 ....

13J2.......

13J3.......
13E2......

13R3......

13R4......

13R5 ...

13R6......

Date

Oct. 30, 1945 s<

Oct. 31,1945

Oct. 24,1944
Apr. 13,1945
July 20,1945
Oct. 30,1945
Apr. 9, 1946
Oct. 13,1943
Aug. 11,1944
Oct. 24,1944*
Oct. 13,1943
Aug. 11,1944
Oct. 24,1944
Apr. 13,1945
Oct. 30,1945
Oct. 13,1943

Aug. 11,1944
Oct. 24,1944
Apr. 13,1945
Oct. 30,1945
Oct. 13,1943
Aug. 11,1944
Oct. 24,1944

Aug. 11,1944
Oct. 24,1944
Apr. 13,1945
Oct. 30,1945
__ do ____
Oct. 13,1943
Aug. 11,1944
Oct. 24,1944
Apr. 13,1945
Oct. 30,1945
Oct. 13,1943
Aug. 11,1944
Oct. 24,1944
Apr. 13,1945
Oct. 30,1945
Oct. 13,1943
Aug. 11,1944
Oct. 24,1944
Apr. 13,1945
Oct. 30,1945
Aug. 11,1944
Oct. 24, 1944 1
Apr. 13,1945
Oct. 30,1945
Apr. 13,1945
Oct. 30,1945

Chloride
ion (Cl)
(parts per
million)

928
923
911
894
885

830
814
786
750
741

160
152
- 176
180
201
173
196
224
128
129
148
145
109
T7Q
68
66
137
67
68
110
130
151

76
80
51
93
107
80
68
70
83
99
138
133
140
141
143
74
77
79
86
98
62
61
61
68
62
66

Soap
hardness
as

CaCOs

(parts per
million)

-. ...

....

990
925

215
180
235

290
370
260
220
170
190
175
260
245
, 175
120
145
160
185
175

180

135
120
105
230
290

195
175
140
245
200
240

215
265
160
135
160
130
230
155

130
200
150
189

Specific
conduct-
ance (mi-
cromhos
at 25°C)

3,650
3,650
3,670
3,660
3,650
3,590
3,480
3,450
3,410
3,350
3,220
3,150
3,150
3,060
3 run

SO Q
86.1
99.6

1,060
1,050
1,180
1,220
923
936
903
933
868
1,050
737
. 740
- 688
725
665
808
900
944

772
730
727
775
886
722
713
677
729
819
QAO

844
834
834
855
718
740
732
722
748
720
697
705
682
660
650

Tem-

pera-
ture

70
70
70

70 """ro"

70
70

71
70

72

73
73
73

74

y 74
74
74
74

75

73

74
73
72
74
73
7<J
73
72
73
79

73
71
71
72
72
73

72
73
73
73

73
72
73

Remarks

lOmin.
20min.
SOmin.
Ihr.
2hr.
3 hr 4 min.
4hr.
5 hr 31 min.
6 hr 30 min.
9 hr 4 min.
13 hr 4 min.
22 hr.
26 hr.
30 hr.
37 hr.
Time elapsed after pumping:
2hr.
4hr.

3*ihr.

See footnotes at end of table.

394 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 29. Field analyses of waters from wells in the coastal zone of the Torrance-Santa Monica area, 1948-46 Continued

Well

3/15-24D1 ___

26A1......

25A2... ...

25A3 ......

25H1 .

Date

July 14,19443«

Oct. 8,1943

Aug. 7,1944

A iicr 1 K 1 Q44

Oct. 3,1944
..... do. ....
Oct. 24,1944 »
Jan. 19,1945
do
Feb. 1,19453

Oct. 8, 1943

Aug. 7,1944
.. do.... __
Aug. 16,1944
... .. do . .
Aug. 7, 1944

Jan. 16,19453

Jan. 16,19453

Apr. 13,1945

Oct. 31,1945
Oct. 8, 1943
Aug. 7, 1944

Aug. 15,1944

Oct. 27,1944
do...
... .. do.. -
. . do .
do.".
Jan. 2,19453

Chloride

ion (Cl)
(parts per
million)

418
418
385
379
370
366
147

337
335
334
324

319

588
549
520
515
499
524
598
594
632
555
635

620
605

550
123

448
398
388
370
301
311
343

341

342

340
397

513

521
496
427
440
490
478
471
472
468
403
501
500
491
478
470
449
454

Soap
hardness
as

CaCOs

(parts per
million)

410

850

750 fton
565
575
600
725
650
"~"*606*

730

700
660

610
160

550
475
490
475

350 4fln
360

360

360

350
440

ocn

675
650
475
CfiK

490
440
475
450

425
565
550

550
525
565
575

Specific
conduct-
ance (mi-
cromhos

at 25°C)

1,810
1,780
1,720
1,710
1,690
1,650
1,610
1,570
1,570
1,570
1,540
1,500
1,400

2,280
2,160
2,120
2,100
2,100
1,990
2,280
2,100
2,670
2,150
2,370
2,410
2,360
2,320
2,350
2 280
2,180
2,120
778

1,780
1,640
1,650
1,600
1,320
1,370
1,420
1,420
1,430
1,410
1,420
1 430
1,430
1,420
1,430

1,430
1,600

2,020
1,200
2,070
1,980
1,810

1,830
1

QAA

1,880

1,880
1,650

1,970
1,940
1,890
1,860
1,800
1.820

Tem-
pera-
ture

72

72

72
72

72
72

72
72
72

....

72
72

79

72
72

72
79

72

72

Remarks

1 hr 53 min.
2 hr 37 min.
4 hr 15 min.
5 hr 15 min.
6 hr 15 min.
7 hr 15 min.
13 hr 45 min.
21 hr 53 min.
23 hr 15 min.
26 hr 15 min.
39 hr.
47 hr 15 min.
Time elapsed after pumping since October'6:
5 min.
30 min.
5hr.
14 hr.
15 hr.
30 min.

0.
2 min.
4 min.
6 min.

10 min.
12 min.
27 min.
Ihr.
2hr.

Time elapsed after'pumping:
30 min.
5 min.

2hr.
5hr.

30 min.
0.
30 min.
40 min.

1 hr 25 min.

Time elapsed after pumping:
15 min.

5 min.

2hr.
5hr.
8hr.
10 hr.
12 hr.

Nearly 13 hr.

0.

53 min.

4 hr 31 min.
7 hr 31 min.

See footnotes at end of table.

WELL RECORDS 395

TABLE 29. Field analyses of waters from wells in the coastal zone of the Torrance-Santa Monica area, 1943-4& Continued

Well

3/15-25H1 ......

25H2...
4/14-5N2-. __ .

8C1 »._-.-

11F2. .....
16L2......

1601......

Date

Jan. 3, 1945

Oct. 8, 1943
May 29,1944
June 5, 1944
Aug. 14,1944

Sept. 18, 1944 » Dec. 4,19443

Apr. 13,19453
July 20,1945'

July 21,1945

Aug. 16,1944
Sept. 4,1944
Sept. 18, 1944
Oct. 9, 1944
Dec. 4, 1944
Apr. 13,1945
July 20,1945
Sept. 3,1945
Sept. 24, 1945

Oct. 22,1945
Nov. 12, 1945
Nov. 26, 1945
Nov. 19, 1943
Nov. 27, 1943
Nov. 2,1944
Apr. 13,1945
Apr. 14,1945
Nov. 8,1945
Nov. 27, 1943

Chloride

Ion (01)
(parts per
million)

454
458
455
457
456
110
762
780
987
1,070
1,530
1,600
1,560
1,540
1,520
1,520
1,500
1,500
1,490
1,480
1,480
1,470
1,730

1,870

1,820
85
87
87
85
85
88
95
93
91
92

35
69
64
116
73
70
63
63
71
95

Soap
hardness
as

CaCOs

(parts per
million)

525
525
525
525
525
165
775
1,150
1,250
1,550
1,700
1,650
1,600
1,700

1,650

1,600
2,000

2,060

1,800
140
140
145
140
140
145
170
175
185
180

105
170
160
150
95

105

135
125

Specific
conduct-
ance (mi-
cromnos

at 25°C)

1,830
1,820
1,830
1,830
1,810
781
2,800
2,880
3,480
3,720
4,720

5,010
5,080
4,890
4,850
4,840
4,790
4,760
4,740
4,760
4,720
5,490
5,930
6,480
6,330
6,330
6,370
6,230
6,230
6,200
6,140
6,140
6^120
6,080
6,050
6,030
6,080
6,140
5,960
5,960
5,940
5,960
5,960
5,920
5,870
5,910
5,870
5,820
655
658
654
660
637
647

685
676
RQfi

456
546
609
793

631
613
609
663
702

Tem-
pera-
ture

72
72
72

72

Remarks

8min.

16min.

5 min.
lOmin.

21 min.
27 min.

40 min.

Ihr.
15 min.
0.
30 min.
Ihr.

2hr.

3hr.
3 hr 30 min.
4hr.
4 hr 30 min.
5hr.

6hr.
7hr.
9hr.
10 hr.
11 hr.
12 hr.
13 hr.
14 hr.
15 hr.
16 hr.
23 hr.
23 hr 30 min.
24 hr 30 min.
25 hr.

Time elapsed after pumping:
5 min.
25 min.
5 min.

See footnotes at end of table.

396 GEOLOGY, HYDROLOGY, TORRANCE-SANTA MONICA AREA

TABLE 29. Field analyses of waters from wells in the coastal zone of the Torrance-Santa Monica area, 1943-46 Continued

Well

4/14-17G1. - .

17H1

17N1- .
20J1 ....
22D2 _ ...
22K.1 ...
2213......
23N2 ...
24C1.. -

24C2.. -
24E1 ...

24R2.. -
25C1 ...
25Q3 _
25J1 ... .
27L1 _ ...
27M1......

27M2...

28J3 ....
35D1 ...
35E1.. .
35E2..-.-

Date

Dec. 23,1943
Oct. 24,1944
A rvr 1^ 1Q4t

Apr. 14,1945 Aug 14. 1944

"\TrtT7 9 1Q44

Apr. 13,1945
Apr. 14,1945
"NTVrtT ft 1Q4,*t

May 29, 1944
Nov. 9,1944
Dec. 17,1943
Don 91 1Q4S

Dec. 14,1943
Dec. 17,1943
Nov 2 1944

Nov. 9,1944
Apr. 14,1945
Nov. 8,1945
Dec. 17,1943
Nov. 20, 1943
Nov. 2,1944
Apr. 13,1945

A nr 14 104f\

Nov. 8,1945
Ton R 1Q44

Jan. 10,1944
Tori f\ 1Q44.

Ton 1 1 Q44

Mar 1944

Nov. 9,1944
Anr 14 1Q4fi

Nov. 8,1945
Jan. 3, 1944
Nov 9 1944

Apr. 14,1945

"NTrtTT ft 104**

Sept. 9,1944
Oct. 27,1944
Jan. 10,1944

Oct. 27, 1944 »

Chloride

ion (Cl)
(parts per
million)

66
59
68
CO

4.Q

51
53
52
EQ

111 i^n
01

53
66
50
son
K1Q

501
RO4

146
24
24
35
Oft

24
OQ

235
66
23

110
107

108
on

91QI;
94

130
129
140

141

Soap
hardness
as

CaCOj
(parts per
million)

115

160 i Kft
105
110

110 iw
115
150
160
215
55
55
75
110
370

465 *un
540
7flA

120
65
on

100
105
95
QC

160
115
75
185
245
215
180
245
295
onn

350
qen
°.4A

165

190 ion

175

Specific
conduct-

ance (mi-
cromhos

at 25°C)

657
624
647
R49

coo

572
579
570
617
son

1,010
485
565
587
*Q7

1,890
2 94ft
9 Iflft

2,240
2,480
1,050
443
497

456 Atyj
4.4A

1,200
690
4-lfi
Qftft

928
870
QA4.

900
874
851
876
QQQ

1 080
*960
984
Q01

990

Tem-
pera-
ture

75

75

75

Remarks

Time elapsed after pumping:
Several hr.

' Complete analysis in table 30.
2 Preliminary analysis in table 30.
* Water quality test by pumping method; elapsed time indicated under "Rei Rmarks" column.
4 Well yielding water only through perforations 222-248 ft below land surface.
* Approximated because pump operation was intermittent. Well yield about 9 gpm.
* Well yielding water only through perforations 250-267 ft below land surface.
i Pump shut off for 30 min after preceding sample.

TABLE 30. Chemical analyses of representative native and contaminated waters from the deposits penetrated by water wells, 1925-46

[Analysis taken as essentially typical of the water native to a single stratigraphic zone in the locality of the source well; *> calculated;«iron and aluminum oxides (FejOs-f AljOs) a includes small equivalent quantity of carbonate (COs). Minor constituents and additional data are listed in notes at end of table]

Well

1/14-19R1

20M1-
1/15-2501...
28B2

32A1-.-

2/13-20H1...

3202

2/14-4N1....

502 I

Source

City of Beverly Hills:

La Cienaga well 1 ....
Roxbury Park well 2.
U. S. Government, Sol-
diers Home well 11.

City of Santa Monica,
Arcadia plant.
Goodyear Tire and Rub-
ber Co., well 3.
Southern California Wa-

ter Co., Towne plant
well 2.

Baldwin Village ____

City of Beverly Hills,
Castle well 1.

See notespage

Ifklftlfk *>. *".*».rfx Ik

OOO 0

Depth
in
feet

331

290
450
300

200

260

800

300
752
333

Date of
collection

IVTar OR 1(Uf>a
A 11 IT Q 1Q43

Mar. 9, 1938 ». _ ..
Dec. 22, 1932 ».._._.
July 30, 1931 » ...

July 30, 1931 ». _ .

Aug. 6, 1931.. .....

Feb. 25, 1938.......

Apr. 18, 1938
Apr. 24, 1938.......
Apr. 26, 1938
May 2, 1938--
Nov. 30, 1944.. ....
Feb. 8,1946" .
Mar. 30, 1931 » .
Feb. 10, 1936 ..
Jan. 21, 1938 ....
Sent. 9, 1938. .

£"

03

- - - - -

Parts per million

Dissolved solids at

180° C

b719
b714
b&83
b2,670
b569

b577

b686

496

652
b375
477
503
497
b350
b313
666
540
629

Silica (SiO2)

10
14
30

21

11

15
7.8
21
16

8
16
30

Iron (Fe)

0
0
.2

«4.4

«2.7
1.0
«2.7
«3.2

ios

.1
.2
.3

Calcium (Ca)

131
123
50
405
103

87

124

63

104
66
58
68
62
60
41
70
76
54

Magnesium (Mg)

55
57
29
185
40

46

35

15

28
18
15
17
14
16
24
23
27
36

I

1CQ

47
39
bl
341
46

51

74

b4

b 4
b
bj
bi
b£

b!3
b'

bl

8

"o

75""

5

15
46
>3

)0
3
10
13
0

r7
28

Bicarbonate (HCO»)

456
470
536
396
324

259

354

232

213
237
195
195
232
234
214
387
364
378

Carbonate (OOs)

1

0

6.0
0
3.0

0
0
0

Sulfate (SOO

136
148
27
171
127

212

165

89

133
92
99
108
66
82
50
60
66
45

Chloride (Cl)

108
110
134
1,363
50

48

73

26

114
34
34
54
46
23
48
125
96
146

Borate (BO.)

6.6
1.1

1.4

2.7

.5

.2

.2
.2
Tr.
.5

Nitrate (NO.)

14
1.5
0
0
40

2

35

.2

0
0

Hardness asCOOj

(calculated)

553
541
244
1,771
422

406

454

219

375
239
207
240
212
216
201
269
301
283

CO
co

TABLE 30. Chemical analyses of representative native and contaminated waters from the deposits penetrated by water wells, 1925-46 Con.

Well

2/14-5D5.

5D6-...

5D8..._

5D9..._

7P2 .

8C1
14C2

Source

Southern California Wa-
ter Co.:

Sentney plant well 5.

Sentney plant well 6.

Sentney plant well 8-

Sentney plant well 9.

Metro-Goldwyn-Mayer
Corp.

Los Angeles Investment
Co.

§n

co

1
0
a

9
02

410

410

411

411

411

411
411

Depth
in
feet

266

810

425

54

265

185
1,015

Date of
collection

Mar. 23, 1931
Oct. 2, 1931,
Dec. 10, 1931
Sept. 22, 1932.. _ .
Nov. 6, 1933.. __
Sept. 11, 1935
Oct. 20, 1936 ...
Mar. 15, 1939
Mar. 3, 1943
Jan. 24, 1944. ......
Mar. 1, 1935
Mar. 7, 1935
Mar. 11, 1935.. ....
Apr. 24, 1935 »- _ .
May 19, 1936. .....
Nov. 18, 1937.. __
Sept. 5, 1939.... ...
Mar. 3, 1943 ..
June 6, 1939 ...
Mar. 3, 1943 -
Jan. 24, 1944.. .....
Aug. 23, 1940". __
Oct. 10, 1940
Aug. 17, 1944
June 22, 1945
Feb. 8, 1946
Feb. 8, 1946.
Oct. 16, 1931 ...
Nov. 12, 1931... ...
Nov. 13, 1931 ......
Nov. 20, 1931 ...
Sept. 8, 1937

Temperature (°F)

Parts per million

OS

1m
T3

go
"Sea
"1

Q

805
b573
835
861
812
863
832
788
791
656
515
511
477
473
547
503
461
595
784
727
841
»>747
b766
b969
1,751
b2,280
b978
b430
b322
t>286
b273
i>371

Silica (SiO)

33

26
28
25
32
40
32
30
12
35
35
31
24
23
35
25

35
37
11
19
19
21
34
32
25

Iron (Fe)

4.0

5.0
2.8
5.6
5.5
5.5
2.7
.3
.2

°e!7
«5.5
°5.4
«8.3
«4.5
"3.9

«2.2
«.5
«.8
°3.2
«3.8
"4.0
Tr.
.07
.09

Calcium (Ca)

54
54
53
53
54
61
61
58
66
69
31
26
30
44
38
36
23
44
63
47
72
118
138
151
133
199
120
66
79
96
77
68

"55

§

ca

§

30
32
19
27
24
27
30
32
38
22
12
12
12
14
14
13
15
22
30
30
22
48
22
60
73
122
55
23
12
12
9
16

"c?

g,

%02

bl

132
bl
bl
bl
bl
bl
bl
M
b$
bj
bj
b"

b(
b£
b'
b'

bj
bl
bl
bl
b
bl
bl
b3
4691
168
58
b
b]
b
b4

Potassium (K)

26

56
54
43
46
26
12

)6
51
58
58
re

>1
58
'8

r9
57
08
08
41
85
07
13
33
13
13

9
8
5
17

Bicarbonate (HCOs)

409
421
439
415
397
390
384
384
378
336
244
262
238
232
268
244
226
280
390
384
421
396
378
476
427
432
462
183
189
a 236
130
248

Carbonate (CO3)

- -

6.0
6.0
2.9

0

Sulfate (SO4)

49
24
15
53
36
65
67
84
98
74
19
18
38
60
40
48
55
54
52
13
39
185
214
260
152
156
23
108
82
12
83
83

Chloride (Cl)

102
119
122
129
128
137
118
83
84
62
70
53
41
33
64
45
35
77
102
106
135
113
96
147
600
1,100
344
83
35
30
34
29

B orate (BO3)

1.7

Tr.

.2

Tr.
Tr.
Tr.
Tr.

3.5
.7

Nitrate (NO3)

0

1.9
23
0

4

Hardness asCCOa

(calculated)

258
266
210
243
233
263
276
276
321
263
127
114
124
167
152
143
119
200
281
241
270
492
435
624
632
998
526
259
247
289
229
236

00
CO
00

2/14-18F1

19C1

22N3
22N4

22P2

23H2...

27D2...
27D3
27J1

.

28F1

29K1...
32E1._.
32F1...

2/15-102
1C5-

9N6.

11C6

11D2

Fox Hills Country Club,
well 1.

City of Inglewood: Well 11
- Well 12... .... - .
Well 19 --
Well 24 .. ...

-

City of Los Angeles, Manhattan plant well
3A.

City of Inglewood:
Well 10 .
Well 14 ..... .__
Well 16 ---

Well 25 . ....

Frank Abell __ .. _ .. Wm. Krutz _
City of Inglewood well
21.

Southern California
Water Co.:

Manning plant: Well 2~
wellS

City of Santa Monica:
Marine new well 5.

.

Charnock well 6 _ .

Southern California
Water Co., Charnock plant well 3.

411

411

411
411
411
410

410

410
410
410

410

410
410
410

411
411

411

411

411

265.

501

290
283
314
400

827

293
355
1,097

398

180
210
400

261
865

204

384

480

July 24, 1939 ....._ Feb. 2, 1925
Mar. 25, 1932. _ .. Dec. 21, 1945... .... Nov. 17, 1928

Dec. 9, 1939« ..-

Sept. 25, 1939
Nov. 3, 1944.__--_- Apr. 29, 1937 «... .. Mar. 22, 1940
Nov. 3, 1944._--
JulyS, 1942 «... -.-

Nov. 3, 1944 .... Aug. 6, 1941 ...

-

July 31, 1931....... Aug. 3, 1931 ». .. Apr. 11, 1932. . _

-

Apr. 12, 1932--. Nov. 14, 1932
Nov. 18, 1932 . Apr. 6, 1934...--. Sept. 8, 1937 .... May 2, 1940

Jan. 10, 1929
. do.- ....
Jan. 20, 1938
Feb. 23, 1940...... May 26, 1941 ...

Oct. 16, 1936 _.

.

May 3, 1944 ...... Aug. 31, 1944

-

July 30, 1931-...- Aug. 26, 1937

_

Oct. 27, 1937 July3, 1939
Sept. 26, 1939
Jan. 15, 1940
Apr. 24, 1940. .. ... July 30, 1931 »
Aug. 26, 1937
Oct. 7, 1930 ... Oct. 21, 1935 » __

.

Aug. 21. 1942 ...

.....

b360
b823
b 1, 338
1,127
696
b593
b535

b366

b355
b400

b371

1>454

1,389
b 1,225
b284
b239
424
369
331
b300
b448
b440
442
b496
474
b518
b506

b563
b 1, 698
683

b654
1,670
1,924
2,009
2,435
1,961
2,415
b483
b524
b642
b557
b640

21
24

12

22

30

35

7.5
16
33

15

23

18

43
48
8.9

28
28
43

Tr.
1.2

1.5

".2

. 1

"4.6

°.5
".5
.01

.3
.4

.3
2
.4

«5.5
2.0
o.l

«5.0
«3.4
.47

63
97
163
52
74
72
81

67
100
69
71
60
67

200
90
16
19
38
40
34
37
43
42
69
68
58
70
77
100
82

95
24
57

97
265
268
309
447
277
380
77
85
98
99
108

16
40
66
56
28
14
18

16

14
14

21

19
8
8
7
11
9.3
11
11
14
19
23
16
27
22
27
26

33
23
28

51
127
126
150
168
132
60
33
34
43
43
49

44
bl
237
b2
bl
bl

blb

|
57

.....

42
48
34
01

43

b42
b66

37

63
b
479
b
b
b]
b]
b
52
b
b
b
b
b

b bb

»> b

69
153
255
211
217
242
346
46
58
b

b b

3

541

,.

60
38
18
03
46

72
63
48
82
57
54
74

61
29
90

65
36
42

245
408
445
250
362
364
395

230
232
242
244
234
238

427
253
1,254
1,266
178
225
353
334
206
240
289
264
218
337
268
264
349

323
711
403

277
293
301
265
285
250
250
274
281
313
311
293

280

0 30

180

- -..-

85
143
182
97
99
103
57

97
46
82
100
50

150

36

178
249
244
245
333
279
323
134
138
242
182
251

27
182
467
410
122
88
80

27
29
27
27
23
31

160
91
144
66

422
13
27
28
23
57
68
70
87
71
131
87

62
666
61

119
719
873
959
1,127
899
1,180
52
61
37
41
43

c

1.6

1.6

1.1

Tr.

1.4

. 8

20

Tr.

1.0 000000

107207
4 7

223
407
678
360
300
237
276

233
192
230
235
192
254

502
303
73
80
124
145
123
138
153
162
250
264
211
286
283
361
312

373
154
257

452
1,183
1,187
1,388
1,806
1,234
1,196
328
352
421
424
471

TABLE 30. Chemical analyses of representative native and contaminated waters from the deposits penetrated by water wells, 1925-46 Con.

Well

2/15-11E1

11E3...

11J1

11J2....

12B1

14A1...

14Q1...

15A2...

15A4...

15F2...

15H1

Source

McCoy (formerly Revo-
lon).
Southern California
Water Co.: Charnock
plant well 3.

Sepulveda plant
well 1.

Sepulveda plant
well 2.

Metro-Goldwyn-Mayer
Corp.
City of Los Angeles,
Berryman well 1.
E. S. Merrill Sanitarium.

Southern California
Water Co.:

Pacific plant well 2. .
Pacific plant well 4_.

Venice High School well
1.

Washington Park Mu-
tual Water Co.

<o

ft

3
§
CQ

411

411

411

411

411.

411

411
412

412

412

Depth
in
feet

405

402

277

400

550

120

200
335

200

108

Date of
collection

June 6, 1931 ».. __

Oct. 16, 1936 .
Aug. 21, 1942.
Oct. 12, 1944.......

Sept. 30, 1935......
Oct. 16, 1936

Sept. 5, 1939.......
Mar. 20, 1940 .
Oct. 12, 1944.......
Feb. 26, 1945... ...

Aug. 8, 1932 ......

Oct. 9, 1931 .
Nov. 3, 1932. .

Dec. 10, 1931......
June 11, 1932 ».____
Qct 21, 1935.. ......
Sept. 24, 1936 ...
Apr. 24, 1940--.
Oct. 12, 1944... ....
May 2, 1930 ».--..

Mar. 2, 1931.......
Oct. 9, 1931 ».....-

Temperature (°F)

T

Parts per million

OS

S"§
o

go

5"1

b546

773
773
851
b476
b536
b572
809
917
b728
905
894

b558

b948
b899

841
b631
b605
b595
b658
b641

b604
b636
bS67

Silica (SiOi)

25

35
36
28
28
34
41
24
42

9.4
41

26
25
21
34

30

Iron (Fe)

2.9

.35
.55
1.1
«4.0
2.7
"6.7
027
"5.5
2.0
1.3
Tr.

«5.6
.2
.2

1.0

Calcium (Ca)

89

90
92
107
61
77
80
84
92
105
103
91

90

127
120

94
97
94
95
113
105
125
117
100
93

Magnesium (Mg)

35

38
45
44
20
31
37
37
44
44
45
42

38

56
51

31
29
38
44
46
43
24
26
28
40

"0?

g,

CQ

b

b
b
b
b
b
b
b
b
bl
b
b

60

144
137

b
b
b
b
69
b
b
b
b
67

Potassium (K)

55

62
51
61
92
80
79
82
99
03
95
93

95
87
69
54

. .

64
59
56
85

.....

Bicarbonate (HCOs)

285

293
299
323
317
345
348
360
378
395
372
390

324

403
393

329
299
305
311
312
336
<J286
254
d272
284

Carbonate (COs)

0

0

0
0
0
Tr.

Sulfate (800

173

206
191
240
82
96
111
107
124
130
141
144

131

216
209

185
197
173
176
182
179
204
218
210
151

Chloride (Cl)

51

43
59
47
62
79
91
97
133
148
139
93

77

202
180

75
71
78
70
89
82
65
60
77
59

Borate (B0»)

Tr.

.4

1.0
1.4

.6

Nitrate (N0»)

0

0
4

3
Tr.

14

6

O03

S

'S

jg

H ®

366

381
415
448
235
320
352
362
410
443
442
400

381

547
509

362
361
391
418
471
439
411
399
365
397

2/15-16J2- - -

16J3--
22B2._.

22B4...
22F2...

22J1---

2301...

23H1...

23N1...
OQTJ1

23Q1
23Q2...
24C1
24D3
24L2...

26B1...
26B3

26F1 ...

27R1

34A1

Southern California

Water Co., Zanja plant well 11.
Win. Home ....

do-
Del Bay Land and
Water Co. well 2.

Formerly George San-
ford.
Machado _______

do...... __ . _ ...

Los Angeles County
Flood Control Dis-
trict:
Test hole 6 __ :...
Test hole 2.- ....

Mesmer City Corp, Ltd. Formerly Joseph Mes-
mer.

Formerly Mesmer
Ranch.

Palisades del Key Water
Co.:
Well 6... ....
TXtont 9 TOall 3

412

412
412

412
412

412

412

413

413
413

413
413
413
413
413

413
413

413

413
413

277

210
Un-
known
207
145

77.3

126

114

151
185

11.4
24.2
402
122
200

400
176

101.0

237
305

Apr. 16, 1930.. . ...

Oct. 9, 1931. .... Apr. 19, 1945..-.- Mar. 2, 1931

Feb. 9, 1931....... Aug. 8, 1939 .... Apr. 16, 1946-- . Jan. 30, 1936
Dec. 9, 1939-.- Apr. 17, 1945.-..-. Apr. 16, 1945... Jan. 30, 1936. . Dec. 12, 1939...... Apr. 16, 1945 __ .. Apr. 16, 1945-. . Apr. 3, 1930-.
Oct. 9, 1931 . Jan. 30, 1936. _ ...
Tiop Q 1 030

Dec. 14, 1939-..

July 30, 1931 »
Jan. 30, 1936 ._.
July 31, 1931 »-. - Aug. 26, 1937 ._ July3, 1939-,..... Apr. 26,1940-...
A£ar 29 1932 *
Oct. 21/1929..
Oct. 2, 1930 - Oct. 1, 1931
Dee. 12, 1939 __
Oct. 9, 1931. .... Aug. 8, 1932

Aug. 26, 1937
Oct. 21,1929- __ .. Nov. 18, 1929 __._ Apr. 1,1931 .... July 31, 1931 __ .. May 14, 1932
July 13. 1944......

67

1,147

bl,468
2,480

b893

b 1,362

b 1,220
b 1,634
2,510
b 1, 876
b2,255
4,300
1,700

b 1,285
b 1, 716
2,010
2,300
b631
b689
b752
b937

b5,182
b 1, 715
b567
b 1,111
b 1, 163
b 1, 719
b 1,744
b 1, 721
b492
b696
b714
b?84
b 1, 419
b 1,005
b 1,089

b481
b915
b474
b521
b478
b478
b616

36

31

3

12
23
28

12
34
22

22

5
3

34

2.6

.09

. 10

0
.09
.06

1.6
.08
. 10

.2

727
151

6.6

156

240
219

72
222

182
289
283
204
282
432
192

154
183
197
199
116
89
100
126

186
140
88
150
153
230
240
266
49
83
91
87
170
136
146

48
62
67
65
56
68
65

55

97
112

38
53

59
110
136
90
144
319
86

73
93
117
105
36
46
45
34

197
116
40
60
82
130
127
63
32
45
44
61
66
70
74

23
19
17
18
23
23
23

M

1511

437|

bl
bl

bl
bl
322

bj
b 2

652
242

b2

b2
265
401
b
123
bl
bl

b l,
bj
59
b;
128
162
179
220
97
b]
b]
b]
bj
127
135

107
b;
b
b]
100
97
b

63

4.8

96
73

65
92
8.8
34
75
9.6
2.8

02
57
6.4
4.8
31

35
95

321
66
52""

19
18
28
48

286
94
14

L04

386

361
702

355
503

483
503
550
592
659
678
430

582
540
504
635
548
616
616
672

606
395
314
444
436
586
484
590
372
475
464
476
659
430
457

325
832
330
343
348
336
349

0

0

. -..

0

...

0

......

......

......

330

325
931

288
518

395
304
716
665
805
755
477

394
634
730
408
28
17
23
51

2,234
871
184
419
437
701
760
670
39
90
105
144
441
284
318

29
32
33
29
29
32
36

218

462
222

121
144

177
427
530
284
295
1,650
340

168
20«
300
45.'

9
10H
Ml
1(5

941
124
38
106
142
200
196
206
87
120
124
126
162
172
181

111
100
98
123
94
98
113

. 8
. 3

""."3

2.8
"~.'8~

. 3

3.4
~".~6~

4

"i.T

1.7
3.3
2.2

~~i"3~

"I.Y

. 9

. 8

1.9
1.2

16
153

60
79
124""

46
57

~70~"

2.4
263

0
0
0

Tr.
Tr.
0
. . .

1
0
1
1

0
0
0
6

0
1

613

998
1.007

336
772

697
1,174
1,290
879
1,295
2,388
833

684
839
972
928
438
411
435
454

1,273
826
384
621
719
1,108
1,121
923
254
392
408
468
692
627
668

214
233
237
236
234
239
257

TABLE 30. Chemical analyses of representative native and contaminated waters from the deposits penetrated by water wells, 1925-46 Con.

Well

2/15-34H1-,
34K1...

3/13-6G1
8C2.__ ,

17Q1-,

20H1__,

27B1...
30P1-.

31H4...
36D1

3/14-1 Gl .

3K2

4N1 .

Source

Palisades del Key Water
.Co. well 1.

t.

Southern California
Water Co.:

Figueroa plant well 1,
Delmar plant well 1 .

Southern California
Water Co., Wads-
worth plant well 1.

Test hole. _ ._. _ .
Formerly Ken Ayala... ,

City of Long Beach,
North Long Beach
well 2.
Southern California
Water Co.:

Normandie plant
well 3.

Yukon plant well 2.

Truro plant well I,..

See notes page

412
412

412
412

412

412
412

412
412

412
412

412

413

413

Depth
in
feet

250
208

301
549

362

250

8
42

SO
200

598

756

636

Date of
collection

Jan. 8, 1930 ».... _.
Oct. 21, 1929.. _ ..
May 14, 1932
Aug. 26, 1937- -
June23, 1944-.-.-.
Nov. 2, 1944- __ .

Dec. 18, 1933 ......
Aug. 6, 1931. ......
Feb. 25, 1938---
Sept. 19, 1939. --
Nov. 29, 1944.__
May 23, 1924. -
Aug. 6, 1931
July 23, 1931 » ...

Feb. 25, 1938.-.
Nov. 30, 1945
Feb. 15, 1932 ». ..
Apr. 6, 1932. . __.
Jan. 4, 1933 ....
Apr. 10, 1942 ...
1932-37 »-...

Nov. 29, 1944 *.-- .

Aug. 21, 1945. .....
Sept. 19, 1932......
Sept. 23. 1932......

F

1 »
I
e

Parts per million

Dissolved solids at

180° C

b445
b485
b386
b339
b327

b363
b319
b320
b312
457
b270
b270
b362
487
486
b349
b954
b 1, 171

b 1, 125
924
404

t-349

b335
b386
b315

»>283

Silica (SiO2)

42

11

21

15

11
22
19

20
17

19

6.3
26
17
17

Iron (Fe)

0

«3.9

.25

Tr.

0 1.7
.01
Tr.

1.6
o.49

«2. 1

. 1
Tr.
. 1
Tr.

Calcium (Ca)

56
42
38
28
40
28

60
57
58
56
60
46
41
71
61
65
09
120
188
166
146
61

65

50
54
45
35

Magnesium (Ms)

22
20
18
12
14

2.4
15
16
12
13
5.3
13
16
6.7
19
15
52
66
67
38
9.6

12

16
16
7.6
10

Sodium (Na)

Potassium (K)

b85
b 122
b 85
b79
b 66

b

40
b
b

44
b

44
47
b
b
b

168
134
167
105
M

b

b
b
b
b

74
-"

11

iO

63
33
38

"3.1

5

49

58
71
72
65

Bicarbonate (HCO3)

300
344
168
146
180
189

250
220
220
210
226
232
217
229
232
232
232
479
473
384
244
242

244

281
281
293
256

Carbonate (COs)

0

0
.... -

Tr.
0

0
0
0

"""6"

Tr.

0
0
0
0

6
w_

"§

3
CO

46
29
30
30
29
24

76
72
72
75
72
26
38
84
85
84
83
185
154
157
160
54

73

34
59
7.2
14

Chloride (C 1)

86
100
103
86
88
89

26
23
26
23
27
27
20
27
27
2C
28
181
371
348
255
24

28

36
46
37
31

Borate (BOa)

0.7
1.9

.7

0
1.6
.3

Tr.

5.4
1.9
0
3

2.1
1.2
1.3
.2

Tr.

Tr.

Tr.
Tr.

Nitrate (NO3)

27
29

0

0

0
Tr.

6
20
27
16

Hardness as CCOs

(calculated)

230
187
169
119
157
116

160
204
211
189
203
137
156
243
180
240
234
513
741
690
521
192

212

191
201
144
129

O
to

3/14-8D2.
8E2

.

9N2.-..

9N3..J.

10C1

10G1...

12Q2_-

13J3..._

15G1
17T1

17L1

18N3

21B2...

Airways Water Co.:
. Welll.-
Well 2^- ------

City of Hawthorne:
Well 2-.. ...

'Woll

3

'28.
Southern California
Water Co.:

3.

well 9.

well 3.

Southern California
Water Co.:

well

2

413
413

413

413

413

413

413

413

413
413

414

414

200
279

679

760

437

798

800

620

410

506

197

Oct. 11, 1932. --
A no- 14. 1Q34.

June 15, 1944

Nov. 9, 1944 .

A Feb. 12, 1929..
B July 31, 1931
C Sept. 8, 1937
D Sept. 25, 1939-.
E Sept. 9, 1941
F June 12, 1941..
G Apr. 13, 1945.. Sept. 9, 1941 »._ June 12, 1944.-.--
Aiio1 7 1Q4H

June 15, 1944-..... Aug. 21, 1945 »_._. Apr. 29, 1943"

,

July 21, 1943.. Dec. 5, 1940 "
Sept. 7, 1945
Aug. 7, 1940 »__.-. Aug. 1-5, 1946 »- -

.

July 31, 1931--

A Mar. 25, 1930..
B Nov. 25, 1930-
C Mar. 16, 1931-
D Sept. 8, 1937
E July3, 1939.-.
F Sept. 26, 1939-G Jan. 15, 1940
H Apr. 24, 1940..
I Aug. 27, 1942-
J Jan. 9, 1945
K June 22, 1945.

.

L Jan. 14, 1946

1930 (?)".

May 11, 1944
Oct. 1.1945 ...

b310

b325

b 305
b297

988

b332
b316
b324
b289
b334
b329
345
b327
b464
b279
b315
b347

451

b319
b329
b359
b481
472
b389

b421
b393

b387

b480
b520
b654
b418
425
446
442

b319
b313
b309
b318

16
10
10

22
28

5.4

28

22
42
31
18
36

26
19
26

11
19
18
10
22
59
20

28

12
17
42
33

Tr.

"2.8 0
.05
Tr.

° 17

1

1

.2
. 1
.05

.25
«3.8

Tr.
.05

.2
Tr.

Tr.
. 1

0

°2

<>2.6
<=4.4
.3
Tr.

48
QQ

4.9

42
42

80
192

70
37
41
31
32
41
34

74

32
44
42

44
Q4

57
58
56

356
38

49
47
51
62
68
65
70
89
80
54
53
55

39
44
48
43

5.5
16
16
16

43

11
17

14
15
12
15
15
21
TO

4

9
14

159

0

10
13
12
17
16
Tr.
21

20
16
17
20
9c

25
25
33
23
19
19
19

11
17
15
15

bbbbb
b

bbb
65bb

68bbbbbbbbbbb

bl
bl

90b
blb
78
84
86
94

108bbbbbbbb

66
OK

59
57
54

111

48
67
69

|.
84
70
5.8
70
69

90
71
12

65
60
43
48
56
37
23

90
02
73

49
74
80
77

75
54
55
65

299
9 KA

293
253

251

340
320
327
307
343

324
090

99

c

271

431

232
238

226

427 "(JO
396

336
333
320
229
274

273

250
256
262

318
262
296
308

0000

9.0

160

130

Tr. 000000

6000

Tr.

13
9.6
7.2

30

3906400

Tr. 0
.5

264

0

4.8
42

59
22
66
70
62
27
16
Tr.

267
10
10
18
21
20
4.Q

14
22
16

3.2

287
2.4

41
09

Q4.
42

1Q9

420

33
28
Q9

Q1
09

28

148
Q1
QQ

38

9Q
90

9O

36
19

34
41

68

CO

101

i AR

246
114
109
107
107

39
36
39

0.3

.7

1.0
1.0

1.0

Tr.
Tr.

.9
Tr.
1.1

1.1 1

.54

0

0

.2

010112

153
120
171
171
171

258
656

220
162
156
i<?i

142
119

147
167
271
158
100
167
167

126

194

153
15

one

183
197
237
97O

265
278
358

213
91

n

215

143
180
182
169

TABLE 30. Chemical analyses of representative native and contaminated waters from the deposits penetrated by water wells, 1925-46 Con.

Well

3/14-22A1...

23L1 ...

26Q2
26J1....
26R1...
29N1...

30A2...
30D1...

80H1...

Source

Chadron plant well

Compton plant well
1.

Mrs. E. U. Knape __ ..
Beatrice M. Henderson.
Califomia Water Serv-
ice Co., station 12.

City of Manhattan
Beach:
Well 10... ....
Well 8-.-.... ....

Well 9...............

See notespage

414

414

414
414
414
414

414
415

416

Depth
in
feet

710

397

67.6
231
132.6
500

525
350

390

Date of
collection

May 6, 1941 .
May 9, 1941
May 29, 1941...
May 11, 1944.. .
Sept. 17, 1945... ...
Dec. 5, 1940 a ......
Jan. 4, 1945 . ...
Apr. 23, 1945. .....
Feb. 11, 1946».._.
Feb. 8, 1946 a. ....
Oct. 24, 1944
A Oct. 24, 1930...
B Feb. 13, 1931...
C Mar. 9, 1931 ...
D Apr. 6, 1931-..
E July 13, 1931
F July 21, 1931
G June 19, 1945. .
H Jan. 29, 1946...

Oct. 4, 1946 a.. ....
Oct. 20, 1938 ....
Mar. 31, 1944
Aug. 15, 1944......
Sept. 25, 1944 ...
Oct. 24, 1944 ...
Oct. 29, 1944..,. ...
Apr. 9, 1941... ....
Mar. 31, 1944... ...
Aug. 4, 1944. ...
Aug. 15, 1944... ...
Oct. 24, 1944.......
Oct. 4, 1945..... ...

Temperature (°F)

73

72

Parts per million

"S

a> 1
73

go

If

3

523
607
450
b294
473
b323
b309
b311

b3,907
b377

b368
b358
b406
b405

b367
b363
b346

b343
528
b428
b507
b660
677
b717
529
»401
385
»387
b379
b378

Silica (SiOj)

21
19
22
42
26
21
23
26
13
20

63

21

36
36
30
25
28

36
30

26
26

Iron (Fe)

o a

tJ-> _ WCO toto oostoos

Tr.
.03
.02

.35
.23

.2

.1
.3
. 1
.02
. 1

.2
.4
.3
.02
.05

Calcium (Ca)

60
49
46
55
60
54
50
51
517
61
240
64
58
94
65
66
56
64
54

45
55
65
80
89
90
136
59
60
67
58
55
62

1

1

S

24
19
18
16
15
15
12
15
177
17

9
11
9
15
16
18
20
13

14
20
19
19
26
26
27
21
17
17
17
16
17

Sodium (Na)

g

"o

PH

i>64
b67
b46
b35

b44
b51

657 18
49 12

b
b
b
b
b
64
b
b

b
b
b
b
b
b
b
b
b
b
b
b
b

56
55
49
70
61
.V-

)O

64

75
57
73
36
86
93
95
66
72
69
68
69
61

Bicarbonate (HCOs)

220
238
238
221
250
223
226
226
234
230
103
248
236
260
260
254
256
254
249

337
262
252
220
212
215
210
214
273
271
271
271
272

Carbonate (COs)

12
15
2.9

0
Tr.
0

0

6

0

Sulfate (SO4)

48
31
40
42
41
69
50
58
217
29
10
31
34
32
33
35
33
43
30

0
32
34
40
41
41
52
27
24
26
27
26
26

Chloride (01)

82
67
34
36
38
28
33
29
2,150
89
1,020
74
72
92
92
66
69
56
60

40
67
111
172
212
226
303
116
91
80
81
76
76

Borate (BO3)

0
0

Tr.
1.1
Tr.

.3
.6
.2

Tr.

.6

1.6

.7

Nitrate (N03)

54
4.0

2.0

0.2

Hardness asCaCOt

(calculated) _..

248
200
189
199
187
197
174
189
2,018
222
960
197
190
272
224
206
211
217
188

170
220
240
278
329
332
448
234
220
212
215
203
225

8/14-30M1..

31A6

31E1-..

32A1

35R1...

SS/15-1H1

.

12B1...
12G1...

12G2...

3/15-12L1...

Star Nursery.. ....

California Water Serv-
ice Co., station 5, well
6.

Howard J. Lovely ....

California Water Serv-
ice Co., station 8, well
8.

Southern California Ed-
ison Co., Ltd.

Andrew Bennett . _ _.

City of El Segundo:
WelllO
Well 6 ....

Well 5 ......

Well 1 ....

415

415

415

415

415

415

415
414

414

414

276.5

502

260

449

550

625

400
349

394

355

Apr. 10, 1944-.. Oct.24, 1944....... Dec. 14, 1944....-
July 21, 1931

Oct. 6,1931..... -_ Mar. 24, 1932. . Sept. 2, 1937 .. __ Oct. 24, 1944 -
A Nov. 13, 1929-

.

B Oct. 21, 1930
C Mar. 9, 1931...
D July 21, 1931
E Sept. 2, 1937-

_

F Jan. 4, 1945
July 23, 1931"__-_. Sept. 20, 1937
Sept. 26, 1939...-- Feb. 8,1946-. July 31, 1931 a
Sept. 21, 1939

Aug. 15, 1945» Dec. 18, 1939. ..... Feb. 17, 1942.__-_ Feb. 25, 1945-
Oct. 14, 1939 May4, 1941. _ ... Feb. 7, 1942_
Oct. 24, 1944

-

Feb. 25, 1945...--
A Dec. 6, 1929
B Mar. 4, 1930-

.

C Mar. 28, 1930-
D May 9, 1930...
E June 9, 1930
F Nov. 25, 1930-
G Feb. 13, 1931..
H Mar. 16, 1931..
I Apr. 6, 1931...
J Aug. 25, 1936-
K Sept. 15, 1936-
L Oct. 14, 1936.

.

M Sept. 8, 1937.

.

b555

b633
b349

i>387
b314
b354

b373
b344
»>353
b364
b361
3S4
b251
b232
b237
b241
b583
b585

b484
425
420
b422
470
596
660

b508
b303
b426
b377
b397
b439
b390
b340
b408
>>440
b445
b427
b472
b672

24

in

97

13

30

15

11

.35

. 10

.06

11

.2

.5

.3

80
80
98
54

61
48
57
48
61
75
61
57
57
56
35
98

28
29
66
61

63
69
55
60
64
110
99
100
88
61
59
80
66
98
59
61
67
71
72
68
74
90

22

fa
16

21
14
17

1202

17
15
16
12
11
18
12
32
28

21
13
17
20
19
27
28

20
11

236
19
11

179
22
18
22
21
24
49

bl

bl
61

61
55

53bbb

61

58b
52
51
47
39
123
131

blbbbbb

blbbbbbbbbbbbbb

77

00

m"

34
57
70

59

12

03M
77
7R
79
33
01

73
37
80
55
60
54
67
60
68
72
75
72
84

219
253
220
247

268
_!5»
255
262
242
223
177
244
237
249
241
224
231
230
480
506

427
159
206
310
171
188
181
182
180
132
297
214
250
249
282
223
312
236
180
180
180
205

000

33
16
43
50
49
34
46
45
42
44
3

Tr. 4

4.0
30
27

41
17
39
64
74
85
57
28
23
33
27
27

1407

33
42
44
44
161

20?
165
247
57

76
53
56
57
66
66
85
62
69
59
27
29
24
28
91
85

8?!
133
116
92
16?
214
252
173
180
100
92
96
inn
124
9?
98
88
128
144
13?
156
190

. 6

. 3

. 5
. 8
. 8
0

1.5

1.4
.7

.5
. 8

. 8

1.3

oooo 0

Tr.

Tr. 0
1.3

Tr. 0I

290
246

201

239
177
212
142
202
188
161
212
204
206
137
115
144
122
296
267

244
226
207
232
238

207
302
198
242
225
243
290
217
189
258
251
270
256
283
426

TABLE 30. Chemical analyses of representative native and contaminated waters from the deposits penetrated by water wells, 1925-46 Con.

Well

3/15-12L6

13A2

13E1

13R1...

13R4...

13R5

Source

Well 7

Standard Oil Co.:
Well 13... ....

WelHb... .

Well 9.. - ......

Well 19.-... .... -

Well 20....... __

o>

1o> <u

no

414

414

414

414

414

415

Depth
in
feet

350

450

404

400

440

504

Date of
collection

A Nov. 16, 1939-
B Nov. 16, 1939-
C Nov. 16, 1939-
D Jan. 4, 1940--.
E Mar. 30, 1941..
F Feb. 8, 1942 _
G Sept. 2, 1942. .
H Apr. 24, 1943..
I Oct. 24, 1944. .
J Feb. 25, 1945-

Oct. 10, 1939
Dec. 19, 1940 ...
Dec. 18, 1941......
June 22, 1942.. __
June 21, 1943......
June 1944..........
Oct. 24, 1944.......
Aug. 8, 1929

June 12, 1930-...
Mar. 25, 1930
Mar. 26, 1942 »....
June 21, 1943...
Apr. 27, 1943..
Jan. 6, 1944
Jan. 10, 1945. ......
Jan. 8, 1946 . ....
June 1944- __ :.
Oct. 24, 1944.......
Jan. 10, 1945.. __
July 16, 1945. ..
Jan. 8. 1946........

Temperature (°F)

71

73

Parts per million

ta

1

1

T3

go

3^

550
570
420
695
553
570
808
630
1,330
966

589
b393
b510

b531
b526
859

942
6,618
1,516
b404
b367
»>360
b368
585
b423
b444
603
422
545
445
464

9
s_
83
i>

1

18
21

12

27

28

34
25
19
21
29

29
31
28
31
27
24
33

"a?

b

1

0.06
.25

eg

"29
"305
"20
"10
«2

"2
1

.43
1
1
2

"os

0

s

1

0

79
82
44
82
80
90
115
102
194
202

61
39
80
87
87
97
160
75
400
158
52
52
53
53
53
60
69
56
53
56
58
59

"53

s

IH)

83

s

15
17
9
15
22
24
27
28
61
49

20
22
25
26
27
25

14
260
50
17
17
17
19
16
19
23
18
19
18
19
19

"c?

g.
a
3

?
02

b
b
b
b]
b
b
b
b
b
b

b
b
b
b
b
b

M

1

1
o
PH

)5
96
94
07
86
84
43
89
145
82

76
85
82
80
76
122
1
b230
b 1,163
blOl
b99

b72
b68
b67
b81

b82
b73
b?6

b79
»>78
»>79
b83

O
O
B

3
83

S

144
159
105
184
213
206
215
211
250
232

323
256
296
284
287
366
319
321
230
283
329
337
323
311
329
327
317
345
368
360
366
363

6
o

1
o
. £
83

O

0

0

0

18
0

6
0

0

0
0
0

0

<5
0
£

&

i03
69
75
43
90
73
72
20
76
119
97

11
23
31
29
6
36
117
1,020
320
5
0

1
2
3
11
1
1.6
3
Tr.
3

O

1

1

O

195
195
157
181
160
186
208
220
520
420

Qfi
108
152
165
163
194
224
253
2,400
210
60
57
60
72
73
95
109
68
59
61
66
75

6
e

1
s
«

0

.4

.6

.8

6
£
3
83

g

0.1

.1

6
o83
O

af

s|
§s
11
W

259
275
147
267
290
323
398
370
735
706

235
188
303
324
328
345

245
2,066
600
200
200
202
210
198
228
267
214
210
214
223
225

3/15-24D1.

25A1.

25A4.
25H1-

4/13-2P4
6J1 .

8L1

12A2-

14Q4-

15A2..

15A3-

19H1..
19J4--

21Q1-

22E1..

City of Manhattan
Beach:
Well 5.. ... ...

.

Well 3 - - -

Woll

9

Well

1

Dominguez Estate Co_-

City of Long Beach, North Long Beach
well 6.

Dominguez Water Corp.:

Woll

8

Well 10---

.

Mrs. Addie V. Stewart..

Shell Oil Co., Inc.. Wil-m ing ton well 1. Richfield Oil Corp., well
5.

415

415

415
415

415
415

415

415

415

416

416

416
416

416

416

390

547

1,000

161
95

32.2

1,946

900

998

158

90
100

750

650

Apr. 3, 1936 » .... July 14 1944
Nov. 13, 1929
Oct. 22, 1930.,
Feb. 13, 1931
Apr. 6, 1931
Sept. 4, 1942
June 11, 1943
Aug. 15, 1944
Oct. 24, 1944

Mar. 24, 1932 »
June 11, 1943- -

-

Feb. 29, 1944
Sept. 25, 1944
Oct. 27, 1944
Oct. 3, 1945
July 22, 1931 »
Aug. 19, 1931
Mar. 31, 1932 »-
Apr. 11, 1932
July 5, 1932

.

Mar. 6, 1933
June 12, 1946 «...

July 22, 1931.

-

Mar. 21, 1932 »
May 11, 1932
Aug. 8, 1932.-
Nov. 2, 1932
Jan. 4, 1933.

July 23, 1931 » Junel, 1945
July 23, 1931 »
July 20, 1943--
Oct. 11, 1943-
May 2, 1944. __ -. Apr. 22, 1942 ... Apr. 11, 1932 . --

Feb. 7. 1938 »

Apr. 10, 1942 ».. .

7?

75

69

M33
b906
b357
>>349
b4i2
b390
784
b615

b 1,106
1,220
b 1,068
b365
b526
b?66
b 1,090

b 1,250
b338
b318
b308
b 3,454
b 4,014
b 3,611
b452

b230
b236
b224
b239
b225
b233
b219

b208
b239
b449
693
768
689
518
b 787
b849
b218

221

17
34

10
30
24
30

7
28
28

30

48

16

15
16
26
22

31

24

1
b5.4

°5
. 1
0
10

°4

.3
. 1

.45

«10

Tr.

.4
.4
Tr.
.41

0

.01

71
176
53
68
43
62
100
107
209
180
205
51
89
139
200
170
259
65
55
56
331
408
317
8.2

24
24
24
23
24
23
22

20
21
83
85
84
105
76
100
113
13

20

21
47
10
6
8
13
29
34
52
54
49
15
25
38
54

62
9
16
10
190
223
214
2.0

2

6 5
7
5

5 4

7
6.8
17
7.9
8.9
16
17
34
37
2.5

5.1

b?l
blOO
b?2

b58
b!09

b71

b56
b74
b!28
b!37
b!22
62|
b72
b95
b!28
1

-

b]
52
44
42
580
638
681
b]

67
62
60
62
61
62
56

59
b
62
b]

b] b
68
156

152 b

53

14

.....

.....

71

.....

53 """

.....

05
30
67
3.9

74"""

1.9

337
306
236
223
283
236
222
177
219
216
219
247
171
260
219
213
220
223
d216
217
250
253
259
413

168
168
168
171
165
171
173

174
159
253
268
256
244
196
265
287
204

185

0

...... 0

......

"12"

0
0

0 00

10
16
24
29
30
23
15
41
62
63
62
23
51
47
63
50
71
72
66
67
1,356
1,596
1,300

6.7 9

32
108
128
182
137
58
37

390

91
414
80
76
SO

103 m
wo
KAK

522
5?0
89
W3
317
535
465
634
27
27
23
870
1,021
967
58

21
23
20
25
21
23
">1

23
25
52
84
91
94
132
325
358
26

?2

0

.5

1.0

. 7

1.9
1.6
.7
1.5

1.6 2

2.2
.8
.8
.8
.8

1.6
Tr.
0.27
Tr.
Tr.
Tr.

.7

19

0
0
0
0

0 0

2
0

0 001
2.1

2 6

264
633
174
195
140
208
369
407
736
671
713
189
325
503
721
518
902
199
203
181
1,607
1,934
1,670
29

68
85
81
86
81
78
71

79
80
277
245
246
329
260
389
434
45

71

TABLE 30. Chemical analyses of representative native and contaminated waters from the deposits penetrated by water wells, 1925-46 Con.

Well

4/13-30K1

31E3
31E4
35M3-.

4/14-1H

5N1

5"N2....

7J3.---

801....

Source

City of Los Angeles:
Lomita plant:
Well7

WellS.-
Well 4. ....
Southern California Edi-
son Co., Ltd., west
Gaspur well.

Aluminum Company of
America.
California Water Serv-
ice Co., station 19,
well 1.
Redondo Union High
School.

California Water Serv-
ice Co.

Dominguez Water
Corp., well 12A.

See notespage

416

416
416
416

417

417

417

416

416

Depth
in
feet

676

671
680
201

533

312.8

306

518

Date of
collection

Dec. 11, 1941-
Jan. 14, 1942 ..
Mar. 25, 1932 _.__
July 26, 1932 »
Jan. 8, 1923 a

Apr. 28, 1942-.
Aug. 28, 1942 a. _

Sept. 2, 1942... ....

Oct. 6, 1931 a_ __
Mar. 24, 1932
May 11, 1932- ....
Nov. 3, 1932. ___
Sept. 2, 1937 .
Sept. 4, 1942..
Sept. 18, 1944
Apr. 13, 1946
Aug. 26, 1930 ».

Apr, 7, 1944... _ .

July 20, 1944. .....
Oct. 30, 1944 ....
June 1. 1945

F

2

!&H

69

Parts per million

"3

3

1

0

go

ll
ft

b272
b239
b377
b388
b318

8,200
b252

b392

b303
b299
b283
b301

b369
b647
2,280
3,370
b320

b361

b354
b344
b369

Silica (SiOs)

20
13

29
25
32

16

20
23
17

Iron (Fe)

0.97
«6.0

0
.13
.05

. 1

Tr.
.08
Tr,

Calcium (Ca)

24
15
18
16
27

438
41

66

43
43
37
43
45
140
350
547
43

78

46
42
46

Magnesium (Mg)

13
10
9
7
11

418
8.1

30

18
13
16
14
13
34
105
186
13

17

13
15
16

I

1CO

b
b
123
b;
b

1,865
b

b

55
66
54
56
56
b
b]
293
b

b

b
b
b

8

o

PH

56
51
§1""

82

56
46

43

.....

95
14
67

38

77
73
77

Bicarbonate (HCO3)

224
211
311
258
b235

193
196

259

235
223
220
220
337
256
226
216
251

262

259
252
250

Carbonate (COj)

9
22

0

......

0
0

0

Tr.
0
0

Sulfate (SO4)

6
1
0
36
40

565
25

20

12
16
7
14
15
10
85
142
3.0

3.8

3.9
2.5
12

Chloride (Cl)

42
24
69
69
40

4,410
34

104

57
67
59
62
70
278
1,060
1,770
68

93

84
85
93

Borate (BOs)

2.0

COCDCDOOl

.6
.1

Tr.

Tr.
0.6

Nitrate (NO3)

1.8

0
1
0
1
0

2.5
2.0

. 1

Hardness asCaCOs

(calculated)

113
79
82
69
113

3,809
136

286

181
161
154
165
166
489
1,306
2,130
161

265

168
167
181

00

4/r4-8'El::-

9K1..._

11G2

16L3-1
17E1

17G1...

17N1

20J1_._

23N2

35E2

36H1

5/13-3H _
5/14-12C1

California Water Serv-
ice Co., station 3, well
4.

Chanslor, Canfleld, Mid-way Oil Co. Columbia Steel Co.,
well 1.

California Water Serv-
ice Co., well 10.

California Water Serv-
ice Co., station 11.

8. Correia (Ellen wood well 3).

Narbonne Ranch Water
Co., well 2.
Los Angeles County
Water Works District
No. 13.
Palos Verdes Water Co.,
welll.

Oil well. .. _ _

-

Royal Palms Golf Club,
well 1.

416

416

416

416
416

416

416

416

416

417

417

417
417

440.5

557

613

300
556

418

400

367

640

630

610

1,300
200

July 21, 1931-.-

Oct. 3, 1936 .
fitmf- 9^ 1Q3Q

Oct. 21, 1929- -

A Tiff ft 1Q4R

Oct. 21, 1929

July 23, 1931.--
Oct. 21, 1928 "-

-

Mar. 24, 1932
May 11, 1932 »--- Nov. 5, 1930 »_

July 21, 1931.-- July 23, 1931--

Sept. 8, 1937
IQ^d

a

Oct. 27, 1944 a -

June 11, 1930-.

.

May 20, 1942.- __ Mar. 11, 1942(?)a__ May23, 1930

-

Oct. 30, 1930... __
"M"ar 1Q 1QQ1

July 5, 1939.. __

.

Sept. 26, 1939 ...

b327

b346
b402
383

553
b267

b277
b291
923

b325
b325
b427

b442
b560

b573
b332

b547

b334

b-387
b454
b368
b408
750
b 1,004

b 1, 059
b999
b 1,270
b 1,271

32

28
24

37
40

45

23

«11

2.9

. 12

°1

. 1

42

50
54
39

80
29

32
21
88

34
34
46

46
70

70
19

60

28

14
26
17
18
18
166

145
127
172
167

17

16
18
11

18
13

17
5.0
134

11
13
20

23
36

33 6
b8

15

6
13
8
7
5
33

36
42
71

67 :

78b

b] b

60
b
b]

83I1

106
103

104
b]

b]b
b]
b]
b]
b]
bS
b]

b b
187
193

r
87

00
62

.....

94
86

ft

to

48

86

38
43
23
41
240
63

169
.87

244

214
251
348

270
279

244
293
304

293
290
341

351
415

431
300

389

281

324
388
293
354
b487
473

485
414
471
454

...... 06
......

3

2
6
Tr.

3
Tr.

6
Tr.
7.4

0
0
7.1

0
17

15 15

0 2
0 3
5
150

94
161
356
256

71

96
119
33

189
23

39
24
404

50
52
86

91
126

133
46

129

64

65
72
73
62
130
255

372
275
244
354

.3

1.4

.3
.2

.3

1.6

2.0

11
.30

00

0 0147

175

191
209
143

274
126

150
73
769

130
138
197

209
323

310
72

183

132

60
118
75
74
66
550

510
490
721
692

CO

Notes to table 30

1/14-19R1. Drilled public-supply well; diameter 16 in; easing perforated 195-217, 256-266, and 303-312 ft below land surface in deposits of Pleistocene age. Essentially native calcium bicarbonate water. Analysis by California Division of Water Re-
sources.

1/14-20M1. Drilled public-supply well; diameter 14 in; easing perforated 156-174, 206-234, and 258-271 ft below land surface in deposits of Pleistocene age. Sodium bicarbonate water, native to range penetrated. Analysis by city of Beverly Hills. 1/15-25O1. Drilled public-supply well; diameter 12 in; casing perforated 318-450 ft below land surface, probably in the upper division of Pieo formation of Pliocene age. Inferior calcium, sodium chloride water; locally native. Analysis by Cal-ifornia Division of Water Resources.

1/15-28B2. Drilled public-supply well; taps deposits of Pleistocene age. Native calcium bicarbonate water. Analysis by California Division of Water Resources. 1/15-32A1. Drilled public-supply well; taps deposits of Pleistocene age. Calcium sulfate, bicarbonate water, locally native. Analysis by California Division of Water

2/13-20H1. Drilled industrial well; diameter 18 in; easing perforated 93-125, 133- 145, and 156-170 ft below land surface in the westerly arm of the Qaspur water-bearing eone; lowest perforations probably in unnamed upper Pleistocene deposits. Essen-tially native calcium bicarbonate water. Analysis by California Division of Water Resources.

2/13-32C2. Drilled public-supply well; diameter 14 in; easing perforated 604-645 ft below land surface in lower part of San Pedro formation. Analysis of Apr. 18,1938, on water reported from 390 ft below land surface in the upper part of the San Pedro formation but probably not native to that range. Analyses of Apr. 24 and 26,1938, reported from 630 ft below land surface; analysis of May 2, 1938, reported from 790 ft below land surface in the lowermost part of the San Pedro formation. Analysis of Nov. 30,1944, represents a calcium, sodium bicarbonate water essentially native to the lower part of the range tapped but may be blended in small part with inferior waters. Analysis of Apr. 24,1938, by Dr. Carl Wilson; others by Smith-Emery Co. 2/14-4N1. Drilled irrigation well; casing perforated 123-147 and 182-219 ft below land surface in the San Pedro formation. Native calcium, sodium bicarbonate water. Fluoride 0.2 ppm; electrical conductivity 582 micromhos. Analysis by U. S. Geo-logical Survey. Field analysis in preceding table.
2/14-5C1. Drilled unused well; diameter 12 in. Taps San Pedro formation of Pleistocene age. Calcium, sodium bicarbonate water; locally native. Analysis by Los Angeles Department of Water and Power.
2/14-5C2. Drilled public-supply well; diameter 26 and 16 in; casing perforated 201-320 ft below land surface in the San Pedro formation of Pleistocene age. Sodium to calcium, sodium bicarbonate water, resulting from a blend with one or more in-ferior waters of unknown source. Analyses by city of Beverly Hills.
2/14-5D5. Drilled public-supply well; diameters 30 and 16 in; easing perforated 152-160,174-199, and 214-266 ft below land surface in the upper part of the San Pedro formation. Sodium bicarbonate water; fluctuations in chloride and sulfate probably due to blending with an inferior water, present locally. Analysis of Oct. 2.1931, by California Division of Water Resources; others by Smith-Emery Co. Field analysis in preceding table.
2/14-5D6. Drilled public-supply well; diameter 16 in; casing perforated 326-342 and 492-515 ft below land surface in the middle and lower parts of the San Pedro formation. Sodium bicarbonate water, essentially native to range penetrated.

tion. Calcium bicarbonate water, native to range tapped. Analysis by Los Angeles Testing Laboratory.
2/14-22P2. Drilled public-supply well; easing perforated 216-227, 267-277, and 285- 290 ft below land surface in San Pedro formation. Analysis suggests calcium bicar-bonate water, native to range tapped. Analysis of 1944, iodide absent, electrical conductivity 570 micromhos. Analysis in 1940 by Dr. Carl Wilson, that in 1944 by T. Downer, U. S. Geological Survey. Field analyses in preceding table. 2/14-23H2. Drilled public-supply well; diameter 20 in; easing perforated 455-480, 495-520, and 725-775 ft below land surface in Silverado water-bearing zone in San Pedro formation. Native calcium bicarbonate water, a blend from all parts of range tapped. 2/14-27D2. Drilled public-supply well; diameter 18 in; easing perforated 110-130 ft below land surface in unnamed upper Pleistocene deposits, and 181-197 and 256-273 ft in San Pedro formation. Analysis suggests calcium bicarbonate water, essentially native. Well located just west of Potrero fault; chloride content markedly higher than from wells inland from the fault. Iodide absent, electrical conductivity 1,420 micromhos. Analysis by T. Downer, U. S. Geological Survey. Field analyses in preceding table.
2/14-27D3. Drilled public-supply well; diameter 18 in; casing perforated 102-104 ft below land surface in unnamed upper Pleistocene deposits, and 169-189 and 240-242 ft in San Pedro formation. Native calcium bicarbonate water. Well located just west of the Potrero fault; chloride content higher than from wells inland from the fault (analyses 22N4, 22P1, and 22P2). Analysis by California Division of Water Resources.

2/14-27J1. Drilled irrigation well; diameter 18 in; casing perforated 236-283 ft below land surface in the Silverado water-bearing zone of San Pedro formation. Analyses of 1931 on water from 1,047-1,087 ft below land surface in the upper division of the Pico formation of Pliocene age; represent a native sodium bicarbonate water. Later samples indicate a sodium, calcium bicarbonate water native to the Silverado zone. Analyses of July 31,1931, Nov. 14 and 18,1932, by Los Angeles Testing Laboratory; analyses of Aug. 3,1931, and Sept. 8,1937, by California Division of Water Resources; analysis of Apr. 11,1932, by Los Angeles Department of Water and Power; that of Apr. 6,1934, by Los Angeles Health Department. Field analyses in preceding table. 2/14-28F1. Drilled public-supply well; diameter 18 in; easing perforated 166-176 ft below land surface in "200-ft sand" of unnamed upper Pleistocene deposits, and 274- 294 ft in "400-ft gravel" in upper part of San Pedro formation. Calcium, sodium bi-carbonate water, a blend of native waters from the zones tapped. Analyses by Dr. Carl Wilson. Field analyses in preceding table.
2/14-29K1. Drilled domestic well. Probably taps "200-ft sand" in unnamed upper Pleistocene deposits. Native calcium, sodium bicarbonate water. Analysis by Los Angeles Testing Laboratory.
2/14-32E1. Drilled irrigation well; diameter 10 in. Taps unnamed upper Pleisto-cene deposits. Sodium, calcium bicarbonate water, locally native. Analysis by Los Angeles Testing Laboratory. Chloride content 83 parts in 1944. Field analyses in preceding table.
2/14-32F1. Drilled public-supply well; casing perforated 175-205 ft below land surface in "200-ft sand" in unnamed upper Pleistocene deposits, and 327-357 ft in "400-ft gravel" of San Pedro formation. Calcium bicarbonate water, blend of waters from the two zones. Analysis of 1940 may represent a blend with an inferior water, present locally. Analysis of 1938 by Los Angeles Testing Laboratory; others by Dr. Carl Wilson. Field analyses in preceding table.

Analysis of Mar. 1,1935, on water from 330 ft below land surface; that of Mar. 7,1935, on water from 462 ft below land surface; that of Mar. 11,1935, on water from 504 ft below land surface. Analysis of 1943 by Los Angeles Testing Laboratory; all others by Smith-Emery Co. Field analysis in preceding table.
2/14-5D8. Drilled public-supply well; casing perforated 70-80, 160-224, 248-282, 342-355, and 362-370 ft below land surface In the San Pedro formation. Sodium bicar-bonate water, a blend of waters from the San Pedro formation. Analyses by Smith-Emery Oo.
2/14-5D9. Drilled public-supply well; casing perforated 26-50 ft below land surface in the "50-ft gravel" of Recent age. Calcium sulfate, bicarbonate water. Analyses by Smith-Emery Co.
2/14-7P2. Drilled industrial well; diameter 16 in; casing perforated 122-213 ft below land surface in the San Pedro formation. Sodium chloride water; marked contam-ination indicated. Analysis of 1946, fluoride 0.2 ppm, electrical conductivity 4,050 micromhos. Analysis In 1945 by Smith-Emery Co.; that In 1946 by II. S. Geological Survey.
2/14-8C1. Drilled stock well. Probably taps San Pedro formation. Sodium, calcium chloride water, resulting from contamination. Fluoride 0.3 ppm. electrical conductivity 1,780 micromhos. Analysis by II. S. Geological Survey. Field analysis in preceding table.
2/14-14C2. Drilled public-supply well; diameter 16 in; casing perforated at inter-vals 410-973 ft below land surface. Well taps most of San Pedro formation. Analysis of Oct. 16,1931, on sample from 622 to 632 ft below land surface. Analysis since Nov. 12,1931 Indicate native calcium bicarbonate water. Sulfate content in analy-sis of Nov. 13,1931 probably In error. Analyses of Oct. 16, 1931 and Sept. 3,1937 by California Division of Water Resources; others by Los Angeles Department of Water and Power.
2/14-18F1. Drilled irrigation well; diameter 12 in. Taps San Pedro formation. Water initially sodium, calcium bicarbonate, chloride in character, probably native but may be Influenced by blending with Tertiary waters. (See analysis for well 5/14-12C1.) Later analyses show contamination; that of 1945 on bailed sample, from or slightly below water surface. Analysis In 1932 by California Division of Water Resources; that in 1945 by Smith-Emery Co.
2/14-19C1. Drilled domestic and irrigation well; diameter 18 in; casing perforated at Intervals 55-305 and 419-428 ft below land surface in San Pedro formation. Analy-sis of 1928 suggests contamination but analyses in 1930 and 1939 indicate an essentially native sodium bicarbonate water. Chloride content of about 100 ppm in 1944 sug-gests recurrence of contamination. Analysis in 1928 by Los Angeles Testing Labora-tory; in 1930 by Los Angeles Department of Water and Power; in 1939 by Dr. Carl Wilson. Field analysis In preceding table.
2/14-22N3. Drilled public-supply well; diameter 18 in; casing perforated 104-117 ft below land surface in unnamed upper Pleistocene deposits, and 176-196 and 246-267 ft in the San Pedro formation. Well is east of the Potrero fault and yields regionally native calcium bicarbonate water. Analysis by California Division of Water Re-sources. Field analysis In preceding table.
2/14-22N4. Drilled public-supply well; diameter 18 in; casing perforated 104-115 ft below land surface in unnamed upper Pleistocene deposits, and 122-130, 175-195, and 239-260 ft below land surface In the San Pedro formation. Analysis suggests a oalclum bicarbonate water, regionally native. Iodide absent, electrical conductivity 698 micromhos. Analysis by T. Downer, II. S. Geological Survey. Field analyses in preceding table.
2/14-22P1. Drilled public-supply well; diameter 18 In; casing perforated 190-211 and 260-292 ft below land surface in the middle and lower parts of San Pedro forma-

2/15-1C2. Drilled abandoned well; formerly public-supply; diameter 14 in. Well taps San Pedro formation of Pleistocene age. Calcium, sodium bicarbonate water, essentially native. Analysis by Smith-Emery Co.
2/15-1C5. Drilled public-supply well; diameter 20 and 10 in, gravel-packed well; casing perforated initially 672-852 ft below land surface in upper division of Pico forma-tion; subsequently plugged by cement bridge at 464 ft and reperforated 146-321 and 370-374 ft below land surface, in San Pedro formation. Analysis of Aug. 31, 1944, represents sodium, calcium bicarbonate water, native to San Pedro formation. Analysis of May 3, 1944, on water from well before lower perforations were plugged indicates a saline water native to the upper division of the Pico formation. Analysis of May 3.1944, by Dr. Carl Wilson; that of Aug. 31,1944, by Smith-Emery Co. Field analysis in preceding table.
2/15-9N6. Drilled abandoned well; formerly public-supply; diameter 16 in; casing perforated 35-146 ft below land surface In the "50-ft gravel" of Recent age and in the San Pedro formation of Pleistocene age. Calcium, sodium bicarbonate water. All analyses indicate contamination. Analyses by California Division of Water Resources.

2/15-11C6. Drilled public-supply well; diameter 18 in; casing perforated 178-198 and 220-228 ft below land surface in San Pedro formation of Pleistocene age. Calcium, sodium bicarbonate water, native to the range penetrated. Analyses by California Division of Water Resources. Field analysis by California Division of Water Resources.

2/15-11D2. Drilled public-supply well; diameter 18 in; casing perforated 240-276 and 300-340 ft below land surface in the San Pedro formation of Pleistocene age. Calcium, sodium bicarbonate, sulfate water, locally native. Analyses by Smith-Emery Co. Field analysis in preceding table.
2/15-11E1. Drilled well, now abandoned. Chemical character suggests water from the San Pedro formation of Pleistocene age. Native calcium, sodium bicar-bonate, sulfate water.
2/15-11E3. Drilled public-supply well; diameter 18 in; casing perforated 210-393 ft below land surface in San Pedro formation. Calcium, sodium bicarbonate, sulfate water, locally native. Analysis by Smith-Emery Co. Field analyses in preceding table.

2/15-11J1. Drilled abandoned well; formerly public-supply, diameter 18 in; casing perforated 164-222 ft below land surface in San Pedro formation. Sodium, calcium bicarbonate water; initial analysis represents water essentially native to zone tapped. Subsequent analyses show increasing contamination. Analyses by Smith-Emery Co. 2/15-11J2. Drilled public^supply well; diameter 16 in; casing perforated 177-253 ft below land surface in San Pedro formation. Well 11J2 taps range similar to that tapped by 11J1. Analyses show increasing contamination. Analyses by Smith-Emery Co. Field analysis in preceding table.
2/15-12B1. Drilled industrial well; gravel-packed; casing perforated 134-191 ft below land surface in the San Pedro formation. Calcium, sodium bicarbonate water, incipiently contaminated. Analysis by Smith-Emery Co. Field analysis in preceding table.
2/15-14A1. Drilled well; diameter 16 in; casing perforated 163-168,200-212, and 230- 244 ft below land surface in San Pedro formation of Pleistocene age. Native calcium, sodium bicarbonate water. Analysis by California Division of Water Resources. 2/15-14Q1. Drilled unused well; diameter 12 in. Probably taps the "50-ft gravel" in Recent deposits and the San'Pedro formation beneath. Calcium, sodium bicar* bonate chloride water; incipiently contaminated. Analyses by California Division of Water Resources.
2/15-15A2. Drilled unused well; diameter 14 in; casing perforated 62-116 ft below

Notes to table 30 Continued

land surface In San Fedro formation of Pleistocene age. Native calcium, sodium bi-carbonate, sulfate water. Analysis by Smith-Emery Co.
2/15-15A4. Drilled public-supply well; diameter 16 in; casing perforated 70-178 ft below land surface in San Fedro formation of Pleistocene age. Calcium, sodium bicarbonate, sulfate water, locally native: analyses beginning In 1940 show incipient contamination. Analysis in 1940 by California Division of Water Resources; others by Smith-Emery Co. Field analysis in preceding table.
2/15-15F2. Casing perforated 74-104 ft below land surface in San Pedro formation of pleistocene age. Native calcium bicarbonate, sulfate water; analysis of 1931 indi-cates incipient contamination. Analysis by Los Angeles Department of Water and Power.

2/15-15H1. Drilled public-supply well; diameter 16 in; casing perforated 84-108 ft below land surface m San Pedro formation of Pleistocene age. Native calcium, sodium bicarbonate water. Analysis by California Division of Water Resources. 2/15-16J2. Drilled abandoned well; diameter 18 in; casing perforated 56-136 and 196-211 ft below land surface in San Pedro formation of Pleistocene age. Calcium, sodium sulfate, bicarbonate water, definitely contaminated. Analysis by Smith-Emery Co.
2/15-16J3. Drilled unused well; diameter 12 in. Probably taps San Pedro forma-tion of Pleistocene age. Water badly contaminated. Analysis by California Divi-sion of Water Resources.

2/15-22B2. Drilled irrigation well. May tap deposits of both Recent and Pleisto-cene age. Sodium sulfate water. Analysis indicates contamination although periodic chloride determinations show no increase in intensity since 1936. Strontium 14 ppm; electrical conductivity 3,270 micromhos; fiuoride, barium, and iodide absent. Analysis by T. Downer, U. S. Geological Survey. Field analysis in preceding table. 2/15-22B4. Drilled unused well; diameter 16 in; casing perforated 120-124 and 150- 171 ft below land surface in San Pedro formation. Sodium sulfate, bicarbonate water; analysis indicates contamination.
2/15-22F2. Drilled irrigation well; diameter 12 In. May tap deposits of both Recent and Pleistocene age. Calcium sulfate water; early analyses indicate moderate contamination, with consistent increase in intensity becoming ultimately a calcium sulfate chloride water. Analysis of 1945, fiuoride 0.1 ppm: strontium 22 ppm: elec-trical conductivity 3,450 micromhcs; barium and iodide absent. Analyses in 1929 and 1931 by Los Angeles Department of Water and Power; in 1939 by California Division of Water Resources; in 1945 by T. Downer, U. S. Geological Survey. Field analysis in preceding table.
2/15-22J1. Drilled domestic and irrigation well; diameter 12 in. Taps "50-ft gravel" of Recent age and possibly uppermost part of San Pedro formation of Pleistocene age. Calcium, sodium bicarbonate sulfate water; all analyses show marked contamination. Analysis of 1945, fiuoride 0.3 ppm; strontium 30 ppm; electrical conductivity 6,350 micromhos; barium and iodide absent. Analyses in 1936 and 1939 by Dr. Carl Wilson; in 1945 by T. Downer, U. S. Geological Survey. Field analysis in preceding table.

2/15-23C1. Drilled irrigation well: diameter 16 in. Taps the "50-ft gravel" of Recent age and probably the San Pedro formation of Pleistocene age. Sodium, calcium sulfate, chloride water, analysis indicates marked contamination. Fiuoride 0.4 ppm: strontium 8.5 ppm: electrical conductivity 2,460 micromhos; barium and iodide absent. Analysis by T. Downer, U. S. Geological Survey. Field analysis in preceding table.

Los Angeles Department of Water and Power; on July 31,1931, and in 1932 by Cali-fornia Division of Water Resources; in 1944 by Dr. Carl Wilson. Field analyses In preceding table.
2/15-34H1. Drilled unused well; diameter 12 in; casing perforated 185-203 ft below land surface in the San Pedro formation. Native sodium, calcium bicarbonate water. Analysis by Los Angeles Department of Water and Power.
2/16-34K1. Drilled public-supply well; diameter 16 in; casing perforated 97-133 ft below land surface in the San Pedro formation. Sodium bicarbonate water, essen-tially native. Analysis of November 1944, electrical conductivity 710 micromhos; iodide absent. Analysis in 1929 by Los Angeles Department of Water and Power; In 1932 and 1937 by California Division of Water Resources; in June 1944 by Dr. Carl Wilson; and in November 1944 by T. Downer, U. S. Geological Survey. Field anal-yses in preceding table.
3/13-6G1. Drilled public-supply well; diameter 12 in; casing perforated 250-256 and 271-298 ft below land surface in the upper and middle parts of the Silverado zone of Pleistocene age. Sodium bicarbonate water, typical of that zone but possibly blended to a small extent with waters above the Silverado water-bearing zone. Analysis by Smith-Emery Co.
3/13-8C2. Drilled public-supply well; diameter 12 in; casing perforated 165-175,301- 319, and 390-425 ft below land surface in the unnamed upper Plesitccene deposits and in the Silverado water-bearing zone. Calcium bicarbonate water, a blend of waters essentiallynative to range tapped. Analyses in 1931 and 1939 by California Division of Water Resources; others by Smith-Emery Co.
3/13-17Q1. Drilled unused well, formerly irrigation; diameter 14 in; casing per-forated at intervals 136^356 ft below land surface in the unnamed upper Pleistocene deposits and in the Silverado water-bearing zone. Calcium, sodium bicarbonate water, a blend of native waters. Analysis in 1931 by California Division of Water Resources.

3/13-20H1. Drilled public-supply well, diameter 12 in; casing perforated 178-195 ft below land surface in the '200-ft sand" in the unnamed upper Pleistocene deposits. Native calcium bicarbonate water. Analysis in 1931 by California Division of Water Resources; others by Smith-Emery Co.
3/13-27B1. Bored well. Taps shallow unconflned water. Sodium, calcium bicarbonate, chloride water, probably native. Analysis by California Division of Water Resources.

3/13-30P1. Drilled well, now abandoned; diameter 8 in. Taps shallow, unconfined water. Analyses by California Division of Water Resources.
3/13-31H4. Domestic well; diameter 3 in. Well taps shallow unconflned water. Calcium, sodium chloride, bicarbonate water. Fiuoride 0.2 ppm; iodide 0.0 ppm; electrical conductivity 1,470 micromhos. Analysis by E. W. Lohr, U. S. Geological Survey.
3/13-36D1. Drilled public-supply well; diameter 10 in. Taps Gaspur zone in alluvial deposits of Recent age. Calcium bicarbonate water native to the Gaspur. Periodic analyses indicate virtually no range in chemical character over 5-year term beginning in 1932. Average of 24 analyses between July 5,1932, and Mar. 3,1937, by
city of Long Beach chemical and physical testing laboratory.
3/14-1G1. Drilled public-supply well; diameter 14 in; casing perforated 220-256 and 265-270 ft below land surface in the Silverado water-bearing zone of the San Pedro formation. Calcium bicarbonate water, locally native. Analysis by Smith-Emery
Co.

to

2/15-23H1. Drilled irrigation well: diameter 14 in: casing perforated 33-102 ft below land surface in the "50-ft gravel" of Recent age and in the San Pedro formation of Pleistocene age. Sodium, calcium bicarbonate, sulfate water. Analyses show contamination. Analysis in 1945, fiuoride 0.3 ppm: strontium 16 ppm; electrical conductivity 2;670 micromhos; barium and iodide absent. Analyses in 1936 and 1939 by Dr. Carl Wilson; analysis in 1945 by T. Downer, U. 8. Geological Survey. Field analysis in preceding table.
2/15-23N1. Drilled domestic well. Taps the "50-ft gravel" of Recent age and the San Pedro formation. Sodium chloride, bicarbonate water, contaminated. Fiuo-ride 1.1 ppm; strontium 17 ppm: electrical conductivity 3,330 micromhos; barium and iodide absent. Analysis by T. Downer, U. S. Geological Survey. Field analysis in preceding table.
2/15-23P1. Drilled irrigation well: diameter 14 in; casing perforated 45-101 and 119- 140 ft below land surface in the "50-ft gravel" and in the San Pedro formation of Pleistocene age. Initially a native calcium, sodium bicarbonate water, contaminated since 1931. Analysis in 1930 by Los Angeles Department of Water and Power; that in 1931 by California Division of Water Resources; others by Dr. Carl Wilson. 2/15-23Q1. Bored well; now abandoned. Taps shallow unconfined waters. Sodium sulfate water, probably concentrated by evaporation from the capillary fringe. Analysts by Dr. Carl Wilson.
2/15-23Q2. Bored well; now abandoned. Probably taps both shallow, unconflned body and "50-ft gravel". Sodium, calcium sulfate water. Analysis by Dr. Carl Wilson.

2/15-24C1. Drilled unused well; diameter 16 in; casing perforated at intervals from 215 to 350 ft below land surface, in the San Pedro formation. Calcium, sodium bicarbonate water, essentially native. Analysis by California Division of Water Resources.

2/15-24D3. Drilled unused well; diameter 14 in: casing perforated 35-65 ft below land surface in the "50-ft gravel" of Recent age. Calcium, sodium sulfate, bicarbon-ate water, definitely contaminated. Analysis by Dr. Carl Wilson.
2/15-24L2. Drilled unused well; casing perforated 30-75 ft below land surface, principally in the "50-ft gravel" of Recent age. Calcium, sodium sulfate water, definitely contaminated. Analyses by California Division of Water Resources. 2/15-26B1. Drilled irrigation and public-supply well; diameter 18 in; casing per-forated 152-164, 218-221, and 276-292 ft below land surface in San Pedro formation of Pleistocene age. Sodium, calcium bicarbonate water, locally native. Analysis by California Division of Water Resources.

2/15-26B3. Drilled abandoned well; diameter 16 in; casing perforated 40-68 ft below land surface in the "50-ft gravel" of Recent age. Initial analysis indicates possible incipient contamination. Analysis in 1939 by Dr. Carl Wilson; others by Los An-geles Department of Water and Power.
2/15-26F1. Drilled unused well; diameter 10 in; casing perforated 55-67 ft below land surface in the "50-ft gravel" of Recent age. Calcium, sodium bicarbonate, sulfate water, definitely contaminated, although analyses of chloride in 1942 indicate little increase in intensity. Analyses by California Division of Water Resources. 2/15-27R1. Drilled unused well. Taps San Pedro formation of Pleistocene age-Sodium bicarbonate water, incipient contamination. Analysis by California Divi-sion of Water Resources.

2/15-34A1. Drilled public-supply well; diameter 18 in: casing perforated 137-200 ft below land surface in the San Pedj-o formation. Sodium bicarbonate water: initial analysis suggests incipient contamination by a sodium bicarbonate water, although subsequent analyses show no increase in intensity to 1944. Chloride determinations since 1944 show definite increase in salinity. Analyses in 1929 and on Apr. 1,1931, by

3/14-3K2. Drilled public-supply well; casing perforated 368-404 ft below land surface in the Silverado water-bearing zone. Initial analysis indicates sodium, calcium bicarbonate water, probably locally native although both analyses indicate possible blending with slightly inferior waters native to overlying zones.
3/14-4N1. Drilled public-supply well; diameter 12 in; casing perforated 323-336, 499-537,548-576, and 586-628 ft below land surface in the Silverado water-bearing zone. Sodium, calcium bicarbonate water, typically native to the Silverado zone. Sample of Sept. 19, 1932, from 329 ft, that of Sept. 23, 1931, from 504 ft below land surface. Analyses by Smith-Emery Co.
3/14-8D2. Drilled public-supply well; diameter 10 in. Presumably taps unnamed upper Pleistocene deposits. Analysis suggests a calcium bicarbonate water, probably a blend with shallow waters which here may be definitely inferior. Electrical con-ductivity 890 micromhos; iodide absent. Analysis by T. Downer, U. S. Geological Survey.
3/14-8E2. Drilled public-supply well: casing perforated 111-135 and 162-177 ft below land surface in "200-ft sand" within the unnamed upper Pleistocene deposits, and 270-275 ft in the Silverado zone. Calcium chloride water probably locally native but may be contaminated by an overlying inferior water of local origin.
3/14-9N2. Drilled public-supply well; diameter 14 in: casing perforated 321-360, 400-403,454-469, and 622-634 ft below land surface in the Silverado water-bearing zone and underlying basal Pleistocene deposits. Native sodium bicarbonate water. Analysis of 1945, fiuoride 0.4 ppm: strontium 1.5 ppm; electrical conductivity 555 micromhos: barium and iodide absent. Analysis A by Smith-Emery Co.; B, C, D, by California Division of Water Resources; E, F, by Dr. Carl Wilson: O, by T. Downer, IT. S. Geological Survey. Field analyses in preceding table.
3/14-9N3. Drilled public-supply well; diameter 16 in; casing perforated 295-318, 322-348 ft in upper part of Silverado water-bearing zone. Analysis of 1941 indicates sodium, calcium bicarbonate water locally native to that zone; analysis of 1944 sug-gests blending with inferior waters in the unnamed upper Pleistocene deposits. Analyses by Dr. Carl Wilson. Field analyses in preceding table.
3/14-10C1. Drilled public-supply well: diameter 12 in; casing perforated 361-368, 370-374, and 378-396 ft below land surface in the "400-ft gravel" in the upper part of the San Pedro formation. Analyses indicate blending in varying proportions of two or more native water types. Analysis of 1945 indicates water most characteristic of the "400-ft gravel." Analyses by Smith-Emery Co. Field analysis in preceding table. 3/14-10G1. Drilled public-supply well; diameter 18 hi; casing perforated 492-527, 546-568, 638-654, 676-680, and 703-711 ft below land surface in the Silverado zone. Sodium bicarbonate water, characteristic of that zone. Analysis by Dr. Carl Wilson. Field analyses in preceding table.
3/14-12Q2. Drilled public-supply well: diameter 16 in; casing perforated 250-260, 269-279, and 360-395 ft below land surface in Silverado water-bearing zone. Sodium bicarbonate water. Analyses by Smith-Emery Co. Field analysis in preceding table. 3/14-13J3. Drilled public-supply well; diameter 16 in; casing perforated 359-368, 400-452,498-538, and 586-602 ft below land surface in the Silverado water-bearing zone. Calcium bicarbonate water possibly locally native. Analyses by Smith-Emery Co. 3/14-15G1. Unused public-supply well; diameter 10 in: casing perforated 363-379 and 383-397 ft below land surface hi the "400-ft gravel" in the upper part of the San Pedro formation. Calcium, sodium bicarbonate water, believed native to the range tapped. Analysis by Smith-Emery Co.
3/14-17J1. Originally an oil well, but reperforated at intervals from 1,089 to 1,294
ft below land surface in the upper division of the Pico formation of Pliocene age, for pumping test of that water-bearing zone. Initial analysis, a composite of 7 samples collected during pumping test from Aug. 1 to about Aug. 4,1946; sodium bicarbonate CO

Notes to table 30 Continued

water believed essentially representative of interval tapped. Second analysis col-lected at some time during bailing test, Aug. 19-26,1946; believed not representative. Analyses by Standard Oil Oo.
3/14-17H. Drilled well; diameter 14 in; casing perforated 196-206, 304-370, 420-435, and 470-485 ft below land surface, principally in the Silverado water-bearing zone but also in the unnamed upper Pleistocene deposits. Water essentially native to Sil-verado zone. Analysis indicates only slight increase in chloride due to blending with shallow waters. Analysis by Smith-Emery Co.
3/14-18X3. Drilled industrial well; diameter 16 in; casing perforated 200-377 ft below land surface, aim- st wholly in Silverado water-bearing zone but also in bottom few feet of "200-ft sanrt" in unnamed upper Pleistocene deposits. Initial analysis indicates possible incipient contamination. Later analyses to 1940 indicate definite and progressive contamination. Chloride concentration of sample depends on when taken after pump started. Analyses D, E, F, O, II, by California Division rf Water Resources; I. by Los Angeles County Flood Control District; others by Standard Oil Co.

3/14-21B2. Drilled public-supply well; diameter 14 in; casing perforated 323-356, 379-406, and 430-468 ft bebw land surface in the Silverado water-bearing zone of the San Pedro formation. Sodium, calcium bicarbonate water, essentially native. Analysis of 1930 by Los Angeles County Flor d Control District; analyses of 1937 and 1945 by Smith-Emery Co.: that of 1944 by Dr. Carl Wilson.
3/14-22A1. Drilled public-supply well; diameter 16 in; casing perforated 319-382 ft below land surface in "400-ft gravel" and at intervals from 540 to 668 ft in Silverado water-bearing zone, both in San Pedro formation. Sample of May 5, 1941, from 325 ft and that of May S, 1941, from 548 ft below land surface. Calcium bicarbonate to calcium, sodium bicarbonate water, native blend from the two zones but analyses indicate water is largely from the f '4$9-ft gravel." Analysis of 1944 by Dr. Carl AVils n: others by Smith-Emery Co.
3/14-23L1. Drilled public-supply well; diameter 16 in; casing perforated 334-353 ft below land surface in the "400-ft gravel" in the San Pedro formation. Water essen-tially native. Analyses by Smith-Emery Co.
3/14-26G2. Drilled irrigation well; diameter 6 in. Taps shallow unconflned water. Inferior sodium, calcium chloride water, native to the unconflned body at shallow depth. Fluoride 0.2 ppm; electrical conductivity 6,770 micromhos. Analysis by U. S. Geological Survey. Field analysis in preceding table.
3/14-26J1. Drilled domestic and irrigation well; diameter 8 in; casing perforated 175-231 ft below land surface in "200-ft sand" in unnamed upper Pleistocene deposits. Calcium, sodium bicarbonate water, possibly incipiently contaminated. Fluoride 0.3 ppm; electrical conductivity 676 micromhos. Analysis by U. S. Geological Survey. Field analysis in preceding table.
3/14-26R1. Drilled irrigation and stock well; diameter 7 in. Taps shallow un-conflned water. Native inferior water. Electrical conductivity 3,320; iodide absent. Analysis by T. Downer, U. S. Geological Survey. Field analyses in preceding table. 3/14-29N1. Drilled public-supply well; diameter 16 in; casing perforated 206-227 and 265-275 ft below land surface in the upper part of the Silverado water-bearing zone. Calcium, sodium bicarbonate water, locally native to the range tapped. Analyses A, B, C, D, by Lcs Angeles Department of Water and Power; F, by California Divi-sion of Water Resources; others by California Water Service Co. Field Analyses in preceding table.
3/14-30A2. Drilled public-supply well; diameter 16 in; casing perforated 235-281

ft below land surface in the Silverado water-bearing zone of the San Pedro formation. Native sodium bicarbonate water, similar to that produced from 1H1. Analysis by Dr. Carl Wilson.

3/15-12G1. Drilled public-supply well; diameter 16 in; casing perforated 139-155 ft below land surface in the "200-ft sand" of the unnamed upper Pleistocene deposits, also 205-221 and 292-332 ft in the Silverado water-bearing zone of the San Pedro forma-tion. Lower zone probably correlative with that tapped in well 12B1. Analyses indicate blending of waters of the two zones in varying proportions. Analyses by Dr. Carl Wilson. Field analyses in preceding table.
3/15-12G2. Drilled public-supply well; diameter 16 in; casing perforated 135-153 ft below land surface in the "200-ft sand" of the unnamed upper Pleistocene deposits; also 197-203 and 318-323 ft in the Silverado water-bearing zone of the San Pedro forma-tion. Analyses indicate water chiefly from upper part of range penetrated. Calcium, sodium chloride water, definitely contaminated. Analysis of October 1944, electrical conductivity 936 micromhos; iodide absent. Analysis of 1944 by T. Downer, U. S. Geological Survey, others by Dr. Carl Wilson. Field analyses in preceding table. 3/15-12L1. Drilled public-supply well now abandoned; diameter 16 in; casing perforated 236-256 ft below land surface in the "200-ft sand" of upper Pleistocene age, also 290-320 ft in the Silverado water-bearing zone. Initially calcium bicarbonate water, essentially a native blend; later analyses indicate contamination, beginning about in mid-1931. Analyses B, F, and H by Standard Oil Co., M by California Division of Water Resources; others by Los Angeles Department of Water and Power.

3/15-12L6. Drilled public-supply well, now abandoned; diameter 16 in; casing perforated 222-248 ft below land surface in the "200-ft sand" of the unnamed upper Pleistocene deposits, and 298-318 ft in the Silverado water-bearing zone of the San Pedro formation. Calcium, sodium chloride water, contaminated. Analysis of September 1942, iodide, trace. Analysis of 1944, fluoride 0.2 ppm; strontium 12 ppm; electrical conductivity 2,150 micromhos; barium, trace; bromide, less than 10 ppm; iodide, absent. Analysis A from 210-222 ft below land surface; B from 222-248 ft below land surface; (7from 320-336 ft below land surface. Analysis 0 by Los Angeles County Flood Control District; I by T. Downer, U. S. Geological Survey; others by Dr. Carl Wilson. Field analyses in preceding table.
3/15-13A2. Drilled industrial well; diameter 16 in; casing perforated 249-276, 294-302 ft below land surface in the Silverado water-bearing zone of the San Pedro formation. Analysis of 1939 indicates sodium, calcium bicarbonate water essentially native to zone tapped. Later analyses indicate progressive contamination. Analysis of October 1944, electrical conductivity 1,270 micromhos; iodide absent. Analysis of Oct. 24, 1944, by T. Downer, U. S. Geological Survey; others by Standard Oil Co. Field analyses in preceding table. '
3/15-13E1. Drilled industrial well, now abandoned; diameter 26 in; casing per-forated 169-181 and 181-204 ft below land surface hi the upper part of the Silverado water-bearing zone cf the San Pedro formation. Water highly contaminated. Analyses by Standard Oil Co.
3/15-13R1. Drilled industrial well; diameter 16 in; casing perforated 294-342 and 372-396 ft in the middle and lower parts of the Silverado water-bearing zone of the San Pedro formation. Native sodium, calcium bicarbonate water. Analyses by Standard Oil Co.

3/15-13R4. Drilled industrial well; diameter 16 in; casing perforated 368-408 ft in the lower part cf the Silverado water-bearing zone in the San Pedro formation.

ft below land surface in the Silverado water-bearing zone. Sodium bicarbonate water, Ircally native to the lower part of the range tapped. Analysis by Dr. Carl Wilson,
3/14-30D1. Drilled public-supply well; diameter 16 in: casing perforated 2267252 ft below land surface in the Silverado water-bearing zone in the San Pedro formation. Under native conditions, water probably similar to that of well 31A8: however, analyses indicate progressive contamination beginning in 1938 or earlier. Analysis of Oct. 24, 1944, fluoride 0.2 ppm; strontium 4.1 ppm; electrical conductivity 1,120 micromhos; barium, iodide, and bromide absent. Analysis in 1938 by Smith-Emery Co.: that of Oct. 24,1944, by T. Downer, U. S. Geological Survey: others by Dr. Carl Wilson. Field analyses in preceding table.
3/14-30H1. Drilled public-supply well: diameter 18 in: casing perforated 142-154 ft below land surface in the unnamed upper Pleistocene deposits and at intervals from 218 to 300 ft in the Silverado water-bearing zone. Analyses since that of 1941 indicate a calcium, sodium bicarbonate water, probably a blend of native waters in the two zones tapped. Analyses of October 1944, fiuoride, 0.2 ppm; strontium 3.4 ppm; elec-trical ccnductivity 891 micromhos: barium, iodide, and bromide absent. Analysis in 1941 by Smith-Emery Co.; that of Oct. 24, 1944, by T. Downer, U. S. Geological Survey; < thers by Dr. Carl Wilson. Field analyses in preceding table. 3/14-3(Ml. Drilled irrigation well. Probably taps chiefly the unnamed upper Pleistocene deposits. Water markedly contaminated. Analysis of Oct. 1944. electrical conductivity 977 micromhcs; iodide absent. Analysis of Oct. 24, 1944, by T. Downer, U. S. Geological Survey; others by Dr. Carl Wilson. Field analyses in preceding table.
3/14-31A8. Drilled well, formerly public-supply; diameter 16 in; casing perforated 190-472 ft below land surface in the Silverado water-bearing zone. Of the several

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ublic-supply wells in this local area, 31A6 spans the largest vertical range in the ilverado zone. Native calcium, sodium bicarbonate water. Analysis by California Division of Water Resources.

3/14-31 El. Irrigation well; diameter 8 in. Position of perforations not known but comparatively low chloride content suggests that only the topmost part of Silverado water-bearing zone is tapped. Calcium, sodium bicarbonate water, essentially native. Analysis of October 1944, electrical conductivity 644 micromhos; iodide absent. Analyses in 1931,1932, and 1937 by California Division of Water Resources; that in 1944 by T. Downer, U. S. Geological Survey. Field analyses in preceding table.

3/14-32A1. Drilled public-supply well; diameter 16 in.; casing perforated 173-327 ft below land surface in the Silverado water-bearing zone. Native calcium bicar-bonate water. Analyses A, B, C, by Los Angeles Department of Water and Power; D, E, by California Division of Water Resources; F, by California Water Service Co. Field analyses in preceding table.
3/14/-35R1. Drilled industrial well; diameter 8 in; casing perforated 470-485 and 522-528 ft. below land surface in the Silverado water-bearing zone of the San Pedro formation. Sodium, calcium bicarbonate water, native to this zone. Analysis of February 1948, fluoride 0.3 ppm; electrical conductivity 435 micromhos. Analysis in 1946 by U. S. Geological Survey; others by California Division of Water Resources. Field analysis in preceding table.
3/15-1H1. Drilled, domestic and irrigation well; diameter 12 in; casing perforated 120-*132 and 180-190 ft below land surface in the Silverado water-bearing zone of the San Pedro formation. Sodium bicarbonate water, presumed native to the range tapped. Analyses by California Division of Water Resources. Field analysis in preceding table.
3/15-12B1. Drilled public-supply well; diameter 16 in; casing perforated 186 to 21

Analyses in 1943-44 indicate a sodium, calcium bicarbonate water slightly contami-nated; later analyses show definite contamination. Analyces by Standard Oil Co. Field analyses in preceding table.
3/15-13R5. Drilled industrial well; diameter 16 in; casing perforated 284-310 and 426-456 ft below land surface in the middle and lower parts of the Silverado water-bearing zone of the San Pedro formation. Sodium, calcium bicarbonate water native to range perforated. Analysis of October 1944, fluoride 0.2 ppm; strontium 4.8 ppm; electrical conductivity 718 micromhos; barium, bromide, and iodide absent. Analysis of Oct. 24,1944, by T. Downer, U. S. Geological Survey; others by Standard Oil Co. Field-analyses in preceding table.
3/15-24D1. Drilled unused well, formerly public-supply; diameter 16 in; casing perforated 1S9-184,196-212, and 242-2SO ft below land surface in the Silverado water-bearing zone of the San Pedro formation. Sample of 1936 a calcium, sodium bicar-bonate water, probably native; later sample contaminated. Analysis of 1938 by Srnith-Emery Co.; that of 1944 by Dr. Carl Wilson. Field analyses in preceding table.

3/15-25A1. Drilled public-supply well; diameter 14 in; casing perforated 214-218 and 225-235 ft below land surface in the Silverado water-bearing zone of the San Pedro formation. Earliest analysis of a sodium, calcium bicarbonate water essentially native; later analyses indicate contamination beginning in 1931. Analysis of 1942, iodide absent. Analysis of October 1944, strontium 23 ppm; electrical conductivity 2,080 micromhos; bromide, iodide, barium, and fluoride absent. Analyses in 1929, 1930, and 1931 by Los Angeles Department of Water and Power; that in 1943 by R. G. Osborne; that of Aug. 15,1944, and of Jan. 15,1945, by Dr. Carl Wilson; that of Oct. 24,1944, by T. Downer, U. S. Geological Survey. Field analyses in preceding table. 3/15-25A4. Drilled public-supply well; now abandoned; diameter 16 in; casing per-forated 222-252 and 284-293 ft below land surface in the Silverado water-bearing zone of the San Pedro formation. Sodium, calcium bicarbonate water, locally native. Analysis by California Division of Water Resources.
3/15-25H1. Drilled public-supply well; diameter 16 in; casing perforated 221-240 ft below land surface in the Silverado water-bearing zone of the San Pedro formation; also 527-541 ft below land surface, probably in the upper division of the Pico formation of Pliocene age. Series of analyses show increasing contamination. Probably most of the water is produced from the upper zone perforated. Analysis of October 1944, electrical conductivity 1,920 micromhos; iodide absent. Analyses in 1943 by R. G. Osborne; on Oct. 27,1944, by T. Downer, U. S. Geological Survey; others by Dr. Carl Wilson. Field analyses in preceding table.
4/13-2P4. Drilled stock and irrigation well; diameter 14 in. Doubtless taps Gaspur zone in alluvial deposits of Recent age. Essentially native calcium bicar-bonate water; incipient contamination possible. Analysis by California Division of Water Resources.

4/13-6J1. Domestic and stock well; diameter 4 in. Taps unconfirmed water in unnamed upper Pleistocene deposits. Analyses by California Division of Water Resources.

4/13-8L1. Dug domestic and irrigation well; diameter 38 in. Taps water in un-confined body at shallow depth. Sodium sulfate water, probably concentrated by evaporation or possibly by blending with saline waters. Analyses by California Division of Water Resources.
4/13-12A2. Drilled unused well; diameters 26 and 16 in. Native sodium bicar-bonate water, from upper division of Pico formation. Analysis by city of Long Beach chemical and physical testing laboratory.
4/13-14Q4. Drilled domestic and irrigation well; casing perforated 800-900 ft below land surface, in central part of Silverado zone ta San Pedro formation. Sodium

Notes to table 30 Continued

bicarbonate water; character essentially native to upper and central parts of Silverado water-bearing zone. Analyses by California Division of Water Resources. 4/13-15A2. Drilled public-supply well; diameter 10 in; casing perforated 830-980 ft below land surface, in central part of Silverado water-bearing zone in San Pedro formation. Sodium bicarbonate water; native to the zone perforated. Analysis in 1931 by California Division of Water Resources; that in 1945 by Smith-Emery Co. 4/13-15A3. Drilled public-supply well; diameter 10 in; casing perforated 100-135 ft below land surface, in Qaspur zone in alluvial deposits of Recent age. Initial analysis indicates calcium bicarbonate water essentially native to the Qaspur zone, though perhaps incipiently contaminated; later analyses indicate definite contami-nation. Analysis in 1931 by California Division of Water Resources; later analyses by Smith-Emery Co.
4/13-19H1. Domestic well. Taps unnamed upper Pleistocene deposits. Calcium chloride, bicarbonate water; essentially native to zone perforated. Fluoride 0.4 ppm; bromide 0.0 ppm; iodide 0.0 ppm; electrical conductivity 849 micromhos. Analysis by E. W. Lohr, U. S. Geological Survey.
4/13-19J4. Formerly domestic and irrigation well. Taps unnamed upper Pleisto-cene deposits. Sodium chloride, bicarbonate water; locally native to zone perforated. Analyses by California Division of Water Resources.
4/13-21Q1. Drilled industrial well; diameters 20 and 12 in; casing perforated 435-625 and 641-661 ft below land surface, in upper and central parts of Silverado water-bearing zone in San Pedro formation. Sodium bicarbonate water, essentially native to the deeper part of the range perforated. Analysis by Shell Oil Co.
4/13-22E1. Drilled industrial well; diameter 18 in; casing perforated 415-425,447-527, and 590-645 ft below land surface, in upper and central parts of Silverado water-bearing zone in San Pedro formation. Sodium bicarbonate water, essentially native to the zones perforated. Pluoride 0.2 ppm; electrical conductivity 370 micromhos. Analysis by E. W. Lohr, U. S. Geological Survey.
4/13-30K1. Drilled public-supply well. Probably taps Silverado water-bearing zone in San Pedro formation. Sodium bicarbonate water; character essentially native to upper part of Silverado zone. Analyses by Los Angeles Department of Water and Power.
4/13-31E3. Drilled public-supplv well, now abandoned; diameters 16 and 12 in; casing perforated 206-212,235-240,340-420,440-450,475-E30, and 610-630 ft below land surface in upper and central parts of Silverado water-bearing zone in San Pedro formation. Sodium bicarbonate water, locally native to zone perforated; character probably influenced by connate water in the Silverado zone southeast of well. Analy-sis by California Division of Water Resources.
4/13-31E4. Drilled public-supply well, diameter 20 in; casing perforated 440-560 and 605-655 ft below land surface, in central part of Silverado water-bearing zone in San Pedro formation. Sodium bicarbonate water; local native character, probably influenced by connate water in the Silverado zone southeast of well. Sulfate content here greater in the central part of the Silverado zone than in the upper part. (See analysis 31E3.) Analysis by Los Angeles Department of Water and Power. 4/18-35M3. Drilled industrial well, diameter 12 in; casing perforated 115-139 ft below land surface, in Gaspur zone of alluvial deposits of Recent age. Analysis of Jaiiu&ry 1928 is approximate but may indicate roughly the character of water locally native to the Gaspur; later analysis indicates gross contamination. Analysis of 1942, fluoride, bromide, and iodide, 0.0 ppm; electrical conductivity 13,500 micromhos.

4/14-7J3. Drilled abandoned well; diameter 14 in; casing perforated 210-241 ft below land surface in upper part of Silverado water-bearing zone in San Pedro formation. Native sodium bicarbonate water. Analysis by California Water Service Co. 4/14-8C1. Drilled public-supply well; diameter 16 in; casing perforated at intervals 232-450 ft below land surface in the Silverado water-bearing zone of the San Pedro formation. Analysis of October 1944, strontium 3.0 ppm; fluoride 0.2 ppm; electrical conductivity 644 micromhos; bromide, iodide, and barium absent. Analysis of Oct. 30, 1944, by T. Downer, U. S. Geological Survey; others by Smith-Emery Co. Field analyses in preceding table.
4/14-8E1. Drilled unused well; formerly public-supply. Diameter 18 in; casing perforated 228-259 ft below land surface in the Silverado water-bearing zone of the San Pedro formation. Initial analysis indicates sodium bicarbonate water, presumed native; later analyses show definite contamination. Analyses in 1931 and 1939 by California Division of Water Resources, that in 1936 by Los Angeles Department of Water and Power.

4/14-9K1. Drilled industrial well; diameter 12 in; casing perforated 241-252,300-312, and 380-395 ft below land surface in Silverado water-bearing zone of San Pedro for-mation. Sodium bicarbonate water native to range tapped in central part of Tor-ranee plain. Analysis in 1946 indicates contamination, doubtless from local source. Analyses by Chanslor, Canfleld, Midway Oil Co.
4/14-11G2. Drilled industrial well, now abandoned; diameter 14 in; casing per-forated 293-304,350-364, 380-388, and 577-588 ft below land surface in Silverado water-bearing zone of San Pedro formation. Native sodium bicarbonate water, typical of the Silverado zone in the trough of its syncline in Torrance-Inglewood subarea. Analysis in 1929 by Smith-Emery Co.; that in 1931 by California Division of Water Resources.

4/14-16L3. Drilled abandoned well, formerly public-supply; diameter 14 in; casing perforated 244-275 ft below land surface in upper part of Silverado water-bearing zone of San Pedro formation. Sodium bicarbonate water, essentially native to range penetrated in central part of Torrance plain. Analysis by Smith-Emery Co. 4/14-17E1. Drilled abandoned well; diameter 18 in; casing perforated 257-268 and 379-400 ft below land surface in the Silverado water-bearing zone of the San Pedro formation. Inferior water, possibly locally native. Analysis by California Water Service Co.

4/14-17G1. Drilled domestic and irrigation well; diameter 16 in; casing perforated at intervals 305-390 ft below land surface in Silverado water-bearing zone of San Pedro formation. Water essentially native. Analyses by California Division of Water Resources. Field analyses in preceding table.
4/14-17N1. Drilled public-supply well; diameter 18 in; casing perforated 224-338 ft below land surface in the Silverado water-bearing zone of San Pedro formation. Water native. Analysis in 1930 by California Water Service Co.; that in 1931 by California Division of Water Resources. Field analysis in preceding table. 4/14-20J1. Drilled irrigation well; diameter 12 in; casing perforated 282-297 and 346-360 ft below land surface in the Silverado wa^er-bearing zone of San Pedro for-mation. Sodium, calcium bicarbonate water; a blend of native Silverado water with diluted connate water underlying the flank of Palos Verdes Hills. Analyses by California Division of Water Resources. Field analysis in preceding table. 4/14-23N2. Drilled public-supply well; diameter 16 in; casing perforated 560-614
ft below land surface in the lowermost part of the Silverado water-bearing zone of

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Analysis in 1923 by A. R. Maas Laboratories, Los Angeles; that in 1942 by E. W. Lohr, U. S. Geological Survey.
4/14-1H. Drilled industrial well; diameter 14 in. Sample may be from HI, H2, or H3, whose reported depths below land surface are respectively 600, 596, and fi96 ft. All tap the Silverado water-bearing zone of the San Pedro formation. Calcium, sodium, bicarbonate water, locally native. Analysis by R. G. Osborne. 4/14-5N1. Drilled observation well; formerly public-supply. Diameters 28 and 16 in. Gravel-packed from 98 ft to bottom of well. Taps Silverado water-bearing zone in San Pedro formation. Calcium, sodium bicarbonate water, incipiently contaminated. Analysis by Los Angeles County Flood Control District. 4/14-5N2. Drilled abandoned well; formerly public-supply. Diameter 12 in; casing perforated 224^230 and 250-267 ft below land surface in the upper part of the Silverado water-bearing zone of San Pedro formation. Sodium, calcium bicarbonate water, locally native within upper part of range penetrated. Analyses since 1932 indicate increasing contamination. Analysis of 1942, iodide, trace. Analysis of 1944, strontium 36 ppm; electrical conductivity 3,680 micromhos; bromide, iodide, and fiuoride absent. Analysis of 1945, strontium 32 ppm; electrical conductivity 5,580 micromhos; iodide, barium, and fiuoride absent. Analysis in 1942 by Los Angeles County Flood Control District; those in 1944 and 1945 by T. Downer, U. S. Geological Survey; others by California Division of Water Resources. Field analyses in preceding table.

San Pedro formation. Sodium bicarbonate water, of a type generally native to that part of range tapped. Analysis by Dr. Carl Wilson. Field analysis in preceding table.

4/14-35E2. Drilled public-supply well; diameter 18 in; casing perforated 348-402, 430-460, and 570-630 ft below land surface in Silverado water-bearing zone of San Pedro formation. Analysis shows effect of blending with diluted connate waters underlying the flank of Palos Verdes Hills. Electrical conductivity 982 micromhos; iodide absent. Analysis by T. Downer, U. S. Geological Survey. Field analyses in preceding table.
4/14-36H1. Drilled public-supply well; diameters 26-12 hi; casing perforated 208-214 and 332-610 ft below land surface hi Silverado water-bearing zone of San Pedro for-mation. Water essentially native. Analyses by Dr. Carl Wilson.
5/13-3H. Formational sample at 1,300 ft below land surface in upper division of Pico formation of Pliocene age. Sodium bicarbonate water, probably native to the zone locally.
5/14-12C1. Abandoned well, formerly irrigation. Probably taps San Pedro for-mation and possibly also underlying deposits of Tertiary age. Sodium, calcium chloride, bicarbonate water, native within range tapped. Analyses hi 1930 and 1931 by Los Angeles Department of Water and Power; in 1939 by California Division of Water Resources.

TABLE 31. Chemical analyses representing the character of known or potential contaminants in the Torrance-Santa Monica area
[a When analyzed, 0.03 ppm in solution; b calculated; ° iron and aluminum oxides (FeaOs+AljOs). Minor constituents are listed in notes at end of table. For representative ,N. chemical analyses of connate waters from the Dominguez and Wilmington oil fields, oil-field wastes, industrial and miscellaneous wastes, and streams contaminated by |_i those wastes, sec an earlier report (Piper, Garrett and others, 1953, table 29). Analyses of connate waters from the Inglewood oil field after Jensen (1934)] QQ

Well Source

Depth
(feet)

Date of col-
lection

Tem-
per-
ature
(°F)

Parts per million

Dissolved
solids at
180° C

Silica
(SiOs)

Iron

(Fe)

Cal-
cium

(Ca)

Mag-
ne-

sium

(Mg)

Sodium
(Na)

Po-
tas-
sium

(K)

Bicar-
bonate

(HC03)

Car-
bon-
ate

(C03)

Sul-
fate
(S04)

Chlo-
ride

(Cl)

Bo-
rate

(B03)

Hard-

ness
as

CaCOj
(calcu-
lated)

Ocean water

Standard analysis as of
1940.
Gan Pedro, from'seaward
side of breakwater, 1
mile offshore.

May 18,1941 65

34, 482

34,100 0.8 "0.04

400

393

1,272

1,228

10, 556

blO, 220

380

363

140

139 0

2,649

2,560

18,980

18,360

25

6,030

Connate waters from the Inglewood oil field

2/14-7H..
7H___-.
7J_.._..
8E___.-

8K__,__
17H.._-

Tidewater Associated Oil
Co.:

Vickerswell34__--___

The Texas Co., Meynier
well 1.
Standard Oil Co.:
Baldwin well 19_ ..
Baldwin well 21 ___

2,545
2,177
3,210
1.750

2,741
2,410

Oct. 20,1925
Aug. 30,1925
Apr. 19,1926
Oct. 15,1925

Mar. 19, 1926
July 27,1925

b 32, 695
b 32, 876
b 31, 078
b 30, 275

b 28, 210
b 33, 160

404
304
468
400

590
668

673
650
537
583

345
540

b 11, 195
b 11, 527
b 10, 802
b 10, 407

b 9, 745
b 11, 466

1,925
823
1,335
1,981

297
1,730

54
13
56
37

53
39

19, 406
19, 970
18, 547
17, 857

17, 328
19, 582

3,769
3,425
3.372
3,390

2,890
3,884

Connate waters from the Rosecrans oil field

3/13-7. .-

19A..-

19A__-

19B__-

19G---

19H(?)_

Union Oil Co.:
Rosecrans lease, well
1.
Rosecrans lease, well
24.
Rosecrans lease, well
34.
Rosecrans lease, well
40.

Superior Oil Co.. Max-

4,948

Unknown

Unknown

Unknown

Unknown

Unknown

Apr. 24,1924

Mar. 17,1924

Apr. 29,1940

..... do........

_ do.

Mar. 14. 1939

b 30, 652

b 33, 569

b515

b 24, 557

b 20, 488

b 31. 335

80 ° 13

599

436

19

616

503

959

151

591

8

142

78

204

b 11, 237

b 12, 135

bl!7

b8,882

b7,487

b 11. 139

65

1,222

410

3,532

3,052

5.431

116

0

6.1

52

1

1

8

5

18, 510

19, 744

165

13, 150

10,886

16. 312

2,117

3,513

80

2,122

1,577

3.234

Connate waters from the Playa del Ray'oil field

2/15-21M(?)_

21N(?)_

Union Oil Co.:
Del Key welll.... _
Del Key well 2.. . ....
Elmer Oil Co., Venice
well 6.
Twin Buttes Oil Co.,
Byrens well 1.
Pacific Western Oil Co.,
Stanley Lieber well 1.

3,585
5,740
Unknown

6,190

6,100

May 12,1930
Feb. 20,1931
Feb. 16,1931

Feb. 17,1931

Feb. 16,1931

b 30, 726
b 17, 864
b 13, 496

b 26, 247

b 24, 820

436
356
136

262

311

368
157
32

52

17

b 11, 039
b 6, 695
b5,183

b 10, 183

b9,458

437
9,481
2,267

7,077

1,989

0
0
0

0

0

191
51
4

131

25

18, 473
5,864
7,007

12, 198

14, 014

2,599
1,534
471

868

847

Connate waters from the Torrance oil field

4/14-9D_ .

15A __

Southern Midway Co.,
Grindy lease, well 1.
Southland Petroleum
Co., Winship lease,
well 1.
Fullerton Oil Co., Lenz
lease, well 1.
Chanslor, Canfleld, Mid-
way Oil Co., Torrance
lease, well 12.

3,421

3,514

3,925

Unknown

Feb. 2, 1924

Apr. 10,1924

July 3, 1923

Oct. 22,1923

b 33, 147

b 30, 641

b 28, 970

b 26, 560

165 "170

497

465

393

576

265

292

224

223

b 12, 116

b 11, 220

b 10, 444

b 9, 375

162

632

650

445

0

38

18

23

4.2

20, 150

18, 332

17, 561

16, 159

2,329

2,360

1,901

2,354

Notes to table 31

Ocean water, standard. Referred to astandard "chlorinity" of 19,000 ppm (Sverdrap and others, 1942, p. 166). Strontium 13 ppm, bromide 65 ppm, fiuoride 1 ppm. Ocean water, San Pedro. From seaward side of breakwater, 1 mile offshore. Iodine less than 0.5 ppm, bromide 49 ppm. Analysis by O. J. Petretic, Geological Survey. 2/14-7H. VickerswellS, Water shutoff reported at 1,309ft. Ammonium 305 ppm. 2/14-7H. Vickerswell34. Water shutoff reported at 1,379ft. Ammonium 254 ppm. 2/14-7J. Water shut off reported at 2,566 ft. Ammonium 168 ppm.
2/14-8E. Water shutoff reported at 1,255 ft. Ammonium 331 ppm.
2/14-8K. Plugged at 2,500 ft. Ammonium 157 ppm.
2/14-17H. Water shut off reported at 1,775 ft. Ammonium 201 ppm.
3/13-7. Sampled from interval 4,938 to 4,948 ft.
3/13-19 A (Rosecrans lease, well 1). Sampled during swabbing after fourth re-cement job. Analysis by Union Oil Co.
3/13-19A (Rosecrans lease, well 24). Sampled from flow line. Ammonium 85 ppm. Analysis by Union Oil Co.

3/13-19B. Sampled from flow line. Analysis by Union Oil Co. 3/13-19G. Sampled during swabbing. Analysis by Union Oil Co. 3/13-19H(?). Sampled from dehydrator. Analysis by Union Oil Co.
Del Rey well 1. Sampled during swabbing. Analysis by Union Oil Co. 2/15-21M (?). Analysis by Union Oil Co.
2/15-21N(?). Analysis by Union Oil Co.
Stanley Lieber well 1. Analysis by Union Oil Co.
Grindy lease, well 1. Sampled from flow line. Analysis by Standard Oil Co. Winship lease, well 1. Sample bailed from bottom of well. Analysis by Union Oil Co.

4/14-9D. Sampled from settling tank. Ammonium 213 ppm. Analysis by Pacific Oil Co.

4/14-15A. An 8}£-inch casing perforated 3,514 ft below land surface. Analysis by Pacific Oil Co.

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238, 245, 247, 256, 258, 386-396, 397-409;
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