# Hydrology of the Long Beach-Santa Ana Area, California

WITH SPECIAL REFERENCE TO THE WATERTIGHTNESS OF THE NEWPORT-INGLEWOOD STRUCTURAL ZONE

*By* J. F. POLAND

*With a section on* WITHDRAWAL OF GROUND WATER, 1932-41

*By* ALLEN SINNOTT *and* J. F. POLAND

---

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1471

*Prepared in cooperation with the Orange County Flood Control District, the Orange County Water District, the Los Angeles County Flood Control District, and the Board of Water Commissioners of the city of Long Beach*

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1959

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U. S. Geological Survey Library catalog card for this publication appears after page 257.

---

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D.C.

# CONTENTS

Regional ground-water conditions—Continued

Principal fresh-water body—Continued

---

# ILLUSTRATIONS

[Plates 1–11 in Plate Volume]

---

## TABLES

# HYDROLOGY OF THE LONG BEACH–SANTA ANA AREA, CALIFORNIA, WITH SPECIAL REFERENCE TO THE WATERTIGHTNESS OF THE NEWPORT–INGLEWOOD STRUCTURAL ZONE

By J. F. Poland

## ABSTRACT

This is the last of three reports describing ground-water features in the Long Beach–Santa Ana area and examines the hydrology with special reference to the watertightness of the Newport–Inglewood structural zone. The first section of this report presents results from an inventory of withdrawal of ground water in the Long Beach–Santa Ana area from 1932 through 1941 and in part through 1944—specifically, it describes the methods used in evaluating withdrawal, presents the yearly withdrawal by each city with a municipal water-supply system, and summarizes the estimated yearly withdrawal in each county by cities with municipally-owned systems and by private agencies for industrial, agricultural, and domestic uses. The area of inventory embraces all the coastal plain east of Vermont Avenue, including the relatively small La Habra basin. The next section of this report describes the principal water-bearing zones from which the ground water is withdrawn.

Mendenhall in 1903–4 made the only comprehensive previous estimate of ground-water withdrawal within the area, at which time about 160,000 acre-feet a year was used from flowing and pumped wells. Other estimates by several different agencies, made in the late twenties and in the thirties, are summarized in this report. However, each of these covered only a part of the subject area and was concerned more with over-all use than with ground-water draft.

In the evaluation of ground-water withdrawal, records were collected directly from the nine cities in Los Angeles County and the nine cities in Orange County that operate municipal water systems; these records are tabulated by years through 1944. Withdrawal by industrial plants was estimated through a brief but reasonably comprehensive field canvass, that embraced about 80 percent of such withdrawal in Los Angeles County and 90 percent in Orange County. Withdrawal for irrigation, which comprises about half the total in Los Angeles County and more than 80 percent of the total in Orange County, was evaluated 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. Adjustments were made for an estimated 10 percent of irrigation water raised by nonelectric pumps.

From 1932 through 1941 the yearly withdrawal of ground water from the part of the area in Los Angeles County ranged from 164,000 to 197,000 acre-feet and the average was about 182,000 acre-feet; from the part of the area in Orange County the yearly withdrawal ranged from 114,000 to 181,000 and the average was about 142,000 acre-feet. For the entire area the average was about 324,000 acre-feet a year.

Within the Long Beach–Santa Ana area, the aquifers that yield ground water are tapped by 6,000 to 8,000 active or potentially active water wells of substantial capacity. Their depths range from 6 to 1,755 feet. In the coastal zone 32 percent of the wells range from 100 to 199 feet deep and only 3 percent (50 wells) are more than 1,000 feet deep. The wells of largest capacity commonly tap one or more of a few principal water-bearing zones. In Los Angeles County the wells of largest capacity occur (1) in and near Whittier Narrows, where many of the wells yield more than 1,000 gpm (gallons per minute) and a few yield more than 3,000 gpm; and (2) in the Long Beach district, where almost all the deeper wells yield more than 1,000 gpm and two wells yielded 4,000 gpm or more on initial test. Most of the productive wells in the Long Beach district tap the Silverado water-bearing zone of Pleistocene age. In Orange County the wells of largest capacity occur (1) in and near Santa Ana Canyon, where most wells yield more than 1,000 gpm and a very few yield more than 3,000 gpm; and (2) locally on and near the north end of Newport Mesa, where several of the deeper wells yield more than 2,000 gpm. In the remainder of the project area, yields commonly range from 300 to 1,000 gpm.

With respect to principal water-bearing zones, this report summarizes their depth below land surface and thickness from place to place, the districts where each is tapped by wells, their relative water-yielding capacities, their estimated over-all yield, and the uses to which the water is put.

The two principal aquifers in the alluvial deposits of Recent age are the Gaspur and Talbert water-bearing zones. The Gaspur zone extends inland 21 miles from Terminal Island to the Whittier Narrows, ranges in width from 1 to 4 miles, and ranges in thickness from 40 to 80 feet; its top is from 50 to 100 feet below land surface. It is tapped by wells throughout its full reach and the estimated withdrawal as of 1941 was about 25,000 acre-feet a year. The Talbert zone extends inland 20 miles from the Pacific Ocean to the Santa Ana Canyon, ranges in width from 1.2 to 6 miles, and ranges in thickness from 40 to 110 feet; its top is from 50 to 90 feet below land surface. It is tapped by wells from the coast inland about to Anaheim; the estimated withdrawal as of the early forties was between 25,000 and 30,000 acre-feet a year. The "80-foot gravel" underlies Bolsa Gap, has an over-all extent of about 10 square miles between Midway City and the coast, and yields an estimated 2,500 acre-feet of water a year. This local aquifer is in hydraulic continuity with the Talbert zone.

In the coastal zone of Los Angeles County the water-bearing deposits of Pleistocene age include (1) minor zones at shallow depth, (2) the Silverado water-bearing zone in the central and lower parts of the San Pedro formation, and (3) the water-bearing zone in the basal Pleistocene deposits northeast of Signal Hill.

Although the minor water-bearing zones are thin and discontinuous, they are tapped by many water wells of small capacity, of which most yield lightly to plunger pumps but a few yield several hundred gallons a minute to turbine pumps.

The Silverado water-bearing zone of the Long Beach district is the most extensive and productive single aquifer in the project area. It is tapped by many wells of large capacity, chiefly for industrial and municipal supply. The total withdrawal from the Silverado zone within the area has been from 30,000 to 35,000 acre-feet a year in the late thirties. In the war period from 1941 to 1945, industrial expansion in the vicinity of Long Beach and Wilmington increased the yearly draft from the Silverado zone by about 9,000 acre-feet.

The water-bearing zone in the basal Pleistocene deposits northeast of Signal Hill ranges from 250 to 500 feet in thickness and, as tapped by 7 active wells, its top is from 725 to 1,361 feet below land surface. During the early forties, nearly half the yearly withdrawal by the city of Long Beach—that is, about 10,000 acre-feet—was from this zone.

In the inland area of Los Angeles County the deposits of Pleistocene age range from 1,200 to 3,000 feet in thickness except along the south flank of the inland hills where they thin to a featheredge. Water-bearing zones in these deposits are tapped by wells to depths as great as 1,755 feet. Most of these wells yield from 400 to 1,000 gpm. In 1941 the several zones supplied about 100,000 to 110,000 acre-feet of water.

In the coastal zone of Orange County the water-bearing deposits of Pleistocene age include (1) dispersed zones between the San Gabriel River and Huntington Beach Mesa, (2) several zones beneath Huntington Beach Mesa, and (3) a single principal zone beneath Newport Mesa.

The dispersed water-bearing zones between the San Gabriel River and Huntington Beach Mesa occur in a wedge of deposits which are 500 to 900 feet thick along the Newport–Inglewood uplift and from 1,100 to 1,700 feet thick along the inland edge of the coastal zone. These deposits are tapped by many wells which in 1945 yielded about 10,000 acre-feet a year, largely for agricultural use.

Beneath Huntington Beach Mesa the Pleistocene deposits contain three water-bearing zones. The two upper zones are each about 50 feet thick and have become contaminated by salt water. The lowest zone, which is about 250 feet thick, has been tapped by relatively few wells but presumably was uncontaminated as of 1945 and presumably affords a large reserve source of water.

The principal water-bearing zone of Newport Mesa underlies at least 16 square miles, is from 300 to 521 feet thick, and is tapped by more than a score of wells. It dips northward beneath and beyond the mesa and its top is from 236 to as much as 1,065 feet below land surface. Individual wells yield more than 2,000 gpm and the over-all draft was somewhat more than 3,000 acre-feet a year in 1945.

In the inland area of Orange County the water-bearing zones of Pleistocene age range from a featheredge to more than 3,000 feet in thickness. They are tapped by several thousand wells which are from 150 to 1,300 feet deep, which range in yield from a few hundred to 3,000 gpm, but for which the average yield is about 600 to 800 gpm. As of the early forties about 80,000 to 100,000 acre-feet of water was withdrawn yearly from these deposits.

The distinct bodies of ground water of the area are (1) a body of semiperched water which occurs at shallow depth; (2) the principal body of fresh ground water which occurs in the coarser basal deposits of the Recent alluvium, in about all the deposits of Pleistocene age, and in the upper division of the Pico formation; and (3) a body of saline water which underlies the fresh-water body throughout the area.

The semiperched body is unconfined and almost everywhere is separated from the underlying fresh-water body by fairly impermeable layers of silt or clay. It is replenished chiefly by rainfall and irrigation return water, and to a minor extent by the streams. Beneath most of the Downey plain it is less than 15 feet below land surface. Under initial conditions it was fed in part by upward circulation from the underlying water body but from 1918 to 1945 the pressure levels of the deeper zones have been drawn down below the water table of the shallow body and it has become semiperched artificially.

In the several gaps, the depth to its top ranges from a few feet to 25 feet and its annual fluctuation is from 1 to 4 feet. In most of the gaps it is not a true semiperched water body at the present time because, except locally in Dominguez and Santa Ana Gaps, its top is below the pressure surface of the underlying confined water.

The semiperched body is of interest in this investigation because it is of poor quality near the coast and is a potential source of contamination, by movement either downward through wells or landward during long periods of depressed water level. Because its level in 1945 was generally below that of the underlying principal body in the several gaps, however, it cannot pass into that body extensively at present.

The principal water body of the Long Beach–Santa Ana area has been extensively utilized, beginning about in 1870 and reaching a maximum in 1936. In the latter year, about 374,000 acre-feet of water was withdrawn from the entire area. The decline in water levels which developed as a result of this increase in use has crystallized the need for appraising the watertightness of the structural zone and has furnished specific evidence that is of great aid in such an appraisal.

Hydrographs, water-level contour maps, and profiles are introduced to show the changes that have developed in response to that use and to variations in rainfall.

The longest records of water-level fluctuation are for wells near Anaheim, in the intake area of the Sana Ana River alluvial fan, and for the Bouton wells, in the pressure area near Long Beach. Both show a decline of several tens of feet from about 1895 into the early 1900's, a fluctuating but fairly uniform level into 1917, and a second decline of about 70 feet into 1936. These periods of decline were concurrent with periods of subnormal rainfall. During the wet cycle from 1936 into 1944, water levels near Anaheim recovered about 17 feet but those at the Bouton wells continued to decline, contrary to the general regional recovery in Los Angeles County.

In Los Angeles County, the fluctuations in water level are treated separately for the Gaspur water-bearing zone of Recent age and for the deposits of Pleistocene age. In general, changes in water level in the Gaspur zone and in the Pleistocene deposits have been of the same order. In the Gaspur zone the greatest changes have occurred in or near the intake area below Whittier Narrows; in the Pleistocene deposits, however, lowering of several tens of feet has developed in critical areas near the coast.

Because of local concentrated draft, markedly disparate levels have developed in two or more water-bearing zones northeast of Signal Hill, in the Huntington Park area, and in the part of Dominguez Gap within the west basin. The disparate levels developed northeast of Signal Hill have resulted in substantial artificial recharge to the basal water-bearing zone of Pleistocene age; in the latter two areas they have developed grave danger of saline contamination from overlying zones of Recent age.

In Orange County the long-term change in water level is discussed separately for the Talbert water-bearing zone of Recent age and for the deposits of Pleistocene age. In general, changes in water level in the Talbert zone and in the Pleistocene deposits have been of the same order. By 1928 most wells had ceased to flow and in the autumn of 1936 water levels were below sea level beneath about 155 square miles of the county. Recovery from 1936 to 1944 was sufficient to redevelop flowing wells locally proximate to the structural zone.

At the coastal end of Santa Ana Canyon near Olive, a ground-water barrier apparently occurs in the deposits of Pleistocene age and partly restrains movement to the intake area.

Owing to the anticipated recurrence of periods of low-water level such as the one culminating in 1936, which depressed levels below sea level beneath about 185 square miles within the main coastal basin in the two counties, the watertightness of the structural zone is a critical issue. That watertightness has been appraised largely by comparing hydrographs for wells on opposite sides of the barrier features. Conclusions based on hydrologic data, supplemented by geologic and geochemical evidence, are as follows:

For the reach in Los Angeles County: 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 evidence suggests that they are not wholly watertight 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 virtually watertight.

For the reach in Orange County: The barrier within the Pleistocene deposits beneath Landing Hill appears to have been watertight initially but in the late thirties a leak developed under a differential head of not more than 15 feet, presumably less than the initial differential head. In Sunset Gap no barrier is believed to have been developed in the deposits of Recent age but presumably they are not more than 20 feet thick and of low permeability. At least in the central part of Sunset Gap, near Hog Island, the barrier in the underlying Pleistocene deposits is almost watertight below a depth of about 145 feet but between land surface and that depth sufficient leakage now occurs to sustain a fresh-water lens coastward from the barrier features.

Beneath Bolsa Chica Mesa, the barrier features appear to be wholly watertight within the differential pressures imposed to 1945. In Bolsa Gap, there is no barrier to movement of ground water in the deposits of Recent age which contain the thin but permeable "80-foot gravel." In the subjacent San Pedro formation the barrier is inferred to be watertight within the range of historic pressure differentials.

Beneath Huntington Beach Mesa the faults of the structural zone have formed only a partial barrier to water movement. For the lower and main water-bearing zone, however, direct ingress of ocean water seemingly is prevented by a lithologic discontinuity.

In Santa Ana Gap the barrier faults do not transect the Talbert water-bearing zone and so form no barrier to water movement in that zone.

Thus, for the full reach of the Newport–Inglewood structural zone from Dominguez Gap to Newport Mesa, although the barrier features in the deposits of Pleistocene age are substantially watertight along most of that reach, no barrier whatsoever has been developed in the deposits of Recent age flooring the several gaps.

Under native conditions of ground-water circulation across the coastal plain the hydraulic barrier to landward encroachment was absolute. With the increasing development of the ground-water supplies, recurrent decline has developed in two periods of subnormal rainfall and has lowered water level about to sea level along the inland flank of the structural zone. Because the

barrier features of that zone are not watertight, substantial encroachment of saline water can be anticipated during the next dry cycle unless protective measures are taken.

Methods to protect the invaluable ground-water supplies must be two-fold in nature. First, long-term basin-wide balance of draft and replenishment must be attained or the saline encroachment cannot be restrained. Secondly, even if that balance is achieved, in dry periods local control doubtless will be necessary proximate to the barrier features. There appear to be only three possibilities for such local control: (1) the maintenance of fresh-water head above sea level inland from the saline front, either by regulated draft or by artificial replenishment or both; (2) dewatering coastward from the saline front; or (3) the construction of impervious subsurface dikes.

Conditions within the several critical reaches are discussed. Those in Santa Ana Gap are the most criical. In that gap, in paricular, and along the structural zone in general, the maintenance of fresh-water head above sea level appears to be the most feasible method and the construction of subsurface dikes the least feasible.

## INTRODUCTION

### PURPOSE AND SCOPE OF REPORT

This third and final report of a comprehensive series discusses ground-water features in the southern part of the coastal plain in Los Angeles and Orange Counties, Calif., with special reference to the effectiveness of the so-called coastal barrier—the Newport–Inglewood structural zone—in restraining landward movement of saline water. The investigation was begun in 1940 and was done by the Geological Survey in cooperation with the Los Angeles County Flood Control District, the Orange County Flood Control District, the Orange County Water District, and the Board of Water Commissioners of the city of Long Beach. Field investigation was completed in 1945, and by 1946 all basic data and interpretive findings from the investigation had been released to the public in duplicated form. Except for two open-file reports (Piper, Poland, and others, 1942; Piper, Poland, and others, 1943), all basic data resulting from the comprehensive investigation have been published in three interpretive reports (Water-Supply Papers 1109, 1136, and 1471).

The other two interpretive reports on ground-water features of the Long Beach–Santa Ana area have been published separately (Piper, Garrett, and others, 1953; Poland, Piper, and others, 1956). The report on ground-water geology (Poland, Piper, and others, 1956, p. 4-5; fig. 2) describes the general objectives and scope of the investigation; shows the extent of the Long Beach–Santa Ana area in relation to the coastal plain and the south coastal basin; and briefly describes the three regional bodies of ground water which underlie this area and discusses replenishment to and circulation in the principal body of fresh water (p. 107-118).

The present report in its published form is a combination of three reports issued separately in duplicated form at an earlier date.[1] It presents results from an inventory of withdrawal of ground water in the Long Beach–Santa Ana area from 1932 through 1944, and describes the principal sources from which ground water is withdrawn, chiefly those in the coastal zone of the Long Beach–Santa Ana area but in part those in the inland zone of the area. The report describes the regional ground-water conditions in the body of semiperched water and in the principal body of fresh water, insofar as they are pertinent to an understanding of the hydrologic evidence relating to the watertightness of the Newport-Inglewood structural zone; that evidence is presented on pages 111–141. With respect to the principal body of fresh water, evaluation of the fluctuations of ground-water head brought about by the heavy withdrawal from 1920 to 1945 is a prerequisite to discussion of the ultimate objective of this cooperative investigation—that is, the outline of methods for so conserving or protecting the fresh-water supply as to prevent or minimize further saline encroachment.

The preparation of this report was under the general direction of O. E. Meinzer, geologist in charge of the Division of Ground Water, and under the supervision of A. M. Piper, district geologist, to whom the author is grateful for a careful and constructive editorial review. Substantial assistance has been given by A. A. Garrett, Allen Sinnott, J. C. Fredericks, T. E. Eakin, A. S. Sollid, W. C. Reimund, and Miss A. G. Husted of the Long Beach office.

The compilation of water-level data from other agencies was accomplished largely during the first year of the investigation by G. A. La Rocque, Jr., assisted by G. F. Worts, Jr., E. D. McCormick, and Harold McClelland; the measurements of water level have been made principally by A. A. Garrett, Allen Sinnott, T. E. Eakin, J. C. Fredericks, and L. C. Phelps, also by A. L. Detweiler, E. D. McCormick, R. C. Newcomb, J. F. Poland, Henry Vaughan, and G. F. Worts, Jr.

The field canvass of withdrawal was begun by A. L. Detweiler late in 1941, but most of the canvass and the office compilation of records was accomplished by Allen Sinnott, largely in the spring and summer of 1942.

---

[1] Poland, J. F., and others, 1942, Descriptions of water wells in the coastal zone of the Long Beach–Santa Ana area, Calif.: U. S. Geol. Survey duplicated report, 152 p. Poland, J. F., Sinnott, Allen, and others, 1945, Withdrawals of ground water from the Long Beach–Santa Ana area, Calif.: U. S. Geol. Survey duplicated report, 112 p. Poland, J. F., and others, 1946, Hydrology of the Long Beach–Santa Ana area, Calif.: U. S. Geol. Survey duplicated report, 198 p.

## ACKNOWLEDGMENTS

The Geological Survey wishes to acknowledge the full cooperation of the Southern California Edison Co., Ltd., chiefly through F. T. Schell, in confidentially furnishing data on power consumed in the various operating districts of the area, together with many efficiency tests on individual pumping plants. Without these confidential data the methods used would not have been applicable.

Acknowledgment is also due to the Los Angeles County Health Department through Herbert Jewett, the Orange County Flood Control District, Mr. W. W. Hoy, the Los Angeles County Flood Control District, the Los Angeles Department of Water and Power through H. A. Van Norman and Milton Anderson, the California Division of Water Resources through G. B. Gleason, and the Metropolitan Water District through H. P. Vail. All these agencies or individuals supplied information of value in making the pumpage inventory. Finally, we wish to acknowledge the cooperation of municipalities, water companies, and industrial plants in making available records of ground water pumped from their own wells.

The writer also acknowledges with gratitude the full cooperation of Burt Harmon and W. M. Brown of the Long Beach Water Department; Paul Baumann, F. B. Laverty, L. W. Jordan, W. N. Thayer, and E R. Koch of the Los Angeles County Flood Control District; N. M. Thompson and J. A. Bradley of the Orange County Flood Control District; and W. W. Hoy and D. L. Gardner of the Orange County Water District. Records of great utility were supplied by G. B. Gleason of the California Division of Water Resources, by S. B. Morris, D. A. Lane, and Milton Anderson of the Los Angeles Department of Water and Power, by W. H. Stevens and E. W. Honeyman of the San Gabriel Valley Protective Association, by L. J. Alexander of the Southern California Water Company, by R. A. Shafer, J. B. Lippincott, and W. M. Browning, consulting engineers, and by many others.

Of all these agencies, special recognition is due the California Division of Water Resources which for the past two decades has been collecting and compiling selected records from the many agencies both public and private, which are concerned with the utilization or conservation of the ground-water supply of the coastal plain. The efforts of the Geological Survey in this coopertive investigation were greatly facilitated by the availability of the composite records on file at the office of the Division of Water Resources.

## WITHDRAWAL OF GROUND WATER, 1932–41

By Allen Sinnott and J. F. Poland

This inventory of withdrawal of ground water in the Long Beach–Santa Ana area from 1932 through 1941 was undertaken because no comprehensive estimate of the withdrawal of ground water from the entire coastal plain or of the area included within this project had been made since 1904 (Mendenhall, 1905a, 1905b, 1905c); also, as necessary background for examining the hydrologic features of the coastal zone in accord with the objectives of the cooperative investigation. The inventory was not extended into the years prior to 1932 because few records or estimates of withdrawal were available for years preceding the middle or early thirties.

The text on ground-water withdrawal briefly describes the methods used in evaluating withdrawal; table 2 presents the measured or estimated yearly withdrawal by each city in the area which has a municipal water-supply system; and table 5 summarizes the estimated yearly withdrawal in each county according to the following classes: (1) withdrawal by cities with municipally-owned systems, (2) withdrawal for industrial use, (3) withdrawal for agricultural use (including those by water companies and by land companies if chiefly for irrigation), and (4) withdrawal for domestic use—exclusive of that by municipally-owned plants but including that by many water companies whose service is primarily for domestic purposes.

Because the withdrawal for agricultural use was calculated largely from records of electric power used in certain operating districts of the Southern California Edison Co., Ltd., the inventory of that withdrawal was made within an arbitrary boundary which necessarily followed the boundaries of the operating districts at some places, and which was about coincident with the Long Beach–Santa Ana area. However, the area of inventory was extended northward beyond the Long Beach–Santa Ana area to include the relatively small La Habra basin, where withdrawal for agricultural purposes could not conveniently be evaluated separately, and in the area east of the Los Angeles River was extended slightly to reach the Repetto Hills. Also, it was extended westward to Vermont Avenue, in order to include most of the large pumping plants that withdraw ground water for industrial use within the city of Los Angeles. Hence, the area of inventory embraces all the coastal plain east of Vermont Avenue, which follows the boundary between R. 13 W. and R. 14 W.

## HISTORICAL REVIEW

Development and utilization of ground-water supplies in the coastal plain of Los Angeles and Orange Counties began about 1870; in 1903 and 1904 Mendenhall (1905a, 1905b, 1905c) canvassed and described 8,200 wells within the coastal plain, of which about 2,500 were flowing in the spring of 1904. With respect to the utilization of ground waters in the coastal plain prior to 1904, Mendenhall (1905b, p. 10) wrote:

> The first settlers, the Mission Fathers, after them the Mexicans, and still later the Americans, secured their first holdings near the flowing streams of the "ciénaga" lands, the sites of perpetual springs. As the areas under cultivation slowly increased, the waters of the mountain canyons were gradually appropriated and applied to the adjacent lands. Then engineering devices were resorted to for increasing the flow of springs, for intercepting the underflow of streams, or for storing the flood waters by means of dams and reservoirs. Lastly, attention was turned to the underground waters, which proved to occur in large quantities and to be widely distributed, so that entire communities have sprung up which depend wholly on these sources for their irrigation water. Developments during the last ten years [1894–1904] have been chiefly those of underground sources * * *

Table 1, which is based on data by Mendenhall (1905b), shows the rate of well construction prior to 1904 in the central part of the coastal plain—that is, in the Downey and Las Bolsas quadrangles. This table indicates progressive acceleration in water-well drilling, especially after 1880. However, most of these wells were 7 inches or smaller in size—too small to accommodate irrigation pumps of large capacity.

TABLE 1.—*Wells constructed in the Downey and Las Bolsas quadrangles from 1860 to 1904, by 10-year periods*

| | 10-year period | | | | |
|---|---|---|---|---|---|
| | Before 1870 | 1870–79 | 1880–89 | 1890–99 | 1900–04 [1] |
| Downey quadrangle: | | | | | |
| Total | 9 | 133 | 507 | 1, 297 | 734 |
| Average per year | 1 | 13 | 51 | 130 | 173 |
| Las Bolsas quadrangle: | | | | | |
| Total | ------ | 5 | 2 | 93 | 123 |
| Average per year | ------ | . 5 | . 2 | 9 | 29 |
| The two quadrangles: | | | | | |
| Total | 9 | 138 | 509 | 1, 390 | 857 |
| Average per year | 1 | 14 | 51 | 139 | 202 |

[1] Field canvass completed about March 1904.

As of 1904, Mendenhall estimated that the average discharge of all flowing and pumped wells within the coastal plain was about 250 cfs, equivalent to a yearly withdrawal of about 180,000 acre-feet. From a field canvass, Mendenhall estimated the irrigated area to be about 96,000 acres, of which nearly three-quarters was supplied from wells. At that time the area of flowing wells had decreased from an estimated 290 square miles initially to about 190 square miles. During the quarter century following the canvass by Mendenhall the rate of withdrawal from the coastal plain increased steadily owing to (1) increased demand for irrigation water, (2) lack of additional surface-water sources, and (3) improvement and widespread installation of deep-well turbine pumps.

Owing to the large and constantly increasing withdrawal, by 1928 the head on the principal ground-water bodies almost universally had declined below the land surface and nearly all wells had ceased to flow. The magnitude of this decline of pressure head in the Long Beach area is shown by the following striking example, which represents the greatest known decline rather than the average. From 1890 to 1903 the five wells of the so-called Bouton group were constructed about 2½ miles north of Signal Hill to furnish water for Long Beach. Available records [2] indicate that when the first well, No. 4/12-8P5, was completed in 1891, its static head was about 80 feet above the land surface or 150 feet above sea level. In July 1903 this well ceased to flow for the first time. By July 1928 the static head in another well of the same group, No. 4/12-8P1, had declined to about 73 feet below the land surface or about 3 feet below sea level. Thus, in 37 years the head of the confined water body or bodies tapped by the Bouton wells apparently declined about 153 feet or at the average rate of 4.1 feet per year.

Continued heavy draft of ground water, together with subnormal rainfall in 6 of the 8 years following 1928, resulted by 1936 in the lowest water levels of record in the main basin of the coastal plain; in the autumn low-water period of that year, the water levels in wells were below sea level beneath about 320 square miles or about 40 percent of the coastal plain. From 1936 into 1944 rainfall was above normal in 6 of the 8 years, while withdrawal from much of the main basin remained about constant. Water levels have risen considerably, so that in 1941 flow by artesian pressure was rejuvenated in an area of about 25 square miles lying immediately northeast of the Newport–Inglewood zone and extending from Long Beach into Santa Ana Gap. From 1941 to 1944 the area of artesian flow was perennial and has expanded slightly.

---

[2] Unpublished notes in files of U. S. Geological Survey, in part from W. M. Brown and Burt Harmon of the Long Beach Water Department.

The recession of ground-water head prior to 1936 occurred generally throughout the coastal-plain area and so indicates that the aggregate withdrawal of water exceeded the aggregate replenishment in that period. However, the substantial recovery of head after 1936, while withdrawal was about constant, indicates that withdrawal did not exceed replenishment in all years. Thus, although withdrawal from the principal ground-water bodies has been excessive at certain places, it seems that the cumulative overdraft to 1944 has been only moderate for the area as a whole.

The recession of the ground-water head below sea level over extensive areas in the late twenties and into the thirties produced a downward hydraulic gradient from the ocean inland; wherever the fresh-water-bearing beds were in contact with the ocean this gradient would favor a landward movement of salt water from the ocean. Also, the recession of fresh-water head would favor invasion of the water-bearing beds by brine from the several producing oil fields of the area and by wastes from the industrial district in the western part of the area.

Ground waters of inferior chemical quality apparently have existed naturally in certain permeable beds in some parts of the area, particularly along the lower reach of the Los Angeles River just west of Long Beach, locally in the Irvine tract east of the Santa Ana River, and elsewhere. With these exceptions, however, water of good quality was yielded by virtually all wells in the area until the late twenties, when a few wells near the coast began to yield salty water; some wells were abandoned subsequently as the quality of the water deteriorated progressively. This deterioration in water quality, in conjunction with the continuing recession of ground-water head into the middle thirties, caused deep concern on the part of local public agencies charged with the conservation of ground-water supplies in the coastal-plain area and resulted ultimately in the cooperative investigation of the critical question at issue—could withdrawal of ground water for the many considerable requirements of the area be continued freely and indefinitely without an ultimate substantial increase of salt-water contamination? An inventory of withdrawal was an essential element of the investigation.

## PREVIOUS ESTIMATES

So far as is known to the writers, the only comprehensive previous estimate of ground-water withdrawal from the entire coastal plain was that of 1903-4 by Mendenhall—specifically, about 180,000 acre-feet per year from flowing wells and pumped wells within all the coastal plain and about 160,000 acre-feet within the area covered in this report.

From 1923 to 1928, the California Division of Water Rights investigated the surface- and ground-water supplies believed to be tributary to the San Gabriel River. In connection with that study, the pumping draft in the coastal-plain area thought to be affected by recharge from the San Gabriel River was estimated by applying a duty-of-water factor to the irrigated acreage. The yearly draft was estimated to be about 85,000 acre feet (Conkling, 1929, p. 39, pl. 7). Apparently, this estimate included some water from surface sources near Whittier Narrows and, therefore, the withdrawal of ground water probably was somewhat less than 85,000 acre-feet.

In the investigation of the Santa Ana River drainage basin from 1925 to 1928, the California Division of Engineering and Irrigation estimated the utilization of water in that part of the coastal plain within Orange County. This estimate was derived by applying a duty-of-water factor to irrigated acreage and to residential acreage; use of about 225,000 acre-feet of water per year was so calculated (Post, 1928, p. 217). However, no estimate was published for the proportion of this water that was drawn from wells.

In 1932, J. H. Dockweiler[3] made a systematic inventory of water pumped from wells within the central part of the coastal plain—specifically, within the area believed to be affected by percolation from the San Gabriel River and from the Rio Hondo. This investigation included a field inventory of plants withdrawing about 66,000 acre-feet of ground water, also an additional draft of 23,000 acre-feet which was estimated by applying a duty-of-water factor to irrigated lands classified according to type of crop. However, it is not known what proportion of this estimated 23,000 acre-feet was drawn from wells. Thus, although the total use was estimated to be about 89,000 acre-feet in 1932, this total may include some surface water.

Use of water in Orange County from 1932 to 1936 was appraised in a report of the Metropolitan Water District, issued in 1936[4]. From a field canvass of the larger users of water, and an estimate for the remainder of the irrigated acreage, the average yearly use of water in the 5-year period was estimated to be about 196,000 acre-feet[5]. The estimated use in south Orange County (San Juan Capistrano region) was estimated as about 6,000 acre-feet a year.

---

[3] Dockweiler, J. H., Report on flood control and water supply for the area of the coastal plain below Whittier Narrows affected by percolation of the waters of the Rio Hondo and San Gabriel Rivers: Unpublished report to Los Angeles County Flood Control District, July 1933.

[4] Vail, H. P., Use of irrigation and domestic water in Orange County, and Whittier–La Habra area of Los Angeles County: Metropolitan Water District private report, August 1936.

[5] Vail, H. P., op. cit., pl. 9.

The latter area is outside the drainage basin of the Santa Ana River and is beyond the Long Beach-Santa Ana area of the present inventory. If the use of 6,000 acre-feet in that area is deducted, there remains an estimated 190,000 acre-feet of water used in the main Santa Ana basin and in the Whittier–La Habra district. The Geological Survey estimates that about two-thirds of Vail's subtotal for the Whittier–La Habra district would have been used in Los Angeles County and therefore derives from Vail's estimates a value of about 170,000 acre-feet per year for the part of the Long Beach–Santa Ana area that is in Orange County. Assuming that about 50,000 acre-feet was derived from surface-water diversions in that part of the area, a rough estimate of 120,000 acre-feet of water withdrawn yearly from underground sources is deduced for the period from 1932 to 1936.

In the late thirties, the Board of Supervisors for Orange County appointed a committee to study water problems in the county. In the committee report (Anon., 1939), it was estimated that about 73,000 acres was in irrigated orchards, 57,000 acres in irrigated farmlands, and 20,000 acres was used for residences and for business and industrial activities. From independent studies of water use by several investigators, it was concluded that the average yearly use in Orange County was as follows: orchards, 19.87 acre-inches to the acre; field crops, 16.4 acre-inches; domestic, 15.6 acre-inches; industrial, 16 acre-inches; and recreational, 21.7 acre-inches. Assuming an average minimum use of 18 inches per acre, the over-all use in Orange County was estimated to be about 225,000 acre-feet per year. Of this amount, about 50,000 acre-feet was supplied from the streams. Thus, the draft from ground-water sources was estimated to be about 175,000 acre-feet per year.

## METHODS OF EVALUATING WITHDRAWAL

### PUMPAGE BY MUNICIPALITIES

As of 1942, nine cities in Los Angeles County and nine cities in Orange County operated municipal water systems within the Long Beach–Santa Ana area. For each of these cities, records of the ground-water withdrawal were collected by the Geological Survey directly from officials of the water departments or from the city engineers. The 18 cities are listed in table 2, which also gives the volume of ground water withdrawn by each in the calendar year 1941. With the exception of Los Angeles, all these cities derived their supply exclusively from wells during the period of inventory, except as noted in table 4.

Records of the yearly withdrawal by each of these cities for periods beginning as early as 1900, are presented in table 4 in

TABLE 2.—*Municipalities withdrawing ground water in the Long Beach–Santa Ana area, as of 1941*

| Los Angeles County | | Orange County | |
|---|---|---|---|
| City | Withdrawal (acre-feet) | City | Withdrawal (acre-feet) |
| Compton [1] | 1, 006 | Anaheim [1] | 1, 514 |
| Huntington Park | 3, 338 | Brea | 49 |
| Long Beach [1] | 18, 685 | Fullerton [1] | 1, 391 |
| Los Angeles [1] | 105 | Laguna Beach [2] | 1, 285 |
| Lynwood | [3] 1, 878 | La Habra | 122 |
| Signal Hill | 1, 900 | Newport Beach | 1, 160 |
| South Gate | 3, 824 | Orange | 1, 154 |
| Vernon | 3, 584 | Santa Ana [1] | 3, 547 |
| Whittier | 2, 935 | Seal Beach | 168 |

[1] Member city, Metropolitan Water District.
[2] Through Laguna Beach County Water District.
[3] July 1, 1940 to June 30, 1941.

acre-feet and in the units adopted as the standard by the several cities. Table 5 gives the total yearly withdrawal by all cities in each county from 1932 through 1941.

### INDUSTRIAL CONSUMPTION

The western part of the Long Beach–Santa Ana area is highly industrialized but there are relatively few industrial plants in its eastern part, in Orange County. The withdrawal of ground water by the industrial plants in Los Angeles County was estimated from the results of a brief but comprehensive field canvass by the Geological Survey, based partly on lists of plants believed to be large consumers of ground water (lists which were supplied by the Los Angeles County Flood Control District and by the Los Angeles Department of Water and Power, and which were of considerable assistance). So far as is known, all the industrial plants using large quantities of ground water, also many of those using smaller quantities, were contacted by a visit in the field, by correspondence, or by telephone. Table 3 indicates that 64 of the 122 industrial

TABLE 3.—*Distribution of representative industrial plants according to source of water*

| Type of industry | Water drawn from own wells | Water purchased from municipal system or from water company |
|---|---|---|
| Petroleum refineries | 8 | 1 |
| Rubber plants | 4 | 0 |
| Laundries | 4 | 16 |
| All others [1] | 48 | 41 |
| Total | 64 | 58 |

[1] Includes paper mills, steel mills, breweries, gun clubs, railroad yards, meat packers, soap manufacturers, construction companies, and miscellaneous.

plants contacted—52 percent—were supplied by their own wells. The others were supplied by water purchased from municipalities or water companies.

The field canvass yielded water-meter records or estimates of withdrawal from most of the industrial plants using ground water in the coastal zone of the Long Beach–Santa Ana area. Also, the canvass included about 80 percent of the total withdrawal by plants in the part of the project area that is in Los Angeles County, and 90 percent of the total by plants in the part that is in Orange County. Accordingly, totals for industrial withdrawal were derived for summary table 5 by increasing the canvass subtotals by 25 percent for Los Angeles County and by 11.1 percent for Orange County.

The several gun clubs in Orange County whose withdrawal is classed for convenience as "industrial," were not contacted directly. Estimates of their water use were furnished by the Orange County Flood Control District and are embodied in the subtotals of table 5.

### PUMPAGE FOR AGRICULTURAL PURPOSES

In the Long Beach–Santa Ana area irrigation constitutes the largest single use of ground water, which as of 1941 was nearly half the total of all uses in the part of the area that is in Los Angeles County and was slightly more than 80 percent of the total for the part of the area in Orange County (table 5). Thus, the accuracy of the over-all inventory depends largely on the accuracy with which the withdrawal of ground water for agricultural purposes can be evaluated.

Most of the ground water withdrawn for irrigation in the Long Beach–Santa Ana area is raised by electrically-driven pumps and only about 10 percent by nonelectric pumps—that is, by pumps driven by internal-combustion engines using natural gas, diesel oil, butane, or gasoline as fuel. This estimate is derived from data of the field canvass, and from suggestions and information by the Southern California Edison Co., Ltd., the Southern California Gas Co., the Orange County Flood Control District, and other agencies. Under these conditions, the withdrawal for agricultural purposes was evaluated with reasonable accuracy 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. Suitable adjustments were made for the water raised by nonelectric pumps and for certain other factors, as will be developed specifically.

The yearly energy factors were derived from data on more than 1,000 pump-efficiency tests made throughout the area by the Southern California Edison Co. from 1918 through 1941; also, from about 70 such tests by the Orange County Flood Control District in 1937–38, from 23 tests by Tavernetti and Huberty[6] in the vicinity of Garden Grove in 1935, and from 12 tests by the Geological Survey in 1941–42. From each such test under representative conditions, there was derived an individual energy factor, in terms of kilowatt-hours expended in delivering one acre-foot of water onto the land. From these tests average energy factors were then calculated by years for each of eight power-distribution districts of the Southern California Edison Co. In turn, these average factors were plotted on a time graph separately for each district, a somewhat smoothed curve was drawn through the plotted values, and mean energy factors for each district and for each year were read from the smoothed curves. From the "spread" of the basic data, it is believed that the mean yearly energy factors for each of eight power-distribution districts compensate rather thoroughly for variations in the efficiencies of individual pumps and in pumping lifts in the Long Beach–Santa Ana area.

Energy expended on pumps withdrawing ground water for agricultural purposes constitutes most of that sold in the Long Beach–Santa Ana area under the "agricultural" rate schedule of the Southern California Edison Co., Ltd. Yearly totals of kilowatt-hours under that particular rate schedule were made available to the Geological Survey by the power company for eight so-called operating or power-distribution districts, which together encompass all the extramunicipal area and most of the municipal area of the field inventory. These include the Long Beach, Compton, Huntington Park, Montebello, and Whittier districts in Los Angeles County; also the Huntington Beach, Santa Ana, and Fullerton districts in Orange County.

To reduce this record of agricultural kilowatt-hours to the needs of the inventory, certain adjustments were made, as follows:

1. Certain large water companies or land companies use considerable agricultural energy to boost irrigation water to hillside areas; other such companies, to pump water from streams. Records of their withdrawals of ground water were transcribed from data on operations and the electric energy used by them was deducted from the total agricultural energy of the corresponding operating districts. In Los Angeles County these include the Murphy Ranch Co., the Hillside Distribution Co. (including the La Habra Heights Mutual Water Co. and the Orchard Dale Service Co.), and the booster operations of the Cole Ranch. In Orange County they include the Anaheim Union Water Co., The Irvine Co., the Santa Ana Valley Irrigation Co., the Sunny Hills Ranch, and the Yorba Linda Water Co.
2. Some agricultural power is used for purposes other than pumping water—that is, to operate milking machines, farm-shop tools, and miscellaneous farm equipment. From information given by the Southern California

---

[6] Tavernetti, J. R., and Huberty, M. R., Preliminary report on a study of group and individual pumping plants in Orange County: Unpublished report, May 1936.

Edison Co. and from general knowledge gained in the field, it was estimated that these nonpumping uses accounted for 5 percent of the electrical energy sold under the agricultural classification.

By the two adjustments just indicated, the record of agricultural kilowatt-hours per year per operating district was reduced essentially to kilowatt-hours expended in the withdrawal of ground water by individuals and by the smaller water companies for agricultural purposes. The adjusted values of kilowatt-hours were then converted to equivalent acre-feet of water pumped, by applying the corresponding mean yearly energy factors whose derivation has been explained. From the basic data available, these estimates of the yearly withdrawal of ground water for agricultural purposes were practicable for the 10-year period from 1932 through 1941. Corresponding estimates for the years following 1941 have not been made, because data for determining adequate mean yearly energy factors have not been obtained during that war period.

As mentioned on page 16, an estimated 10 percent of the water withdrawn for irrigation is raised by nonelectric pumps. For most of the large operators using nonelectric pumps, records of withdrawal were transcribed from operating logs. In Los Angeles County, the records so obtained by direct canvass included the withdrawal by the Bellflower Water Co., the Dominguez Water Corp., the East Bell Land Co., the Los Nietos Irrigating Co., the Maywood Mutual Water Co. No. 1, the Montebello Land and Water Co., and the Somerset Mutual Water Co. Two other companies in the county—the California Domestic Water Co. and the Whittier Water Co.—have nonelectric pumps and supply water to the northern fringe of the Whittier district. However, these two companies withdraw water from wells outside the coastal plain and were disregarded. Of the seven water companies listed, several supply water almost exclusively for domestic use but others supply water for a considerable agricultural use. It is estimated that this agricultural use in the 10-year period from 1932 through 1941 has averaged about 4,500 acre-feet per year and, further, that this water is half the total withdrawn for agricultural purposes by nonelectric pumps in the part of the inventory area that is in Los Angeles County. These estimates agree reasonably with the antecedent estimate that about 10 percent of all withdrawal for agricultural uses is by nonelectric pumps, and with the calculated values for withdrawal by electric pumps.

In Orange County, the principal users of nonelectric energy to withdraw ground water for irrigation include the Anaheim Eucalyptus Water Co., the Emery Ranch, the Carpenter Irrigation District, and the John T. Carpenter Water Co. Withdrawal by these several companies was obtained by direct canvass, has aggregated about 2,000 acre-feet in the early forties, and is estimated to be 20 percent of the over-all draft of ground water for agricultural use by nonelectric pumps in the part of the inventory area which is in Orange County. These values for canvassed withdrawal and percentage are also in reasonable agreement with the calculated values for withdrawal by electric pumps.

Table 5 gives a summation of yearly withdrawal of ground water for agricultural use from 1932 through 1941, which was obtained by adding (1) withdrawal by individuals and small organizations, calculated by the energy-factor method; (2) withdrawal by the large water companies, land companies, or ranches for which an adequate record was obtained by direct canvass; (3) withdrawal by the larger organizations using nonelectric pumps, also canvassed directly; and (4) small percentage allowances for withdrawal neither calculated by the energy-factor method nor canvassed directly, in accord with the preceding explanation.

## PRIVATE WITHDRAWAL FOR NONINDUSTRIAL AND NONAGRICULTURAL PURPOSES

In the area of inventory, many water companies deliver water chiefly for domestic use, but do not operate with agricultural energy from the Southern California Edison Co. Most of these water companies that supply more than 200 services were contacted by telephone or by correspondence. Records of metered or estimated water use were obtained from 30 of these water companies, several of which have plants in more than one locality. Similar records were obtained from the several county water works or county water districts.

In all, the records of metered or estimated water use so obtained in Los Angeles County included about 60,000 services. Assuming that each service averaged four persons, the total use so estimated was that by 240,000 people—that is, by about 92 percent of the population outside of municipalities that operate their own water systems, but within the area of inventory. This percentage estimate is based on figures from the Federal Census of 1940.[7]

In Los Angeles County, for the larger companies not furnishing a record of water use and for all companies with less than 200 services, the withdrawal was estimated from the total of services and an average use factor of 0.446 acre-foot per service per year.

---

[7] Final population figures for the United States, by States, 1940; population of the State of California, final figures, 1940: U. S. Bur. Census (16th), ser. P–2, no. 35 (A1–4, G–49), released Jan. 9, 1941. Populations of the counties of California by minor civil divisions (judicial townships) 1940: U. S. Bur. Census, ser. P–2a, no. 31 (A1–4, G–49), released Feb. 16, 1941.

This use factor was derived from the records supplied by eight representative water companies in the county, which in 1941 delivered 12,449 acre-feet of water to 27,884 domestic services. No additional allowance was made for domestic use in Los Angeles County by individuals not supplied by a municipal, water-company, or county system. The total number of such users is probably less than 10,000, and some of these are supplied from irrigation wells.

According to the Federal Census, the population within the area of inventory in Orange County was 128,328 people in 1940. Of this number, 76,812 persons lived in cities supplied by municipal water systems. It is estimated that an additional 28,900 persons were supplied by water companies or by county water districts whose delivery records had been canvassed directly. For the remainder, about 22,600 persons as of 1940, it was assumed that the average use was 100 gallons per person per day, or 0.112 acre-foot per person per year. This allowance agrees almost precisely with the figure of 0.446 acre-foot per service per year that was applied in Los Angeles County. The domestic use so derived for Orange County was 2,529 acre-feet in 1940; for other years the water use was prorated in accordance with the growth of extramunicipal population between 1930 and 1940, based on the Federal Census.

## DATA ON YEARLY WITHDRAWAL

Table 4 lists yearly withdrawal of ground water by each municipal water system, 9 cities in Los Angeles County, and 9 cities in Orange County operating municipal water systems within the area of inventory (table 2). In table 4, each record is carried back for as many years as data are available and is extended into or through 1944. The longest record, that of Santa Ana, begins with 1900.

TABLE 4.—*Yearly withdrawal of ground water by municipalities in the Long Beach–Santa Ana area*

LOS ANGELES COUNTY

**Compton, 1937–44**

[Estimates by Water Department, from metered consumption]

| Year | Millions of gallons | Acre-feet | Year | Millions of gallons | Acre-feet |
|---|---|---|---|---|---|
| 1935 | | | 1940 | 688 | 2, 111 |
| 1936 | | | 1941 | 328 | [1] 1, 006 |
| 1937 | 621 | 1, 906 | 1942 | 652 | 2, 002 |
| 1938 | 648 | 1, 988 | 1943 | 779 | 2, 391 |
| 1939 | 667 | 2, 048 | 1944 | [2] 414 | [2] 1, 271 |

See footnotes at end of table.

TABLE 4.—*Yearly withdrawal of ground water by municipalities in the Long Beach–Santa Ana area*—Continued

LOS ANGELES COUNTY—continued

**Huntington Park, 1925–44**

| Year | Millions of gallons | Acre-feet | Year | Millions of gallons | Acre-feet |
|---|---|---|---|---|---|
| 1925 | 357 | 1, 096 | 1935 | 945 | 2, 899 |
| 1926 | ---------- | -------- | 1936 | 967 | 2, 966 |
| 1927 | 672 | 2, 063 | 1937 | 968 | 2, 969 |
| 1928 | 560 | 1, 718 | 1938 | 1, 022 | 3, 135 |
| 1929 | 801 | 2, 459 | 1939 | 1, 120 | 3, 437 |
| 1930 | 843 | 2, 588 | 1940 | 1, 118 | 3, 430 |
| 1931 | 882 | 2, 706 | 1941 | 1, 088 | 3, 338 |
| 1932 | 912 | 2, 799 | 1942 | 1, 210 | 3, 713 |
| 1933 | 936 | 2, 872 | 1943 | 1, 308 | 4, 016 |
| 1934 | 955 | 2, 931 | 1944 | 1, 338 | 4, 105 |

**Long Beach, 1915–44**

[Includes withdrawal for city of Signal Hill through October 1929]

| Year | Acre-feet | Year | Acre-feet |
|---|---|---|---|
| 1915 | 6, 032 | 1930 | 18, 170 |
| 1916 | 6, 021 | 1931 | 17, 152 |
| 1917 | 6, 794 | 1932 | 16, 022 |
| 1918 | 7, 455 | 1933 | 15, 810 |
| 1919 | 8, 373 | 1934 | 14, 949 |
| 1920 | 8, 660 | 1935 | 15, 369 |
| 1921 | 8, 549 | 1936 | 17, 115 |
| 1922 | 9, 520 | 1937 | 16, 558 |
| 1923 | 14, 683 | 1938 | 17, 323 |
| 1924 | 15, 549 | 1939 | 17, 939 |
| 1925 | 14, 596 | 1940 | 17, 700 |
| 1926 | 15, 838 | 1941 | 18, 685 |
| 1927 | 16, 943 | 1942 | [3] 21, 580 |
| 1928 | 21, 549 | 1943 | [3] 21, 733 |
| 1929 | 22, 170 | 1944 | [3] 22, 317 |

**Los Angeles, 1918–44**

[Total withdrawal from Figueroa Street, Green Meadows, Lomita, Manhattan, Slauson, and Wilmington pumping plants; these are local sources supplementing surface-water supply imported principally from Owens Valley]

| | | | |
|---|---|---|---|
| 1915 | ---------- | 1930 | 12, 040 |
| 1916 | ---------- | 1931 | 13, 828 |
| 1917 | ---------- | 1932 | 8, 208 |
| 1918 | 1, 043 | 1933 | 8, 434 |
| 1919 | 5, 489 | 1934 | 8, 055 |
| 1920 | 7, 312 | 1935 | 7, 211 |
| 1921 | 10, 135 | 1936 | 802 |
| 1922 | 9, 267 | 1937 | 1, 137 |
| 1923 | 12, 888 | 1938 | 934 |
| 1924 | 15, 638 | 1939 | 90 |
| 1925 | 17, 085 | 1940 | 0 |
| 1926 | 17, 521 | 1941 | 105 |
| 1927 | 14, 480 | 1942 | 180 |
| 1928 | 14, 399 | 1943 | 1, 240 |
| 1929 | 17, 882 | 1944 | 1, 790 |

See footnotes at end of table.

## TABLE 4.—*Yearly withdrawal of ground water by municipalities in the Long Beach–Santa Ana area*—Continued

### LOS ANGELES COUNTY—continued

### Lynwood, 1936–44

[For years ending June 30]

| Year | Millions of gallons | Acre-feet | Year | Millions of gallons | Acre-feet |
|---|---|---|---|---|---|
| 1935 | | | 1940 | 604 | 1, 854 |
| 1936 | 492 | 1, 510 | 1941 | 612 | 1, 878 |
| 1937 | 477 | 1, 464 | 1942 | 754 | 2, 315 |
| 1938 | 499 | 1, 532 | 1943 | 871 | 2, 672 |
| 1939 | 544 | 1, 670 | 1944 | 912 | 2, 798 |

### Signal Hill, 1929–44

| | | | | | |
|---|---|---|---|---|---|
| 1925 | | | 1935 | [4] 1, 120 | 3, 440 |
| 1926 | | | 1936 | 868 | 2, 664 |
| 1927 | | | 1937 | 791 | 2, 427 |
| 1928 | | | 1938 | 751 | 2, 304 |
| 1929 | [4] [5] 325 | 997 | 1939 | 702 | 2, 154 |
| 1930 | [4] 1, 710 | 5, 247 | 1940 | 721 | 2, 213 |
| 1931 | 1, 391 | 4, 268 | 1941 | 619 | 1, 900 |
| 1932 | 1, 150 | 3, 529 | 1942 | 553 | 1, 696 |
| 1933 | 1, 091 | 3, 347 | 1943 | 621 | 1, 906 |
| 1934 | [4] 1, 100 | 3. 375 | 1944 | 546 | 1, 675 |

### South Gate, 1927–44

| | | | | | |
|---|---|---|---|---|---|
| 1925 | | | 1935 | 451 | 1, 384 |
| 1926 | | | 1936 | 531 | 1, 630 |
| 1927 | 172 | 527 | 1937 | 586 | 1, 799 |
| 1928 | 203 | 622 | 1938 | 687 | 2, 108 |
| 1929 | 353 | 1, 083 | 1939 | 851 | 2, 613 |
| 1930 | 406 | 1, 245 | 1940 | [6] 1, 061 | 3, 256 |
| 1931 | 464 | 1, 425 | 1941 | [6] 1, 246 | 3, 824 |
| 1932 | 442 | 1, 357 | 1942 | [6] 1, 368 | 4, 197 |
| 1933 | 438 | 1, 344 | 1943 | [6] 1, 614 | 4, 952 |
| 1934 | 465 | 1, 427 | 1944 | [6] 1, 610 | 4, 942 |

### Vernon, 1938–44

| Year | Thousands of cubic feet | Acre-feet | Year | Thousands of cubic feet | Acre-feet |
|---|---|---|---|---|---|
| 1935 | | | 1940 | 127, 674 | 2, 931 |
| 1936 | | | 1941 | 156, 126 | 3, 584 |
| 1937 | | | 1942 | 185, 225 | 4, 253 |
| 1938 | 130, 506 | 2, 996 | 1943 | 246, 745 | 5, 665 |
| 1939 | 125, 293 | 2, 876 | 1944 | 256, 902 | 5, 898 |

See footnotes at end of table.

TABLE 4.—*Yearly withdrawal of ground water by municipalities in the Long Beach–Santa Ana area*—Continued

LOS ANGELES COUNTY—continued

**Whittier, 1927–44**

| Year | Thousands of cubic feet | Acre-feet | Year | Thousands of cubic feet | Acre-feet |
|---|---|---|---|---|---|
| 1925 | ---------- | -------- | 1935 | 107, 347 | 2, 464 |
| 1926 | ---------- | -------- | 1936 | 118, 974 | 2, 731 |
| 1927 | 103, 437 | 2, 375 | 1937 | 111, 207 | 2, 553 |
| 1928 | 110, 731 | 2, 542 | 1938 | 127, 005 | 2, 916 |
| 1929 | 123, 506 | 2, 835 | 1939 | 133, 798 | 3, 072 |
| 1930 | 123, 465 | 2, 834 | 1940 | 132, 325 | 3, 038 |
| 1931 | 126, 427 | 2, 902 | 1941 | 127, 832 | 2, 935 |
| 1932 | 116, 930 | 2, 684 | 1942 | 141, 612 | 3, 251 |
| 1933 | 113, 273 | 2, 600 | 1943 | 151, 529 | 3, 479 |
| 1934 | 110, 098 | 2, 528 | 1944 | 151, 030 | 3, 467 |

ORANGE COUNTY

**Anaheim, 1918–44**

| Year | Millions of gallons | Acre-feet | Year | Millions of gallons | Acre-feet |
|---|---|---|---|---|---|
| 1915 | ---------- | -------- | 1930 | 465 | 1, 426 |
| 1916 | ---------- | -------- | 1931 | 469 | 1, 439 |
| 1917 | ---------- | -------- | 1932 | 451 | 1, 385 |
| 1918 | 186 | 571 | 1933 | 446 | 1, 370 |
| 1919 | 190 | 584 | 1934 | 444 | 1, 363 |
| 1920 | 197 | 604 | 1935 | 471 | 1, 446 |
| 1921 | 244 | 748 | 1936 | 505 | 1, 550 |
| 1922 | 305 | 937 | 1937 | 479 | 1, 470 |
| 1923 | 289 | 888 | 1938 | 546 | 1, 677 |
| 1924 | 398 | 1, 222 | 1939 | 591 | 1, 814 |
| 1925 | 406 | 1, 247 | 1940 | 572 | 1, 756 |
| 1926 | 470 | 1, 441 | 1941 | 493 | [7] 1, 514 |
| 1927 | 409 | 1, 254 | 1942 | ---------- | 1, 756 |
| 1928 | 426 | 1, 307 | 1943 | ---------- | 2, 224 |
| 1929 | 472 | 1, 449 | 1944 | ---------- | [8] 1, 280 |

**Brea, 1937–41**

[No record of production available but estimated by the water superintendent to have been on the order of 16 million gallons (49 acre-feet) per year from 1937 through 1941]

See footnotes at end of table.

TABLE 4.—*Yearly withdrawal of ground water by municipalities in the Long Beach–Santa Ana area*—Continued

ORANGE COUNTY—continued

**Fullerton, 1914–44**

[Pumpage from 1914 through 1927 and for 1929 is for fiscal years ending June 30; pumpage for 1928 and beginning 1930 is for calendar years]

| Year | Millions of gallons | Acre-feet | Year | Millions of gallons | Acre-feet |
|---|---|---|---|---|---|
| 1910 | ---------- | -------- | 1930 | 431 | 1, 324 |
| 1911 | ---------- | -------- | 1931 | 437 | 1, 340 |
| 1912 | ---------- | -------- | 1932 | 422 | 1, 295 |
| 1913 | ---------- | -------- | 1933 | 426 | 1, 307 |
| 1914 | 24 | 75 | 1934 | 413 | 1, 267 |
| 1915 | 60 | 185 | 1935 | 423 | 1, 299 |
| 1916 | 71 | 218 | 1936 | 514 | 1, 577 |
| 1917 | 65 | 200 | 1937 | 556 | 1, 707 |
| 1918 | 71 | 217 | 1938 | 555 | 1, 703 |
| 1919 | 72 | 220 | 1939 | 636 | 1, 951 |
| 1920 | 75 | 230 | 1940 | 647 | 1, 985 |
| 1921 | 30 | 92 | 1941 | 453 | [9] 1, 391 |
| 1922 | 44 | 135 | 1942 | 545 | 1, 672 |
| 1923 | 85 | 261 | 1943 | 647 | 1, 985 |
| 1924 | 300 | 921 | 1944 | 562 | 1, 725 |
| 1925 | 326 | 1, 000 | | | |
| 1926 | 320 | 982 | | | |
| 1927 | 319 | 979 | | | |
| 1928 | 416 | 1, 278 | | | |
| 1929 | 458 | 1, 404 | | | |

**Laguna Beach County Water District, 1927–44**

[Water supply used almost exclusively by city of Laguna Beach]

| Year | Thousands of cubic feet | Acre-feet | Year | Thousands of cubic feet | Acre-feet |
|---|---|---|---|---|---|
| 1925 | ---------- | -------- | 1935 | 32, 279 | 741 |
| 1926 | ---------- | -------- | 1936 | 39, 946 | 917 |
| 1927 | 10, 475 | 240 | 1937 | 43, 096 | 989 |
| 1928 | 13, 546 | 311 | 1938 | 46, 582 | 1, 069 |
| 1929 | 18, 509 | 425 | 1939 | 48, 914 | 1, 123 |
| 1930 | 20, 560 | 472 | 1940 | 49, 329 | 1, 123 |
| 1931 | 25, 888 | 594 | 1941 | 55, 959 | 1, 285 |
| 1932 | 22, 889 | 525 | 1942 | 49, 931 | 1, 146 |
| 1933 | 24, 398 | 560 | 1943 | 53, 272 | 1, 223 |
| 1934 | 29, 220 | 671 | 1944 | [10] 5, 475 | 126 |

See footnotes at end of table.

TABLE 4.—*Yearly withdrawal of ground water by municipalities in the Long Beach–Santa Ana area*—Continued

ORANGE COUNTY—continued

**La Habra, 1934–41**

| Year | Millions of gallons | Acre-feet | Year | Millions of gallons | Acre-feet |
|---|---|---|---|---|---|
| 1930 | ---------- | -------- | 1940 | 64 | 198 |
| 1931 | ---------- | -------- | 1941 | 40 | 122 |
| 1932 | ---------- | -------- | | | |
| 1933 | ---------- | -------- | | | |
| 1934 | 31 | 95 | | | |
| 1935 | 45 | 137 | | | |
| 1936 | 54 | 166 | | | |
| 1937 | 45 | 138 | | | |
| 1938 | 79 | 243 | | | |
| 1939 | 58 | 179 | | | |

**Newport Beach, 1930–44**

[For years ending May 30]

| Year | Thousands of cubic feet | Acre-feet | Year | Thousands of cubic feet | Acre-feet |
|---|---|---|---|---|---|
| 1930 | 36, 076 | 828 | 1940 | 49, 799 | 1, 143 |
| 1931 | 39, 609 | 909 | 1941 | 50, 517 | 1, 160 |
| 1932 | 43, 040 | 988 | 1942 | 59, 667 | 1, 370 |
| 1933 | 37, 187 | 854 | 1943 | 73, 626 | 1, 690 |
| 1934 | 37, 946 | 871 | 1944 | 80, 441 | 1, 847 |
| 1935 | 37, 984 | 872 | | | |
| 1936 | 44, 064 | 1, 012 | | | |
| 1937 | 47, 539 | 1, 091 | | | |
| 1938 | 47, 128 | 1, 082 | | | |
| 1939 | 45, 694 | 1, 049 | | | |

**Orange, 1922–44**

| Year | Millions of gallons | Acre-feet | Year | Millions of gallons | Acre-feet |
|---|---|---|---|---|---|
| 1920 | ---------- | -------- | 1935 | 304 | 933 |
| 1921 | ---------- | -------- | 1936 | 332 | 1, 018 |
| 1922 | 236 | 723 | 1937 | 341 | 1, 048 |
| 1923 | 240 | 736 | 1938 | 364 | 1, 116 |
| 1924 | 275 | 843 | 1939 | 369 | 1, 131 |
| 1925 | 284 | 871 | 1940 | 375 | 1, 150 |
| 1926 | 262 | 804 | 1941 | 376 | 1, 154 |
| 1927 | 263 | 808 | 1942 | 428 | 1, 314 |
| 1928 | [11] 273 | 838 | 1943 | 456 | 1, 398 |
| 1929 | 298 | 914 | 1944 | 457 | 1, 401 |
| 1930 | 307 | 941 | | | |
| 1931 | 318 | 977 | | | |
| 1932 | 309 | 949 | | | |
| 1933 | 295 | 906 | | | |
| 1934 | 291 | 892 | | | |

See footnotes at end of table.

TABLE 4.—*Yearly withdrawal of ground water by municipalities in the Long Beach–Santa Ana area*—Continued

### ORANGE COUNTY—continued

**Santa Ana, 1900–44**

| Year | Millions of gallons | Acre-feet | Year | Millions of gallons | Acre-feet |
|---|---|---|---|---|---|
| 1900 | 237 | 727 | 1925 | 1,314 | 4,033 |
| 1901 | 248 | 761 | 1926 | 1,403 | 4,305 |
| 1902 | 256 | 786 | 1927 | 1,336 | 4,101 |
| 1903 | 294 | 903 | 1928 | 1,312 | 4,027 |
| 1904 | 355 | 1,090 | 1929 | 1,345 | 4,128 |
| 1905 | 379 | 1,162 | 1930 | 1,344 | 4,123 |
| 1906 | 514 | 1,577 | 1931 | 1,314 | 4,033 |
| 1907 | 456 | 1,400 | 1932 | 1,238 | 3,800 |
| 1908 | 477 | 1,461 | 1933 | 1,134 | 3,480 |
| 1909 | 458 | 1,406 | 1934 | 1,123 | 3,448 |
| 1910 | 544 | 1,668 | 1935 | 1,116 | 3,425 |
| 1911 | 539 | 1,654 | 1936 | 1,212 | 3,721 |
| 1912 | 779 | 2,390 | 1937 | 1,124 | 3,450 |
| 1913 | 810 | 2,486 | 1938 | 1,273 | 3,908 |
| 1914 | 785 | 2,409 | 1939 | 1,255 | 3,852 |
| 1915 | 884 | 2,713 | 1940 | [12] 172 | 3,944 |
| 1916 | 955 | 2,929 | 1941 | [12] 155 | [13] 3,547 |
| 1917 | 893 | 2,741 | 1942 | [12] 196 | 4,506 |
| 1918 | 868 | 2,664 | 1943 | [12] 218 | 4,010 |
| 1919 | 634 | 1,946 | 1944 | [14] 76 | 1,753 |
| 1920 | 970 | 2,977 | | | |
| 1921 | 1,014 | 3,111 | | | |
| 1922 | 1,099 | 3,373 | | | |
| 1923 | 1,291 | 3,961 | | | |
| 1924 | 1,436 | 4,407 | | | |

**Seal Beach, 1937–44**

[Prior to October 1937, all water purchased from city of Long Beach. Pumpage since 1937 equals metered consumption plus 18 percent to cover estimated losses, less water purchased from Long Beach]

| Year | Thousands of cubic feet | Acre-feet | Year | Thousands of cubic feet | Acre-feet |
|---|---|---|---|---|---|
| 1935 | --- | --- | 1940 | 7,624 | 175 |
| 1936 | --- | --- | 1941 | 8,942 | 205 |
| 1937 | 800 | 18 | 1942 | 10,106 | 232 |
| 1938 | 5,005 | 115 | 1943 | 11,612 | 267 |
| 1939 | 5,571 | 128 | 1944 | 13,680 | 314 |

---

[1] In addition, 1,328 acre-feet supplied by Metropolitan Water District.

[2] Through June 1944, only.

[3] Additional water supplied by Metropolitan Water District.

[4] Metered consumption plus 11 percent to cover estimated losses.

[5] November and December only; through October 1929 water supplied by city of Long Beach.

[6] Metered at wells; in antecedent years, quantities by city engineer from metered consumption and coefficient for losses.

[7] In addition, 479 acre-feet supplied by Metropolitan Water District.

[8] Water supplied chiefly by Metropolitan Water District beginning in July 1944.

[9] In addition, 845 acre-feet supplied by Metropolitan Water District.

[10] Water supplied chiefly by Metropolitan Water District beginning in February 1944.

[11] Pumpage for April and December estimated.

[12] Millions of cubic feet.

[13] In addition, 320 acre-feet supplied by Metropolitan Water District.

[14] Water supplied chiefly by Metropolitan Water District beginning in May 1944.

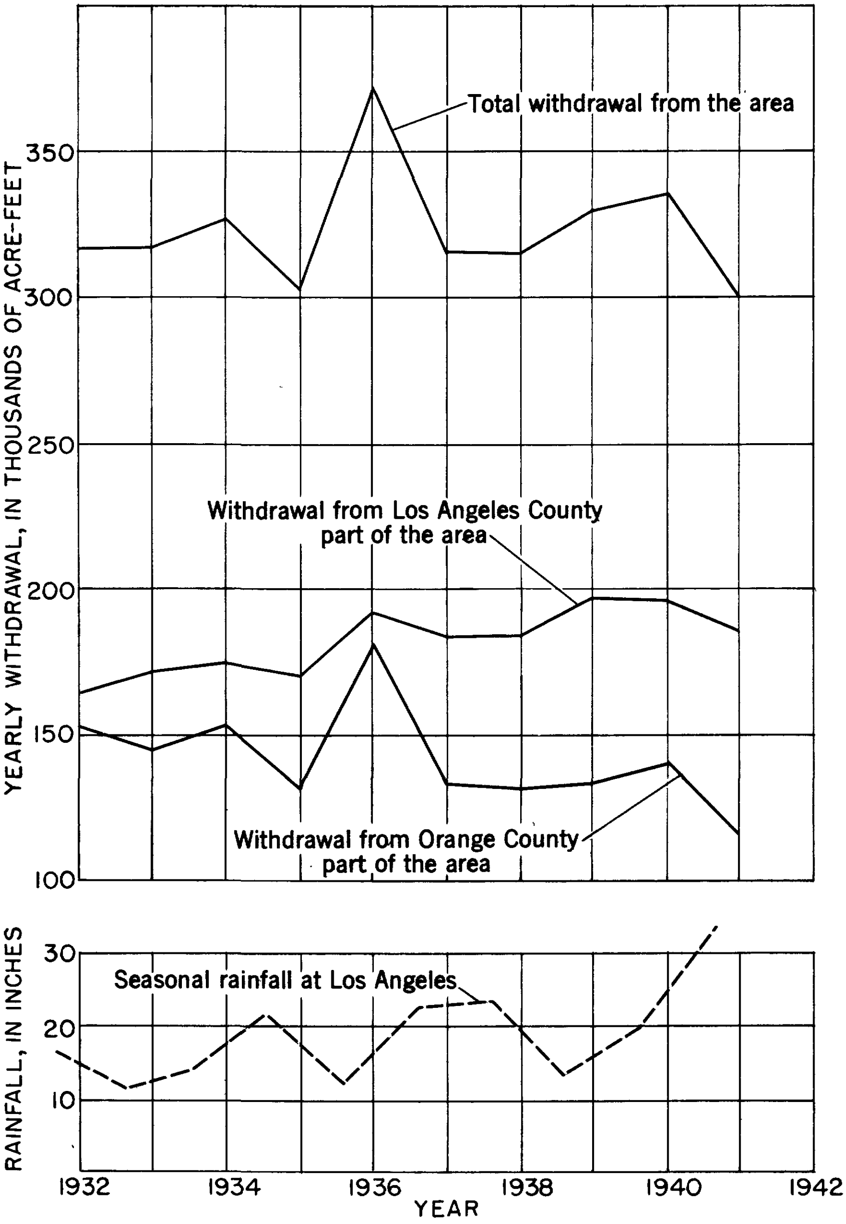

FIGURE 1.—Withdrawal of ground water from the Long Beach Santa-Ana area 1932–41.

Table 5 and figure 1 summarize the yearly withdrawal of ground water from the area of inventory (p. 9) for the 10 years from 1932 through 1941, by counties and according to type of use. The use classification cannot be applied rigorously, however. For example, the industrial withdrawal as listed does not include deliveries by several water companies for industrial use—this water is included in part in the total for "miscellaneous" and in part in the total for "agricultural;" also, a few of the water companies whose production is included under agricultural deliver a minor proportion of their water to domestic services, and other companies whose pumpage is included under "miscellaneous" deliver part of their water for irrigation as well as for the industrial uses to which reference has been made above. The primary purpose of the inventory was to estimate the over-all withdrawal of ground water from the area, which is given in table 5; a strict breakdown according to use was not feasible in the time and with the personnel available. Table 5 indicates that during the 10 years from 1932 through 1941 the average yearly withdrawal of ground water was about 182,000 acre-feet from the part of the area in Los Angeles County, about 142,000 acre-feet from the part in Orange County, and about 324,000 acre-feet from the area of inventory.

TABLE 5.—*Summary of yearly ground-water withdrawal from the Long Beach–Santa Ana area, in acre-feet, 1932–41*

| | 1932 | 1933 | 1934 | 1935 | 1936 | 1937 | 1938 | 1939 | 1940 | 1941 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Los Angeles County** | | | | | |
| Municipal systems | 41, 500 | 40, 400 | 39, 200 | 38, 700 | 33, 900 | 33, 400 | 35, 000 | 35, 900 | 36, 600 | 37, 300 |
| Industrial | 24, 200 | 22, 500 | 21, 900 | 23, 100 | 26, 900 | 24, 100 | 22, 200 | 27, 100 | 28, 300 | 32, 800 |
| Agricultural [1] | 75, 100 | 81, 600 | 84, 700 | 79, 500 | 101, 200 | 94, 500 | 93, 000 | 96, 500 | 92, 000 | 77, 700 |
| Miscellaneous [2] | 23, 500 | 27, 300 | 28, 400 | 29, 100 | 30, 900 | 32, 500 | 34, 300 | 37, 800 | 39, 200 | 38, 400 |
| The county | 164, 300 | 171, 800 | 174, 200 | 170, 400 | 192, 900 | 184, 500 | 184, 500 | 197, 300 | 196, 100 | 186, 200 |
| | | | | | **Orange County** | | | | | |
| Municipal systems | 9, 100 | 8, 600 | 8, 600 | 8, 900 | 10, 000 | 10, 100 | 11, 100 | 11, 300 | 11, 500 | 10, 400 |
| Industrial [3] | 4, 300 | 4, 300 | 4, 400 | 4, 400 | 4, 800 | 5, 600 | 5, 900 | 4, 200 | 4, 400 | 4, 500 |
| Agricultural [1] | 134, 800 | 127, 400 | 135, 100 | 113, 600 | 160, 300 | 110, 700 | 109, 000 | 112, 400 | 118, 700 | 93, 300 |
| Miscellaneous [2] | 4, 500 | 4, 900 | 5, 200 | 5, 200 | 5, 500 | 5, 600 | 5, 500 | 5, 700 | 5, 800 | 5, 800 |
| The county | 152, 700 | 145, 200 | 153, 300 | 132, 100 | 180, 600 | 132, 000 | 131, 500 | 133, 600 | 140, 400 | 114, 000 |
| The whole area | 317, 000 | 317, 000 | 327, 500 | 302, 500 | 373, 500 | 316, 500 | 316, 000 | 330, 900 | 336, 500 | 300, 200 |

[1] Includes withdrawal by water companies that pump water chiefly for agricultural use.
[2] Chiefly by water companies for domestic use.
[3] Includes water pumped by gun clubs.

# PRINCIPAL SOURCES OF THE WATER WITHDRAWN

## GENERAL FEATURES

Within the Long Beach–Santa Ana area, the aquifers that yield ground water are tapped by many thousands of water wells. The exact number of wells is not known but it is estimated that as of 1944 there are between 6,000 and 8,000 active or potentially active water wells within the project area. Of these, about 1,550 wells are in the coastal zone and have been canvassed by the Geological Survey (table 29).

These many wells vary widely in depth. Commonly, where productive water-bearing zones occur at shallow depth beneath land surface, the bulk of the wells tap the uppermost zone whose water is of suitable quality. If this uppermost zone does not yield sufficient water to supply the requirements for which the well is constructed, and if underlying water-bearing zones occur at economic depths, wells are drilled sufficiently deep to reach and tap several water-bearing zones. In the coastal zone, the depth is known for 1,540 wells; these depths range from 6 to 1,700 feet. Depths for 1,524 of these wells have been summarized in table 6.

TABLE 6.—*Depth range for 1,524 water-supply wells and observation wells in the coastal zone of the Long Beach–Santa Ana area*

| Depth range (feet) | Number of wells of known depth | Depth range (feet) | Number of wells of known depth |
|---|---|---|---|
| <50 | 183 | 400–499 | 86 |
| 50–99 | 195 | 500–749 | 132 |
| 100–199 | 482 | 750–999 | 81 |
| 200–299 | 176 | 1,000+ | 50 |
| 300–399 | 139 | | |

Thus, in the coastal zone, 32 percent of the wells range from 100 to 199 feet in depth and only 3 percent (50 wells) are more than 1,000 feet deep. Most of the wells that are more than 1,000 feet deep are in Los Angeles County. In the inland zone the wells vary about as widely in depth as in the coastal zone, but their average depth is probably much greater. So far as known, the deepest water well in Los Angeles County in 1944 was 3/12–8F1 at the Los Angeles County Farm, drilled to a depth of 1,755 feet; the deepest in Orange County was I–121D1, well 1170 of the Irvine Co., drilled to a depth of 1,660 feet.

In the Long Beach–Santa Ana area, the yield of a well does not vary in proportion to its depth, but the wells of large capacity commonly tap one or more of a few principal water-bearing zones and usually are the deeper.

In Los Angeles County the wells of largest capacity occur in two widely separated areas. (1) In and for a few miles coastward from the Whittier Narrows, many of the wells yield more than 1,000 gpm, several yield in the range from 2,000 to 3,000 gpm, and a few yield more than 3,000 gpm. These wells of large capacity commonly are several hundred feet deep and tap not only the Gaspur water-bearing zone of Recent age but also underlying water-bearing beds of Pleistocene age. The aquifers tapped are chiefly gravel and coarse sand of fluvial origin and of high permeability. (2) In the Long Beach district, specifically in the reach from Wilmington to Dominguez Gap and in the area extending a few miles north and northeast of Signal Hill, almost all the deeper wells yield more than 1,000 gpm, several yield more than 2,000 gpm, and two wells in the Wilmington area yielded 4,000 gpm or more on initial test. Most of these wells tap the Silverado water-bearing zone of Pleistocene age and range in depth from 600 to 1,000 feet. A few municipal wells of large capacity tap basal Pleistocene aquifers underlying the Silverado water-bearing zone and are as much as 1,700 feet deep. These deeper wells in the Long Beach area commonly tap gravel and sand in an aggregate thickness of more than 200 feet—beach or shallow-marine deposits of medium to coarse texture and of fairly high permeability.

In Orange County also, the wells of largest capacity occur in two widely separated areas, which in their geologic features correspond to the two areas of high yield in Los Angeles County. (1) In and for a few miles coastward from the Santa Ana Canyon, most wells yield more than 1,000 gpm, several which are more than 500 feet deep yield in the range from 2,000 to 3,000 gpm, and a very few yield more than 3,000 gpm. Although many of these wells tap the Talbert water-bearing zone, their water is drawn currently from the underlying Pleistocene deposits because the Talbert zone is above the water table in this reach. (2) Locally, on the north end of Newport Mesa, several of the deeper wells yield more than 2,000 gpm. These wells tap a thick water-bearing zone of Pleistocene age—beach or shallow-marine deposits correlative to but much less extensive than the Silverado water-bearing zone of the Long Beach area.

In the remainder of the Long Beach–Santa Ana area, although the wells vary widely in depth, their yields commonly range from 300 to 1,000 gpm.

With respect to the principal water-bearing zones, the report on geologic features (Poland, Piper, and others, 1956) has presented specific information relating to location, extent, range in thickness, physical character, and water-bearing character, and has reported briefly on their general hydrologic features. The present discussion will summarize their depth below land surface and thickness from place to place, the districts where each is tapped by wells or is beyond economic reach of the drill, their relative water-yielding capacities, their estimated over-all yield where available, and the uses to which this water is put.

## SOURCES IN THE ALLUVIAL DEPOSITS OF RECENT AGE

With respect to the occurrence and withdrawal of ground water, the two principal aquifers in the alluvial deposits of Recent age are the Gaspur and Talbert water-bearing zones, together with the minor tongues in physical continuity with these zones. Where present, these zones constitute a basal division of the Recent deposits and are covered by the heterogeneous but predominantly fine-textured deposits of an upper division whose upper surface is the Downey plain. Their geologic features have been discussed elsewhere (Poland, Piper, and others, 1956, p. 44-51, and pl. 7.)

### GASPUR WATER-BEARING ZONE

The Gaspur water-bearing zone extends inland 21 miles from Terminal Island to the Whittier Narrows and ranges in width from a minimum of 1 mile where the channel crosses the Newport–Inglewood zone in Dominguez Gap, to a maximum of 4 miles in the vicinity of Downey. Throughout this 21-mile reach, the top of the zone ranges from 50 to 100 feet below land surface. From Terminal Island northward through Dominguez Gap, its top is from 50 to 80 feet below land surface and its thickness ranges from 40 to 70 feet. From Artesia Street northward to Firestone Boulevard in the vicinity of Downey, its top ranges from 50 to 100 feet below land surface and its thickness ranges from 50 to 80 feet. Northward from Firestone Boulevard to Whittier Narrows, its top is 40 to 60 feet below land surface and its thickness ranges from 50 to 75 feet. However, in the northern part of this segment—that is, northward from Foster Bridge Boulevard near the Rio Hondo, and from Anaheim–Telegraph Road near the San Gabriel River—the Gaspur zone commonly is unconfined and is overlain by medium- to coarse-grained sand of fair permeability.

The Gaspur water-bearing zone is tapped by wells throughout its full 21-mile reach from Terminal Island to Whittier Narrows. Because it is the uppermost aquifer and because it has large water-yielding capacity, most wells drilled into this zone are bottomed within it or a few feet below its base. However, in most of the reach from Terminal Island into Dominguez Gap—that is, about 6 miles inland almost to Del Amo Street—the zone has been invaded by salty waters unfit for most uses. (Piper, Garrett, and others, 1953, p. 177) Here, 13 wells have been drilled through the Gaspur water-bearing zone to tap the thick, productive, and still uncontaminated Silverado water-bearing zone beneath. Of these, 10 wells were still active as of January 1945; only two wells, 4/13–23M1 and 27K1, were perforated in both the Gaspur zone and the Silverado zone. Well 23M1 collapsed several years ago and has been abandoned; well 27K1 is not now used except as an observation well.

The Gaspur water-bearing zone yields water copiously, as might be expected of a uniform and highly permeable deposit. See table 7.

TABLE 7.—*Yield characteristics of five wells drawing from the Gaspur water-bearing zone in the Dominguez Gap*

| Well | Depth (feet) | Water-yielding zone or zones | | | | | |
|---|---|---|---|---|---|---|---|
| | | Depth range (feet) | Thickness (feet) | Yield (gpm) | Drawdown (feet) | Specific capacity[1] | Yield factor[2] |
| 4/13- 2P1 | 118 | 83-117 | 34 | 860 | 11 | 78 | 230 |
| 14D2 | 161 | 80-138 | 58 | 1, 500 | 17 | 88 | 152 |
| 14G1 | 187 | ---------- | -------- | 210 | 18± | 12 | ---------- |
| 14N3 | 128 | 60-127 | 67 | 210 | ---------- | ---------- | ---------- |
| 15R2 | 135 | 80-126 | 46 | 430 | 6 | 72 | 156 |

[1] Gallons per minute per foot of drawdown.

[2] $\text{Yield factor} = \frac{\text{Specific capacity x 100}}{\text{Thickness of aquifer, in feet}}$

NOTES.—In table 7 and similar tables to follow, specific capacity (relation of drawdown to discharge) is used as the convenient rough scale for the water-yielding capacity of a well and for the relative transmissibility of the water-bearing zone at the place. The additional concept, defined by the "yield factor," is introduced as an approximate relative 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-bearing material tapped but also on the number, size, and condition of perforations in the casing and their distribution within the water-bearing zones tapped.

In this report, especially in table 7 and other tables to follow, yield and drawdown are given for a substantial number of wells tapping one or more of the principal water-bearing zones. From these data, specific capacity or gallons per minute per foot of drawdown has been computed. 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."

In Geological Survey Water-Supply Paper 887, pages 147–151, Wenzel has pointed out the shortcomings of the relation between drawdown and discharge as an index of relative permeability. Nevertheless, it is believed that in the absence of more specific data the yield factors of this report afford a useful rough index of the average permeabilities of the water-bearing material, because:

1. Yield factors are derived only for wells which tap confined water bodies and whose drawdowns are so moderate that none of the permeable material is unwatered, and that a straight-line relation of drawdown to discharge holds in most cases.
2. Virtually all the wells are of the common "California" or stovepipe construction, with casings in the range from 12 to 16 inches in diameter and perforated alike.
3. So far as possible, the yield factor was calculated from data taken early in the life of the well, commonly at the end of the period of development and test-pumping. The more reliable values probably are those obtained from relatively new wells, because there is a tendency for specific capacity to decrease with age of casing, presumably owing to encrustation or other processes that decrease the effective size of perforations or otherwise increase entrance friction.

Data for calculating specific capacity or yield factor are not available for wells that tap the Gaspur water-bearing zone inland from the Dominguez Gap. However, it is known that the most copious yields from the zone are from wells in or near the Whittier Narrows—commonly more than 1,000 gpm.

The Gaspur water-bearing zone yields copiously to wells for irrigation, municipal, domestic, and industrial uses. Initially, this zone sustained a heavy draft throughout the reach from Whittier Narrows to Terminal Island. However, since the early twenties the chemical quality of its water has deteriorated greatly in and coastward from the Dominguez Gap, withdrawal from the zone in that area has decreased sharply and currently is small. Inland from the Dominguez Gap, withdrawals have been about constant in the past decade, although there has been a continued shift from irrigation to domestic use as agricultural developments have been transformed to residential areas.

In its 6-mile reach between the coast and the Dominguez Gap (Del Amo Street) the Gaspur water-bearing zone covers about 11 square miles and has been tapped by about 85 percent of the wells of known depth in that area. From a map showing irrigated area as of 1932 (Calif. Div. Water Resources, 1933, pl. A), it is estimated that about 3 square miles of the area then was under irrigation, and probably used about 2,500 acre-feet of water a year. At that time a few wells were pumped for industrial use and possibly 50 wells for domestic or stock use, but the yearly withdrawal by all these did not exceed a few hunded acre-feet. Although this area is underlain at greater depth by the prolific Silverado water-bearing zone, the field canvass of wells by the Geological Survey showed that this land has been irrigated almost exclusively by water drawn from the Gaspur zone. In addition to this draft for irrigation, some water was exported by wells of the Dominguez Water Corp. (written communication, 1944), which has estimated from records that its withdrawals from the zone was 3,736 acre-feet in 1928, 470 acre-feet in 1933, nothing in 1938, and 153 acre-feet in 1943.

Thus, the aggregate withdrawal from the Gaspur water-bearing zone between the coast and Del Amo Street in 1932 is estimated to have been about 3,500 acre-feet, or about equal to that by the Dominguez Water Corp. as of 1928. This suggests that withdrawal diminished about 50 percent from 1928 to 1932. As of 1941, there were 24 more or less active irrigation wells, 3 public-supply wells, and 2 industrial wells tapping the Gaspur zone in this same area. By then, the water within the zone had become grossly contaminated beneath about 7 square miles of the area, and 8 of the 29 wells equipped with turbine pumps were within the area whose water contained more than 500 ppm of chloride (Piper, Garrett, and others, 1953, pl. 17). With contamination in this degree, withdrawal from the zone had diminished to an estimated 2,000 acre-feet a year, or to about 25 percent of the withdrawal of 1928. Since 1941 withdrawal has diminished still more, owing to spread of contamination and to construction of housing propects in areas that formerly were irrigated. Domestic water for these housing propects is supplied chiefly by the city of Long Beach, and thus is not drawn from the Gaspur zone.

In its 15-mile reach from the Dominguez Gap inland to the Whittier Narrows, the Gaspur water-bearing zone underlies about 34 square miles and is estimated to be (as of 1944) the source of 75 percent of the water drawn from wells in this reach. All this area is intensively developed—most of the 6-mile reach downstream from Whittier Narrows is planted to citrus groves and the succeeding 9-mile reach downstream to Del Amo Street is planted to garden and field crops or is used for domestic and industrial purposes. Under these conditions, it is estimated that from this 34-square-mile area the aggregate withdrawal in 1944 was about 30,000 acre-feet a year and the withdrawal from the Gaspur zone about 23,000 acre-feet a year (75 percent of the aggregate). Although several thousand acres in this reach are irrigated by water diverted from the San Gabriel River and the Rio Hondo (Conkling, Harold, 1927, p. 116-119, pl. 18; Blaney and Huberty, 1930, table 5), an equal area beyond the reach of the Gaspur water-bearing zone is irrigated by water withdrawn and exported from that zone and from underlying deposits. Thus, the evidence suggests that ground water exported from the Gaspur zone to irrigate outlying lands more than offsets the surface water imported. Accordingly, it is estimated that as of 1941 the withdrawal from the entire Gaspur water-bearing zone from Whittier Narrows to Terminal Island was about 25,000 acre-feet a year. Since 1941, during the war, the withdrawal from the Gaspur zone has diminished between Del Amo Street and the coast (p. 33) but probably has increased substantially from Del Amo Street inland to Whittier Narrows, especially with respect to water exported. Therefore, as of 1944 the withdrawal from the entire zone probably was not less than 25,000 acre-feet.

The minor water-bearing tongue which trends southward from the Los Angeles Narrows and merges into the Gaspur zone about a mile northeast of Compton (Poland, Piper, and others, 1956, p. 47) was not examined with respect to productivity and yield. Thus, the relative importance of this arm of the Gaspur zone with respect to yield is not known. The chemical character of its water is substantially inferior to that of the Gaspur zone (Piper, Garrett, and others, 1953, p. 203), and most public-supply and industrial wells of the area are cased through the tongue to tap one or more of several underlying water-bearing zones of Pleistocene age which contain water of good quality.

### TALBERT WATER-BEARING ZONE

The Talbert water-bearing zone extends continuously from the Pacific Ocean inland 20 miles to the Santa Ana Canyon. It ranges in width from a minimum of about 1.2 miles in lower Santa Ana Canyon to a maximum of about 6 miles between Garden Grove and Anaheim. In the Santa Ana Gap its average width is about 2.1 miles. (Poland, Piper, and others, 1956, pl. 7) Within its full extent, the top of the Talbert water-bearing zone is from 50 to 90 feet below land surface. In the Santa Ana Gap south of Talbert Avenue, its top ranges from 50 to 90 feet below land surface and its thickness ranges from 40 to 100 feet. From Talbert Avenue inland to Garden Grove, its top ranges from 60 to 90 feet below land surface and its thickness from 70 to 110 feet. Northward to Anaheim, its top is from 60 to 90 feet below land surface and its thickness ranges from 60 to 100 feet. Beyond Anaheim and northeastward into the Santa Ana Canyon, coarse water-bearing deposits extend continuously from land surface down to the base of the Talbert zone—that is, to about 150 feet below land surface.

Because the Talbert water-bearing zone is everywhere at shallow depth, it is tapped by several hundred water wells. Initially the zone was saturated from the coast inland into the Santa Ana Canyon and was tapped by water wells throughout this full reach. From 1860 to 1890, it sustained many flowing wells from the coast inland to and about 2 miles beyond Garden Grove (Mendenhall, 1905a, pls 6, 7), owing to a relatively impervious confining bed that extends inland about 3 miles beyond Garden Grove or about to Highway 101. The area of initial artesian flow is also the area within which the Talbert zone has remained saturated through several decades of water use. Inland from a line between Anaheim and Orange, the water table fell many tens of feet between 1890 and 1930 and has remained below the Talbert zone almost continuously since 1930. In this inland area the Talbert zone attains its coarsest texture and probably its highest permeability, and transmits large quantities of water from the Santa Ana River to underlying aquifers and to its downstream reach. However, since about 1930 it has been largely unwatered and has yielded almost no water to wells.

The Talbert zone is highly permeable throughout, but its permeability diminishes substantially toward the coast. This is shown by the data of table 8.

TABLE 8.—*Yield characteristics of eight wells withdrawing from the Talbert water-bearing zone*

| Well | Depth (feet) | Water-yielding zone or zones | | | | | |
|---|---|---|---|---|---|---|---|
| | | Depth range (feet) | Thickness (feet) | Yield (gpm) | Drawdown (feet) | Specific capacity [1] | Yield factor [1] |
| 4/10-27F1 | 185 | 90–139 | 40 | 760 | 4 | 190 | 475 |
| 28A2 | 152 | 110–145 | 35 | 435 | 3.5 | 124 | 354 |
| 32A1 | 149 | 110–148 | 38 | 695 | 4.5 | 154 | 406 |
| 5/11-12A1 | 150 | ---- | ---- | 730 | 6 | 122 | ---- |
| 6/10- 8D5 | 279 | [2] 18–212 | 42 | 1,060 | 13 | 82 | 194 |
| 18C1 | 196 | 95–136 | 41 | 820 | 18 | 46 | 112 |
| 18C2 | 190 | 95–140 | 45 | 970 | 15 | 65 | 144 |
| 6/11- 13J1 | 150 | ---- | ---- | 480 | 13 | 37 | ---- |

[1] For definition see table 7.

[2] Taps 10 ft of Pleistocene water-bearing material also.

Of the eight wells included in table 8, Nos. 4/10-27F1, 28A2, and 32A1 are about 1 mile north of Garden Grove and 11 miles inland from the ocean; the average of their yield factors is 412. Wells 6/10-8D5, 18C1, and 18C2 are in the Santa Ana Gap and about 2 miles from the ocean; the average of their yield factors is 150. These two averages suggest that the permeability of the Talbert water-bearing zone in the reach between Garden Grove and Anaheim is about three times its permeability in the Santa Ana Gap. Such a difference in permeability is compatible with the known texture of the materials—coarse and well-sorted gravel in the vicinity of Garden Grove but finer and more heterogeneous gravel and sand in the Santa Ana Gap. It is believed likely that from Anaheim northeastward into the Santa Ana Canyon the permeability of the Talbert water-bearing zone is substantially greater than in the vicinity of Garden Grove and greater than any shown by the data of table 8. Available data (tables 7 and 8) suggest that, at least near the coast, the Talbert and Gaspur water-bearing zones have permeabilities of about the same order of magnitude.

The Talbert water-bearing zone yields freely to many hundred wells for agricultural, municipal, and domestic uses. Initially, withdrawal for irrigation supply was made from wells less than half a mile from the ocean but, owing to deterioration of water quality in the Santa Ana Gap from 1930 to 1945 (inland about to Atlanta Avenue), all these particular wells near the ocean have been abandoned. In this area of deterioration, only 10 wells withdrew appreciable quantities of water from the zone in 1944.

From Atlanta Avenue in the Santa Ana Gap (at Atlanta Avenue) inland to Highway 101, about 11 miles along the axis of the Talbert zone, yearly withdrawal of ground water has been reasonably constant from 1935 to 1945. This is the reach between the coastal area of water now contaminated and the inland area now unwatered. Within a mile-wide strip of this reach, 89 percent of the 122 wells of known depth are not more than 200 feet deep; most of these wells draw water solely or chiefly from the Talbert zone. For 30 wells that draw solely or chiefly from the Talbert zone, yields are known from tests by the Orange County Flood Control District, by J. R. Tavernetti and M. R. Huberty of the University of California, by the Southern California Edison Co., and by the Geological Survey; the average of these yields is 713 gpm to the well. Yields are known also for 67 wells drawing water from both the Talbert and underlying aquifers within this same area; the average of these yields is 691 gpm to the well. Because these two averages are about equal, and because the casings of the deeper wells commonly are perforated both in the Talbert and in underlying zones, it seems conservative to assume that within the 11-mile reach from Atlanta Avenue inland to Highway 101, the Talbert zone sustains at least 75 percent of the over-all draft as of 1945.

In this reach, in which its water is utilized currently, the Talbert zone underlies about 37 square miles, of which virtually all is intensively cultivated. As of 1932, about the inland half of the acreage was planted to orange groves and the coastal half to garden and field crops (Calif. Div. Water Resources, 1933, pl. A) ; there has been little change in crop distribution since that time. Because the area is so extensively cultivated by irrigation from wells, it is estimated that the average yearly ground-water withdrawal is about 35,000 acre-feet, equivalent to an average duty of water of about 1.6 feet a year on 90 percent of the 37 square miles. Thus, if from 75 to 80 percent of the water pumped from wells in this 37-square-mile area is withdrawn from the Talbert zone, as appears reasonable from the distribution of well depths previously summarized, the average yearly draft from the zone for irrigation and for domestic use probably ranges from 25,000 to 28,000 acre-feet. As of 1941, an additional 3,340 acre-feet of water was exported from the zone in Santa Ana Gap from the well fields of the Laguna Beach County Water District, the city of Newport Beach, the Fairview Farms Water Co., and the Newport Mesa Irrigation District. Therefore, it appears that in the late thirties and early forties the maximum yearly withdrawal from the Talbert zone for all purposes was about 30,000 acre-feet, and that the average yearly draft can be conservatively estimated as to range from 25,000 to 30,000 acre-feet.

### "EIGHTY-FOOT GRAVEL"

The thin water-bearing zone known as the "80-foot gravel" underlies the Bolsa Gap and is in hydraulic continuity with the

Talbert water-bearing zone to the northeast. (Poland, Piper, and others, 1956, p. 45, pls. 5, 7). Its average length from the coast to its juncture with the Talbert zone near Midway City is 6 miles, its average width is 1.5 miles in the Bolsa Gap and 2 miles near Midway City, and its over-all extent is about 10 square miles.

In the vicinity of Midway City and Westminster, the top of the "80-foot gravel" is from 80 to 100 feet below land surface and the zone ranges from 15 to 30 feet in thickness; in the Bolsa Gap its top is 50 to 70 feet below land surface and it ranges from 10 to 30 feet in thickness. Thus, because the zone is shallow throughout, it is tapped by many water wells for irrigation and domestic use.

About 200 water wells were active within the extent of the "80-foot gravel" at the time of field canvass by the Geological Survey early in 1941. Of these, 90 had turbine or centrifugal pumps in 1941 and were used for irrigation. Of these 90 wells, 44 are known or inferred to draw water exclusively from the "80-foot gravel," and 43 tap the underlying San Pedro formation of Pleistocene age. For three wells no information is available with respect to the water-bearing zone or zones tapped. For the area of about 10 square miles underlain by the "80-foot gravel," the map showing irrigated areas as of 1932 (Calif. Div. Water Resources, 1933, pl. A) indicates that at that time about 7.5 square miles was under irrigation in garden and field crops (a small part of this area took water for domestic or industrial use). All supply is from ground-water sources. Because there has been little if any change in irrigated area from 1932 to 1945, the average yearly use of ground water on the 7.5 square miles can be estimated conservatively as about 6,000 acre-feet. About half the wells used for irrigation tap only the "80-foot gravel" and some of the deeper wells draw water both from this zone and from the underlying San Pedro formation. However, many of the deeper wells tap water-bearing deposits in the San Pedro formation that in the aggregate are several times as thick as the "80-foot gravel." Thus, these wells yield several times as much water as do many of the wells tapping only the thin "80-foot gravel." Therefore, it is estimated that slightly less than half the water pumped from the area, or about 2,500 acre-feet, is drawn from the "80-foot gravel."

### SOURCES IN THE DEPOSITS OF PLEISTOCENE AGE IN LOS ANGELES COUNTY

With respect to a description of sources in that part of the coastal zone of the Long Beach–Santa Ana area which is in Los

Angeles County (Poland, Piper, and others, 1956, pl. 3), the water-bearing deposits of Pleistocene age can be classified into three groups. In downward succession these are: (1) minor water-bearing zones in the Palos Verdes sand, in the unnamed upper Pleistocene deposits, and locally in the uppermost part of the San Pedro formation; (2) the Silverado water-bearing zone, which southwest of the Newport-Inglewood structural zone occupies the central and lower parts of the San Pedro formation, but which northeast of Signal Hill is chiefly in the central part of that formation; and (3) the somewhat discontinuous but prolific water-bearing zones in the basal Pleistocene deposits northeast of Signal Hill.

### MINOR WATER-BEARING ZONES

The Palos Verdes sand, the unnamed upper Pleistocene deposits, and the part of the San Pedro formation that is above the Silverado water-bearing zone all contain thin and somewhat discontinuous aquifers which yield water to many wells of small capacity and to a few wells of large capacity. Throughout most of the coastal part of Los Angeles County here considered, the Palos Verdes sand, the unnamed upper Pleistocene deposits, and the upper part of the San Pedro formation together are several hundred feet thick. Thus, beneath the southern part of the Torrance plain in the general vicinity of Wilmington their thickness is about 300 feet; northward their thickness increases gradually to as much as 700 feet in the syncline at the south flank of Dominguez Hill. Because the top of these deposits forms the land surface, their thicknesses here given also represent depth below land surface to their base. Along the crest of the Newport-Inglewood structural zone these deposits range commonly from 50 to 250 feet in thickness; along the inland flank of that structural zone—that is, along a line about through Compton and Los Alamitos—they range from 400 to 600 feet in thickness and extend to almost that depth below land surface. They contain a succession of gravel layers from 10 to 50 feet thick, interspersed within material of small average permeability. Locally beneath the Torrance plain they contain a sand member about 200 feet thick.

These minor water-bearing zones are tapped by many water wells widely distributed and of diverse depths. The shallowest wells include several on the Torrance plain which have a minimum depth of 30 feet and which have meager supplies of ground water in the uppermost Pleistocene deposits, presumably in the Palos Verdes sand. Within the area here discussed, most of the domestic or stock wells of small diameter and low yield and the wells for small irrigation use draw water from these minor zones, except where those zones are overlain by the highly prolific Gaspur water-bearing zone previously described or by other water-bearing deposits of Recent age.

Table 10 lists the wells active in this part of the Long Beach area as of 1941–43, and classifies them according to the geologic age of their water-bearing zones. Of 323 active wells there classified, 104 wells tap undifferentiated Pleistocene deposits; most of these draw water from the minor zones here treated. Of these 104 wells, 48 were equipped with turbine pumps or with other pumping equipment of moderately large capacity but 56 were equipped with plunger pumps and windmills, or other equipment suggesting light withdrawal. Nearly all the lightly pumped wells and probably about half of the 48 wells equipped with turbine pumps draw from the minor water-bearing zones.

Many of the pumps in these wells have capacities of only a few gallons per minute for domestic or stock purposes, and many of the zones tapped comprise sand or fine gravel from only a few feet to 30 feet thick. Thus, many of the wells could not sustain large yields even if pumping equipment of larger capacity were to be installed. On the other hand, a few wells tapping the most prolific of the minor water-bearing zones are equipped with turbine pumps and yield as much as 1,000 gpm for irrigation. For example, about 4 miles northeast of Signal Hill, well 4/12-4J3 was drilled to a depth of 354 feet and reportedly yields 1,200 gpm from one of these minor water-bearing zones. Also, well 4/12-14C1 (city of Long Beach, Commission well 5)—which was drilled to a depth of 324 feet below land surface and perforated from 240 to 260 and 294 to 300 feet in the unnamed upper Pleistocene deposits or in the uppermost part of the San Pedro formation—has a sustained yield of about 600 gpm, a specific capacity of 10, and a yield factor of 38. On the average, this well has yielded about 900 acre-feet of water a year from 1935 to 1945. It is probably the most productive well drawing from the minor water-bearing zones of Pleistocene age.

From data now available, it is not possible to estimate with accuracy the over-all yield from wells tapping these minor zones. However, from the number of active wells and the known facts concerning pumping equipment and use of water, the aggregate yearly withdrawal as of 1945 probably is between 2,500 and 3,500 acre-feet.

### SILVERADO WATER-BEARING ZONE OF THE SAN PEDRO FORMATION

The Silverado water-bearing zone is the most extensive and most productive single aquifer in the deposits of Pleistocene age in all the Long Beach-Santa Ana area. Its extent, physical character, and general water-bearing character have been described in the report on geologic features (Poland, Piper, and others, 1956, p. 69-71, 80-86, pl. 8). Because the Silverado zone was deposited chiefly along a shoreline or in shallow-marine waters during and prior to periods of substantial warping and faulting, the depth of its top below land surface, its thickness, and the depth to its base now vary widely. The depth to its base and its thickness have been shown in some detail in the report on geologic features just cited, but are here summarized in table 9 because the Silverado water-bearing zone is so important a source of water in the vicinity of Long Beach.

TABLE 9.—*Depth to top and thickness of the Silverado water-bearing zone*

| Place | Depth to top (feet below land surface) | Thickness (feet) |
|---|---|---|
| Terminal Island, eastern part | 700 | 250 |
| Bixby Slough, north side | 150 | 700 |
| Alameda St. and Pacific Coast Highway | 400 | 400 |
| Wilmington Ave. and Sepulveda Blvd | 450 | 350 |
| Alameda and Carson Sts | 770 | 450 |
| Main and Carson Sts | 500 | 200 |
| Dominguez St., 0.5 mile east of Santa Fe Ave | 250 | 380 |
| Dominguez Hill, crest | 250 | [1] 300 |
| Dominguez Gap, 0.5 mile north of Del Amo St | 400 | 290 |
| Wardlow Rd. and Cherry Ave | 300 | 400 |
| Lakewood Blvd. and Stearns St | 120 | [1] 620 |
| Atlantic Ave., 0.5 mile south of Artesia St | 620 | 300 |
| Spring St. near San Gabriel River | 300 | [1] 700 |

[1] Includes one or more partings of silt or clay.

As a nearly uniform body of water-bearing material, the Silverado zone attains its maximum thickness of about 700 feet in the vicinity of Bixby Slough. The over-all thickness of the zone is slightly greater, 715 feet, northeast of Signal Hill at well 4/12-14P1 (Wilson Ranch well, city of Long Beach), but there it includes layers of silt and clay and the thickness of water-bearing material within the zone is substantially less than in the vicinity of Bixby Slough. The known minimum thickness of the Silverado zone is about 1.5 miles southwest of the crest of Dominguez Hill at well 4/13-5J1, where only 81 feet of sand and gravel was tapped.

As described in the report on geologic features (Poland, Piper, and others, 1956, p. 69, pl. 8) the Silverado water-bearing zone underlies some 68 square miles in the Long Beach-Santa Ana area. Almost everywhere within this reach it is tapped by wells and nowhere is it beyond economic reach of the drill when a well of large capacity is required. At most places, it is overlain by one or more of the minor water-bearing zones previously described, but even so nearly all the industrial and municipal wells of large capacity, and many of the irrigation wells are cased through these minor zones and draw exclusively from the Silverado water-bearing zone. Table 10 lists the active wells within the known extent of the Silverado zone, and classifies them according to the geologic age of the water-bearing zones they tap.

TABLE 10.—*Geologic classification of 323 among 348 active water wells within known extent of the Silverado water-bearing zone, as of 1941–43*

| Geologic classification of water-yielding zones | Municipal, industrial, or irrigation wells; heavily pumped, commonly with turbine pump | | | | | Domestic or stock wells; lightly pumped, commonly with plunger pump | | | | | All wells |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. 3 S., R. 12 W. | T. 3 S., R. 13 W. | T. 4 S., R. 12 W. | T. 4 S., R. 13 W. | Total | T. 3 S., R. 12 W. | T. 3 S., R. 13 W. | T. 4 S., R. 12 W. | T. 4 S., R. 13 W. | Total | |
| Recent: | | | | | | | | | | | |
| Undifferentiated deposits | 4 | ------ | 3 | 3 | 10 | 1 | ------ | 2 | 10 | 13 | 23 |
| Gaspur water-bearing zone | ------ | 9 | ------ | [1] 35 | 44 | ------ | 2 | ------ | 35 | 37 | 81 |
| Pleistocene: | | | | | | | | | | | |
| Undifferentiated deposits | 3 | 9 | 24 | 12 | 48 | ------ | 14 | 18 | 24 | 56 | 104 |
| Silverado water-bearing zone | 2 | 6 | 37 | 58 | 103 | ------ | ------ | 3 | 3 | 6 | 109 |
| Basal zone | ------ | ------ | 6 | ------ | 6 | ------ | ------ | ------ | ------ | ------ | 6 |
| Total | 9 | 24 | 70 | 108 | 211 | 1 | 16 | 23 | 72 | 112 | 323 |

[1] Many of these wells are no longer heavily pumped, because much of the Gaspur water-bearing zone is contaminated in this area.

As shown in table 10 about half the heavily pumped wells draw from the Silverado water-bearing zone. However, the proportionate draft from that zone is much larger than is indicated by the percentages of active wells, because the Silverado is the principal source of water for the municipal and industrial wells of the Long Beach area, which are commonly the largest and most heavily pumped wells of all the area.

Table 11 shows the yield characteristics of 28 wells that draw from the Silverado water-bearing zone. The table is divided into two parts, in order to compare the characteristics on opposite sides of the Newport–Inglewood structural zone.

As table 11 indicates, the wells southwest of the Newport-Inglewood structural zone generally tap the greater thickness of sand and gravel, have somewhat the greater yield, and have the larger specific capacity and yield factor. The data on yield factors suggest strongly that the Silverado water-bearing zone is most permeable in the area southwest of the structural zone. From these yield factors, it is estimated that for the full thickness of the Silverado water-bearing zone the average field coefficient

TABLE 11.—*Yield characteristics of 28 wells withdrawing from the Silverado water-bearing zone*

| Well | Depth (feet) | Water-yielding zone or zones | | | | | |
|---|---|---|---|---|---|---|---|
| | | Depth range (feet) | Thickness (feet) | Yield (gpm) | Drawdown (feet) | Specific capacity | Yield factor [1] |
| **Wells southwest of (coastward from) Newport-Inglewood structural zone** | | | | | | | |
| 4/13-15N1 | 925 | 483-785 | 302 | 1,270 | ------ | ------ | ------ |
| 15A11 | 1,054 | 765-990 | 235 | 2,000 | 14.5 | 138 | 59 |
| 15P1 | 571 | 465-571 | 106 | 1,030 | ------ | ------ | ------ |
| 21H5 | 731 | 440-731 | 291 | 1,450 | 5 | 290 | 100 |
| 22E1 | 650 | 410-645 | 235 | 1,200 | 18 | 67 | 29 |
| 27M1 | 900 | 412-810 | 398 | 2,400 | 18.4 | 130 | 33 |
| 27M3 | 946 | 266-800 | 534 | 3,000 | 12 | 250 | 47 |
| 27M4 | 825 | 435-825 | 390 | 2,000 | ------ | ------ | ------ |
| 30G2 | 695 | 216-492 | 276 | 2,900 | 28 | 104 | 38 |
| 31E4 | 680 | 230-655 | 425 | 4,000 | 10 | 400 | 94 |
| 31P1 | 900 | 675-822 | 147 | 1,650 | 28 | 59 | 40 |
| 33D1 | 888 | 669-800 | 131 | 2,500 | 19 | 131 | 100 |
| 5/13- 6D1 | 1,016 | 809-888 | 79 | 454 | 34 | 13 | 17 |
| 6D2 | 990 | 735-842 | 107 | 1,470 | 32 | 46 | 43 |
| Averages | ------ | ------ | 261 | 1,952 | 20 | 148 | 55 |
| **Wells northeast of (inland from) Newport-Inglewood structural zone** | | | | | | | |
| 4/12-14A1 | 720 | 658- 720 | 62 | 900 | 30 | 30 | 48 |
| 15B1 | 1,570 | 952-1,010 | 58 | 790 | 29 | 27 | 47 |
| 17N1 | 650 | 390- 570 | 180 | 1,990 | 15 | 133 | 74 |
| 17N2 | 662 | 364- 550 | 186 | 1,900 | 15 | 127 | 68 |
| 18R1 | 962 | 287- 615 | 93 | 1,610 | 25 | 64 | 69 |
| 20C1 | 752 | 153- 602 | [1] 278 | 3,650 | 27 | 135 | 49 |
| 20L1 | 700 | 266- 638 | [2][3] 312 | [2] 750 | [2] 30 | [2] 25 | [2] 8 |
| 21M4 | 1,422 | 420- 792 | 261 | 1,140 | 37 | 31 | 12 |
| 21M5 | 695 | 208- 610 | 364 | 2,500 | 33 | 76 | 21 |
| 24M2 | 1,086 | 330-1,046 | 367 | 1,370 | 16 | 86 | 23 |
| 24M4 | 1,041 | 320- 952 | 216 | 1,620 | 20 | 81 | 37 |
| 27K2 | 835 | 450- 815 | 329 | [4] 3,470 | 34 | 102 | 31 |
| 28H4 | 505 | 114- 470 | 136 | 890 | 59 | 15 | 11 |
| 28H7 | 500 | 170- 494 | 70 | 1,000 | 46 | 22 | 31 |
| Averages | ------ | ------ | 200 | 1,756 | 30 | 72 | 40 |

[1] Includes thin aquifer above Silverado water-bearing zone.
[2] Excluded from average.
[3] Casing perforated for only 26 ft within this interval.
[4] Reported initial artesian flow in 1915.

of permeability [8] is about 1,000 to 2,000 for the area southwest of the structural zone and is about 800 to 1,600 for the area northeast of the structural zone. It is wholly probable that the most permeable layers of gravel within the Silverado zone may have coefficients of permeability as much as 10 or even 20 times greater than the average coefficient for the whole zone.

It is estimated that as of 1941 the withdrawal from the Silverado water-bearing zone on the southwest or coastal side of the Newport–Inglewood structural zone was about 19,000 acre-

---

[8] The field coefficient of permeability, $P_f$, is defined as the number of gallons of water per day that percolates under prevailing conditions through each mile of water-bearing bed under investigation (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. For a more complete discussion of this subject see Wenzel (1942).

feet per year within the area described in the report on geologic features. (Poland, Piper, and others, 1956, pl. 8) This withdrawal is largely by industrial plants and by the Dominguez Water Corp. and is metered in large part. Accordingly, the writers believe that the foregoing estimate of aggregate withdrawal is correct within 10 percent plus or minus.

For the area inland from the Newport–Inglewood structural zone and within the area of the report on geologic features, the withdrawal from the Silverado water-bearing zone cannot be estimated as closely from information available. Thus, the withdrawal by wells of the cities of Long Beach and Signal Hill in 1941 was about 11,000 acre-feet; in addition, there is considerable agricultural use but little industrial use. The withdrawal for all purposes is estimated to have been about 16,000 acre-feet a year as of 1941.

Thus, the total of withdrawal from the Silverado zone as here discussed is estimated to have been from 30,000 to 35,000 acre-feet a year from the late thirties through 1941. From 1941 through 1944, industrial expansion west of Long Beach and southwest of the Newport–Inglewood structural zone increased the draft on the Silverado about 9,000 acre-feet a year—that is, to 28,000 acre-feet in that district. Inland from the structural zone, however, withdrawal from the Silverado increased much less.

### WATER-BEARING ZONE IN THE BASAL PART OF THE SAN PEDRO FORMATION

In the area northeast of Signal Hill, the Silverado water-bearing zone is underlain by water-bearing deposits of early Pleistocene age (Poland, Piper, and others, 1956, p. 71, pl. 4, *C–C′*). Although deposits of correlative age occur locally on the north and east flanks of the Palos Verdes Hills and locally beneath Landing Hill (Timms Point silt and Lomita marl members of the San Pedro formation), these correlative deposits do not contain layers of coarse and highly permeable gravel.

So far as known, the water-bearing zone in these basal deposits northeast of Signal Hill has been tapped by only 15 wells. All these wells are within an area of about 25 square miles which is bounded on the east by the San Gabriel River, on the west by the Los Angeles River, on the southwest by the Signal Hill uplift, and on the northeast by a line about through Compton and Los Alamitos. Table 12 shows characteristics of these wells.

The Development, Citizens, and Alamitos well fields of the city of Long Beach all are located about a mile inland from the crest of the Signal Hill uplift. In each field three wells have tapped this basal water-bearing zone, whose top was reached between

TABLE 12.—*Wells tapping water-bearing zone in basal part of the San Pedro formation northeast of Signal Hill*

Altitude: Land surface, chiefly from topographic maps.
Water-yielding zone: Ps, Silverado water-bearing zone; Pb, water-bearing zone in basal Pleistocene deposits.
Use: A, abandoned; Irr, irrigation; Obs, observation; PS, public supply.

| Well | Owner or tenant | Local designation | Altitude, above sea level (feet) | Depth (feet) | Water-yielding zone or zones | | | Geologic classification of water-yielding zone | Use |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | |
| 4/12- 6K1 | City of Long Beach | North Long Beach well 4 | 47 | 1,160 | 960 | 194 | Gravel, sand, and clay | Pb | PS |
| 8L2 | Montana Land Co. | Well 16 | 69 | 981 | 835 | 124 | Gravel and sand | Pb | A |
| 14D1 | City of Long Beach | Commission well 1 | 45 | 1,668 | 1,361 | 17 | do. | Pb | PS |
| | | | | | 1,402 | 8 | Coarse gravel | | |
| | | | | | 1,430 | 48 | Gravel | | |
| | | | | | 1,560 | 95 | do. | | |
| 14P1 | do. | Wilson Ranch | 27 | 1,700 | 1,024 | 208 | Gravel and sand | Pb | PS |
| | | | | | 1,260 | 94 | do. | | |
| 17Q1 | do. | Development well 4 | 47 | 1,004 | 390 | 200 | Gravel, clay, sand | Ps | PS |
| | | | | | 934 | 28 | Sand and gravel | Pb | |
| 20D1 | do. | Well 1 | 55 | 1,017 | 959 | 42 | Gravel | Pb | A |
| 20G1 | do. | Well 5 | 47 | 1,016 | 345 | 12 | Sand and gravel | Ps | PS |
| | | | | | 420 | 80 | do. | | |
| | | | | | 707 | 13 | do. | | |
| | | | | | 814 | 14 | Gravel | Pb | |
| | | | | | 859 | 61 | Gravel and sand | | |
| | | | | | 972 | 38 | Sand and gravel | | |
| 21L1 | do. | Citizens well 4 | 28 | 1,155 | 790 | 238 | Gravel and sand | Pb | Obs |
| 21M2 | do. | Well 7 | 37 | 1,105 | 725 | 51 | Coarse gravel | Pb | PS |
| | | | | | 874 | 11 | do. | | |
| | | | | | 912 | 22 | Gravel | | |
| | | | | | 952 | 10 | do. | | |
| 21M4 | do. | Well 6 | 33 | 1,422 | 420 | 224 | Gravel and sand | Ps | PS |
| | | | | | 755 | 37 | do. | Pb | |
| 22J1 | Bixby Land Co. | | 23 | 1,014 | 961 | 54 | do. | Pb | Irr |
| 28H1 | City of Long Beach | Alamitos well 9 | 23 | 1,184 | 756 | 18 | Sand and gravel | Pb | PS |
| | | | | | 804 | 132 | do. | | |
| | | | | | 1,086 | 62 | do. | | |
| 28H6 | do. | Well 8 | 25 | 982 | 515 | 125 | do. | Ps | PS |
| | | | | | 796 | 182 | Gravel and sand | Pb | |
| 28H10 | do. | Well 7 | 25 | 1,114 | 570 | 60 | Coarse sand | Ps | Obs |
| | | | | | 866 | 6 | Sand and gravel | Pb | |
| | | | | | 876 | 24 | do. | | |
| | | | | | 918 | 36 | Coarse gravel | | |
| | | | | | 1,015 | 5 | Sand and gravel | | |
| | | | | | 1,028 | 4 | Coarse gravel | | |
| 4/13-12K1 | Virginia Country Club | | 91 | 1,010 | 980 | 31 | Sand and boulders | Pb | Obs |

814 and 959 feet below land surface in the Development field, between 725 and 790 feet in the Citizens field, and between 756 and 866 feet in the Alamitos field. Three miles northeast, at well 4/12–14D1 (Commission well 1), its top was 1,361 feet below land surface. Thus, in the reach where tapped by wells the top of the zone dips 2–3° NE.

The thickness of the basal part of the San Pedro formation, which contains this water-bearing zone, increases northeastward—specifically, from about 250 feet at the Citizens well field to about 500 feet near Carson Street (Poland, Piper, and others, 1956, pl. 4, *C–C′*). The aggregate thickness of water-bearing materials in this basal part ranges about from 100 to 300 feet, and in general increases to the northeast also.

Although not now known to be tapped by wells beyond the area here described, this water-bearing zone in the basal part of the San Pedro formation may extend northwest to the vicinity of Compton and southeast for several miles into Orange County. Thus, along the inland flank of the Newport–Inglewood structural zone it may be within economic reach of the drill for many miles beyond the area within which it is now tapped. The top of this basal water-bearing zone doubtless continues to dip inland or northeastward to the synclinal axis beneath the central part of the Downey plain. Accordingly, the top of the zone is inferred to be at least 2,000 feet below sea level in the vicinity of Artesia and Bellflower and it is doubted that the zone will be tapped by many wells inland from the area of present development.

Of the 10 wells listed in table 12 as currently active, 9 are public-supply wells of the city of Long Beach. Among these, however, wells 4/12–17Q1 and 21M4 draw largely from the Silverado water-bearing zone and only in very small part from the underlying basal zone. Also, well 20G1 as of 1945 is inaccessible beneath pavement at the airport and has not been pumped since 1940. Thus, except for withdrawal by irrigation well 4/12–22J1, the basal water-bearing zone of the San Pedro formation now yields water chiefly to six public-supply wells of the city of Long Beach. Table 13 shows the productivity of these wells.

Disregarding that of well 4/12–21M2, which is anomalous in magnitude, the yield factors of table 13 suggest that the average permeability of the water-bearing zone in the basal part of the San Pedro formation is about half that of the overlying Silverado water-bearing zone, and that the average field coefficient of permeability is about 400 to 800 (table 11, also definition of field permeability, p. 43).

TABLE 13.—*Yield characteristics of six wells withdrawing water from the basal water-bearing zone of the San Pedro formation northeast of Signal Hill*

| Well | Depth (feet) | Water-yielding zone or zones | | | | | |
|---|---|---|---|---|---|---|---|
| | | Depth range (feet) | Thickness (feet) | Yield (gpm) | Drawdown (feet) | Specific capacity | Yield factor [1] |
| 4/12- 6K1 | 1,160 | 960–1,154 | 194 | 1,720 | 31 | 55 | 28 |
| 14D1 | 1,668 | 1,361–1,655 | 168 | 1,590 | 57 | 28 | 17 |
| 14P1 | 1,700 | 1,024–1,354 | 312 | 1,850 | 22 | 84 | 27 |
| 21M2 | 1,105 | 725–962 | [2] 94 | [2] 1,210 | [2] 12 | [2] 100 | [2] 106 |
| 28H1 | 1,184 | 756–1,148 | 212 | 2,190 | 38 | 58 | 27 |
| 28H6 | 982 | 515–978 | 307 | 2,150 | 50 | 43 | 14 |
| Averages | | | 239 | 1,900 | 40 | 54 | 23 |

[1] For definition, see table 7.
[2] Excluded from average.

During the past few years, nearly half the yearly withdrawal of ground water by the city of Long Beach has been drawn from the basal water-bearing zone of the San Pedro formation by the six wells of the foregoing table. Table 14 shows the distribution of this withdrawal among the several wells.

TABLE 14.—*Withdrawal, in acre-feet, from the basal water-bearing zone of the San Pedro formation by wells of the city of Long Beach*

| Designation of well | | Year | | | | |
|---|---|---|---|---|---|---|
| Geological Survey | City of Long Beach | 1940 | 1941 | 1942 | 1943 | 1944 |
| 4/12- 6K1 | North Long Beach well 4 | 2,340 | 2,462 | 2,407 | 2,370 | 2,261 |
| 14D1 | Commission well 1 | 2,495 | 2,250 | 2,379 | 2,402 | 2,377 |
| 14P1 | Wilson Ranch well | 2,064 | 1,954 | 1,932 | 2,280 | 2,150 |
| 21M2 | Citizens well 7 | 596 | 814 | 556 | 367 | 337 |
| 28H1 | Alamitos well 9 | 713 | 1,089 | 1,323 | 2,125 | 1,716 |
| 28H6 | Well 8 [1] | 702 | 570 | 1,715 | 1,304 | 1,605 |
| | Total | 8,910 | 9,139 | 10,312 | 10,848 | 10,446 |

[1] Probably about half of withdrawal is from Silverado water-bearing zone but approximately offset by withdrawal from basal zone of the Pleistocene by wells 4/12–21M4 and 17Q1, which are not listed in table.

In addition to the withdrawal by these six public-supply wells, water has been drawn from the basal water-bearing zone in the San Pedro formation by well 4/12–22J1 for irrigation since the summer of 1941. Therefore, it is estimated that the over-all withdrawal from this basal zone was about 9,000 acre-feet in 1941 and averaged about 11,000 acre-feet a year in 1943–44.

With respect to withdrawal from and replenishment to this water-bearing zone of the basal San Pedro formation, recurrent chemical analyses of the water withdrawn by the public-supply wells at Long Beach indicate that, beginning about in 1934, a large volume of water has moved downward from the Silverado water-bearing zone into the basal zone of the San Pedro, and that this movement has taken place through the deep public-supply wells that tap both these water-bearing zones. The chemical evidence is discussed elsewhere (Piper, Garrett, and others, 1953, p. 45–49). Pertinent and confirmatory hydrologic evidence is given on pages 99 to 101.

### WATER-BEARING ZONES OF THE INLAND AREA

Inland from the coastal zone of the Long Beach-Santa Ana area the ground-water supplies of Los Angeles County are drawn almost exclusively from deposits of Pleistocene age, except those drawn from the Gaspur water-bearing zone and its minor tongue to the west, as discussed previously. The top of these Pleistocene deposits is believed to be within 100 feet of land surface everywhere except within the reach of the Gaspur water-bearing zone, and there to be from 150 to 175 feet below land surface. The thickness of these deposits ranges about from 1,200 to 2,000 feet along the inner margin of the coastal zone, increases to at least 3,000 feet beneath the central part of the Downey plain in the vicinity of Artesia, Bellflower, and Downey, and then decreases northward to a featheredge along the south flank of the Elysian, Repetto, and Puente Hills (Eckis, 1934, pl. *B*).

These deposits of Pleistocene age are tapped by wells throughout this inland area. In the central part of the Downey plain, from Downey to Artesia, the deeper wells reach from 800 to as much as 1,755 feet below land surface but tap only about the upper one-third to one-half of the Pleistocene water-bearing deposits, which there are thickest. To the northwest, in the vicinity of Huntington Park, the deeper wells reach from 1,000 to 1,600 feet below land surface and, by inference from general knowledge of the geologic structure, are believed to tap nearly the full thickness of the Pleistocene deposits of that area. To the northeast, along the flanks of the Elysian and Repetto Hills and on the Coyote Hills uplift, virtually the full thickness of these deposits is tapped by wells of which some probably enter underlying rocks of Tertiary age.

Throughout this inland area, the Pleistocene deposits tapped by wells are chiefly of continental or lagoonal origin, and so commonly include elongate lenses and tongues of sand and gravel radiating in a general seaward direction from the apexes of buried alluvial fans. These tongues afford the highly permeable materials that sustain wells of large capacity, but extensively they are embedded in materials of finer texture whose permeability is believed to be relatively low. (Poland, Piper, and others, 1956, p.83)

Most wells that tap these water-bearing zones in the Pleistocene deposits yield from 400 to 1,000 gpm; a very few yield more than 1,500 gpm.

It is estimated that in 1941 the withdrawal of water from these Pleistocene deposits ranged from 100,000 to 110,000 acre-feet—that is, slightly more than twice that withdrawn from all aquifers of Pleistocene age in the coastal zone of the county. Of this volume, about 14 percent was withdrawn by municipalities, 20 percent by industries, and the remainder by water companies and by private plants for agricultural and some domestic use.

### SOURCES IN THE DEPOSITS OF PLEISTOCENE AGE IN ORANGE COUNTY

In the part of the coastal zone of the Long Beach–Santa Ana area which is in Orange County the water-bearing deposits of Pleistocene age are heterogeneous and thus do not occur in a reasonably distinct vertical zonation as in Los Angeles County to the west. Therefore, with respect to a description of sources of water, these deposits can be described most effectively by geographic areas in eastward progression as follows: (1) dispersed water-bearing zones between the San Gabriel River and Huntington Beach Mesa; (2) water-bearing zones of Huntington Beach Mesa; and (3) principal water-bearing zone of Newport Mesa. In Orange County there is no known correlative of the water-bearing zones that occur in the basal part of the Pleistocene northeast of Signal Hill.

#### DISPERSED WATER-BEARING ZONES BETWEEN THE SAN GABRIEL RIVER AND HUNTINGTON BEACH MESA

The heterogeneous physical character of the Pleistocene deposits in the reach between the San Gabriel River and Huntington Beach Mesa has been discussed elsewhere (Poland, Piper, and others, 1956, p. 71). It is inferred from general stratigraphic and structural relations that here the Pleistocene deposits are almost exclusively of the San Pedro formation of early Pleistocene age, although no satisfactory lithologic or faunal basis has been established for discriminating this formation from the late Pleistocene deposits.

These deposits of Pleistocene age occur as a wedge which thickens inland from the Newport–Inglewood structural zone, and whose top is at land surface on Landing Hill and on Bolsa Chica Mesa and probably not more than 100 feet below land surface throughout the remainder of this area. The base of the wedge ranges in depth from 500 to 900 feet below land surface along the Newport–Inglewood zone and dips gently northeastward to the inland edge of the coastal zone, where it is about from 1,200 to 1,800 feet below land surface.

The layers of sand and gravel in this wedge commonly are less than 50 feet thick but locally a single layer may be 200 feet or more thick. The thicker bodies of sand and gravel are commonly in the lower half of the San Pedro formation; inland more than 1 to 2 miles from the Newport–Inglewood structural zone, only the wells of depths exceeding 600 to 900 feet reach these thicker aquifers. Along the inland edge of the coastal zone, between Los Alamitos and Westminster, only a very few water wells are more than 1,000 feet deep and none are more than 1,200 feet deep. Thus, here the lower one-third to one-half of the San Pedro formation is not tapped by water wells. However, inland occurrence of aquifers in the lower part of the San Pedro formation is indicated by the electric logs of random oil-test holes.

These Pleistocene deposits are tapped by many wells. The canvass of wells, which was made as part of this investigation shows that there are about 500 wells with deep-well turbines or centrifugal pumps in the part of the coastal zone in Orange County. A large proportion of these are pumped rather heavily for irrigation, about 40 are public-supply wells, and a few are industrial wells. About 200 of these wells are in the part of the area here discussed and of these, about 140 draw water from the Pleistocene deposits. These wells that draw water from the Pleistocene commonly are from 400 to 800 feet deep, they are much more costly than the shallow wells that tap the "80-foot gravel" of the same area (see p. 38), and commonly they have greater yields. Commonly they are more widely spaced and are used to irrigate more land. It is estimated that slightly more than three-quarters of the withdrawal in the area between the San Gabriel River and Huntington Beach Mesa is from the deposits of Pleistocene age. From all water-bearing deposits within the coastal zone in Orange County the withdrawal is estimated to be about 25,000 acre-feet per year. Of this total, it is believed that about half—12,500 acre-feet—is taken from wells in the area between the San Gabriel River and Huntington Beach Mesa. Probably about 10,000 acre-feet of this latter volume is from the Pleistocene deposits of this area.

Table 15 shows the productivity of 13 wells that draw water exclusively or chiefly from the aquifers of Pleistocene age in this area, and for which fairly complete data are available.

TABLE 15.—*Yield characteristics of 13 wells withdrawing water from the deposits of Pleistocene age between the San Gabriel River and Huntington Beach Mesa*

| Well | Depth (feet) | Water-yielding zone or zones | | | | | |
|---|---|---|---|---|---|---|---|
| | | Depth range (feet) | Thickness (feet) | Yield (gpm) | Drawdown (feet) | Specific capacity | Yield factor [1] |
| 4/11- 28J1 | 1,001 | 432-530 | 60 | 790 | 22.5 | 35 | 59 |
| 29L2 | 710 | 381-402 | 15 | 785 | 87 | 9 | 60 |
| 29L3 | 483 | 388-408 | 20 | 1,020 | 59 | 17 | 86 |
| 5/11- 2N1 | 438 | 387-432 | 45 | 390 | 6 | 65 | 144 |
| 2Q2 | 440 | | | 450 | 12 | 38 | |
| 3A1 | 525 | | | 480 | 9 | 53 | |
| 7L1 | 796 | 212-406 | 102 | 600 | 11 | 55 | 54 |
| 8C1 | 915 | 633-870 | [2] 117 | [2] 550 | [2] 20 | [2] 28 | [2] 24 |
| 18R1 | 895 | 677-835 | 158 | 640 | 9.6 | 67 | 41 |
| 26M1 | 201 | [3] 28-179 | 94 | 1,050 | | | |
| 29H1 | 500 | 328-500 | 172 | 1,100 | 12 | 92 | 53 |
| 5/12-12L1 | 723 | 660-709 | [2] 49 | [2] 500 | [2] 37 | [2] 14 | [2] 28 |
| 12P3 | 500 | 132-360 | 86 | 560 | 28 | 20 | 23 |
| Averages | | | 84 | 715 | 26 | 45 | 65 |

[1] For definition, see table 7.
[2] Excluded from average; recent test on old well.
[3] Probably taps some deposits of Recent age.

### WATER-BEARING ZONES OF HUNTINGTON BEACH MESA

In contrast to the irregular and dispersed water-bearing zones of the area to the northwest, just described, the water-bearing zones in the Pleistocene deposits beneath Huntington Beach Mesa are reasonably uniform in hydraulic characteristics and persist beneath and possibly beyond the mesa. As discussed in the report on geologic features (Poland, Piper, and others, 1956, p. 73, pl. 4, *A–A′*), the deposits of Pleistocene age contain three water-bearing zones, of which the uppermost averages about 50 feet in thickness and which from logs of wells can be traced from the coast inland some 4 miles, or to Wintersburg Avenue. Along Main Street its top is not more than 50 feet below land surface from the shore northward to and beyond Garfield Avenue. Owing to a substantial eastward dip along Garfield Avenue, its top declines to about 120 feet below land surface at the east edge of the mesa. To the west the top of the zone rises and crops out along the edge of the mesa, in the angle between Garfield Avenue and Edwards Street. Northward from Garfield Avenue, the zone seems to dip gently northward, so that its top was reached 160 feet below land surface in well 5/11–23R1, near the intersection of Wintersburg Avenue and Huntington Beach Boulevard. Here the zone is about 90 feet thick.

The intermediate one of the three water-bearing zones is also about 50 feet thick and has the same general easterly dip as the upper zone, from which it is separated by 60 to 100 feet of silt or clay. Between the coast and Garfield Avenue, near Main Street, its top is about 200 feet below land surface. This intermediate zone cannot be traced with assurance for more than 0.5 mile northward from Garfield Avenue, but probably it is tapped by public-supply wells 5/11–26M1 and 26M2 of the Southern California Water Co.

The lowest water-bearing zone of the three is about 250 feet thick, at least beneath the central part of the mesa near the intersection of Garfield and Golden West Avenues. Here its top is about 300 feet below land surface. Southward the zone seems to thin or finger out and it is largely replaced by silt, as in well 6/11–11E1. From Garfield Avenue it dips northward and at well 5/11–26P3 its top is 394 feet below land surface. The top of this same zone presumably was reached in well 5/11-22H1 at 612 feet below land surface. Thus, the zone is believed to extend at least 3 miles northward from Garfield Avenue.

The upper and intermediate zones are tapped by many water wells on Huntington Beach Mesa. However, the upper zone has been contaminated with salt water progressively since the middle and late twenties (Piper, Garrett, and others, 1953, p. 133). For this reason some wells have cased off the upper zone and draw from the intermediate zone only; however, the intermediate zone also has become somewhat contaminated by salt water so that several wells which tap one or both of these zones in the central and southern parts of the mesa have been abandoned.

The deepest zone of the three has been tapped by relatively few wells, of which most are industrial wells. So far as is known, this zone is not contaminated (in 1945). Because it is thick and permeable and is tapped by few wells, it affords a large reserve source of water for the vicinity of Huntington Beach. However, because within the area in which the upper zone and probably the intermediate zone are contaminated, as of 1945, this lower zone is pierced by several wells which reach and may tap one or both of those overlying contaminated zones, this thick and potentially very productive lower zone is in great danger of becoming contaminated and even now may be receiving salt water. This condition is most serious in the central part of the mesa, north of Garfield Avenue and west of Huntington Beach Boulevard. Here, at least seven wells tap the lower zone, of which five are known to be perforated in both the intermediate and the lower zones. The condition is discussed more fully by Piper, Garrett, and others (1953, p. 152–154) who stress the urgency of plugging abandoned wells and possibly of reconstructing some now in use.

Little information is available concerning the yield of wells that tap these water-bearing deposits on Huntington Beach Mesa. Well 6/11–2M2 at the Huntington Beach Union High School, which taps the intermediate zone from 200 to 226 feet below land surface, is reported to have yielded 330 gpm with drawdown of 4.4 feet. The indicated specific capacity is 75 and the yield factor 288, which suggests that the water-bearing material is substantially more permeable than any tapped by the wells listed in tables 7, 8, 11, 13, and 15. Well 5/11–26P3, which taps the third and deepest zone from 439 to 577 feet below land surface, reportedly produced 450 gpm with a drawdown of 4.5 feet; these data on performance indicate a specific capacity of 100 and a yield factor of 72. Although inconclusive, this fragmentary evidence suggests that the lower of the three water-bearing zones of Huntington Beach Mesa is fully as permeable as the Silverado water-bearing zone in Los Angeles County.

The withdrawal from water-bearing zones in the Pleistocene deposits beneath Huntington Beach Mesa has not been discriminated from the over-all withdrawal from Pleistocene deposits in the coastal zone in Orange County. In 1941 the field canvass listed 39 wells on the mesa which were equipped with turbine pumps. At least six of these are industrial wells which jointly yield about 400 acre-feet a year, almost exclusively from the lower zone. Most of the additional use is for irrigation. Probably not more than 1,500 acre-feet of water is pumped yearly for all purposes from wells on the mesa, although beyond the mesa to the north and west a substantial quantity may be withdrawn from extensions of the three zones here described.

### PRINCIPAL WATER-BEARING ZONE OF NEWPORT MESA

Beneath the north half of Newport Mesa many of the deeper water wells tap a persistent water-bearing zone within the San Pedro formation. The physical character and general extent of this water-bearing zone have been described elsewhere (Poland, Piper, and others, 1956, p. 74-75, pl. 4, *D–D′*).

The depth to the top of this zone varies widely. At the head of Newport Bay, the upper part of the zone is believed to crop out (Poland, Piper, and others, 1956, p. 64, 74, pl. 3). Inland 1.2 miles from the head of the bay this zone was reached in well 6/10–11B2 at a depth of 236 feet and here is about 300 feet thick. About 2 miles from the bay and 700 feet north of Baker Street, in well 6/10–1E2, the top of this principal zone is 425 feet below land surface and the zone is at least 521 feet thick. About 2.4 miles still farther north (inland), near the intersection of Delhi Road and Main Street, well 5/10–25A2 tapped sand and gravel from 1,065 to 1,197 feet below land surface; this body of sand and gravel probably is an extension of the principal water-bearing zone of Newport Mesa.

In the northeastern part of the mesa and east of Newport Boulevard this principal zone is tapped by the wells of the Newport Heights Irrigation District in block 6 of the Irvine tract. The top is about 300 feet below land surface and it is about 300 feet thick. To the west, near the intersection of Harbor Boulevard and Baker Street, the top at well 6/10–3LI is 386 feet below land surface and its thickness is at least 166 feet.

As exposed at the head of Newport Bay, the outcropping layers of sand and gravel which are inferred to constitute this principal water-bearing zone are semiconsolidated at least at land surface. To the extent that these layers are permeable at the outcrop, they offer an avenue for possible encroachment of salt water down the dip from Newport Bay northward toward the area in which the water-bearing zone is tapped by wells. The outcrop area is of small extent and seemingly of low permeability.

Within about the northern third of Newport Mesa—specifically, north of the inferred fault which passes northwestward through the center of sec. 10 (pl. 1)—this principal water-bearing zone is tapped by at least 23 wells equipped with turbine pumps. Several additional wells of unknown depth also may tap the zone, as is inferred from the chemical quality of the water yielded or from the absence of any known substantial aquifer at shallower depth. North of the inferred fault and west of Harbor Boulevard—in sec. 4, T. 6 S., R. 10 W. and in sec. 33, T. 5 S., R. 10 W.—several irrigation wells of large diameter may tap the principal water-bearing zone but neither depths nor logs of these wells are available to confirm this inference. As has been mentioned, this principal zone is believed to be tapped by wells northward beyond Newport Mesa, to the vicinity of Santa Ana Gardens. The zone may extend beneath the city of Santa Ana but there its top would be about 1,600 feet below land surface—a depth commonly considered as beyond economic limits for irrigation wells but not necessarily so for public-supply wells. Thus, the principal water-bearing zone of Newport Mesa now is tapped within an area about 4 miles wide, which extends inland for about 4 miles from the inferred fault—that is, to and beyond the inland edge of the mesa or about to Santa Ana Gardens. Doubtless additional wells will be drilled to the zone within or near this area; still farther inland, however, the depth to the zone is so great that probably few wells will be drilled.

South of the inferred fault only well 6/10–9B1 draws water from the Pleistocene deposits. It is doubtful whether this well, which is reported 380 feet deep, taps the principal zone of Newport Mesa. Within the past 70 years several other water wells have been drilled south of the inferred fault but all have tapped water of inferior quality and all are now unused. The chemical character of the water tapped by one of these unused wells, 6/10–10D3, is described in the reports on geologic features and on chemical character of the ground waters (Piper, Garrett, and others, 1953, p. 258; Poland, Piper, and others, 1956, p. 104).

Table 16 presents available data on the yield of wells tapping this principal water-bearing zone on Newport Mesa. The five wells of this table have large capacities and the average of their yields doubtless is substantially larger than the average for all wells that draw water from the zone. However, the yield factors of table 16 are believed to be representative.

Table 16.—*Yield characteristics of five wells withdrawing from the principal water-bearing zone of Newport Mesa*

| Well | Depth (feet) | Water-yielding zone or zones | | | | | |
|---|---|---|---|---|---|---|---|
| | | Depth range (feet) | Thickness (feet) | Yield (gpm) | Drawdown (feet) | Specific capacity | Yield factor [1] |
| 6/10- 1E2 | 945 | 580–946 | 365 | 2, 250 | 21 | 107 | 29 |
| 11B1 | 602 | 350–438 | 88 | 900 | 12 | 75 | 85 |
| 11B2 | 586 | 271–404 | 97 | 800 | 21 | 38 | 39 |
| 18J2 | 270 | 126–267 | 141 | 1, 360 | 27 | 51 | 36 |
| I- 6E1 | 609 | 353–609 | 205 | 2, 240 | 22 | 102 | 50 |
| 6E3 | 600 | | | 990 | 16 | 62 | |
| Averages | | | 179 | 1, 423 | 20 | 73 | 48 |

[1] For definition, see table 7.

The data of table 16 and of table 11 suggest that the average permeability of the principal water-bearing zone of Newport Mesa is about the same magnitude as that of the Silverado water-bearing zone on the inland side of the Newport–Inglewood structural zone in Los Angeles County.

As of 1941, about 2,000 acre-feet of water was being withdrawn yearly from this principal water-bearing zone underlying Newport Mesa by the wells of the three largest users—the Newport Heights Irrigation District, the Santa Ana Heights Water Co., and the Golden West Ranch. Probably at least 3,000 acre-feet per year was being withdrawn from the zone by all users on the mesa at that time. Information which is in part confidential indicates that after 1941 the over-all use may have increased as much as one-third owing to new activities related to the war.

## WATER-BEARING ZONES OF THE INLAND AREA

In Orange County inland from the coastal zone, ground water is withdrawn almost exclusively from deposits of Pleistocene age, except within the extent of the Talbert water-bearing zone of Recent age. The top of these Pleistocene deposits probably is less than 100 feet below land surface everywhere except within the reach of the Talbert zone, where it is from 130 to 175 feet below land surface. The base of the deposits is from 1,200 to 2,000 feet below land surface along the inland edge of the coastal zone, probably increases to slightly more than 3,000 feet beneath the central part of the Downey plain (along a line through Cypress, Stanton, Garden Grove, and Santa Ana), and remains about 3,000 feet below land surface from Anaheim to Buena Park. Still farther inland the deposits thin to a featheredge on the crest of the West Coyote Hills and along the south flank of the Puente Hills. Southeastward from Santa Ana, in a lobe underlying the Irvine tract, the base of these deposits rises steeply and is only a few hundred feet below land surface at Irvine.

These water-bearing deposits of Pleistocene age are tapped by wells almost throughout this inland area. With few exceptions these wells range in depth from about 150 to 1,100 feet and, except within the area underlain by the Talbert water-bearing zone, range from 200 to 800 feet for most wells. Thus, because these deposits of Pleistocene age are more than 2,000 feet thick throughout most of this inland area and as much as 3,000 feet thick over about a third of the area, not more than a quarter to a third of the potential water-yielding beds are tapped commonly by existing wells. However, water-bearing zones more than about 1,500 feet below land surface commonly are not considered within economic reach, especially for irrigation wells. For wells exceeding 1,000 feet in depth, the cost of construction doubtless would increase more rapidly than the yield per unit depth of penetration. Therefore, the lower half of these deposits in much of this inland area probably will not be tapped by many water wells.

In physical character the Pleistocene deposits of the inland area of Orange County as now tapped by wells are similar to those of the inland area of Los Angeles County. They are largely of alluvial origin, but in minor part, of lagoonal origin; only a few tongues of marine sediments have been tapped. The deposits consist mainly of silt and clay, enclosing lenses and tongues of coarse sand and gravel; these coarse materials are the deposits of ancient stream channels and are the source of water for wells of substantial yield. Near the central part of the Downey plain, the deeper wells commonly reach successive water-bearing zones that in the aggregate occupy from 10 to 30 percent of the footage tapped. Farther inland, however, in the vicinity of Anaheim the water-bearing materials occupy from 60 to 80 percent of the footage tapped by wells between 300 and 400 feet deep, and from 30 to 50 percent of the footage tapped by several wells more than 1,000 feet deep.

As previously mentioned, the yield of wells tapping these Pleistocene deposits ranges from a few hundred to more than 3,000 gpm (see p. 30). For the area as a whole, it is estimated that the average yield is about 600 to 800 gpm.

Because the present investigation is concerned basically with ground-water conditions in the coastal zone, extensive data on the yield of wells in the inland zone have not been collected. However, data on yield characteristics are given in table 17 for five of the public-supply wells of the city of Santa Ana, located some 6 miles inland beyond Newport Mesa. The deposits tapped by these wells are believed to be largely of late Pleistocene age.

Table 17.—*Yield characteristics of five public-supply wells of the city of Santa Ana*

| Well | Depth (feet) | Water-yielding zone or zones | | | | | |
|---|---|---|---|---|---|---|---|
| | | Depth range (feet) | Thickness (feet) | Yield[1] (gpm) | Drawdown[1] (feet) | Specific capacity | Yield factor[2] |
| 5/10-12K1 | 466 | 330–456 | 54 | 1, 170 | 11. 5 | 102 | 188 |
| 12L1 | 1, 100 | 910–1, 090 | 54 | 1, 235 | 30. 5 | 40 | 75 |
| 13B3 | 960 | 432–905 | 42± | 1, 360 | 13. 5 | 100 | 240 |
| 13B7 | 950 | | | 1, 160 | 11. 5 | 101 | |
| 13C1 | 1, 140 | 214–1, 048 | 70± | 2, 200 | 17. 5 | 126 | 180 |
| Averages | | | 55± | 1, 425 | 17 | 94 | 171 |

[1] Averages from capacity tests in May and October 1940.
[2] For definition, see table 7.

The average of the four yield factors in table 17 is 171 gpm per foot of drawdown per foot thickness of water-yielding material; this average is about three times that for the water-bearing materials of Pleistocene age in the coastal zone (table 16). However, the logs of these public-supply wells show that the deposits tapped are of alluvial origin and consist mainly of silt and clay. For example, in well 5/10-12L1 (city of Santa Ana, well 11), only about 190 feet of water-bearing sand and gravel was tapped in the full depth of 1,100 feet; thus, 17.3 percent of the deposits was reported as water-bearing. Likewise, in well 5/10-13C1 (city of Santa Ana, well 15), only about 72 feet of water-bearing material was tapped in the full depth of 1,140 feet; here only 6.3 percent of the deposits is reported as water-bearing material. These small percentages account for the small average thickness of water-yielding material (55 feet). Although the permeability of these materials is relatively large, as indicated by the average yield factor of 171, these Pleistocene deposits beneath the central part of the Downey plain probably transmit water somewhat less freely than the principal water-bearing zone beneath Newport Mesa.

It is estimated that as of the early forties from 80,000 to 100,000 acre-feet of water was withdrawn yearly from these Pleistocene deposits in the inland zone of the Long Beach–Santa Ana area within Orange County or about six times that withdrawn from the

Pleistocene deposits within the coastal zone of the county. Of this withdrawal, about 10 percent was by municipalities, about 4 percent by industries, and the remainder (some 86 percent) by private pumping plants and by water companies almost exclusively for agricultural uses.

### WATER-BEARING ZONES IN THE UPPER PART OF THE PICO FORMATION

The physical character, extent, thickness and water-bearing characteristics of the upper division of the Pico formation have been described in the report on geologic features (Poland, Piper, and others, 1956, p. 87-89, 90-91, pl. 4, *A–A′*, *B–B′*). Of necessity, that description is somewhat superficial because it is based on fragmentary information from oil wells along the crest of the Newport–Inglewood structural zone between Dominguez Hill and Newport Mesa. Because only one active water well, No. 5/11–28K1, is believed to tap the upper part of the Pico formation in the coastal zone of the Long Beach–Santa Ana area, little is known concerning its productivity beyond the facts and inferences summarized elsewhere and just cited. However, it appears advisable here to repeat that within substantially all the area from Dominguez Hill southeastward to and including Huntington Beach Mesa, and from the coast inland from 4 to 8 miles, the permeable sand zones of the upper part of the Pico may afford a large reserve supply of fresh water, now virtually untapped.

## REGIONAL GROUND-WATER CONDITIONS

### SOURCES AND SCOPE OF WATER-LEVEL MEASUREMENTS

In 1903–4 Mendenhall (1905a, 1905b, 1905c) made single measurements of depth to water or of artesian-pressure head in many hundred wells on the coastal plain. To extend these data, water-level measurements were made by the Geological Survey at irregular intervals in the next two decades on 41 representative wells. Of these, 11 wells were within the coastal and inland zones of the present investigation. The records through 1920 were published by the Geological Survey (Ebert, 1921, p. 39–46); from 1920 to 1923, by the California Division of Water Rights (Conkling, 1927, p. 593–640).

In connection with its investigation of water resources of the San Gabriel Valley, the Division of Water Rights in the California Department of Public Works, in cooperation with Los Angeles County and the city of Pasadena, measured depths to ground water periodically from 1923 until 1928 (Calif. Div. Water Rights, 1929,

p. 171–200). This program superseded and greatly extended the earlier program by the Geological Survey in that area.

This program of water-level measurements by the California Division of Water Rights led to similar continuing programs by many other agencies and individuals that ultimately extended throughout the area of the present cooperative investigation. The principal agencies and individuals and the dates of inception of their continuing programs are as follows: the Los Angeles Department of Water and Power, 1923; the city of Long Beach, 1924; the San Gabriel Valley Protective Association, 1928; the Los Angeles County Flood Control District, 1928; the Orange County Flood Control District, principally in 1930; the city of Pasadena, from 1928 until 1933; J. B. Lippincott, for several county and municipal agencies, intermittently from 1923 to 1942; the Irvine Co., 1931; the I. W. Hellman Ranch, 1933; the several Bixby interests, 1933; and the Montana Land Co., 1935. Altogether, about 2,280 observation wells have been established by these several agencies in the coastal and inland zones of the present investigation; in about 32 percent of these wells, the measurements of ground-water level have been periodic. Relatively few of the periodic records have been discontinued or terminated by destruction of wells. However, measurements being made monthly by the Los Angeles Department of Water and Power on several hundred wells in the coastal-plain segment of Los Angeles County were discontinued in 1941.

Nearly all the water-level records by the several agencies just listed have been deposited with the Division of Water Resources in the California Department of Public Works, and have been made available to the public. Representative records from selected observation wells have been published (Gleason, 1932, and annual supplements).

As of the end of 1940—that is, shortly after the start of this investigation—water-level recorders had been operated for a year or more on 61 wells in the coastal and inland zones of the project area, as follows: by the San Gabriel Valley Protective Association, on 19 wells for 1 to 10 years each; by the Orange County Flood Control District, on 12 wells for 1 to 10 years; by the city of Long Beach, on 29 wells for 1 to 8 years; and by the Los Angeles County Flood Control District on 1 well for 2 years. These records include 84 wells and 343 well-years. As of December 1940, water-level recorders were in operation on 45 wells.

Table 18 shows the general scope of the water-level records made available to the Geological Survey by all the agencies of the area.

TABLE 18.—*Scope of data on ground-water levels as of December 1940*

| | Coastal zone | Inland zone | Total |
|---|---|---|---|
| Number of wells having water-level records, as follows: | | | |
| Nonperiodic and miscellaneous measurements | 305 | 721 | 1, 026 |
| Periodic measurements discontinued | 171 | 343 | 514 |
| Weekly measurements | 56 | 36 | 92 |
| Monthly measurements | 155 | 475 | 630 |
| Water-level recorder operating currently | 32 | 13 | 45 |
| Water-level recorder discontinued | 15 | 21 | 36 |
| Total | 734 | 1, 609 | 2, 343 |

Late in 1940 and early in 1941 the Geological Survey began quarterly measurements of water level in 134 wells in the coastal zone to supplement the water-level data available from other sources. These wells were selected primarily to obtain records in areas not intensively covered by other agencies, to afford the closest feasible determination of pressure level in the several confined water-bearing zones near the Newport-Inglewood structural zone. They included closely spaced wells of different depths paired to indicate differences in pressure level within the several zones. So far as possible, wells were selected for which depths and perforated intervals were known.

Water levels also have been measured periodically in 64 shallow observation wells constructed by the Geological Survey on low lands in and near the five gaps through the coastal hills and "mesas." These shallow wells were constructed to obtain measurements on the body of semiperched ground water that occurs in the upper 20 to 50 feet of the deposits of Recent age within the several gaps. A table listing 62 of these wells has been published (Meinzer, Wenzel, and others, 1944, p. 79–80). The two additional shallow wells, 5/11–26M3 and 26N3, at the east edge of Bolsa Gap, were constructed in 1943 for hydrologic information in connection with saline contamination on and near the northwest edge of Huntington Beach Mesa.

Water-level recorders have been operated by the Geological Survey on 30 wells for periods ranging from 1 month to more than 2 years, chiefly on observation wells paired to determine differences in pressure level or in character of water-level fluctuations across or near the Newport–Inglewood structural zone. Along the coast between Seal Beach and Huntington Beach three pairs of deep observation wells were constructed on the coastal side of the structural zone as part of the cooperative program—wells 5/12–13D1 and 13D2 near Seal Beach; wells 5/11–18N1 and 18P1 in Sunset Gap; and wells 5/11–29E1 and 29E2 on Bolsa

Chica Mesa (for logs and brief descriptions, see Poland, Piper, and others, 1956, p. 132–134). Water-level recorders have been operated on these wells also. Table 19 lists all these wells by number and gives for each its depth, the position of the water-yielding zone it taps, and the period during which the water-level recorders were operated.

TABLE 19.—*Wells in the coastal zone of the Long Beach–Santa Ana area on which water-level recorders have been maintained by the Geological Survey, 1940–44*

| Well | Depth [1] | Water-yielding zone (feet below land surface) | Period of operation |
|---|---|---|---|
| 3/13-35C2 | 595.9 | ------------ | Nov. 1, 1943–Feb. 7, 1944 |
| 4/13- 2J4 | 178.4 | ------------ | July 25, 1942–June 22, 1943 |
| 14L1 | 114.3 | 86–114 | Dec. 15, 1942–June 22, 1943 |
| 23M2 | 115.2 | 77–118 | Apr. 29, 1941–June 22, 1943 |
| 31L1 | 629.8(910) | 274–438<br>530–908 | Oct. 30, 1942–Dec. 14, 1942 |
| 33D1 | 888.2 | 669–800 | Sept. 10, 1941–Jan. 5, 1942 |
| 5/11-18J2 | 215.7 | ------------ | Oct. 9, 1943–Jan. 24, 1944 |
| 18N1 | 250.0(380) | 172–212<br>221–251 | Aug. 23, 1941–June 15, 1942<br>Sept. 9, 1943–Mar. 13, 1944 |
| 18P1 | 125.0(240) | 110–148 | Aug. 22, 1941–June 15, 1942<br>Sept. 9, 1943–Mar. 13, 1944 |
| 20L2 | 157.5 | ------------ | Jan. 23, 1942–July 27, 1942 |
| 26M3 | 9.4 | 6–10 | Sept. 24, 1943–Nov. 1, 1943 |
| 26N3 | 9.7 | 6–10 | Sept. 24, 1943–Nov. 1, 1943 |
| 29C4 | 157.0 | ------------ | Dec. 23, 1941–Aug. 14, 1942 |
| 29E1 | 220.0(410) | 158–212 | Aug. 23, 1941–June 15, 1942<br>June 22, 1943–Nov. 1, 1943 |
| 29E2 | 120.0(131) | 85–129 | Aug. 23, 1941–June 15, 1942<br>June 22, 1943–Nov. 1, 1943 |
| 5/12- 2B1 | 255.2(547) | 460–541 | June 18, 1942–Dec. 14, 1942 |
| 10A1 | 296.6 | [2] 124–143 | Sept. 15, 1941–Dec. 19, 1941<br>Aug. 15, 1942–Mar. 22, 1943 |
| 11H1 | 296.0 | ------------ | July 2, 1942–Aug. 9, 1943 |
| 11L1 | 810.0 | 320–358 | June 16, 1942–Aug. 9, 1943 |
| 12P3 | 362.6(500) | 348–360 | June 16, 1942–Aug. 9, 1943 |
| 13D1 | 210.0(381) | 183–258 | Feb. 20, 1942–Oct. 4, 1943 |
| 13D2 | 140.0(160) | 125–158 | Feb. 18, 1942–Oct. 4, 1943 |
| 6/10- 6P1 | 150.5 | ------------ | Nov. 29, 1940–Jan. 11, 1943 |
| 6P2 | 24.7 | 11–25 | Apr. 4, 1941–July 11, 1942 |
| 6/11- 1Q1 | 380.0 | ------------ | Nov. 30, 1940–Aug. 11, 1941 |
| 2G2 | 123.3 | 78–126 | Nov. 28, 1940–Feb. 25, 1941 |
| 2G3 | 258.5 | 100–118<br>214–224<br>242–254 | Feb. 25, 1941–Aug. 22, 1941 |
| 13G4 | 12.7 | 6–7 | June 23, 1941–Feb. 18, 1942 |
| 13M1 | 364.1 | ([3]) | Apr. 4, 1941–Sept. 9, 1941 |
| 13M3 | 13.7 | 6–12 | Apr. 4, 1941–Feb. 18, 1942 |

---

[1] Measured by the Geological Survey. For wells 4/13-31L1, 5/12-2B1, and 5/12-12P3, figures in parentheses indicate reported depths; for the paired permanent observation wells 5/11-18N1 and 18P1, 5/11-29E1 and 29E2, and 5/12-13D1 and 13D2, figures in parentheses indicate depth to which well was drilled before backfilling and setting casing.

[2] Available records disagree concerning position of water-yielding zone.

[3] Probably below 300 feet.

All periodic measurements of depth to water made by the Geological Survey in the Long Beach-Santa Ana area from 1940 through 1942 have been published (Meinzer, Wenzel, and others, 1944, p. 89–169). Water-level measurements in 202 wells were discontinued late in 1942 but water-level recorders were maintained or established in 1943 on 16 wells (table 19). Records for these wells also have been published (Meinzer, Wenzel, and others, 1945, p. 113–124). For three of these wells, water-level recorders were maintained into 1944 and records have been published (Sayre and others, 1947, p. 102).

From late 1940 through 1944, the Geological Survey has made about 3,615 individual measurements of depth to water in 224 observation wells. From 1904 through 1944, it is estimated that nearly 200,000 water-level measurements were made in the Long Beach–Santa Ana area by all agencies. Thus the measurements by the Geological Survey beginning in 1940 make up about 2 percent of the total.

Locations of observation wells measured by the Geological Survey are shown on a map previously published (Poland, Piper, and others, 1956, pl. 3), which shows all active wells in the coastal zone as of 1941 and any abandoned wells for which there are records of water level or chemical analyses. All wells in the coastal zone then accessible were identified in the field and assigned "USGS" numbers. Locations of observation wells are also shown on plate 1 of this report. Of observation wells in the inland zone of the Long Beach–Santa Ana area, locations were not verified in the field by the Geological Survey, and had been verified by the California Division of Water Resources only for selected wells whose records have been published by that agency. To all unverified locations "USGS" numbers have been assigned according to locations shown on the master maps of the California Division of Water Resources.

For all of the 224 observation wells measured by the Geological Survey in the coastal zone, descriptions are given in table 29. Insofar as known or available from the field canvass of wells, this description lists the following information: owner or tenant; altitude; depth; diameter of casing; position, thickness, and character of the zone or zones yielding water to the well; type of pump and power; use; and the types of data available—chemical analyses, log, or water-level measurements.

## OCCURRENCE OF GROUND WATER

As discussed elsewhere (Poland, Piper, and others, 1956, p. 107–118) at least three distinct bodies of ground water exist in the Long Beach–Santa Ana area. In downward succession these three are (1) a body of semiperched water which occurs in the upper part of the alluvial deposits of Recent age and which is virtually continuous from the ocean through the five gaps between the coastal hills and mesas, and far onto the Downey plain (2) the principal body of naturally 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 certain parts of the underlying Pliocene rocks; and (3) a body or bodies of saline connate water which underlies the principal fresh-water body throughout the area. The upper two of these ground-water bodies are described in considerable detail in following pages.

## SEMIPERCHED WATER BODY

### OCCURRENCE AND RELATION TO THIS INVESTIGATION

The body of semiperched water is virtually unconfined and supplies only a relatively few water wells of small capacity. Beneath the Downey plain and in the several gaps between the coastal hills and mesas, it occurs commonly in thin layers of sand and silty sand within the upper 20 to 50 feet of the Recent deposits, and almost everywhere is separated from the underlying fresh-water zone by more or less impermeable layers of silt and clay. It is not present in the intake areas below Whittier Narrows and Santa Ana Canyon—there a regional water table exists. This semiperched water body is replenished principally by infiltration of rain and of irrigation water, also to an unknown extent by influent seepage from the rivers which traverse the coastal plain. Beneath most of the Downey plain the semiperched water table is less than 15 feet below land surface. Its slope conforms fairly closely with that of the land surface and thus the water moves generally coastward. However, the containing deposits are of low permeability, so that the movement probably is not more than a few feet per year on the average, nor more than a few tens of feet per year in the more permeable layers. Under native conditions the piezometric head in underlying aquifers was above that of the shallow (but not then semiperched) water body, so that a very slow upward percolation of water doubtless fed the shallow body. In the last three decades, the pressure levels of the underlying principal water body have been drawn down below the water table of the shallow body by continuing heavy withdrawals. Thus, the shallow body has become semiperched artifically and any vertical movement of water now would be downward from the shallow body to the confined principal body, rather than upward as under native conditions.

The semiperched water body is of interest in the present investigation for two principal reasons, as follows:

1. At places beneath the Downey plain and everywhere between the Newport–Inglewood zone and the coast, it was naturally of markedly inferior quality (Piper, Garrett, and others, 1953, p. 51–52) and locally, as in the Santa Ana and the Dominguez Gaps, its chemical quality has deteriorated substantially by evaporation from the capillary fringe, by landward movement of ocean water, or by additions of industrial wastes and oil-field brines. Thus, in the area from the coast about to the inland flank of the coastal hills and mesas, this semiperched saline water is a source from which the underlying principal fresh water body in the past has been contaminated locally and in the future may become contaminated widely by downward movement of saline water through defective well casings or by direct percolation. Hence, further contamination of the fresh-water body from this overlying saline semiperched water can be partly restrained if all deep water wells are maintained with tight casings within this zone, and if all abandoned wells are adequately plugged above the fresh-water zone. In areas such as the Dominguez Gap, however, where inferior water has percolated directly from the unconfined water body into the Gaspur water-bearing zone through semipermeable deposits that intervene, continued contamination will cease only if (1) the sources of such contamination are eliminated or (2) the pressure head of water in the Gaspur zone is raised above that in the semiperched water body.

2. The water-bearing deposits of this semiperched zone are chiefly fine sand and silt and these are of relatively low permeability. Nevertheless, in all the gaps, they constitute a more or less pervious layer across the "barrier" through which the water of naturally inferior quality, the contaminated water, and ultimately additional ocean water might reach some of the water-bearing zones of good quality in the coastward half of the Downey plain, if water levels in the principal body of ground water should be drawn down a substantial distance below sea level for a long period of time.

### DEFINITION OF SEMIPERCHED WATER

This regional shallow water body which is termed "semiperched" in this report has a water table which at some places beneath the Downey plain is continuously above the pressure (piezometric) surface of the confined aquifers beneath, and at other places, chiefly near the coast, is at times above and at times below this pressure surface. This regional variability in relative position of the several water levels has led to some confusion in terminology. It appears advisable, therefore, to examine the definitions of "perched" and "semiperched" water, and then to consider the available facts.

According to Meinzer (1923, p. 40-42),

> ground water is said to be perched if it is separated from an underlying body of ground water by unsaturated rock [including unconsolidated material]. Perched water belongs to a different zone of saturation from that occupied by underlying 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.

### PREVIOUS REGIONAL INVESTIGATIONS

Because of its very minor utility the semiperched body of ground water within the coastal plain has received little attention in published reports; in fact, such discussion has developed largely because of detrimental character rather than utility. In 1927, Conkling (1927, p. 41–42, 633–639, pl. 13) discussed the general nature of this body in the central part of the coastal plain and presented a map showing that as of October 1926 this "high water table" was less than 8 feet below land surface beneath some 34,000 acres extending irregularly from the Newport–Inglewood zone northeasterly about to a line through Maywood, Downey, Norwalk, and Buena Park. Post (1928, p. 161–162, pl. 12) noted that:

> A high water table occurs in the Santa Ana River plain south and west of the 75-foot contour of surface elevation. Within this area the high water table generally stands three to eight feet below the ground surface regardless of soil type, elevation above sea level or the depth of water table as indicated by deep wells.

Post (1928, pl. 12) prepared a profile showing that about 6 miles inland from the mouth of the Santa Ana River, in the spring of 1928 the pressure surface in deeper wells was several feet above this shallow water table, which was termed a perched water table on the profile.

Further details on this "semiperched" body in Orange County were published in 1930 (Calif. Div. Water Resources, 1930, p. 141–146, pl. 11) together with a map showing "surface-water contours" for April 1930 in the area from the coast to a line through Buena Park and Santa Ana. In most of that area, depth to water was less than 8 feet. At least for the inland part, the regional pressure level in deeper wells stood below the "surface" water table.

About in 1937, the Los Angeles County Flood Control District began construction of shallow wells within the central part of the coastal plain, largely for the purpose of determining depth to the water table in areas where housing projects were proposed. From 1937 to 1945, about 42 shallow wells have been bored in the area east of Alameda Street, west of the County line, north of Signal Hill, and south of Firestone Boulevard. For 36 of these wells, the average depth is 17 feet; almost all are constructed with 2-inch casings and some are gravel-packed. The Flood Control District also constructed about 40 shallow wells in the vicinity of the spreading grounds below Whittier Narrows and about 20 wells in Alamitos Gap. Most of these wells have been measured periodically—about 8 times a year for the 42 wells—and paired measurements on nearby deeper wells have been obtained simultaneously.

From a review of these paired measurements by the Los Angeles County Flood Control District, the following conclusions are drawn concerning fluctuations of the semiperched water table in the central area above defined, from 1927 through 1944:

1. During this 8-year period, the depth to water has ranged from a minimum of 3 to 5 feet (spring of 1941) to a maximum of 11 to 15 feet.
2. The annual range in depth to water is about 3 feet.
3. In most of the area the semiperched water table has been higher at all times than the water level of subjacent aquifers as registered in companion wells. During the spring high-water period, the difference in levels has ranged from 0 to 20 feet, and during the autumn low-water period, has ranged from 10 to 40 feet. Locally, however, in the area south of Artesia Avenue and east of Lakewood Boulevard, beginning in 1941 the pressure level in subjacent aquifers has raised several feet above that of the semiperched body, concurrently with rejuvenated artesian flow from wells tapping the deeper aquifers.

### OCCURRENCE WITHIN THE SEVERAL GAPS

During the current investigation the Geological Survey bored 64 shallow observation wells along lines placed about centrally in the five gaps of the coastal zone (p. 60). The wells are from 0.25 to 0.5 mile apart, and each line of wells spans the Newport–Inglewood structural zone. Of these wells, 19 are in the Dominguez Gap, 10 in the Alamitos Gap, 11 in the Sunset Gap, 10 in the Bolsa Gap, and 13 in the Santa Ana Gap; in addition, 1 well was constructed on Huntington Beach Mesa. Five of the wells, 5/11–26M3 and N3 in Bolsa Gap, and 6/10–7P2, 6/11–13G4, and 13M3 in Santa Ana Gap, were completed with light 8-inch casing to accommodate water-level recorders. The remaining wells were bored with a 4-inch post-hole auger and were completed with screened well-points affixed to 1¼-inch galvanized pipe, all surrounded with a layer of fine gravel. In the top few feet below land surface clay was tamped outside the casing to prevent direct inflow of rainwater. About quarterly in 1941 and 1942 water-level measurements were made to determine depth to the water table, its relation to the pressure levels in wells tapping subjacent confined aquifers, and character of annual range in fluctuation; also, to see whether any discontinuity in water surface could be detected across major faults known or inferred to occur at greater depth.

Profiles showing water level in the shallow wells within the five gaps are presented on plate 2. Because the levels for January 20–22, 1942 represent the average high level for the several profiles within the period of measurement and because the levels for November 6, 1942, represent the average lowest levels for that same year, these two sets of measurements have been plotted on the several profiles to indicate the general magnitude of yearly fluctuation. Water levels for virtually the same dates in selected deeper wells tapping subjacent confined aquifers have been superposed on the profile to show, insofar as feasible, the relation of the water table to the pressure (piezometric) levels for the water-bearing zones of the principal water body. As is shown by plate 2, certain definite statements can be made with respect to these relations as they existed in the year 1942.

Thus, in the Dominguez Gap the depth to the water table ranged from 15 to 25 feet, and its yearly fluctuation ranged from 0 to 3 feet. In 1942 the water table was below sea level south of Willow Street and about 24 feet above sea level at well 4/13–2K1, 3.5 miles to the north and 7 miles from the coast. In wells tapping the Gaspur water-bearing zone the pressure surface coincided closely with the water table north of well 4/13–14P1 and to the south was no more than 2 to 3 feet below the water table. In the southern part of the Dominguez Gap, at least, the water table for 1942 was truly semiperched because it was higher than the pressure level for the underlying body of confined water and was not separated from that body by any unsaturated rock.

In the Alamitos Gap the depth to the water table ranged from 0 to 9 feet below land surface and its yearly fluctuation was from 1 to 4 feet. In wells tapping underlying aquifers of Pleistocene age (Nos. 5/12–2B1 and 11H1) the pressure surface remained above the water table throughout most of the year (discounting drawdown due to pumping of nearby wells). Thus, at least inland from the principal fault of the Newport–Inglewood zone, the water table as of 1942 in Alamitos Gap was neither semiperched nor perched. Under such conditions, it may receive very slow recharge from the underlying aquifers. However, under the low-water conditions of the thirties, this water table was a true, even though temporary semiperched table.

In the Sunset Gap the depth to the water level in shallow wells ranged from 1.5 to 8 feet and the yearly fluctuation was from 0 to 5 feet. In January 1942, water levels in three of the shallow observation wells (5/11–18G1, 18G2, and 18P3) were above land surface; these walls reached confined water at shallow depth; hence if a true water table exists here, it must occur in the top few feet of fine sand or silt. In one nearby deep well (5/11–18J2) tapping a subjacent aquifer in deposits of Pleistocene age, the pressure level was several feet above the level in the shallow wells throughout the year. Hence, in the Sunset Gap the water level in shallow wells did not represent a semiperched water table; in part of this gap apparently even the shallowest permeable zone contains water confined under sufficient pressure that at times it rises above land surface.

In the Bolsa Gap the depth to the water table ranged from 1.5 to 8 feet below land surface and its yearly fluctuation was from 1 to 3 feet. In the area near Slater Avenue and to the north, the water table is believed to have been depressed artificially by the effect of local drainage ditches. In well 5/11–27M1 which taps water-bearing gravel from 40 to 52 feet below land surface in deposits of Recent age, and in well 5/11–27D1 which taps a much deeper zone in the San Pedro formation, the pressure surfaces were substantially above the water table throughout the year. Thus, in the Bolsa Gap the water table was neither perched nor semiperched as of 1942.

In the Santa Ana Gap the depth to the water table ranged from 2 to 11 feet below land surface and its yearly fluctuation was from 1 to 3 feet. As in the Bolsa Gap the water table is depressed artificially, by the gathering system of the Talbert Drainage District. In wells tapping the Talbert water-bearing zone the pressure surface was above the water table throughout most of 1942, except near Atlanta Avenue where it was more or less continually depressed by the pumping of the wells of the Laguna Beach County Water District, also of other wells for local irrigation. In the Santa Ana Gap, therefore, as in all others except the Dominguez Gap, the water table was neither perched nor semiperched. In years such as 1942, when the pressure level in deeper wells was high compared to its level in the thirties, the level of the water table in all except the Dominguez Gap—that is, all four gaps southeast of Long Beach—doubtless is maintained in part by slow upward percolation from the underlying confined water body.

Direct evidence of replenishment to the unconfined body in the Santa Ana Gap by rain and by irrigation water is given on figure 2.

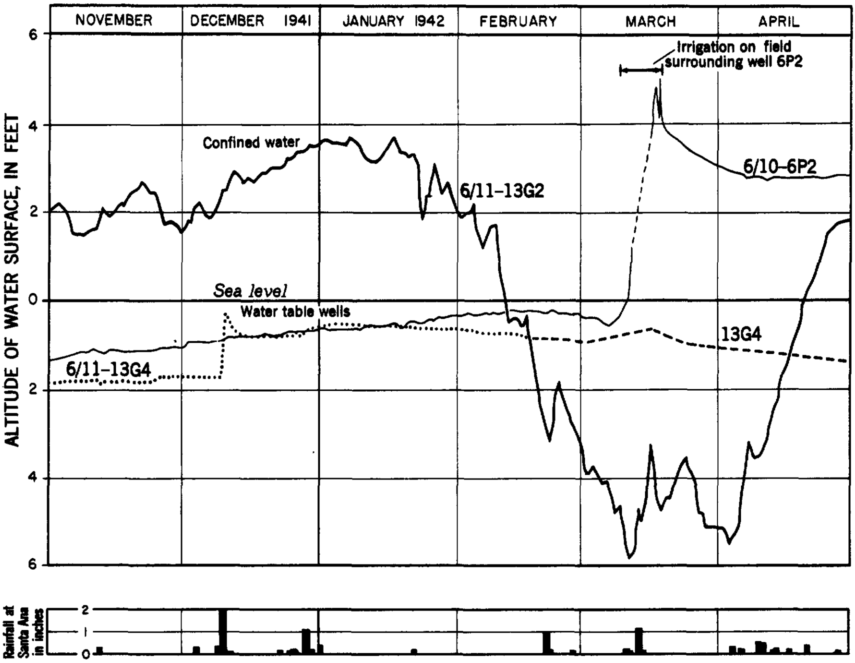

FIGURE 2.—Hydrographs showing relation between shallow and confined water in Santa Ana Gap.

This figure shows hydrographs for shallow wells 6/10–6P2 and 6/11–13G4, which are 24.7 and 12.7 feet deep and which tap the unconfined waters; also for deep well 6/11–13G2, which taps the Talbert water-bearing zone. All graphs are plotted from recorder charts. In well 13G4 the water level rose 1.35 feet in response to the 2.26 inches of rain that fell on December 9 and 10, 1941, whereas in well 6P2 the water level rose very little, if at all. Prior to that storm, the depth to water in well 13G4 was only 4.7 feet, whereas the depth in well 6P2 was 10.8 feet; seemingly the rainfall was sufficient to replenish moisture deficiency in the soil where the water table was at the smaller depth but not at the greater depth. The field of alfalfa surrounding well 6P2, which doubtless was responsible for much of the moisture deficiency there, was irrigated from March 9 to 18; concurrently the water table rose 5.5 feet. In about a month it had adjusted itself to a semipermanent rise of about 3 feet. If the specific yield of the material at the water table is as much as 10 percent, a recharge of nearly 4 inches of water is suggested. The heavy withdrawal for irrigation from the Talbert water-bearing zone following the 50-day dry period from January 1 to February 21 is reflected in the graph for 6/11–13G2, but not in the graphs for the two wells tapping the unconfined water body.

Inland from the five gaps, however, data accumulated in the several investigations reviewed heretofore (p. 65–66) show that at least in the past two decades the water table as indicated by measurements in shallow wells has consistently stood above the pressure levels of underlying aquifers throughout most of the Downey plain. Information obtained from wells of unequal depths indicates that all pervious layers below the water table are saturated. Thus, over most of the Long Beach–Santa Ana area, if not universally near the coast, the water table is truly semiperched but not perched. Accordingly, this shallow water body is denoted a "semiperched water body" in this report. It should be noted, however, that this semiperched condition has been developed largely by the continuing heavy withdrawals of the past four decades, which everywhere has lowered the pressure levels of the aquifers of the principal water body beneath. Under the initial natural conditions of high pressure head that produced flowing wells for about 290 square miles of the coastal plain, the area of the true semiperched water table must have been only a narrow local fringe inland from the limits of flowing wells (Mendenhall, 1905b, pl. 1). Throughout the artesian area of that time, the shallow water body must have been replenished both by rainfall and by slow upward percolation from the zones beneath.

With respect to the two elements of critical interest, outlined on page 64, the data here presented on the semiperched water body lead to certain conclusions, as follows:

1. Along the coastal reach, only locally in the Dominguez and the Santa Ana Gaps has the level of the semiperched water of inferior quality been consistently above that of the subjacent aquifers since 1940, and thus only in parts of those two gaps could this shallow water have passed downward through any defective well casings to enter the Gaspur and Talbert water-bearing zones beneath. In the intervening three gaps, the pressure level in the subjacent aquifers has been substantially above that of the semiperched water body for most of the period since 1940. However, in dry periods similar to that which culminated in 1936, the semiperched water would have the greater head in all the gaps and thus in all would be a potential source of contamination.
2. In all except the Dominguez Gap, the semiperched water table has been close to sea level and virtually without gradient, even during the high-water period since 1940. Hence, if this water table fell only slightly during a dry cycle, a gentle landward gradient would be produced across the principal faults of the Newport–Inglewood system; then, only the low permeability of the containing deposits would restrain further encroachment of oceanic and other saline waters in the semiperched body. However, this low permeability would afford considerable restraint.

## PRINCIPAL FRESH-WATER BODY

### GENERAL FEATURES OF THE GROUND-WATER REGIMEN

The principal fresh-water body underlies most of the Long Beach–Santa Ana area. Its general nature has been described briefly in the report on geologic features (Poland, Piper and others, 1956, p. 109–112) with respect to (1) its extent, depth, and origin by displacement of saline water from the containing marine deposits; (2) its replenishment, principally through the coarse permeable deposits of the intake areas below the Whittier Narrows and the Santa Ana Canyon by downward percolation from streams, of rain and of irrigation water; (3) its confinement coastward from the intake areas by overlying beds of silt or clay and by the "barrier" action of the Newport–Inglewood uplift; and (4) its coastward circulation through the confined aquifers and the pressure head so developed, which created an initial area of flowing wells about 290 square miles in extent.

For each of the several major water-bearing zones of the principal water body that are now tapped by wells, the depth below land surface, the thickness, the relative water-yielding capacity, and the estimated yield have been treated on p. 31 to 58. For critical segments of certain aquifers in the coastal area, the permeability and transmission capacity (transmissibility) have been treated briefly in the report on geologic features (Poland, Piper, and others, 1956, p. 114–115).

The increasing withdrawal of water from the fresh-water body since 1904, especially in the twenties and early thirties, has been discussed on pages 10 to 12.

In the following pages specific evidence is presented in the form of hydrographs, water-level contour maps, and water-level profiles to show the changes that have taken place in this water body during its intensive utilization. The decline in water levels, which developed as a result of increase in use and which has occurred largely during periods of subnormal rainfall, on the one hand has crystallized the need for appraising the effectiveness of the Newport–Inglewood uplift as a barrier to landward movement of saline water and on the other hand has furnished certain specific evidence of great aid in such an appraisal.

For reference in the succeeding discussion of hydrologic conditions, table 20 presents yearly rainfall for four representative stations near the periphery of the Long Beach–Santa Ana area. For the two stations of longest record—Los Angeles and Tustin—yearly and cumulated departures from the 68-year average are shown by the table; the accumulated departure is plotted on figure 3.

TABLE 20.—*Rainfall, in inches, at four climatological stations near Los Angeles, in the years ending June 30, 1877–1944; also, surplus or deficiency (−) at two stations with respect to 68-year average*

[Data from publications of United States Weather Bureau]

| Year | Los Angeles | | | Long Beach | Anaheim | Tustin | | |
|---|---|---|---|---|---|---|---|---|
| | Rainfall | Surplus or deficiency | Cumulated surplus or deficiency | Rainfall | Rainfall | Rainfall | Surplus or deficiency | Cumulated surplus or deficiency |
| 1877–78 | 21.26 | 5.73 | 5.73 | -------- | -------- | 19.60 | 6.27 | 6.27 |
| 1878–79 | 11.35 | −4.18 | 1.55 | -------- | 4.35 | 5.75 | −7.58 | −1.31 |
| 1879–80 | 20.34 | 4.81 | 6.36 | -------- | 11.31 | 16.58 | 3.25 | 1.94 |
| 1880–81 | 13.13 | −2.40 | 3.96 | -------- | 7.08 | 9.49 | −3.84 | −1.90 |
| 1881–82 | 10.40 | −5.13 | −1.17 | -------- | 7.12 | 7.74 | −5.59 | −7.49 |
| 1882–83 | 12.11 | −3.42 | −4.59 | -------- | 8.60 | 7.56 | −5.77 | −13.26 |
| 1883–84 | 38.18 | 22.65 | 18.06 | -------- | 26.17 | 32.65 | 19.32 | 6.06 |
| 1884–85 | 9.21 | −6.32 | 11.74 | -------- | 5.76 | 9.61 | −3.72 | 2.34 |
| 1885–86 | 22.31 | 6.78 | 18.52 | -------- | 14.75 | 16.38 | 3.05 | 5.39 |
| 1886–87 | 14.05 | −1.48 | 17.04 | -------- | 8.68 | 9.11 | −4.22 | 1.17 |
| 1887–88 | 13.87 | −1.66 | 15.38 | -------- | 16.94 | 17.53 | 4.20 | 5.57 |
| 1888–89 | 19.28 | 3.75 | 19.13 | -------- | 18.14 | 15.42 | 2.09 | 7.46 |
| 1889–90 | 34.84 | 19.31 | 38.44 | -------- | 20.00 | 22.21 | 8.88 | 16.34 |
| 1890–91 | 13.36 | −2.17 | 36.27 | -------- | 15.93 | 14.76 | 1.43 | 17.77 |
| 1891–92 | 11.85 | −3.68 | 32.59 | -------- | 7.42 | 12.13 | −1.20 | 16.57 |
| 1892–93 | 26.28 | 10.75 | 43.34 | -------- | 13.95 | 18.10 | 4.77 | 21.34 |
| 1893–94 | 6.73 | −8.80 | 34.54 | -------- | 4.42 | 6.42 | −6.91 | 14.43 |
| 1894–95 | 16.11 | .58 | 35.12 | -------- | 16.17 | 17.00 | 3.67 | 18.10 |
| 1895–96 | 8.51 | −7.02 | 28.10 | -------- | 7.73 | 9.47 | −3.86 | 14.24 |
| 1896–97 | 16.86 | 1.33 | 29.43 | -------- | 14.52 | 14.51 | 1.18 | 15.42 |
| 1897–98 | 7.06 | −8.47 | 20.96 | -------- | 5.65 | 5.82 | −7.51 | 7.91 |
| 1898–99 | 5.59 | −9.94 | 11.02 | -------- | 5.45 | 6.64 | −6.69 | 1.22 |
| 1899–1900 | 7.91 | −7.62 | 3.40 | -------- | 8.37 | 7.29 | −6.04 | −4.82 |
| 1900–01 | 16.29 | .76 | 4.16 | -------- | 14.65 | 15.46 | 2.13 | −2.69 |
| 1901–02 | 10.60 | −4.93 | −.77 | -------- | 10.08 | 8.84 | −4.49 | −7.18 |
| 1902–03 | 19.32 | 3.79 | 3.02 | -------- | 19.47 | 15.38 | 2.05 | −5.13 |
| 1903–04 | 8.72 | −6.81 | −3.79 | -------- | 6.45 | [1] 6.77 | −6.56 | −11.69 |
| 1904–05 | 19.52 | 3.99 | .20 | -------- | -------- | 18.78 | 5.45 | −6.24 |
| 1905–06 | 18.65 | 3.12 | 3.32 | -------- | -------- | 19.00 | 5.67 | −.57 |
| 1906–07 | 19.30 | 3.77 | 7.09 | -------- | 15.00 | 19.68 | 6.35 | 5.78 |
| 1907–08 | 11.72 | −3.81 | 3.28 | -------- | [1] 9.98 | 9.04 | −4.29 | 1.49 |
| 1908–09 | 19.18 | 3.65 | 6.93 | -------- | 18.79 | 14.45 | 1.12 | 2.61 |
| 1909–10 | 12.63 | −2.90 | 4.03 | -------- | [1] 7.45 | 11.87 | −1.46 | 1.15 |
| 1910–11 | 16.18 | .65 | 4.68 | -------- | -------- | 13.05 | .28 | .87 |
| 1911–12 | 11.60 | −3.93 | .75 | -------- | -------- | 7.89 | −5.44 | −4.57 |
| 1912–13 | 13.42 | −2.11 | −1.36 | -------- | -------- | 8.11 | −5.22 | −9.79 |
| 1913–14 | 23.65 | 8.12 | 6.76 | -------- | -------- | 15.66 | 2.33 | −7.46 |
| 1914–15 | 17.05 | 1.52 | 8.28 | -------- | -------- | 18.31 | 4.98 | −2.48 |
| 1915–16 | 19.92 | 4.39 | 12.67 | -------- | -------- | 15.87 | 2.54 | .06 |
| 1916–17 | 15.26 | −.27 | 12.40 | -------- | -------- | 10.38 | −2.95 | −2.89 |
| 1917–18 | 13.86 | −1.67 | 10.73 | -------- | -------- | 9.49 | −3.84 | −6.73 |
| 1918–19 | 8.58 | −6.95 | 3.78 | -------- | -------- | 8.47 | −4.86 | −11.59 |
| 1919–20 | 12.52 | −3.01 | .77 | -------- | -------- | 13.03 | −.30 | −11.89 |
| 1920–21 | 13.65 | −1.88 | −1.11 | -------- | -------- | 12.23 | −1.10 | −12.99 |
| 1921–22 | 19.66 | 4.13 | 3.02 | 16.31 | -------- | 17.51 | 4.18 | −8.81 |
| 1922–23 | 9.59 | −5.94 | −2.92 | 10.72 | -------- | 7.21 | −6.12 | −14.93 |
| 1923–24 | 6.67 | −8.86 | −11.78 | 8.60 | -------- | 11.09 | −2.24 | −17.17 |
| 1924–25 | 7.94 | −7.59 | −19.37 | 5.63 | -------- | 6.48 | −6.85 | −24.02 |
| 1925–26 | 17.56 | 2.03 | −17.34 | 9.21 | -------- | 13.45 | .12 | −23.90 |
| 1926–27 | 17.76 | 2.23 | −15.11 | 10.10 | -------- | 4.79 | 1.46 | −22.44 |
| 1927–28 | 9.77 | −5.76 | −20.87 | 7.98 | -------- | 11.05 | −2.28 | −24.72 |
| 1928–29 | 12.66 | −2.87 | −23.74 | 6.38 | -------- | 9.57 | −3.76 | −28.48 |
| 1929–30 | 11.52 | −4.01 | −27.75 | 11.71 | -------- | 13.76 | .43 | −28.05 |
| 1930–31 | 12.53 | −3.00 | −30.75 | 8.75 | -------- | 9.94 | −3.39 | −31.44 |
| 1931–32 | 16.95 | 1.42 | −29.33 | 15.66 | -------- | 15.10 | 1.77 | −29.67 |
| 1932–33 | 11.88 | −3.65 | −32.98 | 9.56 | -------- | 10.64 | −2.69 | −32.36 |
| 1933–34 | 14.55 | −.98 | −33.96 | 6.07 | -------- | 8.75 | −4.58 | −36.94 |
| 1934–35 | 21.66 | 6.13 | −27.83 | 17.73 | -------- | 15.85 | 2.52 | −34.42 |

TABLE 20.—*Rainfall, in inches, at four climatological stations near Los Angeles, in the years ending June 30, 1877–1944; also, surplus or deficiency (−) at two stations with respect to 68-year average*—Continued

| Year | Los Angeles |  |  | Long Beach | Anaheim | Tustin |  |  |
|---|---|---|---|---|---|---|---|---|
|  | Rainfall | Surplus or deficiency | Cumulated surplus or deficiency | Rainfall | Rainfall | Rainfall | Surplus or deficiency | Cumulated surplus or deficiency |
| 1935–36 | 12.07 | −3.46 | −31.29 | 10.33 | ---------- | 8.60 | −4.73 | −39.15 |
| 1936–37 | 22.41 | 6.88 | −24.41 | 20.54 | ---------- | 22.56 | 9.23 | −29.92 |
| 1937–38 | 23.43 | 7.90 | −16.51 | 18.28 | ---------- | 16.64 | 3.31 | −26.61 |
| 1938–39 | 13.07 | −2.46 | −18.97 | 11.65 | ---------- | 14.12 | .79 | −25.82 |
| 1939–40 | 19.21 | 3.68 | −15.29 | 17.69 | ---------- | 15.93 | 2.60 | −23.22 |
| 1940–41 | 32.76 | 17.23 | 1.94 | 29.09 | ---------- | 29.50 | 16.17 | −7.05 |
| 1941–42 | 11.18 | −4.35 | −2.41 | 11.14 | ---------- | 12.77 | −.56 | −7.61 |
| 1942–43 | 18.17 | 2.64 | .23 | 14.43 | ---------- | 16.26 | 2.93 | −4.68 |
| 1943–44 | 19.22 | 3.69 | 3.92 | 18.55 | ---------- | 17.33 | 4.00 | −.68 |
| 1944–45 | 11.59 | −3.94 | −.02 | 15.46 | ---------- | 13.95 | .62 | −.06 |
| Average for 68 seasons | 15.53 | ---------- | ---------- | ---------- | ---------- | 13.33 | ---------- | ---------- |

[1] Estimated from surrounding stations.

## NATURE OF THE EVIDENCE SHOWING CHANGES IN GROUND-WATER REGIMEN

### FIFTY-YEAR HYDROGRAPHS

Figure 3 shows the longest known records of water-level fluctuations available for wells in the Long Beach–Santa Ana area—that is, in the central and eastern parts of the coastal plain. Specifically, it shows (1) the composite of fluctuations in four wells near Anaheim in Orange County, which jointly afford one nearly continuous record beginning in 1894; (2) fluctuations beginning in 1895 in well 4/12–8P1 (Bouton well 1) near Long Beach in Los Angeles County; and (3) long-term variation in rainfall at Los Angeles and Tustin, plotted as cumulative departure in inches from the yearly mean for the 68 years of record at each station (years ending June 30). Plate 6 shows the location of these wells, also of others for which hydrographs are presented in this report.

The group of wells in Orange County—Nos. 4/10–22L1, 22L2, 26C1, and 26C2—is about 1.5 miles south of Anaheim and within the area of unconfined ground water, the intake area of the Santa Ana River fan. When well 4/10–22L1, the "J. B. Neff" well, was drilled in 1894 to a depth of 100 feet to tap the Talbert water-bearing zone, the water stood 13 feet below land surface (Mendenhall, 1905a, p. 57; also unpublished field notes of the Geological Survey). This well was destroyed in 1926 but subsequent measurements of the water-table stage have been made on nearby

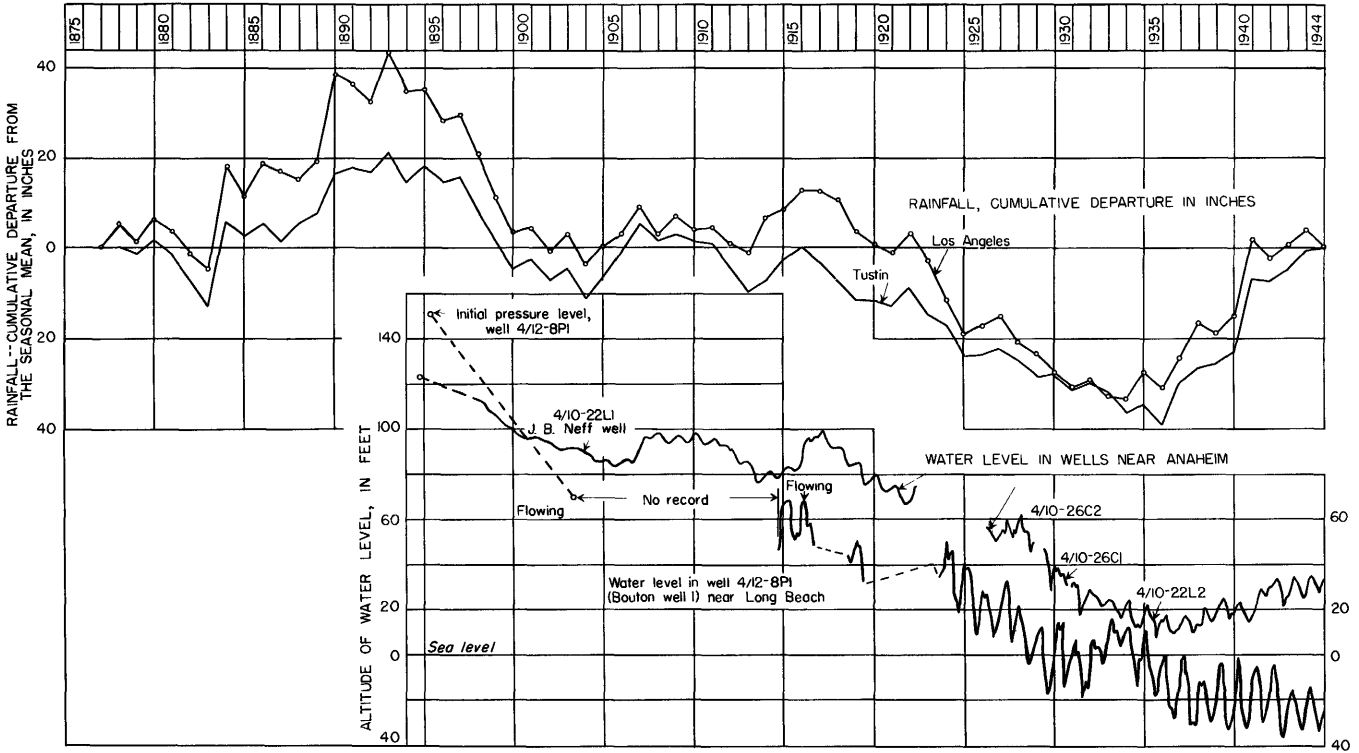

FIGURE 3.—Hydrographs of longest record for wells, and long-term records for rainfall in the Long Beach–Santa Ana area.

wells of somewhat greater depth.[9] This group of wells, shown on plate 6, is about a mile inland beyond the initial artesian area (Mendenhall, 1905a, pl. 6) and it is believed that the water-surface altitude of 122 feet in 1894 represents essentially undepleted ground-water storage at this place. Thus, this composite hydrograph for the four wells near Anaheim indicates (1) a decline in water table of about 37 feet in the 10 years from 1894 to 1904, which included 6 years of greatly subnormal rainfall; (2) a fluctuating but virtually stabilized water table in the 13 years from 1904 to 1917, which included only 6 years of slightly subnormal rainfall; (3) a fairly steady decline of about 82 feet in the 19-year dry period from 1917 to 1936, which included 13 years of subnormal rainfall; and (4) a recovery of 17 feet in the 8-year wet period beginning from 1937, which at Tustin has included 2 years of slightly subnormal rainfall and 3 years of excessive rainfall. During the 19-year period that ended with 1936 the withdrawal of ground water from beneath the coastal plain was increasing most rapidly and probably nearly doubled. This composite graph is believed to represent long-time water-level fluctuations beneath most of the coastal plain in Orange County, although the historic low-water level in the autumn of 1936 is more clearly defined in hydrographs for certain other wells, submitted on subsequent pages.

A composite record of monthly water levels beginning in 1907 and continuing to date (1945) is available from two wells of the city of Anaheim (wells 4/10–15B5 and 15B1). These two wells are 330 and 329 feet in depth, respectively, and tap aquifers of Pleistocene age underlying the Talbert water-bearing zone. Their composite hydrograph coincides so closely with that of wells 4/10–22L1 and 22L2 that it could not be shown clearly on figure 3. However, it is here cited as evidence that in the upper reach of the Santa Ana alluvial fan, where the ground water is largely unconfined, fluctuations are nearly alike for wells tapping the Talbert zone and for wells tapping the underlying deposits of Pleistocene age.

The Bouton wells (see record for 4/12–8P1, Bouton well 1, fig. 3) are about 2½ miles north of Signal Hill, were drilled between 1891 and 1903, and all tap the Silverado water-bearing zone of the San Pedro formation. Their interesting history has been recorded by Brown (1944, p. 25–30). The first successful well, 4/12–8P5, apparently was completed in 1891 at a depth of 339 or 400 feet in the uppermost part of the Silverado zone and

---

[9] For published record see Ebert, F. C., 1921, p. 44–46; also U. S. Geol. Survey Water-Supply Papers 817, p. 7, 1937; 840, p. 28, 1938; 845, p. 18, 1939; 886, p. 24, 1940; 911, p. 120, 141; 1941, p. 123, 1943; 949, p. 117, 1944; and 991, p. 118, 1945.

is reported by two independent sources[10] to have flowed with a jet reaching 7 feet above the top of its 7-inch casing at the time of completion. Also, reportedly it threw a "stream 20 feet above the mouth of a 2-inch nozzle situated 22 feet 4 inches above the surface." Burt Harmon of the Long Beach Water Department has calculated that this discharge height indicates a static head about 80 feet above land surface. This well is now known as Bouton No. 4 because J. B. Proctor, who drilled the last three wells, numbered them 1, 2, and 3, respectively, and then numbered the two earlier wells 4 and 5. These numbers have become fairly fixed in the records of the city of Long Beach and of other agencies, and so are used by the Geological Survey.

The third well of the Bouton group, 4/12–8P1, now known as Bouton No. 1, apparently was completed in 1895. It is variously reported to have been drilled 714, 722, and 730 feet deep and its casing is reported to have been perforated from 674 to 714 feet below land surface in the lower part of the Silverado water-bearing zone. This lower part of that zone is hydraulically separated from the upper part, which is tapped by well 8P5, by a layer of clay about 75 feet thick. Initially well 8P1 flowed 8½ inches over its 14-inch casing and reportedly had a static head about equal to that of well 8P5—that is, 80 feet above land surface and about 148 feet above sea level. The record of water level for this well plotted on plate 3 is chiefly from the Long Beach Water Department.[11] The latest recorded flow was in 1916; subsequently the pressure level declined almost steadily to 20 feet below sea level in 1931, recovered about 23 feet in 1932 and 1933, and since then has declined to 28 feet below sea level at the end of 1944. Since 1936 the water level in this well thus has moved contrary to the regional recovery in water level, probably because of heavy and sustained pumping from a nearby well which is used in part to maintain Bouton Lake. Nevertheless, it substantiates the record for the group of wells near Anaheim in showing a regional decline in water level of about 70 feet from 1917 into the middle thirties.

### TWENTY-YEAR HYDROGRAPHS

Measurements of water level giving representative geographic coverage do not extend back more than about two decades—as mentioned earlier in this report (p. 59), extensive measurements were begun by several agencies in the middle and late twenties.

---

[10] Unpublished notes in files of Geological Survey, in part from W. M. Brown and Burt Harmon of the Long Beach Water Department.

[11] For published record, see U. S. Geol. Survey Water-Supply Papers 941, p. 110–114, 1943; 949, p. 93, 1944; and 991, p. 114–115, 1945.

These programs developed chiefly because local agencies became disturbed by the continuing decline in water levels caused by increasing withdrawals during the period of deficient rainfall which commenced in 1918 but which was most severe from 1923 through 1925 and from 1927 through 1931 (fig. 3). Thus, records of water-level fluctuations extending back about 15 years are available for several hundred wells within the project area, and for a 21-year period for scattered wells. From all these, 30 records have been selected to represent the water-level fluctuations within the principal water-bearing zones; these representative records are shown by the hydrographs of plates 3 and 4. Certain pertinent details of the records are given in table 21 and 22, respectively.

TABLE 21.—*Wells in Los Angeles County for which hydrographs are plotted on plate 3*

| Well | Depth (feet) | Water-yielding zone or zones | | Agency supplying principal record[1] |
|---|---|---|---|---|
| | | Feet below land surface | Stratigraphic correlation | |
| **Wells tapping Recent alluvial deposits** | | | | |
| 2/12-13A1 | 81 | | Gaspur water-bearing zone | SGVPA |
| 35C1 | 73 | | do | Do. |
| 3/12- 8D3 | 117 | | do | Do. |
| 8L3 | 248.2 | | do | Do. |
| 3/13-26Q1 | 200 | | do | Do. |
| 35B2 | 174.0 | | do | LADWP |
| 4/13-14K1 | | | do | DWR |
| 14L1 | 114.3 | 86–114 | do | LB |
| 35M1 | 137 | | do | Do. |
| **Wells tapping Pleistocene deposits** | | | | |
| 2/12-16F2 | 400 | | San Pedro formation | LADWP, SGVPA |
| 2/13-22D4 | 752 | 258–714 | San Pedro formation, upper part | Owner |
| 27B11 | 1,600 | 938–1,575 | San Pedro formation, lower part | Do. |
| 3/12- 8F1 | 1,755 | 578–1,492 | San Pedro formation | LADWP |
| 4/13-12H1 | 674 | 424–624 | Silverado water-bearing zone in San Pedro formation. | Do. |
| 21H3 | 800 | 430–788 | do | LADWP, owner |
| 23G2 | 1,074 | 596–1,066 | do | LB |

[1] Names of agencies used in this and following tables are indicated as follows: DWR, Division of Water Resources, State of California; LACFCD, Los Angeles County Flood Control District; LADWP, Los Angeles Department of Water and Power; LB, City of Long Beach; OCFCD, Orange County Flood Control District; SGVPA, San Gabriel Valley Protective Association; RAS, R. A. Shafer for Bixby-Bryant interests; and USGS, United States Geological Survey.

## WATER-LEVEL CONTOUR MAPS

To show regional water-level conditions for the lowest and highest ground-water levels that have developed during the period of heaviest withdrawal, two water-level contour maps have been prepared. Specifically, plate 5 shows the historic low-water conditions of September 1936, near the end of the irrigation season in that year; also, plate 6 shows conditions during the high-water stage of April 1941, when substantial recovery had occurred over much of the coastal plain owing to increased replenishment

TABLE 22.—*Wells in Orange County for which hydrographs are plotted on plate 4*

| Well | Depth (feet) | Water-yielding zone or zones | | Agency supplying principal record[1] |
|---|---|---|---|---|
| | | Feet below land surface | Stratigraphic correlation | |
| **Wells tapping Pleistocene deposits in western part of county** | | | | |
| 3/10-31R2 | 385 | | Upper Pleistocene | SGVPA |
| 3/11-36Q2 | 666 | 500–650 | San Pedro formation | OCFCD |
| 4/11-19K1 | 448.4 | 440–460 | do | LB |
| 19M1 | 332 | | Upper Pleistocene | SGVPA |
| 5/11-16A1 | | | San Pedro(?) formation | Do. |
| 16D2 | 400 | | do | OCFCD |
| **Wells tapping Recent alluvial deposits** | | | | |
| 4/9- 7B1 | 208.3 | 140–230 | Talbert water-bearing zone and upper Pleistocene. | OCFCD |
| 4/10-26C1 | 200 | | Talbert water-bearing zone | W. W. Hoy |
| 26C2 | 115 | | do | Do. |
| 5/10-32C1 | 105 | | do | OCFCD |
| 6/11-13G2 | 154 | | do | Do. |
| **Wells tapping Pleistocene deposits beneath Newport Mesa** | | | | |
| 6/10- 1L2 | 142.6 | | Upper Pleistocene | W. W. Hoy |
| 3H2 | 637 | | Principal water-bearing zone in San Pedro formation. | OCFCD |
| 11-G2 | 804 | 246–425 | do | Do. |

[1] For explanation of symbols see table 21.

coupled with decreased draft in the wet seasons of 1936–37, 1937–38, 1939–40, and 1940–41 (table 20).

As is shown by the hydrographs of plates 3 and 4, also by those of other plates presented, water levels have risen slightly since 1941 in some segments of the main coastal basin, especially in Orange County. Thus, a contour map for 1942 or 1943 would show a somewhat higher level, at least locally, but would be less comprehensive than plate 6 because in 1941 the Los Angeles Department of Water and Power made its last measurements of depth to water in several hundred wells and discontinued its program by year-end.

Water-level contours by Mendenhall as of 1904 (1905a, 1905b, 1905c) show a substantially higher water level than does the map here introduced for April 1941 (pl. 6), but do not cover the belt of wells then flowing—that is, they do not cover the greater part of the main coastal basin. The field notes taken in 1903–4 show several hundred measurements for height of flow above the casings of the flowing wells. However, it is not considered practicable at this time to convert these measurements to piezometric levels as of that date, because interference between the wells would preclude a close approximation of such levels. For this reason a map showing water-level contours as of 1904 is not included in this report.

Water-level contour maps for other periods since 1904 have been prepared by several agencies. For example, beginning in 1930 the Los Angeles County Flood Control District (Baumann and Laverty, 1930–44) has prepared contour maps of the high- (April–May) and low-water (October–November) stages of each year for the coastal plain in Los Angeles County. The California Division of Water Resources has published ground-water contour maps (1) as of April 1926 for part of the central coastal plain (Conkling, 1927, pl. 13); (2) as of autumn 1927 for nearly all of Orange County (Post, 1928, map 8); (3) as of January 1933 for much of the coastal plain (Eckis, 1934, pl. E); and (4) as of December 1936 and December 1944 for Orange County (Gleason, 1945, pls. 4 and 5). Also, for selected periods since 1928 the Orange County Flood Control District has prepared ground-water contour maps for Orange County; of these maps, one for the autumn of 1930 has been published (Elliott, Etcheverry and Means, 1931, pl. 5). Of all these maps antecedent to this report, none spans the full reach of the Long Beach–Santa Ana area.

The two water-level contour maps of this report, plates 5 and 6, have been drawn from water-level altitudes in wells tapping the water-bearing zones most heavily pumped. No single water-bearing zone extends over all the area or even over the part of the area in either county. Within the extent of the Gaspur and Talbert water-bearing zones (pls. 5, 6) most of the active wells tap only these zones and relatively few tap underlying zones within the Pleistocene deposits. Thus, within the reaches of these two zones, except in the Dominguez Gap (p. 80) the water-level contours show the pressure level or, in the respective intake areas, the water table. Elsewhere, the contours are based on water levels in wells tapping aquifers of Pleistocene age. In general, in such wells tapping Pleistocene deposits less than about 200 feet below land surface—upper Pleistocene deposits in most part—water levels are somewhat higher than those in deeper wells and were disregarded in drawing the contours. On the other hand, throughout most of the area there is no marked difference in pressure level (piezometric surface) among the deeper wells, whether a few hundred or as much as 1,000 feet deep. Thus, data from most of the observation wells more than 200 feet deep were used as control for the contours of plates 5 and 6. For the area extending from Long Beach southeast to Huntington Beach and lying southwest of the major faults of the Newport–Inglewood structural zone, water-level contours could not be drawn on either map because sufficient wells are not available to furnish control on water levels. For that area, available data are shown on paired hydrographs presented in the latter part of this report.

However, in both Los Angeles and Orange Counties, there are certain areas where two or more water-bearing zones are tapped extensively by wells and where pressure levels in the deeper zones are several tens of feet the lower. These inequalities in pressure level occur commonly where the water-bearing zones are separated by extensive impervious layers; they have developed through the period of draft, owing to disproportionate withdrawal from the several water-bearing zones, or to unequal facility for replenishment, or both. For all such areas, the contours have been drawn from water levels in wells tapping the zone of heaviest draft.

In Los Angeles County, water-bearing zones with markedly disparate levels are tapped in three principal areas, as follows:

1. In the vicinity of Huntington Park, three major water-bearing zones are tapped (p. 92–95); among these three the uppermost is the westerly arm of the Gaspur water-bearing zone of Recent age, whereas the middle and lower zones occur in deposits of Pleistocene age. The middle zone, in the upper and middle parts of the San Pedro formation and from 500 to 1,100 feet below land surface, is the one now (1945) pumped most heavily and the one for which contours are shown on plates 5 and 6. Its pressure level is from 10 to 40 feet below that of the upper zone and from 10 to 30 feet above that of the lower zone.
2. Northeast of Signal Hill the Silverado water-bearing zone is the chief source of water. However, it is underlain by a water-bearing zone within the basal division of the San Pedro formation which supplies nearly half the current demand by the city of Long Beach (table 24), and whose water level currently is from 10 to 30 feet below that of the Silverado zone (p. 95–101). Accordingly, levels from wells tapping the basal division of the San Pedro have been omitted in preparing the contour maps.
3. Southwest of the Newport–Inglewood uplift in the Dominguez Gap, the Silverado water-bearing zone is again the chief source of supply. However, it is overlain at shallow depth by the Gaspur water-bearing zone of Recent age (see Poland, Piper, and others, 1956, pl. 4, *B–B′*) which once was pumped heavily, but now is contaminated and is pumped only lightly. Thus, here also, only water levels for wells tapping the Silverado zone have been utilized in preparing plates 5 and 6.

In Orange County, water-bearing zones with markedly disparate levels are tapped in one substantial area—specifically, the Irvine tract where wells range in depth from as little as 31 to as much as 1,660 feet below land surface. Several of the deeper wells tap as many as a dozen aquifers, which commonly are not more than 20 feet thick and which are separated by layers of silt, clay, or shale. Although they tap several aquifers, most of the wells that are perforated below 300 feet appear to have a common water level, which has fluctuated widely during the past decade. On the other hand, most wells less than 200 to 300 feet deep have a water level substantially above that of the deeper wells—in 1936 it was locally as much as 75 feet higher and in 1941 as much as 25 feet higher. Because the aquifers below 300 feet yield most of the ground water withdrawn in the Irvine tract, only levels in the deeper wells have been used in preparing plates 5 and 6.

The areas of disparate levels in Los Angeles County are discussed in some detail on pages 92–101. However, in the Irvine tract of Orange County hydrologic conditions are so complex that it was not considered feasible within the scope of this investigation to attempt their detailed study; therefore, no further elucidation of those conditions will be undertaken.

Certain water-level contour maps that have been prepared by other agencies (p. 79) have been drawn in part from water levels in wells tapping zones shallower than those most heavily pumped. Hence plates 5 and 6 of this report do not necessarily agree with maps of other agencies for similar periods.

### WATER-LEVEL PROFILES

The movement of water in the Gaspur and Talbert water-bearing zones is the most critical element in the ground-water regimen of the area, not only with respect to regional circulation and replenishment (Poland, Piper, and others, 1956, p. 111–113), but also with respect to a fundamental problem of this cooperative investigation—that is, encroachment of saline water across the barrier features of the Newport–Inglewood uplift. Accordingly, plates 7 and 8 are introduced to show profiles along the full reach of these two zones from the two inland narrows to the ocean with selected water-level stages. Thus, these plates show the position of the Gaspur and Talbert zones in relation to historic changes in water level, and indicate (1) the extent of dewatering that has occurred within their intake reaches, (2) the decline in artesian pressure that has taken place within their confined reaches, downgradient from the respective intake areas, and finally (3) the landward gradients that have developed within them at and near the coast, under which the natural direction of ground-water movement has been reversed and oceanic or connate waters have moved landward within the Dominguez and the Santa Ana Gaps.

## CHANGES IN GROUND-WATER REGIMEN IN LOS ANGELES COUNTY

In the following pages the long-term fluctuations in water level are analyzed separately for the two counties in some detail, with specific reference to the hydrographs, water-level contour maps, and profiles just introduced. Those fluctuations can best be examined in relation to the several water-bearing deposits tapped, because certain features of and changes in pressure level are critical with respect to the major issue in this investigation—that is, with respect to the effectiveness of the Newport–Inglewood uplift as a barrier to further inland movement of saline water.

## CHANGES IN THE GASPUR WATER-BEARING ZONE

### DECLINE OF HEAD PRIOR TO 1926

Plate 7 has introduced profiles of water level at selected time intervals from 1903–4 into 1941 for many representative wells tapping the Gaspur water-bearing zone—among these wells, the six whose hydrographs are given in plate 3 are indicated by lines of extra weight. These profiles follow line *A–A′* of plate 6, which is identical in position with line *A–A′* on plate 7 of the report on geologic features (Poland, Piper, and others, 1956). They show the water levels for April 1926, for the high stages of 1930 and 1936, for the low stage of 1936 (historic low water), and for the high stage of 1941 (about in April)—all in comparison with the water level for 1903–4, the earliest level of record.

Mendenhall's field notes of 1903–4 have been reviewed with the hope of obtaining data on the initial height of piezometric surface within the Gaspur water-bearing zone, but information so gleaned is fragmentary and insufficient for plotting a profile on plate 7 (the profile 1903–4 is somewhat below that of native conditions). However, it was learned that initially the wells tapping the Gaspur zone from Artesia Street north to and about a mile beyond Firestone Boulevard flowed slightly. Specifically, the most northerly well for which initial flow is recorded from the Gaspur zone was Mendenhall's No. 2679 (Downey quadrangle), which projects on to plate 7 about at the position of well 2/12–28R1. This well "flowed ½-inch over pipe [4-inch casing] when drilled in 1875;" thus, it is suggested that, at least in the mile north from Firestone Boulevard, the pressure head in the Gaspur zone declined about 12 to 15 feet from 1875 to 1904.

With respect to the profile for 1903–4, particular attention is called to the fact that the wells then flowing from the Gaspur water-bearing zone reached coastward only about 2.5 miles from well 3/12–8L3 (from 0.4 mile south of Imperial Highway about to Compton Boulevard), whereas Mendenhall's map (1905b, pl. 4) shows the area of flowing wells ("artesian area" in his terminology) to have extended about 5 miles (from Imperial Highway to Del Amo Street). However, his notes indicate that south of Compton Boulevard all wells flowing as of 1903–4 tapped deposits of Pleistocene age underlying the Gaspur zone.

In the Dominguez Gap as of 1904, the pressure level in the Gaspur zone ranged from 4 to 8 feet below land surface inland from the Pacific Coast highway; coastward from that highway, to Terminal Island, it was from 1 to 2 feet below land surface. Except at Mendenhall's well No. 882 (in 4/13–34P, tideland area as of 1904), nowhere in the gap did the pressure level in the Gaspur zone rise above land surface to produce flowing wells.

Plate 7 shows a decline of water level for the Gaspur zone from 1904 to 1926 that was substantial but not excessive. In the 5-mile reach from Whittier Boulevard to Firestone Boulevard, the greatest decline was 14 feet and the average decline was about 10 feet; in the 6-mile reach from Firestone Boulevard to Artesia Street, the greatest and average declines were 10 feet and about 6 feet, respectively; and in the 7½-mile coastal reach from Artesia Street to Terminal Island the greatest and average declines were 16 feet and about 9 feet. However, from the hydrographs of figure 3 and from published records of water levels from 1904 to 1918 it is concluded that for the area north of Firestone Boulevard and east of the San Gabriel River (Ebert, 1921, wells 37 and 40), the water levels of 1918 were equal to or slightly above those of 1904, and that the decline summarized above occurred entirely from 1918 to 1926—that is, during the period of deficient rainfall beginning in 1917 and in the early half of the period of declining water levels that continued into 1936.

### DECLINE AND PARTIAL RECOVERY FROM 1926 THROUGH 1944

On plate 3 hydrographs are given for 6 wells tapping the Gaspur water-bearing zone at intervals of from 3 to 4 miles between Whittier Narrows and Terminal Island. These show water-level fluctuation from 1926 through 1944 throughout the full reach of the Gaspur zone. (See pl. 6 for location, also table 21 for other pertinent data.) Four of the six wells are inland from the Newport–Inglewood uplift, and so are in the main coastal basin; the remaining two, wells 4/13–14L1 and 35M1, are southwest of the uplift in Dominguez Gap, and are in the southeastern segment of the so-called west basin. Within the reach of the Gaspur zone across the main basin the early record for well 3/12–8D3 has been plotted to supplement the later record for well 3/12–8L3, and the early record for well 3/13–26Q1 to extend that of well 3/13–35B2; within the Dominguez Gap, the early record for well 4/13–14K1 supplements that of well 14L1.

The continued recession of water level from 1926 into 1936 and the partial recovery to the end of 1944, as revealed on plates 3 and 7, can best be summarized separately for (1) the area from Whittier Narrows to Del Amo Street and (2) the Dominguez Gap, or from Del Amo Street southward to Terminal Island.

*Whittier Narrows to Del Amo Street.*—Hydrographs and profiles for wells within this reach reveal the following common trends:

1. A general decline in water level from 1926 into 1936, ranging from 36 feet at well 2/12–35C1 to 16 feet at well 3/13–35B2.
2. A substantial recovery from 1936 into 1941, especially in the wet seasons of 1937–38 and 1940–41; this recovery ranged from 34 feet at well 2/12–35C1 to 6 feet at well 3/13–35B2.
3. Essential stability from 1941 through 1944.

On plates 6 and 7, the recharge area of free water-table fluctuation is shown as extending from Whittier Narrows coastward some 5 miles, or about to well 2/12–35C1. Thus, changes in water level inland from this well represent changes in ground-water storage, whereas changes in the confined reach coastward from this well commonly indicate fluctuations of the pressure head but not of storage. However, from 1933 to 1938 dewatering occurred in the previously confined reach of the Gaspur water-bearing zone; at its greatest reach in 1936 this dewatering extended coastward about to Firestone Boulevard.

The recovery of 1936–41 was greater at well 2/12–35C1 (34 feet) than at well 2/12–13A1 (22 feet). These two wells are about midway between the Rio Hondo and the San Gabriel River. However, well 13A1 is near the upper end of the recharge area and about 1 mile upstream from the spreading basins of the Los Angeles County Flood Control District. (For location of these basins, see plate 6.) On the other hand, well 35C1 is near the lower edge of the recharge area and about 2 miles downstream from the spreading basins. The basins adjacent to the Rio Hondo were constructed in 1938 (Jordan, Keim, and Thayer, 1939), and those contiguous to the San Gabriel River in 1939 (Jordan and Thayer, 1940). In the period ending October 1, 1943, about 25,000 acre-feet of water had been spread in these basins.[12] Natural replenishment in the recharge (intake) area is chiefly from channel percolation, underflow, and rainfall penetration; the artificial spreading operations, which have been carried on mostly in the summer, have contributed substantially to the recovery of water level and in part explain the greater recovery at well 2/12–35C1.

As shown by the profiles of plate 7, by the spring of 1941 the natural and artificial recharge had built a water-table mound in the reach between Whittier Boulevard and Anaheim–Telegraph Road, and there had raised the water level substantially above the high stage of 1926 and locally to the water-table stage of 1904.

---

[12] Figures from Annual reports on hydrologic data: Los Angeles County Flood Control District, 1937–38, 1938–39, 1939–40, 1940–41, 1941–42, and 1942–43.

This local mound apparently had not extended coastward beyond well 2/12–28R1 as of early 1941; had the mound reached the confined segment of the Gaspur zone, it might be expected that pressure effects would have been transmitted coastward rapidly and immediately. As inferred on plate 7, this lack of pressure response suggests that confinement is incomplete in the reach from well 2/12–35C1 to well 28R1. This suggestion is substantiated by such well logs as are available, especially for the area near the Rio Hondo.

*Del Amo Street to Terminal Island.*—Hydrographs for the two wells tapping the Gaspur water-bearing zone in the Dominguez Gap coastward from the Newport–Inglewood fault zone reveal:

1. A declining water level from 1926 into 1931—8 feet at wells 4/13–14K1 and 14L1, or about 2 feet per year.
2. A consistent but slow rise in water level from 1931 to 1940, averaging about 1 foot per year.
3. A stable level from 1940 through 1944 (however, for erratic fluctuation in well 4/13–35M1, see below).

Thus, from 1931 into 1936 for wells tapping the Gaspur zone within the Dominguez Gap the water levels moved contrary to the general trend for wells tapping this same zone in the main coastal basin to the north. This recovery of the pressure surface in the Dominguez Gap in the early and middle thirties occurred because in that area saline contamination then was increasing, water from many irrigation wells was becoming unusable, and draft from the Gaspur zone was decreasing accordingly.

*Anomalous fluctuation in well 4/13–35M1.*—In well 4/13–35M1 the water level declined suddenly about 11 feet in July 1941 and fell an additional 4 feet in September of that year concurrently with the dewatering for construction of the large graving dock at the Naval Operating Base on Terminal Island, about 9,000 feet south of the well. A brief description of this dewatering operation, its effect on water levels in nearby wells, and the local but substantial subsidence of land surface that quickly developed has been given by Grant. (1944, p. 149–154.) This dewatering was carried out by turbine pumps in 36 gravel-envelope wells which tapped the Gaspur water-bearing zone. The first pumps were started on June 27, 1941. The discharge reached a maximum during August, when the average rate was about 35,000 gpm, or about 4,600 acre-feet for that month. From October into late February 1942, the average rate was about 20,000 gpm. On April 4, 1942, all pumping operations at the drydock ceased, after removal of about 26,000 acre-feet of water from the Gaspur zone in 9 months, or slightly more than was pumped concurrently from this same zone by all water wells from Terminal Island to Whittier

Narrows (p. 34). The hydrograph for well 35M1 (pl. 3) indicates recovery of water level until about mid-May 1942, when dewatering operations at the base were resumed for construction of two cruiser docks; this second dewatering continued into February 1943, and then stopped. At that time the water level in well 35M1 finally recovered about to sea level.

## CHANGES IN THE DEPOSITS OF PLEISTOCENE AGE

### GENERAL CHARACTER OF THE DEPOSITS

Because in Los Angeles County the major water-yielding zones in deposits of Pleistocene age are within the San Pedro formation, the present discussion will be concerned almost exclusively with fluctuations of water level in wells tapping some part of that formation. As described in the report on geologic features, (Poland, Piper, and others, 1956, p. 78–84) well logs and cuttings disclose the physical character of the San Pedro formation about as follows:

1. During most of San Pedro time continental alluvial-fan deposits were dominant within the inland half of the Downey plain and there developed a series of trunk aquifers radiating from the apexes of the fans, which were near the inland narrows.
2. Immediately inland from the shoreline of San Pedro time—that is, from Lynwood and Compton southeast past Bellflower to Los Alamitos and Stanton—fine-grained lagoonal deposits were dominant. These were transected by relatively few of the gravel-filled tongues or "spokes" radiating coastward from the apexes of the alluvial fans; thus, the over-all transmissibility of these lagoonal deposits is substantially less than that of the continental deposits farther inland.
3. Southwestward beyond this lagoonal fringe, a littoral and shallow-marine environment produced the Silverado water-bearing zone with its deposits of highly permeable sand and gravel alined about parallel to the Newport–Inglewood structural zone and normal to the radial gravel "spokes" of the inland alluvial fans, somewhat as the rim of a wheel is fitted to its spokes.

### DECLINE IN HEAD PRIOR TO 1904

With respect to initial pressure level in the San Pedro formation and the decline that developed into 1904, details available for the Bouton group of wells north of Signal Hill have been summarized earlier (p. 75–76). From the investigation in 1903–4 by Mendenhall (1905b) the data furnish a basis for summarizing additional pertinent facts as follows:

Initially, the pressure level in the San Pedro formation was sufficient to produce flowing wells from about Washington Boulevard on the Rio Hondo and from Whittier Boulevard on the San Gabriel River, southward about 12 miles to the Newport–Inglewood fault zone in the Dominguez Gap. The extent of this area of initial artesian flow as shown by Mendenhall (1905b, pl. 4) has been indicated on plate 6. As of 1903–4, the general pressure level within the San Pedro formation had been drawn down below land surface within about all the area north of Imperial Highway; thus the reach of flowing wells was only about 6 miles inland from the Newport–Inglewood zone.

For the greater part of the Dominguez Gap, coastward from the Newport–Inglewood structural zone, no data are available concerning initial pressure head but so far as known, as of 1903 only one well had been drilled sufficiently deep to tap the Silverado water-bearing zone of the San Pedro formation. This well, No. 4/13–26P3 (Mendenhall well 885, Downey quadrangle), was drilled to a reported depth of 784 feet although the log is available only to 633 feet. Its casing was never perforated but the well flowed slightly over the top of casing in 1903. Apparently this well is about at the east edge of the Silverado zone, because reportedly it tapped clay in the depth range from 350 to 770 feet below sea level whereas the Silverado zone occurs at this depth only half a mile to the west and to the south. In any case, it bottomed in deposits believed to be in hydraulic continuity with the Silverado zone to the west, and thus it indicates that the pressure level of water in the Silverado zone at that date was somewhat above land surface. This inference is substantiated by data from a well (Mendenhall No. 879, Downey quadrangle) at the very west edge of the Dominguez Gap, about 500 feet west of well 4/13–15N1. Well 879 was completed in 1900 at a depth of 459 feet and tapped about the top 10 feet of the Silverado zone. In July 1903, it was flowing "½-inch over the top" of the 2-inch casing, with a water temperature of 80°F. Thus, the records for these two wells indicate that throughout the Dominguez Gap in 1903, the pressure level of water in the Silverado zone was at or above land surface. As of 1903 essentially no water had been drawn from it in or near the Dominguez Gap, therefore, it is believed that here the initial ground-water head of the Silverado zone had changed little, except as it may have been modified by the decline of head in this same water-bearing zone northeast of (inland from) the Newport–Inglewood fault zone.

### DECLINE IN HEAD FROM 1904 INTO 1926

With respect to change in water level from 1904 into 1926 for wells tapping the San Pedro formation, the record for the Bouton group of wells north of Signal Hill has been presented (fig. 3 and p. 75). Additional information is available for well 4/12–26M1, 2.5 miles east of Signal Hill and 0.5 mile west of Palos Verde

Avenue, at Stearns Street (extended). The casing of this well is perforated from 667 to 777 feet below land surface, in the Silverado water-bearing zone. According to Fred H. Bixby (oral communication, Feb. 26, 1941), when drilled in January 1903 the well flowed 515 inches (4,635 gpm) at land surface and its artesian head was sufficient to cause flow over the top of a pipe extended 100 feet above land surface (118 feet above sea level). When visited by A. C. Hansen on August 4, 1903,[13] the well was capped and its shut-in pressure was 23.5 pounds per square inch at 7 feet above land surface; its artesian head then was sufficient to raise water 61 feet above land surface. Hansen measured an artesian flow of 6.13 cfs (2,750 gpm). From 1903 through 1923 no measurements are known for this well, but on March 8, 1924, a measurement by J. B. Lippincott showed pressure head about 16 feet above land surface. Thus, since January 1903, the water level had declined about 84 feet; it is not recorded how much of this decline of head in the Silverado zone may have occurred by 1917—that is, within the period of generally stable ground-water heads throughout the Long Beach–Santa Ana area, and particularly in the Gaspur water-bearing zone which overlies the zone tapped by the well here discussed. (See fig. 3; also p. 83.)

Records are available for the decrease in area of flowing wells within the Downey quadrangle through 1923. Specifically, this area initially was 150 square miles and was about 105 square miles in 1904—a decrease of 30 percent. In December 1923 Lippincott[14] measured the depth to water or the pressure head in wells within the Downey quadrangle. From these measurements he determined the area of flowing wells as 82 square miles—in the 19 years since 1904 the area had decreased an additional 15 percent of its initial extent. Thus, it is concluded that the decline in pressure head at well 4/12–26M1, described in the preceeding paragraph, is greater than the average for the eastern part of Los Angeles County.

From the record for the Bouton wells, and from data cited previously on fluctuations of head in the Gaspur water-bearing zone from 1904 to 1917 and from 1917 to 1926, it is concluded that in wells tapping the San Pedro formation the water levels of 1917 were about equal to those of 1904. The 84-foot decline of head in well 4/12–26M1 presumably occurred largely or wholly in the 9 years from 1917 to 1926, whereas in well 4/12–8P1 (Bouton No. 1) the concurrent decline was about 45 feet.

---

[13] Field notes taken during Mendenhall well canvass of 1903–4, on file at office of Geological Survey, Long Beach, Calif.

[14] Lippincott, J. B., Report on the conditions of the water table in the coastal plain: Private report to city of Long Beach, April 1924.

### DECLINE AND LOCAL PARTIAL RECOVERY FROM 1926 THROUGH 1944

On plate 3 four of the hydrographs have been plotted to indicate regional trends in water level within the San Pedro formation from 1926 through 1944. Two hydrographs are for wells in the inland area of alluvial-fan deposits: (1) well 2/12–16F2, about midway between the Rio Hondo and the Los Angeles River and about 5 miles north from their junction; and (2) well 3/12–8F1, near the junction of the same two rivers, but about midway between the intake area and the Newport–Inglewood uplift and about at the inland edge of the lagoonal facies of the San Pedro formation. To avoid confusion with other hydrographs on plate 3, the measurements of water-level at this well have been plotted as disconnected points. The other two hydrographs are for wells tapping the Silverado water-bearing zone: (1) well 4/13–12H1, at the northwest edge of the Signal Hill uplift and about 1 mile inland or northeast from Cherry-Hill fault of the Newport–Inglewood system, which here forms the southwest boundary of the main coastal basin (pl. 6); and (2) well 4/13–23G2, about centrally located in the Dominguez Gap and 1 mile coastward or southwest from the Cherry-Hill fault. The record for well 23G2 has been supplemented by the antecedent record for well 4/13–21H3, located 1.7 miles to the west and likewise tapping the Silverado zone.

These four wells whose hydrographs have been selected to show regional trends in water level all tap confined aquifers; the hydrograph for each shows fluctuation in the pressure level.

Two additional hydrographs for wells tapping the San Pedro formation have been plotted on plate 3—for wells 2/13–22D4 and 27B11, west of the Los Angeles River in the Huntington Park area where several zones with disparate levels are found. Because they present a local condition they will be discussed elsewhere (p. 92).

*Pleistocene deposits of inland area.*—Well 2/12–16F2 is 400 feet deep and taps about half the thickness of the Pleistocene water-bearing deposits there present. Presumably the deposits tapped are in the central part of the San Pedro formation. The hydrograph for this well shows a decline and recovery of the pressure level similar to the decline and recovery in the Gaspur water-bearing zone at well 2/12–35C1, about 3 miles southeast, except that the recovery since 1936 has been about 15 feet at well 16F2 as compared with 34 feet at well 35C1. As shown on plates 6 and 7, the Pleistocene water-bearing zones tapped by well 16F2 are being replenished by water moving generally westward from the recharge area below Whittier Narrows. However, the recovery level at this well is controlled not only by the quantity of water that can move westward from the recharge area but also by the amount that is being withdrawn from the several large well fields near Huntington Park to the west and in eastern Los Angeles to the northwest. Because that withdrawal (for domestic and industrial uses) has increased substantially since 1937, the pressure level has not risen near Huntington Park and in well 16F2 has risen only about 50 percent as much as in wells tapping the Gaspur zone within the recharge area.

Situated about centrally between Whittier Narrows and Dominguez Gap and 1 mile southeast of the junction of the Los Angeles River and Rio Hondo at the County Farm, well 3/12–8F1 is the deepest well on the coastal plain, although not the well of deepest casing perforations. Its casing is perforated at intervals from 578 to 1,492 feet below land surface, in deposits of Pleistocene age and probably exclusively within the San Pedro formation. The water supply for the County Farm, about 550 acre-feet a year, is drawn largely from this well. From completion of the well in 1931 to 1941, the water level was measured about monthly by the Los Angeles Department of Water and Power; these measurements give the levels plotted on plate 3 as disconnected points. If these are compared with the hydrograph for well 8L3, which taps the Gaspur water-bearing zone about 600 feet to the south, it is noted that the fluctuations of pressure level in the two wells have been almost identical. Measurements of depth to water were not made in well 8F1 from 1941 through 1944, but measurements by the Geological Survey in 1945 showed that the pressure levels in the two wells were still almost identical. It is concluded that for 8 miles or more downstream from Whittier Narrows and about 4 miles downstream from the recharge area, since 1936 the pressure head in some of the deeper and confined aquifers of Pleistocene age has recovered as rapidly as that in the overlying Gaspur zone. In other words, the increased replenishment of the past 8 years has been effectively transmitted to certain deeper aquifers of Pleistocene age across at least half the confined reach between the recharge area and the Newport–Inglewood structural zone. However, evidence not here presented shows that in well 2/12–33B2, which is less than a mile coastward from the recharge area and which taps a water-bearing zone in Pleistocene deposits from 349 to 421 feet below land surface, the pressure level currently is about 10 to 20 feet below that in adjacent well 33B3 which taps the overlying Gaspur zone—in other words, the recovery of head in the Pleistocene there has lagged substantially. Such lagging recovery at certain places within the aquifers of Pleistocene age is expected owing to the manner in which those aquifers were deposited—the intricate details of hydraulic continuity between the several aquifers in this inland part of the area never have been traced out, and are beyond the scope of the investigation here reported. However, no program for increasing recharge to the coastal segments of the aquifers of Pleistocene age—especially the Silverado water-bearing zone and the basal part of the San Pedro formation northeast of Signal Hill—can hope to be fully effective until the pattern of hydraulic continuity has been unraveled to the fullest extent commensurate with the economic benefits sought.

*Silverado water-bearing zone.*—The hydrographs for wells 4/13–12H1 and 4/13–23G2 show conditions in the Silverado water-bearing zone a mile on either side of the Cherry-Hill fault of the Newport–Inglewood system. In well 12H1, on the inland side of the fault, the water level remained surprisingly stable throughout the thirties, with the high level of each year about 16 to 19 feet above sea level. No measurements were made from 1941 through 1944 but the high level of 1945 was 18 feet above sea level. Thus, although this well is only 1.5 miles west of the Bouton well field (pl. 3, hydrograph 4/12–8P1) and about 2 miles northwest from the Development well field of the city of Long Beach, both of which draw chiefly from the Silverado zone, its average water level has remained about 14 feet above sea level. During this same period of heavy draft from the Development well field, in well 4/12–8P1 at the Bouton well field the water level has declined to about 25 feet below sea level on the average (fig. 3.) These features of water-level altitudes suggest strongly that some lithologic or structural barrier imposes an hydraulic discontinuity in the Silverado zone between well 4/13–12H1 and the Bouton and Development well fields to the east.

In sharp contrast to the changes of water level just described, the composite hydrograph for wells 4/13–34G2 and 21H3 on the coast side of the Cherry-Hill fault shows that there the water level of the Silverado zone declined about 10 feet from 1926 into 1933, fluctuated but gently recovered to about 40 feet below sea level between 1933 and 1939, declined gently into 1942, and then fell rapidly in the war period since mid-1942. As of the end of 1944 the water level was 60 feet below sea level and nearly 80 feet lower than at well 12H1, only 2 miles to the north but across the Cherry-Hill fault. As discussed in a report by Poland, Garrett, and Sinnott (1944), the so-called west basin on the coast side of the fault is greatly overdrawn, and the decline of water level here described is common to most wells that tap the Silverado zone or its westward equivalent.

These contrasts indicate an abrupt break in hydraulic gradient within the Silverado zone across the Cherry-Hill fault. Thus, the high water levels of 1932, 1936, and 1941 show hydraulic gradients of 9, 7, and 9 feet per mile, respectively, between wells

3/12–8F1 and 4/13–12H1 within the inland or main basin, whereas they show a uniform apparent gradient of 25 feet per mile across the fault—that is between wells 4/13–12H1 and 23G2. Doubtless this steep apparent gradient occurs largely as an abrupt discontinuity at the Cherry-Hill fault, which may have been as great as 35 feet before 1942 and which now may approach 60 feet.

The great disparity between the pressure level in the Silverado water-bearing zone and that in the overlying Gaspur water-bearing zone within the Dominguez Gap is shown by the hydrographs for wells 4/13–14L1 and 23G2. Although these wells are less than a mile apart, as of late 1944 the pressure level in well 23G2 was about 60 feet below that in well 14L1. As has been discussed elsewhere (Piper, Garrett, and others, 1953, p. 195–197) owing to this great disparity in pressure levels there is danger of saline water entering the Silverado zone from the grossly contaminated overlying Gaspur zone.

## CHANGES IN AREAS OF DISPARATE WATER LEVELS

### HUNTINGTON PARK AREA

In the Huntington Park area, in the vicinity of wells 2/13–22D4 and 27B11, three major and one minor water-bearing zones are tapped by wells. In downward succession from land surface, these are:

1. The westerly arm of the Gaspur water-bearing zone of Recent age, tapped by wells from 70 to 150 feet below land surface but erratic in thickness. Its extent is shown on plates 5 and 6. It is highly permeable and yields as much as 2,000 gpm to single wells, about twice as much as any underlying zone.
2. A zone which spans several layers of sand or gravel in the Pleistocene deposits, generally ranging from 200 to 450 feet below land surface but at shallower depth where the westerly arm of the Gaspur zone is not present. This minor water-bearing zone is cross connected with the overlying Gaspur arm by many wells which are from 350 to 500 feet deep and in which the casings have been perforated in both zones—for example, at least four such wells occur in the 40-acre tract 2/13–27B.
3. A major zone in the upper part of the San Pedro formation and about 500 to 1,000 feet below land surface, spanning several thin layers of gravel or of sand and gravel, interbedded with silt and clay. This zone, which will be called the "middle" zone in further reference, yields as much as 1,000 gpm to single wells.
4. A major zone in the lower part of the San Pedro formation, ranging from 1,230 to 1,600 feet below land surface. This zone also spans several layers of sand and gravel from 10 to 50 feet thick and is interbedded with silt or clay. It will be called the "lower" zone in this discussion. It yields as much as 750 gpm to single wells.

A non-water-bearing layer of silt or clay occurs rather consistently from about 1,050 to 1,230 feet below land surface and separates the middle and lower water-bearing zones. The great difference between pressure levels in the overlying and underlying water-bearing zones strongly suggests that this impermeable body is extensive. Of the three major zones the middle zone currently is the most heavily pumped but the lower zone also yields a substantial withdrawal for public supply.

So far as known to the writer, distinct water-bearing zones in the Huntington Park area were first discriminated by Alexander[15] after well 2/13-28G2 (Miramonte well 1 of the Southern California Water Co.), had been test pumped and sampled in all main aquifers as drilling progressed. The zonation has been confirmed by a score of logs for deep wells and by disparate water levels in wells tapping aquifers of dissimilar depth. On the basis of review by the writer, however, the water-bearing zones of the area have been divided into four elements rather than into three as by Alexander.

Fluctuation of water level in the middle zone is shown on plate 3 by the hydrograph for well 2/13-22D4; that in the lower zone, by the hydrograph for well 2/13-27B11. These wells are about a mile apart and 0.3 mile or less east of Alameda Street. Each is one of several active wells in two separate, heavily pumped well fields. Nevertheless, so far as known, they furnish as good a record as is available for water-level fluctuation within the two major Pleistocene water-bearing zones of this district.

In well 2/13-22D4, early in 1929 the water level was about 95 feet above sea level and about 10 feet below that in well 2/12-16F2, about 5 miles east. From 1929 to 1936 the water level declined in both wells, but more rapidly in well 22D4; this decline followed the general downward trend of water levels throughout the Long Beach-Santa Ana area at that time. However, since 1936 the water level in well 22D4—that is, in the middle zone—has not followed the general recovery of pressure head elsewhere but has remained low; as of 1944 it was only about 55 feet above sea level, and almost 40 feet below that in well 16F2.

In well 2/13-27B11, the water level was about 60 feet above sea level in 1930-31, declined slowly into 1934, dropped about 30 feet into 1936, was about constant and nearly 30 feet above sea level into 1942, and declined another 10 feet in the next 3 years. This continued loss of head in the lower water-bearing zone also is contrary to the general recovery of pressure head elsewhere, even more so than the stable low head in the middle water-bearing zone. The withdrawal from this zone has been increased substantially since 1936 by the construction of several wells ranging from 1,300 to 1,600 feet in depth, especially those completed by

---

[15] Alexander, L. J., Character, quality, and treatment of well waters on the Los Angeles Coastal Plain: Unpublished report presented before the Am. Soc. of Civil Engineers, July 1941.

the city of Huntington Park and by the Southern California Water Co. Thus, as of 1944, the pressure level in the lower zone locally was only about 20 feet above sea level and about 30 to 35 feet below that in the middle zone. Wells whose casings are perforated in both zones currently act as conductors of water from the middle zone to the lower zone except when they are being pumped. Such a "recharging" well is No. 2/13–23D5, city of Huntington Park well 11, whose casing is perforated in 12 water-bearing layers between 480 and 1,534 feet below land surface. Recharging wells are functioning similarly in the well fields of the city of Long Beach, about 15 miles to the southeast (pp. 99–101).

In the upper zone of Recent age—the westerly arm of the Gaspur water-bearing zone—the altitude of water level as revealed by records for well 2/13–28H2 (not plotted on plate 3) was about 78 feet above sea level in 1932 and about 67 feet in 1944. Although this upper aquifer once was the main source of water in that area (Mendenhall, 1905b, pl. 4; 1905c, pl. 5) and will yield as much as 2,000 gpm to single wells, it no longer is the main source because its water has deteriorated greatly in the past 15 years, principally by an increase in hardness. For example, in well 2/13–28H2, hardness (as $CaCO_3$) increased from about 230 ppm in 1932 to about 500 ppm in the early forties. Because the water level in this upper zone now (1945) is from 10 to 40 feet above that in the middle zone and about 50 feet above that in the lower zone, any well perforated jointly in the upper zone and in either of the two major underlying zones will serve as a recharging well and will conduct hard water from shallow depth into the water of good quality below. Blakely (1945, p. 111) reports that, to be assured of water uncontaminated by industrial wastes dumped into sewer wells, food processing plants in the industrial city of Vernon (immediately north of Huntington Park) now must install a "contamination string" of casing to shut off all water-bearing strata above a depth of 600 feet.

To protect and conserve the very valuable ground-water supply in the lower two zones near Huntington Park, it is suggested that: (1) the area of deteriorated water in the shallow zone be determined and, at least within that area, any wells be repaired that may feed deteriorated water into the underlying Pleistocene water-bearing zones; (2) the source of the deterioration be determined, and eliminated if feasible; and (3) the rate at which the deteriorated water moves coastward be appraised. Because the deteriorated water is moving southward through the westerly arm of the Gaspur zone and eventually will reach the junction with the main Gaspur zone near Compton, all deeper wells in its downstream path should be repaired as necessary to prevent contamination of the Pleistocene zones beneath.

### AREA NORTHEAST OF SIGNAL HILL

*General relations.*—Two major and one minor water-bearing zones are tapped by wells in an area northeast of Signal Hill which includes some 25 square miles and which is bounded roughly on the east by the San Gabriel River, on the west by the Los Angeles River, on the southwest by the Signal Hill uplift, and on the northeast by a line about through Compton and Los Alamitos. In downward succession from land surface the three water-bearing zones are:

1. A minor so-called zone in the unnamed upper Pleistocene deposits and in the uppermost part of the San Pedro formation. This zone includes many inextensive and irregular lenses or tongues of sand and gravel interbedded with silt and clay, ranging from a few feet to as much as 50 feet in thickness. The over-all thickness of the zone is from 150 to 300 feet at the Alamitos, Citizens, and Development well fields of the city of Long Beach but locally is as much as 500 feet at the northeast edge of the area. Few wells reach more than one or two water-bearing beds in the zone, but the most productive wells withdraw several hundred acre-feet a year from it (p. 39).
2. The major zone of the area—specifically, the Silverado water-bearing zone, which has been described in some detail in the report on geologic features (Poland, Piper, and others, 1956, p. 70, 80–83, pls. 4, *C–C'*, and 8) and on page 40–44. On the flank of the Signal Hill uplift its top ranges from 100 to 300 feet below land surface and its thickness ranges from 400 to 600 feet; about 2 or 3 miles to the northeast its top ranges from 300 to 600 feet below land surface and its thickness ranges from 300 to 700 feet.
3. A lower major zone in the basal part of the San Pedro formation. The top of this zone is from 700 to 900 feet below land surface at the Citizens, Alamitos, and Development well fields of the city of Long Beach; it is as much as 1,360 feet below land surface 3 miles to the northeast, near Carson Street and Palo Verde Avenue, at well 4/12–14D1 (Commission well 1). As discussed on page 96 and in tables 12, 13, and 14, it is known to be tapped by only 15 wells. However, it supplies nearly half the current (1945) yearly withdrawal of ground water by the city of Long Beach.

The local hydrologic relations within the Silverado water-bearing zone and the water-bearing zone in the basal part of the San Pedro formation are of interest because:

1. A marked disparity in water levels of the two has occurred during the period of use; hence, water-level contour maps and hydrographs must be prepared and interpreted with this understanding.
2. As discussed in the report on chemical character (Piper, Garrett, and others, 1953, p. 45–49), this disparity in water levels at times has induced downward migration of water from the Silverado zone into the basal zone in substantial volume, and has changed the chemical quality of water yielded by the basal zone, at least locally.
3. This downward migration of water exemplifies a method for water conservation and for artificial replenishment of water-bearing zones with subnormal pressure—a method which has been operative for many years in many

well fields of the Long Beach–Santa Ana area, but fortuitously rather than by plan.

4. The Alamitos and Citizens well fields of the city of Long Beach are less than a mile inland from the Newport–Inglewood structural zone—that is, from the coastal "barrier" of this investigation. These two fields have produced many thousands of acre-feet of water since their initial wells were drilled in 1901 and 1903, respectively. Since about 1927, the "static" pressure levels in the two major water-bearing zones of both fields have been below sea level most of the time, and the pumping levels in wells commonly have ranged from 20 to 80 feet below sea level. Nowhere else along the inland side of the barrier have either static or pumping levels been so low, nor has the drop in head inland across the barrier been so great. Thus, provided the necessary hydraulic continuity exists, salt water that is native in the Pleistocene deposits on the coast side of the barrier is likely to be drawn into the wells of these two fields through their water-bearing zones.

Table 23 shows the dates of completion for the 15 wells tapping the basal part of the San Pedro formation. The first well 4/12–20D1 (Development well 1) was drilled in 1904. As of 1923 only three additional wells had tapped this zone and withdrawal had been small. The first well with the casing perforated in both the Silverado zone and basal zone of the San Pedro formation, was well 4/12–28H10 (Alamitos well 7), drilled in 1920. In 1923–24, seven additional wells were completed to tap the basal zone. Of these seven, well 4/13–12K1 never has been used; the other six included two wells each in the Development, Citizens, and Alamitos fields of the city of Long Beach. In four of these wells the casings were perforated in both water-bearing zones. In 1932–34 three additional wells were drilled by the city of Long Beach to tap the basal part of the San Pedro formation—Nos. 4/12–14D1 (Commission well 1), 4/12–14P1 (Wilson Ranch well 1), and 4/12–6K1 (North Long Beach well 4). Finally in 1941 the Bixby Land Co. drilled irrigation well 4/12–22J1 to tap the basal zone.

As table 23 shows, only five wells are known to tap both the Silverado water-bearing zone and the basal part of the San Pedro formation. All are within the Development, Citizens, and Alamitos well fields of the city of Long Beach. Their locations and relation to other wells tapping the basal part of the San Pedro formation in these same well fields are shown by Piper, Garrett, and others (1953, fig. 5).

*Withdrawals from the basal zone.*—Withdrawal from the basal zone was light prior to 1923, but had greatly increased by 1924 with the completion of six additional wells. Table 24 indicates the approximate yearly withdrawal from the basal zone by the city of Long Beach from 1925 through 1944; values for the antecedent years are not available. It will be noted that withdrawal increased sharply in 1935 following completion of the three wells 4/12–6K1, 14D1, and 14P1. Because several of the producing

TABLE 23.—*Wells tapping basal part of San Pedro formation northeast of Signal Hill, arranged in order of date of completion*

| Well | Year completed | Water-yielding zone tapped [1] | Remarks |
|---|---|---|---|
| 4/12-20D1 | 1904 | Pb | Discontinued in October 1927; abandoned and filled prior to 1934. |
| 8L2 | 1913 | Pb | Never pumped much; discontinued about 1925. |
| 21L1 | 1913 | Pb | Discontinued in March 1932. |
| 28H10 | 1920 | Ps, Pb | Discontinued in April 1923. |
| 21M2 | 1923 | Pb | |
| 21M4 | 1923 | Ps, Pb | Only small part of withdrawal from Pb. |
| 28H1 | 1923 | Pb | |
| 28H6 | 1923 | Ps, Pb | |
| 17Q1 | 1924 | Ps, Pb | Only small part of withdrawal from Pb. |
| 20G1 | 1924 | Ps, Pb | Not pumped since 1935 except in 1939 and 1940. |
| 4/13-12K1 | 1924 | Pb | Converted oil well, never used for water supply; water-level recorder in operation. |
| 4/12-14D1 | 1932 | Pb | |
| 14P1 | 1932 | Pb | |
| 6K1 | 1934 | Pb | |
| 22J1 | 1941 | Pb | |

[1] Ps, Silverado water-bearing zone; Pb, water-bearing zone in basal Pleistocene deposits.

TABLE 24.—*Approximate yearly withdrawal, in acre-feet, from the basal water-bearing zone of the San Pedro formation by the city of Long Beach, also total withdrawal from all city wells, 1925–44*

| Withdrawal | | | Withdrawal | | |
|---|---|---|---|---|---|
| Year | Basal zone [1] | All wells | Year | Basal zone [1] | All wells |
| 1925 | 5, 178 | 14, 596 | 1935 | 7, 272 | 15, 369 |
| 1926 | 6, 033 | 15, 838 | 1936 | 7, 428 | 17, 115 |
| 1927 | 5, 957 | 16, 943 | 1937 | 7, 573 | 16, 558 |
| 1928 | 6, 685 | 21, 549 | 1938 | 8, 558 | 17, 323 |
| 1929 | 7, 049 | 22, 170 | 1939 | 8, 415 | 17, 939 |
| 1930 | 5, 346 | 18, 170 | 1940 | 8, 987 | 17, 700 |
| 1931 | 4, 667 | 17, 152 | 1941 | 9, 139 | 18, 685 |
| 1932 | 3, 627 | 16, 022 | 1942 | 10, 312 | 21, 580 |
| 1933 | 5, 329 | 15, 810 | 1943 | 10, 848 | 21, 733 |
| 1934 | 5, 280 | 14, 949 | 1944 | 10, 446 | 22, 317 |

[1] Aggregate of withdrawals from wells 4/12-6K1, 14D1, 14P1, 20D1, 21L1, 21M2, 28H1, and 28H6; and half of that from 4/12—20G1.

wells also tap the Silverado zone, their withdrawal from the basal part of the San Pedro formation has been approximated by proration.

*Diverse fluctuations of head in the Silverado and basal water-bearing zones.*—The hydrographs of plate 9 contrast the fluctuations of water level in three representative wells tapping the Silverado water-bearing zone or its stratigraphic equivalent, with those in three wells tapping the basal part of the San Pedro formation in the Citizens, Alamitos, and Commission well fields of the city of Long Beach. Table 25 gives pertinent details for these six wells. The several hydrographs all show perennial drawdown because the public-supply wells of the city of Long Beach commonly are operated in rotation—each active well is pumped continuously for one to several months and then may stand idle through a like interval. While a well is being pumped continuously, the pump is shut down only once a month for 10 minutes to one-half hour to obtain a measurement of water level; levels so measured involve drawdown residual from the antecedent pumping of the particular well. Even if a well is idle for days or weeks prior to the measurement, its water level is drawn down by pumping of other wells. With the exception of observation well 4/12–28H6, all wells for which hydrographs are plotted on plate 9 are pumped. Well 4/12–14D1 has been pumped nearly continuously since its completion in 1932.

With respect to fluctuations of water level in the Silverado water-bearing zone and in the basal part of the San Pedro formation at the Citizens and Alamitos well fields, plate 9 shows that:

1. At both fields, in the winter of 1924 the pressure level in the basal zone was above land surface but the pressure level in the Silverado zone was from 5 to 15 feet below land surface.
2. In the 8 years from 1924 through 1931, the pressure level in both zones declined about 50 feet at a relatively uniform rate, about 6 feet per year, whereas the level in the Silverado zone remained from 5 to 15 feet the lower.
3. In 1932 and 1933, the pressure level of the basal zone recovered about 30 feet and that of the Silverado zone recovered about 40 feet, so that by mid-1934 the two were about equal. This recovery developed in response to completion of nine wells at the Commission, Wilson, and Wise well fields in 1931–32 and a corresponding relief of pumping draft at the older fields. As of 1934–35, the nine new wells were yielding 66 percent of the over-all municipal draft.
4. From 1934 through 1936, at both fields the pressure level of the basal zone commonly was a few feet below that of the Silverado zone, although both levels receded about 20 feet.
5. Beginning in 1937 and continuing through 1944, in the Citizens field the levels in both zones have coincided very nearly, but have receded a few feet. In the Alamitos field, however, the pressure level of the Silverado zone has neither declined nor recovered appreciably but that of the basal zone has declined about 20 feet. Thus, at both the fields the water levels have not followed the general recovery of head that took place widely over the Long Beach–Santa Ana area at this time.

With respect to fluctuations of water level at the Commission well field:

1. As shown by the hydrograph for well 4/12–13F1 (Commission well 6), the pressure level of the Silverado zone was about the same in 1932 and in 1944, although it declined into 1937 and then recovered nearly 20 feet from 1937 into 1943. Thus, in this zone, the trend of pressure levels followed the regional decline and recovery.

2. As shown by the hydrograph for well 4/12-14D1 (Commission well 1), the pressure level of the basal zone declined about 30 feet from 1932 into 1936 and has been virtually stable from 1936 into 1944. Thus, it has followed the trend of the Citizens and Alamitos fields, but not that of the region as a whole.

TABLE 25.—*Wells for which hydrographs are plotted on plate 9*

[All water-level records supplied by city of Long Beach]

| Well | Local designation | Depth (feet) | Water-yielding zone or zones | | Water levels June 30, 1944 [2] (feet above or below (—) sea level) | |
|---|---|---|---|---|---|---|
| | | | Feet below land surface | Stratigraphic correlation [1] | Static | Pumping |
| **Commission well field** | | | | | | |
| 4/12-13F1 | Well 6 | 986 | 490-914 | Ps [3] | 16 | ---------- |
| 14D1 | 1 | 1,668 | 1,361-1,655 | Pb | —26.9 | —83.9 |
| **Citizens well field** | | | | | | |
| 4/12-21M2 | Well 7 | 1,105 | 725- 962 | Pb | —31.3 | —44.3 |
| 21M5 | 5 | 695 | 208- 610 | Ps | —35.4 | —67.4 |
| **Alamitos well field** | | | | | | |
| 4/12-28H1 | Well 9 | 1,184 | 756-1,148 | Pb | —49.6 | —86.6 |
| 28H7 | 11 | 500 | 170- 494 | Ps | —24.1 | ---------- |
| 28H8 | 2 | 273 | (?) | Uppermost part of San Pedro formation | | |

[1] Ps, Silverado water-bearing zone; Pb, water-bearing zone in basal Pleistocene deposits.
[2] After City of Long Beach, History and annual report, Water Dept., 1943-44: 1944, table 2.
[3] Stratigraphic equivalent of the Silverado water-bearing zone.

*Circulation between the two zones.*—Conclusions regarding circulation between the two major water-bearing zones in the area of disparate levels northeast of Signal Hill should be tempered by the following considerations:

1. Unless the two zones have physical and hydraulic continuity locally on the northeast or inland flank of the Signal Hill uplift, circulation of water must occur chiefly through the five wells whose casings are perforated in both zones (see table 23). Two of these wells are in the Development field (Nos. 4/12-17Q1 and 20G1), one in the Citizens field (No. 4/12-21M4), and two in the Alamitos field (No. 4/12-28H6 and 28H10).

2. Whenever the two zones are under different pressures water will pass to the zone of lower pressure through the casings of any of these five potential "recharge" wells, provided the wells are not being pumped. As stated previously, the city wells are pumped in rotation, so that at the five wells the pressures within the two water-bearing zones may change greatly from month to month.

3. At the potential "recharge" wells the differential head between the two zones is greatest whenever the zone with the lower static pressure is under heavy draft but the zone with the greater pressure is under no local draft. With the draft wholly from the zone with the higher static pressure, the differential head might approach zero or be reversed in direction. However, quantitative evaluation of the differential is not feasible from data now avail-

able; for such evaluation it would be necessary to (1) construct two paired observation wells close to each "recharge" well, one observation well tapping each water-bearing zone; (2) obtain records of water levels in the two observation wells; and (3) by use of a deep-well current meter, establish a rating curve for circulation through the casing of the recharge well (Livingston and Lynch, 1937). Given such data, reasonably accurate values for overall water-exchange between zones could be derived.

4. For periods when the static levels of the two zones are about coincident in nearby wells (as shown on pl. 9 by the hydrographs for wells 4/12-21M2 and 21M5 from 1936 through 1944), only the evidence of chemical data (Piper, Garrett, and others, 1953, p. 45-49) furnishes a clue for inferring the direction and general magnitude of circulation.

Within the limitations just stated, the hydrographs of plate 9 and the chemical evidence jointly lead to the following conclusions:

1. From 1924 into 1934, circulation through all five recharge wells was upward from the basal zone into the Silverado zone, under an average differential head which seems to have been generally about 10 feet. Data on the specific capacity of wells tapping the basal zone (table 13) suggest that during the 10-year period, this upward circulation may have been as much as 500 gpm through each of the two recharge wells most extensively perforated (Nos. 4/12–20G1 and 28H6), when those two wells were not being pumped; also, that the circulation through the remaining three recharge wells may have been as much as 250 gpm each, likewise. Thus, through all five wells as much as 10,000 acre-feet of water may have circulated from the basal zone into the Silverado zone prior to 1934.

2. In the three recharge wells of the Citizens and Development well fields, since 1934 any circulation has been downward from the Silverado zone into the basal zone.

3. In the two recharge wells of the Alamitos well field, from 1934 into 1939 any circulation also was downward from the Silverado zone into the basal zone. For the period from 1939 into 1943, the hydrographs for wells 4/12-28H1 and 28H7 show that the nonpumping head in the basal zone commonly was about 20 feet below that of the overlying Silverado zone, so that substantial recharge of the basal zone would be expected; however, chemical evidence suggests that no such recharge occurred. This seeming anomaly is explained by the history of operation of the Alamitos field—specifically, (1) in this field only two wells have been pumped since 1939; (2) of these, well 28H1 taps only the basal zone but well 28H6 taps both zones; and (3) since 1939 both these wells have been pumped much more heavily than ever before, and since 1942 each has been operating more than half the time. Thus, although recharge to the basal zone doubtless has been taking place through well 28H6 when its pump was idle, evidently the quantity of recharge was much less than the total withdrawal, so that the water feeding from the Silverado zone into the basal zone through well 28H6 was withdrawn from this same well before any reached well 28H1. Because the other potential recharge well in the Alamitos field, No. 28H10, has not been pumped since 1923, the conclusions just reached would suggest that it is sanded up or for some other reason has failed to recharge the basal zone.

4. For reasons given before, the over-all recharge from the Silverado water-bearing zone to the basal zone in the 10 years from mid-1934 to mid-1944 cannot be estimated accurately. However, figures on production from the individual wells indicate that in the 10-year period the wells tapping the basal zone have withdrawn from that zone at least 10,000 acre-feet of water whose

general chemical character suggests an initial source in the overlying Silverado water-bearing zone. Further, about 8,000 acre-feet of this Silverado-zone water has been yielded by two wells perforated only in the basal zone; one of these, well 21M2, is 1,000 feet from the nearest potential recharge well. The amount of water which has passed from the Silverado zone into the basal zone in the 10-year period must be substantially greater than 10,000 acre-feet, because that Silverado-zone water would have to occupy the basal zone over a large acreage before any could reach remote wells such as 21M2. It is probable that in this period the recharge from the Silverado zone to the basal zone has been about 20,000 acre-feet. However, unless other avenues of recharge are open in addition to the five recharge wells now known, many years will elapse before water from the Silverado zone could reach wells 4/12–14P1 (Wilson well 1) and 14D1 (Commission well 1), which tap the basal zone about 2 and 2.5 miles, respectively, northeast of the recharge wells.

## CHANGES IN GROUND-WATER REGIMEN IN ORANGE COUNTY

### CHANGES IN THE TALBERT WATER-BEARING ZONE

#### DECLINE OF HEAD AND DEWATERING PRIOR TO 1930

Plate 8 shows profiles of the ground-water level at selected time intervals from the eighties into 1941, plotted from measurements in representative wells tapping the Talbert water-bearing zone. These profiles are alined along line *B-C-D* of plate 6, which is modified somewhat from line *E-E'* of plate 7 in the report on geologic features (Poland, Piper, and others, 1956). For the inland reach near Anaheim, the approximate position of the water table in the eighties has been indicated on plate 8 according to information from Mendenhall's field notes of 1903-4. Also, for the reach coastward from Bolsa Avenue, the pressure level of 1903-4 has been drawn from basic data contained in these same field notes.

At least in the 6-mile segment of the Talbert zone extending inland from well 4/10–27Q1 to well 4/9–5M2, between the eighties and 1904 the water level declined about 40 feet. In most part this decline represented a change in storage because it occurred chiefly in the intake area. Presumably it developed largely in response to discharge from several hundred flowing wells sunk to tap the confined segment of the Talbert zone. As of the eighties, the Talbert zone was saturated in the vicinity of well 4/9–7B1 near Olive; by 1904 it was about half dewatered. Also as of the eighties, the reach of flowing wells extended inland about 11 miles or about 2 miles beyond Garden Grove; by 1904 it had retreated 3.5 miles or about to Bolsa Avenue.

Coastward from Bolsa Avenue the pressure gradient of 1904 was uniformly about 7 feet per mile, and the pressure level was about 3 feet above the ocean at the coast. Clearly, considerable water then was escaping from the Talbert zone at and nearshore, and virtually all such escape occurred less than a quarter mile offshore. Therefore, the nearshore deposits between the top of the Talbert zone and the ocean bottom are continuously permeable. Such facility for escape of fresh water when its head is above sea level affords equal facility for landward advance of ocean water whenever the pressure head in the Talbert zone is drawn down below sea level.

From 1904 into 1930, the water level declined as much as 60 feet at well 4/9–7B1, near Olive; 30 feet at well 5/10–9D1, a mile south of Garden Grove; and about 14 feet at well 5/10–32C1, at Talbert Avenue within the Santa Ana Gap. However, from the long-term hydrograph for well 4/10–22L1 near Anaheim, it is concluded that the water level of the Talbert zone did not recede from 1904 to 1917 and that the decline shown by plate 8 occurred wholly in the ensuing 13 years—that is, in a period of very deficient rainfall. (See fig. 3.) In that 13-year period the average rate of decline was nearly 5 feet per year east of Anaheim, about 2.3 feet per year at Garden Grove, and 1 foot per year near the coast. As of 1930 the Talbert zone had been entirely dewatered at well 4/9–7B1 and partly dewatered to about half a mile coastward from Highway 101.

### DECLINE AND RECOVERY OF HEAD, ALSO DEWATERING AND RESATURATION FROM 1930 THROUGH 1944

Plate 4*B* includes hydrographs for four wells which tap the Talbert water-bearing zone and which span the reach from the mouth of the Santa Ana Canyon to the coast. The hydrographs show water-level fluctuations beginning in 1930 or earlier and extending through 1944. For the inland segment of the Talbert zone they cover an early record for well 4/10–26C2, to extend the record for well 26C1. Three of these wells are inland from the Newport–Inglewood fault zone and one, well 6/11–13G2, is coastward from the main fault and 0.8 mile from the ocean. (See pl. 6 for location and table 22 for other pertinent details.)

From 1930 into early 1936 heavy withdrawals and several years of low runoff and slight recharge caused the water level of the Talbert zone to fall about another 25 feet (4 feet a year) within the 6-mile segment from Anaheim Boulevard to Garden Grove Boulevard (pl. 8), 14 feet at Talbert Avenue, and 7 feet at well 6/10–7L1 near Atlanta Avenue and Bushard Street—that is, the amount of decline diminished coastward. During 1936 about 180,000 acre-feet of ground water was withdrawn in Orange County; or about 30 percent more than the average yearly withdrawal from 1932 through 1941. Under this excessive draft, during the pumping season of 1936 water level declined still another 15 to 20 feet through most of the reach of the Talbert zone. At the historic low-water level of autumn 1936 (see pls. 4*B*, 5, and 8) the hydraulic gradient was landward about 2.5 miles from the coast, or about to well 6/10–7B1 near Adams Avenue; there the water level receded temporarily to 16 feet below sea level. At that time the pressure level in the Talbert zone was below sea level inland to within a mile of Garden Grove; also, that water-bearing zone was partly dewatered from Garden Grove inland about 6 miles, and was completely dewatered beyond well 4/10–13B2. At well 4/9–7B1 the water level was 140 feet below that of the eighties, 60 feet below the base of the Talbert zone, and only 10 feet above sea level. Plate 5 shows that in Orange County as of September 1936 the water level was below sea level in nearly all the Irvine alcove, in most of the area from the coast inland to Garden Grove and Buena Park—in all, it was below sea level for about 155 square miles. Throughout half that area, levels were more than 5 feet below sea level. So far as known, however, all the area coastward from the sea-level contour of that date was within the confined-water reach and thus the excessive lowering did not represent appreciable change in storage.

The increased precipitation in the wet years following 1936 lessened the draft and increased the recharge, especially in 1938 and 1941. The effect of increased recharge is shown prominently on the hydrograph for well 4/9–7B1 (pl. 4*B*) which is only about 0.3 mile from the Santa Ana River and whose water level responds rapidly to streamflow. By 1941 (high level for the year) recharge had been sufficient to resaturate temporarily nearly half the thickness of the Talbert zone at this well. Coastward from U. S. Highway 101, the average rise in water level from 1936 to 1941 (high level for each year) was about 8 feet along profile B–C–D. Because this rise was almost exclusively within the confined reach of the Talbert zone it did not represent appreciable change in storage but it did substantially increase the ground-water head which retards ocean-water encroachment into the Santa Ana Gap. As of the spring of 1941, within the Santa Ana Gap the water level ranged from about 17 feet above sea level at the inland end to about 3 feet above sea level at the coast (pl. 6); also, wells flowed in a strip about 0.8 mile wide extending from Garfield Avenue coastward about 3 miles or to within about 0.4 mile of the shore. Subsequently, into 1944, the reach of flowing wells extended only slightly.

## CHANGES IN THE DEPOSITS OF PLEISTOCENE AGE

### DECLINE OF HEAD PRIOR TO 1930

Beyond the Talbert water-bearing zone and the "80-foot gravel" of the Bolsa Gap, in Orange County ground water is withdrawn almost exclusively from deposits of Pleistocene age. Although a substantial part is pumped from the upper Pleistocene deposits, probably a much larger quantity is taken from the underlying San Pedro formation.

In the intake area near Anaheim the initial water level in the aquifers of Pleistocene age is believed to have been about equal to that in the overlying Talbert water-bearing zone. As noted earlier (p. 75), a composite hydrograph beginning in 1907 is available for two wells of the city of Anaheim (Nos. 4/10–15B5 and 15B1) which tap aquifers of Pleistocene age beneath the Talbert zone. This hydrograph nearly coincides with that for well 4/10–22L1 (J. B. Neff well) which tapped the Talbert zone; thus free hydraulic continuity between the two zones is indicated. Therefore, the graph of water-level fluctuations in the group of wells near Anaheim (fig. 3) is representative for the Pleistocene deposits of the intake area since 1907 and is inferred to be representative since its beginning in 1894.

Beneath most of the coastal plain in Orange County, however, the water body in the Pleistocene deposits is confined and little is known concerning its initial head. Mendenhall (1905a, pls. 6, 7; 1905b, pl. 4) has shown the initial extent of the area of flowing wells (pl. 6) together with the extent as of 1903–4. Initially this area of flowing wells extended inland about 10 miles from the mouth of the Santa Ana Gap, or about to the confluence of Santiago Creek and the Santa Ana River. As of 1904, the pressure level had been drawn down below land surface in the vicinity of Garden Grove and the reach of flowing wells extended inland only about 6 miles from the ocean. In the western part of the county the area of flowing wells initially extended inland some 11 miles, from Landing Hill to and beyond Buena Park; here no recession of the area had occurred as of 1904. For the eastern part of the county, Mendenhall's field notes yielded information on the initial pressure head for one well on Newport Mesa (No. 1210, Santa Ana quadrangle; in 6/10–10A). This well was drilled in 1886 and probably was the first to tap the principal water-bearing zone of Newport Mesa. When visited in 1904 it was flowing only a trickle but its pressure surface reportedly had declined 50 feet in the 18 years since 1886. Because the land-surface altitude is about 56 feet, the initial pressure surface apparently was about 106 feet above sea level.

From 1904 to 1930, in the forebay area near Anaheim the water level in wells tapping deposits of Pleistocene age has fluctuated as in well 4/10–22L1 (fig. 3). Thus, in that area the water level was virtually stable from 1904 into 1917, and then declined about 60 feet from 1917 to 1930.

For the western part of the county, and for the deeper wells south of Lincoln Avenue, Mendenhall's field notes show that as of August 1903 the pressure heads ranged from a few feet to as much as 20 feet above land surface. No measurements are available for the ensuing two decades but in December 1923 Lippincott[16] made extensive measurements of depth to water or of pressure head within the central part of the coastal plain. From those measurements the boundary of the area of flowing wells in western Orange County was drawn by Lippincott about half a mile inland beyond Orangethorpe Avenue or about 10 miles from the coast. Thus, the inland margin of this area had retreated only 1 to 2 miles between 1904 and 1923. However, in the 5 years from 1923 to 1928 the decline in level was so great that about all wells within the coastal plain ceased to flow. Thus, in those 5 years, along the county boundary the area of artesian flow retreated about 9 miles.

Post (1928, map 5) prepared a map of Orange County showing irrigated areas as of 1888, 1904, 1912, and 1927. His map indicates that in the area south of Lincoln Avenue and west of Stanton and Westminster as of 1912 only about 2 square miles of land was irrigated, whereas by 1927 the irrigated area had increased to about 18 square miles. It is inferred that most of the increase occurred after 1918, and that a substantial part of the land was put under irrigation after 1923. The rapid lowering of water level in western Orange County from 1923 into 1928 probably was caused in large part by the increasing draft of ground water required to irrigate the land brought under irrigation in a period of deficient rainfall.

In the southeastern part of the county—specifically, in the northern part of Newport Mesa and north to Santa Ana—as of May 1904 about all wells flowed and for the deeper wells, those from 200 to 400 feet deep, the water level ranged from a few feet to as much as 24 feet above land surface. In the vicinity of Baker Street on the northern part of the mesa, the pressure level was about 12 feet above land surface. As of June 1922, the pressure level in the principal water-bearing zone here was 6.5 feet above land surface (well 6/10-3H2). Also, 2 miles to the north, about at the intersection of Talbert Avenue and Fairview Road, the pressure level was 15 feet above land surface in May 1904; and was still 8 feet above land surface in June 1922 (at well 5/10-27R3). Thus, from 1904 into 1922 the pressure level declined only a few feet. By 1928, however, all wells in southeastern Orange County had ceased to flow and in wells tapping the principal water-bearing

---

[16] Lippincott, J. B., Report on the conditions of the water table in the coastal plain: Private report to city of Long Beach, April 1924.

zone of Newport Mesa the water levels were from 10 to 30 feet below land surface.

### DECLINE AND RECOVERY OF HEAD FROM 1930 THROUGH 1944

*Western part of county.*—Plate 4*A* includes hydrographs for three wells plotted to show change in water level within the San Pedro formation in the western part of Orange County from 1930 through 1944. One of these, well 5/11–16D2, is 2.5 miles inland from the coast at Sunset Beach; the second, well 4/11–19K1, is at Los Alamitos, 5.3 miles from the coast; the third, well 3/11–36Q2, is about 1 mile east of Buena Park, about 11 miles from the coast and near the inland margin of the coastal plain (pl. 6). Records for each well have been extended back a few years by plotting earlier records for wells 5/11–16A1, 4/11–19M1, and 3/11–31R2, respectively. All tap confined water in the main coastal basin. As indicated in table 22, wells 3/10–31R2 and 4/11–19M1 are believed to tap deposits of late Pleistocene age but the other four wells probably tap the upper part of the San Pedro formation.

These hydrographs, which are believed to be representative for the deeper wells of western Orange County, all show water levels declining steadily from 1930 into 1936, concurrently with the decline of head in the Talbert water-bearing zone, previously described. Based on the high level of the year, the decline ranged from 25 feet at well 3/11–36Q2 to 10 feet at well 5/11–16D2. In the autumn of 1936 the water level in well 3/11–36Q2 was only about 3 feet above sea level and about 10 feet above the level in well 5/11–16D2. In the 8 years from 1936 through 1944 the pressure level recovered only moderately in all three wells—about 17 feet in well 3/11–36Q2, about 9 feet in well 4/11–19K1, and about 8 feet in well 5/11–16D2. In 1944, however, the water level in well 16D2 was above sea level throughout the year, for the first time since 1929.

Two of the three wells (Nos. 36Q2 and 19K1) tap the west edge of the alluvial fan built by the Santa Ana River and its tributaries during Pleistocene and Recent times; also, they are 7 and 11 miles west, respectively, from the river. The more southerly of the two, well 19K1, is about midway between and about 11 miles from the two intake areas which receive direct percolation from the Santa Ana and the San Gabriel Rivers. Thus, the fluctuations of its water level might correlate with the recharge effects of either stream. The water-level contours of plate 6 indicate that replenishment from the intake area below Whittier Narrows has substantial effect about to the Orange County boundary, but little or no effect beyond. However, in neither of the two wells did the water levels react sharply to the increased replenishment from high streamflow in 1938 and to the excessive rainfall in 1940–41.

*Newport Mesa and vicinity.*—To show fluctuations in water level from 1930 through 1944 for the two water-bearing zones of Newport Mesa, hydrographs for three wells are plotted on plate *4C*. One of the three, well 6/10–1L2, taps the deposits of late Pleistocene age which extend to about 250 feet below land surface (table 22) ; the other two wells, 6/10–3H2 and 11G2, tap the underlying principal water-bearing zone within the San Pedro formation.

As shown by the full record for well 6/10–1L2 (Mendenhall No. 1356, Santa Ana quadrangle), the water level in the upper Pleistocene deposits was initially a pressure level many feet above land surface. In May 1904 this well was flowing 9 miner's inches (80 gpm). In the spring of 1923, its pressure level was at land surface and 40 feet above sea level. Then, as indicated by the hydrograph, its level declined 15 feet from 1923 into 1926, declined another 8 or 10 feet from 1927 into 1936, remained almost constant and about 20 feet above sea level through 1940, rose about 5 feet in 1941, and subsequently has declined somewhat. For these upper Pleistocene deposits the withdrawal is light and the average yearly range of head is only about 3 feet. Because the pressure level initially was many feet above land surface and the gradient was coastward, replenishment to these deposits must be derived mainly from distant sources such as the recharge areas on the alluvial fans of the Santa Ana River and Santiago Creek. However, the rapid rise of the water level in well 1L2 in January 1932 and January 1941, following substantial rainfall in the respective preceding months, suggests that some local replenishment may occur. Also, the recent deterioration in the chemical quality of the water (Piper, Garrett, and others, 1953, p. 162–166) suggests that some recharge may be derived from overlying sources. Whatever the source of replenishment, the hydrograph for well 1L2 and the records for other wells agree in indicating that during the past 14 years—that is, from 1930 through 1944—in these upper Pleistocene deposits the replenishment has been nearly equal to withdrawal.

With respect to fluctuations of head in the principal water-bearing zone of Newport Mesa, the hydrograph for well 6/10–3H2 is representative. Although used for irrigation the well probably is not pumped heavily enough to affect seriously its utility as an index well. As discussed on page 105, at or near this well the pressure level declined only slightly from 1904 into 1922; from June 1922 to March 1930, however, it declined 36 feet. The hydrograph suggests that nearly two-thirds of the decline occurred between 1928 and 1930. From 1930 into 1933 the level rose slightly, declined about 14 feet into 1936, rose about 4 feet into 1937, was about constant into 1940, rose 6 feet in 1941, and then remained virtually constant through 1944.

Because of the deteriorated quality of the water in the upper Pleistocene deposits which overlie the principal water-bearing zone, it is pertinent to point out that in the twenties the pressure level in the two zones was about equal, but that from 1932 through 1940 the level in the principal water-bearing zone was about 20 feet below, and in the early forties was about 15 feet below the level in the upper Pleistocene deposits. Thus, any idle well whose casing is open in both zones would act as a conduit transmitting deteriorated water from the upper Pleistocene deposits downward into the principal water-bearing zone, whose native water has been of good quality. Hence, for the future protection of that zone, it is suggested that wells drilled to tap it be constructed so as to seal off the aquifers in the upper Pleistocene deposits; that wells now active be kept in good repair; and that wells to be abandoned be plugged with cement between the two water-bearing beds.

In the autumn of 1941 wells 6/10–11B1 and 11B2 were drilled into the principal water-bearing zone to supply water for the then-proposed Santa Ana Army Air Base. These wells are about 0.6 mile south of Baker Street and immediately west of Newport Boulevard. Withdrawal began in April 1942 and has been continued into 1946. In March 1943 the Air Base began taking water from wells 6/10–11G1, 11G2, and 10N1 also. The latter three wells had been utilized through 1941 for irrigation on the Golden West Ranch, but were not pumped from 1941 to March 1943. They likewise tap the principal water-bearing zone, so that all withdrawal by the Air Base has been from that zone. The monthly withdrawal through 1944 is plotted on plate 4*C*. The total withdrawal from April through December 1942 was 640 acre-feet, in 1943 was 1,588 acre-feet, and in 1944 was about 1,680 acre-feet—that is, about 3,900 acre-feet was withdrawn in 3 years. Of this amount, about 3,700 acre-feet was pumped from the four wells 11B1, 11B2, 11G1, and 11G2—all within a 10-acre area. The withdrawal for irrigation by the Golden West Ranch in the 10 years ending in 1941 has been estimated as about 500 acre-feet per year. Thus, the draft of 1942–44 was about 2,400 acre-feet greater than the antecedent draft for irrigation during a like period.

The hydrograph for one of the four closely spaced wells at the Air Base, No. 6/10–11G2, has been plotted on plate 4*C* to show the effect of the concentrated pumping on the water level at well 6/10–3H2, which is 1.1 miles to the northwest. The hydrographs for both wells show a peak level in 1942 about 16 feet above sea level. The graph for 11G2 shows immediate and continued drawdown from the pumping at the Air Base, such that by the spring of 1944 its water level was about at sea level. However, the graph for 3H2 suggests that at that well the water level was not drawn down more than a few feet by the pumping. In the spring of 1944 its level was 13 feet above sea level and, accordingly, 13 feet above the level in 11G2.

The graphic record presented demonstrates the great water-yielding capacity of the principal water-bearing zone of Newport Mesa and vicinity. As discussed on pages 53–55, this zone has a known extent of at least 16 square miles. Only because it is so extensive, exceptionally thick (521 feet at well 6/10–1E2), highly permeable, and freely recharged, could the removal of 1,600 acre-feet of water per year from one 10-acre tract have so little effect on water level in a well a mile away.

While the Air Base was operating under peak load, local agencies raised the question of whether its concentrated pumping was drawing water levels down in the Santa Ana Gap, where a satisfactory balance between fresh water and sea water is the critical control on saline encroachment. The evidence presented here, and the known geologic structure both indicate that the heavy draft from the principal water-bearing zone at the Air Base in the war years 1942–45, inclusive, had no immediate effect on the water levels in Santa Ana Gap. With respect to the long-time adjustment of water levels, the removal of about 3,800 acre-feet of ground water anywhere within the coastal plain in Orange County ultimately will draw water levels down throughout a wide area. However, the area is so extensive that the ultimate drawdown in the Santa Ana Gap probably would be no more than a few tenths of a foot. Full adjustment of the water level in the gap probably would lag for years, but might be reached in a highly critical period when water levels in the gap were at or below sea level. Therefore, in the interest of ground-water conservation in the county, it is suggested that such additional drafts on the ground-water supply be discouraged except in times of great emergency, and when no other source is available.

### GROUND-WATER DISCONTINUITY AT LOWER END OF SANTA ANA CANYON

During a substantial part of the period of declining water levels that culminated in 1936, a striking discontinuity in water levels developed in the lower part of the Santa Ana Canyon near Atwood. From the nature of this discontinuity as revealed by hydrologic data, it is inferred to be a barrier caused by faults—probably by the intersection of two (or more?) faults. Its inferred position is shown on plates 5 and 6. On plate 8 this barrier is shown between wells 4/9–5A1 and 3/9–33N3; the water-level profiles of 1936 suggest a water-surface offset of as much as 80 to 100 feet across the barrier. Other records not here plotted suggest an offset of about 60 feet in 1930. On the other hand, the profile for 1941 (high level) suggests no offset as of that date.

Thus, from the hydrologic data now available, it is tentatively concluded that a substantial barrier to movement of ground water lies athwart the mouth of the Santa Ana Canyon; also, that this barrier partly dams coastward circulation through the water-bearing beds of Pleistocene age, but offers little or no impedance to circulation in the overlying Talbert water-bearing zone (which is of Recent age).

With respect to replenishment in the intake area east of Anaheim, it would seem advisable to obtain as much factual information as possible concerning the location, extent, and physical character of this barrier. Because the barrier restrains free movement of ground water from the canyon to the intake area, water levels immediately to the west at times are drawn down to within 10 to 20 feet above sea level, as in 1936.

Maintenance of water level at a substantial altitude above sea level in the intake area would be an aid in maintaining the pressure level above sea level near the coast. Possibly recharge wells could be drilled through this barrier to feed water by gravity from the canyon (upstream) side to the intake (downstream) side—to build up the water table in the intake area, and to increase the ground-reservoir capacity available within the lower canyon. By this means it might be possible to salvage part of the flood waters of the Santa Ana River, which otherwise would escape to the ocean—that is, salvage by increased ground-water storage in Orange County. However, the feasibility of any such program would depend upon (1) the capacity of the storage basin upstream from the barrier and (2) the amount of water available for salvage. At present the Santa Ana River is so fully utilized that in a dry period the yearly waste to the ocean is very small. It is assumed commonly that the flow gaged at Santa Ana measures waste to the ocean because that gaging station is about at the lower edge of the intake area of free percolation. In the 9 water-years from 1928 through 1936, inclusive, the average river discharge at Santa Ana was 2,166 acre-feet per year. The maximum discharge was 7,850 acre-feet in 1932 and the minimum discharge was 102 acre-feet in 1929. Since that time the Prado Dam has been constructed at the upper end of the Santa Ana Canyon to regulate the flood flow. Therefore, in a future period of rainfall equal to that of 1928–36, the waste to the ocean may be even smaller. Thus, presumably only in periods of normal or above-normal rainfall might additional water be salvaged by breaching the inferred barrier at the lower end of the canyon.

# WATERTIGHTNESS OF THE NEWPORT–INGLEWOOD STRUCTURAL ZONE

## METHODS OF APPRAISAL

The effectiveness of the Newport–Inglewood structural zone as a barrier to the inland movement of salt water from the ocean is the most critical element of this cooperative investigation. In a qualitative sense, its watertightness can be appraised separately by geologic, geochemical, and hydrologic evidence. However, quantitative estimates of underflow across the barrier features must be made largely on hydrologic evidence. At places where the hydrologic evidence shows that the structural zone affords effective barriers to water movement, presumptive confirmatory evidence commonly is supplied by geologic and by geochemical data. On the other hand, at places where hydrologic evidence shows little or no restraint on water movement, geologic and geochemical data may not furnish conclusive evidence. In either case, however, quantitative estimates of underflow across the structural zone must depend not only on the basic hydrologic elements, gradient and permeability; but also on the basic geologic factors, physical character of the deposits and area of permeable saturated cross section.

The geologic and geochemical evidence relating to the barrier features of the Newport–Inglewood structural zone has been discussed elsewhere (Poland, Piper, and others, 1956, p. 119–126; Piper, Garrett, and others, 1953). The following pages introduce the hydrologic evidence pertaining to the effectiveness of the structural zone as a barrier to water movement. This effectiveness is evaluated chiefly from simultaneous water-level fluctuations in one or more wells on opposite sides of known or inferred faults along that zone. Selected data collected or assembled as a part of this investigation are presented in nine pairs or sets of hydrographs which follow; plate 6 shows the locations of the wells for which the hydrographs were plotted. Certain features of ground-water circulation which have been described earlier in this report also are critical in this evaluation; attention will be drawn to them as pertinent. The hydrologic evidence will be discussed separately for Los Angeles County on the northwest and for Orange County on the southeast.

## HYDROLOGIC EVIDENCE

### LOS ANGELES COUNTY

For Los Angeles County, figure 4 and plates 10 and 11 show hydrographs for four wells tapping deposits of Recent age along a profile about at right angles to the coast and through the Dominguez Gap; for two groups of three wells each, showing conditions within the San Pedro formation in the Dominguez Gap and across

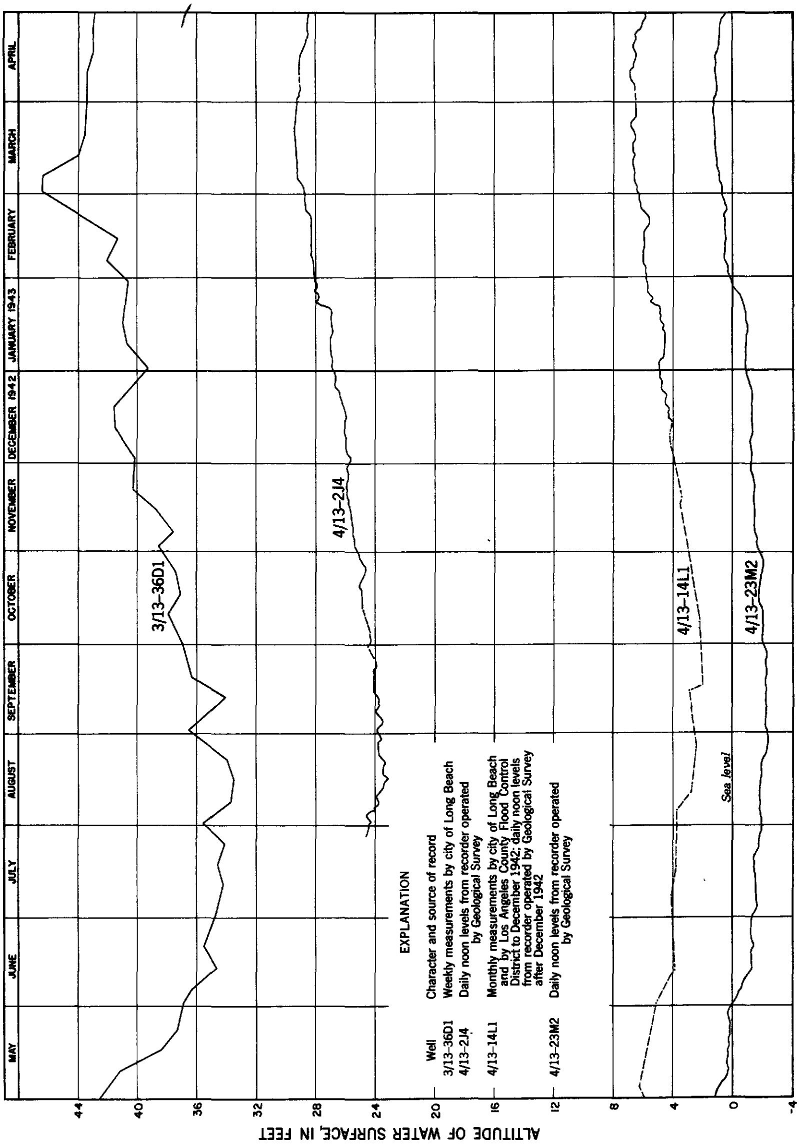

FIGURE 4.—Hydrographs for four wells in Dominguez Gap tapping the Gaspur water-bearing zone, 1942–43.

the Signal Hill uplift; and for four wells, which also tap the San Pedro formation, along a profile through the Alamitos Gap (pl. 11). Pertinent hydrologic data are given in table 26.

TABLE 26.—*Wells in Los Angeles County for which hydrographs are plotted on figure 4 and plates 11 and 12*

| Well | Depth (feet) | Water-yielding zone or zones | | Agency supplying principal record [1] |
|---|---|---|---|---|
| | | Feet below land surface | Zone or formation | |
| 3/13–36D1 | 200 | | Gaspur water-bearing zone | LB |
| 4/12–18R1 | 962 | 287– 615 | Silverado water-bearing zone | LB |
| 20C1 | 752 | 153– 602 | do | LB |
| 32G1 | 130 | | San Pedro(?) formation | LACFCD |
| 34B1 | 849 | 355– 422 | San Pedro formation | OCFCD<br>RAS |
| 4/13– 2J4 | 178. 4 | | Gaspur water-bearing zone | USGS |
| 12E1 | 336 | | Silverado water-bearing zone | LB |
| 12K1 | | 915–1, 010(?) | Basal part of San Pedro formation | LB |
| 14L1 | 114. 3 | 86– 114 | do | USGS |
| 21H3 | 800 | 430– 738 | Silverado water-bearing zone | Owner |
| 23G2 | 1, 074 | 596–1, 066 | do | LB |
| 23M2 | 115. 2 | 77– 118 | Gaspur water-bearing zone | USGS |
| 5/12– 2B1 | 255. 2<br>(547) | 460– 541 | San Pedro formation | USGS<br>RAS |
| 10A1 | 296. 6 | 124– 143(?) | do | USGS |
| 11H1 | 296. 0 | | do | USGS |
| 11L1 [2] | 810 | 320– 358 | do | USGS |

[1] For explanation of symbols see table 21.

[2] Well 5/12–11L1 is in Orange County.

### DOMINGUEZ GAP

Within the range of deposits tapped by water wells, at the crest of the structural zone the Dominguez Gap is underlain to a depth of about 130 feet below land surface by deposits of Recent age, and from 130 feet to 630 feet by deposits of Pleistocene age. (See Poland, Piper, and others, 1956, pls. 4, 7.) The deposits of Recent age include a shallow semiperched water body in relatively fine-grained deposits within the upper division, and the highly permeable Gaspur water-bearing zone in the lower division. The deposits of Pleistocene age contain the permeable and highly productive Silverado water-bearing zone.

*Semiperched water body.*—For the semiperched water body, hydrologic data presented on plate 2 indicate a uniform water-table gradient across the position of the fault inferred to occur at depth. Thus, it is concluded that this fault does not transect the upper division of the deposits of Recent age in the Dominguez Gap, and interposes no barrier to free movement in the semiperched zone.

*Gaspur water-bearing zone.*—All four hydrographs of figure 4 are from relatively shallow wells in the Dominguez Gap that tap the Gaspur water-bearing zone of Recent age. These wells are in the area of greatest inland reach of contaminated waters in the Long Beach–Santa Ana area (Piper, Garrett, and others, 1953, pl. 17). In order toward the coast they are: well 3/13–36D1, which is inland from the Newport–Inglewood structural zone and inland beyond the front of contaminated ground water; well 4/13–2J4, also inland from the structural zone and about at the inland edge of the area of contaminated water; and wells 4/13–14L1 and 4/13–23M2, both of which are oceanward from the structural zone and far within the area of contaminated water. The four hydrographs are similar in form; there is no marked dissimilarity to suggest a hydraulic discontinuity across the structural zone. The fluctuations of water level probably are due primarily to withdrawals from the Gaspur water-bearing zone; the yearly range is notably greatest in the inland well (36D1), probably because withdrawals are greater inland from the Dominguez Gap than in the area of contaminated water within the gap.

Other hydrologic evidence is available from plate 7, which presents water-level profiles for the Gaspur water-bearing zone from 1903 into 1941. The position of the fault inferred to be present at depth is indicated on that plate. None of these several profiles show a hydraulic discontinuity. The profile for 1903, which is considered most reliable because the water levels then were least disturbed by local withdrawals, maintains a uniform gradient across the fault and thus is considered to be decisive evidence that there is no barrier across the Gaspur water-bearing zone in Dominguez Gap. Supporting hydrologic evidence has been presented in figure 4. There is no geologic evidence that any fault of the structural zone transects the deposits of Recent age. Geochemical data have shown that the area of contamination within the Gaspur zone extends about half a mile inland beyond the inferred fault, and that no discontinuity in chemical quality has developed. Thus, both geologic and geochemical data confirm the conclusion from hydrologic data that there is no barrier in the Gaspur water-bearing zone—that throughout this artery, ground water moves in complete freedom according to the natural or artificial hydraulic gradients prevailing at the time, either landward or toward the ocean.

From the evidence presented here and elsewhere in this report several critical conclusions may be drawn, as follows:

1. During the historic low-water year of 1936 the general water level in the Gaspur water-bearing zone was such that ocean water could ultimately have moved inland about half a mile beyond Carson Street—about to the crest of the Newport-Inglewood zone, but not beyond.
2. As discussed in the report on chemical character of the water (Piper, Garrett, and others, 1953, pl. 17 and p. 182), evidence indicates that ocean-water contamination now (1945) reaches inland only about to the Pacific Coast Highway and that the inland contamination extending about 4.5 miles north from the Pacific Coast Highway, to and beyond Del Amo Street, is almost exclusively from oil-field brines and industrial wastes. Under the hydraulic gradient currently prevailing in the Gaspur zone, the inland contaminated water must be moving continuously coastward, almost as far south as Willow Street.
3. The area of contaminated waters will extend inland beyond its present front only if (1) water levels in the Gaspur zone should fall below the levels of 1936 for a long period of time or (2) a source of saline water is present at or near land surface inland from the structural zone and downward percolation develops. At times the Los Angeles River and, more continuously, Compton Creek are such sources.

*Silverado water-bearing zone.*—Hydrographs for wells 4/13–12E1 and 23G2 (pl. 10), show contrasting fluctuations in the pressure surface for the Silverado water-bearing zone beneath the Dominguez Gap and on opposite sides of the Cherry-Hill fault of the Newport–Inglewood uplift (pl. 6). Well 4/13–12E1 is 0.5 mile inland from the fault and in the main coastal basin; well 4/13–23G2 is 1 mile coastward from the fault and in the west basin. The record for well 23G2 has been supplemented by plotting the early record for well 4/13–21H3, which also taps the Silverado zone 1.7 miles to the west; for these two wells, the water-level fluctuations of the thirties were almost identical.

The hydrograph for well 4/13–12E1 is unlike that for well 23G2–21H3 in water-level stage, in amplitude of yearly fluctuation, and in general trend of water levels. In well 12E1 the water level has been about at sea level since 1931; has varied about 8 feet each year; and has recovered about 5 feet since 1938. In well 23G2–21H3, however, the water level was about 40 feet below sea level from 1929 into 1942, varied about 15 feet each year through 1938 and about 20 feet from 1939 through 1944, and declined about 25 feet from the year end of 1941 to that of 1944. For two wells which tap the same water-bearing zone and which are only 1.8 miles apart (1.5 miles measured normal to the water-level contours), these contrasts in stage and fluctuations of water level are striking.

The differential in water level between these two wells increased from 30 feet in January 1938 to 50 feet in January 1944, and to about 65 feet (estimated) at the end of December 1944. Thus the apparent hydraulic gradient across the Cherry-Hill fault steepened from 20 feet per mile to about 43 feet per mile in 7 years. However, the actual gradient is even steeper. For example, abandoned well 4/13–14Q4, which likewise taps the Silverado water-bearing zone, is 0.4 mile north of well 23G2 and about 1.3 miles from well 12E1 (1.1 miles measured normal to the water-level contours). In that abandoned well, the water level, as measured on October 31, 1935, was 47.5 feet below sea level, or almost identical with the level in well 23G2. At that same time the water level in well 12E1 was 1 foot above sea level. Thus, even then the apparent gradient between wells 12E1 and 14Q4 was about 44 feet per mile and the actual gradient across the fault must have been much steeper.

Although wells are not available to establish closely the current magnitude of the discontinuity in the pressure level of the Silverado water-bearing zone across the inferred extension of the Cherry-Hill fault in the Dominguez Gap, facts cited here and additional data incorporated in the water-level contours of plates 5 and 6 indicate conclusively that such a discontinuity does exist. As discussed on page 91, the hydraulic gradient within the San Pedro formation from the junction of the Rio Hondo and the Los Angeles River to the Dominguez Gap has been about 9 feet per mile. If this gradient is projected to the Cherry-Hill fault, the water level on the north (inland) side of the fault as of year-end 1944 would have been at sea level, whereas the level projected northeastward through wells 4/13–23G2 and 14Q4 would have been 53 feet below sea level at the south (coastal) side of the fault. The actual pressure-surface profile doubtless is modified by the heavy withdrawal from the well fields of the Dominguez Water Corp. about 1.2 miles northwest of well 14Q4. The inferred configuration of this profile for 1941 has been indicated on plate 6.

This discontinuity is a feature of long standing. Thus, information compiled in 1903–4 by Mendenhall (1905b, pl. 4) shows that the area in which the initial pressure head of the Silverado zone stood appreciably above land surface was wholly inland from the inferred extension of the Cherry-Hill fault—it reached to but not beyond that fault. In 1903, after the artesian pressure had diminished substantially, a well tapping the Silverado zone in the Dominguez Gap about 0.7 mile northeast of the Cherry-Hill fault flowed all year. This well (No. 4/13–2J1) was flowing 35 miner's inches (315 gpm) through a 12-inch casing on July 21, 1903. Doubtless the initial pressure level here was several tens of feet above land surface. Coastward from the fault, however, two wells tapping the Silverado water-bearing zone in the gap barely flowed as of 1903; there is reason to believe that the pressure surface then had not declined substantially from its stage under natural conditions (p. 87).

From the hydrologic evidence here presented, it is concluded that the Cherry-Hill fault is a substantial barrier to water movement through the Silverado water-bearing zone in the Dominguez Gap. Geologic evidence is confirmatory to the extent that substantial displacement along the Cherry-Hill fault occurred along the south side of the Signal Hill uplift, and that a northwestward extension of the fault for at least half a mile into the gap is indicated (Poland, Piper, and others, 1956, p. 98). Geochemical data neither confirm nor disprove the presence of a barrier transecting the Silverado zone. Thus, as shown elsewhere (Piper, Garrett, and others, 1953, pl. 4), the chemical quality of the water within the Silverado zone is virtually the same on either side of the Cherry-Hill fault.

The watertightness of this local barrier cannot be evaluated specifically from data now available, although the differential head across it (50 to 65 feet as of late 1944) indicates a relatively high degree of watertightness. However, watertightness has little significance regarding possible movement of salt water inland—because the water confined in the Silverado zone on the inland side of the barrier always has had the greater head (under natural conditions and to an aggravated degree under the heavy withdrawals of the thirties and early forties) such water as may have leaked through the barrier has moved coastward rather than landward. Only in the unlikely contingency of the head being the higher on the coast side, could water—either fresh or salt—move inland and cross the barrier within the Silverado water-bearing zone.

### SIGNAL HILL UPLIFT

*Silverado water-bearing zone.*—Not more than a mile inland from the three faults of the Newport–Inglewood zone which cut across the Signal Hill uplift, water is withdrawn from several wells tapping the Silverado water-bearing zone. Most of these wells supply water for the city of Long Beach, which has made periodic measurements of depth to water; in the same area water levels have been measured periodically in additional observation wells by other agencies. Of the many water-level records available, two have been plotted on plate 10—those for active well 4/12–18R1 (Development well 6, city of Long Beach), which taps the Silverado water-bearing zone, and for active well 4/12–34B1, which taps the San Pedro formation in a stratigraphic interval hydraulically connected with but beyond the extent of the Silverado water-bearing zone. Hydrographs for well 4/12–21M5 in the Citizens field and for well 4/12–28H7 in the Alamitos field have been shown on plate 9; both these wells tap the Silverado zone.

On the coastal side of the uplift, periodic measurements have been made in only one well, 4/12–32G1, which is at the north edge of the Long Beach plain about 0.6 mile coastward from the Cherry–Hill fault (pl. 6), and which probably taps the upper part of the San Pedro formation in a stratigraphic interval about equivalent to the upper part of the Silverado water-bearing zone. As shown elsewhere (Poland, Piper, and others, 1956, pls. 5*a–a'*, 8), that water-bearing zone extends beyond the faults but probably is not present extensively beneath the Long Beach plain. Well 32G1 formerly was pumped lightly for industrial purposes but has not been used during the last decade owing to the presence of sand and the poor quality of its water.

If the hydrograph for well 4/12–32G1 is contrasted with those for wells 18R1 and 34B1 (pl. 10), or with the hydrographs for wells 21M5 and 28H7 (pl. 9), all of which are inland from the faults and tap the Silverado zone or its stratigraphic equivalent, it becomes obvious that the water body beneath the Long Beach plain is hydraulically distinct and separate from the inland water body. In well 32G1 the water level ranged from 1 foot below to 3 feet above sea level from 1930 through 1944. The low stage was in 1932 while the well was still active; the high stage developed beginning in 1937 and culminating in 1943—during a succession of wet years. On the other hand, in well 4/12–18R1 in that same period the static level ranged from 50 feet below to 12 feet above sea level and the pumping level was as much as 66 feet below sea level. For well 4/12–34B1 the range in water level has been much less and its water-level stage of the early forties was about equal to that of 1930. Evidently it is distant enough from the Alamitos, Citizens, and Development well fields of the city of Long Beach not to have been drawn down appreciably by the heavy withdrawal from those fields in the early thirties. Because it is only a mile from the Alamitos field, however, the lack of such drawdown there suggests poor hydraulic continuity, presumably associated with and explained by the tapering out of the Silverado zone between the Alamitos field and well 34B1 (Poland, Piper, and others, 1956, pl. 8). Although the hydrograph for well 34B1 is unlike those for well 18R1 or well 28H7 in range of fluctuation, and even though since 1935 its average yearly level has been within a few feet of the level for well 4/12–32G1 across the Seal Beach fault, the character of its fluctuations is wholly different from that of the latter well.

Information concerning initial hydraulic conditions beneath the Long Beach plain suggests that a gentle seaward gradient once existed. In 1903 Mendenhall canvassed 10 wells on the Long Beach plain and obtained measurements of depth to water in 9 of these; although the water levels were decidedly nonuniform and near the west edge of the plain were as much as 16 feet above sea level, the suggested coastward gradient was 3 to 5 feet to the mile across the central segment of the plain. Hence, a small quantity of water apparently was moving coastward at that time. If precipitation on the plain could furnish sufficient recharge to maintain such movement, the water level in well 4/12–32G1 should have recovered substantially more in the past decade than it has actually done. Accordingly, it is inferred that the movement of 1903 must have been caused, at least in part, by coastward leakage of ground water though the Newport–Inglewood fault system under the high pressure differential that then prevailed across those faults. For example, the record for well 4/12–26M1 has been cited (p. 87) to indicate the magnitude of the initial pressures within the Silverado zone inland from the partitioning faults. That well, which is 1.5 miles northeast of the Seal Beach fault and 2.5 miles distant from well 4/12–32G1, in 1903 tapped artesian pressure sufficient to raise its water level 100 feet above land surface or 116 feet above sea level. Also, at the extreme south margin of the main coastal basin—about 1.3 miles east of well 32G1, 0.2 mile south of Anaheim Street, and 200 feet north from the Seal Beach fault—well 1002 (Downey quadrangle) of Mendenhall was drilled in 1887 on property of the Alamitos Beach Water Co. and then reportedly flowed 5 inches over the top of its 8-inch casing. Because its altitude is about 40 feet above sea level, the initial pressure level there probably was 50 to 60 feet above the water level beneath the Long Beach plain.

Geochemical evidence indicates, however, that under the initial conditions of high pressure differential across the structural zone the quantity of water moving coastward beneath the Long Beach plain must have been small. Tests of water quality made during the Mendenhall canvass indicate that water beneath the plain initially was of poor quality, and similar in total solids content to the water in well 32G1 as of 1932. Thus, although water-level measurements of 1903 suggest that some water was moving coastward across the plain, presumably in part by leakage through the echelon faults of the Signal Hill uplift, the quantity of that water clearly had not been sufficient to displace all saline water from beneath the plain, even during the period of several thousand years spanning recent geologic history. Geologic data available from logs of wells which formerly tapped the deposits beneath the Long Beach plain indicate that the water-bearing beds are thin and of relatively low permeability. From all these data, it is concluded that the quantity of water moving coastward beneath the plain under initial conditions was not more than a few tens of acre-feet per year, at most. Of even that small amount, part doubtless was supplied by rainfall infiltrating the water-bearing beds of the San Pedro formation where they are upwarped and exposed on the coastward flank of the Signal Hill uplift, oceanward from the Cherry-Hill fault.

The present gradient of the water surface beneath the Long Beach plain cannot be determined directly because its stage can be measured only in well 32G1. That well, which is 1.5 miles from the ocean, had a water level 3 feet above sea level as of mid-1944. If the aquifer it taps has hydraulic continuity with the ocean, as seems likely, the seaward gradient now is about 2 feet per mile. This seaward gradient currently must be sustained almost exclusively by recharge from rainfall because, as shown by the hydrographs for wells 4/12–18R1, 21M5, and 28H7, water levels in the Silverado water-bearing zone on the inland side of the uplift are below sea level at the Development, Citizens, and Alamitos well fields. Only beneath Alamitos Heights has the pressure level proximate to the fault been above sea level consistently in the forties (see pl. 10 for well 34B1).

Thus, although it has been suggested that a small quantity of water once leaked coastward through the barrier features of the Signal Hill uplift to the Long Beach plain, from the hydrologic and geochemical evidence here cited, it is concluded that those features virtually prevent movement of water through the Pleistocene deposits under differential heads of as much as 50 to 60 feet such as prevailed under native conditions. During at least the past decade, a differential head of that magnitude again has existed across the uplift with the lower head on the inland side owing to drawdown by heavy withdrawals—under this artificial condition, any leakage inland must be small likewise. Indeed, under any differential head that conceivably can result from withdrawals inland from the uplift, such leakage here would be almost negligible.

Geologic knowledge soundly supports hydrologic evidence for a reasonably effective barrier to water movement along almost the full reach of the Signal Hill uplift (Poland, Piper, and others, 1956, p. 98–100, pl. 8). In fact, this is the single segment of the Newport–Inglewood structural zone within which vertical displacement is sufficiently great to impose a substantial hydraulic discontinuity in the water-bearing zones of the San Pedro formation—in this area the Silverado water-bearing zone. As has been discussed elsewhere (Poland, Piper, and others, 1956, p. 122), from Dominguez Hill to Alamitos Heights the Silverado zone spans the crest of the uplift. Beneath Alamitos Heights and southward to the San Gabriel River, however, it grades or fingers into deposits that are largely silt or clay. Of itself, that lithologic discontinuity is an effective local barrier against widespread invasion of ocean water across the uplift. Also, at land surface on and near Signal Hill, fractures and faults in the exposed segments of the San Pedro formation are filled with a dense calcareous cement (Poland, Piper, and others, 1956, p. 105). This cementation probably has been a major element in development of the barrier.

However, the fault pattern (Poland, Piper, and others, 1956, pl. 3) suggests that the continuity of the barrier may be interrupted by a gap about 1,000 feet wide between the Northeast Flank fault and the Reservoir Hill fault, directly south of the Citizens well field of the city of Long Beach, and that here an opportunity for leakage may exist. It is not known whether any water leaked coastward through this gap in the fault system under native conditions of high artesian pressures. If so, its quantity was not large. However, with the direction of potential circulation now reversed so that salt water can move landward through this gap, even in small quantity, the chemical quality of the water withdrawn from the Citizens field might deteriorate appreciably over a period of many years. Specifically, as of the early thirties the withdrawals from the Alamitos, Citizens, and Development well fields had so lowered water levels that for several years the average static water level in these fields was 30 to 40 feet below sea level (pls. 9, 10). Thus, the initial differential, with the greater hydraulic head on the inland side of the faults, had been destroyed and there had been developed a differential of nearly the same magnitude but with the greater head on the coastal side. By 1933 the water levels in these well fields recovered about to sea level and the landward hydraulic gradient disappeared, at least temporarily. However, in the early forties the withdrawal increased and the lower head on the inland side of the faults is reappearing (pl. 9). In other words, conditions hydraulically favorable to landward movement of salt water again exist. It has been suggested elsewhere that sinking of outpost wells to the Silverado zone would be of advantage if withdrawals from these well fields are to be continued or increased (Piper, Garrett, and others, 1953, p. 200). Such an outpost well would have particular value if located directly south of the Citizens well field and about 0.9 mile south of Spring Street, so as to furnish advance warning of any inland movement of salt water.

*Water-bearing zone in the basal part of the San Pedro formation.*—The water-bearing zone in the basal part of the San Pedro formation is extensive northeast of Signal Hill (p. 44–48) but probably tapers out along the north flank of the uplift and does not reach the faults at the crest of that uplift. Nevertheless, in order to complete the hydrologic comparison, a hydrograph for one well tapping this basal zone at the northwest edge of the Signal Hill uplift is shown on plate 10 (No. 4/13–12K1); hydrographs for three other wells tapping this zone have been introduced earlier on plate 9 (Nos. 4/12–14D1, 21M2, and 28H1). In water-level stage, amplitude of fluctuations, and trend, the hydrograph for well 4/13–12K1 is nearly identical with that for well 4/12–14D1 (Commission well 1) some 5 miles east, also with the hydrograph for well 4/12–6K1 (North Long Beach well 4) not here shown. All three show that the respective water levels declined about 30 feet from 1934 to 1938 and subsequently have been about 20 to 25 feet below sea level on the average. The hydrographs for wells 4/12–21M2 and 28H1 (pl. 9), respectively in the Citizens and Alamitos well fields, show that their water levels declined from above land surface (artesian flow) in 1924 to about 20 feet below sea level in 1931, and in 1932 and 1933 recovered about to sea level or to a stage about equal to that in the overlying Silverado zone. By 1944 the average static water level in well 21M2 had been drawn down to about 20 feet below sea level and that in well 28H1 to about 40 feet below sea level. As of June 1944 their respective pumping levels were 44 feet and 87 feet below sea level. However, the basal zone has no known direct hydraulic communication with the water of poor quality on the coastal side of the uplift and thus the maintenance of its pressure level at or near sea level is not of paramount importance so long as saline waters do not encroach across the Signal Hill uplift and into the overlying Silverado zone.

### ALAMITOS GAP

Within the range of deposits tapped by water wells, the Alamitos Gap is underlain by deposits of Recent age to a depth of not more than 100 feet below land surface and beneath these, to a depth of about 500 feet, by the San Pedro formation of Pleistocene age (Poland, Piper, and others, 1956, p. 43, 67, pl. 4, *A–A′*). The deposits of Recent age include a shallow semiperched water body in sediments ranging from coarse sand to silt. Logs of test wells 5/12–11M1 and 11M2, drilled by the Los Angeles County Flood Control District at the county line and about 0.4 mile from the coast indicate that water-bearing deposits there extend almost continuously from land surface to a depth of 100 feet and it is inferred that these are entirely of Recent age. Thus, at this locality the deposits of Recent age contain no substantial confining layers; also, the log of well 5/12–11G1 suggests that the same conditions exist locally at the concealed Seal Beach fault, and that more or less free hydraulic communication occurs from land surface to a depth of 92 feet. Throughout the gap, however, these Recent deposits are underlain by an extensive layer of silt (or clay) from 50 to 100 feet thick and inferred to be part of the San Pedro formation. Beneath this silt layer are water-bearing beds of sand and gravel in the San Pedro formation; from well to well their thickness and texture varies widely.

*Semiperched water body.*—For the semiperched water body, profiles shown on plate 2 indicate a uniform hydraulic gradient immediately coastward from the Seal Beach fault, but inland from that fault a gradient that is variable in both direction and magnitude. Thus, the profiles do not afford clear evidence of hydraulic continuity or discontinuity in the shallow deposits of Recent age across the Seal Beach fault; however, it is inferred from evidence in the other gaps that full continuity exists and that the semiperched water can move freely across the fault.

*San Pedro formation.*—The four hydrographs of plate 11 are for wells tapping confined aquifers in the San Pedro formation. (For details see table 26.) In order toward the coast these are: well 5/12–2B1, which is 1 mile inland from the Seal Beach fault and from the contaminated water along that fault; well 5/12–11H1, which is about 200 feet inland from the fault but which yielded contaminated water when drilled and never has been utilized; and wells 5/12–10A1 and 11L1, about 0.3 and 0.4 mile coastward from the Seal Beach fault and within the area underlain by highly saline water. These hydrographs show certain striking and contrasting features with respect to fluctuations of pressure head on opposite sides of the Seal Beach fault, as follows:

1. On the inland side of the fault, the pressure head (water level) fluctuates primarily in response to seasonal withdrawals; these fluctuations are common to all wells tapping the productive water-bearing zones of the main coastal basin. Water-level recorders at the two inland wells (2B1 and 11H1) show secondary fluctuations due to tidal loading but those for 2B1 are so small (about 1 percent of tidal range) that they could not be shown on plate 11. For well 11H1, tidal efficiency is about 10 percent. Even though water levels in wells generally were high in 1942–43, that in well 11H1 was below sea level for 2½ months in the summer of 1942.
2. On the coastal side of the fault, the pressure head fluctuates primarily in synchrony with and in proportion to the tidal range in the local estuaries. For well 11L1, the tidal efficiency is about 3 percent; for well 10A1 the tidal efficiency was about 6 percent in September 1942 but, as explained in subsequent paragraphs, decreased to zero by November of that year.
3. Inland pressure changes in the confined aquifers are not transmitted across the Seal Beach fault; also the tidal effects on the coastal side of the fault are not transmitted inland as such through the aquifers transected by the fault, although direct-loading effects are caused by a tidal prism which reaches inland beyond the fault each day and reaches as much as a mile during extreme high tides.

The hydrograph for well 5/12–10A1 on the coastal side of the fault is erratic in trend. When first established on this well by the Geological Survey in September 1941, a water-level recorder disclosed subdued pressure fluctuations. Subsequently perforations in the well casing about 140 feet below land surface were reopened by bailing and by use of "dry ice." The recorder was re-established in August 1942 and the water level then was observed to be about 1 foot below sea level and to fluctuate in synchrony with tidal loading, with an efficiency of about 6 percent. In the first half of November the tidal fluctuations gradually ceased and by early December the water level had declined about 9 feet, or slightly below the level in well 11L1. By March 1943 the level was 12 feet below the sea and was still declining. No explanation is offered for this anomalous decline beyond the conclusion that the perforations about 140 feet below land surface had become resealed, presumably by chemical action. However, it is clear that whatever the explanation, the water-bearing zone in hydraulic continuity with the water level in the casing as of March 1943 did not have hydraulic continuity with the confined aquifers inland from the Seal Beach fault.

Geochemical data indicate that on the inland side of the Seal Beach fault, except at well 11H1 and recently at well 11G1, the confined water always has been of excellent quality and has contained less than 20 ppm of chloride. However, on the coastal side of the fault the water in the San Pedro formation has been strongly saline, at least since about 1920 when the earliest wells of record were drilled. Because pressure levels inland from the fault were still far above sea level at that time, it is inferred that water in the San Pedro formation initially was saline on the coastal side of the fault, and hence that within the San Pedro formation virtually no fresh water has passed coastward across the Seal Beach fault in historic time. In the deposits of Recent age coastward from the fault, the water was saline as early as 1926 (well 5/12–10A1). The contaminant in well 5/12–11G1, which has been described elsewhere (Piper, Garrett, and others, 1953, p. 158–161), may have advanced inland and crossed the Seal Beach fault through the deposits of Recent age; if so, saline water would have entry to this well through casing perforations about from 70 to 92 feet below land surface in an aquifer inferred to be of Recent age.

From the hydrographs of plate 11 and from the substantiating geologic and geochemical data, it is concluded that in Alamitos Gap the Seal Beach fault forms an almost watertight barrier to movement through the confined aquifers of the San Pedro formation. However, it is not believed to be a barrier to movement of ground water in the deposits of Recent age which probably occur to a depth of about 100 feet.

### ORANGE COUNTY

For Orange County, figures 5 through 9 include hydrographs that show conditions along five hydraulic profiles about at right

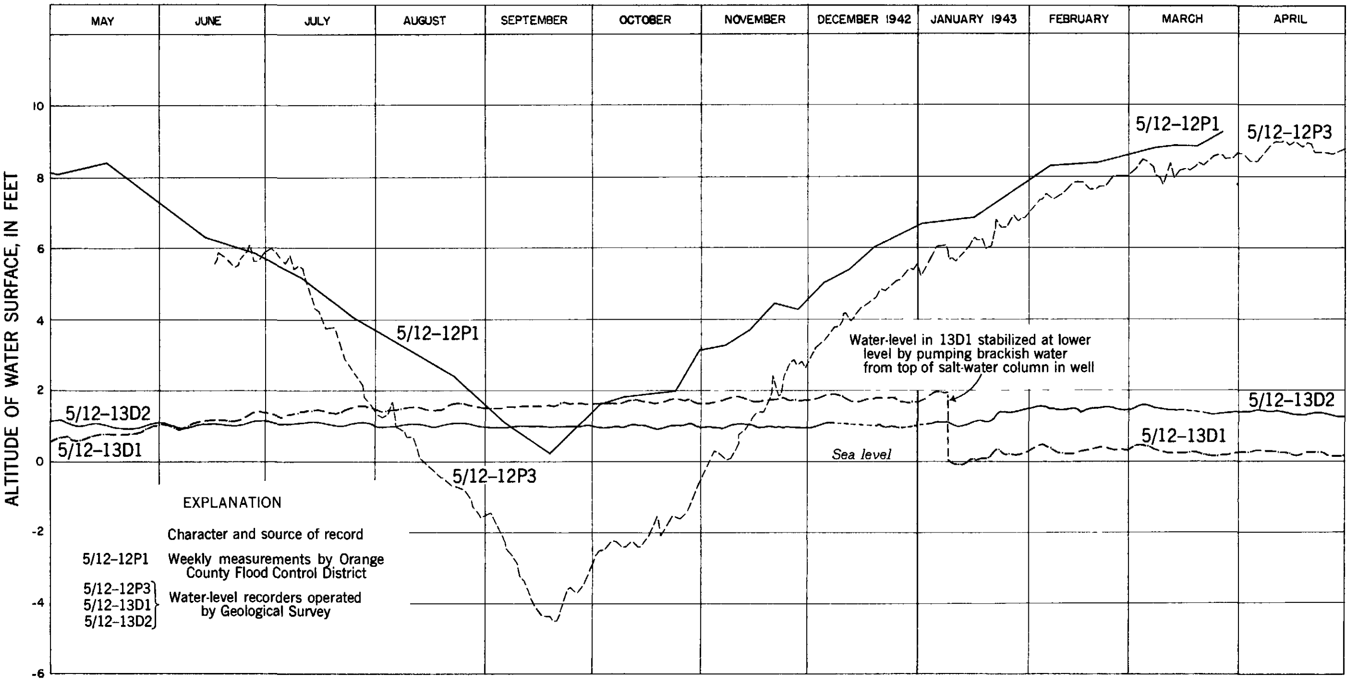

FIGURE 5.—Hydrographs for four wells on Landing Hill tapping the San Pedro formation, 1942–43.

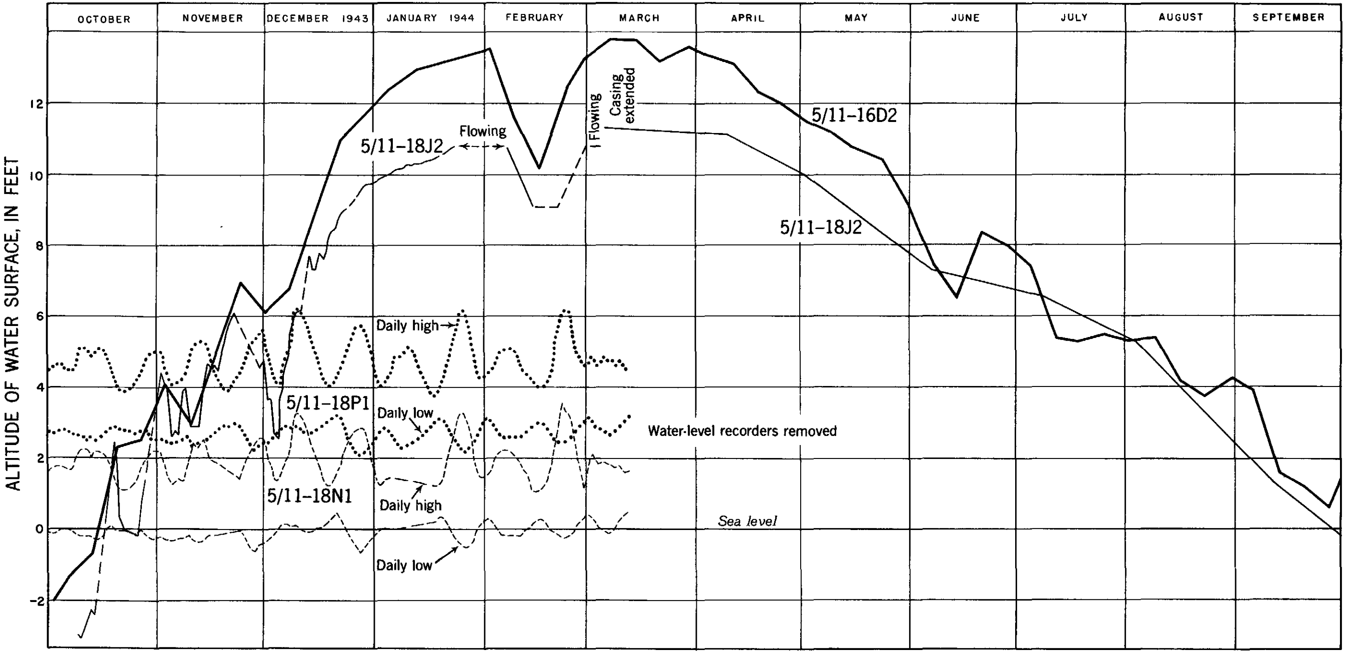

FIGURE 6.—Hydrographs for four wells in Sunset Gap tapping the San Pedro formation, 1943–44.

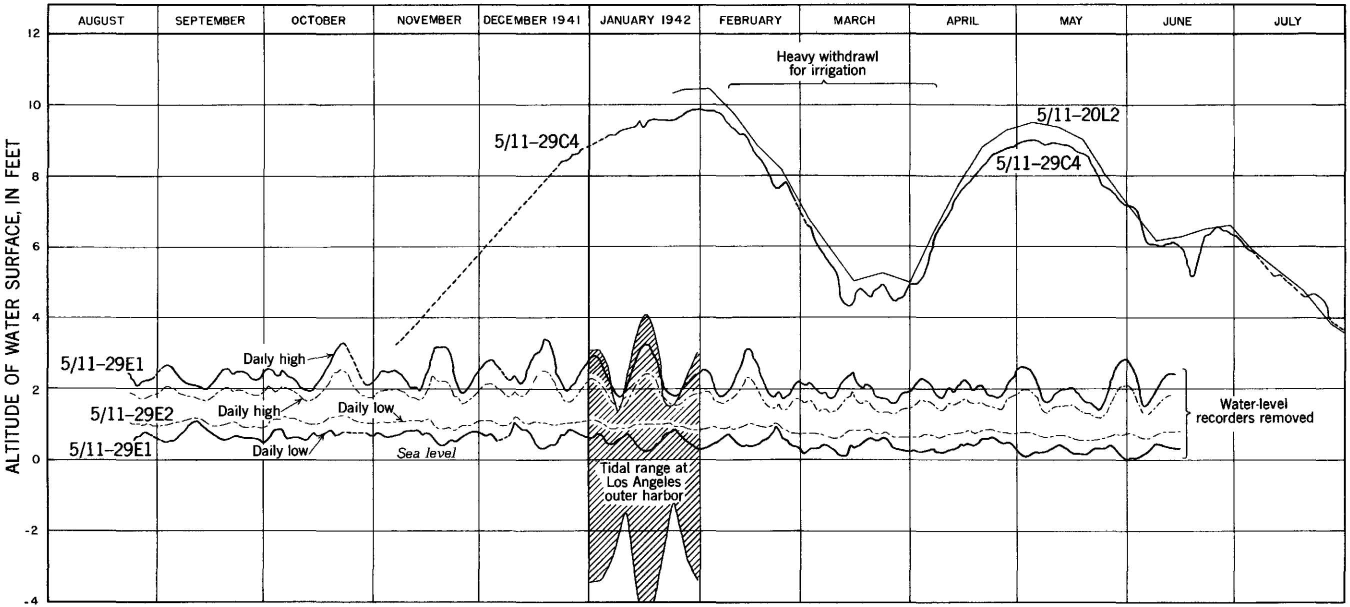

FIGURE 7.—Hydrographs for four wells on or near Bolsa Chica Mesa tapping the San Pedro formation, 1941–42.

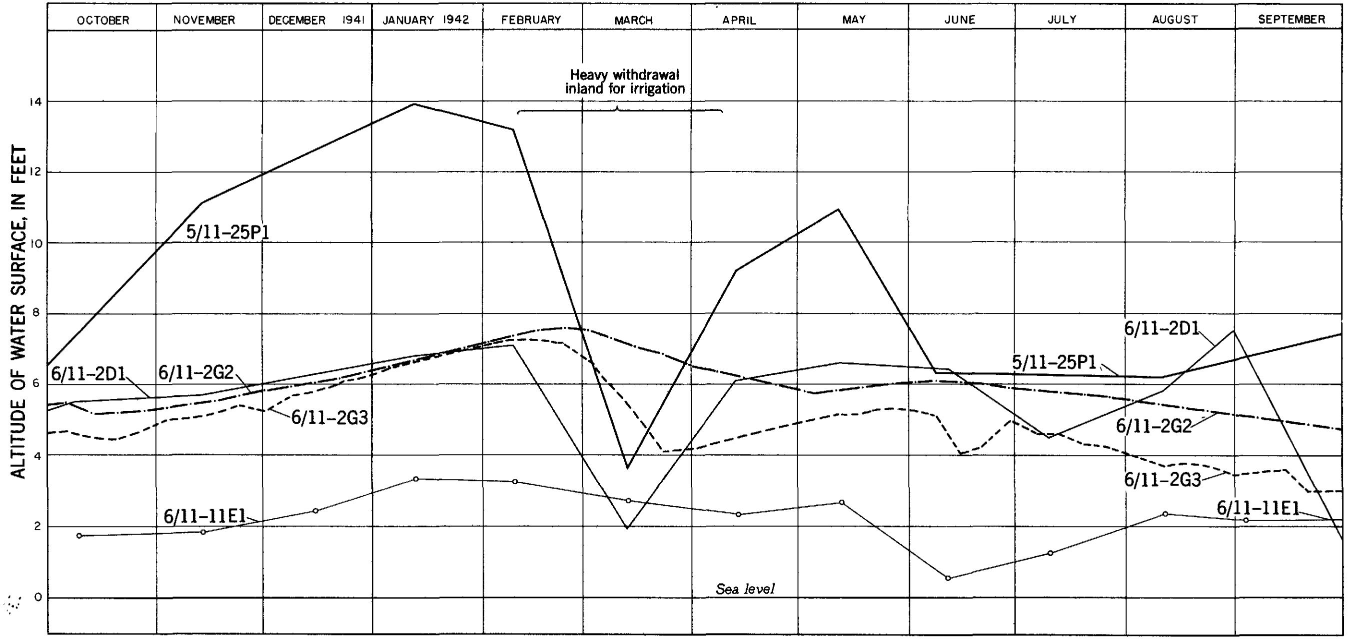

FIGURE 8.—Hydrographs for five wells on Huntington Beach Messa tapping the San Pedro formation, 1941–42.

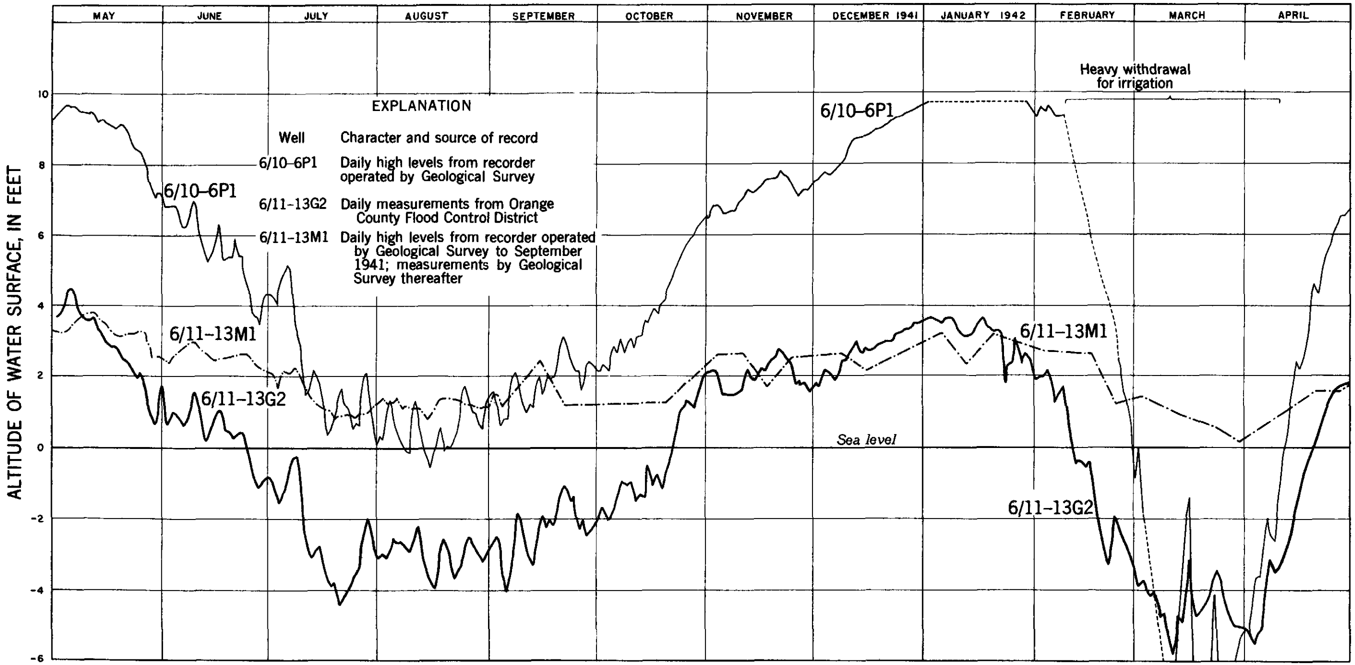

FIGURE 9.—Hydrographs for three wells in Santa Ana Gap, 1941–42.

angles to the coast and alined across Landing Hill, through Sunset Gap, across Bolsa Chica Mesa, across Huntington Beach Mesa, and through Santa Ana Gap. Except for two hydrographs of plate 9, all are for wells tapping the San Pedro formation of Pleistocene age. Hydrologic data for these wells are given in table 27.

TABLE 27.—*Wells in Orange County for which hydrographs are plotted on figures 5 to 9, inclusive*

| Well | Depth (feet) | Water-yielding zone or zones | | Agency supplying principal record [1] |
|---|---|---|---|---|
| | | Feet below land surface | Zone or formation | |
| 5/11-16D2 | 400 | | San Pedro formation | OCFCD. |
| 18J2 | 215.7 | | do | USGS and OCFCD. |
| 18N1 | 250 | 172–251 | do | USGS. |
| 18P1 | 125.0 | 110–148 | do | Do. |
| 20L2 | 157.5 | | do | Do. |
| 25P1 | 150 | | San Pedro (?) formation. | OCFCD. |
| 29C4 | 157.0 | | San Pedro formation | USGS. |
| 29E1 | 220.0 | 158–212 | do | Do. |
| 29E2 | 120.0 | 85–129 | do | Do. |
| 5/12-12P1 | 185.3 | | do | OCFCD. |
| 12P3 | 362.8 | 348–360 | do | USGS. |
| 13D1 | 210.0 | 183–258 | do | Do. |
| 13D2 | 140.0 | 125–158 | do | Do. |
| 6/10-6P1 | 150.5 | | Talbert water-bearing zone. | Do. |
| 6/11-2D1 | 202.5 | | San Pedro formation | OCFCD. |
| 2G2 | 123.3 | 78–126 | do | USGS. |
| 2G3 | 258.5 | 100–254 | do | Do. |
| 11E1 | 447 | 50–234 | do | OCFCD. |
| 13G2 | 154 | | Talbert water-bearing zone. | Do. |
| 13M1 | 364.1 | (2) | San Pedro formation | USGS. |

[1] For explanation of symbols see table 21.

[2] Probably below 300 ft.

### LANDING HILL

The four hydrographs of figure 5 are from wells on Landing Hill, all of which tap the San Pedro formation. They include (1) one pair of permanent observation wells, 5/12–13D1 and 13D2, constructed for the Geological Survey on the coastal side of the fault zone to tap distinct water-bearing beds from 183 to 258 feet and from 125 to 158 feet below the land surface, respectively; and (2) wells 5/12–12P1 and 12P3, which are about 0.25 mile to the northeast and on the inland side of the fault zone, and which tap water-bearing beds about from 170 to 190 feet and from 348 to 360 feet below the land surface, respectively. Evidently there is some hydraulic connection between the water-bearing beds tapped by these two inland wells, because in each well the water level fluctuates primarily in response to withdrawals from the adjacent public-supply wells of the city of Seal Beach. Also, the shallower of these two wells (12P1) taps a water-bearing bed which, at the fault zone, presumably abuts against one or both of the water-bearing beds tapped by the two coastal observation wells. The geologic relations along this hydraulic profile have been shown elsewhere (Poland, Piper, and others, 1956, pl. 5, *a–a′*).

Of the two permanent observation wells on the coastal side of the fault zone, the deeper taps water whose chloride content is nearly identical with that of the ocean and the shallower taps water whose chloride content is about 70 percent of that of the ocean. In contrast, the deeper of the two inland wells (12P3) yields water whose chloride content is less than 50 ppm, whereas the shallower (12P1) yields water which once was of good quality but now (1945) is somewhat contaminated.

The data on fluctuations of ground-water head in the wells near Landing Hill bring out these striking and contrasting features, namely: (1) on the coastal side of the fault zone the head fluctuates primarily in synchrony with and in proportion to the tidal range in the ocean, (2) on the inland side of the fault zone the head fluctuates primarily in response to withdrawals, and in the deeper wells is at times substantially below sea level, and (3) the pressure effects of the inland withdrawals are not transmitted across the fault or faults of the Newport–Inglewood structural zone. Apparently a substantial hydraulic discontinuity exists between the pairs of wells on opposite sides of the fault zone, even though their water-bearing beds probably butt against one another at the fault zone, at least in part.

However, geochemical evidence reveals that the hydraulic discontinuity developed across Landing Hill by the Seal Beach fault is not wholly watertight. The saline contamination which developed in well 5/12–12P1 between 1931 and 1941 moved inland across the fault under a differential head not exceeding 15 feet (Piper, Garrett, and others, 1953, p. 155–158). As shown by figure 5, the water level on the coastal side of the fault remains almost at sea level, whereas on the inland side the pumping level in well 12P1 has been as low as 12 to 15 feet below sea level (as during late summer in the middle thirties). Because this well is only about 100 feet inland from the fault, the differential head across the fault must also have been about 10 to 15 feet, but not more. Thus, it is concluded that across Landing Hill the fault barrier has been nearly but not wholly watertight against the differential ground-water pressures thus far imposed upon it by the inland withdrawals. It follows, therefore, that if greater differentials should be imposed in the future, substantial quantities of saline water presumably would migrate across the fault and pass into the main coastal basin beneath the northern flank of the hill.

In one aspect, the initial and the present hydraulic conditions seem to be mutually contradictory. For example, the two permanent observation wells on the coastal side of the fault tapped water which is about as saline as the ocean and which has been concluded to be connate water in the sense that it reoccupied the deposits several thousands of years ago (Poland, Piper, and others, 1956, p. 110). Thus, it follows that in historic times there cannot have been appreciable coastward leakage of fresh water or the saline water would have been displaced seaward. Accordingly, if no fresh water moved coastward through the fault under the initial artesian conditions (which must have involved a differential head across the fault at least two or three times as great as that induced by withdrawal from well 12P1), why has saline water moved landward across the fault under the nominal differential head of recent years? The saline water contaminating well 12P1 possibly may have come from within a shear zone of the fault and may not have migrated across the full barrier. If so, it should prove small in quantity and the contamination limited in extent. Also, there is a possibility that the barrier may have been ruptured locally by recent tectonic disturbances, such as the Long Beach earthquake of 1933.

Although the earthquake is not known to have caused any vertical displacements, many cracks developed in the land surface along and near the structural zone, especially near Hog Island in the Sunset Gap and near the coast in the Santa Ana Gap (Browning, C. R., written communication). Also, the earthquake displaced water levels as much as 10 feet in wells northeast of Signal Hill (La Rocque, 1941). If any cracks or fissures were so developed in the barrier, under present ground-water conditions they probably would remain open, whereas fissures developed in prehistoric time presumably have since been sealed by deposition of calcium carbonate from the ground water escaping coastward. However, until proved otherwise, it is inferred that the contaminant in well 12P1 has moved across the barrier from the coastal side, and that further drawdown of water level in the main basin would accelerate such movement.

### SUNSET GAP

Sunset Gap is underlain by deposits of Recent age to a depth inferred not to exceed 20 feet, and beneath by deposits of Pleistocene age believed to extend to a depth of about 900 feet near Hog Island. These deposits of Pleistocene age are largely if not wholly within the San Pedro formation.

*Semiperched water body.*—The profiles of water level for shallow wells in the Sunset Gap (pl. 2) indicate that at least three of these wells inland from the master fault tap a confined aquifer. The profiles suggest also that an hydraulic discontinuity exists between shallow wells 18P2 and 18P3—that is, at the position of the master fault at depth. It is possible that (1) about all the wells reach the deposits of Pleistocene age and thus reflect a discontinuity in those deposits or (2) about all the wells tap deposits of Recent age in which faulting has produced a discontinuity. Specific hydraulic evidence for the other gaps, indicates that the first explanation is the more logical.

*San Pedro formation.*—The four hydrographs of figure 6 are for wells tapping confined aquifers in the San Pedro formation in or near the Sunset Gap. They include (1) a pair of permanent observation wells, 5/11–18N1 and 18P1, constructed for the Geological Survey on the coastal side of the master fault to tap distinct water-bearing beds from 172 to 251 feet and from 110 to 148 feet below the land surface, respectively; and (2) wells 5/11–18J2 and 16D2, 0.8 mile and 2 miles inland from the master fault. Well 16D2 is inland beyond the gap but its hydrograph is plotted to show that the fluctuation in well 18J2 is characteristic for the deeper wells of that area.

Of the two permanent observation wells on the coastal side of the master fault, the deeper well taps water whose chloride content is nearly equal to that of the ocean but the shallower well taps water whose chloride content is less than 50 ppm. Although no chemical analyses have been made of the water from the two inland wells, the chloride content in water from adjacent wells ranges from 16 to 20 ppm.

The hydrographs of figure 6 reveal a sharp contrast in fluctuations on the coastal and inland sides of the master fault. As at the inland wells on Landing Hill, in the two inland wells of the Sunset Gap the head (water level) fluctuates primarily in response to seasonal withdrawals and replenishment within the main coastal basin. Also, for the two permanent observation wells on the coastal side of the fault, the head fluctuates primarily in response to and in proportion to the tidal range in the ocean. The tidal efficiency for fluctuations in shallower well 18P1 is 46 percent; that for deeper well 18N1 is 45 percent. The pressure effects of the inland fluctuations are not transmitted across the master fault. Evidently here also there is a substantial hydraulic discontinuity between the pairs of wells on opposite sides of the master fault, even though the water-bearing beds probably are not displaced substantially at that fault.

Although Sunset Gap is 2.5 miles wide, no other wells have been constructed on the coastal side of the master fault. Hence, no supplementary hydrologic or geochemical data are available to give further evidence on the watertightness of the fault barrier in this reach. However, the effectiveness of the barrier can be appraised in part from the chemical character of the water in the permanent observation wells. As previously noted, the chloride content in the shallower well (5/11–18P1) is less than 50 ppm and its average water level is about 3.5 feet above sea level. Under conditions of unconfined circulation in hydraulic continuity with the ocean, application of the Ghyben-Herzberg principle would suggest a salt-water contact about 140 feet below sea level or 145 feet below land surface. As worked out by Badon Ghyben and by Herzberg in Europe and as applied by Brown (1925) and others in this country, the principle of fresh-water flotation on salt water states in effect that for coastal areas in which a dynamic balance is attained, the depth to salt water below sea level is a function of the height of fresh water above sea level, in the ratio of about 40 to 1. For well 5/11–18N1 an electric log shows that the salt-water contact occurs at 135 feet below sea level; there, evidently a lens of fresh water occupies the water-bearing deposits to that depth on the coastal side of the fault. Whether that fresh-water body is maintained by percolation through the fault "barrier" or is stagnant, it floats on underlying salt water. If the body has hydraulic continuity with the ocean, it cannot be stagnant, because its pressure head is currently above sea level. Of the two alternatives, it is more probable that the fresh-water lens is maintained by leakage through the fault barrier, under the pressure differential of as much as 6 feet prevailing early in 1944 (fig. 6). The amount of such leakage must be small; otherwise, some seasonal fluctuation of pressure head would be transmitted to the coastal side of the fault. Formerly, when the head on the inland side was much greater than now, a fresh-water spring existed on the coastal flank of Hog Island. That spring no longer flows and the only leakage of fresh water now is underground. The quantity of such leakage currently could be determined only by constructing a number of test wells to indicate the length and hydraulic gradient of the fresh-water body coastward from the fault, also the permeability of the aquifers through which that body moves.

It is concluded from the hydrologic and geochemical data discussed that in the central part of Sunset Gap the fault barrier is watertight below a depth of 145 feet, even against the high differential pressures that occurred under native conditions; but that from land surface to a depth of 145 feet a small quantity of leakage does occur. Thus, if inland pressure heads ever should be drawn down several tens of feet below sea level, saline water probably would move inland across the master fault.

### BOLSA CHICA MESA

The hydrographs of figure 7 are for wells on and near the Bolsa Chica Mesa. As at Landing Hill, all four wells tap the San Pedro formation. On the coastal side of the fault zone these wells include another of the three pairs of permanent observation wells constructed for the Geological Survey—Nos. 5/11–29E1 and 29E2, on the south side of Los Patos Avenue and about 700 feet coastward from the fault. These two wells separately tap aquifers which are respectively from 158 to 212 feet and from 85 to 129 feet below land surface, and which contain water whose chloride content is about 70 and 90 percent of that of the ocean (Poland, Piper, and others, 1956, pl. 5, *b–b′*). As the hydrographs show, in both these wells the water level fluctuates primarily with the tide. For well 29E1 the tidal efficiency is about 35 percent; for well 29E2, the shallower, it is about 17 percent. On the inland side of the fault zone the hydrographs are for wells 5/11–29C4 and 20L2, which are respectively about 200 feet and 2,000 feet inland from the fault zone. Each of the two inland wells taps a permeable bed which is about the same distance below sea level as that tapped by well 29E2. The water from each of the inland wells contains only about 15 ppm of chloride. In these wells the water level fluctuates in response to the pressure effects of withdrawals from inland water wells, although at each well a secondary fluctuation develops in response to tidal loading.

From the hydrographs and from supplementary data it is concluded that:

1. In the vicinity of Bolsa Chica Mesa the master fault of the structural zone produces a substantial hydraulic discontinuity in the San Pedro formation.
2. Even under the initial high artesian pressures, no fresh water moved coastward across the fault to flush the aquifers tapped by wells 5/11-29E1 and 29E2.
3. The fault zone here is watertight against the differential ground-water pressures that have been applied to it to date.

### BOLSA GAP

To a depth of about 80 feet below land surface the Bolsa Gap is underlain by deposits of Recent age which contain the permeable "80-foot gravel" at their base. About from 80 feet to 600 feet below land surface it is underlain by the San Pedro formation. The general geologic relations have been shown elsewhere (Poland, Piper, and others, 1956, pls. 4, *A–A′*, 5 *b–b′*). The Geological Survey drilled three shallow observation wells coastward from the inferred faults but, as shown by the profiles of plate 2, they have not suggested any hydraulic discontinuity in the semiperched water body. Only one deep well, 5/11–29P1, has been drilled on the coastal side of the structural zone. That well, which is at the southeast edge of Bolsa Chica Mesa, tapped brackish water in the San Pedro formation and flows intermittently by natural gas lift.

Thus, there is no opportunity to compare water-level fluctuations across the fault zones of Bolsa Gap, either in the "80-foot gravel" or in the San Pedro formation. However, from analogy in geologic features among the several coastal gaps, it is inferred that hydraulic continuity within the "80-foot gravel" is not interrupted by the faults. In 1941 the "80-foot gravel" was contaminated at well 5/11–33H1, 0.4 mile inland from the master fault; however, it is not known whether that contamination was derived from the ocean or from local sources.

On the other hand, geologic evidence shows that the San Pedro formation has been displaced substantially at the inland fault of the two which cross the Bolsa Gap. Also, inland from the faults, certain wells tapping aquifers in the San Pedro formation have shown more persistent artesian pressures during the past 15 years than are known anywhere else from Newport Mesa to Signal Hill. For example, wells 5/11–28A1 and 27D1 tap an aquifer whose top here is about 370 feet below sea level. At well 28A1 the water level has been measured about monthly by the Orange County Flood Control District since 1930. Only in the low-water year of 1936 did this well cease to flow in winter months; in May 1945 its pressure level was 20.7 feet above land surface or 30.3 feet above sea level. This unusually strong artesian pressure is interpreted as indicating that (1) the aquifer tapped is highly permeable and extends inland to the area of free recharge, presumably to the vicinity of Anaheim; and (2) in the Bolsa Gap, the faults of the Newport–Inglewood zone constitute a substantially watertight barrier in the San Pedro formation.

From the data here presented it is concluded that:

1. There is no structural barrier to movement of water through the "80-foot gravel;" initially and currently any movement has been and is coastward, but in periods of low water such as 1936 (pl. 5) the direction of movement has been landward and ocean water could move inland without restraint.
2. A structural barrier which is also an effective hydraulic barrier occurs across the San Pedro formation. Salt water cannot encroach across the faults in aquifers within the San Pedro formation as long as their artesian pressure is sufficient to produce flowing wells. Even if the pressure levels in these aquifers were reduced to or below sea level, in an amount equal to the current artesian head, it is doubted that substantial quantities of saline water would pass across the fault zone within the San Pedro formation.

### HUNTINGTON BEACH MESA

The Huntington Beach Mesa is underlain from land surface to a depth of about 600 feet by Pleistocene deposits, almost exclusively the San Pedro formation. In general, beneath the mesa the San Pedro formation contains three distinct water-bearing zones (Poland, Piper, and others, 1956, p. 73, pl. 4, *A–A'*). It is believed that two fault zones strike southeastward across the mesa, about parallel to and respectively about 1 mile and 0.5 mile from the coast. The aquifers within the San Pedro formation presumably are cut by, but are not known to be displaced by these faults.

The five hydrographs of figure 8 are for wells tapping the upper or middle water-bearing zones of Huntington Beach Mesa, or both those zones. Four are inland from the master fault and one is about at the coastward fault. In order toward the coast they are: well 5/11–25P1, which is 2 miles inland from the master fault, about 1 mile inland from contaminated water, and which taps the upper zone; wells 6/11–2G2, 2G3, and 2D1, all about 0.4 mile inland from the master fault and near the focus of an inland area of contamination (Piper, Garrett, and others, 1953, pl. 11); and well 6/11–11E1, which is about 0.7 mile oceanward from the master fault, about at the coastal fault, and within a coastal area of contamination. Of the four wells last listed, No. 6/11–2G2 taps the upper zone, Nos. 2G3 and 11E1 tap the upper and middle zone, and No. 2D1 taps the upper zone and probably the middle zone.

The hydrographs for wells 5/11–25P1 and 6/11–2D1 are similar in form to the extent that each reflects the heavy inland withdrawal for irrigation in February and March of 1942 (which also affected water levels in wells on Bolsa Chica Mesa and in Santa Ana Gap; see figs. 7 and 9). The hydrograph for well 2G3 apparently reflects this draft to some extent but probably shows chiefly the effect of local draft from a well immediately north of Clay Street. The graph for well 6/11–11E1 shows only gentle response to winter replenishment and none to the late winter draft. Presumably the fluctuation of the water level in that well is largely due to variation in the rate of pumping from well 6/11–2M2, at the Huntington Beach Union High School.

Initially the water within the upper and middle zones and coastward from the master fault was of good quality and its pressure level was at least several feet above sea level, and locally may have been several tens of feet above. Both these features suggest oceanward circulation in those zones at that time. However, hydrologic data taken in the canvass of 1904 by Mendenhall are not sufficient to indicate the shape of the pressure surface nor the amount of the oceanward gradient. As of 1942 the apparent oceanward gradient between wells 6/11–2G3 and 11E1 was 3 feet per mile in January and 1 foot per mile in September; between wells 5/11–25P1 and 6/11–2G2 it was 4.5 feet per mile in January and 1.5 feet in September (fig. 8).

Because the ground waters beneath Huntington Beach Mesa have been contaminated largely by water migrating downward from the land surface, the pattern of that contamination does not indicate the effectiveness of the faults as barriers to circulation. In the future, however, the anticipated expansion of the contaminated area may be controlled to some extent by the fault zones and thus ultimately may furnish information on their barrier capacity.

From the hydrologic data of figure 8 and from supplementary data it is inferred that the master fault of the structural zone—the inland fault near the Huntington Beach High School—interposes only a partial barrier to water movement through the upper and middle water-bearing zones of the mesa.

As discussed on page 52, the lowest and relatively thick water-bearing zone appears to finger out coastward into clay and silt, as shown by the log of well 6/11–11E1. The lithologic discontinuity so developed presumably is an effective and complete barrier to movement of water inland from the ocean through that lower zone. The lithologic discontinuity may be supplemented by a structural barrier at the master fault.

With respect to current spread of contamination on the mesa, the relative stage of water level in the three zones is critical. Wells 6/11–2G2 and 2G3 are near the focus of the inland contamination. In 1942 the water level in well 2G2 consistently was from 1 to 2 feet the higher. Accordingly, because well 2G2 taps only the upper zone but well 2G3 taps both the upper and middle zones, the hydraulic circulation is downward. This condition is favorable to spread of contamination.

However, in the lower and main water-bearing zone the water level currently is several feet above those of the upper and middle zones. For example, well 5/11–35A4, near the intersection of Huntington Beach Boulevard and Talbert Avenue, is 499 feet deep and taps the lower zone. Quarterly measurements of depth to water by the Geological Survey in 1941–42 show that its water level ranged from 2 to as much as 7 feet above that of well 5/11–25P1 which taps the upper zone half a mile northeast. On January 14, 1942, the altitude of water surface in well 35A4 was 19.79 feet above sea level, or about 12 feet above the water level in either the upper or the middle zone in wells 6/11–2G2 and 2G3, about 1.2 miles to the south. As long as the lower zone has the greater pressure head, saline water from the overlying contaminated zones cannot pass downward through connecting well casings. However, in years of low rainfall and consequent heavy withdrawal, the water level in the lower highly productive zone may be drawn down substantially below those of the upper two zones. At such times, therefore, there would be great hazard of contaminating the lower zone unless all defective wells had been repaired or plugged. It is suggested that periodic measurements be made on a few wells tapping the lower water-bearing zone so that a continuing record of water level in all three zones will be available as an aid in the control of the saline contamination now so widespread in the upper zone and, to a lesser extent, in the middle zone.

### SANTA ANA GAP

*Semiperched water body.*—For the semiperched water table in Santa Ana Gap, the profiles of plate 2 suggest no break in gradient across the position of the master fault at depth. As for Dominguez, Alamitos, and Bolsa Gaps, it is concluded that no faults impede circulation in the semiperched water body and it is inferred that faults do not transect the upper division of the deposits of Recent age.

*Talbert water-bearing zone.*—In the Santa Ana Gap, the Newport–Inglewood structural zone probably comprises two faults or fault zones that are almost parallel to one another and to the coast. The inland fault, which passes about through the intersection of Bushard and Hamilton Streets, is considered the master fault of the structural zone.

In the central part of Santa Ana Gap and inland for about a mile from the master fault, the Talbert water-bearing zone is the only permeable deposit tapped by water wells (Poland, Piper, and others, 1956, pl. 5, *c–c′*) ; thus, lateral hydraulic continuity in this zone is critical with respect to saline encroachment. Pertinent hydrologic evidence has been introduced by the three hydrographs of figure 9. In order toward the coast the three wells represented are: No. 6/10–6P1, which is inland from both faults and inland beyond the area of contaminated water, which taps the Talbert zone, and which is within an area of heavy withdrawals for municipal use and irrigation; No. 6/11–13G2, which is between the two faults and about 0.2 mile within the area of contaminated water, and which also taps the Talbert zone; and No. 6/11–13M1, which is seaward from both faults, only about 400 feet from the coast, and about half a mile from the nearest heavily pumped wells, and which probably taps the San Pedro formation but not the overlying Talbert zone. No well taps the Talbert zone coastward from the two faults. However, the zone tapped by well 6/11–13M1 is probably hydraulically connected with the Talbert zone which overlies it. Thus, all three hydrographs relate to confined water in what is the one productive water-bearing zone in that area. All show the same general trend in ground-water levels—note particularly the sharp recession and recovery of level in well 6P1 caused by the heavy pumping for irrigation from February into

April 1942, the less pronounced recession and recovery concurrently in well 13G2, and the relatively small fluctuation in well 13M1. The range of water-level fluctuations is about that which might be expected if the three wells tapped continuously permeable material and, as is the case, if the withdrawals were concentrated near the inland well but the level in the coastal well were stabilized by the ocean. Furthermore, the hydrographs for wells 6/10–6P1 and 6/11–13G2, which were plotted from the charts of water-level recorders, correspond strikingly in many of their minor peaks and depressions; thus, pressure is transmitted freely through the Talbert water-bearing zone across the position of the master fault.

Additional hydrologic evidence is derived from plate 8—attention is called to the piezometric profile for 1904, which held a uniform gradient to the very coast or across both the faults of the structural zone. As in the case of the corresponding profile for the Gaspur zone in the Dominguez Gap (pl. 7), this hydraulic profile of 1904 is considered to be decisive evidence that no barrier interrupts hydraulic continuity in the Talbert zone in the Santa Ana Gap. Thus, the conclusion drawn from the profile of 1904 substantiates the data of figure 9.

Geochemical evidence also is confirmatory because contamination now has advanced inland about half a mile beyond the master fault with no hydraulic interruption.

Certain other critical conclusions can be drawn with respect to circulation of ground water through the Talbert zone, as follows:

1. Along the coast and for about a mile inland, the ground-water head is currently too low to prevent inland movement of water from the ocean during the greater part of the year (fig. 9 and pl. 4, long-term graph for well 6/11-13G2).
2. During periods of heavy draft, the pressure level is continuously so low throughout the gap that—if the low-water head were sustained indefinitely—ocean water could ultimately move inland through the entire length of the gap. For example, if water levels in the gap were maintained for many years about at the high level for 1936 (see pl. 8), ocean water could move inland about to Adams Avenue or about half a mile beyond the partial barrier of impermeable rocks in the core of the structural zone; thence, it could move into water-bearing zones in the underlying deposits of Pleistocene age (Poland, Piper, and others, 1956, pl. 5, *c–c'*). Further, if water levels were maintained for many years about at the low level for 1936 (pls. 5 and 8), ocean water ultimately could move inland within the Talbert zone nearly to Garden Grove. However, the possibility of such extreme encroachment is remote because water-levels would have to be drawn down continuously for several decades to accomplish it.

### NEWPORT MESA

Along the full reach of the ocean-facing bluff at the south edge of Newport Mesa, from Santa Ana Gap to Newport Bay, impervious rocks of Pliocene and Miocene age extend continuously above sea level and form a wholly impermeable barrier between the ocean and the inland fresh-water bodies. Only at the extreme north end of Newport Bay, in the south angle of block 5 of the Irvine tract, do water-bearing beds of the San Pedro formation crop out at land surface (Poland, Piper, and others, 1956, p. 63–64). These beds are in partial contact with saline waters of the bay. It is possible that if water-levels in the principal water-bearing zone beneath Newport Mesa were drawn below sea level for a substantial period, saline water ultimately might advance inland through the beds here exposed. However, there is no evidence that such encroachment has yet taken place. The nearest well fields are those of the Newport Heights Irrigation District and the Santa Ana Army Air Base, 1.1 and 1.2 miles from this outcrop. Although both have been under intensive draft in the past few years, neither has shown any deterioration of water quality. In the reach between these well fields and Newport Bay, there are no wells to furnish either chemical or water-level data.

## SUMMARY OF CONCLUSIONS FROM THE HYDROLOGIC EVIDENCE

For the reach from Dominguez Hill to Newport Beach, the features of watertightness along the Newport–Inglewood uplift which have been treated at length in preceding pages are summarized as follows:

1. No impediment to movement across the uplift occurs in the semiperched water body, but this body is naturally of inferior quality and is not a serious threat of contamination if casings of wells tapping underlying water bodies are maintained so as to prevent downward leakage.
2. No impediment to movement across the uplift occurs in the two regional arteries in the deposits of Recent—the Gaspur and Talbert water-bearing zones. Gross contamination occurs locally, which under certain conditions might extend inland. Also no impediment occurs in the thinner but permeable tongues of the Recent deposits in Alamitos and Bolsa Gaps, which also might act as conduits for inland advance of saline waters if water levels should be drawn down substantially below sea level.
3. In the San Pedro formation, the barrier features are: (1) virtually watertight under differential heads so far imposed and probably under any differential likely to be imposed along the reach of the Cherry-Hill fault from the Dominguez Gap to Signal Hill, along the reach of the Seal Beach fault from Reservoir Hill through Alamitos Gap, beneath Bolsa Chica Mesa and the Bolsa Gap, and beneath Newport Mesa, in all about 56 percent of the reach from Dominguez Hill to Newport Mesa; (2) not watertight and subject to leakage, either current or potential, beneath Dominguez Hill, in Dominguez Gap (especially the western part), from Signal Hill to Reservoir Hill, beneath Landing Hill, and in the Sunset Gap—in all about 31 percent of the reach from Dominguez Hill to Newport Mesa; and (3) the watertightness is not determinable from hydrologic data now available along the reach beneath Huntington Beach Mesa, and beneath the western and eastern fringes of the Santa Ana Gap—in all about 13 percent of the reach here investigated.

## CONTROL OF SALINE ENCROACHMENT

### NEED FOR PROGRAM

Under natural conditions, ground-water movement beneath the coastal plain to the ocean was fairly effectively restrained by confining beds, by resistance to movement through the aquifers themselves, and by structural traps along the Newport–Inglewood uplift. Because of these restraints, high pressures were built up in the aquifers inland from the uplift and the over-all barrier to landward movement of ocean water across the uplift was absolute. Even then, the aquifers of the main coastal basin functioned more as a tremendous storage reservoir than as conduits for escape of fresh water to the ocean.

For example, coastward movement through the Gaspur and Talbert water-bearing zones of Recent age is not restrained by any physical barriers at the structural zone and thus they are the chief conduits to the ocean; initially their joint discharge to the ocean probably was on the order of 8,000 to 10,000 acre-feet of water each year. For their extent and thickness (Poland, Piper, and others, 1956, pl. 7), and assuming that their average specific yield is 20 percent (Eckis, 1934, pl. E), it is estimated that their total reservoir capacity from the inland narrows to the sea was about 1,000,000 acre-feet under the conditions of full saturation (table 28). Thus, the yearly initial escape to the ocean was about 1 percent of that reservoir capacity. At present there is no escape from either zone.

TABLE 28.—*Estimated reservoir capacity, in acre-feet, of Gaspur and Talbert water-bearing zones under conditions of full saturation*

| | *Acre-feet* | |
|---|---|---|
| Gaspur water-bearing zone: | | |
| 1. Whittier Narrows to Newport-Inglewood uplift | 270, 000 | |
| 2. Westerly arm of Gaspur zone—Los Angeles Narrows to Compton | 150, 000 | |
| Reservoir capacity within main coastal basin | 420, 000 | |
| 3. Newport-Inglewood uplift to San Pedro Bay (west basin) | 70, 000 | |
| Total reservoir capacity of Gaspur zone | | 490, 000 |
| Talbert water-bearing zone: | | |
| 1. Santa Ana Canyon to ocean | 477, 000 | |
| 2. "80-foot gravel" of Bolsa Gap | 23, 000 | |
| Total reservoir capacity of Talbert zone | | 500, 000 |
| Both zones | | 990, 000 |

For the deposits of Pleistocene age, the total reservoir capacity in the main coastal basin is many times greater, probably as much as the capacity of Lake Mead or about 30,000,000 acre-feet. Even initially, the coastward escape from the Pleistocene deposits was negligible in comparison with this large reservoir capacity. The over-all reservoir capacity estimated here is not to be confused with the usable storage capacities within the area of unconfined water; estimates for such usable capacity have been made by Eckis (1934, table 1).

The increasing development of this tremendous ground-water reservoir in the past 70 years has gradually lowered the pressure head or water level about to sea level immediately inland from the Newport–Inglewood uplift. As reviewed in this report, that drawdown developed in two stages. The first stage, from the eighties about to 1900, occurred through the drilling and unrestrained flow of several thousand artesian wells, which literally released the pent-up waters, set the ground-water bodies in motion, and so quickly dissipated the initial high pressures. The second stage, from 1918 to 1936, occurred through accelerated development of the available supply, caused jointly by a substantial expansion of land under irrigation, an 18-year dry period, and increased efficiency of the deep-well turbine pump. During that 18-year period, in Orange County the decline of water levels ranged from 80 feet near Anaheim to 15 feet 1 mile from the coast; in Los Angeles County it ranged from 50 feet in the intake area below Whittier Narrows to 15 feet 1 mile from the coast. As of autumn 1936, in the main coastal basin water levels were below sea level beneath 155 square miles in Orange County and 30 square miles in Los Angeles County (pl. 5).

From 1936 into 1944 the coastal plain as a whole has experienced its wettest 8-year span since the systematic collection of rainfall records began in 1877. In those 8 years the average excess of rainfall above the long-term mean for Los Angeles and Tustin together has been 4.6 inches per year. The concurrent draft of ground water from the main coastal basin in the two counties has averaged about 300,000 acre-feet yearly. In that same period the average recovery in water level has been about 16 feet in 16 selected index wells in Orange County and has been about 12 feet in 12 selected index wells in Los Angeles County. These index wells are distributed about proportionally in the intake and pressure areas. Thus, the recovery of the 8 years has been about one-third of the decline in the 18 preceding years. It appears that the ground-water supplies are now so fully utilized that even in extremely wet periods the replenishment exceeds the draft only nominally, whereas during periods of subnormal rainfall there is a substantial yearly deficit in replenishment. For Orange County, the present overdraft from the main basin has been estimated as

12,200 acre-feet per year (Gleason, 1945). That overdraft, however, is an average expectancy over a long-term period under present conditions of operation. In a dry period, a much greater temporary deficit would occur—conceivably from two to eight times as great as the long-term yearly deficit. An estimate of the long-term unbalance between supply and demand in Los Angeles County under present conditions of use is being prepared by the California Division of Water Resources. That estimate is not yet available but the record of water-level fluctuations and the recent increase in use indicate that a long-term overdraft exists there also. The decline in water levels that would develop during an extreme drought presents the most critical immediate problem in relation to restraint of saline encroachment.

Until recently, the municipalities, water companies, industrial plants, and private irrigators withdrawing water from the coastal plain have not concerned themselves with the problems of balancing the long-term supply and demand. Some may have assumed tacitly that the barrier features of the Newport-Inglewood structural zone would completely prevent extensive inland encroachment by ocean water, even if water levels in the main coastal basin were drawn far below sea level. This investigation has shown that for the reach of the Newport-Inglewood structural zone from Dominguez Gap to Santa Ana Gap, both gaps included, the structural zone interposes no barrier to circulation of water through the deposits of Recent age. Thus, in those deposits, circulation is limited only by their permeability, cross section, and effective hydraulic gradient. On the other hand, about all the deposits of Pleistocene age within this reach are transected by the barrier faults. For most of the reach from Signal Hill to Bolsa Gap, inclusive, these deposits are substantially watertight against the differential heads of several tens of feet that existed across the barrier under initial conditions. However, even in that reach a few permeable segments occur—specifically, along a part of the Signal Hill uplift, on Landing Hill, and near Hog Island in Sunset Gap.

Accordingly, the water users of the main coastal basin now face the necessity of guarding their invaluable ground-water supply from saline encroachment. That necessity will become urgent with the arrival of the next period of subnormal rainfall. It cannot be emphasized too strongly that in another period of deficient rainfall similar to that of 1918-36, water levels probably would be drawn down at about the same rate as in that period, unless draft is reduced or replenishment is increased in substantial amount. In Orange County the drawdown might be somewhat slower than in 1918-36, because certain municipalities now are importing about 8,000 acre-feet of water each year through the Metropolitan Water District; in Los Angeles County, however, the draft by municipalities and water companies has been increased substantially since 1936, that increased draft exceeds the current increased replenishment through spreading basins of the Los Angeles County Flood Control District below Whittier Narrows, and so the rate of drawdown probably would be at least as rapid as that from 1918 through 1936. Because the water levels of 1946 are far below those of 1918 throughout most of the coastal plain, only about 6 years of rainfall deficiency comparable to that of 1918–36 would suffice to return to the water levels of 1936. As shown by the water-level contours of plate 5, conditions in Orange County would then be much more critical.

## METHODS FOR CONTROL

### BASIN-WIDE BALANCE OF DRAFT AND REPLENISHMENT

For an ultimate and lasting solution to the problem of restraining saline encroachment into the main coastal basin from the ocean in each county the draft must be reduced or the replenishment increased so that the two are in long-term balance. Fully effective utilization of the basin might require the lowering of water level substantially below sea level in certain areas distant from the coast. However, the over-all balance should be so regulated as to keep water levels above or near sea level proximate to the barrier features of the Newport–Inglewood uplift.

To attain a basin-wide balance between draft and replenishment, so far as economically justified, all possible means of water conservation should be practiced and all remaining sources of replenishment should be developed fully. Conservation agencies in both counties fully realize the long-term consequences of an unbalance between supply and demand and those agencies are undertaking to remedy the situation. They will need full support by all water users in order to attain their objectives. The problems are broad in scope and in some aspects involve water supplies stored in or escaping from the inland basins; no attempt is made to treat them in this report which is concerned fundamentally with coastal conditions. In a recent statement, the Orange County Water District (1945) has outlined a policy for balancing supply and draft in Orange County.

The general geologic and hydrologic conditions within the coastal plain have a major influence on the development of the most effective program for replenishment to the ground-water supply. Certain pertinent aspects of these conditions which have been studied as a part of this investigation are commented on briefly herewith.

### SPECIAL ASPECTS IN LOS ANGELES COUNTY

In Los Angeles County the spreading basins established and operated by the County Flood Control District are near the central part of the area of free recharge below Whittier Narrows. The program of replenishing that area by regulating flow in the channels of the Rio Hondo and the San Gabriel River, and by spreading water has been so successful that in the intake area the water table has been raised about 50 feet since 1936 and the storage capacity is no longer sufficient to hold all water available for recharge in wet years. The stored water does not move away from the area of replenishment quickly enough to make sufficient storage available in following years. These recharge waters have been introduced into the Gaspur water-bearing zone. The capacity of that zone to transmit water coastward is limited by its permeability, cross section, and the hydraulic gradient that can be developed. Some of the water percolates into aquifers of Pleistocene age in hydraulic continuity with the Gaspur zone, but the rate of escape in those is limited by the same physical factors. As previously discussed (p. 90), the coastward movement in certain aquifers of Pleistocene age is about as free as in the Gaspur water-bearing zone, at least to the confluence of the Rio Hondo and the Los Angeles River. Nearer the coast, however, between Compton and Los Alamitos, lagoonal deposits of low permeability form a secondary barrier within the Pleistocene deposits, between the inland aquifers and the extensively permeable Silverado water-bearing zone. This lithologic barrier is believed to cause the steepened hydraulic gradient shown on plate 6 about 2 to 3 miles north of the Development, Citizens, and Alamitos well fields of the city of Long Beach (wells 4/12–18R1 to 28H8). Thus, it restricts replenishment from the intake area to the permeable deposits proximate to the structural barrier.

To increase the replenishment in the intake area and at the same time ameliorate conditions immediately inland from the barrier faults, either of two methods could be considered.

The first, which has been suggested by others, would involve the installation of wells and pumping plants to withdraw additional water from the permeable deposits of the intake area and thus make more storage capacity available there. The water so withdrawn could be distributed to areas within the coastal plain where its use would prove most beneficial, within limits of economic feasibility. If such a plan were put in operation, doubtless those now pumping ground water from the intake area would have to be compensated for increased pumping lifts. If a pipeline were constructed to deliver water to areas nearer the coast, the draft adjacent to the barrier could be reduced in proportion to the amount of pipeline delivery; the threat of saline encroachment would diminish accordingly. At the same time, the over-all efficiency of the main coastal basin as a storage reservoir would be increased. If all unpotable wastes could be eliminated from the Los Angeles River and the Rio Hondo, their channels could be used as a conduit and a pipeline might not be necessary.

The second method, which would require more complete knowledge of the distribution of aquifers within the central coastal plain than is now available, would depend on construction of recharging wells to conduct water from the Gaspur water-bearing zone into those aquifers in the underlying Pleistocene deposits that have freest hydraulic communication with the coastward reaches of the main basin in the vicinity of Compton and Long Beach. Such wells could be perforated jointly in the Gaspur zone and in selected subjacent aquifers and would operate by gravity feed, as do certain municipal wells near Long Beach which recharge the basal water-bearing zone in the Pleistocene deposits northeast of Signal Hill (p. 99–101). They would be operated continuously or, with the installation of a control gate, could be regulated as desired. Economic justification for such wells would be contingent on their ability to increase storage within the Gaspur zone and to increase replenishment to the Pleistocene deposits coastward from the intake area. As the structure and distribution of the arterial conduits beneath the coastal plain become more fully known, it may prove feasible to construct such recharge wells.

### SPECIAL ASPECTS IN ORANGE COUNTY

In Orange County the historic decline in water levels has dewatered a large volume of water-bearing materials in the intake area and so has made a large underground reservoir available for recharge. Replenishment during the wet years has resaturated a relatively small part of the reservoir capacity of the Talbert water-bearing zone in this upper reach.

In the entire county the most effective areas for replenishment or artificial spreading are those underlain by the Talbert water-bearing zone. For example, the Santa Ana River channel east of Anaheim is ideally situated for recharging the ground-water basin because here it overlies that zone (see Poland, Piper, and others, 1956, pl. 7), and the intervening deposits are extensively permeable. Much of the natural replenishment to the ground-water basin occurs in this area where the Orange County Water District has applied methods for spreading the river flow extensively over the channel bottom.

Recharging through wells also should be most effective—in general, if those wells tap the Talbert water-bearing zone or underlying Pleistocene deposits where highly permeable. The one known instance of recharging through wells in the county has been fairly successful even though the wells do not tap the Talbert zone. Specifically, as part of a program of water salvage, six recharge wells were constructed by the county in 1936 in the SE¼ sec. 7, T. 4 S., R 10 W., west of Brookhurst Avenue and north of Lincoln Avenue. As shown by plate 6, they are about 2.5 miles southeast of Buena Park and about 0.4 mile beyond the west boundary of the Talbert zone. They range in depth from 176 to 389 feet and are perforated chiefly in deposits of Pleistocene age. Effluent from the west Anaheim storm drain is fed into these wells through a net of tiles beneath a storage basin. From their first operation in December 1936 to April 1944, a total of 3,575 acre-feet of water had been fed through the six wells.[17] The greatest monthly input was 388 acre-feet in February 1937, an average per well of 65 acre-feet per month or 2.3 acre-feet per day, equal to a constant input of 520 gpm per well. Because the water level in the well casings was maintained about at land surface during the month, it is assumed that this is the maximum rate at which water can be introduced through these wells. Although this rate is substantial, the recharge capacity probably would have been greater if the wells had been located to tap the Talbert water-bearing zone.

A barrier to movement of ground water from Santa Ana Canyon to the intake area east of Anaheim has been described on pages 109–110. It has been suggested that this barrier might feasibly be breached by recharge wells, if such an operation could be utilized to salvage additional water for the ground-water basin of Orange County.

### PRINCIPLES OF CONTROL ADJACENT TO THE COASTAL BARRIER

No matter how successful a program for basin-wide balance may be, it probably cannot maintain water levels above the sea throughout the basin at all times, especially during a protracted dry period. Water levels near the coast commonly are the first to decline below sea level because they are farthest from the sources of replenishment. Therefore, it is probably inevitable that with full utilization of the ground-water reservoir, supplementary methods of control will be necessary if saline encroachment is to be restrained. There appear to be only three possibilities for such local control: (1) maintenance of fresh-water head above sea level inland from the saline front, (2) dewatering coastward from the saline front, and (3) the construction of subsurface dikes.

*Maintenance of fresh-water head above sea level.*—In the several permeable gaps through the barrier features of the Newport–

---

[17] Records from Orange County Flood Control District.

Inglewood structural zone, the maintenance of fresh-water head at an adequate height above sea level is probably the most feasible method for control of saline encroachment. It can be accomplished either by decreasing draft or by artificial recharge or by both. Its application to specific areas is discussed on pages 150–158.

It has long been known that for coastal areas in which permeable deposits are in hydraulic contact with the ocean, fresh water moving oceanward will float on the salt water because of its lesser density. This principle was first applied to coastal areas by Badon Ghyben who made investigations in Holland in 1887 and was first published by Herzberg in 1900 after study of relations at an island off the coast of Germany. Their work has been reviewed by Brown (1925) who applied the principle in a study of the coastal ground waters of Connecticut in 1919. The work of those investigators has shown that in such coastal areas, the depth of fresh water below sea level is a function of the height of fresh water above sea level and of the specific gravity of the ocean water. In other words,

$$h=\frac{t}{g-1}$$

in which $h$ equals depth of fresh water below sea level; $t$ equals height of fresh water above sea level; and $g$ equals the specific gravity of the salt water. If the specific gravity of sea water is taken as 1.025, a value which applies commonly along the California coast, the total thickness of the floating fresh-water lens theoretically would be 41 times the height of fresh water above sea level.

For example, in a coastal deposit which is permeable to a depth of 120 feet below sea level and which has hydraulic continuity with the ocean, a fresh-water head maintained uniformly at a height of 2 feet above sea level theoretically would develop a fresh-water lens to a depth of 80 feet below sea level but salt water would occupy the bottom 40 feet of the deposit, whereas a fresh-water head maintained invariably at 4 feet above sea level theoretically would produce a complete hydraulic barrier to any inland advance of salt water.

*Dewatering coastward from the saline front.*—In the areas of coastal contamination it may not be feasible at all times to maintain water levels at a height above sea level adequate to restrain saline advance. In such instances it may prove temporarily expedient to install a row of wells coastward from and parallel to the saline front, and to pump these wells in order to develop a seaward gradient on the inland side of the well line. Such wells should be spaced closely enough to form a trough of water-level influence entirely across the gap and thus divert all saline water into the wells. Such a program would be defensive rather than remedial because it could not move the saline front coastward beyond the line of wells and as soon as they were shut down, salt water would advance inland some distance beyond that line. The extent of that advance would depend on the height to which fresh water would recover above sea level. Also, such a program would have the disadvantage of wasting fresh water with the salt water as long as the barrier wells were pumped—ultimately, conditions would only be aggravated.

*Construction of subsurface dikes.*—Landward movement of saline ground water through permeable gaps in the structural zone could be wholly prevented by constructing impermeable subsurface dikes or cutoff curtains across those gaps. To be effective, such dikes would have to be constructed through the full depth of the permeable deposits of Recent age. It would appear that the most practical method for their construction might be grouting through wells. That method has been employed in sealing permeable reaches beneath or adjacent to surface dams. However, construction of such dikes in one or more of the several gaps would be difficult and probably excessively costly. If the barrier features of the structural zone were wholly adequate within the deposits of Pleistocene age, it is possible that construction of one or more such dikes within the gaps might be justified economically. However, those barrier features are not wholly adequate as has been shown.

### CONTROL ADJACENT TO BARRIER FEATURES IN LOS ANGELES COUNTY

Along the reach of the structural zone in Los Angeles County from Dominguez Hill through Alamitos Gap, if water levels were drawn down substantially below sea level the most acute danger of saline encroachment probably would develop within the Recent deposits of the Alamitos Gap. In the Dominguez Gap, if that drawdown were intensive and protracted, concentrated saline waters eventually would advance inland beyond the structural crest. Within the Pleistocene deposits of this reach, encroachment across the Signal Hill uplift very possibly would occur locally; beneath the Alamitos Gap, however, within those deposits the barrier is probably watertight.

#### ALAMITOS GAP

In the Alamitos Gap the deposits of Recent age have a maximum inferred thickness of about 100 feet and, at least in much of the area between the Seal Beach fault and the coast, are fairly permeable throughout their depth. The shallow water table in those deposits currently is almost flat; near the coast it is believed to reflect the general hydraulic conditions to the base of the deposits. The lack of coastward flow at this time probably is due to lack of hydraulic connection with any substantial ground-water artery similar to the Gaspur and Talbert water-bearing zones.

Saline encroachment already has reached several hundred feet beyond the Seal Beach fault, at least to active well 5/12–11G1. If a substantial decline in water level now should ensue, this encroachment doubtless would advance inland and ultimately probably would invade the underlying deposits of Pleistocene age. Those deposits may now be contaminated in the vicinity of well 11G1.

Additional landward encroachment beyond the Seal Beach fault can be greatly restrained and possibly wholly prevented if water levels in the Recent deposits can be maintained consistently at least 4 feet above sea level along the fault. Two general procedures seem potentially effective—first, to regulate withdrawal from the deposits of Recent age adjacent to, and possibly as much as a mile inland from the Seal Beach fault; or, second, at such times as this regulation does not suffice to maintain water levels at a height of 4 feet above sea level at the fault, to recharge artificially these deposits of Recent age in order to sustain the required protective head at the fault. Possibly this could be done in part through trenches or pits excavated at land surface but in much of the gap it probably could be accomplished more effectively through recharging wells. Existing wells which are near the fault and which are producing part of their water from the deposits of Recent age might be utilized in such a program. If water for replenishment were available only from a local ground-water source, it probably could be taken from the San Pedro formation beneath the inland flank of Alamitos Heights or beneath the inland part of Alamitos Gap without affecting water levels in the Recent deposits adjacent to the Seal Beach fault. Because the deposits of Recent age are not highly permeable and are chiefly sand, it is believed that a recharge supply of a few hundred gallons per minute would be ample to maintain the required head and to develop a protective coastward gradient even in dry periods, if it could be fairly evenly distributed across the gap. Whether or not recharging were found necessary, supplementary observation wells probably would prove advantageous in order to determine the effectiveness of the program by measurement of water levels and by sampling for chemical analysis.

Saline encroachment through the gap probably could be effectively restrained by construction of a subsurface dike to the base of the deposits of Recent age. In the Alamitos Gap, such a dike would be about 2 miles long and presumably about 100 feet deep. Thus, its construction would be very costly and probably far greater than the cost of maintaining a hydraulic barrier as just outlined.

### DOMINGUEZ GAP

In the Dominguez Gap the crest of the structural zone is about 6 miles from the coast and nearly 4 miles from the landward front of ocean-water contamination. However, in this gap an inland body of contaminated water extends inland for about a mile beyond the fault but under the prevailing hydraulic gradient is being displaced southward. Thus, under present hydraulic conditions that contaminated body is maintained across the crest of the structural zone—the Cherry-Hill fault—only by continued contamination from land surface or from the overlying semiperched water body.

At the structural crest the Gaspur water-bearing zone is 1.2 miles wide and about 60 feet thick. For the past 10 years the average hydraulic gradient for that zone across the crestal fault has been about 12 feet per mile (pls. 5 and 6). If the average permeability coefficient is assumed to be 3,000 meinzer units, the quantity of water currently transmitted coastward through the Gaspur zone and across the crestal fault is about 4 cfs, about 2,600,000 gpd, or about 2,900 acre-feet per year. None of that water now reaches the ocean and little if any has escaped to the ocean since the late twenties.

As stated earlier, further northward extension of the inland body of contaminated water in the Dominguez Gap is possible only if (1) contaminating waters percolate to the Gaspur zone from an overlying or adjacent source inland from the structural crest or (2) water levels in the Gaspur zone are drawn down below those of 1936 for a substantial period of time. The latter possibility is unlikely, first because natural recharge to the Gaspur zone in the intake area is supplemented by operation of the spreading basins, and second because coastward from the crestal fault the draft from the Gaspur zone is now much less than in the early and middle thirties.

Therefore, control of contamination by artificial hydraulic methods appears wholly unnecessary, either now or in the immediate future. For the present, the greatest benefit would be derived if the overlying sources of contamination could be eliminated and if the waters of the Los Angeles River and Compton Creek were kept sufficiently pure that the small amount of recharging they accomplish in their lower reaches would be beneficial.

### SIGNAL HILL UPLIFT

The well fields along the inland flank of the Signal Hill uplift have a fair measure of protection from inland advance of saline waters owing to structural and lithologic barrier features within and along the uplift. However, those features probably are not wholly watertight against differential heads of several tens of feet. Therefore, for the future protection of those well fields and of the extensive water-bearing zones inland from the uplift, it would appear advisable to maintain water levels in the Silverado water-bearing zone so that they do not decline appreciably below sea level. Maintenance of these levels above or near sea level can be effected most easily by regulating withdrawal. For example, the hydraulic conditions developed in the Alamitos, Citizens, and Development well fields about from 1928 through 1932 are believed to have been hazardous (pls. 9, 10). The recovery in water level that was accomplished in 1932 and 1933 by decreasing the draft from those fields demonstrates the effectiveness of regulated withdrawal, especially as that recovery occurred during a period of subnormal rainfall.

### CONTROL ADJACENT TO BARRIER FEATURES IN ORANGE COUNTY

Along the reach of the structural zone in Orange County, lowering of water levels to a substantial distance below sea level would accelerate the advance of saline encroachment in two existing areas of contamination and probably would induce contamination in two additional areas, as follows:

1. In the Santa Ana Gap, saline encroachment now (1945) extending inland about to Atlanta Avenue would resume its inland march and within about 1 mile would pass beyond the impermeable lip of non-water-bearing rocks that underlies the Talbert zone at the present front.
2. On the Huntington Beach Mesa, the saline contamination which now underlies about 2,100 acres doubtless would advance inland. That contamination now is confined largely if not wholly to the upper and middle water-bearing zones beneath the mesa, but surely would invade the lower or main water-bearing zone unless full precautionary measures were taken (Piper, Garrett, and others, 1953, p. 152–154).
3. In the Bolsa Gap, within a few years oceanic contamination possibly would appear in wells tapping the "80-foot gravel" south of Slater Avenue.
4. Also, along the reach of Pleistocene deposits which are at land surface on Bolsa Chica Mesa and Landing Hill and which are near land surface across the Sunset Gap, saline contamination presumably would move landward locally through the barrier features.

### SANTA ANA GAP

It is of critical importance to the ground-water supply of Orange County to restrain saline waters from advancing far beyond their present front in the Santa Ana Gap. There appear to be only three methods for preventing ultimate movement of this front to and beyond the partial barrier of impermeable rocks in the core of the structural zone and thence into water-bearing beds beneath the Downey plain: (1) by maintaining a head of fresh water about 5 feet above sea level just inland from the present front of contamination; (2) by installing a line of barrier wells coastward from and parallel to the saline front and by pumping those wells in order to develop a seaward gradient along their inland side; or (3) by constructing an impermeable subsurface dike or cutoff curtain across the gap in the Talbert zone.

In order to maintain a fresh-water head about 5 feet above sea level just inland from the front of contamination, presumably the most economical initial procedure would be to reduce draft locally within the gap. If this reduction in draft was not effective in maintaining water levels at the required height, the Talbert water-bearing zone probably could be recharged through a group of wells alined across the gap. It is believed that these wells could be installed to recharge at somewhat greater capacity than the recharge wells now operated by the Flood Control District southeast of Buena Park (p. 148). Possibly several existing wells could be utilized in such a program.

The front of saline contamination in 1944 was about 400 feet south of the intersection of Bushard Street and Atlanta Avenue (Piper, Garrett, and others, 1953, pl. 11). If the fresh-water head there could be maintained uniformly at 5 feet above sea level, the salt-water contact theoretically would be depressed to 200 feet below sea level and, because underlying impermeable deposits there begin 130 feet below sea level, that contact eventually would be driven oceanward beyond the master fault. Coastward from that fault, permeable deposits extend to a depth of about 300 feet below sea level and there the fresh-water head would have to be maintained at least 8 feet above sea level to expel the saline waters. It is doubted that a fresh-water head of that magnitude would be practical so close to the coast.

The quantity of recharge water necessary to maintain a fresh-water head of 5 feet above sea level at or near the present salt-water front basically would depend on the general pressure head within the Talbert zone at the time such recharging was undertaken. Subsequent changes in that general level during recharging operations would modify requirements. For use in establishing the general order of the quantity of recharge water that might be required, an estimate of the quantity of water that would move through the Talbert zone under a particular gradient is of interest. Specifically, at the master fault the width of the gap is 2.6 miles and the average thickness of the Talbert zone is about 60 feet. If the permeability of the zone is taken as 3,000 (meinzer units), the quantity of water moving under a gradient of 1 foot per mile would be 468,000 gpd, about 330 gpm, or 0.74 cfs. If recharging were necessary, a gradient would be built up both landward and seaward when water was introduced to wells. Thus, for each foot per mile of gradient so developed, the quantity of recharge water required probably would be about 1.5 cfs.

There are several possibilities for a source of supply, first, it might be feasible to reclaim water from the Orange County outfall sewer, or to obtain water from the Metropolitan Water District. Another potential source, which might prove to be the most economical, is the semiperched water body inland from the gap. The chemical quality of that water now is being investigated by the Orange County Water District. If it should prove to be of satisfactory quality locally, it could be gathered and conducted by gravity to areas in need of water or to the line of recharging wells. More water would be available from this source in winter than in summer, but it is possible that the summer yield would be sufficient to accomplish the desired result. If not, as a third and last resort, water might be withdrawn from remote wells, keeping in mind that at least half of the water so used would not be wasted but would in effect be reintroduced to the usable supply. It would be undesirable to pump ground water from water-bearing beds in close hydraulic connection with the critical reach of the Talbert zone. Water might be withdrawn from the Talbert zone farther inland, or for a time could be withdrawn from the principal water-bearing zone beneath Newport Mesa without appreciably depressing water levels in the Santa Ana Gap (see p. 109). If an additional supply of water can be made available to Santa Ana Gap, presumably that supply could be utilized most economically as a substitute for water now pumped from wells, provided that (1) the quality was satisfactory, and (2) the water was available at the time of need. Otherwise, recharging through wells might be the most effective procedure.

Construction of a line of barrier wells coastward from the salt-water front in the Santa Ana Gap and pumping those wells so heavily as to develop a seaward gradient along the inland side of the line is an alternative means of control. It is considered to be a much less satisfactory method, chiefly because it would of necessity waste fresh water which would be discharged seaward as part of the effluent. The number and spacing of the wells would depend upon the drawdown and the reach of the cones of pressure relief. If constructed, such a line of barrier wells probably would be placed coastward from the master fault where the Talbert water-bearing zone is underlain by water-bearing beds of Pleistocene age to a depth of about 300 feet below land surface. However, the dewatering wells would not have to tap the Pleistocene deposits to be effective; they would be less costly if they tapped only the overlying Talbert zone, which extends to a depth of about 150 feet below land surface.

If construction of an impermeable subsurface dike or cutoff curtain across the Santa Ana Gap were considered, the most effective location for the least costly structure would be immediately inland from the master fault where the Talbert water-bearing zone rests on impermeable deposits across a substantial part of the gap. If placed there, such a dike would be about 2.5 miles long and probably about 150 feet in average depth in order to reach the impermeable rocks in the core of the structural zone. In the southeastern part of the gap, east of the Wright Street fault, its depth would be substantially greater, about 300 feet. Near the Huntington Beach Mesa also, its depth might be nearly as great. It is believed that even if such a dike were constructed by grouting through wells, presumably the least costly and simplest method, that cost probably would be excessive.

### HUNTINGTON BEACH MESA

The conditions of saline encroachment on Huntington Beach Mesa have been discussed in detail in the report on chemical character (Piper, Garrett, and others, 1953, p. 129–154), which has shown saline waters to be confined largely if not wholly to the upper and middle water-bearing zones at the present time (1945). It is highly desirable to restrain that contamination from invading the lower or main water-bearing zone and to restrict the lateral extension of contamination in the upper and middle zones as fully as possible. Suggested methods for well repair and proper construction to protect the lower zone have been outlined (Piper, Garrett, and others, 1953, p. 152–154). To restrict lateral extension in the upper and middle zones and to protect the lower zone, only one general method appears feasible for supplementing the program of well repair previously cited. That method is to maintain water levels in all three zones as far above sea level as is practicable, by regulating the pumping draft. If the water levels in the upper and middle zones can be sustained sufficiently far above sea level to maintain a coastward gradient or at least to prevent a landward gradient, the salt water now accumulated beneath the mesa will not disperse much farther inland. Also, if the water level in the lower and main water-bearing zone can be sustained above those of the upper and middle zones, as at present, it will not be possible for saline water to enter that zone from the overlying zones even through wells which are perforated jointly in the several zones (p. 138.) However, if it becomes impossible to maintain levels above sea level in all three zones, it would be preferable to reduce the draft from the upper and middle zones to a minimum within and near the area now contaminated, and to draw water wholly from the lower zone—provided that all casings perforated in the lower zone are kept watertight opposite the upper and middle zones.

### BOLSA GAP

In the Bolsa Gap the Recent deposits are about 80 feet thick and in the bottom 20 feet contain the permeable "80-foot gravel." So far as known, but with the possible exception of well 5/11-16H1, oceanic contamination has not reached any wells inland from the master fault.

Periodic water-level measurements are available for only one well tapping the deposits of Recent age in the Bolsa Gap—No. 5/11-27H1. That well is 2.5 miles from the ocean. As shown by monthly measurements taken by the Orange County Flood Control District, from 1931 into 1942 its average water level was 3.1 feet above sea level. The lowest level was 3.3 feet below sea level in late summer of 1936. If the water-level record for this well is representative for the gap, it can be inferred that the pressure head in the "80-foot gravel" was above sea level throughout most of the low-water period of the early thirties. Thus, if another similar period of lowered water levels should develop, encroachment by ocean water presumably would be slow.

Such encroachment could be prevented by maintaining the pressure level in the "80-foot gravel" as much as 3 feet above sea level at the master fault. As in the Santa Ana Gap, this could be accomplished by regulating withdrawal from the "80-foot gravel" and, as necessary, by recharging through wells tapping that zone.

Because the "80-foot gravel" is only about 20 feet thick, the quantity of recharge water needed to maintain a barrier head would not be large. At the master fault the "80-foot gravel" is about 1.5 miles wide. If it is assumed that the permeability of that gravel is 3,000 (meinzer units), the quantity of water moving under a gradient of 1 foot per mile would be 90,000 gpd. Thus, it would require about 180,000 gpd to maintain a gradient of 1 foot per mile sloping both landward and seaward away from the recharge wells. However, the differential head required would depend not only on the stage of the pressure surface when recharging operations started, but also on the change in water level inland from these wells with lapse of time.

For such recharge operations it is possible that, except when the water level declined to or below that of 1936, water could be obtained by tapping the underlying aquifers of Pleistocene age. As noted elsewhere (p. 136), except in the low-water year 1936 well 5/11–28A1 had sufficient artesian pressure to flow throughout the thirties, at least in the winter months. Thus, if the casing of well 5/11–28A1 had been perforated in the "80-foot gravel" as well as in the San Pedro formation, it would have recharged the "80-foot gravel" at least intermittently during all years except 1936.

It has been suggested elsewhere (Piper, Garrett, and others, 1953, p. 202) that from two to four observation wells be drilled to the "80-foot gravel" in the strip of land immediately inland from the master fault. Samples taken from these wells would indicate whether oceanic contamination extended inland across this master fault, and whether a program of maintaining a barrier head in the "80-foot gravel" would be of immediate concern. If and when such a program is found necessary, additional observation wells probably would prove advantageous to furnish data on the rate of development and extent of the artificial hydraulic barrier.

If construction of an impermeable subsurface dike across the Bolsa Gap were to be considered, the most effective location would be along the master fault. Such a dike would be 1.5 miles long and about 85 feet deep on the average, in order to seal the "80-foot gravel." The cost probably would far exceed that of controlling salt-water invasion by maintaining water levels a few feet above sea level.

### LANDING HILL TO BOLSA CHICA MESA

It has been concluded that the deposits of Pleistocene age within the reach from Landing Hill to the Bolsa Chica Mesa, both inclusive, are nearly sealed by the barrier features of the structural zone against differential heads occurring to date. However, leaks exist on Landing Hill and near Hog Island and those leaks have developed or persisted with differential pressures of not more than 10 to 15 feet. Thus, it would seem imprudent to allow water levels to decline far below sea level on the inland side of the Newport–Inglewood uplift. Within this reach, systematic regulation of draft would appear to be the only practical means of control. Whether such a program would achieve success in maintaining water levels above or near sea level would depend in large measure upon the success achieved in a basin-wide program for balancing supply and demand. Even by rigorous control of local draft, water levels near the uplift cannot be maintained close to sea level if water levels several miles inland are drawn down far below sea level.

## REFERENCES

Baumann, Paul, and Laverty, F. B., 1930–44, Annual report on hydrologic data: Los Angeles County Flood Control District [published in separate volumes for each water year].

Blakeley, L. E., 1945, The rehabilitation, cleaning, and sterilization of water wells: Am. Water Works Assoc. Jour., v. 37, p. 111.

Blaney, H. F., and Huberty, M. R., 1930, Cost of irrigation water in California: California Dept. Public Works, Div. Water Resources Bull. 36.

Brown, J. S., 1925, A study of coastal ground waters with special reference to Connecticut: U. S. Geol. Survey Water-Supply Paper 537, 101 p.

Brown, W. M., 1944, History and annual report, 1943–44: City of Long Beach Water Dept.

California Division Water Resources, 1930, Rainfall penetration and consumptive use of water in Santa Ana River Valley and coastal plain: California Dept. Public Works, Div. Water Resources Bull. 33.

——— 1933, Value and cost of water for irrigation in coastal plain of southern California: California Dept. Public Works, Div. Water Resources Bull. 43.

California Division Water Rights, 1929, San Gabriel investigation: California Dept. Public Works, Div. Water Rights Bull. 6.

Conkling, Harold, 1927, San Gabriel investigation, report for the period July 1, 1932 to September 30, 1926: California Dept. Public Works, Div. Water Rights Bull. 5.

——— 1929, San Gabriel investigation, analysis and conclusions: California Dept. Public Works, Div. Water Rights Bull. 7.

Ebert, F. C., 1921 Records of water levels in wells in southern California: U. S. Geol. Survey Water-Supply Paper 468.

Eckis, Rollin, 1934, South Coastal Basin investigation, Geology and groundwater storage capacity of valley fill: California Dept. Public Works, Div. Water Resources Bull. 45.

Elliott, G. A., Etcheverry, B. A., and Means, T. H., 1931, Control and conservation of flood waters in Orange County, California: Orange County Flood Control District, pl. 5.

Gleason, G. B., 1932, South Coastal Basin investigation, records of groundwater levels at wells: California Dept. Public Works, Div. Water Resources, Bull. 39, 590 p. Also, annual supplements [mimeographed], as follows: Bull. 39–A, for 1932; Bull. 39–B, for 1933; Bull. 39–C, for 1934; Bull. 39–D, for 1935; Bull. 39–E, for 1936; Bull. 39–F, for 1937; Bull. 39–G, for 1938; Bull. 39–H, for 1939; Bull. 39–I, for 1940; Bull. 39–J, for 1941.

——— 1945, Present overdraft on and safe yield from the ground water of the coastal plain of Orange County: California Dept. Public Works, Div. Water Resources, June 1945, *in* Statement regarding the present condition of the underground water basin of Orange County: Orange County Water District, pls. 4 and 5.

Grant, U. S., 1944, Subsidence and elevation in the Los Angeles region: Science in the University, Univ. California Press, Berkeley and Los Angeles, p. 129–158.

Jordan, L. W., Keim, P. E., and Thayer, W. N. 1939, Report on spreading grounds below Whittier Narrows Rio Hondo spreading operations 1938: Los Angeles County Flood Control District, open-file rept., 50 p. maps, profiles.

Jordan, L. W., and Thayer, W. N., 1940, Report on the San Gabriel coastal plain spreading test of 1939: Los Angeles County Flood Control District open-file rept., 73 p.

La Rocque, G. A., Jr., 1941 Fluctuations of water level in wells in the Los Angeles Basin, California, during five strong earthquakes 1933–1940: Am. Geophys. Union Trans., p. 374–386.

Livingston, Penn, and Lynch, Walter, 1937, Methods of locating salt-water leaks in water wells: U. S. Geol. Survey Water-Supply Paper 796–A, p. 1–20.

Meinzer, O. E., 1923, Outline of ground-water hydrology with definitions: U. S. Geol. Survey Water-Supply Paper 494.

Meinzer, O. E., Wenzel, L. K., and others, 1944, Water levels and artesian pressure in observation wells in the United States in 1942, pt. 6, Southwestern states and Territory of Hawaii: U. S. Geol. Survey Water-Supply Paper 949.

——— 1945, Water levels and artesian pressure in observation wells in the United States in 1943, pt. 6, Southwestern states and Territory of Hawaii: U. S. Geol. Survey Water-Supply Paper 991.

Mendenhall, W. C., 1905a, Development of underground waters in the eastern coastal-plain region of southern California: U. S. Geol. Survey Water-Supply Paper 137, 140 p.

——— 1905b, Development of underground waters in the central coastal-plain region of southern California: U. S. Geol. Survey Water-Supply Paper 138, 162 p.

——— 1905c, Development of underground waters in the western coastal-plain region of southern California: U. S. Geol. Survey Water-Supply Paper 139, 105 p.

Orange County Water District, 1945, Proposed policy for balancing the present supply and draft on the Orange County underground water basin, by the Directors of the Orange County Water District, 4 p.

Piper, A. M., Garrett, A. A., and others, 1953, Native and contaminated ground waters in the Long Beach–Santa Ana area, California: U. S. Geol. Survey Water-Supply Paper 1136, 320 p.

Piper, A. M., Poland, J. F., and others, 1942, Index of factual data from water wells on a part of the coastal plain in Los Angeles and Orange Counties, California: U. S. Geol. Survey open-file rep., 298 p.

Piper, A. M., Poland, J. F., and others, 1943, Progress report on the cooperative ground-water investigation in the Long Beach–Santa Ana area, California: U. S. Geol. Survey open-file rep., 46 p.

Poland, J. F., Garrett, A. A., and Sinnott, Allen, 1944, Progress report on the cooperative ground-water investigation in the Torrance–Santa Monica area, California: U. S. Geol. Survey open-file rep., 53 p.

Poland, J. F., and Piper, A. M., and others, 1956, Ground-water geology of the coastal zone, Long Beach–Santa Ana area, California: U. S. Geol. Survey Water-Supply Paper 1109, 162 p.

Post, W. S., 1928, Santa Ana Investigation, flood control and conservation: California Dept. Public Works, Div. of Engr. and Irr., Bull. 19, 357 p.

Sayre, A. N. and others, 1947, Water levels and artesian pressure in observation wells in the United States in 1944, pt. 6, Southwestern states and Territory of Hawaii: U. S. Geol. Survey Water-Supply Paper 1021.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials with special reference to discharging-well methods: U. S. Geol. Survey Water-Supply Paper 887, 192 p.

Anonymous, 1939, Report of Orange County Water Committee: Board of Supervisors for Orange County, duplicated report, 24 p.

## DESCRIPTION OF WATER WELLS

Table 29 of this report consists of brief tabulated descriptions of most of the active or potentially active water wells, and of those abandoned water wells for which there are available data pertinent to the objectives of the investigation and of relatively few selected oil wells for which there are data on the chemical character of the ground waters. All wells described are in the coastal zone of the Long Beach-Santa Ana area. Most of the descriptive data were taken by the Geological Survey in a field canvass of water wells in the coastal zone, largely from December 1940 to June 1941; these data have been supplemented by the antecedent information which was made available to the Geological Survey by many other agencies, public and private, and whose scope is indicated in the index to data heretofore released (Piper, Poland, and others, 1942, p. 19–218). In addition to the descriptions to which reference has been made, the report also describes 62 shallow observation wells and 6 deep observation wells constructed by the Geological Survey to furnish critical information for the cooperative investigation.

With respect to the descriptions of the wells, certain features of the form of tabulation are worthy of particular comment. Thus, all wells are listed in order of "USGS number," which indicates the location in the area as explained elsewhere (Poland, Piper, and others, 1953, p. 7–8). Those wells for which antecedent data were made available to the Geological Survey also have "serial" and "location" numbers ascribed by other agencies; cross references to these additional numbers are also contained in the index to data (Piper, Poland, and others, 1942, p. 5–7, 19–218).

The table lists the owner or tenant of the land on which each well is located; however, certain wells have been drilled and are operated under an easement or other authority from the legal owner of the land whose name is entered in the table. For example, wells 5/11–18N1 and 5/11–18P1 are on land owned by the Alamitos Land Co., but were drilled by the Geological Survey as observation wells to furnish critical hydrologic information.

The table indicates the kind or kinds of hydrologic data available for the several wells, including both the data taken by the Geological Survey and the antecedent data by other agencies. For certain wells the scope of the data so indicated may differ from that shown in the index heretofore released, to the extent that observations were started after the index was released. These data include records of water levels, chemical analyses of the water, and drillers' logs.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*

Altitude: Land-surface altitude, from topographic maps.
Depth of well: Indicated in whole feet; those to a tenth of foot are measured by the Geological Survey.
Type of pump: Al, air lift; C, centrifugal; J, jet-centrifugal; P, lift or jack (plunger); T, deep-well turbine.
Type of power: E, electric motor; I, internal-combustion engine; M, manual; S, steam engine; W, windmill.
Use of well: A, abandoned and generally destroyed; Dom, domestic; Ind, industrial; Irr, irrigation; Obs, observation; PS, public supply.

Data available: C, three or less "complete" chemical analyses; Cr, four or more "complete" chemical analyses; Cp, "partial" chemical analyses only; Cpr, four or more "partial analyses; L, driller's log or record of cuttings; W, miscellaneous water-level measurements, nonperiodic; Wd, water-level measurements discontinued, formerly periodic; Wm, periodic measurements at monthly or less frequent intervals; Ww, weekly periodic measurements regardless of term of record; Wr, water-level recorder operated currently; Wrd, water-level recorder discontinued.

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 3 S., R. 12 W. | | | | | | |
| 3/12-31C1 | City of Long Beach | 57 | | | | | | | A | W | |
| 31C2 | Mrs. L. Handrup | 56 | | 3 | | | | P, W | Stock | W | |
| 31C3 | Mrs. H. Klippel | 54 | 86 | 2 | | | | P, W | Stock | Cp | |
| 31C4 | do | 54 | 98 | 12 | | | Gravel | T | Irr | | |
| 31D1 | Frank Stimson | 57 | 175 | 12 | | | | | Irr | W | |
| 31D2 | do | 57 | 130 | 6 | | | | C, E | Dom, Irr. | | |
| 31E1 | North Long Beach Extension Water Co., Inc. | 54 | 907 | 12 | 550 | 357 | Gravel and sand | | | L, W | Well reported measured 749 feet deep. Casing perforated, 660–749 ft. |
| 31E2 | Mrs. Goodfellow | 54 | 935 | 12 | 701 | 232 | Gravel | | Obs | L, Wr | |
| 31E3 | Burrows Mortgage Co. | 53 | 907 | 12–10 | 705 | 202 | do | T, E | PS | C, L | |
| 31E4 | North Long Beach Extension Water Co., Inc. | 54 | 335 | 12 | 290 | 10 | do | T, E | PS | Cp, L | |
| 31G1 | City of Long Beach, North Long Beach well 1. | 53 | 1,000 | 16 | 316 | 8 | Gravel and sand | T, E | PS | Cr, L, Ww. | |
| | | | | | 368 | 30 | Gravel | | | | |
| | | | | | 790 | 30 | Sand and shells | | | | |
| | | | | | 966 | 14 | Sand and gravel | | | | |
| 31G2 | Piedmont Heights Water Club. | 53 | 75 | 5 | | | | C, E | PS | Cp, W | |
| 31G3 | Glenn Lucas | 52 | | 3 | | | | P, W | Dom | Cp | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31H1 | Cherryville Tract Water Co. | 52 | 90 | 4 | | | | T, E. | PS | Cp | |
| 31K1 | | 51 | 400 | 4 | | | | | A | Wd | |
| 31M1 | F. E. DeKay | 53 | 682 | 12 | 267 | 73 | Sand and gravel | | A | L, W | Casing perforated at 320–340 ft. |
| 31R1 | Mrs. E. Emery | 50 | 90 | 4 | | | | C | | | |
| | | | | | T. 3 S., R. 13 W. | | | | | | |
| 3/13-31A1 | Ethel McClain | 30 | 200 | 6 | | | | P, E. | Dom | Cp | |
| 31B1 | Ella Hitchcock | 26 | 25 | | | | | | | Cp, W. | |
| 31B2 | State of California | 26 | 700 | | | | | | | | |
| 31B3 | Ralph Marsh | 26 | 65 | 2 | | | | E. | Dom | Cp | |
| 31B4 | A. Herzog | 27 | 300 | | | | | P. | Dom | Cp | |
| 31B5 | Ella Hitchcock | 26 | 79 | 3 | | | | P, W. | Dom, Irr. | Cp, W. | |
| 31C1 | M. Takeshita | 27 | | | | | | T, E. | Dom, Irr. | Cp | |
| 31C2 | Gunderson | 27 | 650 | 12 | | | | T, E. | Dom, Irr. | | |
| 31F1 | Nancy Coleman | 27 | 159 | 6 | | | | P, W. | Dom, Irr. | Cp | |
| 31F2 | J. E. Rochon | 27 | | | | | | T, E. | Dom | Cp | |
| 31F3 | | 30 | 30.0 | | | | | | | Cp, W. | Pit with curbing 4 ft. sq. |
| 31F4 | J. J. Bruckshaw | 30 | | | | | | T, E. | Dom | Cp | |
| 31H1 | J. H. Bush | 26 | 30 | | 8 | 22 | Gravel and sand | T. | Irr. | L. | |
| 31H2 | do | 26 | | | | | | P, E. | Dom, Stock. | Cp | |
| 31H3 | Clyde E. Sheets | 26 | | 3 | | | | P, E. | Dom, Irr. | Cp | |
| 31H4 | Joe Claro | 26 | 50 | 3 | | | | P, W. | Dom | C. | |
| 31H5 | Bernardino | 26 | | 2 | | | | P, E. | Dom | Cp | |
| 31L1 | Mrs. Woods | 31 | 700 | 10 | | | | T, E. | Irr. | Cp, W. | |
| 31L2 | Charles Anderson | 31 | 50 | 6 | | | | P, W. | Dom | Cp | |
| 31L3 | Bert B. Bynum | 31 | 70 | 6 | | | | P, E. | Dom | Cp, W. | |
| 32C1 | John Larronde | 32 | 275 | | | | | P, E. | Dom, Stock, Irr. | Cp, Wm. | |
| 32C2 | do | 35 | | 8 | | | | T, E. | Ind. | Cp | |
| 32D1 | J. Segovia | 30 | | 5 | | | | P, I. | Dom | | |
| 32F1 | L. B. Chase Oil Co. | 33 | | | | | | | Obs. | L, Wm. | Abandoned oil well. |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 3 S., R. 13 W. —Continued | | | | | | |
| 3/13-32F2 | John Larronde | 49 | 543.0 | 12 | ........ | ........ | ........ | ........ | Obs. | Wm. | |
| 32F3 | Hata | 43 | 550 | 10 | ........ | ........ | ........ | T, E. | Dom, Irr. | C, Wd. | |
| 32F4 | ........ | 46 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | C. | |
| 32F5 | Hata | 42 | 1,500 | 10 | ........ | ........ | ........ | ........ | A. | ........ | |
| 32F6 | Ed Cost | 43 | 662 | 10 | 530 | 130 | Sand and gravel | T, E. | Irr. | L. | |
| 33A1 | Union Oil Co. | 146 | 250 | ........ | ........ | ........ | ........ | T. | Ind. | Wm. | |
| 33A2 | .....do | 146 | 350 | ........ | ........ | ........ | ........ | T. | Ind. | Cp, Cpr. | |
| 33B1 | I. W. Hellman Estate | 153 | 375 | 16 | ........ | ........ | ........ | T, E. | Irr. | Wm. | |
| 33E1 | Union Oil Co. | 115 | 700 | 12-10 | 272<br>410 | 30<br>70 | Gravel<br>Coarse sand | ........ | ........ | C, L, Wd. | Casing perforated at 272-302 and 450-480 ft. |
| 34B1 | Dominguez Estate Co. | 115 | ........ | ........ | ........ | ........ | ........ | T, E. | Dom, Irr. | Cp. | |
| 34D1 | I. W. Hellman Estate | 125 | 500 | 16 | ........ | ........ | ........ | T, E. | Irr. | L, Wm. | |
| 34D2 | G. D. Hufford and Morrell. | 125 | 374 | 16 | ........ | ........ | ........ | ........ | Obs. | C, Wm, Cp. | Casing perforated at 335-360 ft. |
| 35A1 | Carson Estate Co. | 53 | 100 | ........ | ........ | ........ | ........ | T, E. | Irr. | W. | |
| 35B1 | H. Y. Sasaki | 57 | ........ | ........ | ........ | ........ | ........ | T, E. | Irr. | ........ | |
| 35B2 | .....do | 56 | 174.0 | 12 | ........ | ........ | ........ | ........ | Obs. | Wm. | |
| 35B3 | .....do | 56 | 92 | ........ | ........ | ........ | ........ | T, E. | ........ | Cp. | |
| 35B4 | Dominguez Estate Co. | 56 | 140 | ........ | ........ | ........ | ........ | ........ | A. | W. | |
| 35C1 | Carson Estate Co. | 57 | ........ | 8 | ........ | ........ | ........ | T, E. | ........ | Wd. | |
| 35C2 | .....do | 57 | 595.9 | 8? | ........ | ........ | ........ | ........ | Obs. | Wm. | |
| 35E1 | Dominguez Estate Co. | 74 | 400 | 6 | ........ | ........ | ........ | P, E. | ........ | ........ | |
| 35G1 | Carson Estate Co. | 52 | ........ | 10 | ........ | ........ | ........ | T, E. | Irr. | Wm. | |
| 35H1 | .....do | 51 | 60 | 3-1½ | ........ | ........ | ........ | P, W. | Dom, Stock. | Cpr. | |
| 35J1 | Dominguez Estate Co. | 47 | ........ | 10-8 | ........ | ........ | ........ | C, I. | Irr, Obs. | Wm. | |
| 35J2 | .....do | 47 | ........ | 10-8 | ........ | ........ | ........ | T, E. | Dom, Irr. | Cp. | |
| 35K1 | .....do | 49 | 175 | 12-10 | ........ | ........ | ........ | T, E. | ........ | W. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35L1 | .....do........ | 51 | 154 | 12-10 | 86 | 35 | Gravel........ | ........ | ........ | L........ | Casing perforated at 95-122 ft. |
| 35M1 | Pacific Electric Railway Co. | 49 | 129 | 7 | 60 | 41 | Gravel and Sand........ | ........ | A........ | L, Wd.... | Casing perforated at 82-100 ft. |
| 35N1 | Dominguez Estate Co.... | 47 | ........ | ........ | ........ | ........ | ........ | P, E..... | Dom, Ind.... | Cpr...... | |
| 36A1 | Carson Estate Co........ | 57 | 350 | 12 | ........ | ........ | ........ | T, I..... | Irr........ | C........ | |
| 36A2 | ........ | 57 | 18 | 6 | ........ | ........ | ........ | ........ | A........ | Cpr, W.. | |
| 36B1 | Southern California Edison Co., Ltd. | 56 | ........ | ........ | ........ | ........ | ........ | T, E..... | Irr........ | Wm...... | |
| 36B2 | .....do........ | 54 | 260 | ........ | 124 | 6 | ........ | T, E..... | Irr........ | L........ | Casing perforated at 124-130 ft. |
| 36C1 | ........ | 56 | ........ | 12 | ........ | ........ | ........ | ........ | ........ | W........ | |
| 36D1 | City of Long Beach, North Long Beach well 2. | 56 | 200 | ........ | ........ | ........ | ........ | T, E..... | PS........ | Cr, Ww.. | |
| 36G1 | City of Long Beach...... | 51 | 29 | 6 | ........ | ........ | ........ | ........ | A........ | Cp, W.... | |
| 36J1 | J. Imseng........ | 52 | ........ | 10 | ........ | ........ | ........ | T, E..... | Irr........ | ........ | |
| 36P1 | City of Long Beach...... | 46 | 30 | 6 | ........ | ........ | ........ | ........ | A........ | Cp, W.... | |
| 36P2 | .....do........ | 44 | 21 | 6 | ........ | ........ | ........ | ........ | A........ | Cp, W.... | |
| 36P3 | .....do........ | 44 | 15 | 6 | ........ | ........ | ........ | ........ | A........ | Cp, W.... | |
| 36Q1 | ........ | 50 | 15 | ........ | ........ | ........ | ........ | ........ | ........ | C........ | |
| 36Q2 | North Long Beach Extension Water Co., Inc. | 50 | 190 | 8 | ........ | ........ | Gravel........ | T, E..... | Dom........ | Cp....... | Casing perforated near bottom. |

Wells in T. 4 S., R. 11 W.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/11-19A1 | ........ | 29 | 5 | ........ | ........ | ........ | ........ | ........ | ........ | C........ | |
| 19A2 | E. Vandemaele........ | 28 | 204 | 6 | ........ | ........ | ........ | T, E..... | Dom, Stock. | Cp....... | |
| 19B1 | Jotham Bixby Co........ | 27 | 475 | 4 | ........ | ........ | ........ | ........ | Obs........ | Wm...... | Casing perforated at 157-171 ft. |
| 19B2 | .....do........ | 27 | 253 | 5 | 157<br>241 | 14<br>12 | ........ | P, E..... | Dom, Stock. | Cp, W.... | |
| 19H1 | Bixby Land Co........ | 27 | ........ | 4 | ........ | ........ | ........ | ........ | A........ | Wd....... | |
| 19H2 | .....do........ | 27 | 300 | 3 | ........ | ........ | ........ | Al, E.... | Stock....... | Cp, W.... | |
| 19J1 | Roy Visbeck........ | 27 | 532.8 | 12 | 505 | 75 | Gravel and sand........ | T, E..... | Obs........ | Cp, L, Wm. | Casing perforated at 518-532 and 548-556 ft. |
| 19J2 | .....do........ | 27 | 600 | 12 | ........ | ........ | ........ | T, E..... | ........ | ........ | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | | | **T. 4 S., R. 11 W.—Continued** | | | | |
| | Los Alamitos Sugar Co.: | | | | | | | | | | |
| 4/11-19K1 | Well 6 | 26 | 448 | 12 | 440 | 20 | | | Obs. | Wr. | |
| 19K2 | Well 3 | 27 | 443 | 10 | 417 | 15 | | T, E. | Ind. | Cp. | |
| 19K3 | Well 11 | 26 | 500 | 12 | | | | P, E. | Ind. | W. | |
| 19K4 | Well 12 | 26 | 1,099 | 12 | | | | | A. | Cp, L. | |
| 19L1 | R. Longwall | 26 | 355 | 2 | | | | Al, E. | Dom. | C, Wd, Cpr. | |
| 19L2 | Southern California Edison Company, Ltd. | 26 | 338 | 12 | 117<br>311 | 11<br>19 | Gravel<br>Sand and rocks | Al, E | Ind. | Cp, L, Wm. | Casing perforated at 125–128 and 327-330 ft. |
| 19L3 | The Texas Co. | 27 | 309 | 5–3 | | | | Al, E. | Dom, Ind. | Cp. | Casing perforated at 299–309 ft. |
| 19L4 | Bixby Land Co. | 24 | 108 | 4 | | | | P, W. | Stock. | Cp, W. | Casing perforated at 102–108 ft. |
| 19M1 | J. P. Labourdette | 24 | 332 | 2 | | | | Al, E. | Dom. | Cp, Wm. | |
| 19N1 | Bixby Land Co. | 20 | 160 | 2 | | | | P, W. | Dom, Stock. | Cp, W | |
| 19P1 | H. E. Thompson | 23 | | 4 | | | | P, E. | Irr. | Cp, W. | |
| 19P2 | do. | 23 | 60 | 5 | | | Sand. | P, W. | Irr. | Cp. | |
| | Southern California Water Co.: | | | | | | | | | | |
| 19Q1 | Los Alamitos plant, well 1. | 24 | 285 | 12 | | | | | | C, W. | |
| 19Q2 | Los Alamitos plant. | 24 | 300 | | | | | | | | |
| 19Q3 | Los Alamitos plant, well 2. | 24 | 306 | 12 | 264 | 17 | Sand and gravel | T, E. | PS. | L. | Casing perforated at 266–279 ft. |
| 19Q4 | Los Alamitos plant, well 3. | 24 | 632 | 12 | 265 | 367 | do. | T, E. | PS. | L. | Casing perforated at 346–356, 540–546, and 578–593 ft. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 28J1 | Bryant Ranch | 36 | 1,001 | 12 | 435<br>495 | 25<br>35 | Fine gravel<br>Coarse gravel | T, E | Dom, Stock, Irr. | Cp, L, Wm. | Casing perforated at 435–460 and 500–530 ft. |
| 28L1 | Artesia Land Co | 29 | 386.0 | 4 | | | | | Obs | Cp, Wm. | |
| 29D1 | P. D. Milne | 23 | 55 | 6 | | | | P, E | Irr | Cp | |
| 29G1 | U. S. Government Naval Reservation. | 24 | 418 | | | | | | A | W | |
| 29J1 | .....do | 28 | 300 | 12 | | | | P, E | Dom, Stock. | Cp, Wm. | |
| 29J2 | .....do | 29 | 725 | 12 | 190<br>385<br>447 | 35<br>20<br>82 | Gravel<br>.....do<br>Gravel, sand and clay. | T, E | Irr | Cp, L, Wm. | Casing perforated at 211–225, 390–405 and 448–486 ft. |
| 29L1 | .....do | 23 | | 3 | | | | P, W | Dom, Stock. | Cp, W. | |
| 29L2 | .....do | 23 | 710 | 16 | 381 | 15 | Gravel | T, E | Dom | C, L | Casing perforated at 382–398 ft. |
| 29L3 | .....do | 23 | 483 | 16 | 388 | 20 | Gravel and rock | T, E | Dom | C, L | Casing perforated at 390–410 ft. |
| 30A1 | E. D. Miller and L. Dunn. | 22 | 82 | 8–4 | 70 | 12 | Gravel and sand | P, W | Dom, Irr. | L, W | Casing perforated at 70–82 ft. |
| 30A2 | Mrs. Grace Johnson | 23 | 75 | 6 | | | Sand and gravel | P, W | | | |
| 30J1 | U. S. Government Naval Reservation. | 21 | 965 | 10 | 335 | 30 | Gravel | T, E | Irr | L, Wm. | Casing perforated at 333–363 ft. |
| 30K1 | Bryant Ranch | 19 | | 4 | | | | P, E | Dom | Cp | Casing perforated 252–262 ft. |
| 30K2 | .....do | 18 | 275.3 | 2 | | | | | Obs | Wm | |
| 30M1 | .....do | 18 | 277 | 4 | 262 | 15 | Coarse gravel | C, E | Dom, Stock. | Cp, L, Wd. | Casing perforated at 265–277 ft. |
| 31F1 | Fred H. Bixby Co | 16 | 965 | 12 | | | | T, I | Irr | C, Wm, Cp. | |
| 31F2 | .....do | 16 | 350 | 6 | | | | P, E | Dom | Cp | Casing perforated at 194–204 ft. |
| 32G1 | .....do | 20 | 350 | 3 | | | | P, W | Dom, Stock. | Cp | |
| 32H1 | .....do | 25 | 834 | 10 | | | | T, E | Dom, Irr. | Cp, Wm. | |
| 32M1 | .....do | 17 | 300 | 4 | | | | P, W | Dom | Cp | |
| 33D1 | Bryant Ranch | 26 | 400 | 3 | | | | P, W | Dom, Stock. | Cp, Wd. | |
| 33H1 | Fred H. Bixby Co | 31 | 1,103 | 12 | | | | T, I | Dom, Stock. Irr. | Cp, Wm. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 4 S., R. 12 W | | | | | | |
| 4/12-4J1 | Montana Land Co. | 51 | 717 | 12 | ... | ... | ... | ... | A. | Cp, L, W. | (2) |
| 4J2 | .....do. | 51 | 258.0<br>1,061 | 14 | 925<br>990 | 14<br>39 | Gravel.<br>Coarse sand. | P, W. | Obs. | Cp, L, Wm. | |
| 4J3 | .....do. | 51 | 354 | 14 | 310 | 33 | Sand and gravel. | T, E. | Irr, Obs. | Cp, L, Wm. | Casing perforated at 313-343 ft.[2] |
| 4P1 | Los Angeles County. | 47 | 15.5 | 2 | ... | ... | ... | ... | Obs. | Cp, W. | Yield about 1,200 gpm. |
| 5B1 | Wawona Park Water Co. | 52 | 65 | 4 | ... | ... | Gravel. | T, E. | PS. | ... | |
| 5B2 | .....do. | 52 | 95 | 7 | 65 | ... | .....do. | C, E. | PS. | Cp. | |
| 5E1 | Montana Land Co. | 48 | 20 | 1½ | ... | ... | ... | M. | Stock. | W. | |
| 5E2 | Gust A. Larson Refining Co. | 50 | 300 | 7 | ... | ... | ... | C, E. | Dom, Ind. | Cp, W. | |
| 5F1 | Compton Gun Club. | 51 | 64 | 8 | 35 | 29 | Gravel. | T, E. | ... | Cp, L, Wd. | |
| 5F2 | .....do. | 50 | ... | 5 | ... | ... | ... | ... | ... | ... | |
| 5F3 | .....do. | 49 | ... | 4 | ... | ... | ... | ... | ... | ... | |
| 5F4 | .....do. | 50 | 60 | 8 | ... | ... | ... | M. | ... | ... | |
| 5G1 | Frank Burke. | 51 | 1,245 | ... | ... | ... | ... | ... | ... | L. | |
| 5G2 | .....do. | 51 | ... | 4 | ... | ... | ... | P, W. | Stock. | Cp, W. | |
| 5H1 | Standard Oil Co. | 50 | 648 | 15-12 | 320 | 2 | Fine gravel. | Al, S. | Ind. | C, L, Cp, Wm. | Casing perforated at 319-323 and 625-630 ft. |
| 5H2 | .....do. | 50 | 1,371 | ... | ... | ... | ... | Al, S. | Ind. | C, L, Cp, Wm. | |
| 5L1 | Montana Land Co., well 80. | 51 | 212 | 4 | 206 | 6 | Gravel. | ... | Stock. | L, Wm. | Casing perforated at 207-212 ft. |
| 5M1 | Montana Land Co. | 48 | ... | 2 | ... | ... | ... | P, W. | Stock. | Cp, W. | |
| 5M2 | Mrs. Freda Norton. | 50 | 500 | 2 | ... | ... | ... | P, E. | PS. | Cp. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6G1 | William Bartosh | 48 | 195 | 4 | ... | ... | ... | C, E | PS | Cp | ... |
| 6H1 | City of Long Beach | 50 | 160 | ... | ... | ... | ... | ... | A | Wd | ... |
| 6K1 | North Long Beach, well 4. | 47 | 1,160 | 26-16 | 960 | 194 | Gravel, sand, and clay. | T, E | PS | Cr, L, Cp, Wr, Ww. | Casing perforated at 972-1,142 ft. Yield about 1,720 gpm. |
| 6Q1 | Steiner | 51 | 252 | ... | ... | ... | ... | T, E | Dom | Cp, Wd. | Casing perforated at 127-128 and 140-146 ft. |
| 6Q2 | C. J. Jones and Associates. | 49 | 1,000 | 12 | ... | ... | ... | ... | ... | ... | |
| 6Q3 | Jotham Bixby Co | 50 | 672 | 10 | ... | ... | ... | ... | ... | L | |
| 6R1 | C. J. Jones and Associates. | 51 | 1,200 | 12 | ... | ... | ... | T, E | Ind | Cp, W. | |
| 7A1 | Pacific Builders, Inc | 67 | 500 | 10 | 284<br>392<br>482 | 26<br>44<br>18 | Coarse sand and gravel. | T, E | Dom, Irr | Cp, L | Casing perforated at 284-295, 302-310, 392-400, and 465-480 ft. |
| 7A2 | C. J. Jones and Associates. | 67 | 578 | 12 | 518 | 60 | do | T, E | PS | ... | |
| 7J1 | Jotham Bixby Co | 73 | 235 | ... | ... | ... | ... | ... | A | Wd | |
| 8D1 | Pacific Builders, Inc | 65 | 360 | 10 | ... | ... | ... | T, E | ... | W | |
| | Montana Land Co: | | | | | | | | | | |
| 8L1 | Well 17 | 67 | 816 | 12 | 241<br>481 | 58<br>180 | Sand and gravel<br>do | T, E | Obs | L, Wm. | Casing perforated at 291-299, and 593-604 ft. |
| 8L2 | Well 16 | 69 | 981 | 12 | 835 | 124 | Gravel and sand | ... | A | L, Wm. | Casing perforated at 870-916 ft. |
| 8L3 | Montana Land Co. | 68 | 833 | ... | 670 | 163 | do | ... | A | L | |
| 8N1 | Bouton well 2 | 70 | 767 | 12 | 702 | 38 | Heavy gravel | ... | Obs | L, Wrd, Wm. | |
| 8P1 | Bouton well 1 | 69 | 714 | 14 | 674 | 40 | Gravel and clay | ... | Obs | Cp, Wr, L. | |
| 8P2 | Well 91 | 66 | 570 | 14 | ... | ... | ... | T, E | Dom, Stock. | Cp, W. | |
| 8P3 | Bouton well 3 | 66 | 841 | 14-12 | ... | ... | ... | ... | ... | L, Wd. | |
| 8P4 | Bouton well 5 | 69 | 400 | 10 | ... | ... | ... | ... | ... | ... | |
| 8P5 | Bouton well 4 | 64 | 297.5 | 7 | ... | ... | ... | ... | ... | W | |
| 9B1 | Well 15 | 48 | 1,104 | 3 | 609<br>692<br>1,016 | 23<br>8<br>81 | Coarse gravel<br>Gravel<br>Coarse sand | ... | A | L, Wd. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 4 S., R. 12 W.—Continued | | | | | | |
| 4/12-13A1 | City of Long Beach....... | 32 | 703 | 12 | 295<br>660 | 19<br>25 | Sand and gravel.......<br>Gravel.................. | P, E..... | Dom......... | Cp, L, W. | Casing perforated at 660–685 ft and for 10 ft between 295–314 ft. |
| 13B1 | .....do....................... | 33 | 338 | 16 | 88<br>146<br>193<br>302 | 14<br>45<br>5<br>19 | Sand and gravel.......<br>.....do...................<br>Sand.....................<br>.....do................... | T, L..... | Dom......... | Cp, L, W. | Casing perforated at 88–326 ft. |
| 13D1 | City of Long Beach:<br>Commission well 4... | 36 | 920 | 26–16 | 472<br>530<br>720<br>820 | 12<br>20<br>22<br>72 | Coarse gravel.........<br>Sand and gravel......<br>.....do...................<br>Gravel and sand...... | T, E.... | PS........... | Cr, L, Ww, Wr. | Casing perforated at 470–484, 530–550, 720–742, and 820–890 ft. Yield about 1,760 gpm. |
| 13F1 | Commission well 6... | 32 | 986 | 26–16 | 490<br>822 | 76<br>92 | Sand and gravel......<br>.....do................... | T, E.... | PS........... | Cr, L, Ww, Wr. | Yield about 1,710 Gpm. |
| 13G1 | Bixby Land Co., well 1.. | 30 | 875 | 12 | 135<br>512 | 40<br>28 | Gravel..................<br>Coarse gravel......... | T, E.... | Irr........... | L, Wrd, Wd. | Casing perforated at 140–165 and 512–540 ft. |
| 13J1 | Bixby Land Co............ | 27 | 275 | 4 | .......... | ......... | ........................... | P, W.... | Dom, Stock. | Cp..... | |
| 14A1 | .....do....................... | 35 | 720 | 12 | 658 | 62 | Gravel.................. | T, E.... | Irr........... | L, Wm, Cp. | Yield about 900 gpm. Casing probably perforated at 656–720 ft. |
| 14B1 | City of Long Beach:<br>Commission well 2... | 37 | 1,080 | 26–16 | 274<br>354<br>610 | 68<br>40<br>18 | Sand and gravel......<br>.....do...................<br>.....do................... | T........ | PS........... | Cr, L, Ww, Wr. | Casing perforated at 300–316, 364–394 and 618–628 ft. Yield about 1,180 gpm. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14C1 | Commission well 5 | 46 | 324 | 16 | 240 | 20 | Sand and gravel | T, E | PS | Cr, L, Ww, Wr. | Yield about 650 gpm. |
| | | | | | 294 | 6 | do | | | | |
| 14C2 | Los Angeles County | 38 | 18 | 2 | | | | | Obs. | Cp, W. | |
| 14C3 | do | 38 | 14 | 2 | | | | | Obs. | Cp, W. | |
| 14D1 | City of Long Beach, Commission well 1. | 45 | 1, 668 | 26-16 | 1,361 | 17 | Gravel to sand | T, E | PS | Cr, L, Ww, Wr. | Yield about 1, 590 gpm. |
| | | | | | 1,402 | 8 | Coarse gravel | | | | |
| | | | | | 1,430 | 48 | Gravel | | | | |
| | | | | | 1, 560 | 95 | do | | | | |
| 14D2 | City of Long Beach | 45 | 717 | 12 | 175 | 5 | Gravel | | Obs. | L, Wm. | |
| | | | | | 608 | 10 | Coarse gravel | | | | |
| 14D3 | J. Turner | 44 | 231 | 8 | 201 | 24 | Gravel | T, E | Dom. | Cp. | |
| 14F1 | Montana Land Co., well 80a. | 33 | 780 | 4 | | | | P, W. | | Cp, W. | |
| 14H1 | Bixby Land Co. | 32 | 300 | 2 | | | | Al, I. | Dom, Stock. | Cp. | |
| 14H2 | do | 33 | 210 | 3 | | | | | | W. | |
| 14M1 | Montana Land Co. | 40 | 250 | 4 | 225 | 25 | Coarse sand | | Obs. | L, Wm. | Casing perforated at 233-249 ft. |
| 14P1 | City of Long Beach: Wilson Ranch | 27 | 1, 700 | 26-16 | 1, 024 | 218 | Gravel and sand | T, E | PS | Cr, L, Ww, Wr. | Yield about 1, 850 gpm. |
| | | | | 13 | 1, 260 | 94 | do | | | | |
| 14P2 | Police Pistol Club | 26 | | | | | | P, W. | Dom. | Cp. | |
| 14Q1 | Bixby Land Co. | 28 | 701 | 12 | 315 | 5 | Fine gravel | | | L, W. | |
| | | | | | 334 | 30 | do | | | | |
| 14Q2 | do | 28 | 882 | 12 | 701 | 14 | Broken clay | T, E | Irr. | Cp, L, Wm. | |
| | | | | | 780 | 80 | Gravel | | | | |
| 15B1 | City of Long Beach, Commission well 3. | 40 | 1, 570 | 26-16 | 952 | 58 | do | T, E | PS | Cr, L, Wr, Ww. | Yield about 790 gpm. |
| | | | | 13 | | | | | | | |
| 15C1 | Los Angeles County | 40 | 18 | 2 | | | | | Obs. | Cp, W. | |
| 15D1 | City of Long Beach | 40 | 270 | 4 | 230 | 40 | Gravel and sand | | | C, L. | Casing perforated at 256-270 ft. |
| 15E1 | Montana Land Co. | 37 | | | | | | | A. | W. | |
| 15K1 | Well 30 | 38 | 622 | 12 | | | | T, E. | Irr. | Wd. | Yield about 585 gpm. |
| 15K2 | Well 76 | 37 | 300 | 4 | 240 | 60 | Sand and gravel | Al, E. | Dom., Stock. | Cp, L. | Casing perforated at 279-299 ft. |
| 15K3 | Well 89 | 37 | 368 | 16 | 225 | 81 | Gravel and sand | T, E | Irr. | L, W. | Casing perforated at 230-250, 256-272, 278-292, 298-302, and 322-340 ft. |
| | | | | | 322 | 18 | Coarse sand | | | | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| T. 4 S., R. 12 W.—Continued | | | | | | | | | | | |
| 4/12-15M1 | Montana Land Co.:<br>Well 26 | 30 | | | | | | | A | W | |
| 16C1 | | 47 | 22.5 | 2 | | | | | Obs | Cp, W. | |
| 16H1 | Well 71 | 36 | 986 | | 525 | 14 | Gravel | | Irr | L, Wm. | |
| 16H2 | Well 69 | 36 | | | | | | | A | Cp, W. | |
| 16H3 | Montana Land Co. | 36 | 380 | 4 | 369 | 11 | Small gravel | T, E. | Dom, Stock. | L. | Casing perforated at 370–380 ft. |
| 16J1 | Well 90 | 34 | 275 | 14 | | | | T, E. | Irr | L, Wm. | |
| 16M1 | City of Long Beach:<br>Airport | 43 | 380 | 4 | 280 | | Coarse sand | | A | L, W. | Casing perforated at 329–349 ft. |
| 17C1 | Street Department | 67 | 907 | | | | | | A | C, W. | |
| 17G1 | Montana Land Co. | 56 | 900 | 12 | | | | | A | Wd. | |
| 17G2 | Well 21 | 56 | | | | | | | A | Wm. | |
| 17G3 | Well 66 | 56 | 91.0 | 12 | | | | | Obs | Wm. | |
| 17H1 | Well 52 | 47 | | | | | | | A | Wd. | |
| 17N1 | City of Long Beach:<br>Development well 7. | 57 | 650 | 26–16 | 390 | 180 | Gravel, sand, with cemented streaks. | T, E. | PS | Cr, L, Ww, Wr. | Casing perforated at 395–570 ft. Yield about 1,990 gpm. |
| 17N2 | Development well 8. | 55 | 662 | 26–16 | 364 | 186 | Loose sand and gravel. | T, E. | PS | Cr, L, Ww. | Casing perforated at 375–550 ft. Yield about 1,900 gpm. |
| 17P1 | Richfield Oil Corp. | 51 | | | | | | | A | W | |
| 17P2 | do. | 49 | 264 | 10 | 245 | 16 | Fine gravel and sand. | T, E. | Ind | Cp, L. | Casing perforated at 249–259 ft. |
| 17Q1 | City of Long Beach, Development well 4. | 47 | 1,004 | 26–16 | 390<br>934 | 200<br>28 | Gravel, clay, sand<br>Sand and gravel | T, E. | PS | Cr, L. Ww, Wr. | Casing perforated at 390–590 an 936–970 ft. Yield about 3,120 gpm. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17Q2 | Perfect Caster Manufacturing Co. | 50 | 180 | 5 | 168 | 12 | Fine gravel | | A | L, Wd. | Casing perforated at 172–179 ft. |
| 18C1 | Jotham Bixby Co. | 102 | | 12 | | | | | | Wd. | |
| 18R1 | City of Long Beach, Development well 6. | 66 | 962 | 26–16 | 287 | 18 | Coarse gravel | T, E. | PS | Cr, L, Ww, Wr. | Yield about 1,610 gpm. |
| | | | | | 540 | 75 | Sand and gravel | | | | |
| | City of Signal Hill: | | | | | | | | | | |
| 19A1 | Well 3 | 73 | 500 | | | | | T, E. | PS | Cp, L. | |
| 19B1 | Well 5 | 75 | 404 | | 301 | 95 | Good gravel | T, E. | PS | L. | Probable perforated zone. |
| 19B2 | Well 1 | 75 | 541 | | | | | T, E. | PS | Cp, L. | |
| 19B3 | Well 2 | 75 | 504 | | | | | | A | L. | |
| 19B4 | Well 4 | 75 | 255 | | 129 | 6 | Coarse sand and gravel. | | | L. | |
| | | | | | 140 | 22 | | | | | |
| | | | | | 174 | 6 | do. | | | | |
| 19G1 | Burgess | 83 | 410 | 12 | 273 | 131 | Sand and gravel | | | Cp, L, W. | Casing perforated at 277–404 ft. |
| | City of Long Beach: | | | | | | | | | | |
| 20C1 | Development well 3. | 50 | 752 | 26–16 | 153 | 37 | Coarse sand | T, E. | PS | Cr, L., Ww, Wr. | Yield about 3,650 gpm. |
| | | | | | 286 | 14 | Sand and gravel | | | | |
| | | | | | 315 | 15 | Gravel | | | | |
| | | | | | 390 | 212 | Sand and gravel | | | | |
| 20D1 | Development well 1. | 55 | 1,017 | 12 | 959 | 42 | Gravel | | A | C, L. | Casing perforated at about 960–1,010 ft. |
| 20D2 | Development well 2. | 56 | 684 | 14? | 384 | 300 | Gravel and sand | | A | L, Wrd, Wd. | Casing perforated at 390–684 ft. |
| 20G1 | Development well 5. | 47 | 1,016 | 26–16 | 345 | 12 | Sand and gravel | | Obs. | Cr, L, Ww. | |
| | | | | | 420 | 80 | do. | | | | |
| | | | | | 707 | 13 | do. | | | | |
| | | | | | 814 | 14 | Gravel | | | | |
| | | | | | 859 | 61 | Gravel and sand | | | | |
| | | | | | 972 | 38 | Sand and gravel | | | | |
| 20J1 | Citizens well 3. | 39 | 713 | 16 | 445 | 100 | Gravel | | Obs. | L, Ww. | |
| 20L1 | The Hancock Oil Co. of California. | 64 | 700 | 16 | 266 | 64 | Sand and gravel | T, I. | Ind. | C, L, W, Cp. | Casing perforated at 295–300, 455–470, 534–536, and 567–571 ft. Yield about 150 gpm. |
| | | | | | 390 | 248 | Coarse sand and gravel. | | | | |
| | Montana Land Co.: | | | | | | | | | | |
| 21A1 | Well 27 | 29 | | 2 | | | | P, W. | | Wd, Cp. | |
| 21A2 | Well 88 | 29 | | 3? | | | | P, W. | Dom, Stock. | Cp, Wd. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | **T. 4 S., R. 12 W.—Continued** | | | | | | |
| 4/12-21G1 | Montana Land Co. | 27 | 339 | 10 | | | | | Obs. | Wr. | |
| 21K1 | Bixby Land Co. | 27 | 207 | | 182 | 25 | Sand and gravel | | A. | L. | Casing perforated at 199-206 ft. |
| | City of Long Beach: | | | | | | | | | | |
| 21L1 | Citizens well 4 | 28 | 1,155 | 12-10 | 790 | 238 | Gravel and sand | | Obs. | C, L, Wr. | Casing perforated at 800-860 ft. |
| 21M1 | Citizens well 2 | 33 | 456 | 14 | 415 | 41 | Sand and gravel | | Obs. | L, Ww. | |
| 21M2 | Citizens well 7 | 37 | 1,105 | 26-16 | 725 | 51 | Coarse gravel | T, E. | PS. | Cr, L, Ww. | Yield about 1,210 gpm. |
| | | | | | 874 | 11 | do. | | | | |
| | | | | | 912 | 22 | Gravel | | | | |
| | | | | | 952 | 10 | do. | | | | |
| 21M3 | Citizens well 1 | 35 | 420 | 12 | | | | | Obs. | C, L, Ww. | |
| 21M4 | Citizens well 6 | 33 | 1,422 | 26-16<br>14-10 | 420 | 224 | Gravel and sand | T, E. | PS. | Cr, L, Ww. | Casing perforated at 467-514, 560-600, 755-765, and 785-792 ft. Yield about 1,140 gpm. |
| | | | | | 755 | 37 | do. | | | | |
| 21M5 | Citizens well 5 | 39 | 695 | 26-16 | 208 | 122 | Coarse sand, clay | T, E. | PS. | Cr, L, Cp, Ww, Wr. | Yield about 2,500 gpm. |
| | | | | | 368 | 242 | Sand and gravel | | | | |
| 21P1 | Bixby Land Co. | 35 | 505 | 12 | 438 | 63 | Gravel | T, E. | Irr. | L. | Casing perforated at 458-501 ft. |
| 21P2 | do. | 33 | 619 | 12 | 450 | 169 | Gravel and sand | T, E. | Dom, Stock, Irr. | Cp, L. | Casing perforated at 470-540 ft. |
| 22F1 | Montana Land Co. | 24 | 11 | | | | | | A. | C. | |
| 22J1 | Bixby Land Co. | 23 | 1,014 | 14 | 961 | 54 | Gravel and sand | T, E(?). | Irr. | L. | Casing perforated at 963-1,003 ft. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 22L1 | do. | 23 | 223 | 4 | | | | P, W. | Stock. | Cp, Wm. | Casing perforated at 216-223 ft. |
| 22M1 | do. | 25 | | 10? | | | | T. | Obs. | Wm. | |
| 22M2 | City of Long Beach. | 25 | 300 | 4 | | | | | Obs. | Cp, Wm. | |
| 22P1 | Bixby Land Co. | 19 | 180 | 4 | | | | P, W. | Dom, Stock. | Cp. | |
| 22R1 | do. | 22 | 268 | 4 | | | | P, E. | Stock. | Cp, W.. | |
| 23A1 | do. | 26 | 200 | 2 | | | | A1, E. | Dom, Stock. | Cp. | |
| 23D1 | Montana Land Co., well 38. | 25 | 300 | | | | | | A. | Wm. | |
| 23J1 | Bovandaerde. | 21 | 854 | 14 | 476<br>753 | 55<br>99 | Sand and gravel.<br>do. | | Irr. | L. | Casing perforated at 507-527, 757-776, 793-801, 808-812, 835-838 ft. |
| 23K1 | Bixby Land Co. | 21 | 225 | 2 | | | | P, W. | Dom. | Cp, W.. | |
| 23L1 | do. | 22 | 330 | 2 | | | | A1, E. | Dom, Stock. | Cp, W.. | Casing perforated at 322-330 ft. |
| 23M1 | do. | 24 | 270 | 4 | | | | P, E. | Dom, Stock. | Cp, Wd.. | |
| 23M2 | Los Angeles County. | 24 | 16 | 2 | | | | | Obs. | Cp, W.. | |
| 24B1 | Bixby Land Co. | 26 | 780 | 14 | 327<br>533<br>633 | 4<br>15<br>157 | Sand and gravel.<br>do.<br>do. | T, E. | Irr. | L, W... | Casing perforated at 327-331, 535-554, 702-705, and 726-734 ft. |
| 24C1 | do. | 26 | 470 | | 402 | 59 | Sand, gravel, and clay. | T, E. | Irr. | Cp, L... | Casing perforated at 416-462 ft. |
| 24F1 | | 23 | 11 | | | | | | A. | C. | |
| 24J1 | Bixby Land Co. | 23 | 639 | 12 | 458<br>505 | 22<br>132 | Gravel.<br>Gravel and sand. | T, E. | Irr. | Cp, L, Wm. | Casing perforated 458-480, 528-539, 549-561, and 600-637 ft. |
| 24K1 | | 23 | 13 | | | | | | A. | Wd. | |
| 24K2 | | 23 | 21 | | | | | | A. | Wd. | |
| 24K3 | | 23 | 10 | | | | | | A. | Wd. | |
| 24K4 | Los Angeles County. | 24 | 17 | 2 | | | | | Obs. | Cp, W.. | |
| 24L1 | | 23 | 11 | | | | | | A. | Wd. | |
| 24L2 | | 23 | 16 | | | | | | A. | Wd. | |
| 24L3 | | 23 | 14 | | | | | | A. | Wd. | |
| 24L4 | Bixby Land Co. | 21 | 304 | 4 | | | | | A. | W. | |
| 24L5 | do. | 23 | 432 | 16-12 | 352 | 49 | Gravel, sand, and some clay. | T, E. | Irr. | L. | Yield about 1,125 gpm Casing perforated at 361-401 ft. |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 4 S., R. 12 W.—Continued | | | | | | |
| 4/12-24M1 | City of Long Beach | 22 | 318 | 4 | ........ | ........ | ........ | C, E | Obs | Wm | Casing perforated at 300-318 ft. |
| 24M2 | Wise Ranch, well 1 | 22 | 1,086 | ........ | 330 | 108 | Gravel and sand | T, E | PS | Cr, L, Ww, Wr. | Casing perforated at 330-410, 570-600, 632-654, 874-938, and 953-980 ft. Yield about 1,370 gpm. |
| | | | | | 570 | 102 | Sand and shells | | | | |
| | | | | | 874 | 64 | Sand and gravel | | | | |
| | | | | | 953 | 93 | .....do | | | | |
| 24M3 | City of Long Beach | 22 | 310 | 3 | ........ | ........ | ........ | ........ | A | Wm | Casing perforated at 300-310 ft. |
| 24M4 | Wise Ranch, well 2 | 21 | 1,041 | ........ | 320 | 24 | Gravel | T, E | PS | Cr, L, Ww, Wr, | Casing perforated at 320-344, 380-400, 570-595, 890-910, and 930-952 ft. Yield about 1,620 gpm. |
| | | | | | 380 | 30 | Sand with shells | | | | |
| | | | | | 570 | 110 | Sand and gravel | | | | |
| | | | | | 890 | 20 | Clay and sand | | | | |
| | | | | | 920 | 32 | Fine sand | | | | |
| 24M5 | Bixby Land Co | 20 | 300 | 4 | ........ | ........ | ........ | P, W | Dom, Obs. | Cp, W. | Casing perforated at 285-293 ft. |
| 24M6 | .....do | 22 | 199 | 4 | ........ | ........ | ........ | P, E | Dom, Stock. | Cp | Casing perforated at 191-199 ft. |
| 25H1 | Bryant Ranch | 16 | 547 | 10 | 390 | 117 | Gravel and sand | ........ | Obs | L, Wm. | Casing perforated at 397-496 ft. |
| 25L1 | .....do | 16 | ........ | ........ | ........ | ........ | ........ | ........ | A | Wd | |
| 25M1 | .....do | 15 | 575 | 16 | ........ | ........ | ........ | T, I | Irr | L, Wm, Cp. | Casing perforated at 192-244, 259-265, 275-300, 312-376, 395-408, 420-452, 466-512, and 525-575 ft. |
| 26A1 | Bixby Land Co | 17 | ........ | 2 | ........ | ........ | ........ | P, W | Dom | Cp | |
| 26C1 | Tubach, Murdy, and Fallen. | ........ | 987 | 14 | 510 | ........ | Sand, gravel | T, E | Dom, Irr | L | Casing perforated at 510-530, 610-620, 665-760, and 780-785 ft. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 26D1 | ....do | 20 | 175 | 2 | ... | ... | ... | P, W. | Dom. | Cp. | Casing perforated at 202-211 ft. |
| 26F1 | Bryant Ranch | 14 | ... | ... | ... | ... | ... | ... | A. | Wd. | |
| 26J1 | Tract 11A | 15 | 357 | ... | ... | ... | ... | C, I. | Dom. | Cp, L, W. | |
| 26K1 | Los Angeles County | 14 | 25 | 2 | ... | ... | ... | ... | Obs. | Cp, W. | |
| 26M1 | Bryant Ranch well 7 | 15 | 849 | 12 | 627 | 166 | Gravel and sand | T, E. | Dom, Stock. | C, L, Cpr, Wm. | Casing perforated at 667-777 ft. |
| 26R1 | Bryant Ranch | 13 | 156 | 4 | ... | ... | ... | P, W. | ... | Cp. | |
| 27K1 | ....do | 17 | 238 | 4 | 224 | 14 | Coarse gravel | T, E. | Dom, Stock. | C, L, W, Cpr. | Casing perforated at 228-237 ft. |
| 27K2 | Bryant Ranch, well 8 | 17 | 498.3 | 12 | 450 | 124 | Gravel and sand | ... | Obs. | L, Wm, Wr. | Casing perforated at 500-570, 695-735, and 745-815 ft. |
| | | | | | 610 | 205 | ....do | | | | |
| 27M1 | Bryant Ranch | 20 | 283 | 4 | ... | ... | ... | P, E. | Dom, Stock. | C, L, Cpr, Wd. | Yield about 3,470 gpm. |
| 27M2 | ....do | 20 | ... | 8 | ... | ... | ... | ... | Obs. | Wm. | |
| 27M3 | Los Angeles County | 19 | 11 | 2 | ... | ... | ... | ... | Obs. | Cp, W. | |
| 27M4 | ....do | 19 | 18 | 2 | ... | ... | ... | ... | Obs. | Cp, W. | |
| 28B1 | Bixby Land Co. | 25 | 15 | ... | ... | ... | ... | ... | A. | C. | |
| | City of Long Beach: | | | | | | | | | | |
| 28G1 | Alamitos well 3 | 28 | 189 | 8 | 161 | 25 | Coarse sand | ... | A. | L. | |
| 28H1 | Alamitos well 9 | 23 | 1,184 | 26-16 | 756 | 18 | Sand and gravel | T, E. | PS. | Cr, L, Ww, Wr. | Casing perforated at 768-774, 804-936, and 1,086-1,148 ft. Yield about 2,190 gpm. |
| | | | | | 804 | 132 | ....do | | | | |
| | | | | | 1,086 | 62 | ....do | | | | |
| 28H2 | Alamitos well 5 | 25 | 994 | 12 | ... | ... | ... | ... | Obs. | L, Wr. | |
| 28H3 | Alamitos well 4 | 24 | 351 | 12 | ... | ... | ... | ... | ... | L. | |
| 28H4 | Alamitos well 12 | 24 | .505 | 26-16 | 114 | 61 | Sand and gravel | ... | Obs. | Cr, L, Ww. | Casing perforated at 163-175, 196-205, 322-328, 355-365, 370-394, and 442-470 ft. Yield about 890 gpm. |
| | | | | | 185 | 41 | Fine sand | | | | |
| | | | | | 322 | 6 | Sand and gravel | | | | |
| | | | | | 442 | 28 | Cemented sand and gravel. | | | | |
| 28H5 | Alamitos well 6 | 23 | 949 | 16 | ... | ... | ... | ... | ... | C, L. | |
| 28H6 | Alamitos well 8 | 25 | 982 | 26-16 | 515 | 125 | Sand and gravel | T, E. | PS. | Cr, L, Ww. | Casing perforated at 515-528, 542-635, and 796-978 ft. Yield about 2,150 gpm. |
| | | | | | 796 | 182 | Gravel and sand | | | | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 4 S., R. 12 W.—Continued | | | | | | |
| 4/12-28H7 | City of Long Beach:<br>Alamitos well 11 | 23 | 500 | 26-16 | 170 | 20 | Sand and shells | T, E | PS | Cr, L., Ww, Wr. | Casing perforated at 170-190, 444-468, and 480-494 ft. Yield about 1,000 gpm. |
| | | | | | 444 | 50 | Fine to coarse sand | ... | ... | | |
| 28H8 | Alamitos well 2 | 31 | 273 | 12 | ... | ... | ... | ... | Obs. | C, L, Wr. | |
| 28H9 | Alamitos well 1 | 31 | 745 | 12 | ... | ... | ... | ... | Obs. | Cr, L, Wr. | |
| 28H10 | Alamitos well 7 | 25 | 1,114 | 26-16 | 570 | 60 | Coarse sand | ... | Obs. | C, L, Wr. | Casing perforated at 570-630, 866-872, 876-900, 918-954, 1,015-1,020, and 1,028-1,032 ft. |
| | | | | | 866 | 6 | Sand and gravel | | | | |
| | | | | | 876 | 24 | do | | | | |
| | | | | | 918 | 36 | Coarse gravel | | | | |
| | | | | | 1,015 | 5 | Sand and gravel | | | | |
| | | | | | 1,028 | 4 | Coarse gravel | | | | |
| 28H11 | Alamitos well 10 | 20 | 1,290 | 26-16 | ... | ... | ... | ... | ... | L, W. | |
| 28H12 | City of Long Beach | 26 | 74.0 | 2 | ... | ... | ... | ... | ... | W. | |
| 29K1 | Richfield Oil Co. | 200 | 650 | 12 | 340 | 7 | Black Sand | ... | ... | L. | Casing perforated at 250-400 ft. Yield about 60 gpm. |
| 30B1 | do | 126 | 254 | 12? | 58 | 196 | Gravel and sand | AL | Ind. | Cp, L, W. | Casing perforated at 138-148 and 160-168 ft. |
| 32G1 | Long Beach Peoples Ice and Cold Storage Co. | 38 | 107.5 | 5? | ... | ... | ... | ... | Ind. | Cr, Wm, Cpr. | |
| 33A1 | Bixby Land Co. | 23 | 209.7 | 4? | ... | ... | ... | P, W. | Dom. | Cp, Wm. | |
| 34B1 | Bryant Ranch | 32 | 849 | ... | 355 | 67 | Sand | T, E. | Dom, Stock. | C, L, Ww. | Casing perforated for 20 ft between 400-422 ft. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34H1 | Fred H. Bixby Co. | 20 | ... | 12 | ... | ... | ... | P, E. | Dom, Stock. | Cp, W. | ... |
| 34J1 | U. S. Naval Hospital | 80 | 460 | 10 | ... | ... | ... | ... | ... | ... | Test hole, casing pulled. |
| 34J2 | .....do | 80 | 768 | 16 | 92<br>158 | 39<br>10 | Sand and gravel<br>.....do | T, E.<br>... | PS. | L. | Yield 450 gpm.<br>... |
| 35C1 | Fred H. Bixby Co., well 1A. | 12 | 700 | 14 | 325<br>593 | 43<br>72 | Gravel and sand<br>.....do | T, E. | Dom, Irr. | Cp, L, Wm. | Casing perforated at 331-340, 348-360, 364-367, 597-608, and 655-668 ft. |
| 35C2 | Fred H. Bixby Co. | 13 | ... | 12 | ... | ... | ... | ... | Obs. | Wr. | ... |
| 35D1 | .....do | 13 | 661 | ... | 495 | 166 | Sand and gravel | ... | ... | L. | Casing perforated at 557?-622 ft. |
| 35L1 | .....do | 11 | 10 | ... | ... | ... | ... | ... | A. | C. | ... |
| 35Q1 | .....do | 22 | 1,243 | 12 | 95<br>206 | 53<br>42 | Sand and gravel<br>.....do | T, E. | Dom, Irr. | Cp, L., Wm. | Casing perforated at 141-148 and 241-248 ft. |
| 36G1 | .....do | 13 | 350 | 4 | ... | ... | ... | C, I. | Dom, Stock. | Cp, Wm. | (2) |
| 36H1 | .....do | 13 | 240 | 4 | ... | ... | ... | ... | ... | W. | Casing perforated at 230-240 ft. |
| | | | | | T. 4 S., R. 13 W. | | | | | | |
| 4/13-1C1 | North Long Beach, Extension Water Co. | 47 | 236 | 12 | 190 | 24 | Gravel and sand | T, E. | Dom, PS. | Cp, L. | Casing perforated at 203-216 ft. |
| 1F1 | City of Long Beach | 46 | 467 | 16 | 380 | 59 | .....do | T, E. | Dom, PS. | Cr, L, Ww, Wr | Casing perforated at 385-439 ft. |
| 1F2 | Orchard Park Water Co. | 46 | 85 | 8 | ... | ... | ... | T, E. | Dom. | Cp. | |
| 1M1 | Mrs. Cope | 45 | 43.0 | 4 | ... | ... | ... | P, W. | Dom, Stock. | Cp, W. | |
| 1N1 | ... | 42 | ... | ... | ... | ... | ... | ... | A. | W. | |
| 1P1 | Eugene Tincher | 42 | 400 | 8 | ... | ... | ... | C, I. | PS, Irr. | Cp. | |
| 1P2 | J. C. McPherson | 43 | 100 | 4 | ... | ... | ... | P, E. | Irr. | Cp. | |
| 1P3 | ... | 44 | ... | ... | ... | ... | ... | T, E. | PS. | ... | |
| 1P4 | James R. Ellis | 43 | 162 | 4 | ... | ... | Gravel | P, E. | Dom, PS. | Cp. | Casing perforated near bottom. |
| 1Q1 | R. W. Mackie | 44 | 60 | 4 | ... | ... | ... | ... | ... | ... | |
| 1Q2 | T. W. Bishop | 43 | 400 | ... | ... | ... | ... | P, I. | PS. | W. | |
| 2A1 | Dominguez Estate Co. | 45 | 160 | 12 ? | ... | ... | ... | T, E. | Irr. | Wm. | |
| 2J1 | .....do | 45 | 927 | ... | 419 | 251 | Gravel and sand | ... | A. | L, W. | |
| 2J2 | Del Amo Estate Co. | 42 | 155 | 12 | 49 | 74 | .....do | T, E. | Dom, Stock, Irr. | Cp, L, Wm. | Casing perforated at 90-120 ft. |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| T. 4 S., R. 13 W.—Continued | | | | | | | | | | | |
| 4/13-2J3 | Del Amo Estate Co. | 44 | 168 | 14 | | | | T, E. | Irr. | Cp, Wm. | |
| 2J4 | do. | 44 | 178.4 | 14 | | | | | Obs. | Cp, Wm. | |
| 2K1 | do. | 44 | 24.5 | 1¼ | 22 | 3 | Silty sand. | | Obs. | Cp, L, Wm. | |
| 2N1 | George Mindrup. | 41 | 100 | 2½ | | | | P, E. | Dom. | Cp. | |
| 2P1 | Del Amo Estate Co. | 37 | 118 | 12 | 29 | 88 | Gravel and sand. | T, E. | Irr. | L, Wm. | Casing perforated at 90–117 ft. |
| 2P2 | do. | 37 | 97 | 4 | | | | P, E. | Dom. | Cp. | Casing perforated at bottom 12 ft. |
| 2P3 | C. H. Eilers. | 37 | 145 | 12 | | | | T, E. | Irr. | W. | |
| 2P4 | George Mindrup. | 41 | 161 | 14 | | | | T, E. | Stock, Irr. | C. | |
| 2R1 | Del Amo Estate Co. | 41 | 85.3 | 12 | | | | | Obs. | W. | |
| 5J1 | Dominguez Estate Co. | 13 | 750 | 12 | 633<br>688 | 44<br>26 | Gravel and sand.<br>do. | | A. | Cp, L, W. | Casing perforated at 633–671 ft and for 1 ft between 688–703 ft. |
| 5L1 | do. | 12 | 751 | 12 | 350<br>587 | 5<br>164 | Coarse sand.<br>Gravel and sand. | | | L, Wrd, Wd. | Casing perforated at 350–355, 630–637, and 640–735 ft. |
| 5Q1 | Los Angeles County Flood Control District. | 11 | 105 | 6 | | | | | A. | Cp, L. | |
| 6J1 | Dominguez Estate Co. | 20 | 95 | 4 | | | | P, W. | Dom, Stock. | C, Cpr, W. | |
| 6J2 | do. | 20 | 173.3 | 8 | | | | | | Cp, W. | |
| 6K1 | M. B. Beauley. | 23 | 82 | 5 | | | | P, W. | Dom. | Cp, L, Wm. | |
| 6K2 | George N. Branning. | 23 | 70 | 3 | | | | P, E. | Dom. | Cp. | |
| 7E1 | Frank S. Austin. | 34 | 99.9 | 7 | | | | P. | Obs. | Cp, Wm. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8L1 | Joseph Loria | 18 | 32.2 | 36 | ... | ... | ... | P, W | Obs | Cr, Wm, Cpr. | |
| 8P1 | ... | 18 | 9.3 | 2 | ... | ... | ... | ... | ... | W | |
| 9B1 | Shell Oil Co., Inc | 21 | 1,060 | ... | ... | ... | ... | ... | A | W | |
| 9E1 | Del Amo Estate Co | 16 | ... | ... | ... | ... | ... | T, E | Irr | Cp, W | |
| 9H1 | Shell Oil Co., Inc | 24 | 1,202 | 32?<br>16-12 | 25<br>... | 284<br>128 | Sand, in streaks<br>Sand and gravel | T, E | Ind | C, L | Gravel envelope well, open 26-1,202 ft. |
| 9R1 | Richard Brothers | 24 | ... | ... | ... | ... | ... | T, E | Stock, Irr | | |
| 10A1 | Jesus Cruz | 33 | 175 | 10 | ... | ... | ... | P, E | Dom, Irr | Cpr, Wm. | |
| 10A2 | .....do | 32 | 112 | ... | ... | ... | ... | T, I | Irr | Cpr, Wd. | |
| 10B1 | John Malcom | 29 | 141 | 10 | 93<br>120 | 3<br>10 | Sand and gravel<br>Gravel | T, E | Irr | Cpr, L | Casing perforated at 93-96 and 120-130 ft. |
| 10E1 | Shell Oil Co., Inc | 25 | 1,092 | 12 | 63<br>907 | 3<br>50 | .....do<br>Sand and gravel | ... | ... | L | Casing perforated at 925-940 ft and for 2 ft between 63-66 ft. |
| 10F1 | Dominguez Estate Co | 28 | 17.6 | 1¼ | 12 | 6 | Sand | ... | Obs | C, L, Cpr, Wm. | |
| 10G1 | Martin Brothers | 29 | 185 | 7 | ... | ... | ... | P, E | Dom | Cpr, Wd. | |
| 10G2 | Ben Maciel | 30 | 90 | 5 | ... | ... | ... | P, W | Dom | Cp | |
| 10G3 | Melandras | 30 | 80 | 5 | 63 | 17 | Sand and gravel | P, W | Dom | C, L, Cpr. | |
| 10G4 | Joe Uribe | 30 | 115 | 6 | 70 | 32 | .....do | P, M | Dom | Cp, L | Casing perforated at 93-96 ft. |
| 10H1 | Jesus Cruz | 31 | 370 | 10 | ... | ... | ... | P, W | Dom | Cpr, Wm. | |
| 10H2 | Grande | 30 | ... | ... | ... | ... | ... | P, W | Dom | Cp | |
| 10H3 | Manuel Lopez | 30 | 85 | 4 | ... | ... | ... | P, W | Dom | Cpr, L | |
| 10J1 | Mrs. Jeannette Jones | 29 | 157 | 4 | 42 | 115 | Gravel and sand | ... | A | Cp, L, Wd. | Casing perforated at 105-157 ft. |
| 10J2 | .....do | 29 | 160 | 10 | 123 | 20 | Coarse gravel | ... | A | L | |
| 10J3 | .....do | 29 | 350 | 10 | ... | ... | ... | T, E | Irr | W | |
| 10J4 | .....do | 30 | ... | ... | ... | ... | ... | P, W | Dom | Cpr | |
| 10N1 | L. Machado | 24 | ... | 4 | ... | ... | ... | P, W | Dom | Cp | |
| 10R1 | Los Angeles County | 29 | 20.5 | 1¼ | 20 | 2 | Sand | ... | Obs | Cpr, L, Wm. | |
| 11B1 | Del Amo Estate Co | 38 | 27.9 | 1¼ | 24 | 4 | .....do | ... | Obs | Cp, L, Wm. | |
| 11B2 | Los Angeles County | 37 | 26.0 | 1¼ | 26 | 1 | Fine sand | ... | Obs | L, Cp, Wm. | Casing perforated at 25-28 ft. |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 4 S., R. 13 W.—Continued | | | | | | |
| 4/13-11C1 | Los Angeles County | 38 | 30.4 | 1¼ | 27 | 1 | Fine sand | ........ | Obs. | L, Cp, Wm. | Casing perforated at 27-30 ft. |
| 11D1 | C. H. Eilers | 35 | 149 | 12 | ........ | ........ | ........ | T, E. | Irr. | Cp, L, Wd. | Yield about 990 gpm. |
| 11D2 | Los Angeles County | 34 | 28.6 | 1¼ | 30 | 2 | Silty fine sand | ........ | Obs. | Cpr, L, Wm. | |
| 11E1 | C. H. Eilers | 31 | 145 | 12 | ........ | ........ | ........ | P, L. | Dom. | Cp. | |
| 11E2 | .....do | 31 | 110 | 2 | ........ | ........ | ........ | P, W. | Dom. | Cp. | |
| 11F1 | Dominguez Estate Co. | 34 | 30.8 | 1¼ | 27 | 5 | Fine silty sand | ........ | Obs. | Cpr, L, Wm. | |
| 11H1 | Los Angeles County | 37 | 14 | 6 | ........ | ........ | ........ | ........ | A. | Cpr, W. | |
| 11J1 | Southern California Edison Co., Ltd. | 36 | ........ | ........ | ........ | ........ | ........ | P, W. | Stock. | Cpr. | |
| 11K1 | Carson Estate Co. | 34 | 127 | ........ | ........ | ........ | ........ | P, W. | ........ | Cpr. | |
| 11K2 | ........ | 34 | 140 | ........ | ........ | ........ | ........ | ........ | A. | L. | |
| 11K3 | Carson Estate Co. | 33 | 167 | 14 | 60 | 53 | Gravel and sand | T, E. | Irr. | Cpr, L, W. | Casing perforated at 87-113 ft. |
| 11K5 | .....do | 36 | 20.9 | 1¼ | 13 | 7 | Silty sand | ........ | Obs. | Cpr, L, Wm. | |
| 11L1 | Dominguez Estate Co. | 33 | 140 | ........ | ........ | ........ | ........ | ........ | A. | L. | |
| 11L2 | .....do | 34 | 144 | ........ | 50 | 65 | Gravel and sand | T, E. | Irr. | Cp, L, Wd. | Casing perforated at 89-115 ft. |
| 11L3 | Los Angeles County | 33 | 30.5 | 1¼ | 22 | 7 | Sand | ........ | Obs. | Cp, L, Wm. | |
| 11P1 | .....do | 30 | 23.3 | 1¼ | 17 | 6 | .....do | ........ | Obs. | Cp, L, Wm. | |
| 12A1 | ........ | 35 | 330 | 6 | ........ | ........ | ........ | C, L. | PS, Irr. | Cp. | |
| 12B1 | Pillow | 40 | 130 | 4 | 106<br>130 | 14<br>........ | Sand<br>Coarse gravel | ........ | A. | L. | |
| 12C1 | Virginia City | 42 | 138 | ........ | ........ | ........ | ........ | ........ | A. | Wd. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12E1 | Virginia Country Club | 38 | 336 | 12 | | | | P, W. | Obs. | Cp, Wm. | |
| 12E2 | | 38 | 35 | 6 | | | | | A. | Cp, W. | |
| 12F1 | Llewellyn Bixby | 77 | 177 | | | | | | Obs. | Wm. | |
| 12F2 | | 35 | 27 | 6 | | | | | A. | Cp, W. | |
| 12G1 | J. C. Erickson | 37 | 22 | | | | | P, W. | | | |
| 12G2 | C. S. Johnson | 37 | | | | | | P, W. | | | |
| 12H1 | Jotham Bixby Co. | 54 | 674 | 12 | 424 | 200 | Gravel | T, L. | Dom, Stock, Irr. | Cp, L, Wm. | |
| 12H2 | do. | 81 | | | | | | | Obs. | Wm. | |
| 12K1 | Virginia Country Club | 91 | 1, 010 | 16 | 980 | 31 | Sand and boulders | | Obs. | L, Wr. | Casing perforated at 915–965, and 980–1, 010 ft. |
| 12K2 | do. | 44 | 295 | 14 | 188 | 72 | Sand and gravel | T, E. | Irr. | Cpr, L, W. | Casing perforated at 209–218 ft. |
| 12K3 | do. | 45 | 350 | 14 | | | | T, E. | Irr. | L. | Yield about 360 gpm. |
| 12M1 | Carson Estate Co. | 38 | 475 | 12? | 280 | 80 | Gravel and sand | T, E. | Irr. | L. | Casing perforated at 280–295 ft. |
| 13D1 | C. S. Jones, Los Cerritos Estates. | 60 | 358 | 12 | 256 | 101 | Sand and gravel | | Dom. | L. | Casing perforated at 267–288 and 310–334 ft. |
| 13E1 | Cheney | 47 | 121 | | | | | | A. | L. | |
| 13J1 | L. B. Hodges Nursery | 106 | 295 | 6 | | | | T, E. | Dom, Irr | | |
| 13M1 | Alfred Encinas | 52 | 450 | 6 | | | | P, L. | | W. | |
| 13M2 | | 30 | 35 | | | | | | Obs. | Cpr, W. | |
| 13N1 | Paul Valenzuela | 58 | 205.0 | 4 | | | | | Obs. | CprWm. | |
| 13N2 | do. | 58 | 240 | 5 | | | | | A. | W. | |
| 14A1 | Dominguez Water Corp. | 30 | 500 | | 220 | 200 | Gravel and sand | | A. | L. | Casing perforated at 250–320 and 331–361 ft. |
| 14A2 | | 30 | 31 | 6 | | | | | A. | Cpr. | |
| 14B1 | Dominguez Estate Co. | 31 | 230 | 12 | 63<br>176 | 37<br>33 | Gravel and sand<br>do. | C, E. | Irr. | Cpr, L, W. | Casing perforated at 85-101 and 190–209 ft. |
| 14B2 | do. | 31 | 200 | 12 | | | | T, E. | Dom, Irr. | Cp. | |
| 14C1 | Dominguez Water Corp. | 31 | 193 | 12 | 88 | 61 | Gravel and sand | T, E. | PS, Irr. | Cp, L. | Casing perforated at 32 ft between 115–149 ft. |
| 14D1 | do. | 30 | 189 | 12 | 77 | 44 | Sand and gravel | | A. | L. | Casing perforated at 16 ft between 93–111 ft. |
| 14D2 | Dominguez Water Corp.: Well 11. | 28 | 161 | 16 | 80 | 58 | Gravel, sand, and clay. | T, E. | PS. | C, L, W. | Casing perforated at 108–138 ft. |
| 14D4 | Well 9. | 28 | 1, 013 | 12 | 791 | 222 | Fine gravel and sand. | T, E. | PS. | L. | Casing perforated at 847–981 ft. |

See foot at end of table

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | | | T. 4 S., R. 13 W.—Continued | | | | |
| 4/13-14F1 | Dominguez Estate Co. | 30 | 130 | 12 | 50 | 59 | Sand and gravel | | A | C, Cpr, L. | Casing perforated at 96-109 ft. |
| 14F2 | do | 30 | 135 | 12 | 75 | 28 | do | T, E | Dom, Irr | Cpr, L. | Casing perforated at 89-101 ft. |
| 14F3 | Los Angeles County | 24 | 22.3 | 1¼ | 18 | 4 | Sand | | Obs | Cpr, L., Wm. | |
| 14G1 | Dominguez Estate Co. | 32 | 187 | | | | | T, E | Irr | Cp | Yield about 210 gpm. |
| 14H1 | Fitzgerald Engineering Construction Co. | 32 | 164 | 8 | 143 | 2 | Gravel | | A | Cp, L, W. | |
| 14J1 | Oil Operators, Inc. | 27 | 600 | | | | | | A | W | |
| 14J2 | | 28 | 33 | 6 | | | | | A | Cp, W. | |
| 14J3 | | 25 | 26 | 6 | | | | | A | Cp, W. | |
| 14K1 | H. E. Dickson | 29 | | | | | | | A | Cp, Wd. | |
| 14K2 | do | 29 | 71 | 5 | | | | | | Cpr, W. | |
| 14K3 | Southern California Edison Co., Ltd. | 31 | 130 | | | | | P, I. | Dom | Cpr, W. | |
| 14K4 | Mrs. Myers | 29 | 110 | 2 | | | | | A | Cpr | |
| 14K5 | Southern California Edison Co., Ltd. | 30 | 49.2 | 6 | | | | | Obs | Cpr, Wm. | |
| 14K6 | City of Long Beach | 29 | 20.3 | 1¼ | 16 | 5 | Sand | | A | Cpr, L, Wm. | |
| 14L1 | Southern California Edison Co., Ltd. | 29 | 114.3 | 10 | 86 | 28 | Gravel | | Obs | Cr, L, Ww. | Casing perforated at 90-116 ft. |
| 14L2 | Baxter Ranch | 28 | 140 | | | | | | A | W | |
| 14M1 | M. Heratsuki | 27 | 145 | 8 | | | | | A | L | |
| 14M2 | Mrs. E. Lester | 26 | 83 | 4 | | | | P, W | | Cp | |
| 14M3 | J. K. Raven | 26 | 87 | 2 | | | | P, W | | C | |
| 14M4 | N. Namura | 26 | | 8 | | | | T, E | Irr | Cpr | |
| 14M5 | C. F. Smith | 26 | 129 | 10 | 89<br>116 | 25<br>4 | Gravel and sand<br>Gravel | T, E | Dom | Cpr, L. | Casing perforated at 101-114 and 116-120 ft. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14M6 | P. Carmona | 27 | 112 | 2 | | | | P, W. | Irr. | | |
| 14M7 | C. T. Nakashima | 27 | 100 | 3 | | | | P, W. | | Cp. | |
| 14M8 | S. D. Wilson | 27 | 125 | 12 | | | | | A. | C, L, Cpr. | |
| 14M9 | | 27 | 98 | | | | | | A. | W. | |
| 14M10 | Charles Kull | 26 | 97.0 | 4 | | | | | A. | W. | |
| 14N1 | Watson Land Co. | 22 | 110 | 8 | | | | | A. | Cpr, L. W. | |
| 14N2 | Dominguez Estate Co. | 25 | 140 | | | | | | A. | Cp, L. | |
| 14N3 | do. | 26 | 128 | 8 | 60 | 67 | Gravel and sand | T, E. | Irr. | Cpr, L. | Casing perforated at 102-127 ft. Yield about 210 gpm. |
| 14P1 | City of Long Beach | 26 | 29.5 | 1¼ | 25 | 5 | Sand and silt | | Obs. | C, L, Cpr, Wm. | |
| 14Q1 | D. S. Bell | 27 | | 8 | | | | | | | |
| 14Q2 | Oil Operators, Inc. | 28 | 134 | 8 | 50 | 69 | Sand and gravel | | A. | C, L, W, Cpr. | Casing perforated at 90-112 ft. |
| 14Q3 | Bell Ranch | 26 | 54.3 | 4 | | | | | A. | Cp, W. | |
| 14Q4 | do. | 27 | 900 | | 744 | 156 | Gravel and sand | | A. | Cr, L, W. | Casing perforated at 800-900 ft. |
| 14Q5 | do. | 27 | | 12 | | | | P, M. | | Cpr, Wd. | |
| 14R1 | Fitzgerald Engineering Construction Co. | 27 | 200 | | 65 | 3 | Coarse gravel | | A. | Cp, L, W. | |
| 14R2 | | 21 | 24 | 6 | | | | | A. | Cpr, W. | |
| | Dominguez Water Corp.: | | | | | | | | | | |
| 15A1 | Well 7A | 27 | 1,161 | 16 | 68 | 76 | Gravel and sand | T, E. | PS. | C, L, Cpr. | Casing perforated at 112-146 ft. |
| 15A2 | Well 8 | 28 | 998 | 12 | 769 | 229 | do. | T, E. | PS. | C, Cpr, L. | Casing perforated at 830-980 ft. |
| 15A3 | Well 10 | 28 | 158 | 16 | 76 | 57 | do. | T, E. | PS. | C, L, Cpr. | Casing perforated at 100-135 ft. |
| 15A4 | Well 2, old series | 28 | 164 | 12 | 65 | 54 | do. | | A. | Cp, L. | Casing perforated at 105-119 ft. |
| 15A5 | Well 6 | 28 | 1,001 | 12-10-6 | 777 | 224 | do. | T, E. | PS. | C, L. | Casing perforated at 799-811 and 891-970 ft. |
| 15A6 | Well 1 | 28 | 1,226 | | 775 | 451 | do. | T, E. | PS. | C, L, W. | Casing perforated at 780-800, 830-1,000, and 1,040-1,050 ft. |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | T. 4 S., R. 13 W.—Continued | | | | | | | |
| 4/13-15A7 | Dominguez Water Corp.:<br>Well 4 | 28 | 1,027 | 12 | 750 | 277 | Gravel and sand | T, E | PS | Cr, L | Casing perforated at 763-783, 814-905, 918-938, and 967-987 ft. |
| 15A8 | Well 5 | 28 | 980 | 12 | 744 | 236 | do | T, E | PS | C, W, L | Casing perforated at 790-910 and 924-959 ft. |
| 15A9 | O. E. Elftman | 28 | 159 | 12 | 94 | 36 | do | ... | A | L | Casing perforated at 104-130 ft. |
| 15A11 | Dominguez Water Corp.:<br>Well 15 | 27 | 1,054 | 16 | 800 | 190 | do | T, E | PS | C, L | Casing perforated at 802-1,000 ft. Yield about 2,000 gpm. |
| 15B3 | Well 3 | 27 | 947 | 12 | 760 | 187 | do | T, E | PS | C, L | Casing perforated at 760-780 and 800-923 ft. |
| 15B4 | Well 2 | 27 | ... | 12 | 767 | 380 | do | T, E | PS | C, L | Casing perforated at 787-859 and 873-965 ft. |
| 15C1 | Watson Land Co | 24 | ... | ... | ... | ... | ... | ... | ... | ... | |
| 15D1 | J. P. Hoeptner | 21 | 461 | 10 | 203<br>380 | 102<br>15 | Sand and gravel<br>Gravel and sand | T, E | Irr | C, Cpr, L, Wm. | Casing perforated at 257-265 and 380-395 ft. |
| 15E1 | Cedric Seabranch | 21 | 117.5 | 16 | 193<br>325 | 36<br>65 | Sand and gravel | ... | Obs | Cp, L, Wm. | Casing perforated for 2 ft between 219-225 ft, for 6 ft between 335-345 ft, and between 225-229 ft. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15E2 | .....do. | 21 | 360 | 10 | ........ | ........ | ........ | T, E. | Dom, Irr. | Cpr, L. | |
| 15H1 | Dominguez Estate Co. | 26 | 130 | 5 | 50 | 59 | Sand and gravel. | P, W. | Irr. | Cp, L. | Casing perforated at 96-109 ft. |
| 15J1 | M. H. Nance. | 24 | 76 | 4 | ........ | ........ | ........ | P, W. | Irr. | Cp. | Casing perforated at bottom. |
| 15K1 | K. Kuramoto. | 24 | 136 | 5-3 | 80 | 56 | Gravel and sand. | P, W. | Dom. | Cp, L, Wm. | Casing perforated at 107-136 ft. |
| 15K2 | J. Kawaichi. | 24 | 140 | 12 | ........ | ........ | ........ | C, I. | Irr. | Cp, Wm. | |
| 15K3 | Gay Land Co. | 23 | 110 | 5 | ........ | ........ | ........ | E. | Ind. | Cp, W. | |
| 15N1 | Johns-Manville Products Corp. | 20 | 925 | 16 | 483 | 302 | Sand and gravel. | T, E. | Ind. | C, L. | Yield about 1,270 gpm. Casing perforated at 483-743 ft. |
| 15P1 | .....do. | 20 | 571 | 12 | 465 | 106 | Gravel and sand. | T, E. | Ind. | C, L, Cp. | Yield about 1,030 gpm. Casing perforated at 500-560 ft. |
| 15P2 | .....do. | 20 | 183 | 8 | 147 | 31 | Sand and gravel. | ........ | A. | L. | Casing perforated at 155-165 ft. |
| 15P3 | Dominguez Estate Co. | 21 | 650 | 12 | ........ | ........ | ........ | T, E. | Dom, Irr. | Cp. | |
| 15Q1 | Y. Muranaka. | 22 | 150 | 10 | ........ | ........ | ........ | T, E. | Dom, Irr. | Cp. | |
| 15R1 | Nakashima. | 22 | ........ | 6 | ........ | ........ | ........ | T, E. | Dom, Irr. | Cpr. | |
| 15R2 | Dominguez Estate Co. | 22 | 135 | 12 | 80 | 46 | Gravel. | T, E. | Irr. | Cpr, L, Cpr. | Casing perforated at 116-126 ft. Yield about 430 gpm. |
| 16A1 | J. P. Hoeptner. | 21 | 200 | 6 | ........ | ........ | ........ | P, W. | Dom. | C, Cpr, Wm. | |
| 16D1 | Luigi Debernardi. | 14 | 80 | 8 | 60 | 20 | Sand and gravel. | P, W. | Dom. | Cp, Wm. | Perforation not certain. |
| 16H1 | Cedric Seabranch. | 21 | 147.3 | 4 | ........ | ........ | ........ | ........ | Obs. | Wm. | |
| 16M1 | Watson Estate Co. | 28 | ........ | 5 | ........ | ........ | ........ | P, W. | ........ | ........ | |
| 17C1 | ........ | 26 | ........ | 3? | ........ | ........ | ........ | P, W. | Dom. | Cp. | |
| 17D1 | Dominguez Water Corp. | 26 | 1,701 | 12 | ........ | ........ | ........ | ........ | Obs. | Cpr, L, Wm. | |
| 17E1 | Crook and Huffin. | 35 | 121 | ........ | ........ | ........ | ........ | ........ | A. | W. | |
| 17G1 | H. Diego. | 27 | 87 | 8 | ........ | ........ | ........ | ........ | Irr. | ........ | |
| 18A1 | J. E. Hoepner. | 33 | 461 | ........ | ........ | ........ | ........ | ........ | ........ | W. | |
| 18A2 | .....do. | 35 | 200 | ........ | ........ | ........ | ........ | ........ | A. | Wd. | |
| 18H1 | ........ | 36 | ........ | ........ | ........ | ........ | ........ | ........ | A. | W. | |
| 18J1 | J. J. Dunlop. | 38 | ........ | ........ | ........ | ........ | ........ | ........ | A. | W. | |
| 18J2 | Griggs. | 38 | 67 | 5 | ........ | ........ | ........ | P, W. | ........ | Cpr, W. | |
| 18N1 | C. F. Fiesel. | 39 | 250 | ........ | ........ | ........ | ........ | P, W. | Dom. | Cpr, Wm. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 4 S., R. 13 W.—Continued | | | | | | |
| 4/13-18P1 | Bank of America | 39 | 500 | 12-10 | | | | T, I. | | | |
| 18Q1 | General Petroleum Corp. | 39 | 251 | 12 | 203 | 48 | Sand and gravel | T. | Ind. | L, Wm. | Casing perforated at 212-245 ft. |
| 18Q2 | .....do | 39 | 250 | | 212 | 38 | .....do | T. | Ind. | L, Wd. | Casing perforated at 224-231 ft. |
| 19D1 | C. F. Fiesel | 44 | 220 | 7 | 200 | 30 | | P, W. | Dom. | Cpr, Wm. | Perforation not certain. |
| 19E1 | Spenser Coates | 34 | 180 | 8 | | | | AL. | Dom, Ind. | Cp. | |
| 19H1 | F. L. Forrester | 37 | 90 | | | | | P, E. | Dom. | C, W, Cpr. | |
| 19H2 | C. Stuffers | 37 | 70 | 8-6 | | | | P, E. | Dom. | Cp. | |
| 19H3 | Carlson | 36 | 70 | 4 | | | | P, W. | Dom. | Cp. | |
| 19H4 | A. E. Smith | 36 | 180 | | | | | P, W. | | Cp. | |
| 19H5 | .....do | 35 | 70 | | | | | P, W. | | Cp. | |
| 19J1 | J. C. Anderson | 40 | 262 | 12 | | | | | A. | Cp, L. | |
| 19J2 | Theodore E. Kleinmeyer | 41 | 325 | 12 | 238 | | Gravel | T, E. | Dom. | C, Cpr, Wm. | Perforation not certain. |
| 19J3 | Hughes Tool Co. | 41 | | | | | | | A. | | |
| 19J4 | Mrs. Addie V. Stewart | 41 | 100 | | | | | P, E. | | Cr, W, Cpr. | |
| 19R1 | F. T. Woodman | 41 | | 8 | | | | P, E. | Dom, Stock. | Cp, Wm. | |
| 20K1 | Southern California Edison Co., Ltd. | 37 | 550 | 12 | 433 | 117 | Gravel and sand | Al, E. | Dom, Ind. | Cpr, L, Wd. | Casing perforated at 461-550 ft. |
| 20L1 | Mrs Ana-May Kreyssler | 37 | 554 | 12-10 | 173 | 384 | Sand and gravel | T, E. | PS. | C, L, W, Cpr. | Casing perforated at 454-554 ft. |
| 20R1 | Harbor View Dairy Co. | 40 | 586 | 12 | 460 | 126 | .....do | T, E. | Dom, Ind. | Cp, L, Wd. | Casing perforated at 558-581 ft and 20 ft, including 517-521 ft. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 21H1 | Richfield Oil Corp. | 20 | 156 | 16 | 114 | 18 | Fine sand | | A | L |  |
| 21H2 | Well 4 | 34 | 800 | 24-12 | 435 | 116 | Sand and gravel | T, E | Ind | Cr, L | Casing perforated at 430-550 ft. Yield about 1,200 gpm. |
| 21H3 | Well 3 | 35 | 800 | 24-12 | 430 | 358 | Gravel and sand | T, E | Ind | C, Cp, L, Wm. | Casing perforated at 430-535 and 560-605 ft. Yield about 1,000 gpm. |
| 21H4 | Well 2 | 35 | 800 | 24-12 | 430 | 356 | Sand and gravel | T, E | Ind | C, L | Casing perforated at 430-550 ft. Yield about 750 gpm. |
| 21J1 | Well 1 | 35 | 643 | 18 | 428 | 215 | do | | Ind | C, L, Cp. | Casing perforated at 428-580 ft. Yield about 1,500 gpm. |
| 21Q1 | Shell Oil Co., Inc.: Wilmington well 1 | 36 | 750 | 20-12 | | | | | Ind | C, L | Casing perforated at 435-625 and 641-661 ft. |
| 21R1 | Wilmington well 2 | 34 | 846 | 16 | 440 | 330 | | | Ind | C, L | Casing perforated at 440-670 and 761-780 ft. |
| 22E1 | Richfield Oil Corp., well 5. | 18 | 650 | 18 | 410 | 235 | Gravel and sand | T, E | Ind | C, Cpr, L | Casing perforated at 415-425, 447-527, and 645-690 ft. |
| 22G1 | Watson Estate Co. | 25 | 50 | 4 | | | | P, W | Dom, Irr | Cpr, Wm. | |
| 22G2 | do | 21 | 149 | 2½ | 93 | 30 | Gravel | P, W | | Cpr, L, W. | Casing perforated at 95-120 ft. |
| 22H1 | Los Angeles Harbor Commission. | 23 | 120 | 12 | | | | T, E | Dom, Irr | Cpr | |
| 22H2 | David D. Brymer | 20 | 82 | 4 | | | | P, W | | Cpr | |
| 22J1 | City of San Pedro | 19 | 165 | 8 | 133 | 28 | Sand and gravel | T, E | Irr | Cpr, L, W. | Casing perforated at 140-147 ft. |
| 22K1 | Dominguez Estate Co. | 20 | 590 | 14 | | | | T, E | Obs | Cpr, L, Wm. | |
| 22L1 | do | 20 | 18.5 | 2 | | | | E | Ind | | |
| 22L2 | Tide Water Associated Oil Co. | 14 | 728 | 20-12 | 411 | 317 | Sand and gravel | T, E | Ind | C, L | Casing perforated at 411-518, 549-570, and 614-716 ft. Yield about 125 gpm. |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | | | T. 4 S., R. 13 W.—Continued | | | | |
| 4/13-22Q1 | Alphonse Watson | 31 | 250 | 10 | ...... | ...... | ...... | P, E | Dom | Cp | |
| 22R1 | Watson Estate Co | 17 | 170 | 6 | 107 | 38 | Gravel and sand | T, E | Dom, Irr | Cpr, C, L, Wd. | Casing perforated at 107–130 and 140–145 ft. |
| 22R2 | Los Angeles County | 20 | 19.5 | 2 | ...... | ...... | ...... | ...... | Obs | W | |
| 23A1 | ...... | 21 | 30 | 6 | ...... | ...... | ...... | ...... | A | Cpr, W. | |
| 23B1 | Chambers | 25 | 142 | ...... | 57 | 85 | Sand and gravel | ...... | A | L | Casing perforated at 111–125 ft. |
| 23C1 | C. H. Barnes | 24 | 77 | 2 | 73.5 | 3 | Gravel | P, W | Irr | C, L | Yield about 7 gpm. |
| 23C2 | R. E. Rose | 24 | 80 | 2 | 75 | 5 | do. | P, W | Irr | Cp | |
| 23C3 | Mrs. Mosely | 24 | 84 | ...... | ...... | ...... | ...... | P, W | Irr | ...... | |
| 23D1 | S. D. Wilson | 24 | ...... | ...... | ...... | ...... | ...... | T, E | Obs | Cpr, Wm. | |
| 23D2 | Meecham Ranch | 21 | 63.2 | 10 | ...... | ...... | ...... | ...... | Obs | Cpr, Wm. | |
| 23E1 | Imai | 22 | ...... | 12 | ...... | ...... | ...... | ...... | A | Cpr, Wd. | |
| 23E2 | Mrs. Hill | 20 | 160 | 10 | ...... | ...... | ...... | T | Obs | Cpr, Wm. | |
| 23F1 | W. F. Moulton | 23 | 149 | 12 | 46 | 59 | Sand and gravel | ...... | A | L, W | Casing perforated at 86–105 ft. |
| 23F2 | City of Long Beach | 22 | 24.3 | 1¼ | 21 | 4 | Sand and silt | ...... | Obs | Cpr, L, Wm. | |
| 23G1 | R. J. Whetnall | 23 | 54.3 | 4–3 | ...... | ...... | ...... | ...... | Obs | Cpr, Wm. | |
| 23G2 | City of Long Beach, Silverado well 1. | 25 | 1,074 | 26–16 | 596 | 470 | Gravel and sand | T, E | Obs | Cr, L, Wr, Ww. | Casing perforated at 650–900 ft. |
| 23H1 | Bonnie Brackett | 23 | 100 | 4 | 90 | 10 | Gravel | P, W | ...... | W | Perforation uncertain. |
| 23J1 | City of Long Beach | 21 | 10 | ...... | ...... | ...... | ...... | ...... | A | Cpr | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23L1 | Manuel Pimentell | 21 | 135 | | | | | | A | Cp,Wd. | |
| 23L2 | H. & J. Maybury Co. | 21 | 145 | 12 | 71 | 61 | Sand and gravel | | A | Cp, L. | Casing perforated at 98-110 and 120-131 ft. |
| 23L3 | Irwin Stewart | 20 | 115 | 5 | | | | | A | Cr,Wd, Cpr. | |
| 23M1 | do | 21 | 912 | 10 | 71 | 50 | Gravel and sand | | A | Cp, L, Wm. | Casing perforated at 88-121, 144-147, 260-270, 430-438, 439-444, 509-530, and 553-570 ft. |
| | | | | | 130 | 30 | Sand and gravel | | | | |
| | | | | | 260 | 24 | do | | | | |
| | | | | | 410 | 502 | Gravel and sand | | | | |
| 23M2 | do | 21 | 115.2 | 14 | 77 | 41 | Sand and gravel | | Obs | Cpr, L, Wr. | Casing perforated at 103-120 ft. |
| 23N1 | do | 18 | 106 | | | | | | A | Cp. | |
| 23P1 | Carlson Ranch | 19 | | | | | | | A | Cpr,W. | |
| 23P2 | City of Long Beach | 20 | 26.5 | 1¼ | 24 | 2 | Silt and sand | | Obs | Cpr, L, Wm. | |
| 23Q1 | M. F. Knoy | 19 | 56.9 | 1½ | | | | P, W. | Irr. | W. | |
| 23R1 | | 15 | 33 | 6 | | | | | A | Cpr,W. | |
| 24E1 | | 24 | 26.0 | 6 | | | | | Obs | Cpr,W. | |
| 24E2 | | 24 | 38.1 | 6 | | | | | Obs | Cpr,W. | |
| 24F1 | | 23 | 25 | 6 | | | | | A | Cpr,W. | |
| 24F2 | | 22 | 26 | 6 | | | | | A | Cpr,W. | |
| 24G1 | | 19 | 31 | 8-6 | | | | | Obs | Cpr,W. | |
| 24G2 | | 20 | 28.3 | 8-6 | | | | | Obs | Cpr,W. | |
| 24G3 | | 20 | 22 | 8-6 | | | | | Obs | Cpr,W. | |
| 24K1 | | 19 | 25 | 8-6 | | | | | Obs | Cpr,W. | |
| 24K2 | | 21 | 25 | 6 | | | | | A | Cpr,W. | |
| 24K3 | | 20 | 27 | 6 | | | | | A | Cpr,W. | |
| 24L1 | | 22 | 28 | 6 | | | | | A | Cpr,W. | |
| 24L2 | | 22 | 28 | 6 | | | | | A | Cpr,W. | |
| 24M1 | | 21 | 25.0 | 6 | | | | | Obs | Cpr,W. | |
| 24M2 | | 21 | 28 | 6 | | | | | A | Cpr,W. | |
| 24N1 | J. B. Mosher | 21 | 54 | 2 | | | Sand | P, W. | Irr. | | |
| 24N2 | | 21 | 29.4 | 6 | | | | | Obs | Cpr,W. | |
| 24N3 | | 21 | 31 | 6 | | | | | Obs | Cpr,W. | |
| 24P1 | | 19 | 27 | 6 | | | | | A | Cpr,W. | |
| 24P2 | | 20 | 28 | 6 | | | | | A | Cpr,W. | |
| 24Q1 | | 16 | 20.5 | 6 | | | | | Obs | Cpr,W. | |
| 24Q2 | | 16 | 18.1 | 6 | | | | | Obs | Cpr,W. | |
| 24Q3 | | 20 | 25 | 6 | | | | | A | Cpr,W. | |
| 24Q4 | | 19 | 22 | 6 | | | | | A | Cpr,W. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach - Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 4 S., R. 13 W.—Continued | | | | | | |
| 4/13-24Q5 | ... | 18 | 31 | 6 | ... | ... | Sand | ... | A | Cpr, W. | |
| 24Q6 | ... | 18 | 26 | 6 | ... | ... | ... | ... | A | Cpr, W. | |
| 24Q7 | ... | 16 | 16 | ... | ... | ... | ... | ... | A | Cpr, W. | |
| 25N1 | ... | 12 | ... | ... | ... | ... | ... | ... | A | Cpr. | |
| 26A1 | Oil Operators, Inc. | 18 | 131 | 8 | 105 | 26 | Gravel | ... | ... | C, L, Cp, Wd. | Casing perforated at 105–120 ft. |
| 26B1 | Dora E. Kahler | 18 | 60 | 2 | ... | ... | ... | P, W. | Irr. | C, Cpr. | |
| 26B2 | R. C. Vaughan | 19 | 69 | 2 | 40 | 29 | Gravel | P, W. | Stock | Cpr, L. | |
| 26C1 | Peterson | 18 | 84.1 | 7 | ... | ... | ... | P, W. | Obs. | Cpr, Wm. | |
| 26D1 | Long Beach Archers | 15 | 85 | 2 | ... | ... | ... | P, W. | ... | ... | |
| 26E1 | M. M. Thomas | 15 | 147 | 12 | 63<br>110 | 39<br>36 | Sand and Gravel<br>Gravel and sand | ... | A | L. | Casing perforated at 95–102, 110–125, and 134–140 ft. |
| 26E2 | R. S. Hubert | 15 | 99 | 3 | ... | ... | ... | C, E. | Irr. | Cp, W. | |
| 26F1 | Lever | 16 | ... | 12 | ... | ... | ... | ... | A | Wd. | |
| 26F2 | C. Smith | 16 | 200 | 12 | ... | ... | ... | C. | Stock, Irr. | Cpr. | |
| 26G1 | L. D. Rosser | 17 | 80 | 2 | ... | ... | Sand | P, E. | Stock | Cp. | |
| 26G2 | ... | 16 | 107 | 26–16 | ... | ... | ... | ... | A | Cpr. | |
| 26J1 | W. I. Engvalson | 15 | 16.0 | 4 | ... | ... | ... | P, W. | ... | Cpr, W. | |
| 26K1 | G. Schreckengast | 13 | 71 | 2 | 43 | 28 | Sand and gravel | P, W. | Irr. | Cpr, L. | |
| 26L1 | City of Long Beach | 15 | 19.3 | 1¼ | 17 | 3 | Sand | ... | Obs. | Cpr, L, Wm. | |
| 26P1 | C. D. Fisher | 12 | 98 | 12 | ... | ... | ... | ... | A | L. | |
| 26P2 | Mary Lou Evans | 12 | 83.7 | 2 | ... | ... | ... | ... | Obs. | Cpr, Wm. | |
| 26P3 | John Ena | 12 | 633 | 12 | ... | ... | ... | ... | ... | Cpr, L. | |
| 26P4 | S. Wheeler | 13 | 85 | 4 | ... | ... | ... | P, W. | Dom. | Cpr. | Casing perforated for 4 ft at bottom. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 26P5 | C. J. Link | 13 | ...... | 4 | ...... | ...... | ...... | P, W | Dom | Cpr | |
| 26P6 | City of Long Beach | 12 | 18.4 | 1¼ | 13 | 3 | Sand | ...... | Obs | Cpr, L, Wm. | |
| 26Q1 | Fred Exner | 12 | 85 | ...... | ...... | ...... | ...... | C, E | Irr | Cpr | Casing perforated at 13 ft near bottom. |
| 26Q2 | A. S. Curtis | 13 | 64 | 2 | ...... | ...... | ...... | P, W | Irr | Cpr | Casing perforated for 5 ft at bottom. |
| 26Q3 | Mrs. Eulia Harmonson | 13 | ...... | 2 | ...... | ...... | ...... | P, W | Irr | Cpr | |
| 26Q4 | .....do | 13 | ...... | 2 | ...... | ...... | ...... | P, W | Irr | Cpr | |
| 26Q5 | R. B. Harding | 13 | 70 | 2 | ...... | ...... | ...... | P, W | Irr | Cpr | Yield about 15 gpm. |
| 26Q6 | Hauge | 12 | ...... | 2 | ...... | ...... | ...... | P, W | ...... | Cpr | |
| 26Q7 | J. F. Browne | 11 | 87 | 2 | ...... | ...... | ...... | ...... | ...... | Cpr | Casing perforated for 4 ft at bottom. |
| 26R1 | W. L. Jones | 13 | 96 | ...... | ...... | ...... | ...... | P, W | ...... | Cpr, W. | |
| 27J1 | U. S. Naval Reserve | 14 | 140 | 12 | ...... | ...... | ...... | C, E | ...... | Cpr, W. | |
| 27K1 | Watson Estate Co | 12 | 493 | 12 | 87<br>383 | 108<br>110 | Sand and gravel<br>.....do | ...... | A | Cpr, L, Wm. | Casing perforated at 102-129 and 463-481 ft. |
| 27L1 | Tide Water Associated Oil Co. | 27 | 230 | 20-12 | 200 | 30 | Coarse gravel | ...... | A | L | Casing perforated for 15 ft between 200-230 ft. |
| | The Texas Co.: | | | | | | | | | | |
| 27L2 | Well 2 | 13 | 820 | 14 | 196<br>371<br>740 | 9<br>317<br>20 | Gravel<br>Sand and gravel<br>Sand and clay | ...... | A | Cpr, L, Wd. | Casing perforated at 196-217, 397-405, 445-470, 498-521, 553-556, 642-688, and 740-760 ft. |
| 27M1 | Well 3 | 33 | 900 | 24-12 | 412 | 398 | Sand and gravel | T, E | Ind | Cpr, L, W. | Yield about 2,800 gpm. Casing perforated at 412-810 ft. |
| 27M2 | Well 1 | 35 | 842 | 14 | 500 | 306 | .....do | ...... | A | Cpr, L, Wd. | Casing perforated at 520-806 ft. |
| 27M3 | Well 5 | 34 | 946 | 20-16 | 266 | 534 | Gravel, sand, and clay. | T, E | Ind | Cpr, L, Wm. | Yield about 4,800 gpm. Casing perforated at 226-256 and 420-800 ft. |
| 27M4 | Well 6 | 36 | 825 | 16 | 435 | 390 | Sand and gravel | T, I | Ind | L | Yield about 2,000 gpm. Casing perforated at 487-499, 515-561, 695-734, and 776-805 ft. |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 4 S., R. 13 W.—Continued | | | | | | |
| 4/13-27R1 | ........ | 10 | 336 | ........ | ........ | ........ | ........ | ........ | A........ | L...... | |
| 27R2 | ........ | 11 | 115 | 6 | ........ | ........ | ........ | ........ | ........ | Cpr, Wd. | |
| | Wilmington Cemetry: | | | | | | | | | | |
| 28N1 | Well 1........ | 45 | 300 | 8 | 200 | 100 | Pea gravel........ | P, W..... | Irr........ | Cp, Wm. | |
| 28N2 | Well 2........ | 45 | 200 | 8 | ........ | ........ | ........ | P, W..... | Irr........ | Cpr, Wm. | |
| 29A1 | Traub Land Co........ | 41 | 366 | ........ | 185<br>200 | 9<br>166 | Gravel........<br>Sand and gravel...... | T, E..... | Dom, Irr... | Cp,L... | Casing perforated at 187-194, 208-234, and 240-260 ft. |
| 29B1 | E. W. Sanderson........ | 42 | 415 | 14 | 285 | 74 | Medium gravel....... | ........ | Obs........ | Cp, L, Wm. | Casing perforated at 330-370 ft. |
| 29C1 | John Holbauch........ | 50 | 600 | 12 | 207<br>485 | 239<br>115 | Coarse sand........<br>Sand and gravel...... | T, E..... | Dom, Irr... | Cp,L... | Casing perforated at 275-281, 295-305, 327-331, and 501-509 ft. |
| 29E1 | B. F. Christiansen....... | 42 | ........ | 2 | ........ | ........ | ........ | P, E..... | Dom....... | Cp, Wm. | |
| 29E2 | Smutzler........ | 43 | 80 | 6 | ........ | ........ | ........ | P, W..... | Dom....... | Cp..... | |
| 29F1 | Rowan........ | 41 | 403 | 15 | ........ | ........ | ........ | ........ | A........ | L,Wd.. | |
| 29M1 | Robert Tracy........ | 37 | 685 | 15? | ........ | ........ | ........ | ........ | Obs........ | C,Ww, Cpr. | |
| 29M2 | Wood........ | 37 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | W...... | |
| 29P1 | Mrs. E. Schneider....... | 40 | 84.1 | 8 | ........ | ........ | ........ | P, W.... | Obs........ | Wm.... | |
| 29R1 | City of Los Angeles....... | 43 | 375 | 6 | ........ | ........ | ........ | Al, E... | PS........ | ........ | |
| | Fletcher Oil Co.: | | | | | | | | | | |
| 30A1 | Well 7........ | 36 | 400 | ........ | ........ | ........ | ........ | T, E.... | Ind........ | ........ | Yield about 400 gpm. |
| 30A2 | Well 2........ | 37 | ........ | ........ | ........ | ........ | ........ | A, L.... | Ind........ | ........ | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30C1 | Los Angeles County, Sanitation District No. 2. | 15 | 300 | 8 | 194 | 106 | Gravel and sand | T | Ind | L | Yield about 600 gpm. |
| 30D1 | Poggie Ranch:<br>Well 1 | 40 | 314 | 12 | 212 | 102 | Sand and gravel | T, E | Irr, Dom | Cp, L, Wm. | Casing perforated at 232-237, 260-277, and 293-297 ft. |
| 30D2 | Well 2 | 46 | 189.8 | 12 | ........ | ........ | ........ | ........ | Obs | Wm | |
| 30E1 | Oliver McCoy | 14 | 285 | ........ | ........ | ........ | ........ | ........ | A | L | |
| 30G1 | City of Los Angeles:<br>Lomita plant, well 6 | 31 | 682 | ........ | 204<br>380 | 130<br>35 | Sand and gravel<br>.....do | T, E | PS | Cr, Cpr, L, Wm. | Casing perforated at 210-340 and 400-420 ft. |
| 30G2 | Lomita plant well 5. | 30 | 695 | 16 | 216 | 276 | .....do | ........ | A | Cpr, L, Wm. | Location of perforations unknown. Yield about 2,900 gpm. |
| 30K1 | Lomita plant, well 7. | 33 | 675 | ........ | ........ | ........ | ........ | T, E | PS | Cr, Cpr. | |
| 31E1 | Lomita plant, well 1. | 17 | 716 | 16 | 350 | 205 | Fine gravel | ........ | A | C, Cpr, L, Wm. | Casing perforated at 355-544 ft. |
| 31E2 | Lomita plant, well 2. | 22 | 509 | 16-12 | 224 | 285 | Sand and gravel | T, E | PS | C, Cpr, L, Wm. | Casing perforated at 425?-500 ft. |
| 31E3 | Lomita plant, well 3. | 21 | 671 | 16-12 | 165 | 506 | .....do | ........ | A | C, Cpr, L, W. | Casing perforated at 206-212, 235-240, 340-420, 440-450, 475-530, and 610-630 ft. |
| 31E4 | Lomita plant, well 4. | 21 | 680 | 20 | 230 | 425 | .....do | T, E | PS | C, L, Wm. | Yield about 4,000 gpm. Casing perforated at 440-560 and 605-655 ft. |
| 31L1 | Palos Verdes Estates | 30 | 629.8 | 26-12 | 274<br>530 | 164<br>378 | .....do<br>.....do | ........ | ........ | C, L, Cpr, Wd. | Casing perforated at 280-300, 314-318, 624-682, and 746-762 ft. |
| 31P1 | Union Oil Co | 40 | 900 | 24-14 | 675 | 147 | Fine to coarse sand | T, E | Ind | L | |
| 32D1 | Daniel Hanson | 38 | 73.3 | 8 | ........ | ........ | ........ | ........ | Obs | Cp, Wm. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 4 S., R. 13 W.—Continued | | | | | | |
| 4/13-33D1 | City of Los Angeles: Wilmington plant; Well 14. | 34 | 888.2 | 20 | 669 | 131 | Sand and gravel | Al | PS, Obs | C, L, Cp Wrd, Wm. | Casing perforated at 720-800 ft. Yield about 2,500 gpm. |
| 33D2 | Well 7 | 29 | 502 | 12 | 264 | 138 | do | Al | PS, Obs | C, L, Wm. | |
| 33E1 | Well 2 | 24 | 856 | 12 | 697 | 94 | do | Al, S | PS, Obs | L, Wm. | Casing perforated at 739-769 ft (?). |
| 33E2 | Well 1 | 26 | 716 | 12 | | | | Al, S | PS, Obs | C, Cp, Wm. | |
| 33E3 | Well 5 | 27 | 526 | 12 | 135<br>270 | 20<br>180 | Sand and gravel<br>do | Al, S | PS, Obs | Cpr, L, Wm. | Casing perforated at 135-155, and 370-450 ft. |
| 33E4 | Well 3 | 25 | 887 | 12 | 667 | 114 | do | Al, S | PS, Obs | L, Wm. | Casing perforated at 730-763 ft. |
| 33E5 | Well 12 | 26 | 529 | | | | | | PS, Obs | L, Wm. | |
| 33E6 | Well 10 | 25 | 563 | 12 | 138<br>262<br>501 | 38<br>139<br>60 | Sand and gravel<br>do<br>Sand and shells | Al, S | PS, Obs | L, Wm. | Casing perforated at 155-164, 172-176, 292-296, 312-315, 318-334, 336-338, 359-363, 381-390, and 543-561 ft. |
| 33E7 | Well 9 | 25 | 577 | 12 | 129<br>260 | 39<br>317 | Gravel and sand<br>Coarse sand and gravel. | Al, S | PS, Obs | L, Wm. | Casing perforated at 129-139, 142-168, 260-265, 287-294, 305-311, 316-335, and 559-570 ft. |
| 33E8 | Well 13 | 25 | 566 | 20 | | | | Al, S | Obs, PS | C, L, Wm. | |
| 33E9 | Well 6 | 26 | 466 | 12 | 267 | 107 | Sand and gravel | | PS | L, Wd. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 33E10 | Well 11 | 26 | ... | ... | ... | ... | ... | ... | PS | W | |
| 33F1 | Well 8 | 24 | 346.8 | 12 | ... | ... | ... | Al, S. | Obs, PS. | Wm. | |
| 33H1 | Bob Dihase | 21 | 25 | 2 | ... | ... | ... | ... | A. | Cp, W. | |
| 33K1 | Consolidated Lumber Co. | 12 | 320 | 12 | ... | ... | ... | ... | A. | C, L, Cpr, Wd, Wrd. | |
| 34C1 | The Texas Co., well 4 | 10 | 1,047 | ... | ... | ... | ... | ... | ... | L. | |
| 34K1 | Frank Martinez | 7 | 101 | 2 | ... | ... | ... | M. | Dom. | Cr, Cpr. | |
| 35A1 | ... | 10 | 21 | 6 | ... | ... | Sand | ... | A. | Cpr, W. | |
| 35B1 | Empire Woolen Mills | 11 | 250 | 16 | 50<br>135 | 73<br>115 | Coarse gravel<br>Fine gravel | C, E. | Obs. | Cr, L, Cpr, Ww. Wrd. | Casing perforated at 103-123 and 135-250 ft. |
| 35C1 | Gilmore Oil Co. | 12 | ... | 11 | ... | ... | ... | ... | Obs. | Cpr, Wm. | |
| 35C2 | D. D. Murray | 11 | 98 | 2 | ... | ... | Gravel | P, W. | Irr. | Cpr. | |
| 35F1 | Electrified Water Co. | 9 | 200 | 4 | ... | ... | ... | P, E. | PS. | Cpr. | |
| 35L1 | Pan Pacific Oil Co. | 9 | 153 | 8 | 125 | 12 | Gravel | ... | A. | L, W. | |
| 35M1 | City of Long Beach | 10 | 137 | 12 | ... | ... | ... | P, S. | Obs. | Cr, Cpr, Wm. | |
| 35M2 | Southern California Edison Co., Ltd. | 11 | 201 | 12 | 73 | 64 | Sand and gravel | T, E. | Ind. | L. | Casing perforated at 111-139 ft. |
| 35M3 | do | 10 | 201 | 12 | 67 | 70 | do | T, E. | Ind. | Cr, L, W. | Casing perforated at 115-139 ft. |
| 35Q1 | California Sea Food Co., Inc. | 5 | 443.0 | 12 | ... | ... | ... | ... | Obs. | Cpr, L, Wm. | |
| 35Q2 | do | 9 | 121 | ... | 77 | 28 | ... | ... | A. | L. | |
| 35Q3 | do | 9 | 125 | ... | ... | ... | ... | ... | A. | C, L, Cpr, Wrd, Wd. | |
| 35Q4 | do | 9 | 124 | ... | 60 | 34 | Sand and gravel | ... | A. | Cr, L, Cpr, Wd. | Casing perforated at 87-109 ft. |
| 35Q5 | Star Drilling Machine Co. | 9 | 70 | ... | ... | ... | ... | ... | A. | W. | |
| 36E1 | Home Ice & Cold Storage Co. | 11 | 310 | 12 | 230 | 10 | Gravel | ... | A. | L, W. | |
| 36M1 | Soft Water Laundry Co. | 15 | 280 | 8 | ... | ... | ... | ... | A. | ... | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] |  |  | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Depth to top (feet) | Thickness (feet) | Character of material |  |  |  |  |
|  |  |  |  |  | T. 5 S., R. 10 W. |  |  |  |  |  |  |
| 5/10-19A1 | Fred Wright | 41 | 83.3 | 4-2 | 75 | ? | Gravel | ........ | Obs. | Wm. |  |
| 19A2 | do. | 41 | 123 | 4 | 109 | 12 | do. | T, E. | Dom. | Cp. |  |
| 19B1 | Ernst Goubert | 35 | ........ | 10? | ........ | ........ | ........ | T, E. | Dom. | Cp. |  |
| 19B2 | do. | 39 | ........ | 12 | ........ | ........ | ........ | T, E. | Irr. | ........ |  |
| 19C1 | Sterling Price | 37 | ........ | ........ | ........ | ........ | ........ | T, I. | Irr. | Cp, W. |  |
| 19D1 | Charles Heil | 35 | ........ | ........ | ........ | ........ | ........ | T, I. | Irr. | Cp. |  |
| 19F1 | do. | 32 | ........ | 4 | ........ | ........ | ........ | P, E. | Dom, Stock. | Cp. |  |
| 19G1 | do. | 36 | ........ | ........ | ........ | ........ | ........ | T, E. | Irr. | ........ |  |
| 19H1 | Huntington Beach Co. | 38 | 300 | 14 | 65 | 79 | Sand and gravel | T, E. | Stock, Irr. | Cp, L, W. | Yield about 1,465 gpm. Casing perforated at 274-276, 277-281 ft and for 50 ft between 75-144 ft. |
|  |  |  |  |  | 274 | 7 | Gravel and sand |  |  |  |  |
| 19K1 | Joe Ishii | 33 | 300 | 12 | 135, 265 | ........ | ........ | T, E. | Dom, Irr. | Cp. |  |
| 19L1 | E. S. Heil Estate, Inc. | 32 | 100 | 7 | ........ | ........ | ........ | T, E. | Irr. | W. |  |
| 19L2 | J. House | 52 | ........ | 10 | ........ | ........ | ........ | T, E. | Irr. | ........ |  |
| 19M1 | E. S. Heil Estate, Inc. | 31 | 90 | 4 | ........ | ........ | ........ | P, E. | Dom. | Cp. |  |
| 19M2 | do. | 31 | 128 | 7 | ........ | ........ | ........ | ........ | ........ | ........ |  |
| 19N1 | Max C. Hoeptner | 26 | 109 | 4 | ........ | ........ | Gravel | ........ | A. | W. |  |
| 19Q1 | ........ | 34 | ........ | 12 | ........ | ........ | ........ | ........ | ........ | W. |  |
| 19R1 | Raymond Seward | 34 | ........ | 6 | ........ | ........ | ........ | T, I. | Irr. | ........ |  |
| 20A2 | John Endo | 53 | 190 | ........ | ........ | ........ | ........ | T, E. | Dom, Irr. | Cp. |  |
| 20A3 | Bert Snyder | 51 | 110 | 12 | ........ | ........ | ........ | T, I. | Dom, Irr. | Cp. |  |
| 20A4 | Leonard De Hoog | 50 | 146 | 7 | 80 | ? | Gravel | T, E. | Dom, Stock. | Cp. |  |
|  |  |  |  |  | 110 | ? | do. |  |  |  |  |
|  |  |  |  |  | 140 | ? | do. |  |  |  |  |
| 20A5 | C. W. Baxter | 51 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |  |
| 20B1 | N. R. Post | 50 | 100 | 8 | ........ | ........ | ........ | T, E. | Dom, Irr. | Cp. |  |
| 20B2 | do. | 50 | 100 | 6 | ........ | ........ | ........ | P, E. | Dom. | Cp. |  |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20C1 | Manuel Vaz | 46 | 160 | 10 | ........ | ........ | ........ | T, E. | Dom, Stock, Irr. | Cp, Wm. | |
| 20C2 | .....do | 47 | ........ | ........ | ........ | ........ | ........ | T, I. | Irr. | ........ | |
| 20D1 | Fred Wright | 45 | 300 | 14 | ........ | ........ | ........ | T, E. | Irr. | Cp, W. | |
| 20G1 | Ralph Chaffee | 46 | ........ | 10 | ........ | ........ | ........ | ........ | A. | Wd. | |
| 20G2 | .....do | 46 | 225 | 14? | ........ | ........ | ........ | T, E. | Irr. | ........ | |
| 20H1 | P. Karales | 49 | ........ | ........ | ........ | ........ | ........ | ........ | A. | Wd. | |
| 20H2 | .....do | 49 | ........ | 12 | ........ | ........ | ........ | T, E. | Irr. | W. | |
| 20H3 | .....do | 48 | ........ | 12 | ........ | ........ | ........ | P, E. | Dom. | Cp, W. | |
| 20J1 | Overacker | 45 | 160 | 7 | ........ | ........ | ........ | T, E. | ........ | ........ | |
| 20J2 | Z. Sato | 44 | 150 | 6 | ........ | ........ | ........ | T, E. | Dom, Irr. | Cp. | |
| 20L1 | W. K. Stock | 43 | 210 | 15 | 175 | ........ | Gravel | T, I. | Dom, Irr. | Cp. | Capped under field. |
| 20L2 | .....do | 41 | 109.0 | 5 | ........ | ........ | ........ | ........ | ........ | W. | |
| 20N1 | Fred Wright | 36 | 105 | 4 | 88 | 15 | Gravel | P, E. | Dom. | Cp. | |
| 20N2 | Huntington Beach Co. | 38 | 232 | 12 | ........ | ........ | ........ | T, E. | Irr. | W. | Casing perforated at 90-100, 134-144, and 174-180 ft. Partial record? |
| 20Q1 | Mrs. Joseph H. Mefford | 37 | 150 | 10 | 98<br>133 | 19<br>17 | Gravel<br>.....do | T, I. | Irr. | L. | Casing perforated at 133-150 ft and for 6 ft between 98-117 ft. |
| 20Q2 | Downey Fertilizer Co. | 41 | ........ | ........ | ........ | ........ | ........ | T, E. | Irr. | ........ | |
| 20R1 | D. Frye | 42 | ........ | 10 | ........ | ........ | ........ | T, E. | Irr. | ........ | |
| 21A1 | Louis Jacober | 60 | 165 | 12 | ........ | ........ | ........ | T, E. | Dom, Stock, Irr. | Cp, Wd. | |
| 21B1 | A. H. Gritton | 56 | 125 | 7 | ........ | ........ | ........ | T, E. | Dom, Irr. | Cp. | |
| 21B2 | I. E. Moore | 54 | 10 | 36 | 2 | 9 | Sand | ........ | Dom, Irr. | Cp, W. | |
| 21C1 | Holmes Loan & Realty Co. | 56 | ........ | 12? | ........ | ........ | ........ | T, E. | Dom, Stock, Irr. | Cp. | |
| 21C2 | .....do | 56 | 150.0 | 7 | ........ | ........ | ........ | ........ | ........ | W. | |
| 21D1 | J. L. Marshall | 53 | ........ | 12 | ........ | ........ | ........ | T, E. | Dom, Irr. | Cp. | |
| 21D2 | L. J. Hull | 55 | ........ | 7 | ........ | ........ | ........ | T, E. | Dom, Stock, Irr. | W. | |
| 21E1 | ........ | 49 | ........ | ........ | ........ | ........ | ........ | ........ | A. | W. | |
| 21E2 | Mrs. Rose A. Morely | 47 | 116 | 7 | ........ | ........ | ........ | P, I. | Dom. | W. | |
| 21F1 | L. E. Wilson | 51 | ........ | ........ | ........ | ........ | ........ | T, I. | Dom, Irr. | W. | |
| 21F2 | J. W. Martin | 51 | 128 | 10 | 114 | 12 | Gravel | T, E. | Dom, Irr. | Cp, Wm. | |

See footnotes at end of table.

Table 29. —*Description of water wells in the coastal zone of the Long Beach - Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] |  |  | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Depth to top (feet) | Thickness (feet) | Character of material |  |  |  |  |
| T. 5 S., R. 10 W.—Continued |  |  |  |  |  |  |  |  |  |  |  |
| 5/10-21G1 | Albert Trudeau | 52 | 145 | 7 | 128 | 20 | Gravel | T, E | Dom, Stock, Irr. | Cp |  |
| 21J1 | Tony Osterkamp | 55 |  |  |  |  |  | T, E | Dom, Irr. | Cp |  |
| 21J2 | .....do | 54 | 135 | 10 |  |  |  | T, E | Dom, Stock. | Cp |  |
| 21J3 | J. W. Martin, Jr. | 53 | 135 | 4 | 115 | 15 | Gravel | T, E | Dom |  |  |
| 21L1 | Mrs. Elizabeth Randall | 48 | 160 | 10 |  |  |  | T, E |  | Cp |  |
| 21N1 | M. F. McDonald | 42 |  | 10 |  |  |  | T | Irr. |  |  |
| 21N2 | H. A. Ketelle | 41 | 161 | 10 |  |  |  | T, E | Dom, Stock, Irr. | Cp |  |
| 21P1 | Mrs. Henson | 45 | 110 |  |  |  |  | P, I | Dom | C |  |
| 21P2 | .....do | 46 |  | 10 |  |  |  | T |  |  |  |
| 21R1 | McKinsey | 50 |  |  |  |  |  |  | A | W |  |
| 28B1 | John Sturtevant | 45 | 122.0 | 10 |  |  |  |  | Obs. | Wm |  |
| 28B2 | B. Ueda | 45 |  |  |  |  |  | T, I | Irr. | W |  |
| 28C1 | Albert Trudeau | 43 | 166 | 10 | 156 | 10 | Gravel | T, E | Irr. |  | Yield about 675 gpm. |
| 28C2 | Kozina Estate | 42 |  |  |  |  |  | T, E | Dom, Stock, Irr. | Cp |  |
| 28D1 | J. Inako | 38 | 210.0 | 7 |  |  |  |  | Obs. | Wm |  |
| 28E1 | A. Naritoku | 35 | 160 |  |  |  |  | T, E | Dom, Stock, Irr. | Cp |  |
| 28F1 | Albert Trudeau | 41 | 400 | 10 |  |  |  | T | Dom, Irr. | Cp, W. | Yield about 450 gpm. |
| 28F2 | W. Kozina | 38 |  | 10 |  |  |  | T, E | Irr. |  |  |
| 28F3 | .....do | 38 |  |  |  |  |  | P, W | Dom, Stock. |  |  |
| 28H1 | H. Yamamota | 42 | 300 | 12? |  |  |  | T, E | Dom, Irr. |  |  |
| 28K1 | Boyer | 40 |  | 4 |  |  |  | P, W | Stock | W |  |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 28L1 | Newhope Drainage District. | 34 | 165 | 12 | 111 | 18 | Gravel and sand | ..... | ..... | L | Casing perforated at 111-120 ft. |
| 28L2 | C. H. Castle | 37 | ..... | 4 | ..... | ..... | ..... | P, W | ..... | Cp | |
| 28M1 | ....do | 33 | ..... | ..... | ..... | ..... | ..... | T | Irr. | ..... | |
| 28M2 | ....do | 33 | ..... | ..... | ..... | ..... | ..... | P, E | Dom | Cp | |
| 28R1 | F. Steigmeyer | 35 | ..... | 4 | ..... | ..... | ..... | P, W | Dom, Stock. | Cp, W. | |
| 28R2 | ....do | 38 | 580.0 | 9 | ..... | ..... | ..... | ..... | ..... | ..... | |
| 29A1 | ..... | 35 | ..... | ..... | ..... | ..... | ..... | ..... | A | W | |
| 29A2 | ..... | 35 | ..... | 10 | ..... | ..... | ..... | T, I | Dom, Irr. | ..... | |
| 29B1 | ..... | 37 | ..... | ..... | ..... | ..... | ..... | T, E | Dom, Stock. | Cp, W. | |
| 29B2 | M. Pimentel | 36 | ..... | 12 | ..... | ..... | ..... | T, E | ..... | ..... | |
| 29C1 | Marshall | 37 | ..... | 10 | ..... | ..... | ..... | T, E | Dom, Irr. | Cp | |
| 29D1 | Roy Neishi | 35 | ..... | 10 | ..... | ..... | ..... | T, E | Dom, Stock. | Cp, Wrd, Ww. | |
| 29E1 | H. Kato | 33 | 217.0 | 16 | ..... | ..... | ..... | T, E | Irr. | Cp, W. | |
| 29F1 | J. Yakura | 33 | ..... | ..... | ..... | ..... | ..... | T, E | Irr. | ..... | |
| 29G1 | Mrs. Nellie Adams | 35 | 44.0 | 6 | ..... | ..... | ..... | T, I | Dom, Stock, Irr. | W | |
| 29G2 | First National Bank of Santa Ana. | 32 | ..... | ..... | ..... | ..... | ..... | ..... | A | W | |
| 29G3 | ....do | 33 | ..... | ..... | ..... | ..... | ..... | T, E | Irr. | ..... | |
| 29J1 | Paul Playan | 33 | ..... | ..... | ..... | ..... | ..... | T, E | Dom, Irr. | Cp | |
| 29K1 | Ann Warner | 32 | 110 | 7 | ..... | ..... | ..... | T, E | Irr. | Cp | |
| 29L1 | Edward Hoffman | 31 | 110 | 7 | ..... | ..... | Gravel | T, E | Dom, Irr. | Cp | |
| 29L2 | George Kanno | 30 | ..... | 7 | ..... | ..... | ..... | T, E | Dom, Irr. | Cp | |
| 29M1 | C. Syester | 23 | ..... | 4 | ..... | ..... | ..... | P, E | Dom | W | |
| 29M2 | Harry Titus | 30 | 83.0 | 4 | ..... | ..... | ..... | ..... | ..... | Cp, W. | |
| 29M3 | G. Gonzales | 28 | ..... | ..... | ..... | ..... | ..... | T, E | Dom, Stock, Irr. | W | |
| 29M4 | N. Matsumota | 27 | 160 | 7 | ..... | ..... | ..... | T, E | ..... | Cp, W. | |
| 29M5 | C. Syester | 31 | ..... | 7 | ..... | ..... | ..... | T, E | Irr. | Cp | Yield about 360 gpm. |
| 29M6 | ..... | 29 | ..... | 10 | ..... | ..... | ..... | T, E | Dom, Stock. | Cp, W. | |
| 29N1 | Mrs. J. Preston | 28 | 265 | 7 or 8 | ..... | ..... | Gravel | T, E | Dom, Irr. | W | |
| 29P1 | George Iwakoshi | 29 | 151 | 12 | 75 | 25 | Gravel and sand | T, E | Irr. | Cp, L. | Casing perforated at 85-100 and 107-117 ft. |
| | | | | | 107 | 10 | Gravel | | | | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5 S., R. 10 W.—Continued | | | | | | |
| 5/10-29P2 | George Iwakoshi | 28 | | 7 | | | | P, W. | Dom. | Cp. | |
| 29P3 | do. | 30 | 120 | 8 | | | | T, E. | Dom, Irr. | Cp. | |
| 29Q1 | C. H. Reed | 29 | | | | | | T, E. | Irr. | Cp. | |
| 29R1 | Elizabeth Ater | 32 | 92 | 7 | | | | T, L. | | W. | |
| 29R2 | L. E. Ater | 31 | 92 | 6 | | | | T, E. | Dom, Stock. | Cp. | |
| 29R3 | L. T. Ater | 32 | 95 | 8 | | | Gravel | P, E. | Dom. | Cp. | |
| 29R4 | Paul Navarez | 32 | | 8 | | | | T, L. | Dom, Irr. | Cp. | |
| 29R5 | R. B. Kmapke | 31 | 92 | 6 | 77 | 14 | Coarse gravel | T, E. | Dom, Irr. | Cp, W. | |
| 30A1 | H. Y. Evans | 33 | 200 | 7 or 8 | | | | T, L. | Irr. | Wd. | |
| 30A2 | Robert Wardlow | 32 | 600 | 14 | | | | T, L. | Irr. | | |
| 30A3 | H. Y. Evans | 35 | | 3 | | | | | | | |
| 30B1 | Mrs. Moore | 33 | 64.0 | 4 | 95<br>280<br>303 | 20<br>18<br>15 | Gravel and sand | | | W. | |
| 30B2 | J. Ishii and M. Neishi | 32 | 320 | 8-6 | 302 | 16 | Gravel | T. | Irr. | | |
| 30B3 | J. Ishii | 31 | 282.3 | 7 | | | | | Obs. | Cp, Wm. | |
| 30C1 | Max C. Hoeptner | 30 | | | | | | | A. | W. | |
| 30C2 | do. | 30 | | | | | | | A. | W. | |
| 30C3 | do. | 30 | 180 | 10 | | | | T, E. | Irr. | Cp. | |
| 30C4 | do. | 30 | 105 | 4 | | | | P, W. | Dom. | Cp. | Casing perforated at 95-105 ft. |
| 30D1 | U. Plavan | 28 | | | | | | | A. | W. | |
| 30E1 | do. | 27 | 240 | 7 | | | | T, E. | Irr. | Cp. | |
| 30E2 | do. | 25 | 240 | 7 | | | | P, E. | Dom. | Cp. | |
| 30F1 | Mrs. N. S. DuRall | 30 | 120 | 4 | | | | P, W. | Dom. | Cp, W. | |
| 30F2 | do. | 28 | 150 | | | | | T, E. | Irr. | | |
| 30H1 | J. O. Harper | 32 | 132 | 10 | 49 | 27 | Sand and gravel | T, L. | Irr. | L, W. | |
| 30H2 | H. Harper | 32 | 90 | 4 | | | | P, W. | Dom. | Cp. | |
| 30H3 | Annie Harper | 32 | | 4 | | | | P, E. | Dom. | Cp. | |
| 30H4 | do. | 30 | | | | | | T, E. | Irr. | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30H5 | J. O. Harper | 31 | 100 | 4 | | | | | | | |
| 30J1 | Fred Pope | 30 | 87 | 4 | | | | | A. | W. | Casing perforated at 79-87 ft. |
| 30J2 | .....do | 29 | 99 | 4 | | | | | A. | W. | Casing perforated at 91-99 ft. |
| 30J3 | .....do | 28 | 97 | 4 | | | | | A. | W. | Casing perforated at 89-97 ft. |
| 30K1 | E. Martin; Shell Oil Co. | 27 | | 18 | | | | | | L. | |
| 30K2 | .....do | 28 | | | | | | T, E. | Irr. | Cp. | |
| 30L1 | Robert Wardlow | 28 | 154 | 14 | | | Gravel | T, E. | Irr. | W. | |
| 30M1 | Mrs. H. Cheney | 23 | | 7 | | | | T, E. | Irr. | | |
| 30N1 | .....do | 23 | | | | | | | A. | W. | |
| 30N2 | .....do | 22 | | | | | | | A. | W. | |
| 30P1 | Robert Wardlow | 27 | | | | | | | A. | W. | |
| 30P2 | Ray Wardlow | 25 | 125.0 | 8 | | | | P, W. | Stock | Cp, W. | |
| 30P3 | Fountain Valley School District. | 26 | | 7 | | | | T, E. | PS. | Cp, W. | |
| 30P4 | Robert Wardlow | 27 | 87 | 4 | | 4 | Gravel | T, E. | Dom. | Cp. | |
| 30Q1 | Edward Muller | 26 | 140 | 7 | 85 | 53 | Gravel and sand | T, E. | Dom, Stock, Irr. | C, L. | Casing perforated at 104-138 ft. |
| 30Q2 | Ray Wardlow | 25 | 100 | 7 | | | | P, E. | Dom. | Cp. | |
| 30R1 | W. Ascherman | 25 | | 7 | | | | T, E. | Irr. | | |
| 30R2 | Robert Wardlow | 27 | | | | | | T, I. | Irr. | Cp. | |
| 31A1 | H. C. Gordon | 25 | 70.0 | 2 | | | | | Obs. | Wm. | |
| 31A2 | J. W. Davis | 25 | | 8 | | | | T, E. | Dom, Irr. | Cp, W. | |
| 31A3 | .....do | 24 | | | | | | | A. | W. | |
| 31A4 | Talbert Drainage District | 24 | | 4 | | | | | | W. | |
| 31A5 | Roy Chaffee | 24 | | 6 | | | | T, I. | Irr. | W. | |
| 31A6 | Robert S. Harper | 25 | 77 | 5 | 60 | 17 | Gravel and boulders | P, E. | Dom. | Cp, W. | |
| 31A7 | J. W. Davis | 24 | 168 | 7 | | | | T, E. | Dom, Irr. | Cp. | |
| 31A8 | Frank Harper | 23 | 75 | 6 | | | | Al, I. | Dom, Stock. | Cp. | Casing perforated at 68-75 ft. |
| 31A9 | Ramon L. Lopez | 20 | 77 | 6 | 71 | 6 | Gravel | C. | Dom. | Cp. | |
| 31A10 | )H. C. Gordon | 25 | 160 | 4 | | | | P, E. | Dom, Stock, Irr. | Cp. | |
| 31A11 | J. O. Harper | 22 | 84 | 4 | 60 | 24 | Gravel and boulders | P, W. | Dom. | Cp. | |
| 31B1 | D. J. Harper | 25 | 100 | 2 | | | | | A. | W. | |
| 31B2 | .....do | 24 | 100 | 4 | | | | P, E. | Dom. | Cp. | |
| 31B3 | T. Kato | 22 | 100 | 2 | | | | P, E. | Dom. | Cp. | |
| 31B4 | E. Callens | 23 | | 7 | | | | T, E. | Irr. | Cp. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5 S., R. 10 W.—Continued | | | | | | |
| 5/10-31C1 | T. V. Talbert | 24 | | | | | | T, E | Dom, Irr | Cp, Wm. | |
| 31C2 | | 21 | 162 | 4 | | | | C, E | Dom | Cp | Casing perforated at 152–162 ft. |
| 31C3 | John E. Brewer | 24 | 100 | 8 | | | | | Obs | Cpr, Wm. | |
| 31C4 | Mrs. Hattie Talbert | 22 | 101 | 6 | 65 | 36 | Gravel | T, E | Dom | C | |
| 31C5 | T. Talbert | 18 | | | | | | | A | W | |
| 31C6 | Mrs. Hattie Talbert | 22 | 47.0 | 2 | | | | | Obs | Wm | |
| 31D1 | Eva L. Gunn | 22 | 87 | 4 | | | | P, E | Dom | Cp | |
| 31D2 | B. Rogers | 22 | | 4 | | | | P, E | Dom | Cp | |
| 31D3 | Good Subdivision Mutual Water Co. | 21 | 165 | | | | | T, E | PS | Cp | |
| 31D4 | O. J. Cox | 20 | 115 | 6 | 84 | 31 | Gravel | C, I | Dom | Cp, W. | |
| 31D5 | J. Boer | 21 | 105 | 6 | | | do | P, E | Dom, Irr | Cp | |
| 31D6 | Mrs. L. Titus | 20 | | 7 | | | | C | | | |
| 31E1 | Joseph Callens | 17 | 120.0 | 7 | | | | | Irr | Cp, W. | |
| 31F1 | Fred Pope | 17 | 120.0 | 7 | | | | | | Cp, W. | |
| 31F2 | Otto Folkerts | 23 | 142 | 7 | | | | | | Cpr, Wd. | |
| 31F3 | do | 20 | 103 | 6 | 78 | 25 | Gravel | T, E | Dom, Stock, Irr. | Cp | |
| 31G1 | J. Moiole | 21 | | | | | | T, E | Irr | | |
| 31H1 | do | 21 | | | | | | T, E | Irr | | |
| 31H2 | R. Farnsworth | 20 | | | | | | T, E | Irr | | |
| 31J1 | E. Callens | 20 | 60 | 2 | | | | P, E | Dom | Cp | |
| 31J2 | do | 15 | 120.0 | 10 | | | | | | W | |
| 31K1 | J. Moiole | 20 | | | | | | T, E | Dom, Stock. | Cp | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31L1 | John Pope | 14 | 119.0 | 7 | | | | | Obs | Cp, Wm. | |
| 31L2 | do | 19 | | | | | | T, E | Dom, Irr | Cp | |
| 31M1 | do | 15 | 127.5 | 10 | | | | C, E | Irr | W | |
| 31N1 | do | 15 | 141.5 | 7 | | | | | | Cp, W. | |
| 31P1 | do | 18 | 118 | 10 | | | | | | Cp, W. | |
| 31Q1 | F. Palmer | 15 | | | | | | T, E | | Cp, W. | |
| 31R1 | Mrs. A. M. Nolin | 14 | 16 | 10 | | | | P, W | | W | |
| 31R2 | do | 14 | | 4 | | | | P, E | Dom, Stock. | | |
| 31R3 | Mrs. Acres | 14 | 90 | 4 | 70 | 20 | Sand and gravel | P, W | Dom | Cp, L, W. | |
| 31R4 | Phillip O'Connell | 14 | 91 | 4 | 70 | 20 | do | I | Dom, Stock. | Cp, L | |
| 31R5 | | 15 | | | | | | T, E | Irr | | |
| 31R6 | Mrs. Acres | 14 | 68 | 2 | 60 | 8 | Sand | | | L | Casing perforated at 64-68 ft. |
| 32A1 | Fred Pope | 29 | | | | | | | A | W | |
| 32A2 | do | 28 | | 7 or 8 | | | | T, E | Irr | | |
| 32B1 | R. W. Gisler | 26 | 150 | | | | | | A | W | |
| 32B2 | do | 27 | | | | | | T, E | Irr | | |
| 32B3 | do | 26 | | 3 | | | | P, E | Dom | Cp | |
| 32C1 | Mrs. H. E. Chan | 26 | 105 | 7 | | | | T, E | Dom, Irr | C, Wm, Cpr. | |
| 32C2 | H. C. Troop | 26 | 100 | 4 | | | | C, I | Dom, Irr | Cp, W. | |
| 32C3 | E. Fowler | 26 | 94 | 4 | | | | P, E | Dom, Irr | Cp, W. | Casing perforated at 87-94 ft. |
| 32C4 | Frank Nolan | 26 | 100 | 4 | | | Sand and gravel | J, E | Dom | Cp, W. | |
| 32C5 | do | 26 | 100 | 4 | | | | | | | |
| 32C6 | William McCormack | 26 | 90 | 4 | | | Gravel | I | Dom, Irr | Cp | |
| 32C7 | D. B. Cook | 26 | 97 | 4 | | | do | P, E | Dom, Irr | | Open bottom; no perforation. |
| 32C8 | | 26 | 100 | 4 | | | | | | | |
| 32C9 | Crew | 25 | 125 | 7 | | | | T, E | Irr | | |
| 32D1 | John E. Brewer | 25 | 298 | 10 | 60 | 47 | Gravel and sand | T, I | Irr | L | Casing perforated at 73-83, 105-107, 183-185, and 218-220 ft. |
| | | | | | 166 | 19 | Rock and sand | | | | |
| | | | | | 189 | 31 | Sand and gravel | | | | |
| 32D2 | do | 26 | 120 | 7 | 85 | 5 | Gravel | P, E | Dom | Cp | |
| | | | | | 120 | ? | do | | | | |
| 32D3 | J. F. Sauers | 25 | 125 | 7 | | | | T, E | Dom, Irr | Cp | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5 S., R. 10 W.—Continued | | | | | | |
| 5/10-32D4 | R. McDonald | 25 | 99 | 4 | ........ | ........ | Gravel | P, E | Dom, Irr | Cp | |
| 32E1 | Mrs. Jessie Preston | 21 | 32.0 | 7 | ........ | ........ | ........ | ........ | ........ | Cp, W. | |
| 32E2 | .....do | 21 | 91.0 | 7 | ........ | ........ | ........ | ........ | ........ | W | |
| 32E3 | John E. Brewer | 20 | ........ | ........ | ........ | ........ | ........ | ........ | A | W | |
| 32F1 | George Page and others | 22 | 110 | 7 | ........ | ........ | ........ | T, E | Dom, Irr | Cp, W. | |
| 32F2 | ........ | 24 | ........ | 6? | ........ | ........ | ........ | C, I | ........ | W | |
| 32F3 | George Page and others | 23 | 98.0 | 10 | ........ | ........ | ........ | ........ | ........ | W | |
| 32F4 | Mrs. Masuda | 25 | ........ | ........ | ........ | ........ | ........ | T, E | Dom, Irr | Cp | |
| 32G1 | Robert Gisler | 24 | ........ | ........ | ........ | ........ | ........ | ........ | A | W | |
| 32H1 | M. Gisler and brothers | 25 | ........ | 7 | ........ | ........ | ........ | T, E | ........ | ........ | |
| 32J1 | Orange County Joint Outfall Sewer District. | 27 | ........ | 10 | ........ | ........ | ........ | T, E | Ind | C, W, Cp. | |
| 32J2 | .....do | 25 | 163 | 6 | ........ | ........ | ........ | ........ | A | C, W | Casing perforated at 149–163 ft. |
| 32J3 | .....do | 25 | ........ | ........ | ........ | ........ | ........ | ........ | A | Wd | |
| 32K1 | Mrs. M. L. Jones | 24 | 90 | 7 | ........ | ........ | ........ | P, W | Dom | Cp, W. | |
| 32K2 | .....do | 24 | 160 | 12 | ........ | ........ | ........ | T, E | Irr | Cp | |
| 32L1 | M. Gisler | 23 | ........ | 4 | ........ | ........ | ........ | P, E | Dom | Cp | |
| 32L2 | Robert Gisler | 23 | 112.0 | 10 | ........ | ........ | ........ | ........ | Irr | Cp, W. | |
| 32M1 | John E. Brewer | 21 | 120 | 7 | ........ | ........ | ........ | T, I | Irr | W | |
| 32N1 | .....do | 17 | ........ | ........ | ........ | ........ | ........ | ........ | A | W | |
| 32N2 | .....do | 17 | ........ | ........ | ........ | ........ | ........ | ........ | A | W | |
| 32P1 | Robert Gisler | 19 | 128.0 | 10 | ........ | ........ | ........ | ........ | ........ | Cp, W. | |
| 32P2 | .....do | 20 | 5.7 | 1 | ........ | ........ | ........ | ........ | Obs | W | |
| 33A1 | Antonio Bushard | 36 | ........ | 10? | ........ | ........ | ........ | T, E | Irr | Cp, Wm, L. | Yield about 580 gpm. |
| 33C1 | Frederick Steigmeyer | 34 | ........ | 7 | ........ | ........ | ........ | T, E | Dom, Irr | Cp, W. | |
| 33G1 | Antonio Bushard | 31 | ........ | ........ | ........ | ........ | ........ | T, E | ........ | ........ | |
| 33H1 | .....do | 32 | 258.6 | 10 | ........ | ........ | ........ | ........ | Irr | Cp, L, Wm. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 33J1 | do | 32 | 215.0 | 3 | | | | | | W | |
| 33N1 | E. V. S. Pomeroy | 40 | 180 | 8 | | | | T, E | Dom, Irr | Cp | |
| 33N2 | do | 35 | | 4? | | | | P | | | |
| 33P1 | Arthur Gisler | 40 | 226 | 12 | 160 | 7 | Gravel | T, E | Irr | Cp | |
| 33Q1 | Sam Gisler | 38 | 297 | 12 | | | | T, E | Dom, Irr | Cp, Wd. | |
| 33Q2 | do | 37 | 296.0 | 3 | | | | | Dom | Cp, Ww. | |
| 33Q3 | do | 38 | 188.7 | 2½ | | | | | | W | |
| 34B1 | M. M. Graser | 35 | 297 | 12 | | | | T, E | Irr | | |
| 34C1 | Mrs. Stanley | 35 | 500 | 12 | | | | T, E | Irr | | |
| 34C2 | do | 35 | 398 | 12 | | | | | | W | |
| 34D1 | City of Newport Beach | 34 | 375 | 12 | | | | T, E | Irr | Cp, Wm. | |
| 34D2 | Frederick Steigmeyer | 37 | | 10 or 12 | | | | T, E | Dom, Irr | Cp | |
| 34E1 | City of Newport Beach | 33 | 411.0 | 18-12 | 250 | 36 | Gravel and sand | | | L, Wm. | Casing perforated at 350-372 and 336-342 ft. |
| | | | | | 336 | 6 | Gravel | | | | |
| 34F1 | C. J. Segerstrom Sons | 32 | 800 | 10 | | | | T, E | Irr | | |
| 34G1 | M. M. Graser | 33 | 792 | 6 | 664 | 4 | Gravel | P, E | Dom | Cp, L. | Casing perforated at 664-668 and 760-770 ft. |
| | | | | | 750 | 20 | Gravel and sand | | | | |
| 34H1 | Greenville School | 33 | 188 | 4 | | | | T, E | PS | Cp | Casing perforated at 179-188 ft. |
| 34H2 | Charles Griset | 33 | 760 | 10 | | | | T, E | Irr | L | |
| 34J1 | Gus Callens | 31 | 93 | 4 | 85 | 8 | Gravel | C, E | Dom | Cp | |
| 34K1 | Anna Kuffel | 32 | 150 | 4 | | | | P, W | Dom | Cp | |
| 34Q1 | C. J. Segerstrom Sons | 31 | 210 | 12 | 37 | 21 | Gravel | T, E | Dom, Stock. | Cp, L. | Yield about 900 gpm. Casing perforated at 37-58, 81-82, 114-126, 155-161, and 205-206 ft. |
| | | | | | 114 | 12 | Sand and shells | | | | |
| | | | | | 135 | 26 | Sand and gravel | | | | |
| | | | | | 192 | 14 | do | | | | |

T. 5 S., R. 11 W.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/11-2A1 | Miss Ruth Johnston | 53 | | 3 | | | | P, E | Dom | Cp | |
| 2A2 | H. A. Guertin | 53 | 265 | 4 | | | | P | Dom, Stock. | Cpr | |
| 2B1 | Maussnest Estate | 50 | 500 | 12 | | | | T, I | Irr | Wd | |
| 2B2 | Charles Walton | 48 | 500 | | | | | T, I | Dom, Irr | Cp | |
| 2C1 | | 50 | 1,020 | | | | | T, E | Dom | | |
| 2D1 | B. S. Benson | 50 | 268 | 7 | | | | P, W | Dom | Cpr, Wd. | |
| 2D2 | J. L. Sutton | 48 | | | | | | T, I | Irr | Cp | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach - Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] |  |  | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Depth to top (feet) | Thickness (feet) | Character of material |  |  |  |  |
| T. 5 S., R. 11 W.—Continued |  |  |  |  |  |  |  |  |  |  |  |
| 5/11-2E1 | Western Trust and Savings Bank. | 47 | 517 |  |  |  |  | T, L | Irr | Cp, Wm. |  |
| 2E2 | Roy A. Blakeney | 45 | 230 | 7 |  |  |  |  |  | W. |  |
| 2E3 | W. A. Gill | 43 | 221 | 12 | 185 | 19 | Gravel | T, I. | Dom, Irr. | Cp, L, Wd. | Casing perforated at 186–204 ft. |
| 2E4 | Mountain Properties Inc. | 45 | 220 | 10–4 |  |  |  | T, E. | PS | Cp, W. |  |
| 2F1 | Charles Parr | 47 | 533 | 12 |  |  |  | T, E. | Irr | Wd. |  |
| 2F2 | do | 46 | 100 | 4 |  |  |  | P, W. |  | Cp. |  |
| 2G1 | A. F. Caldillo | 47 | 110 | 12 |  |  |  | T, E. | Dom, Irr. | Wm. |  |
| 2G2 | J. H. Walton | 46 | 100 | 4 | 98 | ? | Coarse gravel | P, E. | Dom. | Cp. |  |
| 2H1 | Miss Ruth Johnston | 51 | 500 | 14 |  |  |  | T, I. | Dom, Irr. | Cp, W. |  |
| 2K1 |  | 46 | 101 | 7 |  |  |  | T. |  | Cp, Wd. |  |
| 2K2 | M. B. Eder | 44 | 92 | 12 | 84 | 5 | Gravel | T E. | Dom, Irr. | Cp, L, W. |  |
| 2K3 | C. J. Harris | 46 | 96 | 4 |  |  |  | T, E. | Dom, Irr. |  |  |
| 2K4 | C. L. Baker | 44 | 100 | 4 |  |  |  | T, I. | Dom. | Cp. |  |
| 2K5 | C. P. Terrass | 46 | 93 | 8 |  |  | Sand and gravel | T, I. | Dom. | Cp. |  |
| 2K6 | Virgil Ferguson | 46 | 200 | 7 |  |  |  | E. | Dom. |  |  |
| 2K7 | do | 45 | 96 | 4 |  |  |  | E. | Dom. |  |  |
| 2L1 | L. Firsick | 44 | 400 | 12 |  |  |  | T, E. | Dom, Irr. | Cp, Wm. |  |
| 2N1 | Orange County Water District 5. | 39 | 438 | 16 | 387 | 45 | Gravel | T, E. | PS | L, Wm. | Casing perforated at 397–432 ft. Yield about 390 gpm. |
| 2Q1 | Westminster School | 43 |  |  |  |  |  |  | A. | Wd. |  |
| 2Q2 | Wells B. McCoy | 45 | 440 | 10 |  |  |  | T, E. | Dom, Irr. | Cp, Wd. |  |
| 2Q3 | Miss Ruth Johnston | 44 | 135 | 10 |  |  |  | T. | Irr. |  |  |
| 2Q4 | do | 44 |  | 6 |  |  |  | P, W. | Dom. | Cp. |  |
| 2Q5 |  | 44 |  | 4 |  |  |  | P, W. | Dom. | Cp. |  |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2R1 | ........ | 47 | 151 | 11 | 80<br>108 | 10<br>32 | Gravel and sand<br>Sand and gravel | ........ | A | L, Wd. | Casing perforated for 4 ft between 80-90 ft and for 25 ft. between 112-140 ft. |
| 3A1 | T. Shiba | 46 | 525 | 8? | ........ | ........ | ........ | T, E | Irr | Wm |  |
| 3A2 | Mrs. E. L. Green | 46 | ........ | 7 | ........ | ........ | ........ | T, I | Dom, Stock, Irr. | Cp |  |
| 3A3 | I. W. Hellman Ranch, well 2. | 45 | ........ | 12 | ........ | ........ | ........ | T, E | Dom, Irr | Cp, Wd. |  |
| 3H1 | Creedmoor Land & Water Co. | 40 | 900 | 12 | ........ | ........ | ........ | P, E | Dom, Stock. | Cp, Wrd, Wd. |  |
| 3H2 | .....do | 37 | ........ | 12 | ........ | ........ | ........ | ........ | ........ | ........ |  |
| 3L1 | A. W. Cowdin Estate | 34 | 780 | 10 | 280<br>780 | ?<br>? | Gravel<br>.....do | T, E | Dom, Irr | Cp |  |
| 3M1 | J. G. Ward | 33 | 250 | 7 | ........ | ........ | ........ | T, E | Dom, Irr | ........ |  |
| 3N1 | I. H. Moulden | 30 | 386 | 10 | 380 | 20 | Sand and gravel | T, E | Dom, Irr | Cp, W. |  |
| 3N2 | L. C. McGarvin | 27 | 137 | 4 | 130? | 7 | Gravel | P, W | Dom | Cp |  |
| 3N3 | L. S. Ivy | 28 | 118 | 4 | 100 | 8 | .....do | C, E | ........ | Cpr |  |
| 3N4 | H. G. Stevenson | 29 | 148 | 8 | 146 | 2 | Sand and gravel | T, E | Dom | Cpr |  |
| 3P1 | Mitchell | 32 | 190 | 7 | ........ | ........ | ........ | P, I | Dom | ........ |  |
| 3P2 | A. D. Mitchell | 31 | 318 | 8 | ........ | ........ | ........ | T, E | Irr | Cp | Yield about 170 gpm. |
| 3P3 | Mrs. Millard | 30 | 100 | 4 | ........ | ........ | ........ | P, W | Dom | ........ |  |
| 3Q1 | Mountain Properties Inc. | 37 | 175 | 10 | 90 | 10 | Gravel | T, E | PS | ........ |  |
| 3R1 | Larry Swarts | 37 | 400 | 16 | ........ | ........ | ........ | T, I | Irr | ........ |  |
| 4A1 | I. W. Hellman Ranch, well 9. | 31 | 921 | 12 | 802<br>861 | 47<br>52 | Sand and gravel<br>Gravel and sand | T, E | Dom, Irr | Cp, L, Ww. | Casing perforated at 830-849 and 875-913 ft. |
| 4R1 | Western Trust and Savings Bank. | 27 | 165 | 10 | ........ | ........ | ........ | C, I | Dom, Irr | ........ |  |
| 4R2 | I. W. Hellman Ranch | 28 | 733 | ........ | 323<br>340<br>563<br>694 | 4<br>23<br>104<br>20 | Coarse gravel<br>.....do<br>Sand and gravel<br>Gravel | T, E | Irr, Obs | L, Wm. | Casing perforated at 323-327, 340-363, 655-667, and 694-714 ft. |
| 5A1 | .....do | 21 | ........ | 12 | ........ | ........ | ........ | T, E | Dom, Irr | C, Ww, Cp. |  |
| 5Q1 | .....do | 17 | 100 | 7 | ........ | ........ | ........ | T, E | Dom | Cp, Wm. |  |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—*Continued*

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] |  |  | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Depth to top (feet) | Thickness (feet) | Character of material |  |  |  |  |
| T. 5 S., R. 11 W.—Continued |  |  |  |  |  |  |  |  |  |  |  |
| 5/11-6A1 | I. W. Hellman Ranch | 17 | 1,030 | 12-10 | 815 | 160 | Gravel and sand | T, I | Dom, Irr | Cpr, L, Wm. | Casing perforated at 818-841 and 925-975 ft. |
| 6D1 | do | 12 | 247 |  |  |  |  |  | A | Cpr, W. |  |
| 6D2 | do | 12 | 105.8 | 2 |  |  |  |  | Obs | Ww | Casing perforated at 185-195 ft. |
| 6D3 | do | 12 | 259 | 2 |  |  |  | P, W | Dom | Cp | Casing perforated at 251-259 ft. |
| 7A1 | do | 12 | 230 | 4 |  |  |  | C, E | Dom | Cp, Wd. |  |
| 7G1 | do | 6 | 21.3 | 1¼ | 18 | 4 | Sand |  | Obs | Cp, L, Wm. |  |
| 7L1 | do | 6 | 796 | 12 |  |  |  | P, E |  | Cp, L, W. | Yield about 600 gpm.[2] |
| 8C1 | do | 16 | 915 | 12 | 633<br>685<br>800 | 35<br>12<br>70 | Coarse gravel<br>do<br>Sand and gravel | P, E | Dom | C, L, Cp, Wd. | Casing perforated at 633-655, 685-697, and 850-870 ft. Yield about 550 gpm. |
| 8D1 | do | 12 | 104.3 | 2 |  |  |  |  | Obs | Wm | Casing perforated at 110-118 ft. |
| 8J1 | Carl A. Johnson | 16 | 400 | 12 |  |  |  | T, I | Irr |  |  |
| 8M1 | I. W. Hellman Ranch | 11 | 150 | 2 |  |  |  | P, W | Dom | Cp |  |
| 9A1 | Peter Callos | 26 | 151 | 6-4 |  |  |  | P, E | Dom | W |  |
| 9A2 | do | 27 | 450 | 6 |  |  |  | T, E | Irr |  |  |
| 9A3 | Hess Vande Velda | 27 | 224 | 8 | 173 | 51 | Gravel | T | Irr | Cp, W. | Casing perforated at 204-224 ft. |
| 9A4 | do | 27 | 121 | 4-2¼ | 90 | 31 | Gravel and sand | T, E | Dom | Cp |  |
| 9B1 | Russel Estate | 25 | 145 | 6 |  |  | Coarse gravel | T, E | PS | Cp | Casing perforated at about 100 ft. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9C1 | I. W. Hellman Ranch | 21 | ...... | ...... | ...... | ...... | ...... | ...... | A | W | |
| 9F1 | Anaheim Sugar Co. | 21 | 900 | 12 | ...... | ...... | ...... | T, E. | Dom, Irr. | Cp. | |
| 9G1 | .....do | 24 | 900 | 12 | ...... | ...... | ...... | T, E. | Dom, Irr. | Cp. | |
| 10A1 | B. B. Taylor | 36 | 187.0 | 4 | ...... | ...... | ...... | ...... | ...... | Cp, W. | |
| 10A2 | .....do | 36 | 425 | 10 | ...... | ...... | ...... | T, I. | Irr. | ...... | |
| 10A3 | .....do | 36 | 31.6 | 2 | ...... | ...... | ...... | ...... | ...... | W. | |
| 10A4 | C. A. Eastwood | 36 | 80 | 4 | ...... | ...... | ...... | P, W. | Dom, Stock. | Cpr. | |
| 10A5 | W. L. Johnson | 36 | 100 | ...... | ...... | ...... | ...... | P, E. | Dom, Irr. | ...... | |
| 10A6 | Laurence | 35 | 80 | 4 | ...... | ...... | ...... | ...... | Dom, Stock, Irr. | ...... | Casing perforated at 72-80 ft. |
| 10A7 | B. N. Blair | 35 | 80 | ...... | ...... | ...... | ...... | P, E. | Dom. | Cp. | |
| 10B1 | B. B. Stakemiller | 35 | 400 | 8 | ...... | ...... | ...... | T, E. | Irr. | ...... | |
| 10B2 | Fred Basse | 35 | 294 | 4 | 286 | ...... | Gravel | T, E. | Dom. | Cp. | |
| 10B3 | K. R. Boulton | 33 | 100 | 6 | ...... | ...... | .....do | P, I. | Dom, Stock, Irr. | Cp, W. | |
| 10B4 | .....do | 34 | 140 | 2 | ...... | ...... | ...... | ...... | ...... | W. | |
| 10B5 | H. A. Call | 26 | 97 | 4 | 98? | ...... | ...... | T, E. | Dom. | ...... | |
| 10B6 | E. A. Call | 26 | 132 | 4 | ...... | ...... | Gravel | T, E. | Dom. | Cp. | |
| 10B7 | M. C. Dressler | 32 | 130 | 4 or 6 | ...... | ...... | ...... | T, E. | Dom. | ...... | |
| 10B8 | R. J. Frenzel | 32 | 142 | 4 | 100 | 42 | Gravel | T, E. | Dom. | Cp. | |
| 10B9 | Mrs. Henry Myers | 32 | 107 | ...... | 60 | 10 | .....do | P, E. | Dom. | Cp. | |
| | | | | | 90 | ? | .....do | | | | |
| 10C1 | E. B. Finley | 32 | 100 | 7 | 100 | ...... | .....do | P, E. | PS. | Cp. | Casing not perforated. |
| 10C2 | .....do | 31 | 386 | 10 | 336 | 34 | ...... | T, I. | Irr. | ...... | |
| 10C3 | P. S. Wildman | 30 | 321 | 4 | ...... | ...... | ...... | P, W. | Dom, Irr. | Cp. | |
| 10C4 | H. T. Stone | 30 | ...... | 2 | ...... | ...... | ...... | P, W. | Dom. | W. | |
| 10C5 | F. S. Van Uden | 30 | 128 | 2 | 120 | 8 | Gravel | P, E. | Dom. | L. | |
| 10C6 | .....do | 29 | 248 | 5 | ...... | ...... | ...... | Al. | Irr. | ...... | Casing perforated at 236-248 ft. |
| 10C7 | A. F. Milton | 28 | 124 | 3 | 115 | 124 | Gravel | P, W. | Dom, Irr. | Cp. | |
| 10C8 | Mrs. Edna Gill | 29 | 152 | ...... | ...... | ...... | ...... | P, W. | Dom. | Cp. | |
| 10C9 | Mrs. A. Carnaghan | 30 | 100 | 3-4 | ...... | ...... | ...... | P, W. | Dom. | Cp. | |
| 10C10 | Roy Smith | 31 | 120 | 2 | ...... | ...... | ...... | P, W. | Dom. | ...... | |
| 10D1 | L. H. Shinpaugh | 27 | 135 | 3 | ...... | ...... | ...... | P, E. | Dom. | Cp. | |
| 10D2 | O. J. Slate | 27 | 135 | 3 | 80 | 55 | ...... | P, W. | Dom. | ...... | |
| 10D3 | Elizabeth Smith | 27 | 128 | 4 | ...... | ...... | ...... | P, E. | Dom, Irr. | Cp. | |
| 10D4 | Aldridge Estate | 29 | 409 | 10 | 335 | 30 | Gravel | T, E. | Irr. | ...... | Casing perforated at 335-365 ft. |
| | | | | | 385 | 20 | Sand | | | | |
| 10D5 | G. H. Finley | 29 | 319 | 4 | 128 | 4 | Gravel | P, W. | Dom. | Cp, W. | |
| | | | | | 210 | ? | .....do | | | | |
| | | | | | 290 | 29 | .....do | | | | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5 S., R. 11 W.—Continued | | | | | | |
| 5/11-10F1 | George Frizby | 29 | 390 | 10 | ........ | ........ | ........ | P, W | Dom | Cp, W | |
| 10F2 | Fred Croxton | 28 | 95 | 3 | ........ | ........ | ........ | C, E | Dom, Stock. | Cp | |
| 10F3 | Mrs. B. C. Best | 29 | 80 | 7 | 80 | ........ | Gravel | P, W | Dom | Cp | |
| 10F4 | W. M. Sell | 28 | 92 | 3 | ........ | ........ | ........ | C, I | Dom, Irr | ........ | |
| 10F5 | M. P. Sullivan | 28 | 90 | 3? | ........ | ........ | ........ | P, E | Dom | Cp | |
| 10F6 | Vande Vin | 28 | 270 | ........ | ........ | ........ | ........ | P, E | Dom | Cp | |
| 10F7 | C. Livingston | 28 | 100 | 3 | ........ | ........ | ........ | P, E | ........ | Cp | |
| 10G1 | R. W. Edwards | 32 | 354.5 | 7 | ........ | ........ | ........ | T, E | Dom | Cp, W | |
| 10H1 | R. W. Edwards Ranch | 34 | 80 | 7 | ........ | ........ | ........ | P, W | Dom | C, Wd, Cp. | |
| 10H2 | R. W. Edwards | 36 | 420 | 7 | ........ | ........ | ........ | T | Irr | ........ | |
| 10J1 | A. J. Folger | 32 | 387 | 10 | 80<br>320 | 10<br>67 | Sand<br>Coarse gravel | T, I | Irr | ........ | |
| 10J2 | .....do | 32 | 80 | 7 | ........ | ........ | ........ | P, E | Dom | Cp | |
| 10J3 | .....do | 32 | 380 | 2 | ........ | ........ | ........ | ........ | ........ | ........ | |
| 10K1 | Perry Hurst | 29 | 408 | 10 | 280<br>390 | ........<br>18 | ........ | T, I | Dom, Irr | Cp | Yield about 765 gpm. |
| 10L1 | Anaheim Sugar Co | 26 | 650 | 6 | ........ | ........ | ........ | T, I | Dom, Irr | Cp | |
| 10Q1 | A. J. Hauptman | 26 | 95 | 4 | ........ | ........ | ........ | P, W | Dom | Cp | |
| 10Q2 | .....do | 25 | 334 | 10 | ........ | ........ | ........ | T, I | Irr | ........ | |
| 10R1 | C. D. Cole | 27 | 360 | 12 | ........ | ........ | ........ | T, E | Dom, Irr | Cp | |
| 11B1 | George E. Burnell | 44 | 135 | 12 | ........ | ........ | ........ | T, I | Dom, Irr | Cp | |
| 11B2 | A. B. Grane | 44 | 160 | 6 | ........ | ........ | Gravel | T, E | Dom, Irr | Cp | Casing perforated at 119 ft. |
| 11B3 | Mrs. Nannie Gibbons | 40 | ........ | 6 | ........ | ........ | ........ | T, E | Dom, Irr | Cp | |
| 11B4 | Mrs. J. J. Pyle | 38 | 127 | 6 | ........ | ........ | ........ | P, I | Dom | Cp | |
| 11K1 | Westminster Memorial Cemetery: Well 3 | 36 | 160 | 16 | ........ | ........ | ........ | T, E | Irr | Cp, Wd. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11K2 | Well 1 | 36 | 488 | 16 | 95<br>424 | 50<br>18 | Gravel<br>Sand and gravel | T | | L, Wd. | |
| 11M1 | H. O. Smith | 32 | 815 | | 358<br>371<br>754 | 5<br>24<br>41 | Gravel<br>.....do<br>Gravel and clay | T, E. | Dom, Irr. | Cp, L. | Casing perforated at 358-363, 371-395, 754-765, 768-787, and 789-795 ft. |
| 11N1 | R. W. Edwards | 28 | 120 | 10 | 80 | 35 | Gravel | T, L. | Irr. | | Yield about 675 gpm. |
| 11N2 | .....do | 27 | 100 | 7 | | | | | A. | | |
| 11P1 | Taylor Estate | 34 | 152 | 12 | 92 | 58 | Gravel | T, E. | Irr. | Cp. | Yield about 1, 290 gpm. |
| 11P2 | Southern Pacific Co. | 34 | 150 | 7 | | | | | | Wd. | |
| 11Q1 | Westminster Memorial Cemetry. | 35 | | | | | | | A. | W. | |
| 11Q2 | .....do | 36 | 165 | 16 | 94 | 46 | Rock and gravel | T, E. | Irr. | L, Wm. | Casing perforated at 97-135 ft. |
| 13A1 | Sterling Price | 44 | 138.0 | 7 | | | | | Obs. | Wm. | Casing perforated at about 115-150 ft. |
| 13A2 | .....do | 42 | 764 | 12-10 | | | | T, E. | Obs. | Cp, L, Wm. | |
| 13A3 | .....do | 42 | 136.4 | 10 | | | | P, L. | Obs. | Cp, Wm. | |
| 13C1 | W. C. Leake | 40 | 135 | 3 | | | | P, W. | Dom. | Cp. | |
| 13C2 | Worthy Estate | 40 | 160 | 7 | | | | C, E. | Dom. | Cp. | |
| 13C3 | .....do | 40 | 160 | 10-8 | | | | T. | Irr. | | |
| 13D1 | R. F. Hazard | 38 | 80 | 8 | | | | T, E. | Dom, Stock. | C, Cp. | |
| 13D2 | .....do | 37 | 402 | 10 | | | | T, E. | Irr. | C, L. | Yield about 700 gpm. |
| 13D3 | .....do | 38 | 6.5 | 3 | | | | | | W. | |
| 13D4 | South Midway City Water Co. | 36 | 160 | 12-10 | | | | T, E. | PS. | Cp. | |
| 13E1 | George Meinhardt | 34 | 130 | 12 | | | | T, L. | Dom, Irr. | Cp. | |
| 13F1 | Mrs. L. M. Walker | 35 | 105.0 | 7 | | | | P, W. | Dom. | Cp, W. | |
| 13J1 | Watson Estate | 38 | | 2 | | | | Al, E. | | | |
| 13J2 | .....do | 37 | | | | | | T, E. | Dom, Irr. | Cp. | |
| 13L1 | Ben Justice | 35 | 392 | 7 | 280 | 20 | Sand and gravel | T, L. | Irr. | Cp. | |
| 13L2 | .....do | 35 | 108 | 4 | | | | P, M. | Dom. | Cp. | |
| 13M1 | L. L. Gallup | 32 | 140 | 7-8 | | | | T. | Dom, Irr. | Cp. | |
| 13M2 | .....do | 32 | 77.4 | 5 | | | | | Obs. | Wm. | |
| 13Q1 | Gilbert Estate | 31 | | 4 | | | | T, E. | | | |
| 13Q2 | Worthy Estate | 35 | 140 | 12 | | | | T. | Irr. | | |
| 13R1 | Vernon Heil | 36 | | | | | | T, E. | Irr. | | |
| 14A1 | C. M. Rood | 35 | 110 | 8 | | | | T, E. | Dom. | Cp. | |
| 14A2 | Store | 35 | | 7 | | | | P, L. | Dom. | W. | |
| 14A3 | L. W. Wright | 35 | 115 | 6 | 94 | 20 | Coarse sand | T, E. | Dom. | | |
| 14A4 | O. B. Byram | 35 | 106 | 6 | 93 | 13 | .....do | P, E. | Dom. | Cp, L. | Casing perforated at 98-105 ft. |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach- Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] |  |  | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Depth to top (feet) | Thickness (feet) | Character of material |  |  |  |  |
| T. 5 S., R. 11 W.—Continued |  |  |  |  |  |  |  |  |  |  |  |
| 5/11-14A5 | John E. Miller | 37 |  |  |  |  |  | P, E | Dom |  |  |
| 14A6 | Harold Spafford | 36 |  |  |  |  |  | T, E | Dom, Irr | Cp |  |
| 14A7 | Peterson | 36 |  | 14? |  |  |  | T, E | Dom |  |  |
| 14B1 | Mrs. M. R. King | 35 | 325 | 7 |  |  |  | T, E | Dom | Cp |  |
| 14B2 | .....do | 31 | 548 | 10 | 92 | 24 | Gravel |  | Irr, Obs | L, Wm | Casing perforated at 92-116, 272-282, 422-428, and 534-548 ft. |
|  |  |  |  |  | 270 | 12 | Sand |  |  |  |  |
|  |  |  |  |  | 422 | 8 | Coarse sand |  |  |  |  |
|  |  |  |  |  | 524 | 24 | Gravel |  |  |  |  |
| 14C1 | R. W. Edwards | 30 |  | 12 | 600 | 100 | Gravel and sand | T, L |  | Wm |  |
| 14C2 | .....do | 31 | 850 | 8 or 10 | 600 | 100 | Gravel | T, E | Irr |  |  |
| 14C3 | .....do | 30 |  | 2 |  |  |  |  |  |  |  |
| 14D1 | .....do | 28 | 137 | 7 |  |  |  |  | A |  |  |
| 14E1 | Big Four Drilling Co., Inc. | 25 | 82 | 7 |  |  |  | P, W | Stock | Cp |  |
| 14F1 | W. G. Lewis | 28 | 600 | 10 |  |  |  |  |  | W |  |
| 14G1 | J. E. S. Heath | 30 | 128 | 12 | 92 | 28 | Gravel | T, E | Dom, Irr | Cp, L | Casing perforated at 100-120 ft. |
| 14H1 | D. McMillan | 31 | 132 | 10 | 120 | 11 | .....do |  |  | W |  |
| 14H2 | Andrew W. Mefford | 35 | 130 | 4 | 75 | 25 | Sand | P, E | Dom | Cp |  |
|  |  |  |  |  | 120 | 10 | Gravel |  |  |  |  |
| 14H3 | C. B. Cunningham | 35 | 136 | 10 |  |  |  | T, E | Dom, Irr | Cp |  |
| 14J1 | Don McMillan | 25 | 125.3 | 12 |  |  |  | C | Irr | Cp, Wm. |  |
| 14J2 | M. E. Taggart | 27 | 80 | 4 |  |  |  | P, W | Dom | W |  |
| 14K1 | Joda Sork | 29 | 130 | 10 | 103 | 22 | Gravel | T, E | Irr |  |  |
| 14L1 | W. G. Lewis | 26 | 850 | 10 | 600 | ? | .....do | T, E | Irr | C |  |
|  |  |  |  |  | 900 | ? | Coarse gravel |  |  |  |  |
| 14M1 | .....do | 20 | 475 | 10 |  |  |  | Al, E | Dom | Cp |  |
| 14P1 | Anaheim Sugar Co | 23 | 99 | 12 | 72 | 23 | Gravel and sand | T, L | Irr | L |  |
| 14Q1 | J. A. Murdy | 20 |  | 7 |  |  |  | T, E | Irr | Cp |  |
| 14Q2 | James Estate | 24 | 80 | 4 |  |  |  | C |  |  |  |
| 14R1 | D. McMillan | 26 | 840 | 10-8 |  |  |  | T, E | Irr | Wd |  |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14R2 | Miles | 26 | 1,000 | 14 | | | | | | W. | Casing reported perforated for as much as 1,000 ft. |
| 15A1 | Viola Edwards | 26 | 126 | 10 | | | | T, L. | Irr. | Wd. | |
| 15A2 | do. | 26 | 126 | 7 | | | | P, W. | Dom. | Cp. | |
| 15D1 | Green Wing Land and Water Co. | 23 | 450 | 10 | | | | T, E. | Irr. | Cp. | |
| 15D2 | do. | 23 | 600 | 7 | | | | P, W. | Dom. | Cp. | Casing reported perforated at 525 ft. |
| 15F1 | do. | 20 | 650 | 10 | | | | T, L. | Irr. | | |
| 15J1 | William Miles | 21 | 400 | 12 | 370 | 25 | Gravel | T, E. | Dom, Irr. | Cp. | |
| 15K1 | do. | 18 | 85.0 | 12 | 80 | 5 | do. | | | W. | |
| 15L1 | Anaheim Sugar Co. | 17 | 500 | 12 | | | | T, E. | Irr. | | Casing perforated at 500 ft. |
| 15L2 | do. | 17 | 750 | 12 | | | | | | W. | |
| 15M1 | do. | 16 | 20 | 12 | | | | | | | |
| 15M2 | do. | 18 | 130 | 3 | | | | P, E. | Dom. | Cp. | |
| 15M3 | do. | 19 | 130 | 3¼ | | | | | | L. | |
| 15P1 | do. | 12 | | 8 | | | | T, E. | Irr. | | |
| 15R1 | E. Roy Moore | 21 | 401 | 12 | 345 | 45 | Gravel and some cobbles. | T, E. | Irr. | L. | Yield about 1,020 gpm. |
| 15R2 | do. | 20 | | 10 | | | | C, E. | Dom. | | |
| 16A1 | Anaheim Sugar Co. | 21 | | 7 | | | | | A. | Wd. | |
| 16A2 | do. | 21 | | 7 | | | | | Irr. | Cp. | |
| 16B1 | do. | 18 | | 3 | | | | P, E. | Dom. | Cp. | |
| 16C1 | do. | 17 | 801 | 10 | | | | | A. | Cp, W. | |
| 16C2 | do. | 17 | 900 | 12 | | | | T, E. | Dom, Irr. | Cp, L. | Yield about 1,125 gpm. |
| 16D1 | do. | 17 | 393.3 | 10 | | | | | Obs. | Cp, Ww. | (2) |
| 16D2 | do. | 16 | 400 | 10 | | | | | Obs. | Wr. | |
| 16E1 | A. L. Kavanaugh | 15 | 232.7 | 10 | | | | | | Wrd, Wd. | |
| 16M1 | Christopher | 13 | | 2 | | | | P, M. | Dom. | Cp, W. | |
| 16M2 | do. | 15 | | 12 | | | | T, L. | Irr. | Cp. | |
| 17A1 | Blue Wing Shooting Club, well 1. | 15 | 689.0 | 12 | | | | | | Cp, Wd. | (2) |
| 17B1 | | 10 | | 18 | | | | T, E. | | | (2) |
| 17D1 | L. W. Hellman Ranch, well 16. | 8 | | | | | | | A. | Wd. | |
| 17E1 | Bovandaerde | 7 | 320 | 2 | | | | P, E. | Dom. | Cp, L. | (2) |
| 17E2 | Casa Tores Gun Club | 6 | 153 | 3 | | | | C, E. | Dom. | C, Cp. | Casing perforated at 145-153 ft. |
| 17F1 | Bovandaerde | 7 | 124 | 2 | | | | | | L. | |
| 17H1 | Blue Wing Shooting Club | 13 | | 2 | | | | | A. | W. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach- Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5 S., R. 11 W.—Continued | | | | | | |
| 5/11-17H2 | Blue Wing Shooting Club, well 2. | 13 | 320 | | 130<br>230<br>295 | 76<br>9<br>3 | Sand and gravel<br>Gravel<br>do. | T, E. | | Cp, L, W. | Casing perforated at 203-208, 233-240, and 297-299 ft.[2] |
| 17H3 | Blue Wing Shooting Club | 13 | | 2 | | | | P, E. | Dom. | Cp. | |
| 17H4 | do. | 13 | | 10 | | | | | | W. | |
| 17J1 | Westminster Gun Club | 13 | | | | | | T, E. | | Cp, W. | (2) |
| 17J2 | do. | 13 | 480 | | | | | T, E. | Dom. | Cpr, W. | |
| 17M1 | Casa Tores Gun Club | 6 | | 4 | | | | | | | |
| 17M2 | do. | 6 | | 4 | | | | | | | |
| 17M3 | do. | 6 | 299 | 10 | | | | C, E. | | L. | |
| 17P1 | Laurence Lemo | 8 | 190 | 2 | | | | | A. | L. | |
| 17P2 | do. | 8 | 177.1 | 4 | | | | | Obs. | Cp, Wm. | (2) |
| 17P3 | do. | 6 | 209 | 3 | | | | P, E. | Dom. | Cp. | Casing perforated at 290-300 ft.[2] |
| 17P4 | do. | 8 | | 8 | | | | T, E. | Irr. | W. | |
| 18A1 | West Shore Gun Club | 7 | 680 | 12 | | | | T, E. | Dom. | Cpr, Wd. | (2) |
| 18B1 | State of California | 5 | 23.3 | 1¼ | 15 | 8 | Sand | | Obs. | Cpr, L, Wm. | |
| 18G1 | L. W. Hellman Ranch | 2 | 20.3 | 1¼ | 16 | 4 | Medium sand | | Obs. | Cpr, L, Wm. | |
| 18G2 | Alamitos Land Co. | 3 | 20.3 | 1¼ | 12 | 8 | Sand | | Obs. | Cpr, L, Wm. | |
| 18H1 | I. W. Hellman Ranch | 5 | 220.0 | 10 | 551<br>600 | 43<br>90 | do.<br>Sand and gravel | | | Cpr, L, W. | Casing perforated at 551-572 and 610-625 ft. Well reported 902 ft. deep[2]. |
| 18J1 | | 5 | 7 | | | | | | A. | C. | Test well. |
| 18J2 | Center Gun Club | 2 | 215.7 | 6 | | | | | Obs. | Wm, Wrd. | (2) |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18N1 | Alamitos Land Co. | 5 | 380 | 6-4 | 172<br>221 | 40<br>30 | Gravel and sand.<br>Sand and gravel. | | Obs. | Cp, L, Wrd. | Observation well, cooperative investigation. Casing perforated at 179-209 and 229-249 ft. |
| 18P1 | .....do. | 5 | 240 | 6 | 110 | 38 | Gravel and sand. | | Obs. | Cp, L, Wrd. | Observation well, cooperative investigation. Casing perforated at 109-124 ft. |
| 18P2 | .....do. | 4 | 16.1 | 1¼ | 13 | 4 | Silty sand. | | Obs. | Cpr, L, Wm. | |
| 18P3 | .....do. | 4 | 23.3 | 1¼ | 21 | 2 | Sand. | | Obs. | Cpr, L, Wm. | |
| 18P4 | .....do. | 5 | 8.3 | 1¼ | 4 | 5 | .....do. | | Obs. | C, L, Cpr, Wm. | |
| 18P5 | .....do. | | 15.3 | 1¼ | 13 | 2 | .....do. | | Obs. | L, Cp. | Casing perforated at 15-18 ft. |
| 18P6 | .....do. | | 17.0 | 1¼ | 16 | 1 | Sand and clay. | | Obs. | L, Cp. | Casing perforated at 15-18 ft. |
| 18R1 | Lomita Land and Water Co. | 4 | 895 | 12 | 677 | 158 | Gravel. | T, E. | | C, Cp, L, W. | Casing perforated at 700-830 ft.[2] |
| 19D2 | Alamitos Land Co. | 3 | 19.4 | 1¼ | 17 | 3 | Silty fine sand. | | Obs. | Cpr, L, Wm. | |
| 20A1 | Blue Bill Gun Club. | 11 | | | | | | T, E. | | | |
| 20C1 | Wilson. | 7 | | 10 | | | | | Obs. | Cp, Ww. | (2) |
| 20D1 | Lomita Land and Water Co. | 4 | 320 | | | | | T, E. | | Cp, W. | Flow about 150 gpm.[2] |
| 20D2 | .....do. | 5 | | 4 | | | | | | | |
| 20E1 | .....do. | 5 | 170.4 | 4 | | | | | Obs. | Cp, Wm. | (2) |
| 20E2 | .....do. | 5 | 100.9 | 4 | | | | | | Cp, W. | (2) |
| 20E3 | .....do. | 5 | 161.1 | 4 | | | | | | Cp. | (2) |
| 20F1 | .....do. | 7 | 101 | 3 | | | | | | | (2) |
| 20G1 | Saamae Gun Club. | 11 | 80 | 3 | | | | P, E. | Dom. | Cp. | |
| 20G2 | .....do. | 10 | | 7 | | | | T, E. | | Cp. | (2) |
| 20G3 | .....do. | 10 | 108 | 4 | | | | | | Cp, W. | |
| 20G4 | .....do. | 9 | | 2 | | | | P, M. | | | |
| 20H2 | Joseph Brazil. | 13 | 226.7 | 12 | 560 | 25 | Gravel. | E. | Dom. | Cp, Wm. | |
| 20J1 | P. F. Duc. | 16 | 482 | 7 | 482<br>565 | 10<br>20 | .....do.<br>Gravel and sand. | C, E.<br>P, W. | Dom, Stock. | Cp, W. | |
| 20J2 | Winfred Wenrick. | 22 | 29 | 8 | | | | P, M. | | Cpr, L. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach–Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5 S., R. 11 W.—Continued | | | | | | |
| 5/11-20L1 | Lomita Land and Water Co. | 10 | 159.3 | 4 | .... | .... | .... | .... | .... | Cp, W. | (2) |
| 20L2 | ....do | 7 | 157.5 | 4 | .... | .... | .... | .... | Obs. | Cp, Wr. | (2) |
| 20Q1 | Campbell | 33 | .... | .... | .... | .... | .... | T, E. | Dom, Irr. | Cp. | |
| 20Q2 | M. H. Dosney | 33 | 100 | 4 | 90 | 10 | Sand and gravel | P, E. | Stock | .... | |
| 20R1 | W. F. Good | 31 | .... | .... | .... | .... | .... | .... | A | W. | |
| 20R2 | ....do | 35 | 130 | 5 | 113 | 17 | Gravel and sand | P, W. | Dom. | Cp, L. | Casing perforated at 119-129 ft. |
| 20R3 | ....do | 35 | 135 | 8 | 119 | 16 | ....do | .... | Irr. | Cp, L. | Casing perforated at 126-134 ft. |
| 21A1 | Lloyd Edwards | 14 | 233 | .... | .... | .... | .... | T, E. | Irr. | Cp, Ww. | |
| 21A2 | William Kettler | 14 | 400 | 4 | .... | .... | .... | P, W. | Dom. | Cp. | |
| 21D1 | A. L. Kavanaugh | 11 | 186.1 | 4 | .... | .... | .... | .... | Obs. | Cp, Ww. | |
| 21D2 | ....do | 11 | 18.4 | 7 | .... | .... | .... | .... | .... | Cp, W. | |
| 21D3 | ....do | 11 | .... | .... | .... | .... | .... | .... | A | W. | |
| 21F1 | Murdy | 14.8 | .... | .... | .... | .... | .... | T, E. | Irr. | Cp, Ww. | (2) |
| 21F2 | ....do | 14 | .... | 2 | .... | .... | .... | P, M. | Dom. | Cpr. | |
| 21H1 | John Kettler | 15 | .... | .... | .... | .... | .... | .... | A | W. | |
| 21H2 | Lloyd Edwards | 15 | 525 | 4 | .... | .... | .... | .... | Stock | Cp, Wm. | (2) |
| 21H3 | John Kettler | 15 | 98 | .... | .... | .... | .... | E. | Dom. | Cp. | |
| 21J1 | E. Kettler | 10 | 300 | .... | .... | .... | .... | .... | A | C. | |
| 21J2 | ....do | 15 | 194 | 4 | .... | .... | .... | P, W. | Dom. | .... | Casing perforated at about 173-193 ft. |
| 21K1 | ....do | 15 | 250 | .... | .... | .... | .... | .... | A | L. | |
| 21L1 | J. J. Graham | 22 | 282 | 7 | 280 | .... | Gravel | P, W, C, E. | Dom, Irr. | Cp, L. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21M1 | George J. McDonald | 18 | 200 | 1½ | ...... | ...... | ...... | ...... | A. | Cpr, Wd. | |
| 21M2 | Blue Bill Gun Club | 14 | 135 | 2 | ...... | ...... | ...... | P, E. | Dom. | L. | |
| 21M3 | George J. McDonald | 18 | 225.7 | 8 | 171 | 57 | Sand and gravel | T, E. | Dom, Irr. | Cp, L, Wm. | Casing perforated at 203-213, and 225-228 ft. |
| 21N1 | C. R. Brothers | 28 | 221 | 6 | 211 | 10 | Sand | T, E. | Dom. | Cp. | |
| 21N2 | H. D. Anderson | 30 | 399 | 14-12 | ...... | ...... | ...... | T, I. | Dom, Stock, Irr. | Cp. | |
| 21P1 | William A. Schonle | 15 | 20 | 6 | ...... | ...... | ...... | ...... | ...... | Wd. | |
| 21P2 | .....do | 5 | 10 | ...... | ...... | ...... | ...... | ...... | A. | C. | |
| 21P3 | ...... | 5 | ...... | ...... | ...... | ...... | ...... | ...... | A. | Cp. | Test well. |
| 21P4 | William A. Schonle | 10 | 102 | 10 | 50<br>70 | 3<br>3 | Gravel and shells<br>Fine gravel | C, E. | Dom, Irr. | Cp, L, Wm. | |
| 21Q1 | Meadow Lark Country Club. | 25 | 537 | 12 | ...... | ...... | ...... | T, I. | Dom, Irr. | C, L, W, Cp. | |
| 21Q2 | .....do | 4 | 100 | 4 | ...... | ...... | ...... | ...... | A. | C. | |
| 21Q3 | .....do | 25 | 180 | 7 | ...... | ...... | ...... | ...... | ...... | C, W, Cp. | |
| 21R1 | E. Kettler | 8 | 100.0 | 8 | 60 | 40 | Sand | C, I. | Irr. | Cp, Wm. | (2) |
| 22A1 | W. G. Lewis | 20 | 400 | ...... | ...... | ...... | ...... | ...... | ...... | Wd. | |
| 22A2 | .....do | 19 | 277 | 10 or 12 | 100<br>250 | 3<br>...... | Gravel<br>Sand | T, E. | Irr. | L, Wm. | |
| 22B1 | C. J. Porter | 16 | 613 | ...... | ...... | ...... | ...... | T, E. | Dom, Irr. | Cp, W. | |
| 22B2 | W. F. Lewis | 15 | ...... | ...... | ...... | ...... | ...... | P, E. | Dom. | Cp. | |
| 22C1 | C. E. Houser | 12 | ...... | 4 | ...... | ...... | ...... | C, E. | Dom. | Cp. | |
| 22D1 | C. A. Reed | 14 | 106 | 6 | ...... | ...... | ...... | T, E. | Dom. | Cp. | |
| 22E1 | John Kettler | 12 | 300 | 12 | ...... | ...... | ...... | C, E. | Irr. | ...... | Casing perforated at about 290 ft. |
| 22G1 | Don Barthole | 14 | 94 | 7 | ...... | ...... | ...... | P, M. | Dom. | Cp. | |
| 22H1 | D. E. Woodington | 17 | 660 | 12 | 612 | 30 | Sand and gravel | T, E. | Irr. | L. | Casing perforated at 630-650 ft.[2] |
| 22H2 | .....do | 16 | 90 | ...... | ...... | ...... | ...... | T, E. | Dom. | Cp. | |
| 22J1 | W. G. Lewis | 12 | ...... | ...... | ...... | ...... | ...... | ...... | A. | W. | |
| 22J2 | .....do | 13 | 113 | 10 | 100 | 20 | Gravel | T. | Irr. | Cp. | |
| 22K1 | J. A. Murdy | 10 | 99.5 | 12 | ...... | ...... | ...... | C. | Dom, Irr. | Cp, L, W. | |
| 22L1 | J. Barthole | 11 | 305 | 4 | ...... | ...... | ...... | P, W. | Dom. | ...... | |
| 22L2 | Nettie McCoy | 12 | 83 | 5 | ...... | ...... | ...... | C, E. | Dom. | Cp, W. | |
| 22L3 | George B. Crane | 11 | 112 | 12 | ...... | ...... | ...... | C, E. | Irr. | Cp, Wm. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach - Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5 S., R. 11 W.—Continued | | | | | | |
| 5/11-22L4 | George B. Crane | 11 | 300 | 4 | ... | ... | ... | P, W. | Dom. | Cp. | (2) |
| 22L5 | Nettie McCoy | 11 | 67.0 | 4 | ... | ... | ... | ... | Irr. | W. | |
| 22L6 | ... | 11 | 77.0 | 4 | ... | ... | ... | ... | Irr. | L, W. | |
| 22M1 | Z. D. Crane | 9 | ... | ... | ... | ... | ... | ... | A. | W. | |
| 22M2 | .....do | 10 | 65 | 4 | ... | ... | ... | E. | Dom. | C, Cp. | (2) |
| 22M3 | .....do | 10 | 456 | 4 | ... | ... | ... | ... | ... | Cp, W. | |
| 22N1 | George B. Crane | 10 | ... | 4 | ... | ... | ... | ... | A. | W. | |
| 22N2 | .....do | 9 | 76.0 | 8 | ... | ... | ... | ... | Irr. | Cp, W. | |
| 22N3 | Springdale School | 7 | 86 | 4 | ... | ... | ... | P, E. | PS. | Cpr. | Casing perforated at 79-86 ft. |
| 22Q1 | L. E. Barry | 9 | 72 | ... | ... | ... | ... | ... | A. | L. | |
| 22Q2 | .....do | 10 | 173 | 12 | 140 | 32 | Gravel | C, E. | Dom, Irr. | Cp, L. | Casing perforated at 145-170 ft. |
| 22R1 | R. E. Beem | 11 | 558 | 12 | ... | ... | .....do | T, E. | Irr | L. | |
| 22R2 | .....do | 11 | 280 | 7 | ... | ... | ... | T, E. | Dom. | Cp. | |
| 23A1 | Boulevard Gardens Water Co. | 26 | 263 | 12 | 208<br>247 | 35<br>11 | Gravel<br>.....do | T, E. | PS. | C, L, Cp. | Casing perforated at 247-258 ft. and for 20 ft between 208-243 ft. |
| 23A2 | .....do | 26 | 219.7 | 7 | ... | ... | ... | ... | Obs. | Cp, Wm. | |
| 23B1 | Charles Cook | 26 | ... | 10 | ... | ... | ... | T, E. | Irr. | Cp, Wm. | |
| 23C1 | Anaheim Sugar Co. | 20 | ... | ... | ... | ... | ... | T, E. | Irr. | ... | |
| 23C2 | .....do | 20 | ... | ... | ... | ... | ... | P, E. | Dom. | ... | |
| 23C3 | Smeltzer Lima Bean Growers' Association. | 20 | ... | 7 or 8 | ... | ... | ... | P, E. | Ind. | ... | |
| 23H1 | J. G. Brown | 25 | 290 | 4 | 280 | 10 | Gravel | Al, L. | Irr. | W. | |
| 23J1 | Anaheim Sugar Co. | 25 | 400 | 10? | ... | ... | ... | T, E. | Irr. | ... | |
| 23J2 | G. E. Hillman | 25 | 300 | 10 | ... | ... | ... | T, E. | Irr. | ... | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23L1 | Joseph Callens | 21 | | 10 | 335 | 30 | Gravel | T, E. | Irr. | | |
| 23N1 | Winters Oil Lease, Inc. | 17 | 350 | 10 | 320 | | do. | | | W. | |
| 23N2 | do. | 12 | | 8 | | | | T, E. | Irr. | W. | |
| 23N3 | do. | 13 | | | | | | | A. | W. | |
| 23N4 | do. | 15 | | | | | | | A. | W. | |
| 23P1 | Mrs. L. Worthy | 23 | | | | | | | A. | W. | |
| 23P2 | Taylor, Keener, and Phillips. | 25 | 80 | | | | | P, E. | Dom. | Cp. | |
| 23P3 | Harvey Molton | 34 | 350 | | | | | | A. | W. | |
| 23P4 | do. | 20 | 350 | 4 | 335 | 15 | Gravel | | Irr. | | |
| 23P5 | Mrs. L. Worthy | 20 | 172 | 10 | 130 | 42 | do. | T, L. | Irr. | W. | |
| 23P6 | do. | 20 | 330 | 2 | | | do. | T, E. | Dom. | Cp. | |
| 23P7 | do. | 20 | 350 | 4 | | | | | | W. | |
| 23P8 | Harvey Molton | 25 | 167 | 8 | 128 | 39 | Gravel and sand | T, L. | Irr. | | |
| 23P9 | W. R. Hurst | 25 | 145 | 4 | 135 | 10 | Sand and gravel | P, E. | Dom. | Cp. | |
| 23P10 | H. Letson and L. L. Letson. | 25 | 142 | 4 | 135 | 10 | do. | P, E. | Dom. | Cp. | |
| 23P11 | Harvey Molton | 25 | 350 | 3-2 | 335 | | Gravel | P, E. | Dom. | Cp. | |
| 23Q1 | C. H. Maddux | 22 | | | | | | | A. | W. | |
| 23Q2 | North Wintersburg Co-operative Well Co. | 25 | 600 | 12 | | | | T, E. | PS. | Cp. | |
| 23Q3 | Martin Thiebold and others. | 21 | 130 | 6 | 75 | 25 | | C, E. | Irr. | | |
| 23R1 | C. H. Maddux | 25 | 252 | 10 | 160 | 90 | Sand and gravel | T, E. | Irr. | L. | Casing perforated for 40 ft. between 160-250 ft. |
| 23R2 | Chris Nelson | 25 | 300 | 7 | | | | T, L. | Irr. | Cp, W. | |
| 23R3 | C. H. Maddux | 25 | 171 | 4 | 161 | 10 | Gravel and sand | P, E. | Dom. | Cp. | |
| 23R4 | L. Worthy | 25 | 93 | 4 | | | | P, E. | Dom. | Cp. | |
| 23R5 | Eva J. Combs | 25 | 69 | 4 | 50 | 10 | Gravel | P, E. | Dom. | Cp, L. | |
| 23R6 | M. L. Russell | 25 | 158 | 4 | 150 | 8 | do. | J. E. | Dom. | Cp. | |
| 23R7 | C. H. Maddux | 25 | 165 | 4 | | | Gravel and sand | | | W. | |
| 24A1 | Anaheim Sugar Co. | 33 | 26.0 | 7 | | | | | Obs. | Wm. | |
| 24A2 | | 33 | | | | | | | A. | W. | |
| 24A3 | Anaheim Sugar Co. | 35 | 500.1 | 10 | | | | | Obs. | Wm. | |
| 24D1 | Vernon C. Heil | 27 | | 4 | | | | T, E. | Dom. | Cp, W. | |
| 24D2 | do. | 27 | 400 | 12 | | | | T, E. | Irr. | Wm. | |
| 24F1 | E. L. Worthy | 27 | 200 | 5 | | | | P. | Dom. | Cp. | |
| 24F2 | Mrs. L. Worthy | 25 | 420 | 10 | | | | T, L. | Irr. | | |
| 24G1 | Joung John | 30 | | 10? | | | | T, E. | Dom, Irr. | Cp. | Yield about 540 gpm. |
| 24J1 | E. S. Heil Estate | 31 | 550 | 7 | | | | T, E. | Irr. | Cp. | |
| 24L1 | C. A. Brush | 26 | 290 | 7 | | | | T. | Irr. | C. | |
| 24L2 | F. L. Brush | 26 | 240 | 2 | | | | Al, E. | Dom, Stock. | Cp. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5 S., R. 11 W.—Continued | | | | | | |
| 5/11-24M1 | C. A. Brush | 25 | 225 | 2 | 210 | 5 | Gravel | AL, E | Dom | Cp | |
| 24N1 | J. A. Murdy, Jr. | 26 | ...... | ...... | ...... | ...... | ...... | T, E | Irr | W | |
| 24N2 | Southern California Edison Co., Ltd. | 25 | ...... | ...... | ...... | ...... | ...... | P, E | Dom, Ind | Cp | |
| 24N3 | Ocean Park Water Co | 25 | 305 | 6 | 260 | 40 | Gravel | P, E | Dom | Cp | Casing perforated from bottom for about 60-75 ft upward. |
| 24N4 | S. M. Hosack | 25 | 158 | 4$\frac{3}{4}$ | ...... | ...... | ...... | P, E | Dom | Cp | Casing perforated at 150-158 ft. |
| 24N5 | Mrs. L. F. Payne | 25 | 125 | 4 | ...... | ...... | ...... | P, E | Irr | ...... | Casing perforated at 121-125 ft. |
| 24N6 | George Holler | 25 | 18 | 16 | 15 | 3 | Gravel | ...... | ...... | ...... | |
| 24P1 | William Preston | 25 | ...... | ...... | ...... | ...... | ...... | C | Irr | ...... | |
| 24R1 | T. Asari | 30 | ...... | 6 | ...... | ...... | ...... | P, E | Dom | Cp, W | |
| 24R2 | .....do | 27 | ...... | ...... | ...... | ...... | ...... | T, E | Ind | Cp | |
| 25A1 | J. Ishii | 26 | ...... | 10 | ...... | ...... | ...... | T, E | Irr | Cp, Wm. | Yield about 465 gpm. |
| 25B1 | D. C. Fouts | 26 | 595 | 12-10 | ...... | ...... | ...... | T, L | Irr | L | |
| 25C1 | .....do | 26 | 230 | 14-7 | 178<br>210 | 30<br>20 | Gravel<br>Gravel and sand | T, E | Dom, Irr | Cp, L. | Casing perforated at 196-207 and 220-229 ft. |
| 25C2 | Alfonso Sevilla | 26 | 171 | 4 | 155 | 16 | .....do | P, W | Dom, Stock. | Cp | |
| 25D1 | D. Dekker | 24 | 165 | 4 | | ...... | ...... | P, L | Dom, Irr | Cp, W | |
| 25D2 | Ocean View Mutual Water Co. | 24 | 165 | 8 | ...... | ...... | ...... | E | PS | C | |
| 25D3 | Worthy Estate | 27 | ...... | 7-4 | ...... | ...... | ...... | E | Dom | Cp | |
| 25D4 | .....do | 25 | ...... | ...... | ...... | ...... | ...... | T, L | Irr | ...... | |
| 25D5 | Mrs. Emma Blalock | 24 | 150 | 4 | ...... | ...... | ...... | P, E | Dom | Cp, W | |
| 25E1 | W. T. Vandruff | 31 | 420 | 10 | ...... | ...... | ...... | C, L | Dom, Irr | Cp, W | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25E2 | Ruth Ferguson | 31 | 183 | 7 | ........ | ........ | ........ | C, E. | Dom. | L. | |
| 25E3 | Preston Estate | 25 | ........ | 4 | ........ | ........ | ........ | T, I. | Irr. | W. | |
| 25F1 | B. D. Elliot and P. W. Elliot. | 29 | 245 | 7 | ........ | ........ | ........ | T, E. | Dom., Irr. | Cp. | |
| 25G1 | M. B. Erburu | 30 | 165 | 4 | ........ | ........ | ........ | P, W. | Dom. | Cp, W. | |
| 25G2 | .....do | 26 | 176.6 | 7 | ........ | ........ | ........ | ........ | ........ | Cp, W. | |
| 25H1 | Trudeau | 25 | ........ | 8 | ........ | ........ | ........ | ........ | ........ | W. | |
| 25H2 | ........ | 25 | ........ | 10 | ........ | ........ | ........ | C. | Irr. | ........ | |
| 25J1 | P. A. Isenor | 24 | ........ | 7 | ........ | ........ | ........ | T, E. | Irr. | ........ | |
| 25K1 | .....do | 36 | ........ | ........ | ........ | ........ | ........ | E. | Dom. | ........ | |
| 25L1 | Otto Sievers | 24 | 161 | 7 | ........ | ........ | ........ | C, L. | Dom, Irr. | Cp, L, W. | |
| 25L2 | Frank Morris | 38 | ........ | ........ | ........ | ........ | ........ | P, E. | Dom. | ........ | |
| 25L3 | L. L. Oldfield | 37 | ........ | ........ | ........ | ........ | ........ | P, L. | Dom, Stock. | Cp. | |
| 25L4 | Thomas Dillon | 37 | ........ | ........ | ........ | ........ | ........ | P, E. | Dom. | Cp. | |
| 25L5 | M. M. Coker | 34 | ........ | ........ | ........ | ........ | ........ | P, L. | Dom. | ........ | |
| 25L6 | Charles Durego | 25 | 150 | 3 | ........ | ........ | ........ | P, M. | ........ | Cp. | |
| 25M1 | Cameron Tract Community well. | 25 | 379.2 | 4 | ........ | ........ | ........ | ........ | Obs. | Wm. | |
| 25M2 | .....do | 27 | 412 | 7 | ........ | ........ | ........ | T, E. | PS. | ........ | |
| 25M3 | Alex Cameron | 33 | 217 | 7 | 96 | 110 | Coarse gravel | T, E. | Dom, Irr. | Cp. | |
| 25M4 | Ray McCormick | 24 | 190 | 2 | ........ | ........ | ........ | P, E. | Dom. | ........ | |
| 25M5 | C. Struven | 24 | 107 | 4 | ........ | ........ | ........ | P, E. | Dom, Irr. | ........ | |
| 25M6 | R. Shunway | 26 | 141 | 4 | ........ | ........ | ........ | P, E. | Dom. | Cp. | |
| 25N1 | Huntington Beach Land Co. | 43 | 123.4 | 7 | ........ | ........ | ........ | ........ | Obs. | Cp, Wm. | |
| 25P1 | E. J. Lecrivain | 44 | 150 | 12 | ........ | ........ | ........ | ........ | Obs. | C, Wm, Cpr. | |
| 25Q1 | John Courreges | 43 | 138 | 7 | ........ | ........ | ........ | T, L. | Dom, Irr. | Cp, L. | |
| 25Q2 | Henry Lacabonne | 40 | 138 | 7 | ........ | ........ | ........ | P, W. | Dom. | ........ | |
| 25Q3 | .....do | 24 | 200 | 7 | ........ | ........ | ........ | T. | Irr. | ........ | |
| 25R1 | J. B. Lecirvain | 23 | ........ | 10 | ........ | ........ | ........ | T, E. | Irr. | W. | |
| 25R2 | P. A. Isenor | 25 | ........ | 8 | ........ | ........ | ........ | T, E. | Dom. | W. | |
| 26A1 | Ocean View School District. | 25 | 300 | 6 | ........ | ........ | ........ | C, E. | PS. | Cp. | |
| 26B1 | C. M. Furuta | 26 | 162 | 2 | ........ | ........ | ........ | T, E. | Dom, Ind. | Cp. | |
| 26B2 | John W. Stinson | 29 | 68 | 7 | ........ | ........ | ........ | P, W. | Dom, Irr. | Cp. | Casing perforated at 59-68 ft. |
| 26B3 | Daniel J. Bowman | 30 | 108 | 2 | ........ | ........ | ........ | P, L. | Dom. | Cp. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5 S., R. 11 W.—Continued | | | | | | |
| 5/11-26B4 | Sam Rorabaugh | 32 | | 7 | | | | P, W. | Dom. | Cp. | |
| 26B5 | Mrs. Arlington Lewis | 26 | 154 | 6 | | | | P, W. | Dom. | Cp. | |
| 26B6 | George Nichols | 25 | 151 | 2 | | | | C, E. | Dom. | Cp. | Casing perforated at 143-151 ft. |
| 26B7 | David Gardner | 27 | 137 | 2 | | | | L. | Irr. | | Casing perforated at 130-137 ft. |
| 26B8 | .....do | 27 | 115 | | | | | L. | Dom. | Cp. | |
| 26B9 | Gardner Nichols | 28 | 150 | | | | | C, E. | Dom. | | |
| 26C1 | Albert Eastman | 25 | | 7 | | | | P, E. | Dom, Irr. | Cp, W. | |
| 26C2 | W. F. Slater | 31 | | | | | | | PS. | Cp, W. | |
| 26C3 | Robert C. Flowers | 26 | 185 | | | | | P, E. | Dom, Irr. | Cp, W. | |
| 26C4 | Wintersburg Methodist Church Cooperative Well Co. | 26 | 145 | 4 | | | | T, E. | Dom. | Cp. | |
| 26C5 | Frank Ulrich | 25 | 157 | 4 | | | Gravel | P, E. | Dom. | Cp. | Casing perforated near bottom. |
| 26D1 | Albert Eastman | 11 | | 7 | | | | T, L. | Irr. | Cp. | |
| 26E1 | Nelson Brothers | 8 | | 6 | | | | C, E. | Irr. | | |
| 26E2 | Oscar Stricklin | 9 | 150 | 8 | | | | C, L. | Dom, Irr. | Cp, W. | |
| 26F1 | The Texas Co. | 32 | 525 | 5 | | | | | Ind. | W. | Yield about 730 gpm. |
| 26F2 | Oscar Stricklin | 35 | | | | | | P, W. | | | |
| 26G1 | Mrs. E. M. Fox | 36 | | 4? | | | | C, E. | Dom, Stock. | Cp. | |
| 26G2 | Beach Packing Co. | 33 | 550 | 6 | | | | T, E. | Dom, Ind. | Cp. | Casing perforated at bottom. |
| 26G3 | .....do | 32 | 350 | 6 | | | | T, E. | Ind. | | Casing perforated at bottom. |
| 26H1 | Preston Estate | 37 | 400 | 7-4 | | | | C, E. | Dom, Irr. | Cp. | |
| 26H2 | Moore Mutual Water Co. | 31 | 420 | | | | | T, E. | PS. | Cp. | |
| 26J1 | H. V. Brewster | 25 | 126 | 7 | | | | T, E. | Dom, Stock. | Cpr, W. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 26K1 | Emma Youngblood | 25 | 150 | 12 | | | | C, L. | Dom, Irr. | | Casing perforated at bottom. |
| 26K2 | McCallum | 34 | 350 | | | | | T. | Irr. | | |
| 26L1 | C. O. Jaggers tract | 30 | 213 | 7 | | | | P, W. | Dom. | Cp, L. | |
| 26L2 | George Gothard | 20 | 267 | 4 | 253 | 14 | Fine gravel | P, W. | Dom. | Cp. | |
| 26L3 | Peat Land &Manufacturing Co. | 8 | 150 | 6 | | | | C. | | Cp. | (2) |
| 26L4 | Harold R. Preston | 20 | | | | | | C, E. | Dom, Irr. | Cp. | |
| 26M2 | Southern California Water Co. | 4 | 282 | 12 | 60<br>175<br>254 | 25<br>63<br>21 | Coarse gravel<br>Sand and gravel<br>.....do. | T, E. | PS. | Cr, L, Cp, W. | Casing perforated at 60-85, 175-180, 254-256 ft. |
| 26M1 | .....do. | 4 | 201 | | 28<br>153 | 68<br>26 | Gravel and sand<br>Sand and gravel | T, E. | PS. | C, Cp, L. | Yield about 1,050 gpm. Casing perforated at 35-62, 74-96, and 153-179 ft.[2] |
| 26N1 | Peat Humus Co. | 15 | 53.8 | 5 | | | | P, E. | Dom. | Cpr, W. | |
| 26N2 | Orange County | 5 | 13.3 | 1¼ | 10 | 3 | Sandy silt | | Obs. | Cpr, L. Wm. | |
| 26P1 | Harry T. Groves | 24 | 510 | 6 | | | | | | L, Wd. | |
| 26P2 | T. Shigaki | 47 | | | | | | | A. | W. | |
| | Standard Oil Co.: | | | | | | | | | | |
| 26P3 | Well 2 | 25 | 577 | 16 | 439 | 138 | Gravel and sand | T, E. | Ind. | C, L, Cp, Wd. | Yield about 350 gpm. Casing perforated at 488-548 ft. |
| 26P4 | Well 1 | 20 | 250 | | | | | | | C. | |
| 26R1 | Jake Davis | 49 | 200 | | | | | P, E. | Dom. | Cp. | |
| 26R2 | R. J. Carey | 49 | 160 | 8 | | | | T, E. | PS. | Cp. | |
| 27A1 | Hill | 11 | 112 | | | | | | | W. | |
| 27A2 | Charles Cook | 11 | 120 | 7 | | | | C, E. | Dom. | Cp, Wm. | |
| 27A3 | | 10 | | | | | | | A. | W. | |
| 27A4 | H. L. Hopkins and F. E. Starr. | 10 | 100 | 6 | | | | C, E. | Dom. | Cp, W. | |
| 27A5 | .....do. | 10 | 200 | 12 | | | | C, E. | Irr. | W. | |
| 27B1 | A. A. Mallet | 8 | | | | | | C, E. | Dom, Irr. | Cp. | |
| 27B2 | Orange County | 7 | 23.5 | 1¼ | 20 | 4 | | | Obs. | Cpr, L, Wm. | |
| 27C1 | H. Kitajima | 7 | 200 | 12 | | | | T, E. | Dom, Irr. | Cp. | (2) |
| 27C2 | G. M. Roberson | 6 | 100 | 2 | | | | P, E. | Dom. | Cp. | |
| 27C3 | Barry | 6 | | 4 | | | | | | | (2) |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5 S., R. 11 W.—Continued | | | | | | |
| 5/11-27C4 | Jim Kobata | 6 | 65 | 4 | ... | ... | ... | C, L | Dom, Irr | Cp | |
| 27D1 | Mrs. Goldie Cleaver | 6 | 490 | 4 | ... | ... | ... | ... | Dom, Irr | Cpr, Wm. | (2) |
| 27D2 | .....do | 6 | 60 | 7 | ... | ... | ... | M | Dom | Cp | |
| 27F1 | C. Mukai | 6 | 189 | 10 | ... | ... | Gravel | C, E | Irr | L | Yield about 585 gpm.[2] |
| 27F2 | .....do | 6 | 85 | 10 | ... | ... | ... | P, E | Dom | Cp | |
| 27G1 | B. T. Gothard | 6 | 98.2 | 6 | ... | ... | Gravel | C, L | Irr | Cp, W. | Casing perforated at 74-91 ft. |
| 27H1 | .....do | 6 | 50 | 3 | 40 | 12 | Gravel and boulders | P, E | Dom | Cp, L, Ww. | |
| 27H2 | .....do | 5 | 88 | 8 | ... | ... | Gravel | C, L | Irr | ... | Casing perforated at 71-88 ft. |
| 27H3 | H. I. Hopkins and F. E. Starr. | 7 | 48.1 | 3 | ... | ... | ... | ... | ... | W | |
| 27J1 | W. Preston | 4 | ... | 4 | ... | ... | ... | ... | ... | ... | |
| 27K1 | Slater | 4 | ... | 10 | ... | ... | ... | ... | ... | Wrd, Wd. | (2) |
| 27K2 | .....do | 5 | ... | 1½ | ... | ... | ... | M | Dom | Cp | |
| 27L1 | Joseph Callens | 4 | 500 | 10 | ... | ... | ... | C, L | Irr | Cpr, L, Wm. | (2) |
| 27L2 | .....do | 3 | ... | 7 | ... | ... | ... | ... | Irr | W | (2) |
| 27N1 | .....do | 3 | ... | ... | ... | ... | ... | ... | A | W | |
| 27N2 | Bolsa Land Co | 2 | 9.0 | 4 | ... | ... | ... | ... | ... | Cp, W. | (2) |
| 27N3 | .....do | 2 | ... | 4 | ... | ... | ... | ... | ... | Cp, W. | (2) |
| 27P1 | Charles Swarner | 3 | ... | 12 | ... | ... | ... | ... | ... | Cp, W. | |
| 27P1 | First National Bank of Santa Ana. | 3 | 40 | 4 | ... | ... | ... | L | Ind | W | (2) |
| 27P3 | .....do | 3 | ... | 2 | ... | ... | ... | P, E | Dom | Cp | (2) |
| 27Q1 | W. L. Slater | 4 | 553 | ... | ... | ... | Gravel | T, E | Irr | Cp, W. | (2) |
| 27Q2 | .....do | 4 | 260 | 12 | ... | ... | .....do | C, E | Dom | Cp | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 27R1 | R. Huff | 5 | 6.0 | | | | | P, E | Dom, Irr | Cpr | Spring in 4- by 6-ft. pit. |
| 28A1 | A. Ruoff | 6 | 453 | 10 | | | | T, E | Irr | Cpr, L, Wm. | |
| 28A2 | do | 6 | 70 | 1½ | | | | P, E | Dom | Cpr | |
| 28A3 | do | 5 | 67.0 | 4 | | | | | | Cp, W. | (2) |
| 28B1 | do | 3 | | | | | | | A | Wd | |
| 28C1 | | 3 | | | | | | | A | Cpr, Wrd, Wd. | |
| 28C2 | S. Mikawa | 17 | 80 | | 80 | | | P, W | | | |
| 28C3 | do | 13 | 165 | 14 | 140 | 20 | Sand and gravel | T, E | Dom, Irr | Cp | Casing perforated at 80-? and 140-160 ft. |
| 28C4 | George J. MacDonald | 2 | 151.4 | 6 | | | | | | W | (2) |
| 28C5 | do | 2 | 51.7 | 6 | | | | | | Cp, W. | (2) |
| 28D1 | Fred Vervorn | 25 | 85 | 3 | | | Coarse gravel | P, E | Dom | Cp | Casing perforated at 80-85 ft. |
| 28D2 | C. F. McDonald | 3 | 65 | 3 | | | | P, W | Dom | Cp | (2) |
| 28D3 | do | 2 | 4 | | | | | | | W | 3- by 6-foot pit. |
| 28F1 | Bolsa Land Co | 4 | | 4 | | | | C | Irr | Cp, W. | (2) |
| 28G1 | do | 4 | 58.8 | 4 | | | | | | Cp, W. | (2) |
| 28H1 | Callens Brothers | 6 | 100 | 7 | | | | | A | Wd | |
| 28H2 | do | 5 | 354 | 14 | 70<br>306 | 12<br>48 | Gravel<br>Coarse gravel | | Irr | Cpr, L, Wm. | (2) |
| 28H3 | do | 5 | 65 | 3 | | | | P, E | Dom | | |
| 28H4 | | 5 | 10.7 | 1½ | | | | | Obs | Cpr, Wm. | |
| 28J1 | Callens Brothers | 5 | 190 | 4 | | | | | A | Wd | |
| 28J2 | Orange County | 3 | 14.3 | 1¼ | 7 | 7 | Silty Sand | | Obs | Cpr, L, Wm. | |
| 28K1 | Bolsa Land Co | 4 | 917 | 14 | 272<br>390<br>713<br>756 | 58<br>4<br>33<br>110 | Gravel<br>do<br>do<br>Sand and gravel | T, E | | C, L, Cpr. | Casing perforated at 292-332, 391-396, 721-749, 766-782, 810-817, and 840-848 ft.[2] |
| 28K2 | Bolsa Land Co | 2 | 67.3 | 2 | | | | | | Cp, W, Cpr. | (2) |
| 28L1 | Well 1 | 2 | 54 | 7 | | | | C, E | Dom | C, W | Flow about 75 gpm.[2] |
| 28Q1 | Bolsa Land Co | 2 | 273 | 4 | | | | P, M | Dom | Cp | (2) |
| 28R2 | do | 2 | 65 | 2 | | | | P, W | Stock | | |
| 28R3 | do | 2 | | 1½ | | | | | | | (2) |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] |  |  | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Depth to top (feet) | Thickness (feet) | Character of material |  |  |  |  |
| T. 5 S., R. 11 W.—Continued |  |  |  |  |  |  |  |  |  |  |  |
| 5/11-28R4 | The Texas Co., Buck well 4 | 2 | ... | 6⅝ | ... | ... | ... | ... | ... | C, Cp | Casing perforated at 4,256-4,402 ft. |
| 29A1 | J. C. Carroll | 39 | 110 | 4 | 80<br>106 | ...<br>4 | Coarse sand<br>Gravel | P, W | Dom | Cp |  |
| 29A2 | Mrs. Mabel Reynolds | 40 | 38 | ... | ... | ... | Sand | P, E | Dom | Cp |  |
| 29A3 | J. Tismerat | 47 | 65 | 8 | 45 | 19 | Gravel | P, W | Dom | Cp, L |  |
| 29A4 | W. Mason | 48 | 117 | 4 | ... | ... | ... | ... | Dom | W |  |
| 29A5 | Mrs. M. Curtin | 51 | 89 | 6 | ... | ... | ... | P, E | Dom | Cp | Casing perforated at 83-89 ft. |
| 29A6 | Mrs. J. Carsons | 47 | 65 | 3 | ... | ... | ... | P, E | Dom | Cp |  |
| 29B1 | H. Elliott | 51 | 117 | 4 | ... | ... | ... | P, W | Dom, Stock. | Cp |  |
| 29B2 | Cal Mallonee | 40 | 65 | 5 | 50 | 15 | Gravel | P, W | Dom | Cp, L |  |
| 29B3 | M. H. Dosney | 36 | 65 | 10 | 50 | 15 | do | P, W | Dom | Cp, L |  |
| 29B4 | H. B. Lamb | 34 | 90 | ... | ... | ... | do | P, E | Dom | Cp |  |
| 29B5 | C. A. Bateman | 50 | 111 | 4 | 101 | 10 | do | P, W | Dom | Cp |  |
| 29B6 | A. Hollenbeck | 46 | 97 | 4 | ... | ... | ... | P, W | Dom | ... |  |
| 29B7 | Cazery | 50 | 37.5 | 3 | ... | ... | ... | ... | ... | ... |  |
| 29C1 | Sunset Land and Water Co. | 45 | 450 | 12 | 333 | 96 | Sand and gravel | T, E | PS | C, L, Cpr, Wm. | Casing perforated at 333-357 and 384-416 ft. |
| 29C2 | do | 45 | 630 | ... | 336<br>540 | 169<br>84 | Gravel and sand<br>Sand and gravel | T, E | PS | L, Wd | Casing perforated at 460-505 and 603-614 ft. |
| 29C3 | do | 8 | 52.3 | 5 | ... | ... | ... | ... | Obs | Cp, Wm. |  |
| 29C4 | do | 8 | 157.0 | ... | ... | ... | ... | ... | Obs | Cp, Wr, Wm. |  |
| 29D1 | Lomita Land and Water Co. | 34 | 200 | 6 | ... | ... | ... | P, W | Dom | Cp |  |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 29E1 | Bolsa Land Co. | 8 | 410 | 6–4 | 158 | 54 | Sand, gravel, and clay. | | Obs. | Cp, L, Wrd. | Observation well, co-operative investigation. Casing perforated at 169–219 ft. |
| 29E2 | ....do. | 7 | 131 | 6 | 85 | 44 | Sand and gravel. | | Obs. | Cp, L, Wrd. | Observation well, co-operative investigation. Casing perforated at 100–120 ft. |
| 29H1 | U. S. Government. | 52 | 500 | 16 | 328 | 172 | ....do. | T, E. | PS. | L. | Casing perforated at 340–466 ft. Yield about 1, 100 gpm. |
| 29P1 | ....do. | 3 | 539 | 12 | 407 | 132 | Gravel. | | | Cp, L. | Flow about 150 gpm. Casing perforated at 484–524 ft.[2] |
| 30B1 | Robert Gilchrest. | | 15 | 2 | | | | P, M. | | Cp. | |
| 33A1 | Bolsa Land Co. | 4 | 11.3 | 1¼ | 6 | 6 | Silty sand. | | Obs. | Cpr, L, Wm. | |
| 33G1 | ....do. | 2 | 11.1 | 1¼ | 6 | 6 | ....do. | | Obs. | Cpr, L, Wm. | |
| 33H1 | Signal Oil and Gas Co. | 2 | 365 | 12 | | | | T, E. | Ind. | Cp. | |
| 33L1 | Bolsa Land Co. | 1 | 10.9 | 1¼ | 7 | 4 | Silty sand. | | Obs. | Cpr, L, Wm. | |
| 33M1 | ....do. | 1 | 11.6 | 1¼ | 9 | 3 | ....do. | | Obs. | Cpr, L, Wm. | |
| 33N1 | ....do. | 3 | 11.3 | 1¼ | 6 | 6 | Sand. | | Obs. | Cpr, L, Wm. | |
| 34A1 | A. Steck. | 50 | 110 | 6 | | | | | Obs. | Cp, Wm | |
| 34A2 | ....do. | 45 | 110 | | | | | | A. | Cp, W. | |
| 34A3 | Davis. | 41 | | 6? | | | | P. | Irr. | Wd. | |
| 34A5 | | 34 | | | | | | P, E. | | | |
| 34B1 | W. Slater. | 4 | | | | | | | A. | Cp, W. | |
| 34C2 | Bolsa Land Co. | 3 | | 4 | | | | | | | (2) |
| 34G1 | J. R. Clarke. | 67 | 210 | 8 | | | | P, E. | | | |
| 34G2 | Pacific American Oil Co. | 55 | 118.0 | 10 | | | | | Obs. | Cp, Wm | |
| 34H1 | | 41 | 72.0 | 6 | | | | | Obs. | Wm. | |
| 34H2 | R. W. Brown. | 60 | 73.3 | 7 | | | | P, E. | Obs. | Wm. | |
| 35A1 | | 57 | | 4 | | | | P, M. | Dom, Irr. | Cp, W. | |
| 35A2 | Mrs. Bonnie M. Sage. | 52 | 90 | 5? | | | | P, I. | Irr. | | |
| 35A3 | F. M. Packard. | 55 | 184 | 4 | 96<br>140 | 36<br>38 | Gravel and sand.<br>Sand and gravel. | T, E. | Irr. | Cp, L. | Casing perforated at 115–131 and 145–161 ft. |
| 35A4 | Mrs. Bonnie M. Sage. | 54 | 499.4 | 5 | | | | | Obs. | Wm. | |
| 35A5 | B. H. Stewart. | 55 | 170 | 6 | | | | T, E. | Dom. | | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T., 5 S., R. 11 W.—Continued | | | | | | |
| 5/11-35B1 | Mrs Haynes | 53 | ... | 7 | ... | ... | ... | P, W | A | W | |
| 35B2 | T. G. Harriman Estate | 60 | ... | ... | ... | ... | ... | T, E | Dom, Irr | Cp | |
| 35C1 | Paul Janke | 51 | 110 | ... | ... | ... | ... | P, I | Dom | Cp | |
| 35C2 | Baldwin and McIntosh Pig Ranch. | 35 | 105.0 | ... | ... | ... | ... | P, W | Stock | Cp, Wd | |
| 35C3 | do | 25 | 49.5 | 2 | ... | ... | ... | P, M | ... | W | |
| 35D1 | A. G. Thornton | 38 | 167 | 7 | ... | ... | ... | C, W | ... | ... | |
| 35D2 | Orange County | 30 | 19.5 | 1¼ | 11 | 9 | Sand and gravel | ... | Obs | Cpr, L, Wm. | |
| 35F1 | La Bolsa Tile Co | 58 | 110 | 10 | ... | ... | ... | P, E | Ind | Cp, W | |
| 35F2 | Mrs. T. G. Harriman | 62 | ... | ... | ... | ... | ... | T, I | Irr | ... | |
| 35H1 | Mrs. M. V. Gibbs | 51 | ... | ... | ... | ... | ... | P, E | Dom | Cp | |
| 35H2 | Mrs. Sam E. Hern | 57 | ... | ... | ... | ... | ... | P, M | ... | ... | |
| 35L1 | Frank Dispalatro | 57 | 350 | 16 | ... | ... | ... | P, W | Dom, Irr | C, Wm, Cpr, | |
| 35M1 | Edward Russell | 56 | 150 | 6 | ... | ... | ... | P, W | Dom, Stock. | Cp | |
| 35M2 | Mrs. E. M. Vavra | 50 | ... | ... | ... | ... | ... | P, I | ... | ... | |
| 35N1 | The Texas Co | 67 | 125 | 5 | ... | ... | ... | P, E | Ind | C | |
| | Holly Sugar Co.: | | | | | | | | | | |
| 35P1 | Well 6 | 67 | 391 | 12 | 209<br>319 | 37<br>48 | Gravel<br>Gravel and clay and shells. | T, E | Ind | C, L, W, Cp. | Casing perforated at 213-246 and 337-367 ft. |
| 35P3 | Well 4 | 69 | 394 | 12 | 187<br>325<br>340 | 58<br>9<br>50 | Gravel and clay<br>Gravel<br>Sand and gravel | A1 | ... | L, W | Casing perforated at 216-246, 328-334, and 341-358 ft. |
| 35P4 | Well 3 | 69 | 391 | 12 | 185<br>339 | 60<br>48 | Gravel and clay<br>Gravel and sand | A1 | ... | L, W | Casing perforated at 215-245 and 340-362 ft. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35P5 | Well 2 | 68. | 383 | 12 | 195<br>334 | 48<br>48 | Gravel<br>Gravel and sand | Al | | L, W | Casing perforated at 198–240 and 333–357 ft. |
| 35P6 | Well 1 | 68 | | 14 | | | | Al | | W | |
| 35P7 | Well 5 | 67 | 387 | 12 | 181<br>341 | 65<br>18 | Gravel and clay<br>Gravel | Al, S | Ind | C, L, W | Casing perforated at 209–246 and 341–359 ft. |
| 35R1 | J. W. Renfro | 62 | 158 | 6 | | | | P, L | Irr | Cp, L | |
| 36A1 | E. J. Lecrivain | 21 | | 12 | | | | T, E | Irr | Wd | |
| 36A2 | John Courreges | 22 | 156 | 6 | | | | T | Irr | W | |
| 36B1 | Joseph J. Courreges | 49 | 160 | 7 | | | | T, E | Irr | W | |
| 36B2 | do | 44 | 150 | 8 | | | | P, E | Dom | Cp | |
| 36D1 | H. T. Grove | 53 | 122.1 | 7 | | | | P, W | Irr | C, W | |
| 36D2 | N. E. Clemens | 53 | 87 | | | | | P, W | Dom | Cp | |
| 36E1 | Tarver Montgomery | 60 | | 8 | | | | T | | Cp | |
| 36F1 | R. Dobkins and Wells | 19 | | 4 | | | | T, E | Dom, Irr | Cp, W | |
| 36F2 | do | 18 | | | | | | P, L | Dom | Cp, W | |
| 36F3 | H. M. Zerom | 55 | 115 | 2½ | | | | P, W | Dom | | |
| 36G1 | | 5 | | 2 | | | | P, W | Irr | Wd | |
| 36G2 | | 16 | 132.0 | 5 | | | | | | Cp, W | |
| 36J1 | | 15 | | | | | | | A | Wd | |
| 36J2 | | 17 | 124.9 | 12 | | | | | | W | |
| 36J3 | E. J. Lecrevain | 14 | 131.5 | 10 | | | | | Irr | Cp, W | |
| 36K1 | | 16 | | | | | | | | Wd | |
| 36K2 | J. A. Dunn | 16 | 129.0 | 8 | 92 | 55 | Gravel | C | Irr | L, Wm, Cp. | Casing perforated at 100–140 ft. |
| 36K3 | do | 15 | | 9 | | | | | | Cp, W | |
| 36L1 | N. Williams | 15 | 41.8 | 5 | | | | C, L | Dom, Irr | Cp, W | |
| 36M3 | Cecil Moody | 59 | 145 | | | | | | | | |
| 36M4 | C. Valentini | 59 | 140 | | | | | T, E | Dom | Cp | |
| 36M5 | Caroline Schaaf | 62 | 167 | 6½ | | | | T, E | Dom, Ind, Irr. | | |
| 36M6 | Samuel Greer | 56 | 140 | 8 | | | | P, W | Dom | Cp | |
| 36N1 | Mrs. Crutchey | 60 | 83 | | | | | | A | C, Wd | |
| 36N2 | C. J. Yost | 58 | | | | | | T, E | Dom | Cp | |
| 36P1 | Ivan Harper | 60 | 148 | 10 | 120 | 26 | Rock and gravel | T, E | Dom, Irr | Cp, L | Casing perforated at about 138–146 ft. |
| 36P2 | | 15 | | 7 | | | | C | | | |
| 36Q1 | | 15 | 126.3 | 3 | | | | | | Cp, Wd | |
| 36Q2 | | 14 | | | | | | | A | Wd | |
| 36R1 | Anna Bushard | 16 | | 4 | | | | E | Dom | Cp, W | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach–Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | **T. 5 S., R. 12 W.** | | | | | | |
| 5/12-1A1 | I. W. Hellman Ranch | 12 | 712 | 12 | 662 | 22 | Coarse gravel | T, E | Dom, Stock, Irr. | Cp, L, Wm. | |
| 1A2 | ...... | 12 | 18 | ...... | ...... | ...... | ...... | ...... | Obs. | C. | |
| 1D1 | I. W. Hellman Ranch | 9 | 18.8 | 1¼ | 8 | 7 | Silt with sandy streaks. | ...... | Obs. | Cp, L, Wm. | |
| 2A1 | Bryant Ranch | 7 | 20.3 | 1¼ | 16 | 4 | Silty sand | ...... | Obs. | Cpr, L, Wm. | |
| 2B1 | .....do | 8 | 255.2 | 10 | 460 | 81 | Sand and gravel | ...... | Obs. | Cp, L, Wr, Wm. | Yield about 540 gpm. Casing perforated at 460–507 ft.[2] |
| 2B2 | Bryant Ranch, well 12 | 8 | 436.3 | 7 | 257 | 18 | Sand and gravel | ...... | Obs. | Cpr, L, Wm. | Casing perforated for 15 ft. between 257–275 ft. and for 8 ft between 472–483 ft.[2] |
| | | | | | 312 | 171 | Coarse sand | | | | |
| 2B3 | Bryant Ranch | 14 | 103.0 | 4 | ...... | ...... | ...... | ...... | Obs. | Cp, Wm. | |
| 2B4 | .....do | 8 | 730 | ...... | 34 | 43 | Gravel | ...... | A. | L, Wd. | Casing perforated at 43–77 and 451–555 ft. |
| | | | | | 451 | 104 | Gravel and sand | | | | |
| 2C1 | Fred H. Bixby Co. | 24 | 1,020 | 14 | 75 | 15 | Sand and gravel | T, E | Irr. | C, L, Cpr, Wm. | |
| 2C2 | .....do | 26 | 100 | 8 | ...... | ...... | ...... | T, E | Irr. | Cp, Wd. | |
| 2C3 | .....do | 14 | ...... | 1 | ...... | ...... | ...... | P, M | Dom. | Cp. | |
| 2C4 | .....do | 15 | 130 | ...... | 21 | 2 | Sand and gravel | T, E | Irr. | Cp, L, Wm. | Casing perforated at 22–23, 39–42 and 90–100 ft. |
| | | | | | 39 | 3 | Gravel | | | | |
| | | | | | 76 | 23 | Sand and gravel | | | | |
| 2D1 | .....do | 25 | ...... | 6–4 | ...... | ...... | ...... | T, E | Dom, Irr. | Cp. | |
| 2D2 | .....do | 10 | ...... | 6 | ...... | ...... | ...... | T, E | Dom, Irr. | Cp. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2G1 | Bryant Ranch | 10 | 400 | 2 | 392 | 8 | Fine sand | .......... | .......... | Cp | |
| 2G2 | .....do | 8 | 98 | 4 | 91 | 7 | Coarse sand | P, E | Dom | Cp | |
| 2H1 | .....do | 7 | .......... | 5? | .......... | ........ | .......... | P, E | Dom, Stock. | Cp | |
| 2H2 | .....do | 7 | 40. 0? | 4 | .......... | ........ | .......... | .......... | .......... | Ww | |
| 2H3 | .....do | 7 | 11. 8 | 1¼ | 8 | 4 | Silty sand | .......... | Obs | Cpr, L, Wm. | |
| | City of Los Angles:<br>Department of Water and Power; | | | | | | | | | | |
| 2J1 | Well 4 | 7 | 325 | 10 | 280 | 31 | Gravel | .......... | A | C, L, Wd. | |
| 2J2 | Well 5 | 7 | 404 | .......... | 278 | 54 | Gravel, coarse and medium sand. | T, E | Ind | Cp, L | Casing perforated at 290-326 ft. |
| 2J3 | Well 6 | 5 | 386 | 18 | 90<br>329 | 38<br>33 | Gravel and sand<br>.....do | T, E | Ind | Cp, L | Casing perforated at 101-125 and 336-354 ft. |
| 2K1 | Bryant Ranch | 4 | 17. 5 | 1¼ | 15 | 3 | Silty fine sand | .......... | Obs | Cpr, L, Wm. | |
| 2P1 | Fred H. Bixby Co | 5 | .......... | 5 | .......... | ........ | .......... | .......... | Ind | Cp | Yield about 40 gpm. |
| 2P2 | .....do | 5 | 244 | 4 | .......... | ........ | .......... | P, W | Ind | Cp, W. | Yield about 110 gpm. Casing perforated at 231-244 ft. |
| 2P3 | .....do | 5 | 177 | 5½ | 145 | 30 | Gravel | Al, S. | Ind | Cp, L. | Yield about 30 gpm. |
| 2P4 | .....do | 4 | 11. 9 | 1¼ | 6 | 11 | Sand | .......... | Obs | Cpr, L, Wm. | |
| 2P5 | .....do | 5 | 150 | 8½ | .......... | ........ | .....do | .......... | Ind | L | Casing perforated at 37-150 ft. |
| 3A1 | .....do | 23 | 335 | 10 | 32 | 70 | Coarse sand and gravel. | T | Irr | Cp, L, W. | Casing perforated at 40-102 ft. |
| 10A1 | Standard Oil Co | 4 | 296. 6 | 16 | 124 | 19 | Gravel and sand | .......... | Obs | L, Wrd. | Casing perforated at 130-143 ft. |
| 10H1 | City of Long Beach | 6 | 11. 5 | 1¼ | 6 | 6 | Sandy silt | .......... | Obs | Cpr, L, Wm. | |
| 10H2 | McGrath | 6 | 17. 3 | 1¼ | 12 | 4 | Sand | .......... | Obs | Cpr, L, Wm. | |
| 10K1 | City of Long Beach | 7 | 15. 3 | 1¼ | 7 | 9 | .....do | .......... | Obs | Cpr, L, Wm. | |
| 10P1 | .....do | 5 | 9. 3 | 1¼ | 3 | 6 | .....do | .......... | Obs | Cpr, L, Wm. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach–Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 5. S., R. 12 W.—Continued | | | | | | |
| 5/12-11A1 | City of Los Angeles, Department of Water and Power. | 5 | 1,178 | 16–12 | ... | ... | ... | ... | Obs. | Cpr, L, Wd. | Casing not perforated. |
| 11C1 | Fred H. Bixby Co. | 5 | 280 | 4 | ... | ... | ... | P, W. | Ind. | Cp, W. | Casing perforated at 268–280 ft. |
| 11D1 | .....do. | 3 | 13.3 | 1¼ | 6 | 6 | Silty sand | ... | Obs. | Cpr, L, Wm. | |
| 11G1 | Bryant Ranch | 5 | 740 | 14 | 70<br>187 | 22<br>27 | Gravel and clay<br>Sand and mud | T, E. | Ind. | Cr, L, Cpr, W. | Perforations not reported, water yielding zones inferred from log. (2) |
| 11H1 | ....do. | 4 | 296.0 | 8 | ... | ... | ... | ... | Obs. | C, Wrd, Cpr, Wm. | |
| | City of Los Angeles: Department of Water and Power; | | | | | | | | | | |
| 11L1 | Well 2 | 10 | 810 | 10 | 320 | 38 | Grave | ... | Obs. | L, Wr. | |
| 11L2 | Well 1 | 4 | 933 | 12 | ... | ... | ... | ... | A. | L. | |
| | Los Angeles County Flood Control District: | | | | | | | | | | |
| 11M1 | Test well 2 | 2 | 100 | ... | ... | ... | ... | ... | A. | L. | |
| 11M2 | Test well 1 | 15 | 100 | ... | ... | ... | ... | ... | A. | Cp, L. | |
| 12A1 | I. W. Hellman Ranch | 7 | 164 | 2 | ... | ... | ... | C, E. | Dom, Stock. | Cp, Ww. | Casing perforated at 156–164 ft.[2] |
| 12C1 | I. W. Hellman Ranch, well 1. | 27 | 705 | 12 | 405 | 68 | Gravel | T, E. | Dom, Stock, Irr. | Cp, L, Wd. | Casing perforated at 417–473 ft.[2] |
| 12F1 | ... | 23 | 994 | 14 | ... | ... | ... | ... | Obs. | Cp, Wm. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12L1 | I. W. Hellman Ranch, well 12. | 25 | 723 | 12 | 660 | 49 | Gravel | T, E. | Dom, Irr. | Cp, L, W. | Casing perforated at 668-709 ft. Yield about 500 gpm (Navy well 3). |
| 12N1 | I. W. Hellman Ranch | 35 | ......... | 8 | ......... | ......... | ......... | ......... | ......... | L, W. | Oil test hole. |
| 12P1 | .....do | 15 | 185.3 | 12 | ......... | 50 | Gravel and sand | T, E. | Dom, Irr. | C, Cpr, Ww. | Yield about 390 gpm. |
| | City of Seal Beach: | | | | | | | | | | |
| 12P2 | Well 1 | 27 | 782 | ......... | 678 | 44 | Sand, gravel and clay. | ......... | A. | L. | Casing perforated at 684-715 ft. |
| 12P3 | Well 2 | 22 | 362.6 | 16 | 132<br>348 | 74<br>12 | Sand and gravel<br>Coarse sand and gravel. | ......... | Obs. | Cp, L, Wr. | Yield about 560 gpm. Casing perforated at 169-195 and 348-362 ft. Perforations at 169-195 ft., later cemented off. |
| 12P4 | Well 4 | 21 | 620 | 12 | 528 | 58 | Sand and gravel | T, E. | PS. | Cpr, L. | Casing perforated at 561-586 ft. |
| 12P5 | Well 3 | 22 | 451 | 12 | ......... | ......... | ......... | ......... | A. | L. | |
| 12P6 | Well 5 | 30 | 670 | 12 | 472 | 164 | Coarse sand and gravel. | T, E. | PS. | Cp, L, W. | Casing perforated at 540-575, 598-604, and 626-637 ft. |
| 13D1 | I. W. Hellman Ranch | 23 | 381 | 6-4 | 183 | 75 | Fine to coarse sand and gravel. | ......... | Obs. | C, Cp, L, Wr. | Observation well, cooperative investigation. Casing perforated at 190-210 ft. |
| 13D2 | .....do | 25 | 140.0 | 6-4 | 125 | 33 | Gravel, coarse sand, and clay. | ......... | Obs. | Cp, L, Wr. | Observation well, cooperative investigation. Casing perforated at 130-140 ft. |
| 13D3 | .....do | 23 | 23.4 | 1¼ | 5 | 18 | Fine to coarse sand | ......... | Obs. | Cp, L, Wm. | |
| 14B1 | Seal Beach Oil Co. | 8 | ......... | ......... | ......... | ......... | ......... | ......... | A. | W. | |
| 24H1 | Alamitos Land Co. | 10 | 14.8 | 1¼ | 9 | 6 | Sand | ......... | Obs. | Cpr, L, Wm. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach–Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | T. 5 S., R. 13 W. | | | | | | | |
| 5/13-1H1 | | 40 | 70 | | | | | | | L. | |
| 3D1 | Long Beach Salt Co. | 6 | 116 | 3 | | | | P, E. | Ind. | C, Wd, Cpr. | |
| 3D2 | do. | 6 | 158 | | | | | | A. | L. | |
| 3K1 | Southern California Edison Co., Ltd. | 11 | 1,200 | 16 | 147-189 | 33-86 | Boulders and sand. | | A. | L. | Casing perforated at 137-155 and 189-275 ft. |
| 3K2 | do. | 10 | 250 | 16 | | | | | | Cpr, W. | |
| | Southern California Edison Co. Ltd: | | | | | | | | | | |
| 3K3 | Observation well 14. | | 151 | | | | | | Obs. | L. | |
| 3L1 | Observation well 4. | | 372 | | 140 | 14 | Gravel and sand. | | Obs. | L, Wm. | |
| 3N1 | Observation well 10. | | 150 | | | | | | Obs. | L. | |
| 3P1 | Observation well 13. | | 150 | | | | | | Obs. | L. | |
| 3P2 | Observation well 2. | | 35 | | | | | | Obs. | Wm. | |
| 3P3 | Observation well 5. | | 155 | | 65 | 90 | Sand and gravel. | | Obs. | L, Wm. | Casing perforated at 111-119 and 134-150 ft. |
| 3P4 | Observation well 6. | | 159 | | 85 | 74 | do. | | Obs. | L, Wm. | Casing perforated at 109-149 ft. |
| 3P5 | Observation well 3. | | 35 | | | | | | Obs. | Wm. | |
| 3P6 | Observation well 12. | | 150 | | | | | | Obs. | L. | |
| 3P7 | Observation well 11. | | 150 | | | | | | Obs. | L. | |
| 3Q1 | Observation well 15. | | 151 | | | | | | Obs. | L. | |
| 3Q2 | Observation well 1. | | 35 | | | | | | Obs. | Wm. | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4Q1 | City of Los Angeles: Terminal Island, well 1. | 3 | 470 | 18 | 235 | 86 | Very fine gravel | ...... | Obs. | L, Wm. | Casing perforated at 245-270 ft., later shut off. |
| 6D1 | Union Oil Co. | 25 | 1,016 | 26-12 | 600 | 299 | Sand | Al. | Ind. | Cr, Wm. | Casing perforated at 809-888 ft. |
| 18J1 | Van Camp Sea Food Co. | 3 | 582 | 16 | ...... | ...... | ...... | ...... | ...... | Cp, L, W. | Not perforated. |
| | T. 6 S., R. 10 W. | | | | | | | | | | |
| 6/10-1E1 | Frank Ey | 34 | 300 | ...... | ...... | ...... | ...... | T, E. | Dom, Irr. | Cp, Ww. | |
| 1E2 | Santa Ana Heights, Water Co. | 35 | 945 | 16 | 580 | 365 | Gravel and sand | T, E. | PS | C,Ww, Cp. | Casing perforated at 720-926 ft. Yield about 2,250 gpm. |
| 1E3 | Alamquist Brothers | 35 | 208 | 4 | ...... | ...... | ...... | P, W. | Dom, Stock. | Cp,W. | Casing perforated at about 200-208 ft. |
| 1E4 | W. P. Knight | 38 | 340 | 5 | ...... | ...... | ...... | P, E. | Dom. | Cp. | |
| 1F1 | J. T. Chilcoat | 42 | 165.0 | 12 | ...... | ...... | ...... | T, I. | Irr. | Cp, Wd. | |
| 1F2 | .....do | 42 | 200 | 4 | ...... | ...... | ...... | T, E. | Dom. | Cp. | |
| 1L1 | I. A. W. Henry | 40 | 460 | 12-7 | 159-417 | 29-43 | Gravel, gravel and sand. | T, I. | Dom, Irr. | Cp,L. | Casing perforated at 160-161 and 417-460 ft. |
| 1L2 | .....do | 40 | 142.6 | 2½ | ...... | ...... | ...... | ...... | Obs. | Cp, Wm. | |
| 1L3 | .....do | 40 | 29.8 | 3 | ...... | ...... | ...... | ...... | Obs. | Cp,W. | |
| 1M1 | Baker Estate | 37 | 451.0 | 3 | ...... | ...... | ...... | ...... | ...... | W. | |
| 2B1 | J. W. Shiffer | 33 | 265 | 8 | ...... | ...... | ...... | T, I. | Dom, Irr. | Cp,L. | |
| 2B2 | .....do | 33 | 33.2 | 8 | ...... | ...... | ...... | ...... | Obs. | Cp, Wm. | |
| 2B3 | .....do | 33 | ...... | ...... | ...... | ...... | ...... | P, E. | Dom, Stock. | Cp. | |
| 2C1 | Mrs. C. M. Remsberg | 33 | 298 | 8 | ...... | ...... | ...... | T, E. | Dom, Stock, Irr. | Cp. | Yield about 360 gpm. |
| 2E1 | L. E. Platt | 35 | 44.0 | 5 | ...... | ...... | ...... | ...... | ...... | Cp,W. | |
| 2F1 | C. A. Fortner | 37 | 218 | 8 | ...... | 40 | ...... | P. | Dom. | Cp. | Casing perforated at about 206-218 ft. |
| 2F2 | Leonard | 36 | ...... | ...... | ...... | ...... | ...... | T, E. | ...... | Cp. | |
| 2G1 | Harry Mansperger | 37 | 516 | 12 | ...... | ...... | ...... | T, E. | Dom, Irr. | Cp, Wm. | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach–Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 6 S., R. 10 W.—Continued | | | | | | |
| 6/10-2G2 | J. W. Shiffer | 40 | 180 | 3 | | | | E | Dom. | Cp | |
| 2G3 | do | 40 | 350 | 12 | | | | T, I | | | |
| 2G4 | Harry Mansperger | 40 | 200 | 2 | | | | | Obs. | Cp, W. | |
| 2G5 | Mrs. Medlock | 40 | 157.4 | 4 | | | | | Obs. | Cp, Wm. | |
| 2H1 | Nate Hughes | 35 | 200 | 12-10 | | | | T, E | Dom, Irr. | C, L, Cp, Wm. | |
| 2H2 | The Irvine Co. | 40 | 480 | 10 | | | | T | Irr. | | |
| 2H3 | E. E. Jamieson | 37 | 680 | 10 | | | | T, E | Dom, Irr. | Cp | |
| 2J1 | L. V. Davis | 40 | 240 | 8? | 25 | 215 | Mud and sand | T, I | Dom, Irr. | Cpr, L. | Casing perforated full length. |
| 2J2 | G. W. Cox | 40 | 202 | 6 | 194 | 8 | Sand and gravel | P, E | Dom. | Cp | Casing perforated at 190-202 ft. |
| 2J3 | Britts Price | 40 | 121.0 | 3 | | | | P, W | Stock. | Cp, W. | |
| 2K1 | L. L. Brown | 38 | 280 | | | | | T, E | Dom, Irr. | Cp, W. | |
| 2L1 | H. Moore | 40 | | 4 | | | | | Dom. | Cp | |
| 3D1 | Charles Borchard | 37 | | | | | | T, E | Irr. | | |
| 3E1 | Mary E. Peroni | 42 | 186 | 5? | | | | P, W | Dom. | Cp, Wm. | |
| 3E2 | do | 41 | 118.4 | 5-3 | | | | | Obs. | Wm. | |
| 3E3 | Charles Borchard | 38 | 140.5 | 3 | | | | | Obs. | Wm. | |
| 3F1 | W. E. Barias | 42 | | 2 | | | | P, E | Dom, Stock. | Cp | |
| 3H1 | C. J. Segerstrom Sons | 36 | 600 | 12 | | | | T, E | Irr. | Cp, L. | |
| 3H2 | W. S. Babb | 40 | 637 | 10 | | | | T, E | Dom, Irr. | Cp, Wm. | |
| 3H3 | L. E. Platt | 33 | 190 | 11 | | | | T, E | Irr. | Cp | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3J1 | J. P. Cote | 37 | 75 | 3 | ... | ... | ... | P, W | Dom. | Cp, W. | |
| 3J2 | E. C. Winder | 43 | ... | ... | ... | ... | ... | ... | Irr. | ... | |
| 3K1 | M. H. Whittier Co. | 45 | ... | ... | ... | ... | ... | T, E. | Irr. | | |
| 3K2 | C. M. McClintock | 43 | ... | 4? | ... | ... | ... | ... | Dom, Irr. | Cp. | |
| 3L1 | M. Colombini | 46 | 564 | 10 | ... | ... | ... | P, E. | Dom, Stock, Irr. | Cp, L. | |
| 3M1 | Vermillion | 48 | ... | 7 | ... | ... | ... | P, E. | Dom, Stock | Cp, Wd. | |
| 3M2 | D. J. Hollingsworth | 51 | 58 | 6 | ... | ... | ... | P, W | Dom. | Cp. | |
| 3M3 | S. Duarte | 51 | ... | ... | ... | ... | ... | E. | Dom. | Cp. | |
| 3N1 | F. Clark | 55 | 158.0 | 16 | ... | ... | Quicksand | S. | Obs. | Wm. | |
| 3N2 | F. L. Spoonhauer | 54 | 80 | 2 | ... | ... | ... | P, I. | Dom. | Cp. | |
| 3N3 | C. Turner | 59 | 80 | 6 | ... | ... | ... | P, W | Dom. | Cp. | |
| 3P1 | Anthony Borchard | 56 | 200 | ... | ... | ... | ... | P, W | Dom. | Cp. | |
| 3Q1 | ... | 56 | ... | ... | ... | ... | ... | T, I. | Irr. | ... | |
| 3Q2 | ... | 57 | 582.1 | ... | ... | ... | ... | ... | Obs. | Wm. | |
| 4C1 | Bank of America | 46 | ... | ... | ... | ... | ... | P. | Dom. | Cp. | |
| 4D1 | Charles Griset | 41 | ... | 14 | ... | ... | ... | T, I. | Dom, Irr. | Cp. | |
| 4F1 | Bank of America | 50 | ... | 14 | ... | ... | ... | T, E. | Irr. | ... | |
| 4H1 | ... | 43 | ... | 6 | ... | ... | ... | T, E. | Stock | ... | |
| 5B1 | Robert Gisler | 19 | 73.7 | 10 | 85 | 10 | Gravel | ... | Obs. | Cp, L, Wm. | |
| 5B2 | do. | 18 | 140 | ... | ... | ... | ... | ... | A. | C. | |
| 5C1 | do. | 19 | 209 | 14 | 70<br>102<br>126 | 22<br>18<br>58 | Sand and gravel<br>Cemented gravel<br>Sand, gravel, and clay. | T, E. | Irr. | Cp, L, Ww. | Yield about 770 gpm. Casing perforated at 85-92, 102-120, 126-144, and 165-184 ft. |
| 5C2 | do. | 18 | 120 | 7 | ... | ... | ... | P, E. | Dom. | Cp. | |
| 5C3 | do. | 18 | 135.0 | ... | ... | ... | ... | ... | ... | ... | |
| 5D1 | Mrs. L. L. Harper | 17 | ... | ... | ... | ... | ... | T, E. | Irr. | Wd. | |
| 5K1 | Miyado | 16 | 125.8 | ... | ... | ... | ... | ... | Irr. | W. | |
| 5N1 | Nagamatsu | 12 | ... | 6 | ... | ... | ... | P. | Dom. | Cp, Wm. | |
| 5N2 | do. | 14 | ... | 6 | ... | ... | ... | T, E. | Irr. | ... | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach–Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] |  |  | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Depth to top (feet) | Thickness (feet) | Character of material |  |  |  |  |
| T. 6 S., R. 10 W.—Continued |  |  |  |  |  |  |  |  |  |  |  |
| 6/10-5R1 | C. J. Segerstrom Sons | 69 | 200 |  |  |  |  |  | A | W |  |
| 5R2 | do | 65 | 325 | 12 |  |  |  | P, E | Irr. | Cp |  |
| 5R3 | do | 65 | 132.0 | 4 | 110 | 25 | Gravel | P, E | Dom. | Cpr, L, W. |  |
| 6A1 | Lamb | 15 | 139.0 |  |  |  |  | C | Obs. | Wm |  |
| 6A2 | Mrs. G. L. Harper | 14 | 143.0 | 6½ |  |  |  |  |  | Cp, Wd. | (2) |
| 6B1 | H. J. Lamb | 14 | 139.7 | 10 |  |  |  | C, E | Irr. | Cp, Wm. |  |
| 6C1 | Mrs. G. L. Harper | 13 |  |  |  |  |  |  |  |  |  |
| 6C2 | do | 17 |  | 8 |  |  |  |  | Obs. | Wm |  |
| 6D1 | Walter Lamb | 12 | 128.0 | 5 |  |  |  |  | Obs. | Cp, Wm. | (2) |
| 6E1 | do | 10 |  | 5 |  |  |  | C, E | Irr. |  |  |
| 6F1 | Earl Lamb | 11 | 200 | 6 |  |  |  | C | Irr. | Cp |  |
| 6H1 | Lamb | 13 | 100.0 |  |  |  |  | C | Irr. | Wm |  |
| 6K1 | Ansen Hamman | 13 | 140 | 4 |  |  |  | P, W | Dom. | Cp |  |
| 6L1 | Lamb | 11 |  | 10 |  |  |  | C, E | Irr. | W |  |
| 6L2 | H. J. Lamb | 12 | 150 | 7 |  |  |  | P, W | Dom. | C, Wm, Cpr. |  |
| 6N1 | do | 8 | 150 | 7 |  |  |  | T, E | Irr. | Wm | (2) |
| 6P1 | do | 10 | 150.5 |  |  |  |  |  | Obs. | Cp, Wr. |  |
| 6P2 | do |  | 24.7 | 8 | 11 | 14 | Sand and clay |  | Obs. | Cp, L, Wr. |  |
| 6Q1 | Hamman | 12 | 144 | 8 |  |  |  | C, E | Irr. | L |  |
| 6R1 |  | 12 |  |  |  |  |  |  | A | Wd |  |
| 7B1 | Anaheim Sugar Co. | 10 | 114.9 | 12 |  |  |  |  | Obs. | Cp, Ww. |  |
| 7B2 | do | 11 |  | 12 |  |  |  | T, E | Irr. | W | Yield about 1,125 gpm. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7C1 | George Bushard | 10 | 134.0 | 10 | ... | ... | ... | ... | Obs. | Cp, L, Wm. | (2) |
| 7C2 | do | 10 | ... | ... | ... | ... | ... | ... | A. | W. | |
| 7C3 | W. W. Bushard | 9 | 145 | 5 | ... | ... | ... | C, E. | Irr. | Cp, W. | |
| 7D1 | George Bushard | 57 | 138.0 | 9 | ... | ... | ... | P, W. | Dom, Irr, Obs. | Cp, Wm. | Unused. |
| 7D2 | W. W. Bushard | 7 | 261.5 | 10 | ... | ... | ... | ... | Irr. | Cp, W. | Abandoned. |
| 7F1 | do | 10 | 150 | 7 | ... | ... | ... | P, W. | Dom. | Cp. | |
| 7G1 | Alban Holtz | 11 | 30 | 2 | ... | ... | ... | P, E. | Dom. | Cp. | |
| | The Irvine Co.: | | | | | | | | | | |
| 7J1 | Prospect well 9 | 9 | 460 | ... | ... | ... | ... | ... | A. | L. | |
| 7J2 | Prospect well 8 | 8 | 460 | ... | ... | ... | ... | T, I. | Irr. | L, Wm. | |
| 7J3 | Prospect well 1 | 8 | 397 | ... | ... | ... | ... | ... | A. | L. | |
| 7K1 | Prospect well 2 | 8 | 415 | 12 | ... | ... | ... | T, E. | Irr. | Cp, L, W. | |
| 7K2 | Prospect well 3 | 8 | 455 | ... | ... | ... | ... | ... | A. | L. | |
| 7K3 | Prospect well 4 | 8 | 382 | ... | ... | ... | ... | ... | A. | L. | |
| 7K4 | Prospect well 5 | 8 | 460 | ... | ... | ... | ... | ... | A. | L. | |
| 7K5 | The Irvine Co. | 8 | 202 | ... | ... | ... | ... | T, E. | PS. | C, Wm, Cp. | |
| 7L1 | R. L. Farnsworth | 8 | 81.4 | 6 | ... | ... | ... | P, W. | Dom. | C, Wm, Cpr. | |
| 7L2 | Louis Bushard | 6 | 150 | 6 | ... | ... | ... | T. | Irr. | ... | |
| 7L3 | do | 9 | 128 | 7 | ... | ... | ... | T, E. | Dom. | Cp. | |
| 7L4 | Orange County | 8 | 18.4 | 1¼ | 12 | 6 | Sand and silt | ... | Obs. | Cp, L, Wm. | |
| 7M1 | F. W. Farnsworth | 5 | ... | 4 | ... | ... | ... | C, E. | Irr. | W. | |
| 7N1 | Wyrick | 6 | ... | 4 | ... | ... | ... | P, W. | Dom, Stock. | C, Cpr. | |
| 7P1 | Orange County | 8 | 17.3 | 1¼ | 10 | 7 | Silty sand | ... | Obs. | Cpr, L, Wm. | |
| | The Irvine Co.: | | | | | | | | | | |
| 7Q1 | Prospect well 6 | 7 | 413 | ... | ... | ... | ... | ... | A. | L. | |
| 7Q2 | Prospect well 7 | 7 | 460 | ... | ... | ... | ... | ... | A. | L. | |
| 8A1 | ... | 14 | 108.5 | 12 | ... | ... | ... | ... | ... | Cp, W. | |
| 8B1 | C. J. Segerstrom Sons | 13 | 220.5 | 12 | 88 | 42 | Gravel and sand | T, E. | Irr. | Cp, L, Wm. | Casing perforated at 88-100 and 115-130 ft. |
| 8B2 | do | 13 | 225.0 | 14 | 70 | 113 | Sand, gravel, and silt | T, E. | Irr. | Cpr, L. | Yield about 1,250 gpm. Casing perforated at 72-126, 130-155, and 168-172 ft. |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 6 S., R. 10 W.—Continued | | | | | | |
| 6/10-8D1 | City of Newport Beach | 12 | | | | | | | A | Cp, Wd. | |
| 8D2 | Well 9 | 12 | 176 | 18 | 58 | 50 | Gravel, sand, and rock. | T, E | PS | Cr, L, Cpr, Ww. | Casing perforated at 75–108 ft. |
| 8D4 | Well 8 | 11 | 288 | 18 | 60<br>202 | 46<br>38 | Gravel and sand | T, E | PS | Cr, L, Ww. | Yield about 1,000 gpm. Casing perforated at 86–106 and 211–240 ft. Lower perforations plugged off. |
| 8D5 | Well 7 | 12 | 279 | 12 | 78<br>95<br>192<br>207 | 15<br>17<br>5<br>5 | Gravel<br>do.<br>do.<br>do. | T, E | PS | Cr, L, Cp, Ww. | Yield about 1,060 gpm. |
| 8D6 | Well 11 | 12 | 204 | 18 | 66 | 46 | Sand and gravel | T, E | PS | C, L, Cp. | Casing perforated at 82–116 ft. Yield about 1,000 gpm. |
| 8E1 | Test well 2 | 11 | 185 | 2 | | | | | A | L | |
| 8G1 | Sasoku | 11 | 303 | 12 | | | | | A | Cr, L | |
| 8G2 | Banning | 10 | | | | | | P, E | Dom | Cp | |
| 8M1 | | 9 | 134.3 | 10 | | | | | | Cp, W | |
| 9B1 | John G. Clark | 62 | 380 ? | 12 | | | | T, E | Irr | Wm | |
| 9B2 | | 69 | 62.0 | $2\frac{1}{2}$ | | | | | | | |
| 10A1 | M. H. Whitter Ranch Co. | 63 | | | | | | T, E | Dom | C, Cp | |
| 10D1 | J. Melgosa | 61 | | 5 | | | | P, W | Dom, Stock. | Cp | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10D2 | E. A. Stockton | 63 | | 6 | | | | T, I | Dom, Stock. | Cp | Well drilled to 1,060 ft., perforated at 725-770 and 850-1,045 ft.; later plugged from bottom to 844 ft. |
| 10D3 | The Irvine Co. | 65 | 844 | 12 | 710 | 54 | Gravel | | Obs | C, Wm, L. | Yield about 900 gpm from upper zone. |
| 10E1 | First National Bank of Santa Ana. | 66 | | | | | | | A | Wd | |
| 10H1 | Golden West Ranch Co. | 57 | 804 | | | | | T, E. | Irr | L, Cp. | |
| 11B1 | U. S. War Department | 52 | 380 | 16 | 240 | 28 | Sand and gravel | T, E. | PS | C, L, Cpr. | Yield about 900 gpm. Casing perforated at 240-262 ft. |
| 11B2 | do | 51 | 586 | 16 | 271 | 31 | do | T, E. | PS | C, L, Cpr. | Yield about 800 gpm. Casing perforated at 271-292, 298-301, and 338-372 ft. |
| | | | | | 338 | 66 | do | | | | |
| 11G1 | Golden West Ranch Co. | 53 | 725 | | 236 | 26 | Gravel and sand | T, E. | Irr | Cp, L, W. | Casing perforated at 254-262 and 365-407 ft. |
| | | | | | 342 | 149 | do | | | | |
| 11G2 | do | 53 | 804 | | 246 | 13 | Sand and gravel | T, E. | Irr | L, Wm. | Casing perforated at 247-260, 345-360, 373-383, and 423-427 ft. |
| | | | | | 343 | 15 | Gravel | | | | |
| | | | | | 371 | 9 | do | | | | |
| | | | | | 387 | 38 | Coarse sand | | | | |
| 17C1 | Myers | 6 | 600 | | | | | T, E. | Irr | C, Cp. | |
| 17E1 | Fairview Farms | 7 | | | | | | | A | Cpr, Wd. | |
| 17L1 | H. A. DeWolf | 6 | 47.1 | 12 | | | | | A | C, W, Cp. | |
| 17L3 | Farmers and Breeders Trust. | 7 | 167 | 16 | 110 | 57 | Gravel | | A | Cp | |
| 17L4 | do | 7 | 238 | | 208 | 30 | do | | A | Cp, L. | |
| 17L5 | do | 7 | 238 | 12 | 208 | 30 | do | T, E. | Irr | Cp | |
| 17M1 | Fairview Farms | 7 | | | | | | | A | W | |
| 18B1 | | 7 | | | | | | | A | Wd | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach–Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] |  |  | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Depth to top (feet) | Thickness (feet) | Character of material |  |  |  |  |
|  |  |  |  |  | T. 6 S., R. 10 W.—Continued |  |  |  |  |  |  |
| 6/10-18B3 | E. Gisler | 7 | 193 | 12 | 83<br>124<br>168 | 24<br>5<br>2 | Sand and gravel<br>Gravel<br>Fine sand | T, E | Irr | Cp, L, W. | Yield about 500 gpm. |
| 18B4 | ....do | 7 | 89.0 | 4 | ........ | ........ | ........ | P, W | Dom | Cp, Wm. |  |
| 18B5 | A. Gisler | 7 | 173 | 16 | ........ | ........ | ........ | T, E | Irr | ........ |  |
| 18B6 | E. Gisler | 7 | 171 | 16 | ........ | ........ | ........ | T, E | Irr | Cp, L. | Casing perforated at 90–141 ft. |
| 18C1 | Laguna Beach County Water District:<br>Well 3 | 9 | 196 | 16 | 95 | 41 | Sand and gravel | T, E | PS | C, L, Cpr, W. | Yield about 1,200 gpm. Casing perforated at 100–136 ft. |
| 18C2 | Well 2 | 8 | 190 | 16 | 95 | 45 | Gravel and clay | T, E | PS | Cr, L, Wm, Cpr. | Yield about 820 gpm. Casing perforated at 98–143 ft. |
| 18C3 | Laguna Beach County Water District. | 6 | 200 | 12 | ........ | ........ | ........ | T, E | Irr | Cp, Wrd, Wd. |  |
| 18C4 | Well 1 | 8 | 410 | 16 | 85 | 75 | Gravel and sand | ........ | A | Cp, C, L, W. | Yield about 1,170 gpm. Casing perforated at 100–163 ft. |
| 18C5 | Orange County | 8 | 16.2 | 1¼ | 9 | 7 | Silty sand | ........ | Obs | Cp, L, Wm. |  |
| 18E1 | J. A. Alford | 5 | 222 | 12 | 120 | 100 | Gravel and sand | T, E | Irr | Cp, L, W. | Yield about 640 gpm. Casing perforated at 150–186 ft. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18E3 | do. | 5 | 137 | 3 | | | | | A | Cp | Casing perforated at 127-137 ft. |
| 18F1 | Standard Oil Co. | 7 | | 7 | | | | C, E. | Irr. | Cp. | |
| 18F2 | Orange County | 7 | 17.2 | 1¼ | 7 | 10 | Sand and clay | | Obs. | Cpr, L, Wm. | |
| | The Irvine Co.: | | | | | | | | | | |
| 18G1 | Prospect well 11 | 8 | 369 | | | | | | A | L | |
| 18G2 | Prospect well 12 | 8 | 353 | | | | | | A | L | |
| 18G3 | Prospect well 13 | 8 | 351 | | | | | | A | L | |
| 18G4 | Santa Ana River well 2. | 7 | 142.9 | 18 | 90 | 20 | Gravel and sand | | Obs. | C, L, Cp, Wm. | Casing perforated at 100-125 ft. |
| 18G5 | Santa Ana River well 3. | 7 | 320 | 18 | 95 | 45 | Gravel with clay | | Obs. | L, Wd. | Casing perforated at 95-147 ft. |
| 18G6 | Santa Ana River well 1. | 7 | 233.3 | 18 | 85 | 25 | Gravel and sand | | Obs. | C, L, Cp, Wm. | Casing perforated at 95-120 ft. |
| 18G7 | Prospect well 18 | 7 | 352 | | | | | | A | L | |
| 18G8 | Prospect well 17 | 7 | 155 | | | | | | A | L | |
| 18G9 | Prospect well 16 | 7 | 350 | | | | | | A | L | |
| 18G10 | Prospect well 15 | 7 | 353 | | | | | | A | L | |
| 18G11 | Prospect well 14 | 6 | 350 | | | | | | A | L | |
| 18H1 | Prospect well 21 | 7 | 254 | | | | | | A | L | |
| 18H2 | Prospect well 20 | 7 | 258 | | | | | | A | L | |
| 18H3 | Prospect well 19 | 7 | 350 | | | | | | A | L | |
| 18J1 | Newport Mesa Irrigation District, well 4. | 6 | 270 | | 124 | 145 | Gravel, rocks, and sand. | T, E. | PS. | C, L, Cp, Wm. | Casing perforated at 145-245 ft. |
| | Fairview Farms Water Co.: | | | | | | | | | | |
| 18J2 | Well 4 | 7 | 270 | 18 | 126 | 141 | Gravel | T, E. | PS. | Cr, L, W. | Yield about 1,690 gpm. Casing perforated at 156-256 ft. |
| 18J3 | Well 2 | 6 | 290 | 12 | | | | T, E. | PS. | Cr, Wm, Cpr. | Yield about 1,520 gpm. |
| 18J4 | Well 3 | 6 | 255.7 | 10 | | | | | Obs. | Cp, Wm. | |
| | Newport Mesa Irrigation District: | | | | | | | | | | |
| 18J7 | Well 2 | 7 | 101 | | 65 | 36 | Sand and gravel | | A | L | |
| 18J8 | Well 3 | 7 | 165 | | | | | | A | L | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach–Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | **T. 6 S., R. 10 W.—Continued** | | | | | | |
| 6/10-18J9 | Fairview Farms Water Co., well 1. | 7 | 302 | | | | | | A | W | Casing reported perforated at 150–300 ft. |
| | City of Newport Beach: | | | | | | | | | | |
| 18K1 | Well 4 | 6 | 234 | 18 | 96 | 124 | Gravel and sand | | A | Cr, L, Cpr, Wd. | Casing perforated at 100–200 ft. |
| 18K2 | Well 6 | 6 | 330 | 18 | 98 | 42 | Gravel and clay | | A | Cr, L, Wd. | Casing perforated at 100–142 ft. |
| 18K3 | Well 5 | 6 | 336 | 18 | 190<br>276<br>312 | 70<br>30<br>18 | Coarse gravel<br>.....do<br>.....do | | A | Cr, L, Cp, Wd. | |
| 18K4 | Well 3 | 6 | 270 | 14 | | | | | A | C, L, W. | |
| 18K5 | Well 2 | 6 | | | | | | | A | Wd. | |
| 18K6 | Harvey Bear | 7 | | 6 | | | | T, E. | Irr. | Cp, Wm. | |
| 18L1 | Orange County | 7 | 14.2 | 1¼ | 8 | 7 | Silt and sand | | Obs. | C, L, Wm, Cpr. | |
| 18P1 | I. Oka | 6 | | 7 | | | | C, I. | Irr. | Cp, Wm. | |
| 18P2 | Orange County | 6 | 13.6 | 1¼ | 8 | 6 | Silty sand | | Obs. | Cpr, L, Wm. | |
| 19B1 | Peter Karales | 6 | 135.0 | 8 | | | | | Obs. | Cp, W. | |
| 19B2 | .....do | 6 | 138 | 14 | | | | | A. | Cp. | |
| 19B3 | .....do | 6 | 100.7 | 12 | 85 | 35 | Gravel | T, I. | Irr. | Cpr, Wm. | |
| 19C1 | Orange County | 6 | 14.2 | 1¼ | 6 | 9 | Silty sand | | Obs. | Cpr, L, Wm. | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19C2 | ....do | 5 | 13.0 | 1¼ | 7 | 6 | Fine sand | | Obs. | Cpr, L, Wm. | |
| 19F1 | | 3 | 11 | | | | | | A | C | |
| 19F2 | Orange County | 3 | 8.0 | 1¼ | 4 | 4 | Fine sand | | Obs. | Cpr, L, Wm. | |
| 19L1 | ....do | 7 | 11.2 | 1¼ | 3 | 8 | ....do | | Obs. | Cpr, L, Wm. | |
| 19R1 | O'Donnell Oil Syndicate | 6 | | 15 | | | | | A | Cp, L, W. | Oil well. |
| 20D1 | Townsend Land Co. | 4 | 200 | 5 | | | | | A | L | Not perforated. |

T. 6 S., R. 11 W.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/11-1A1 | T. Yoshikawa | 13 | 84 | | | | | | | Cp | Casing perforated at 77-84 ft. |
| 1A2 | | 12 | | 12 | | | | C, E. | Irr. | Cp,W. | |
| 1B1 | Anaheim Sugar Co. | 14 | 200 | 12 | | | | T, E. | Irr. | W | Yield about 900 gpm. |
| 1C1 | Associated Oil Co. | 55 | 182 | 10 | 119 | 63 | Gravel and sand | T, E. | Dom, Ind, Irr. | C,L,Cp, W. | Casing perforated at 130-146 and 168-182 ft. |
| 1C2 | Anaheim Sugar Co. | 55 | 100 | 7 | | | | P, W. | Stock | W | |
| 1D1 | Standard Oil Co. | 56 | | | | | | T | | | |
| 1E1 | Mrs. Elizabeth Wright | 55 | | | | | | T, E. | Dom. | Cp | |
| 1F1 | Anaheim Sugar Co. | 10 | 90.5 | 6 | | | | | | W | |
| 1H1 | U. H. Plaven | 10 | 125 | 6 | | | | C, I. | Irr. | Wd. | |
| 1J1 | ....do | 10 | 125 | 7 | | | | C, I. | Irr. | | |
| 1J2 | ....do | 10 | 125 | 4 | | | | P, W. | Dom. | Cp,Wd. | |
| 1J3 | ....do | 10 | 138 | | | | | T, E. | Irr. | | |
| 1L1 | Mrs. W. T. Newland | 10 | | 10 | | | | C | Obs. | Wm. | |
| 1N1 | ....do | 45 | 600 | 16 | | | | T, E. | Dom, Irr. | C,W, Cp. | |
| 1P1 | ....do | 10 | | | | | | | A | W | |
| 1P2 | ....do | 10 | 161 | 10 | | | | C, E. | Irr. | L | |
| 1Q1 | ....do | 9 | 380.0 | | | | | | Obs. | Cp, Wrd, Ww. | |
| 1R1 | | 8 | | | | | | | A | W | |
| 2A1 | | 56 | | | | | | P | | | |
| 2A2 | McCallen Refining Co. | 59 | 314 | 10 | 224<br>301 | 46<br>13 | Gravel<br>....do | T, E. | Ind. | Cp, L. | Casing perforated at 230-270 and 304-314 ft. |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach—Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | T. 6 S., R. 11 W.—Continued | | | | | | |
| 6/11-2A3 | L. J. Stearns | 59 | 103 | ........ | ........ | ........ | ........ | P, E | Dom | Cp, Wm. | |
| 2A4 | J. E. Winters | 56 | 6.0 | 36 | 3 | ........ | Gravel | P | Irr | ........ | |
| 2B2 | Richfield Oil Corp. Pacific lease. | 62 | ........ | 16 | ........ | ........ | ........ | P, E | ........ | Cpr | |
| 2D1 | Turley | 74 | 202.5 | 10 | ........ | ........ | ........ | ........ | Obs | C, L, Cpr, Wm. | |
| 2F1 | Standard Oil Co | 65 | 150.0 | 16 | 94 | 20 | Gravel | ........ | ........ | Cp, L, W. | Casing perforated at 100-114 ft. |
| 2G1 | Southern California Water Co. | 60 | 251.8 | 12 | 48 | 70 | Gravel and sand | ........ | Obs | Cp, L | Casing perforated at 80-118 ft. |
| 2G2 | .....do | 61 | 123.3 | 12 | 78 | 48 | Gravel | ........ | Obs | Cp, L, Wrd, Wm. | |
| 2G3 | .....do | 60 | 258.5 | 12 | 100 | 18 | Coarse sand and gravel. | ........ | Obs | Cp, L, Wrd, Wm. | Well reported to be plugged back as far as 172 ft. |
| | | | | | 214 | 10 | .....do | | | | |
| | | | | | 242 | 12 | Gravel | | | | |
| 2G4 | .....do | 56 | 263 | ........ | 88 | 23 | .....do | T, E | ........ | C, L | Casing perforated at 90-111, 208-216, and 228-248 ft. Cemented back to 196 ft. |
| 2H1 | W. H. Armstrong | 52 | ........ | 7 | ........ | ........ | ........ | ........ | Obs | Wm | |
| 2H2 | Miss Mary Williams | 56 | 108.6 | 9 | ........ | ........ | ........ | ........ | Dom, Irr | Wm | |
| 2H3 | L. R. McDowell | 55 | 94 | 4 | 68 | 22 | Gravel | P, W | Stock | ........ | Casing perforated at 82-94 ft. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2J1 | Henry Lacabonne | 55 | 113 | 7 | ... | ... | ... | P, L | Irr | C, W | |
| 2J2 | S. E. Cole | 56 | 113 | 5 | 90 | 23 | Gravel | P, W | Irr | ... | |
| 2J3 | O. L. Matthew | 53 | 113 | 7 | ... | ... | ... | ... | Irr | ... | |
| 2K1 | The Texas Co | 51 | 53 | 8 | ... | ... | ... | ... | A | Cpr | |
| 2M2 | Huntington Beach, Union High School. | 64 | 237 | 12 | 200 | 26 | Gravel | T, E | PS | Cpr,L | Yield about 370 gpm. |
| 2Q1 | L. A. Stevenson | 37 | 87 | 4½ | ... | ... | ... | P | Dom | W | |
| 2Q2 | Richfield Oil Co | 37 | 200 | 16 | ... | ... | ... | ... | ... | W | |
| 2R1 | C. G. Ward | 33 | 160 | 12 | ... | ... | ... | ... | A | W | |
| 2R2 | Thompson | 36 | 122 | 6 | ... | ... | ... | ... | A | Cp | |
| 2R3 | Jacob A. Miller | 48 | 88.6 | 6 | ... | ... | ... | P, W | Irr | Cpr,W | |
| 3J1 | Huntington Beach Co | 63 | 235 | 16 | 52 | 63 | Sand and gravel | ... | Irr | L | Casing perforated for 22 ft, between 70-97 ft, 97-100 ft, and 9.5 ft including 205-212 ft. |
| | | | | | 190 | 22 | do | | | | |
| 11A2 | The Texas Co | 17 | ... | 8½ | 3,751 | 81 | Sand | P | ... | C, Cp | Yield about 20 gpm. Casing perforated at 3,751-3,832 ft. |
| 11D1 | Huntington Beach, Elementary School. | 63 | 279 | ... | 114 | 11 | Coarse sand and gravel. | ... | A | L | Casing perforated at 115-125, 230-242, and 253-259 ft. |
| | | | | | 217 | 40 | Sand and gravel | | | | |
| 11E1 | American States Water Service Co. (former owner) | 35 | 447 | 16 | 50 | 16 | Coarse gravel | ... | Obs | L,Wm | |
| | | | | | 84 | 16 | do | | | | |
| | | | | | 216 | 18 | do | | | | |
| 11G1 | M. H. Spoonhauer | 33 | ... | ... | ... | ... | ... | P, L | Irr | Cpr | |
| 11H1 | E. G. Ford | 28 | 76 | 6 | ... | ... | ... | ... | ... | Wd | |
| 11J1 | Mrs. David Stewart | 5 | 88.0 | ... | ... | ... | ... | ... | Obs | Cpr, Wm. | |
| 11J2 | L. W. Cady | 31 | 130 | 7 | ... | ... | ... | ... | A | C,Wd | |
| 11J3 | Mrs. David Stewart | 30 | 144 | ... | ... | ... | ... | ... | A | C, Wd, Cpr. | |
| 11J4 | do | 4 | ... | 6 | ... | ... | ... | C | Irr | Cp | |
| 11K1 | Vernon U. Brown | 44 | 110 | 7 | ... | ... | ... | ... | Dom | C, Wd, Cpr. | |
| 11K2 | Jack Long | 44 | 90 | 8? | ... | ... | ... | ... | ... | C, Wd | |
| 11K3 | S. O. Renick | 32 | 46.5 | 7 | ... | ... | ... | ... | Obs | C, Wm, Cp. | |
| 11Q1 | Superior Oil Co | 25 | 323.3 | 12 | ... | ... | ... | ... | Obs | L,Wm | |
| 11R1 | ... | 2 | 440.0 | 12 | ... | ... | ... | ... | ... | W | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach —Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] |  |  | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Depth to top (feet) | Thickness (feet) | Character of material |  |  |  |  |
| **T. 6 S., R. 11 W.—Continued** |  |  |  |  |  |  |  |  |  |  |  |
| 6/11-12A1 | Mrs. W. T. Newland | 10 | 154.0 | 10? | ......... | ......... | ......... | T, E. | Irr. | Cp, Wm. | (2) |
| 12A2 | .....do | 10 | ......... | 2 | ......... | ......... | ......... | P, W. | Dom. | Cp. |  |
| 12B1 | Reed | 8 | 125.5 | 12 | ......... | ......... | ......... | ......... | Obs. | Wm. | (2) |
| 12C1 | Thompson | 8 | 167 | 10 | ......... | ......... | ......... | T, E. | Irr. | Cp, L, Wm. | (2) |
| 12C2 | .....do | 8 | 161 | 12 | ......... | ......... | ......... | ......... | A. | L. |  |
| 12D1 | ......... | 8 | ......... | ......... | ......... | ......... | ......... | ......... | A. | Wd. |  |
| 12E1 | F. E. Farnsworth | 26 | 94.7 | 8 | ......... | ......... | ......... | P, W. | Dom. | C, Wm, Cp. |  |
| 12F2 | Thompson oil lease | 26 | 115 | 7 | ......... | ......... | ......... | ......... | Dom. | C, Wd. |  |
| 12F3 | F. E. Farnsworth | 6 | 161 | 10 | ......... | ......... | ......... | T, E. | Irr. | Cp, L. |  |
| 12H1 | ......... | 5 | ......... | 4 | ......... | ......... | ......... | ......... | ......... | Cpr, W. |  |
| 12J1 | Mrs. W. T. Newland | 6 | ......... | 10 | ......... | ......... | ......... | C. | Irr. | Cp, Wd. |  |
| 12J2 | ......... | 6 | 82.2 | 8 | ......... | ......... | ......... | ......... | Obs. | Cp, Wm. |  |
| 12N1 | Standard Oil Co. | 3 | 333 | 20-15 | ......... | ......... | ......... | ......... | A. | C, L. |  |
| 12N2 | .....do | 3 | 273 | 16-12 | 135 | 20 | Gravel and sand | ......... | ......... | L. | Casing perforated at 112-136 ft. Perforation at 245-265 ft. Cemented off at 162 ft. |
| 13A1 | Anaheim Sugar Co. | 5 | 300 | 10 | ......... | ......... | ......... | T, E. | Dom, Irr. | C, Wd, Cpr. |  |
| 13B1 | Surf Land and Water Co. | 5 | 200 | 4 | ......... | ......... | ......... | P, E. | Dom. | Cp. |  |
| 13C1 | I. Oka | 4 | ......... | ......... | ......... | ......... | ......... | ......... | A. | C, W. |  |
| 13C2 | .....do | 4 | 229.8 | 16 | ......... | ......... | ......... | C, E. | Irr. | Cpr, Wm. | Yield about 490 gpm. |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13D1 | Standard Oil Co.......... | 4 | 420 | 16 | ......... | ......... | Sand and gravel....... | .......... | Obs.......... | C, L, Cpr, Wm. | Casing perforated at 100-180 ft. |
| 13F2 | Mills Land and Water Co.. | 2 | 110.6 | 7 | ......... | ......... | ......................... | .......... | Obs.......... | Cp,Wrd, Wm. | (2) |
| 13F3 | ............................ | 2 | 142.5 | 16 | ......... | ......... | ......................... | .......... | Obs.......... | Wm, Cp. | Abandoned Oil well. |
| 13G1 | Surf Land and Water Co.. | 4 | 169.8 | 12 | ......... | ......... | ......................... | C, E...... | Irr........... | C, Wm, Cpr. | |
| 13G2 | .....do...................... | 3 | 141 | ............ | ......... | ......... | ......................... | .......... | Obs.......... | C, Wr, Cpr. | |
| 13G3 | .....do...................... | 3 | 11.0 | 1½ | ......... | ......... | ......................... | .......... | Obs......... | Cp, Ww. | |
| 13G4 | ............................ | 3 | 12.7 | 8 | 6 | 1 | ......................... | .......... | Obs......... | Cp, L, Wrd. | Casing perforated at 6-13 ft. |
| 13J1 | Deeble-Chapman Corp... | 4 | 150 | 10 | ......... | ......... | ......................... | T, E..... | Irr........... | C,Wm, Cpr. | Yield about 475 gpm. |
| 13K1 | City of Huntington Beach, Treatment Plant. | 3 | 145 | 6 | ......... | ......... | ......................... | T, E..... | Irr........... | ......... | Casing perforated at 125-145 ft. |
| 13K2 | .....do...................... | 3 | 134.7 | 5 | ......... | ......... | ......................... | P, E..... | Ind......... | C, W, Cpr. | Casing perforated at 115-138 ft. |
| 13M1 | Mills Land and Water Co. | 6.5 | 363.1 | ............ | ......... | ......... | ......................... | P, I..... | Dom....... | Cp, Wrd, Wm. | Initial depth 450 ft.; Casing reported perforated near bottom. |
| 13M3 | .....do...................... | ....... | 13.7 | 8 | 6 | 6 | ......................... | .......... | Obs......... | Cp, L, Wrd, Wm. | Casing perforated at 7.7-13.7 ft. |
| 13P1 | Negro colony............. | 11 | 172 | 10 | 150 | 22 | Gravel.................. | .......... | A........... | Cp, L, Wd. | |
| 13Q1 | Globe Petroleum Co..... | 3 | 229.0 | 8 | ......... | ......... | ......................... | .......... | A........... | C, L, W. | Abandoned Oil well. |
| 13R1 | ............................ | 4 | 168 | 6 | ......... | ......... | ......................... | .......... | A........... | Wd..... | |
| 14B1 | ............................ | 30 | .......... | 16 | ......... | ......... | ......................... | .......... | A........... | Wd..... | |

See footnotes at end of table.

Table 29.—*Description of water wells in the coastal zone of the Long Beach–Santa Ana area*—Continued

| Well | Owner or tenant | Altitude above sea level (feet) | Depth (feet) | Diameter (inches) | Water-yielding zone or zones[1] | | | Pump, type and power | Use | Data available | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top (feet) | Thickness (feet) | Character of material | | | | |
| | | | | | | | Irvine tract | | | | |
| I-5H1 | The Irvine Co............ | 33 | 412 | .............. | 140<br>248<br>322 | 60<br>52<br>82 | Sand and gravel.......<br>Gravel and sand.......<br>Sand and gravel....... | ........... | A........... | L....... | Casing perforated at 264-274 and 338-358 ft. |
| 5H2 | .....do...................... | 48 | 412 | .............. | ......... | ......... | ......................... | T, E..... | Irr........... | C,Wm.. | |
| 6A1 | .....do...................... | 43 | 160 | 4 | ......... | ......... | ......................... | P, W..... | Dom........ | Cp..... | |
| 6D1 | Santa Ana Heights Water Co. | 35 | 645 | 16-12 | ......... | ......... | ......................... | T, E..... | PS........... | C,Wm.. | |
| 6E1 | Newport Heights Irrigation District. | 48 | 609 | 14 | 298<br>471 | 122<br>138 | Sand and gravel.......<br>.....do.................. | T, E..... | Dom, PS, Irr. | Cr, L, Wd. | Yield about 2,800 gpm. Casing perforated at 355-415 and 480-515 ft. |
| 6E2 | .....do...................... | 46 | 600 | 12 | ......... | ......... | ......................... | T......... | .............. | W...... | |
| 6E3 | .....do...................... | 46 | 600 | 12? | ......... | ......... | ......................... | T, E..... | PS, Irr...... | C, W... | Yield about 900 gpm. |
| 6E4 | .....do...................... | 25 | 314.0 | 12 | ......... | ......... | ......................... | .......... | .............. | Wd..... | |
| 6G1 | The Irvine Co............ | 45 | 952 | 12 | 354 | 190 | Fine to coarse sand and gravel. | .......... | .............. | C, L.... | Yield about 2,700 gpm. Casing perforated at 420-570 ft. |
| 6J1 | .....do...................... | 51 | 1,002 | 12-10 | ......... | ......... | ......................... | ........... | A........... | L....... | |
| 6M1 | .....do...................... | 45 | 160 | 8 | ......... | ......... | ......................... | ........... | A........... | C....... | |
| 51R1 | .....do...................... | 54 | 198 | 7 | ......... | ......... | ......................... | P, E...... | Dom........ | Cp,W.. | |
| 57J1 | .....do...................... | 96 | .......... | 10 | ......... | ......... | ......................... | ........... | .............. | ........ | |

---

[1] Only those aquifers yielding water through perforated sections of the casing are listed; except as otherwise indicated under "Remarks" the casing is perforated opposite the entire water-yielding zone.

[2] Intermittent artesian flow, 1941–42.

# INDEX

The U. S. Geological Survey Library has cataloged this publication as follows:

**Poland, Joseph Fairfield,** 1908–

Hydrology of the Long Beach-Santa Ana area, California, with special reference to the watertightness of the Newport-Inglewood structural zone. With a section on Withdrawal of ground water, 1932–41, by Allen Sinnott and J. F. Poland. Washington, U. S. Govt. Print. Off., 1959.

vii, 257 p. maps (1 col.) diagrs., profiles, tables. 25 cm. (U. S. Geological Survey. Water-supply paper 1471)

Part of illustrative matter folded in pocket.

Prepared in cooperation with the Orange County Flood Control District, the Orange County Water District, the Los Angeles County Flood Control District, and the Board of Water Commissioners of the city of Long Beach.

(Continued on next card)

G S 59–199

**Poland, Joseph Fairfield,** 1908– Hydrology of the Long Beach-Santa Ana area ... 1959. (Card 2)

Bibliography: p. 159–160.

1. Water, Underground—California—Long Beach-Santa Ana area. 2. Water-supply—California—Long Beach-Santa Ana area. 3. Water-supply—California—Los Angeles Co. 4. Water-supply—California—Orange Co. 5. Salinity—California—Newport-Inglewood structural zone. I. Sinnott, Allen, 1917– II. Title. (Series)

[TC801.U2 no. 1471] G S 59–199

U. S. GOVERNMENT PRINTING OFFICE: 1959 O—468452