THE RESOURCES AGENCY OF CALIFORNIA
Department of Water Resources

BULLETIN No. 107

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN LOS ANGELES COUNTY

AUGUST 1962

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Administrator
The Resources Agency of California
and Director
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TABLE OF CONTENTS

Page

CHAPTER III. GROUND WATER HYDROLOGY

Page

TABLES

TABLES

FIGURES

PLATES

PLATES

APPENDIXES

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THE RESOURCES AGENCY OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

1120 N STREET, SACRAMENTO

September 11, 1962

Honorable Edmund G. Brown, Governor
and Members of the Legislature of
the State of California

Los Angeles Regional Water Pollution Control Board

Gentlemen:

I am pleased to transmit to you Bulletin No. 107 of the Department of Water Resources, entitled "Recommended Water Well Construction and Sealing Standards for the Protection of Ground Water Quality in West Coast Basin Los Angeles County." The investigation was conducted under authority of Section 231 of the Water Code and at the request of interested agencies operating in the county.

This is one of a series of reports designed to formulate and recommend water well construction and sealing standards for particular localities of the state where regulation is deemed necessary for the protection of ground water quality. In the West Coast Basin, Los Angeles County, where no such regulation exists, many water wells, which have been constructed improperly or sealed inadequately, are contributing to quality impairment of ground water by allowing interchange of water between aquifers. The report concludes that water well construction and sealing standards must be employed. The standards presented are based on physical conditions and well construction practices found in the West Coast Basin Los Angeles County, and supplement the minimum standards presented in Bulletin No. 74, entitled "Recommended Minimum Well Construction and Sealing Standards for the Protection of Ground Water Quality, State of California."

The report recommends that the Los Angeles Regional Water Pollution Control Board, local agencies, local water producers, and water well drillers accept these standards, and apply them in a manner that will assist them in preserving and improving the quality of the common ground water supply.

Sincerely yours,

William E. Warne

Director

ACKNOWLEDGMENTS

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

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

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Los Angeles City Department of Water and Power

Los Angeles County Flood Control District

Los Angeles County Health Department

Los Angeles Regional Water Pollution Control Board

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Roscoe Moss Company

United States Geological Survey, Ground Water Branch

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THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

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CHAPTER I. INTRODUCTION

Ground water has played a dominant role in California's diversified economic development; it has supported agricultural growth, permitted the establishment of high-density metropolitan areas, and encouraged the build-up of enormous industrial complexes. This is particularly true in Southern California where, for example, in the Coastal Plain of Los Angeles County, ground water extractions presently (1961) supply about one-half of the total water put to beneficial use in that area.

In the West Coast Basin, a major ground water basin in the Coastal Plain, ground water extractions have exceeded replenishment; as a result, ground water levels have declined below sea level. One result of these subsiding water levels is the intrusion of sea water into coastal portions of the basin, impairing water quality in that section. Other sources of impairment to ground water quality within the West Coast Basin are sewage and industrial wastes that have been improperly disposed of and poor quality ground water that has been allowed to commingle with good quality waters by improperly constructed, utilized, and destroyed water wells.

This investigation was primarily concerned with ground water quality impairment directly attributable to such wells. It was conducted in the West Coast Basin because a continued supply of unimpaired ground water from that basin is of vital importance to the economy of the area. Based on an understanding of the many complex, interwoven roles of geology, hydrology, and well construction and sealing, recommendations are presented that, if followed, will alleviate or halt further impairment of the vital ground water resources of the West Coast Basin by improperly constructed or sealed wells.

Authorization

This report is the result of legislation enacted to protect the ground water quality from impairment by improperly constructed, sealed, or destroyed wells. This legislation has been codified in Section 231, Chapter 2, Division 1 of the California Water Code, as follows:

> "231. The department, either independently or in cooperation with any person or any county, state, federal or other agency, shall investigate and survey conditions of damage to quality of underground waters, which conditions are or may be caused by improperly constructed, abandoned or defective wells through interconnection of strata or the introduction of surface waters into underground waters. The department shall report to the appropriate regional water pollution control board its recommendations for minimum standards of well construction in any particular locality in which it deems regulation necessary to protection of quality of underground water, and shall report to the legislature from time to time, its recommendations for proper sealing of abandoned wells."

Purpose and Scope of Investigation

The purpose of this investigation was to formulate water well construction and sealing standards for the West Coast Basin in Los Angeles County; when implemented, these standards will serve to protect ground water quality from impairment caused by improperly constructed and/or improperly sealed wells.

To achieve this purpose, all available geologic, hydrologic, and water quality data in the Department of Water Resources files and that collected from other agencies and individuals, and abstracts from numerous reports concerning ground water in the coastal portion of Los Angeles County were reviewed and evaluated. These data were used to interpret surface and subsurface geologic conditions, and to locate barriers to ground water movement; to evaluate ground water elevations and direction of ground water movement; to locate sources of ground water replenishment; and to determine the ground water quality characteristics.

Considerable effort was expended in a canvass of the basin to locate water wells and to determine their condition and characteristics. In addition, about 250 ground water samples were collected for mineral analysis to assist in the evaluation of water quality characteristics.

Most of the geologic data concerning the ground water basin was obtained from previous investigations and reports. However, detailed geologic mapping of localized areas was performed to obtain specific information required in the formulation of well construction and sealing standards.

This investigation also included a detailed study of local, state, and federal regulations relating to water well construction and/or sealing standards, and an evaluation of commonly accepted water well construction specifications. These specifications were developed through conferences with principal well drillers in Southern California and, integrated with the basic findings of this investigation, were used in the formulation of the recommended well construction and sealing standards presented herein.

All supporting data used in this investigation are catalogued and maintained in the basic data files of the department. For convenience of use, a list of pertinent references selected from these data sources is given in Appendix A. Appendix B gives a summary list of definitions of certain technical terms, augmenting those definitions given with first usage of the term in the text, and Appendix C gives well location references and numbering methods used. Appendix D presents the casing requirements for drilled and dug wells.

Area of Investigation

The West Coast Basin is the most westerly portion of the Coastal Plain of Los Angeles County, as shown on Plate 1, "Location and Physiographic Features in West Coast Basin"; it is about 19 miles long and averages about nine miles in width, occupying an area of approximately 102,500 acres. Approximately 80 percent of the surface area of the basin consists of a gently rolling, slightly eroded coastal plain which includes such physiographic features as the Torrance Plain, El Segundo Sand Hills, Dominguez Gap, and Long Beach Plain; partially encircling the basin are the bordering hills which constitute the remainder of the basin surface.

Surface elevations range from near sea level on portions of the coastal plain to 1,480 feet above sea level in the Palos Verdes Hills, which are the most dominant structural feature of the southwestern portion of the basin. These hills cover an area about nine miles long and four miles wide, trending in a northwest-southeast direction along the coastal portion of the basin.

The El Segundo Sand Hills extend northward from the Palos Verdes Hills along Santa Monica Bay. Reaching along the coast for about eleven miles, and extending inland three to six miles, these sand hills obtain a maximum height of about 185 feet above sea level.

The main body of the basin is a low lying, poorly drained plain whose original marine surface was partially eroded by an ancestral Los Angeles and San Gabriel River system. North of this plain lies Ballona Gap, a channel cut by an ancestral Los Angeles River, and occupied today by Ballona Creek. This gap is bordered on the south by the Ballona Escarpment, a precipitous bluff which rises 50 to 150 feet above Ballona Creek, and forms the northern boundary of the West Coast Basin.

The eastern boundary of the coastal plain is marked by a discontinuous series of low rolling hills which extend in a northwest-southeast direction, and form the eastern boundary of the West Coast Basin. Extending in order to the southeast and the Los Angeles-Orange County line are the Baldwin Hills, Rosecrans Hills, Dominguez Hill, Signal Hill, and Bixby Ranch Hill. These hills are the surface expression of a series of faults and folds called the Newport-Inglewood uplift.

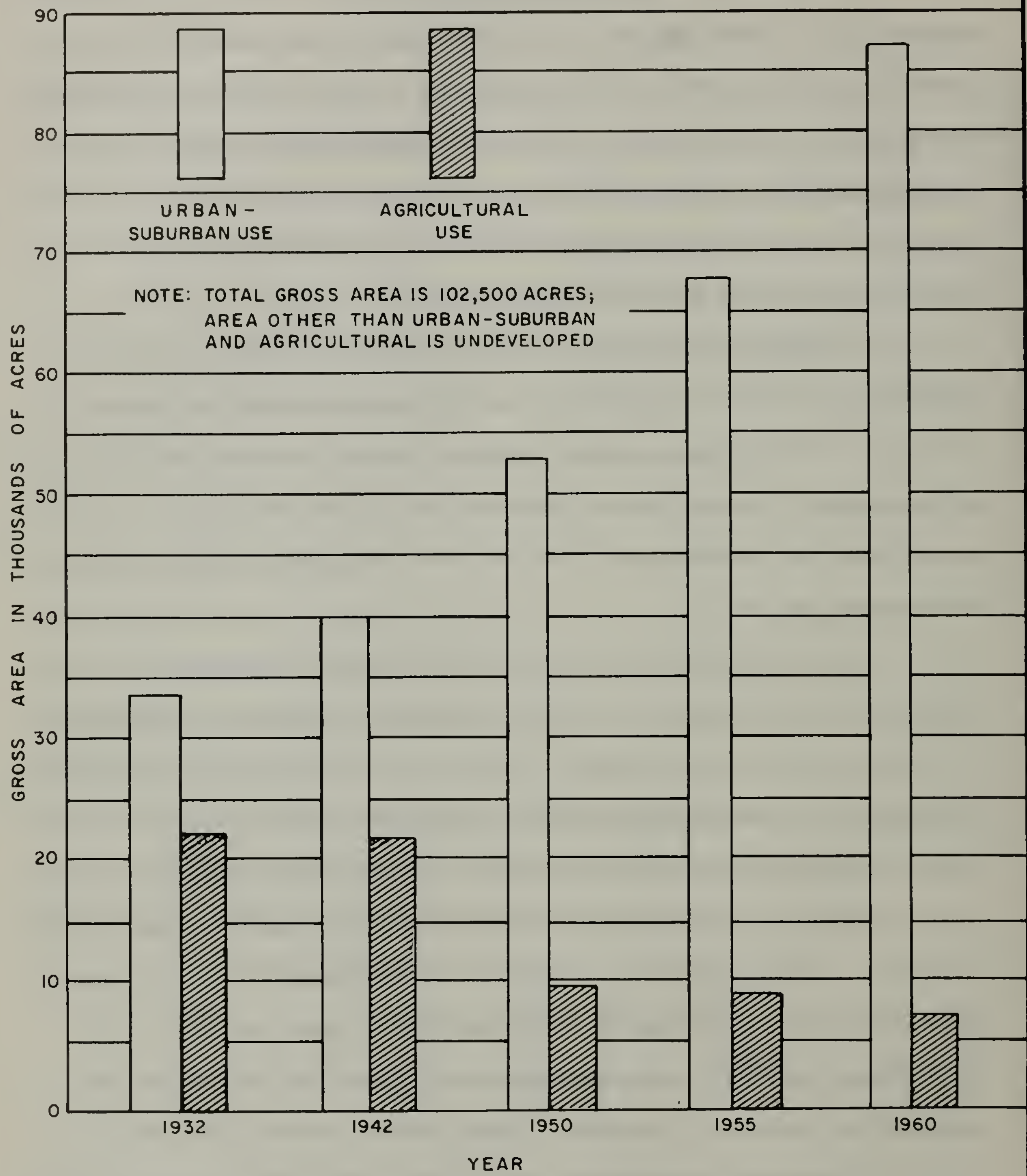
Flowing southward between Dominguez Hill and Signal Hill, the ancestral Los Angeles and San Gabriel River system cut another channel through the coastal plain. This ancestral channel was later backfilled with alluvium, and is known today as Dominguez Gap. The Los Angeles River presently flows through this gap to San Pedro Bay which adjoins the southern boundary of the basin.

Within this basin today is a highly urbanized complex of large residential tracts interspersed with numerous industrial developments and some small agricultural acreages. This was not always so, for as recently as 25 years ago, the West Coast Basin was an area of small suburban communities surrounded by truck farms, orchards, large ranches, and grazing lands.

The change in land use in West Coast Basin during the period 1932 to 1960 is shown graphically on Figure 1. As illustrated, the irrigated agricultural acreage decreased from about 22,100 acres in 1932 to about 7,000 acres in 1960. During the same period, the land devoted to urban-suburban use increased from about 33,800 acres to about 86,300 acres.

The change in population in the West Coast Basin is just as significant as the change in land use. In 1930, the population of the West Coast Basin was about 264,000. In 1940, this figure had increased to

FIGURE I



LAND USE FOR SELECTED YEARS IN WEST COAST BASIN

317,000, and by 1950, under the impetus of a wartime influx, the total population had increased to about 600,000. During the following eleven-year period, from April 1950 to April 1961, the population had increased from 600,000 to just over 1,000,000.

These changes in land use and the population growth resulted in large increases in the demands for water as compared with those of the preceding decades. Prior to 1949, almost all of the water in excess of direct precipitation used in the West Coast Basin came from the ground water resources underlying the basin. The heavy volume of water extracted to meet the demands caused overdraft conditions in the basin, leading to problems such as sea-water intrusion in the coastal areas.

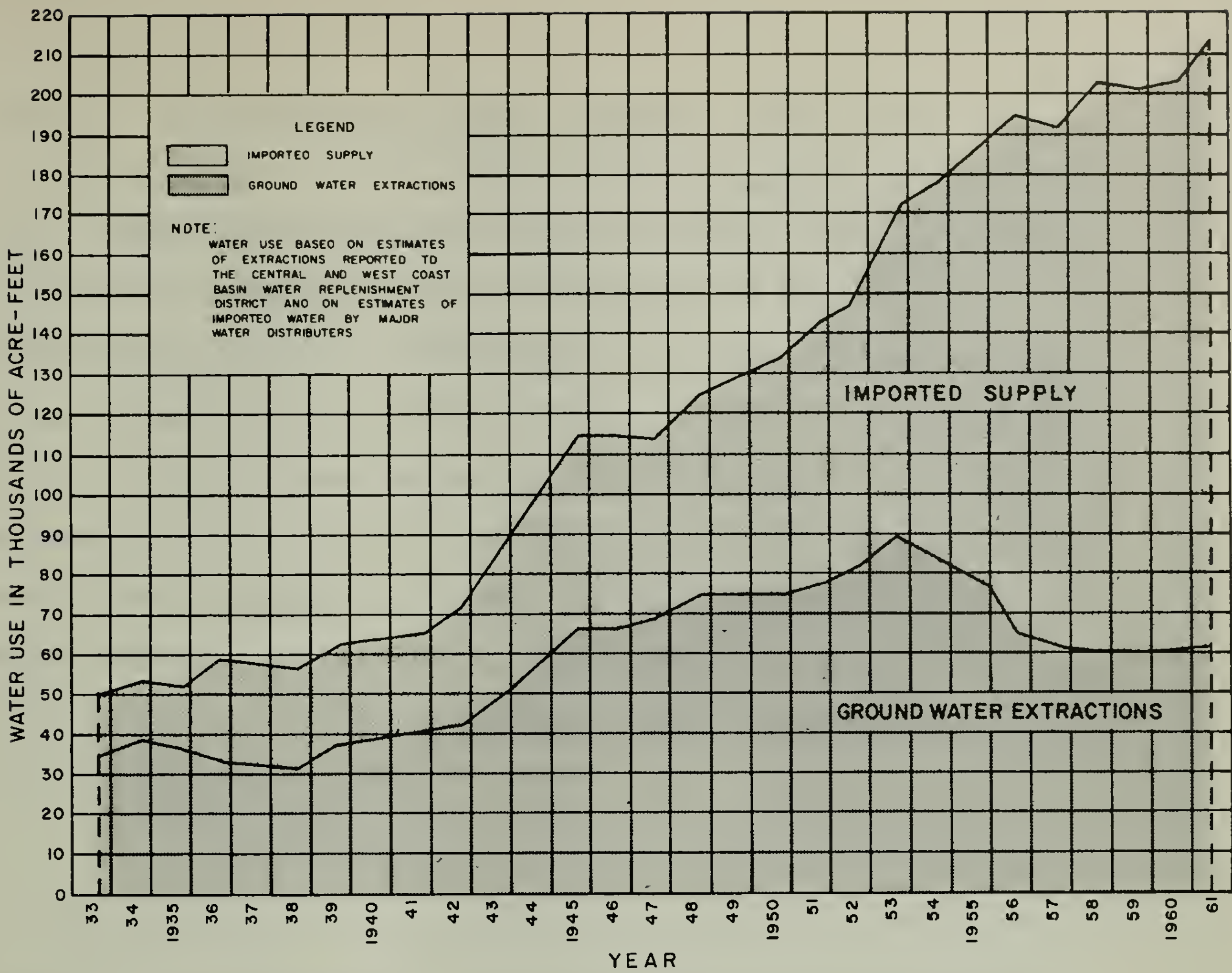
In the early 1900's when small amounts of ground water were being extracted, ground water levels were above sea level throughout the West Coast Basin. Along the western edge of the Newport-Inglewood uplift, ground water levels were 30 feet above sea level; northeast of the Palos Verdes Hills, near the Torrance-Wilmington anticline, ground water levels were more than 40 feet above sea level.

The use of ground water increased, and ground water levels dropped. By 1920, ground water levels at many wells had dropped below sea level, and by 1932, ground water levels were below sea level throughout most of the West Coast Basin. The decline continued until 1955 when a voluntary reduction in extractions by a number of pumpers in the West Coast Basin permitted the ground water levels to recover as much as ten feet in some parts of the basin. However, they were still below sea level throughout most of the basin. Since 1955, water levels have declined only a small amount.

As a consequence of declining water levels, water from wells adjacent to the coast began to deteriorate in quality and over the years the area underlain by degraded ground water has steadily increased. Along Santa Monica Bay, wells were being abandoned prior to 1920 because of excessive chloride concentrations. By 1932, the entire coastal area along Santa Monica Bay and a portion of the basin along San Pedro Bay near Long Beach were being intruded by sea water. By 1961, the coastal area underlain by ground water containing a chloride concentration of more than 500 parts per million extended inland about one and one-half miles along Santa Monica Bay.

Figure 2 indicates that local ground water extractions for agriculture and urban-suburban use totaled about 35,000 acre-feet in 1933, including about 17,000 acre-feet for agriculture. By 1953, local ground water extractions had increased to 90,000 acre-feet; of this amount, water for irrigation purposes had decreased to about 10,000 acre-feet. By 1961, ground water extractions had diminished to about 61,000 acre-feet with about 6,000 acre-feet being used for irrigation.

Because of the serious nature of the overdraft on the ground water resources of the basin, it has been necessary to import water to relieve the demands on the local ground water. The major source of imported water is the Colorado River, and water is imported from there through the facilities of The Metropolitan Water District of Southern California. This water is delivered to member agencies including the City of Long Beach, City of Los Angeles, City of Torrance, and West Basin Municipal Water District, for distribution. Water is also imported from the Owens and Mono Basins through the facilities of the City of Los Angeles;



WATER USE, 1933 TO 1961, IN WEST COAST BASIN

FIGURE 2

the Dominguez Water Corporation, City of Long Beach, and Southern California Water Company, all import water from the Central Basin. During the fiscal year 1949-50, when imported Colorado River water became available, about 1,560 acre-feet were brought into the basin, but by 1960-61, this figure had increased to over 93,600 acre-feet. As shown on Figure 2, total water importations into the West Coast Basin increased from approximately 15,000 acre-feet in 1933 to over 151,000 acre-feet in 1961.

Despite these increasing volumes of imported water, the ground water resources continue to provide a large portion of the water put to beneficial use in the West Coast Basin. Extractions by the numerous wells in the basin continue to contribute to overdraft conditions. Paradoxically, the same wells which are used to extract ground water may also contribute to the impairment of water quality in the ground water reservoir by serving as conduits to interconnect the various aquifers. The discussion of the West Coast Basin geology in Chapter II will indicate how this interconnection exists and will provide information on some of the other factors on the impairment of ground water quality which must be considered in any effective remedial program.

CHAPTER II. GEOLOGY

This chapter presents the location, extent, physical character, structure, and geologic history of the water-bearing and significant nonwater-bearing deposits occurring in the West Coast Basin.

The surface and subsurface geology reported herein is based on field surveys and office studies, including review of published reports, with emphasis given to the nature and extent of aquifers and the confining horizons of low permeability which affect well construction and sealing standards. In addition, mention is made of the areas where hydraulic continuity was found to exist between the ground surface and underlying aquifers, or between aquifers.

Geologic Divisions

In order to discuss the geology of the West Coast Basin, it is necessary to utilize a system of classifying names for divisions of the geologic time scale, and a similar system of names for the geologic material which accumulated or developed during corresponding units of the time scale.

The primary divisions of the geologic time scale are based on changes in life forms, except that the inauguration of the latest major division is based on the advent of glacial activity. Within each of these extensive primary divisions are the smaller geologic time divisions, generally based on major changes in the earth's structure. The generally recognized geologic-time units, in order of decreasing magnitudes of time-span are: era, period, epoch, and age. These geologic-time units and their common names, pertinent to the discussions of the West Coast Basin geology, are given on Figure 3 at the end of this chapter.

Using this type of classification, the San Pedro formation, for example, can be described as having been deposited during the early portion of Pleistocene time, or to be of early Pleistocene age, laid down during the Pleistocene epoch, of the Quaternary period, in the Cenozoic era. It will be seen from Figure 3 that each successively larger geologic-time unit incorporates all of the preceding smaller divisions.

Corresponding to these geologic-time units are the time-stratigraphic units, used to designate the rock material which accumulated or was deposited during an associated geologic-time unit. Ranked in decreasing order of magnitude, these divisions are: system, series, and stage. Thus, as shown on Figure 3, the San Pedro formation is part of the lower Pleistocene stage, which in turn is part of the Pleistocene series of the larger Quaternary system. As in the geologic-time units, each successive time-stratigraphic unit encompasses all preceding smaller units.

It should be noted that a definite correlation exists between the "early" and "late" designations used with subdivisions of geologic-time units (e.g., early Pleistocene), and the "lower" and "upper" designations used with corresponding time-stratigraphic units (e.g., lower Pleistocene). When using geologic-time units, the San Pedro formation is designated as early Pleistocene in age; however, in terms of time-stratigraphic units, the San Pedro formation would be designated as a lower Pleistocene deposit. Thus, "early" would normally be equated with "lower," and "late" normally equated with "upper."

The accumulations of rock material in the time-stratigraphic units may also be further subdivided into mappable assemblages of strata, distinguished and identified by objective physical criteria observed in the field or in subsurface studies; these subunits are called groups, formations, and members. In ground water geology, for example, aquifers are called water-bearing members.

Geologic History

Deposition, compaction, metamorphism, and erosion of Jurassic rocks mark the earliest recorded phase of the geologic history in the West Coast Basin. Younger sediments of Cretaceous and early Tertiary age have not been encountered in the West Coast Basin; this suggests that either this area was a structural high which received no sediments, or that any sediments which may have been deposited were later removed by erosion. The area was intermittently covered by marine seas from middle Miocene time through early Pleistocene time, and a thick section of marine Miocene, Pliocene, and Pleistocene sediments was deposited.

The principal water-bearing materials were deposited in the West Coast Basin during the Pleistocene and Recent epochs. A shallow marine sea covered a large portion of the Coastal Plain of Los Angeles County and all of the area of the West Coast Basin during most of early Pleistocene time. Numerous streams carrying debris from the inland highlands deposited their load on flood plains, in lagoons near the shore line, and in a shallow offshore marine environment. The offshore materials were probably reworked and redistributed by the action of longshore currents. The heterogeneous materials deposited throughout early Pleistocene time are known as the San Pedro formation. This formation was folded and locally faulted toward the close of early Pleistocene time along the crest of the Newport-Inglewood uplift and in the Palos Verdes Hills. Gentle folding also occurred along the Gardena syncline, Wilmington-Torrance anticline, and the Lomita syncline. Structural features are shown on Plate 2, "Areal Geology in West Coast Basin." Few of the present day physiographic features, delineated on Plate 1, existed in the West Coast Basin prior to late Pleistocene time.

The West Coast Basin was a low coastal plain during part of late Pleistocene time. Minor transgressions of the sea occurred intermittently and debris from the bordering highlands was deposited in a shallow marine sea and in brackish water lagoons. These deposits form the Lakewood formation which was formerly known as the "unnamed upper Pleistocene deposits." During the late Pleistocene, an ancient river, responding to lowered sea levels, entrenched a channel through the Rosecrans Hills and thence across the West Coast Basin to the sea. This trench was then backfilled with sediments when the level of the sea subsequently rose during a major interglacial interval.

Near the close of the Pleistocene epoch, at the beginning of the last glacial interval, the level of the oceans once again declined and sand deposits accumulated along the shores as vast sand dunes. The ancestral Los Angeles and San Gabriel River system entrenched a channel through the Newport-Inglewood uplift between Dominguez Hill and Signal Hill and across the West Coast Basin to its new lower base level. With still another rise of sea level in post-glacial, or Recent time, sediments were deposited within this channel.

Structure

The major structural features within the West Coast Basin are shown on Plate 2, and on Plate 3, "Generalized Geologic Sections A-A', B-B', and C-C', in West Coast Basin."

Folding and associated faulting have formed the dominant structural features throughout the West Coast Basin. One of the major structural features in the area is the Newport-Inglewood uplift which forms the eastern boundary of the West Coast Basin. This uplift is marked by a series of low anticlinal folds and en echelon faults, represented by the Baldwin, Rosecrans, Dominguez, Signal, and Bixby Ranch Hills, and the Inglewood-Potrero, Avalon-Compton, Cherry Hill, Reservoir Hill, and Seal Beach faults. From the Miocene epoch to the present, continuous deformation has occurred along this zone of weakness, forming a partial barrier to the movement of ground water in the Pleistocene and Pliocene sediments. However, faulting and folding have not obstructed movement of ground water in the Recent deposits.

Coastward from the Newport-Inglewood uplift, Tertiary and Quaternary deposits are faulted and folded into a complex basin structure. The Pleistocene aquifers dip toward the Gardena syncline which flanks the Newport-Inglewood uplift from Long Beach to Ballona Gap. Along the western flank of the syncline, these deposits are offset in the northern part of the basin by the Charnock fault. West of this fault, the water-bearing deposits rise toward the northwest with a gentle slope. In the southern portion of the West Coast Basin, west of the Gardena syncline, the Pleistocene deposits are deformed over the Torrance-Wilmington anticline and Lomita-Wilmington syncline, and then sharply folded along the

Gaffey anticline and syncline along the northeastern edge of the Palos Verdes Hills.

The Palos Verdes Hills, an isolated structural highland, are composed predominantly of nonwater-bearing Tertiary and Jurassic rocks. The base of the northeastern slope of the Palos Verdes Hills approximates the southwestern limit of the water-bearing sediments in the West Coast Basin.

Sequence and Water-Bearing Characteristics of Sediments

In the West Coast Basin, ground water occurs in aquifers composed of sand and gravel deposits of late Tertiary and Quaternary age. Usually these aquifers are partially or completely separated from one another by variable thicknesses of relatively impermeable strata termed aquicludes. Nearly all of the aquifers and aquicludes found within the West Coast Basin occur within formations of either the Recent series or the Pleistocene series, with the exception of the Bellflower aquiclude and the semiperched aquifer which occur in both the Recent and Pleistocene deposits. Therefore, the Bellflower aquiclude and the semiperched aquifer are discussed under both the Recent series and Pleistocene series.

The deposits in the West Coast Basin are described on the following pages from youngest to oldest, or from the surface downward, and their water-bearing characteristics are also presented. Areal geology and generalized geologic sections of the West Coast Basin are shown on Plates 2 and 3. The sequence of sediments is shown in Figure 3, which also includes the nomenclature used in prior reports.

Recent Series

The Recent series in the West Coast Basin, as described in this report, is divided into active dune sand and alluvial deposits, which in turn are subdivided into the semiperched aquifer, Bellflower aquiclude, and Gaspur aquifer.

Active Dune Sand. The sand dunes which comprise the coastal portion of the El Segundo Sand Hills extend as a narrow strip along Santa Monica Bay from Ballona Gap to Redondo Beach. These windblown deposits are generally less than 70 feet thick and consist of fine to medium-grained, clean, well sorted, white or grayish sands of uniform texture. The dune sands generally occur above the zone of saturation and consequently are not considered to be a part of the ground water reservoir. However, because these deposits are highly permeable, precipitation and runoff are readily absorbed by them and transmitted to the underlying older dune sand which is described later under the Pleistocene series.

Alluvial Deposits. The Recent alluvial deposits are composed of lenticular beds of gravel, sand, silt, and clay which were deposited on broad flood plains, and in the lagoons and stream channels of the West Coast Basin. These sediments comprise the semiperched aquifer, Bellflower aquiclude, and the Gaspur aquifer. These deposits occur along the Los Angeles River and adjacent to the Dominguez Channel. Other Recent deposits accumulated southeast of Redondo Beach, and in the vicinity of Gardena are not discussed herein.

Semiperched Aquifer. The semiperched aquifer, deposited during the Recent epoch, occurs only in Dominguez and Alamitos Gaps. It consists of sands, silty sands, silts, and clays deposited in alluvial and lagoonal environments. No wells are known to extract water from the Recent semiperched aquifer. Available data indicate that water levels in the semiperched aquifer are above water levels in the Gaspur aquifer.

Bellflower Aquiclude. The Bellflower aquiclude, deposited during the Recent epoch, occurs in Dominguez Gap and may exist in Alamitos Gap. It consists of alluvial and lagoonal materials deposited along the Los Angeles and San Gabriel River system. The aquiclude is composed mainly of sediments ranging from clays through sandy silts with lesser amounts of sand and gravel. The Bellflower aquiclude separates the semiperched and Gaspur aquifers, and restricts vertical movement of water between them.

Gaspur Aquifer. Underlying the Bellflower aquiclude in the vicinity of the Los Angeles River are medium to coarse-grained sand, gravel, and cobble deposits designated collectively as the Gaspur aquifer. The Gaspur aquifer is shown on Plate 4, "Areal Extent of the Gage, Gardena, and Gaspur Aquifers in West Coast Basin," and Plate 5, "Contours on the Top of the Gaspur Aquifer in Dominguez Gap, West Coast Basin."

The Gaspur aquifer was deposited by ancestral streams within channels which had been entrenched into the coastal plain during the last glacial interval. Much of the Gaspur aquifer was deposited upon relatively impermeable upper Pleistocene sediments, although in certain areas the aquifer is in hydraulic continuity with the underlying Gage aquifer, as shown on Plate 6, "Contours on the Top of the Gage Aquifer in Dominguez Gap, West Coast Basin."

The Gaspur aquifer is not structurally affected by the Newport-Inglewood uplift, and there is no known restriction to ground water movement across the uplift. This aquifer has been traced for about 23 miles from the Whittier Narrows and the Los Angeles Narrows, southward across Central Basin to Terminal Island in the West Coast Basin, where data suggest that it also extends beneath San Pedro Bay.

In the West Coast Basin, the Gaspur aquifer averages 50 to 60 feet in thickness, and is about one and one-half miles wide and six miles long. Many wells yielding from 200 to 1,500 gallons per minute have extracted ground water from this highly permeable aquifer throughout its reach in the West Coast Basin.

Pleistocene Series

Sediments of Pleistocene age in the West Coast Basin were deposited in shallow marine, littoral, and continental environments. These deposits consist chiefly of unconsolidated sands, sandy silts, silts, and clays with interbedded water-bearing sands and gravels overlying semiconsolidated sands, silts, and clays of Pliocene age. The Pleistocene series includes the older dune sand and the Lakewood formation of late Pleistocene age, and the San Pedro formation of early Pleistocene age.

Older Dune Sand. The sand dunes comprising the major portion of the El Segundo Sand Hills cover an area two to five miles in width and about thirteen miles in length. They underlie and are well exposed east of the sand dunes of Recent age. The older dune sand consists of fine to medium-grained sand with minor amounts of gravel, sandy silt, and clay.

These sand dunes range up to 200 feet in thickness and exhibit thin, irregular, relatively dense cemented layers near the surface.

The older dune sand consists generally of three zones: a deeply weathered surface, an intermediate horizon of clean beach sands and gravels, and a lower horizon of relatively fine-grained materials. The intermediate sands and gravels may be equivalent to the semiperched aquifer of the Lakewood formation, but are included with the older dune sand for convenience.

These dune sands originally were beach deposits; apparently, as sea level declined at the beginning of the last glacial interval they were exposed to the wind and blown inland. The shape of the original sand dunes has been modified by deep weathering and the growth of vegetation. Because of weathering and consolidation, the older dune sand is less permeable than the active dune sand, and data indicate that the limited quantity of water found in the basal portion of the older dune sand moves seaward because of the seaward slope of the top of the Bellflower aquiclude.

Lakewood Formation. The Lakewood formation contains, in downward succession, portions of the semiperched aquifer and Bellflower aquiclude, the Gardena aquifer, and the Gage aquifer.

Semiperched Aquifer. The semiperched aquifer, of late Pleistocene age, occurs throughout the West Coast Basin above the Bellflower aquiclude. As discussed previously, this aquifer also occurs in deposits of Recent age. The Pleistocene portion of the semiperched aquifer includes the terrace cover, the Palos Verdes sand, and other miscellaneous sediments.

A deeply weathered layer covers much of the surface of the West Coast Basin. This cover consists of up to 20 feet of reddish-colored sand and silty sand. In the southwestern part of the Torrance Plain, both the weathered layer and marine sands form the upper Pleistocene portion of the semiperched aquifer. The marine sands generally consist of silty sands with thin gray or brown sand and gravel layers. Where present in the Torrance Plain, the marine sands are generally less than five feet thick but are known to have a thickness greater than 30 feet in other portions of the basin.

The semiperched aquifer contains little available ground water in the northern part of West Coast Basin. In the central and southern part of the basin these sediments are of sufficient permeability to yield water to wells; however, the water is usually of poor quality. This aquifer is of little importance as a source of ground water, but it may be a source of impairment if its poor quality ground water is allowed to percolate to the underlying aquifers.

Bellflower Aquiclude. The Bellflower aquiclude, formerly known as the "clay cap," underlies the semiperched aquifer of late Pleistocene age; it occurs throughout a major portion of the West Coast Basin, but it is absent along Santa Monica Bay, at the base of the northeast slope of the Palos Verdes Hills, and in other local areas. It consists of a heterogeneous mixture of fluvial, lagoonal, and marine sediments composed of clays and silty clays, with lenses of sandy and gravelly clays. Its high silt and clay content restricts the vertical movement of ground water. This aquiclude attains a maximum thickness of about 200 feet along the center and east flank of the Gardena syncline, between the City of Gardena and the City of Inglewood.

Gardena Aquifer. The Gardena aquifer varies in width from approximately one and one-half to four and one-half miles. It spans a distance of about eight miles within the West Coast Basin and extends into the Central Basin, as shown on Plate 7, "Contours on the Top of the Gage and Gardena Aquifers in West Coast Basin." This aquifer is generally composed of sand and gravel layers with a few discontinuous lenses of sandy silt and varies in thickness from 40 feet to a maximum of 160 feet.

The stratigraphic position and physical features of the Gardena aquifer suggest that during the closing stages of the deposition of the Gage aquifer, a lowering of sea level occurred, and an ancestral river incised a channel into the Gage aquifer, and through it into the underlying aquifers in the vicinity of Redondo Beach. A later rise in sea level resulted in the deposition of the coarse fluvial materials which comprise the Gardena aquifer in this channel. These events resulted in the mergence of the western end of the Gardena aquifer with the underlying Lynwood and Silverado aquifers of the San Pedro formation. It also resulted in the northern and southern margins of the Gardena aquifer being placed in hydraulic continuity with the Gage aquifer. In the central part of the West Coast Basin the Gardena aquifer is separated from the underlying aquifers of the San Pedro formation by 55 to 130 feet of fine-grained materials.

The Gardena aquifer is arched across the Newport-Inglewood uplift and appears to be displaced by the Avalon-Compton fault, a feature of the uplift. This feature appears to exert a partial barrier effect on the movement of ground water in the Gardena aquifer.

The highly permeable Gardena aquifer is tapped by many wells in the vicinity of Gardena. Wells producing from this aquifer yield from 100 to 1,300 gallons per minute.

Gage Aquifer. The Gage aquifer is the oldest member of the Lakewood formation. It extends throughout most of the West Coast Basin and across the Newport-Inglewood uplift into the Central Basin. This deposit accumulated at the beginning of late Pleistocene time and appears to have been deposited in a shallow marine sea which fluctuated across the coastal plain. The Gage aquifer is composed of sand containing some gravel and thin beds of silt and clay and varies in thickness from 20 feet along Santa Monica Bay to 160 feet near Torrance. In the vicinity of Hawthorne and southeast of Dominguez Hill, the sands thin or grade laterally into silts and clays. The areal extent of the Gage aquifer is shown on Plate 4 and the elevation of its upper surface is indicated on Plate 7. This aquifer was designated as the "200-foot sand" in prior reports.

Along the north flank of the Palos Verdes Hills, and adjacent to the coast along Santa Monica Bay, the Gage aquifer merges with aquifers of the underlying San Pedro formation resulting in direct hydraulic continuity between these aquifers. Inland, however, the Gage aquifer is separated from the lower aquifers along the Gardena syncline by as much as 230 feet of silts and clays.

As previously noted, the Gage aquifer was eroded in the central portion of the West Coast Basin and the incised channel created was backfilled with coarse sediments known as the Gardena aquifer (see Section C-C', Plate 3). As a result of these processes the northern and southern sides of the Gardena aquifer are in direct hydraulic continuity with the Gage aquifer.

In the southern portion of the West Coast Basin, the Gage aquifer underlies the Gaspur aquifer and in several areas is merged with this overlying aquifer (Plate 5).

The Gage aquifer is arched and thins as it crosses the Newport-Inglewood uplift. Ground water movement is locally affected by features of that uplift. The Gage aquifer is not offset by the Charnock fault which appears to affect only the deeper aquifers.

The Gage aquifer is a confined aquifer of moderate to low permeability. Yields to wells from this aquifer are variable and generally low in comparison to the other main aquifers in the basin.

San Pedro Formation. The San Pedro formation includes all deposits of early Pleistocene age and consists of an upper fine-grained deposit of variable thickness, a sand and gravel portion known as the Lynwood aquifer, previously called in earlier reports, the "400-foot gravel," and the Silverado aquifer, an extensive coarse sand and gravel basal portion.

This formation varies in thickness throughout the West Coast Basin because of deformation which occurred during and after deposition, and subsequent erosion of elevated areas. The thickest section occurs in the Gardena syncline where it varies from 400 feet near Ballona Gap to at least 1,000 feet near Dominguez Gap.

Fine-Grained Deposits. The upper portion of the San Pedro formation comprises an unnamed aquiclude consisting of a series of relatively fine-grained sediments. These sediments occur throughout the major portion of the West Coast Basin and extend inland from the coast over the crest of the Newport-Inglewood uplift. Their lithology is extremely variable, consisting of bluish-gray clay, silt, and sandy silt with occasional sand lenses. The major portion of this deposit is considered to be of marine origin. In Dominguez Gap it appears to be thinner and exhibits much less continuity than elsewhere within the West Coast Basin. These deposits, because of their limited permeability, restrict vertical percolation between aquifers. In Dominguez Gap, this aquiclude constitutes part of the sealing horizon as shown on Plate 8, "Contours on the Top of the Lower Sealing Horizon in Dominguez Gap, West Coast Basin."

Lynwood Aquifer. This aquifer occurs throughout most of the West Coast Basin and extends inland across the Newport-Inglewood uplift into the Central Basin. The Lynwood aquifer is composed mainly of sand and gravel with occasional lenses of sandy silt to fine sand. It ranges in thickness from 100 feet in the vicinity of Gardena to a maximum of about 200 feet across the western portion of the Wilmington anticline.

The Lynwood aquifer merges with the Silverado aquifer along the northeast margin of the Palos Verdes Hills, along the entire Santa Monica Bay portion of the West Coast Basin, and in local areas on the eastern side of the Newport-Inglewood uplift.

In the vicinity of the Gardena syncline the Lynwood aquifer is generally separated from the underlying Silverado aquifer by extensive fine-grained deposits of variable thickness. These fine-grained deposits thin markedly in the westward direction of mergence of the Lynwood aquifer and the underlying Silverado aquifer.

Within the West Coast Basin, the Lynwood aquifer is offset by the Charnock fault which acts as a partial barrier to ground water movement. This aquifer is arched and faulted across the Newport-Inglewood uplift which also forms a partial barrier to the movement of ground water in this aquifer to and from the Central Basin.

The Lynwood aquifer is highly permeable and numerous irrigation wells produce ground water from it. Yields of 500 to 600 gallons per minute have been reported where the aquifer is only about one-fourth its maximum thickness.

Silverado Aquifer. The Silverado aquifer underlies most of the West Coast Basin, cropping out on the northern slope of the Palos Verdes Hills and on the southern slope of the Baldwin Hills, and extends across the Newport-Inglewood uplift into the Central Basin. It is a continuous body of fine to coarse-grained, blue-gray sand and gravel that was deposited in a shallow, open sea by streams carrying sediments from the high inland areas. Along the axis of the Gardena syncline, this aquifer varies in thickness from about 240 feet near the Ballona Escarpment to about 500 feet northeast of Wilmington.

The Silverado aquifer is merged with the overlying Lynwood aquifer along the coast from Ballona Gap to Redondo Beach, and along the north flank of the Palos Verdes Hills. In the Redondo and Hermosa Beach areas, the merged Silverado aquifer is in hydraulic continuity with the overlying Gardena aquifer, and is merged with the Gage aquifer from

Hermosa Beach to Ballona Gap. The merged Silverado aquifer is also in continuity with the Gage aquifer along the north flank of the Palos Verdes Hills.

The Silverado aquifer is offset by the Charnock fault which acts as a partial barrier to the movement of ground water in this aquifer. It is generally deformed to a greater degree than the overlying Lynwood aquifer and its reach across the Newport-Inglewood uplift is warped and faulted, creating a partial barrier to ground water movement.

The highly permeable Silverado aquifer yields large quantities of water to wells which generally produce from 200 to 4,000 gallons per minute.

Pliocene Series

Recent and Pleistocene deposits are underlain throughout most of the West Coast Basin by consolidated and semiconsolidated sediments of Pliocene age. For the purpose of this report, the Pico formation of late Pliocene age has been separated into three subdivisions based mainly upon water-bearing characteristics.

Pico Formation - Upper Division. The upper division of the Pico formation averages 1,000 feet in thickness and consists of interbedded, semiconsolidated sand, micaceous silt, and clay members of probable marine origin. It is relatively thin adjacent to the north flank of the Palos Verdes Hills but thickens to approximately 1,800 feet in the area beneath the Dominguez Hill.

Fresh water sands averaging 200 to 400 feet in thickness and occasional lenses of gravel are interbedded with relatively impermeable silt and clay layers. Beneath the Baldwin Hills the upper division of the Pico formation consists essentially of silt deposits.

Limited data from deep water wells, oil wells, and exploration holes indicate that waters derived from the sand members of the upper division of the Pico formation are essentially fresh and should be suitable for certain industrial uses. The transition zone between the fresh ground water and the underlying saline ground water seems to correspond roughly with the base of the upper division of the Pico formation, except in the vicinity of the Potrero fault southeast of Inglewood, in the Redondo Beach area, and near the Torrance and Wilmington oil fields. In these four areas the transition zone rises as much as 400 feet above the base of the upper division of the Pico formation. In the Torrance-Redondo Beach area, electric logs of oil wells indicate a wedge-shaped zone of saline water near the top of the upper division of the Pico formation with fresh waters above and below.

Pico Formation - Middle and Lower Divisions. The middle and lower divisions of the Pico formation consist of interbedded sandstone, siltstone, claystone, and shale members ranging from 400 to 1,700 feet in thickness. Throughout most of West Coast Basin these sediments are far below the depths reached by the deeper water wells. However, oil well data indicate that portions of these sediments may be sufficiently permeable to transmit water in usable quantities, although this water is generally too saline for most beneficial purposes.

Pre-Pico Rocks

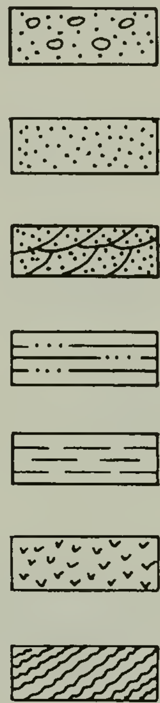
Tertiary sediments of early Pliocene and Miocene age underlie all of the West Coast Basin and crop out in the Palos Verdes Hills. These deposits composed of sandstone, siltstone, claystone, mudstone, shale, diatomite, and conglomerate vary from 4,800 to 14,000 feet in thickness. They are essentially nonwater-bearing, although sandy portions contain saline or brackish water. In the Palos Verdes Hills, outcrops of volcanics of Miocene age and the Catalina schist of Jurassic age occur. Logs of deep oil wells indicate that the Catalina schist underlies the Tertiary sediments throughout a large portion of the basin. The schist and volcanics in the Palos Verdes Hills are essentially nonwater-bearing.

Geology and Ground Water

The brief discussions of the geology of the West Coast Basin given in this chapter are intended to be a point of departure for the remainder of the investigation, providing a description of the physical framework within which the various elements of ground water supply operate. The relationships of these elements and the effect of the geologic characteristics of the basin on them will be described in succeeding chapters.

	PREVIOUS AQUIFER NAMES ✡
	SEMIPERCHED† GASPUR†
ER AND	SEMIPERCHED†
E	GARDENA† "200-FOOT SAND"†
UNCONFORMITY	
	"400-FOOT GRAVEL"† SILVERADO†
UNCONFORMITY	
TE, Y	

LEGEND OF LITHOLOGY



GRAVEL AND SAND

SAND

DUNE SAND

SILTY OR SANDY CLAY

CLAY OR SHALE

VOLCANICS

SCHIST

✡ DESIGNATIONS AND TERMS UTILIZED IN "REPORT OF REFEREE" DATED JUNE 1952 PREPARED BY THE STATE ENGINEER COVERING THE WEST COAST BASIN.

† DESIGNATED AS "WATER BEARING ZONES" IN ABOVE NOTED REPORT OF REFEREE.

BASIN

ERA	PERIOD OR SYSTEM	EPOCH OR SERIES	STAGE *
CENOZOIC	QUATERNARY	RECENT	
		PLEISTOCENE	UPPER PLEISTOCENE
			LOWER PLEISTOCENE
	TERTIARY	PLIOCENE	UPPER PLIOCENE
			LOWER PLIOCENE
		MIOCENE	
		OLIGOCENE	
		EOCENE	
		PALEOCENE	
MESOZOIC	CRETACEOUS		
	JURASSIC		
	TRIASSIC		
PALEOZOIC	PERMIAN		
	PENNSYLVANIAN		
	MISSISSIPPIAN		
	DEVONIAN		
	SILURIAN		
	ORDOVICIAN		
	CAMBRIAN		
PRECAMBRIAN			

* AS FOUND IN THE WEST COAST BASIN

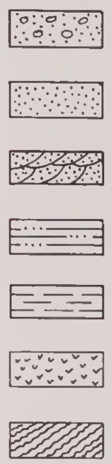
ADAPTED FROM THE U. S. GEOLOGICAL SURVEY PUBLICATION "SUGGESTIONS TO AUTHORS OF THE REPORTS OF THE UNITED STATES GEOLOGICAL SURVEY", 1958

GENERALIZATIONS

GEOLOGIC TIME	AGE OF ROCKS
LATE ↑	YOUNGER ↑
EARLY ↓	OLDER ↓

FORMATION	LITHOLOGY	AQUIFER AND AQUICLUDE	MAXIMUM THICKNESS (FEET)	PREVIOUS FORMATION NAMES ✡	PREVIOUS AQUIFER NAMES ✡
ACTIVE DUNE SAND		SEMIPERCHED (PLAYA AND LAGOONAL)	60	DUNE SAND	SEMIPERCHED†
ALLUVIAL DEPOSITS		BELLFLOWER (PLAYA AND LAGOONAL)	140	ALLUVIUM	
		GASPUR	60		GASPUR†
OLDER DUNE SAND		SEMIPERCHED	—	TERRACE COVER	SEMIPERCHED†
LAKEWOOD FORMATION		BELLFLOWER	200	PALOS VERDES SAND	
		GARDENA	160	UNNAMED UPPER PLEISTOCENE	GARDENA†
		GAGE	160		"200-FOOT SAND"†
LOCAL UNCONFORMITY				LOCAL UNCONFORMITY	
SAN PEDRO FORMATION		UNNAMED AQUICLUDE	—	SAN PEDRO FORMATION	
		LYNWOOD	200		"400-FOOT GRAVEL"†
		UNNAMED AQUICLUDE	—		
		SILVERADO	500		SILVERADO†
LOCAL UNCONFORMITY				LOCAL UNCONFORMITY	
PICO FORMATION — UPPER			1800	PICO FORMATION	
		LOCAL UNCONFORMITY			
PICO FORMATION — MIDDLE AND LOWER			1700		
REPETTO FORMATION MONTEREY FORMATION MIOCENE VOLCANICS			14,000	REPETTO, PUENTE, AND MONTEREY FORMATIONS	
		UNCONFORMITY			
CATALINA SCHIST			—	FRANCISCAN FM	

LEGEND OF LITHOLOGY



✡ DESIGNATIONS AND TERMS UTILIZED IN "REPORT OF REFEREE" DATED JUNE 1952 PREPARED BY THE STATE ENGINEER COVERING THE WEST COAST BASIN

† DESIGNATED AS "WATER BEARING ZONES" IN ABOVE NOTED REPORT OF REFEREE

GEOLOGIC TIMETABLE AND GENERALIZED STRATIGRAPHIC COLUMN IN WEST COAST BASIN

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT

CHAPTER III. GROUND WATER HYDROLOGY

The occurrence and movement of surface and subsurface water in the West Coast Basin are discussed in this chapter. Hydrologic factors which are relevant to this discussion include subsurface inflow and outflow; deep percolation of precipitation, stream flow, and applied water; and artificial recharge. The general factors influencing ground water movement within aquifers including the barriers to ground water movement are also discussed. These factors must be individually and collectively considered in the formulation of recommendations for well sealing and construction standards.

Replenishment and Discharge of Ground Water

Fresh water contributions to the West Coast Basin consist primarily of subsurface inflow across the Newport-Inglewood uplift. Replenishment also occurs to a lesser degree from the infiltration and deep percolation of precipitation, stream flow, and other local sources of water such as excess water applied in irrigation of crops and urban horticulture. In addition, fresh water is added to the ground water basin by injection of imported water into wells of the West Coast Basin Barrier Project, and to a limited extent by the spreading of local surface water at the Dominguez Gap Spreading Grounds.

The ground water supply in the West Coast Basin is principally depleted by well extractions; subsurface outflow does not presently occur.

Subsurface Inflow

The subsurface inflow of fresh water occurs primarily across the Newport-Inglewood uplift from the Central Basin through the Silverado aquifer.

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Subsurface Inflow

The subsurface inflow of fresh water occurs primarily across the Newport-Inglewood uplift from the Central Basin through the Silverado aquifer.

The remainder of the subsurface inflow occurs or has occurred in the Lynwood, Gage, Gardena, and Gaspur aquifers. The Newport-Inglewood uplift exerts a partial barrier effect upon all these aquifers except the Gaspur, impeding the subsurface inflow.

Historically, hydraulic gradients of the ground water in the aquifers of the West Coast Basin sloped toward the sea from the Newport-Inglewood uplift resulting in subsurface outflow of ground water to the ocean. However, as a result of heavy extractions of ground water, ground water levels have been lowered and the slope of the hydraulic gradient has been reversed. This has caused a reversal in the direction of ground water movement along the coastal side of the basin, and as a result sea water has invaded coastal portions of some aquifers. At present, this sea water constitutes a sizable portion of the subsurface flow into the West Coast Basin.

In recent years, ground water levels within the adjoining Central Basin have declined more rapidly than those within the West Coast Basin. Water levels in these two basins are now near the same elevation, and the quantities of ground water moving across the uplift from the Central Basin into the West Coast Basin are less than under previous conditions.

Deep Percolation

As discussed in Chapter II, much of the West Coast Basin is covered by sediments of relatively low permeability. These fine-grained sediments retard the rate of deep percolation of infiltrated surface waters; nevertheless, limited quantities of water reach the underlying aquifers through these sediments.

Precipitation. Precipitation in the West Coast Basin averages less than 13 inches annually; the amount varies widely, both seasonally and monthly. The precipitation which is not consumed by evapotranspiration or carried off by local drainage channels, infiltrates the ground surface and generally percolates to the semiperched aquifer. Percolation to the deeper aquifers is restricted by the underlying Bellflower aquiclude which exists over most of the West Coast Basin. However, as noted in Chapter II, this aquiclude does not occur along Santa Monica Bay, nor along the northeast flank of the Palos Verdes Hills, or in the Baldwin Hills. In these areas and in the area along Santa Monica Bay where highly permeable sand dunes are locally in direct contact with underlying aquifers, infiltration and deep percolation of precipitation to the underlying sediments is unrestricted.

Stream Flow. The only significant stream in the West Coast Basin is the Los Angeles River, which flows southward through Dominguez Gap, to San Pedro Bay. Historical water level measurements in the Gaspur aquifer, underlying the river, indicate that the ground water table sloped away from the river channel. This is characteristic of an influent stream; however, percolation to the underlying aquifers from this source appears to have been limited.

Lining of the Los Angeles River channel was undertaken as a flood control measure; by mid-1956 the channel had been lined downstream to the vicinity of Willow Street in Long Beach, precluding infiltration in about one-third of its four mile length through the West Coast Basin.

Other Sources. In the past, irrigation waters, industrial wastes including oil field brines, and other natural and applied surface waters were discharged on the surface of the ground. The quantities of such water which did not infiltrate the surface drained to low-lying areas where the water evaporated or slowly percolated. The percolating waters formed small, irregularly-shaped ground water mounds in the semiperched aquifer, because deeper percolation was restricted by the underlying Bellflower aquiclude. The construction of the Dominguez Channel served to drain many of these swampy areas and to convey waste waters to San Pedro Bay.

As previously noted, small quantities of rainfall and surface runoff percolate through the sand dunes along Santa Monica Bay into the underlying Pleistocene aquifers. In the remainder of the West Coast Basin, the total quantity of surface and semiperched waters percolating to underlying aquifers is limited, except in some localized areas, or where hydraulic continuity is provided by the improper construction and sealing of wells.

Artificial Recharge

As of December 31, 1961, about 30,700 acre-feet of Colorado River water had been injected into the ground water basin by the wells of the West Coast Basin Barrier Project, located near Manhattan Beach, as shown on Plate 9, "Location and Status of Key Wells in West Coast Basin." This project is operated by the Los Angeles County Flood Control District. The primary long-range purpose of this project, which began operation in February 1953, is to prevent the further intrusion of sea water by creating a pressure ridge in the merged Silverado aquifer along Santa Monica Bay. In the project area, fresh water pressure levels are maintained above sea level in a narrow section which parallels the bay for about one and one-half miles. Present plans call for the completion of this barrier project along the full 11 miles of the basin exposed to the Santa Monica Bay by 1965.

The District is continuing its exploratory program for the design of sea water intrusion barrier projects, similar to the one along Santa Monica Bay, to be located in Dominguez Gap and in Alamitos Gap. These projects will inject imported water to stem sea water intrusion and provide some fresh water replenishment to the basin.

In February 1958, the Los Angeles County Flood Control District began spreading local runoff at the Dominguez Gap Spreading Grounds located near the boundary of the West Coast Basin along the Los Angeles River, as shown on Plate 9. As of December 31, 1961, about 430 acre-feet had been spread at this project.

Discharge

The ground water supply is being depleted only by pumping, since under present conditions there is no subsurface outflow of ground water from the West Coast Basin. Under historic conditions, however, subsurface outflow to the ocean occurred, and could again occur should ground water levels once again be raised above sea level in the basin.

Ground Water Movement

Ground water in the aquifers of the West Coast Basin, which are shown on Plate 3, is generally confined and under hydrostatic pressure. In such aquifers, ground water movement occurs in the direction of the maximum hydraulic gradient or slope of the pressure surface. In the unconfined semiperched aquifer, ground water moves in the direction of the slope of the ground water table. The slope of the pressure surface and the ground water table varies with the amount and location of pumping, and with the amount of recharge.

The surfaces of the ground water table and pressure levels in the West Coast Basin present a complicated and changing pattern of localized depressions caused by the concentration of pumps and extraction practices. However, during recent years certain characteristic patterns in these ground water surfaces have persisted, enabling the general direction of ground water movement to be determined. These generalized patterns and the effects of geologic barriers on ground water movement are discussed in the following paragraphs.

Semiperched Aquifer

Because of the relatively poor quality of the water in the semiperched aquifer, there are few wells extracting water from it, and the data on ground water elevations are limited. These data indicate, however, the existence of a mound in the ground water table west of Gardena roughly aligned along Crenshaw Boulevard. Ground water moving away from this mound appears to have a predominant eastward movement toward shallow depressions near Gardena and the Newport-Inglewood uplift. Ground water movements in other areas of the semiperched aquifer are unknown.

Gaspur Aquifer

Ground water level measurements in 1960 indicate that ground water in the Gaspur aquifer is moving northerly from the vicinity of Terminal Island, and southerly from the Newport-Inglewood uplift, toward a depression between Willow Street and Pacific Coast Highway. This depression is partially due to a lowering of pressure levels in the underlying aquifers in the area, where the Gaspur and Gage aquifers are in hydraulic continuity, as shown on Plate 6. A small depression has also occurred locally around the Terminal Island area as a result of salt water extractions from the Gaspur aquifer for oil field repressurization. Salt water has intruded this aquifer a distance of about one and one-half miles inland.

The Cherry Hill fault, a part of the Newport-Inglewood uplift, extends across the Dominguez Gap but has no effect on the movement of ground water in the Gaspur aquifer.

The main recharge to this aquifer occurs within the free ground water area in the Central Basin and from sea-water intrusion. Replenishment of fresh water to the West Coast Basin portion of the aquifer occurs mainly as ground water underflow in the aquifer across the Newport-Inglewood uplift.

Gardena Aquifer

Ground water in the Gardena aquifer generally moves toward several local depressions within a larger, elongated east-west, shallow depression in the vicinity of the City of Gardena.

The Gardena aquifer has been partially displaced by the Avalon-Compton fault, a unit of the Newport-Inglewood uplift. This fault exerts a partial barrier effect on the movement of ground water between the Central Basin and the West Coast Basin. The Charnock fault appears to terminate at the northern edge of the Gardena aquifer and does not appear to structurally affect the Gardena aquifer nor the movement of ground water within it.

Historically, ground water recharge to the Gardena aquifer occurred by subsurface flow across the Newport-Inglewood uplift from the Central Basin, although the rate of ground water movement was impeded by the Avalon-Compton fault as previously noted. However, 1960 water level data indicate that the gradient of the pressure levels is reversed across the fault and ground water may be moving toward the Central Basin. Some replenishment to the Gardena aquifer occurs by subsurface flow from the Gage aquifer and by percolation of limited quantities of water through the sand dunes in the coastal areas, and locally by slow percolation from the overlying semiperched aquifer where restricted hydraulic continuity exists with the Gardena aquifer. Under favorable hydraulic gradients, subsurface flow into the adjacent Gage aquifer may occur from the Gardena aquifer.

Gage Aquifer

The ground water movement in the Gage aquifer is toward a shallow ground water depression which exists in a broad area near Hawthorne and toward several smaller localized ground water depressions in the vicinity of Inglewood and north of Wilmington.

The Gage aquifer is adjacent to and in direct hydraulic continuity with the Gardena aquifer. In some areas the Gage aquifer is in hydraulic continuity with the Gaspur aquifer which it underlies. Ground water level data for 1960 indicate that, in general, ground water moves downward from the Gaspur aquifer into the Gage aquifer in the areas of mergence, and there is also movement of ground water from the Gage aquifer into the Gardena aquifer. However, the Gage aquifer is generally less permeable than the Gaspur and Gardena aquifers, and is not utilized as extensively as a source of ground water.

The Gage aquifer extends across the Newport-Inglewood uplift which exerts a partial barrier effect on the movement of ground water in this aquifer in some areas. The Charnock fault does not appear to displace the Gage aquifer, and thus does not influence the movement of ground water in the aquifer.

The Gage aquifer probably receives some subsurface flow across the Newport-Inglewood uplift from the Central Basin, and some recharge also occurs from the Gaspur aquifer in Dominguez Gap. In addition, limited quantities of water percolate to this aquifer from the sand dunes in the coastal areas, and from the overlying semiperched aquifer.

Lynwood Aquifer

Pressure elevations of ground water in the Lynwood aquifer indicate the existence of a major pumping depression near Hawthorne between the Charnock fault and the Newport-Inglewood uplift. In the area between Wilmington and Torrance, ground water appears to be moving toward Dominguez Hill under the influence of a gentle slope in the pressure surface.

The Lynwood aquifer merges with the underlying Silverado aquifer along Santa Monica Bay and east of the Newport-Inglewood uplift. It also appears to pinch out west of the Charnock fault between Manchester Avenue and Imperial Highway. Both the Charnock fault and the Newport-Inglewood uplift exert barrier effects on portions of this aquifer.

Most of the recharge to the Lynwood aquifer occurs as subsurface flow across the Newport-Inglewood uplift from the Central Basin. Because of the lowering of pressure levels in the Central Basin, the amount of recharge has been reduced.

Silverado Aquifer

Pressure levels in the Silverado aquifer and its merged phase slope downward and inland from Santa Monica Bay toward the Newport-Inglewood uplift. An elongated pumping depression or "trough" extends from the southerly end of the Charnock fault to the vicinity of Dominguez Gap.

Under this landward gradient, sea water has intruded the merged Silverado aquifer as far as one and a half miles inland in the vicinity of El Segundo. Ground water moves across the Newport-Inglewood uplift from the Central Basin into the West Coast Basin in the Silverado aquifer into the "trough" area from Gardena south to Dominguez Gap. Between the Charnock fault and the Newport-Inglewood uplift, ground water moves southerly from the Ballona Gap area into the West Coast Basin towards a depression between Inglewood and Gardena.

The Charnock fault appears to be a partial barrier to the movement of ground water in the Silverado aquifer from Ballona Gap southward to the vicinity of Gardena. The faults and folds of the Newport-Inglewood uplift appear to constitute partial barriers to ground water movement in the Silverado aquifer. The displacement of this aquifer by the Avalon-Compton fault, a feature of the uplift, has produced a substantial barrier effect, demonstrated by marked discontinuity in ground water pressure elevations across this fault.

The Silverado aquifer is recharged mainly by subsurface flow from the Central Basin across the Newport-Inglewood uplift. As previously noted, minor recharge also occurs from deep percolation of rainfall into the merged Silverado aquifer through the active dune sand bordering Santa Monica Bay.

As can be seen from the preceding discussion, ground water movement in the basin plays an important role in the transmission of impaired quality ground water, once impairment has occurred. The quality of ground water in the West Coast Basin and possible sources of impairment will be discussed in the next chapter.

CHAPTER IV. QUALITY OF WATER

The quality of ground water in the West Coast Basin is considered a key element in the formulation of water well construction and sealing standards. This consideration is based on the fact that ground water quality varies in the several aquifers of the basin, and is subject to impairment from external sources. This chapter presents water quality criteria, quality of ground water, quality of imported water, and impairment of ground water.

Water Quality Criteria

Suitability of water for irrigation, municipal and domestic, and industrial uses depends, in part, upon the kinds and amounts of minerals dissolved in the water. To aid in the interpretation of the analyses presented in this chapter and to evaluate the suitability of a particular water for a specific purpose, water quality criteria and standards used by the Department of Water Resources are presented in this section. Criteria are defined as desirable values or limits of quality based on experience and research which, while generally recognized and accepted, do not have the force of statutes. Standards are official limits of quality established by regulation or statute, and form the basis for formulation of criteria.

The mineral character of water is identified by determining the predominant anions and cations in equivalents per million (epm). Specifically, the name of an ion is used where its chemical equivalent constitutes one-half or more of the total ions for its appropriate group. Where no single ion meets this requirement, a hyphenated combination of the two most predominate ions are used and named in order of magnitude. For example, the character of a water in which calcium constitutes half or more of the total cations, and bicarbonates half or more of the total anions, is calcium bicarbonate. Where the calcium constitutes less than half of the total cations with sodium next in abundance, and where bicarbonates are more than half the total anions, the designation of this water is calcium-sodium bicarbonate in character.

Irrigation

Due to the diverse crops and soil conditions, it is not possible to establish rigid limits for the quality of water used for irrigation purposes for all conditions involved. Therefore, on the basis of mineral quality, irrigation water is divided into three broad classes:

Class 1. Excellent to Good - Regarded as safe and suitable for most plants under most conditions of soil or climate.

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

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

Criteria for irrigation waters are listed below:

Chemical Properties	Class 1	Class 2	Class 3
Total Dissolved Solids	Less than 700	700-2,000	More than 2,000
Chloride, ppm	Less than 175	175-350	More than 350
Sodium in percent of Total Cations	Less than 60	60-75	More than 75
Boron, ppm	Less than 0.5	0.5-2.0	More than 2.0

The values shown in the above tabulation are intended to serve only as a guide and are based on work done at the University of California and the Regional Salinity Laboratory of the United States Department of Agriculture.

Municipal and Domestic

Water that is used for drinking and culinary purposes should be clear, colorless, odorless, pleasant to the taste, free from toxic compounds, should not contain excessive amounts of dissolved mineral solids, and must be free from pathogenic organisms. Probably the most widely used criterion for determining the suitability of a water for this use is the United States Public Health Service Drinking Water Standards.

A partial list of recommended upper limits for mineral constituents in drinking water, extracted from those standards, is tabulated below:

Constituent	Recommended maximum concentration in ppm
Chloride (Cl)	250
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Total Dissolved Solids (TDS)	500

The California State Board of Public Health on December 4, 1959, adopted interim standards for the upper limits of certain mineral constituents in drinking water. Temporary permits to supply water to domestic water systems failing to meet the above recommended upper limits may be issued provided the concentrations of the mineral constituents in the following tabulation are not exceeded:

Constituent	Maximum concentration in ppm	
	Permit*	Temporary permit
Total Dissolved Solids	500 (1000)	1500
Sulfate (SO_4)	250 (500)	600
Chloride (Cl)	250 (500)	600
Magnesium (Mg)	125 (125)	150

* Numbers in parentheses are maximum permissible to be used only where other more suitable water is not available in sufficient quantity for use in the system.

Industrial

It is not feasible to organize into a single tabulation the water quality criteria for water used in each of the many different industrial processes. However, two of the uses common to many industries, are the use of cooling water and boiler feed make-up water. A dominant factor in determining suitability of the water for these two uses is the degree of hardness of the water. While hardness is of significance in industrial processes, in this report it is not considered an important criterion in judging the suitability of water for beneficial use, because of the relative ease with which it can be removed or decreased to acceptable limits.

Quality of Ground Water

The quality of the ground water in the aquifers in the West Coast Basin was evaluated on the basis of past accumulations of data and from over 250 special mineral analyses made in the course of this investigation. The evaluations and many of the mineral analyses of ground water from the various aquifers in the West Coast Basin are presented in the following paragraphs. The water wells for which mineral analyses are tabulated are shown on Plate 9. For method of location and well reference designations, see Appendix C.

Mineral analyses of ground water extracted from the various aquifers in the West Coast Basin prior to 1940 indicate that in general such ground water met the recommended limits for municipal and domestic uses and was Class 1 for irrigation purposes. In general, the character of this water was calcium-sodium bicarbonate. Analyses of ground water considered representative of the water in the several aquifers prior to December 1940 are shown in Table 1.

TABLE 1

ANALYSES OF GROUND WATER FROM REPRESENTATIVE WELLS IN WEST COAST BASIN PRIOR TO DECEMBER 1940

Aquifer	State well number	Date sampled	Constituents in parts per million								Per-cent Na
			Ca	Mg	Na+K	HCO_3	SO_4	Cl	NO_3	TDS	
Semi-perched	3S/13W-30D2	1-13-33	58	18	54	265	51	41	2	356*	48
Gaspur	4S/13W-14L1	3-17-30	180	31	51	263	96	264	0	753*	16
Gardena	3S/13W-20L3	1924	63	13	44	219	82	30	-	341*	31
Gage	4S/13W-16A1	7-22-31	54	18	64	274	59	38	0	370*	--
Lynwood	3S/14W-15G1	8- 7-40	56	17	56	262	62	36	-	358*	37
Silverado	3S/14W-35R1	7-23-31	35	12	52	241	3	27	Tr	249*	45

* Total dissolved solids by summation.

After 1940, it became increasingly evident that the mineral quality of the ground water in the upper aquifers (semiperched, Gaspur, Gage, and Gardena) was being impaired. The ground water from these aquifers is now extremely variable in character and mineral quality. The variation in quality is caused by numerous and complex waste discharges that have percolated and commingled with ground water in the West Coast Basin during the past several decades. The pollution aspects of waste discharges have been substantially reduced through the actions of the Los Angeles Regional Water Pollution Control Board and local agencies. However, impairment of ground water continues, primarily from migrating wastes discharged prior to the control of waste discharges. Impairment due to sea-water intrusion has also occurred and is a serious threat to the water quality in the Gaspur and underlying aquifers.

Ground water from the underlying Lynwood and Silverado aquifers is generally of suitable quality for most uses, but is beginning to show the effects of impairment in a few areas. In the western portion of the basin, adjacent to Santa Monica Bay, sea water has intruded the merged Silverado aquifer; the ground water quality has been impaired and the chloride concentration approaches that of sea water.

Semiperched Aquifer

Mineral analyses of ground water from the semiperched aquifer indicate that the ground water generally does not meet the recommended criteria for municipal and domestic use, and is Class 2 or Class 3 for irrigation purposes. The character of this water is variable. The chloride concentration generally exceeds 250 ppm in the vicinity of Gardena and 1,000 ppm along portions of Dominguez Channel. Analyses of ground water from selected wells in the semiperched aquifer are presented in Table 2.

Gaspur Aquifer

In general, the water in the Gaspur aquifer has deteriorated to the extent that the character and quality of the native water is obscure. Mineral analyses of ground water from this aquifer indicate that the ground

TABLE 2

ANALYSES OF GROUND WATER FROM SELECTED WELLS
IN THE SEMIPERCHED AQUIFER

State well number	Date sampled	Constituents in parts per million								Percent Na
		Ca	Mg	Na+K	HCO_3	SO_4	Cl	NO_3	TDS	
3S/13W-29E11	12-21-49	75	18	70	309	94	46	0	458*	37
	4- 4-57	138	42	126	282	185	198	74	1,030	33
-30M1	5-19-49	65	19	58	253	59	69	--	397*	34
	1-16-57	150	74	208	488	161	365	36	1,432	39
	10-21-59	120	52	186	268	160	348	69	1,280	44
3S/14W-24Q1	10-20-49	175	56	227	450	99	453	85	1,320*	42
	4- 3-57	164	59	239	439	120	440	59	1,492	44
	11-10-59	200	74	269	436	130	585	64	1,701	42
4S/13W- 6K1	10-24-49	67	15	75	186	86	101	4	441*	41
	5- 7-57	118	28	115	250	279	116	--	907*	38
	10-21-58	114	26	105	247	273	96	7	797	35

* Total dissolved solids by summation.

water generally does not meet the recommended criteria for municipal and domestic use, and is Class 2 or Class 3 for irrigation purposes. Several wells in the northern portion of Dominguez Gap produce ground water with a chloride concentration of generally less than 500 ppm. Elsewhere, the chloride concentration varies considerably, exceeding 1,000 ppm throughout a large portion of the aquifer.

In the Terminal Island area, where source wells for oil field repressurization are in operation, the chloride concentration approximates that of the sea water which has intruded this aquifer. The water containing high chloride concentrations in the vicinity of Del Amo and Willow Streets is apparently the result of pollution from oil field brines and other industrial waste discharges. The analyses of ground water from selected wells in the Gaspur aquifer are presented in Table 3.

TABLE 3

ANALYSES OF GROUND WATER FROM SELECTED WELLS
IN THE GASPUR AQUIFER

State well number	Date sampled	Ca	Mg	Na+K	HCO_3	SO_4	Cl	NO_3	TDS	Percent Na
		Constituents in parts per million								
4S/13W-10G5	6-13-49	250	46	165	377	504	250	-	1,404*	31
	3-22-57	388	91	386	348	1,160	490	0	2,760	38
-10J3	3-29-48	--	--	--	262	--	324	-	--	--
	4- 5-57	368	130	598	427	1,427	630	0	3,620	47
-11E2	6-13-49	80	12	86	285	110	58	-	489*	43
	3-20-57	160	28	144	339	263	192	2	974	37
-11L2	8-15-51	123	9	140	343	164	160	2	864	47
	3-20-57	134	16	172	293	226	210	1	955	47
	10-15-59	188	35	265	220	609	269	3	1,562	48
	3-21-61	234	23	227	320	521	262	0	1,444	41
-26R3	9-17-59	392	178	--	580	126	3,120	-	--	--
5S/13W-3P11	3-14-57	593	1,152	9,737	408	2,249	17,498	5	34,291	76

* Total dissolved solids by summation.

Gardena Aquifer

Historically, ground water from the Gardena aquifer generally was acceptable for municipal and domestic uses, and was Class 1 for irrigation purposes. Locally, pumping has ceased at many former producing wells due to various reasons, including the deterioration of the mineral quality of the ground water.

Ground water extracted from this aquifer by wells still in operation usually has a chloride ion concentration of less than 200 ppm, and as a rule, its character is calcium-sodium bicarbonate. It is normally acceptable for municipal and domestic purposes and is Class 1 for irrigation use. Analyses of ground water from selected wells in the Gardena aquifer are presented in Table 4.

TABLE 4

ANALYSES OF GROUND WATER FROM SELECTED WELLS IN THE GARDENA AQUIFER

State well number	Date sampled	Ca	Mg	Na+K	HCO_3	SO_4	Cl	NO_3	TDS	Percent Na
		Constituents in parts per million								
3S/13W-30J5	5-18-49	74	17	67	275	49	85	--	430*	36
	4- 4-57	139	35	94	235	205	188	13	920	28
3S/14W-26K1	5- 5-50	--	--	--	159	--	92	--	--	--
	10-14-59	71	20	97	315	24	123	10	554	44
	5-12-61	58	14	51	271	0	63	0	530	35
-33J3	7-18-49	41	10	57	198	49	36	--	292*	46
	3-12-57	42	11	50	247	0	38	0	360	40
-34D1	3-22-50	84	23	71	250	65	128	4	500*	33

* Total dissolved solids by summation.

Gage Aquifer

Historically, ground water in the Gage aquifer for the most part was acceptable for municipal and domestic purposes and was Class 1 for irrigation use.

Presently, the mineral quality of the ground water extracted from the Gage aquifer in a portion of the West Coast Basin is generally sodium bicarbonate to calcium-sodium bicarbonate in character and for the most part has a chloride concentration of less than 200 ppm. This ground water meets or slightly exceeds the maximum permissible concentration of mineral constituents for municipal and domestic purposes and is Class 1 or Class 2 for irrigation uses. Mineral analyses of ground water from other portions of the Gage aquifer, especially in the coastal areas, indicate the water is often sodium chloride-bicarbonate to sodium chloride in character. The chloride concentrations usually exceed 200 ppm. The ground water in these portions of the aquifers is normally not acceptable for municipal and domestic purposes and is Class 2 or Class 3 for irrigation uses. Analyses of ground water from selected wells in the Gage aquifer are presented in Table 5.

TABLE 5

ANALYSES OF GROUND WATER FROM SELECTED WELLS IN THE GAGE AQUIFER

State well number	Date sampled	Constituents in parts per million								Percent Na
		Ca	Mg	Na+K	HCO_3	SO_4	Cl	NO_3	TDS	
3S/14W-4B1	11-26-48	76	19	94	343	37	102	--	500*	44
	3-18-57	143	44	153	375	114	250	92	1,150	37
-18A1	4-30-50	54	22	78	244	8	117	3	404*	43
	3-12-57	46	21	95	244	26	120	0	504	48
4S/13W-28N2	9-26-50	--	--	--	276	--	160	--	--	--
	1-25-57	81	29	246	293	15	398	0	992	59
	8- 3-59	174	60	284	245	34	752	4	1,431*	--
	3- 2-60	116	50	316	115	4	768	0	1,311*	--
4S/13W-30A4	4-18-50	24	9	63	232	3	23	2	240*	59
	1-28-57	30	8	67	189	42	43	0	308	56

* Total dissolved solids by summation.

Lynwood Aquifer

Mineral analyses of ground water from the Lynwood aquifer indicate the ground water generally is acceptable for municipal and domestic purposes and is Class 1 for irrigation uses. The character of the water extracted from this aquifer varies from sodium bicarbonate to calcium bicarbonate, and the chloride concentration generally does not exceed 100 ppm. Mineral analyses of ground water from selected wells are presented in Table 6

TABLE 6

ANALYSES OF GROUND WATER FROM SELECTED WELLS
IN THE LYNWOOD AQUIFER

State well number	Date sampled	Constituents in parts per million: Ca	Mg	Na+K	HCO_3	SO_4	Cl	NO_3	TDS	Per-cent Na
3S/14W-10C1	7-26-49	40	12	41	238	Tr	35	--	247*	37
	2- 8-57	43	14	69	250	27	60	0	448	45
-14A1	10-20-48	56	18	--	244	71	34	0	--	30
	2- 6-57	--	--	--	226	--	38	--	--	--
-15B1	7-26-49	50	13	48	248	28	35	--	298*	37
	2- 8-57	--	--	--	262	--	40	--	--	--
4S/13W-28N1	3-12-40	--	--	--	225	--	79	--	--	--
	12-20-50	--	--	--	262	--	202	--	--	--
	1-25-57	67	27	293	250	7	505	0	1,276	67
-30K1	8-12-46	20	8	65	229	4	26	0	238*	63
	3-13-57	32	10	80	247	7	57	3	300	57

* Total dissolved solids by summation.

Silverado Aquifer

Mineral analyses of the ground water from the Silverado aquifer indicate that the ground water is generally acceptable for municipal and domestic purposes and is Class 1 for irrigation uses. The character of the water extracted from this aquifer varies from sodium bicarbonate to sodium-calcium bicarbonate. The chloride concentration is generally not in excess of 100 ppm, except where impairment has occurred in the merged Silverado aquifer along Santa Monica Bay due to sea-water intrusion. Here the character of the ground water is sodium chloride. Mineral analyses of ground water from the Silverado aquifer are shown in Table 7.

TABLE 7

ANALYSES OF GROUND WATER FROM SELECTED WELLS
IN THE SILVERADO AQUIFER

State well number	Date sampled	Ca	Mg	Na+K	HCO_3	SO_4	Cl	NO_3	TDS	Percent Na
		Constituents in parts per million								
2S/14W-19K2	10-20-48	59	27	122	351	64	128	0	576*	51
	3-18-57	81	37	147	332	89	215	0	888	46
	11-10-58	42	34	167	370	94	121	0	643*	--
	3- 8-60	121	50	172	442	135	264	1	964*	--
-28F1	7-11-49	72	34	93	434	77	96	--	589*	35
	2- 5-57	77	28	81	281	58	115	16	517*	34
-34C1	4- 3-50	50	14	58	220	56	28	3	319*	41
	4-12-57	40	11	59	244	20	33	0	366	44
4S/13W-15A11	6- 7-49	18	6	53	181	4	25	0	196*	62
	7-18-57	17	5	59	178	8	25	0	241	66
-21H4	5-12-50	26	0	58	196	1	27	0	210*	66
	10-24-56	104	24	85	224	209	98	0	684	32
-30A1	8-29-49	25	7	62	212	Tr	33	--	233*	59
	1-28-57	24	8	65	226	0	35	0	320	57
4S/14W-1F2	5-12-50	46	8	46	231	21	27	0	263*	40
	3-20-57	41	12	45	226	26	23	0	290	36
	10-20-60	40	12	53	200	53	37	0	318	39
-8D2	6-29-57	7	1,204	9,508	259	1,977	17,600	0	30,425	--
-36J1	11- 9-48	29	6	126	340	6	81	--	418*	74
	1-22-57	34	13	181	363	3	150	0	668	71

* Total dissolved solids by summation.

Quality of Imported Water

To insure a continued supply of good quality water, surface water from the Colorado River, Mono and Owens Valleys,and ground water from the Central Basin are being imported into the West Coast Basin.

Imported softened Colorado River water is sodium sulfate in character. Its total dissolved solids generally exceeds 600 ppm. In contrast, imported Mono-Owens water is calcium bicarbonate in character. Its total dissolved solids generally is less than 250 ppm.

The average analyses of treated and untreated Colorado River water for the year ending June 30, 1960, and an analysis for Mono-Owens water are shown in Table 8.

TABLE 8

ANALYSES OF IMPORTED WATER
USED IN WEST COAST BASIN

Water sampled	Constituents in parts per million								Percent Na
	Ca	Mg	Na+K	HCO_3	SO_4	Cl	NO_3	TDS	
MWD untreated[a]	80	26	86	136	263	74	1.3	609[c]	38
MWD treated[a]	47	15	147	134	263	78	1.2	629[c]	64
Mono-Owens[b]	26	6	45	130	23	20	0.1	213[c]	52

a. Colorado River water data from 22nd Annual Report of The Metropolitan Water District of Southern California.
b. Sample taken on April 19, 1960, Los Angeles Department of Water and Power.
c. Total dissolved solids by summation.

Impairment of Ground Water

From the foregoing discussion it can be concluded that although the natural ground water in the aquifers of the West Coast Basin was of excellent quality in the past, at present much of this resource has been impaired in quality. Such impairment has been brought about primarily by man's activities through overdraft and improper waste disposal. Poorly constructed and sealed wells may serve as conduits for impaired water.

Sources of Ground Water Impairment

Ground water in the West Coast Basin has been impaired by the intrusion of sea water in overdrawn aquifers, the improper disposal of industrial wastes including oil field brines, and possibly by the improper disposal of decomposable refuse.

The lowering of ground water levels below sea level in most of the aquifers in the basin, caused by excessive ground water extractions from those aquifers, has caused a reversal in the slope of the pressure surface. The ground water pressure surface now slopes downward and inland from the ocean. Increasing quantities of sea water have entered the merged aquifers in the coastal fringe areas and as a result, extractions have entirely ceased or have been greatly reduced in these areas. By 1960, ground water with a chloride ion concentration in excess of 500 ppm underlay an area of about 8,000 acres along Santa Monica Bay, and in the vicinity of El Segundo, ground water of impaired quality underlay an area which extended inland from the coast about one and one-half miles. Similarly, in the San Pedro Bay area, sea water has intruded inland in the Gaspur aquifer about the same distance.

Improper waste disposal has contributed to the impairment of ground water in some of the aquifers in the West Coast Basin. Although present waste disposal practices are controlled by the office of the County Engineer and the Los Angeles Regional Water Pollution Control Board, in the past, disposals of industrial wastes and decomposable refuse were made without regard to the possible effect that such disposal would have on ground water quality. During the period of most intense industrial growth, 1930 to 1950, large volumes of industrial wastes were discharged directly to the ground surface, and these wastes percolated and intermingled with the ground water of the upper aquifers. In the oil industry, large quantities of oil field brine wastes were percolated from separation ponds, thereby causing impairment to the quality of ground water in the underlying aquifers.

Decomposable refuse deposited in many old dumps, now filled, covered, and laying idle for years, is at elevations subject to intermittent or continuous submergence by ground water. This refuse may be adversely affecting the quality of ground water, particularly in the semiperched aquifer.

Protection Against Further Impairment

The intrusion of sea water is a direct result of overdraft caused by excessive extractions of ground water. The further impairment of ground water quality from this source can be prevented through ground water management practices.

The area of investigation is now part of the Central and West Basin Water Replenishment District which was formed primarily to provide additional water for recharging the ground water reservoirs of these two basins and to assist in reducing ground water extractions to a safe level. The accomplishment of these objectives will reduce the overdraft conditions and decrease the threat of further sea water intrusion. Also, as previously noted, the Los Angeles County Flood Control District is planning for the construction of additional facilities to create an underground pressure ridge by the injection of fresh water into the underground basin that will halt the advancement of sea water into the aquifers of the basin. These measures should alleviate or entirely eliminate further impairment of ground water quality from this source.

The large quantities of ground water of excellent and, as yet, unimpaired quality which exist at present in the aquifers of the West Coast Basin must be protected from other sources of impairment if the full use of this valuable resource is to continue. The recent effort on the part of government, business, and industry to establish laws and regulations to control the discharge and disposal of wastes has been successful in minimizing the threat to ground water quality impairment from existing waste discharges. However, large volumes of ground water impaired by past waste discharges remain in the basin, and could continue to mix with and impair the remainder of the ground water in the basin.

Those aquifers which generally contain ground water of impaired quality are the semiperched, Gaspur, and portions of the Gage and Gardena. These aquifers overlie or are merged with Lynwood and Silverado aquifers which generally contain ground water of suitable quality except as previously noted where sea-water intrusion has occurred. The Gardena aquifer is in direct hydraulic continuity with the adjacent Gage aquifer. The Lynwood and Silverado aquifers are generally separated from the overlying aquifers by relatively continuous sediments which restrict the downward movement of ground water with the exception of the area of mergence along Santa Monica Bay. Where these restricting horizons are absent, or exist as lenticular bodies, ground water of impaired quality from overlying aquifers may migrate downward and commingle with previously unimpaired water of acceptable quality in the underlying aquifers.

Additionally, where the restricting horizons are present, and the aquifers are not naturally merged, improperly constructed or sealed wells may become channels or avenues of interconnection. When this occurs, water of impaired quality, including some surface runoff and industrial wastes, is conducted downward through the well and the quality of water in each of the aquifers perforated by the well may be impaired.

Thus, improperly constructed or sealed wells simultaneously play two incompatible roles: while extracting ground water for beneficial uses, they permit the impairment of ground water quality in the aquifers from which the supply is being drawn. The well construction and sealing standards, presented in the next chapter, are designed to permit the wells in the West Coast Basin to continue in their beneficial role, but at the same time prohibit or alleviate the role played by such wells in the further impairment of ground water quality.

CHAPTER V. WATER WELL CONSTRUCTION AND SEALING STANDARDS

The standards for well construction and the standards for well destruction presented in this chapter are specifically developed for wells in the West Coast Basin. The objective of these standards is to protect the ground water in the basin from the impairment of quality which may occur when such wells are poorly constructed, or improperly destroyed. A discussion of the areas or zones for which these standards have been developed is presented first, followed by a discussion on the standards for water well construction and sealing.

Areas of Recommended Sealing Standards

Geologic, hydrologic, and ground water quality characteristics within the West Coast Basin are so diverse and complex that it was necessary to develop specific standards applicable to the basin. Based on the ground water basin characteristics determined during the course of this study, the West Coast Basin was separated into three areas or zones. Within each zone, a distinct set of specific standards for water well construction and destruction was developed and should be applied. These zones are shown on Plate 10, "Areas of Recommended Sealing Standards in West Coast Basin", as Zone 1, Santa Monica Bay Coastal Area; Zone 2, Inland Area; Zone 3, Los Angeles River Area.

Santa Monica Bay Coastal Area - Zone 1

The Santa Monica Bay Coastal Area, Zone 1, is approximately two and one-half miles wide, and extends southward along the coastal area from the Ballona Escarpment to the Palos Verdes Hills. It also includes the northern portion of the Palos Verdes Hills and the southern flank of the Baldwin Hills. In this area the Bellflower aquiclude is absent; therefore, water can percolate from the surface and commingle with ground water in the underlying aquifers.

Inland Area - Zone 2

The Inland Area, Zone 2, embraces that portion of the West Coast Basin east of the Santa Monica Coastal Area, Zone 1. All aquifers described within this report are found in this area, with the exception of the Gaspur aquifer. The Gage aquifer and the adjacent Gardena aquifer, are generally considered to be the uppermost aquifers containing water which is generally acceptable for most municipal and domestic purposes and irrigation uses. Consequently, standards for construction and sealing, which will protect the Gage aquifer and/or the Gardena aquifer can be assumed to protect the underlying aquifers from water quality deterioration.

Los Angeles River Area - Zone 3

The Los Angeles River area, Zone 3, is an irregular north-south strip of land approximately one and one-half miles wide located in Dominguez Gap. The water-bearing units found in this area include the Gaspur, Gage, Lynwood, and Silverado aquifers. These aquifers are separated in a large portion of this area by varying thicknesses of relatively impermeable sediments. In the remaining portion of the area the aquifers are merged. The areas of mergence between the Gaspur and Gage aquifers are shown on Plates 6 and 7.

The Gaspur aquifer in the West Coast Basin generally contains water of impaired mineral quality. Consequently, any well construction and sealing standards should protect the water of the Gaspur aquifer from further deterioration, and protect the underlying aquifers from downward movement of water from the Gaspur aquifer.

General Water Well Construction Standards

The following general standards for both drilled and dug wells are applicable to the entire West Coast Basin, but are supplemented by additional requirements in specific areas where geologic, hydrologic, or water quality conditions necessitate increased measures of protection. It should be noted that local ordinances, or local health agencies may impose more stringent requirements than those presented in this report. These general standards are also applicable to water wells constructed by other methods. Specific water well construction standards are presented in a subsequent section.

Location of Well Site

The prospective well should be located at the highest point on the premises consistent with the general surroundings. It should be protected from normal flooding, and from any surface or subsurface drainage capable of impairing the quality of the ground water supply. In addition, the well should be located up slope, with respect to the ground water gradient, from possible sources of contamination.

The well should not be located within certain minimum distances of potential sources of contamination. These minimum distances as adopted from recommendations by the California Department of Public Health, Bureau of Sanitary Engineering, are:

Sewer, watertight septic tank or pit privy . . . . 50 feet
Sewage disposal field (subsurface), barnyards, or fenced areas for livestock . . . . 100 feet
Cesspools or seepage pits . . . . 150 feet

In special cases, the local health officer may approve the location of a well within lesser distances if proof can be shown that threat to public health or impairment of ground water will not occur. Conversely, special characteristics of certain areas may require that the local health officer increase these minimum distances to prevent possible contamination of the water in the well.

The well should be located so that it is reasonably accessible, with adequate clearances provided for the proper equipment for cleaning, treatment, repair, test, and other maintenance which may be necessary. When a well is constructed adjacent to a building, it should be located so that a vertical extension of the centerline of the well will clear any projection from the building by a minimum of two feet.

Casing

To obtain and maintain the optimum quality of ground water, and to gain the maximum operational life of the well, the proper casing should be installed. The casing should be designed to withstand the forces which may act upon it during and after installation. It should also be resistant to the electrolytic and corrosive effects of earth and water.

There is a variety of material used for casing. Steel is the material most commonly used for drilled, driven, and jetted wells, and concrete or brick for dug wells. There is also limited use of other material such as galvanized metal, plastic, clay, and asbestos-cement.

Suggestions as to the minimum thickness of steel casings are contained in Appendix D together with a list of applicable specifications of the American Society for Testing Materials and the American Water Works Association. General specifications for concrete casing for dug wells are also presented in Appendix D.

Steel well casing and conductor pipe should not be considered to have an unlimited useful life. It should be inspected from time to time to ensure that it has not deteriorated under conditions of use.

Casing Diameter Reduction. Whenever the casing diameter is reduced, the two casings should overlap by at least eight feet and the annular space thus produced should be adequately sealed to make the joint watertight. This sealing can be accomplished by the proper placement of impervious cement grout or a packer.

Joints. Watertight casing should be used to prevent the entrance of undesirable water and loose material into the well. Steel casing should be made watertight by a method such as butt welding, collar welding, or threaded collars. In a dug well where concrete casing is employed, a sufficient amount of impervious mortar should be used to insure that all sections are securely joined.

Perforations. The perforation of steel casing should not unduly weaken, tear, or deform the casing, and the casing should not be perforated within 50 feet of the ground surface. In dug wells, only standard sections of perforated concrete casing should be used. In drilled wells, perforating more than one aquifer in any well should be discouraged, even under ideal water quality conditions. Multiple aquifer perforations should be made only if all perforated aquifers contain water of similar quality.

Sealing Intervals of Strata Penetrated by Wells

Aquifer or strata (intervals) penetrated during the drilling process which might contribute water of impaired quality to the well should be sealed. All sealing should be permanent, and should completely restrain the movement of undesired water into the well. Standard sealing methods and materials should be employed. In developing, redeveloping, or conditioning a well, care should be taken to preserve the natural barriers to ground water movement between aquifers. Two methods commonly used in sealing undesirable intervals of strata are by pressure grouting and insertion of a liner. These two methods are shown on Figure 4, and are discussed at this point; other suitable methods are discussed later under "Surface Protection of Wells".

Pressure Grouting Method. In this method impervious grout such as portland cement is pumped down the grouting pipe into the well and then forced through existing perforations or new perforations in the casing into the annular space and formation surrounding the well. The interval of undesirable strata is isolated in the well by a packer or a plug set at the bottom and a packer set at the top of the interval to be sealed. The pressure that forces the grout into the annular space to be sealed must be maintained until the grout has set, after which, the material remaining in the well is removed by drilling.

Liner Method. In this method a metal liner is placed inside the original casing so that it extends at least 10 feet above and below

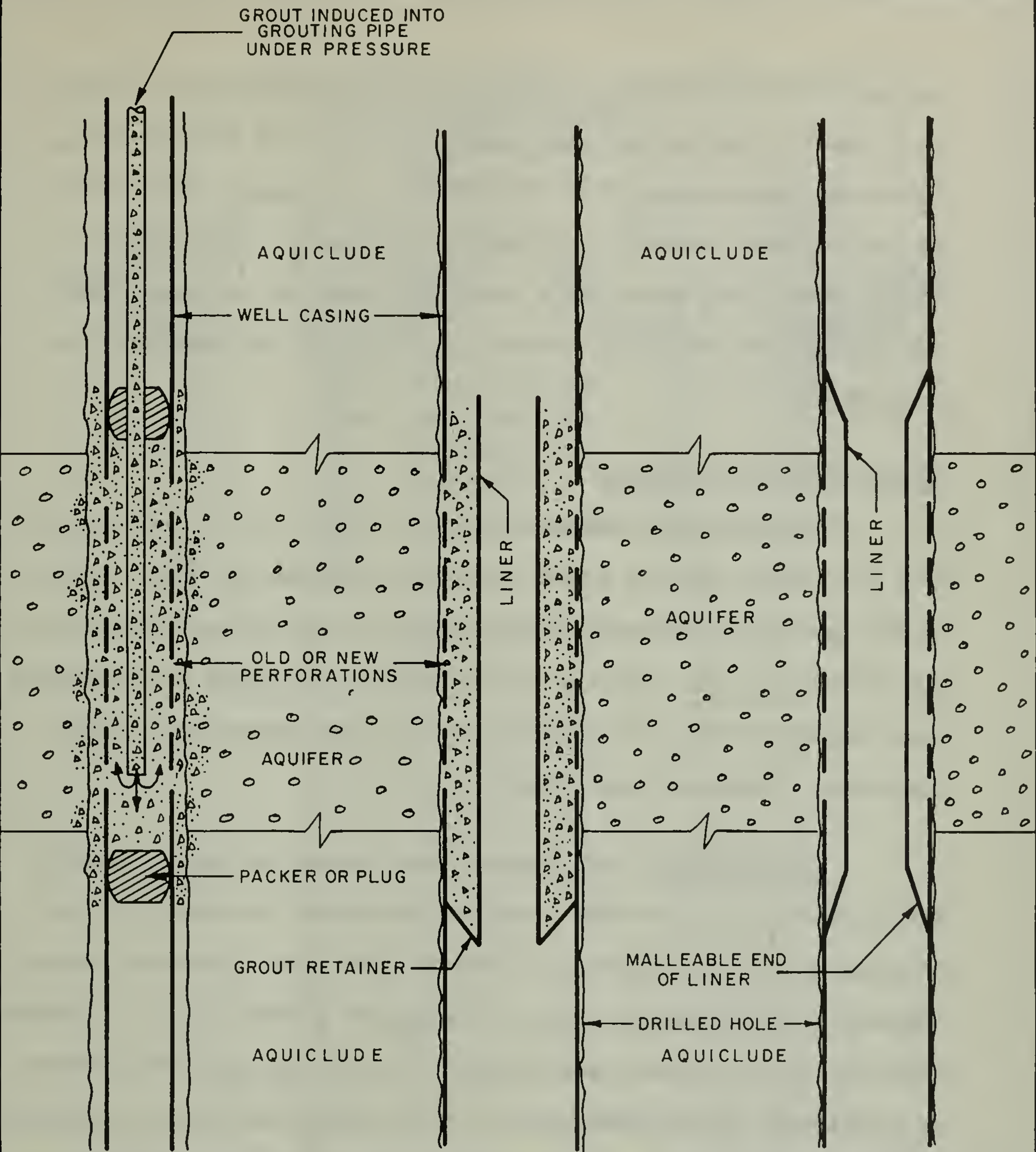


FIG. 4 (a) PRESSURE GROUTING METHOD

FIG. 4 (b) LINER METHOD (CEMENTED IN PLACE)

FIG. 4 (b) LINER METHOD (SWAGED IN PLACE)

NOT TO SCALE

TYPICAL METHODS FOR SEALING INTERVALS OF STRATA the perforated interval to be sealed. A grout retaining seal is placed at the base of the annular space between the liner and the well casing. A grouting pipe is extended to the bottom of the interval to be sealed. The annular space between the liner and well casing is then filled with grout. Where corrosion is not a problem, a liner with malleable metal sections at both ends may be swaged tightly against the casing to form a watertight seal.

Surface Protection of Wells

The following standards should be employed to insure that surface water and/or shallow ground water will not enter the well. These surface protection features, shown on Figure 5, include the requirements for the sanitary seal that extends from the ground surface to the minimum depth required by the well location, and the requirements for the well components located at the surface.

Drilled Wells. The annular space between the drilled hole and either the well casing or the conductor pipe should be sealed with impervious grout such as portland cement or other types of sealing material approved by the inspecting agency. The purpose of this seal is to preclude from the well the downward percolation of surface runoff or the entrance of undesirable shallow ground water. This annular space seal should extend at least 50 feet down from the ground surface and have a minimum thickness of two inches. For wells 50 feet or less in depth, the annular space should be sealed at least three-fourths of the depth of the well from the ground surface downward. Two procedures which are utilized to construct a surface seal in the annular space are given below.

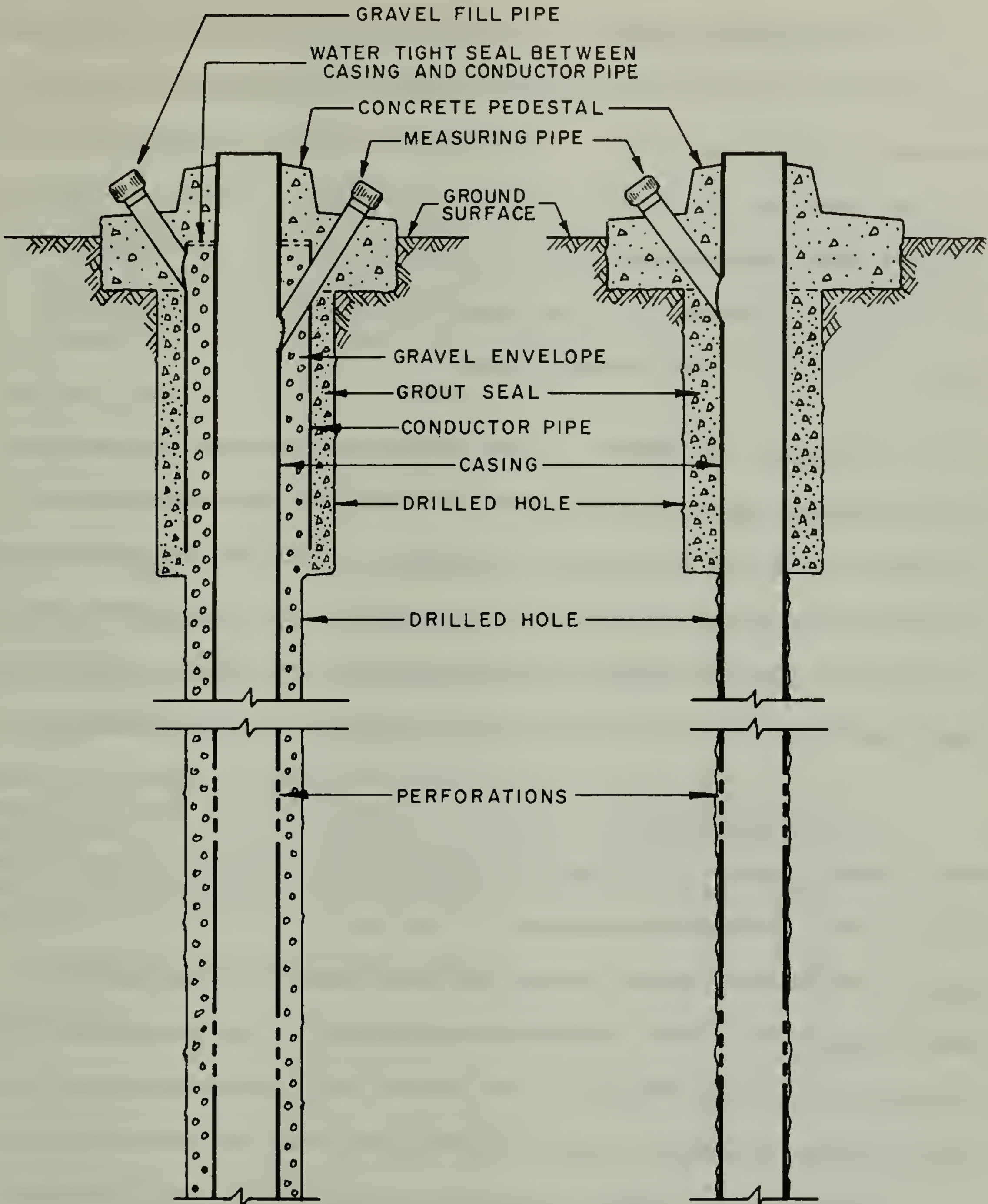


FIG. 5 (a) WELL WITH GRAVEL PACK

FIG. 5 (b) WELL WITHOUT GRAVEL PACK

NOT TO SCALE

TYPICAL SURFACE PROTECTION FEATURES

Grouting Pipe Method. In the grouting pipe method a grout seal is placed in the annular space from the bottom up through a grout pipe suspended in the annular space. If the annular space is restricted, it may be necessary to jet the grout pipe to the required depth. The grouting pipe should remain submerged in the grout during the placement of the seal. It may be necessary in this method to provide a grout retaining seal at the bottom of the annular space.

Pressure Cap Method. In the pressure cap method, the conductor pipe is suspended about two feet above the bottom of the drilled hole, filled with fluid, and capped with a pressure cap. A grout pipe is extended through the pressure cap and the conductor pipe to the bottom of the hole, and impervious grout is forced through the grout pipe, up the annular space between the conductor pipe and the drilled hole, to the ground surface.

Gravel-Packed Wells. In gravel-packed wells the top of the gravel envelope should generally be terminated at least 50 feet below the surface of the ground, although terminations of the envelope at greater depths are required in certain portions of the West Coast Basin, as discussed later under "Specific Water Well Construction Standards". The annular space from the top of the gravel envelope to the surface of the ground should be completely filled and sealed with impervious grout, such as portland cement.

If a conductor pipe is used, the gravel envelope may be terminated at the surface of the ground, providing the annular space between the drilled hole and the conductor pipe is sealed with impervious cement grout to the required depth. A watertight cover should be installed between the conductor pipe and the well casing at the ground surface, as shown on Figure 5. A gravel fill pipe may be installed through the seal if desired, but the fill pipe should be made watertight at the ground surface.

Dug Wells. The annular space between the dug hole and the well casing should be sealed to a minimum depth of 50 feet, or three-fourths of the well depth if it is less than 50 feet deep, in a manner similar to that discussed for drilled wells. Dug wells should also be protected by a surface cover. This cover should be made of reinforced, watertight concrete, at least four inches thick at its outer edge. The upper surface of the cover should be sloped away from the column pipe or pump column in all directions, and extended beyond the outer edge of the curbing. The cover should be sealed watertight to the curbing with a rubber gasket, mortar, mastic, or other suitable material. All openings in the cover should be protected to prevent entrance of water or foreign material into the well. A sounding tube in a dug well should be extended through the cover into the well. This tube should be equipped with a watertight screw cap.

Well Pits. The use of well pits should be avoided whenever possible. Well pits should not be constructed to a depth below the recorded high water table. If a well pit is necessary, the walls and floor should be constructed of watertight reinforced concrete. The top of the pit should be covered with a structurally sound, watertight concrete slab or with a house of satisfactory construction. The floor of the pit should be sloped away from the well casing. A gravity drain or automatic sump pump should be installed so that any water accumulating in the pit will be discharged a minimum distance of 30 feet from the pit.

The well casing should extend at least 18 inches above the floor of the pit.

Pedestal and Pump. In both drilled and dug wells, the top of the casing should extend a minimum of 18 inches above the ground surface and at least one inch above the top of the elevated portion of the pedestal. Upon completion of a well, and until the installation of the pump, a watertight cap or plate should be placed on the top of the casing. This plate should be fastened securely and rigidly enough to support normal external loads.

A monolithically poured concrete pedestal should be constructed in a manner similar to that as shown on Figure 5 on thoroughly compacted earth around the top of a well, irrespective of whether the pump is mounted over the well, is offset from the casing, or is of the submersible type. At its extreme outer edge, the pedestal should rise to at least six inches above the surrounding ground surface. The pedestal should slope away from the casing in all directions.

When a pump is set on top of the casing, a seal should be provided to make a watertight joint between the pump and casing. The seal should be shaped in a manner that will prevent collection and retension of surface water or other matter. If the pump is offset, a packer or seal should be provided to make a watertight seal between the pipe column or other pipes, and the casing or cover in drilled or dug wells. The top of the seal should be so shaped to prevent the collection and retention of surface water or other foreign material.

The pump should be designed and maintained in a manner that will prevent lubricating oil from dripping or discharging into the well. If a pump house is used, it should be equipped with a concrete floor sloped away from the well to prevent retention and inflow of surface water and foreign materials. A drain should be provided which discharges outside the pump house. If there is no natural slope from the pump house, the drain should discharge at least 30 feet from the well. Adequate ventilation should be provided.

Sounding Tube and Air Vent Pipe. In drilled and dug wells, a sounding tube or access pipe at least two inches in diameter should be installed through the surface seal or surface cover into the casing. One end of the tube should be welded flush with the inside of the casing. The other end of the tube should be equipped with a watertight screw cap. If an air relief vent pipe is provided, it should be terminated in a downward direction at least 18 inches above the ground surface. The end of this vent pipe should be screened.

Water Quality Sampling

In order to determine the quality of ground water which will be available, all wells should be sampled for bacteriological and mineral quality immediately following construction. It may also be advisable to take samples of the water during construction. All wells used to supply water for domestic purposes should be sampled and tested in accordance with, and should comply with, the United States Public Health Service Drinking Water Standards, as well as with any other standards established by state, local, or other agencies.

Disinfection

Prior to use for drinking water purposes, the well should be disinfected with a chlorine compound. Sufficient disinfectant should be added to the standing water in the well to give a residual of 50 ppm free chlorine. After the disinfectant has been placed in the well, the pump should be started and stopped several times to thoroughly mix the disinfectant with the water in the well. The pump should then be stopped and not operated for a period of 24 hours. After 24 hours, the pumping should be resumed until the well is free of chlorine. The water should then be tested to see that it is free of coliform bacteria. This procedure should be repeated until the water meets the bacteriological standards prescribed by the California Department of Public Health. The quantities of some standard chlorine compounds required to provide 50 ppm of free chlorine for each 100 feet of water-filled casing are presented in Table 9.

TABLE 9

AMOUNT OF CHLORINE COMPOUNDS REQUIRED TO PROVIDE
50 PPM FREE CHLORINE FOR EACH 100 FEET OF WATER-FILLED CASING

Diameter of casing in inches	(70%) HTH, Perchloron, etc. (Dry weight)	(25%) Chloride of lime (Dry weight)	(5%) Purex, Chlorox, etc. (Liquid measure)
2	1/4 ounce	1/2 ounce	2 ounces
4	1 ounce	2 ounces	9 ounces
6	2 ounces	4 ounces	20 ounces
8	3 ounces	7 ounces	2-1/8 pints
10	4 ounces	11 ounces	3-1/2 pints
12	6 ounces	1 pound	5 pints
16	10 ounces	1-3/4 pounds	1 gallon
20	1 pound	3 pounds	1-2/3 gallons
24	1-1/2 pounds	4 pounds	2-1/3 gallons

Note: It is suggested that where wells to be treated are of unknown depth or volume, at least one pound of 70% available chlorine or two gallons of household bleach such as Clorox or Purex (5% chlorine) should be added in lieu of the use of the above table.

Specific Water Well Construction Standards

All construction standards previously described under "General Water Well Construction Standards" should universally apply and in addition, the following specific construction standards for the individual zones within the West Coast Basin should apply.

Santa Monica Bay Coastal Area - Zone 1

To minimize any further deterioration of ground water, all future water wells constructed in Zone 1 should employ a surface seal to prevent the entrance of surface water into underlying aquifers through the well opening. The complete fulfillment of all requirements listed under general construction standards should be considered as the minimum specific water well construction standards in Zone 1.

Inland Area - Zone 2

In addition to meeting all requirements set forth under general construction standards, all future water wells constructed in Zone 2 should employ an effective seal in the annular space from the top of the Gage aquifer or the Gardena aquifer to the ground surface. The approximate contours on the top of the Gage aquifer and the Gardena aquifer are shown on Plate 7.

Los Angeles River Area - Zone 3

As a result of the rather complex geology, and the difference in quality of waters found in the various aquifers within the Los Angeles River area, three cases for well construction have been derived which are dependent upon well location, aquifer or aquifers penetrated, and producing aquifer or aquifers. The use of information from Plates 5, 6, and 8 is required to determine the applicable case. These plates show contours on top of the Gaspur aquifer, Gage aquifer, and the Lower Sealing Horizon in Dominguez Gap, respectively. All future water wells constructed in Zone 3 should conform to the specific recommendations set forth under any one or a combination of cases described in the following paragraphs.

Case I - Wells Producing from the Gaspur Aquifer or from the Merged Gaspur and Gage Aquifers. All future water wells constructed to produce from these aquifers should comply with the general construction standards. In addition, an impervious seal should be placed in the annular space extending from the top of the Gaspur aquifer or the merged Gaspur and Gage aquifers to the ground surface. The approximate contours on the top of the Gaspur aquifer and the merged Gaspur and Gage aquifers are shown on Plate 5. If a well is perforated in the merged Gaspur and Gage aquifers it should not be perforated in any underlying aquifer.

Case II - Wells Producing from the Gage Aquifer. All future water wells constructed to produce from the Gage aquifer should comply with the general construction standards. In addition, an impervious seal should be placed in the annular space from the top of the Gage aquifer to the ground surface. The approximate contours on the top of this aquifer are shown on Plate 6.

Case III - Wells Producing from Lynwood and Silverado Aquifers. All future water wells constructed to produce from the Lynwood and Silverado aquifers should comply with the general construction standards. In addition, an impervious seal should be placed in the annular space from the ground surface to 10 feet below the top of the "lower sealing horizon." The approximate contours on the top of this horizon are shown on Plate 8. Wells perforated in the lower Pleistocene aquifers should not be perforated in the overlying Gage, Gaspur, or semiperched aquifers.

General Sealing Standards for Water Well Destruction

As discussed in Chapter IV, wells may provide a pathway for the transmission of ground water from one aquifer to another in the West Coast Basin. When a well no longer serves a useful purpose, or has fallen into such a state of disuse and disrepair that it may become a source of impairment to ground water quality, it should be properly sealed and destroyed in order to prevent such impairment. As used in this section, sealing refers to plugging or filling a well with impervious material such as portland cement grout. A properly destroyed well that has been adequately sealed is illustrated in Figure 6.

Prior to destroying any well, either the Los Angeles County Flood Control District, the United States Geologic Survey, Ground Water Branch, or the California Department of Water Resources should be contacted. In this manner, these agencies would be afforded the opportunity of considering the well for possible monitoring of ground water conditions.

The following general procedures for sealing wells which are to be destroyed should be utilized in all zones of the West Coast Basin, but should be supplemented by specific sealing standards where required. The specific sealing standards applicable to water well destruction are presented in the next section.

FIGURE 6

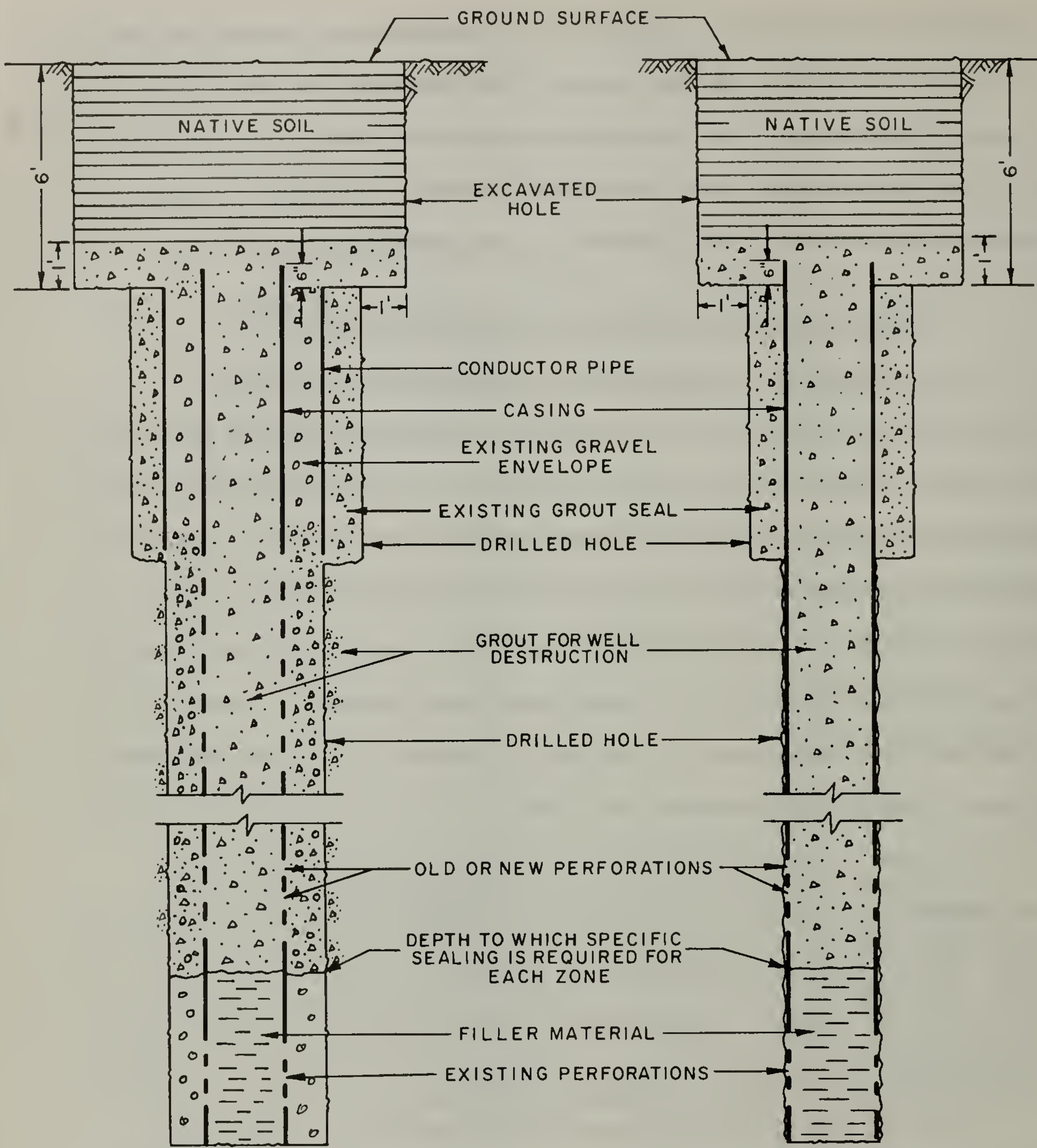


FIG. 6 (a) WELL WITH GRAVEL PACK

FIG. 6 (b) WELL WITHOUT GRAVEL PACK

NOT TO SCALE

TYPICAL SEALING FEATURES OF DESTROYED WELLS

(1) When a well is to be destroyed, the interior of the casing should first be cleaned out to eliminate any obstructions which might interfere with effective sealing procedures. After cleaning, the entire reach to be sealed, from ground surface to the minimum depth required in each zone, should be free of all extraneous materials and obstructions.

(2) The open well should then be filled with impervious filler material from the bottom of the well up to 50 feet below the ground surface or to the minimum depth required for each zone. The filler material may be portland cement grout, impervious native soil, clay, or other suitable impervious material.

(3) If there is an annular space or if its occurrence between the drilled hole and the well casing is unknown, the casing should be ripped or perforated upward, commencing just above the top of this impervious filler material for a distance of approximately five feet. A grouting pipe should be placed inside the well casing and a packer should be installed above the rips or perforations. Portland cement grout should be applied through the rips or perforations by a pressure grouting method until a grout plug forms in the annular space. After the grout has set, the well casing should be perforated at a higher point and the pressure grouting operation repeated until grout returns to the ground surface through the annular space between the drilled hole and the well casing. If the annular sealing operation is not successful, that is, if the grout does not

return to the ground surface, the casing should be ripped or perforated from the top of the upper packer to the ground surface. The annular space and casing should then be filled with portland cement grout by a pressure grouting method. This procedure should apply also to the annular space between a conductor pipe and well casing. If an annular space exists between the drilled hole and the conductor pipe it should also be sealed. If the annular space is restricted, the grouting pipe may be jetted in place.

(4) If a well does not have an annular space between the drilled hole and the casing, the casing should be filled with portland cement grout from the top of the filler material to the top of the casing using a dump bailer, grouting pipe, or similar means. The sealing material should be applied continuously, beginning at the top of the filler material and moving upward to the top of the well casing.

(5) If the annular space of a well has previously been sealed with a sealing material such as portland cement grout during well construction, the seal need not be disturbed. However, if possible, the seal should be inspected to ensure that it conforms with the standards presented in this report. The annular seal should be extended and the well filled with portland cement grout to the depth required for each zone.

(6) Where the maximum depth of a well being destroyed is less than 50 feet, the sealing standards apply to its maximum depth.

(7) For the protection of the seal and to facilitate the future use of the well site, a hole at least one foot larger in diameter than the original drilled hole should be excavated around the outside of the well casing to a depth of six feet below the ground surface. The well casing should then be cut off six inches above the bottom of this excavation and removed. During the sealing operation, the portland cement grout used to fill the well should be allowed to spill over into the excavation and fill it for a thickness of one foot and form a cap which has a diameter of at least one foot greater than the diameter of the original drilled hole. This procedure should result in the exposed edge of the casing being covered with six inches of grout. After the sealing material has set, the excavation should be filled with native soil as shown on Figure 6.

Specific Sealing Standards for Water Well Destruction

All sealing standards previously described under "General Sealing Standards for Water Well Destruction" should universally apply, and in addition the following specific sealing standards for the individual zones within the West Coast Basin should apply.

Santa Monica Bay, Coastal Area - Zone 1

The complete accomplishment of the general sealing standards previously described to a minimum depth of at least 50 feet below the ground surface should be considered the minimum sealing standards for water wells in Zone 1.

Inland Area - Zone 2

The complete accomplishment of the general sealing standards previously described, from the top of the Gage aquifer or the Gardena aquifer to the ground surface, should be considered the minimum sealing standards for water wells in Zone 2. The approximate contours on the top of the Gage aquifer and the Gardena aquifer are shown on Plate 7.

Los Angeles River Area - Zone 3

The complete accomplishment of the general sealing standards previously described, to the depths specified for the following three cases, should be considered the minimum sealing standards for water wells in Zone 3. (The reasons for these cases were described under the section on "Specific Water Well Construction Standards".)

Case I - Wells Producing from the Gaspur Aquifer or from the Merged Gaspur and Gage Aquifer. The sealing of any water well producing from these aquifers should be from the top of the Gaspur aquifer or the top of the merged Gaspur and Gage aquifers to the ground surface. The approximate contours on the top of the Gaspur aquifer and the merged Gaspur and Gage aquifers are shown on Plate 5.

Case II - Wells Producing from the Gage Aquifer. The sealing of any water well producing from the Gage aquifer should be from the top of the Gage aquifer to the ground surface. The approximate contours on the top of this aquifer are shown on Plate 6.

Case III - Wells Producing from Lynwood and Silverado Aquifers.

The sealing of any water wells producing from the Lynwood and Silverado aquifers should be from 10 feet below the top of the "lower sealing horizon" to the ground surface. The approximate contours on the top of this horizon are shown on Plate 8.

CHAPTER VI. SUMMARY OF FINDINGS AND CONCLUSIONS, AND RECOMMENDATIONS

The findings and conclusions presented in this chapter are derived from the results of the investigation which have been presented in the previous chapters. The recommendations are based upon these findings and conclusions and emphasize the need for adopting well construction and sealing standards in the West Coast Basin.

Findings and Conclusions

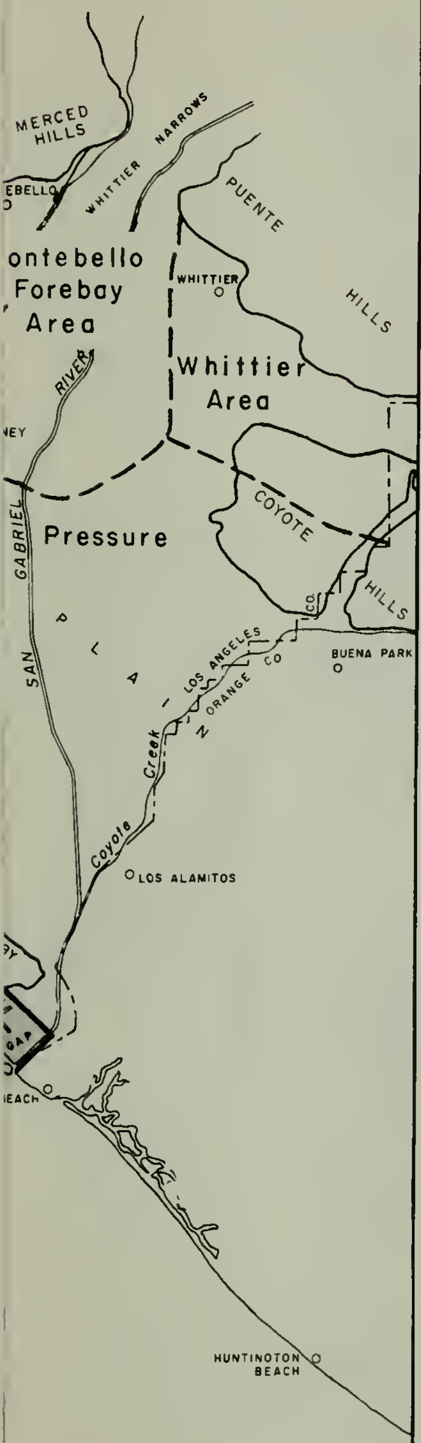
1. Ground water, extracted from underlying aquifers, is an important part of the water supply of the West Coast Basin.
2. Aquifers which occur in the West Coast Basin are generally separated and contain ground waters of varying quality. They are the semiperched, Gaspur, Gardena, Gage, Lynwood, and Silverado aquifers.
3. Generally, ground water in the various aquifers does not commingle; exceptions to this occur where the aquifers are naturally merged, as along Santa Monica Bay, or where faulty well construction or destruction permits an artificial interchange of ground water.
4. The quality of the native ground water in the shallower aquifers, such as the semiperched aquifer, has been impaired or polluted by man's activities to the extent that much of the water is presently unfit for most beneficial uses.
5. The quality of the ground water in the deep aquifers, the Lynwood and Silverado, is generally acceptable for most municipal and domestic purposes and irrigation uses, except in certain

areas where its quality has been adversely affected by the intrusion of sea water.

6. Wells which are improperly constructed or improperly destroyed may act as conduits, transmitting impaired water from the ground surface or from the shallower aquifers to the deeper aquifers.
7. The West Coast Basin can be divided into three major zones on the basis of geology and hydrology. General well construction and sealing standards to be universally applied in all areas of the basin, and unique requirements for specific construction and sealing standards to be applied in each of the major zones have been developed during this investigation to prevent the artificial interchange of ground water between aquifers.
8. Adoption of, and compliance with, the water well construction and sealing standards set forth in this report will prevent the impairment to ground water quality caused by substandard wells.

Recommendations

It is recommended that the Los Angeles Regional Water Pollution Control Board, local agencies, local water producers, and water well drillers accept these standards, and apply them in a manner that will assist them in preserving and improving the quality of the common ground water supply.



LEGEND

WEST COAST BASIN

BOUNDARY OF GROUNDWATER BASIN

BOUNDARY BETWEEN PHYSIOGRAPHIC FEATURES (DOTTED WHERE APPROXIMATE OR POORLY DEFINED)

BOUNDARY OF FOREBAY AREA

NOTE: BOUNDARY BETWEEN FOREBAY AND PRESSURE AREA FROM BULLETIN 45 (CALIF. D.W.R. 1934)

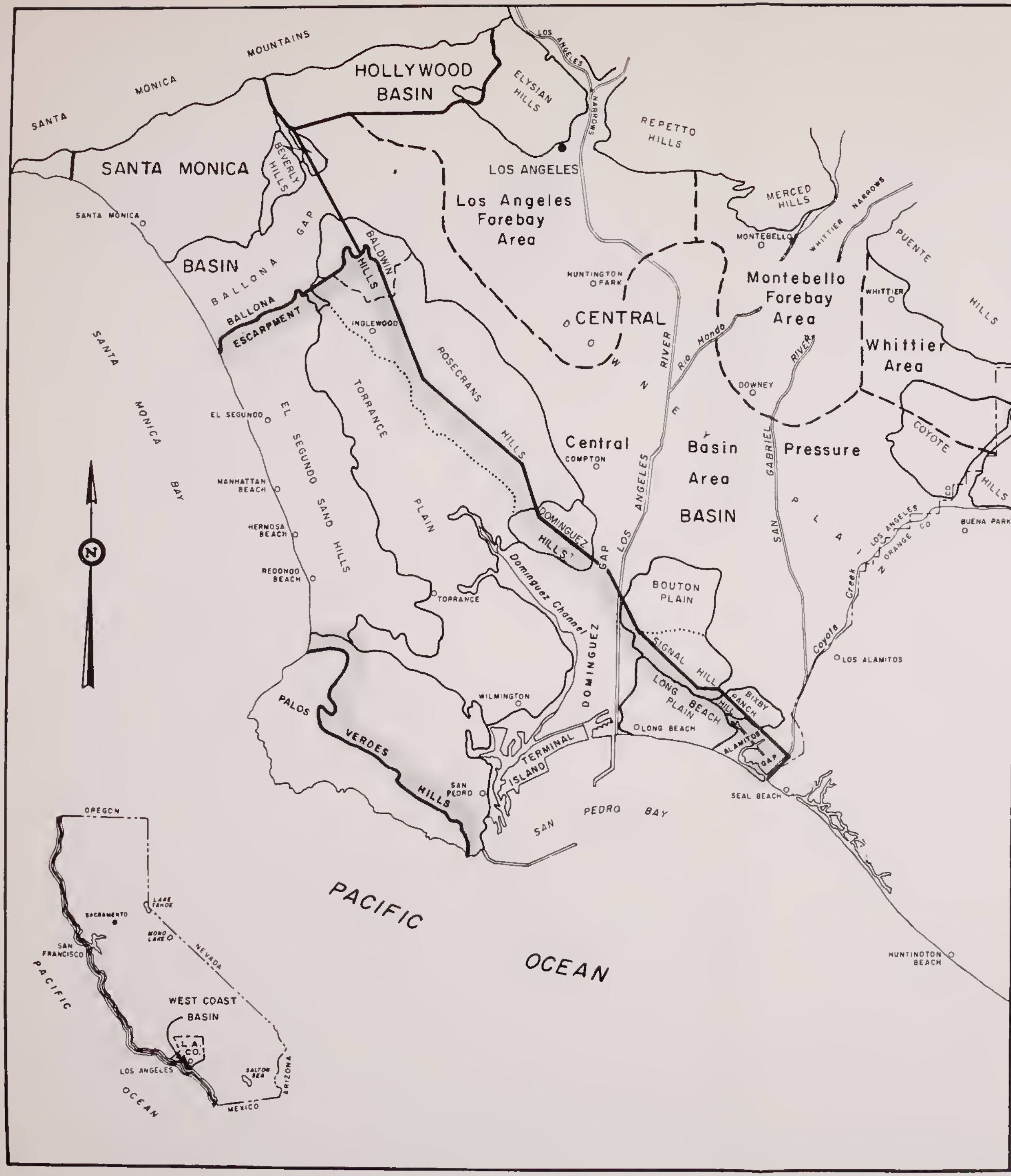
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

LOCATION AND PHYSIOGRAPHIC FEATURES IN WEST COAST BASIN

SCALE OF MILES
2 0 2 4

1962



LEGEND

- WEST COAST BASIN
- BOUNDARY OF GROUNDWATER BASIN
- BOUNDARY BETWEEN PHYSIOGRAPHIC FEATURES (DOTTED WHERE APPROXIMATE OR POORLY DEFINED)
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LOCATION AND PHYSIOGRAPHIC FEATURES IN WEST COAST BASIN

SCALE OF MILES
2 0 2 4

1962

LEGEND

SEDIMENTARY ROCKS

Period	Epoch	Subdivision	Symbol	Description
QUATERNARY	RECENT		Qal	ALLUVIUM GRAVEL, SAND, SILT, AND CLAY.
QUATERNARY	RECENT		Qsr	ACTIVE DUNE SAND WHITE OR GREYISH, WELL SORTED SAND.
QUATERNARY	PLEISTOCENE	UPPER	Qso	OLDER DUNE SAND FINE TO MEDIUM SAND WITH SILT AND GRAVEL LENSES.
QUATERNARY	PLEISTOCENE	UPPER	Qlw	LAKEWOOD FORMATION (INCLUDES "TERRACE DEPOSITS," "PALOS VERDES SAND," AND "UNNAMED UPPER PLEISTOCENE DEPOSITS") MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY WITH SHALE PEBBLES.
QUATERNARY	PLEISTOCENE	LOWER	Qsp	SAN PEDRO FORMATION MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY.
TERTIARY	PLIOCENE		Pp	PICO FORMATION MARINE SAND, SILT, AND CLAY INTERBEDDED WITH GRAVEL.
TERTIARY	PLIOCENE		Pr	REPETTO FORMATION MARINE SILTSTONE WITH LAYERS OF SANDSTONE AND CONGLOMERATE.
TERTIARY	MIOCENE		Ms	MONTEREY FORMATION MUDSTONE, DIATOMITE, AND SHALE.

IGNEOUS AND METAMORPHIC ROCKS

Period	Epoch	Symbol	Description
TERTIARY	MIOCENE	Mv	VOLCANIC ROCKS
JURASSIC		J	CATALINA SCHIST

Symbol	Explanation
U/D ——— — —	FAULT (DASHED WHERE APPROXIMATELY LOCATED)
·····U/D·······	CONCEALED FAULT
——+—— — —	ANTICLINE (DASHED WHERE APPROXIMATELY LOCATED)
——+—— — —	SYNCLINE (DASHED WHERE APPROXIMATELY LOCATED)
——— — —	CONTACT (DASHED WHERE APPROXIMATELY LOCATED)
	LANDSLIDE AREA
● A5	WATER WELL — WELL LOGS USED IN PREPARATION OF GEOLOGIC SECTIONS
✦ I-6	OIL WELL — WELL LOGS USED IN PREPARATION OF GEOLOGIC SECTIONS
A ——— A'	LINE LOCACATION OF GEOLOGIC SECTION PRESENTED ON PLATE 3

STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

AREAL GEOLOGY IN WEST COAST BASIN

SCALE OF MILES

1 1/2 0 2 3

1962

LEGEND

SEDIMENTARY ROCKS

QUATERNARY — RECENT

Qal — ALLUVIUM
GRAVEL, SAND, SILT, AND CLAY

Qsr — ACTIVE DUNE SAND
WHITE OR GREYISH, WELL SORTED SAND

QUATERNARY — PLEISTOCENE — UPPER

Qso — OLDER DUNE SAND
FINE TO MEDIUM SAND WITH SILT AND GRAVEL LENSES

Qlw — LAKEWOOD FORMATION (INCLUDES "TERRACE DEPOSITS," "PALOS VERDES SAND," AND "UNNAMED UPPER PLEISTOCENE DEPOSITS")
MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY WITH SHALE PEBBLES.

QUATERNARY — PLEISTOCENE — LOWER

Qsp — SAN PEDRO FORMATION
MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY.

TERTIARY — PLIOCENE

Pp — PICO FORMATION
MARINE SAND, SILT, AND CLAY INTERBEDDED WITH GRAVEL

Pr — REPETTO FORMATION
MARINE SILTSTONE WITH LAYERS OF SANDSTONE AND CONGLOMERATE.

TERTIARY — MIOCENE

Ms — MONTEREY FORMATION
MUDSTONE, DIATOMITE, AND SHALE.

IGNEOUS AND METAMORPHIC ROCKS

TERTIARY — MIOCENE

Mv — VOLCANIC ROCKS

JURASSIC

J — CATALINA SCHIST

U/D — FAULT (DASHED WHERE APPROXIMATELY LOCATED)

U/D — CONCEALED FAULT

ANTICLINE (DASHED WHERE APPROXIMATELY LOCATED)

SYNCLINE (DASHED WHERE APPROXIMATELY LOCATED)

CONTACT (DASHED WHERE APPROXIMATELY LOCATED)

LANDSLIDE AREA

● A5 — WATER WELL
✦ 1-6 — OIL WELL
WELL LOGS USED IN PREPARATION OF GEOLOGIC SECTIONS

A — A' — LINE LOCACATION OF GEOLOGIC SECTION PRESENTED ON PLATE 3

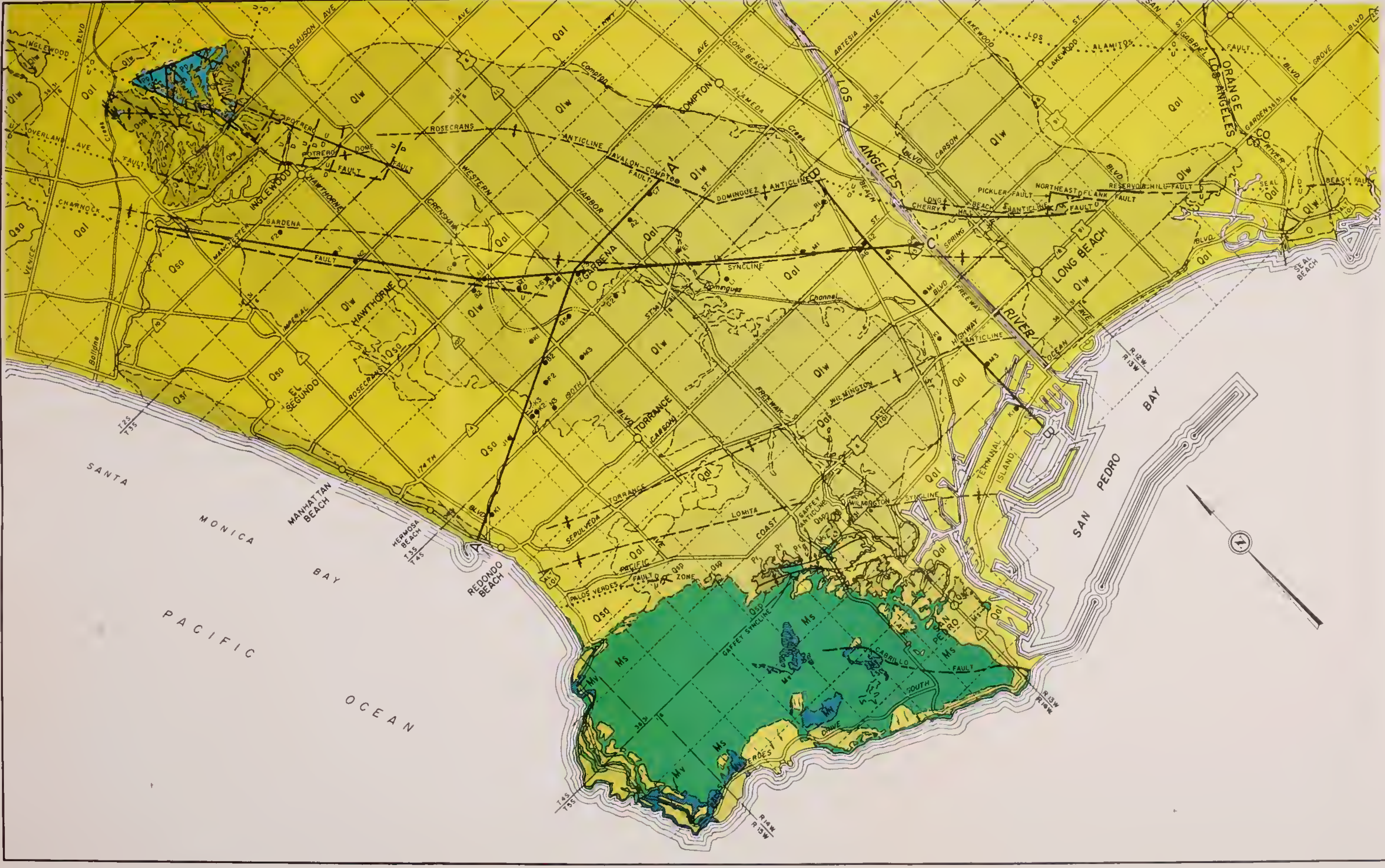
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

AREAL GEOLOGY IN WEST COAST BASIN

SCALE OF MILES
1 1/2 0 2 3

1962



LEGEND

SEDIMENTARY ROCKS

QUATERNARY — RECENT

- **Qal** — ALLUVIUM: GRAVEL, SAND, SILT, AND CLAY
- **Qsr** — ACTIVE DUNE SAND: WHITE OR GREYISH, WELL SORTED SAND

QUATERNARY — PLEISTOCENE — UPPER

- **Qso** — OLDER DUNE SAND: FINE TO MEDIUM SAND WITH SILT AND GRAVEL LENSES
- **Qlw** — LAKEWOOD FORMATION (INCLUDES "TERRACE DEPOSITS," "PALOS VERDES SAND," AND "UNNAMED UPPER PLEISTOCENE DEPOSITS"): MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY WITH SHALE PEBBLES

QUATERNARY — PLEISTOCENE — LOWER

- **Qsp** — SAN PEDRO FORMATION: MARINE AND CONTINENTAL GRAVEL, SAND, SANDY SILT, SILT, AND CLAY

TERTIARY — PLIOCENE

- **Pp** — PICO FORMATION: MARINE SAND, SILT AND CLAY INTERBEDDED WITH GRAVEL
- **Pr** — REPETTO FORMATION: MARINE SILTSTONE WITH LAYERS OF SANDSTONE AND CONGLOMERATE

TERTIARY — MIOCENE

- **Ms** — MONTEREY FORMATION: MUDSTONE, DIATOMITE, AND SHALE

IGNEOUS AND METAMORPHIC ROCKS

TERTIARY — MIOCENE

- **Mv** — VOLCANIC ROCKS

JURASSIC

- **J** — CATALINA SCHIST

- FAULT (DASHED WHERE APPROXIMATELY LOCATED) (U / D)
- CONCEALED FAULT (U / D)
- ANTICLINE (DASHED WHERE APPROXIMATELY LOCATED)
- SYNCLINE (DASHED WHERE APPROXIMATELY LOCATED)
- CONTACT (DASHED WHERE APPROXIMATELY LOCATED)
- LANDSLIDE AREA
- ● A5 WATER WELL; ✦ 1-6 OIL WELL — WELL LOGS USED IN PREPARATION OF GEOLOGIC SECTIONS
- A —— A' LINE LOCATION OF GEOLOGIC SECTION PRESENTED ON PLATE 3

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

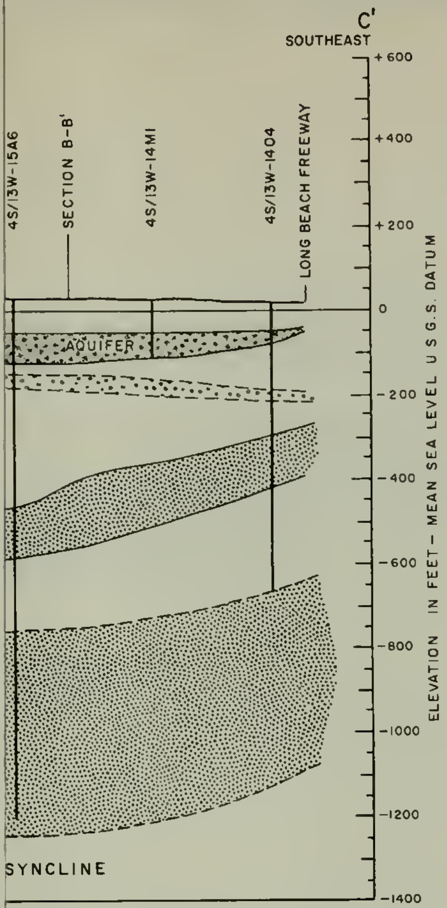
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

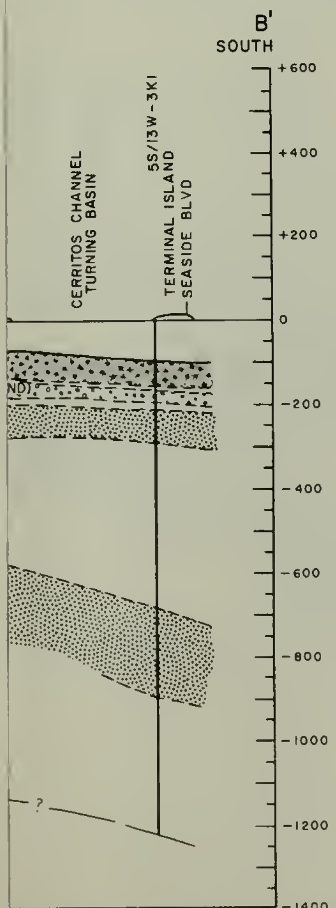
AREAL GEOLOGY IN WEST COAST BASIN

SCALE OF MILES

1 1/2 0 2 3

1962





LEGEND

- AQUICLUDES AND UNDIFFERENTIATED SEDIMENTS
- GASPUR AQUIFER IN THE RECENT ALLUVIUM
- GAGE AND GARDENA AQUIFERS IN THE LAKEWOOD FORMATION
- LYNWOOD AND SILVERADO AQUIFERS IN THE SAN PEDRO FORMATION
- WATER WELL
- OIL WELL
- FAULT

NOTE: LOCATIONS OF GEOLOGIC SECTIONS ARE SHOWN ON PLATE 2

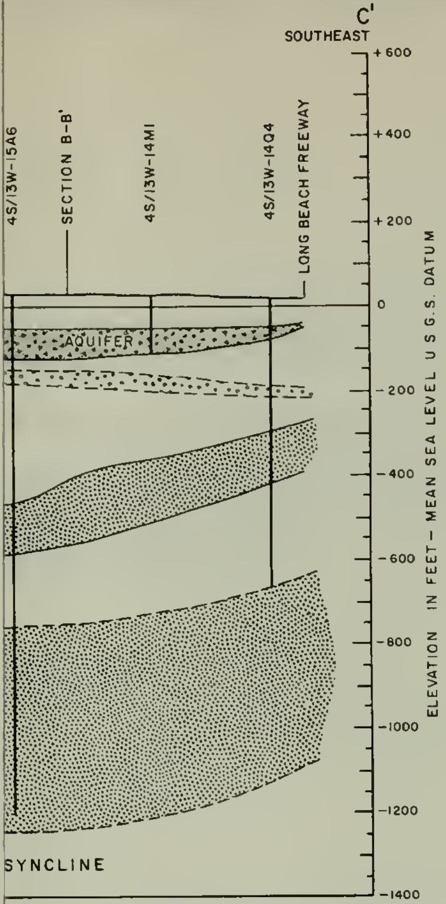
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

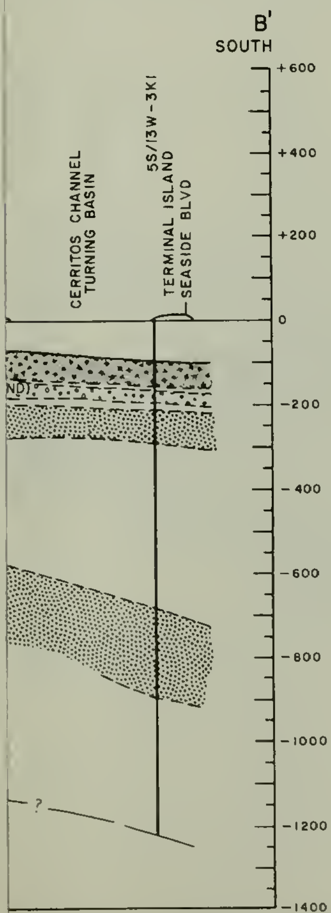
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

GENERALIZED GEOLOGIC SECTIONS A-A', B-B', AND C-C' IN WEST COAST BASIN

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1962





LEGEND

AQUICLUDES AND UNDIFFERENTIATED SEDIMENTS

GASPUR AQUIFER IN THE RECENT ALLUVIUM

GAGE AND GARDENA AQUIFERS IN THE LAKEWOOD FORMATION

LYNWOOD AND SILVERADO AQUIFERS IN THE SAN PEDRO FORMATION

WATER WELL

OIL WELL

FAULT

NOTE: LOCATIONS OF GEOLOGIC SECTIONS ARE SHOWN ON PLATE 2

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

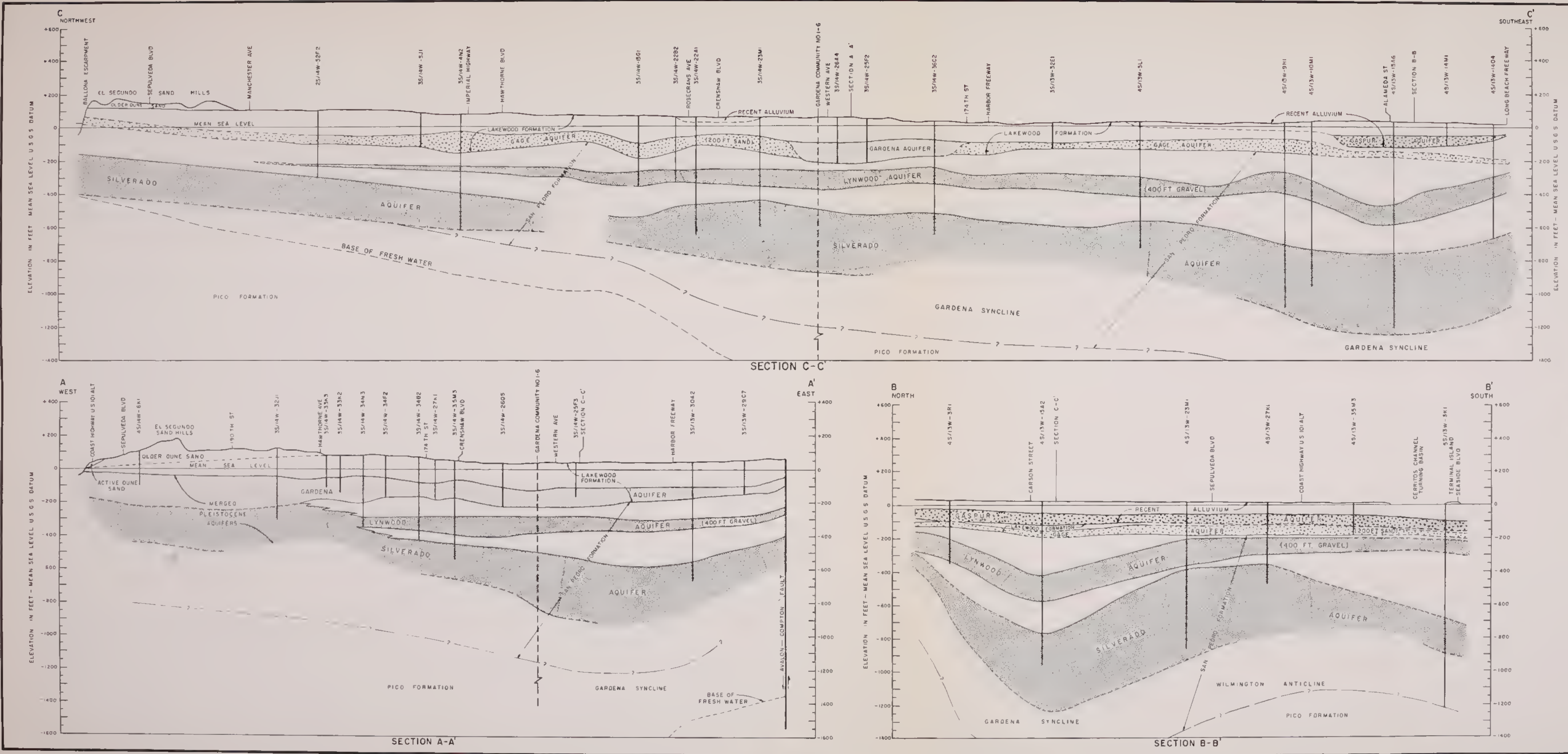
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

GENERALIZED GEOLOGIC SECTIONS A-A', B-B', AND C-C' IN WEST COAST BASIN

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1962

PLATE 3



LEGEND

- AQUICLUDES AND UNDIFFERENTIATED SEDIMENTS
- GASPUR AQUIFER IN THE RECENT ALLUVIUM
- GAGE AND GARDENA AQUIFERS IN THE LAKEWOOD FORMATION
- LYNWOOD AND SILVERADO AQUIFERS IN THE SAN PEDRO FORMATION
- WATER WELL
- OIL WELL
- FAULT

NOTE: LOCATIONS OF GEOLOGIC SECTIONS ARE SHOWN ON PLATE 2

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

GENERALIZED GEOLOGIC SECTIONS A-A', B-B', AND C-C' IN WEST COAST BASIN

HORIZONTAL SCALE OF FEET
2000 0 2000 4000 6000

1962

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

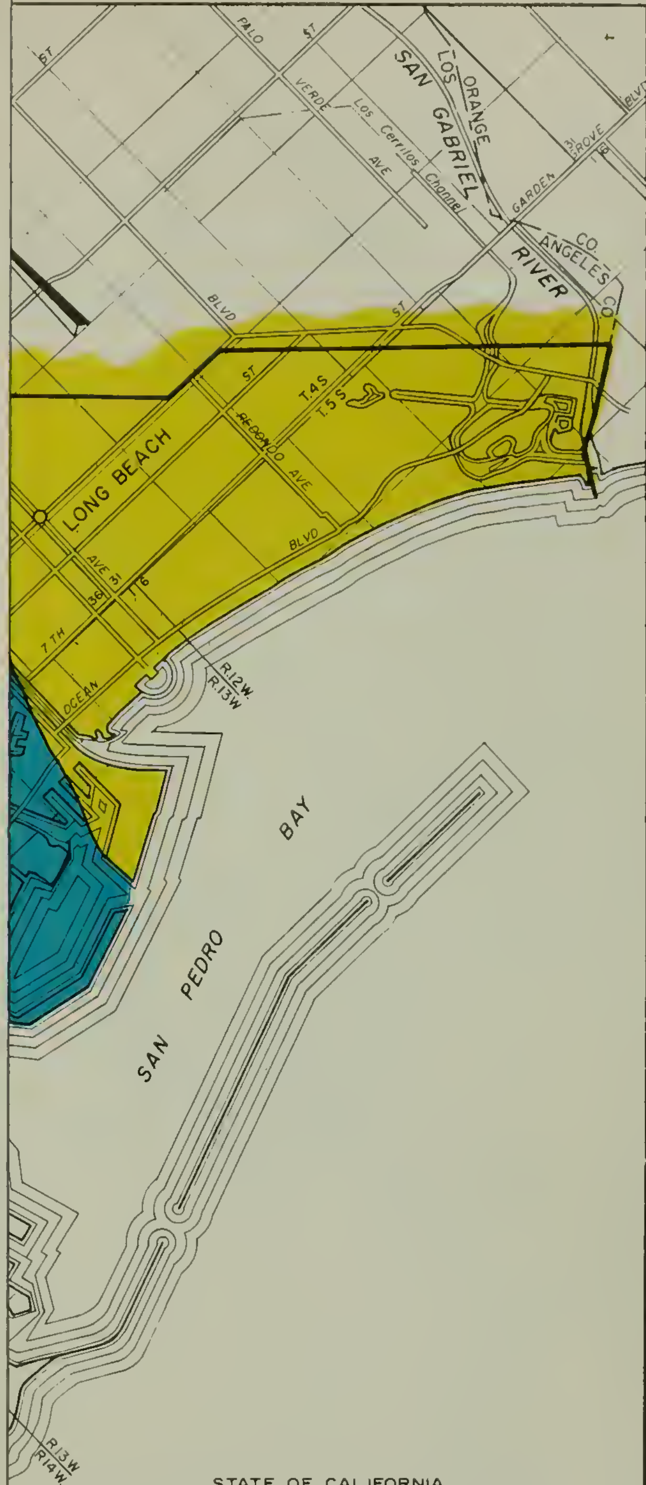
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

AREAL EXTENT OF THE GAGE, GARDENA, AND GASPUR AQUIFERS IN WEST COAST BASIN

SCALE OF MILES
1 0 1 2

1962

PLATE 4



STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

SOUTHERN DISTRICT

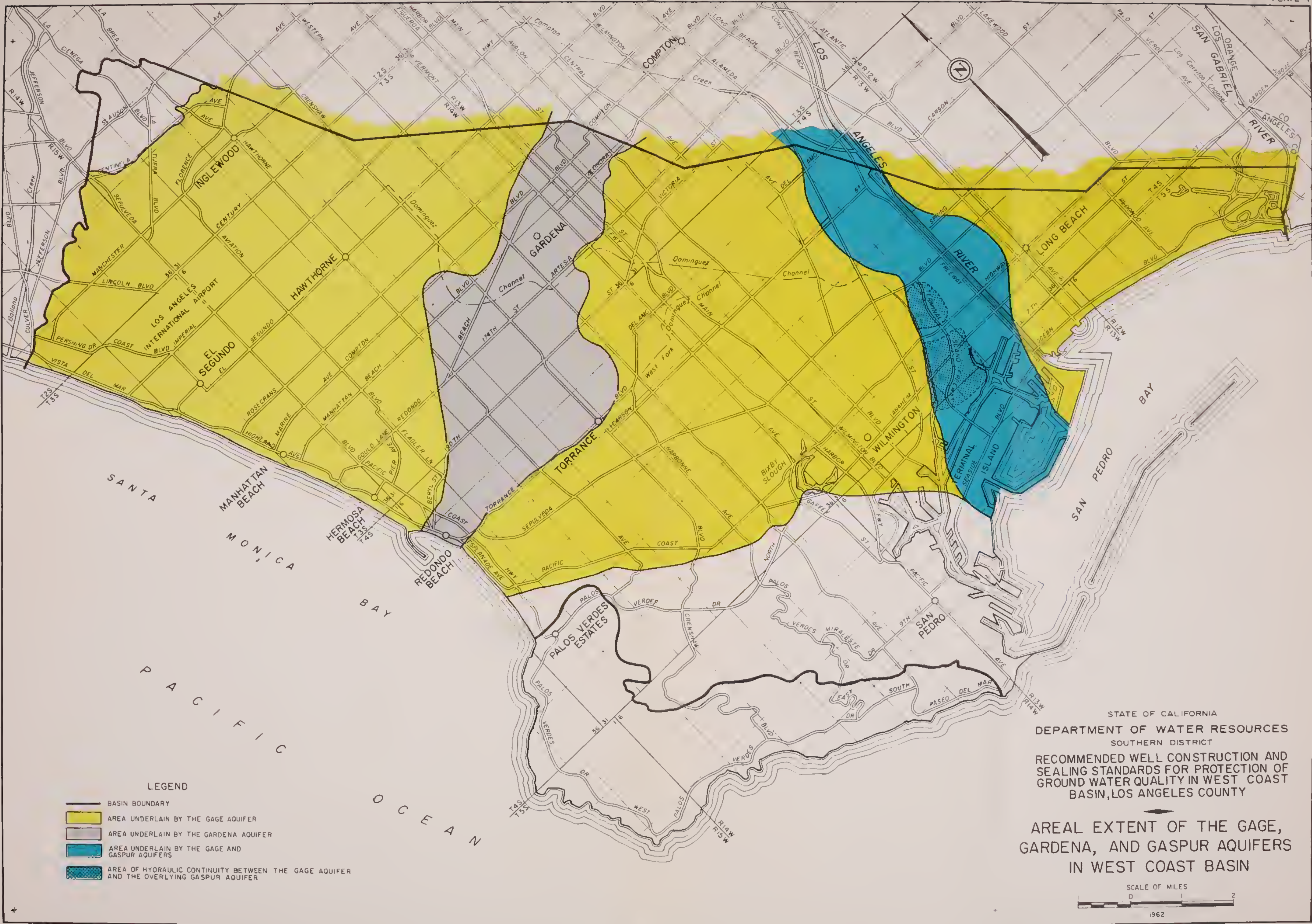
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

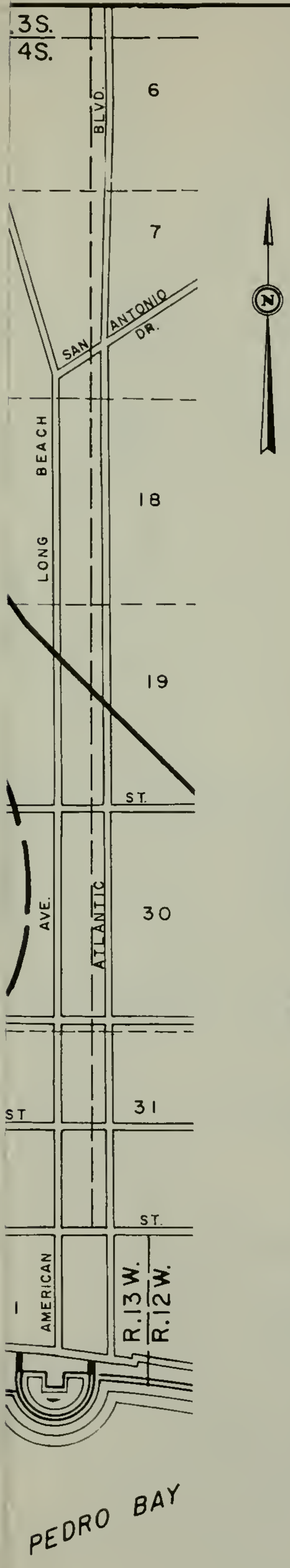
AREAL EXTENT OF THE GAGE, GARDENA, AND GASPUR AQUIFERS IN WEST COAST BASIN

SCALE OF MILES

1 0 1 2

1962


LEGEND
BASIN BOUNDARY
AREA UNDERLAIN BY THE GAGE AQUIFER
AREA UNDERLAIN BY THE GARDENA AQUIFER
AREA UNDERLAIN BY THE GAGE AND GASPUR AQUIFERS
AREA OF HYDRAULIC CONTINUITY BETWEEN THE GAGE AQUIFER AND THE OVERLYING GASPUR AQUIFER
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY
AREAL EXTENT OF THE GAGE, GARDENA, AND GASPUR AQUIFERS IN WEST COAST BASIN
SCALE OF MILES
0
1
2
1962
INGLEWOOD
HAWTHORNE
EL SEGUNDO
LOS ANGELES INTERNATIONAL AIRPORT
GARDENA
COMPTON
TORRANCE
WILMINGTON
LONG BEACH
MANHATTAN BEACH
HERMOSA BEACH
REDONDO BEACH
PALOS VERDES ESTATES
SAN PEDRO
SANTA MONICA BAY
PACIFIC OCEAN
SAN PEDRO BAY
LOS ANGELES RIVER
SAN GABRIEL RIVER
TERMINAL ISLAND



LEGEND

BASIN BOUNDARY

BOUNDARY OF THE GASPUR AQUIFER

—60— APPROXIMATE CONTOURS ON THE TOP OF THE GASPUR AQUIFER

AREA OF HYDRAULIC CONTINUITY BETWEEN THE GASPUR AQUIFER AND THE UNDERLYING GAGE AQUIFER

NOTE: CONTOURS ARE REFERENCED TO MEAN SEA LEVEL U.S.G.S. DATUM

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

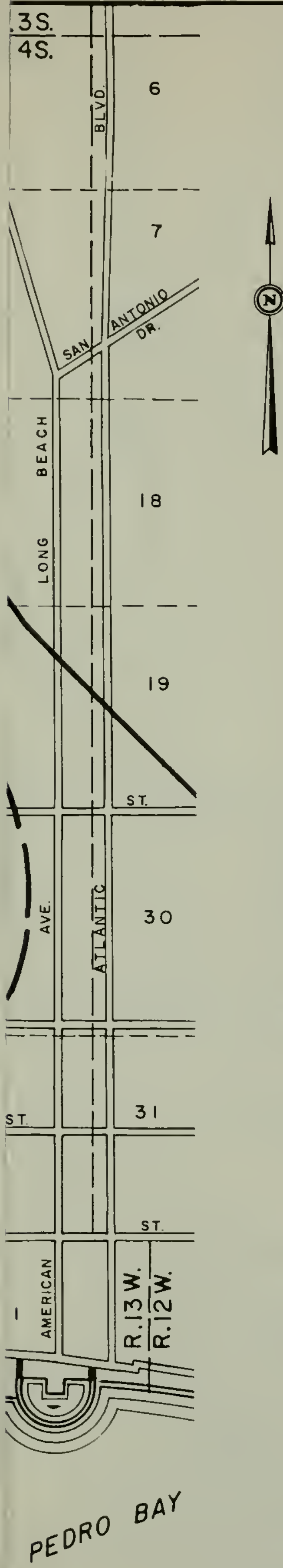
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE GASPUR AQUIFER IN DOMINGUEZ GAP, WEST COAST BASIN

SCALE OF MILES

1/2 0

1962



LEGEND

- BASIN BOUNDARY
- BOUNDARY OF THE GASPUR AQUIFER
- —60— APPROXIMATE CONTOURS ON THE TOP OF THE GASPUR AQUIFER
- AREA OF HYDRAULIC CONTINUITY BETWEEN THE GASPUR AQUIFER AND THE UNDERLYING GAGE AQUIFER

NOTE: CONTOURS ARE REFERENCED TO MEAN SEA LEVEL U.S.G.S. DATUM

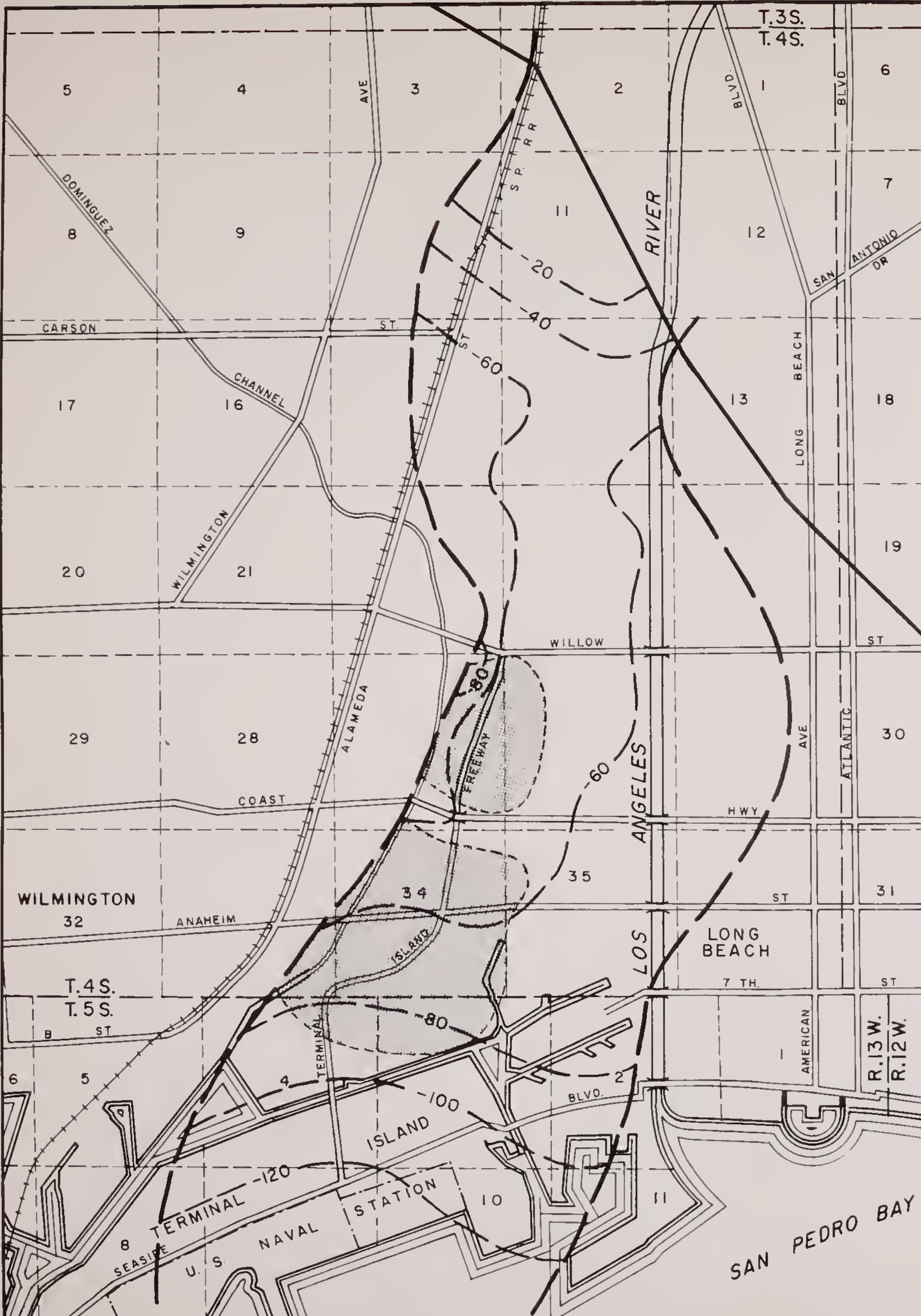
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE GASPUR AQUIFER IN DOMINGUEZ GAP, WEST COAST BASIN

SCALE OF MILES
1/2 0

1962



LEGEND

BASIN BOUNDARY

BOUNDARY OF THE GASPUR AQUIFER

-60 APPROXIMATE CONTOURS ON THE TOP OF THE GASPUR AQUIFER

AREA OF HYDRAULIC CONTINUITY BETWEEN THE GASPUR AQUIFER AND THE UNDERLYING GAGE AQUIFER

NOTE. CONTOURS ARE REFERENCED TO MEAN SEA LEVEL USGS DATUM

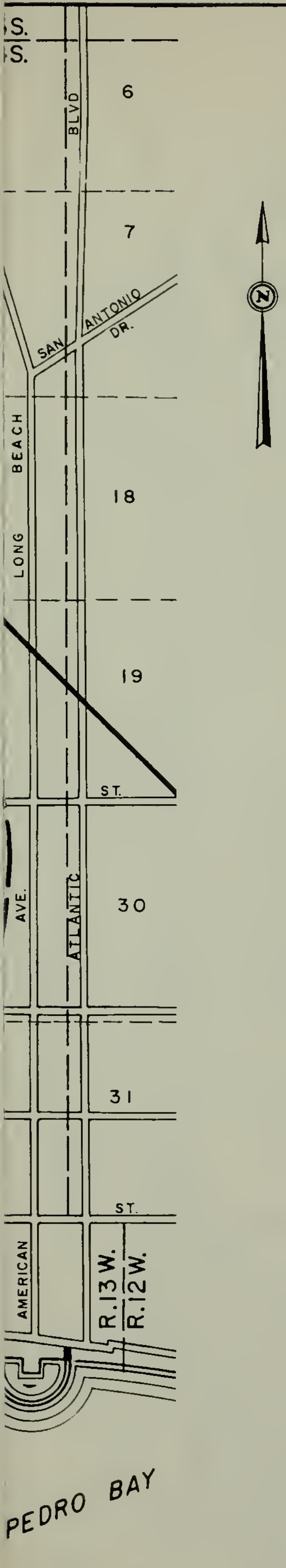
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE GASPUR AQUIFER IN DOMINGUEZ GAP, WEST COAST BASIN

SCALE OF MILES
1/2 0 1

1962



LEGEND

BASIN BOUNDARY

BOUNDARY OF THE GASPUR AQUIFER

—— -140 —— APPROXIMATE CONTOURS ON THE TOP OF THE GAGE AQUIFER

AREA OF HYDRAULIC CONTINUITY BETWEEN THE GAGE AQUIFER AND THE OVERLYING GASPUR AQUIFER

NOTE: CONTOURS ARE REFERENCED TO MEAN SEA LEVEL U.S.G.S. DATUM.

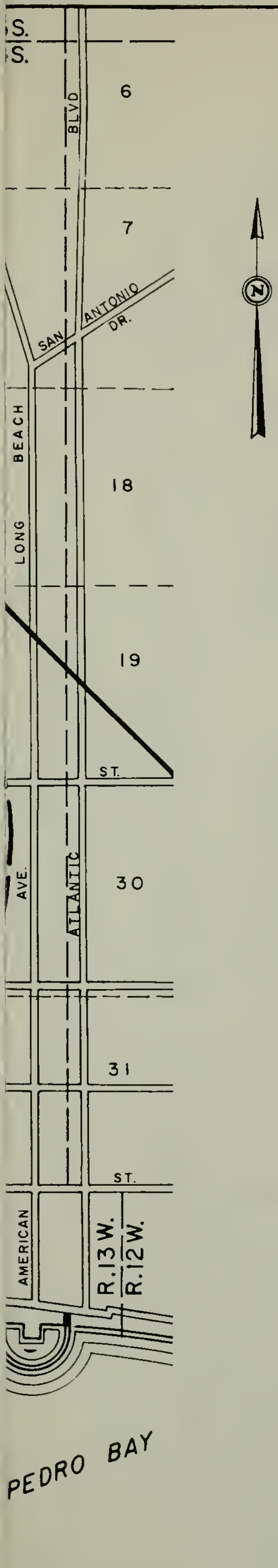
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE GAGE AQUIFER IN DOMINGUEZ GAP, WEST COAST BASIN

SCALE OF MILES
1/2 0 1

1962



LEGEND

BASIN BOUNDARY

BOUNDARY OF THE GASPUR AQUIFER

—— -140 —— APPROXIMATE CONTOURS ON THE TOP OF THE GAGE AQUIFER

AREA OF HYDRAULIC CONTINUITY BETWEEN THE GAGE AQUIFER AND THE OVERLYING GASPUR AQUIFER

NOTE: CONTOURS ARE REFERENCED TO MEAN SEA LEVEL U.S.G.S. DATUM.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

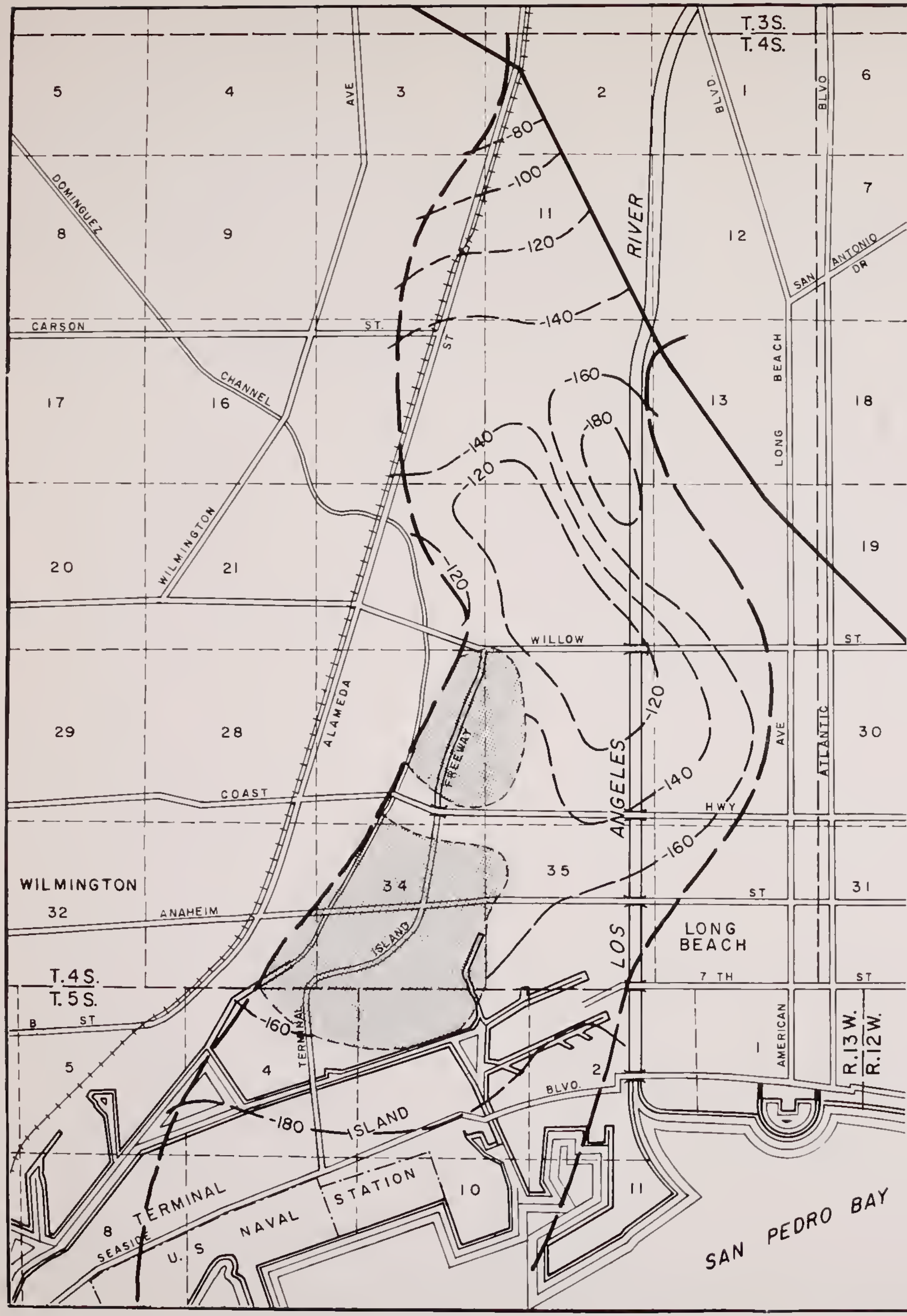
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE GAGE AQUIFER IN DOMINGUEZ GAP, WEST COAST BASIN

SCALE OF MILES
1/2 0

1962

PLATE 6



LEGEND

- BASIN BOUNDARY
- BOUNDARY OF THE GASPUR AQUIFER
- -140 APPROXIMATE CONTOURS ON THE TOP OF THE GAGE AQUIFER
- AREA OF HYDRAULIC CONTINUITY BETWEEN THE GAGE AQUIFER AND THE OVERLYING GASPUR AQUIFER

NOTE CONTOURS ARE REFERENCED TO MEAN SEA LEVEL USGS DATUM

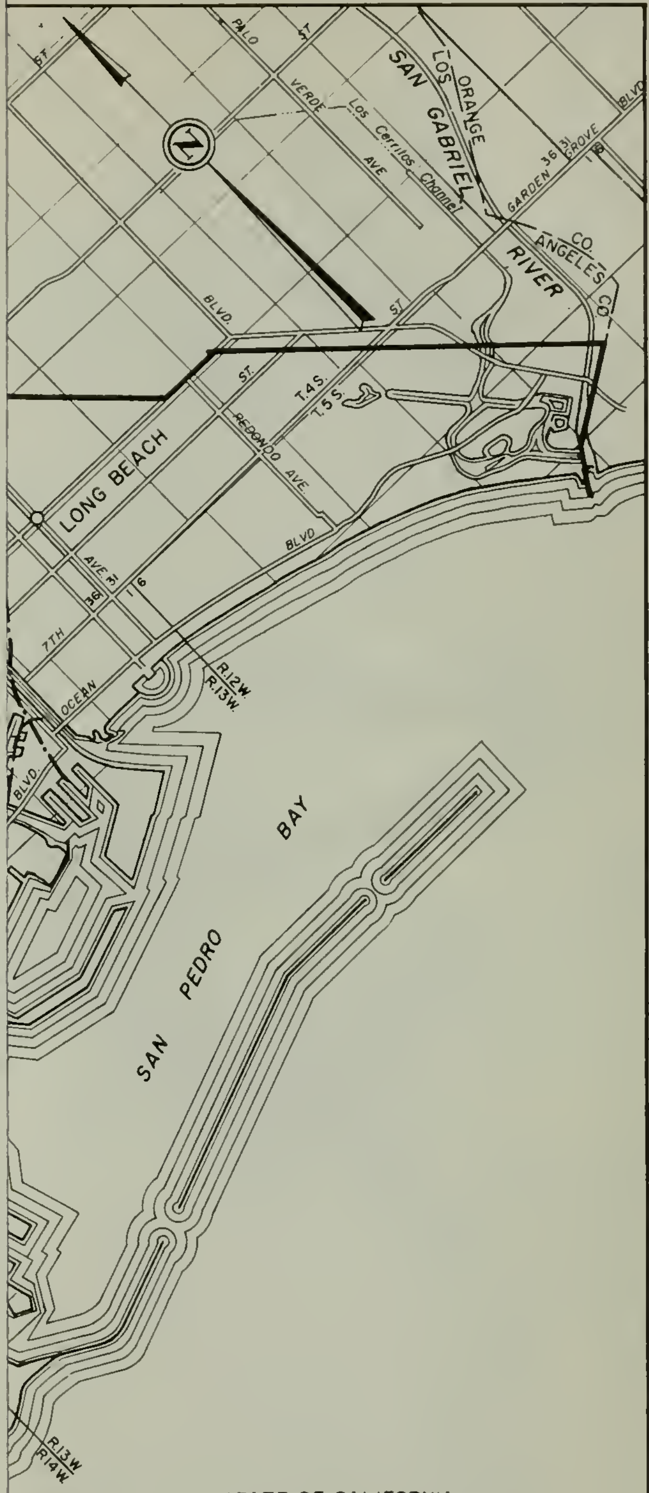
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE GAGE AQUIFER IN DOMINGUEZ GAP, WEST COAST BASIN

SCALE OF MILES
1/2 0

1962



STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

SOUTHERN DISTRICT

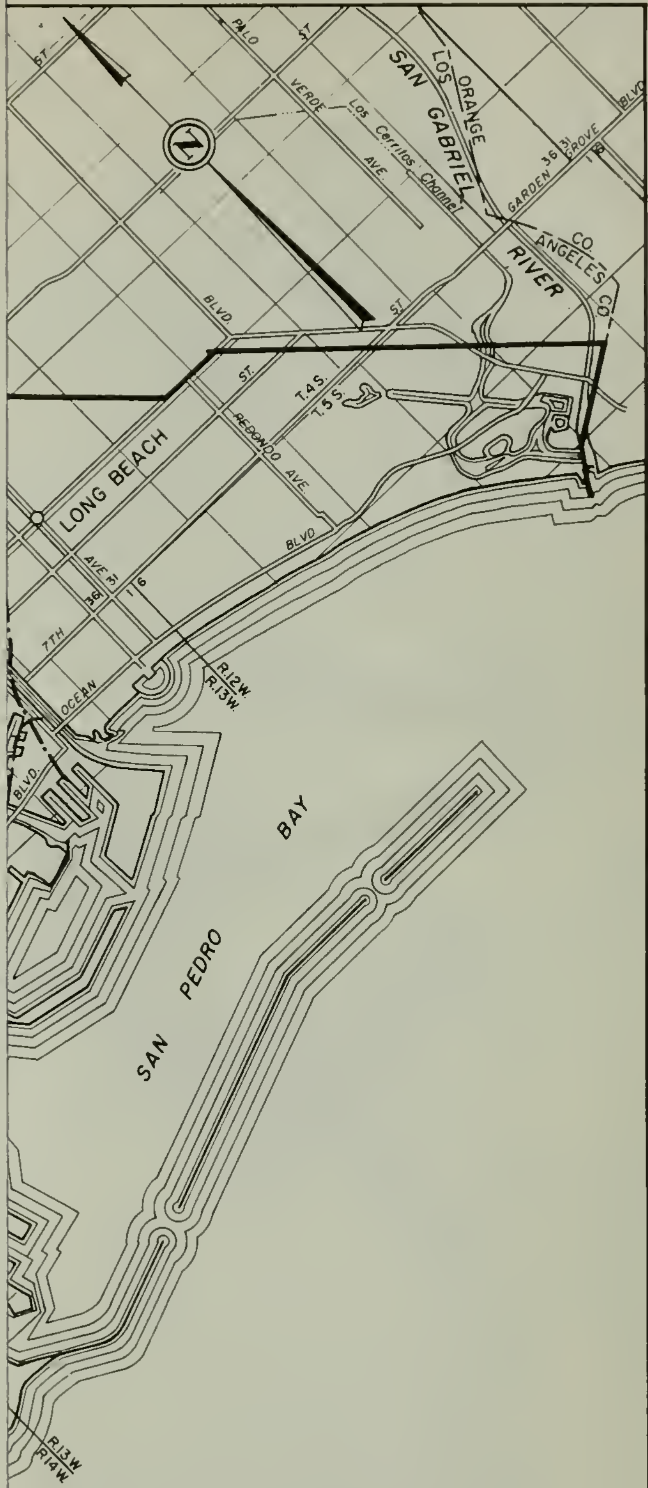
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE GAGE AND GARDENA AQUIFERS IN WEST COAST BASIN

SCALE OF MILES

1 0 1 2

1962



STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

SOUTHERN DISTRICT

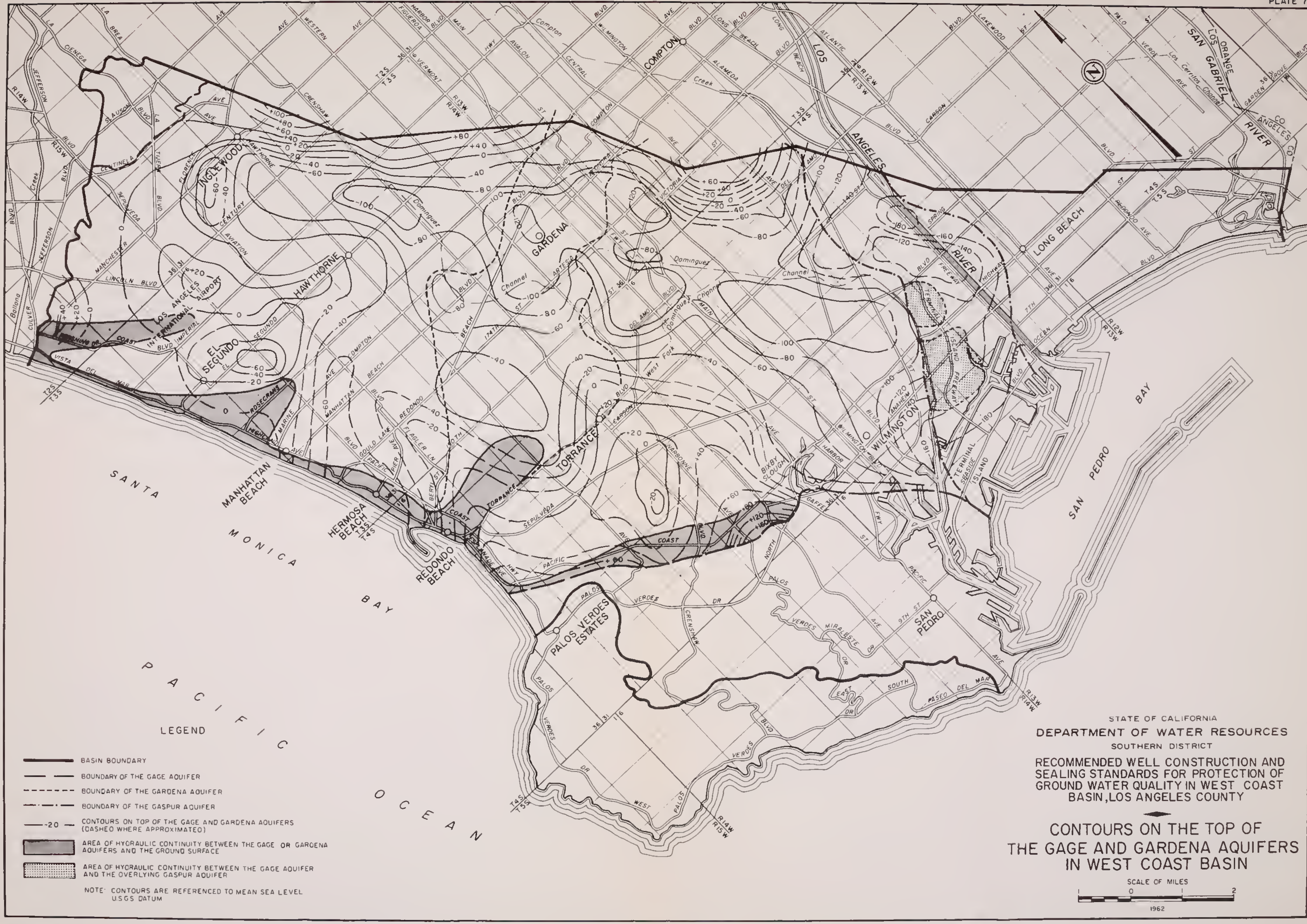
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE GAGE AND GARDENA AQUIFERS IN WEST COAST BASIN

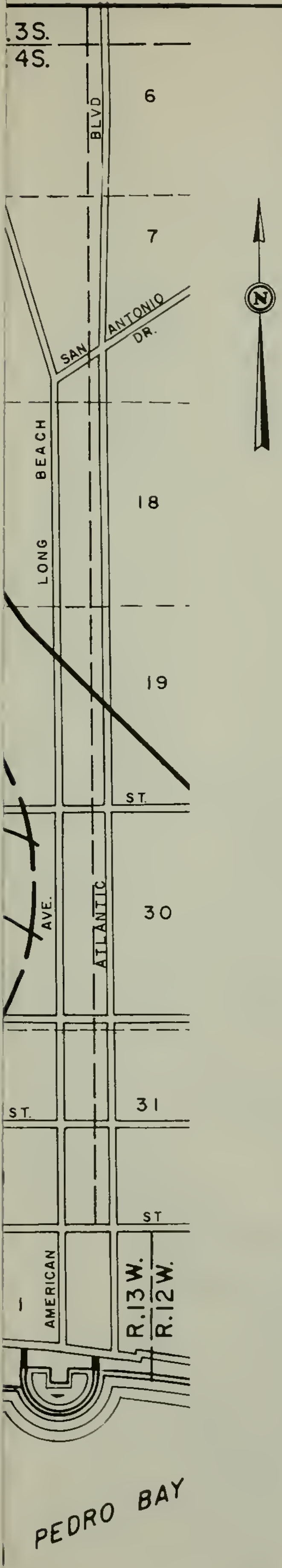
SCALE OF MILES

1 0 1 2

1962



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY
CONTOURS ON THE TOP OF THE GAGE AND GARDENA AQUIFERS IN WEST COAST BASIN
SCALE OF MILES
1 0 1 2
1962
LEGEND
BASIN BOUNDARY
BOUNDARY OF THE GAGE AQUIFER
BOUNDARY OF THE GARDENA AQUIFER
BOUNDARY OF THE GASPUR AQUIFER
-20 CONTOURS ON TOP OF THE GAGE AND GARDENA AQUIFERS (DASHED WHERE APPROXIMATED)
AREA OF HYDRAULIC CONTINUITY BETWEEN THE GAGE OR GARDENA AQUIFERS AND THE GROUND SURFACE
AREA OF HYDRAULIC CONTINUITY BETWEEN THE GAGE AQUIFER AND THE OVERLYING GASPUR AQUIFER
NOTE: CONTOURS ARE REFERENCED TO MEAN SEA LEVEL U.S.G.S. DATUM
PACIFIC OCEAN
SANTA MONICA BAY
SAN PEDRO BAY
INGLEWOOD
HAWTHORNE
EL SEGUNDO
LOS ANGELES INTERNATIONAL AIRPORT
MANHATTAN BEACH
HERMOSA BEACH
REDONDO BEACH
GARDENA
TORRANCE
COMPTON
LONG BEACH
WILMINGTON
SAN PEDRO
PALOS VERDES ESTATES
TERMINAL ISLAND
LOS ANGELES RIVER
SAN GABRIEL RIVER
LOS ANGELES CO.
ORANGE CO.



LEGEND

BASIN BOUNDARY

BOUNDARY OF THE GASPUR AQUIFER

—160— APPROXIMATE CONTOURS ON THE TOP OF THE LOWER SEALING HORIZON

NOTE: CONTOURS ARE REFERENCED TO MEAN SEA LEVEL U.S.G.S DATUM.

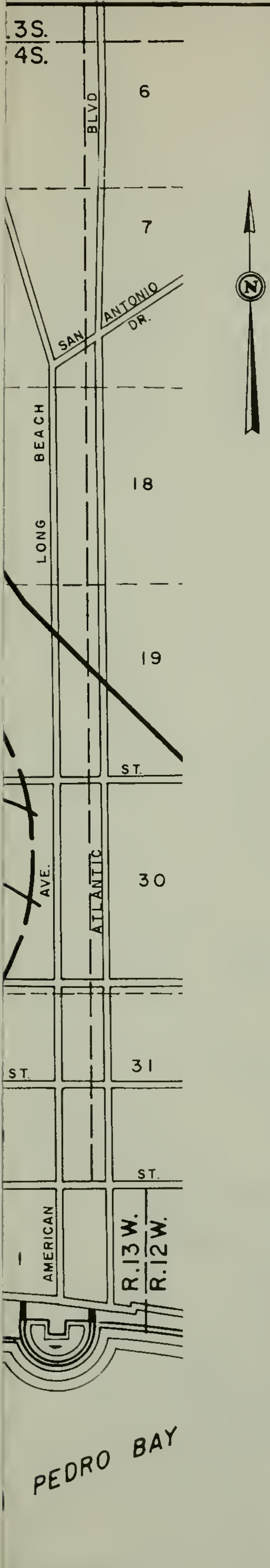
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE LOWER SEALING HORIZON IN DOMINGUEZ GAP, WEST COAST BASIN

SCALE OF MILES
1/2 0

1962



LEGEND

BASIN BOUNDARY

BOUNDARY OF THE GASPUR AQUIFER

—160— APPROXIMATE CONTOURS ON THE TOP OF THE LOWER SEALING HORIZON

NOTE: CONTOURS ARE REFERENCED TO MEAN SEA LEVEL U.S.G.S. DATUM.

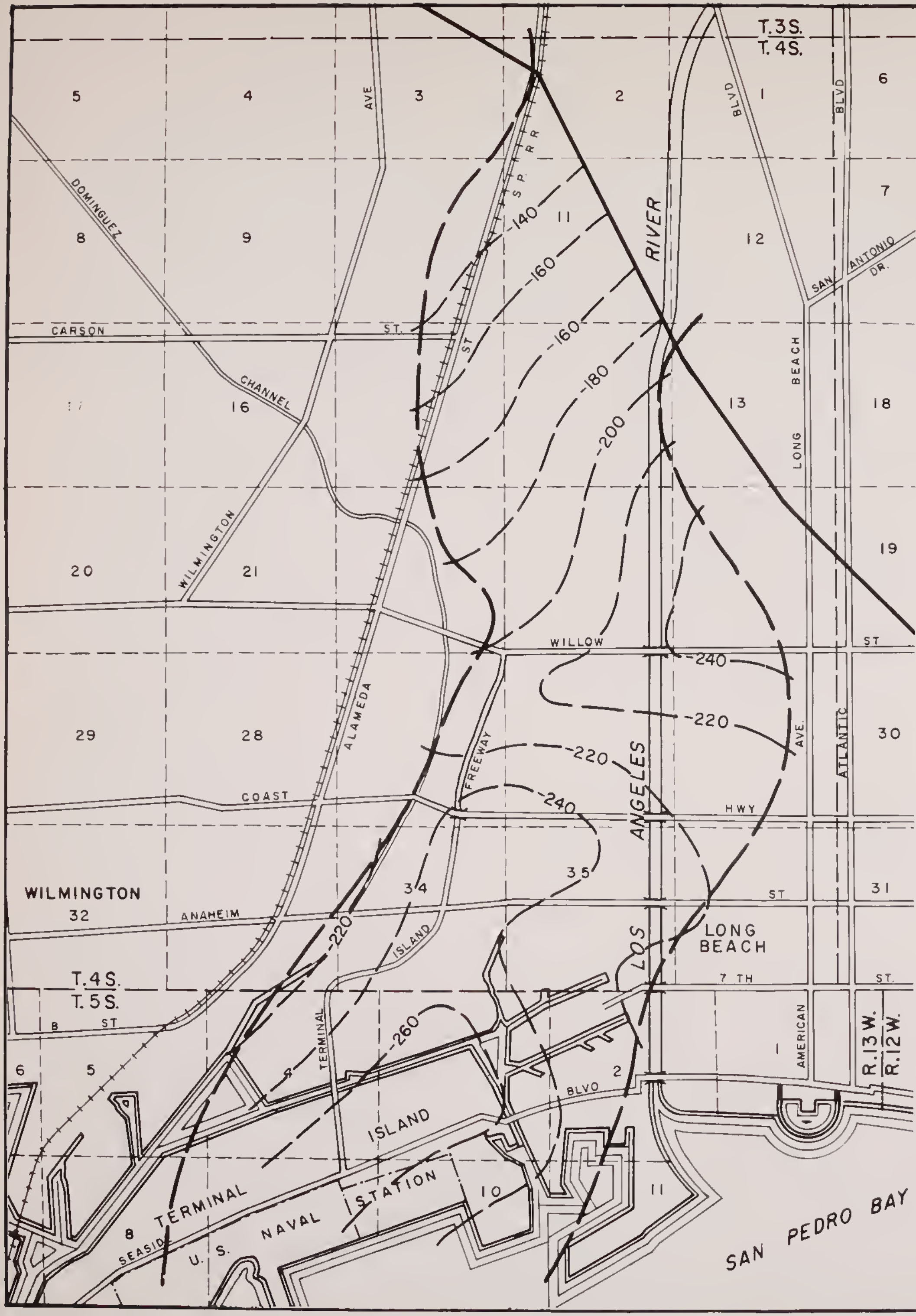
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE LOWER SEALING HORIZON IN DOMINGUEZ GAP, WEST COAST BASIN

SCALE OF MILES
1/2 0

1962



LEGEND

BASIN BOUNDARY

BOUNDARY OF THE GASPUR AQUIFER

—160— APPROXIMATE CONTOURS ON THE TOP OF THE LOWER SEALING HORIZON

NOTE: CONTOURS ARE REFERENCED TO MEAN SEA LEVEL USGS DATUM

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

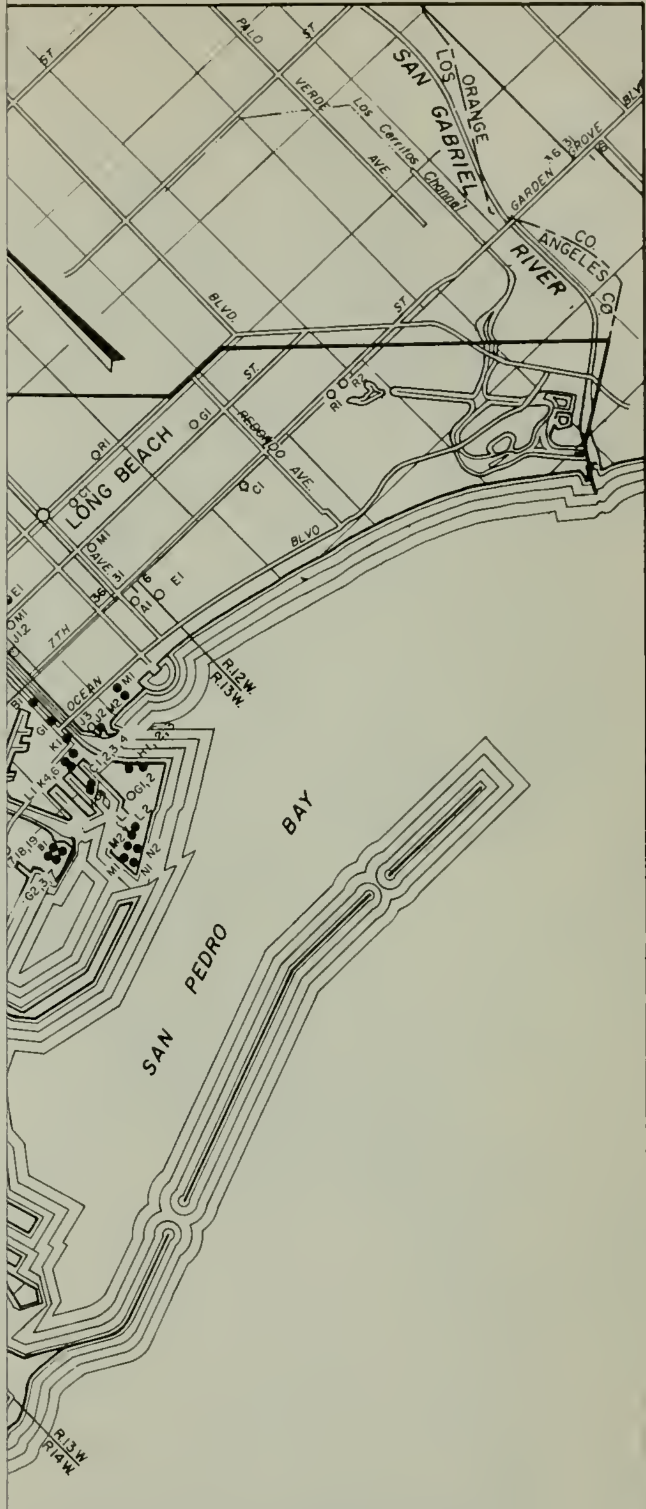
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

CONTOURS ON THE TOP OF THE LOWER SEALING HORIZON IN DOMINGUEZ GAP, WEST COAST BASIN

SCALE OF MILES

1 1/2 0 1

1962



STATE OF CALIFORNIA
PARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

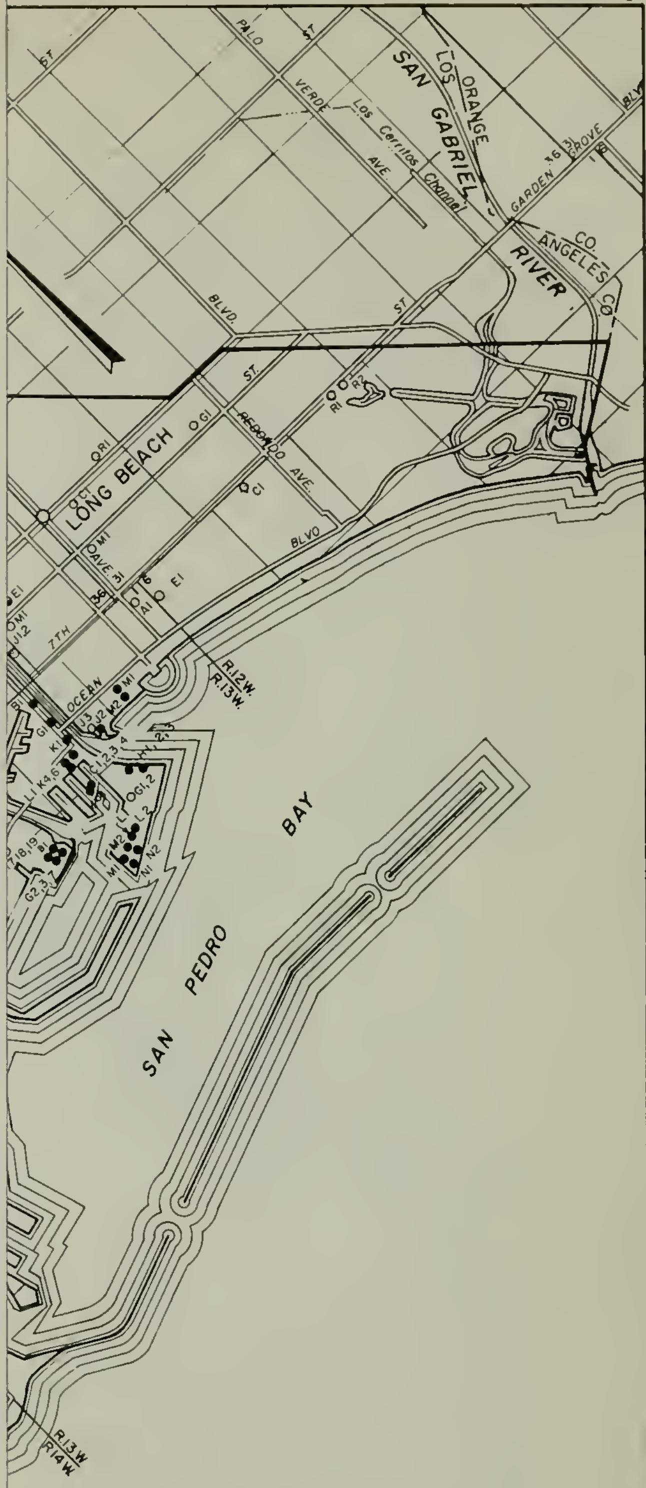
COMMENDED WELL CONSTRUCTION AND
ALING STANDARDS FOR PROTECTION OF
OUND WATER QUALITY IN WEST COAST
BASIN, LOS ANGELES COUNTY

LOCATION AND STATUS OF
WELLS IN WEST COAST BASIN

SCALE OF MILES

1 0 1 2

1962



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PARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

COMMENDED WELL CONSTRUCTION AND
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OUND WATER QUALITY IN WEST COAST
BASIN, LOS ANGELES COUNTY

LOCATION AND STATUS OF
WELLS IN WEST COAST BASIN

SCALE OF MILES
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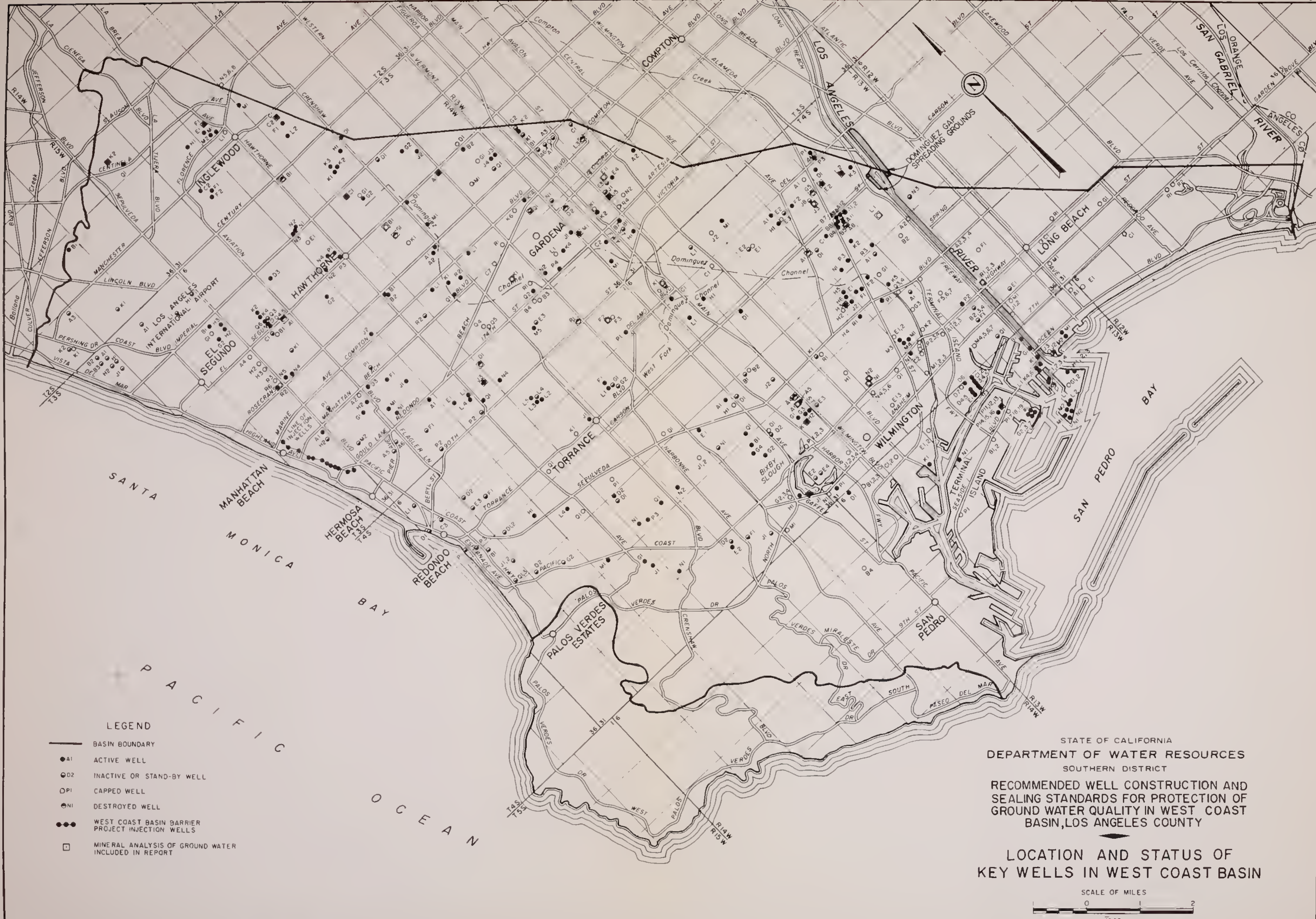
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DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY
LOCATION AND STATUS OF KEY WELLS IN WEST COAST BASIN
SCALE OF MILES
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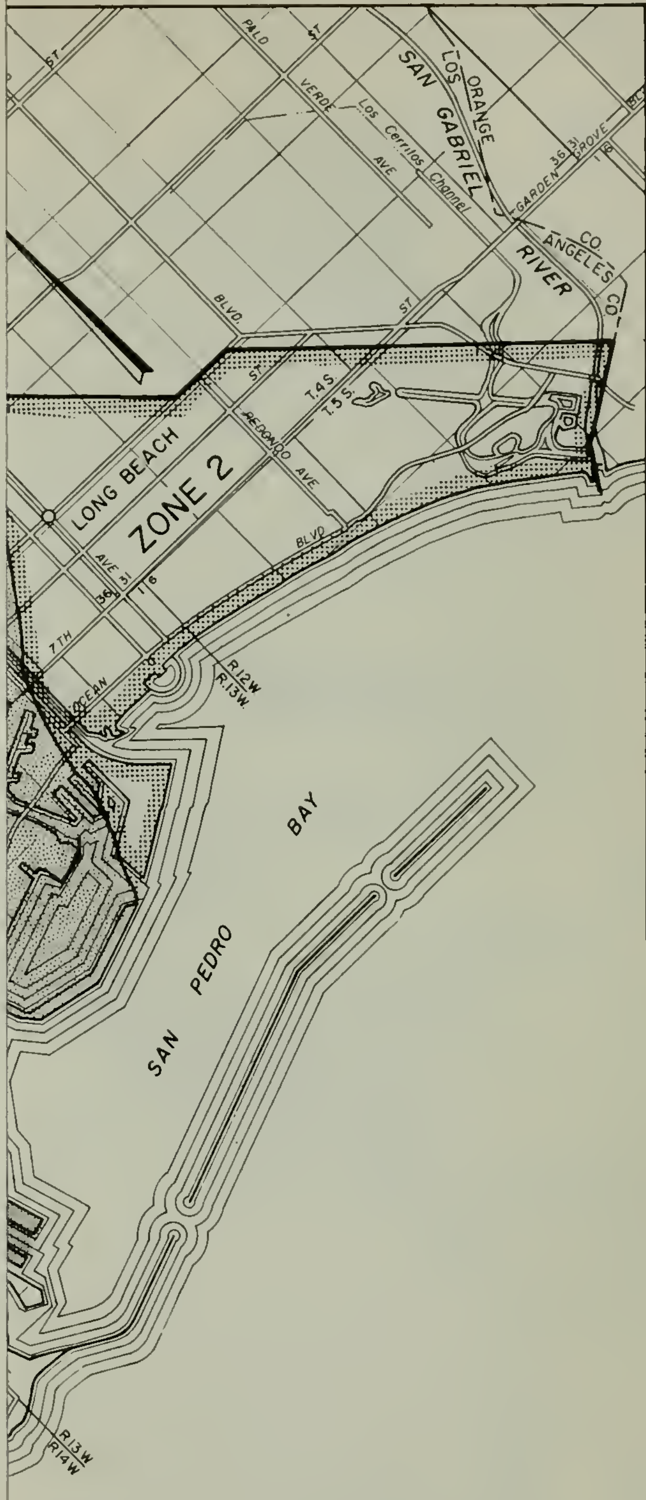
LEGEND
BASIN BOUNDARY
A1 ACTIVE WELL
D2 INACTIVE OR STAND-BY WELL
P1 CAPPED WELL
N1 DESTROYED WELL
WEST COAST BASIN BARRIER PROJECT INJECTION WELLS
MINERAL ANALYSIS OF GROUND WATER INCLUDED IN REPORT
PACIFIC OCEAN
SANTA MONICA BAY
SAN PEDRO BAY
INGLEWOOD
HAWTHORNE
EL SEGUNDO
LOS ANGELES INTERNATIONAL AIRPORT
GARDENA
COMPTON
TORRANCE
MANHATTAN BEACH
HERMOSA BEACH
REDONDO BEACH
PALOS VERDES ESTATES
WILMINGTON
SAN PEDRO
LONG BEACH
LOS ANGELES RIVER
SAN GABRIEL RIVER
DOMINGUEZ GAP SPREADING GROUNDS
LINE OF INJECTION WELLS
BIXBY SLOUGH
TERMINAL ISLAND
Dominguez Channel
LOS ANGELES CO
ORANGE CO



STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

AREAS OF RECOMMENDED SEALING STANDARDS IN WEST COAST BASIN

SCALE OF MILES

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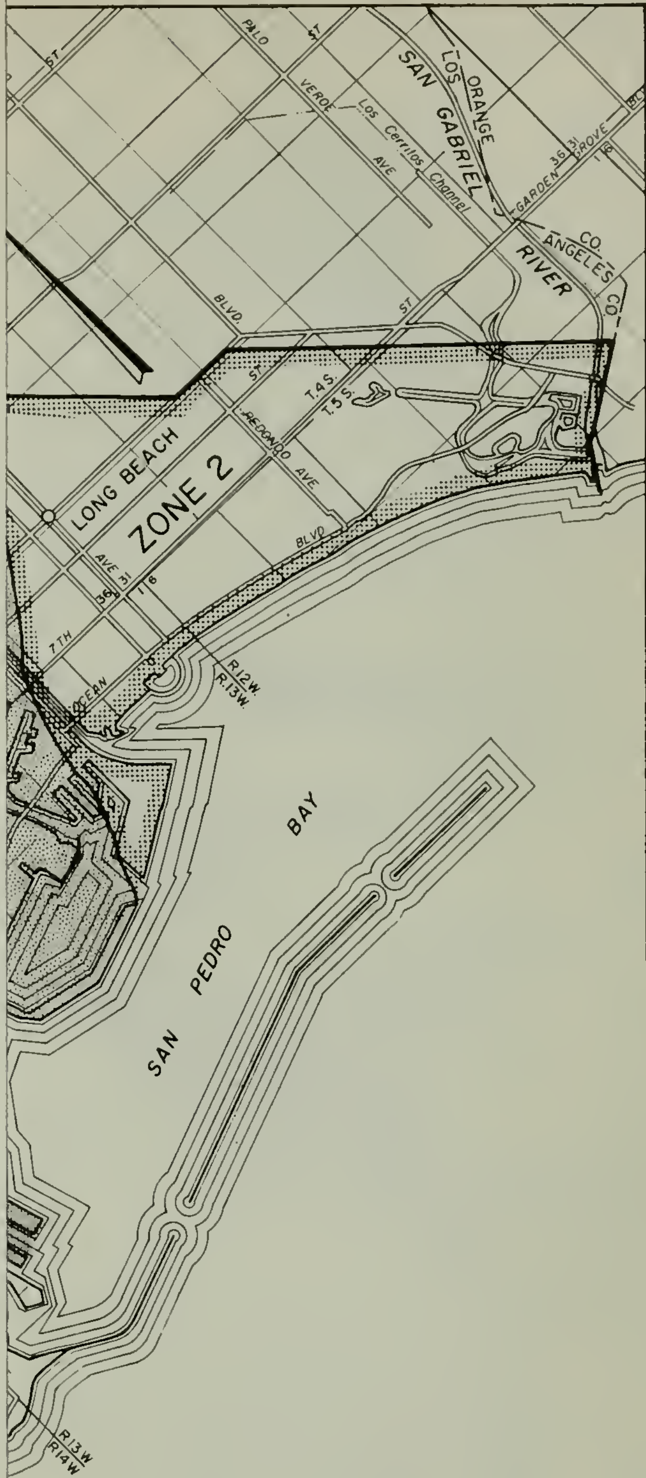
1962



STATE OF CALIFORNIA

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RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

AREAS OF RECOMMENDED SEALING STANDARDS IN WEST COAST BASIN

SCALE OF MILES

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1962

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

RECOMMENDED WELL CONSTRUCTION AND SEALING STANDARDS FOR PROTECTION OF GROUND WATER QUALITY IN WEST COAST BASIN, LOS ANGELES COUNTY

AREAS OF RECOMMENDED SEALING STANDARDS IN WEST COAST BASIN

APPENDIX A

LIST OF REFERENCES

APPENDIX A

List of References

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APPENDIX B

DEFINITION OF TERMS

APPENDIX B

DEFINITION OF TERMS

The following terms are defined as used in this report.

Active Well - An operating water well.

Annular Space - The space between two well casings or a well casing and the drilled hole.

Anticline - A fold in rocks in which the strata dip in opposite directions from a common ridge or axis, like the roof of a house.

Aquiclude - A formation or part of a formation which, although porous and capable of absorbing water slowly, will not transmit it fast enough to furnish an appreciable supply for wells or springs.

Aquifer - A formation or part of a formation which transmits water in sufficient quantity to supply pumping wells or springs.

Capped Well - A water well from which the pump has been removed, and a permanent or locked cap installed on top of the casing.

Casing - A tubular retaining structure, generally metal or concrete, which is installed in the excavated hole to maintain the well opening.

Conductor Pipe - A tubular retaining structure installed between the drilled hole and the inner casing, generally in the upper portion of a well.

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

Connate Water - Water entrapped in the interstices of a sedimentary rock at the time it was deposited. These waters may be fresh, brackish, or saline in character. Because of the dynamic geologic and hydrologic conditions in California, this definition has been altered in practice to apply to water in older formations, even though the water in these formations may have been altered in quality since the rock was originally deposited.

Contamination - Defined in Section 13005 of the California Water Code: "... an impairment of the quality of the waters of the State by sewage or industrial waste to a degree which creates an actual hazard to public health through poisoning or through the spread of disease ...." Jurisdiction over matters regarding contamination rests with the California Department of Public Health and local health officers.

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

Destroyed Well - A water well which has been filled or plugged so that it will not produce water. A properly destroyed well is one which has been destroyed so that it will not produce water nor act as a conduit for the movement of water.

Deterioration - An impairment of water quality.

Drilled Well - A well for which the hole is generally excavated by mechanical means such as the rotary or cable tool methods.

Dug Well - A well for which the hole is generally excavated by hand tools, and which is usually of shallower depth and larger diameter than drilled wells.

Equivalents Per Million (epm) - Equivalent weights of solute contained in one million parts by weight of solution. For practical purposes, epm is the same as milliequivalents per liter.

Filler Material - An inert, impervious material such as portland cement grout, impervious native soil, clay, or other suitable impervious material.

Gravel Packed Well - A well in which a gravel envelope is placed in the annular space to increase the effective diameter of the well, and to prevent fine-grained sediments from entering the well.

Ground Water - That part of the subsurface water which is in the zone of saturation.

Ground Water Basin - An area underlain by one or more permeable formations capable of furnishing a substantial water supply.

Impairment - A change in quality of water which makes it less suitable for beneficial use.

Impermeable - Having a texture that does not permit water to move through it perceptibly under the head differences ordinarily found in subsurface water.

Impervious Grout - A durable cementing agent, such as portland cement, used for sealing water wells during construction or destruction.

Inactive or Stand-by Well - A water well equipped with a pump but not in use.

Industrial Waste - Defined in Section 13005 of the California Water Code: "... any and all liquid or solid waste substance, not sewage, from any producing, manufacturing or processing operation of whatever nature."

Liner - A section of casing of reduced diameter permanently installed within an existing casing to seal openings in the existing casing.

Overdraft - The average annual decrease in the amount of ground water in storage that occurs during a long time period, under a particular set of physical conditions affecting the supply, use, and disposal (including extractions) of water in the ground water basin.

Packer - A device placed in a well which plugs or seals the well at a specific point.

Parts Per Million (ppm) - One weight of solute per one million weights of solution at 20°C.

Permeability - The capacity of a rock to transmit a fluid. The degree of permeability depends upon the size and shape of the pores, the size and shape of their interconnections, and the extent of the latter.

Pollution - Defined in Section 13005 of the California Water Code: "... an impairment of the quality of the waters of the State by sewage or industrial waste to a degree which does not create an actual hazard to the public health but which does adversely and unreasonably affect such waters for domestic, industrial, agricultural, navigational, recreational or other beneficial use, or which does adversely and unreasonably affect the ocean waters and bays of the State devoted to public recreation." Regional Water Pollution Control Boards are responsible for prevention and abatement of pollution.

Pressure Grouting - A method of forcing impervious grout into specific portions of a well, such as the annular space, for sealing purposes.

Sealing Horizon - The boundary below the surface of the ground determined by this investigation to be the level to which a specific well should be sealed, employing the standards set forth in this report, to prevent any undesirable movement of ground water.

Safe Yield - The average annual amount of ground water that could be extracted from a ground water basin over a long time period which would not effect a long time net change in storage of ground water; the extractions must occur under a particular set of physical conditions affecting the water supply, use, and disposal of water in the ground water basin.

Sewage - Defined in Section 13005 of the California Water Code: "... any and all waste substance, liquid or solid, associated with human habitation, or which contains or may be contaminated with human or animal excreta or excrement, offal, or any feculent matter."

Syncline - A fold in rocks in which the strata dip inward from both sides toward a common plane or axis, like the inverted roof of a house.

Total Dissolved Solids (TDS) - The dry residue from the dissolved matter in an aliquot of a water sample remaining after evaporating of the sample at a definite temperature.

Total Dissolved Solids (TDS) By Summation - The TDS determined by summing the total dissolved constituents less one-half the bicarbonate ion.

Transmissibility - The characteristic property of the entire saturated portion of an aquifer to transmit water.

Waste Water - The water that has been put to some use or uses and has been disposed of, commonly to a sewer or wasteway. It may be liquid industrial waste, or sewage, or both.

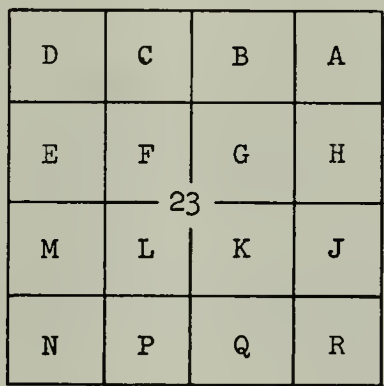
APPENDIX C

WELL NUMBERING SYSTEM

APPENDIX C

Well Numbering System

The well numbers used in this report are referenced by use of the United States Public Land Survey System, and to the San Bernardino Base and Meridian. The well identification consists of a township, range, and section number, a letter which indicates the 40-acre lot in which the well is located, and a final number which indicates the identity of the particular well within the lot. The subdivision of a section is shown below:



For Example, 3S/14W-23A2, S.B.B.&M., is the second well to be identified in Lot A of Section 23 of Township 3 South, Range 14 West, San Bernardino Base and Meridian. Location of wells are shown on Plate 9, "Location and Status of Key Wells in West Coast Basin." These wells are those for which the West Coast Basin Watermaster Service maintains records as of June 1961.

APPENDIX D

CASING REQUIREMENTS

FOR

DRILLED AND DUG WELLS

APPENDIX D

CASING REQUIREMENTS FOR DRILLED AND DUG WELLS

To obtain and maintain the optimum quality of ground water, and to gain the maximum operational life of a well, the proper casing should be installed. The casing should be designed to withstand the forces which may act upon it during and after installation. It should also be resistant to the electrolylic and corrosive effects of earth and water.

Because the majority of water wells are drilled or dug, casing criteria for only these two types of wells are discussed in the following sections. In addition, notes on drive shoe and placement of casing are presented.

Casing Material for Drilled Wells. Casing used in drilled wells should be manufactured from steel meeting the following specifications:

Physical

Property	Minimum values in pounds per square inch
Yield point	33,000
Ultimate strength	60,000

Chemical

Constituent	Limiting values in percent
Carbon	0.20 to 0.30
Copper, minimum	0.20
Manganese, maximum	1.35
Phosphorus, maximum	0.04
Silicon, maximum	0.12
Sulphur, maximum	0.05

In addition, the steel used in manufacturing the water well casing should be a weldable steel and should meet one of the following American Society for Testing Materials (ASTM) specifications, or the requirements for steel manufacture incorporated under the water well casing fabrication specifications, including the latest revisions thereof:

(1) American Society for Testing Materials (ASTM A7). "Tentative Specifications for Steel for Bridges and Buildings."

(2) American Society for Testing Materials (ASTM A245). "Tentative Specifications for Flat Rolled Carbon Steel Sheets of Structural Quality."

(3) American Society for Testing Materials (ASTM A283D). "Standard Specifications for Low and Intermediate Tensile Strength Carbon-Steel Plates of Structural Quality (Plate 2 Inches and Under in Thickness)."

(4) American Society for Testing Materials (ASTM A373). "Tentative Specifications for Structural Steel for Welding."

Casing Fabrication for Drilled Wells. The casing should be fabricated according to the latest revision of one of the following specifications:

(1) American Petroleum Institute (API Std. 5L). "Specifications for Line Pipe."

(2) American Society for Testing Materials (ASTM A53). "Tentative Specifications for Welded and Seamless Steel Pipe."

(3) American Society for Testing Materials (ASTM A134). "Standard Specifications for Electric-Fusion (Arc)-Welded Steel Pipe (Sizes 16 Inches and Over)."

(4) American Society for Testing Materials (ASTM A135). "Tentative Specifications for Electric-Resistance-Welded Steel Pipe."

(5) American Society for Testing Materials (ASTM A139). "Standard Specifications for Electric-Fusion (Arc)-Welded Steel Pipe (Sizes 4 Inches and Over)."

(6) American Society for Testing Materials (ASTM A211). "Standard Specifications for Spiral-Welded Steel or Iron Pipe."

(7) American Water Works Association (AWWA C201). "Tentative Standard for Fabricated Electrically Welded Steel Pipe."

(8) American Water Works Association (AWWA C202). "Tentative Standard for Fabricated Electrically Welded Steel Pipe."

Casing Thickness for Drilled Wells. Steel casing equal to or exceeding the thickness given in the following tabulation should be used for permanent installation in water wells:

MINIMUM THICKNESS FOR STEEL WATER WELL CASING FOR DRILLED WELLS SINGLE CASING

Depth of casing, in feet	Diameter in Inches									
	6	8	10	12	14	16	18	20	22	24	30
0-100	12	12	10	10	8	8	1/4	1/4	1/4	1/4	5/16
100-200	12	10	10	8	8	3/16	1/4	1/4	1/4	1/4	5/16
200-300	10	10	8	8	1/4	1/4	1/4	1/4	5/16	5/16	5/16
300-400	10	8	8	3/16	1/4	1/4	1/4	5/16	5/16	5/16	3/8
400-600	10	8	3/16	1/4	1/4	5/16	5/16	5/16	5/16	3/8	3/8
600-800	3/16	3/16	1/4	1/4	5/16	5/16	3/8	3/8	7/16	7/16	7/16
Over 800	1/4	1/4	1/4	5/16	5/16	3/8	3/8	7/16	7/16	1/2	1/2

Values above diagonal are United States Standard Gage.
Values below diagonal are thickness in inches.

MINIMUM THICKNESS FOR STEEL WATER WELL CASING FOR DRILLED WELLS DOUBLE CASING (CALIFORNIA STOVEPIPE)

Depth of casing, in feet	Diameter in Inches								
	10	12	14	16	18	20	22	24	30
0-100	12	12	12	12	10	10	10	10	8
100-200	12	12	12	10	10	10	10	8	8
200-300	12	12	10	10	10	10	8	8	8
300-400	12	12	10	10	10	8	8	8	8
400-600	10	10	10	10	8	8	8	8	8
600-800	10	10	10	8	8	8	8	8	8
Over 800	10	8	8	8	8	8	8	8	8

Values given are United States Standard Gage.

Casing Material for Dug Wells. Either steel or concrete should be used for casing in dug wells. Steel used in the manufacture of casing for dug wells should conform to the same specifications for casing material previously described under drilled wells, and the thickness should conform to the following specification:

MINIMUM THICKNESS OF STEEL
CASING FOR DUG WELLS

Outside diameter, in inches	Minimum U. S. Standard gage or plate thickness
24	8 gage
30	3/16 inch
36	3/16 inch
42	1/4 inch
48	1/4 inch

When concrete casing is used, it should either be poured in place, or consist of precast concrete rings. The poured-in-place concrete should be sufficiently strong to withstand the earth and water pressures imposed on it. It should be properly reinforced with steel to furnish tensile strength and to resist cracking. Aggregate small enough to insure proper placement without bridging should be used. The finished product should be free from honeycombing or other defects likely to impair the ability of the concrete structure to remain watertight.

Precast concrete casing is usually composed of concrete rings, from three to five feet in diameter, and approximately three feet in length. To serve satisfactorily as casing, these rings should be free of any blemishes which would impair their strength or watertightness. They should conform to the following specifications:

(1) American Water Works Association (AWWA C300). "Standard for Reinforced Concrete Water Pipe-Steel Cylinder Type, Not Prestressed."

(2) American Water Works Association (AWWA C301). "Standard for Reinforced Concrete Water Pipe-Steel Cylinder Type, Prestressed."

Drive Shoe. All driven casing should be equipped with a standard weight drive shoe. The drive shoe should be attached to the bottom of the casing by a screw-type joint or by a continuous circumferential weld both inside and outside of the casing.

Placement. The installation of all casing should be accomplished in such a manner that any possible damage to casing section or to the joints is avoided. When precast concrete casing is used in any well, the casing should rest upon an adequately designed footing or platform at the bottom of the well to prevent settling which would cause cracking and failure of the casing. To reduce the possibility of honeycombing or separation of poured concrete, free fall of the concrete should not be allowed.