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by Robert Crowder

SHALLOW AQUIFERS AND SURFACE CASING REQUIREMENTS FOR WILMINGTON AND BELMONT OFFSHORE OIL FIELDS.

by Larry Olson

CALIFORNIA DEPARTMENT OF CONSERVATION
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SHALLOW AQUIFERS AND SURFACE CASING REQUIREMENTS FOR WILMINGTON AND BELMONT OFFSHORE OIL FIELDS[a]

by L. J. Olson

PURPOSE

Vast, available quantities of fresh groundwater, partially stored within Wilmington and Belmont Offshore fields, played a vital role in the development of the Los Angeles area. Today, these groundwater supplies remain critically important.

This study is intended to add data to groundwater protection programs for Los Angeles and environs by investigating shallow aquifers inside the study area and addressing surface casing requirements for oil and gas wells drilled in the onshore portion of Wilmington oil field. In the study area, the shallow aquifers and the uppermost and lowermost horizons of fresh groundwater were identified and delineated, and the first competent formation suitable for cementing surface casing was mapped.

STUDY AREA

The report study area includes onshore and offshore portions of Wilmington oil field, Belmont Offshore oil field, and an area slightly northeast of these fields (Fig. 1).

Wilmington oil field produces more oil than any other oil field in California. Furthermore, the waterflood repressuring operation conducted in the field is the largest of its type in the world. The field is south of Los Angeles, located in the Long Beach–Los Angeles Harbor area. Proved acreage consists of 6,980 acres onshore and 6,025 acres offshore. Belmont Offshore field, with 760 proved acres, is the southeasterly extension of Wilmington oil field.

GROUNDWATER LOCATION

Fresh groundwater in the study area is contained within the upper 2,000 feet of sediments that are confined laterally between the structural uplift of the Palos Verdes Hills and the Newport–Inglewood fault zone. Figure 3, a cross section through part of the study area, shows the relative positions of the various shallow hydrologic units and aquifers. Cross section locations are also shown on Figures 4, 5, and 6. Table 1 lists the series, formation, thickness, and lithology of each hydrologic unit in the study area.

[a] Manuscript submitted November 1977.

GROUNDWATER QUALITY

Study area groundwater quality was determined through the use of electric logs. An electric log resistivity reading of 30 ohm–meters or more in the shallow aquifers was considered to indicate fresh water. The assumption was made after comparing resistivity readings on electric logs to known formation water–quality information available from chemical analyses in certain wells.

To approximate groundwater salinities, the resistivity of the formation fluid was calculated from the spontaneous potential curve on the electric log. Figure 2 is a typical electric log showing salinity values of water in each aquifer.

Based on the California Department of Water Resources (DWR) criteria, groundwater evaluated in this study was considered fresh when it contained less than 3,000 parts–per–million (ppm) in total dissolved solids (TDS) (Table 2).

HYDROLOGIC UNITS AND SHALLOW AQUIFERS

Hydrologic units are comprised of intervals of water–bearing sediments containing interbedded aquifers and aquicludes. Aquifers are permeable sediments that consist mainly of sand and gravel. Most aquicludes are composed of impermeable sedi-

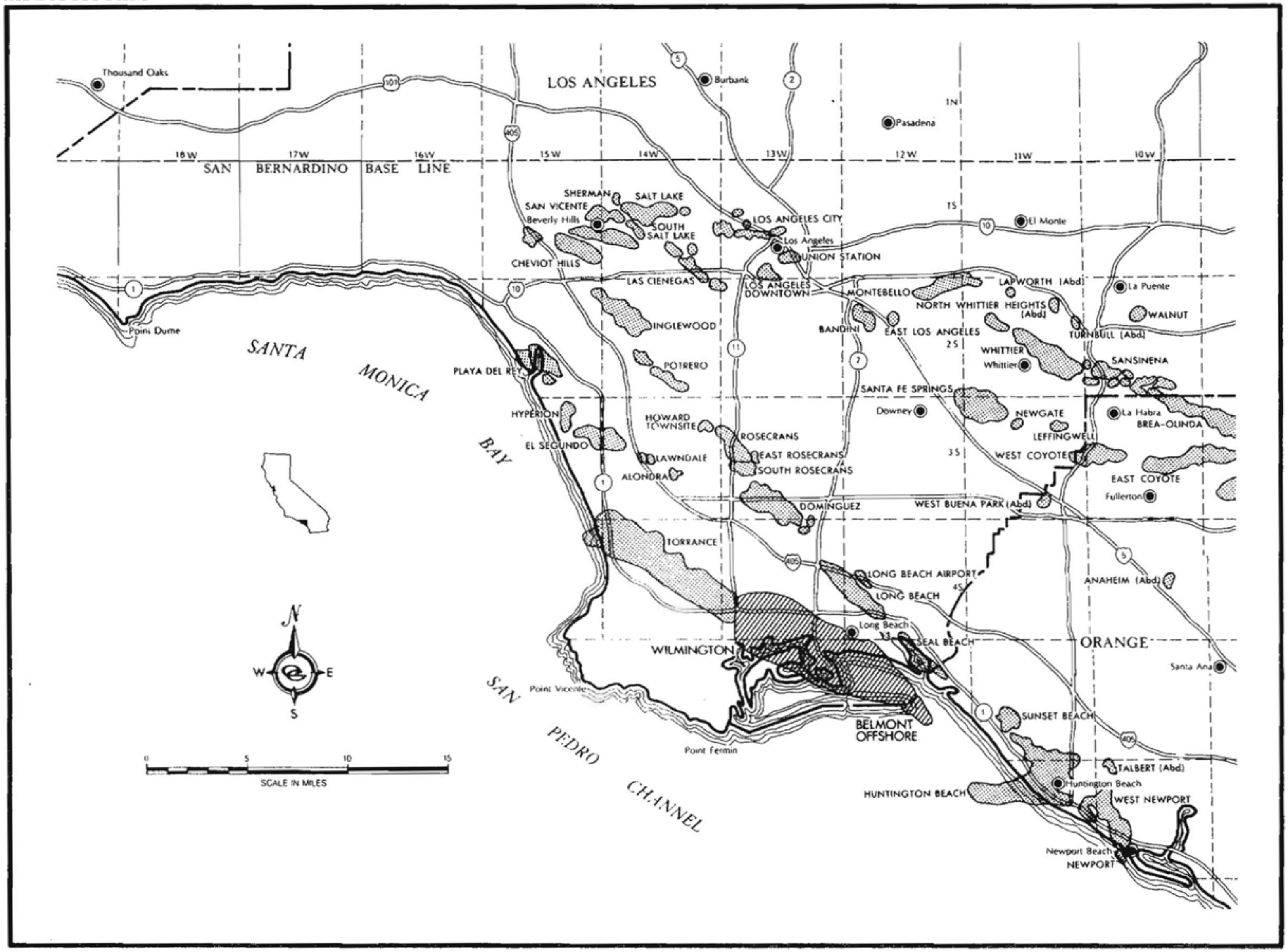


Figure 1. Study area: Wilmington oil field, onshore and offshore areas, and Belmont Offshore oil field.

Table 1. Series, formation, thickness, and lithology of hydrologic units in the study area.[5,8]

Series		Formation and member	Hydrologic (groundwater) unit	Thickness (feet) Avg.	Max.	Lithology
Holocene		River channel gravels	Gaspur Aquifer	70	110	Gravel, gravelly sand, cobbles, overlain by clayey silt and sand.
		(unconformity)				
Pleistocene	upper	unnamed	200–foot sand	150	250	Sand, medium to coarse, variable thickness; clay; interbedded silt, fine sand; gravel lenses.
		(unconformity)				
	lower and middle	San Pedro	400–foot gravel	150	300	Sand, coarse, uniform, highly permeable; minor gravel bed; overlain by silt; clay.
			(unconformity)			
			Silverado upper	250	350	Sand, coarse, thick–bedded, highly permeable; gradational to fine, silty sand, or silt, southward; blue clay.
			Silverado lower	150	250	
		(unconformity)				
Pliocene	upper	"Pico"	Pico	500	700	Sand, fine to medium, thick–bedded, silty, interbedded with silty clay and shale; moderately permeable; marine.
			BASE OF FRESH WATER			
				200	300	Shale, gray–green, saturated with brackish water.
		(unconformity)				
	lower	"Repetto"		1,000	—	Sandstone, greenish–gray, poorly consolidated, marine; interbedded with siltstone and shale. Oil bearing.
Miocene		Puente		4,000	—	Sandstone, gray and brown, marine; interbedded with locally well–indurated siltstone and shale. Oil bearing.
		Monterey: Nodular shale		900	—	Shale, hard, dense; siltstone with interbedded sandstone. Oil bearing.
		Monterey: Schist congl.		25	—	Schist conglomerate and breccia. Oil bearing.
Cretaceous or older		Catalina Schist		—	—	Schist, hard, well–indurated.

ments, largely clay.

Hydrologic units in the study area are named after locally named aquifers within each unit: 200–foot sand, 400–foot gravel, Silverado, and Pico. The Gaspur Aquifer is sufficiently uniform and consistent so that only the aquifer portion of the hydrologic unit is discussed below and shown on Figure 2 and Table 1.

Gaspur Aquifer

The Gaspur Aquifer consists of sand and gravel deposited in the Los Angeles River Channel. The Gaspur transects the study area and lies roughly between the easterly limits of the Los Angeles River Channel on the east and Henry Ford Avenue on the west. The top and bottom of the Gaspur Aquifer are approximately 80 and 180 feet below sea level, respectively. The type section of this aquifer is described by Zielbauer, et al.[8]

Fresh water in the aquifer has been degraded to about 15,000 ppm by seawater intrusion and by the percolation of oilfield brines and other industrial waste waters disposed of in surface sumps, concentration ponds, and disposal pits, espe-

[5] Superior figures refer to a list of references at the end of this report.

Table 2. DWR criteria for water quality.

Parts Per Million (ppm) of Total Dissolved Solids (TDS) or Chemical Constituents	Irrigation Water Quality*
0 to 1,000	Excellent to good
1,000 to 3,000	Good to injurious
3,000 and over	Injurious to unsatisfactory

*Drinking water usually contains less than 1,000 ppm in TDS.

cially during the early development of the Wilmington and Long Beach oil fields.[8] Subsequently, the degraded Gaspur water has been useful only to the oil industry as a source of waterflood injection water for deeper oil zones.

Today, the water is usable only for some industrial purposes.[8] For this reason, protection of fresh water in the Gaspur Aquifer is not considered as important as protection of higher–quality, deeper groundwaters.

200–Foot Sand Hydrologic Unit

The 200–foot sand hydrologic unit extends throughout the study area, except where it was eroded entirely and Gaspur Aquifer sediments redeposited. The

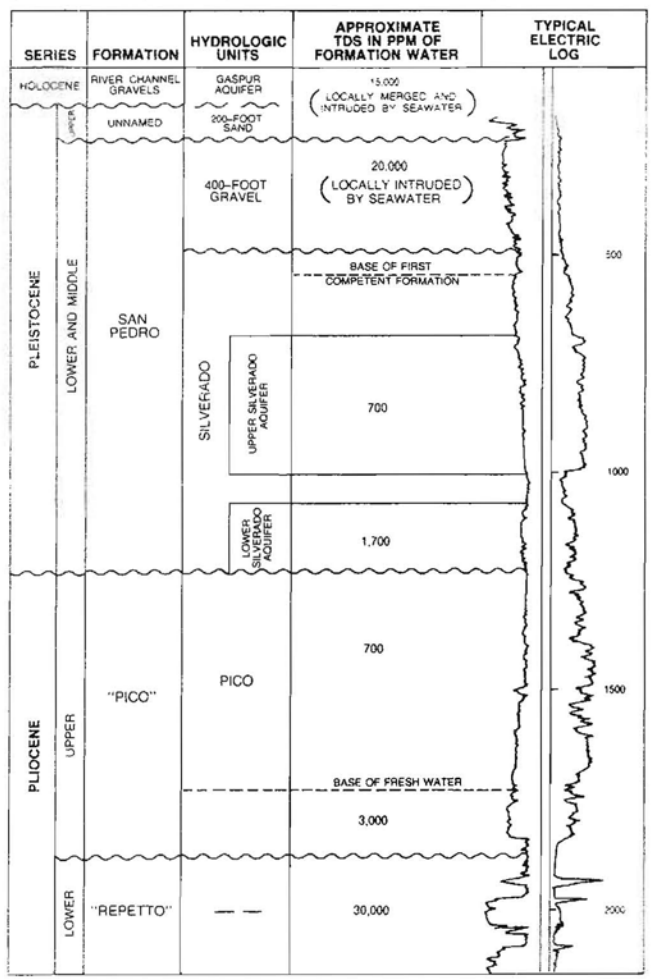


Figure 2. Typical electric log for study area. Water salinity values for each aquifer.

unit merges with, and is in hydraulic continuity with the Gaspur Aquifer in areas where the Los Angeles River trench became incised in the 200–foot sand (Fig. 3). Three–to–four sand beds and alternating clay beds comprise the 200–foot sand. The top and bottom of the 200–foot sand unit are generally found at depths of 25 and 200 feet below sea level, respectively.

The quality of the groundwater in the 200–foot sand has been degraded to about 15,000 ppm throughout much of the study area, most likely by seawater intrusion and by local industrial waste water.[8] However, fresh water can be found in this unit along the northern margins of the study area as well as in all the other hydrologic units and aquifers.

400–Foot Gravel Hydrologic Unit

The 400–foot gravel hydrologic unit extends throughout the study area. The unit consists of marine and continental deposits of uniform, coarse sands and gravels from 50– to 75–feet in thickness and of interbedded clay. The top and bottom of the unit are located at depths of approximately 200 feet and 500 feet below sea level, respectively.

The 400–foot gravel is an important source of fresh groundwater (1,000 ppm) at the northerly margins of the study area because of the high yield (200–to–2,100 gallons per minute) obtained from wells producing from aquifers in this unit. However, the quality of water in this unit has been degraded throughout the southerly portion of the area (20,000 ppm), either from seawater intrusion and local industrial wastes or from native saline water.[8] Native saline water degradation is thought to result from connate brines trapped in the less–permeable portions of the freshwater aquifers. The connate brines are released and degrade the fresh water as pressure differentials are altered and/or landward groundwater gradients established.

Silverado Hydrologic Unit

The Silverado hydrologic unit is composed of two major aquifers that are easily definable and are locally separated by a clay, or clayey silt, about 50 feet thick. Both the upper and lower Silverado Aquifers consist of sands and gravels that grade southward into a predominance of silts, clayey silts, and blue clays. Permeability becomes so severely reduced that aquifer portions of the Silverado hydrologic unit no longer exist in these areas. The top and bottom of the Silverado unit are approximately 600 feet and 1,100 feet below sea level, respectively. The type section of this unit is described in reference No. 1.

The Silverado unit is the principal freshwater source north of the study area. There is no evidence of seawater intrusion; however, the determination of water quality from electric logs in the southern portions of the study area is greatly impaired due to increased clay content within the aquifers. The quality of local water is apparently better in the upper Silverado Aquifer (700 ppm) than in the lower (1,700 ppm), as indicated in Figure 2.

Pico Hydrologic Unit

The Pico freshwater hydrologic unit, which is the deepest, is present uniformly throughout the area. Although fresh water is not usually produced from the unit because of the depth, the fresh water should nevertheless be protected for future use. The Pico unit consists of alternating fine sands, silts and clays, or shales. The top of the aquifer is found about 1,200 feet below sea level, and the base of freshwater sands is about 1,700 feet below sea level within this aquifer. The quality of water in the Pico unit is generally very good (700 ppm); however, the quality becomes transitionally poorer with depth near the base of fresh water (3,000 ppm).

BASE OF FRESH WATER

The base of fresh water in the study area coincides with the base of the deepest, uniformly deposited, freshwater aquifer in the Pico hydrologic unit. The base of fresh water is a prominent feature on electric logs and is known as the K marker in the northwesterly portions of Wilmington field . Stratigraphically, the base of fresh water is found in the "Pico" Formation (Fig. 2).

Figure 4 shows contours drawn on the base of fresh water. The southeasterly portion of Figure 4 extends northeasterly from the Belmont Offshore field and includes part of the Seal Beach oil field.

TOP OF FRESH WATER

Contours drawn on the top of fresh water are shown on Figure 5. No contours are shown where fresh water extends continuously from the ground surface down to the base of fresh water in the northerly portions of the area; however, contours are shown where fresh groundwater is overlain by saline water in the southerly portions.

Saline water overlying fresh groundwater is due to a combination of factors: seawater intrusion, industrial waste–water degradation, the presence of native saline water, and freshwater aquifers merging with aquifers containing degraded water.

DOMINGUEZ GAP BARRIER PROJECT

In February 1971, a recharge project known as the Dominguez Gap Barrier Project was begun by the Los Angeles County Flood Control District to halt seawater intrusion into shallow aquifers. The alignment of injection wells for this project is shown on Figure 5. Currently, Colorado River water is being injected at the rate of 212,000 barrels per day into 29 injection wells. The water is being injected into the merged Gaspur Aquifer and 200–foot sand at the rate of approximately 108,000 barrels per day and into the 400–foot gravel at about 104,000 barrels per day.

The extraction of water by oil operators for waterflood operations from these shallow aquifers on the seaward side of the barrier is thought to be beneficial to the barrier project as water levels must be higher at the barrier than on the seaward side for the barrier to be effective. To date, the project has been only moderately successful.

SURFACE CASING REQUIREMENTS

At a depth suitable for pressure control, surface casing must be cemented into reasonably consolidated or competent strata to provide anchorage for blowout prevention equipment. In the study area, a series of poorly consolidated sands and gravels extends from just below the surface to a depth of about 500 feet on the onshore portion. This series is underlain throughout most of the field by a sandy claystone that is at a suitable depth and sufficiently compacted and impermeable to be considered a competent rock unit in which to cement surface casing.

A typical electric log of the study area shows the shallow sand and gravel aquifers and this competent bed (Fig. 2). Figure 6 shows contours drawn on the base of the competent bed; therefore, the contours can be used to determine the depth at which surface casing will be cemented.

Surface casing requirements on the offshore drilling islands in Wilmington and Belmont Offshore fields were established as the result of a prior investigation and are shown on Figure 6.

CONCLUSIONS

Fresh groundwater in most oil fields is subject only to degradation by poorer–quality waters migrating from below the base of fresh water. In portions of the Wilmington and Belmont Offshore oil fields, fresh groundwater is subject also to degradation by poorer quality waters migrating from above the fresh water.

The first competent formation suitable for the anchorage of surface casing in Wilmington oil field and Belmont Offshore oil field can be adequately delineated with the use of electric logs.

ACKNOWLEDGMENTS

The author thanks Dennis Allen and Mel Wright of the Long Beach Department of Oil Properties for helpful commentary during the preparation of the report.

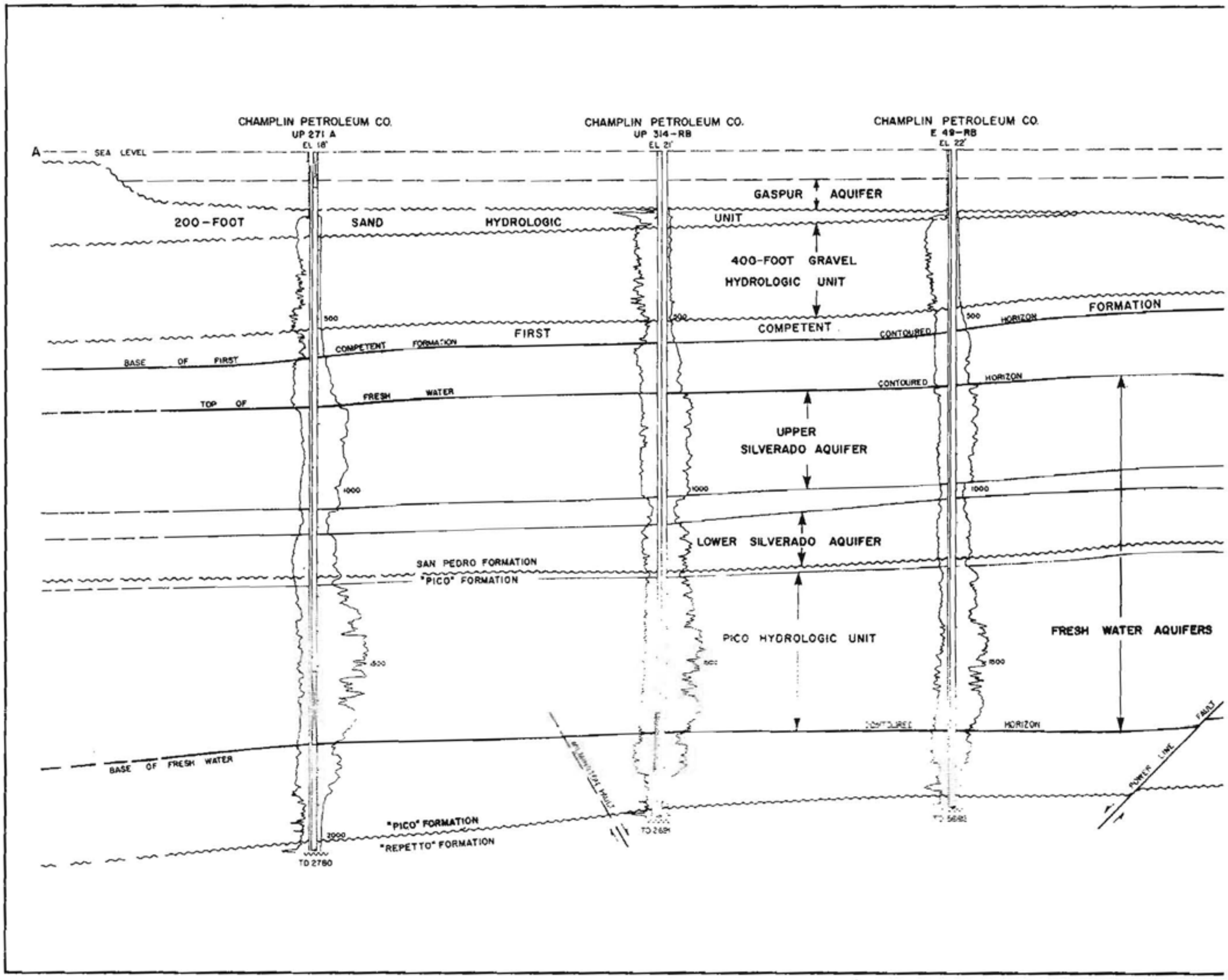
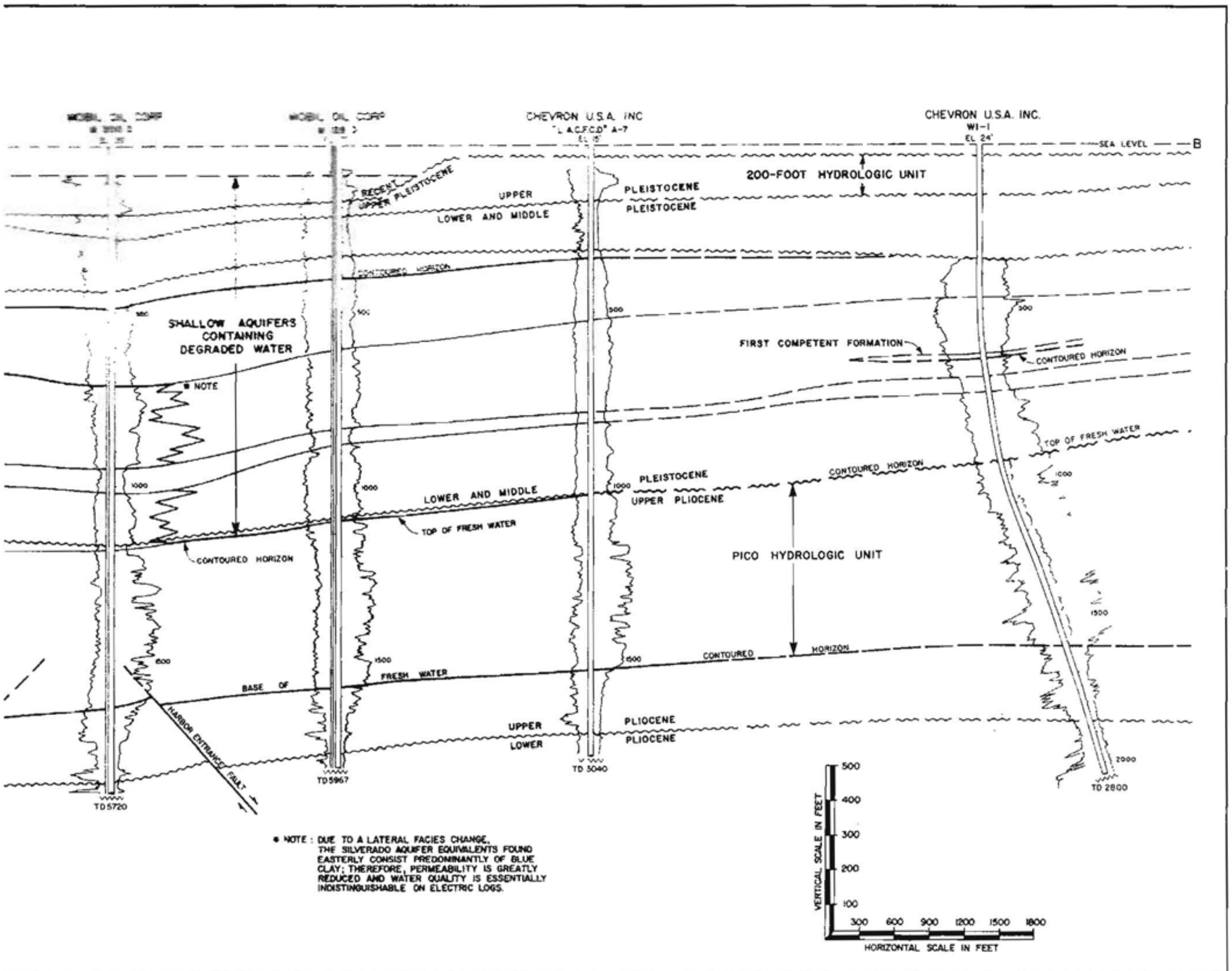


Figure 3. Cross section A'–B, Wilmington oil field.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EL 24'
SEA LEVEL
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200-FOOT HYDROLOGIC UNIT
RECENT
UPPER PLEISTOCENE
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PLEISTOCENE
LOWER AND MIDDLE
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SHALLOW AQUIFERS CONTAINING DEGRADED WATER
FIRST COMPETENT FORMATION
CONTOURED HORIZON
NOTE
TOP OF FRESH WATER
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LOWER AND MIDDLE
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CONTOURED
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HARBOR ENTRANCE FAULT
UPPER
PLIOCENE
LOWER
PLIOCENE
TD 5720
TD 5967
TD 5040
TD 2800
500
1000
1500
2000
• NOTE: DUE TO A LATERAL FACIES CHANGE, THE SILVERADO AQUIFER EQUIVALENTS FOUND EASTERLY CONSIST PREDOMINANTLY OF BLUE CLAY; THEREFORE, PERMEABILITY IS GREATLY REDUCED AND WATER QUALITY IS ESSENTIALLY INDISTINGUISHABLE ON ELECTRIC LOGS.
VERTICAL SCALE IN FEET
100
200
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600
900
1200
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1800
HORIZONTAL SCALE IN FEET