Department of the Interior

U.S. Geological Survey

Preliminary ground-water-quality data and the extent of the ground-water basin from drill-hole, seismic, and gravity data in the Palo Alto 7.5' quadrangle, California

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Editor

Open-File Report 90-74

Prepared in cooperation with the City of Menlo Park

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1990

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Abstract

The repeated droughts of 1976-1977 and 1987-1988 and associated water rationing in many central California coastal cities has increased municipal and county government's interest in local ground-water resources. However, because of the dangerous effects of subsidence in Santa Clara Valley related to excessive pumping of their ground water basin, mid-San Francisco Peninsula cities are considering limited developments of ground water resources to provide emergency supplies during possible future droughts and/or disruption of Hetch-Hetchy flow by possible local fault movements and associated earthquakes.

To help accomplish these objectives, a test study of the nature and extent of the ground water basin in the cities of Menlo Park and Atherton which make up most of the Palo Alto 7 1/2' quadrangle has been made by compiling and studying all reported well logs in these cities, by obtaining and interpreting new gravity data, and by digitizing and integrating previous seismic and aeromagnetic data into the study. A preliminary summary of water quality data from the well compilation is also reported.

Thirty-six wells in the Palo Alto 7 1/2' quadrangle have been drilled to bedrock defined here as the hard, low-porosity sandstones, shales, graywackes, and conglomerates of pre-middle Pliocene age. Younger rocks of the upper Pliocene and lower Pleistocene Santa Clara Formation and the overlying Pleistocene and Holocene alluvial sands, silts, and clays make up the ground-water basin. Bedrock crops out in the southwestern part of the quadrangle and is overlapped by an increasing thickness of the water-bearing alluvial deposits to the northeast to approximately 600 feet along the west edge of San Francisco Bay in Menlo Park, according to both our interpretation of drill-hole records and a previous seismic refraction study in the salt evaporators adjacent to the Bay. In addition, there is a general thickening of the ground-water basin to the southeast along the Peninsula from about 100 feet under Sequoia High School in Redwood City to about 1100 feet under Rinconada Park in Palo Alto. The thickness of basin deposits is not linear between the bedrock outcrop and San Francisco Bay but increases more abruptly about 1/2-mile from the outcrop along a northwest striking area underlying Stanford University and west Menlo Park. This buried monoclinal erosional feature is locally interrupted by two broad valleys in the bedrock surface that apparently represent incisions by the ancestral San Francisquito Creek that separates Menlo Park and Palo Alto as well as another unnamed, modern-day creek in southwest Atherton.

The bedrock surface under Menlo Park and Atherton is poorly defined by only 7 and 9 wells to bedrock, respectively. Thus, 398 new measurements of the gravity field at the surface were made at a quarter-mile grid throughout these cities to look for local bedrock undulations and closures for locating the best sources of ground water. After making corrections for latitude, elevation, terrain, and crustal structure, the gravity measurements show an expected decrease in values over the deeper parts of the ground water basin as determined by drilling, but are complicated by the effects of variations in the densities of rocks within bedrock. By making density measurements of bedrock samples exposed in the southwestern part of the Palo Alto quadrangle and by extensive 3-D computer modeling of the gravity data, the effect of bedrock density variations has been removed from measurements and the residual

gravity field associated with the ground water basin has been determined to a first approximation.

Modeling of residual gravity has uncovered the following subsurface structures of interest to evaluating ground water potential: (1) the thickness of water-bearing alluvial deposits in the vicinity of now-defunct Ravenswood High School in east Palo Alto may be even greater than the approximately 110-foot thickness under Rinconada Park as determined by drilling, (2) a closed basin about 1 mile long and 1/2 mile wide centered near the Menlo Circus Club in west Atherton where computed depths to bedrock are in excess of 500 feet, (3) a structure bedrock high under the Lindenwood area of east Atherton where bedrock rises to within 300 feet of the surface, (4) a smaller structural high centered near the intersection of Willow Road and Ravenswood Slough in east Menlo Park, and (5) a shift in the position of the ancestral San Francisquito Creek perhaps by faulting from its present position about 0.2 miles to the southeast and eroding to a closed depression in the bedrock surface of -650 feet below sea level near the Stanford Shopping Center. Interpretation of the combined drilling, gravity, seismic, and magnetic data also suggests the presence of several previously undiscovered faults under the ground-water basin, both parallel and perpendicular to the San Andreas fault zone. No seismicity has been reported on these proposed buried faults, suggesting they may not be presently active.

Preliminary water quality data for 23 wells in the Palo Alto quadrangle and adjacent areas of Redwood City indicate that the ground water is generally good quality, although somehwat hard containing 120 to 300 ppm $CaCO_3$. Total dissolved iron content in four holes is a bit high (29-65ppb), though within the drinking water EPA standard of 300 ppb. Manganese concentration (47-80ppb) slightly exceeds the limit (50ppb) in 3 of 4 holes recommended by EPA. Salt water intrusion extends inland to approximately Bayshore Freeway and generally affects only shallow aquifers (less than 100 feet).

Additional geophysical work using low-level aeromagnetic, electromagnetic, resistivity, and seismic methods as well as some test drilling are needed to test the gravity model of the ground water basin.

Introduction

by H. W. Oliver

Although the southern San Francisco Peninsula communities from Palo Alto to San Jose have been utilizing their local groundwater resources for some time to supplement other sources (Poland and Ireland, 1988), the mid-Peninsula cities of Menlo Park and Atherton have satisfied most of their municipal water requirements through the purchase of Hetch-Hetchy supplies from the city of San Francisco. Therefore, no previous assessment of the extent of the ground-water basin or its capacity has been made in this area (Wood, 1975).

As the result of the 1976-1977 drought and associated water rationing which was repeated in 1987-1988 to a lesser degree, there has developed a keen interest in local ground-water resources in mid-Peninsula cities to provide emergency supplies during possible future droughts and/or disruption of Hetch-Hetcy flow by possible local fault movements and associated earthquakes. In the latter regard, a more detailed knowledge of local faults and their probable propensities for movement is desirable for planning water piping and storage systems.

For these reasons, a cooperative agreement between the City of Menlo Park, the California Water Service Company, and the U.S. Geological Survey was initiated in March, 1988, aimed at pulling together existing well information and constructing a model of the ground water basin under the Menlo Park-Atherton area. Existing wells that reached basement amount to seven in Menlo Park and nine in Atherton, although a number of additional shallow wells provide minimum depths to basement. Because of the limited well control and the rather large density contrast between the porous basin deposits and the more consolidated rocks beneath, a gravity survey was initiated to provide additional control on the model. Map sheet 1 presents the water basin model based solely on well control, map sheet 2 shows the gravity survey, and map sheet 3 displays the ground water basin as interpreted from both the wells and surface gravity measurements. In addition, a number of suspected faults, most previously unknown, are shown on both sheets 1 and 3 and the evidence for them is discussed.

The following summary of water quality data is based largely on previously published sources although it includes new information on important wells at the U.S. Geological Survey, the O'Connor Water District in Menlo Park, St. Patricks Seminary, and Sunset Magazine.

PRELIMINARY GROUND WATER QUALITY DATA FOR PALO ALTO 7.5′ QUADRANGLE

by V.E. Langenheim, H.W. Oliver and H.V. Leland

Water chemistry data are readily available on 23 wells in the Palo Alto-Menlo Park-Redwood City area obtained from the State of California Department of Water Resources (Sacramento) and the State Water Quality Control Board (Oakland). This information has been previously published, except as noted (*), and probably represents only a fraction of private, confidential water quality data on mineral constituents for the area.

Table 1. Chemistry data for 23 wells in the mid San Francisco Peninsula (Fig. 1)

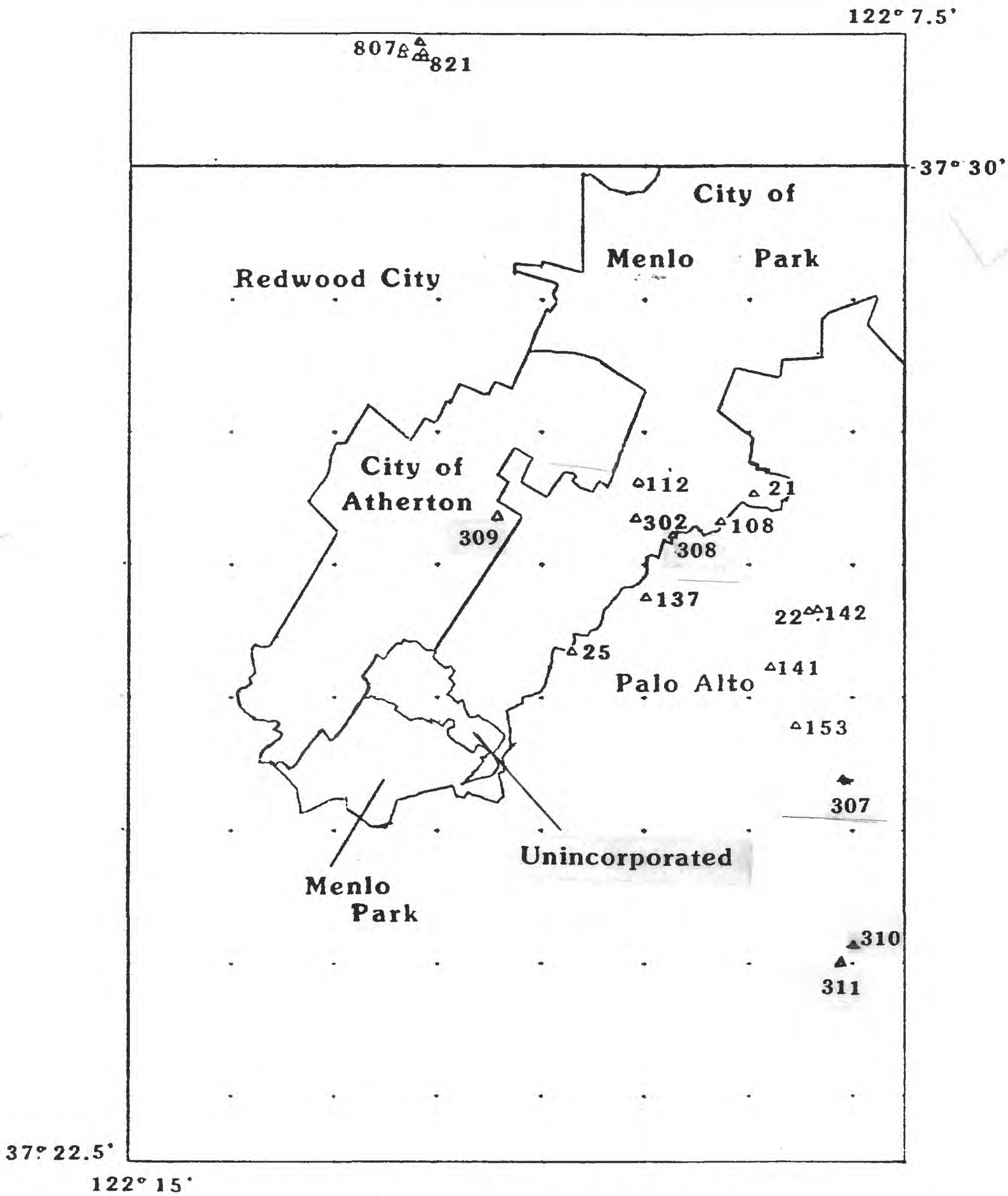
Brabb number	Analysis Done	Chloride ppm	Solids ppm	Hardness ppm (CaC03)	Depth ft.	Ref.
21*	1987	86-88	420	180	608	1
22	1955	194	608	200	1082	2
25	1949	197	450-460	229	746	3
108	1949-1961	55-170	395-567	158-227	303	3,7,8
112*	1983,1988	110	480	220	435	12
137	1949-1961	42-141	354-451	134-265	367	3,7,8
141	1949	141	430-570	--	430	3
142	1949-1961	99-282	430-647	200-220	446	3,7,8
148	1949	113-169	450	--	1080	3
153	1949-1961	42-141	365-390	135-147	526	3,7,8
302	1981	70	438-446	210	310	9
307	1931	52 (NaCl)	--	--	486	6
308*	1983,1988	39-46	314-514	145-307	213-25	11
309*	1980-2	120-40	610-650	360-440	317-30	14
310*	1988	47	440	36	200	15
311*	1988	10	570	140	30	15
818,820,821*	1965	210	611-617	228	350-75	4
807	1928-43	135-296	--	--	316	5
810	1943	144	580	120	330	5
816	1928-43	135-356	1,050	170	375	5
817	1943	166	585	190	330	5

Table 2. Chemistry data from surface water.

Tuolumne	1985	---	23-31	38		10
Bear Gulch	1959-78	16-40	217-351	134-210		13
San Francisquito Creek	1949,1969	23	569-599	110		2

For perspective, ground water in northern Santa Clara County is generally of good quality, although somewhat hard (California Department of Water Resources, 1975; no information is provided on organic concentrations). It is bicarbonate in nature and total dissolved solids (TDS) range from about 300 to 600 ppm. Problems with saline water intrusion from the Bay extend inland to approximately the Bayshore Freeway and generally affect shallow aquifers (less than 100 feet). Chloride concentrations can exceed 1,000 ppm in some wells, but the California Department of Water

FIG. 1. LOCATIONS OF WELLS FOR WHICH CHEMISTRY DATA ARE AVAILABLE (TABLE 1).



Scale approximately 1:100,000

Resources suggests that proper construction of wells can reduce the contamination of good-quality, deeper aquifer waters from saline shallow levels. High chloride concentrations can also be found in deep (500 to 1,000 ft) wells, thought to be the result of connate water from Tertiary marine formations. The electric log of well 5S/2W-31 (1040 ft) indicates that the upper 100 feet contain salt water, below which exists good water to about 280 feet, again followed by a general increase in salt content up to a calculated 3,800 ppm NaCl at the bottom of the well (California Department of Water Resources, 1967a).

Water from San Francisquito Creek is rather high in total dissolved solids (569-599 ppm; Table 2). Its iron content ranges from 16 to 206 ppb and manganese is variable, albeit high, ranging from 40 to 314 ppb (Averett and others, 1971). Water from Bear Gulch Reservoir has less total dissolved solids (217-351 ppm). Iron and manganese contents range from 0 to 140 ppb and 0 to 30 ppb, respectively.

Imported water from Hetch Hetchy project on the upper Tuolumne River is carbonate-bicarbonate in nature. This water is of excellent quality. Its total dissolved solids are about 30 ppm (Table 2). Chloride concentrations are less than 10 ppm and total carbonate concentrations are about 30 ppm (California Department of Water Resources, 1967b)

WATER-YIELD INFORMATION

The continuity of aquifers in the Palo Alto-Menlo Park area seems to be limited to the San Francisquito alluvial cone. One test during 1963 demonstrated very little effect of continuous pumping at a high rate (over 1000 gallons/minute) of the Hale Street well (Brabb well 108) on water levels recorded at seven wells within 4 miles of the well (California Department of Water Resources, 1967). The specific capacities of wells in this area are generally greater than 10 gallons/minute/foot drawdown (GPM/ffdd) and may be as high as 40 GPM/ffdd (Fig. 2; California Department of Water Resources, 1967a).

REFERENCES CITED IN TABLES 1 AND 2.

(1) Sequoia Analytical Laboratories, O'Connor Cooperative Tract Water Company.

(2) Averett, R.C., Wood, P.R., and K.S. Muir, 1971, Water chemistry of the Santa Clara Valley, California, U.S.G.S. Water Resources Division Open File Report.

(3) Division of Water Resources, Appendix G, Partial and Complete Mineral Analyses of Ground Waters in Santa Clara Valley (post 1949).

(4) Cook Research Laboratories, RMC Lonestar Cement (formerly Ideal Cement Company).

(5) Poland, J.F., and A.A. Garrett, 1943, Ground-water conditions in the Redwood City Area, California with particular reference to water supply for the Pacific Portland Cement Company, U.S.G.S. Water Resources Division Open File Report (retyped Sacramento 1970).

(6) Cheryl Jensen, 1989, written communication.

(7) California Department of Water Resources, 1964, Quality of Ground Waters in California 1961 and 1962, Bull. 66-62, Part I. Northern and Central California.

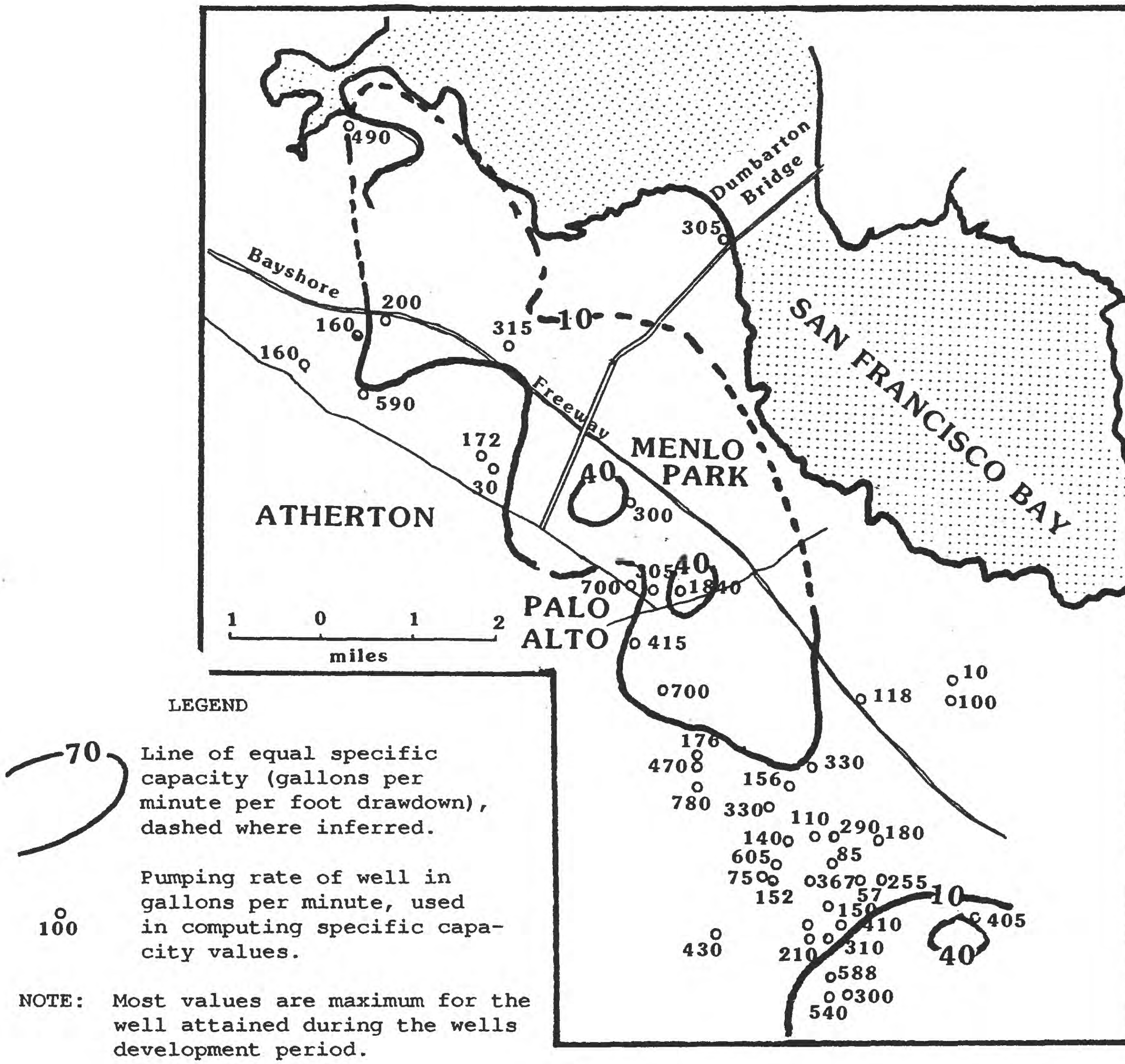


Figure 2. Lines of equal specific capacity of water wells showing pumping rates (from Department of Water Resources, 1967a).

(8) California Department of Water Resources, 1956, Ground water quality monitoring program in California, Water Quality Investigations Report no. 14.

(9) U.S. Geological Survey.

(10) California Department of Water Resources, 1988, Hydrologic Data 1985: San Joaquin Valley, Bull. 130-85, vol. 4.

(11) Scientific Consulting and Perry Laboratories, Lane Publishing Company,

(12) Sequoia Analytical Laboratories, St. Patricks Seminary.

(13) California Water Service Company.

(14) Sequoia Analytical Laboratories, Menlo College.

(15) State of California Water Quality Control Board, Oakland, CA.

Summary of drilling log, electric logs, and water quality of USGS Well 5S/3W-34H1 (Brabb Well 302)

This well, located at the United States Geological Survey Western Regional Headquarters in Menlo Park, was drilled in 1977 and is 310 feet deep. It was constructed in order to provide water for research on aquatic life carried out by the Water Resources Division (see Scudder and others, 1988). For the purpose of preventing any surface contamination of the ground water, the well has a 16-inch casing seal (grout) down to 135 feet. Below 135 feet the well has a 8 5/8-inch casing with two perforated intervals at 180 to 200 feet and 250 to 270 feet. The casing of the well is pulled back to 290 feet. There was no drawdown test performed on this well, but the well is capable of producing 200 gallons/minute for several hours with no significant effect on drawdown. It is usually operated at a pumping rate of 50 gallons/minute for eight hours a day, but it will not be operating the summer of 1989. It has two operational pumps, a primary and a backup.

The well penetrates 310 feet of Quaternary alluvium or about half the depth to basement of about 710 feet as determined by drilling about 0.1 mile to the southeast (see Sheet 1, this report). Samples were taken by the well drillers at five foot intervals starting at 25 feet. The first 40 feet is primarily brown clay with some fine sand, followed by 45 feet of brown clay and gravel. There is a small gravel lens at 85 to 90 feet. This is followed by olive clay and sand down to 130 feet. Between 130 and 170 feet there is olive clay. There is coarse sand and gravel between 170 and 220 feet, followed by clay and sand to 260 feet and clay and gravel to the bottom of the well. The electric resistivity log starts at about 65 feet and shows high resistivity at the following intervals: 70-80, 160-175, 182-192, 196-198, 242-249, and 261-268 ft. There appears to be a correlation between the lithology and the resistivity log in that gravels and sands generally correlate to intervals of higher resistivity and that clayey intervals seem to be more conductive (Fig. 3).

The water chemistry is well known (Table 3). It is hard to very hard water (210 ppm $CaCO_3$) and consistent with water produced by other wells in the area. It has a pH of about 8.2. Its boron content is 0.15 ppm. Its total dissolved solids are about 436 to 446 ppm which is near the limit for drinking water suggested by the Environmental Protection Agency (500 ppm).

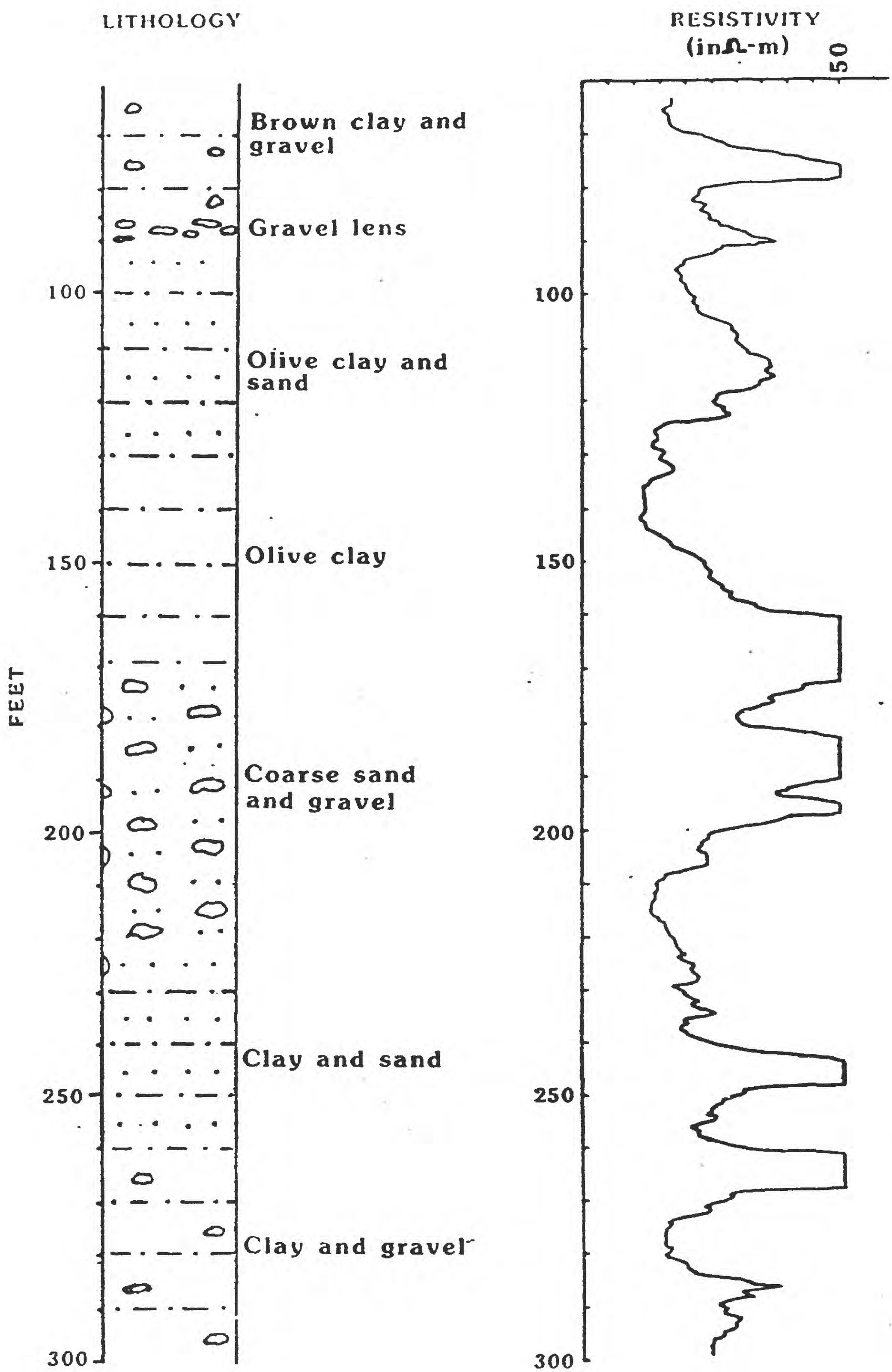


FIGURE 3. Lithologic and electric logs of USGS well.

TABLE 3. Water chemistry for USGS Leland well (labelled -267 on Sheet 1).

Date: 1981
Temperature: 19.0°C
pH: 8.17

Species	Concentration (ppm)
Boron	0.15
Calcium	58
Magnesium	15
Chloride	70
Fluoride	0.2
Potassium	1.5
Silica	22
Sodium	76
Iron	.040*
Manganese	.071
Zinc	.005
Cobalt	.0001
Sulfate	59
Nitrogen (NO_2+NO_3)	2.3
Hardness ($CaCO_3$)	210
Alkalinity ($CaCO_3$)	210
Total Dissolved Solids	446

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*Concentrations range from 0.029 to 0.065 ppm.
From U.S. Geological Survey data and from Scudder et al., 1988.

Its chloride content (70 ppm) is within the drinking water standard of 250 ppm. The dissolved iron content (29 to 65 ppb), though within the drinking water standard of 300 ppb, is high for the purpose of research on aquatic life and thus the Water Resources Division regularly filters the water to reduce iron. The manganese concentration (71 ppb) does exceed the limit (50 ppb) recommended by the Environmental Protection Agency. In short, the water produced by this well is of fairly good quality, though very hard. To be made potatble it may have to be treated to reduce the excess manganese concentration.

The water level of this well has been measured since its construction in 1977. The initial water level was 53.9 feet below land surface in August 1977. It rose to a level of about 26 feet in January, 1985 and since then has fallen to 49.1 feet below land surface in April 1989 (Fig. 4).

O'CONNOR WELLS

The O'Connor Cooperative Tract Water Company has 2 wells near Oak Court in Palo Alto. Well #1 was drilled in 1966 to a depth of 608 feet. It has a sanitary seal to a depth of 71 feet and the depth of casing extends to 550 feet. A drawdown test indicates that the well was pumped at a rate of 1200 gallons/minute (GPM) for six hours without a discernible dropoff at the operating level. After 38 hours of pumping at rates of 600 to 1200 GPM there was a 25-foot drawdown. Thus the specific capacity of the well is 45 GPM/ffdd. The perforated intervals are 181-372, 396-489, and 508-532 feet.

The other well, Well #2, was constructed in 1920. It is 316 feet deep. The specific capacity of this well is about 5 GPM/ffdd (Wood, 1975). The difference in specific capacity probably reflects encrustration on the well casing perforations.

Well #1 has both lithologic and electric logs (Fig. 5) and there are water chemistry data available on both wells (Table 4).

Table 4. Water chemistry data (1987) on O'Connor Wells, Palo Alto (Brabb #21)

Species	Well #1 Concentration (ppm)	Well #2 Concentration (ppm)
Calcium	56	64
Magnesium	11	16
Sodium	60	60
Potassium	1.9	2.3
Carbonate	<0.5	<0.5
Bicarbonate	140	130
Sulfate	50	52
Chloride	86	88
Nitrate	4.0	2.8
Iron	0.060	0.040
Manganese	0.040	0.080
Zinc	<.050	<.050
Copper	0.030	0.010
Total Hardness	180	220
Total Dissolved Solids	420	440

ST. PATRICKS SEMINARY WELLS

The St. Patricks Seminary well (Brabb # 112)was drilled in 1986 to

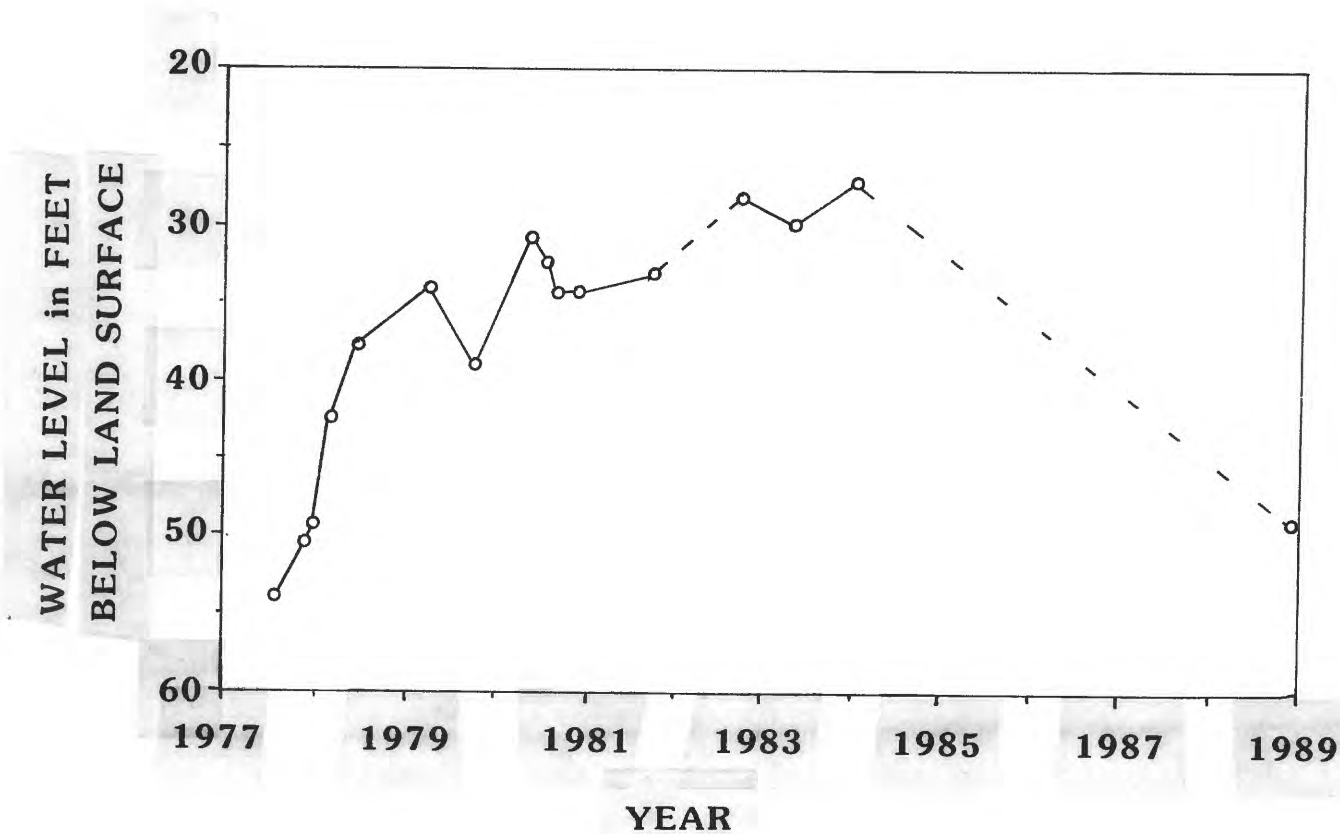


FIG. 4 WATER LEVEL OF USGS LELAND WELL

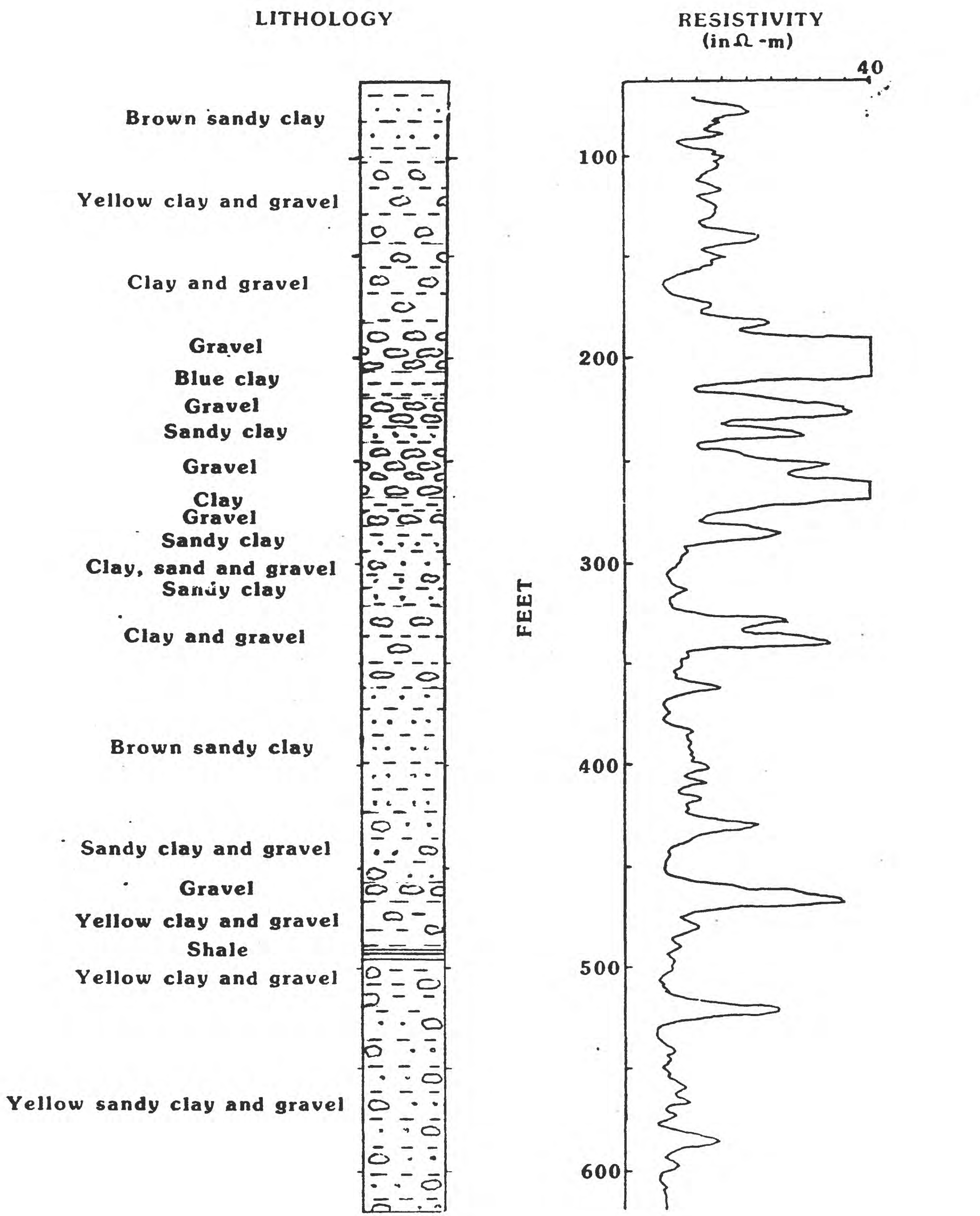


FIG. 5 O'CONNOR WELL

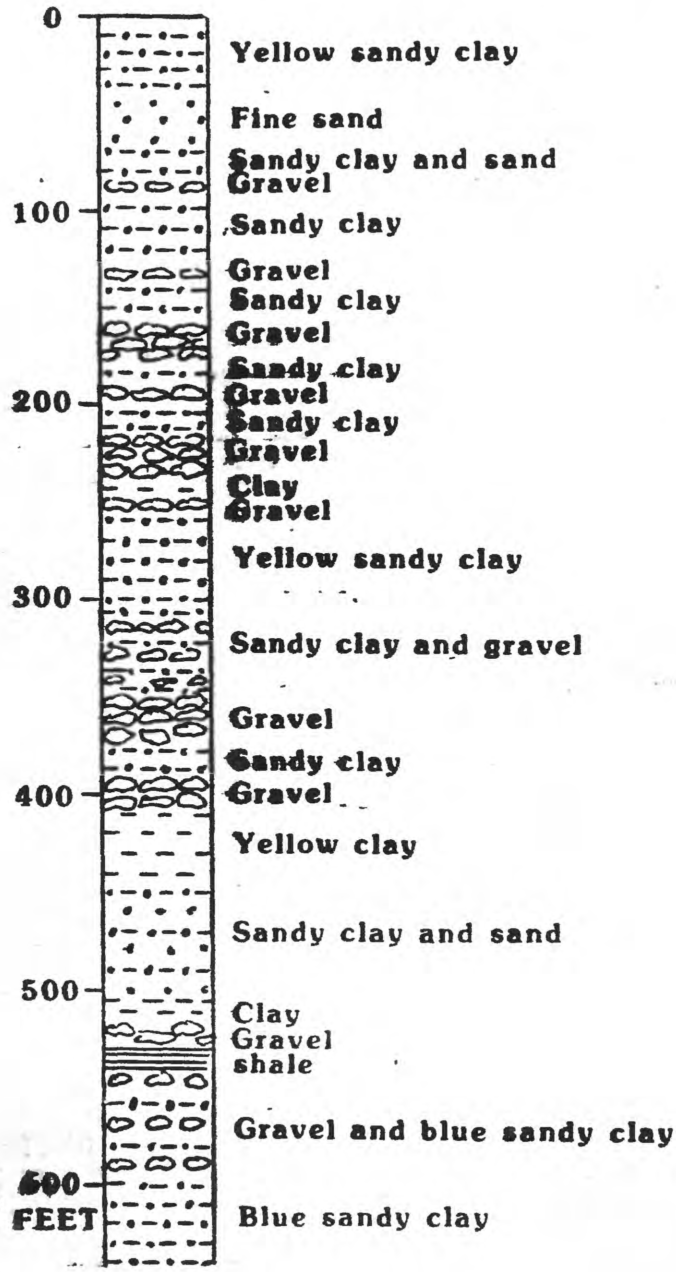
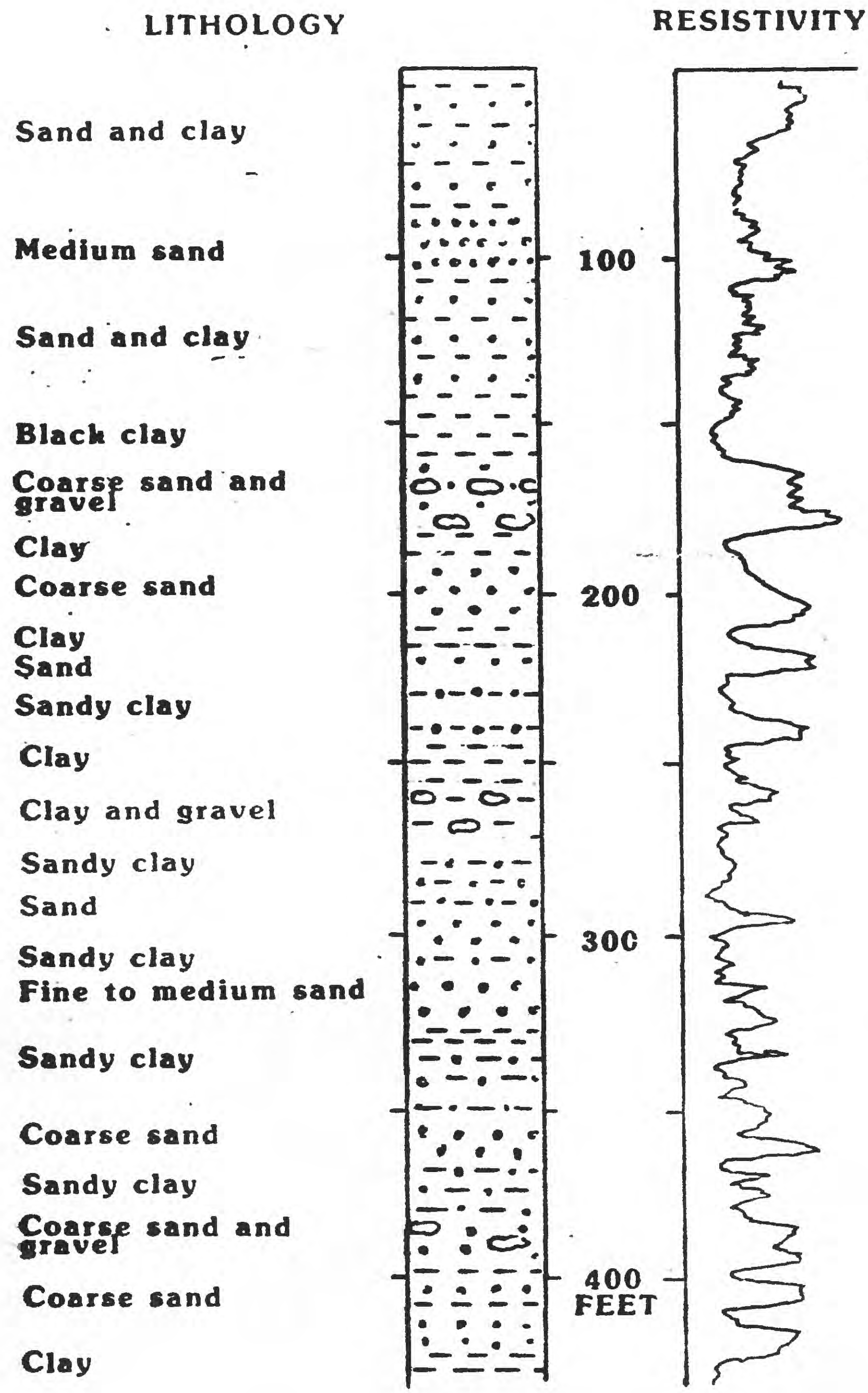


FIG. 6 ST. PATRICKS SEMINARY WELL
BRABB #110

FIG. 7 ST PATRICKS SEMINARY
BRABB#112



a depth of 435 feet through Quaternary alluvium. It has a sanitary seal down to 150 feet. A well test indicates a discharge of 600 gallons/minute (GPM) for 5 hours with a drop in water level from 85 to 96 feet. Thus the well has a specific capacity of about 5.4 GPM/ffdd. The well has 12 3/4"-inch casing down to 425 feet. The perforated intervals are 160-180, 190-220, 230-240, 350-360 and 380-420 feet. There are water chemistry data (Table 5) and lithologic and electric logs for this well (Fig. 6).

There was an older well (Brabb # 110), drilled in 1965, that penetrated 641 feet of alluvium, but in 1985 the well caved in. There is a lithologic log (Fig. 7) and a drawdown test indicated a specific capacity of 16.8 GPM/ffdd.

Table 5. Water chemistry data (1983,1988) of St. Patricks Seminary Well (Brabb

Species	Concentration (ppm)
Calcium	52
Magnesium	22
Sodium	98
Bicarbonate	110
Sulfate	3.8
Chloride	110
Nitrate	3.6
Iron	0.140
Manganese	0.060
Zinc	0.240
Total Hardness	220
Total Dissolved Solids	480

DESCRIPTION OF THE SUNSET WELLS (Brabb #308)

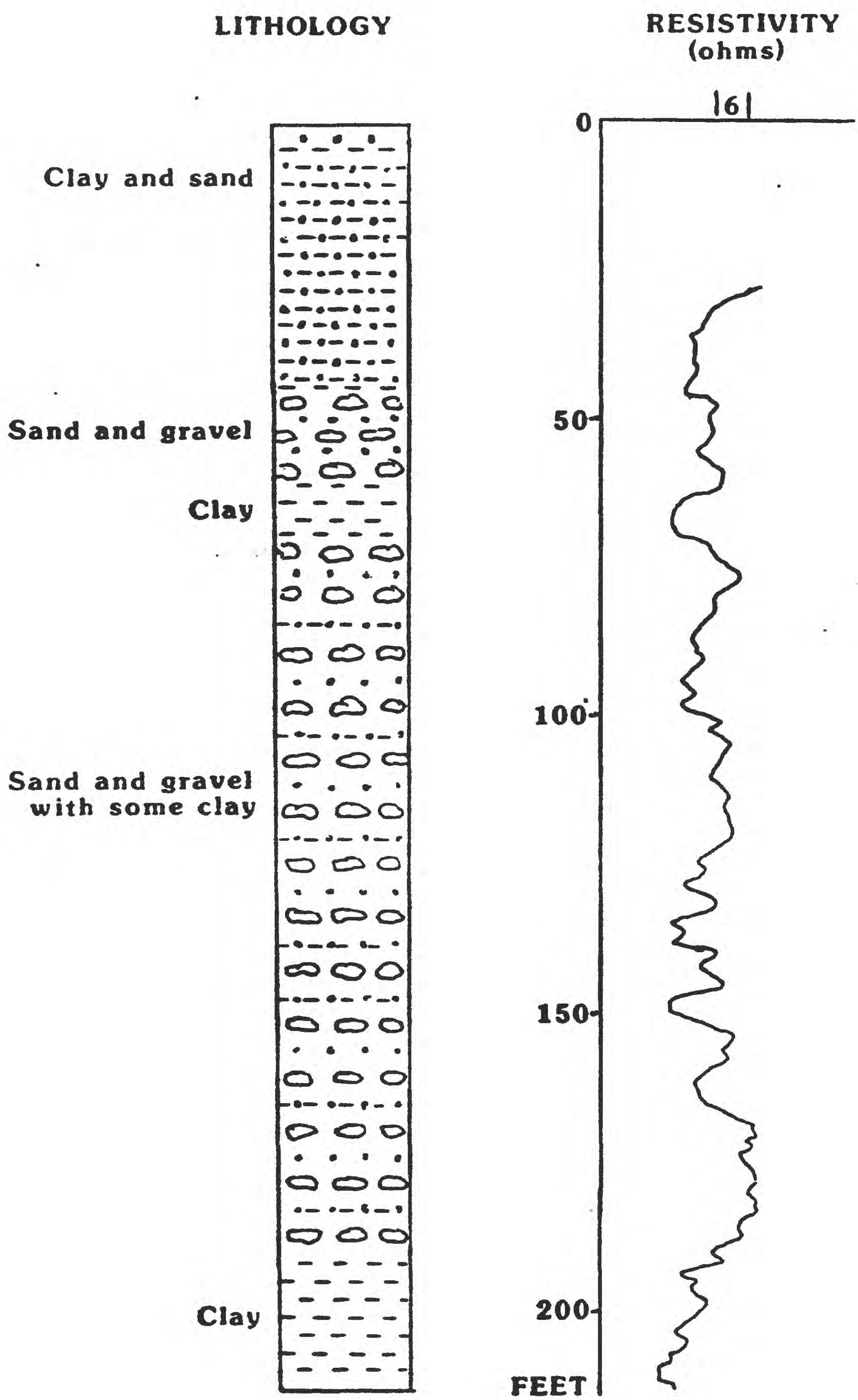
Lane Publishing Company owns 2 wells on its property at 80 Willow Road in Menlo Park. These 2 wells provide water for irrigation purposes. The "South" well was drilled in 1977 to a depth of 225 feet. A drawdown test of this well indicates that after 2 hours of pumping at a rate of 75 gallons per minute (GMP), the water level in the well decreased from 56 to 60 feet. The well is perforated at the following depths: 100-110, 160-165 and 185-195 feet.

The "West" well was constructed in 1983. It penetrates 213 feet of Quaternary alluvium. It can operate at a pumping rate of 310 GPM. The perforated intervals are 100-120 and 150-190 feet. Both wells have water chemistry data (Table 6) and lithologic and/or electric logs (Fig. 8,9).

Table 6. Water chemistry data (1983, 1988) for the Sunset wells

Species	South well Concentration (ppm)	West well Concentration (ppm)
Chloride	40-45	39-46
Iron	0.047-0.050	N.D.
Manganese	0.047-0.050	0.078
Nitrate	5.5	8.0
Hardness	307	145-150
Total Dissolved Solids	485-514	314-455
pH	7.8	7.8

FIG . 8 "WEST" SUNSET WELL



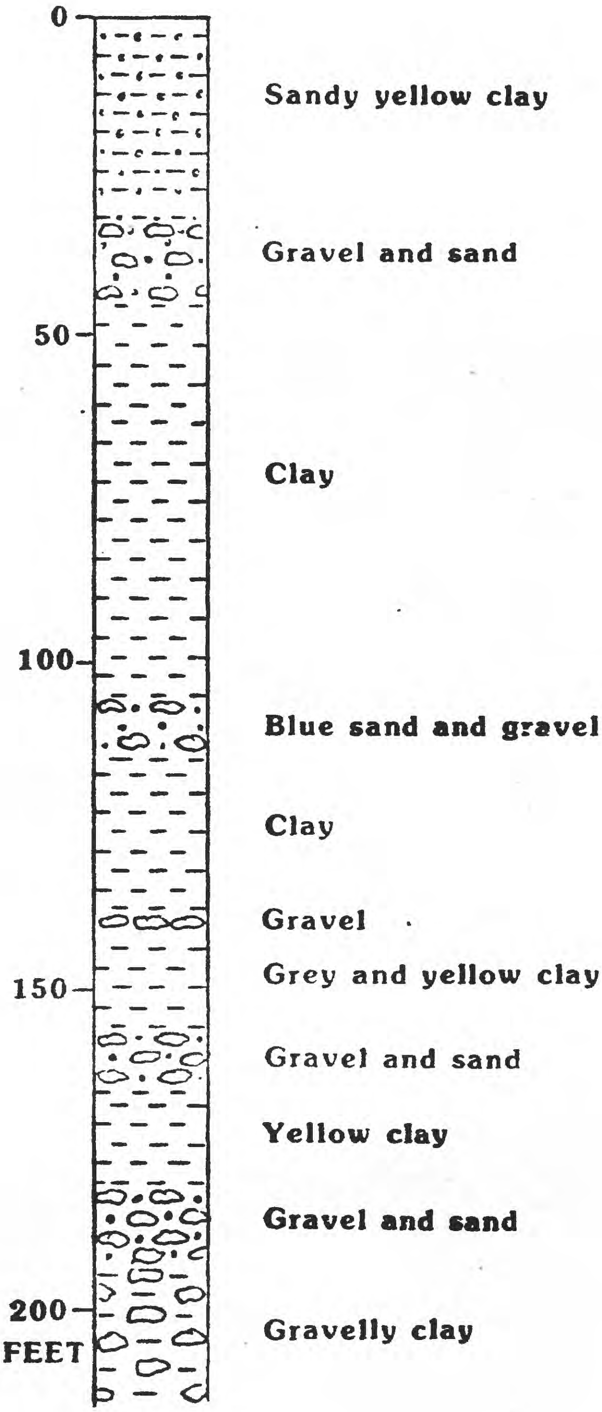


FIG. 9 "SOUTH" SUNSET WELL

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Conclusions

by H. W. Oliver

These sheets represent the first compilation of water-well information together with geophysical studies in the Menlo Park-Atherton area and provide the preliminary geologic basis for recommendations being made by the Barrett Consulting Group (1989) for the drilling of three production wells in and construction of storage tanks to provide an emergency water reserve for Menlo Park. However, much of the information presented on Sheet 1 is a synthesis and interpretation of existing information. The water quality information has been taken primarily from previously published sources and may not be representative of current conditions in the Menlo Park area. Moreover, very little information is presently available on past and present pumping rates and on the ground water basin for recharge. Few of the water quality analyses include more than the most basic chemical characteristics. More complete analyses that include common ions, nutrients, and screening for possible organic and trace element contamination may be advisable.

In addition, the depth and location of the wells with available records are not ideally suited for the critical evaluation of quality and availability of ground-water in the area. In order to properly evaluate the potential for water resource development in the area a more detailed and comprehensive study is needed. This study should include the drilling of additional wells for the definition of the geometry of the ground-water reservoir, aquifer properties, and chemical characteristics of the water. Areas of recharge, discharge, and rates of ground-water movement need to be identified so that water managers can properly plan for the development of the resource.

Additional geophysical work such as low-level aeromagnetic, electromagnetic, resistivity, and seismic surveys as well as some test drilling are needed to test the gravity structural model of the ground water basin (Sheet 3) and to determine its flow characteristics. Leveling and high-precision gravity along at least two SW-NE lines through Menlo Park and Atherton would serve as a check on excessive ground water withdrawal and monitor possible resulting subsidence of the land surface.

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