## Chapter 2

# GROUNDWATER IN BERKELEY

James Romanucci

### Introduction

The purpose of this paper is to describe and where possible to map the groundwater table in Berkeley, to investigate several groundawter users in Berkeley, and to comment on possible future development of the groundwater resource.

### Historical Background

Groundwater has played an important role in the development of the East Bay Area. It was a major source of water in Berkeley into the twentieth century (see Dawkins and Kondor, this report). In 1911 a report on the water supply in the East Bay logged about 80% of the wells in the area (Dockweiler, 1911). At the time, these wells supplied about 90% of all well water in the East Bay. 642 wells were reported in Berkeley. Of these, 55 were abandoned, leaving 587 live wells. Thirty of the live wells were vacant, leaving 557 active wells. These wells pumped an average of 473,820 gallons per day, supplied 714 premises, and supported 3,718 persons and a small amount of livestock.

Interestingly, well levels shown in that report are significantly lower than those in modern records for wells located in the same area. For example, a well at 1120 Fourth Street, near the bay, had a water level of eight feet in 1911 (Dockweiler, 1911). Modern levels shown on Figure 4 are about three to six feet in this area. Wells at 1514 Oxford Street and near Bowditch and Haste had depths of 30 feet and 45 feet, respectively (Dockweiler, 1911). Modern records indicate levels of about 14 to 20 feet for these areas (Figure 4).

Late in the first quarter of this century, some well levels were below sea level (Sander, 1924). In 1918 the East Bay Water Company found five wells below the level of the sea; four of these were seven feet below sea level by 1920. Well levels were above sea level in 1929, but they dropped below that level in 1922-23 (Sander, 1924). By 1924 the groundwater had dropped to 20 feet below sea level and salt water intrusion threatened wells near the bay (Le Van, 1924).

Berkeley is now more developed, with much of the ground buried under concrete and asphalt. The high groundwater levels of today are thus probably due to the significant reduction in the use of groundwater since the completion of the Mokelumne aqueduct.

The laws regarding groundwater have also changed since the beginning of the century. Before 1902 groundwater statutes reflected English Common Law. The Law of the Capture stated that anyone with land overlying groundwater could extract it and use it on any other land. At that time the Supreme Court of California modified these laws by judging that the overlying landowner held a right in common with other landowners in securing groundwater for reasonable, beneficial purpose. This ruling paralleled laws regarding riparian rights and was designed to take into consideration the possibility of overdraft, exceeding the maximum safe yield of a groundwater basin.

The modern groundwater laws were further shaped by two landmark cases. In the 1940's the City of Pasadena vs. City of Alhambra established the right of mutual prescription. Simply stated, each party's rights were dependent on those of all other parties, and each party had to lower its groundwater draw. Remaining balances were imported from the Metropolitan Water DIstrict's Canal which draws water from the Colorado River. In 1975 the Supreme Court gave priority to public agencies by prohibiting private pumpers to obtain prescriptive rights in a groundwater basin against a public water agency. This decision, in City of Los Angeles vs. City of San Fernando, took over twenty years to complete, but it established the laws as they stand today (Kahrl, 1978).

## Geology

Among the many factors affecting the hydrology of groundwater, three--geology, topography and precipitation--are of greatest importance. The topography and precipitation of Berkeley is described in another paper (see Lawler, this report); a brief description of geology is thus in order.

The Berkeley city limits enclose an area of land which can be divided into three geomorphic zones: the hills east of the Hayward Fault zone, the fault zone itself, and the gently sloping alluvial plain on which most of the city lies. Each geomorphic zone has a different geological structure which affects the groundwater.

The hills - Within the city limits, four major geologic formations have been recognized in the Berkeley Hills. From oldest to youngest these include the following: relatively permeable Cretaceous sediments of marine origin, located at the base of the hills; the relatively impermeable cherts and shales of the Middle Miocene Claremont Formation; the highly permeable conglomerates and sandstones of the late Miocene Orinda Formation; and the impermeable basalts of the latest Miocene Grizzly Peak Formation. These different units are covered by a mantle of colluvium that ranges in thickness from a few centimeters or less near the crest of the hills to three meters or more near the base (Lawson, 1902; Radbruch, 1957 and 1969).

An appreciation for the availability of water in each of these formations can be gained by examining the vegetation cover. The relatively impermeable Grizzly Peak and Claremont Formations support mainly xeric communities, including grassland and chapparal. Lush stands of arboreal vegetation, on the other hand, grow on the permeable Orinda Formation and on the Cretaceous sediments.

Groundwater levels in the hills are thus quite variable. Where the rock is relatively non-permeable, groundwater is perched upon the interface between the unweathered bedrock and the overlying colluvium (for a description of landslides attributed to this factor, see Law, this report). Where the rock is permeable, the depth of the groundwater table is also shallow, but water penetrates to deep levels (see Figure 1).

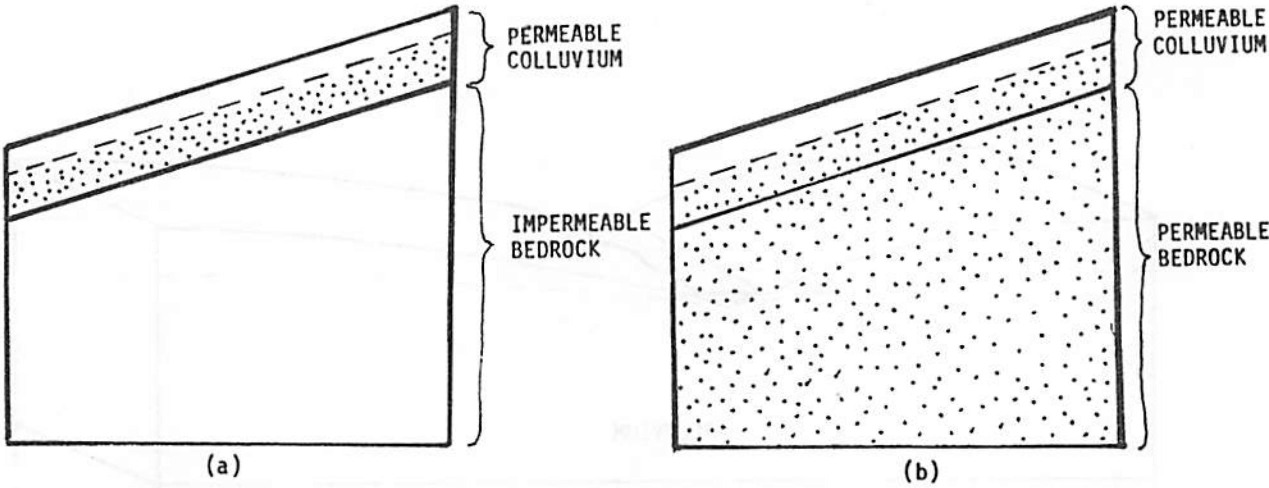

Figure 1: Groundwater Profile in the Berkeley Hills

Figure (a) is for non-permeable formations like the Grizzly Peak and the Claremont
Figure (b) is for permeable formations like the Orinda and the Cretaceous Sediments

Data for groundwater levels in the hills are difficult to find. A boring southeast of the Claremont Hotel at an elevation of about 500 feet in Cretaceous sediments (Bore #1, Figure 4) has a water level of about 30 feet. Another boring in the hills near the Broadway Tunnel has a water level of about 39 feet. This boring is located at about the 1000 to 1200 foot elevation level and is in the Claremont Formation (U.S. EPA, 1971; Radbruch, 1969).

The Hayward Fault-Zone - The Hayward Fault-Zone is a strip of land a few hundred yards wide along which lies the Hayward Fault. It is composed of crushed rock of various types and is overlain by alluvium in most areas (Radbruch, 1969).

The Fault Zone acts as a barrier to groundwater flow and is of major importance to the nature of the groundwater in Berkeley. The zone dams subsurface flow from the hills, causing artesian springs to emerge at or above the fault strike. A spring just east of the running track at the School for the Deaf and Blind is partially caused by this damming effect. The Hayward Springs and other springs which had an important influence upon the settlement of ranches in early East Bay history are also created by the damming effect (see Dawkins, this report).

A boring in the fault zone near the Claremont Hotel (Bore 2, Figure 4) has a water level of 20 feet (Weaver and Radbruch, 1960). A nearby boring east of the fault strike and about 1000 feet southeast of the Claremont Hotel (see Bore 3, Figure 4) has a water level of 11.5 feet (Weaver and Radbruch, 1960). This difference also demonstrates the damming effect, but is partially caused by an influx of water from nearby Claremont Creek (Figure 2).

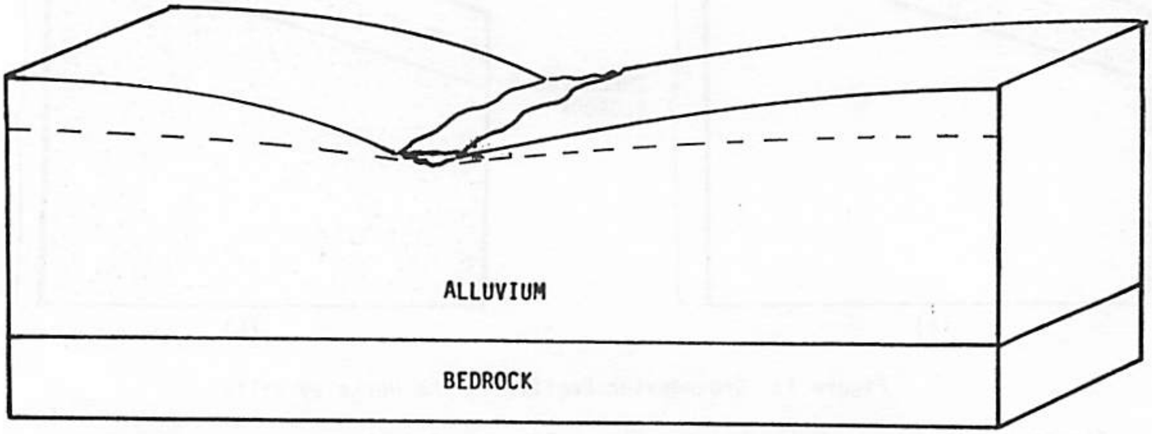

**Figure 2: Idealized Groundwater Table Near a Creek**

<u>The Alluvial Plain</u> - The Alluvial Plain is composed of coalescing alluvial fans (Hogenson, 1967). The alluvial fans are made up of layers of silt, sand, clay, and pebbles; the coarser material tends to be deposited near the head of the fan (at the foot of the hills) and the finer materials are deposited at the toe of the fan (near the bay). For example, a boring near the University designated as Hole G1-13 (see Bore 4, Figure 4) is cut through mostly sand and gravel with some interbedded layers of clay (Weaver and Radbruch, 1960). Another boring near the bay, Hole E1-1 (see Bore 5, Figure 4) is cut through mostly clay (Weaver and Radbruch, 1960).

The layers of coarser material are very permeable, but the layers of finer materials act as aquicludes, barriers to infiltration. For this reason higher water levels would be expected near the bay than near the hills. Also one would expect the levels near the bay to be shallower because the alluvium at lower elevations receives not only percolation from precipitation, but also through-flow from alluvium at higher elevations. The data from the borings, in fact, show the inverse relation between elevation and well water levels (Figure 3). Well water depth varies from 14 to 34 feet near the Hayward Fault Zone to about 3 to 10 feet near the bay.

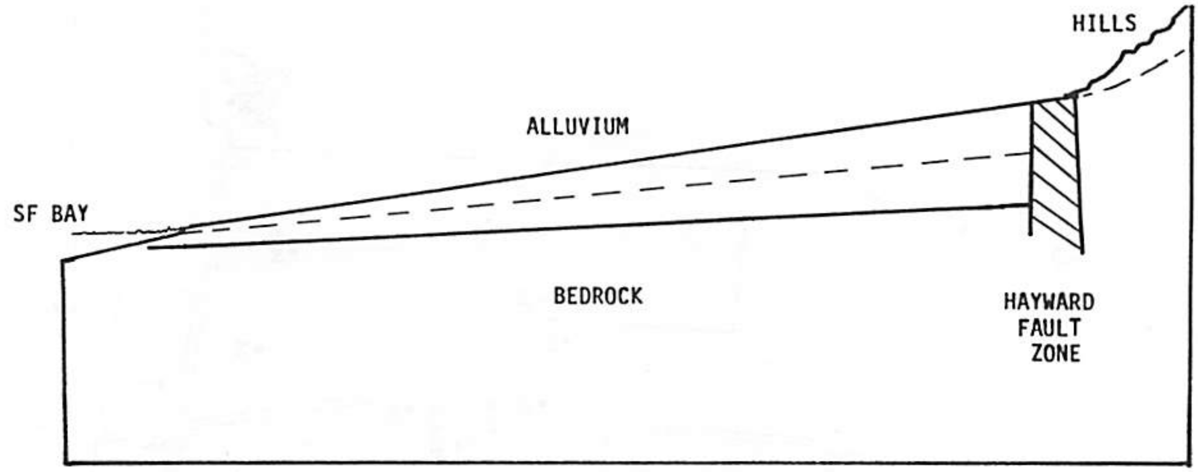

**Figure 3: Groundwater Profile in the Alluvial Plain, Berkeley**

**The groundwater table near the hills is deeper because areas near the bay receive underground flow from areas near the hills in addition to infiltration from precipitation. (Note the damming effect of the fault and associated fine grained fault gouge on the water table in the hills)**

## Fluctuations of the Groundwater

Data from a well at Manasse-Block Tanning Company, located at 1300 Fourth Street in Berkeley indicate that well levels fluctuate with precipitation and other factors. Table 1 shows that during the 1976-77 drought, the water level dropped. (Note the difference between 03/01/76 and 09/20/76 and between 09/20/76 and 03/25/77.) Other drops in 1974 and 1982 may be due to increased well use during these periods.

| Date | Water Depth | Date | Water Depth |
|---|---|---|---|
| 04/11/74 | 43.5' | 09/27/77 | 6.1' |
| 09/03/74 | 52.6' | 09/06/78 | 8.5' |
| 03/13/75 | 1.3' | 04/22/80 | 8.9' |
| 09/29/75 | 3.7' | 05/26/81 | 4.4' |
| 03/01/76 | 2.5' | 10/20/81 | 5.1' |
| 09/20/76 | 10.0' | 05/04/82 | 4.1' |
| 03/25/77 | 28.6' | 10/13/82 | 18.9' |

Table 1: Fluctuating Well Water Levels in a Single Well
Source: Alameda Flood Control Dist. (undated)

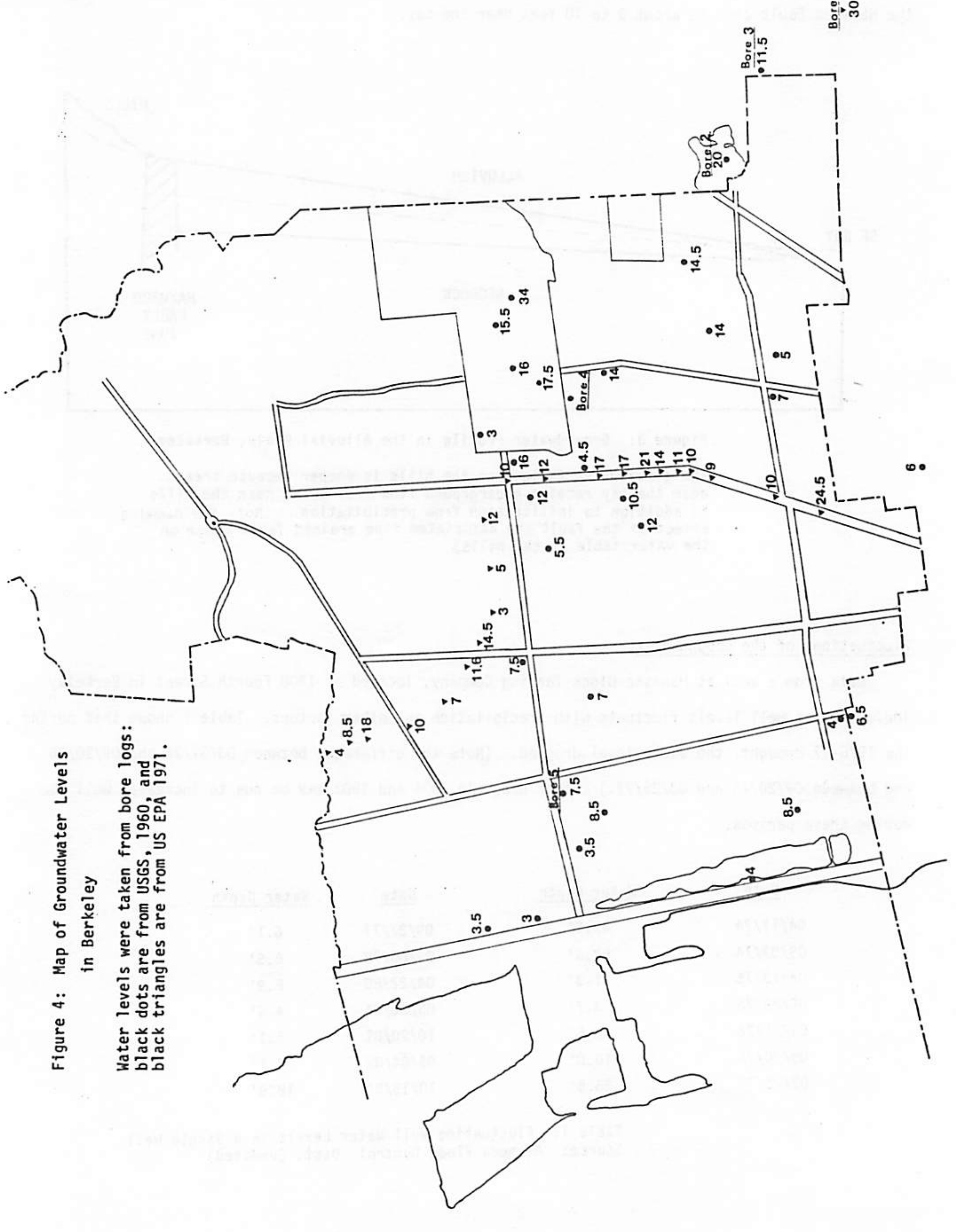

Figure 4: Map of Groundwater Levels in Berkeley

Water levels were taken from bore logs: black dots are from USGS, 1960, and black triangles are from US EPA 1971.

## Map of the Groundwater

Figure 4 is a map of the groundwater in Berkeley. Several aspects about the validity of such a map should be mentioned. First, since this map uses water levels in borings, it is actually a potentiometric surface map or a map of the hydraulic head in the aquifer (Figure 5). The map does, however, provide a picture of the subsurface hydrology.

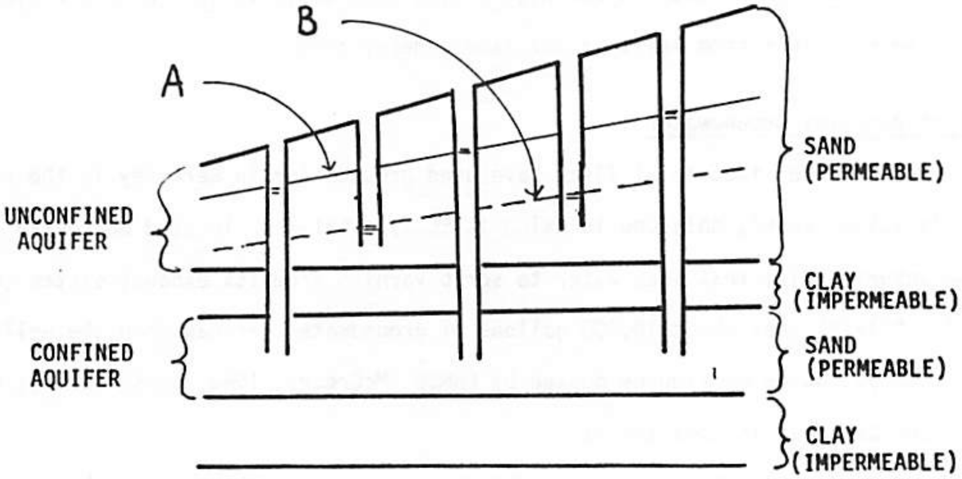

**Figure 5: Potentiometric Sufrace Profile**
**Source: Freeze and Cherry, 1979**

**Figure shows difference between the potentiometric surface (A) from a confined aquifer and a water table (B) from an unconfined aquifer.**

The usefulness of a potentiometric surface map is limited, since it may be misinterpreted if the aquifer is not horizontal (Freeze and Cherry, 1979). A map of such a surface should be drawn using data from wells whose bottoms end at or near the same elevation. These wells would tap the same confine or unconfined aquifer (Freeze and Cherry, 1979). For example, two USGS borings designated as E2-3 and E2-4 in southwest Berkeley are located about 0.2 miles apart and are situated at about the same elevation (Weaver and Radbruch, 1960). The water level for E2-3 is 8.5 feet, but the level for E2-4 is 18 feet. The two borings are very different in depth: E2-3 is 218 feet deep and E2-4 is only 20.5 feet deep.

Since well and boring levels fluctuate depending on seasonal and annual precipitation, and since the well data are not all from the same dates, there are variations in the data which reflect the seasonal or annual fluctuations.

There are also local variations due to the local geology, topography or hydrography (see Figure 2). For example, BART's borings show higher water levels at sites near Codornices Creek than those farther from the creek (U.S. EPA, 1971). Since no specifics of these borings are cited, however, one cannot conclude with absolute certainty that the higher levels are wholly caused by the influx of creek water; the deduction is not unreasonable, though.

The map does show some trends discussed above, including the deeper water levels near the hills. Water levels near the bay are shallow and high yields from wells in this area are likely. Note the difference in water levels from wells in the same general area.

## Present Use of Berkeley Groundwater

Industrial - A handful of industrial firms have used groundwater in Berkeley in the recent past, but so far as this author knows, only one is using it today. Cal-Ink, located on Fourth Street, is a varnish manufacturing firm that uses water to scrub varnish from its exhaust system (Brown, 1983, pers. comm.). Cal-Ink uses about 10,400 gallons of groundwater per day when the well is used (Pierce, 1983, pers. comm.). Based on figures quoted by EBMUD (McCreary, 1983, pers. comm.), Cal-Ink saves about $5,80 each day that it uses the well.

The amounts used by Cal-Ink seem comparable to those used in the past by Manasse-Block Tanning Company. This company consumes about 38,000 gallons per working day but has not used groundwater since its pump broke in 1981 (Malkasian, 1983, pers. comm.). Since the cost to repair the pump was several thousand dollars, Manasse-Block decided it was not worth fixing and has since used water supplied entirely by EBMUD (Malkasian, 1983, pers. comm.). It may be that Manasse-Block used very little groundwater even when the pump worked.

Non-industrial commercial use - One of several non-industrial users of groundwater is the Claremont Hotel. Groundwater is used for irrigating the hotel grounds (Hummel, 1983, pers. comm.). The well is 200 feet deep and the water depth is about 80 feet (Alameda County Flood Control District, undated; Ludorff, 1983, pers. comm.). The pump is submersible and expells 50 gallons per minute, although it has pumped up to 100 gallons per minute on at least one occasion. The well is used from May to September, and is run from four to six hours per day (Ludorff, 1983, pers. comm.). This saves the hotel about $230 to $240 per month if the well is used every day and if the EBMUD rate quoted earlier is used. The above equates to a saving of $1150 to $1200 per watering season (5 months) if the price of pumping the water is not deducted.

Private - There are several privately-owned wells which are still in use in Berkeley. One of these well was used by the author for irrigation at his residence from 1979 to 1981. The well is located at 1306 Haskell Street and is about 30 feet deep. The intake pipe is about 18 to 20 feet long and

1½ inches wide. The pump is a 1 3/4 hp. Berkeley pump which expels 5 gallons per minute through a standard 5/8 inch pipe. The landlord and the author maintained about 500 square feet of vegetable garden, 800 square feet of decorative plants and lawn, several fruit trees and a 30 foot long row of blackberry vines with water from this well. The well was used about 2 hours per day, 4 days per week. At this rate the landlord saved a little over $5 per month, excluding electricity costs for pumping. Since the well was used from April to October, 35 dollars were saved each year, excluding electricity costs. Since the electricity costs were not calculated, it is not clear if using groundwater at this site was economical.

## Suggestions for Future Development

From the above analysis, it is not clear that further development of groundwater for private use is economically promising. It may well be, however, that larger consumers would benefit from using groundwater.

Groundwater could be used as a major source of supply if the Mokelumne water were interrupted by a disaster or severely reduced by drought. During the drought of 1976-77 the University used groundwater for irrigation (Warnke, 1983, pers. comm.). The University had used groundwater until about 1935 when it leaked into the Life Sciences Building. A fear arose that the groundwater might contaminate the drinking water and was discontinued at that time.

During the drought the University used two wells located along Strawberry Creek. One, located near West Circle, is 45 feet deep and had a water depth of 18 feet 7 inches in 1977. The other well, located just south of the Life Sciences Building is 71 feet deep, and had a water depth of 7 feet 4 inches in 1977. The University used two pump trucks to distribute the water: a 100 gallon gallon World War Two surplus airplane fuel tanker rigged with a sprayer, and a 5000 gallon tanker loaned by the Lawrence Berkeley Lab. In addition, the University bought nine 1300 gallon tanks which were placed at strategic locations to reduce transportation costs. (One of these tanks is still visible on the east end of People's Park.) The water was used to keep newly-planted fields alive, to water playfields, and to maintain important trees and shallow-rooted plants on campus. Surprisingly, the University reduced consumption 50 to 60 percent partially as a result of the use of groundwater (Warnke, 1983, pers. comm.).

The University experience demonstrates the complexity of water distribution in a crisis. In the event of a severe water shortage, it may be necessary to implement a simular distribution system if emergency supplies in the local reservoirs are exhausted or interrupted.

It would be practical to identify all existing wells in Berkeley so that they could be brought into use in the event of an emergency. At present, the City of Berkeley is responsible for groundwater records such as well permits, and it would be in the best interst of the city to initiate such a study.

## Conclusion

Before the completion of the Mokelumne aqueduct, groundwater was one main source of water in Berkeley. The recent data show that groundwater could support some light industry in the alluvial plain and domestic use in the hills (Webster, 1972). Groundwater resources in Berkeley are underdeveloped because EBMUD water is very cheap. Hence, development would be most practical for large consumers of water and for emergency uses.

## REFERENCES CITED

1. Alameda County Flood Control District (undated). Miscellaneous Well Records.
2. Brown, Harold, Facilities Manager, Cal-Ink. Personal communication, 3/23/83.
3. Dockweiler, J.H., 1911. Report on the Sources of Water Supply in the East Region of San Francisco Bay Area, CAlifornia: Berkeley, California, Peoples WAter Company, 509pp.
4. Freeze, R. Allan, and John A. Cherry, 1979. Groundwater: New Jersey, Prentice Hall, 604pp.
5. Hogenson, Glenmore M., 1967. Effects of Proposed Salinity-Control Barriers in San Francisco Bay, California, Upon Groundwater Resources: Menlo Park, California, U.S. Geological Survey, Water Resources Division, 99pp.
6. Hummel, George, Chief Engineer, Claremont Hotel. Personal communication, 3/23/83.
7. Kahrl, William L., ed., 1978. California Water Atlas: Los Altos, California, William Kaufman, 118pp.
8. Lawson, Andrew C., 1902. The Berkeley Hills: Berkeley, California, University of California, 102pp.
9. Le Van, E.B., 1924. East Bay Water Problems: Collection of Student Reports on Irrigation, Berkeley, University of California, no. 7.
10. Ludorff, Eugene, Hydrologic Engineer, Sacramento, California. Personal communication, 4/5/83.
11. Malkasian, Robert, Assistant Manager of Operations, Manasse-Block Tanning Company. Personal communication, 3/21/83.
12. McCreary, John, Customer Representative, East Municipal Utility District. Personal communication, 4/18/83.
13. Pierce, Dave, Operations Manager, Cal-Ink. Personal communication, 6/16/83.
14. Radbruch, Dorothy H., 1957. Areal and Engineering Geology of the Oakland West Quadrangle, U.S. Geological Survey Miscellaneous Geological Investigations, Map I-239.
15. _____, 1969. Areal and Engineering Geology of the Oakland East Quadrangle, U.S. Geological Survey Miscellaneous Geologic Investigations, Map GH-769.
16. Sander, C., 1924. East Bay Water Situation: Collection of Student Reports on Irrigation, Berkeley, University of California, no. 8.
17. United States Environmental Protection Agency (EPA), 1971. Storm Water Problems and Control in Sanitary Sewers, Oakland and Berkeley, California: Metcalf & Eddy, Inc.
18. Warnke, Fred, Grounds Superintendent, University of California Facilities Management. Personal communication, 5/3/83.
19. Weaver, Mary A. and Dorothy H. Radbruch, 1960. Selected Logs of Borings on the East Side of San Francisco Bay, California: U.S. Geol. Survey. Open File Report.
20. Webster, D.A., 1972. Map Showing Ranges in Probable Maximum Well Yield from Water-Bearing Rocks in the San Francisco Bay Region, California: U.S. Geol. Survey Miscellaneous Field Studies, Map MF-431.