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PROGRESS REPORT ON WATER STUDIES IN THE SAN TIMOTEO-SMILEY HEIGHTS AREA, UPPER SANTA ANA VALLEY, CALIFORNIA, 1964

By

L. C. Dutcher

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Prepared in cooperation with the
San Bernardino County Flood Control District

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PROGRESS REPORT ON WATER STUDIES

IN THE SAN TIMOTEO-SMILEY HEIGHTS AREA,

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SUMMARY

This report, prepared in cooperation with the San Bernardino County Flood Control District, outlines the preliminary findings of a study of the San Timoteo-Smiley Heights area to determine the scope of a proposed data-collection program and ground-water investigation.

This progress report summarizes the preliminary findings, outlines a proposed program for drilling test wells and geophysical explorations, and describes the method of investigation to estimate the ground-water inflow to Bunker Hill basin from the San Timoteo-Smiley Heights area.

The geology and ground-water hydrology of the area are described in a Geological Survey open-file report (Dutcher and Burnham, 1960) and no new conclusions or interpretations of ground-water conditions in the area can be made because few new wells have been drilled. The water-bearing deposits are mainly alluvium of Quaternary age and in places may be as much as 3,000 feet thick. Ground water moves generally north or northwest toward Bunker Hill basin through the San Timoteo-Smiley Heights area and Sand Canyon which is between Reservoir Canyon Hill and the Crafton Hills. The area is crossed by several known faults, and there may be other faults or ground-water barriers that may influence the movement of ground water.

A program of geophysical explorations will be needed to determine the thickness of the principal geologic units and the displacements on faults along a section where ground-water outflow is to be estimated. The preliminary findings indicate a need for drilling eight shotholes and the use of at least eight "seismic spreads."

Test wells will be needed for water-level control and geologic information. The preliminary findings indicate a need for nine small-diameter test wells ranging in depth from about 100 to 550 feet. Each test well should be cased with a 2-inch perforated pipe and should be cleaned for use as an observation well. In addition, one deep fully developed test well for use as an observation well during pumping tests will be needed. This well, at least 1,000 feet deep, should not be smaller than 8 inches in diameter. Also three dry or unused wells should be deepened or cleaned out for use as observation wells.

After the test-drilling and geophysical-exploration program is completed, pumping tests will be made, and the ground-water movement through the San Timoteo-Smiley Heights area will be estimated. The cross-sectional area of saturated material, the hydraulic gradient, and the average permeability will be determined to estimate the average annual ground-water underflow. If the drilling and seismic work is started by October 1964, it is estimated that the studies could be completed by July 1, 1966.

INTRODUCTION

This report was prepared to determine the scope of a proposed ground-water study in the San Timoteo-Smiley Heights area, Upper Santa Ana Valley, Calif. (fig. 1). The project, in cooperation with the San Bernardino County Flood Control District, extended from January to July 1964. The current needs of the Flood Control District require that additional studies be completed to assist in providing the basis for the solution of the problems listed below.

1. Where are the best places to spread, for ground-water recharge, both imported water and storm runoff?

2. In order to assess the benefits of recharge to different users, where does the spread water go once it has been induced underground?

3. To whom do the benefits of artificial recharge by water spreading accrue? For example, if water is spread in San Timoteo Creek, where does it go as subsurface flow down the Santa Ana River?

4. What subsurface barriers to the movement of ground water exist along the south margin of San Bernardino Valley, and what is the total annual ground-water outflow from the San Timoteo-Smiley Heights area to Bunker Hill basin?

5. What additional data, test drilling, geophysical explorations, and studies will be required to provide quantitative answers to the questions listed above?

This progress report on the San Timoteo-Smiley Heights area is the second of four scheduled progress reports on the Upper Santa Ana Valley and outlines the preliminary findings and studies proposed for the area (fig. 2). The studies proposed are directly related to the general and specific questions listed above. The first progress report (Dutcher, 1964) outlines the preliminary findings and the studies proposed for the Bloomington-Colton area west of the city of San Bernardino (fig. 1).

Location of the San Timoteo-Smiley Heights Area

The San Timoteo-Smiley Heights area, in the Upper Santa Ana Valley near San Bernardino, is in San Bernardino and Riverside Counties and is bordered by the San Jacinto fault on the southwest and the Crafton Hills on the northeast; it includes parts of two major ground-water basins in the Upper Santa Ana Valley: Bunker Hill and Yucaipa basins (fig. 2). The south and north boundaries of the area are along irregular lines in Yucaipa and Bunker Hill basins, respectively, and the Badlands and Reservoir Canyon Hill are important landmarks; Redlands is the main city but the city limits of Colton and San Bernardino extend into the area (fig. 1). San Timoteo Creek is the principal drainage and is an intermittent stream tributary to the Santa Ana River on the north.

Purpose and Scope of the Report

The purpose and scope of this second progress report are, as follows: (1) To summarize the hydrologic background information for the San Timoteo-Smiley Heights area; (2) to outline a proposed test-drilling program to provide geologic and hydrologic data; (3) to outline a proposed program of seismic explorations; (4) to outline the proposed methods of study to quantitatively estimate the subsurface outflow from Yucaipa basin to Bunker Hill basin between the San Jacinto fault and the Crafton Hills; (5) to outline the scope of a report summarizing the findings of the investigation; and (6) to estimate the extent of the proposed test-drilling and geophysical explorations.

This work was done by the U.S. Geological Survey, Water Resources Division in cooperation with the San Bernardino County Flood Control District, under the direct supervision of L. C. Dutcher, geologist in charge of the Garden Grove subdistrict office, and under the general direction of Fred Kunkel, district geologist for California.

Previous Work and Related Studies

The San Timoteo-Smiley Heights area in the Upper Santa Ana Valley is within the larger areas studied by the California Water Resources Board (1951); the California Department of Water Resources (Eckis, 1934; Gleason, 1947; and Post, 1928); and the U.S. Geological Survey (Dutcher and Burnham, 1960; Lippincott, 1902; and Mendenhall, 1905).

The California Department of Water Resources is completing plans to make a study of the south part of San Bernardino Valley (fig. 1) to determine suitable water-management practices. In order to avoid duplication of studies, the Geological Survey met informally with representatives of the Department to discuss the scope of the Department's planned program in the San Timoteo-Smiley Heights area. It was agreed that the planned studies would not be duplicated by the Survey and that no test-drilling or geophysical studies to provide additional data would be planned by the Department.

PRELIMINARY FINDINGS

The San Timoteo-Smiley Heights area is part of the Yucaipa-Beaumont area studied previously by the Geological Survey in cooperation with the San Bernardino County Flood Control District (Dutcher and Burnham, 1960). A principal objective of that study was also to estimate the ground-water outflow from Yucaipa basin to Bunker Hill basin. However, because of a paucity of wells and general lack of available data, and estimate of only a part of the outflow could be made.

The geology and ground-water hydrology of the area are described in the report by Dutcher and Burnham (1960) and no new conclusions or interpretations of ground-water conditions in the area could be made during this preliminary study because additional data are available for only a few new wells in the area. Test wells will be required and geophysical studies must be completed before quantitative estimates can be made of the total subsurface outflow from Yucaipa basin to Bunker Hill basin.

Geology and Ground-Water Hydrology

As described by Dutcher and Burnham (1960), the water-bearing deposits include the San Timoteo beds of Frick (1921) of Pliocene and early(?) Pleistocene age; old red gravel of middle(?) and late Pleistocene age; older alluvium of late Pleistocene age; and the younger alluvium of Recent age. The thickness of the San Timoteo beds of Frick (1921) locally may exceed 2,000 feet; the thickness of the old red gravel locally may exceed 800 feet; and the older alluvium and younger alluvium are probably each not more than 100 feet thick (Dutcher and Burnham, 1960, p. 56-89).

The crystalline and metamorphic rocks of pre-Tertiary age are not water-bearing and form the basement complex and underlie the water-bearing deposits.

Faults strike across the San Timoteo-Smiley Heights area form barriers that impede the movement of ground water through the deposits younger than Recent age,and water levels in wells are at or near record lows. Except for a doubtful fault near the Redlands Country Club, structural features shown on figure 2 are after Dutcher and Burnham (1960).

Ground water moves generally northwest in Yucaipa basin down San Timoteo Canyon toward San Bernardino Valley. The known faults and postulated barriers impede the ground-water movement, and quantitative estimates of outflow must be made along a section between the San Jacinto fault and the Crafton Hills about along the line A-A' (fig. 2), where the cross-sectional area of flow, the transmissibility of the deposits, and the hydraulic gradient can be determined if sufficient geologic and hydrologic data are available.

Ground-Water Outflow

Gleason (1947) estimated the subsurface outflow from Yucaipa and San Timoteo-Beaumont basins to Bunker Hill basin during the 32-year period 1905-36 to be about 13,960 acre-feet a year, based on the difference between the estimated values for recharge from all sources and the estimates of discharge from all other sources (Gleason, 1947, p. 199-213, tables 165 and 166). Dutcher and Burnham (1960) estimated that the outflow averaged at least 20,000 acre-feet a year during the period 1936-55. However, in the vicinity of Bryn Mawr, where part of the ground-water inflow to Bunker Hill basin was estimated, the total thickness of saturated deposits was unknown, and the transmissibility of the water-bearing deposits could be estimated only by a pumping test at a well which penetrated only about 703 feet of saturated unconsolidated deposits. Because the County Flood Control District desires to have estimates of the subsurface outflow derived by direct means, it will be necessary to collect additional geohydrologic data in the area where the outflow is to be estimated.

STUDIES TO BE COMPLETED

Need for Geophysical Explorations

The preliminary findings in the San Timoteo-Smiley Heights area indicate a need for more geologic data before quantitative estimates can be made of the average ground-water inflow to Bunker Hill basin from the south. The cross-sectional area of permeable deposits must be accurately known and the positions of faults and ground-water barriers must be determined. Because the thickness of the water-bearing deposits may be as great as 3,000 feet and probably varies greatly along the line of section through which the underflow must be computed, the cost of drilling enough deep test wells to provide the needed geologic information would be very great. A program of making seismic explorations at selected places should provide the needed data and probably would be much less expensive. Therefore, a program of seismic explorations, both reflection and refraction, should be undertaken about as outlined in the following paragraphs.

For planning purposes, eight shotholes should be drilled to the water table, or below the so-called "weathering zone," approximately at the numbered locations shown on figure 2. Estimated depths of each shothole are given in the following table.

Shothole number	Altitude[1] (feet)	Approximate depth to water (feet)	Estimated altitude of water level (feet)	Depth (feet)
1	1840	390	1470	a450
2	1475	20	1458	50
3	2000	---	---	b100
4	1950	---	---	b100
5	1480	164	1316	a250
6	1360	---	---	b100
7	1550	---	---	b100
8	2120	---	---	b100
			Total for 8 shotholes:	1300

1. Altitude of land surface in feet above sea level.

a. This hole will be completed as a test well if possible.

b. Depth is 100 feet, or 25 feet below zone of weathering.

Instruments (geophones) for recording seismic reflections and refractions should be appropriately spaced along the numbered "spreads" which are also shown on the map (fig. 2). The seismic explorations will have a two-fold purpose: Determination of the thickness of the geologic units in the area of ground-water outflow and the positions of known and postulated faults. Thus, the planned program must be flexible. It will probably be necessary to make changes in the suggested procedures as the work progresses.

The planned procedure and the purpose of the work are outlined in three steps, as follows:

Step 1.--Refraction and reflection to provide geologic data at the upstream margin of the ground-water outflow area.

A. Drill shotholes 1-4.

B. Place geophones along "spread" 1 and record waves reflected or refracted from bedrock and distinct geologic units after timed explosions (called "shots") in shotholes 1 and 2.

C. Place geophones along "spread" 2a and "shoot" at shothole 2 again and at shothole 3. Record data and determine if the postulated fault shown on the map crossing "spread" 2a, possibly the large Banning fault, has displaced bedrock at depth (fig. 2). Repeat this procedure but use "spread" 2b if the fault is not indicated along "spread" 2a.

D. Place geophones along "spread" 3 and "shoot" at shotholes 3 and 4 (also "shoot" at shothole 2 if the fault postulated to pass near "spread" 2a and 2b is not indicated by the previous work).

E. Place geophones along "spread" 6 which crosses the postulated position of the Crafton fault (fig. 2) and "shoot" again at shothole 4.

Step 2.--Reflection (and refraction) to provide geologic data at downstream margin of ground-water outflow area.

A. Drill shotholes 5-7.

B. Place geophones along "spread" 4a and "shoot" at shothole 5 to determine the thickness of the geologic units and the displacement of the Loma Linda fault and if it is an important structural feature.

C. Place geophones along "spread" 4b and "shoot" again at shothole 5 to determine the thickness of the geologic units and the displacement of the Banning fault and if it is an important structural feature.

D. Place geophones along "spread" 5a and "shoot" at shothole 6; this procedure should be repeated, if necessary, using "spread lines" 5b and 5c, to determine the exact locations of the Banning and Redlands faults and if they are important structural features.

E. Place geophones along "spread" 7a and "shoot" at shothole 7 to determine the thickness of the geologic units and displacement on the Redlands fault.

F. Place geophones along "spread" 7b and "shoot" again at shothole 7 to determine possible displacement along the probable fault shown on figure 2.

Step 3.--Reflection to provide geologic data in the Sand Canyon area.

A. Drill shothole 8.

B. Place geophones along "spread" 8 and "shoot" at shothole 8 to determine depth to bedrock.

If the above-outlined program is successful, the data from these seismic reflections and refractions, when interpreted, should make it possible to construct well-controlled geologic cross sections in the area of ground-water outflow, as needed.

The positions and displacements of all important faults should be known and it should be possible to determine the thickness and extent of the important geologic units throughout the area between the "spreads" by extrapolating between the control points.

However, it will be necessary to drill several test wells to provide data on the lithology of the deposits, the hydraulic gradient, and the water table.

Need for Test Wells

The preliminary findings in the San Timoteo-Smiley Heights area indicate a need for more water-level data before quantitative estimates of the annual average ground-water inflow to Bunker Hill basin from the south can be made. The hydraulic gradient must be determined and the top of the zone of saturation must be accurately known. As outlined below, a test-drilling program should provide the needed data. The results of a similar program in the Bloomington-Colton area are described in the first progress report (Dutcher, 1964).

Wells for Water-Level Control

Nine test wells should be drilled by the rotary method and cased with 2-inch pipe having about 20 feet of perforations on the bottom. An electric log of each hole should be made. The test wells are needed to provide water-level control for a water-level-contour map, and the suggested sites are in areas where wells have not been drilled. The small-diameter test wells should be drilled to a depth of about 50 feet below the water table and should be developed by airlifting or bailing to insure that they reflect the true water levels in the aquifer.

The proposed sites for the test wells for water-level control and geologic information are shown on figure 2, and the estimated depths of the wells and water levels are given in the following table; it is emphasized, however, that the location and depth of the wells and the number of wells and order of drilling will be based on the findings during the drilling program. It is probable that some unforeseen results will make it necessary to change the proposed program to some extent.

Test-well number	Altitude 1/	Estimated depth to water level (feet) 2/	Depth (feet)
1	1840	390	a450
5	1480	164	a250
9	1800	155	250
10	1600	300	350
11	1600	200	250
12	1700	375	430
13	1320	25	100
14	2160	360	550
15	2160	460	550
16	1660	242	b1000
		Total for 10 wells:	4180

1. Altitude of land surface in feet above sea level.

2. Estimates based on the water-level contour map for 1955 (Dutcher and Burnham, 1960, fig. 9).

a. Shotholes 1 and 5 will be completed as test wells, if possible.

b. This well should be completed as a fully developed water well having an 8-inch or larger casing and will be used primarily as an observation well during a pumping test.

In addition to the nine test wells for water-level control, there are three dry or unused wells in the area which could be used as observation wells if they were deepened or cleaned out. These wells, 2S/3W-5E1, 5H1, and 9K1, cannot be measured at present but their repair or deepening probably would be less expensive than the drilling of new test wells in these areas where water levels are needed but wells are lacking. Available data for these wells are given in the following table.

Well number	Depth when drilled (feet)	Reported water level (feet)	Depth in 1964 (feet)	Casing diameter (inches)
2S/3W-5E1	448	284	?	16
2S/3W-5H1	300	---	?	12
2S/3W-9K1	235	231	?	10

If the test-drilling program is successful, the water-level measurements should make it possible to construct water-level contours in the area of ground-water outflow, as needed to determine the hydraulic gradient and the top of the saturated deposits.

Wells for Pumping Tests and Geologic Information

Drill cuttings and electric logs of the nine test wells described in the preceding section will provide needed geologic information on the lithology of the water-bearing deposits but are proposed primarily to provide water-level control. To provide additional geologic information and to serve as an observation well during a pumping test, a deep test well should be drilled near well 2S/3W-3K1. The deep test well (test well 16, fig. 2) should be at least 1,000 feet deep and should be fully developed when completed. It will be used as an observation well during a pumping test to determine the coefficient of transmissibility[1/] of the water-bearing deposits of the area. Well 2S/3W-3K1, 800 feet deep, is a public-supply well owned by the city of Redlands.

Because the city may desire to drill another supply well near well 2S/3W-3K1, it may not be necessary to drill a deep test well. Test well 16, or a new supply well, should be drilled to a depth of at least 1,000 feet and should be fully developed. The well should be completed as if it were to be used for supply and the diameter of the casing should not be smaller than 8 inches.

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1. The coefficient of transmissibility of an aquifer is defined as the amount of water which will flow in one day through a segment of the aquifer which is one foot wide and extends to the full thickness, under a hydraulic gradient of one foot per foot.

Logs of other deep wells in the area will provide additional geologic information to supplement the data from the seismic explorations, and several existing supply and observation wells will be used for making pumping tests.

Method of Estimating Ground-Water Outflow

After the proposed test wells are drilled and data from the pumping tests and the geologic studies, including the geophysical data, are compiled, the underflow or ground-water outflow through the water-bearing deposits between the San Jacinto fault and Crafton Hills will be computed by using the equation:

$$Q = TIW$$

in which Q is the underflow, in gallons per day; T is the average coefficient of transmissibility of the deposits through which the flow occurs, in gallons per day per foot of the aquifer, as measured along the geologic section; I is the average hydraulic gradient, in feet per mile; and W is the width of the aquifer, in miles.

This method, or a modification thereof, will be used to compute the underflow through the water-bearing deposits of an "underflow section" which will be approximately along the line labeled A-A' on figure 2.

The water-level gradient through the water-bearing deposits will be determined by water-level measurements in wells, and the average transmissibility of the deposits will be estimated from pumping tests. An attempt will be made to estimate the average annual underflow during past years by using long-term records of water levels in observation wells.

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