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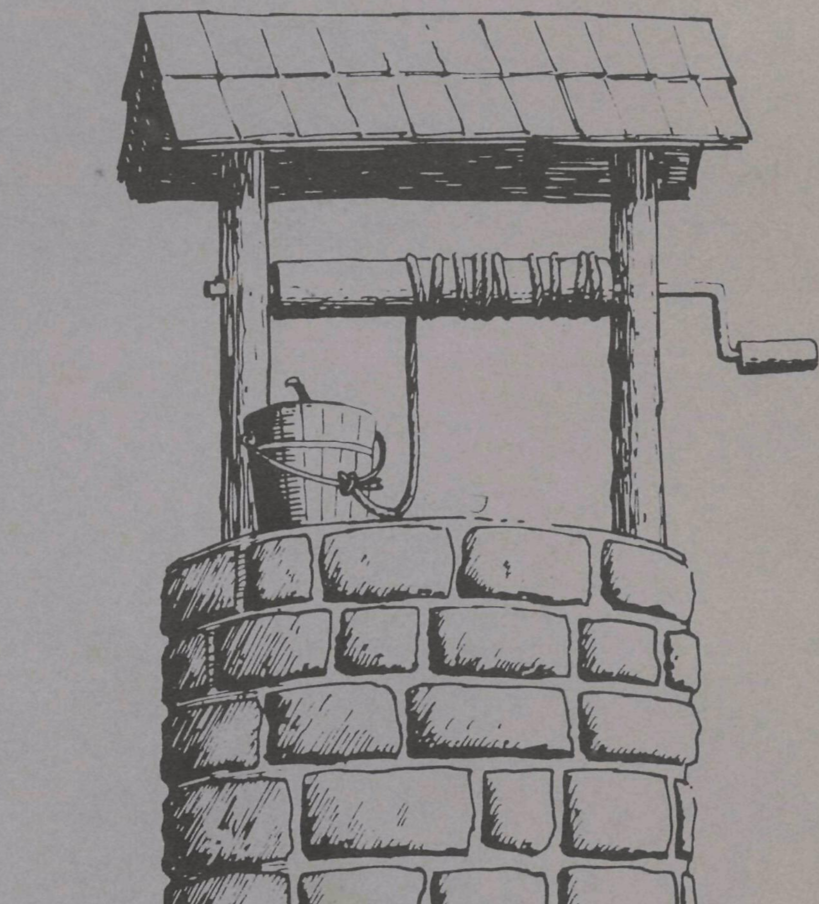
STUDY OF REUTILIZATION OF WASTEWATER RECYCLED THROUGH GROUNDWATER

VOLUME I



U.S. ENVIRONMENTAL PROTECTION AGENCY

WATER POLLUTION CONTROL RESEARCH SERIES

STUDY OF

REUTILIZATION OF WASTEWATER

RECYCLED THROUGH GROUNDWATER

Volume I

BY

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Hemet, California

for the

OFFICE OF RESEARCH AND MONITORING

ENVIRONMENTAL PROTECTION AGENCY

Project 16060 DDZ

July 1971

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ABSTRACT

A project to demonstrate the feasibility and safety of recycling water under operating conditions was performed in the Hemet-San Jacinto Valley of the State of California. Since the Valley is a closed basin, and is dependent in part upon imported water, it was felt that recycling of the water would ultimately lead to a reduction in the salt input and resultant degradation of the existing underground reservoir.

Extensive geological investigations indicated that the basin was not homogeneous in nature, but had clay lenses and faulting which interfered with the creation of a classic mound. Partially as a consequence, the recharge of 5,380 acre feet of wastewater during this six and one-half year period had no effect on surrounding water wells.

The project added considerable knowledge and experience to the technology of intermittent wastewater percolation and associated monitoring techniques. A novel feature of the project was the employment of highly sensitive temperature probes to trace the lateral migration of the recharged water, much of which appears to be escaping as shallow underflow to the San Jacinto River and hence not reaching the deep groundwater table.

This report was submitted in fulfillment of Project Number 16060DDZ, under the partial sponsorship of the Office of Research and Monitoring, Environmental Protection Agency.

CONTENTS

FIGURES

FIGURES
(continued)

FIGURES
(continued)

TABLES

TABLES
(continued)

SECTION I

CONCLUSIONS

1. The Hemet-San Jacinto Groundwater Basin is essentially a closed system with a long-term yield of approximately 11,000 acre feet per year.

2. Groundwater withdrawals from the basin amounted to over 23,000 acre feet per year in 1970.

3. It is possible to recharge to the underground seven and one-half acre feet per acre annually, in the stratified sandy silty soil near the San Jacinto River bed.

4. By the year 1980 sufficient wastewater will be available to recharge a total of 10,500 acre feet per year, which would amount to a doubling of the long-term yield.

5. Recharge of the groundwater aquifers will result in reducing the basin's deficit and the importation of Colorado River water with its high mineral content.

6. Salt inflow into the basin will be reduced by 1.9 tons per acre foot of Colorado River water imported, by reclaiming the water. The quality of the existing groundwater is low in minerals, having a filterable residue averaging approximately 250 mg/l.

7. No evidence has been obtained over this short period of any degradation of the groundwater quality in the water-producing strata in the Upper San Jacinto Groundwater Basin.

8. Water reclamation is an important source of water and should be included in any water management planning within a closed basin.

9. Optimum operation of the percolation basins depends upon the effectiveness of the treatment plant removing pollutants.

10. A spreading operation consisting of alternate wetting and drying is necessary to maintain aerobic conditions in the surface soil and prevent sealing of the basins.

11. Weed growth in the spreading basins is a problem and the best method for their control is a scheduled rototiller program.

12. The use of fine gravel spread on the basins to control weed growth was not effective in this project to improve hydraulic loading rates.

13. Organic materials are oxidized very rapidly, with the level of MBAS decreasing drastically in the first eight feet.

14. Continuous underground sampling is facilitated by the use of glass wool in the collecting medium.

SECTION II

RECOMMENDATIONS

1. The District should continue to spread wastewater at the Hemet-San Jacinto basins on an intermittent wet-dry cycle of three days.

2. The monitoring program should be continued to obtain additional data.

3. Additional studies should be conducted on the relationship of ammonia nitrate and hardness to determine any increase in hardness in the soil column attributable to insufficient nitrification at the Hemet-San Jacinto Water Reclamation Plant.

4. The District should investigate the engineering and institutional feasibility of creating a multi purpose reservoir near the surrounding mountains that could be inundated with plant effluent and used for nonbody-contact recreation and storage for fire-fighting water. The optimum location would be in the alluviums of a river or creek, capable of some percolation into the ground and where the bacteria-free effluent would be flushed with high quality water during flood flows.

5. Efforts should be continued with institutional and political entities to encourage the direct reuse of wastewater that has been recycled through a nominal length of natural soils.

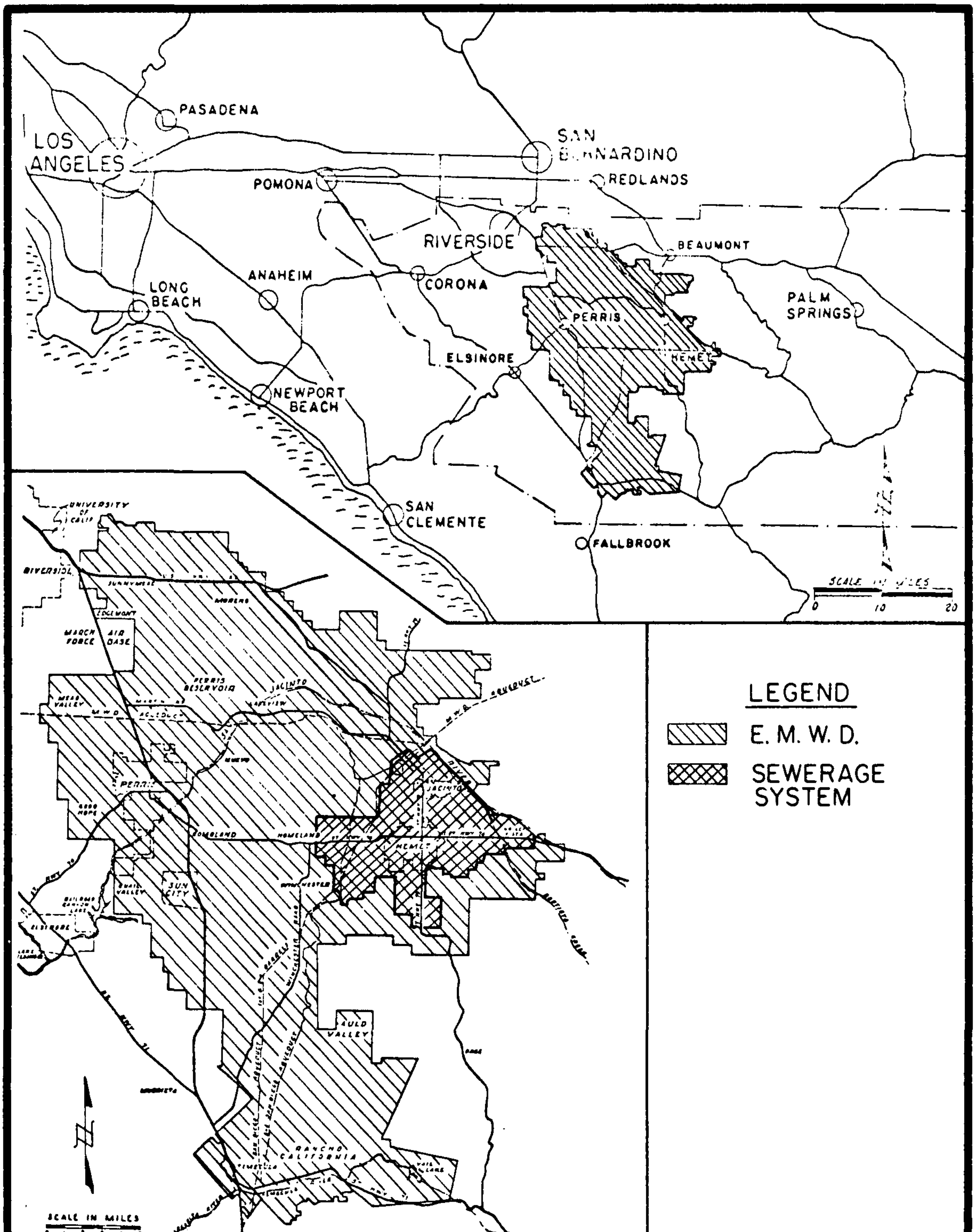


FIGURE I. LOCATION MAP

EASTERN MUNICIPAL WATER DISTRICT

SECTION III

INTRODUCTION

Authority for the Study

On December 21, 1964, the Environmental Protection Agency (then the Division of Water Supply and Pollution Control, U. S. Public Health Service) authorized the Eastern Municipal Water District to undertake a study of water quality factors involved in a program being initiated by Eastern Municipal Water District at that time for reclaiming wastewater through treatment and recharge of groundwater. The original 3-year study was initiated in January 1965 and an additional three and one-half years were authorized to extend the study through June 1971.

Purpose and Scope of the Study

In July 1965 Eastern Municipal Water District completed the construction of and began operating a new 2.5 mgd capacity sewage system and wastewater treatment facility serving the urban area of the Hemet-San Jacinto Valley of Riverside County (see Figure 1). The new activated sludge process facility was designed to dispose of the plant effluent by spreading in basins located in The San Jacinto River alluviums. The basins would also provide a means for recharging the groundwater storage in the Upper San Jacinto Groundwater Basin.

The plant is currently approaching its design capacity and an expansion has begun which will bring the plant to 5.0 mgd. With this increased flow the recharge area is also being increased.

With the availability of large quantities of effluent it was deemed advisable to use a portion of the effluent directly on grazing pastures, thereby reducing the quantity of lower quality Colorado River water imported to the basin. However, a flow of 500,000 gpd was reserved and is being used to recharge into the spreading basins.

The potential long-term yield of this basin was thought to be of the magnitude from 20,000 to 30,000 acre-feet per year, which is far less than the growing water supply needs of the area. The District, working with data supplied by Dr. Henry G. Schwartz,[1] in 1967 determined the long-term yield to be less than 12,000 acre-feet annually. The study was updated in 1970 because of the heavy storms of 1967-68 and 1968-69. This study reaffirmed the long-term yield to be approximately as determined by Dr. Schwartz. This has been supplemented by the District's importation of Colorado River water through The Metropolitan Water District of Southern California's supply system. The amount of this imported water to the Hemet-San Jacinto area has now reached approximately 11,000 acre-feet per year.

During the initial operations, about 9 percent of the potential long-term yield was processed through the plant and disposed of by percolation and irrigation. The present flow of 2.0 mgd produces 2,100 acre-feet per year of rechargeable wastewater. This amounts to about 19 percent of the yield. Projections made by the District[2] indicate that by the year 1980 it will be possible to recycle almost 10,500 acre-feet annually and could almost double the long-term yield and lessen the area's dependence upon imported water.

The Upper San Jacinto Groundwater Basin is essentially a closed groundwater basin. In this situation, it could be expected that water quality changes would be significant and that additional special treatment might be required to remove both specific mineral and gross mineral substances in order to maintain the groundwater at a high quality.

The primary purpose of this study was to evaluate the water quality, infiltration rates and procedures for reclaiming wastewater to furnish data for an overall operation that could be conducted in a manner providing for adequate protection of groundwater quality while permitting maximum recharging of the aquifers by percolation and irrigation as a means of regional water conservation. The plans of the District for the future envision a number of similar reclamation operations throughout the more than 500 square miles of Riverside County included within the District boundaries.

Organization of Study

The administrative organization for the project comprised a work force consisting of a Project Director, Project Engineer, Assistant Engineers, chemist, draftsmen, field personnel and additional supporting personnel of Eastern Municipal Water District.

In addition to the Project Staff, the study participants include a Project Control Board and a Project Advisory Committee.

The purpose of the Project Control Board has been to plan the study and supervise the activities of the staff from a policy point of view.

Members of the Project Control Board are Doyle F. Boen, Project Director and Chairman; Richard Bueeramnn, Executive Officer, California Regional Water Quality Control Board, Santa Ana Region; Prof. Albert Bush, University of California at Los Angeles; Dr. Harvey F. Ludwig, President, Engineering-Science, Inc.; Dr. Jack E. McKee, California Institute of Technology; James E. Lenihan (1965-68), Jack Pierce (1969-70), James H. Bunts, Jr. (1970-71), Project Engineer and Secretary.

The purpose of the Project Advisory Committee was to bring into the study the guidance and advice of all interested public agencies willing to contribute. The members were Paul Bonderson, California Regional Water Quality Control Board, Sacramento; Arthur Reinhardt, California Department of Public Health, Los Angeles; Maurice Hawkins Riverside County Health Department; Robert O. Eid, Riverside County Flood Control and Water Conservation District; David Willets, Mitchell L. Gould and finally Robert Chun, California Division of Water Resources, Los Angeles; John D. Parkhurst, Los Angeles County Sanitation Districts and Arthur E. Bruington, Los Angeles County Flood Control District.

The Advisory Committee met at irregular intervals.

The main work of the project included essentially the following elements:

1. Evaluation and development of pertinent background information
   General description of groundwater basin
   Geology of basin
   Historical water quality and levels of groundwater
   Water balance in basin

2. Spreading activities

3. Sampling and analyses of infiltrated water

4. Study of present groundwater situation
   Hydrology
   Sampling and analyses

5. Determination of degree of change of the groundwater quality by recharge

6. Evaluation of (1) through (5) to develop findings, conclusions and recommendations

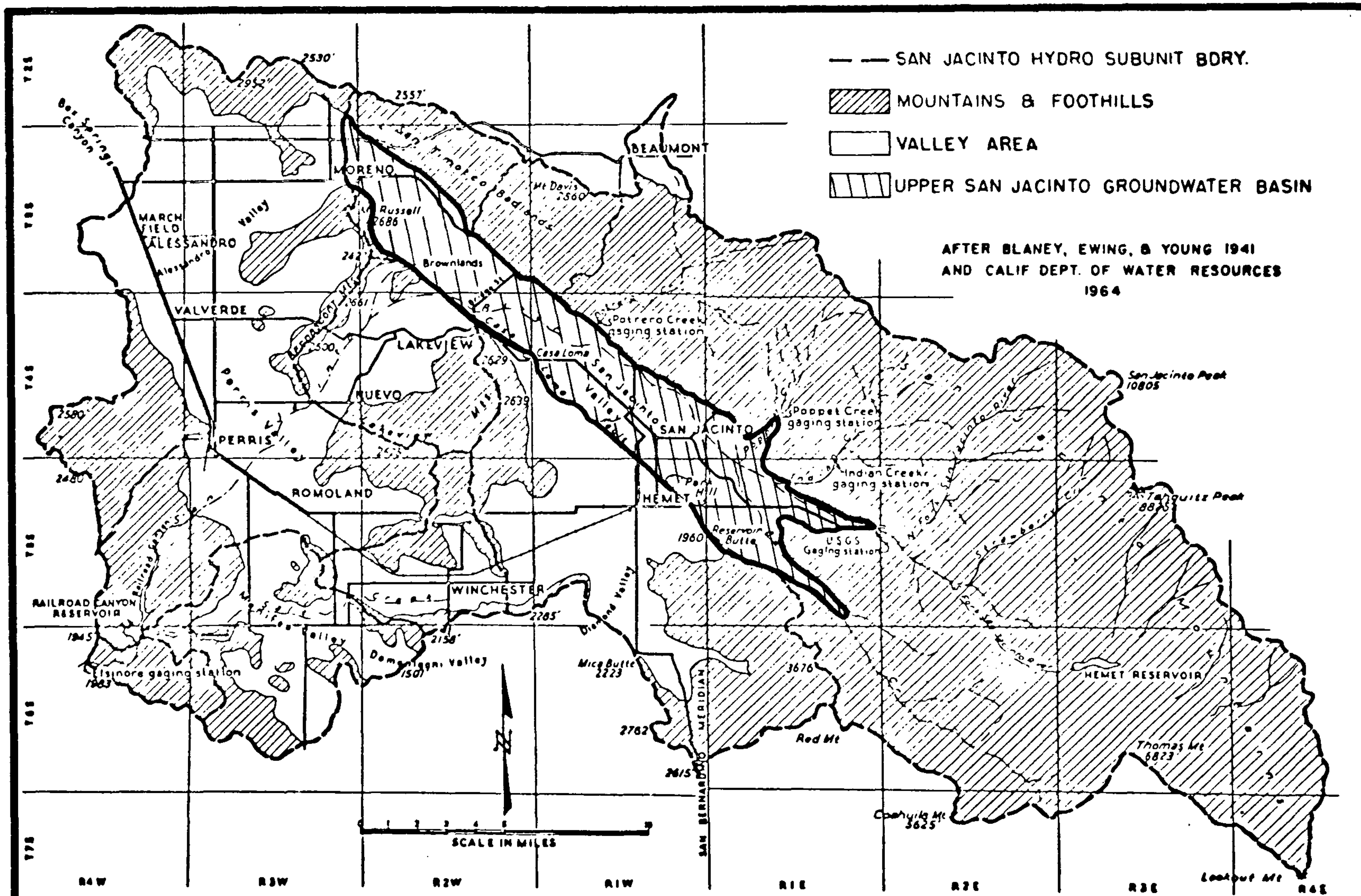


FIGURE 2. UPPER SAN JACINTO GROUNDWATER BASIN LOCATION

SECTION IV

HYDROLOGY OF UPPER SAN JACINTO GROUNDWATER BASIN

Geographical Description

The Upper San Jacinto Groundwater Basin is herewith defined as that group of quaternary sediments that in general are bounded by the Casa Loma Fault on the southwest, the San Jacinto Fault on the northeast, the mouth of Bautista Canyon on the southeast and Theodore Street in the Moreno area on the northwest. Specifically, it lies within the San Jacinto Hydro Sub-Area of the Santa Ana Drainage Province of the Southern District of the State of California, per the California State Water Resources Control Board. Figure 2 graphically depicts the study area.

Surface Hydrology

The Upper San Jacinto Groundwater Basin is located in the western part of Riverside County, California. The major watershed areas associated with the basin are the San Jacinto Mountains on the eastern and northeastern edge, with the highest peak, Mt. San Jacinto, at elevation 10,805 feet above sea level, being more than 8,500 feet above the valley floor. The major drainage channel for the entire Hydro Unit is the San Jacinto River which carries wet weather runoff from the eastern portion of the Hydro Unit northwesterly through and over the Upper San Jacinto Groundwater Basin and thence westerly into and through Railroad Canyon Lake into Lake Elsinore. Historically, Lake Elsinore has overflowed into the Santa Ana River near Corona. However, since 1916 only once (in 1969) has this overflow occurred.

The Upper San Jacinto Groundwater Basin, then, is essentially closed with occasional surface outflow, but no apparent subsurface outflow. The groundwater basin has several sub-areas which have previously been investigated and labeled and will be briefly described on the following page. (Figure 3)

General Description

The Upper San Jacinto Groundwater Basin is a long, narrow groundwater basin, 20 miles by 3 miles, with the long axis oriented in a

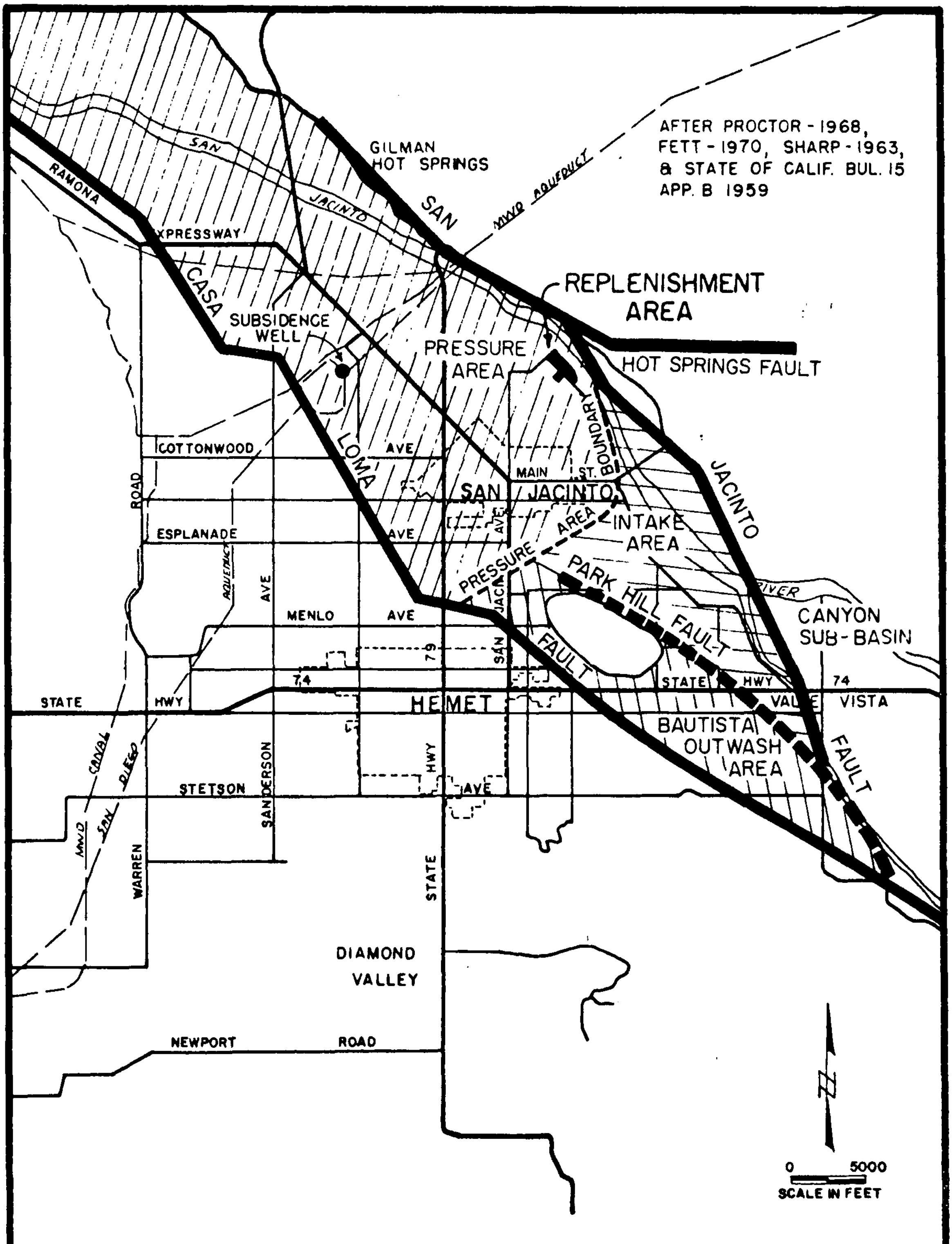


FIGURE 3. UPPER SAN JACINTO GROUNDWATER BASIN SUB-AREAS

northwest-southeast direction. Surface runoff drains from the northeast, southeast and northwest to just northwest of the middle of the groundwater basin and then westerly toward Lakeview. (Figure 3)

The overlying surface of the groundwater basin is sparsely populated, with the City of San Jacinto (population 4,000) being the only moderate concentration of people. The southeast portion of the basin has citrus groves and other types of orchard crops, supported by a good supply of groundwater and a small percentage of imported Colorado River water. The groundwater for this portion is derived from the Canyon Sub-Basin, which here is considered a part of the groundwater basin even though it is apparently east of the San Jacinto Fault. The groundwater becomes less available toward the northwest portion of the basin, and this is reflected on the ground surface by finer sediments and dry farming. Any study of the hydrology of the groundwater basin must include knowledge of groundwater movement in these sub-areas in order to obtain an understanding of the hydraulics of the entire basin.

Hydrogeology

Canyon Sub-Basin - In this area the San Jacinto Fault, and possibly less permeable sediments to the west, apparently restrict the movement of groundwater in the sediments underlying and adjacent to the river channel. The groundwater levels are usually at substantially higher elevations on the upstream or east side than levels on the downstream side. A difference of some 225 feet was observed in the spring of 1968. The majority of the San Jacinto Valley Hydro Unit runoff runs into this sub-basin as the San Jacinto River; and, due to the flat slope and the coarse alluvial material present, it has excellent recharge characteristics with its water table fluctuating more than 100 feet annually. Due to the water table rising to or near the ground surface, local inhabitants have termed this area "Cienega." It is here included as part of the Upper San Jacinto Groundwater Basin since it can act as a buffer or reservoir and undoubtedly has a pronounced effect on the recharge of the main basin.

Bautista Outwash Area - The alluvial fan at the mouth of Bautista Canyon bordered by the San Jacinto Fault on the northeast and the Casa Loma Fault, or possibly the Park Hill Fault,(2) on the southwest, and the area extending to the vicinity of Cedar Avenue, has been termed the "Bautista Outwash Area." The existence of the Park Hill Fault has never been proven. However, the presence of Park Hill and its proximity to the Casa Loma Fault has led some geologists to speculate that a fault must exist. The groundwater hydraulic gradient governs flow into or out of the area.

In 1940 the groundwater levels on opposite sides of the Casa Loma Fault showed higher water levels on the northeast side as compared with those levels on the southwest. In the spring of both 1968 and 1969 the reverse was found to exist, due to continuing overdraft of the groundwater basin. Both situations point to the low permeability of the Casa Loma Fault.

Intake Area - The San Jacinto Fault, the Park Hill Fault and the southeasterly edge of the Pressure Area enclose a roughtly triangular area. This area has been named the "Intake Area."(4) It is probably on the order of 500 feet thick and is underlain by highly permeable sedimentary deposits to a considerable depth. Water flowing in the San Jacinto River channel through this area readily replenishes groundwater storage therein. Water flowing either over the San Jacinto Fault or through the fault near the ground surface from the upstream Canyon Sub-Basin and any underground flow from Bautista Canyon also replenishes storage in this area.

Pressure Area - Within the area between the San Jacinto and the Casa Loma Faults, and from the City of San Jacinto northwestward, data from well logs and excavations reveal a substantial multi-layered zone of relatively impervious sediments and pervious water-bearing sediments. Prior to 1950, when groundwater levels were near the surface, many wells were artesian, indicating that underlying groundwater was under pressure as a result of confinement by impervious layers. In 1942 one well in particular was observed with an artesian head of 45 feet. The southeasterly, or upstream, extremity of this area has been delineated in previous reports(1), (2) and is shown by the dotted line in Figure 3. The area to the northwest of this line has been designated the "Pressure Area." The water stored in the underground historically supplied the confined groundwater underlying the Pressure Area so that extractions of groundwater in both the Intake and Pressure Areas were supplied from recharge of the Intake Area. Recently, heavy pumping has reversed the groundwater gradient from a surface dipping northwesterly to a depression or trough with a major portion of the deep groundwater surface sloping southeasterly from the Pressure Area to the Intake Area (Figures 4 and 5), thus eliminating the artesian effects experienced earlier in the Pressure Area. Today, the groundwater table is more than 200 feet below ground surface in some wells. The pressure effects might still be present to some degree as evidenced by the difference in the level of the groundwater table observed during the period 1968-1970.

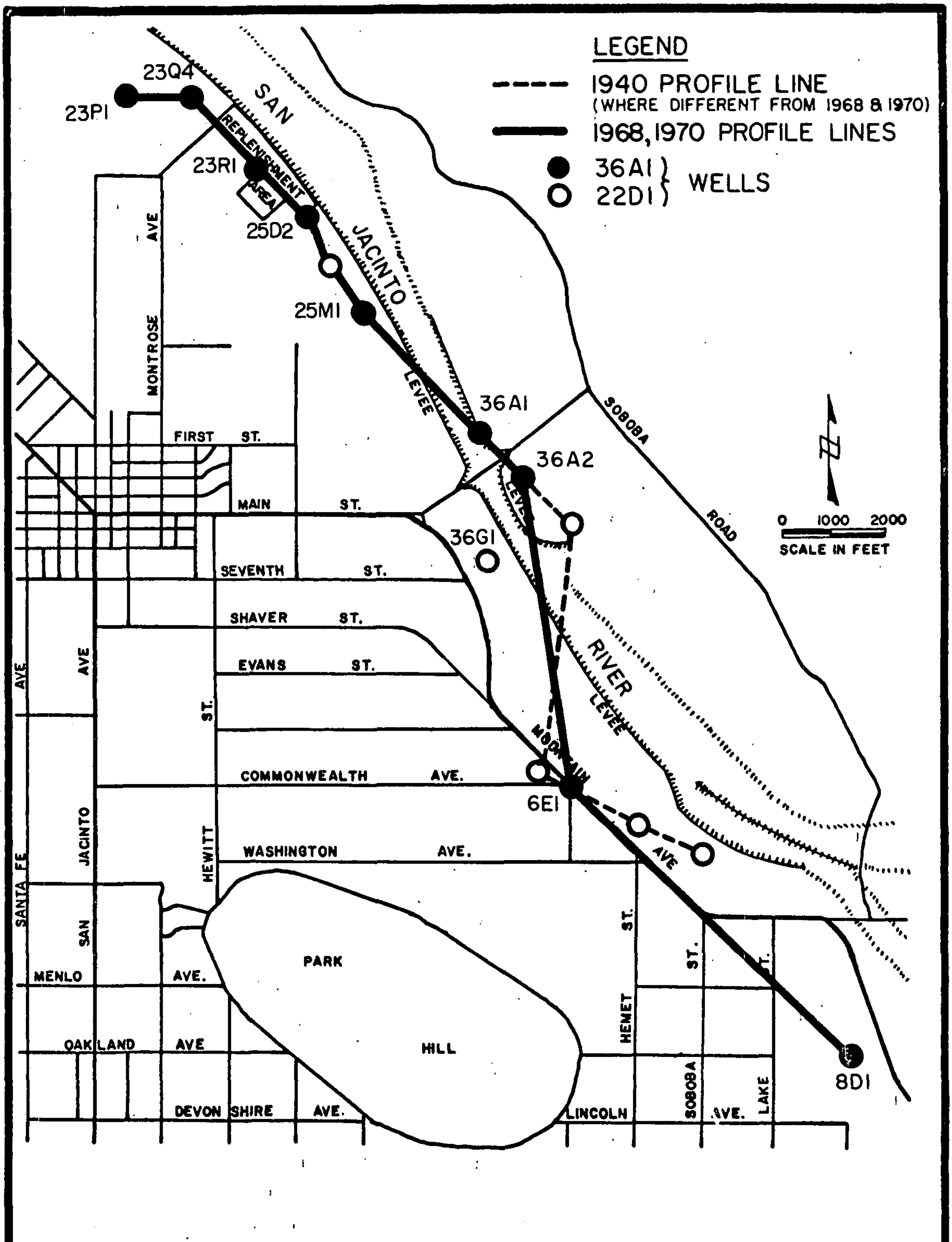


FIGURE 4. 1940, 1968, & 1970 GROUNDWATER PROFILES

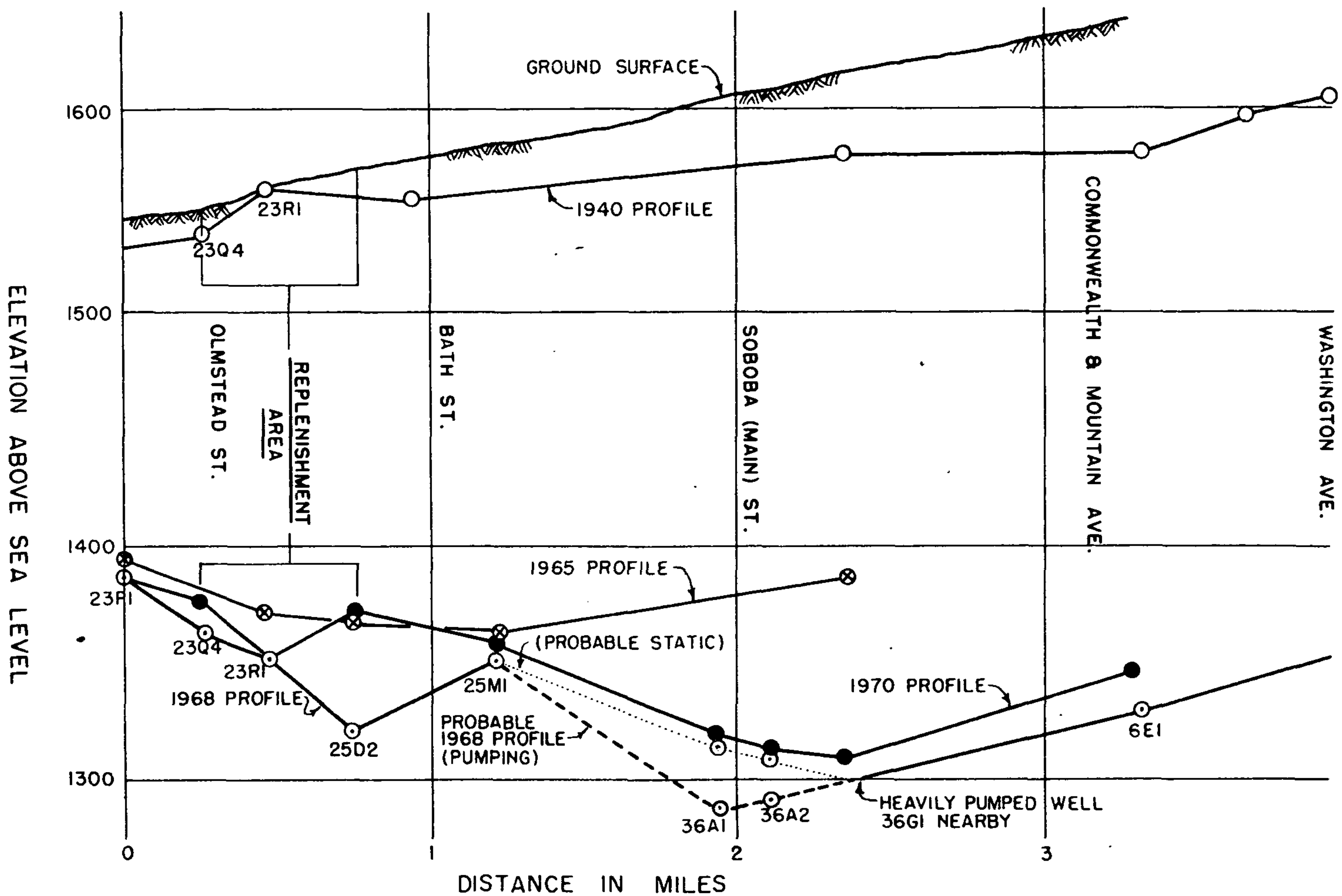


FIGURE 5. GROUNDWATER PROFILE - 1940, 1965, 1968, & 1970

Several miles to the northwest of the Pressure Area impervious sediments, and possibly the Casa Loma Fault, apparently form a barrier to the movement of groundwater. The bottom land or depression formed as a result of faulting, and land subsidence due to water withdrawal, produced wells that yielded "marsh" gas and led to the drilling of speculative oil wells. However, no oil was ever discovered. The land subsidence has also been observed throughout the Pressure Area, and the Eastern Municipal Water District is presently engaged in a cooperative study with the State Division of Water Resources, the United States Geological Survey, and The Metropolitan Water District of Southern California to determine if the subsidence that is taking place is a direct result of water withdrawal and compaction of the water-bearing strata, or rather some deep tectonic movement associated with the graben nature of the valley, or both. A well has been drilled to a depth of 1,238 feet, and compaction and water level recorders have been installed in the well for this purpose. (See Figure 3 for location.) To date, the information is very preliminary and no conclusions have been reached.

Meteorology

The climate of the Upper San Jacinto Groundwater Basin is best described as semi-arid and is characterized by a division of the year into a wet and a dry season, with generally low precipitation, a large percentage of clear days, moderately high summer temperatures, and few days of low winter temperatures. The average seasonal precipitation at San Jacinto is 13.18 inches, while the highest yearly rainfall of record is 25.23 inches and the lowest is 3.70 inches. At the City of Hemet the seasonal average precipitation is 12.35 inches while the yearly high and low are 25.76 and 3.90 inches, respectively. The precipitation is mostly in the form of rain, with occasional snow falling in the groundwater basin.

Temperature data show that the range is from 110° - 115° F on hot summer days to 20° - 25° F on cold winter nights. The average annual temperature in the groundwater basin is about 60° F. Evaporation records kept by the Project Staff since 1965 show that maximum daily evaporation may reach one-half inch, or more, with the yearly rate being 4 to 4-1/2 feet.

The native vegetation of the groundwater basin is sage and other flowering plants that don't require large amounts of water. In order to establish citrus, olive, walnut and other crops, pumpage of and irrigation with the groundwater was necessary. In recent years local farmers have had to supplement the local production with imported Colorado River water.

Hydrography

Any study of a groundwater basin must include a discussion of the relationship between surface run-off and groundwater movement. As previously mentioned, the major drainage channel for the entire San Jacinto Hydro Sub-area is the San Jacinto River. The majority of the tributaries to the San Jacinto River discharge into it either upstream of or adjacent to the Upper San Jacinto Groundwater Basin, and consequently the majority of the run-off from the Hydro-Unit runs into or through the groundwater basin. Essentially all groundwater recharge by the San Jacinto River occurs within the groundwater basin, and then mostly within the Canyon Sub-basin and the Intake Area.

Groundwater flow into and out of the Upper San Jacinto Groundwater Basin is restricted by faults and bordering impermeable sediments, as evidenced by variations of water well levels. The groundwater is apparently able to move freely within the groundwater basin, as demonstrated by the fact that the recharge which takes place in the Intake Area affects both that area and the Pressure Area.

Surface Run-off - The major source of water inflow to the Upper San Jacinto Groundwater Basin is the surface run-off originating in the surrounding watershed. During unusually wet winters a significant quantity of water also leaves the basin as surface flow. The watershed drains into the San Jacinto River through a number of streams and creeks, the more important of which are: The North and South Forks of the San Jacinto River, Strawberry Creek, Bautista Creek, Indian Creek, Poppet Creek, and Potrero Creek. These creeks and their points of discharge into the river are shown on Figure 6. As Strawberry Creek and North and South Forks converge and flow into the basin as the San Jacinto River above the gauging station at the Cranston Bridge the three streams will be considered jointly and included in references to the San Jacinto River.

Data on the amount of flow from the aforementioned streams are unfortunately limited. Using such information as is available, surface inflow and outflow amounts can be calculated as discussed in Section VI of this report, "Long-term Yield of the Upper San Jacinto Groundwater Basin."

Surface Inflow and Outflow - A continuous stream flow record for the San Jacinto River at the Cranston Bridge (see Figure 6) is available, beginning in 1920-21. Limited stream flow data exist for Bautista, Indian, Poppet and Potrero Creeks and mean flows are therefore extrapolated by comparison with the stream flow in the San Jacinto River. The complete records show that over the base period 1920-21 through 1959-60, the combined mean flow for the five streams has been 25,697 acre-feet per year.

All surface outflow from the basin is carried by the San Jacinto River at the northwestern end of the basin. Gauging station records operated at Lake Elsinore and Railroad Canyon Lake show that over the same 1920-21 through 1950-60 base period the mean flow carried out of the basin has been 8,565 acre feet per year. Complete outflow records are also found in Section VI.

The San Jacinto River enters the Upper San Jacinto Groundwater Basin at the mouth of the Canyon Sub-basin and flows into the flat, highly permeable "Cienega." Directly to the northeast of the "Cienega" is the mouth of Indian Creek which joins the San Jacinto River there. Poppet Creek joins the San Jacinto River further downstream but still within the "Cienega" portion of the Canyon Sub-basin. Surface discharge from the area is limited to flood periods as all low flow is absorbed by the alluvial beds extending upstream for several miles.

Bautista Creek joins the accumulated flow of the San Jacinto River and Indian and Poppet Creeks immediately below the "Cienega." Historically, most of the flow in this stream was absorbed in the alluvial fan extending for about 7 miles upstream of its mouth. In 1960, the stream was converted into a concrete-lined flood control channel from a point approximately 4-1/2 miles upstream to a point just above its mouth. Therefore, more water is discharged into the Intake Area and made available to infiltrate to the groundwater. Surface discharge from this area is also limited to flood flows.

Potrero Creek enters the San Jacinto River near the northwestern edge of the Pressure Area where steep gravel fans have been laid over impermeable sediments. Therefore, flood flows are not able to penetrate and are carried downstream while low flows are forced to the surface and are consumed by existing vegetation. Very little of the runoff carried by this stream is contributed to the groundwater supply.

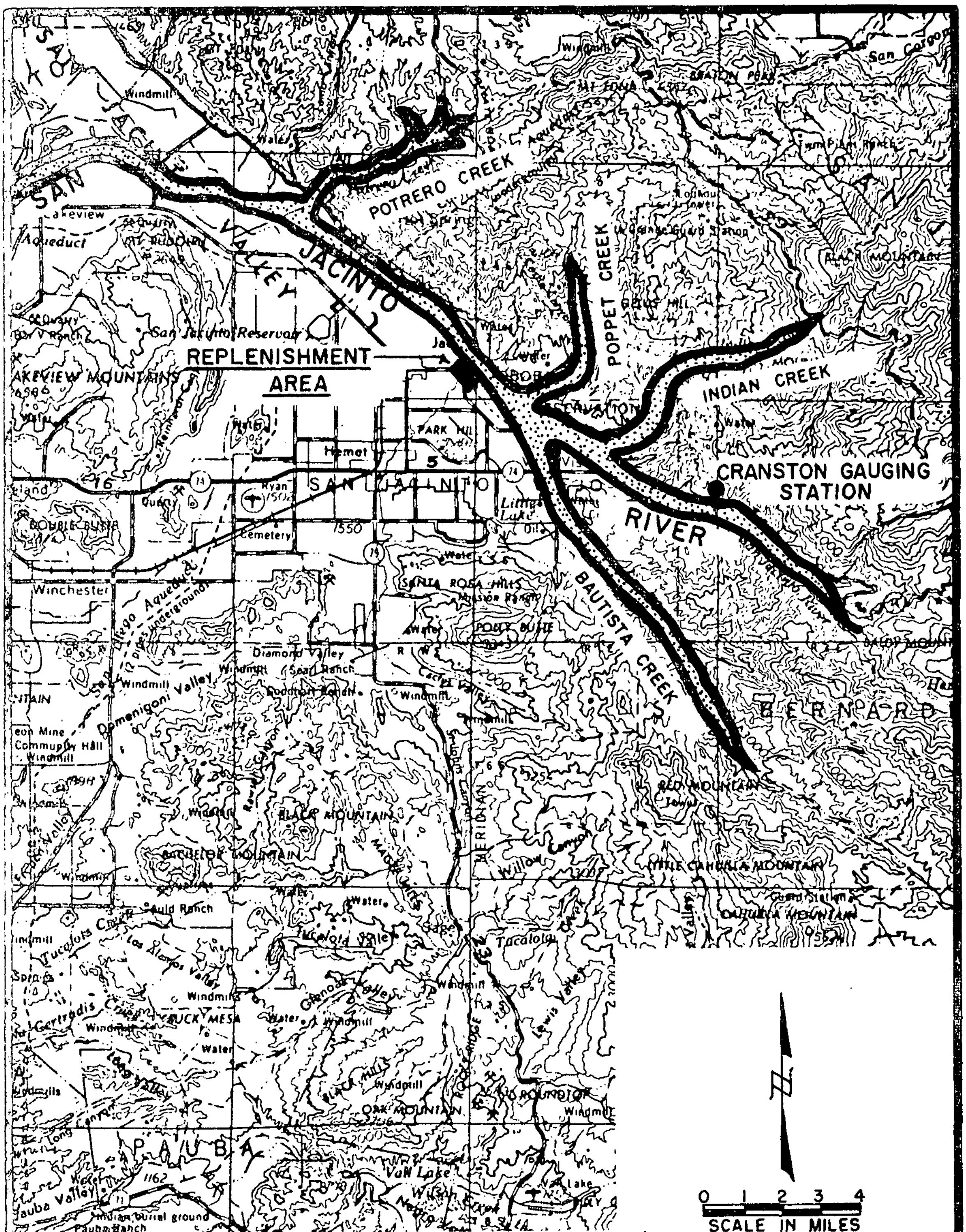


FIGURE 6. SAN JACINTO RIVER & TRIBUTARIES

SECTION V

GEOLOGY OF UPPER SAN JACINTO GROUNDWATER BASIN

In the early stages of the study, as background well data were being collected and examined, an anomaly in the well logs became apparent. None of the wells drilled in the central portion of the groundwater basin (that is, the Pressure Area and the northwestern portion of the Intake Area) had reached bedrock. It was also found that none of the wells drilled between the San Jacinto and Casa Loma Faults had ever reached bedrock. One of these wells was over 2,200 feet deep and only one-half mile from bedrock outcrops across the Casa Loma Fault. Near the San Jacinto Fault the difference was just as surprising where there were bedrock outcroppings just one-quarter of a mile from wells that were over 800 feet deep and had not hit bedrock.

It is imperative that a study such as this have as much knowledge about its groundwater basin as possible, and in view of the above anomalies it was deemed necessary to conduct a geological survey of the Upper San Jacinto Groundwater Basin. The University of California at Riverside, located immediately north of the District, was contacted concerning the availability of geophysics students to assist project personnel in determining the depth of the groundwater basin.

Dr. Gordon Eaton, then chairman of the Geophysics Department at UCR, together with one of his graduate classes and members of the project staff worked over a year on magnetometer, gravity and seismic surveys needed to determine the depth of bedrock in the basin. Drs. Shawn Biehler and Stuart Smith from California Institute of Technology, along with one of their graduate classes, worked diligently on the seismic surveys and the reduction of the data. John Fett, a local geologist, donated many days of work to these surveys, along with the use of his equipment. Mr. Fett was later engaged as a consultant to summarize the geology of the Upper San Jacinto Groundwater Basin based on the findings of the above surveys. Portions of Mr. Fett's report are in the following discussion, with the complete text comprising Appendix I, Volume II of this report.

General Description

The geologic relations in the area are largely controlled by the various faults with alluvial fans and soils filling against faulted blocks and, to the southwest of the Casa Loma Fault, against remnant high points of metamorphic and igneous rocks. The alluvial soils themselves are cut by faults, some forming escarpments, some exhibiting deep cracks, and others evidenced by anomalous groundwater conditions.

The metamorphic rocks are mostly schists and gneisses, while the igneous rocks are mostly cretaceous tonalites and granodiorites.

The groundwater basin is mainly composed of Recent-Late Quatenary sediments which were probably deposited by stream flow, while the Park and Casa Loma Hills, the hills east of Bautista Creek, the Badlands to the northwest of the basin and much of the Soboba Indian Reservation are late Tertiary - early Quatenary sediments. The alluvial material has been washed by the flow into alternate lenses of sand and silt of various thicknesses. These lenses are also interspersed with some clay and boulders as was evidenced while drilling observation wells in and around the replenishment area.

Magnetometer and Gravity Surveys

Five lines crossing the groundwater basin orthogonally to its long axis were developed, using Eastern Municipal Water District surveyors to establish horizontal and vertical control for each station pursuant to directions received from Dr. Eaton. Figure 7 depicts these survey lines, and it is interesting to note that several of the lines traverse steep terrain. This study was also beneficial to the students who learned the techniques of gravity and magnetometer surveying.

Since the work was conducted in part on an experimental basis and the magnetometer survey data yielded no appreciable information, it was discontinued after two lines were run in the vicinity of Survey Lines A and B, since this was sufficient for instructional purposes. The geology is apparently not susceptible to magnetometer work due to the similarity between the magnetic properties of the sediments and the adjoining crystalline rock.

Most of the gravity data obtained were reduced in detail by an electronic computer under the direction of Dr. Shawn Biehler. A portion of the gravity survey conducted by Mr. John Fett has been reduced by a desk calculator without total compensation for terrain correction. A Boughuer anomaly map was prepared from this data and can be found in Appendix 1.

When the gravity survey indicated the depth to bedrock in the graben exceeded 3,000 feet, the gravity survey method of determining depth

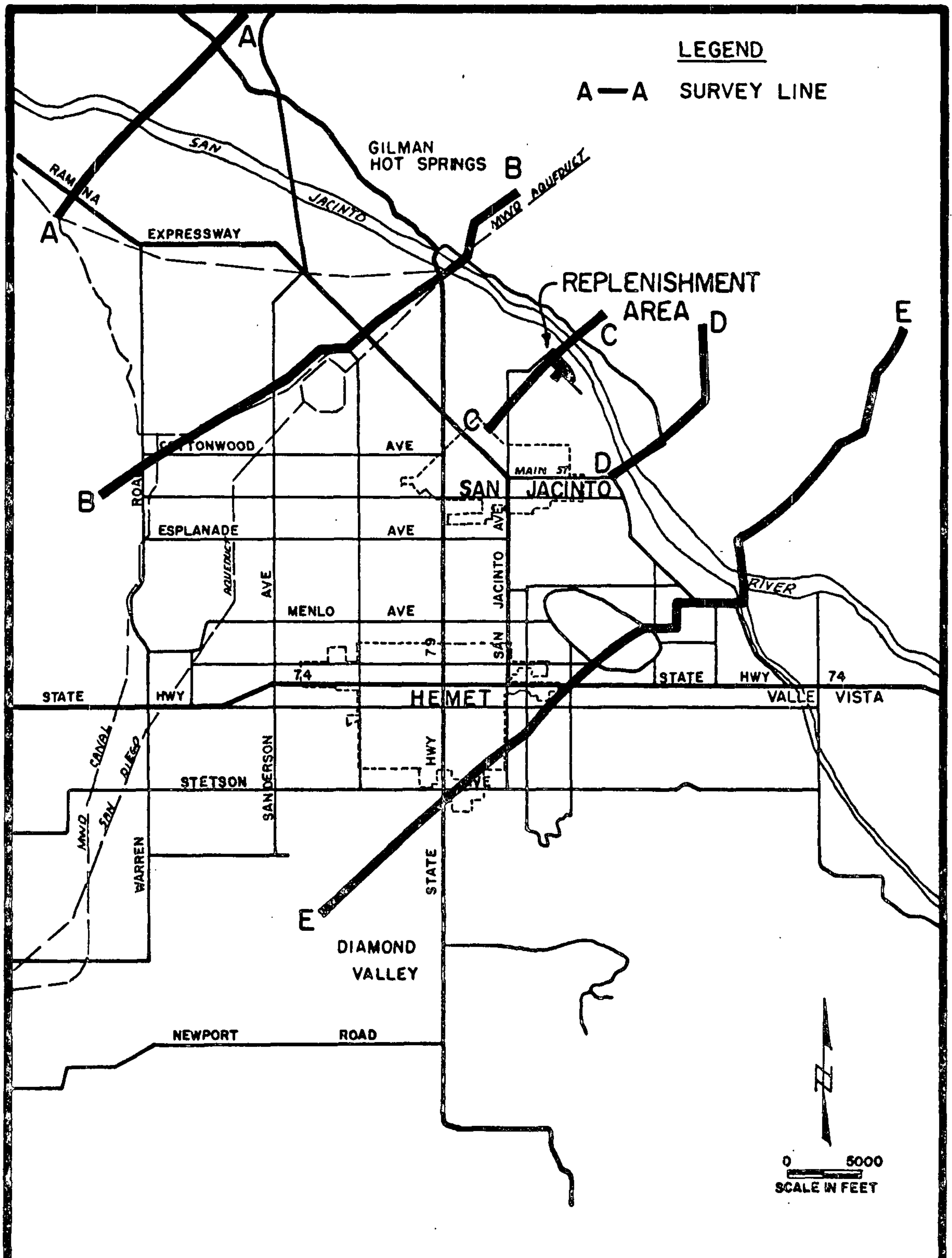


FIGURE 7. LOCATION OF SURVEY LINES

became more qualitative than quantitative as sediment bulk densities are not known in detail.

Seismic Survey

To determine the depth of the valley sediments more accurately, a seismic refraction survey was conducted using dynamite as the charge. The personnel involved at any particular time varied from three District employees and Mr. Fett, to five District employees, Mr. Fett, Drs. Shawn Biehler and Stuart Smith with their graduate geophysics class from California Institute of Technology, and Dr. Eaton and his graduate class from University of California, Riverside.

The seismic velocity of granitic bedrock in the area of investigation was first determined by Dr. Eaton and Mr. Fett, using a Texas Instrument EXPLORER seismograph system. Measurements were made on the northwest side of the Lakeview Mountains, both across foliation and along foliation. The rock was found to be anisotropic, with a minimum velocity of about 14,500 feet per second across foliation and a maximum velocity of about 17,000 feet per second along foliation. A commercial seismic investigation in the area found seismic velocity of unweathered metamorphic bedrock to be 15,000 to 16,000 feet per second.

Four separate seismic lines, as shown on Figure 8, were explored. The major seismic work was conducted along Line A-A. The shot point, Shot Point 1, was at the northwest end of the line and was located in the San Jacinto River bed just west of the junction of Potrero Creek and the river. To facilitate the use of three separate geophone strings during the seismic work on Line A-A, the shot instant was radioed to recording units by CIT's tone-generating blaster. The precise instant of cap detonation was determined by interrupting a radio-transmitted electrical tone. This signal was placed on seismic records by auxiliary galvanometers.

To verify the findings of the above work and to determine the dip of bedrock, Line A-A was reversed by Mr. Fett and Dr. Eaton with his geophysics students. Shot Point 2 was at the southeast end of Line A-A in Bautista Creek, just north of Cedar Avenue.

To reduce the explosive costs, Mr. Fett instructed Eastern Municipal personnel in the substitution of an ammonium nitrate-fuel oil mixture. Use of this explosive reduced costs to one-half that of the more conventional explosive used at Shot Point 1.

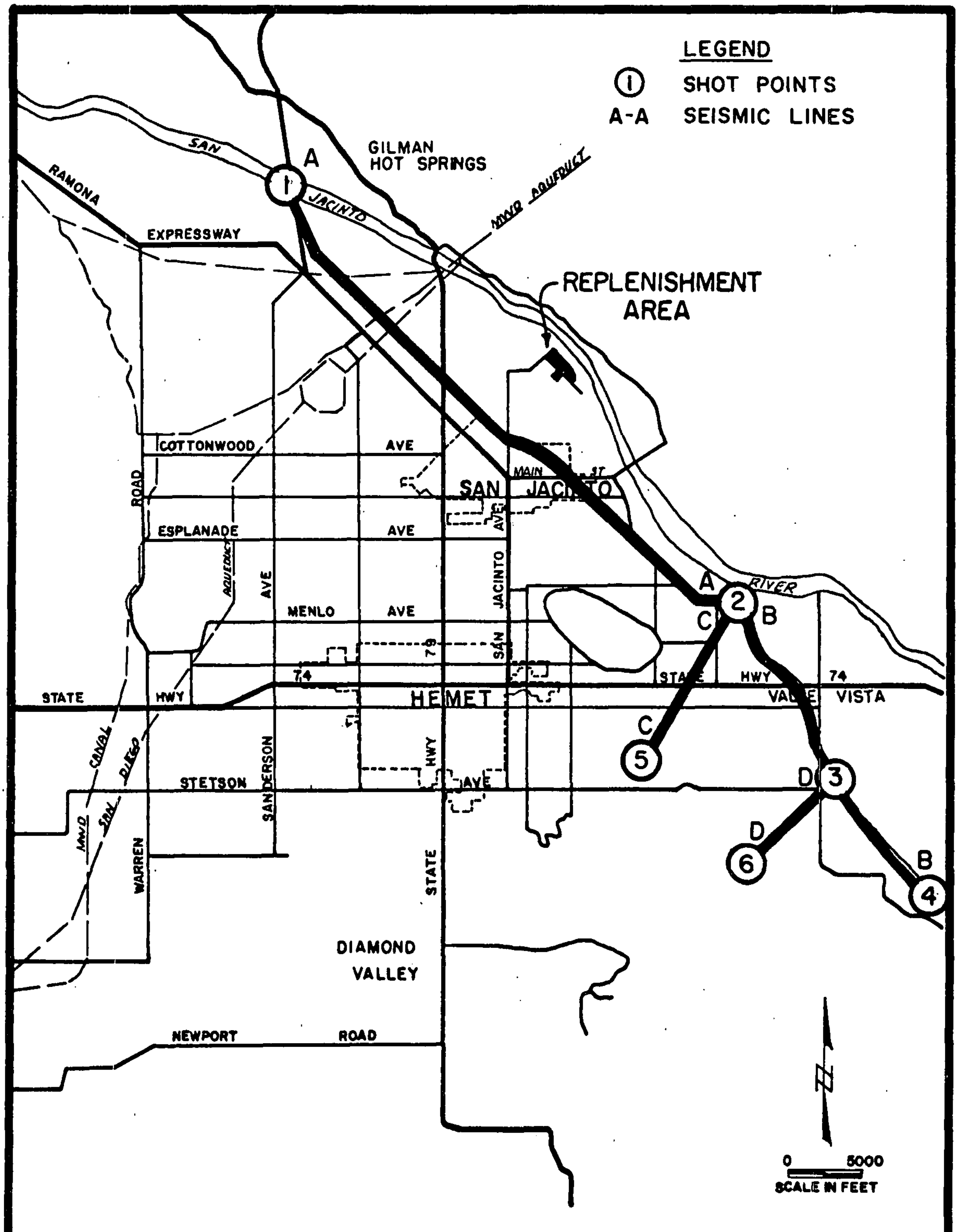


FIGURE 8. LOCATION OF SEISMIC SURVEY LINES

Shot holes were dug with a backhoe to 11 feet in depth. In contrast to Shot Point 1 where up to 500 lbs. of explosive were buried in one hole, charges were limited to 120 lbs. per hole at Shot Point 2. Where additional energy was required, several holes were connected by a primer cord detonating fuse. The shot hole loading techniques used at Shot Point 2 induced more energy into generation of seismic waves and also reduced cratering.

The original data from Shot Point 1 and Line A-A as interpreted by Dr. Eaton as follows:

Sediment layers - V = velocity;

V_0 = 1,300 fps Thickness = 30' - 35'

V_1 = 5,000 - 5,750 fps, Thickness = 1,095' - 1,115'

V_2 = 7,200 - 7,350 fps, Thickness = 1,930' - 2,110'

V_3 = 8,650 - 8,850 fps, Thickness = 2,000' - 3,000'

V_4 = 10,150 - 11,500 fps, Thickness = 5,400' - 7,000'

V_5 = 16,000 - 18,500 fps, Bedrock at minimum depth of 10,400' ± 1,000 feet

The reversal of Line A-A indicated somewhat less depth to bedrock. It showed bedrock at a depth of 8,400 feet approximately 1-1/2 miles southeast of the location established from Shot Point 1. This difference could be attributed to either a dip in bedrock surface of approximately 12 degrees to the northwest or a misinterpretation of the depth to groundwater. This could be clarified by further testing, but for the purpose of the project the bedrock depth of 8,400 feet or greater is sufficiently accurate.

Three other seismic lines were investigated. These lines are designated B-B, C-C, and D-D on Figure 8.

Figure 9 is a block diagram of the San Jacinto Valley based on the seismic surveys and past investigations of others.(5)

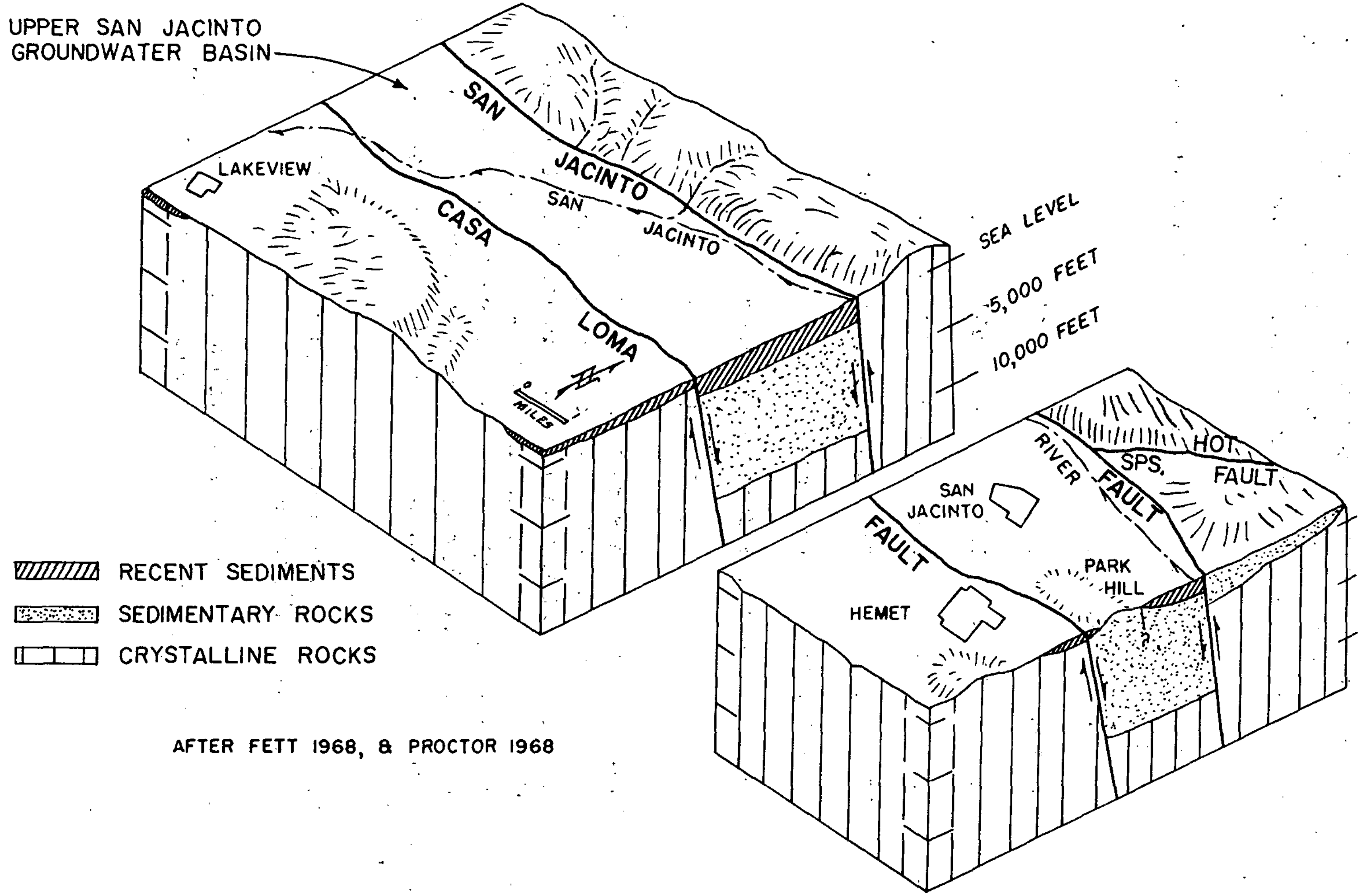


FIGURE 9. BLOCK DIAGRAM OF THE SAN JACINTO VALLEY

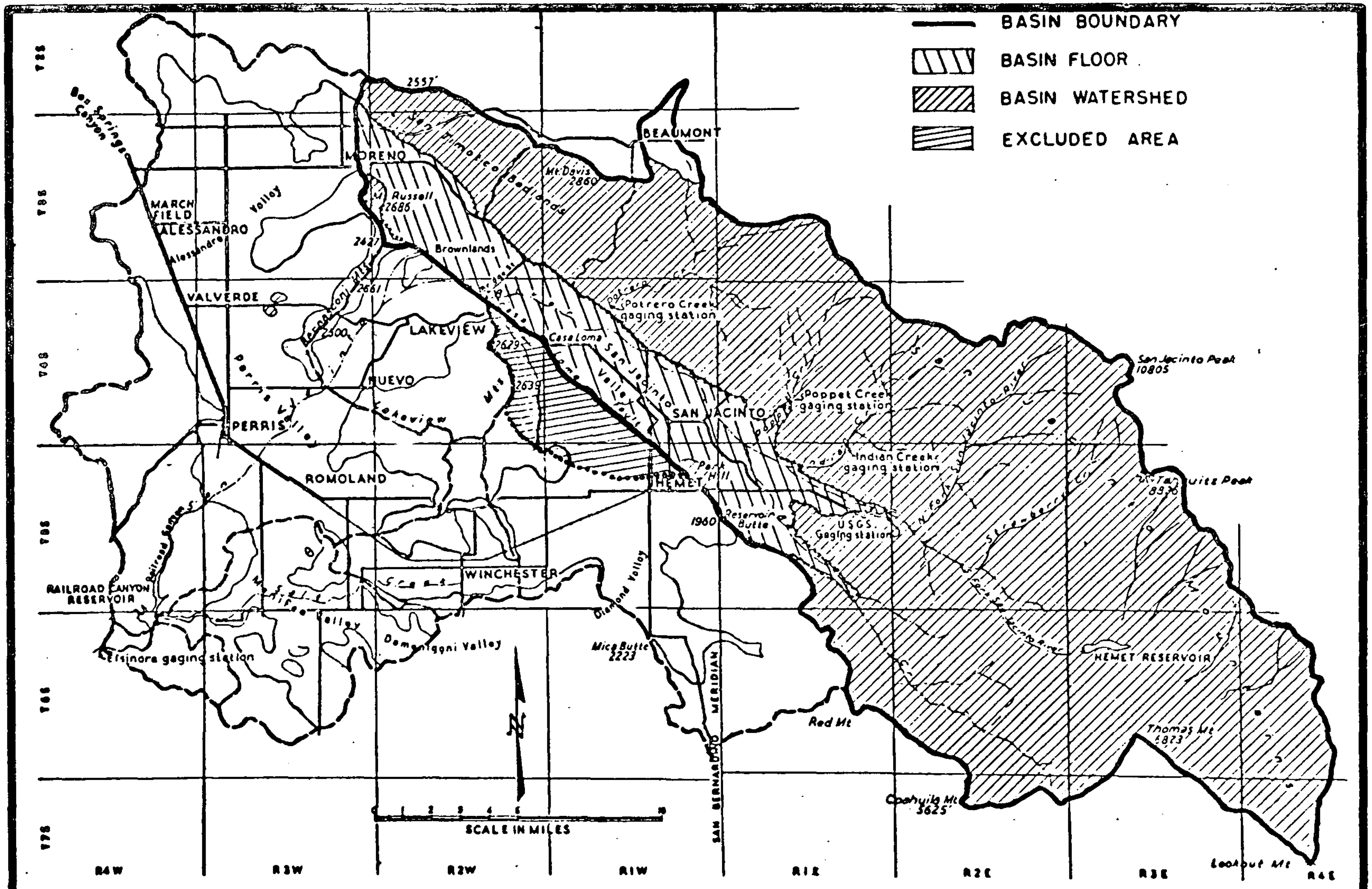


FIGURE 10. UPPER SAN JACINTO GROUNDWATER BASIN AND WATERSHED

SECTION VI

POTENTIAL LONG-TERM YIELD OF THE UPPER SAN JACINTO GROUNDWATER BASIN

Because of the ambiguity surrounding the term "safe yield" it was decided to use the phrase "potential long-term yield" which more accurately reflects the more recent idea that a combination of basin overdraft and more expensive imported water may furnish the greatest benefits to the user.

Past investigations of water use(4) and the potential long-term yield of the San Jacinto Valley area(5), (6), (7) have dealt with the hydrologic areas as defined by the California Department of Water Resources. Since the Replenishment Area is in the Upper San Jacinto Groundwater Basin which, along with its watershed, comprises the San Jacinto Hydro Sub-unit it will be the area under discussion here. The area is shown in Figure 10. Although a portion of the Hemet Hydro Sub-area could theoretically be included since it surficially drains into the San Jacinto unit, it will be excluded here because:

1. it is not part of the hydrologic unit by designation,
2. it is dubious if any appreciable amount of subsurface flow can enter the San Jacinto unit from it, due to the Casa Loma fault,
3. the bulk of the area is valley floor and runoff is undoubtedly minimal. The excluded area is denoted on Figure 10 along with the boundaries of the Upper San Jacinto Groundwater Basin and its watershed.

To calculate the potential long-term yield of this groundwater basin, a great deal of hydrologic data had to be collected and assimilated. The major sources of information were:

1. United States Weather Bureau
2. United States Coast and Geodetic Survey
3. State of California, Department of Water Resources
4. Riverside County Flood Control and Water Conservation District, Riverside, California

Precipitation

Approximately 35 precipitation stations have existed at one time or another in or near the Upper San Jacinto Groundwater Basin and

Watershed. Of these, 20 stations were selected as suitable for this study. The locations of these stations are shown on Figure 11 while a complete tabulation of the precipitation data is presented in Table 1. It is felt that Table 1 represents the most complete set of precipitation data now available. For purposes of this study the term fiscal year is defined as the period July 1 to June 30.

In order to calculate the potential yield, it is necessary to select a suitable base or reference period. Long-term precipitation records provide a convenient means of establishing such a period. The cumulative deviation from the long-term mean precipitation was computed for five separate stations. Based on this information, the 38-year interval beginning with the fiscal year 1922-23 and ending with 1959-60 was selected as the base period. The mean precipitation for this period closely approximates the long-term mean for the entire period of record.

Mean precipitation values for the base period have been calculated and are given in Table 1. By comparison with nearby stations, mean values for stations with incomplete records were extrapolated. Using the mean values for the base period, isohyets were drawn and are shown in Figure 11. The average yearly rainfall on the total basin and the basin floor were, in turn, determined and are presented in Table 2. Of particular importance in the calculation of potential yield is the average precipitation on the groundwater basin, 39,220 acre-feet per year.

Surface Runoff

Surface runoff from the surrounding watershed constitutes a major source of water inflow to the Upper San Jacinto Groundwater Basin. There is also occasionally a significant quantity of water leaving the basin as surface flow. Unfortunately, only limited data on stream flow exist for this area. Using such information as is available, the surface inflow to and outflow from the groundwater basin can be calculated as discussed below.

Surface Inflow - A number of streams debouche upon the San Jacinto Basin floor. The principal one is the San Jacinto River. A continuous record of the stream flow at Cranston Bridge is available for the period 1920-21 to the present, as shown in Table 3. Immediately above the gaging station, however, a portion of the river flow is diverted to Lake Hemet Municipal Water District's water system. A portion of this water does reach the basin floor as irrigation and domestic water and the balance is exported. In this report the diverted, but not exported,

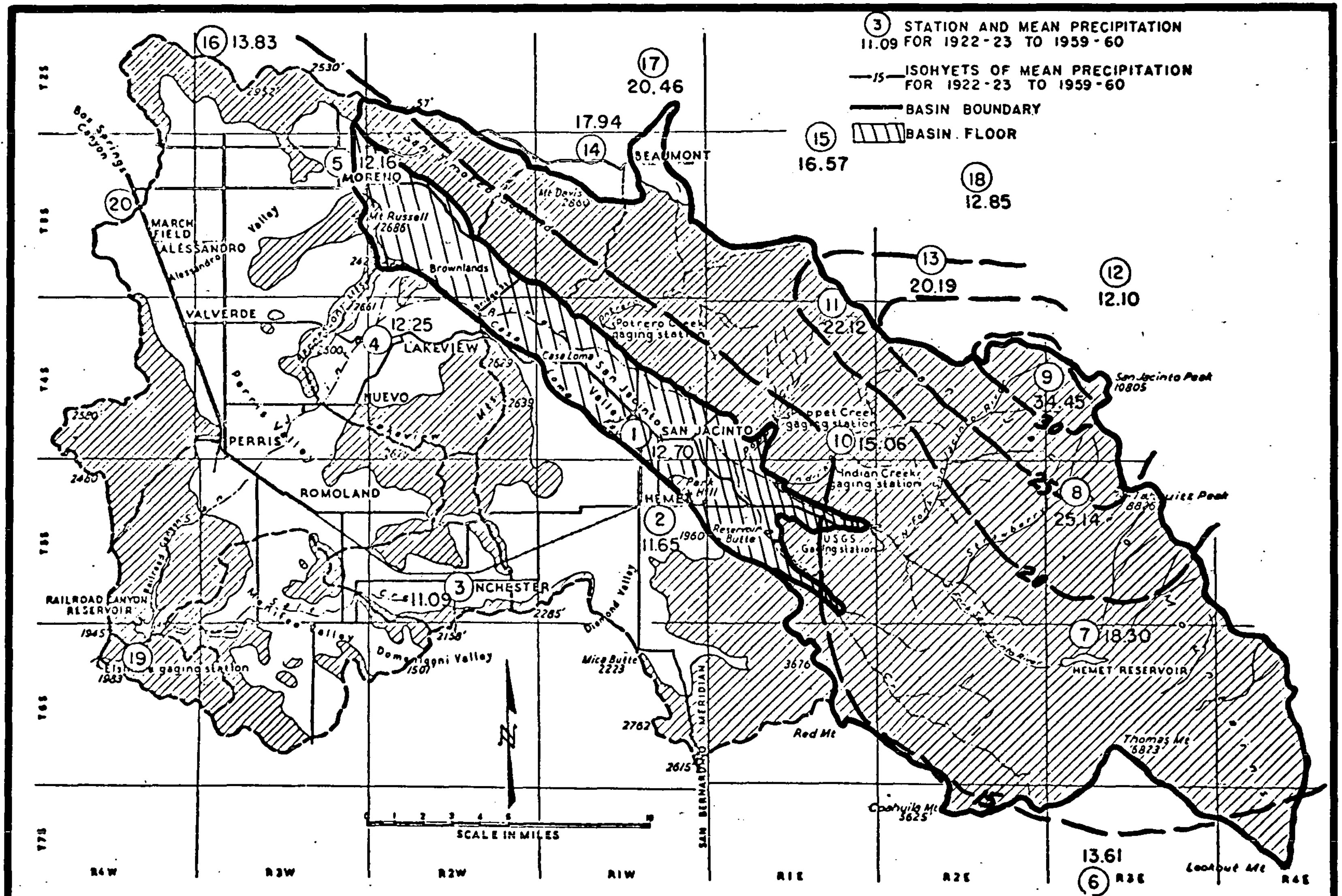


FIGURE II. PRECIPITATION STATIONS & ISOHYETS

TABLE 1
PRECIPITATION RECORDS
(inches)

Fiscal Year Ending	1 San Jacinto	2 Hemet	3 Winchester	4 Lakeview	5 Moreno (Erramuspe)	6 Anza	7 Hemet Reservoir	8 Idyllwild Ranger Station	9 Decker's Ranch	10 Simm's Ranch
1910	12.52			11.33			19.98	25.35		
1	15.44	14.73		12.14			21.17	27.82		
2	12.64	12.48		12.02			17.68	22.14		
3	8.62	12.21		7.30			14.10	19.95		
4	18.87	21.58		15.71			24.38	37.31		
15	18.09	24.00		19.48			27.27	30.11		
6	16.60	19.69		14.77			25.44	31.41		
7	11.45	12.99		10.13			17.34	29.38		
8	12.27	15.24		12.60			16.57	30.85		
9	10.25	9.14		8.95			15.78	24.05		
1920	14.61	13.86		13.39			23.83	29.40		
1	10.82	11.41		9.58			15.23	20.82	31.78	
2	25.23	25.76		26.44	25.77		34.71	52.79	56.99	
3	10.68	9.06		10.91	9.93		20.10	20.76	30.35	
4	9.74	8.66		10.29	9.20		14.20	17.10	26.31	
25	7.28	6.99		7.60	7.91		14.13	15.65	28.45	
6	16.69	14.05		17.31	15.86		25.18	27.00	46.42	
7	19.37	18.41		17.95	18.54		30.86	35.31	60.92	
8	9.44	9.12		10.29	10.24		13.53	22.05	22.63	
9	9.19	8.70		8.11	9.36		12.54	17.76	27.56	
1930	15.10	14.99		15.40	14.71		28.27	29.75	37.40	
1	8.87	9.62		10.16	11.88		11.99	18.75	23.78	
2	19.54	18.98		16.72	18.61		27.61	45.04	48.92	
3	9.94	10.12		12.04	9.47		11.95	20.40	26.56	
4	6.36	6.64		5.77	6.31		6.12	14.91	21.37	
35	15.91	15.18		15.22	17.28		20.56	35.21	36.67	
6	10.07	9.19		9.24	9.12		16.87	17.87	34.68	
7	24.62	24.98		23.58	25.44		31.34	43.96	61.20	
8	14.84	13.35		14.86	15.34		25.53	28.26	45.49	21.02
9	12.88	11.32		12.44	12.23		15.42	25.25	31.08	14.87
1940	16.23	13.65			13.17		21.12	32.91	36.33	21.08
1	24.63	23.73	20.17		24.02		31.95	47.06	64.06	24.33
2	12.26	10.68	9.33		10.98		16.78	26.61		12.09
3	15.46	14.14	12.86		16.55	17.30	23.90	26.69		19.62
4	13.49	12.84	12.07		13.77	16.41	16.18	25.13		14.86
45	12.49	12.52	12.05		11.56	13.80	16.54	22.40		15.12
6	12.39	7.81	9.69		6.29	14.71	21.46	18.73		13.62
7	11.62	10.88	8.86		11.10	13.67	18.29	23.29		14.96
8	7.55	6.44	6.86		8.13	9.77	13.87	19.06		8.44
9	9.45	8.96	8.85		9.22	9.39	13.52	22.78		15.17
1950	7.13	7.17	6.85		8.91	8.26	13.01	19.87		9.59
1	7.27	6.38	4.44		6.39	7.29	10.58	12.80		10.55
2	18.22	17.67	11.89		20.35	23.79	27.58	41.03		24.97
3	11.59	10.16	9.26			11.62	14.94	21.46		13.45
4	10.84	10.02	9.26			10.60	16.14	25.03		14.19
55	11.74	9.88	9.01			8.61	13.50	18.74		15.74
6	6.94	6.13	12.11			7.72	11.18	21.81		9.19
7	10.75	9.45	15.07			9.63	13.58	21.47		12.70
8	24.94	19.10	19.24			20.21	28.34	38.31		25.61
9	6.98	7.31	5.19			5.81	9.51	12.40		5.83
1960	9.99	8.56	7.29			13.31	17.34	22.76		13.20
1	3.71	3.90	3.66			5.30	6.56	8.38		5.69
2	11.27	11.29	10.21			12.26	15.80	22.48		12.84
3	6.88	6.70	6.34			7.57	11.15	14.90		
4	12.05	12.13	9.90			15.13	18.84	26.37		
65	9.64	9.25				10.55		25.29		
Total 1923-1960	482.48	442.84	421.59*	465.59*	462.05*	517.01*	695.50	955.37	1308.96*	572.24*
Mean	12.70	11.65	11.09*	12.25*	12.16*	13.61*	18.30	25.14	34.45*	15.06*

*Extrapolated

Table 1 continued

Fiscal Year Ending	Poppet Flats 11	Snow Creek 12	Twin Pines 13	Beaumont 14	Banning 15	Reche Canyon 16	Beaumont Pump. Plt. 17	Cabazon 18	Railroad Canyon Dam 19	March Field 20
1910				14.49						
1				19.89						
2				17.56			19.34			
3				10.23			11.91			
4				27.48			31.90			
15				28.60			27.90			
6				26.19			31.95			
7				19.44	14.45		25.07			
8				17.08	16.76		19.50			
9				15.68	13.93		14.98			
1920		16.51	26.79	22.93	20.65	16.03	27.23			
1		9.57	16.29	16.88	15.37	11.05	23.65			
2		24.30	34.04	32.89	30.05	27.24	36.43			
3		8.64	18.48	17.21	14.30	11.72	20.12			
4		7.59	14.40	13.77	13.40	9.64	16.48			
25		6.82	14.96	13.29	10.81	12.25	18.19			
6		14.18	26.19	24.52	23.03	17.69	26.16			
7		17.19	31.24	27.75	24.50	17.31	30.84			
8		7.34	10.33	13.16	11.82	12.21	16.01		3.39	
9		6.40	18.44	13.94	12.70	11.44	15.24		6.56	
1930		11.73	21.32	21.92	17.74	16.22	21.95		15.73	12.64
1		7.05	13.61	13.81	11.84	13.21	16.64		9.68	10.25
2		22.78	29.75	26.03	25.36	19.12	27;50		16.62	12.34
3		8.81	13.25	15.36	13.41	9.56	17.77		9.67	6.97
4		5.26	10.75	11.75	10.77	9.13	12.71		7.90	3.53
35		12.69	22.35	20.53	18.64	16.28	21.86		14.89	11.38
6		7.78	20.01	15.65	15.59	12.53	20.64		7.78	6.44
7		22.55	36.06	34.00	31.78	27.78	38.19		20.95	18.62
8	31.19	21.20	29.73	22.89	20.88	17.55	28.95		16.53	11.25
9	20.22	10.97	18.62	18.20	14.54	12.24	18.12		11.80	11.73
1940	29.45	13.96	21.73	22.53	19.66	16.01	22.21	10.43	12.40	
1	40.24	24.74	34.50	30.25	30.04	25.52	33.61	23.86	23.84	21.62
2	17.87	10.72	15.24	14.44	14.42	11.59	17.33	9.33	8.89	9.27
3	28.95	19.59	29.87	23.79	21.51	19.45	29.99	17.71	13.33	10.25
4	21.03	15.94	25.97	20.08	17.56	18.06	20.59	11.98	15.18	13.57
45	23.91	10.81	19.85	19.16	15.37	13.35	20.70	11.13	9.94	8.94
6	18.87	12.87	19.23	15.39	15.62	10.58	18.98	12.71	7.29	7.04
7	28.89	10.43	15.78	17.64	17.48	12.27	20.28	10.64	7.98	8.60
8	13.86	6.95	11.62	11.54	9.72	8.71	12.84	7.60	3.86	5.04
9	16.35	9.77	18.48	14.63	15.20	11.39	17.93	5.93	6.75	5.66
1950	18.05	6.48	13.26	12.93	11.47	10.55	15.67	4.72	3.66	6.06
1	12.54	4.90	10.56	9.34	9.10	7.76	12.33	6.25	5.15	4.67
2	29.71	19.66	35.98	23.66	24.71	23.56	26.69	19.45	14.81	17.48
3		12.18	20.11	14.00	14.24	12.76	16.37	12.69	8.21	10.39
4		12.88	20.48	17.75	15.48	9.46	20.45	12.21	8.79	10.70
55		11.61	14.84	14.13	14.01	12.31	15.74	11.68	8.61	9.86
6		6.61	11.49	12.07	10.80	10.77	18.47	11.62	5.55	6.58
7		8.92	17.13	14.71	13.60	10.98	17.18	11.01	8.36	8.80
8		21.68	31.85	27.32	27.71	18.64	28.06	23.03	16.08	15.04
9		10.90	12.49	9.21	8.30	5.56	10.01	10.12	3.96	4.68
1960		9.31	17.13	13.37	12.43	10.38	14.71	8.98	8.13	8.36
1		5.15	9.98	7.75	6.02	3.92	8.49	4.40	7.38	2.32
2		11.61	24.17	17.03	15.84	12.89	19.86	13.11	11.26	7.83
3		6.40	11.79	8.73	8.97	8.02	10.69	7.54	5.80	4.74
4		14.12	25.23	17.05	15.58	15.45	18.37	14.43	7.75	
65		8.65	19.59	14.49	14.14	11.48	18.02	10.23	9.31	
Total 1923-1960	840.57*	459.89	767.08	681.72	629.54	525.55	777.51	488.47*		
Mean 1923-1960	22.12*	12.10	20.19	17.94	16.57	13.83	20.46	12.85*		

(*Extrapolated)

TABLE 2

AVERAGE PRECIPITATION FOR THE BASE PERIOD

Precipitation, inches		Area, acres		Annual Precipitation, acre-feet per year	
Range	Average	Total Basin	Basin Floor	Total Basin	Basin Floor
11-12	11.5	100	100	100	100
12-13	12.5	26,785±	26,650±	28,010	27,715
13-14	13.5	14,790±	3,310±	16,640	3,725
14-15	14.5	21,520	2,200±	22,530	2,660
15-16	15.5	31,480	2,220±	40,605	2,870
16-17	16.5	33,490	950	46,050	1,310
17-18	17.5	25,700	430	37,480	630
18-19	18.5	17,480	70	26,950	110
19-20	19.5	13,050		21,210	
20-21	20.5	10,000		17,080	
21-22	21.5	8,440		15,120	
22-23	22.5	6,190		11,610	
23-24	23.5	5,470		10,710	
24-25	24.5	4,660		9,510	
25-26	25.5	3,850		8,180	
26-27	26.5	3,160		6,980	
27-28	27.5	2,880		6,600	
28-29	28.5	2,380		5,650	
29-30	29.5	2,010		4,940	
30-31	30.5	1,520		3,860	
31-32	31.5	1,360		3,570	
32-33	32.5	1,010		2,740	
33-34	33.5	460		1,280	
34-35	34.5	70		200	
Totals		240,000±	37,000±	347,665	39,220

TABLE 3

STREAM FLOW INTO UPPER SAN JACINTO GROUNDWATER BASIN
(acre-feet)

Fiscal Year Ending	San Jacinto River, Cranston Bridge Gaging station	Diversions	Total	Bautista Creek	Indian Creek	Potrero Creek	Poppet Creek
1920							
21	5,240						
22	55,400	12,264	67,664				
23	11,640	11,299	22,939				
24	3,920	23,320	27,240				
1925	740	4,170	4,910				
26	17,980	13,850	31,830				
27	26,840	10,110	36,950				
28	5,070	11,100	16,170				
29	3,410	8,980	12,390				
1930	7,260	12,370	19,630				
31	1,070	5,180	6,250				
32	28,610	11,410	40,020				
33	2,180	8,640	10,820				
34	820	7,790	8,610				
1935	5,120	6,010	11,130				
36	8,040	10,270	18,310				
37	94,410	12,770	107,180		12,420	16,300	5,860
38	58,730	12,610	71,340		9,260	8,040	4,000
39	9,400	11,970	21,370		2,260	1,720	550
1940	8,150	10,620	18,770		2,180	850	740
41	55,350	10,630	65,980		7,770	1,840	3,490
42	7,540	13,200	20,740		1,820		
1943	23,780	1,490	25,270		1,970		
44	7,020	1,220	8,240				
1945	14,750	1,300	16,050				
46	4,620	870	5,490		990		
47	2,550	460	3,010		1,020		
48	320	500	820	10	440		
49	3,070	3,650	6,720	0	1,710		
1950	1,710	1,940	3,650	0			
51	40	810	850	10			
52	24,340	1,650	25,990	2,920			
53	3,120	1,230	4,350	0			
54	6,560	370	6,930	350			
1955	1,070	1,210	2,280	20			
56	1,750	910	2,660	350			
57	1,070	4,030	5,100	0			
58	31,010	7,080	38,090	2,600			
59	2,320	3,550	5,870	60			
1960	1,460	4,090	5,550	10			
61	0	1,870	1,870	0			
62	2,570	4,000	6,570	20			
63	250	2,120	3,370	0			
64	1,510	3,910	5,420	10			
1965	3,811	3,967	7,778	10			
66	12,493	8,791	21,284	370			
67	26,149	9,624	35,773	600			
68	2,197	8,605	10,802	81			
69	59,198	9,456	68,654	1,582			
Mean 1922-23 to 1959-60	12,810	6,350	19,160	1,020*	2,310*	1,940*	970*

*Extrapolated by comparison with total flow of San Jacinto River into valley water will be included in the computations as surface runoff into the basin.

Limited stream flow data, included in Table 3, exist for Bautista, Indian, Potrero and Poppet Creeks. Mean flow values over the base period 1922-23 to 1969-70 for these streams were extrapolated by comparison with the stream flow in the San Jacinto River above the diversions; i. e., San Jacinto River gaging station flow plus diverted flow.

Most of the surface runoff into the Upper San Jacinto Groundwater Basin is represented by the flow in the five streams cited above. Areas exist, however, that are not tributory to these five streams. To delineate these areas, the runoff areas for the five streams have been determined and the entire basin divided into 11 segments as shown on Figure 12. Runoff coefficients were calculated for four of the five runoff areas for which rainfall and stream flow data were available. These coefficients were then applied to adjacent areas to obtain values for the runoff as shown in Table 4.

The mean runoff reaching the basin floor, therefore, is seen to be 28, 590 acre-feet per year for the base period 1922-23 to 1959-60. Of this amount, 19, 160 acre-feet per year is attributable to the San Jacinto River.

Surface Outflow - The major surface runoff out of the groundwater basin occurs near the northwestern end of the basin through the San Jacinto River. Farther west on this river, a gaging station was operated at Elsinore from 1916-1951 and another at Railroad Canyon Dam from 1952 to 1960. Data collected from these stations are presented in Table 5 with allowances being made for evaporation from Railroad Reservoir from 1927 to 1960 and diversions by Temescal Water Co.

Unusual accretions occurring during the construction of the San Jacinto Tunnel are not included in these values. It appears reasonable to combine the data from the two stations to obtain coverage for the base period 1922-23 to 1959-60 and by so doing, the mean flow is found to be 9, 015 acre-feet per year. It was assumed by Fritz and Rosell and will be assumed here that 95% of 8, 565 acre-feet per year of the flow at Elsinore originated in the San Jacinto Basin. [5]

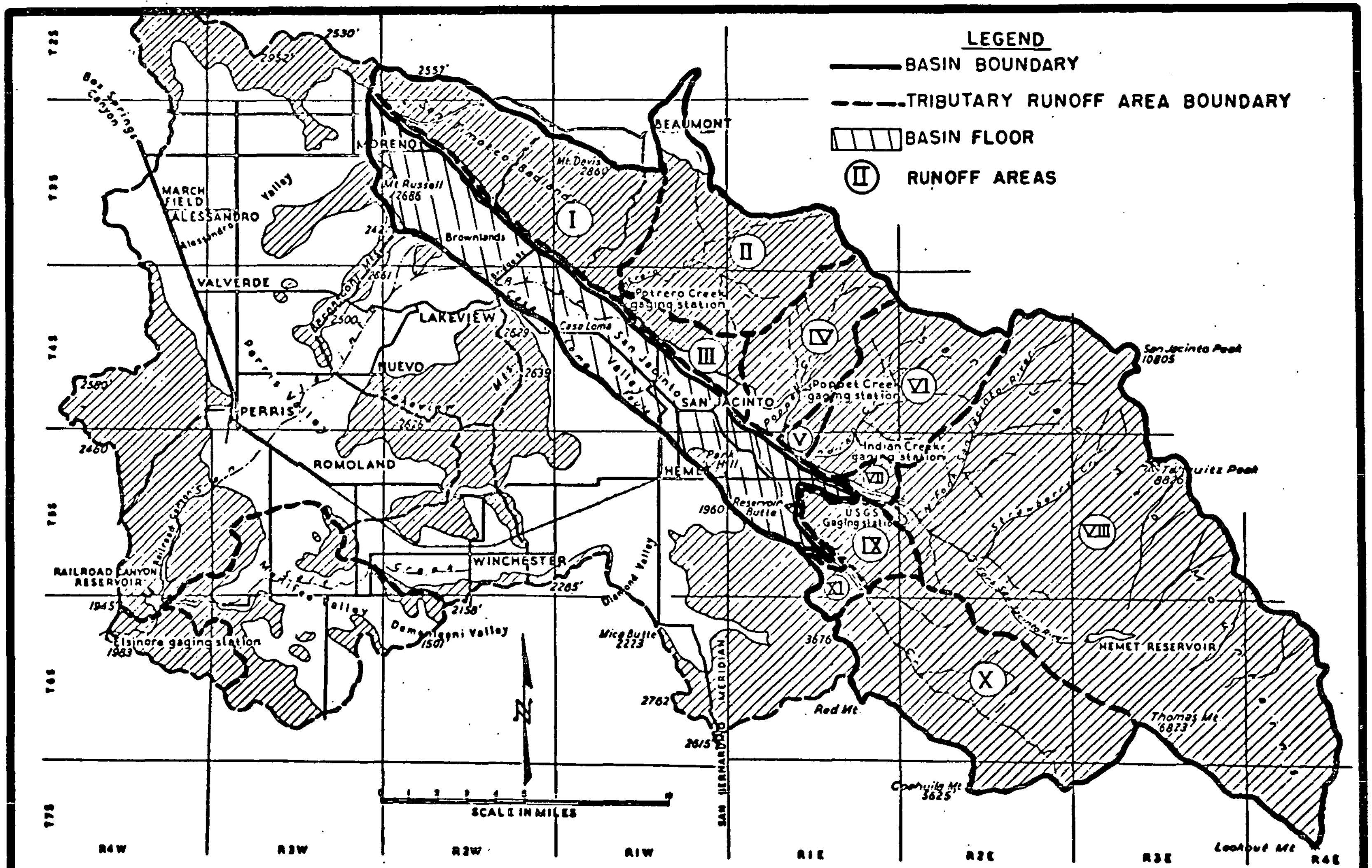


FIGURE 12. RUNOFF AREAS TRIBUTARY TO THE UPPER SAN JACINTO GROUNDWATER BASIN

TABLE 4

SURFACE RUNOFF FROM AREAS TRIBUTARY TO UPPER SAN JACINTO GROUNDWATER BASIN

Area number(a)	Stream	Tributary Mean rainfall(b) acre-feet	Main stream flow(c) ac-ft	Runoff coefficient(d)	Mean runoff(c) ac-ft
I	-	23,290	-	-	1,425
II	Potrero	31,960	1,940	0.0607	1,940
III	-	6,280	-	-	385
IV	Poppet	15,760	970	0.0616	970
V	-	900	-	-	55
VI	Indian	-	2,310	-	2,310
VII	-	2,360	-	-	225
VIII	San Jacinto	147,770	19,160	0.1297	19,160
IX	-	6,530	-	-	845
X	Bautista	37,490	1,020	0.0272	1,020
XI	-	2,075	-	-	255
Totals			25,400		28,590

(a) See Fig. 3 for location of areas
(b) By planimeter
(c) For base period 1922-23 to 1959-60
(d) Ratio-stream flow: rainfall

TABLE 5

STREAM FLOW OUT OF UPPER SAN JACINTO GROUNDWATER BASIN
(Acre-Feet)

Fiscal Year ending		San Jacinto River Elsinore		San Jacinto River Railroad Canyon Dam*
1923		670		
1924		200		
1925		80		
1926		11,960		
1927		83,400		
1928		960		
1929		690		
1930		2,710		
1931		960		
1932		12,060		
1933		650		
1934		20		
1935		240		
1936		0		
1937		78,610		
1938		38,010		
1939		5,980		
1940		1,120		
1941		54,010		
1942		540		
1943		14,330		
1944		4,200		
1945		2,330		
1946		520		
1947		270		
1948		30		
1949		10		
1950		0		
1951		0		
1952				12,770
1953				950
1954				960
1955				390
1956				1,260
1957				720
1958				8,770
1959				50
1960				0
	Subtotals	313,870	+ 2900**	25,870
Total			342,640***	
Mean 1922-23 to 1959-60			9,015***	

* Adjusted to include diversions and evaporation from Reservoir
** Estimated loss of 100 acre-feet per year due to consumptive use by vegetation and percolation loss in 2-mile riverbed area from Railroad Reservoir Station to Elsinore Station during 29-year period 1922-23 to 1950-51. (Pg. 128, Young, Ewing & Blaney[4])
*** Combined to give record for entire period.

Imports and Exports of Water

Water has been imported to the Upper San Jacinto Groundwater Basin through the San Jacinto Tunnel since 1941-42. Records of the Eastern Municipal Water District are summarized in Table 6. During the period 1941-42 to 1959-60, the mean import was 1,930 acre-feet per year.

The water that entered the basin during the tunnel construction years of 1932-1939 has been essentially ignored, based on the following:

1. Its origin is not known and therefore whether it is an export or import is not known;
2. A great portion of it occurred in 1938, a year of high seasonal runoff and therefore any percolation would be minimized;
3. The groundwater level was high or artesian in the area of entry and therefore percolation would be negligible;
4. The proximity to the river bed and silty-clay soil which helped to readily move the water out of the basin and also to prevent percolation;[4]
5. The general lack of agricultural provisions to utilize the varying flow.

Consumptive Water Use

One of the major items to be considered in any water balance is the loss of water through consumptive use. The total water used in plant growth, transpiration from the plant surfaces and evaporation from the soil surface, depends on the geographical location and the land use. The California Department of Water Resources made a land use survey in 1964 for the entire Upper Santa Ana River drainage area[7] and from this information Table 7, a tabulation of the land use categories for the Upper San Jacinto Groundwater Basin was prepared. Unit values for consumptive use for this area were obtained from the report entitled "Santa Ana River Investigation."[8] For the basin floor area of 37,000 acres, the total consumptive use is calculated to be 61,830 acre-feet per year.

TABLE 6

IMPORTS AND EXPORTS OF THE
UPPER SAN JACINTO GROUNDWATER BASIN

Fiscal Year ending	Exported Water Acre-feet				Imported MWD Water Acre-feet	
	L.H.M.W.D. Diversions	L.H.M.W.D. Wells	Fruitvale	Others	Others	E.M.W.D.
1922-23						
24						
25	3,850		5,700			
26		150[a]				
27	1922-23	425	1922-23			
28	to	190	to			
29	1938-39	260	1938-39			
1930	50% of mean	185				
31	diversion	245	80% of			
32	estimated	65	mean pro-			
33	as export	125	duction			
34		310	estimated			
35	see pg. 116	310	as export			
36	of (4)	265				
37		210	see pg. 205			
38		185	of (4)			
39		180				
1940	5,320[b]	160	5,700[e]			
41	5,320	250	5,700			
42	6,600	180	5,700		120	
43	745	385	5,700		1,960	
44	610	380	6,770		2,060	
45	650	420	6,770		1,290	
46	435	480	6,770		870	
47	230	480[a]	6,770		260	
48	250		7,840		70	
49	1,825	estimated	7,840		30	
1950	970	@ 530 AF	7,840		570	
51	405	per yr. [c]	7,840		1,050	
52	825		8,920		860	
53	615		8,920			780
54	185		8,920[e]			250
55	605	5,750[d]	9,110[f]			2,400[g]
56	455	1,580	8,770	298		3,900
57	2,015	3,080	6,800	298		6,000
58	3,540	3,610	5,770	468		3,700
59	1,725	4,460	7,860	471		4,900
1960	2,045[b]	3,310[d]	8,760[f]	424		5,550[g]
Total	100,820	31,340	263,560	1,959	9,140	27,480
Mean	2,653	896	6,936	392	832	3,440

Total of Means - Exported Water 10,877 Mean, Total Imported Water 1,930

(a)
(b) Based on estimate of 50% of diversions exported 1939-40 to 1959-60
(c) 25% of Mean of average from 1925-26 to 1946-47 (1,043) and average from 1954-55 to 1967-68 (3,185)
(d) Based on estimate of 75% of production exported 1954-55 to 1959-60
(e) 1939-40 to 1953-54 estimated by R. K. Morton
(f) 1955-56 to 1959-60 based on 80% export as per G. Black of Fruitvale per 1967-68 production and export data
(g) 1954-55 to 1959-60 estimated by R. K. Morton based on EMWD records and 1958-59 delivery data

TABLE 7

CONSUMPTIVE WATER USE

Land Use Category	Area (acres)	Total Consumptive Use Unit Value Feet	Total Consumptive Use Total Acre-feet	Consumptive Use rainfall only* Unit Value Feet	Consumptive Use rainfall only* Total Acre-feet
I. Water service area					
a. Urban and suburban					
Residential	1,990	1.43	2,846	1.06	2,109
Recreational residential	1,150	3.00	3,450	1.06	1,219
Commercial	430	0.71	305	0.71	305
Industrial	20	7.14	145	1.06	21
Unsegregated urban and suburban	1,150	1.19	1,368	1.06	1,219
Included nonwater service area	2,460	1.10	2,706	1.06	2,608
Gross urban and suburban	7,200		10,820		7,481
b. Irrigated agriculture					
Alfalfa	1,380	3.83	5,285	1.06	1,463
Pasture	1,730	3.83	6,626	1.06	1,834
Citrus and subtropical	1,810	2.62	4,742	1.06	1,919
Truck crops	440	1.41	620	1.06	466
Field crops	0	1.41	0	1.06	0
Desiduous fruits and nuts	1,920	2.32	4,454	1.06	2,035
Small grain	2,270	1.41	3,201	1.06	2,406
Fallow	760	0.50	380	0.50	380
Included nonwater service area	1,420	2.54	3,607	1.06	1,505
Gross irrigated agriculture	11,730		28,915		12,008
Gross water service area	18,930		39,735		19,489
II. Nonwater service area					
a. Non-irrigated agriculture	11,240	1.31	14,724	1.06	11,914
b. Native vegetation*	2,620*	1.11	2,908	1.06	2,777
c. Unclassified*	4,210*	1.06*	4,463	1.06	4,463
Gross nonwater service area	18,070		22,095		19,154
III. TOTALS	37,000		61,830		38,643

*Estimated. Bul 71-64[7] shows total San Jacinto Sub-area to have 54,930 acres of native vegetation and 101,580 acres of unclassified. The bulk of these areas were compensated for in the tributory run-off discussion. The acreage estimates were based on [4], [6] and [7].

For the calculation of the potential long-term yield, information on the total consumptive use of the basin is not sufficient. It is necessary to know the quantity of the precipitation runoff and imports entering the basin which is consumptively used. This amount constitutes only one part of the total consumptive use. The remainder represents consumptive use of water originating in the basin as groundwater and pumped to the surface for irrigation, water supplies, etc.

Two approaches can be used to calculate the partial consumptive use. The first method requires a detailed knowledge of storm intensity. duration and frequency, temperature, open water surface areas during spreading and irrigation operations, percolation rates, and so forth. Such information is only partially available for the Upper San Jacinto Groundwater Basin.

The second method involves comparing unit consumptive use values with the mean precipitation. For the base period, the mean precipitation for the entire valley is found to be on the order of 1.06 feet per year. Where the unit consumptive use values exceed this mean precipitation it is assumed that none of the precipitation reaches groundwater storage. Rather, it is all consumptively used. In two instances, the unit consumptive use values are less than the mean precipitation. The difference is assumed to represent accretion to the groundwater storage. As determined earlier, the mean precipitation on the basin floor was 39,220 acre-feet per year. Of this quantity, the consumptive use is calculated in Table 7 to be 38,643 acre-feet per year.

It should be recognized that deep penetration of precipitation is not dependent only on yearly averages, but is a function of storm intensity, duration, and frequency and other climatic conditions. In the Hemet-San Jacinto area, the influence of these factors on groundwater accretions is quite small and can be neglected. Similarly, the small amount of consumptive use from runoff and other surface waters entering the valley will be neglected.

On this basis, the total consumptive use of water entering the valley is calculated to be 38,643 acre-feet per year.

Groundwater Flow

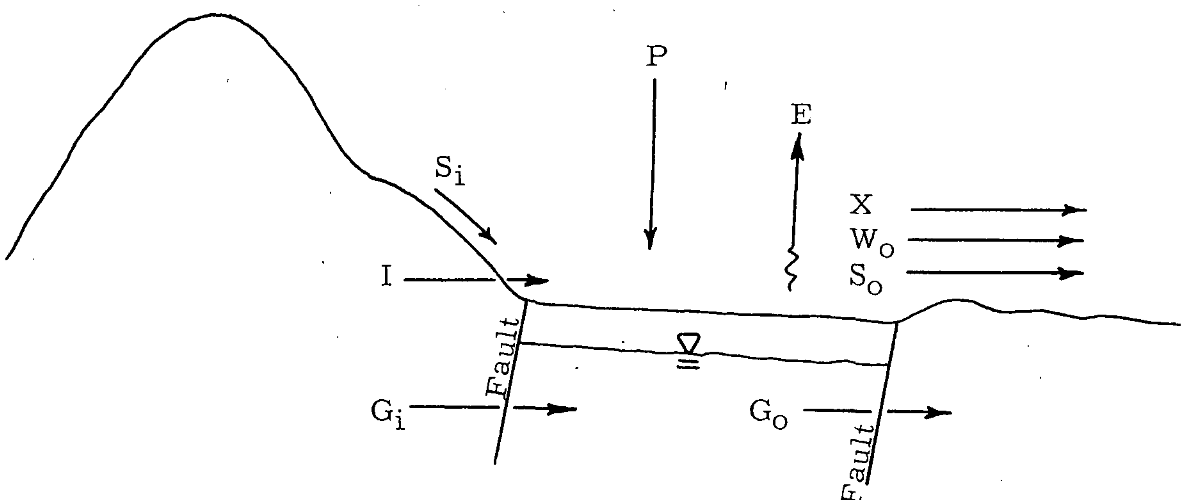
Subsurface flow is of little consequence in the safe yield calculation for this basin. The restriction to subsurface flow both in and out of the basin due to faults and bordering sediments of high impermeability is made evident by records of water well levels as mentioned in

Section IV. If there has been any subsurface inflow within the last 30 years caused by the reversal of groundwater gradients due to the basin being overdrafted, it is assumed here to be comparable to the amount that possibly outflowed during the 30 years prior to that. Recent surveys by the California Department of Water Resources indicate a net inflow of 500 acre-feet per year. With these facts in mind, the net groundwater flow during the base period was assumed to be zero.

The Potential Long-Term Yield

For this report, the potential long-term yield is defined as the annual rate at which water can be withdrawn from the groundwater basin without irreparably damaging this resource, while economically supplying imported water to all users.

To further elucidate this concept, an equation for potential long term yield is similar to that in use for safe yield and can be derived. Consider the following cross-section of a typical drainage basin:



where:
- S_i = surface inflow (runoff)
- S_o = surface outflow (runoff)
- I = imported water
- X = exported water
- P = precipitation
- E = consumptive use (primarily evapotranspiration)
- W_o = wastewater outflow
- G_i = subsurface inflow
- G_o = subsurface outflow

The change in the total groundwater storage, ΔGS, can be defined as:

$$\Delta GS = (P+S_i+I+G_i) - (S_o+E+X+W_o+G_o)$$

With the information developed earlier, the mean change in the groundwater storage for the Upper San Jacinto Groundwater Basin can be calculated thus:

P	= 39,220	acre-feet/year
S_i	= 28,590	
I	= 1,930	
G_i	= 0	
Inflow	69,740	acre-feet/year
S_o	= 9,015	
E	= 61,830	
X	= 10,877	
W_o	= 0	
G_o	= 0	
Outflow	81,722	acre-feet/year

Mean change ΔGS = 11,982 acre-feet/year

It is readily apparent that a large overdraft has been occurring for many years from the Upper San Jacinto Groundwater Basin.

The equation for the potential long-term yield differs only slightly from the equation for ΔGS. In order to establish the potential long-term yield equation, one additional step is necessary. As developed earlier the consumptive use can be divided into two segments; first, consumptive use of precipitation imports and runoff entering the basin and, second, consumptive use of groundwater pumped to the basin surface, or by the formula

$$E = E_p + E_g$$

where:

E	= total consumptive use	= 61,830
E_p	= consumptive use of precipitation, runoff and imports	= 38,643
E_g	- consumptive use of pumped groundwater	= 23,187

The equation for the potential long-term yield can now be written as:

$$\text{Potential long-term yield} = (P + S_i + I + G_i) - (S_o + E_p + X + G_o)$$

or, substituting for GS:

Potential long-term yield - $GS + E_g + W_o$

Finally, the potential long term yield can be calculated:

P = 39,220 acre feet per year		S_o = 9,015	
S_i = 28,590		E_p = 38,643	
I = 1,930		X = 10,877	
G_i = 0		G_o = 0	
69,740	acre-feet per year Inflow	58,535	acre-feet per year Outflow

Potential long term yield = 11,205 acre-feet per year

Thus, the potential long-term yield of the Upper San Jacinto Groundwater Basin is found to be 11,205 acre-feet per year.

SECTION VII

WATER QUALITY OF UPPER SAN JACINTO GROUNDWATER BASIN

Water quality of the existing shallow and deep groundwater, quality of water spread, and quality of the shallow groundwater under the replenishment area is discussed in this chapter. Also discussed are the various procedures used in this study for tracing water quality and the steps taken to prevent misinterpretation of water quality data obtained to determine the extent of mixing and blending of the various waters. Prior to determining the extent of mixing and evaluating the effects on the existing water quality by the water being spread in the replenishment area, it should be noted that long-term trends or short-period fluctuations in the quality of existing groundwater might be occurring. These fluctuations or trends could be taking place due to any of the following factors:

1. Water may be pumped from deeper levels as the upper water zones are depleted in this multilayered basin.

2. Reversal or modification of groundwater slopes and flows due to large groundwater extractions.

3. Increased domestic, agricultural and commercial activities throughout the valley and watershed.

4. Interconnection of different aquifers by piping alongside the well casings of the multitude of wells that have been drilled.

The observed water quality data from wells might also have trends or fluctuations not caused by mixing with the water being spread. Three possible reasons for changes in observed water quality are:

1. Zones in which a well is perforated, together with changing of pump capacity.

2. Modifications of a well or its pumping capacity.

3. Lack of backflow devices.

It has also been observed that the water quality around the replenishment area is very inconsistent, varying by a considerable degree in areas both downstream and upstream of the ponds, as well as varying substantially in the same locations at different times. Further investigation shows that the thermal conditions associated with the San Jacinto fault and its offshoots are apparently responsible for these chemical changes. An ideal example is the hot springs occurring near the Hot Springs (Soboba) Fault.

Groundwater Quality (1915-1948)

In 1915 partial chemical analysis of three wells in and near the replenishment area were made.[10] The total depth of these wells is not known but the static water levels are assumed to be near the ground surface since most of the wells in this area were artesian at that time. The chemical quality of these three wells appears on Table 8. Also shown are analyses of wells 4S1W 25M1 and 23N2, which are also near the replenishment area. (Figure 13)

The historical chemical quality of the deep groundwater in and near the replenishment area was quite similar to that found at present.

Recent Water Quality (1948-1965)

During the late 1940's and continually to the present, several agencies have gathered water quality data within the basin. Unfortunately, most of these data are from wells not in the replenishment area or are very intermittent. Figure 14 is a plot of chloride concentration in Wells No. 4S1W 26J1 and 4S1W 26J2. This plot shows that the chloride concentration is rather stable over a six-year period.

The lack of sufficient long-term data prevents any substantial demonstration of water quality trends over the historical and recent periods. However, the comparison of the three wells sampled in 1915 and Wells No. 4S1W 25M1 and 4S1W 23N2 (Table 8) together with Figure 14, indicate that the water quality has apparently remained fairly constant under the replenishment area from 1915 to 1965.

Present Water Quality (1966-1970)

In conjunction with spreading secondary effluent in the replenishment area which started in 1965, a fairly extensive program of water sampling has been carried out. This program includes water samples from:

TABLE 8

Comparison of Chemical Quality of
Groundwater near Replenishment Area

Well No.	Date	CO_3 mg/l	HCO_3 mg/l	SO_4 mg/l	Cl mg/l	Total Hardness mg/l	Filterable Residue mg/l
Waring No. 97	10/1915	0	181	5	11	99	210
Waring No. 122	10/1915	0	217	10	17	147	260
Waring No. 124	10/1915	0	127	5	9	88	160
Average of the 3 Waring Wells		0	175	7	12	111	210
4S1W-25M1	5/65	0	183	19	18	134	243
	5/67	0	193	25	15	147	179
	11/70	0	220	26	20	160	270
Average of three analyses from 25M1		0	199	23	18	147	231
4S1W-23N2	10/65	0	174	6	12	112	206
	11/68	0	144	8	19	129	244
	5/69	4	142	9	26	133	234
Average of three analyses from 23N2		1	153	8	19	125	228

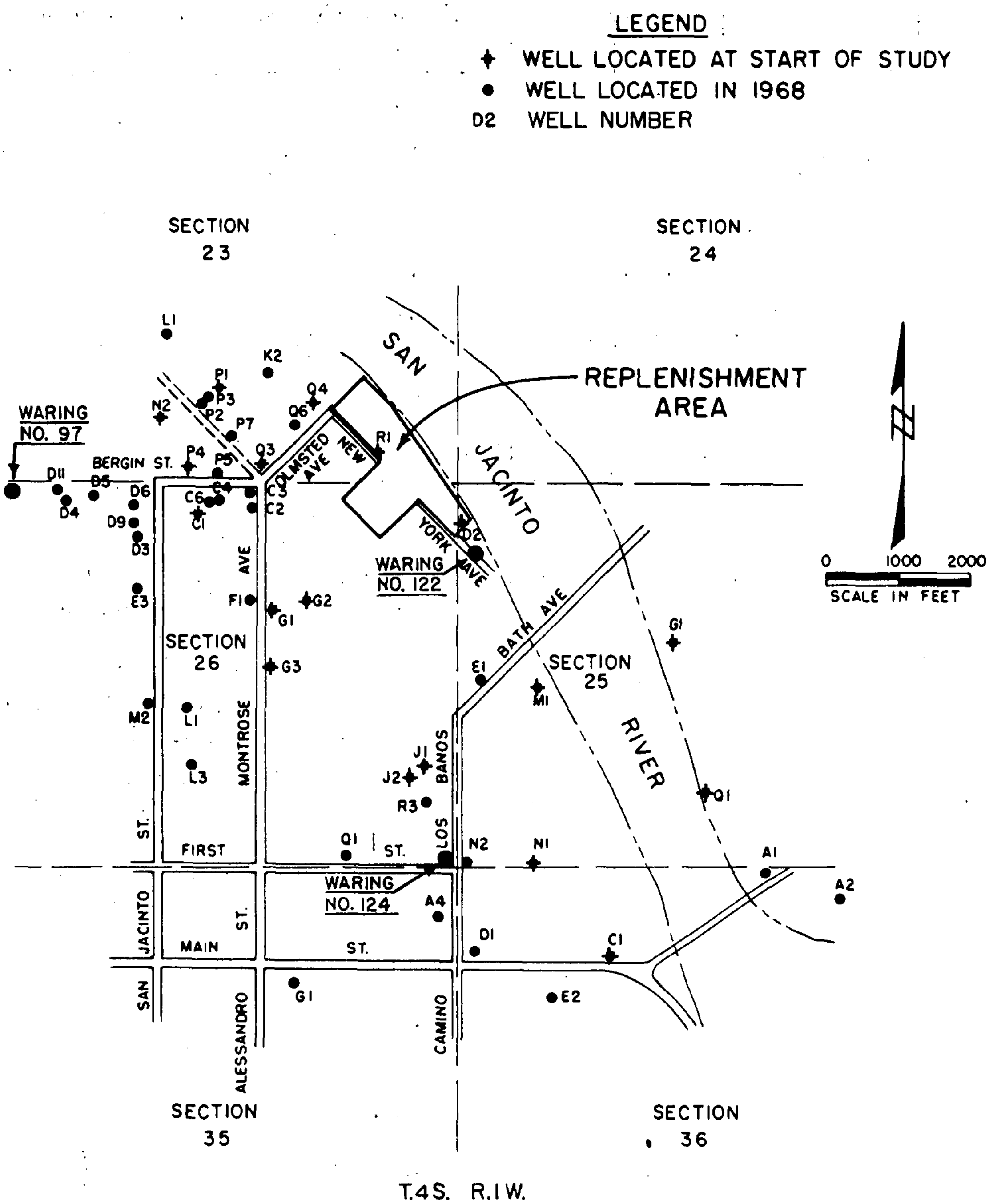


FIGURE 13. WELL LOCATION MAP

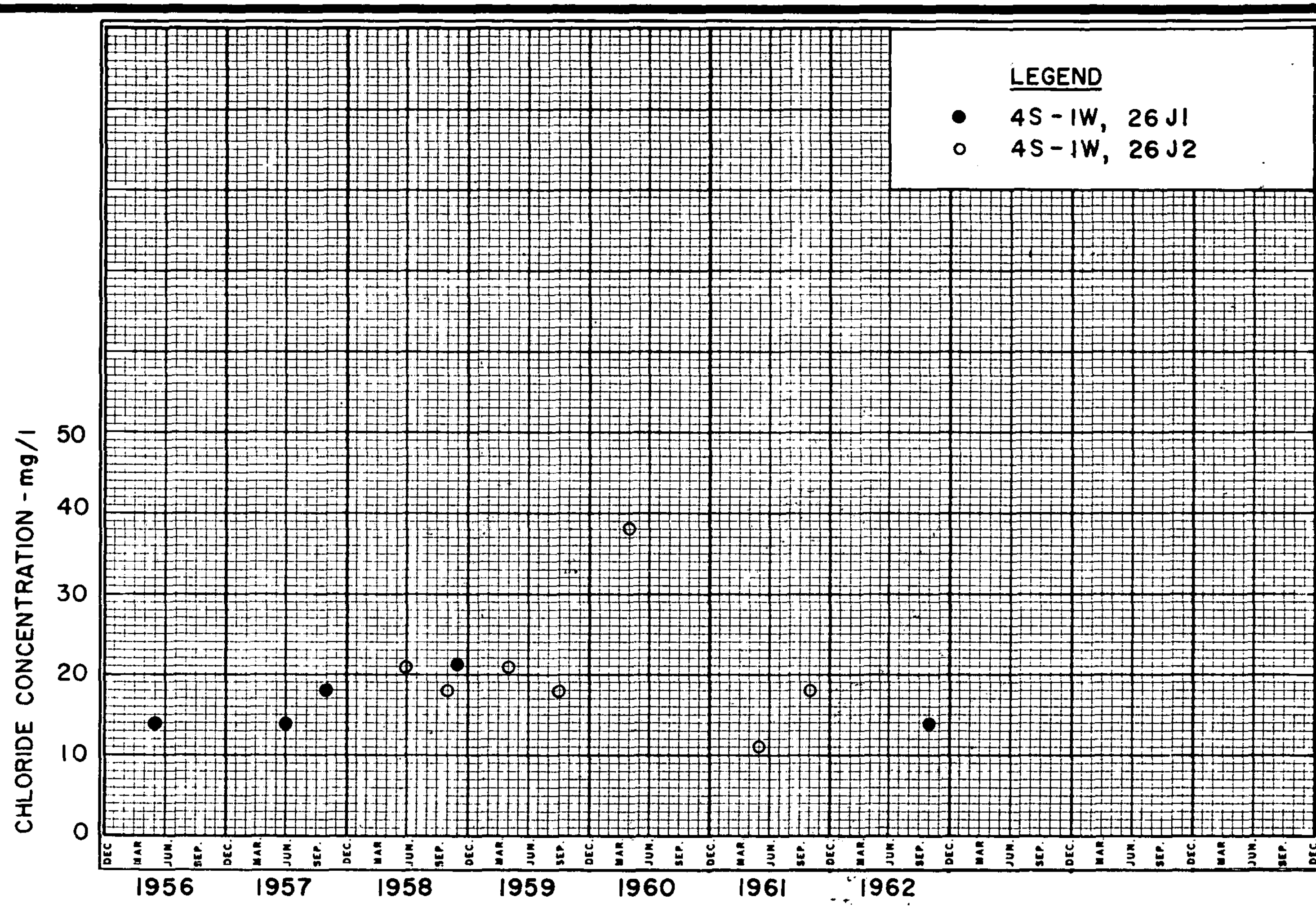


FIGURE 14. CHLORIDE CONCENTRATION IN WELLS - 4S IW, 26J1 & 26J2

1. Existing wells
2. New observation wells installed by District
3. 3/8-inch diameter pipes installed by the District to act as piezometers to measure static water level of the shallow groundwater under the replenishment area
4. Sampling pans beneath a spreading basin, which capture percolating water

Typical analyses of water being spread, water from wells, water from piezometers and water from sampling pans are shown on Table 9.

Sulfate, chloride and electrical conductivity had been used as water quality tracers for the first four years of the study. Results of the analyses on samples from the newly-installed observation wells in 1969 showed that there were unusually high sulfate concentrations and conductivity in the wells closest to the San Jacinto Fault zone. It is believed the thermal condition associated with the fault is responsible for these high readings. (A more extensive discussion of this is contained in the well monitoring section.) Therefore, only chloride concentrations have been plotted for inclusion in this report.

Well Monitoring

Existing Wells - Some of the wells monitored in this program are shallow (less than 200 feet deep with static water levels at 30 feet or less below the ground surface) while others are quite deep (up to 840 feet in depth with static water levels of up to 250 feet below the surface). It is possible that some of the shallow wells might be chemically degraded through septic tank overflows, agricultural return waters or dairy wastes. Any such degradation could be misinterpreted as a chemical change in the well water due to spreading activities. To verify chemical changes, chloride concentrations versus well depth were plotted for the years 1965, 1968 and 1970. (Figure 15)

It would not have been possible for the effluent to have percolated through the soil and entered any of the above wells by 1965, since spreading operations began in July of that year. However, by 1970 some of the effluent could have very easily reached some of the wells.

Figure 15 shows that the highest chloride concentrations are found in the shallowest wells and that there has been no significant overall change in the chloride concentrations in any of the wells. These data indicate that there may be some chemical change in the shallow basin occurring from sources other than the effluent being spread.

TABLE 9

CHLORIDE, SULFATE, AND ELECTRICAL CONDUCTIVITY IN WELLS, PIEZOMETERS AND OBSERVATION WELLS

	Chloride mg/l			Sulfate mg/l			Electrical Conductivity E. C. x 10^6 @ 25° C		
Piezometers	5/67	1/70	4/70	5/67	1/70	4/70	5/67	1/70	4/70
C-3	133	140	152	140	132	156	1100	1180	1160
D-4	126	144	150	163	148	228	1173	1160	1320
D-3	144	140	144	137	133	154	1274	1215	1430
X-O									
Y-O									
X-1		142	156		312	298		1590	1590
Y-1		270	274		474	341		2460	2180
Observation Wells	1/70	8/70		1/70	8/70		1/70	8/70	
#1	22			262			1255		
#3	34	42		720	587		1720	2100	
#5									
#6	84			276			1350		
#7	42			62			705		
#8	54	52		77	108		835	806	
#9	24	26		179	120		915	775	
#10	64	62		239	162		985	840	
Irrigation Wells	11/68	1/70	4/70	11/68	1/70	4/70	11/68	1/70	4/70
23P5	120	132	130	131	133	160	1050	1080	1150
	5/65	11/68	4/70	5/65	11/68	4/70	5/65	11/68	4/70
23Q3	14	44	42	2	44	77	290	525	537
	10/65	11/68	4/70	10/65	11/68	4/70	10/65	11/68	4/70
25G1	28	46	42	25	106	149	526	725	777
	11/65	1/70	4/70	11/65	1/70	4/70	11/65	1/70	4/70
26G1	14	28	30	15	35	53	310	510	475

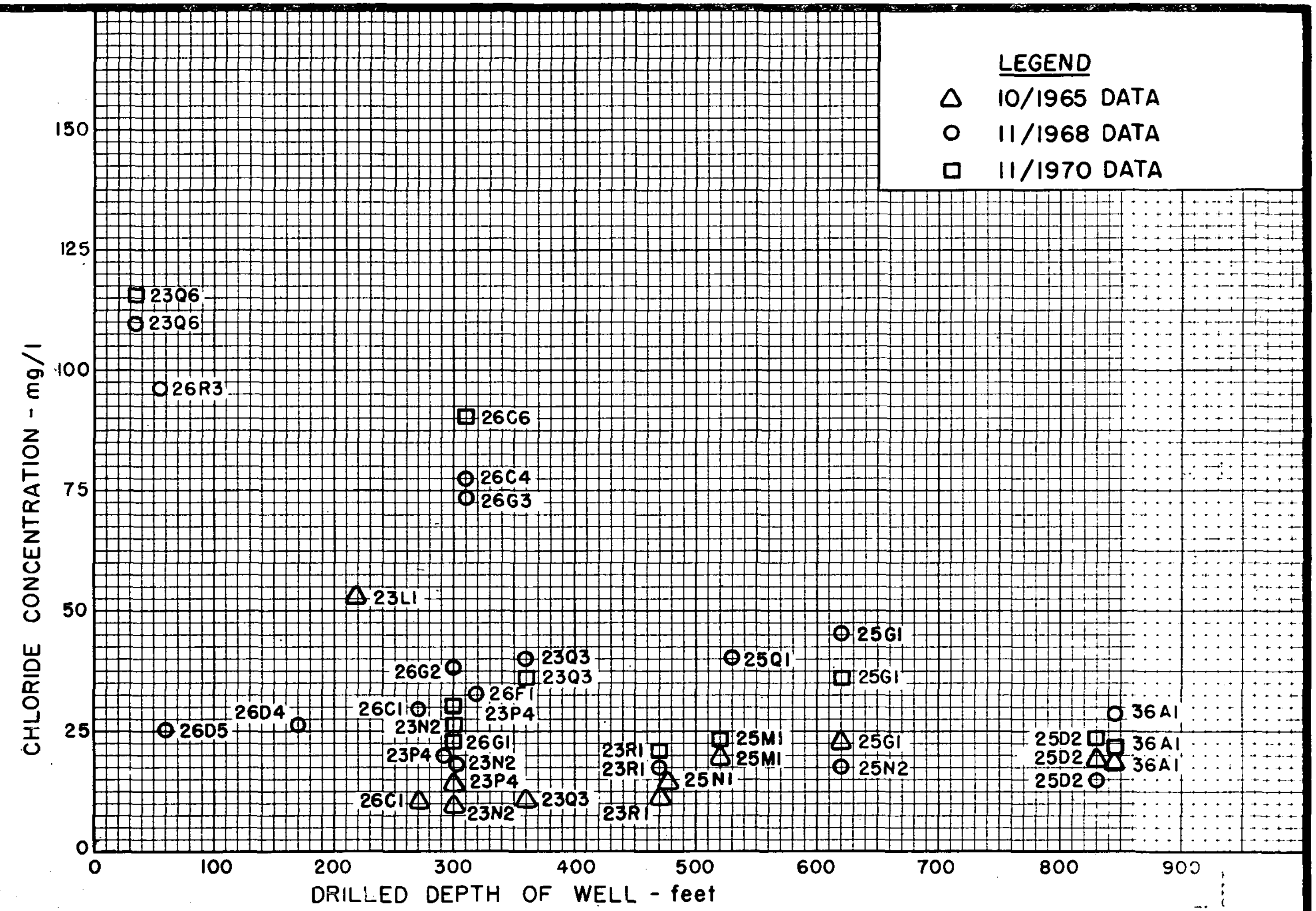


FIGURE 15. <u>CHLORIDE CONCENTRATION IN WELL WATER VERSUS DRILLED DEPTH OF WELLS</u>

Figures 16 and 17 show the chloride concentrations in wells for a ten-year period, covering before and during the spreading of water in the replenishment area. These monitored wells are in or near the replenishment area and have the longest period of known available data. Their depths vary from 296 feet to 820 feet, and they are located from 20 feet to 3100 feet outside the actual spreading area. All of the wells were gravel-packed, with the exception of 4S1W 25D2, which was drilled by Eastern Municipal Water District using a cable tool rig, and is perforated at 170 feet which is believed to be below the percolated wastewater. As would be expected, there is little or no change in the chloride concentration in this well.

Since all the other wells are also within the area expected to be affected and are all gravel-packed, it would be reasonable to expect an increase in the chloride concentration in each one of them. With the exception of Well 25M1, all the wells have shown some increase in chloride concentrations through 1968; after 1969 there is a decline in the level of chloride.

The timing of the decline of chloride concentration in the wells in 1969 and 1970 seems to correspond well with the expected arrival of subsurface flow of the San Jacinto River which ran continuously for five months during the 1968-69 winter. Apparently the higher quality water which flows underground along the river channel has diluted the water which enters these wells.

Observation Wells - The replenishment area was almost completely encircled by existing wells that were available for monitoring. The only area in which no wells existed was along the San Jacinto River to the northwest and northeast. In order to complete the encirclement, and also provide information in some other areas, an observation network of 10 wells, shown on Figure 18, was installed in July 1969. These wells were drilled with a 5-5/8" bit, cased with 2" PVC Schedule 80 pipe and gravel-packed. The driller's logs and perforation schedules are shown in Section X. These wells have provided information as to the chemical quality on both sides of the San Jacinto River.

It is interesting to compare the concentrations of chloride, sulfate and electrical conductivity found in the new observation wells, several of the piezometers and existing wells. Table 9 gives these data for the sample points shown on Figure 19. The sample points closest to the San Jacinto Fault system (X-1, Y-1, #1, #3, #6, #10 and 25G1), exhibit higher electrical conductivity and much higher sulfate concentrations than those found at the other sampling points. The chloride concentrations are much more consistent with those found at the other sampling points.

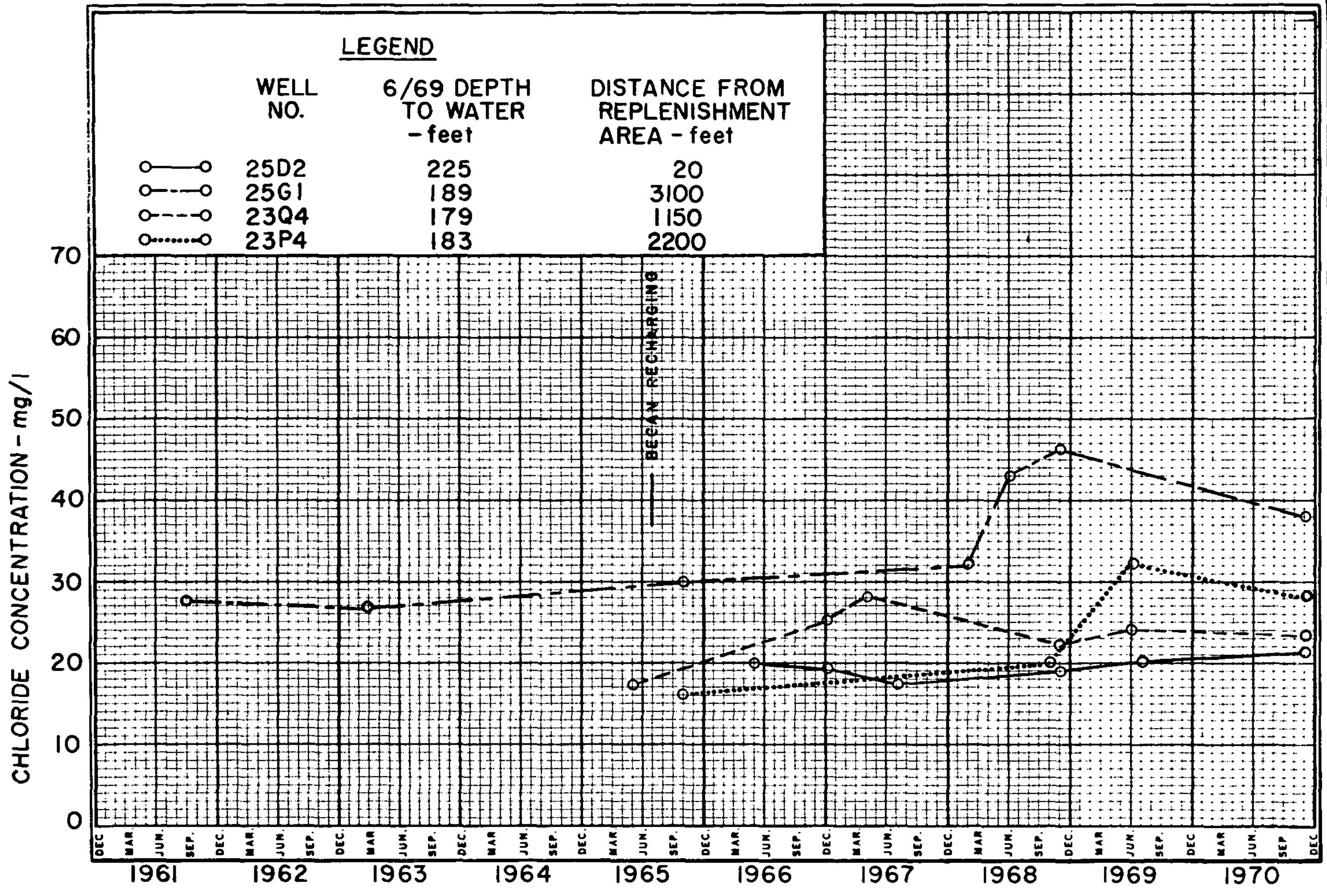


FIGURE 16. CHLORIDE CONCENTRATION IN WELL WATER

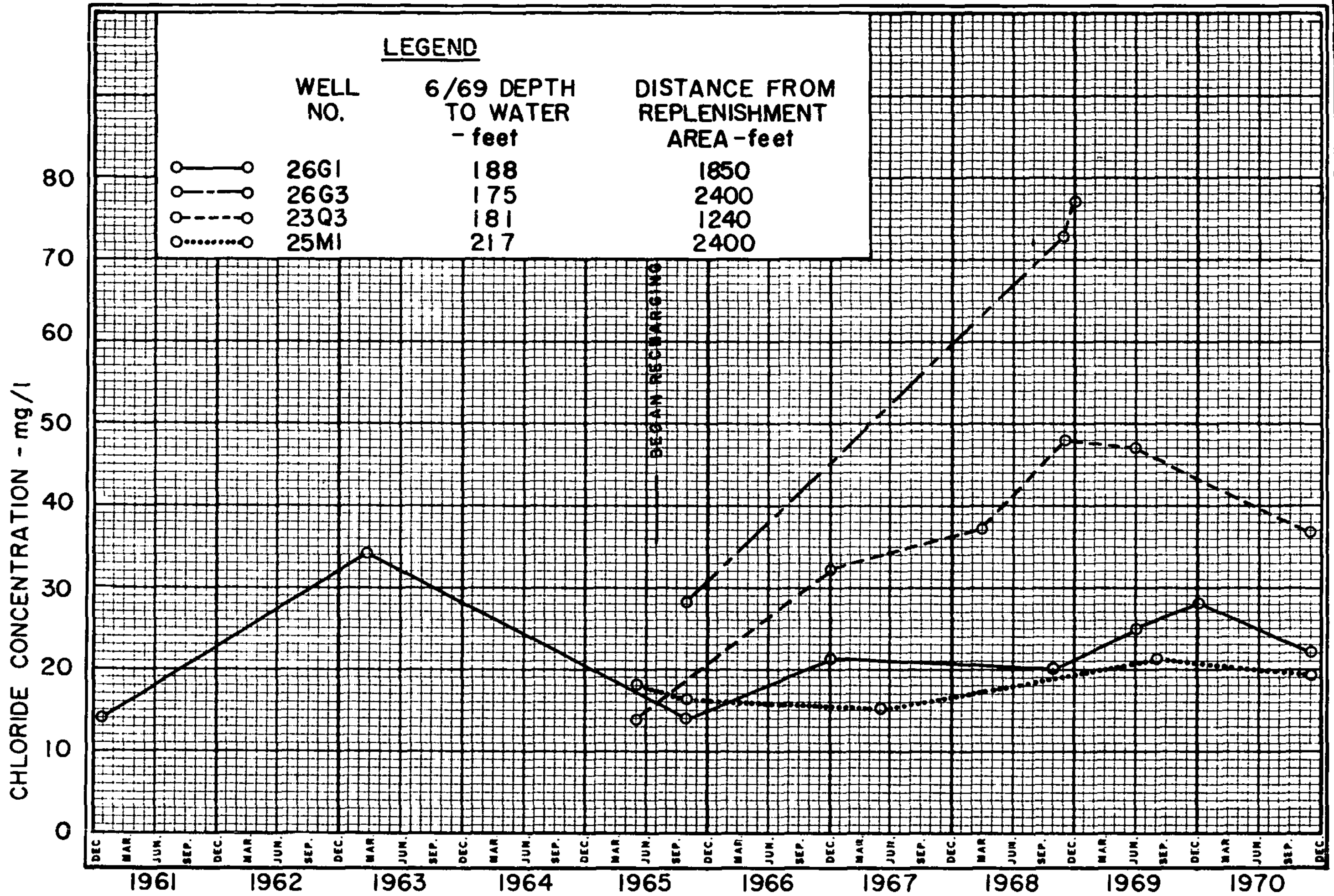


FIGURE 17. CHLORIDE CONCENTRATION IN WELL WATER

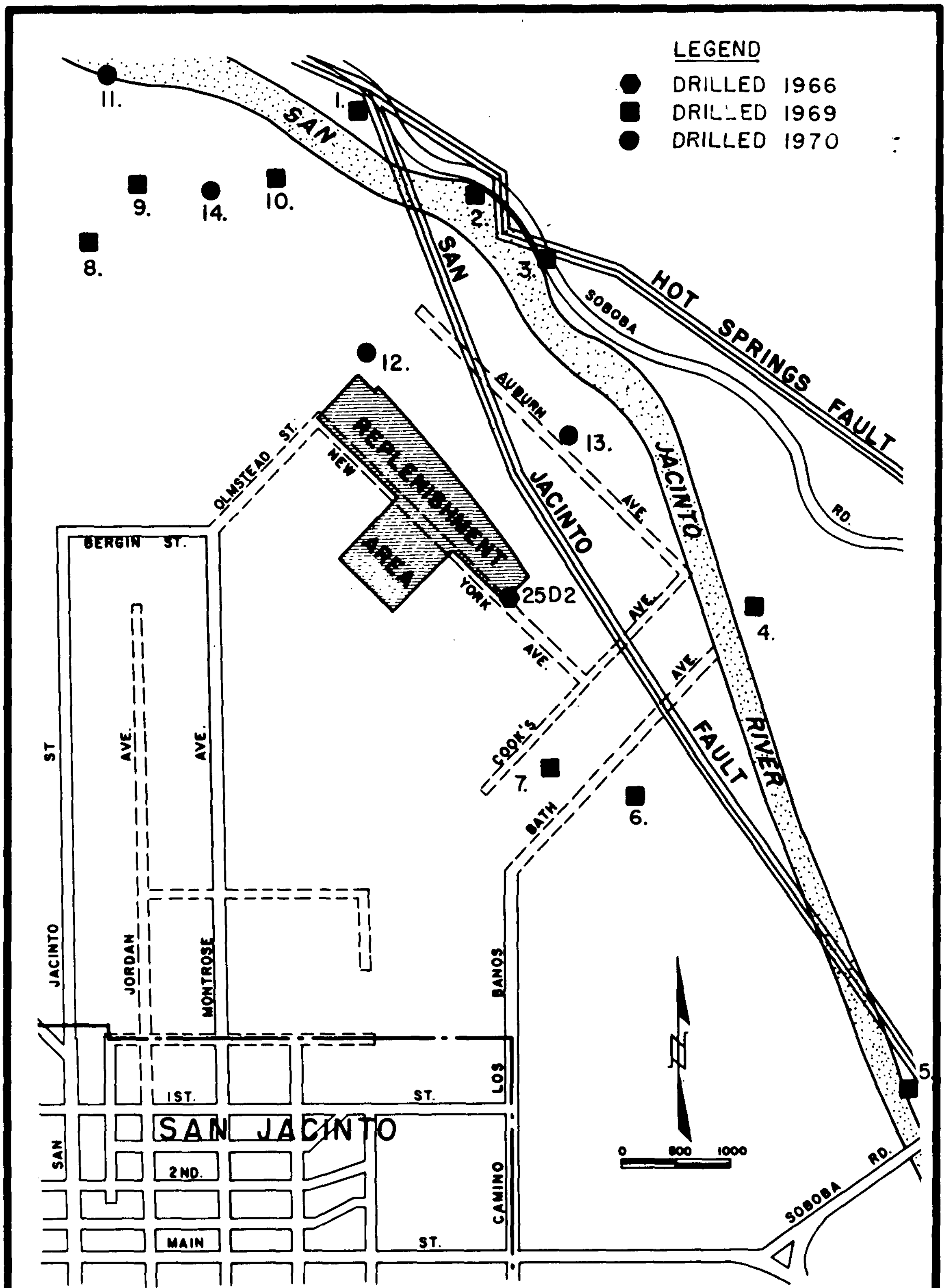


FIGURE 18. OBSERVATION WELL NETWORK

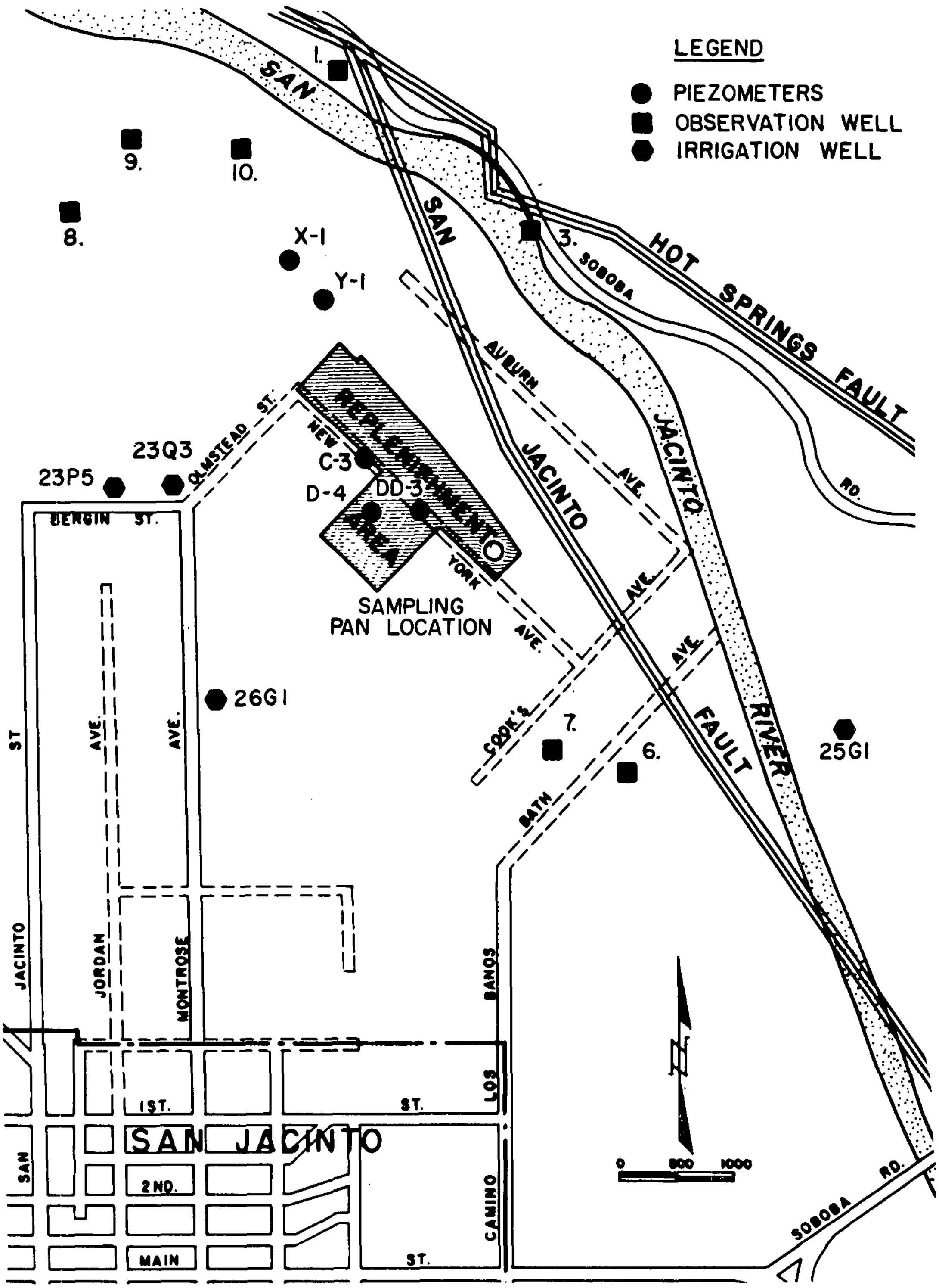


FIGURE 19. LOCATION OF PIEZOMETERS, OBSERVATION WELLS AND EXISTING WELLS

The high sulfates suggest the possibility that the effluent has reached these wells; however, the chloride content tends to contradict this suggestion. These conditions suggest that the fault system of the area may be exerting some influence, perhaps by acting as a barrier which creates a reservoir into which water leaching down from the hot springs in the mountains would tend to increase the sulfate content.

In support of the above theory, examine Observation Well #3 and Well 25G1, located between the San Jacinto and Hot Springs Faults. Observation Well #3 has the highest sulfate content of any of the sampling points examined, while Well 25G1 has had an increase of sulfate concentration from 25 mg/l in 1965 to 106 mg/l in 1968. Well #3 has never been pumped; Well 25G1 was pumped heavily during 1964 and 1965 but has not been pumped to any great degree since. This could mean that while Well 25G1 was being pumped heavily it drew water from across the San Jacinto Fault and this water was of high quality. When pumping stopped, local water adjacent to Soboba Hot Springs, which is normally high in sulfates, moved back into the aquifer.

Piezometer Monitoring

Unfortunately, the piezometer network was not installed prior to the start of spreading operations to establish background on the shallow groundwater. As a result, there is no data available to establish the presence or quality of water in the area presently reached by the spread water. However, the water found in the piezometers has continually been found to be of the same chemical quality as the water being spread and is therefore considered to be the same water. It is interesting to note that the first water found in the first piezometers had very high total dissolved solids (TDS) but in a short time the high TDS water disappeared. When additional piezometers were installed to expand the network, these too had high TDS water at first. This phenomenon, and other aspects of the piezometer monitoring program, are discussed in Section X - Groundwater Investigation.

Water quality from a typical piezometer is shown in Table 10. All chemical analyses obtained from the piezometers comprise Appendix 3 Volume II of this report.

Sampling Pans

A typical analysis of water from a sampling pan is shown in Table 10. Discussion of these pans and the quality of the water collected is contained in Section X.

TABLE 10

TYPICAL WATER QUALITY OF
WELL, PIEZOMETER, SAMPLING PAN
AND RECHARGE WATERS
(milligrams per liter)

	1965-68 Ave. Quality of Water Spread	Well No. 4S1W 25D2 @ 235' 11/1/68	Piezometer C-3 5/67	Sampling Pan 6F 5/67 - 6/68 Average
Calcium	75	44	76	-
Magnesium	12	2	20	-
Sodium	125	23	124	-
Potassium	19	3	4	-
Ammonium	15	trace	0.1	-
Carbonate	0	0	0	-
Bicarbonate	259	136	220	-
Sulfate	131	4	140	-
Chloride	114	19	133	-
Nitrate	24	5	40	12.4
Fluoride	0.8	0.27	0.8	-
Total Dissolved Solids	674	262	700	-
Boron	0.7	0.00	0.6	-
Methylene Blue Alkyl Surfactants	1.4	0.00	0.3	0.51
pH	7.6	7.95	7.6	-
E.C. x 10^6	1053	405	1100	-
Hardness as $CaCO_3$	208	118	276	-
Chemical Oxygen Demand (Dissolved)	20	-	18	13.9
Suspended Solids	-	-	0	2.0
% Volatile Suspended Solids	-	-	-	82.8

Water Analysis Laboratory

In the 1950's, Eastern Municipal Water District had mainly served Colorado River water for both domestic and agricultural needs. In 1960, the District began construction to implement their earlier planning for a wastewater collection, treatment and disposal system in the Hemet-San Jacinto Valley. Prior to starting water reclamation, the District had only a limited need for bacterial and/or chemical water analyses, and the few necessary analyses were being run by local commercial laboratories.

When this study was conceived, water analyses were to be run by commercial laboratories. However, as the program developed, it was apparent that a greater number of analyses than originally anticipated would be desirable. This need, together with the increasing requirements of two water reclamation facilities, prompted the District to purchase equipment and to establish a laboratory for complete chemical and bacterial examinations of water and wastewater.

A laboratory was established at the Hemet-San Jacinto Water Reclamation Facility. This laboratory presently performs all analyses from the District's fresh water system, water reclamation facilities and its research projects. The laboratory has been certified by the State Public Health Department for complete chemical and bacteriological examinations of water and wastewater. This research program, Reutilization of Wastewater Recycled Through Ground Water, has realized a substantial monitary savings by the establishment of this laboratory.

SECTION VIII

GROUNDWATER QUALITY - SPREADING BASIN INVESTIGATIONS

Selection of a site for groundwater recharge close to the treatment plant, one containing sandy soils, or sand and gravel soils which produce high infiltration and percolation rates, was made most difficult because of industrial and economic considerations, the stigma attached to an effluent storage area, and fear of possible degradation of groundwater supplies. The most suitable locations are over seven miles from the Hemet-San Jacinto Water Reclamation Facility. Construction of a seven-mile force main could not be economically justified with the amount of plant flow being discharged. Several other satisfactory locations could be found closer to the treatment facility but these were either privately owned or directly over a domestic water well system. The privately-owned properties were not available at a reasonable cost without undue delays. After considering the above factors, a spreading basin site approximately four and one-half miles from the Wastewater Treatment Plant was chosen and purchased by the District. (Figure 19)

This site, designated the "replenishment area." is approximately 40 acres in area and is 1-1/2 miles northeasterly of the City of San Jacinto. The replenishment area is geographically located within the Pressure Area which was described in Section IV as having artesian groundwater conditions. However, groundwater levels have lowered to almost 200 feet in the past 25 years.

The replenishment area is situated in close proximity to the San Jacinto River in what was probably part of the river channel in past times. The geology of the area indicates it is underlain by irregular lenses of sand and silt of varying thicknesses deposited by the runoff during different storm periods, varying within each storm period as well.

The spreading basins were constructed in the replenishment area, as shown on Figure 20, and are numbered by construction sequence. Basins 1 through 4 were constructed in February 1965, while 5 and 6 were finished in May of that year. Basins 7 through 10 were constructed late in 1965 at a time when the existing basins had low infiltration rates and it appeared that the then-existing basins were not adequate to receive and percolate the entire daily plant flow.

The water percolated was secondary effluent from the Hemet-San Jacinto Water Reclamation Facility, an activated sludge treatment plant, which was pumped through a 14-inch force main, with eight-inch feeders to basins 1 through 6, and 10-inch feeders to basins 7 through

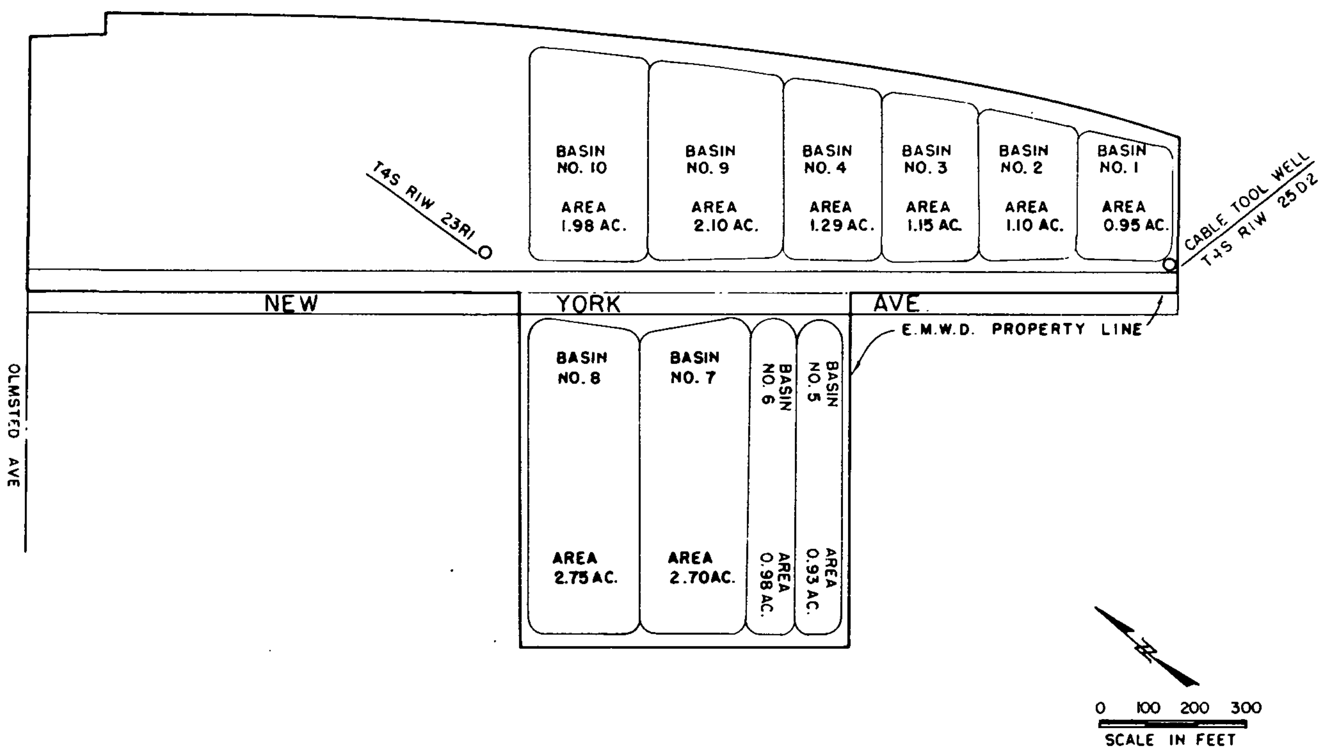


FIGURE 20. **REPLENISHMENT AREA**

10. Each basin is filled through a separate water meter, except basins 5 and 6 which are filled through the same meter. These meters are constantly being calibrated by the District and are accurate within 1 percent.

There have been times when a single water meter for basins 5 and 6 has been desirable and this, as well as several problems mentioned later, have forced the joint consideration of these two basins. All the calculations, graphs and tables consider basins 5 and 6 to be one basin.

Prior to the completion of the Hemet-San Jacinto Water Reclamation Facility, the Board of Directors of Eastern Municipal Water District approved the use of Colorado River water to begin the spreading and replenishment demonstration. Spreading began in basins 1 through 4 on March 12, 1965, and in basins 5 and 6 on May 25, 1965. On June 28, 1965, recharging with Colorado River water was stopped, with 567 acre-feet having been spread in the first six basins. All six basins were allowed to dry until July 20, 1965, when the spreading of approximately 3 acre-feet per day of effluent from the Reclamation Facility began.

Method of Spreading

Of prime importance in developing a spreading operation is the optimization of the hydraulic loading, expressed as acre-feet per acre per day, or feet per day, so as to minimize the land area necessary fro spreading and to provide an optimum degree of tertiary treatment effected by the soil so that the percolated water will receive a high degree of tertiary treatment and will be of the highest quality possible for subsequent beneficial uses.

Both of these objectives are related to the quality of the wastewater and to the nature of the soil system. However, for any given wastewater and soil system, both objectives are a function of the method of spreading. The method of spreading effluent which the District has found to be most satisfactory is the intermittent flooding of the basins so that they are alternately wet and dry.

The intermittent spreading cycle has been varied during this study. A three-day cycle, where the basin receives water for one day and dries for two days, was found to produce the optimum infiltration rate. However, it was necessary during the heavy rains of the winter of 1968-69 to extend this to a four-day cycle to provide additional spreading area to compensate for increased plant flow and rainfall in the area and to overcome the extremely high water table which reduced the infiltration rates.

The amount of water pumped into the basin in order that it be wet for only 24 hours was determined by the infiltration rate for that basin during its last cycle multiplied by its area. Since a volume of water is spread every day, slight variations in any set intermittent cycle were necessary, but these variations were minimized by careful sequencing and use of multiple basins.

During early stages of spreading Colorado River water, the four basins were not free of ponded water before they were refilled. Effectively, the spreading operation was one of constant spreading rather than intermittent cycling. In May 1965, the spreading method was changed so that a three-day intermittent cycle was attained in basins 1 through 4. Basins 5 and 6 were put into operation and constantly flooded as a unit similar to the operation previously used in the original four basins.

The effluent was initially spread in each basin using the three-day cycle in basins 1 through 4 while basin 5-6 was constantly flooded to take advantage of the high evaporation rate (on the order of 4 to 5 feet annually) occurring in the semi-arid region of the Hemet-San Jacinto Valley. If basins 5-6 had been used intermittently at that time, it is doubtful if sufficient water would have infiltrated the soil. With the completion of the four additional basins in January 1966, basin 5-6 and the new basin 7 were put on the intermittent 3-day cycle. Basins 8 through 10 were held as standby basins to receive the water while other basins were shut down for maintenance or to receive occasional high plant flows. At the completion of the demonstration grant there were a total of 10 basins in the replenishment area with a total spreading area of 15.9 acres.

The three-day cycle was continued through the first four years of the program with good results. However, the heavy and prolonged rainfall which occurred during the late 1968 and ealy 1969, together with an increasing plantflow, forced a change in the cycle. The four-day cycle has proved to be the most desirable since late 1969 and is presently being used.

To December 31, 1970, 6,482 acre-feet of water was spread, 567 acre-feet of which was Colorado River water and 5,915 acre-feet was secondary effluent.

Infiltration Rates

A separation by basins of the total amount of water spread is shown in Tables 11 through 16. Each table shows the amount of water applied to a basin monthly, as well as computed monthly average infiltration and hydraulic load rates. While both rates have the same units of measurement, feet per day, they are different measurements. The monthly infiltration rate is the arithmetic average of the daily infiltration rates which are calculated only when a basin has water in it. The formula shown below is used to calculate infiltration rates:

$$IR = \frac{Vm + (h)(A) - Ve + Vp}{(A)(T)} \times \frac{24 \text{ hours}}{\text{day}}.$$

when Ir = Infiltration Rate (acre-feet per acre per day, or feet per day)
Vm = Volume of water through meter during time T (acre-feet)
h = Change in water surface elevation during T (feet)
A = Area of particular spreading basin (acres)
Ve = Volume of water evaporated (acre-feet)
Vp = Volume of precipitation (acre-feet)
T = Time (hours, maximum T = 24 hours)

Thus the infiltration rate obtained by the above calculation measures the velocity with which water passes the soil-water interface. Graphs developed from Tables 11 through 16 are shown on Figures 21 through 26.

All basins exhibit apparent increases in the infiltration rates during the summer and decreases during the winter. These rate changes can probably be atrributed to the change in water viscosity due to water temperature changes. Fluctuations of short duration in the infiltration rates are mainly caused by either a heavy load of suspended solids and/or algae buildup in the pond. During the first few months after the Hemet-San Jacinto Water Reclamation Facility started operations the heavy load of suspended solids in the effluent sealed the basin soil, thereby necessitating scarifying of the soil. The rippers used to scarify were approximately 12 inches long and 9 inches on center. After scarifying, the basins showed an increase in infiltration rates.

During November and December 1965, and January 1966, all spreading basins exhibited a decrease in infiltration rates using a spreading cycle of one day wet, two days dry. The basin soil was not drying within two days and a slime layer, apparently algae, on the wet basin was

TABLE 11

MONTHLY HYDRAULIC LOAD AND INFILTRATION RATES FOR BASIN NO. 1

Date	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
Colorado River Water			
March 1965	45.107	2.37[a]	2.37
April	44.852	1.49	1.63
May	45.824	1.48	1.68
June	41.288	1.45	1.64
Reclaimed Water			
July 1965	5.764	.55[b]	1.08
August	14.983	.51	0.59
September	2.900	.10	0.16[c]
October	2.676	.14[d]	0.56
November	-	-	-
December	-	-	-
January 1966	-	-	-
February	2.778	.16[e]	0.58
March	6.292	.21	0.80[f]
April	7.245	.25	1.07
May	6.391	.22	0.94
June	6.906	.24	1.03
July	1.948	.21[g]	1.03
August	7.979	.27	1.03
September	7.890	.28	1.95
October	5.679	.19	.74
November	4.414	.15	.66
December	- [h]	- [h]	- [h]
January 1967			
February			
March			
April	2.254	.08	.47
May	6.591	.22	.83
June	10.188	.36	1.54[i]
July	10.054	.34	1.56
August	20.646	.70	1.80
September	16.356	.57	1.92
October	23.957	.82	2.00
November	13.389	.47	1.44
December	11.509	.39	1.24

(a) Began spreading March 12 - 20 days in month
(b) Began spreading July 21 - 11 days in month
(c) Basin scarified September 28
(d) Stopped spreading in basin - 20 days in month
(e) Began spreading February 11 - 18 days in month
(f) Basin scarified March 4
(g) 10 days in month
(h) Basin drying, December through March, to install sampler
(i) Basin scarified June 9, 1967

Table 11 continued

	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
Reclaimed Water			
January 1968	3.995	.14	1.26
February	8.556	.31	1.89
March	6.167	.22	1.46
April	16.456	.58	1.91
May	4.361(j)	.47(j)	2.26(j)
June	14.720	.52	2.10
July	12.862	.44	2.14
August	13.335	.45	1.91
September	12.839	.44	1.83
October	13.290	.45	1.61
November	11.986	.44	1.50
December	12.456	.41	1.31
January 1969(k)	9.424	.32	1.21
February	9.044	.34	1.12
March	10.617	.35	.73
April	9.313	.31	.50
May	11.013	.37	.40
June	7.614	.26	.34
July(l)	-		
August	15.415	.50	.70
September	6.031	.20	.76
October	11.417	.38	.81
November	13.567	.46	.97
December(m)	-		
January 1970	6.862	.23	.74
February	4.526	.17	.62
March	4.800	.16	.54
April	2.902	.10	.50
May	3.502	.12	.48
June	2.000	.07	.37
July	3.981	.14	.46
August	2.761	.09	.50
September	3.081	.11	.56
October	3.541	.12	.50
November	3.276	.11	.48
December	3.841	.13	.47
Total to Date	655.511	24.13	67.28
Average		.40	1.10

(j) 10 days in month
(k) Began sprinkling effluent behind Reclamation Facility 1/6/69
(l) Began delivery at Record Meter 7/2/69
(m) Drying for week control

TABLE 12

MONTHLY HYDRAULIC LOAD AND INFILTRATION RATES FOR BASIN NO. 2

Date	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
Colorado River Water			
March 1965	17.784	.90 (a)	1.38
April	15.096	.46	.46
May	8.699	.26	.40
June	5.406	.18 (b)	.48
Reclaimed Water			
July 1965	2.502	.19 (c)	.47
August	6.714	.20	.60
September	4.908	.16	.38 (d)
October	5.434	.18	.53
November	5.750	.17	.50
December	7.703	.23	.43
January 1966	3.362	.10	.30
February	3.366	.11	.36 (e)
March	3.554	.10	.38 (f)
April	4.191	.13	.49
May	4.464	.13	.56
June	4.062	.12	.54
July	2.131	.18 (g)	.86
August	7.790	.23	.74
September	5.715	.17	.57
October	4.911	.14	.52
November	3.630	.11	.49
December	- (h)	- (h)	- (h)
January 1967			
February			
March			
April	.962 (i)	.08 (i)	.28 (i)
May	6.787	.20	.59
June	2.816	.09	.62
July	1.660	.17 (j)	.65
August	9.932	.29	.82
September	7.607	.23	.81
October	1.081	.20 (k)	.49
November	-		-
December	4.542	.13	1.05

Area = 1.10 acre

(a) Began spreading March 14 - 18 days in month
(b) 27 days in month
(c) Began spreading July 20 - 12 days in month
(d) Scarified 9/13
(e) Basin scarified February 23
(f) Began spreading every 4th day, March 2
(g) 11 days in month
(h) Basin drying, December through March, to install sampler
(i) 11 days in month
(j) 9 days in month

Table 12 continued

Date	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
January 1968	5.913	.17	.52
February	4.973	.16	.55
March	- (l)	- (l)	- (l)
April	-	-	-
May	5.749	.17	.65
June	4.290	.13	.58
July	10.681	.31	.80
August	11.244	.36	.73
September	8.568	.26	.57
October	9.583	.28	.56
November	7.839	.24	.48
December	6.138	.18	.38
January 1969(m)	4.092	.12	.26
February	3.081	.10	.20
March	3.761	.11	.18
April	2.897	.09	.16
May	3.471	.10	.15
June	2.983	.09	.17
July(n)	-		
August	12.317	.36	.44
September	5.976	.18	.49
October	9.833	.29	.50
November	12.111	.37	.55
December(o)	-		
January 1970	9.293	.27	.46
February	2.969	.10	.40
March	2.423	.07	.34
April	7.794	.23	.40
May	3.798	.11	.38
June	1.177	.04	.40
July	4.301	.08	.46
August	3.845	.11	.50
September	4.399	.13	.53
October	3.761	.11	.48
November	2.891	.09	.44
December	3.541	.10	.41
Total to Date	348.251	11.35	30.87
Average		.19	.51

(k) 5 days in month
(l) Basin drying for Dike Repair & Weed Control
(m) Began sprinkling effluent behind Reclamation Facility 1/6/69
(n) Began delivery at Record Meter 7/2/69
(o) Drying for Weed Control

TABLE 13

MONTHLY HYDRAULIC LOAD AND INFILTRATION RATES FOR BASIN NO. 3

Date	Vol. of Water Applied Acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
Colorado River Water			
March 1965	21.482	.98[a]	.91
April	17.439	.51	.53
May	10.944	.31	.49
June	9.088	.26	.59
Reclaimed Water			
July 1965	2.505	.18[b]	.40[c]
August	2.556	.07	.38
September	4.967	.14	.40
October	6.680	.19	.50
November	5.623	.16	.38
December	8.138	.26	.32
January 1966	3.081	.09	.26
February	6.028	.19	.29[d]
March	3.043	.09	.29[e]
April	3.829	.11	.42
May	4.566	.13	.47
June	5.144	.17	.50
July	2.200	.17[f]	.61
August	6.135	.17	.51
September	6.003	.17	.39
October	4.199	.12	.40
November	4.386	.13	.38
December	1.789	.14[g]	.24
January 1967	3.230	.09	.21
February	2.139	.07	.27
March	2.422	.07	.32
April	.928	.03	.28
May	2.471	.07	.52
June			
July			
August			
September	3.645	.11	1.14
October	1.662	.24[h]	.73

Area = 1.15 acre

(a) Began spreading March 13 - 19 days in month
(b) Began spreading July 20 - 12 days in month
(c) Basin scarified September 15
(d) Basin scarified February 23
(e) Began spreading every 4th day, March 6
(f) 11 days in month
(g) 11 days in month
(h) 6 days in month

Table 13 continued

Date	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
November			
December	2.605	.07	.57
January 1968	4.535	.13	.43
February	5.547	.17	.65
March	- (i)	- (i)	- (i)
April	3.212	.35 (j)	.56 (j)
May	- (k)	- (k)	- (k)
June	-	-	-
July	2.856	.08	.35
August	3.766	.11	.42
September	3.634	.11	.39
October	3.594	.10	.35
November	3.459	.10	.30
December	2.856	.08	.22
January 1969 (l)	2.852	.08	.19
February	2.898	.09	.18
March	3.107	.09	.13
April	2.954	.09	.14
May	3.614	.10	.17
June	2.534	.07	.13
July (m)	-		
August	-		
September	2.483	.07	.28
October	-		
November	-		
December	-		
January 1970	.323	.01	.24
February	1.215	.04	.20
March	1.305	.04	.20
April	1.278	.04	.18
May	2.215	.06	.24
June	- (n)	- (n)	- (n)
July	2.049	.06	.28
August	3.092	.09	.35
September	1.566	.05	.38
October	1.761	.05	.36
November	1.348	.04	.30
December	1.651	.05	.32
Total to Date	330.631	7.84	21.64
Average		.14	.37

(i) Basin dry for Dike Repair
(j) 8 days in month
(k) Basin dry in May and June to apply rock
(l) Began sprinkling effluent behind Water Reclamation Facility 1/6/69
(m) Began delivery at Record Meter 7/2/69
(n) Basin drying for Weed Control

TABLE 14
MONTHLY HYDRAULIC LOAD AND INFILTRATION RATES FOR BASIN NO. 4

Date	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
Colorado River Water			
March 1965	25.639	.99[a]	1.15
April	27.679	.71	.75
May	16.728	.42	.63
June	8.729	.22	.62
Reclaimed Water			
July 1965	3.892	.25[b]	.37
August	3.905	.10	.26
September	5.306	.14	.18[c]
October	6.910	.17	.38
November	5.725	.15	.40
December	5.449	.14	.19
January 1966	3.698	.09	.25
February	2.472	.10	.24[d]
March	3.779	.09	.28[e]
April	4.225	.14	.34
May	5.847	.15	.40
June	5.113	.13	.50
July	1.899	.12[f]	.73
August	6.643	.17	.47
September	6.558	.17	.33
October	4.987	.12	.42
November	3.908	.10	.29
December	1.636	.21[g]	.61
January 1967	3.212	.08	.16
February	2.208	.06	.18
March	2.645	.07	.29
April	.1274	.04	.37
May	5.203	.13	.36
June	2.502	.06	.72
July	2.069	.05	.59
August	13.110	.33	.82
September	11.137	.29	.68
October	4.337[h]	.17[h]	.76[h]

Area - 1.29 acre

(a) Began spreading March 12 - 20 days in month
(b) Began spreading July 20 - 12 days in month
(c) Basin scarified September 28
(d) Basin scarified February 23
(e) Began spreading every 4th day
(f) 12 days in month
(g) 6 days in month
(h) 20 days in month

Table 14 continued

Date	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
November			
December	4.154	.10	.35
January 1968	2.299	.06	.31
February	6.125	.16	.64
March	1.869	.05	.25
April	3.061	.08	.25
May	2.690	.09	.44
June	3.870	.10	.49
July	7.016	.17	.42
August	7.856	.20	.47
September	7.581	.20	.49
October	7.321	.18	.41
November	6.483	.17	.39
December	6.349	.16	.28
January 1969(i)	3.599	.09	.20
February	1.806	.05	.17
March	2.701	.07	.15
April	1.973	.05	.13
May	2.605	.07	.16
June	2.200	.06	.18
July(j)	-		
August	- -		
September	2.777	.07	.28
October	-		
November	-		
December	-		
January 1970	.530	.01	.22
February	1.335	.04	.19
March	1.534	.04	.14
April	2.376	.06	.16
May	1.948	.05	.17
June	1.840	.05	.19
July	2.317	.06	.26
August	2.000	.05	.29
September	1.337	.03	.33
October	1.486	.04	.31
November	1.310	.03	.28
December	1.561	.04	.31
Total to Date	312.333	8.84	24.03
Average		.14	.38

(i) Began sprinkling effluent behind Reclamation Facility 1/6/69
(j) Began delivery at Record Meter 7/2/69

TABLE 15

MONTHLY HYDRAULIC LOAD AND INFILTRATION RATES FOR BASIN NO. 5-6

Date	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
Colorado River Water			
March 1965			
April			
May	60.347	.91 (a)	1.23
June	32.365	.50 (a), (b)	1.48
Reclaimed Water			
July 1965	18.099	.62 (c)	3.27
August	46.757	.75	1.15
September	57.889	.90	1.04 (d)
October	52.625	1.51	1.60
November	63.336	.97	1.21
December	55.032	.83	1.03
January 1966	14.518	.24 (e)	.43
February	3.468	.30 (f)	.56
March	34.412	.57	2.68 (g), (h)
April	36.240	.63	2.67
May	31.153	.53	2.38
June	40.576	.70	2.34
July	20.628	.92 (i)	2.22
August	42.397	.71	2.32
September	31.767	.82	2.31
October	51.002	.86	2.25
November	42.695	.73	2.08
December	-		
January 1967	-		
February	12.637	1.05 (j), (k)	2.50
March	25.200	.42	1.67
April	34.080	.59	1.06
May	32.087	.54	1.02
June	67.908	1.17	1.62
July	35.334	.59	2.35

Area = 1.93 acre

(a) Basin area 2.14
(b) 10 days in month
(c) Began spreading July 27 - 5 days in month
(d) Basin scarified September 14
(e) Basin area 1.93
(f) 12 days in month
(g) Began spreading every 4th day
(h) Basin scarified March 4
(i) 12 days in month
(j) Basin area .95
(k) 13 days in month
(l) Basin area 1.93

Table 15 continued

Date	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
August	48.630	.82	1.81
September	58.216	1.10	1.78
October	40.494	1.10	1.41
November	18.636	.32	1.34
December	29.517	.49	1.14
January 1968	18.412	.31	1.29
February	24.892	.44	1.28
March	42.022	.73	1.18
April	29.018	.50	1.03
May	32.879	.53	1.17
June	30.888	.53	1.22
July	29.336	.48	1.06
August	31.746	.52	1.14
September	39.637	.67	1.33
October	43.083	.70	1.28
November	30.727	.51	1.11
December	19.642	.32	.98
January 1969(m)	13.163	.22	.62
February	9.187	.17	.58
March	18.176	.30	.41
April	16.214	.27	.33
May	19.614	.32	.36
June	16.113	.30	.50
July(n)	24.391	.39	.56
August	26.083	.42	.68
September	-		
October	16.203	.26	.57
November	26.525	.44	.70
December	30.732	.49	.76
January 1970	13.446	.22	.80
February	43.428	.78	1.45
March	31.908	.52	1.25
April	32.999	.56	1.03
May	25.495	.42	.88
June	21.676	.37	.98
July	22.698	.37	.88
August	39.336	.64	1.19
September	46.665	.79	1.25
October	37.861	.63	1.16
November	30.431	.53	1.08
December	41.203	.69	1.20
Total to Date	2,113.974	38.53	85.24
Average		.58	1.29

(m) Began sprinkling effluent behind Reclamation Facility 1/6/69
(n) Began delivery at Record Meter 7/2/69

TABLE 16

MONTHLY HYDRAULIC LOAD AND INFILTRATION RATES FOR BASIN NO. 7

Date	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
Reclaimed Water			
January 1966	32.866	.49[a]	.70
February	34.538	.46	.77[b], [c]
March	19.731	.24	1.05
April	17.999	.23	.98
May	18.050	.22	1.10
June	21.413	.26	1.00
July	8.708	.29[d]	.97
August	26.090	.31	.94
September	28.112	.35	1.03
October	27.239	.23	1.00
November	23.268	.29	.94
December	26.527	.45[e]	1.18
January 1967	45.848	.55	.89
February	46.140	.60	.83
March	48.368	.58	.62
April	30.482	.38	.64
May			
June			
July	29.553	.35	.97
August			
September	7.382	.55[f]	1.28
October	3.394	.42[g]	1.26
November	73.538	.91	1.18
December	31.866	.38	.74
January 1968	32.641	.39	.69
February	26.927	.34	.71
March	24.173	.30	.51
April	30.482	.37	.58
May	33.480	.40	.62
June	30.780	.38	.65
July	33.678	.40	.78
August	35.263	.42	.73
September	39.707	.49	.86
October	34.561	.41	.80
November	31.798	.39	.74
December	26.784	.32	.67

Area - 2.70 acre

(a) Began spreading January 7 - 25 days in month
(b) Began spreading every 4th day, March 3
(c) Basin scarified
(d) 11 days in month
(e) 22 days in month
(f) 5 days in month
(g) 3 days in month

Table 16 continued

Date	Vol. of Water Applied acre feet	Average Hydraulic Load feet/day	Average Infiltration Rate feet/day
January 1969[h]	20.088	.24	.60
February	13.608	.18	.55
March	18.083	.22	.40
April	14.413	.18	.24
May	17.417	.20	.28
June	15.408	.19	.32
July[i]	18.316	.22	.28
August	21.880	.26	.33
September			
October			
November			
December			
January 1970			
February			
March	47.593	.57	1.05
April	24.675	.30	.76
May	26.136	.31	.72
June	22.486	.28	.82
July	24.322	.29	.68
August			
September			
October	25.662	.31	.63
November	19.437	.24	.48
December	45.833	.55	.99
Total to Date	1,356.703	17.69	37.54
Average		.36	.77

(h) Began sprinkling effluent behind Reclamation Facility 1/6/69
(i) Began delivery at Record Meter 7/2/69

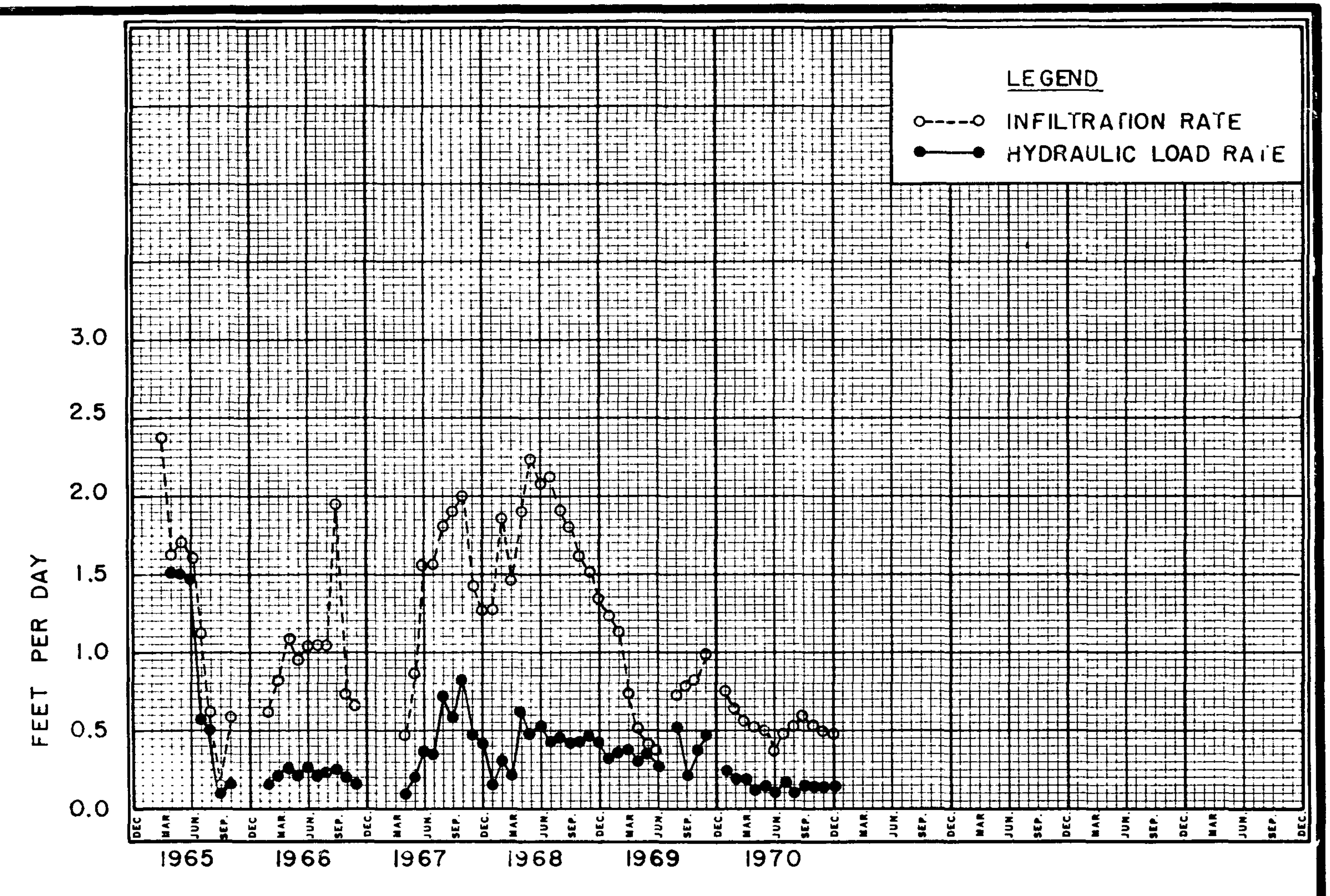


FIGURE 21. BASIN NO. 1 - MONTHLY INFILTRATION & HYDRAULIC LOAD RATES

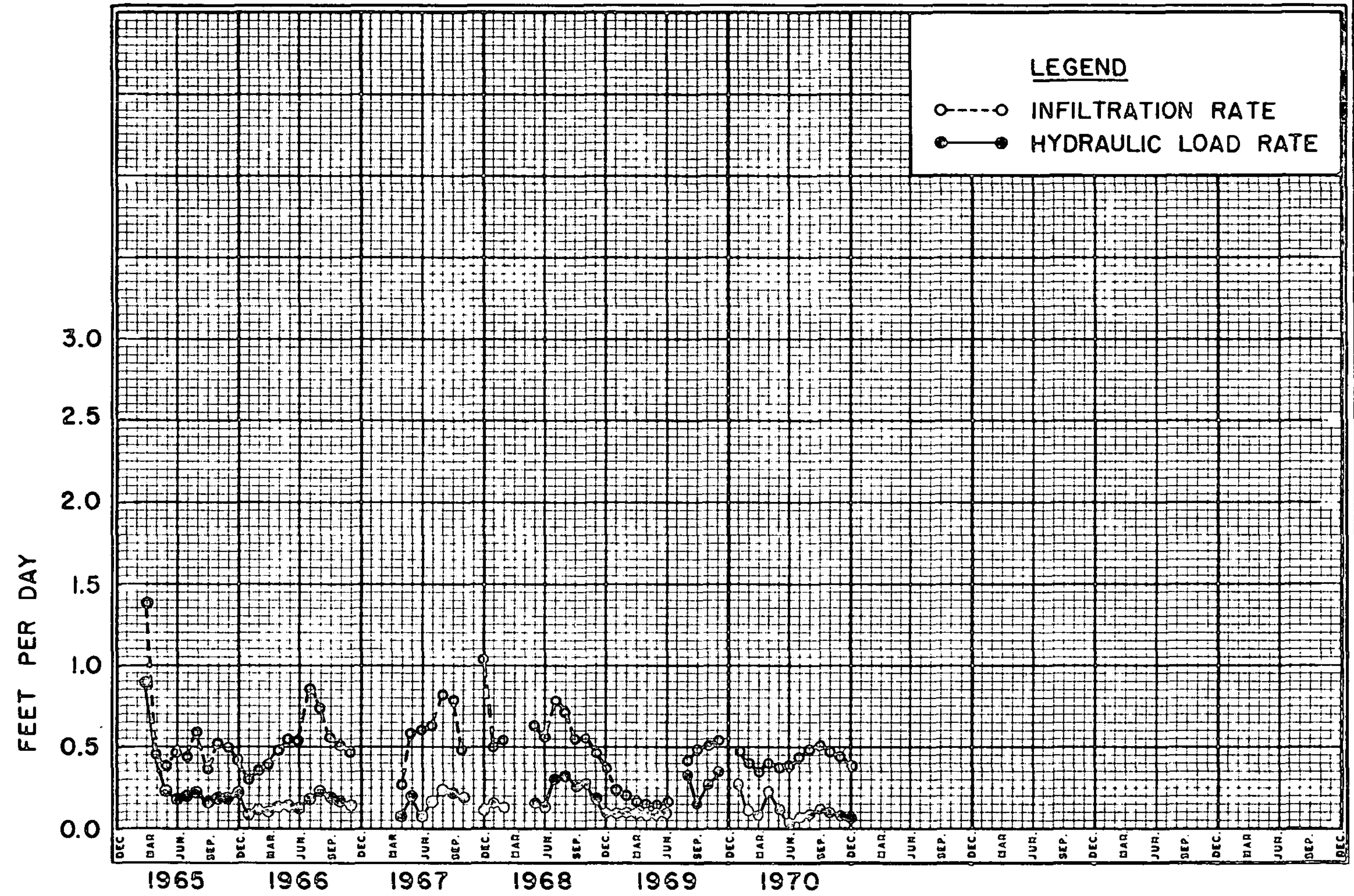


FIGURE 22. BASIN NO. 2 - MONTHLY INFILTRATION & HYDRAULIC LOAD RATES

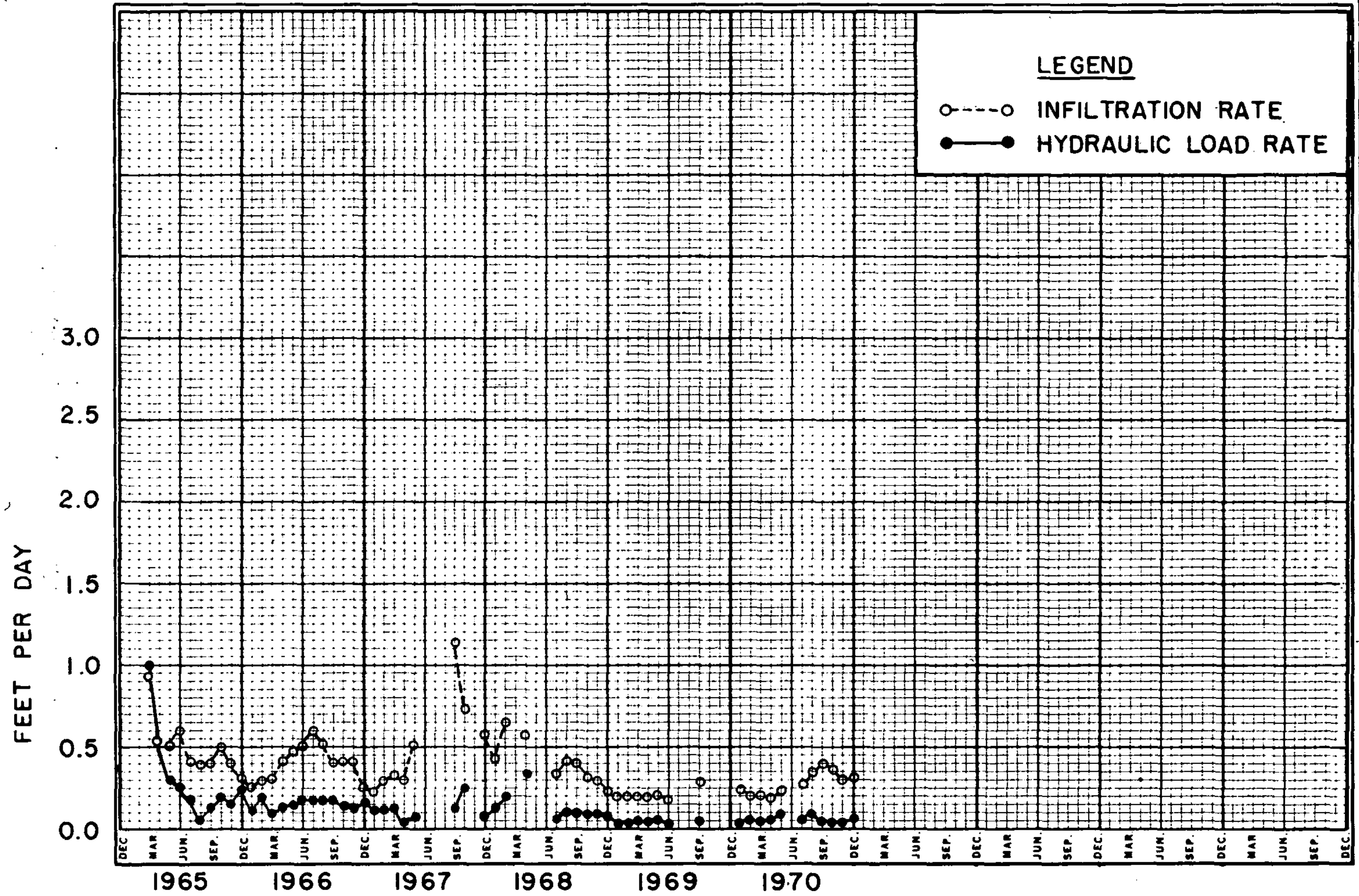


FIGURE 23. BASIN NO. 3 - MONTHLY INFILTRATION & HYDRAULIC LOAD RATES

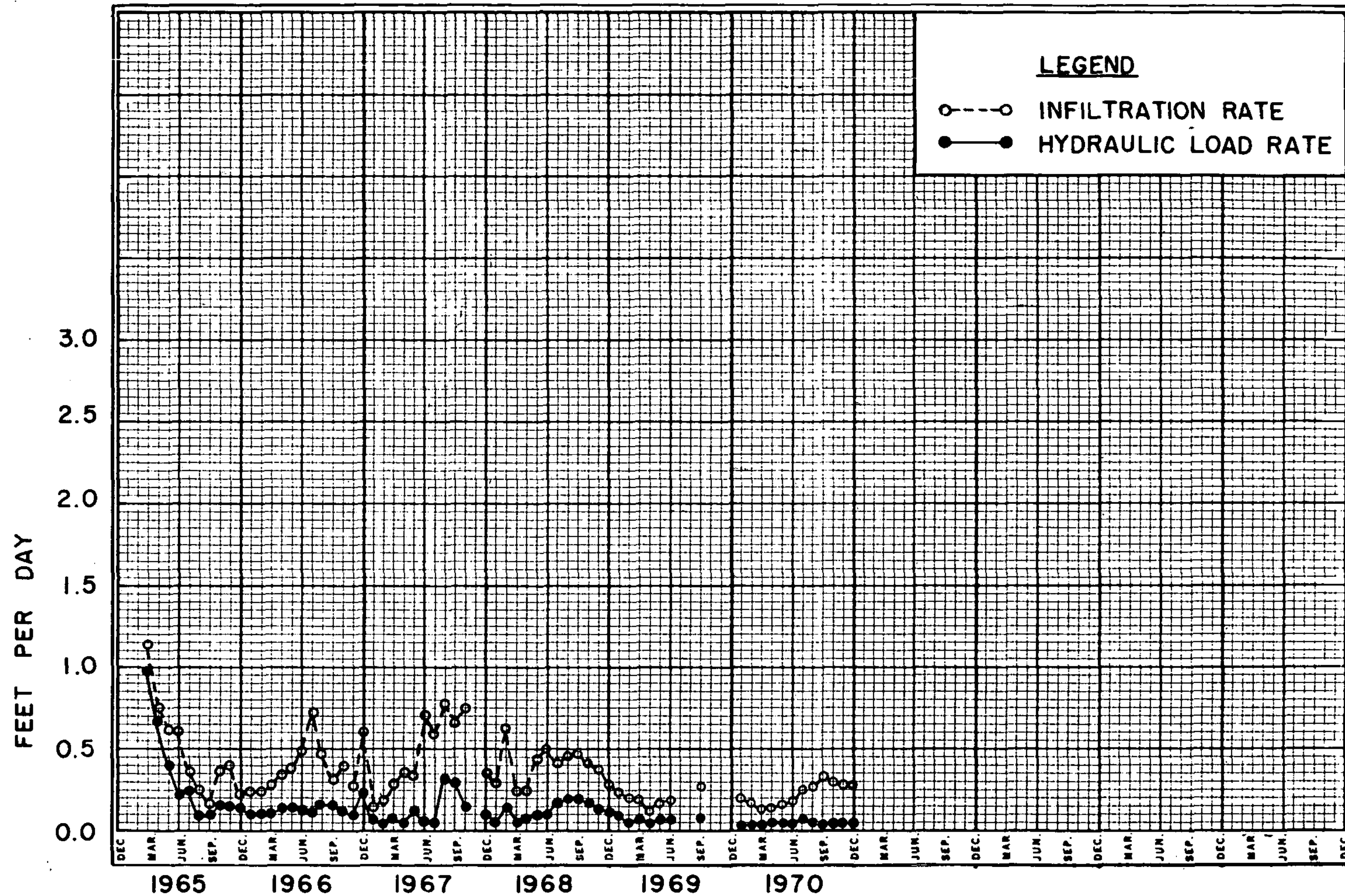


FIGURE 24. BASIN NO. 4 - MONTHLY INFILTRATION & HYDRAULIC LOAD RATES

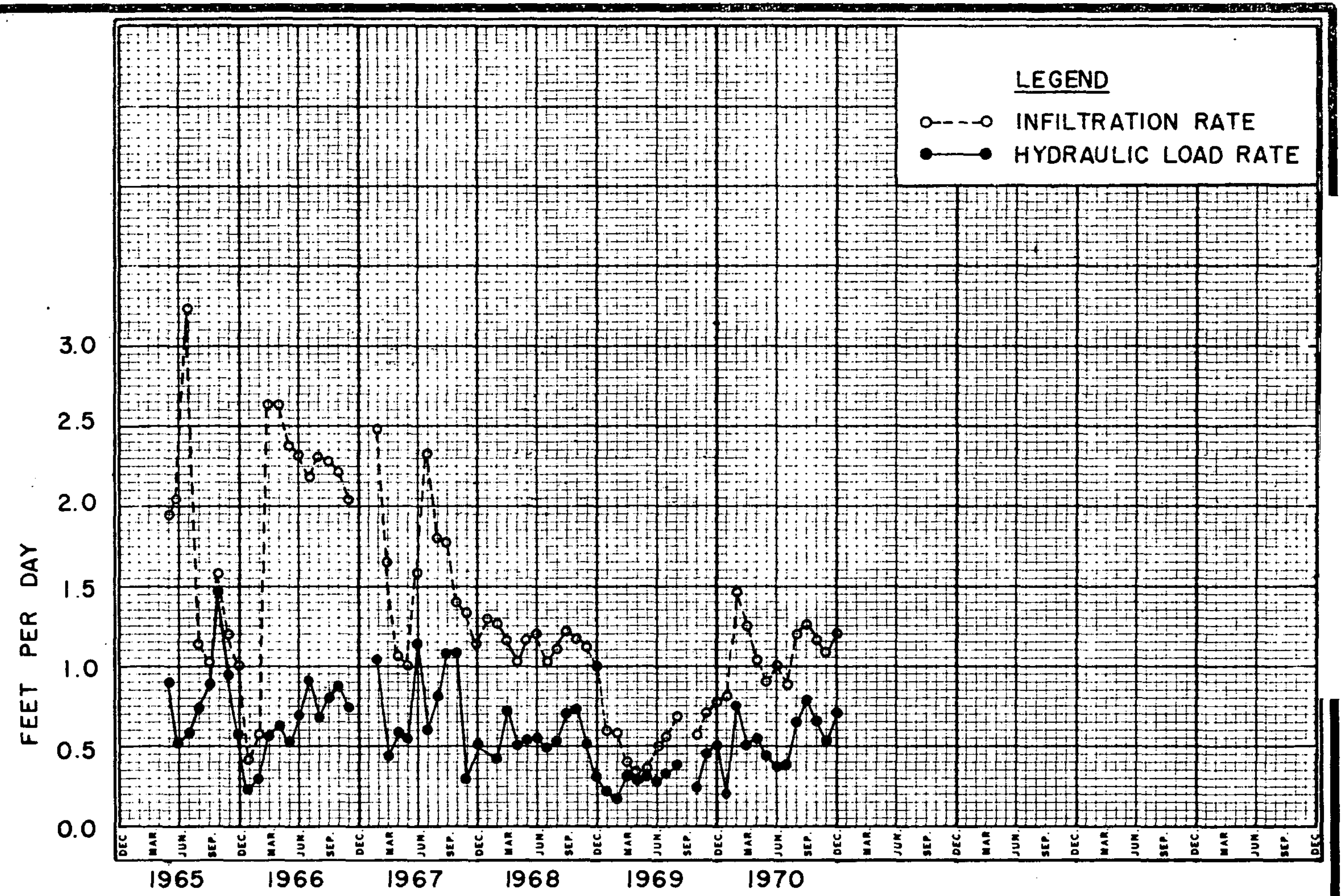


FIGURE 25. BASINS NO. 5 & 6 - MONTHLY INFILTRATION & HYDRAULIC LOAD RATES

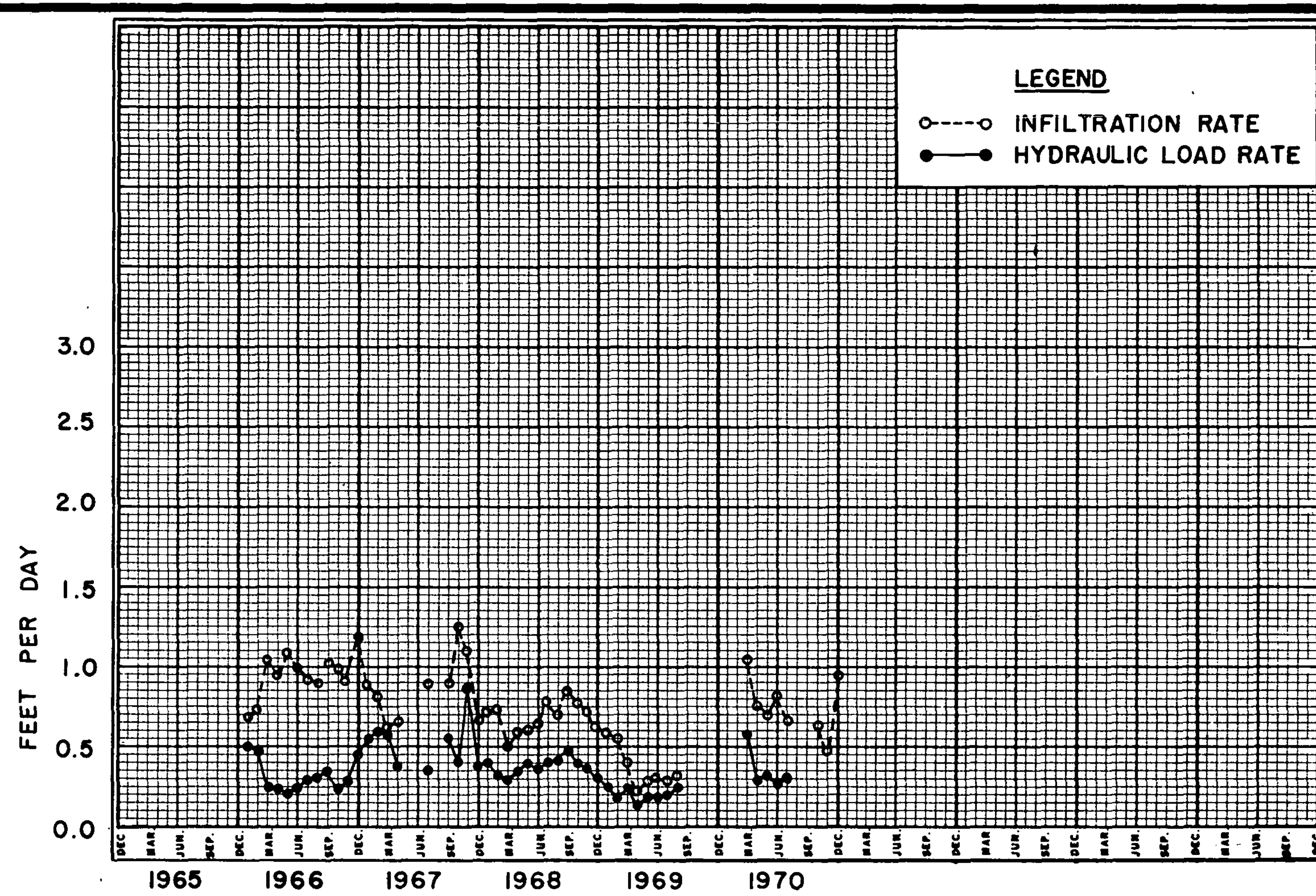


FIGURE 26. BASIN NO. 7 - MONTHLY INFILTRATION & HYDRAULIC LOAD RATES

inhibiting infiltration rates. A four-day cycle, one wet - three dry, allowed sufficient drying to minimize the effect of the algae, but thorough drying was not the complete solution as the basins were continuing to receive algae from the storage ponds at the Hemet-San Jacinto Water Reclamation Facility. These storage ponds at the Reclamation Facility were intended to be used as large "wet wells" from which a constant flow of various magnitudes could be pumped to the spreading basins rather than pumping the fluctuating flows which are typical of treatment plants. A different pumping method was worked out which took the effluent directly from the treatment plant to the spreading basins, bypassing the storage ponds. This method was made operational in June 1966 and eliminated the heavy algae loading the the need at that time for the four-day cycle.

The infiltration rates started increasing in March 1966, when the four-day cycle was in use and continued to increase through July 1966, with the new pumping method and a three-day cycle. The four-day cycle was dropped during the summer of 1966 because it was not necessary, and it was used only sparingly during the following winter. During the spring and summer of 1967 the cycle was again modified as all of the basins demonstrated a rise in infiltration and hydraulic load rates, and it was not possible to match perfectly a three-day cycle to both the quantity of flow and the number of basins. Thus, the number of basins in use was reduced and the cycle was as follows: Basins 1, 2 and 4 wet one day, dry three days; basin 5-6 wet two days, dry two days. Thus, basin 1 received all the flow for one day; the next day's flow was divided between basins 2 and 4; basin 5-6 received the flow for the next two days; and then the cycle repeated. Basins 3, 7 and 8 were not used during these months as they were not needed. As can be seen from Figures 21 through 26, this method obtained high continued rates during 1967, but each basin exhibited a typical predictable decrease in rates during the winter of 1967-68. During the 1967-68 winter, basin 7 was used and this permitted continuation of the cycle.

During the spring and summer of 1968 the same cycle was continued, as was the use of basin 7. The plant flows had increased enough by the summer of 1968 that it was necessary to operate basins 8, 9 and 10 occasionally in order that the other basins might dry. The 1968-69 winter brought with it unusually heavy and prolonged rainfall which resulted in runoff entering the sewerage system with resulting increases in the flow to the spreading basins. The San Jacinto River flowed continuously for 5 months, creating a very high water table in the replenishment area. The spreading cycle had to be completely abandoned as all basins were full by February 1969.

Supplementary methods of disposal had to be initiated to alleviate part of the hydraulic load on the basins. A sprinkling operation on District-owned property at the Reclamation Facility was begun in February 1969 and a local farmer began using effluent for irrigation of approximately 300 acres of permanent pasture in July 1969. These additional disposal methods have allowed the water levels in the replenishment area to subside and the basins returned to a cycle. The pasture irrigation operation is continuing with approximately two-thirds of the effluent being used for that purpose. Beginning in January 1970, a revised spreading cycle was instituted and is presently in use. In this cycle, basins 1 through 4 each receive one day's flow per week and basin 5-6 receives the flow the remaining three days. Basins 7 and 8 are used when other basins are dried for maintenance. This cycle has produced good results at the reduced flow, producing an infiltration rate of 0.63 feet per day in basins 1 through 7.

Since their construction in 1965, basins 8, 9 and 10 have not been continuously used. These three basins have been used only for storage while other basins are drying for maintenance, or during periods of heavy rainfall and subsequent runoff. However, since need for storage has been intermittent, infiltration and hydraulic load data are also intermittent. Thus these scattered data have been omitted from both the tables and graphs.

It is apparent that the infiltration rate is affected by many factors, of which few can be easily and economically controlled. Once the site for spreading is selected, one of the most important controllable factors is the intermittent cycle in use. A second controllable factor is the amount of non-filterable residue in the effluent. A good activated sludge treatment plant effluent will usually have less than 15 milligrams per liter non-filterable residue. However, if the effluent is stored without some means of algae control, algae blooms can cause a non-filterable residue increase of more than 10 times normal. Algae blooms will also occur if basins are not allowed to dry.

The single fact that the infiltration rate is high doesn't necessarily indicate that a large volume of water is infiltrating the soil. The purpose in determining the infiltration rates relates to the need to percolate as much water as possible in the smallest area possible. A better parameter than infiltration rate for measuring the overall efficienty of land area-water volume relationship over a period of time is the hydraulic load rate.

Hydraulic Load Rates

The average hydraulic load rate, as defined in the Report of Research on Wastewater Reclamation at Whittier Narrows, equals the total volume of water applied during the month divided by the number of days in the month divided by surface area of the basin.[10] Thus, hydraulic load can be used to show the amount of water infiltrating the ground during any period of time regardless of the wet-dry spreading cycle used. Hydraulic load rate is a meaningful parameter and can be used to directly compare soils or spreading basins which are being used with different spreading cycles. Hydraulic load rate, by its definition, is equal to the infiltration only when a basin is constantly wet. Tables 11 through 16 show the hydraulic load for each spreading basin, together with the infiltration rates and various unusual factors which had a bearing on either the hydraulic load or the infiltration rate. Figures 21 through 26 include graphs of the hydraulic load rate for each basin.

Basins 2, 3 and 4 have exhibited very low hydraulic load rates since the beginning of spreading operations, as did all the basins during 1965 and 1966. In 1967, and during the first months of 1968, all basins showed an increase in hydraulic load rates. The increase in basins 2, 3 and 4 was small, while in basins 1, 5-6 and 7, the increases were substantial. Two possible explanations for these increases are; 1) the basins may have experienced "ripening" as was evidenced in other similar operations (notably Lodi and Whittier Narrows); 2) the basins were put on a more routine program of maintenance in 1967. However, since the summer of 1968 all basins have demonstrated fairly constant hydraulic load rates and indicated that the increase was due to regularly scheduled maintenance.

Maintenance

The vegetative growth in several of the spreading basins has been quite prolific. Basins 1 through 4 have undergone a complete regrowth within two months after discing. However, rototilling the soil to a 10-14 inch depth has been successful in preventing regrowth for periods of three to four months. Basins 5-6, 7 and 8 have not experienced as severe a growth problem as the original four because they have more sandy soils and are filled to greater depths. Apparently, the most important of the two factors is the depth to which the basins are filled. Growth around the sides or dikes of the basins can be rather easily controlled from the top of the dike by either weed spray or hoeing. Thus, the most serious problem is control of growth occurring in the bottom of the basins.

A single annual application of the pre-emergence chemical Semizine, manufactured by the Geigy Chemical Corporation, in the amount of 34 pounds per acre, was used to control the weed growth on the banks of the ponds. This procedure is being continued because it adequately controls weed growth and does not permanently contaminate the basin as other herbicides investigated might.

Each of the basins have sealed by algae blooms or suspended matter at one time or another, even though they had been intermittently wetted and dried. Discing, rototilling and scarifying have been used to aerate the top few inches of soil. Each method has a different depth to which it breaks up or turns over the soil; discing, to 6 inches; scarifying, to 12 inches; rototilling, to 14 inches. Of the three methods, rototilling has given the most satisfactory results.

In May 1968 gravel ranging in size from 3/4" to pea gravel was spread six inches deep in basin 3. The gravel has reduced the recurring weed problem; however, the basin has exhibited a decrease in the infiltration and hydraulic load rates. The cost for this operation probably exceeded the cost of normal weed maintenance for over 15 years.

For the purpose of unclogging the basin soil and eliminating severe vegetative growth, each basin has been scarified, disced or rototilled at regular intervals; basins 1, 2 and 4 approximately three times per year. With the exception of basin 3, all of the others have been processed about twice a year.

Other than during the wet winter of 1968-69, there has been only one instance where water pumped into one basin would flow under a dike and appear on the surface of an adjoining basin. This problem occurred in January 1966 between basins 5 and 6. This problem has been solved by flooding both basins at the same time, rather than placing an impervious membrane in the dike, and they have been operated jointly since then.

Alternate Methods of Disposal

Because the more desirable spreading areas were not available the site necessarily selected was characterized by layers of silty sand interspersed with sand lenses. Past experience of others[10] indicated that the most efficient operation of the spreading basins could be achieved under an operating procedure of wet and dry cycles, combined with careful basin management. With this in mind, infiltration rates were kept fairly high to late 1968. However, by the end of 1968 the water table had risen to within a few feet of the bottom of the basins and it became obvious that the entire area was becoming saturated and that it would be difficult to sustain high infiltration rates at these flows even under normal circumstances.

Unfortunately, in January-February 1969 the heaviest rainfall for a two-month period ever recorded in the basin fell in the area. This 15" rainfall, falling on the already saturated replenishment area created an untenable situation and other methods for disposal of the effluent had to be developed. Two additional methods of disposal were utilized.

1. A sprinkling operation was instituted to dispose of approximately 750,000 gpd on 30 acres of available District property at the Reclamation Facility. This operation helped alleviate the loading on the replenishment area, but eventually saturated this 30-acre area.

2. Approximately 1,200,000 gpd were delivered to a local farmer for irrigation of pasture land.

Table 17 shows the total amount of wastewater that was used in the sprinkling operation and the totals delivered to Record Rancho through December 1970. Figure 27 shows the location of these operations.

TABLE 17

FLOW TO SPRINKLING OPERATION, PASTURE IRRIGATION AND SPREADING BASINS (in acre feet)

	Plant	Spreading Basins	Irrigated	Sprinkled
January 1969	161.403	94.568		66.835
February	130.302	74.996		55.306
March	140.255	84.760		55.495
April	137.465	81.081		56.384
May	144.600	91.683		52.917
June	138.594	90.233		48.361
July	155.966	54.603	101.363	
August	162.532	75.695	86.837	
September	148.058	17.267	130.792	
October	150.615	37.543	113.072	
November	150.397	52.203	98.193	
December	151.720	30.732	120.988	
January 1970	150.463	30.454	120.006	
February	142.581	53.473	88.127	
March	160.703	89.563	71.137	
April	153.259	72.024	81.276	
May	160.313	62.894	97.406	
June	155.351	49.179	106.221	
July	175.950	59.668	116.232	
August	178.131	51.034	127.066	
September	159.346	57.048	102.252	
October	166.352	74.072	92.280	
November	162.363	58.693	103.670	
December	158.880	97.630	61.250	
Totals	3,695.599	1,541.086	1,818.168	335.298

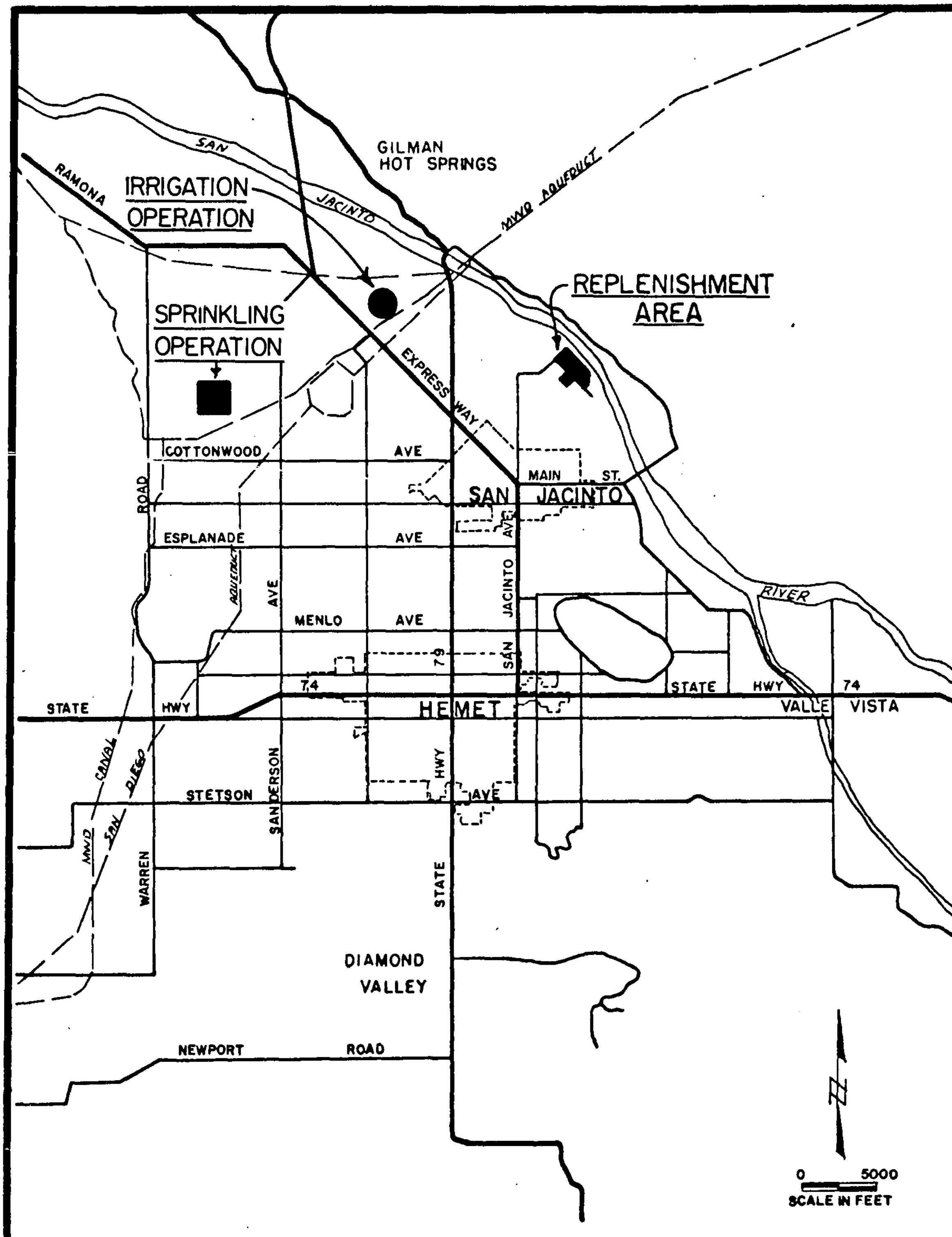


FIGURE 27. LOCATION OF SPRINKLING AND IRRIGATION OPERATIONS

SECTION IX

GROUNDWATER QUALITY - SAMPLING PANS

An understanding and delineation of the various physical and organic chemical changes occurring in the reclaimed water as it percolates through the ground is one of the prime purposes of this project. These changes are a function of many things (e.g., dissolved oxygen concentration, bacterial population, time, type of soil, efficiency of plant operation, etc.) Comparing analyses of representative water samples obtained from the water being spread and after it reaches a nearby water well will show the overall water quality changes. But this comparison will not show all of the intermediate changes which have occurred nor will this method produce sufficient data to indicate the reasons for these changes.

The intermittent spreading cycle produces a soil moisture profile which shows the soil to be completely saturated at the soil-water interface and unsaturated from there down to groundwater. Since many of the water quality changes occur in the unsaturated zone it is advantageous to obtain representative water samples from this zone. Sampling "pans" were designed and installed in spreading basin 1 to serve this purpose. (Figure 28)

Sampling Design Criteria

Theoretically, water percolating through unsaturated soil is acted upon by two forces. Gravity is the major force causing movement downward in the Zone of Aeration. However, because of capillary forces operating in all directions, movement of water into a very dry soil is accelerated because head is sum of gravity and capillary action, and movement out of the unsaturated soil is retarded because the capillary (pore pressure) works against the gravity force. For this reason, tensiometers were originally considered for sampling, but were rejected because they filter various organisms from the sample. Other devices for obtaining water from unsaturated soil were considered, but each device had one or more problems associated with its use.

The device which offered the most promise was a funnel or pan installed in the soil to capture percolating water and drain it to a central well. Since pans of this type captured water in the past[10] it was thought that water might saturate the soil above the pan to some

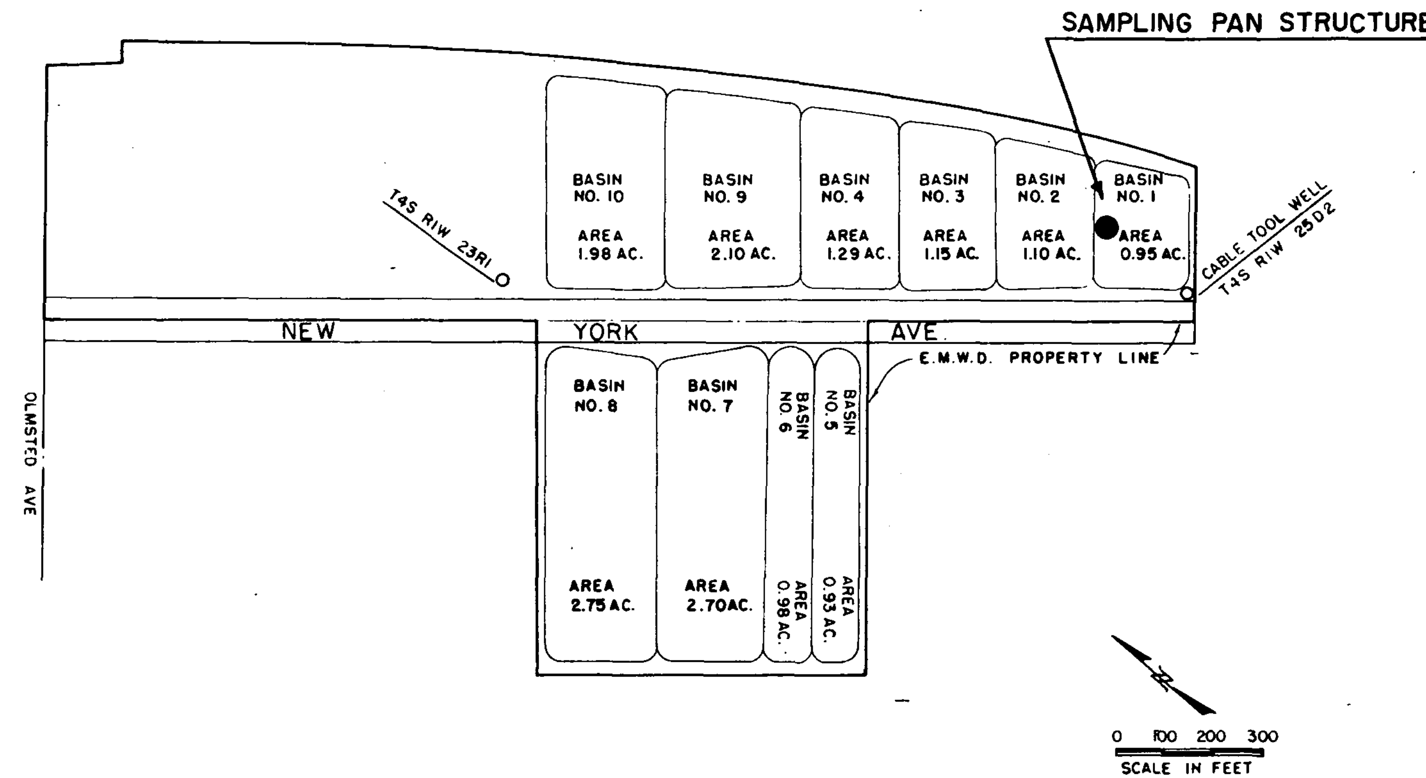


FIGURE 28. LOCATION OF SAMPLING PAN STRUCTURE

height giving sufficient head to overcome the difference between atmospheric and soil pan pressure. Figure 29 depicts the situation which would be necessary to obtain a sample of percolating water from an unsaturated soil.

However, a problem occurs if water is obtained by the method detailed in the sketch. This saturated zone both above and in the pan can hold a considerable amount of water, thereby causing a long delay in getting the water into the sampling pan. For example, if one foot of water is pumped into the basin and h_1 is 3 inches, porosity is 40 percent and the pan diameter is 2 feet, then the volume of water held in the saturated zone above the pan is 2.35 gallons. If each day that water is pumped into the basin only 1 gallon of water passes through the sampling pan, the detention time in the saturated zone above the pan is 2.35 days, in addition to the number of days the basin is allowed to dry. The knowledge of the amount held in the saturated zone is very important to correctly interpret many of the physical and biochemical changes occurring in the water.

It was decided to attempt to reduce the saturated zone above the pan thereby decreasing the detention time and producing a more representative sample of the actual percolating water. It was thought that different materials in a pan would influence any saturated zone above the pan and yield different detention times and different volumes of water.

Model studies were conducted to determine the best pan media that gave the lowest detention time and highest yield of water. The theoretical maximum volume of water which could be obtained from a pan is equal to the height of water applied to the soil times the cross-sectional area of the pan. The theoretical minimum detention time could not be easily computed as the water percolates through a short saturated zone and then through an unsaturated zone before it reaches a pan.

Model Study

Pans were made and placed in three 55-gallon drums. The pans were placed in each drum such that comparison of data from the drums might indicate sidewall influence, if any, and detention time in a saturated zone. Figure 30 shows schematics of the three barrels.

Each barrel was filled with soil obtained from the spreading basin in which the sampling structure would be placed and random samples taken for constant head permeability tests.[11] The results of these

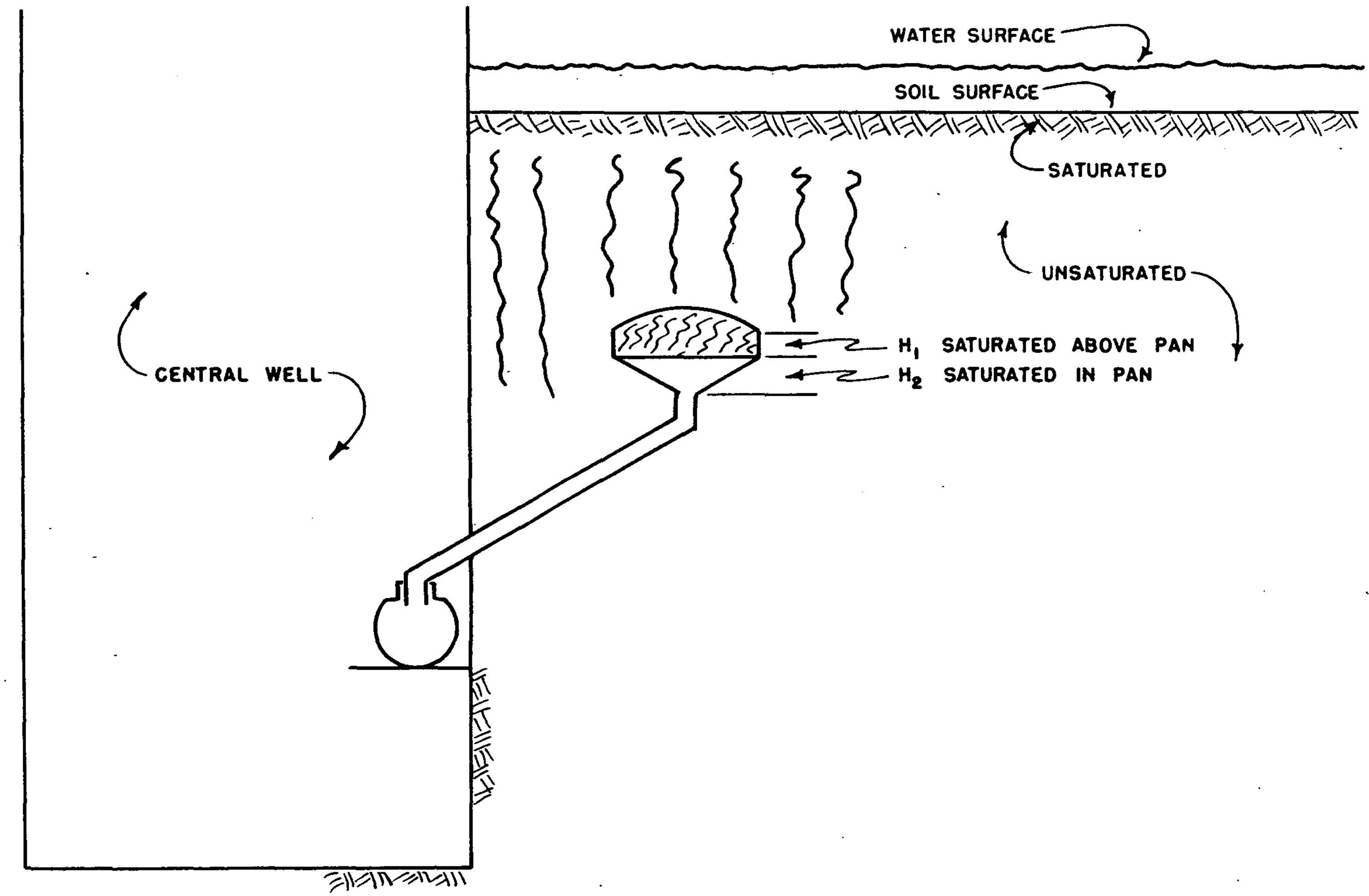


FIGURE 29. SCHEMATIC DIAGRAM — SAMPLING PAN STRUCTURE

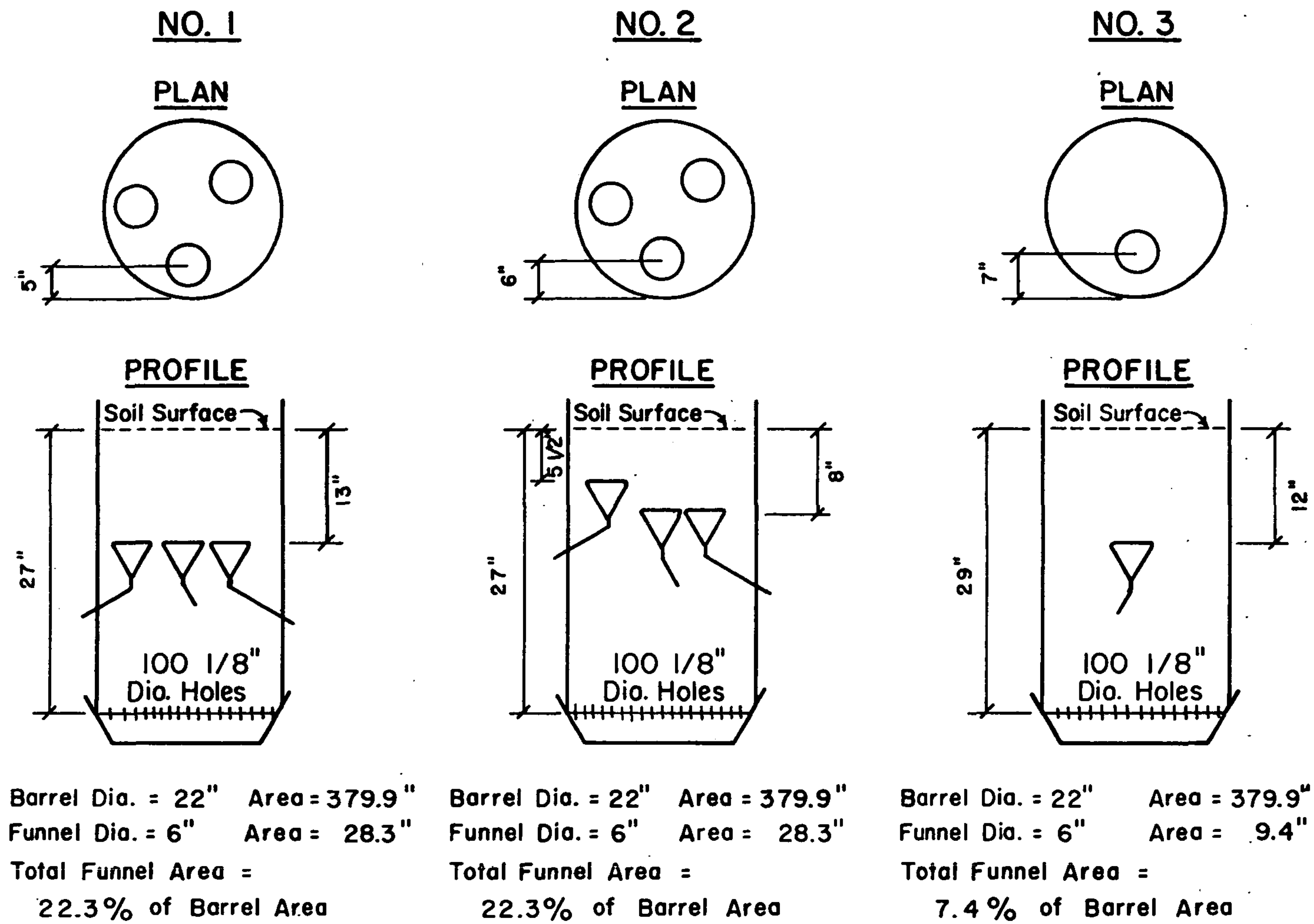


FIGURE 30. SCHEMATIC DIAGRAMS-TEST BARRELS

vertical permeability tests are shown below in centimeters per second and feet per day. The porosities, which ranged from 0.37 to 0.38, are typical of sand.

Permeability Test

Sample	Results	
	cm/sec.	ft./day
A	1.691×10^{-2}	47.8
B	1.356×10^{-2}	38.4
C	0.572×10^{-2}	16.2
D	6.02×10^{-2}	170.0

The first series of tests were run in Barrel No. 1 and the pans were filled with the same material as the barrels. Table 18 shows the results.

The second series of tests were run in Barrel No. 1 after the material was replaced with soil from the replenishment area. The material in the pans was replaced with graded rock and gravel from 1/4" to 1" in size, to approximately 2" above the pan top. The third series of tests were run with replaced soil in Barrel No. 1, using glass wool in the pans. Table 19 shows the results of both the second and third tests.

In addition to the results shown in Tables 18 and 19, 23 additional tests were run in Barrel No. 1 with glass wool as the medium in the pans.

The percent recovery for all 23 tests was 17.8. Ten additional tests were run in Barrel No. 2 using glass wool in the pans with a 17.6 percent recovery factor. The significance of the percent recovery factor as defined in Tables 18 and 19 is demonstrated by comparing the volume of water passing through the pans having different media. If the percolating water flowed without effect from the pans or barrel sides, each pan should collect 7.43 percent of the total amount added while three pans should recover 22.3 percent of the total water added. With either sand or rocks in the pans the recovery was very low, 2.1 percent and 1.2 percent respectively. However, with glass wool in the pans the recovery factor was 17.7 percent, or 77 percent of the 22.3 percent that the pans should recover.

While this recovery factor doesn't necessarily indicate a very small detention time in some saturated zone above the pan, it does indicate a minimum detention time assuming any given saturated zone for any pan regardless of media.

TABLE 18

PARAMETERS AND BASES FOR DESIGN OF SAMPLING PANS

Model Studies

Run No. 1
Basin Soil in Pans in Barrel No. 1

Test No.	Hrs. between Adding water	Amount Added (ml)	Amount Recovered Pan #1	Pan #2	Pan #3	Bottom	% Pan recovery[a]
1-A		50,000	84	115	116		
1-B	4	7,000	0	0	105		
1-C	1	7,000	11	13	66		
1-D	42	14,000	42	10	128		
1-E	6	7,000	0	0	10		
1-F	19	14,000	74	59	170		
1-G	2-1/2	14,000	70	48	140		
1-H	114	14,000	18	41	39		
Total		127,000	299	284	774	63,615[b]	2.1 ave.

(a) Percent pan recovery is equal to the ratio of amount recovered by all pans to the amount recovered by pans and from the bottom.

(b) Amount of water recovered from bottom of the pans was recorded for each test, but the individual recordings were in error due to sand plugging the drain. However, the figure for the total amount recovered from the bottom is correct.

TABLE 19

PARAMETERS AND BASES FOR SAMPLING PAN DESIGN

Model Suudy

Run No. 2
Rocks in Pans in Barrel No. 1

Test No.	Hrs. between adding water	Amount Added (ml)	Amount Recovered				% Pan recovery[a]
			Pan #1	Pan #2	Pan #3	Bottom	
2-A		14,000	0	36	0	2,110	
2-B	4	14,000	5	20	6	7,862	
2-C	2-1/2	14,000	24	26	16	15,343	
2-D	17	14,000	9	39	30	8,820	
2-E	2	14,000	67	121	49	12,840	
2-F	2	14,000	68	131	61	14,830	
2-G	42	14,000	5	29	5	9,670	
2-H	4	14,000	68	86	73	10,790	
Total		112,000	246	488	240	82,265	1.2 ave.

Run No. 3
Glass Wool in Pans in Barrel No. 1

Test No.	Hrs. between adding water	Amount Added (ml)	Amount Recovered				% Pan recovery[a]
			Pan #1	Pan #2	Pan #3	Bottom	
3-A		14,000	0	33	5	3,370	
3-B	18	14,000	590	220	440	5,050	
3-C	2	14,000	1210	1060	1000	11,900	
3-D	2	14,000	770	960	740	11,030	
3-E	2-1/2	14,000	740	940	710	14,370	
3-F	17-1/2	14,000	420	520	320	7,000	
3-G	2-1/2	14,000	1090	1100	760	9,960	
3-H	2	14,000	660	810	780	12,000	
3-I	21	14,000	460	410	210	12,910	
3-J	72	14,000	60	185	53	7,000	
Total		140,000	6000	6238	5018	94,590	14.5 ave.

(a) Percent pan recovery is equal to the ratio of amount recovered by all pans to the amount recovered by the pans and from the bottom

All of the above model studies were run outside without control for evaporation. During each change of soil in a barrel the soil above the funnels did not appear saturated, while the soil in the bottom was definitely saturated.

An attempt was made to measure the detention time in the soil column. As a base, 80 liters of Colorado River water were run through Barrel No. 3. The chloride concentration in the 80 liters average 109 mg/l and ranged from 107 mg/l to 113/mg/l. Following this, 14 liters of water with a chloride ion concentration of 500 mg/l were run through the barrel. Water captured by the pan was analyzed for chlorides and a plot of this information is shown in Figure 31. While it is very difficult to determine the detention time in the saturated zone above any pan, Figure 31 (together with the high percent recovery) indicates that the detention time is much less than one day. Indeed, since the arrival times of the chloride ion can be measured in hours, it was expected that full scale pans with glass wool as a medium would function within the same range.

A comparison of the permeability tests to the actual arrival time of the water during model studies show little correlation. However, this lack of correlation wasn't unexpected, since the permeability tests use a constant head of water; thus, they measure flow rates through saturated soil, whereas the model studies were intended to sample water from unsaturated soil, and they indicate detention time for water which has flowed through saturated and unsaturated soil.

Several additional attempts were made to establish detention times in the soil. One attempt was made by adding 14 liters of distilled water to a barrel, followed by 14 liters of Colorado River water to which fluoride had been added. The amount of fluoride added to the Colorado River water increased the fluoride concentration to 2.2 milligrams per liter. The fluoride concentration in the water obtained from the funnels ranged from 0.85 mg/l to 1.00 mg/l with an average 0.91 mg/l. Ten samples of water were collected from the bottom of the barrel, and fluoride content ranged from 1.00 mg/l to 1.05 mg/l. A second attempt was made by adding another 14 liters of distilled water to the same barrel followed by 14 liters of Colorado River water to which sulfate had been added.

A correlation between the high sulfate concentration water added and the water obtained from either funnels or the bottom of the barrel was never achieved.

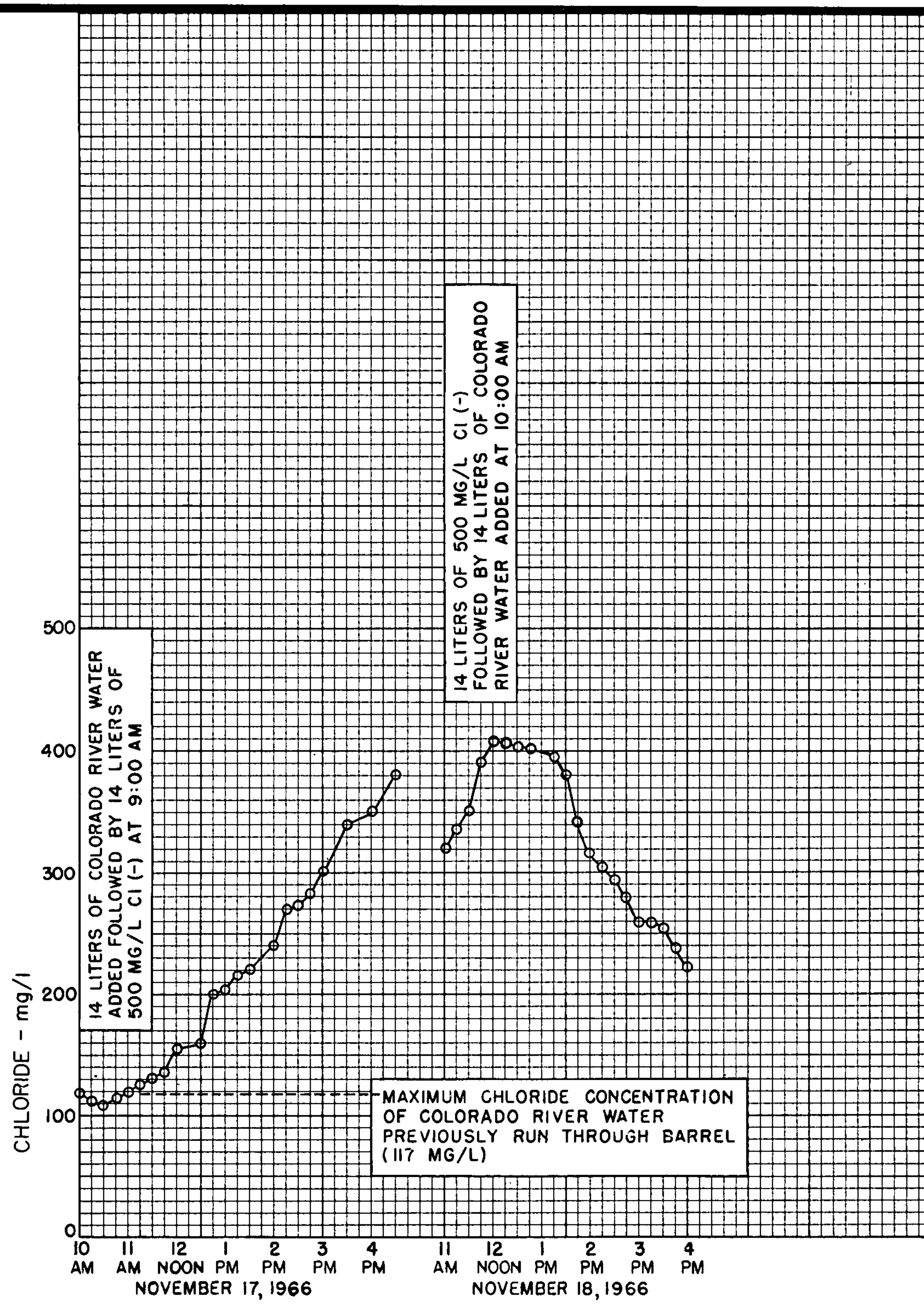
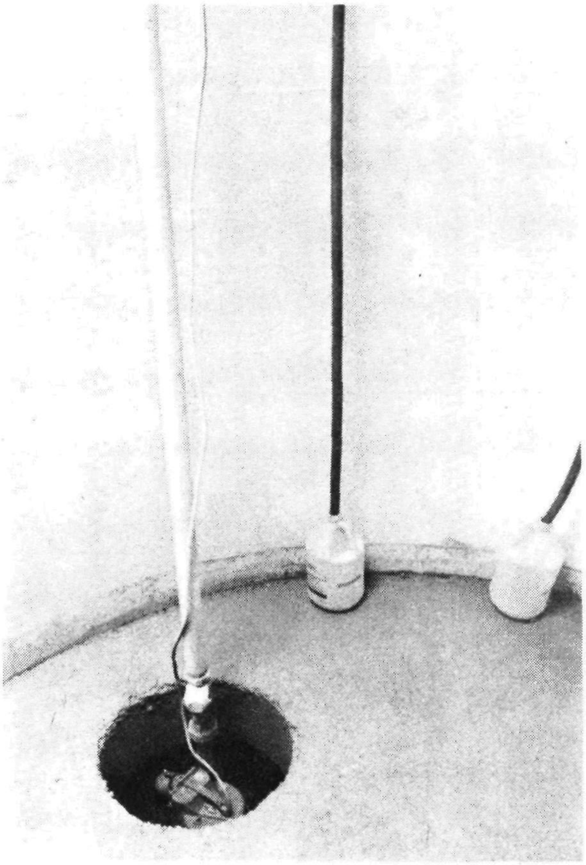


FIGURE 31. CHLORIDE ION ARRIVAL - BARREL NO. 3 MODEL STUDY



Dry well showing sump with collector bottles in place

As a final check of the suitability of glass wool, sewage effluent was run through Barrel No. 3. Coliform counts over 18,000 MPN per 100 ml were observed.

Design and Construction

The model studies were conclusive and spun glass wool was used in the pans in spreading basin 1. The design of the sampling pan structure was based on the material which was at hand. The District had a scrap piece of 8-foot diameter steel pipe which was placed vertically in a 15-foot excavation with a poured concrete floor. A flat piece of steel was welded to the top and a small pipe was used as a hatch to extend the entryway above ground and/or future water surface level.

There are many questions concerning the "ripening" of an intermittently-spread basin. At the time of construction of the sampling structure, spreading basin 1 had been ripening for 13 months. Two pans were set at each level below the soil surface, one pan beneath soil which had not been excavated, and the other in soil which had been removed and replaced during installation of the structure. By dual placement of the pans on each level, an effort was made to duplicate natural conditions (pans in undisturbed soil) and to check as to the need for this highly-specialized construction by installing pans in disturbed soil and comparing results.

After installation of the structure was completed, the basin was flooded and the soil around the structure settled severely. Some of the soil load was transferred to the 3/4" plastic tubes which connect the pans to the structure. The soil was re-excavated and repairs were made. After re compaction the little settlement that did occur caused no apparent damage to the system. A schematic of the Sampling Pan Structure is shown on Figure 32.

Sampling Schedule

The sampling pans were installed in basin 1 in April 1967 and the collection of samples began in May of that year. The first samples contained large amounts of sand, indicating that the plastic tubes connecting the pans to the central well were broken. The necessary repairs were made and the sampling was resumed in June of 1967. The pans were sampled 1 or 2 times per month from June 1967 through November 1968, with occasional disruptions when basin 1 was drying for maintenance. The sampling schedule was temporarily abandoned

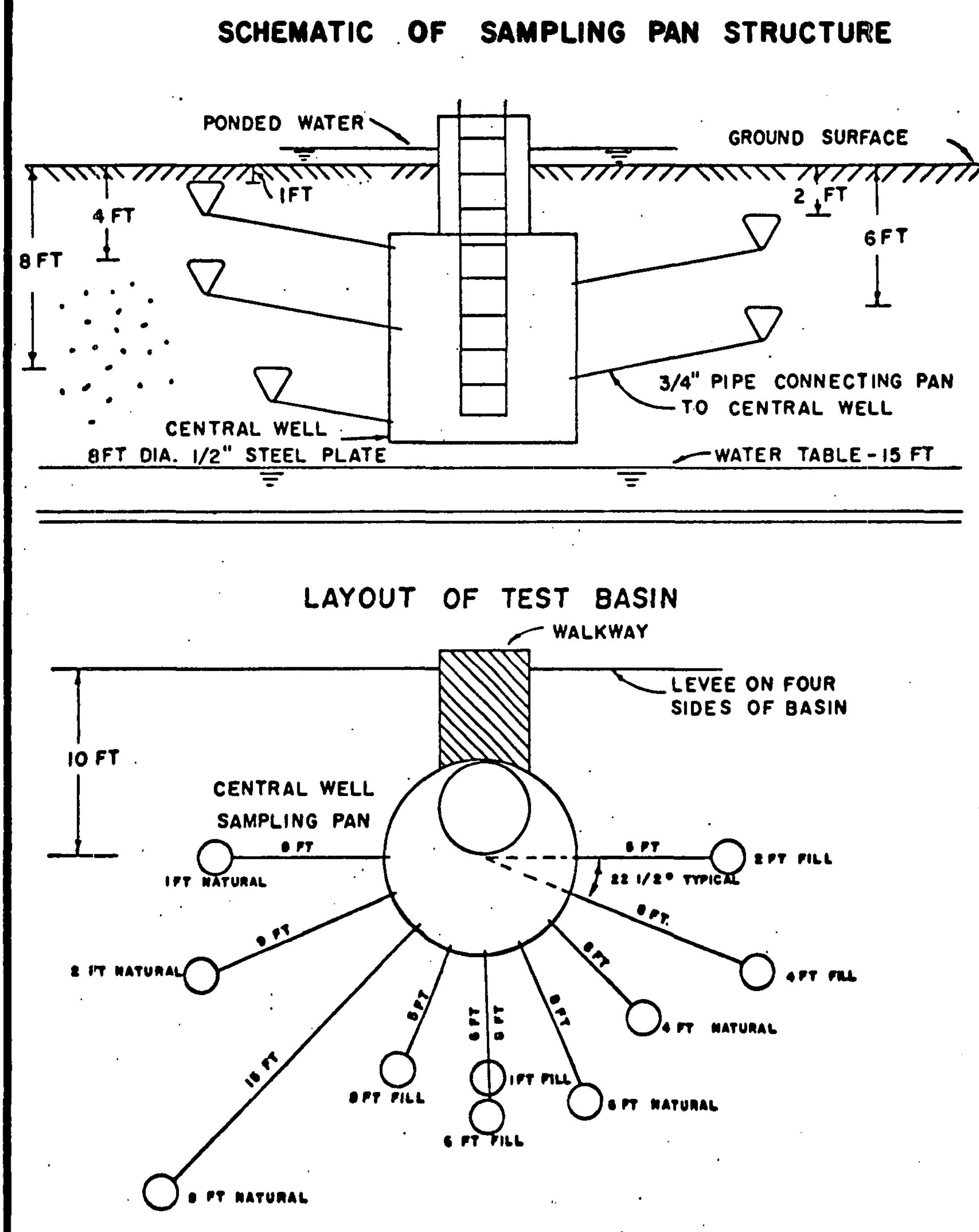


FIGURE 32. SCHEMATIC OF SAMPLING PAN STRUCTURE & LAYOUT OF TEST BASIN

in early 1969 as piezometer readings indicated that the shallow water table in the area had risen above the level of the lower pans. Once the water table subsided the sampling schedule was resumed. Figure 33 is a graph of recovery rates through 1969. However, since the high water table receded, only 4 to 6 of the pans have consistently collected water.

The chemical quality of the water collected by the pans is discussed in Section X.

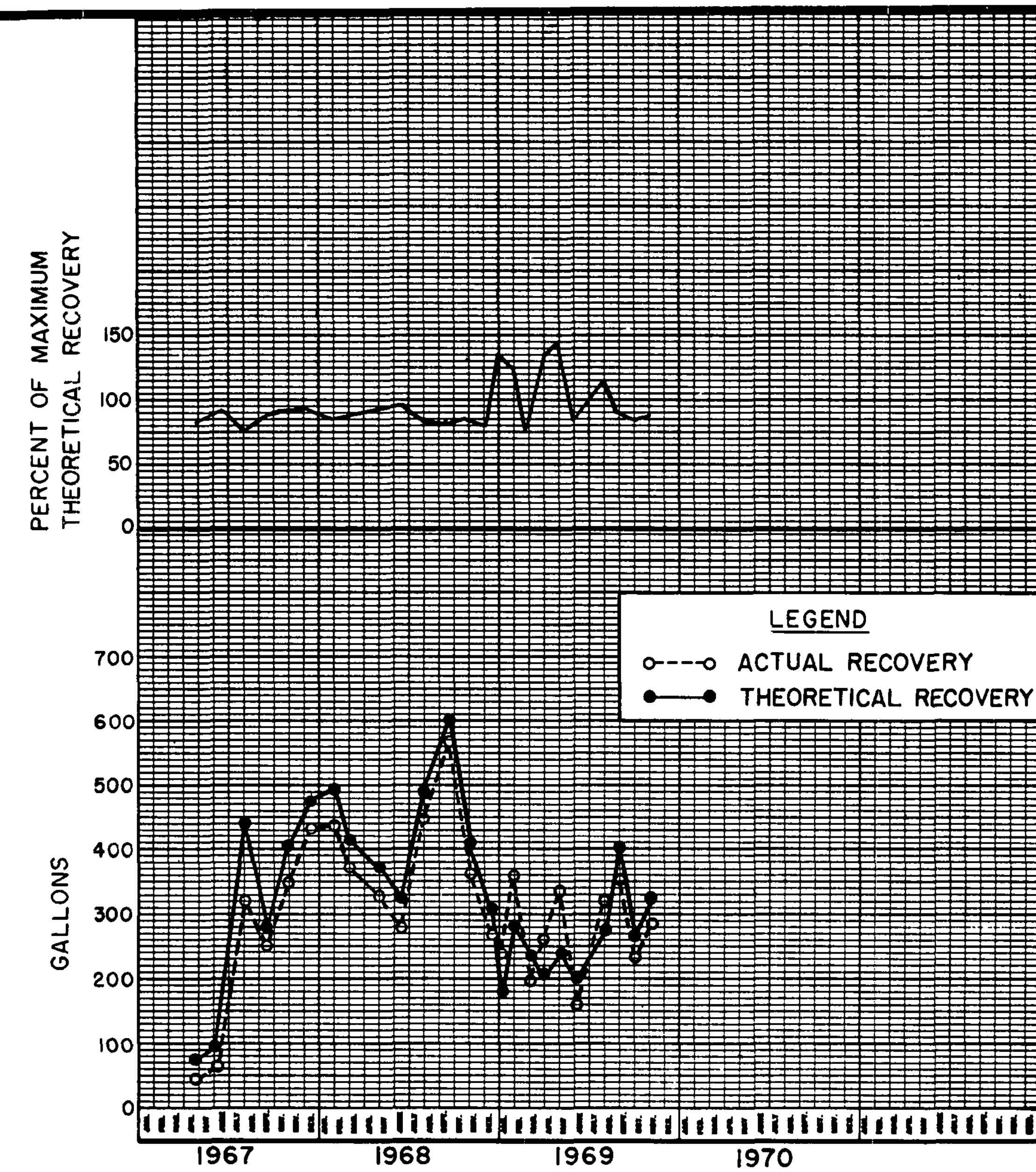


FIGURE 33. SAMPLING PANS RECOVERY RATES

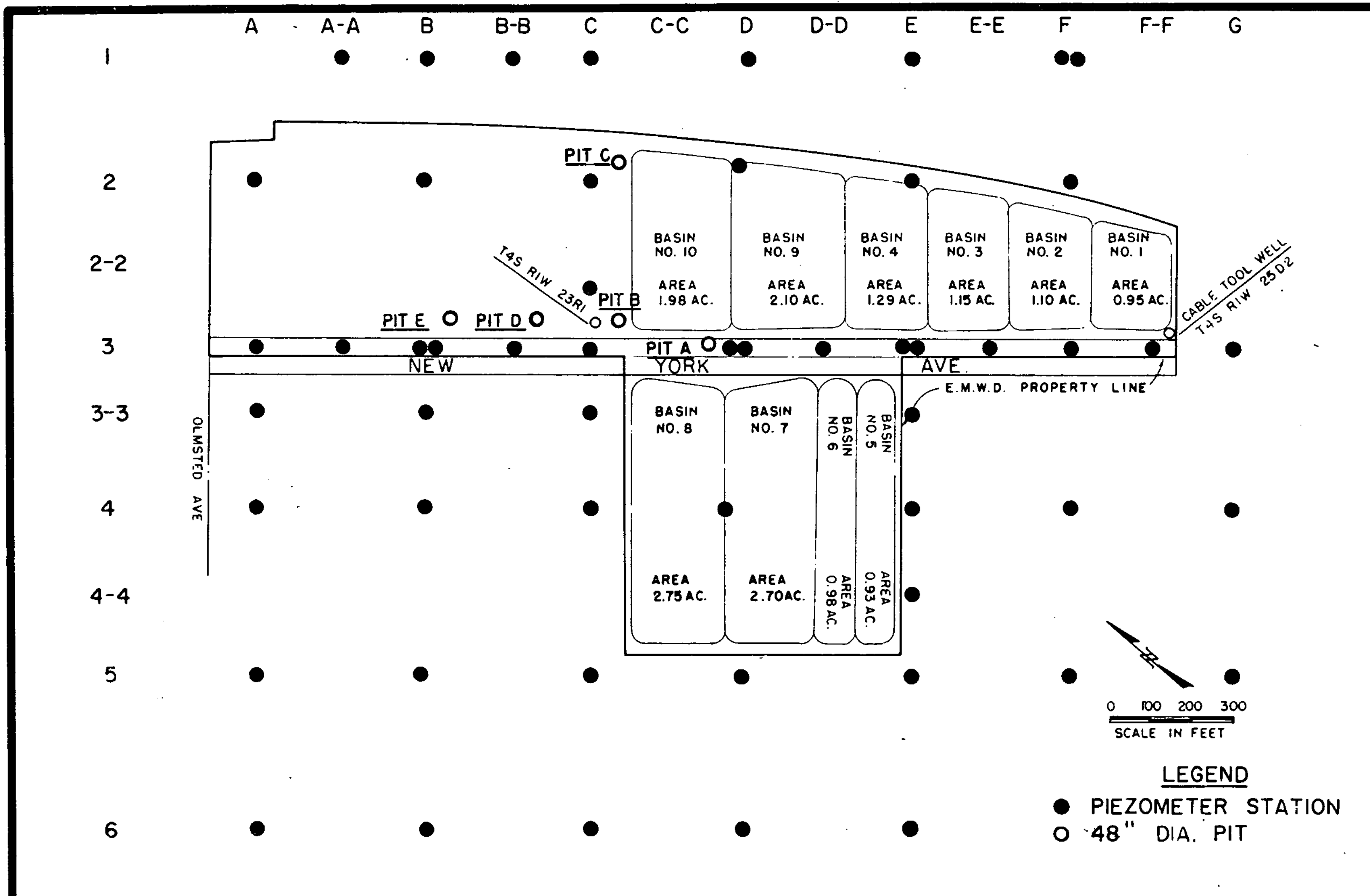


FIGURE 34. PIEZOMETER NETWORK & 48-INCH DIAMETER PIT LOCATIONS

SECTION X

GROUNDWATER QUALITY - GROUNDWATER INVESTIGATIONS

Shallow Groundwater

During installation of the pipelines for spreading basins 7 through 10, in January 1966, water was discovered in the bottom of the 9-foot deep trenches. This water had not been present a year earlier when the pipelines for the first spreading basins were installed. Investigations to determine the extent, quality and volume of this water began in February 1966.

The first step in this operation included drilling five 48-inch diameter pits into this water using unset, unmortared concrete block around the walls to keep the pits open. These pits varied in depth from 8.75 feet to 23.0 feet below the ground surface. Figure 34 shows the location of these five pits, and boring logs are shown on Figure 35. Piezometer pipes, 3/4" in diameter, were jetted to a depth of three feet within a radius of ten feet of four selected pits below the water surface. The elevation of the water in the piezometers and open pits was measured twice, with one week between the readings. These elevations were as follows:

5/19/66	Pit No.	Pit Wtr. Elev.	Piezometer Wtr. Elev.	Difference
	A	1542.0	1541.6	-0.4
	B	1537.6	1534.7	-2.9
	D	1533.4	1535.0	+1.6
	E	1528.1	1527.9	-0.2
5/26/66	A	1541.9	1541.0	-0.9
	B	1536.7	1536.6	-0.1
	D	1533.1	1533.4	+0.3
	E	1528.4	1528.4	0.0

A plus (+) indicates that the water in the piezometer is higher than the water in the open pit.

The large discrepancies in water surface elevation between the piezometers and pits was thought to be due to the piezometers not reflecting a slow change of water surface in the soil. Prior to recording another set of readings, the piezometers were pumped dry, thereby creating a larger hydraulic differential between water in the soil and the empty piezometers. The water levels in the piezometers recovered rapidly and readings taken 24 hours later showed no appreciable difference between the water surface in a pit and adjacent piezometer.

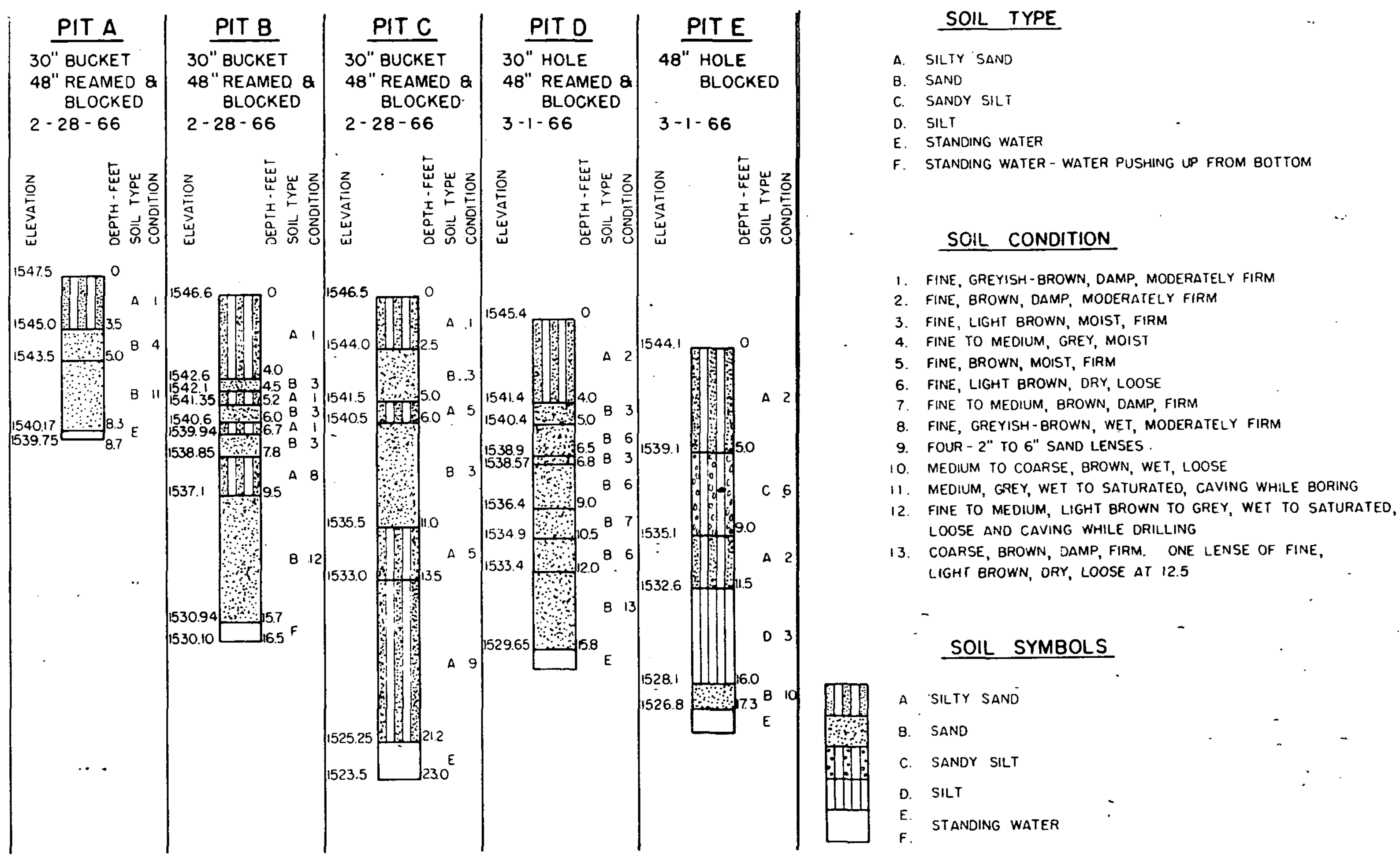


FIGURE 35. BORING LOGS FOR PERCHED EFFLUENT WATER

Subsequently, all piezometers were pumped and allowed to recover prior to obtaining a reading of the water elevation.

Based on the information obtained from these preliminary piezometers, Professor Arthur Pillsbury was retained to assist with installation of a network of piezometers to establish the extent, volume and quality of this shallow groundwater. Under the direction of Professor Pillsbury, 3/8" galvanized piezometers were jetted into place using bentonite as a drilling mud when necessary. However, it was necessary to flush the bentonite with clean water. A 3/8" coupling was screwed onto the top of each piezometer and rivets were placed inside the couplings to form a protective seal to prevent foreign material from entering the piezometer.

The original piezometer network was expanded several times in order to adequately sample the spreading groundwater. The complete network is shown on Figure 34.

At its ultimate expanse the majority of the piezometers within the network were outside District-owned property. Some of these were damaged and replaced between 1966 and 1969. In the spring and summer of 1969 farming operations and flood control work destroyed most of the piezometers that were outside the replenishment area and thereafter no pertinent data was obtained from them. Up to that time, the piezometers were used to obtain shallow groundwater elevations and water samples for both chemical and bacteriological analysis. The laboratory results are discussed later in this section.

Water samples from the 48-inch pits were analyzed for both chemical and bacteriological content in May and August, 1967. Prior to taking bacteriological samples the pits were heavily chlorinated and this water was then pumped out until the water flowing into the pit had a zero chlorine residual. Of the four pits tested in this manner, three were negative for fecal coliform. Results of the fourth, Pit D, although positive, had to be abandoned when a close examination revealed the remains of a dead rabbit in the bottom. Further attempts to obtain bacteriological samples from the pits were thereby abandoned, as it proved to be too difficult to properly disinfect the pits.

Chemical analyses of water from the pits and the first piezometers indicated that the shallow groundwater was the same as the water being spread. However, several piezometers and pits had water with very high filterable residue concentrations in the initial samples. In a short time the high TDS water disappeared. As the shallow mound expanded, additional piezometers were installed over a larger area. Some of these new piezometers experienced the high filterable residue also. Apparently, the high TDS water was the first water that was spread, and had initially leached any accumulated salts from the spreading basins; thus, any samples from the leading edge would have a high TDS.

Figures 36, 37 and 38 are plots of the change in the depth to the shallow groundwater which occurred in 1966-1967, 1967-1968 and 1968-1969 respectively. These figures indicate that the percolated wastewater moved primarily in one direction during some periods, apparently depending upon which basins are being used most heavily, but they indicate that over the entire spreading period the water has expanded in all directions. These figures also indicate that the configuration of the underground area reached by the spread water, which originally was thought to be circular, now appears rather obscure. When comparing the piezometer data with other information obtained from the thermal surveys, it seems that a symmetrical or truncated cone type of mound was never developed because of the non-homogeneity of the graben in the vicinity of the replenishment area and an apparent escape of the water to the river underflows.

Quality of the shallow groundwater has been monitored through the piezometers and sampling pans. Appendix 3, Volume II of this report shows the chemical quality of the water from the piezometers and of the water being spread. It is apparent that the water found in the piezometers is the same as that being spread.

In 1967, 12 water samples from piezometers C-2, -3, D-3, -5, E-3, E-4, -5 and F-3, were analyzed for coliform and fecal coliform. Prior to obtaining a sample, each piezometer was heavily chlorinated and the water withdrawn until a chlorine residual of zero was obtained. Seven of the 12 samples were positive for coliform, but all 12 were negative for fecal coliform. In 1968, 24 additional samples were analyzed for coliform and fecal coliform. Again there were seven positives for coliform and all negative for fecal coliform.

After the sampling pans and sampling structure were installed in basin 1, a routine sampling program was established. Figures 39 through 45 are graphs of the data from the pans. Each point on these graphs represents an average of approximately 35 samples, except where noted.

Figure 39 is a graph of non-filterable residue versus pan depth. The percentages of suspended solids that are volatile are also shown. There are two apparent anomolies on the graph; i.e., high non-filterable residue from the four-foot pan in the fill and high percent

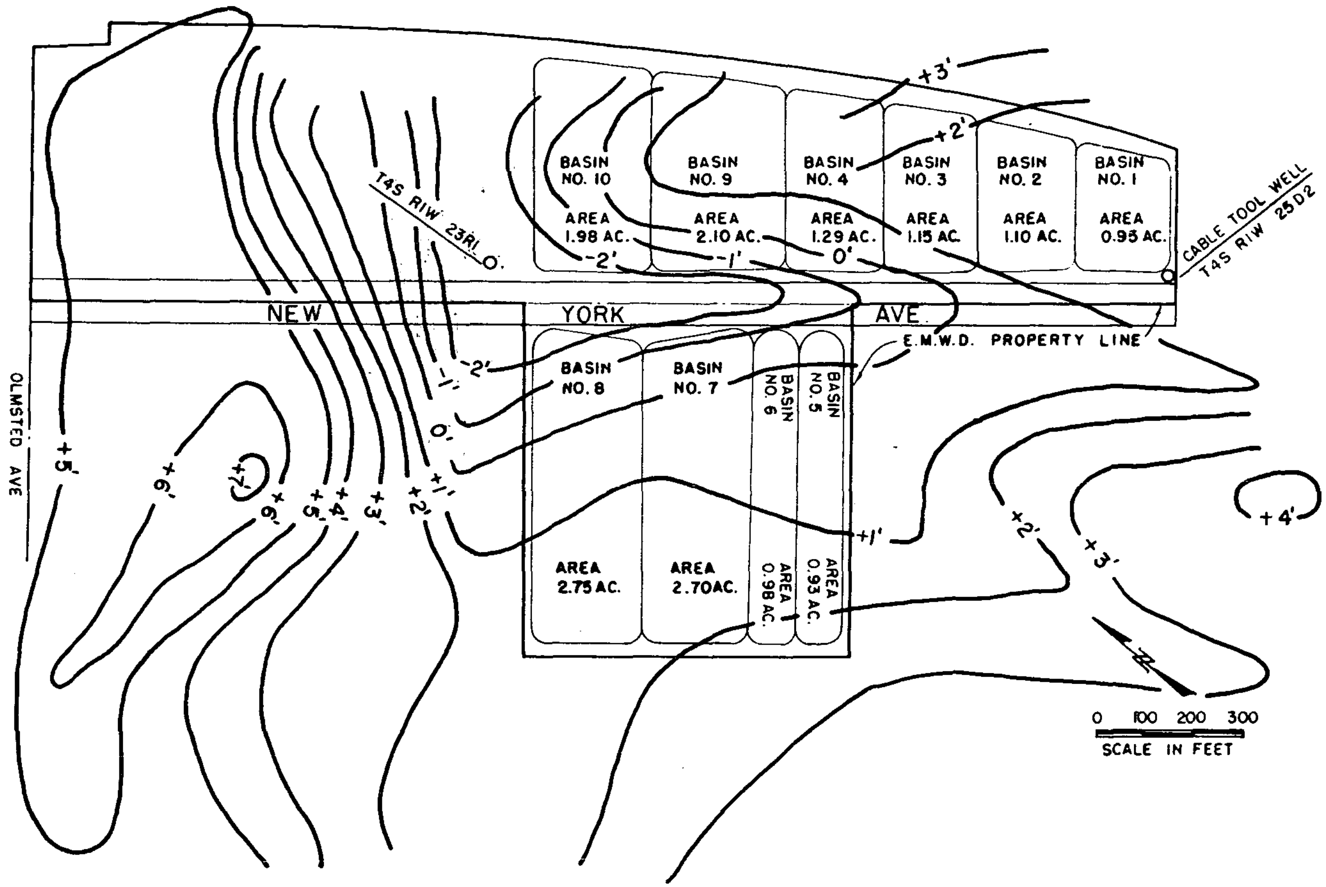


FIGURE 36. GROUNDWATER MOUND CHANGES 1966-1967

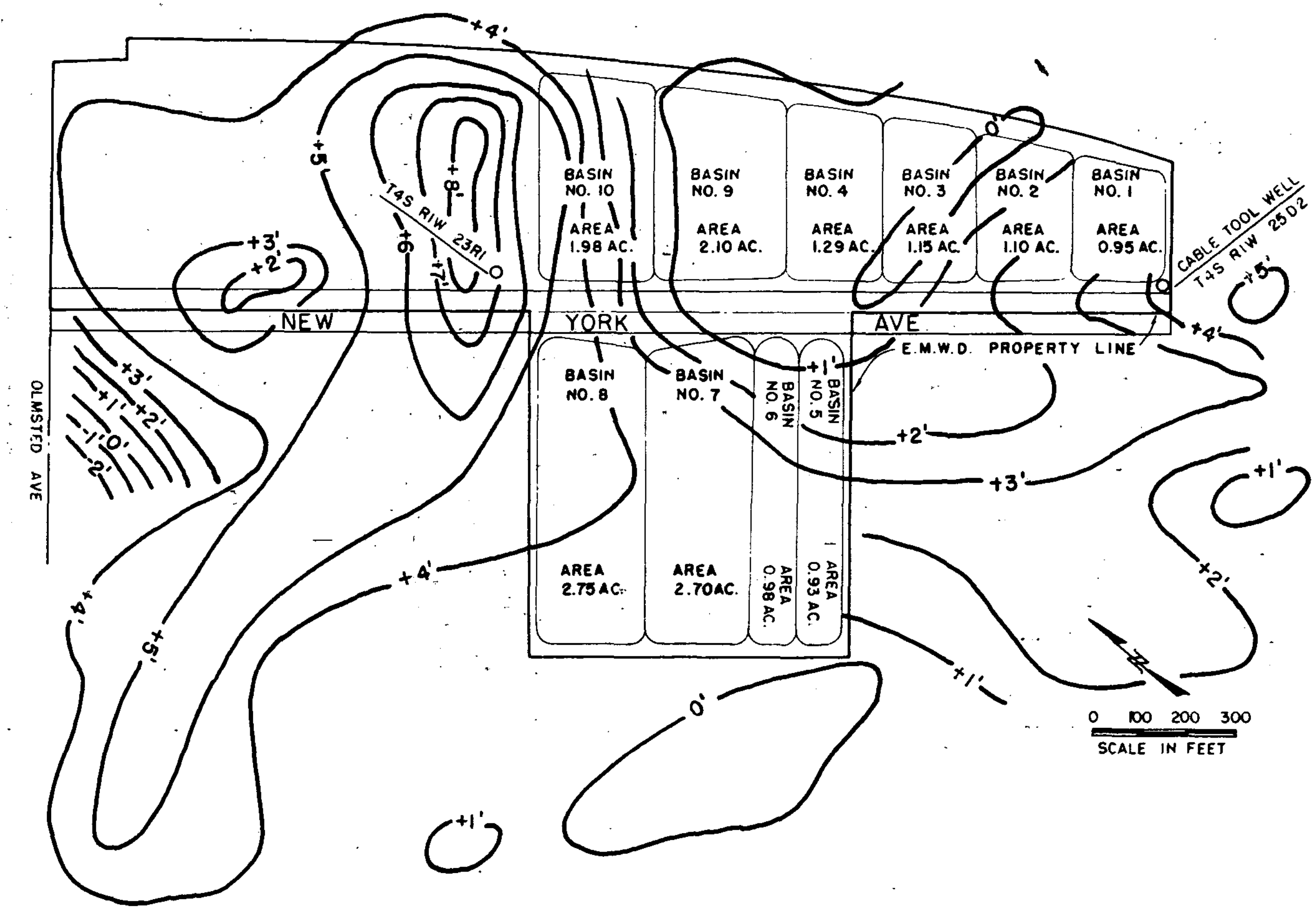


FIGURE 37. GROUNDWATER MOUND CHANGES 1967-1968

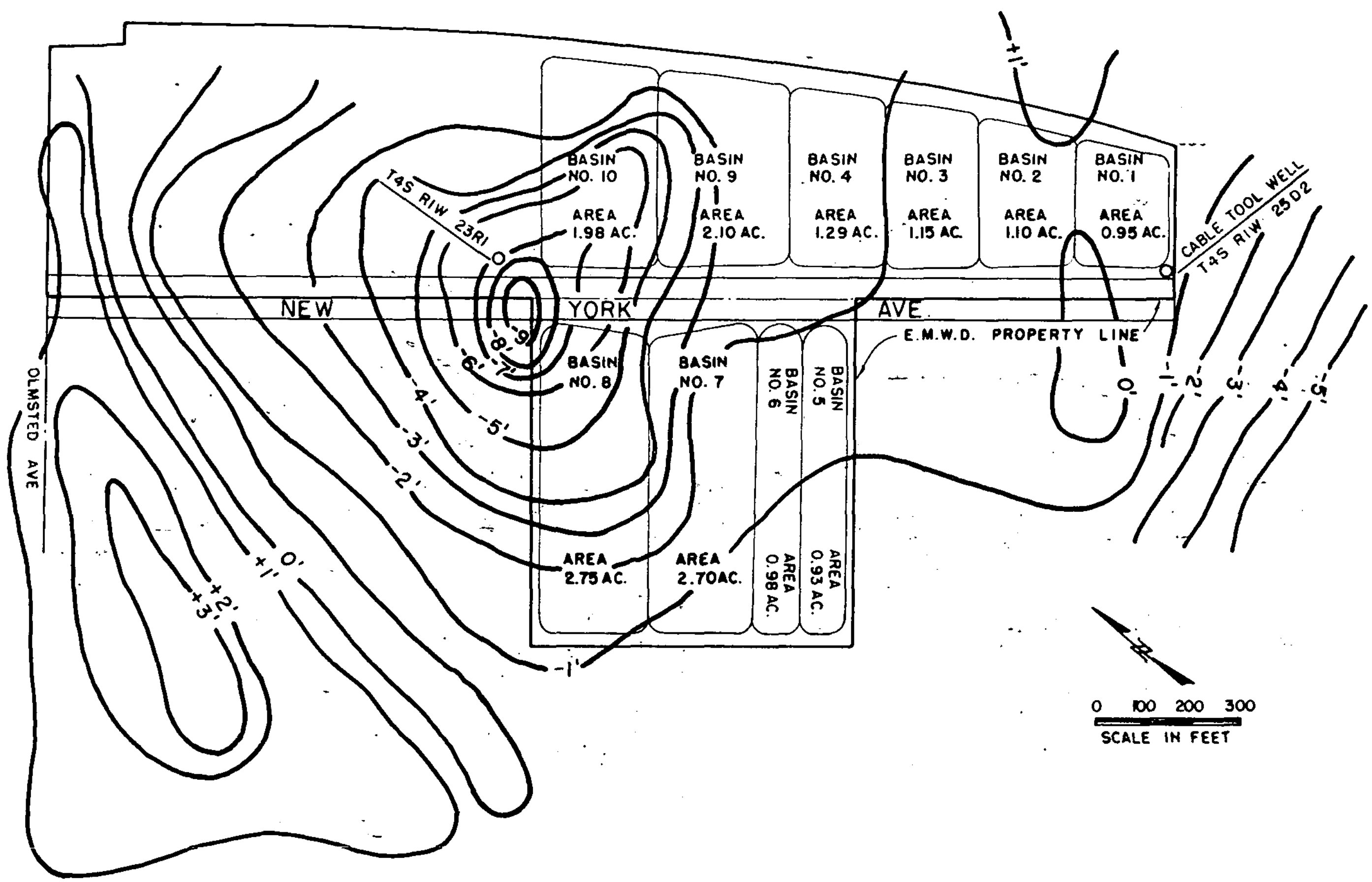


FIGURE 38. GROUNDWATER MOUND CHANGES 1968-1969

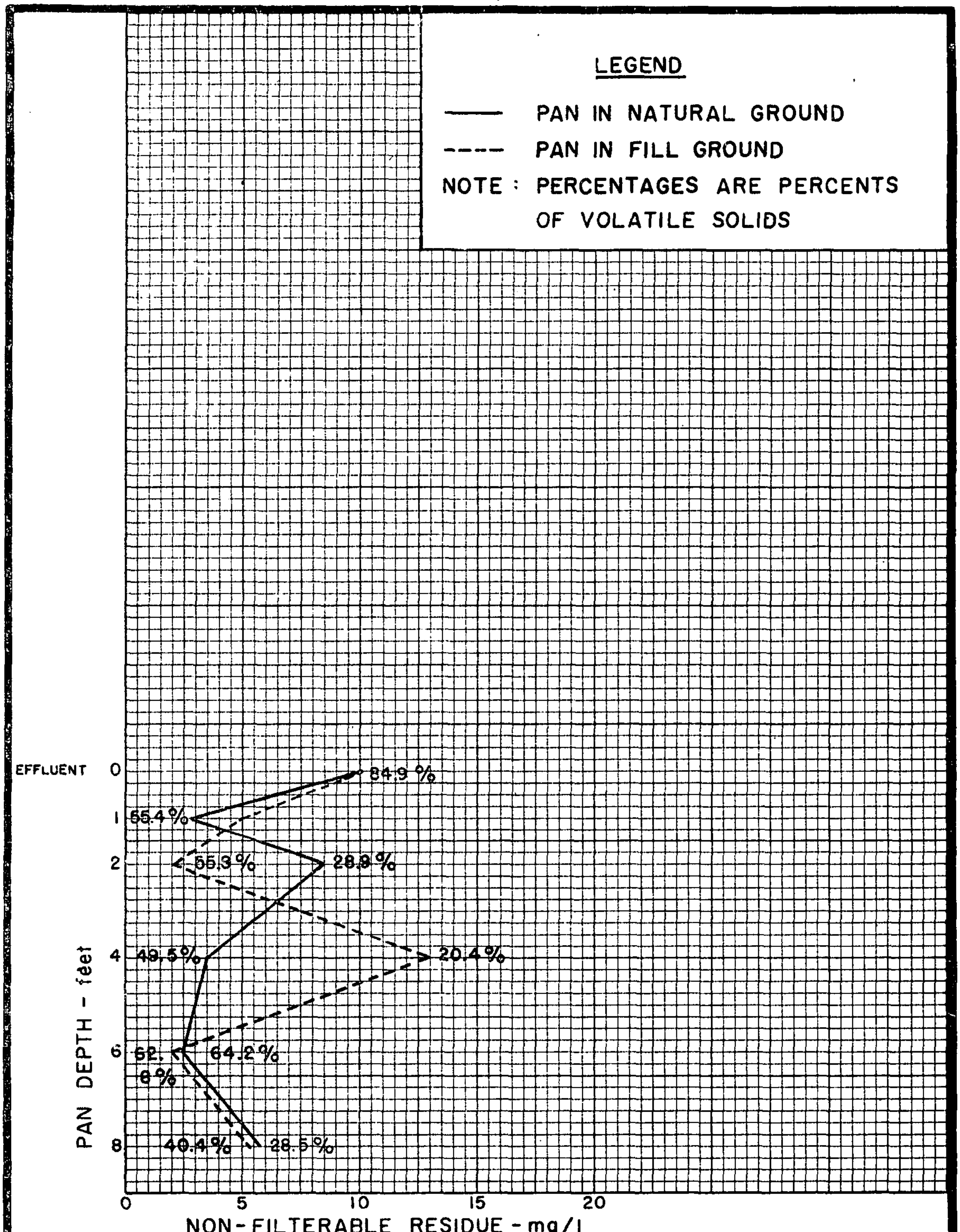


FIGURE 39. ANALYSES OF PERCOLATING WATER FROM SAMPLING PANS - NON-FILTERABLE RESIDUE

volatile solids from both six-foot pans. The material in the sample from four feet is probably sand as it has a low percentage of volatile solids. The reason for the high percent volatile solids at six feet is not known. Figure 40 is a plot of nitrate-nitrogen concentration versus pan depth. It is interesting to note that the two-foot, four-foot, and six-foot pans in the natural soil have higher concentrations than the eight-foot pan in the natural soil. However, pans at the same depths in the fill don't exhibit the same tendencies.

Water samples from each pan have been analyzed for methylene blue active substances (MBAS) concentrations. The results are shown on Figure 41. The concentrations of MBAS found in water from pans in either the fill or natural soil are very similar. The MBAS concentrations found in water from the four-foot, six-foot, and eight-foot pans are sufficiently low that it is no longer a significant factor. Indeed, the sum of the interference with the testing procedure could probably account for most of the MBAS found.

The chemical oxygen demand (COD) both total and dissolved, is plotted on Figures 42 and 43, respectively. COD concentrations found in water from pans in natural soil are generally similar to those found in water from pans in the fill soil. The total COD decreases 24 mg/l in the first one foot of soil, 8 mg/l in the next three feet of soil, and only 2 mg/l in the next four feet. That is equivalent to a 44 percent drop in the first foot, 33 percent drop in the next two feet and 25 percent drop in the next four feet. The dissolved COD undergoes a 53 percent drop in the first foot, 13 percent in the next three feet and 20 percent in the last four feet.

Samples from the pans have been analyzed for both coliform and fecal coliform. Figure 45 is a plot of these data versus pan depth. The figure shows the confirmed coliform concentration for the two-and four-foot depth pans to be approximately equal. The fecal coliform curve indicates less coliform removal per foot in the two- to four-foot range than any other soil section. Studies conducted on the ammonia. nitrate, hardness relationships would lend credence to the report that as ammonia changes to nitrates and the nitrates increase in the soil, the hardness may also increase. However, further study to prove this phenomenon should be conducted.

Deep Groundwater

At the outset of this program, a deep well monitoring program was begun so as to produce a control and standard for later comparisons. The locations of the wells being monitored are shown on Figure 46.

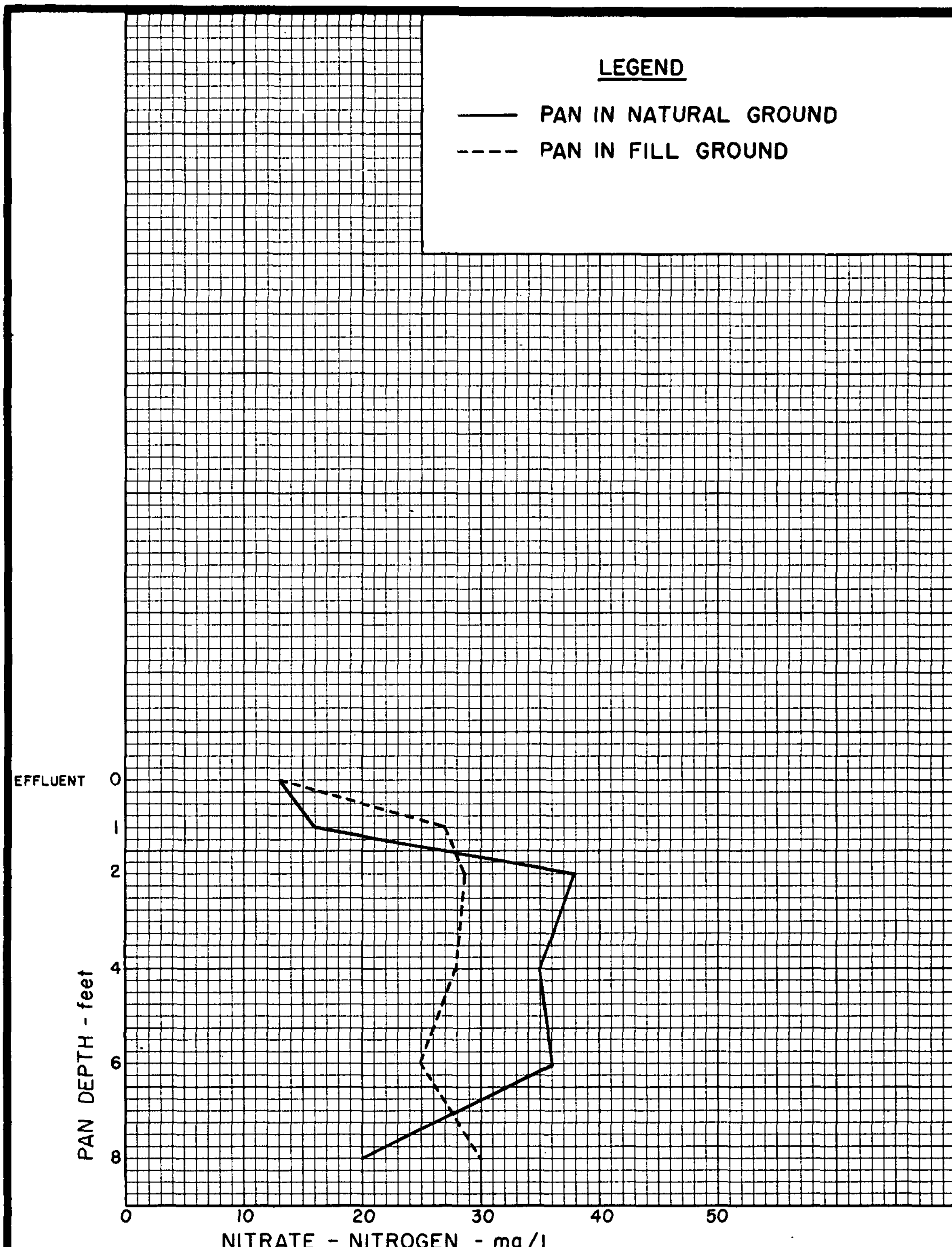


FIGURE 40. ANALYSES OF PERCOLATING WATER FROM SAMPLING PANS – NITRATE - NITROGEN

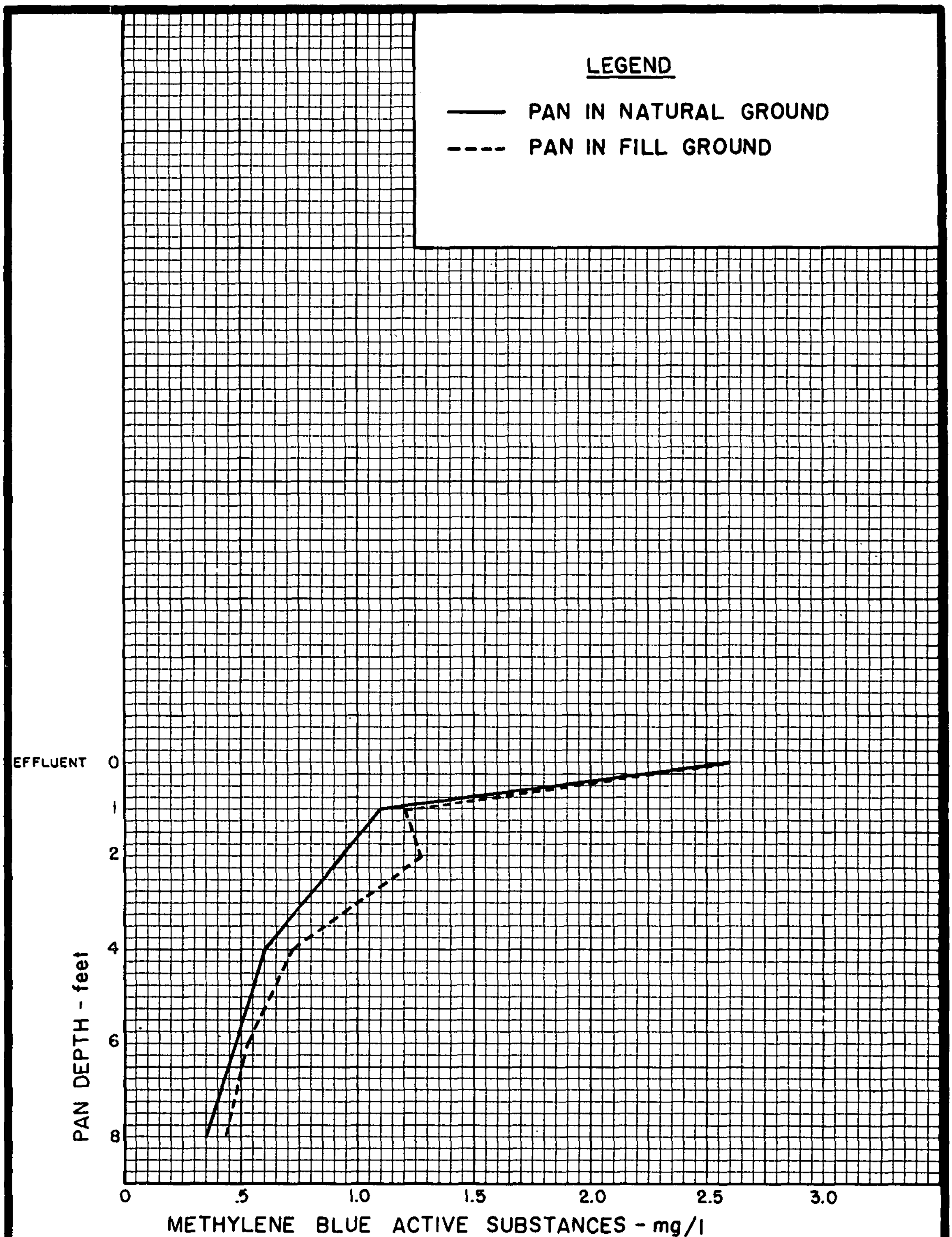


FIGURE 41. ANALYSES OF PERCOLATING WATER FROM SAMPLING PANS - METHYLENE BLUE ACTIVE SUBSTANCES

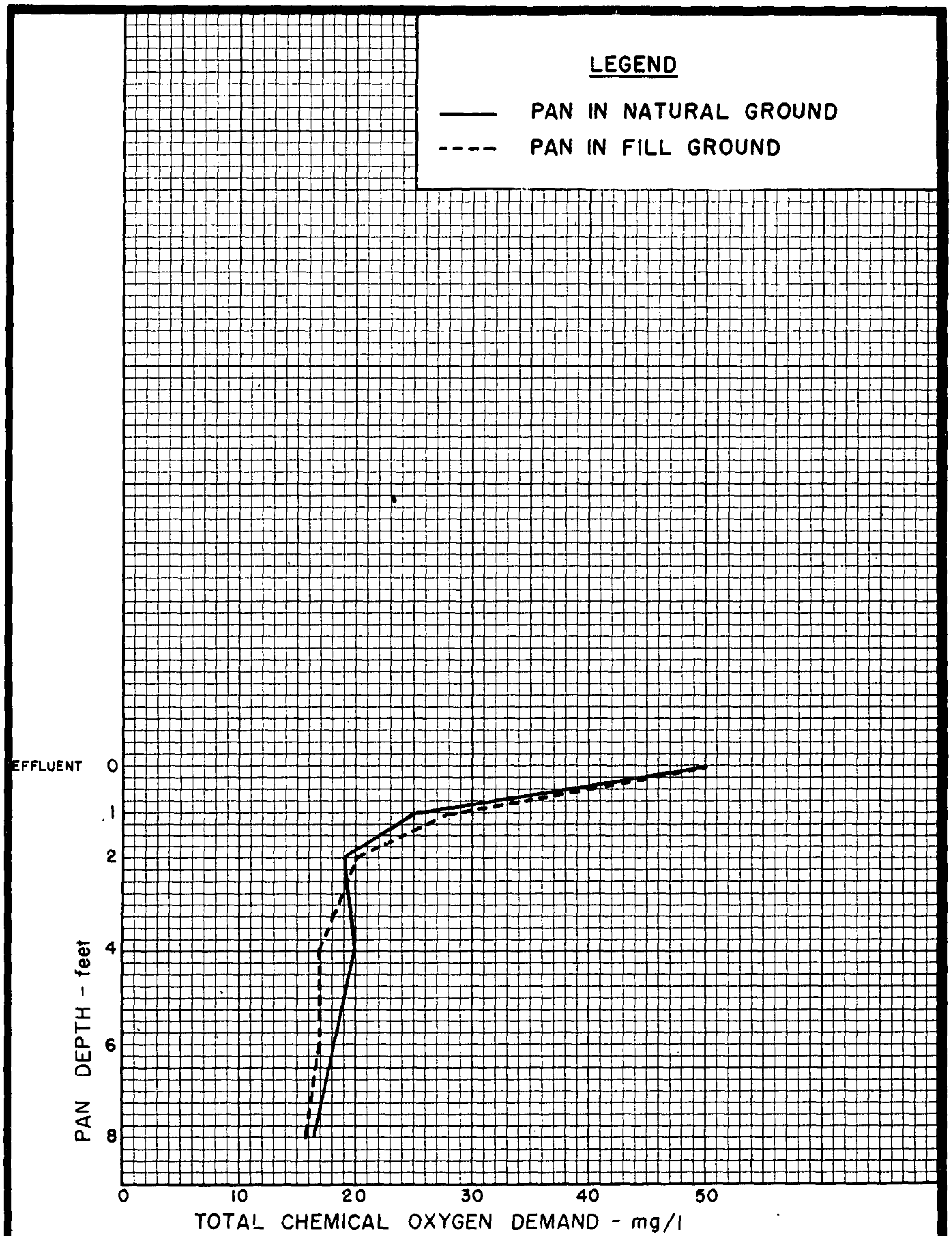


FIGURE 42. ANALYSES OF PERCOLATING WATER FROM SAMPLING PANS - TOTAL CHEMICAL OXYGEN DEMAND

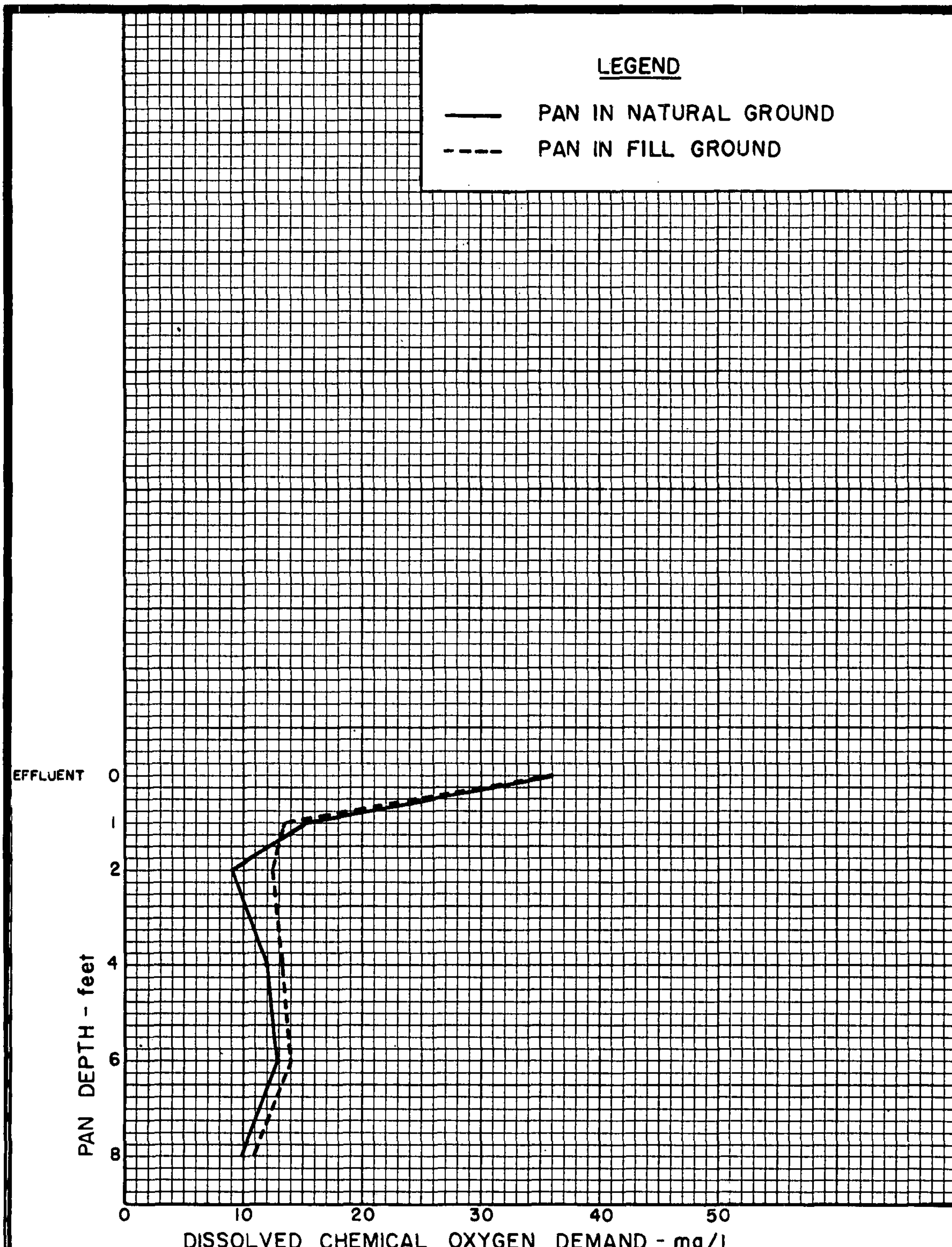


FIGURE 43. ANALYSES OF PERCOLATING WATER FROM SAMPLING PANS - DISSOLVED CHEMICAL OXYGEN DEMAND

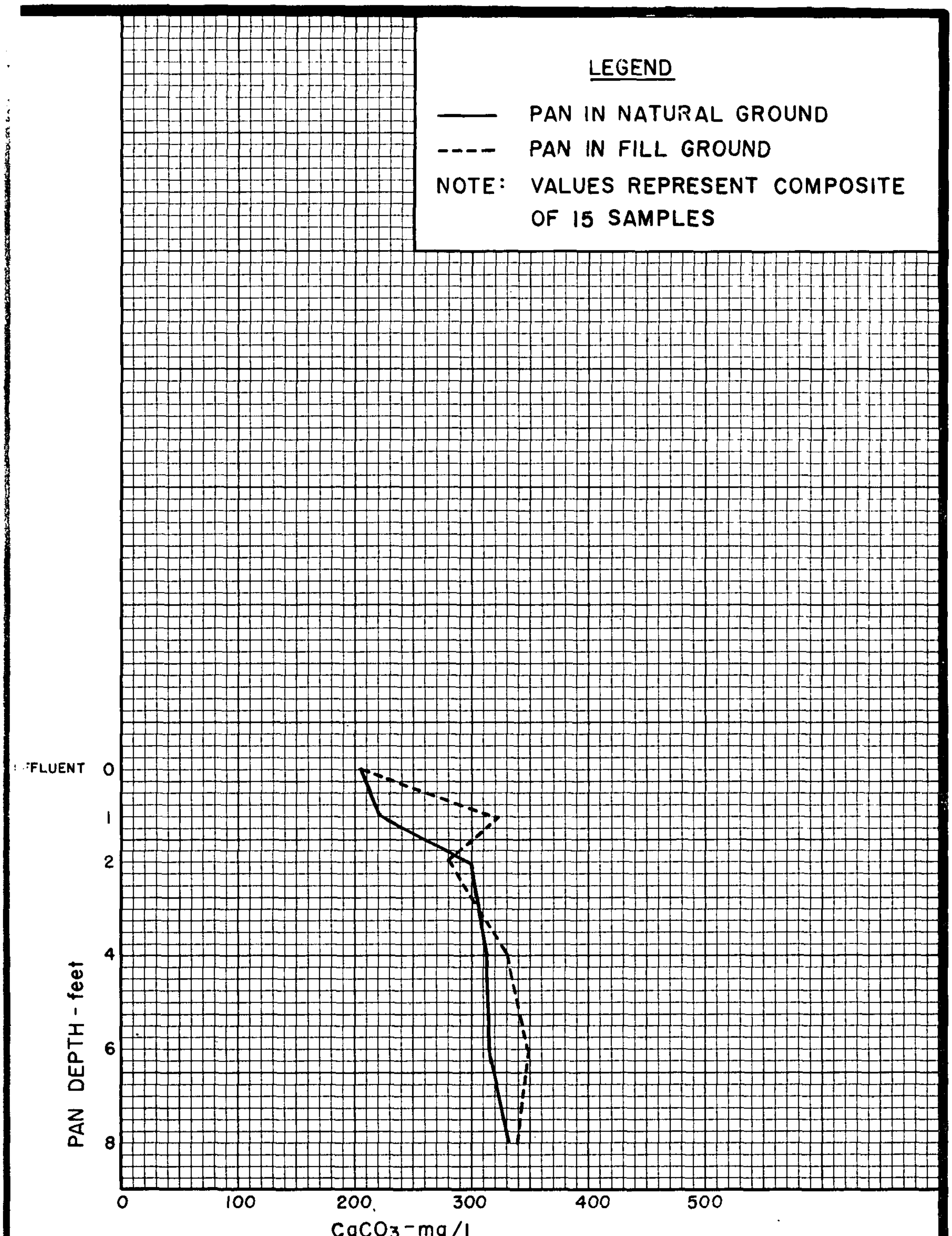


FIGURE 44. ANALYSES OF PERCOLATING WATER FROM SAMPLING PANS - TOTAL HARDNESS AS $CaCO_3$

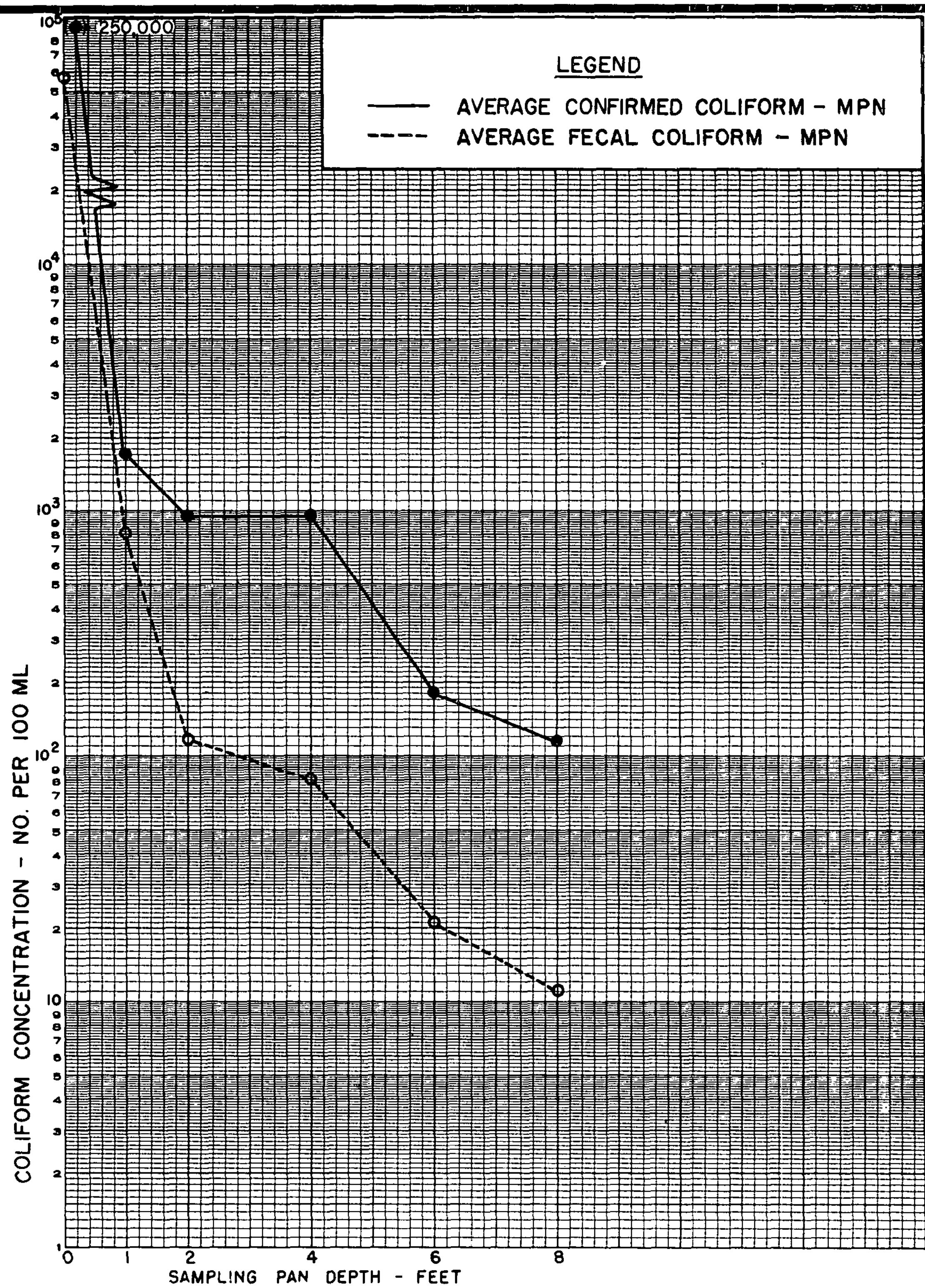


FIGURE 45. ANALYSES OF PERCOLATING WATER FROM SAMPLING PANS - COLIFORM MPN PER 100 ML

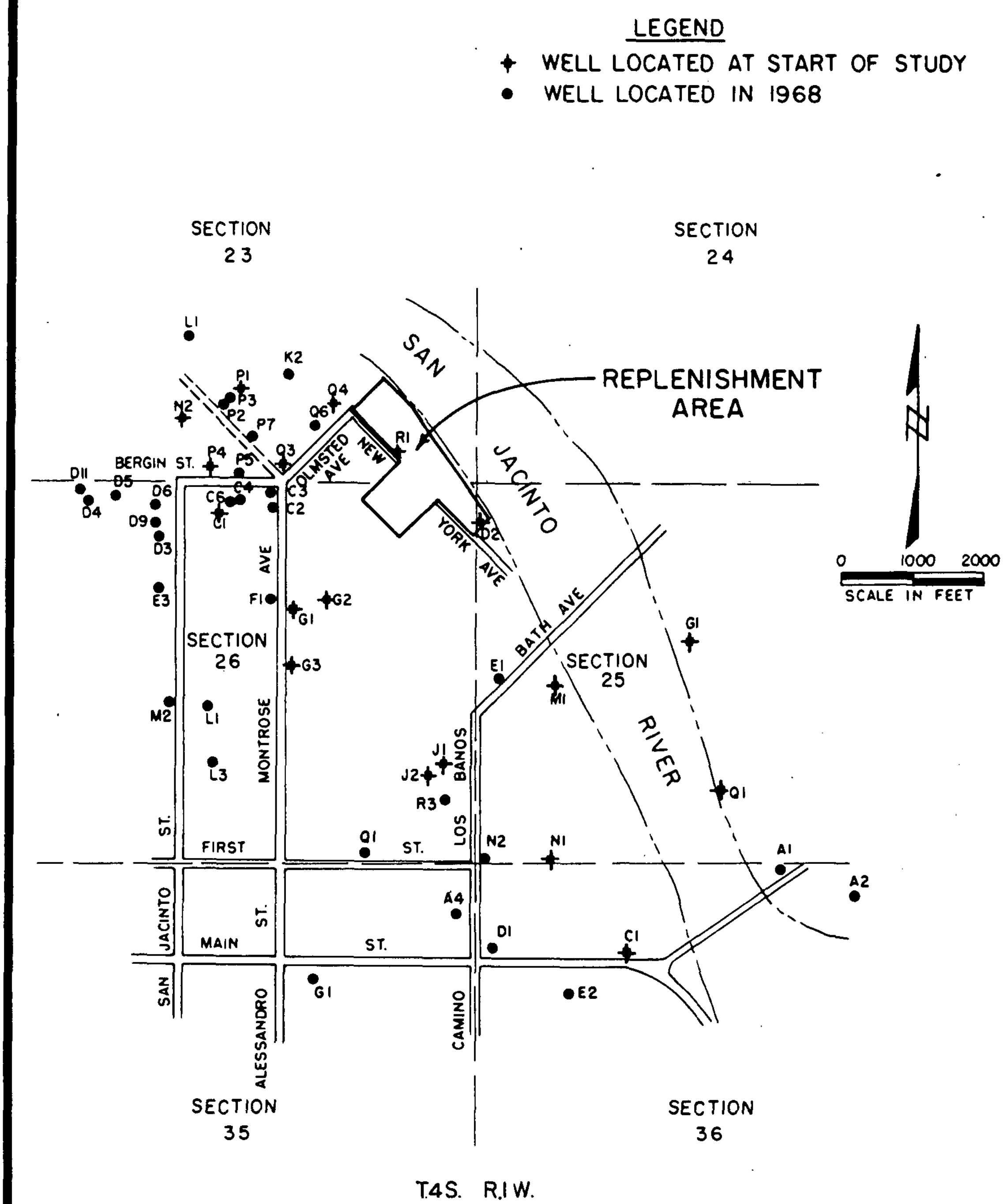


FIGURE 46. <u>WELL LOCATION MAP</u>

The black squares represent wells located at the beginning of the study, while the black circles represent wells added to the program in 1968. Some of the wells are available for both water level and water quality sampling; still others no longer exist, but past data is available. Appendix 4 lists the wells and the information available from them.

As much background data as possible were gathered pertinent to the wells being monitored. These data include past chemical and/or bacterial analyses, well logs and information relative to static water levels of the wells. Samples for chemical analyses have been obtained from all wells that are equipped for such sampling. The results of these analyses are found in Appendix 5, while water level information is found in Appendix 6.

Figures 47 and 48 give deep groundwater contours for 1968 and 1970, respectively. These contours indicate a deep depression north of Main Street from Montrose Avenue easterly to the river. Unquestionably, this depression is caused by heavy pumping. Under the entire area, the groundwater table is reversed by heavy pumping and this reversal might account for some water quality changes. Figure 49 shows annual deep groundwater profiles for the years 1965 through 1970. This profile runs approximately down New York Avenue and is shown in plan view on Figures 47 and 48. (These profiles indicate that the groundwater table has decreased somewhat uniformly along the entire profile line.)

At the beginning of this study it was hoped that groundwater levels and contours would be a valuable tool in tracing the percolated wastewater. These measurements have, however, proven to be inconclusive. Figure 50 represents depth to water in a well versus drilled depth of the well. From this figure it can be seen that the water level in any given well appears to have a definite relationship to the depth to which the well has been drilled. There appear to be a multitude of water levels in the area and deep groundwater contours are therefore not meaningful unless only wells of the same depth are included.

Well 4S1W 23R1 was cleaned out in December 1965. Prior to that time the well was plugged and recorded as being dry. Also late in 1965, well 4S1W 25D2 was dug 820 feet deep using the cable tool drilling method. Soil samples were obtained from each soil lens as the well was being dug. The majority of the soil is a silty sand with various strata ranging from coarse sand to fine silt. Very little gravel and essentially no clay was encountered. The log of this well appears as Table 20.

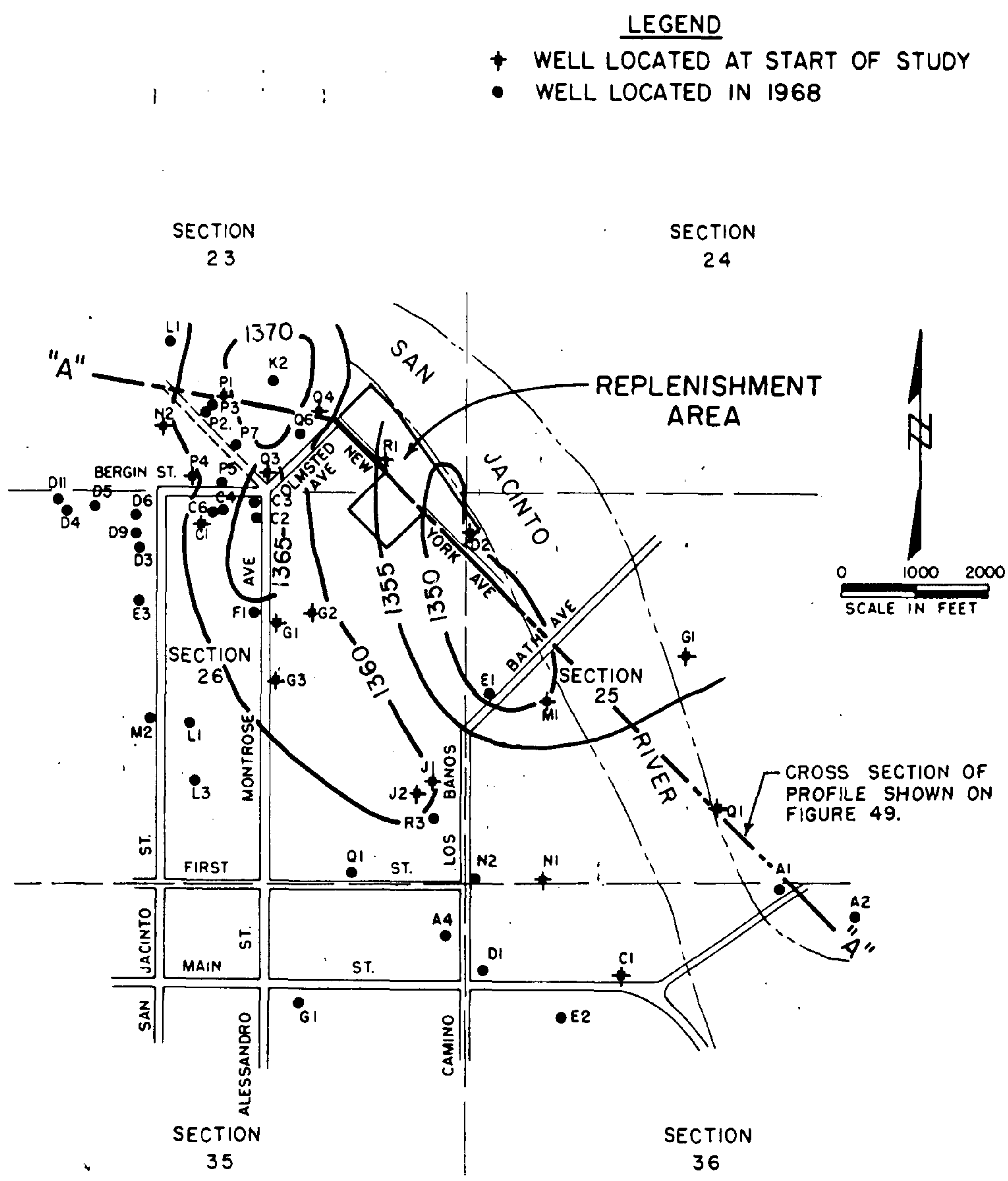


FIGURE 47. DEEP GROUNDWATER CONTOURS NOVEMBER 1968

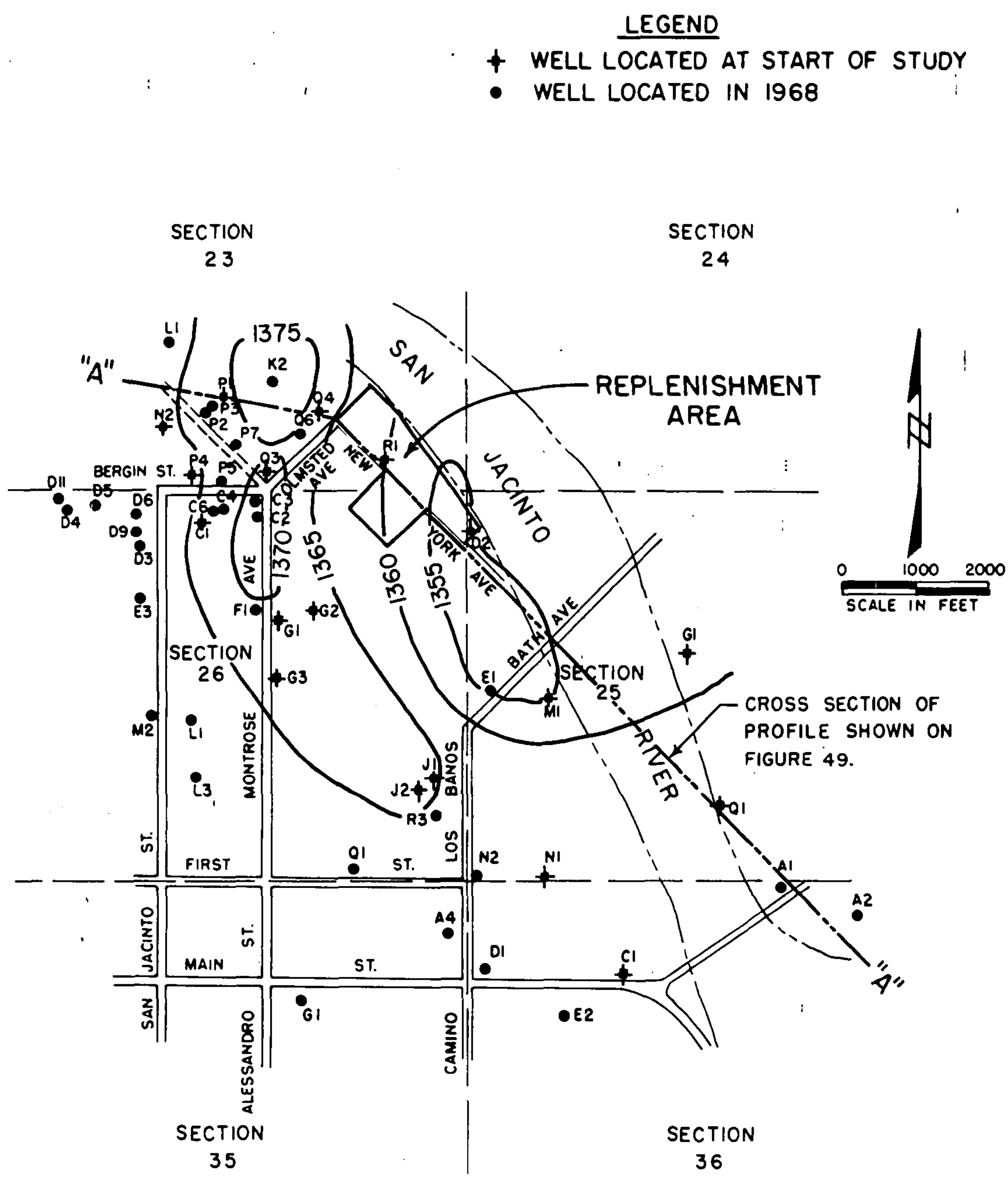


FIGURE 48. DEEP GROUNDWATER CONTOURS NOVEMBER 1970

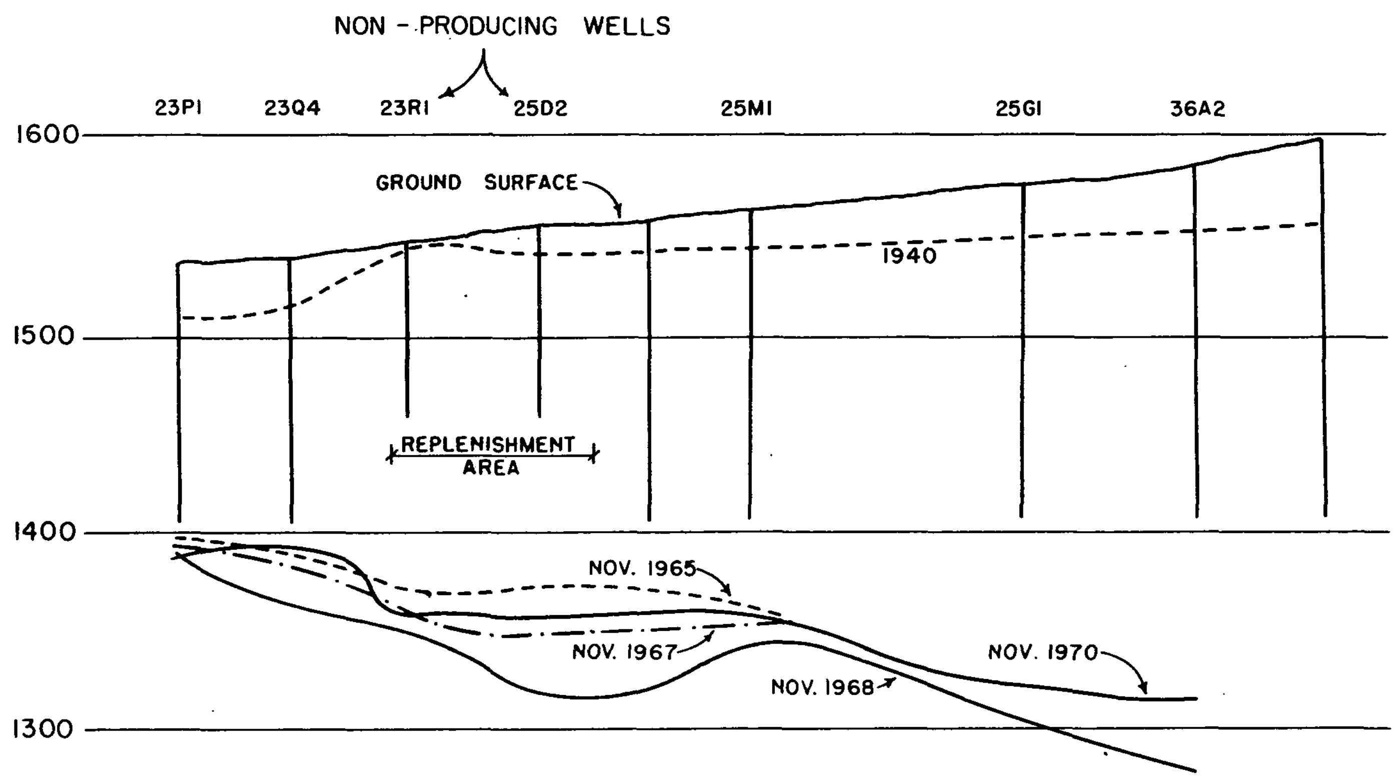


FIGURE 49. PROFILE A-A DEEP GROUNDWATER

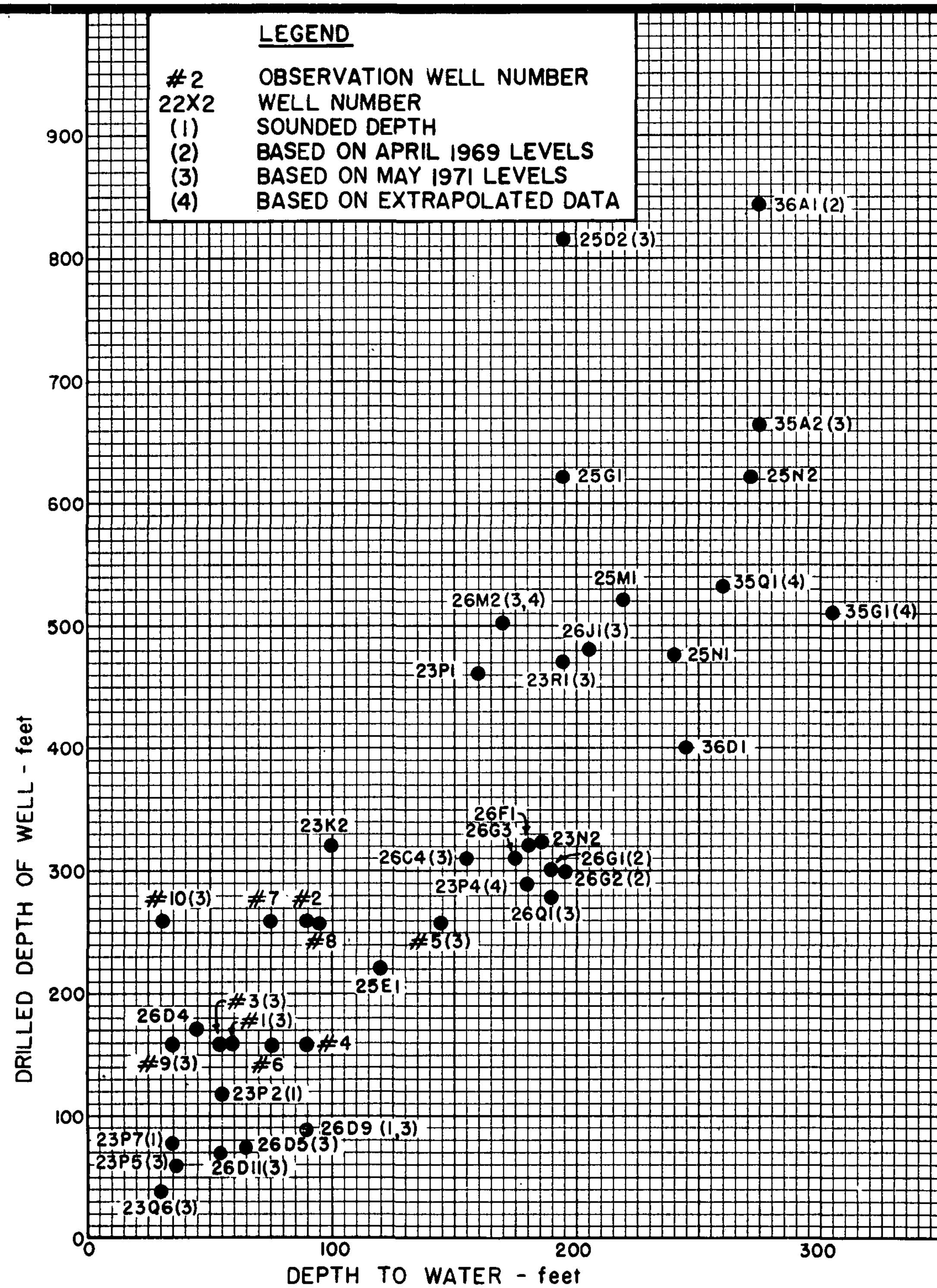


FIGURE 50. DRILLED DEPTH OF WELLS VERSUS DEPTH TO WATER IN WELLS

TABLE 20

Log of Cable Tool Well - 4S1W25D2

			Formation
From	0 feet to	12 feet	Silty sand and sand layers
	12	69	Silt and fine sand
	69	95	Silt and silty clay
	95	111	Silt and fine sand
	111	180	Silt with some fine sand
	180	248	Silt with some fine sand and some clay lenses
	248	263	Silt with some fine-medium sand and pieces of wood
	263	276	Sand and gravel
	276	344	Sand and silt layers
	344	372	Silt and sand with gravelly layers
	372	550	Sand and Silt layers
	550	576	Silt and fine sand
	576	584	Sand
	584	736	Sand and silt with pieces of wood at 720' - 730'
	736	756	Sand
	756	830	Sand and silt with pieces of wood at 790'

Casing Installed

0	692	- 10 gauge double wall 12" diameter
692	820	- 5/16 wall 12" diameter

Perforation - Roscoe Moss Tool

170	300
345	355
395	405
445	455
500	600
645	655
695	705
745	755
795	805

Total Cut - 290'

Both well 4S1W 23R1 and the new cable tool well, 4S1W 25D2, have 12-inch casings, but the perforation depths are unknown in 23R1. The perforations in the cable tool well are as follows: 170 feet below the surface to 300 feet; 10-foot zones at 350 feet, 400 feet, 450 feet; 10-foot zones at 650 feet, 700 feet, 750 feet and 800 feet. The entire casing between 170 feet to 300 feet and 500 feet to 600 feet was perforated, as these are the strata which contain the coarsest sand. The 10-foot zones were perforated for sampling.

The reasons for drilling the cable tool well were:

1. To have a deep groundwater sampling well south of the spreading basins;
2. To establish a deep soil log in the replenishment area;
3. To use this well in the future for pumping the blended groundwater and reclaimed water into a water system for reuse.

Since gravel was not encountered and since the well itself was not gravel-packed it was doubtful if the cable tool well would be a good producing well. This was later confirmed by a pumping test on the well which yielded approximately 350 gpm while producing fine sand. The cable tool method was used for drilling so that different zones within the aquifers could be isolated and sampled with a packer pump. A "packer pump" is a submersible pump with inflatable rubber seals above and below the pump intake. Even though the casing is flush against the soil, the packer pump is not as long as the smallest 10-foot perforated zones and some short-circuiting of the water in the casing above or below the packer pump into into the soil and back into the packer is possible. It is also possible that a certain amount of intrusion by water from one aquifer into another will occur through the perforations in the well casing. This would be due to the difference in static heads between the separate aquifers.

The water samples which were taken from well 23R1 and the cable tool well in May 1966 and shown in Table 21 were obtained by California Department of Water Resources personnel using their packer pump.

A packer pump was built by Eastern Municipal Water District, incorporating the design of packer pumps built by Los Angeles County Flood Control District and by the Department of Water Resources. A sketch of the pump is shown in Figure 51. The cable tool well and Well 23R1 were sampled through the use of the District's packer pump in December 1966, July 1967, November 1968 and July 1969. Results of the analyses of these samples are shown on Tables 21 through 25.

TABLE 21

RESULTS OF ANALYSES OF GROUND WATER
FROM CABLE TOOL WELL AND WELL 4S-1W-23R1
THROUGH USE OF PACKER PUMP
(milligrams per liter)

May, 1966

			4S-1W-23R1	Effluent
	190' deep	350' deep	280' deep	1966 Average
Calcium	49	48	38	64
Magnesium	6	6	4	11
Sodium	30	31	23	125
Potassium	3	3	4	19
Ammonium	-	-	-	-
Carbonate	0	0	0	0
Bicarbonate	206	205	178	268
Sulfate	12	13	7	152
Chloride	20	21	13	107
Nitrate	4	4	5	26
Fluoride	0.5	0.5	0.3	0.7
Total Dissolved Solids	262	262	188	671
Boron	Trace	Trace	Trace	0.8
Surfactants	-	-	-	1.7
Hardness as $CaCO_3$	146	145	114	206
E.C. x 10^6	436	438	327	1053
pH	8.0	8.0	7.9	-

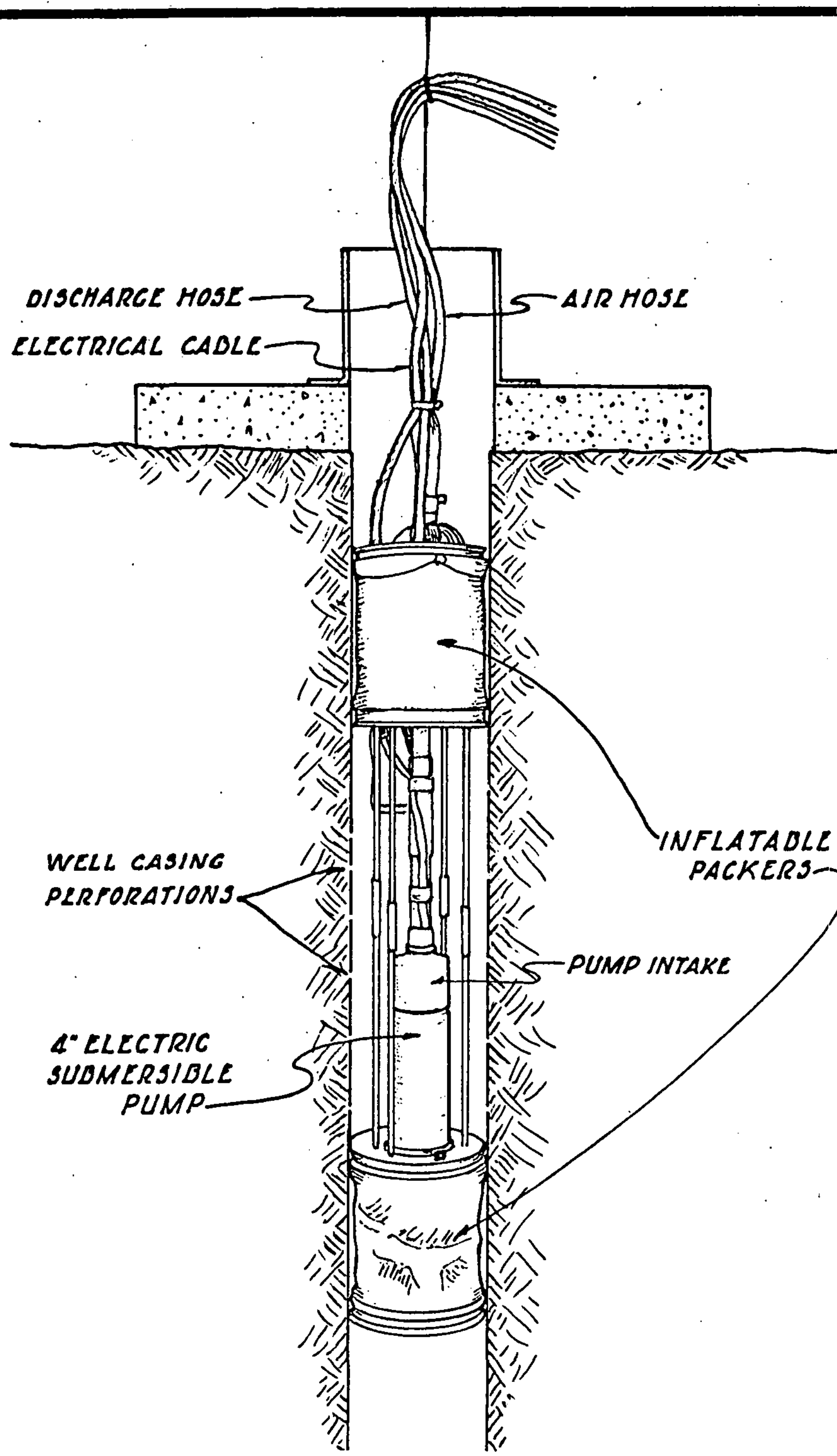


FIGURE 51. DIAGRAM OF PACKER PUMP

TABLE 22

ANALYSES OF SAMPLES FROM GROUND WATER
THROUGH USE OF PACKER PUMP, DECEMBER 1966
(milligrams per liter)

Depth to	Cable Tool Well												Well No. 4S-1W-23R1			Reclamation Facility Effluent 1966 Average
Sample:	200	250	300	350	400	450	500	550	596	650	698	750	200	250	300	
Calcium	46	44	43	44	46	46	46	46	46	44	46	45	34	40	40	64
Magnesium	7	6	6	6	7	7	7	8	8	7	7	6	4	5	6	11
Sodium	33	31	30	29	30	30	30	29	30	29	32	30	[illegible]	26	26	125
Potassium	3	2	2	3	3	2	3	2	3	2	3	3	2	2	2	19
Ammonia	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.5	0.5	0.6	-
Carbonate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate	201	194	192	192	199	200	202	204	206	200	204	202	171	190	190	268
Sulfate	20	13	13	14	14	14	15	14	14	12	24	13	2	1	4	152
Chloride	19	18	17	16	17	16	16	16	16	16	16	16	12	11	12	107
Nitrate	0.9	0.9	1.3	0.9	1.3	1.3	1.8	1.3	1.7	1.3	1.3	1.3	0.5	0.5	0.5	26
Fluoride	0.3	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.3	0.2	0.3	0.2	0.1	0.2	0.2	0.7
T. D. S.	245	226	229	228	235	236	236	244	241	227	234	226	178	194	201	671
Boron	0.12	0.13	0.17	0.20	0.12	0.11	0.16	0.20	0.10	0.16	tr.	0.18	0.17	0.20	0.19	0.8
Surfactants	0.1	0.1	0.1	0	0.1	0	0	0	0	0	0	0	0.1	0.1	0.1	1.75
Hardness as $CaCO_3$	143	136	134	134	142	142	144	146	145	138	142	138	102	122	124	206
ECX 10^6	414	385	384	385	396	393	396	399	397	390	397	392	315	340	339	1053
pH	7.7	7.7	7.6	7.7	7.7	7.7	7.8	7.8	7.8	7.9	7.9	8.0	7.8	7.8	7.8	-

TABLE 23

ANALYSES OF SAMPLES FROM GROUND WATER
THROUGH USE OF PACKER PUMP, JULY, 1967
(milligrams per liter)

Depth to	Cable Tool Well (4S-1W-25D)												Well No. 4S-1W-23R1			Reclamation Facility Average 1966
Sample:	200	250	300	350	400	450	500	550	590	650	700	750	200	250	300	
Calcium	45	39	40	38	38	39	39	39	38	39	40	40	31	39	40	64
Magnesium	8	6	6	5	5	6	5	6	5	6	6	6	4	5	4	11
Sodium	30	25	26	26	25	26	-	-	-	-	-	-	24	21	23	125
Potassium	3	2	2	3	2	2	-	-	-	-	-	-	3	2	2	19
Ammonia	0.2	0.4	0.3	0.3	0.4	0.3	0.2	0.2	0.0	0.0	0.0	0.1	0.3	0.2	0.2	-
Carbonate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate	198	176	181	168	171	176	171	172	167	176	183	189	161	175	176	268
Sulfate	15	11	6	9	13	11	14	13	15	7	6	6	2	1	1	152
Chloride	17	15	14	15	13	14	14	13	13	13	13	13	11	12	13	107
Nitrate	5	0	4	2	2	2	1.3	1.3	0.9	3.2	3.2	3.2	4	4	5	26
Fluoride	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.7
T.D.S.	223	191	193	181	187	181	218	212	213	211	214	219	134	166	177	671
Boron	0.14	0.13	0.10	0.15	0.14	0.14	0.02	0.00	0.02	0.02	0.02	0.10	0.09	0.10		0.8
Surfactants	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	1.75
Hardness as $CaCO_3$	143	122	124	116	118	121	121	120	118	120	124	125	96	119	118	206
ECX 10^6	404	345	345	336	339	349	339	341	340	344	348	354	298	322	340	1053
pH	7.3	7.3	7.4	7.4	7.3	7.3	7.5	7.4	7.5	7.5	7.4	7.5	7.4	7.5	7.5	-

TABLE 24

ANALYSES OF SAMPLES FROM GROUND WATER
THROUGH USE OF PACKER PUMP, NOVEMBER 1968
(milligrams per liter)

Depth to Sample:	Cable Tool Well (4S-1W-25D)												Well No. 4S-1W-34R1				Reclamation Facility Effluent 1965 - 68
	235*	240	295	350	400	450	505	550	595	650	700	750	200	220	250	300	
Calcium	44	42	42	43	43	42	42	42	42	41	41	41	20	39	40	45	75
Magnesium	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	12
Sodium	23	20	18	19	20	18	18	18	17	15	15	15	23	13	13	12	125
Potassium	3	2	2	2	2	2	2	2	2	2	2	2	5	2	2	2	19
Ammonia	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	0.26	Tr.	Tr.	Tr.	
Carbonate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate	136	146	146	150	150	144	144	144	144	140	140	140	110	133	135	133	259
Sulfate	4	5	5	7	7	5	5	5	3	3	3	3	5	1	1	2	131
Chloride	19	17	17	17	17	17	17	17	17	16	16	16	18	18	17	17	114
Nitrate	5	1	2	2	2	4	5	4	3	3	4	4	4	3	2	5	24
Fluoride	.27	.36	.37	.35	.37	.25	.25	.25	.37	.27	.27	.27	.38	.53	.51	.28	0.8
T. D. S.	262	212	210	227	225	242	244	238	227	232	234	233	155	205	201	207	674
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Tr.	Tr.	Tr.	Tr.	0.7
Surfactants	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Tr.	Tr.	Tr.	Tr.	1.4
Hardness as $CaCO_3$	118	133	113	116	116	112	112	112	112	110	110	110	63	108	108	122	208
ECX 10^6	405	410	410	410	410	405	405	405	400	400	400	400	400	400	400	400	-
pH	7.95	7.45	7.45	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.65	7.2	7.2	7.55	-

*water surface sample 11/1/68 - non packer pump

TABLE 25

ANALYSES OF SAMPLES FROM GROUND WATER
THROUGH USE OF PACKER PUMP, JULY 1969
(milligrams per liter)

Depth to Sample:	Cable Tool Well (4S1W25DZ)									Well No. 4S1W23R1			Reclamation Facility Effluent 1965 - 69
	250	292	350	400	450	550	650	700	750	198	250	295	
Calcium	45	43	43	41	43	43	42	41	42	45	46	44	63
Magnesium	4	3	3	1	3	3	3	2	3	4	4	4	12
Sodium	18	21	21	23	20	22	21	22	22	23	29	25	125
Potassium	2	2	2	2	2	2	2	2	2	4	4	4	18
Ammonia	1	1	1	1	1	1	1	1	1	0.70	0.90	0.85	15
Carbonate	0	0	0	0	0	0	0	0	0	0	0	0	0
Bicarbonate	157	144	144	133	135	139	139	141	144	161	166	170	250
Sulfate	8	14	10	13	15	15	14	16	16	2	4	2	130
Chloride	20	22	20	24	24	26	26	28	28	26	24	24	117
Nitrate	0	0	0	0	0	0	0	0	0	0	0	0	27
Fluoride	0.45	0.50	0.60	0.50	0.50	0.55	0.60	0.55	0.50	0.43	0.43	0.35	0.9
T.D.S.	260	262	252	241	245	255	252	265	262	272	281	280	686
Boron	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	0	0	0	0.7
Surfactants	0	0	0	0	0	0	0	0	0	0	0	0	1.34
Hardness as $CaCO_3$	129	117	117	107	117	117	114	110	114	129	133	126	208
EC x 10^6	400	410	400	400	400	400	400	400	400	420	450	410	1130
pH	8.1	8.2	8.1	8.1	7.8	7.6	7.6	7.5	7.5	7.4	7.3	7.4	7.1

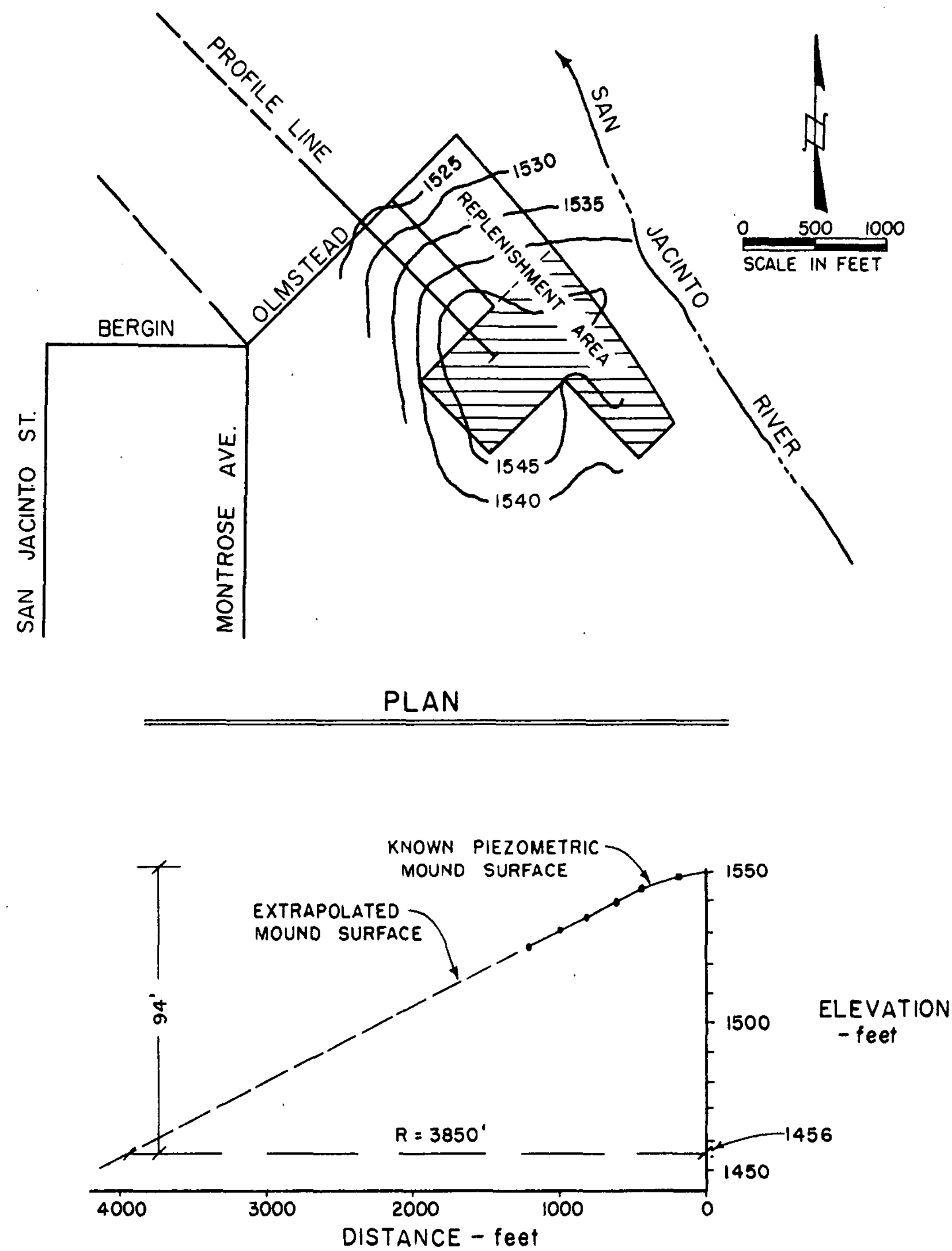
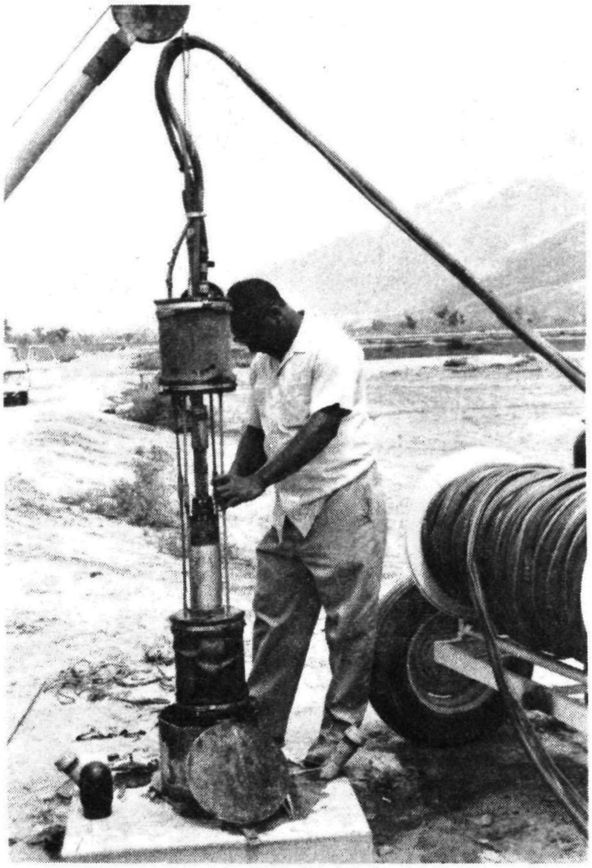


FIGURE 52. PLAN AND PROFILE FOR DEVELOPMENT OF CALCULATION FOR THEORETICAL MOUND SIZE - NOVEMBER 1968

Samples of water obtained through the packer pump indicated that either there is little chemical quality change with depth in the first 700 feet or, more probably, that the well had not been sealed off sufficiently and water from various water-bearing strata was commingling within the casing.



Packer Pump showing inflatable packers

Limits of Wastewater Added to Basin

As noted in Figures 36, 37 and 38, a water mound appeared to be slowly developing and expanding in area. While data were being developed during the early stages of the study, estimates of the amount of water in and the size of the theoretical mound were made by assuming a specific yield of 10 percent, based on recommendations(13) of 12 percent as an average figure for the entire basin. However, this basin includes some very excellent draining sands in both the Canyon Sub-Basin and the Intake Area. The soil under the replenishment area undoubtedly had some undrained water on top of the various silt and/or silty clay lenses which are interlaced throughout the entire area. Thus, the recharging program wouldn't replace 12 percent of the entire volume of soil under the replenishment area.

Late in 1968 a more refined estimate of the mound size was made, using contours and a profile as shown on Figure 52. With a known piezometer mound, a theoretical mound depth was calculated to be 94 feet as of November 1968. The diameter of the theoretical mound at the 94-foot level was calculated to be 7,700 feet. These calculations were based on the assumption that a mound was expanding equally in all directions. However, the wastewater has expanded in an irregular configuration over an area with a long axis of over 6,000 feet. Temperature surveys suggest that this migration could have extended further except that much of the recharged water is flowing underground to the northwest along the subsurface river shannel and its identity has not been traceable.

Many of the wells added to the monitoring program in 1968 had shallow static water levels. The perforation schedules for some of these are known, in addition to perforation schedules for some of the wells that were originally monitored. It was hoped that a good check on the theoretical mound size would be a plot of the increase in concentrations of chloride versus depths to first perforations. Figure 53 is a plot of these changes for the period 1965 1970. There appeared to be little correlation between perforation depth and quality. Since all the wells are gravel packed, with the exception of 25D2, the gravel was apparently allowing the shallow water in the theoretical mound to mix quite rapidly with the deeper groundwater in the well. In order for this comparison to be valid, the wells should have been cable tool drilled, cased, and not gravel-packed.

Another method utilized in obtaining data as to underground flow and the theoretical mound size was a geothermal survey. In the survey, temperature probes were placed on a grid network, the temperature of the underground water taken, and isothermal contours were then developed. The results of this method are included in Section XI of this report with the complete report, "Temperature Study of Spreading Ponds," prepared for Eastern Municipal Water District by Geothermal Surveys, Inc., included as Appendix 2.

Observation Wells

Ten observation wells were drilled around the replenishment area in July 1969 in the locations shown on Figure 54. These wells were

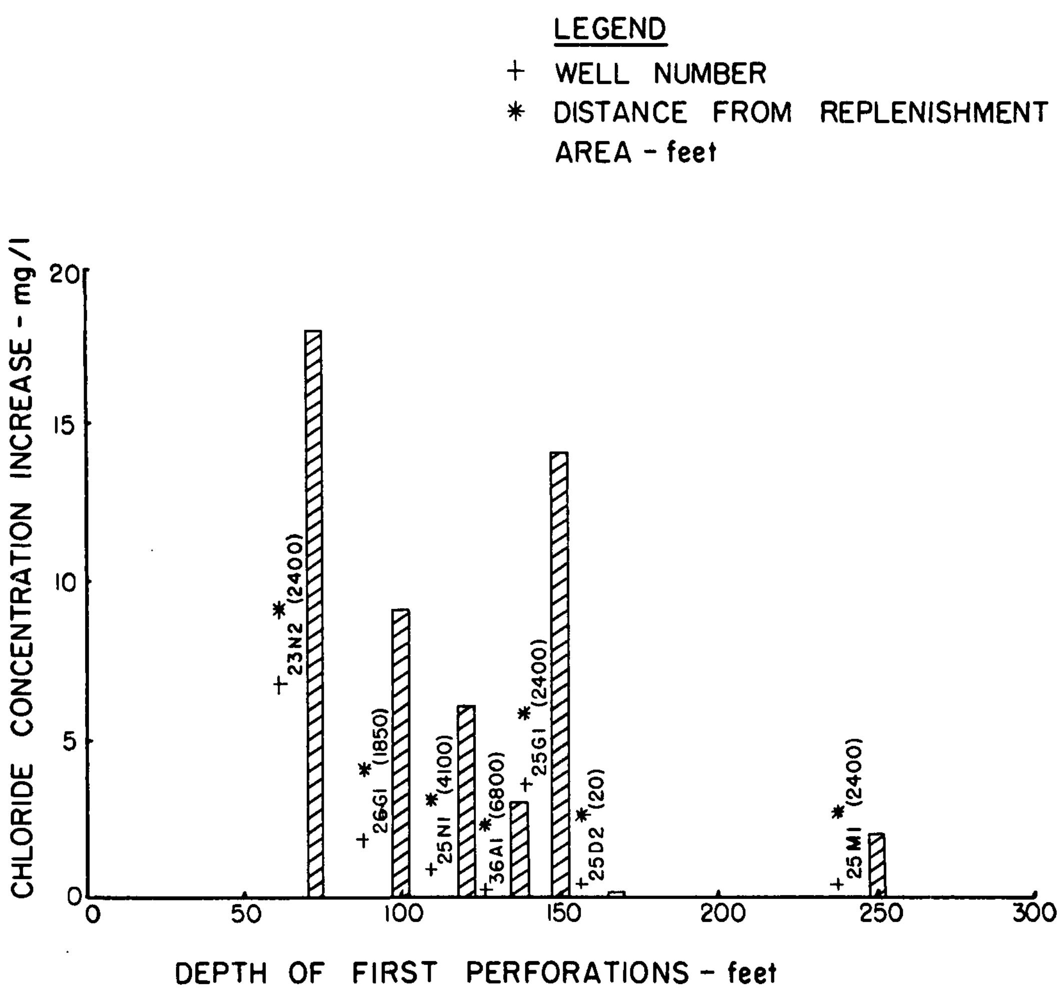


FIGURE 53. CHLORIDE CONCENTRATION INCREASE IN WATER FROM WELLS - 1965 to 1970

drilled with a 5-5/8" bit, cased with 2" PVC Schedule 80 pipe, and gravel-packed. The well logs and perforation schedules are shown in Table 26. These wells have provided water quality data for the groundwater on both sides of the San Jacinto River. Typical analyses from these wells are shown in Table 27. The implications of the gross difference in the quality of the water found in these wells was discussed in Section VII of this report.

To better identify the underlying stratas around the replenishment area four more observation wells were drilled in August 1970, as shown on Figure 54; and, electrical resistivity logs, as well as mechanical and driller's logs, were obtained from three of them. The fourth, #11, was abandoned as rock was encountered at a shallow depth. The mechanical and driller's logs of these wells are shown in Figures 55 through 58. The electrical resistivity logs appear on Figures 59 through 61, respectively. Figure 62 is a gamma ray-neutron log for the cable tool well, 25D2, which was obtained so this well might be correlated with the three newly-drilled wells.

All the logs show a lithology of sand and silt with clay streaks or beds from top to bottom. Porosity in all the wells is 30 percent to 37 percent which is consistent with what might be expected from a sandy soil. However, the wells produced no unexpected results.

TABLE 26

LOGS OF OBSERVATION WELLS
1 THROUGH 10

Well No. 1

0' - 12'	Sand
12' - 25'	Gravel and boulders
25' - 92'	Boulders and clay streaks
92' - 98'	Hard rock
98' - 160'	Boulders and clay

Perforated 60' - 80'
100' - 120'
140' - 160'

Well No. 2

0' - 12'	Sand
12' - 25'	Boulders and gravel
35' - 42'	Clay
42' - 55'	Sandy clay & boulder streaks
55' - 205'	Boulders
205' - 260'	Boulders, gravel & clay streaks

Perforated 200' - 220'
240' - 260'

Well No. 3

0' - 75'	Gravel and boulders
75' - 148'	Blue shale & boulder streaks
148' - 165'	Boulders & clay streaks

Perforated 60' - 80'
100' - 120'
140' - 160'

Well No. 4

0' - 16'	Sand
16' - 125'	Sandy Blue Clay
125' - 160'	Sand

Perforated 60' - 80'
100' - 120'
140' - 160'

Well No. 5

0' - 12'	Sand
12' - 160'	Sandy Clay

Perforated 60' - 80'
100' - 120'
140' - 160'

Well No. 6

0' - 18'	Sand
18' - 165'	Sandy Blue Clay
165' - 260'	Sandstone

Perforated 200' - 220'
2401 - 260'

Well No. 7

0' - 12'	Sand
12' - 108'	Sandy Clay
108' - 265'	Sandstone & clay streaks

Perforated 200' - 220'
240' - 260'

Well No. 8

0' - 10'	Sand
10' - 110'	Sandy Blue Clay
110' - 132'	Gravel and sand
132' - 160'	Blue Clay & sand

Perforated 60' - 80'
100' - 120'
140' - 160'

Well No. 9

0' - 12'	Sand
12' - 225'	Blue Sandy Clay
225' - 260'	Boulders and gravel

Perforated 200' - 220'
240' - 260'

Well No. 10

0' - 12'	Sand
12' - 82'	Blue Clay and sand
82' - 95'	Sand
95' - 215'	Blue Sandy Clay
215' - 265'	Boulders & sandy clay streaks

Perforated 200' - 220'
240' - 260'

TABLE 27

TYPICAL ANALYSES OF WATER FROM OBSERVATION WELLS
(Milligrams per Liter)

	#3			#5	#8		#10	
	1-70	6-70	8-70	8-70	1-70	8-70	1-70	8-70
Calcium		278	264	40		88		96
Magnesium		62	58	9		19		17
Sodium		40	28	24		40		46
Potassium		4	4	4		6		4
Ammonium		5	4	Trace		2		Trace
Carbonate		0	0	0		0		0
Bicarbonate		443	426	146		294		186
Sulfate	720	587	397	26	77	108	239	162
Chloride	34	42	28	22	54	52	64	62
Nitrate		10	4	21		4		1
Fluoride		0.7	1.1	0.5		0.7		0.4
Boron		0.5	0.6	0.5		0.6		0.5
TDS		1470	1220	290		586		590
Hardness as $CaCO_3$		970	920	140		304		320
pH		7.6	7.9	7.5		7.7		7.3
E.C. x 10^6	1720	2100	1620	395	835	806	985	840

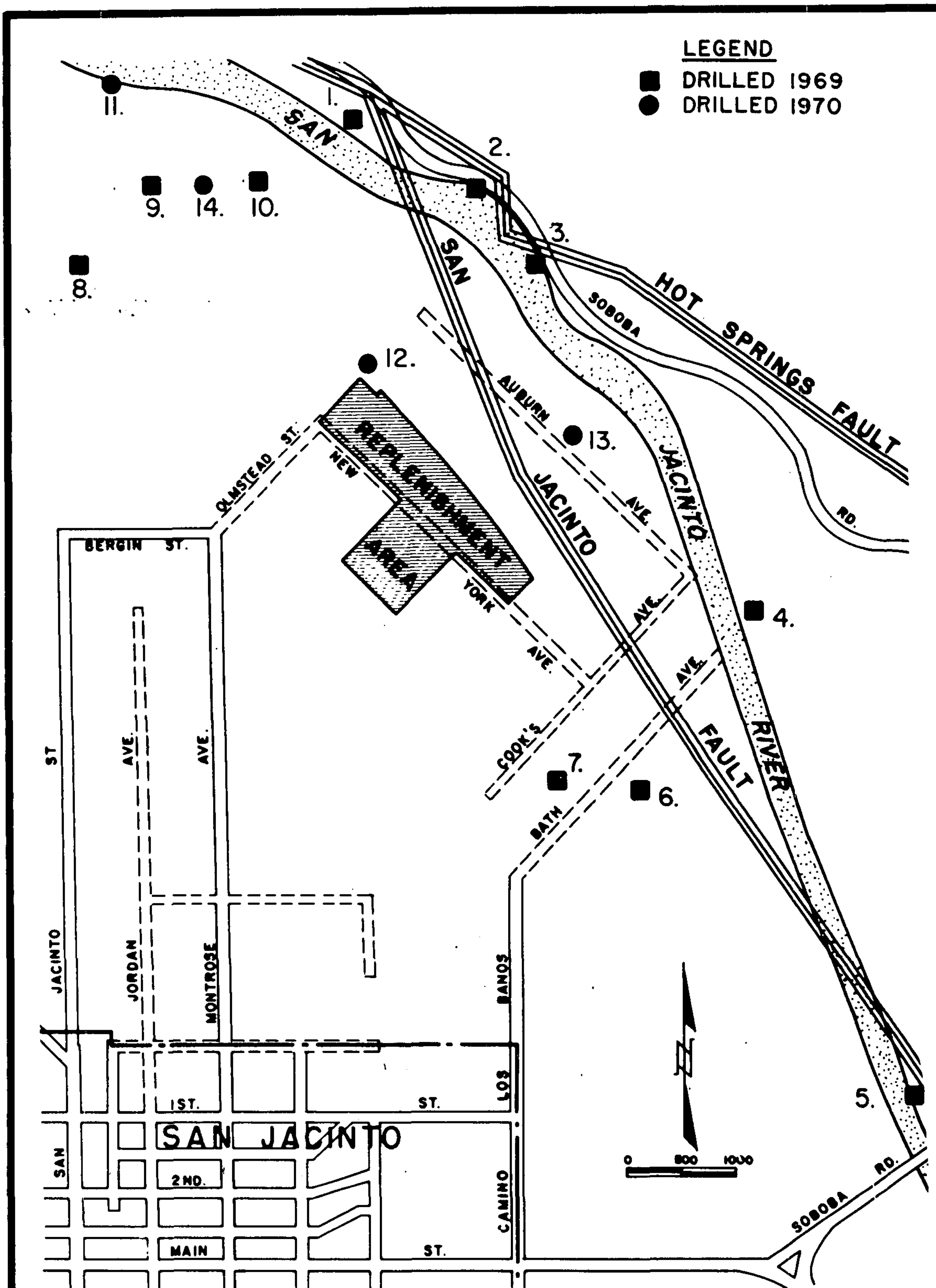


FIGURE 54. OBSERVATION WELL NETWORK

Driller's Log Feet - Feet		Mechanical Log Feet - Feet	
0- 35	Sand	0- 50	Med/Course Sand
35- 50	Blue Clay	50-100	Fine/Med Sand/Some Blue Clay
50-100	Blue Clay	100-150	Fine/Med Sand/Some Blue Clay
100-130	Blue Clay	150-200	Fine/Med Sand/Some Rock
130-150	Sand	200-245	Course Sand/Some Rock
150-165	Sand		
165-200	Rocks, Boulders/Sand		
200-245	Rocks, Boulders/Sand		

No Electric log taken and no casing installed

FIGURE 55. OBSERVATION WELL No. 11

Driller's Log Feet - Feet		Mechanical Log Feet - Feet	
0- 35	Sand	0- 50	Med/Course Sand
35- 50	Sand & Some Clay	50- 65	Med/Course Sand
50- 80	Sand & Some Clay	65-100	Fine/Med Sand/Some Blue Clay
80-100	Sand	100-140	Fine/Med Sand/Some Blue Clay
100-150	Sand	140-170	Fine Sand/Some Blue Clay
150-200	Sand	170-200	Fine/Med Sand/Trace of Blue Clay
200-215	Sand	200-215	Fine/Med Sand/Trace of Blue Clay
215-250	Drill Sand	215-250	Fine/Med Sand
250-300	Drill Sand	250-260	Fine/Med Sand
300-350	Drill Sand	260-300	Fine Sand
350-400	Drill Sand	300-350	Fine Sand
400-450	Drill Sand	350-400	Fine/Med Sand
450-470	Drill Sand	400-450	Fine/Med Sand
		450-470	Fine/Med Sand

Electric Log taken and 30' of casing installed

FIGURE 56. OBSERVATION WELL No. 12

Driller's Log Feet - Feet		Mechanical Log Feet - Feet	
0- 50	Sand	0- 50	Fine/Med Sand
50- 65	Sand	50-100	Fine Sand
65-100	Sand/Very Sandy Streaks	100-125	Fine Sand
100-150	Sand/Very Sandy Streaks	125-140	Fine Sand/Some Clay
150-200	Sand/Very Sandy Streaks	140-150	Blue Clay/Fine Sand
200-250	Sand/Very Sandy Streaks	150-200	Blue Clay/Fine Sand
250-300	Sand/Very Sandy Streaks	200-250	Blue Clay/Fine Sand
300-335	Sand/Very Sandy Streaks	250-300	Blue Clay/Fine Sand
335-350	Sand/Sandy Clay/Some Rock	300-320	Blue Clay/Fine Sand
350-400	Sand/Sandy Clay	320-350	Fine Sand/Some Clay
400-450	Sand/Sandy Clay	350-400	Fine Sand
450-500	Sand/Sandy Clay	400-450	Fine Sand
500-550	Sand/Sandy Clay	450-500	Fine Sand
550-600	Sand/Sandy Clay	500-530	Fine Sand
600-635	Sand/Sandy Clay	530-550	Fine Sand/Blue Clay
635-650	Drill Sand/Sandy Clay	550-560	Fine Sand/Blue Clay
650-700	Drill Sand/Sandy Clay	560-600	Blue Clay/Some Fine Sand
700-710	Drill Sand/Sandy Clay	600-635	Blue Clay/Some Fine Sand
		635-650	Fine Sand/Some Blue Clay
		650-665	Fine Sand/Some Blue Clay
		665-700	Fine Sand
		700-710	Fine Sand

Electric Log taken and 180' of casing installed

FIGURE 57. OBSERVATION WELL No. 13

Driller's Log Feet - Feet		Mechanical Log Feet - Feet	
0- 20	Sand with Some Clay	0- 35	Fine/Med Sand/Some Blue Clay
20- 50	Clay	35- 50	Fine Sand/Blue Clay
50- 80	Clay	50- 80	Blue Clay/Fine Sand
80-100	Sand/Sandy Clay	80-100	Blue Clay
100-150	Sand/Sandy Clay	100-110	Blue Clay
150-200	Sand/Sandy Clay	110-125	Blue Clay/Med Sand
200-250	Drill Sand/Sandy Clay	125-140	Med Sand
250-300	Drill Sand/Sandy Clay	140-150	Med Sand/Some Blue Clay
300-350	Drill Sand/Sandy Clay	150-185	Fine Sand/Some Blue Clay
350-400	Drill Sand/Sandy Clay	185-200	Fine Sand/Tr. Blue Clay
400-450	Drill Sand/Sandy Clay	200-250	Fine Sand/Some Blue Clay
450-470	Drill Sand/Sandy Clay	250-290	Fine Sand/Some Blue Clay
		290-300	Fine Sand
		300-320	Fine Sand
		320-350	Fine Sand/Silt/Tr. Blue Clay
		350-400	Fine Sand
		400-450	Fine/Med Sand
		450-470	Fine/Med Sand

Electric Log taken and 200' of casing installed

FIGURE 58. OBSERVATION WELL No. 14

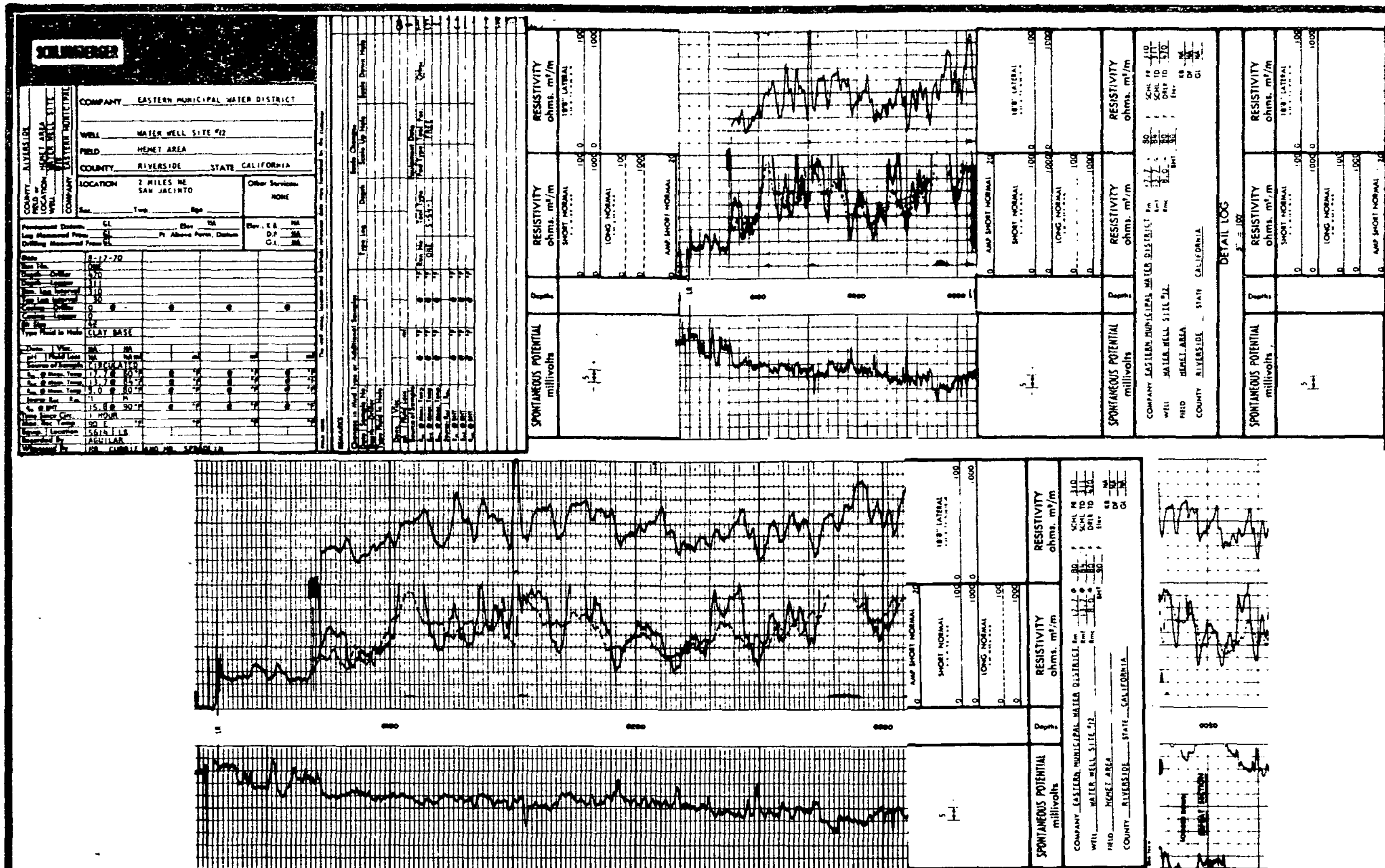


FIGURE 59. ELECTRICAL RESISTIVITY OF OBSERVATION WELL #12

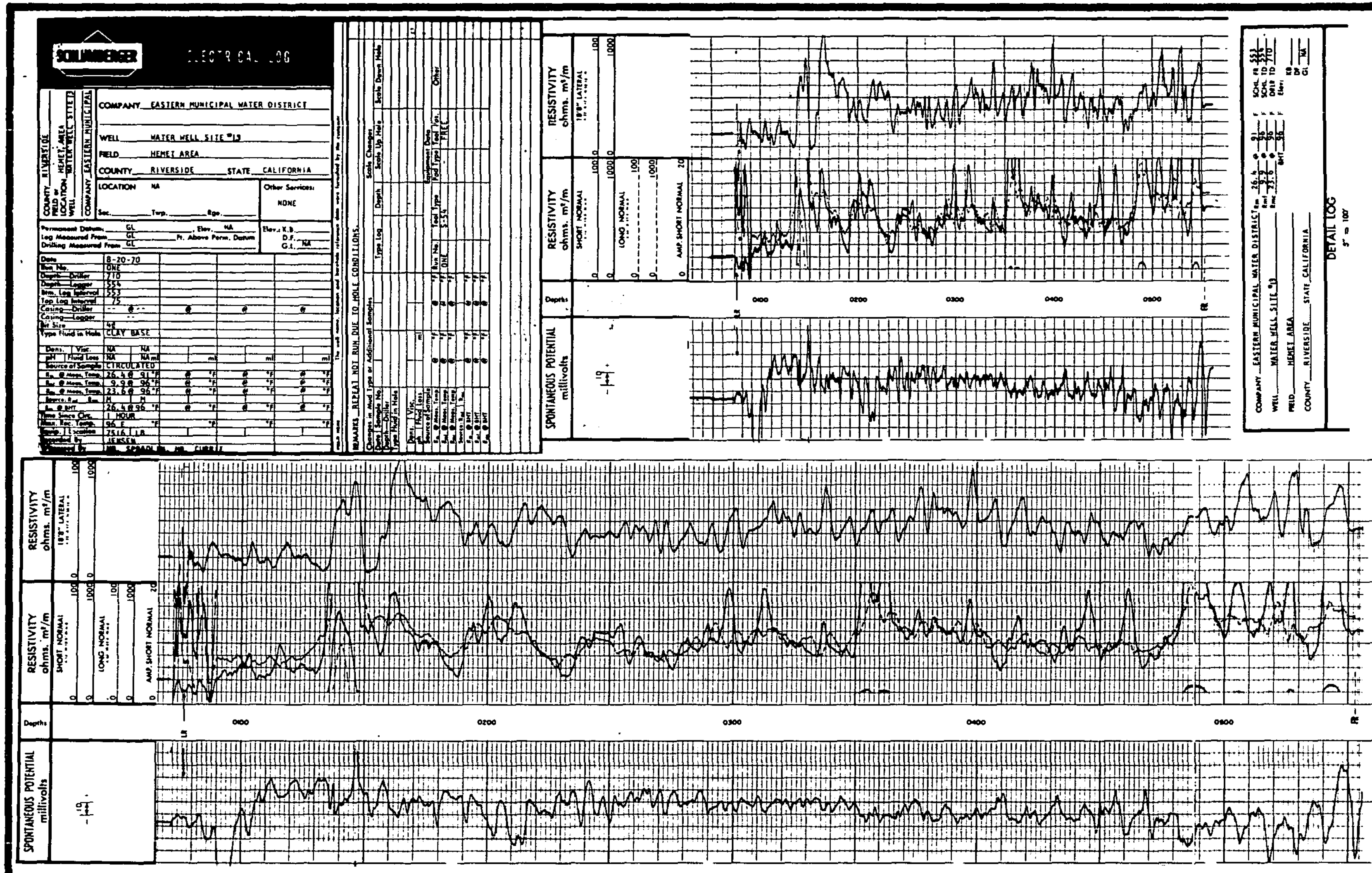


FIGURE 60. ELECTRICAL RESISTIVITY OF OBSERVATION WELL #13

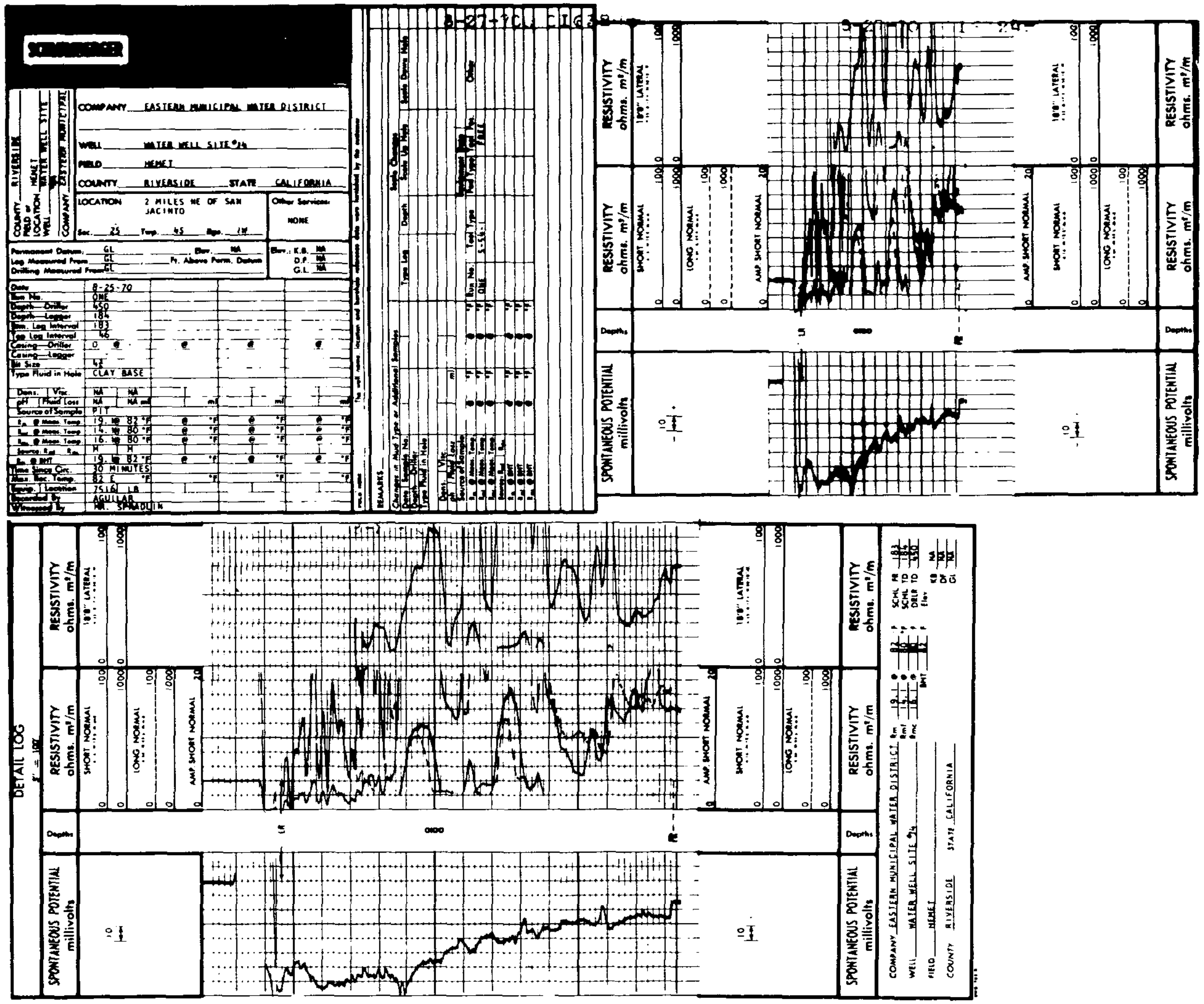


FIGURE 61. ELECTRICAL RESISTIVITY OF OBSERVATION WELL #14

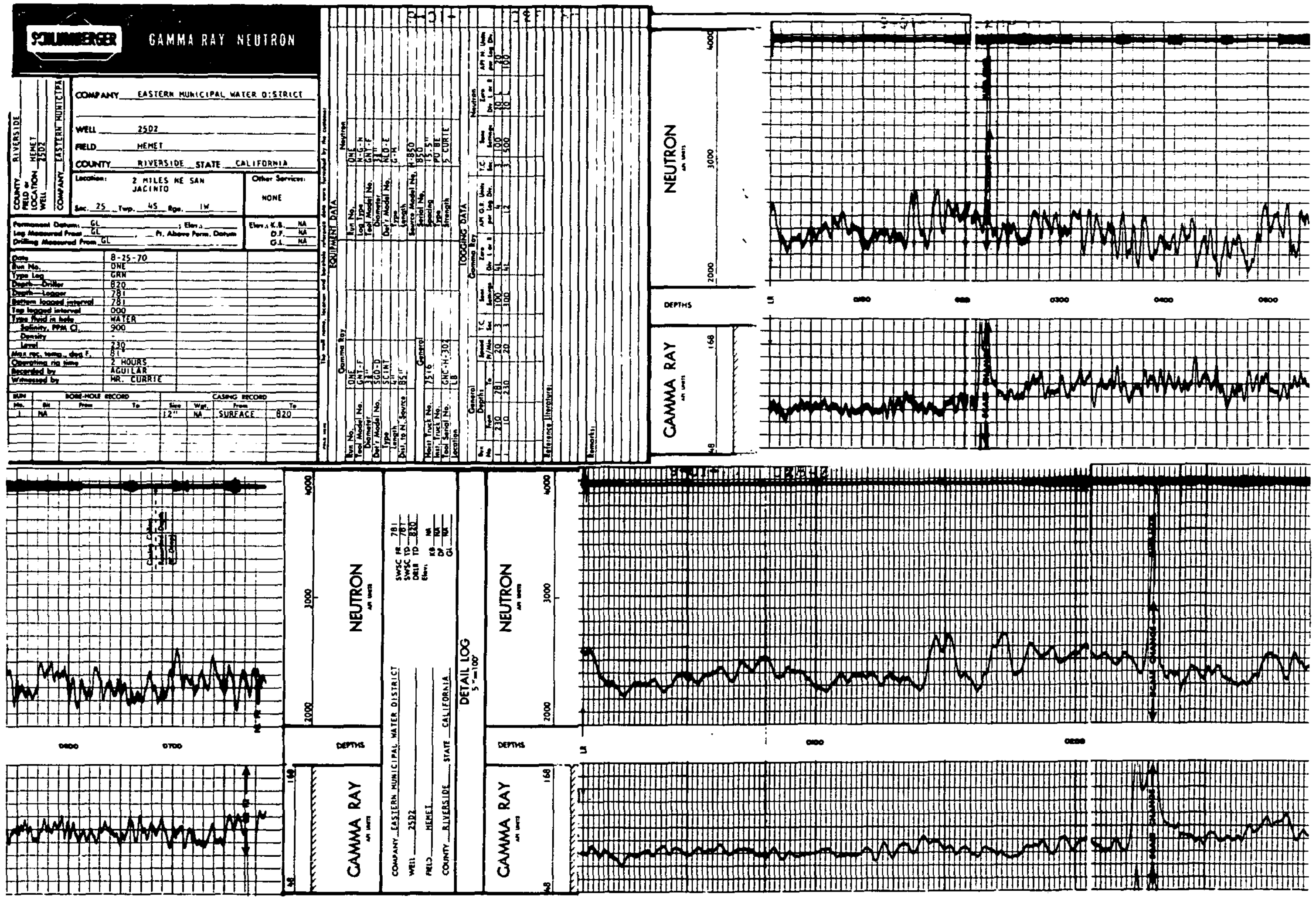


FIGURE 62. GAMMA RAY-NEUTRON LOG OF WELL NO. 4S1W 25D2

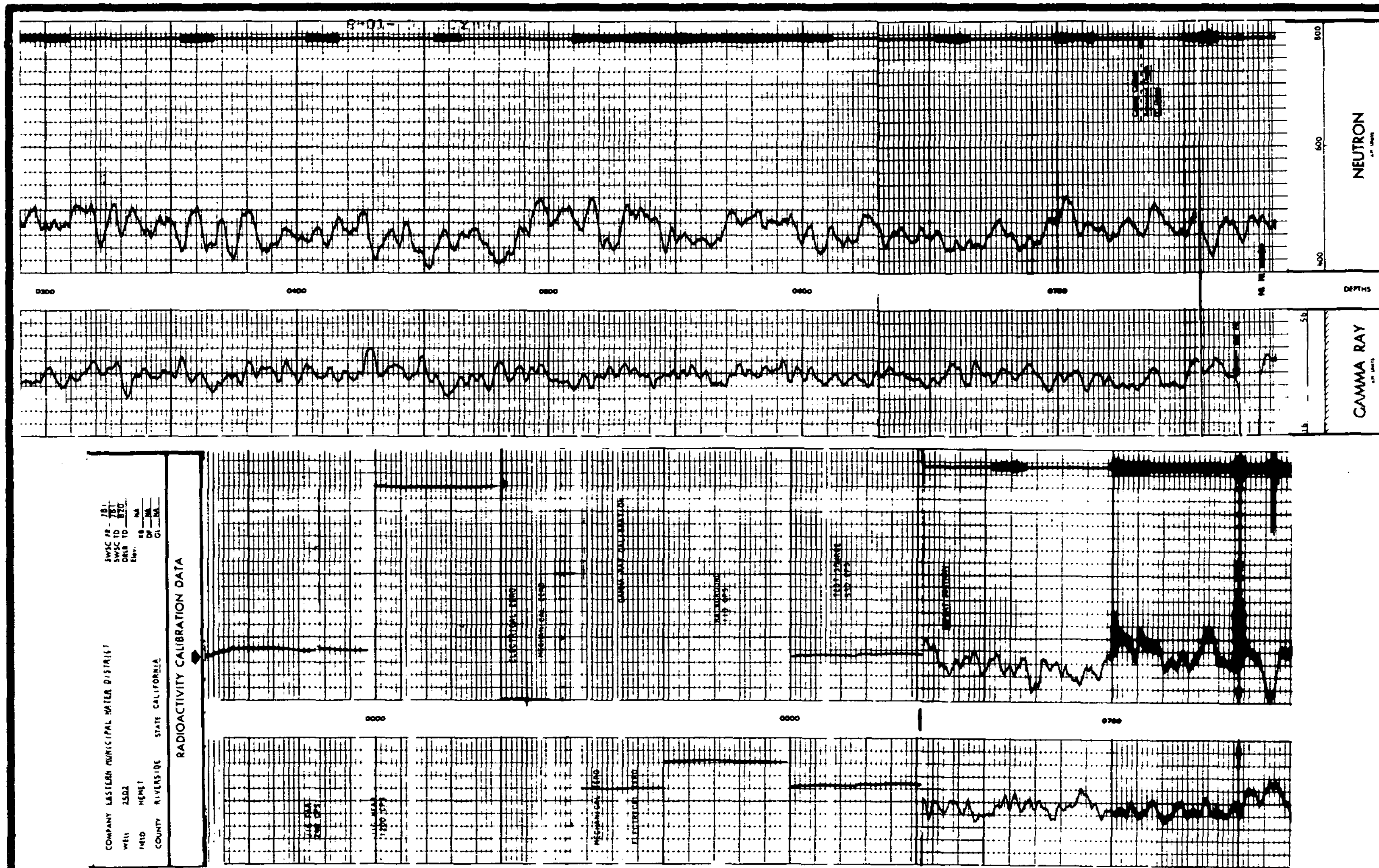


FIGURE 62. (CONT.) GAMMA RAY-NEUTRÓN LOG OF WELL NO. 4S1W 25D2

SECTION XI

GEOTHERMAL INVESTIGATION OF REPLENISHMENT AREA

Information relative to the movement and size of the shallow groundwater created by the spreading operation was limited to that provided by the piezometers and observation wells. As many of the piezometers were damaged or destroyed and access to the area for their replacement was becoming limited, new techniques of tracing the water movement were investigated. One of these methods, which showed great promise, was a geothermal survey whereby water movement is traced and monitored through its temperature. Based on preliminary findings, a thermal monitoring program was established through Geothermal Surveys, Inc. The survey area is shown on Figure 63.

This chapter is a discussion of the findings of this survey. The entire report, "Temperature Study of Spreading Ponds," prepared by Dr. J. H. Birman and A. B. Esmilla, appears as Appendix 2, Volume II of this report.

Objectives

The primary purpose of the survey was to establish a pattern of fluid migration from the replenishment area through the use of groundwater temperature differential. It was felt that the irregular soil conditions in the area, along with its close proximity to the San Jacinto River and San Jacinto Fault zone, would create an irregular wetted formation. By the use of temperature probes placed in boreholes at various times during the year, and analyzing the results and considering other parameters such as chemical quality and physical setting, it was hoped that a more complete understanding of the behavior of the spread water could be obtained.

A secondary objective was the possibility that some information as to the depth of the natural groundwater interface might be provided.

Procedures

The thermistor probes used to obtain ground temperatures are calibrated to 0.01° C and were inserted into plastic sleeves or existing piezometers to a depth of 8-1/2 feet. Some temperature profiles were taken in observation wells using a thermistor cable. The network of probe stations was slightly irregular due to limited access, but most probes were spaced about 1,000 feet apart during the early part of the survey and about 500 feet apart for the later work.

The survey area was monitored several times during the year, and after each set of readings was plotted unessential probe stations were discarded and new stations were added. Interpretations were made using both the temperature and the temperature drift in response to the annual cycle.

Analyses of Results

The temperature of the spread water was observed and compared with the background temperatures emanating from several different sources: normal background temperatures associated with the soil and bedrock, the San Jacinto River system, and the thermal conditions associated with the San Jacinto Fault zone.

The coldest temperatures in all the surveys were found in and near the San Jacinto River Channel. The temperatures found to the west, northwest and south of the replenishment area were found to be somewhat warmer and were assumed to represent the normal background temperatures. Warm temperatures were also found on the east side of the river channel and these were assumed to be associated with the San Jacinto Fault zone. The highest temperatures were repeatedly found in or adjacent to the replenishment area.

The profiles from the observation wells show that the deeper groundwater had a lower temperature than water at shallow depths. Normally, the reverse is true. Some of this effect may be caused by the water being spread, which has a high temperature, raising the temperature of the shallow groundwater, thus reversing the normal gradient.

The thermal relief stayed relatively the same in position and values. There was some response corresponding to the annual thermal cycle and irrigation practices created some differences in the plain to southwest and northwest, but the overall thermal picture persisted.

Figures 64 through 68 are thermal maps for each survey. There have been several isolated areas to the southwest of the replenishment area which have consistently shown high temperatures. These high temperatures seem to be associated with the dairy operations in that area and the resulting high temperatures of the dairy wastes. The persistent cold pattern in the river channel implies an active underflow in the

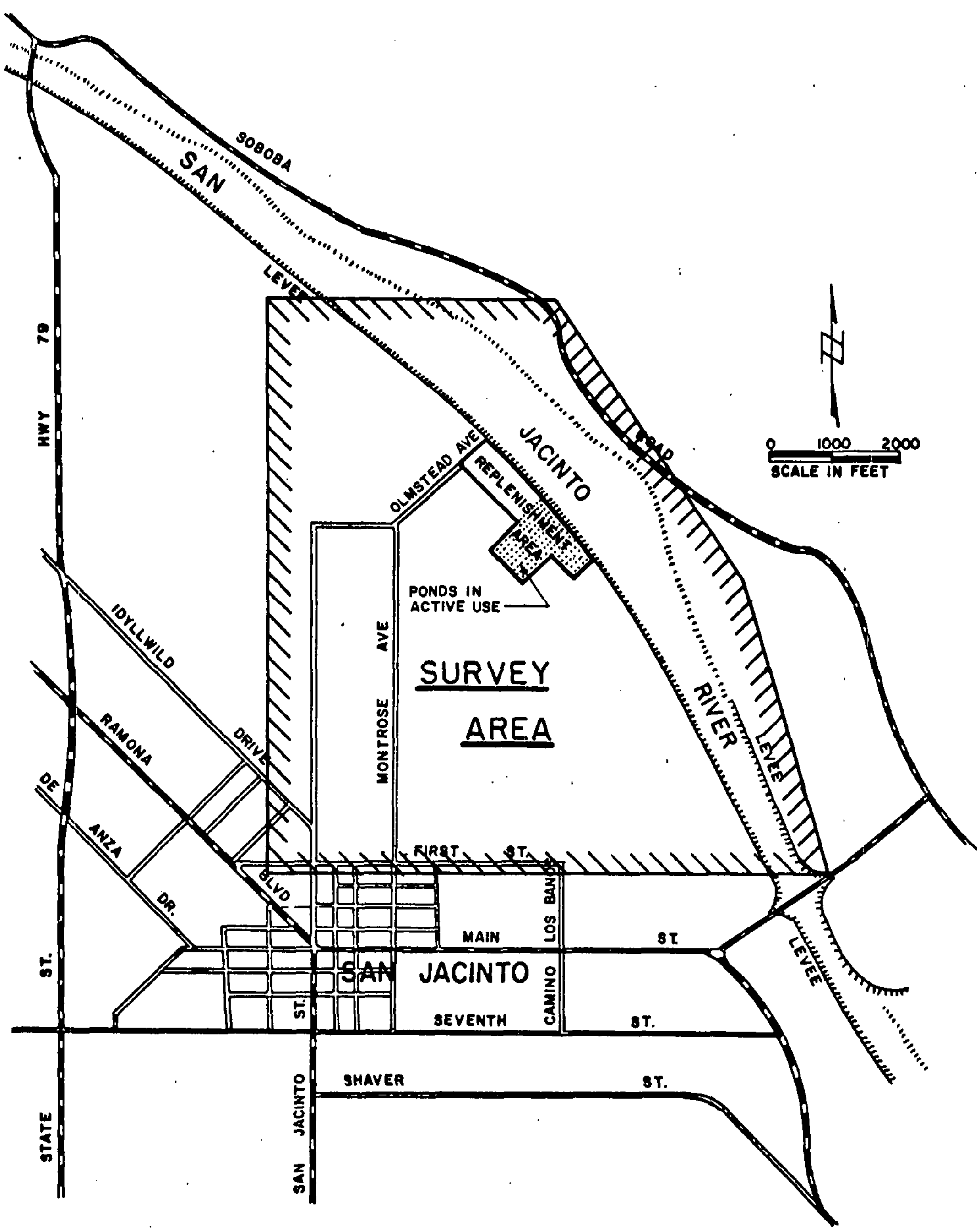


FIGURE 63. GEOTHERMAL SURVEY AREA

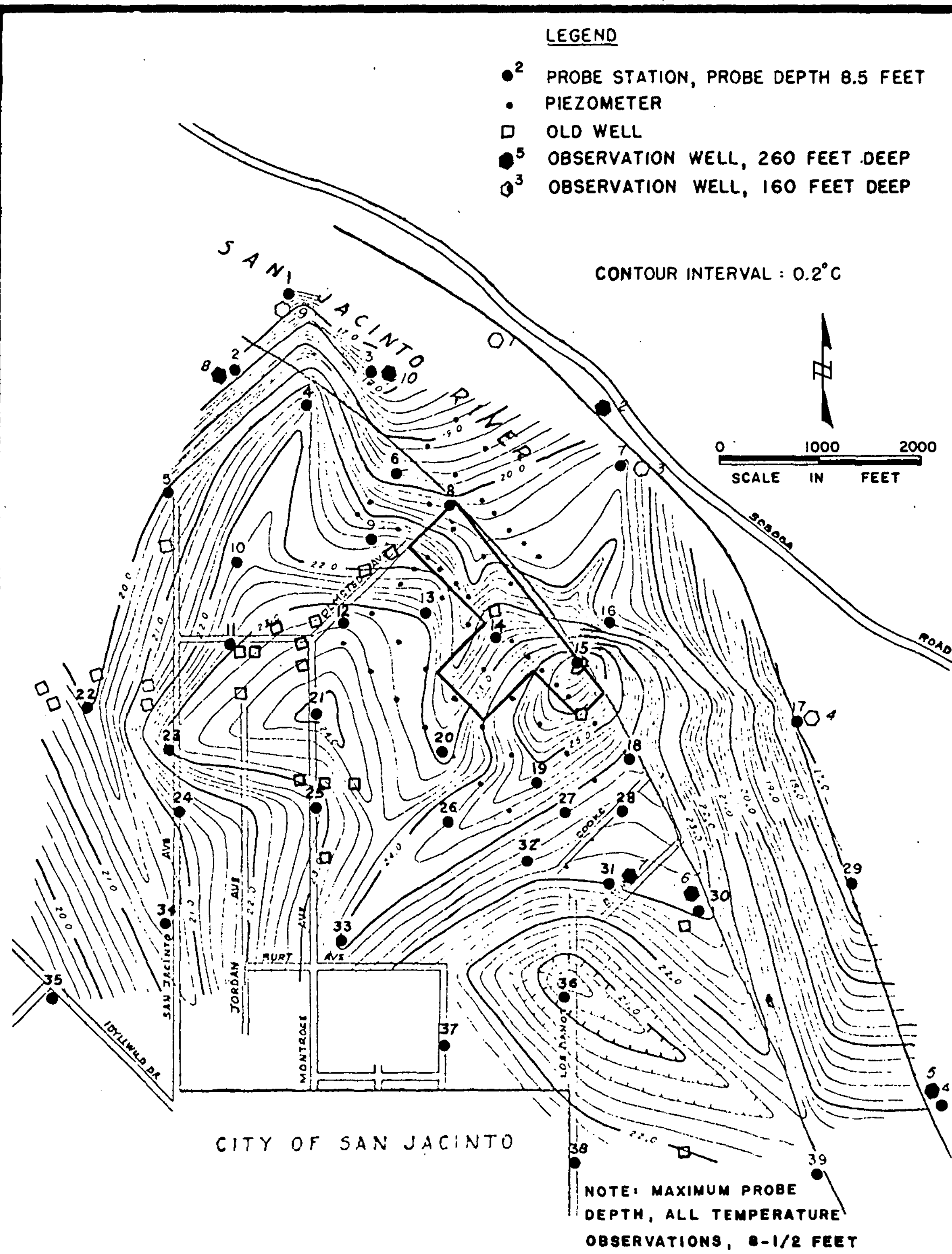


FIGURE 64. TEMPERATURE MAP - SEPTEMBER 3, 1969

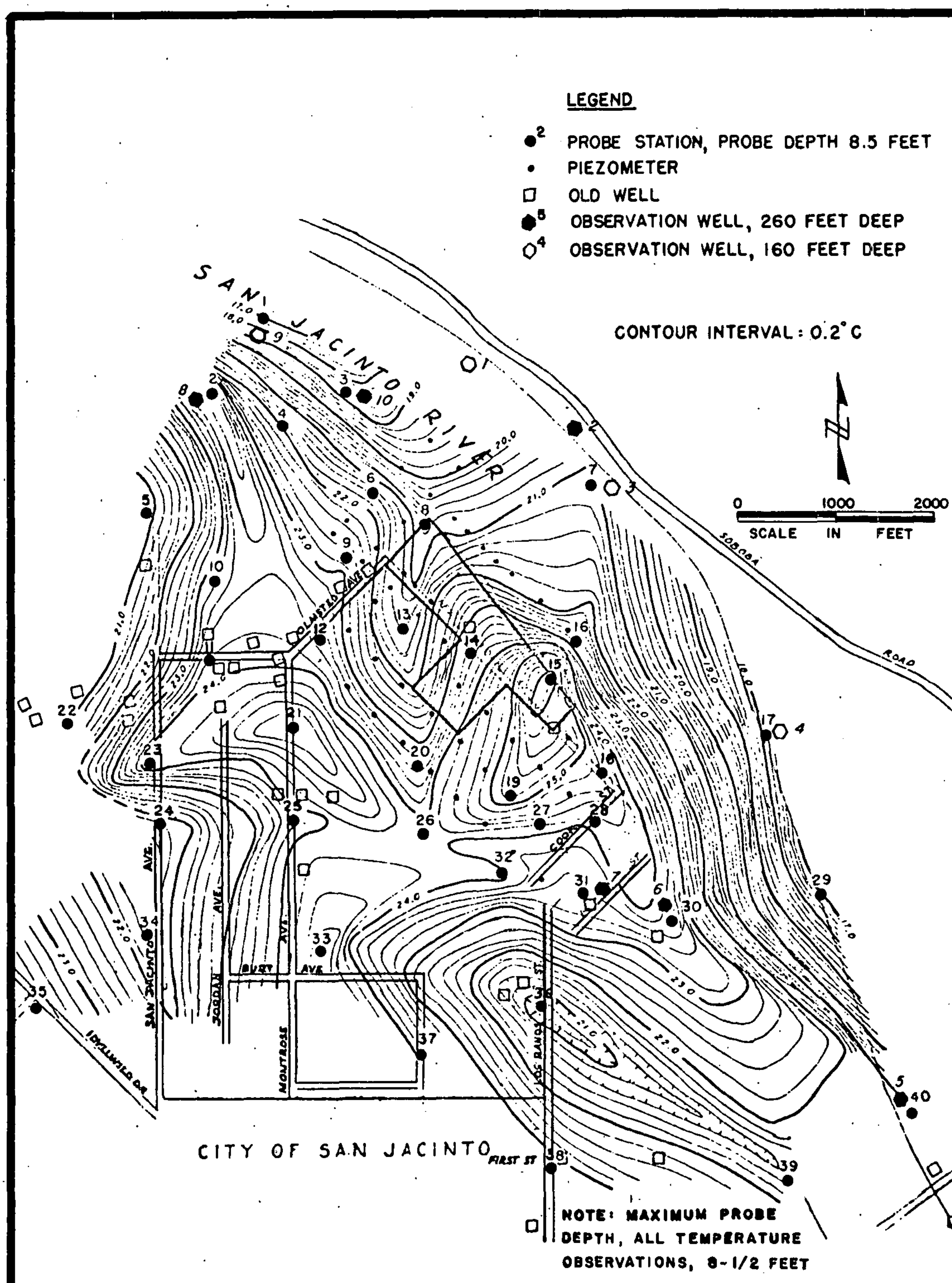


FIGURE 65. TEMPERATURE MAP - SEPTEMBER 19, 1969

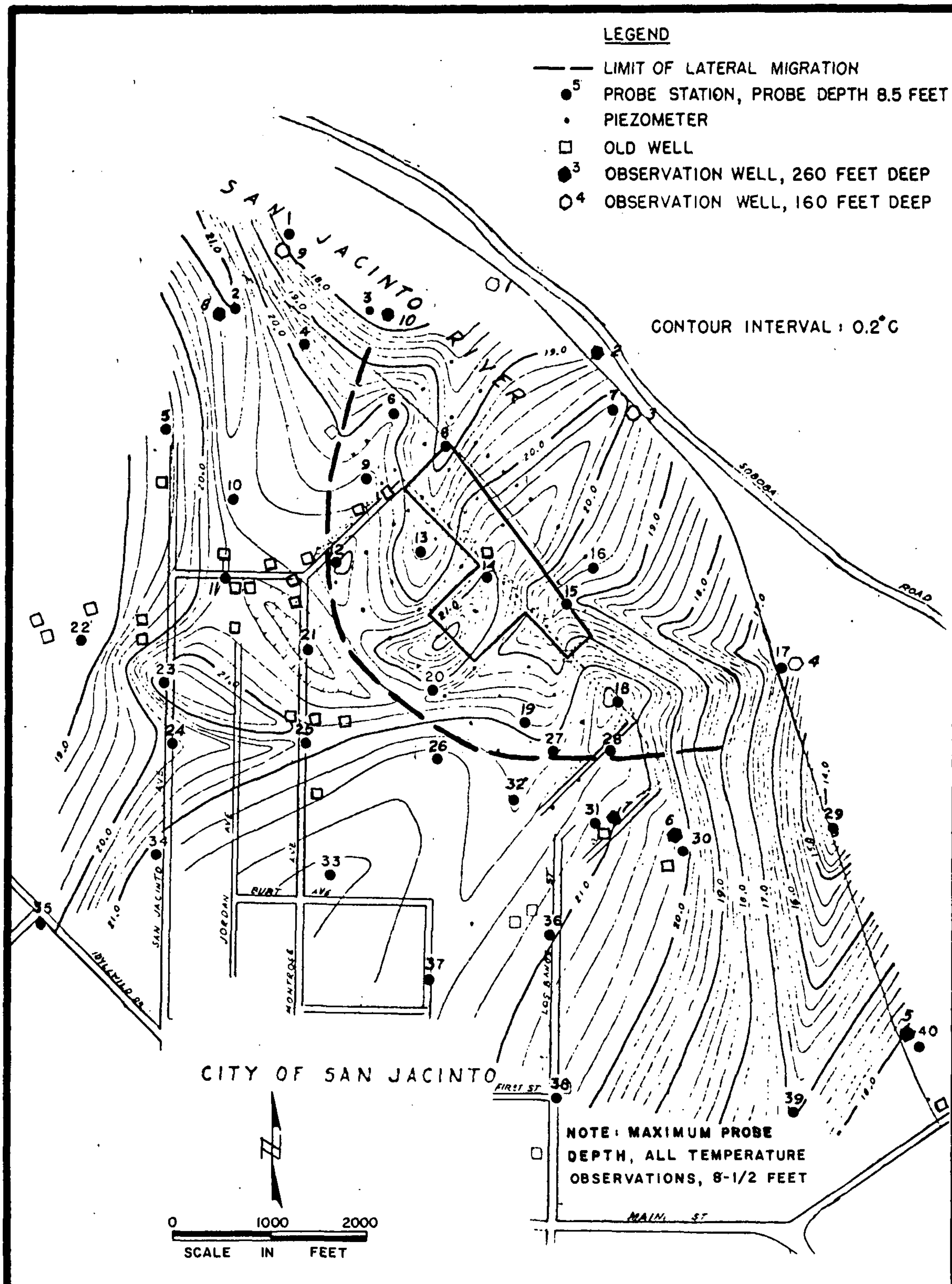


FIGURE 66. TEMPERATURE MAP - DECEMBER 16-17, 1969

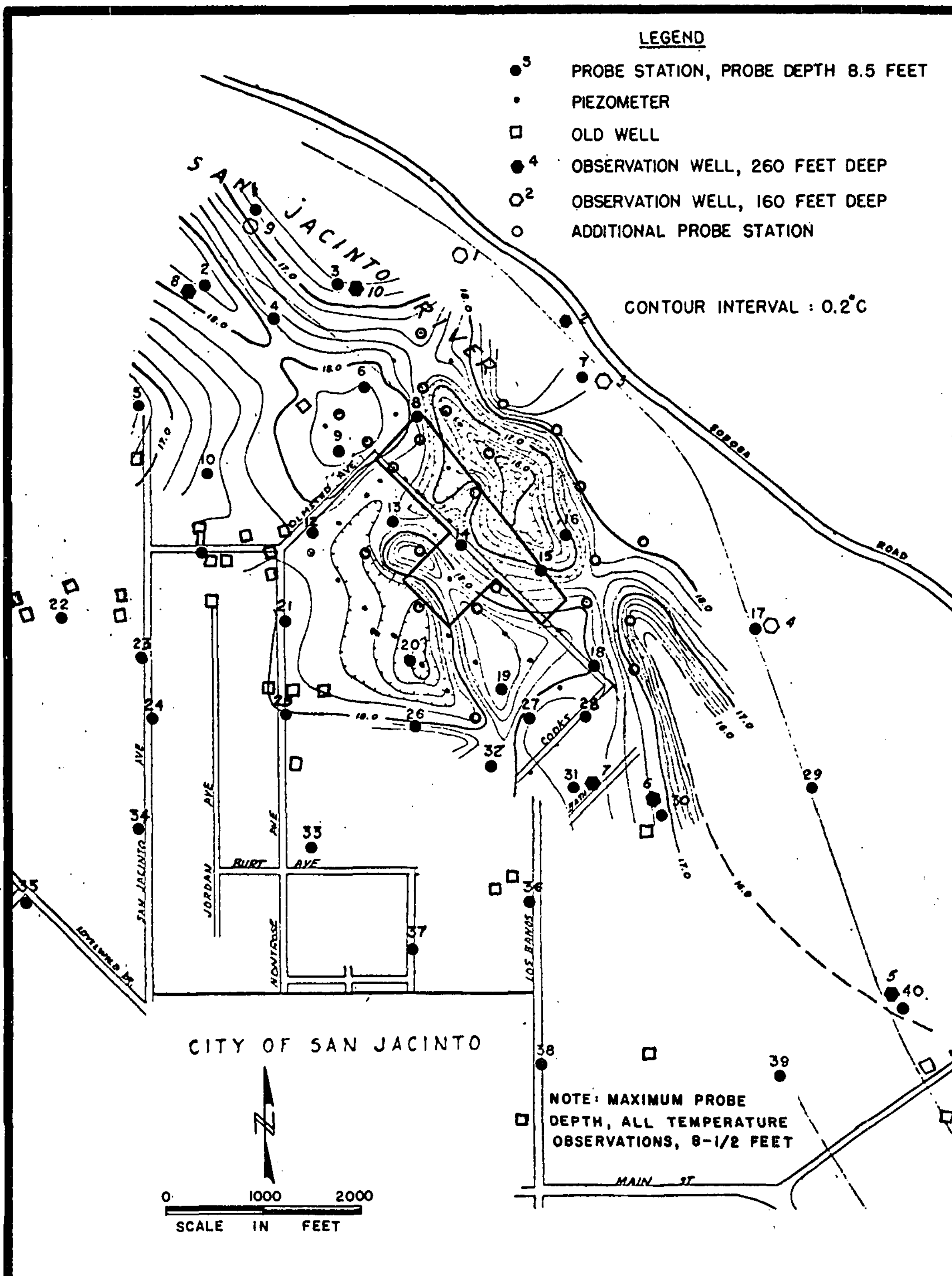


FIGURE 67: TEMPERATURE MAP - MAY 6, 1970

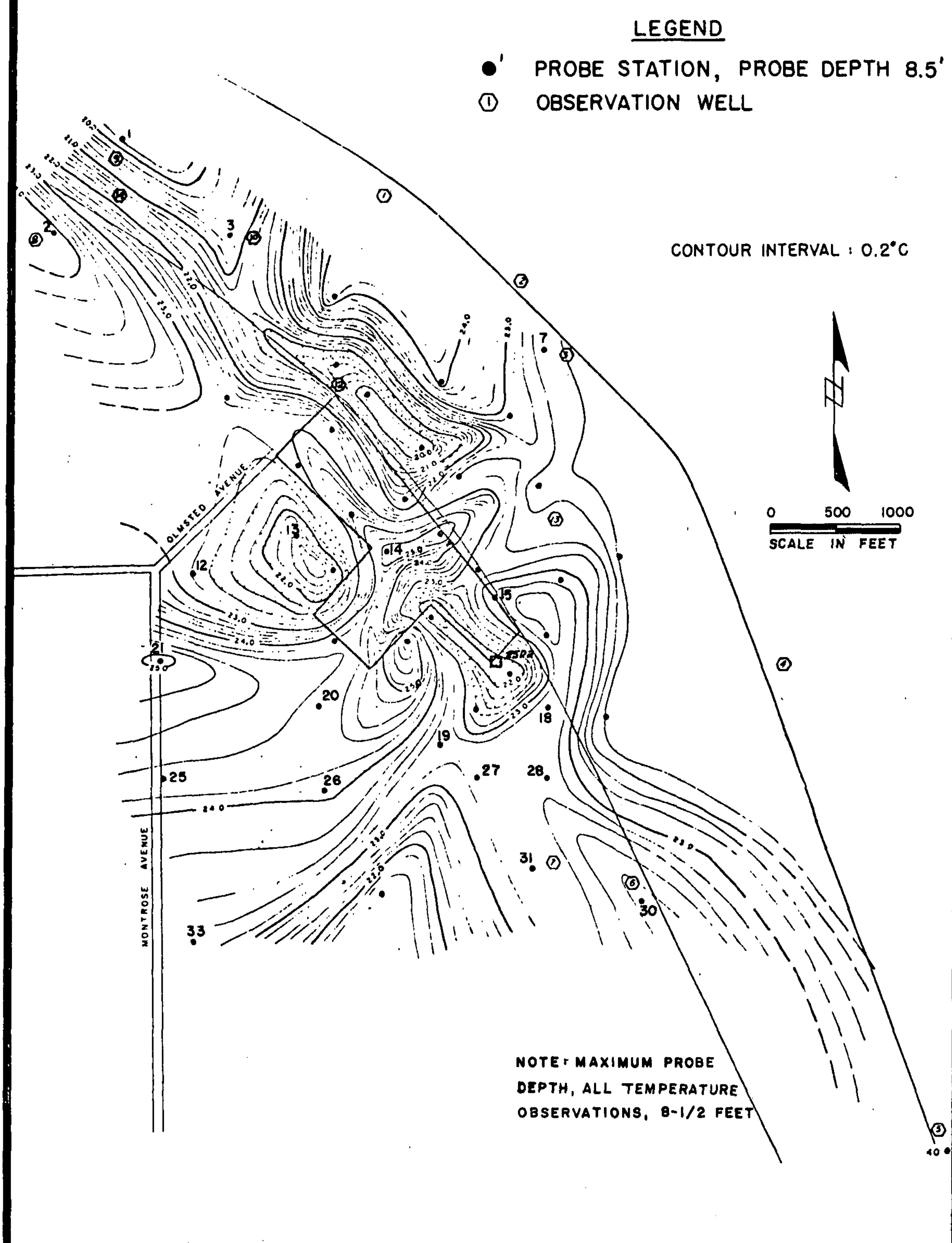


FIGURE 68. TEMPERATURE MAP - SEPTEMBER 22-23, 1970

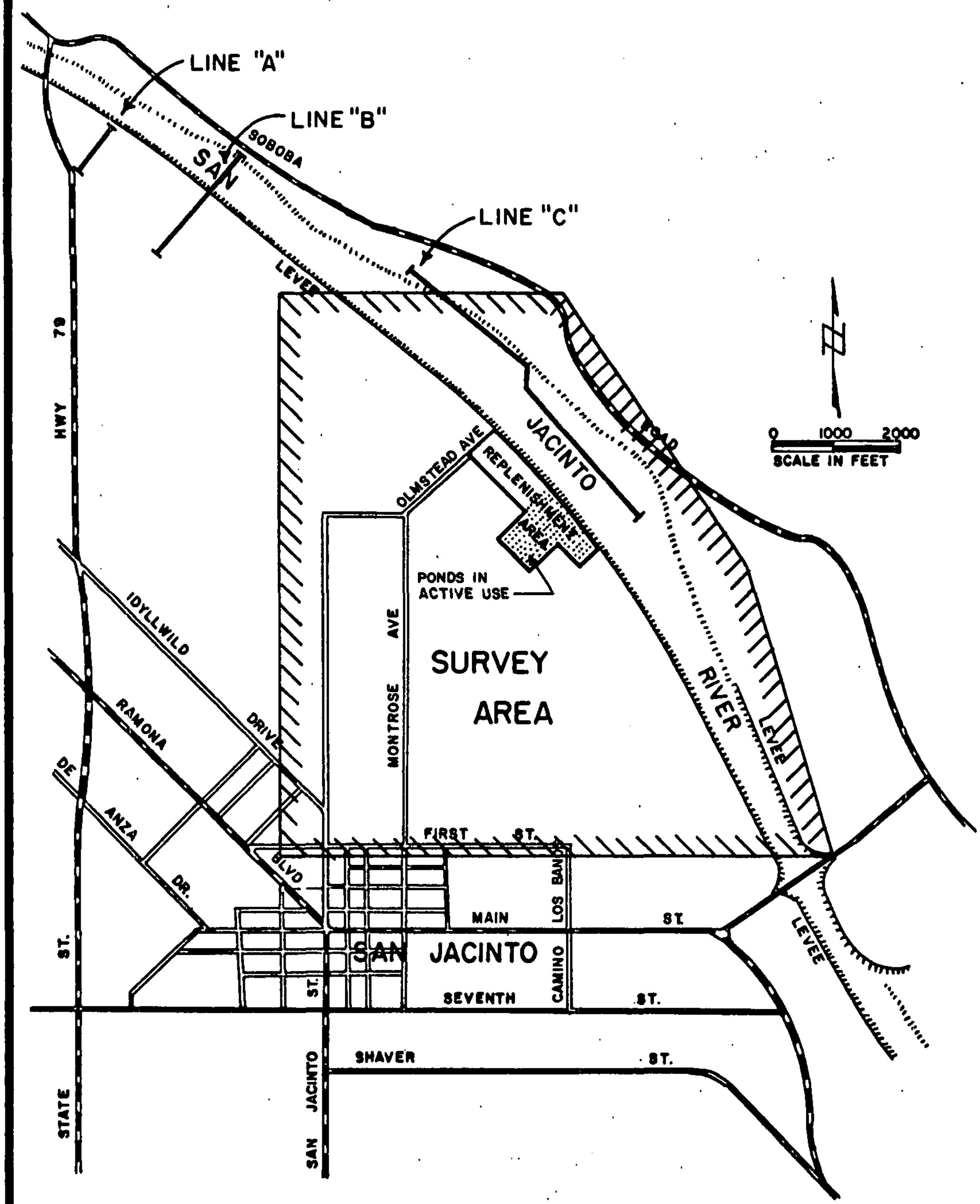


FIGURE 69. TEMPERATURE PROFILE LINES - SURVEYED JULY 7 AND 8, 1970

underground stream bed. It would be reasonable to assume that this underground flow would follow the historical, rather than the existing river bed as the channel has been moved to the north in recent times. In order to develop a better understanding of the configuration of subsurface flow in the river channel, three temperature profiles were made as shown on Figure 69.

The purpose of these profiles was to determine whether the cold temperatures in the river channel adjacent to the replenishment area could be traced further downstream. Two of the profile lines were established 1 to 1-1/2 miles downstream of the replenishment area. A third profile was located adjacent to the replenishment area. This survey did indicate that the underflow did continue downstream and that this underflow was not confined to the river channel. There was also a zone of high temperatures which may be a result of the San Jacinto Fault.

Thermal profiles on well 25D2 and on several observation wells showed the water temperature profile was reversed and indicated that the effects of the spreading operations may not extend much deeper than 60 feet below the surface. The temperatures observed in 25D2 on two different occasions showed wide variations in the zone at 60 feet and above; below 60 feet, the thermal gradient began reacting to the normal deep thermal effects. Similar profiles were observed in several observation wells.

Two observation wells, #1 and #3, exhibited thermal gradients which were quite different from those in all the other holes surveyed. The temperatures observed were up to 2-1/2 degrees warmer and the gradients are positive except for a small segment between 20 and 38 feet in well #3. The gradients were repeatable as similar readings were obtained in both July and September. Both of these wells are on the east side of the San Jacinto River close to the bedrock of the San Jacinto Range. The thermal effects are interpreted as being caused by either the heat from the crystalline basement, the San Jacinto Fault, or both.

Profiles obtained from observation wells #12 and #13 showed wide variation in the results. The reliability of these results is somewhat questionable as the wells were newly drilled and the holes contained some drilling mud, but the information provided is worth mentioning. Well #12 exhibits a similar water temperature to that of well #6, although the perched water level in well #12 is almost 150 feet lower. Observation well #13 shows a somewhat similar thermal gradient to those found in wells #1 and #3, and also has a similar water level.

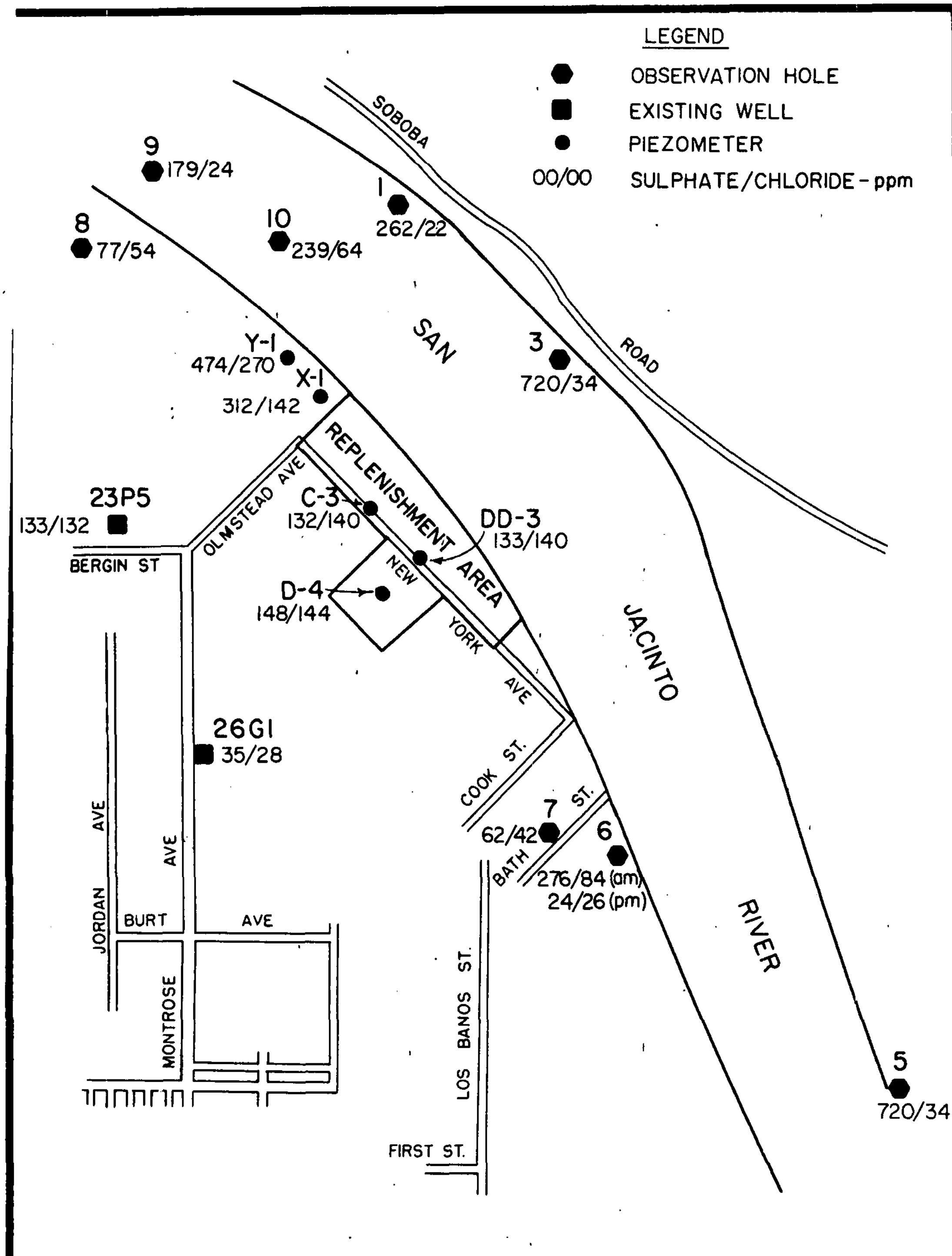


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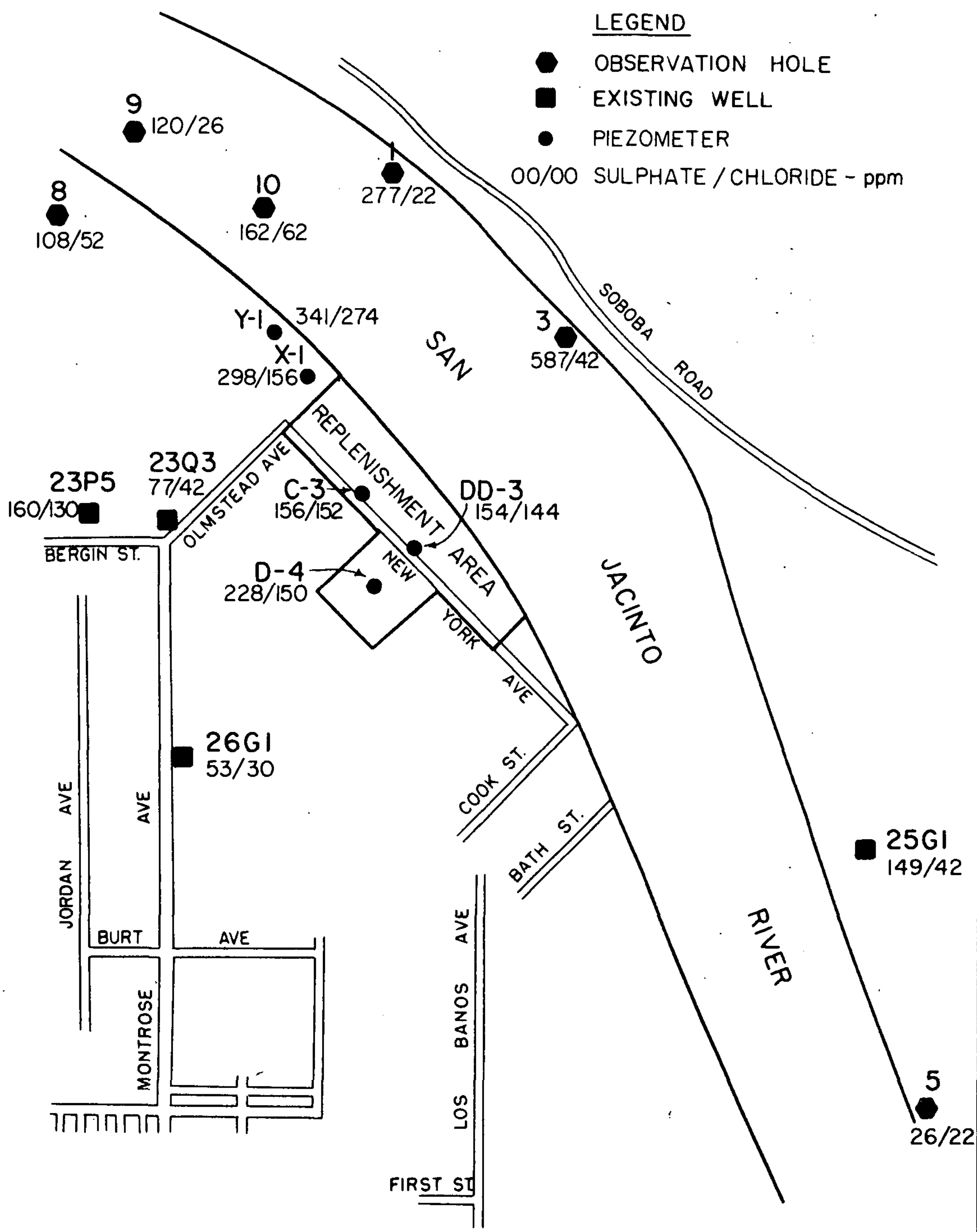
FIGURE 70. SULPHATE / CHLORIDE CONCENTRATIONS



APRIL 1970

FIGURE 71. SULPHATE / CHLORIDE CONCENTRATIONS

Both wells #12 and #13 are clearly within the river channel and therefore should be out of the influence of the fault zone. It is tentatively concluded, therefore, that both of these wells are within the influence of the spreading operations.

Chemical quality of the water found in the piezometers, observation wells and existing wells was compared with thermal results found in the area. The results of this comparison are interesting. Chloride and sulfate concentrations are presented on Figures 70 and 71. The replenishment area is characterized by chloride and sulfate concentrations which are consistent with the concentrations found in the effluent; 124 mg/l chloride and 135 mg/l sulfate as the 1965-1970 average. Much higher sulfate values are found in observation wells #1 and #3 on the northeast side of the river, but the corresponding chloride values are low. This high sulfate and low chloride trend is also found in observation wells #6, #9 and #10, and Well 25G1. Piezometers X-1 and Y-1, however, show high values for both chloride and sulfate which resemble those that were found in the original piezometers and indicate the wave of high TDS water which apparently precedes the spreading effluent.

The remaining wells and piezometers on the southeast and southwest side of the river have low concentrations of both chloride and sulfate. These values are probably indicative of the normal background conditions not influenced by either the spreading operations, the underflow of the river, or the fault zone. Well 23P5 appears to be an exception as its quality resembles the quality of the water being spread. However, this is a very shallow well, on the order of 40 feet deep, and quite possibly could be experiencing changes in chemical quality associated with its shallow nature. Well 23Q3, which is between 23P5 and the replenishment area, does not show comparable concentrations of either chloride or sulfate. Therefore, the high concentrations of chloride and sulfate do not appear to be due to migration of water from the spreading area.

The distribution of sulfate throughout the area does not have a definite correlation with the concentrations found in the effluent being spread in the replenishment area. The observation wells which exhibit the higher sulfate concentrations, 1 and 3, also have given the highest temperature readings found in any of the wells. Apparently the hydrothermal conditions associated with the San Jacinto Fault zone have created solutions of high sulfate concentrations on the northeast side of the river.

SECTION XII

SUMMARY OF FINDINGS

The upper San Jacinto River Groundwater Basin lies 30 miles southeast of the City of Riverside in Riverside County, California, and is approximately 54 square miles in area. Ground elevations vary from 2,000 feet in the southeast section of the basin to 1,420 feet in the northwest section. The San Jacinto Mountains form almost all of the drainage area, with the highest surface expression, Mt. San Jacinto, standing 10,805 feet above sea level. The runoff that originates in this drainage area is carried over and through the groundwater basin in the San Jacinto River which emerges from the mountains into the southeast corner of the basin. This basin was considered ideally suited to study the effects of recycling wastewater on an existing groundwater supply because the basin is essentially closed. Based on existing well data, this basin has been divided into three separate sub-basins, each with distinct groundwater conditions:

> The Canyon Sub-basin is upstream of the nearly impermeable San Jacinto Fault and along the San Jacinto River. This area has high water levels which fluctuate 100 feet or more annually. This fluctuation is caused by recharge from the San Jacinto River in the winter and heavy pumping withdrawal in the summer. These high water levels are partially maintained by the near-impermeability of the San Jacinto Fault.
>
> Downstream from the Canyon Sub-basin is the Intake Area which is underlain by highly permeable sedimentary deposits and is recharged from both Bautista Creek and the San Jacinto River as well as some flow through and/or over the San Jacinto Fault. Also, this area supplies the major portion of water to the Pressure Area.
>
> Within the third or Pressure Area which is bounded by the Casa Loma and San Jacinto Faults from the City of San Jacinto northwestward, well logs reveal a substantial thickness of low water-bearing sediments. This area was historically artesian but over a period of years the groundwater basin has been pumped down resulting in a dropping of the groundwater level as much as 200 feet. The northwest boundary of this zone is immediately north of the San Jacinto River where the sediments become relatively impervious. The major portion of water in this area comes from the Intake Area.

The San Jacinto Fault forms the northern and eastern boundaries of the groundwater basin and is somewhat impervious to groundwater flow. The Casa Loma Fault traverses the western portion of the basin and also inhibits groundwater transfer.

The climate of the Upper San Jacinto Groundwater Basin is dry, with an average annual valley rainfall of between 12 and 13 inches occurring primarily during the winter months. Rain squalls occur occasionally during the summer months. Valley temperatures are high during the summer, with readings over 110°, and during winter nights the temperatures drop below freezing. The average rainfall is insufficient to sustain agricultural crops which require significant amounts of water and hence pumpage of the groundwater or importation of surface water is necessary.

The San Jacinto River and its tributaries carry the runoff which originates in the watershed of the groundwater basin, the San Jacinto Mountains, into the basin where recharge occurs and, during flood times, over the basin into Railroad Canyon Lake and Elsinore Lake. The major tributaries to the San Jacinto River are the North and South Forks of the River and Strawberry Creek, all of which join the river above the Canyon Sub-basin, and Indian Creek, Bautista Creek, Poppet Creek and Potrero Creek.

Stream flow records on the above streams are limited, as is common for many western rivers. Almost all of the stream flow which is contributed to the groundwater supply comes from the San Jacinto River, and Indian, Bautista and Poppet Creeks. Very little of the water which is carried by Potrero Creek is percolated into the ground.

A 47-year period of rainfall records was studied and a 38-year base period, beginning with the 1922-23 fiscal year and ending in 1959-60 was selected. The mean precipitation for this period closely approximates the long-term mean for the entire period of record.

The surface inflow to the basin is mainly from the San Jacinto River, and Bautista, Indian, Poppet and Potrero Creeks while most of the surface outflow is along the San Jacinto River. The net groundwater underflow through the faults is assumed to be zero. The annual average change in the groundwater storage was calculated to be about 12,000 acre feet, and the long-term potential yield was shown to be about 11,300 acre feet.

Lack of continuity of data for the same well over a long period of time in or near the replenishment area made it impossible to determine any trends in the chemical quality of the groundwater. However, from a comparison of Waring's report(9) dated 1915 and this study, it appears that the mineral content has been fairly constant, with the chlorides and sodium increasing slightly. The quality of the water spread was sufficiently different from the existing groundwater that any mixing and blending should have been observable. The basic water quality tracer used in the study was chloride and some changes were indicated. Sulfate and electrical conductivity were also used as quality tracers, but results were masked by the San Jacinto Fault zone which causes high sulfate concentrations in the area.

At the beginning of the project it was decided that the method of applying water in the spreading basins should be one of alternately wetting and drying. It is known that a constantly wet soil will eventually seal. Also, alternately wetting and drying a basin by intermittent spreading permits air to enter the soil, thus allowing oxygen to reach the soil organisms. These organisms, particularly aerobic bacteria, utilize the free oxygen in biochemical oxidation process and provide a tertiary treatment to all water spread on the soil.

During early operations, when Colorado River water was spread, several basins were unavoidably continuously wet and clogged tightly, preventing further infiltration of water. Initially, the effluent from the Hemet-San Jacinto Water Reclamation Facility had a heavy load of suspended solids. These solids clogged many basins and it was necessary to scarify the basin soil. Another source of operational difficulties was occasioned by excessive detention time at the Reclamation Facility which permitted a tremendous load of algae to inundate each basin, eventually clogging the soil again. Bypassing of the regulatory ponds eliminated any algae problem and no sealing problems due to algae or suspended solids have occurred since. The basins were rototilled at regular intervals.

The unusually wet winter of 1968-69 created saturated soil conditions throughout the replenishment area and led to substantial increases in the volume of effluent pumped to the replenishment area as some surface runoff was received by the sewerage system. As a result of the increases in plant flow and the high water table, the spreading operation was augmented by a pasture irrigation operation. This operation allowed the basins to be operated on a uniform cycle at a reduced flow.

The basins have exhibited an overall decrease in infiltration rates since the beginning of the spreading operations. Both the hydraulic load rates and the infiltration rates demonstrate a yearly cycle, with the high in summer and the low in the winter. Most of this variation can be attributed to temperature and viscosity changes of the water. The hydraulic load rates have been fairly constant and low throughout most of the project, rarely going above 0.5 feet/day.

Plant growth in the basins was phenomenal. Several maintenance schedules and weed removal operations were attempted until a system whereby the basins were tilled with a large tractor-mounted rototiller proved to be most effective and economical. Now each basin is rototilled two or three times per year.

To obtain data most efficiently and to fulfill several of the project objectives, an underground sampling structure was installed. Investigation of previous work with these underground structures showed that the gravel-filled funnels used to collect samples created a capillary fringe in the soil above the funnels, thereby causing a long detention time in the capillaries. This detention time, expressed as a lag between the time a particle of water enters the soil and the time this same particle discharges from the sampling system, could be in the magnitude of days. However, it was known that the water actually entered the soil and passed the level of the funnel in a matter of minutes or hours. Model studies were conducted to eliminate or minimize the inherent detention time of a system capable of sampling water for chemical and bacterial analysis from the soil which has water moving at unsaturated flow conditions. These studies were directed toward the funnel or actual sampling device which first meets the water. Six-inch diameter funnels were filled with many different types, grades and graded soils and placed in soil within 55-gallon drums to simulate actual field conditions. These results formed a basis from which the studies were conducted.

The highest rate of water recovery was obtained when glass wool was placed in the funnels. These recovery rates were over 90% for the glass wool and less than 10% for different arrangements of soil in the funnels.

In the field installation, the sampling pan funnels placed at one-, two-, four-, six- and eight-foot depths, in both disturbed (fill) and undisturbed (natural) soils, were connected to the central well by use of a plastic pipe. The original installation in the fill material settled around the funnels and had to be replaced. The recovery rate from this sampling structure through 1968 was over 90%. After the large amount of rainfall during the 1968-69 winter the recovery rates from the sampling structure increased to as much as 140% and a new sampling schedule had to be developed.

The recharge water, rather than percolating directly downward to the deep groundwater, has been spreading laterally. The configuration of the percolating water has been such that its shape is not completely understood. In an attempt to delineate a theoretical mound, a grid of piezometers 200 to 400 feet apart, was established over the entire area. The top of the shallow groundwater was found to be only a few feet below the ground surface directly under the replenishment area. It appeared to shift laterally if one basin was recharging considerably more than another.

The quality of the recharged water has been constantly monitored. Much of the quality data was obtained from analyses of water from both the sampling pans and piezometers. The analyses included Methylene Blue Active Substances, Ammonium-Nitrogen, Nitrate-Nitrogen, Total and Dissolved Chemical Oxygen Demand, Non-filterable and Volatile Residue, Hardness, Filterable Residue, Confirmed and Fecal Coliform. MBAS concentrations dropped to less than 0.2 mg/l at the eight-foot level. This low concentration can partially consist of positive interferences in the analysis. Nitrate-Nitrogen concentrations increased down to the four-foot level, then decreased thereafter. Both dissolved and total chemical oxygen demands decreased rapidly as the water percolates downward. The confirmed and fecal coliform concentrations also decreased rapidly with depth and at the eight-foot level there was approximately 10 fecal coliform per 100 milliliters of water.

As much background data as possible were obtained on the wells surrounding the recharge area. All of these wells were sampled regularly to produce additional background and as a check on the movement of the recharge water. In late 1968, additional wells were found in the nearby area and these wells were incorporated in the study. In July 1969 and again in August 1970 several observation wells were drilled and the information provided by these wells has also been included in the study. The location of these wells is such that the recharge area is encircled in all directions, and it was believed that the wastewater could be traced. The contours of the deep groundwater show a pumping depression upstream, i. e., to the southeast.

A cable tool well was dug in the southeast corner of the replenishment area, providing soil samples during the drilling operations. To date, water samples from this well have shown no traces of the recharged water. A packer pump was built to obtain water samples from both this cable tool well (25D2) and an abandoned well (23R1) immediately northwest of spreading basin 10. It has been carried through each well several times and water obtained from various levels.

It is now known that downward permeability in the area is impeded by a structure characterized by silt and clay layers interbedded by coarser material. A further proof of this phenomenon is apparent from the geothermal survey. Using a series of extremely accurate temperature probes, an irregular elliptical groundwater mound with a long axis of approximately 6,000 feet was developed.

The temperature probes were inserted in a rectangular network of piezometers that were placed about 10 feet deep and temperature probes, called thermisters, were inserted, balanced using a wheatstone bridge, and temperatures read. By monitoring and plotting these temperatures several times during the year, and knowing the temperature effects of the bedrock, gravels and underground waters, the flow of the recharged water could be segregated and the migration of the underflow could be interpreted.

An extremely interesting fact also emerged from the geothermal surveys. They suggest that this migration could have extended further except that much of the recharge water apparently flowed underground to the northwest along the subsurface river channel, and its identity was lost.

SECTION XIII

ACKNOWLEDGMENT

It is neither possible nor practical to list each and every institution, agency and individual contributing to this project, as they are far too numerous. However, in addition to the individuals listed on the Roster of Governing Bodies (following page), the authors (Doyle F. Boen, James H. Bunts, Jr. and Robert J. Currie) are especially indebted to the following:

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Los Angeles County Flood Control District
Riverside County Flood Control and Water Conservation District
Engineering-Science, Inc.
Geothermal Surveys, Inc.
The large group of local farmers and landowners who allowed the District to traverse their lands for geological, seismic, and thermal surveys and for the drilling of observation wells and piezometers.

The District is also indebted to the owners of the wells in the area who have allowed and are continuing to allow unlimited access to their wells.

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GLOSSARY

Acre foot	A volume of water 1 foot deep and 1 acre in area, or 43,560 cu. ft., or 325,900 gallons
Activated sludge	Sludge floc produced in raw or settled wastewater by the growth of zoogleal bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning floc previously formed
Activated sludge process	A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and wasted or returned to the process as needed
Aerobic	Requiring, or not destroyed by, the presence of free elemental oxygen
Algal bloom	Large masses of microscopic and macroscopic plant life, such as green algae, occurring in bodies of water
Alluvial deposit	Sediment deposited in place by the action of streams
Alluvium	Sand, silt or similar detrital material deposited in flowing water, or the permanent unconsolidated deposits thus formed
Anaerobic	Requiring, or not destroyed by, the absence of air or free (elemental) oxygen
Anomaly	A deviation from a norm for which an explanation is not apparent on the basis of available data
Anistropic	Exhibiting different properties when tested along axes in different directions
Aquifer	A porous, water-bearing geologic formation. Generally restricted to materials capable of yielding an appreciable supply of water

Artesian	Pertaining to groundwater, or things connected with groundwater (e.g., a well or underground basin) where the water is under pressure and will rise to a higher elevation if afforded the opportunity to do so
Bedrock	The solid rock encountered below the mantle of loose rock and more or less unconsolidated material which occurs on the surface of the lithosphere. In many places, bedrock appears at the surface
BOD	Abbreviation for biochemical oxygen demand. The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specific conditions. A standard test used in assessing wastewater strength
Cable-tool drilling	A method of drilling wells by the use of cable tools. The hole is drilled by a heavy bit, which is alternately raised by a cable and allowed to drop, breaking and crushing the material which it strikes. Such material is removed from the hole by bailing or sand pumping
Capillary water	Water held above the zone of saturation in the soil or in the interstices of other porous media by capillary force
COD	Abbreviation for chemical oxygen demand. A measure of oxygen-consuming capacity of inorganic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test. It does not differentiate between stable and unstable organic matter and thus does not correlate with biochemical oxygen demand
Cienega	A spring or an area where the water table is at or near the surface of the ground
CIT	California Institute of Technology

Coliform-Group bacteria	A group of bacteria predominantly inhabiting the intestines of man or animal, but also occasionally elsewhere. It includes all aerobic and facultative anaerobic Grain-negative, non-spore-forming bacilli that ferment lactose with the production of gas
District	Eastern Municipal Water District
Effluent	Wastewater or other liquid partially or completely treated, or in its natural state, flowing out of a reservoir, basin, treatment plant, or industrial treatment plant, or part thereof
Electric well log	A record obtained in a well investigation from a traveling electrode: it is in the form of curves that represent the apparent values of the electric potential and electric resistivity or impedance of the formation and their contained fluids throughout the uncased portions of a well
Fecal Coliform	That portion of the coliform group which produces gas from Lactose at 44.5° C. and is present in the gut or feces of warm-blooded animals
Graben	A depressed segment of the earth's crust bounded on at least two sides by faults and generally of considerable length as compared to width.
Hydraulic load rate	The total volume of water applied to a basin during the month, divided by the number of days in the month divided by the area of the basin
Infiltration rate	The short-term rate at which water actually enters the soil
MBAS	Methylene blue active substances - indicates detergent concentration
mgd	Million gallons per day

Milligrams per liter	A unit of the concentration of water or wastewater constituent. It is 0.001 g of the constituent in 1,000 ml of water. It has replaced the unit formerly used commonly, parts per million, to which it is approximately equal, in reporting the results of water and wastewater analysis
MPN	Most probable number - that number of organisms per unit volume that, in accordance with statistical theory, would be more likely than any other number to yield the observed test result or that would yield the observed test result with the greatest frequency. Expressed as density of organisms per 100 ml. Results are computed from the number of positive findings of coliform-group organisms resulting from multiple-portion decimal-dilution plantings
Parts per million (PPM)	The number of weight or volume units of a minor constituent present with each one million units of the major constituent of a solution or mixture
Perched groundwater	Groundwater that is separated from the main body of groundwater by an aquiclude
Piezometer	An instrument for measuring pressure head in a conduit, tank or soil
Potential long-term yield	The annual rate at which water can be extracted from a groundwater basin without causing any long-term lowering of the groundwater table
Ripening	The aerobic conditions created in the soil through intermittent application of the effluent and the subsequent reaeration of the soil

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1 Accession Number	2 Subject Field & Group	
W	Ø3C	SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM

5 *Organization*

Eastern Municipal Water District, Hemet, California

6 *Title*

STUDY OF REUTILIZATION OF WASTEWATER RECYCLED THROUGH GROUND WATER.

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25 *Identifiers (Starred First)*

27 *Abstract*

A project to demonstrate the feasibility and safety of recycling water under operating ditions was performed in the Hemet-San Jacinto Valley of the State of California. Since Valley is a closed basin, and is dependent in part upon imported water, it was felt that recycling of the water would ultimately lead to a reduction in the salt input and result degradation of the existing underground reservoir.

Extensive geological investigations indicated that the basin was not homogeneous in natu but had clay lenses and faulting which interfered with the creation of a classic mound. Partially as a consequence, the recharge of 5,380 acre feet of wastewater during this s and one-half year period had no effect on surrounding water wells.

The project added considerable knowledge and experience to the technology of intermitte wastewater percolation and associated monitoring techniques. A novel feature of the project was the employment of highly sensitive temperature probes to trace the lateral migration of the recharged water, much of which appears to be escaping as shallow under to the San Jacinto River and hence not reaching the deep groundwater table.

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Abstractor	Institution