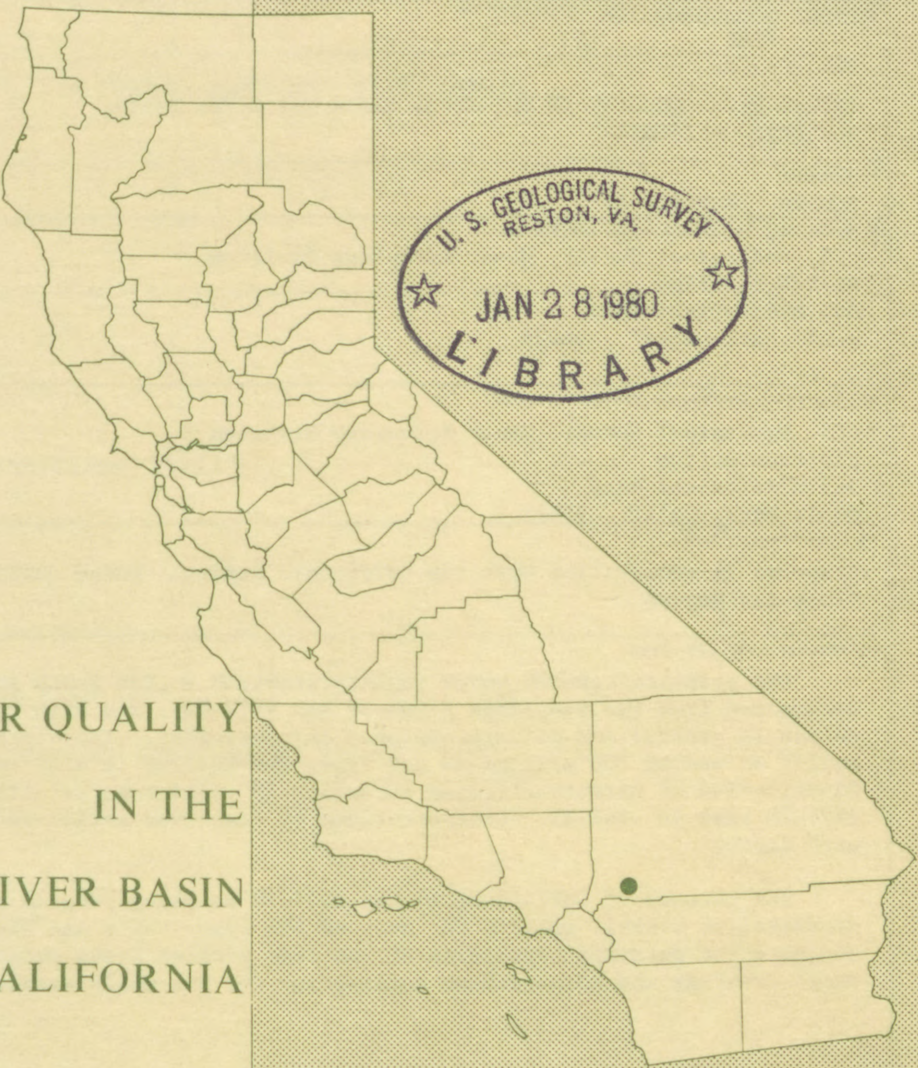

GROUND-WATER QUALITY IN THE UPPER SANTA ANA RIVER BASIN SOUTHERN CALIFORNIA

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 79-113

Prepared in cooperation with the
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The principal ground-water quality problems in the Santa Ana River basin, as determined from two samplings (1968-69 and 1977-78), are high concentrations of dissolved solids in general and nitrate-nitrogen in particular. The distribution of dissolved solids exceeding 800 milligrams per liter was smaller in area in 1977-78 than in 1968-69. Distribution of nitrate-nitrogen exceeding 10 milligrams per liter was larger in area in 1977-78 than in 1968-69. Concentrations of dissolved solids and nitrate-nitrogen decreased with depth.

The network of wells used in the 1977-78 sampling program provides only a general appraisal of overall quality for most of the upper Santa Ana River basin. It is not adequate for detailed appraisals of specific problem areas because it lacks sufficient areal coverage and construction information for the wells sampled.

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By Lawrence A. Eccles

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 79-113

Prepared in cooperation with the

California Regional Water Quality Control Board,

Santa Ana Region

5027-13

December 1979

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

The inch-pound system of units is used in this report. For readers who prefer metric units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
acres	0.4047	hm^2 (square hectometers)
ft (feet)	0.3048	m (meters)
inch	25.4	mm (millimeters)
lb (pounds)	453.6	g (grams)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)

Degrees Fahrenheit (°F) are converted to degrees Celsius (°C) by using the formula: $°C = (°F-32)/1.8$.

GROUND-WATER QUALITY IN THE UPPER SANTA ANA RIVER BASIN, SOUTHERN CALIFORNIA

By Lawrence A. Eccles

ABSTRACT

The principal ground-water quality problems in the Santa Ana River basin, as determined from two samplings (1968-69 and 1977-78), are high concentrations of dissolved solids in general and nitrate-nitrogen in particular. The distribution of dissolved solids exceeding 800 milligrams per liter was smaller in area in 1977-78 than in 1968-69. Distribution of nitrate-nitrogen exceeding 10 milligrams per liter was larger in area in 1977-78 than in 1968-69. Concentrations of dissolved solids and nitrate-nitrogen decreased with depth.

The network of wells used in the 1977-78 sampling program provides only a general appraisal of overall quality for most of the upper Santa Ana River basin. It is not adequate for detailed appraisals of specific problem areas because it lacks sufficient areal coverage and construction information for the wells sampled.

INTRODUCTION

Ground water is the major source of water for public and irrigation supplies in the upper Santa Ana River basin (fig. 1). Land use and water use in the basin are rapidly changing from agricultural to urban. Because water-quality requirements are more strict for public supplies than for agricultural supplies, water managers increasingly are facing the need to monitor changes in ground-water quality. Before the rapid urbanization of the upper basin, ground-water quality was of much less concern.

The principal water-quality problems determined from a sampling program carried out in 1968-69 by a consultant were high concentrations of dissolved solids and nitrate-nitrogen.[1] The local ground-water quality objectives for dissolved solids call for concentrations no higher than 1,050 mg/L (milligrams per liter) and for nitrate-nitrogen no higher than 20 mg/L in part of the Riverside-Arlington subbasin. Quality objectives in other subbasins call for maximum dissolved solids as low as 200 mg/L and maximum nitrate-nitrogen concentrations as low as 1 mg/L (California State Water Resources Control Board, 1975).

Comprehensive ground-water sampling had not been done in the upper Santa Ana River basin since 1968-69, when about 200 wells (fig. 2) were sampled to provide data for constructing water-quality contour maps and for a mathematical model used to predict ground-water quality. Since 1968-69, urban development has increased in the basin, causing increased demands on ground water for public supplies.

Periodic ground-water quality sampling is needed to document changes in quality and to provide data for verification of predictive mathematical models used by the water managers.

The California Regional Water Quality Control Board, Santa Ana Region (Regional Board), is the agency designated to maintain a data base and a centralized storage and retrieval system for water-quality information being collected by local agencies. The Regional Board also plans to document the changes in ground-water quality in the Santa Ana River basin.

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[1]Nitrate concentrations are expressed in terms of an equivalent amount of elemental nitrogen (U.S. Environmental Protection Agency, 1977) and are referred to as nitrate-nitrogen in this report.

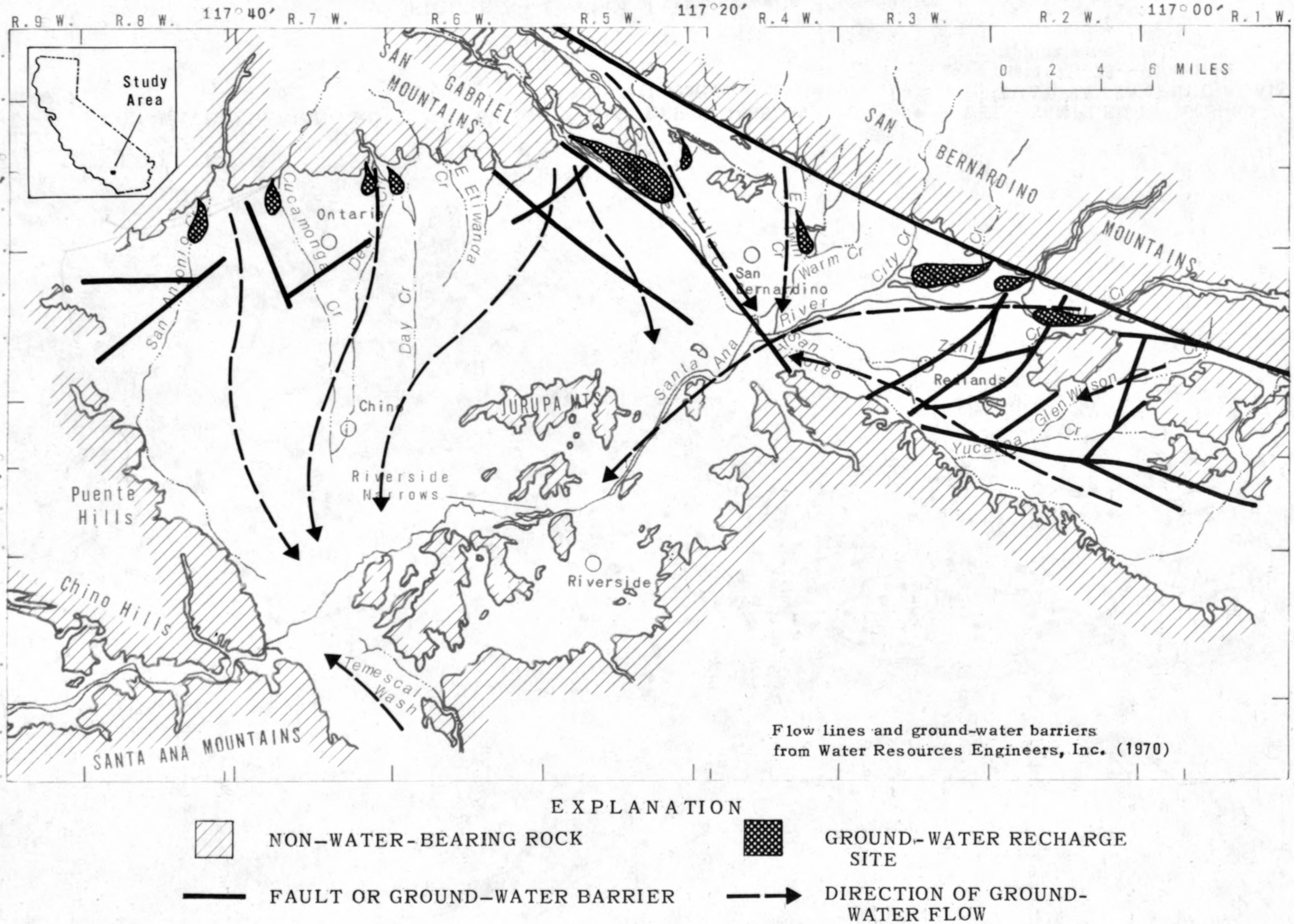
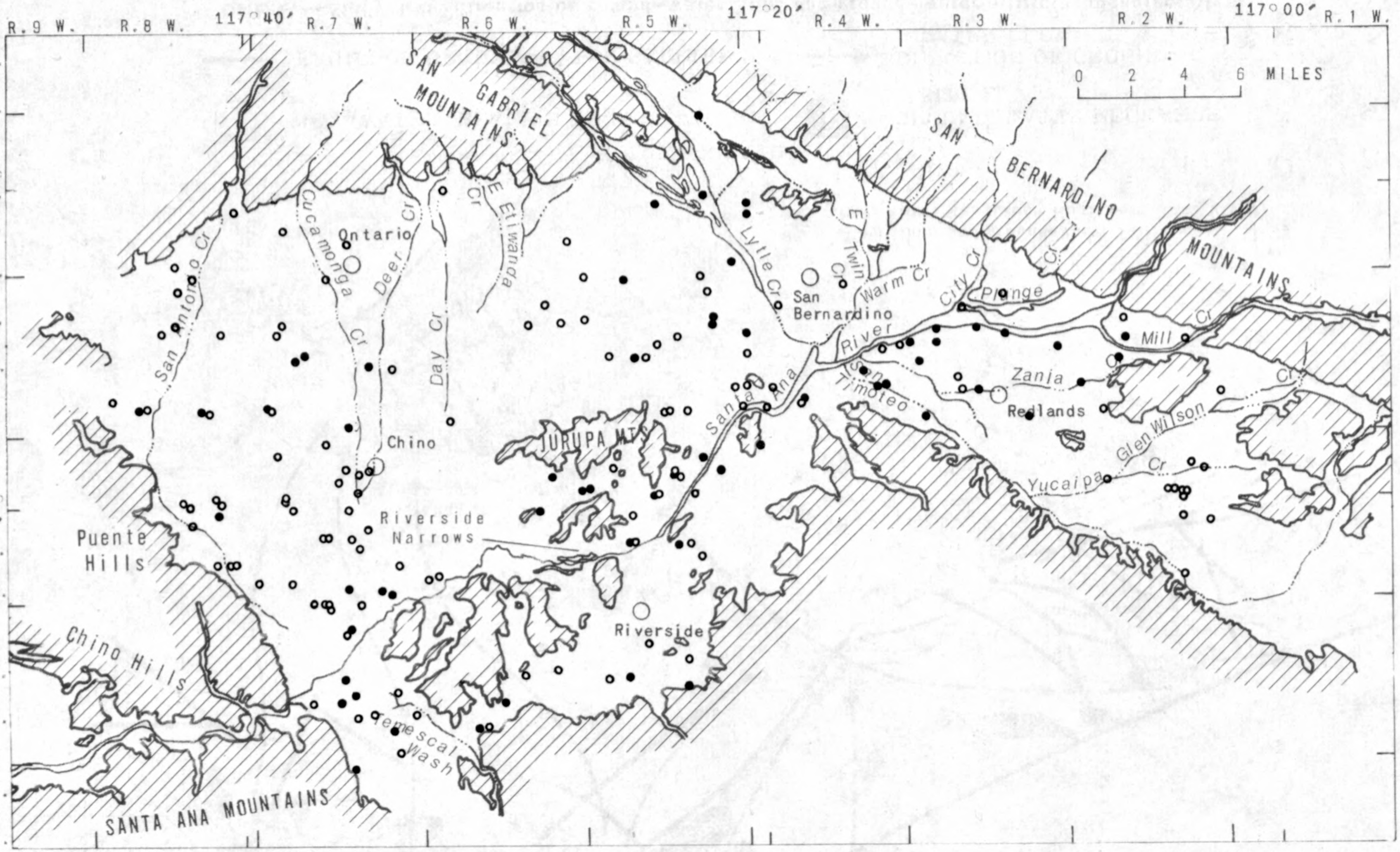


FIGURE 1.--Study area, direction of ground-water flow, and ground-water artificial recharge sites.



EXPLANATION

NON-WATER-BEARING ROCK

○ WELL SAMPLED IN 1968-69 ONLY--(Location approximate)

● WELL SAMPLED IN 1968-69 THAT WAS SAMPLED AGAIN IN 1977-78--(Location approximate)

FIGURE 2.--Location of sampled wells, 1968-69.

Purpose and Scope

The purposes of this study were to appraise current ground-water quality, to compare current quality with quality determined from the 1968-69 sampling, to provide new input for a water-quality model and thereby compare current quality with model predictions, and to appraise the ground-water quality monitoring network.

The information from this study will aid the Regional Board and the basin water managers in designing a long-term ground-water quality monitoring network and in identifying areas that need further study.

The scope of the study included:

1. Collection of ground-water samples and implementation of a program to assure quality and compatibility of water samples. Chemical analyses of samples collected and a quality-assurance program for the analyses were both provided by the Regional Board.

2. Collection of other current ground-water quality data and drillers' logs provided by the Regional Board or filed with the U.S. Geological Survey.

3. Determination of the distribution of dissolved solids, nitrate-nitrogen, chloride, total hardness, boron, sodium, sulfate, ammonia-nitrogen, phosphate, and fluoride.

4. Comparison of the changes in the distribution of dissolved solids, nitrate-nitrogen, chloride, total hardness, and boron that have taken place between the 1968-69 and 1977-78 ground-water samplings.

5. Comparison of the distribution of dissolved solids for 1977-78 with model predictions for 1980.

6. Compilation of water-quality data collected during the study.

7. Appraisal of the network of wells used by the cooperator for the 1977-78 ground-water sampling program and assessment of the adequacy of selected wells to provide long-term representative data.

Previous Studies

An extensive ground-water quality sampling program, two interpretative water-quality studies, and a water-quality-model study of the upper Santa Ana River basin were made during the past 10 years.

1. About 200 wells were sampled in 1968-69 by combined efforts of municipal water districts and several local water agencies in the upper Santa Ana River basin. The data from this extensive sampling were used in the following studies.

2. Water Resources Engineers, Inc. (1969) prepared a report for the California State Water Resources Control Board and the Regional Board describing the study of salt balances and reasons for increasing salt concentrations in the basin. The dissolved-solids water-quality model presently used for the basin planning procedure, described on page 9, was developed by Water Resources Engineers, Inc. for that report.

3. Water Resources Engineers, Inc. (1970) prepared a report for the Santa Ana Watershed Planning Agency to help them develop water-quality management plans for the Santa Ana River basin. The report covered climate, geology, hydrology, and water quality of the Santa Ana River watershed.

4. The Kearney Foundation of the University of California (1973) investigated nitrate-nitrogen in relation to ground-water pollution in the upper Santa Ana River basin.

Acknowledgments

The Chino Basin Municipal Water District, the San Bernardino Valley Municipal Water District, and the Western Municipal Water District collected the water samples. Most of the chemical analyses of the samples were made by Edward S. Babcock and Sons, Inc., Riverside, Calif.

Description of Study Area

The upper Santa Ana River ground-water basin is in a semiarid inland valley in southern California (fig. 1). It is undergoing transformation from an agricultural area to an urban area, with most urbanization taking place in the western part of the study area and around San Bernardino. Ground water is the major source of water supply in the basin.

The basin is surrounded by mountains, with some peaks exceeding 10,000 ft in altitude. Mean annual precipitation in the watershed ranges from 15 to 40 inches, with most occurring during the winter. Precipitation is greatest on the slopes of the San Bernardino and San Gabriel Mountains at altitudes above 5,000 ft. The area of the watershed, which includes the ground-water basin, is about 1,500 mi^2.

The principal stream in the area is the Santa Ana River, which originates in the San Bernardino Mountains. The river crosses the valley floor from northeast to southwest. From the vicinity of San Bernardino eastward to the San Bernardino Mountains, the riverbed, which is nearly a mile wide in some places, is usually dry. Downstream from San Bernardino the river flows continuously to the lower Santa Ana River basin because of rising ground water and additions of treated sewage effluent. As water in the river leaves the upper basin, more than half the dry-weather flow consists of treated sewage effluent (R. R. Nicklen, California Regional Water Quality Control Board, Santa Ana Region, oral commun., 1978). Several other ephemeral streams traverse the basin. Flow in these streams on the valley floor occurs only during unusually heavy rains or because of (1) subsurface barriers that cause ground water to come to the surface, (2) artificial-recharge operations, and (3) additions of treated sewage effluent.

The ground-water basin under the valley floor has an area of about 700 mi^2. The basin is bounded on the north by the San Gabriel and San Bernardino Mountains, on the east by the San Bernardino Mountains, on the southeast by low, barren hills, on the southwest by the Santa Ana Mountains, and on the west by the Chino and Puente Hills (fig. 1).

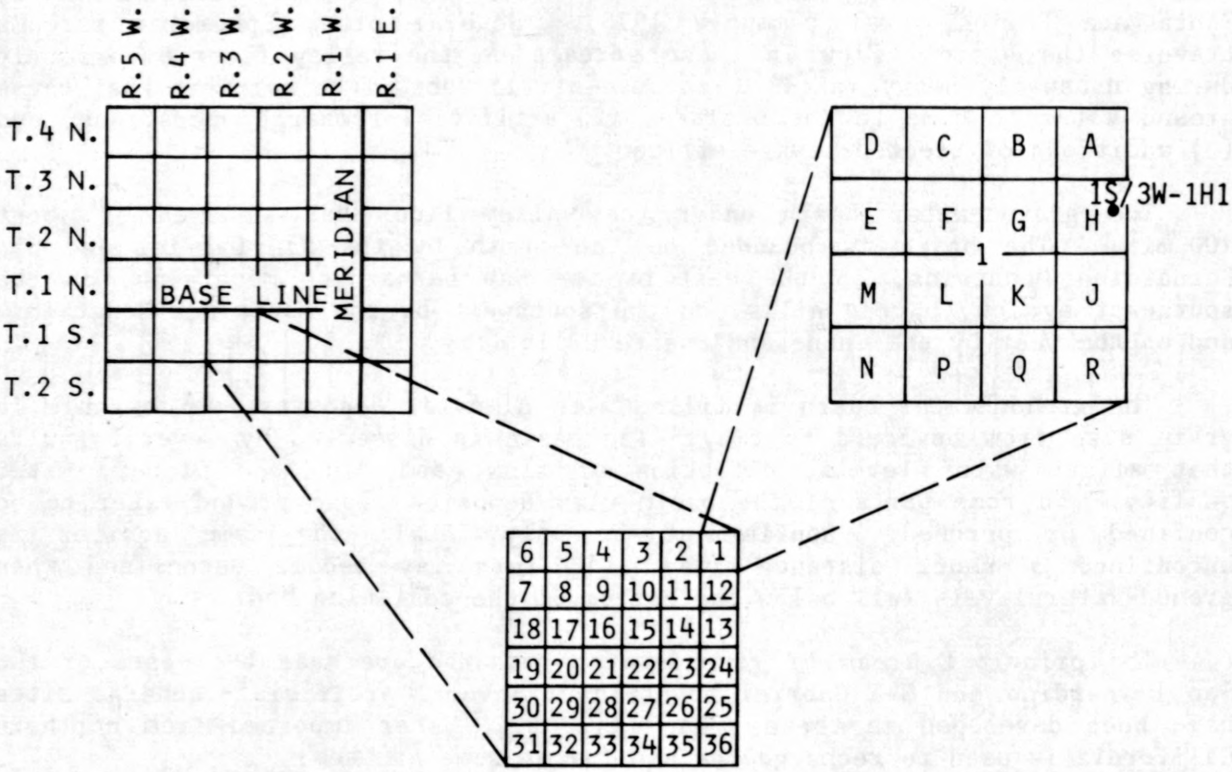
The ground-water basin is filled with alluvial deposits, which range in grain size from boulders to clay. The basin is dissected by several faults that affect water levels, direction of flow, and, in some places, water quality. In some parts of the basin clay deposits cause ground water to be confined or perched. Confinement is only local; the same aquifer is unconfined a short distance away. Aquifers may become unconfined when ground-water levels fall below the bottom of the confining bed.

The principal areas of ground-water recharge are near the bases of the San Bernardino and San Gabriel Mountains. Several artificial-recharge sites have been developed in these areas (fig. 1). Water imported from northern California is used to recharge the aquifer at some of them.

In 1970, ground water made up 73 percent of the water supply of the upper basin. The remaining 27 percent came almost entirely from imported water. Sewered and unsewered wastewater return to the basin during the same period amounted to 74 percent of the total supply (R. R. Nicklen, Regional Board, oral commun., 1978). The wastewater consists of treated sewage effluent, septic tank effluent, and irrigation return. Recycling of wastewater to ground water is one of the major causes of the dissolved-solids buildup.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. For example, in the well number 1S/3W-1H1, the part of the number preceding the slash indicates the township (T. 1 S.); the number and letter following the slash indicate the range (R. 3 W.); the number following the hyphen indicates the section (sec. 1); the letter following the section number indicates the 40-acre subdivision of the section according to the lettered diagram below. The final digit is a serial number designation for wells in each 40-acre subdivision. Some wells have not been assigned a serial number but are designated by either double zero (00) or have no number following the 40-acre subdivision letter designation.



BASIN PLANNING PROCEDURE AND SAMPLING NETWORK

Basin Planning Procedure

A basin planning procedure utilizing several computer models has been developed by local agencies. These models can be used to evaluate alternative water-management plans by performing the following functions:

1. Organizing all hydrologic, population, and land-use data.
2. Calculating water requirements (water-supply plan) and waste loads (wastewater plan).
3. Calculating water levels, flow between ground-water subbasins, and base flow of the Santa Ana River.
4. Calculating dissolved-solids concentrations for ground water and the Santa Ana River.
5. Calculating cost of all factors in the water-management plan and total cost of the plan.

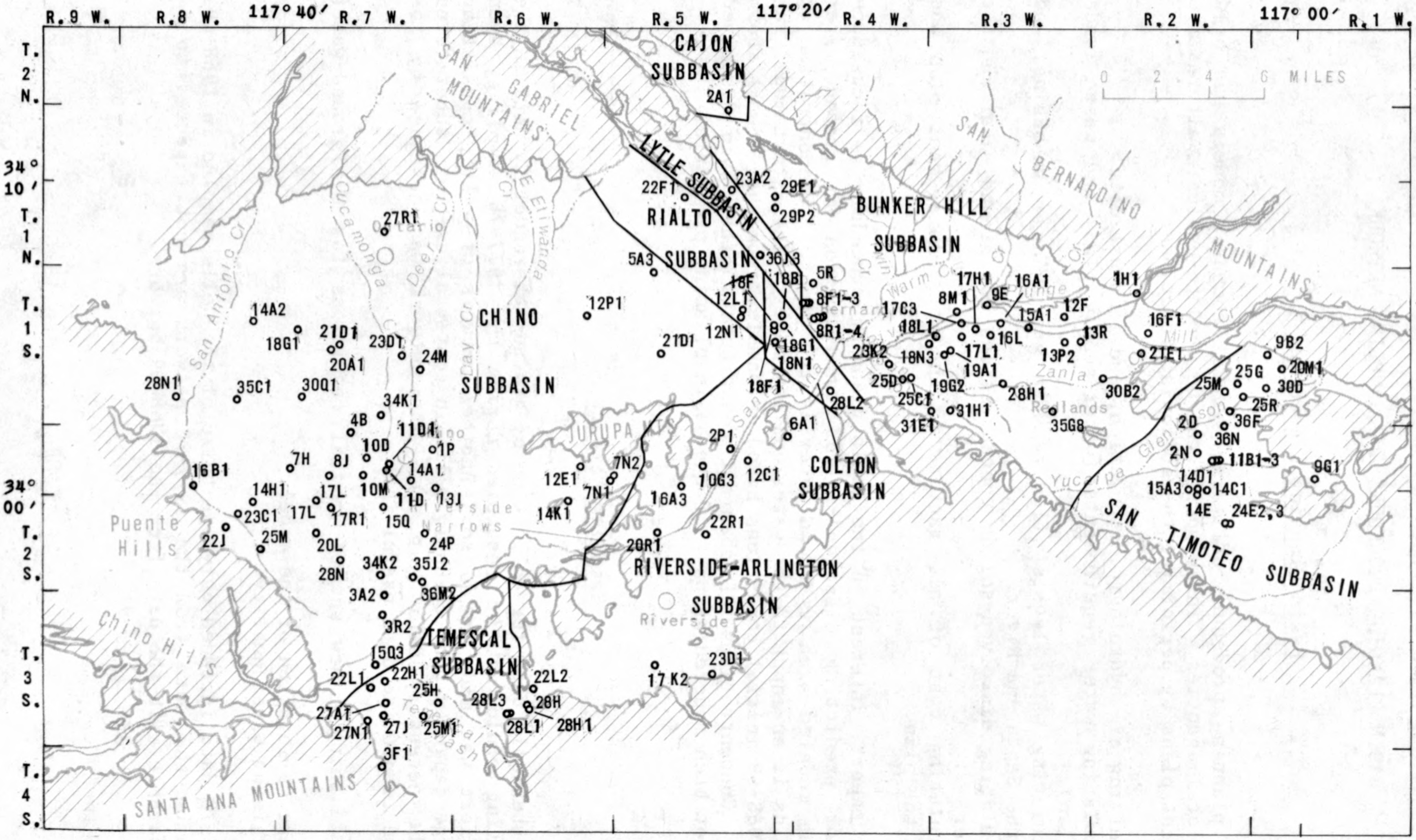
For this report, interest in the basin planning procedure is focused on the model for predicting dissolved-solids concentration in ground water (item 4). The modeled area is shown later in the report. Concentration of dissolved solids is an input to the water-quality model. The latest model run (1974) used 1968-69 initial conditions based on samples from the network shown in figure 2. Concentrations of chemical constituents other than dissolved solids have not been modeled as part of the basin planning procedure.

Sampling Network

Many of the wells used for collection of ground-water quality data in the 1968-69 sampling could not be resampled during the 1977-78 sampling, even though an effort was made to do so. Another network of wells, consisting mostly of large-capacity public-supply wells in continual use, was substituted to gather the necessary data (fig. 3). The network was designed by the Regional Board to provide data useful in:

1. Establishing a new set of initial conditions for the ground-water quality model.
2. Future calibration of the model.
3. Appraising water quality.

The 1977-78 data included only one-third of the wells sampled in 1968-69. For this reason the data from the 1977-78 network are not expected to be entirely comparable with the data from the 1968-69 network.



EXPLANATION

NON-WATER-BEARING ROCK

SUBBASIN BOUNDARY (From Water Resources Engineers, Inc., 1970)

17K2 SAMPLED WELL AND NUMBER (TABLE 2)

FIGURE 3.--Location of sampled wells, 1977-78.

Data from the 1977-78 network were used to construct ground-water quality contour maps for concentrations of dissolved solids, nitrate-nitrogen, chloride, total hardness, boron, sodium, and sulfate. The dissolved-solids contour map will also be used to assign values to each of the 247 elements of the modeled area shown later in the report (fig. 14).

Water Samples and Chemical Analyses

Water samples were collected for this study by the municipal water districts previously identified. Instructions for sample collection were provided by the U.S. Geological Survey and the Regional Board. Most of the samples were analyzed, for the constituents shown in table 1, by Edward S. Babcock and Sons, Inc., Riverside, Calif. Analytical methods described by the American Public Health Association (1975) were used with the applicable U.S. Environmental Protection Agency (1977) restrictions. The sources of a few of the chemical analyses were other laboratories certified by the State of California.

DISTRIBUTION OF CHEMICAL CONSTITUENTS IN GROUND WATER

Quality Appraisal

Appraisal of the ground-water-quality data collected indicates that the most serious problems continue to be high concentrations of dissolved solids and nitrate-nitrogen. Dissolved solids and nitrate-nitrogen are considered to be the characteristics most indicative of ground-water degradation or pollution.

The water-quality control plan for the upper Santa Ana River basin includes ground-water quality objectives for dissolved solids, nitrate-nitrogen, chloride, total hardness, boron, sodium, and sulfate. An extensive list of the objectives can be found in a report of the California State Water Resources Control Board (1975, chap. 4, p. 4-1 to 4-24).

Areal distributions of dissolved solids, nitrate-nitrogen, chloride, total hardness, and boron are focused upon because published information (Water Resources Engineers, Inc., 1970) on previous areal distributions is available and ground-water quality objectives have been set for these characteristics. The distributions of dissolved solids and nitrate-nitrogen are treated extensively because they are considered to be the most important characteristics, and a limit has been established for nitrate-nitrogen in drinking water (U.S. Environmental Protection Agency, 1977). The distributions for sodium and sulfate are presented because they are included in the basin ground-water quality objectives. An appraisal of ammonia-nitrogen and phosphate was made because these constituents could aid in defining areas of polluted or degraded ground water. Fluoride was appraised because there is a standard for drinking water.

Dissolved Solids, 1977-78

Figure 4 shows the 1977-78 distribution for dissolved solids. Dissolved solids are lowest in aquifers located close to the mountains, and they increase with distance downgradient from the mountains. Concentrations are highest at the lower end of the basin, in the Temescal subbasin, Riverside-Arlington subbasin, and lower part of the Chino subbasin. The increase downgradient (see flow pattern in fig. 1) is probably caused by multivaried reuse of the ground water, with return flow from each use moving downgradient.

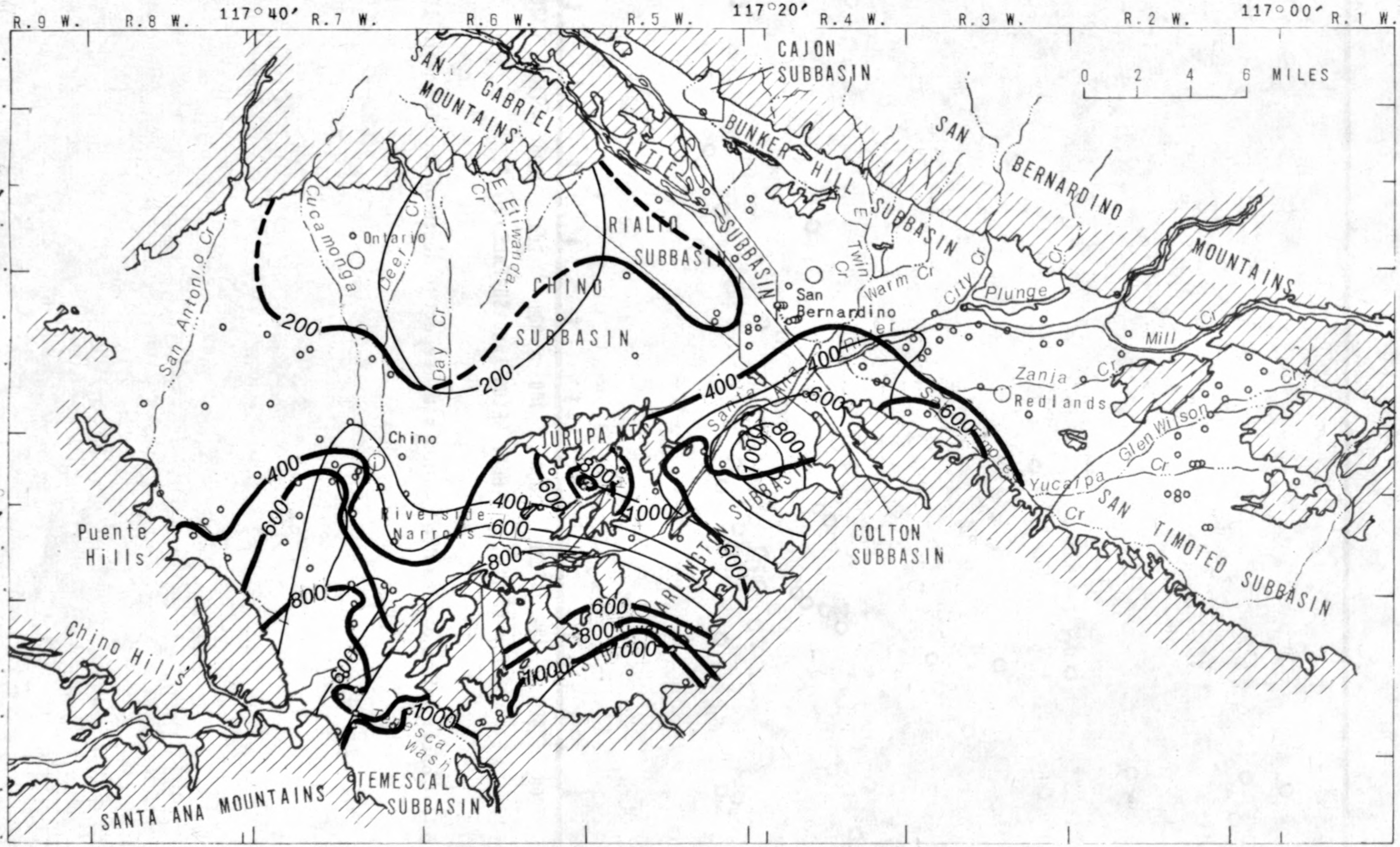
The Riverside-Arlington subbasin historically had a high density of citrus crops. In 1977-78, citrus crops were located principally in the southeastern part of the subbasin. Both the saturated and unsaturated zones in this subbasin are thin (Water Resources Engineers, Inc., 1970, p. 61). The short distance through which the water moves thus results in fairly rapid recharge of ground water. The high concentrations of dissolved solids in water pumped from wells in this subbasin are probably the result of the more highly localized recycling of the ground water here. High concentrations of dissolved solids in the area north of Riverside Narrows also are probably related to the thin saturated and unsaturated zones, which result in localized recycling of ground water.

High concentrations of dissolved solids in water from wells in the Temescal subbasin are probably the result of the same situation that exists in the Riverside-Arlington subbasin. In addition, the Temescal subbasin is at the lower end of the upper Santa Ana River basin and thus receives dissolved solids from water recycled upgradient. Inflow to the Temescal subbasin from the south is relatively slight but has a higher concentration of dissolved solids than water recharging most of the other basins.

High concentrations of dissolved solids in water from wells in the southern part of the Chino subbasin are probably due to location. The southern part of the Chino subbasin, like part of the Temescal subbasin, is at the lower end of the upper Santa Ana River basin and receives dissolved solids from water recycled upgradient.

Local objectives for dissolved solids in public water supplies allow concentrations of as much as 740 mg/L in parts of the Chino subbasin, 840 mg/L in the Temescal subbasin, and 1,050 mg/L in parts of the Riverside-Arlington subbasin (California State Water Resources Control Board, 1975). Objectives for other subbasins in the study area are listed in the basin water-quality control plan (California State Water Resources Control Board, 1975).

Figure 5 shows the dissolved-solids concentration with respect to total well depth for the wells that were sampled for this report (1977-78). Only a few wells had both 1977-78 water-quality data and drillers' logs on file with the U.S. Geological Survey or provided by the Regional Board. Wells yielding water with dissolved-solids concentrations exceeding 720 mg/L are generally less than 250 ft deep, and wells yielding water exceeding 500 mg/L are generally less than 400 ft deep.



EXPLANATION

NON-WATER-BEARING ROCK

SAMPLED WELL, 1977–78

SUBBASIN BOUNDARY

—200— — LINE OF EQUAL DISSOLVED-SOLIDS CONCENTRATION, 1977-78--Dashed where doubtful. Interval 200 milligrams per liter

—600— LINE OF EQUAL DISSOLVED-SOLIDS CONCENTRATION, 1968-69--Interval 200 milligrams per liter (Modified from Water Resources Engineers, Inc., 1970)

FIGURE 4.--Areal distribution of dissolved solids in ground water, 1968-69 and 1977-78.

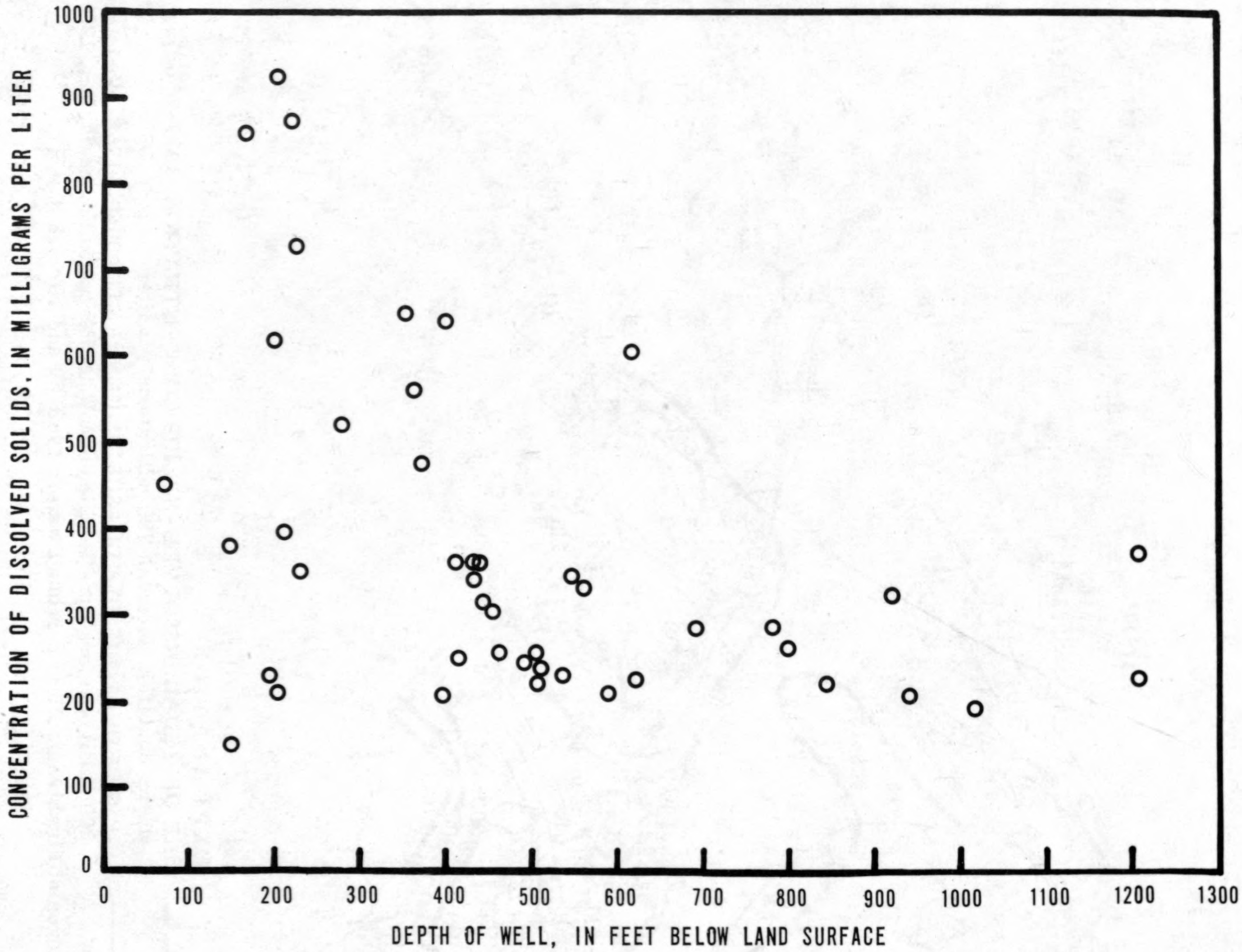


FIGURE 5.--Concentration of dissolved solids with respect to depth of sampled well, 1977-78.

Comparison of Dissolved Solids, 1968-69 and 1977-78

The distribution of dissolved solids in ground water for 1968-69 and for 1977-78 is shown by contour lines in figure 4. The 1968-69 contours presented in this report are from Water Resources Engineers, Inc. (1970). Some of the contours from the Water Resources Engineers report were simplified so that the contour intervals for the 1968-69 data would conform with those for the 1977-78 data. Comparison of the 1968-69 and 1977-78 data shows that the area containing more than 800 mg/L dissolved solids decreased between samplings; whereas the area which had dissolved solids in excess of 400 mg/L increased. Areas of highest concentrations of dissolved solids have generally been dissipated and spread out during the past decade. The causes of this spreading are probably water-management practices such as increased artificial recharge and restrictions on wastewater discharge, changing water use, and a large volume of ground-water recharge from above-normal rainfall since 1976.

The Riverside-Arlington subbasin shows the most pronounced decrease in size among the areas containing high dissolved-solids concentrations in the ground water. This subbasin has thin saturated and unsaturated zones. The low volume of this basin would permit relatively rapid changes in water quality as a result of ground-water recharge. The pronounced decrease in dissolved-solids concentrations during the past decade was due to water-management practices (artificial recharge and restrictions on waste discharge), changing water use, and the large volume of ground-water recharge from above-normal rainfall.

The southwestern part of the Chino subbasin had an increase in the size of the area having dissolved-solids concentrations from 400 to 800 mg/L. Large-scale dairy operations are located in this part of the subbasin, and much growth in these operations has taken place during the past decade. Dairy cattle exceed 200,000 head, probably the highest concentration in the world. Also, the area to the north and upgradient from the southwestern part of the Chino subbasin is one of the most intensely urbanized areas in the upper Santa Ana River basin. It has experienced the most rapid increase in urban development during the past decade. Thus, the increase in dissolved solids in southwestern Chino subbasin is probably caused by the movement of ground water with high concentrations of dissolved solids from areas upgradient, discharges of municipal wastes from the area on the north, and localized discharges of dairy wastes.

Nitrate-Nitrogen, 1977-78

The areal distribution of nitrate-nitrogen data for 1977-78 is shown by symbols in figure 6. Wells producing water with nitrate-nitrogen concentrations exceeding 10 mg/L are found throughout the Riverside-Arlington subbasin, the Temescal subbasin, the southwestern Chino subbasin, and the eastern Bunker Hill subbasin. The limit recommended for nitrate-nitrogen in public water supplies by the U.S. Environmental Protection Agency (1977) is 10 mg/L.

Major sources of nitrate-nitrogen in ground water in the upper Santa Ana River basin include nitrogen fertilizer applied to crops, dairy wastes, and nitrified, treated sewage effluents (Kearney Foundation, 1973). Nitrogen fertilizer application rates for citrus crops were as high as 600 lb of nitrogen per acre per year in the early 1960's but have been greatly reduced during the 1970's. No nitrogen fertilizer has been applied to some orchards in recent years because the irrigation water contains sufficient nitrate-nitrogen to sustain good crop yield.

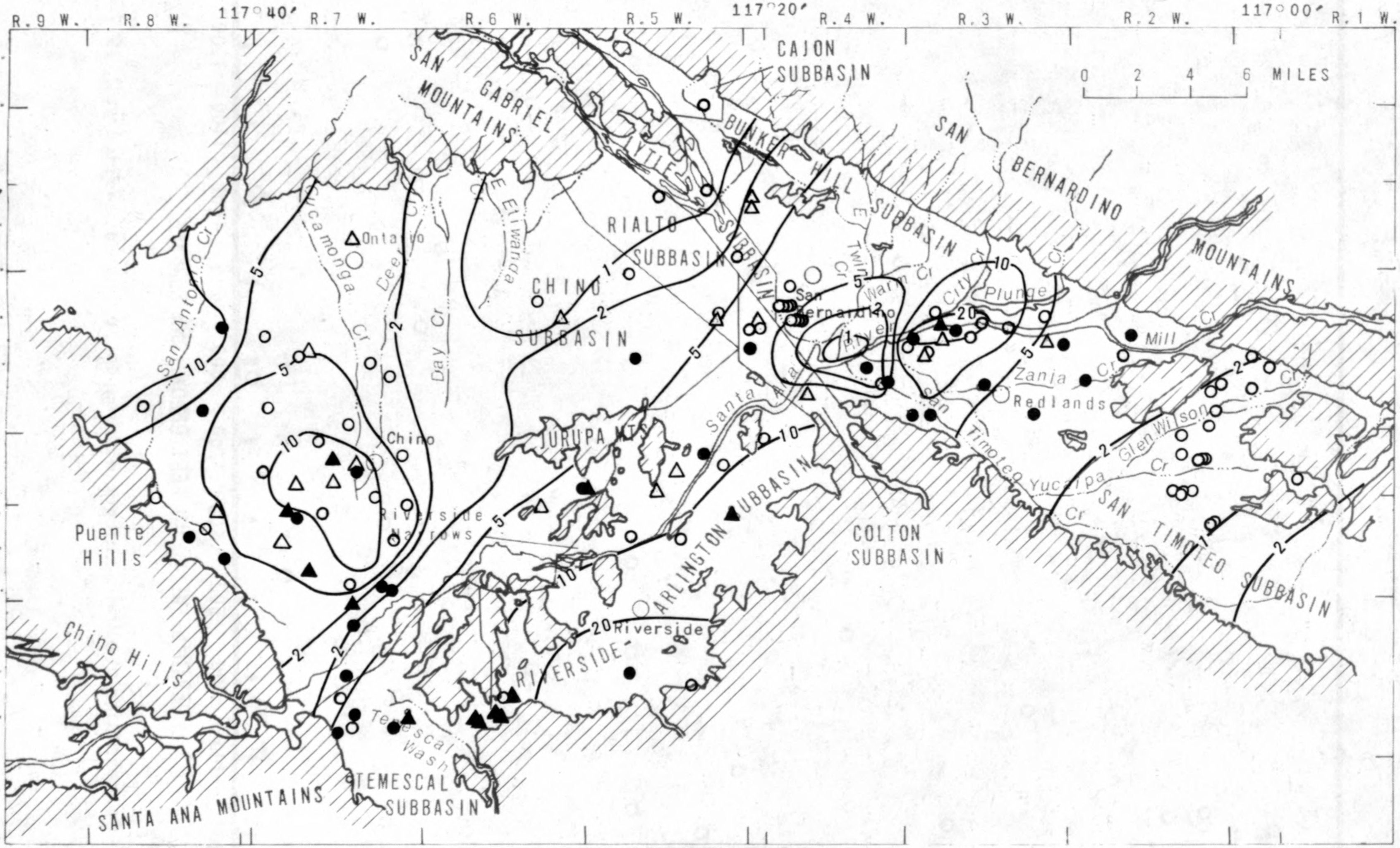
Dairy wastes contain high concentrations of nitrogenous compounds. These wastes receive minimal treatment, if any, before they are disposed of by application to crops or directly to the ground.

Sewage effluents are nitrified to reduce the concentration of ammonia. The effluents are discharged to streams or dry stream channels. Conversion of ammonia to nitrate is desirable because high concentrations of ammonia are toxic to fish, and ammonia can generate additional hardness from soils under certain circumstances.

Figure 7 shows the relation that exists between nitrate-nitrogen concentration and total well depth. Wells used for figure 5 that had analyses for nitrate-nitrogen were included in figure 7. The Kearney Foundation study (1973) indicated that nitrate-nitrogen in ground water in the study area comes from surface sources. Studies by Eccles and Bradford (1977) and Eccles and Klein (1978), also indicated that the concentration of nitrate-nitrogen in ground water in other parts of the upper Santa Ana River basin and in the Redlands area decreased with depth.

The Riverside-Arlington, Bunker Hill, and Temescal subbasins historically have had the most citrus crops that in the past had heavy applications of nitrogen fertilizer. Most of the wells sampled in 1977-78 that had nitrate-nitrogen concentrations exceeding 10 mg/L are in these subbasins.

The wells in the southern and southwestern Chino subbasin that yield water with nitrate-nitrogen concentrations exceeding 10 mg/L are generally either in the same areas as the dairies or near Cucamonga Creek. The city of Ontario discharges its treated sewage effluent to Cucamonga Creek upstream from the area where the nitrate-nitrogen concentrations exceeded 10 mg/L in the wells sampled in 1977-78. This area was more thoroughly investigated in the Kearney Foundation study (1973).



EXPLANATION

NON-WATER-BEARING ROCK

— 2 — LINE OF EQUAL NITRATE-NITROGEN CONCENTRATION, 1968-69--Interval variable, in milligrams per liter (Modified from Water Resources Engineers, Inc., 1970)

NITRATE-NITROGEN CONCENTRATION IN WATER FROM WELL, 1977-78--In milligrams per liter

○ 0.0-4.9
△ 5.0-9.9
● 10-19
▲ 20 +

FIGURE 6.--Areal distribution of nitrate-nitrogen in ground water, 1968-69 and 1977-78.

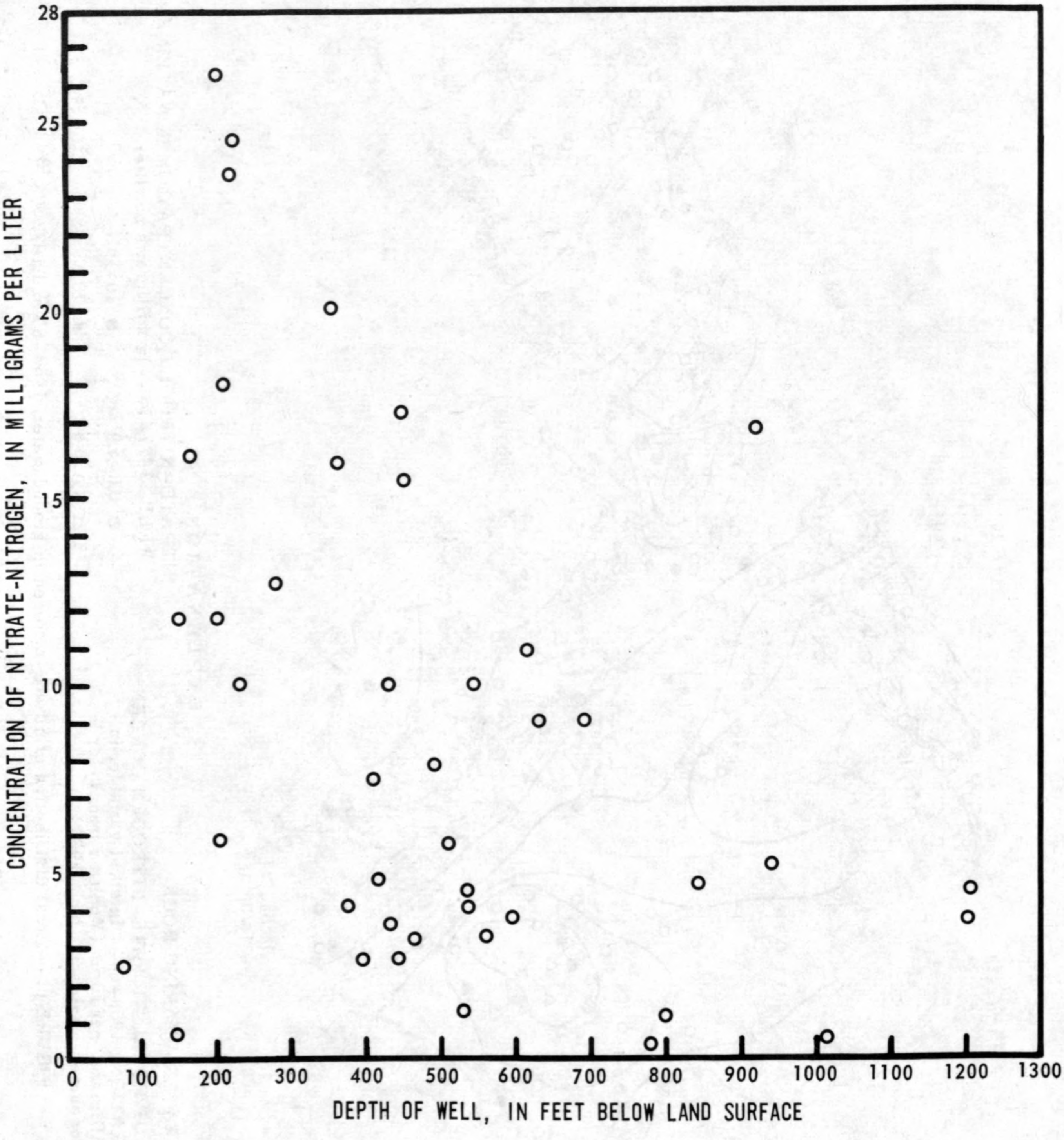


FIGURE 7.—Concentration of nitrate-nitrogen with respect to depth of sampled well, 1977–78.

Comparison of Nitrate-Nitrogen, 1968-69 and 1977-78

The distribution of nitrate-nitrogen in ground water for 1968-69 is shown by contours, as modified from Water Resources Engineers, Inc. (1970), in figure 6.

As previously mentioned, the 1977-78 sampling network was different from the 1968-69 sampling network. Because of the relation of nitrate-nitrogen concentrations to well depth, data from the two sampling networks could yield different interpretations for the areal distribution. Figure 6 shows, in general, that the concentration of nitrate-nitrogen in ground water in the study area has increased. The increases are mostly in the Riverside-Arlington, Temescal, southern and southwestern Chino, and eastern Bunker Hill subbasins.

The distribution of nitrate-nitrogen in ground water in parts of the Bunker Hill subbasin was investigated by Eccles and Bradford (1977), and Eccles, Klein, and Hardt (1976). These investigations showed that the concentration of nitrate in water from a particular well was related not only to depth but also to well construction.

An accurate assessment of the nitrate-nitrogen distribution in ground water in the upper Santa Ana River basin would require much more intensive study than was possible in this study. More quality data, and particularly more construction data and drillers' logs for wells sampled, would be necessary to better describe the nitrate-nitrogen distribution.

Chloride, Total Hardness (Calcium and Magnesium), and Boron, 1977-78 and Comparison between 1968-69 and 1977-78

Chloride, calcium, magnesium, and boron were among the constituents appraised. The distributions of these constituents are of general interest to water users in the study area and are published for 1968-69. The U.S. Environmental Protection Agency (1976) recommended limit for the concentration of chloride in domestic water supplies is 250 mg/L. Hardness, principally caused by calcium and magnesium dissolved in water, is usually reported as an equivalent concentration of calcium carbonate ($CaCO_3$) and is commonly called total hardness. Hardness affects soap requirements, hot-water heaters, and low-pressure boilers. In irrigation water, boron concentrations above 750 µg/L (micrograms per liter) may be harmful to some sensitive plants such as citrus (U.S. Environmental Protection Agency, 1976). The previously published 1968-69 areal distribution of these constituents (Water Resources Engineers, Inc., 1970) is included in this report.

The 1968-69 and 1977-78 areal distributions of chloride, total hardness, and boron in ground water are shown in figures 8, 9, and 10. Wells producing water with the highest concentrations of these three constituents are in the Riverside-Arlington subbasin, the Temescal subbasin, and the southern part of the Chino subbasin. The areas of highest chloride and total hardness concentrations are generally the same areas that have the highest concentration of dissolved solids. Concentrations of chloride ranged from 5 to 359 mg/L, concentrations of calcium ranged from 7.5 to 240 mg/L, and concentrations of magnesium ranged from 1 to 82 mg/L (table 1).

During the 1977-78 sampling, only three wells had chloride concentrations exceeding the 250 mg/L U.S. Environmental Protection Agency recommended limit. These wells are in the Temescal and extreme southern Chino subbasins. Only two wells sampled during 1977-78 had reported boron concentrations exceeding 750 μg/L. These wells are in the Temescal subbasin. Concentrations of boron ranged from undetectable (less than 100 μg/L) to 800 μg/L.

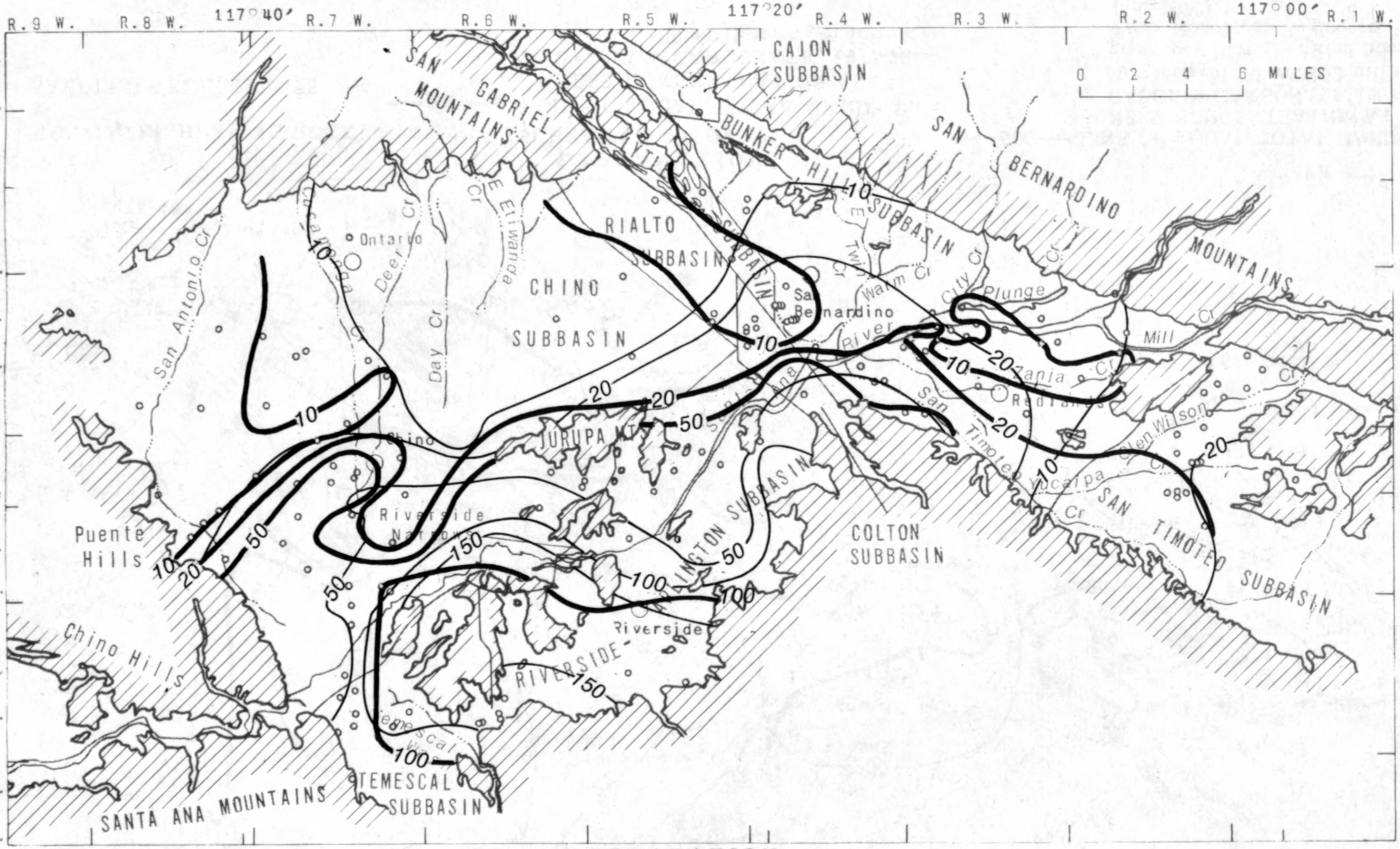
Comparisons of the 1968-69 and 1977-78 distributions of chloride and total hardness show the same trend of change that occurred with dissolved solids; the concentrations decreased but were spread out over a larger area. The boron data available from the 1977-78 sampling were too sparse to permit a comparison.

Sodium and Sulfate, 1977-78

The 1977-78 areal distributions for sodium and sulfate are shown in figures 11 and 12, respectively. The distributions show the same trend as dissolved solids. The highest concentrations of both sodium and sulfate are found in the southern part of the Chino subbasin, in the Temescal subbasin, and in the Riverside-Arlington subbasin.

The U.S. Environmental Protection Agency (1976) recommended limit of 250 mg/L for sulfate in public water supplies was exceeded in samples from five wells. Basin ground-water objectives call for sulfate concentrations lower than the U.S. Environmental Protection Agency recommended limit.

The 1968-69 distributions for sodium and sulfate were not available; therefore, no comparisons of the 1968-69 and 1977-78 distributions could be made.



EXPLANATION

NON-WATER-BEARING ROCK

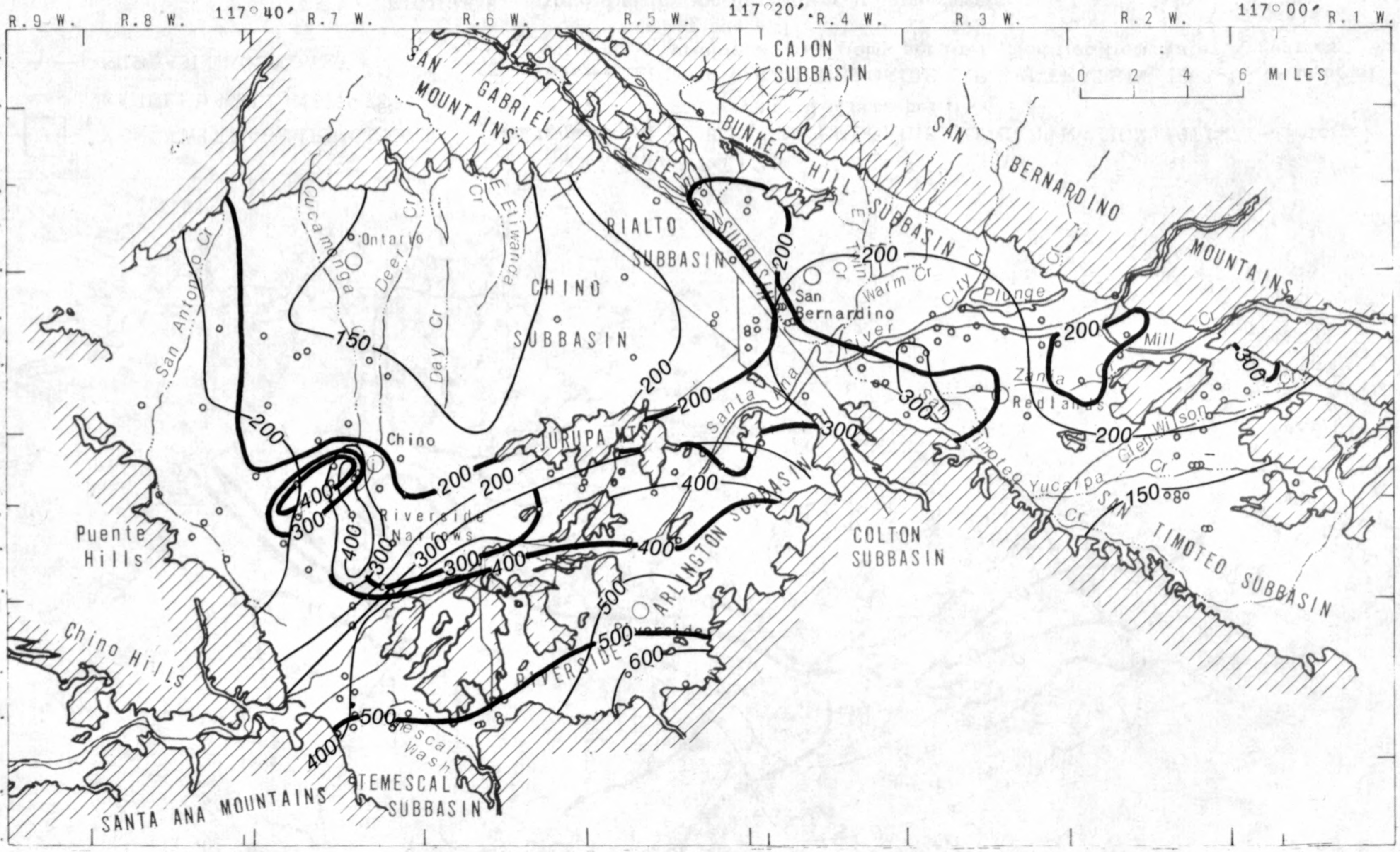
SAMPLED WELL, 1977-78

SUBBASIN BOUNDARY

—100— LINE OF EQUAL CHLORIDE CONCENTRATION, 1977–78 -- Interval variable, in milligrams per liter

—150— LINE OF EQUAL CHLORIDE CONCENTRATION, 1968–69 -- Interval variable, in milligrams per liter (Modified from Water Resources Engineers, Inc., 1970)

FIGURE 8.--Areal distribution of chloride in ground water.



EXPLANATION

NON-WATER-BEARING ROCK

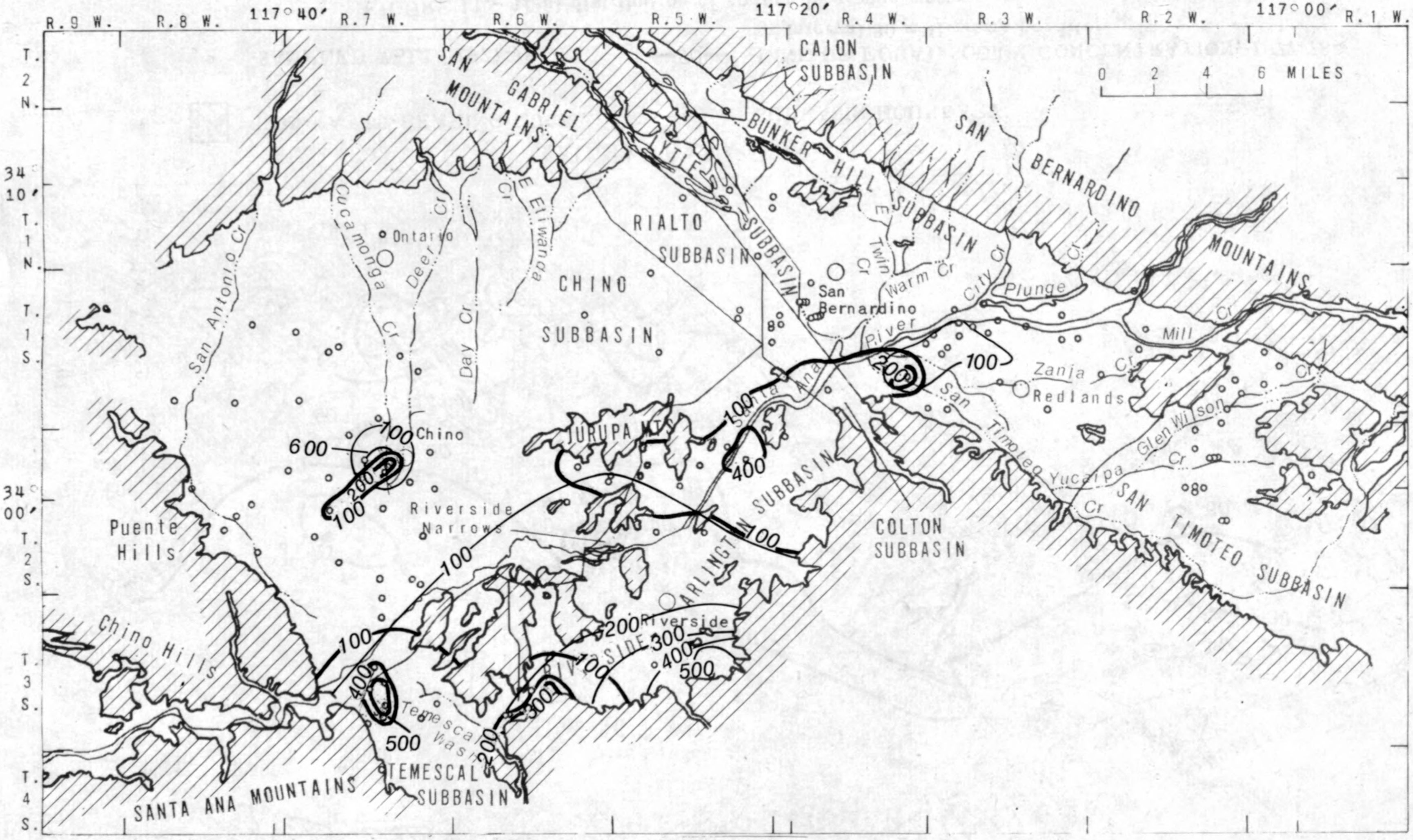
SAMPLED WELL, 1977-78

SUBBASIN BOUNDARY

500 — LINE OF EQUAL TOTAL HARDNESS CONCENTRATION AS CALCIUM CARBONATE, 1977-78--Interval 100 milligrams per liter

600 — LINE OF EQUAL TOTAL HARDNESS CONCENTRATION AS CALCIUM CARBONATE, 1968-69 -- Interval 50 and 100 milligrams per liter (Modified from Water Resources Engineers, Inc., 1970)

FIGURE 9.--Areal distribution of total hardness in ground water.



EXPLANATION

NON-WATER-BEARING ROCK

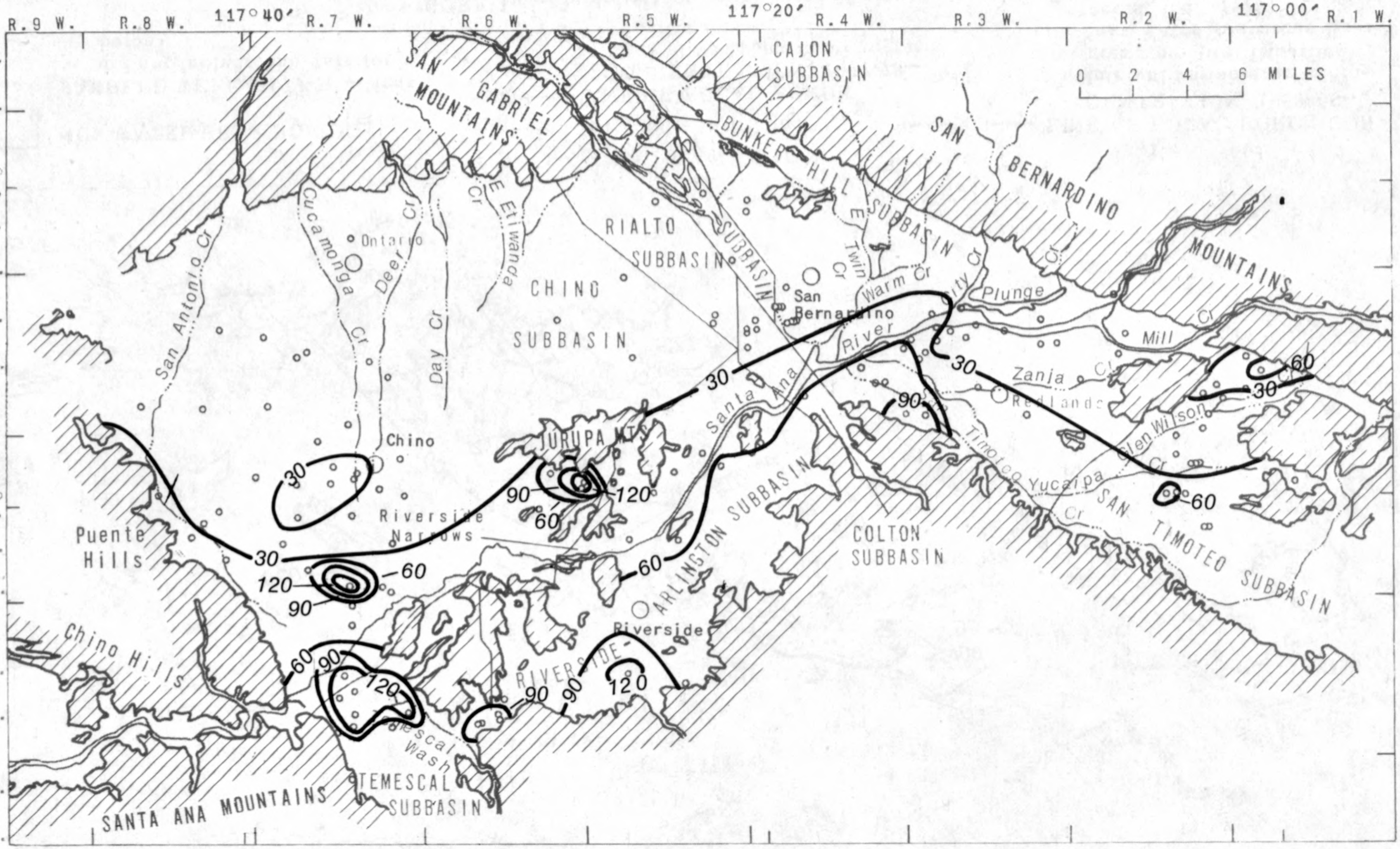
SUBBASIN BOUNDARY

—500— LINE OF EQUAL BORON CONCENTRATION, 1968-69--Interval variable, in micrograms per liter (Modified from Water Resources Engineers, Inc., 1970)

o SAMPLED WELL, 1977-78--(Many did not include analysis for boron)

—300— LINE OF EQUAL BORON CONCENTRATION, 1977-78--Interval variable, in micrograms per liter

FIGURE 10.--Areal distribution of boron in ground water.



EXPLANATION

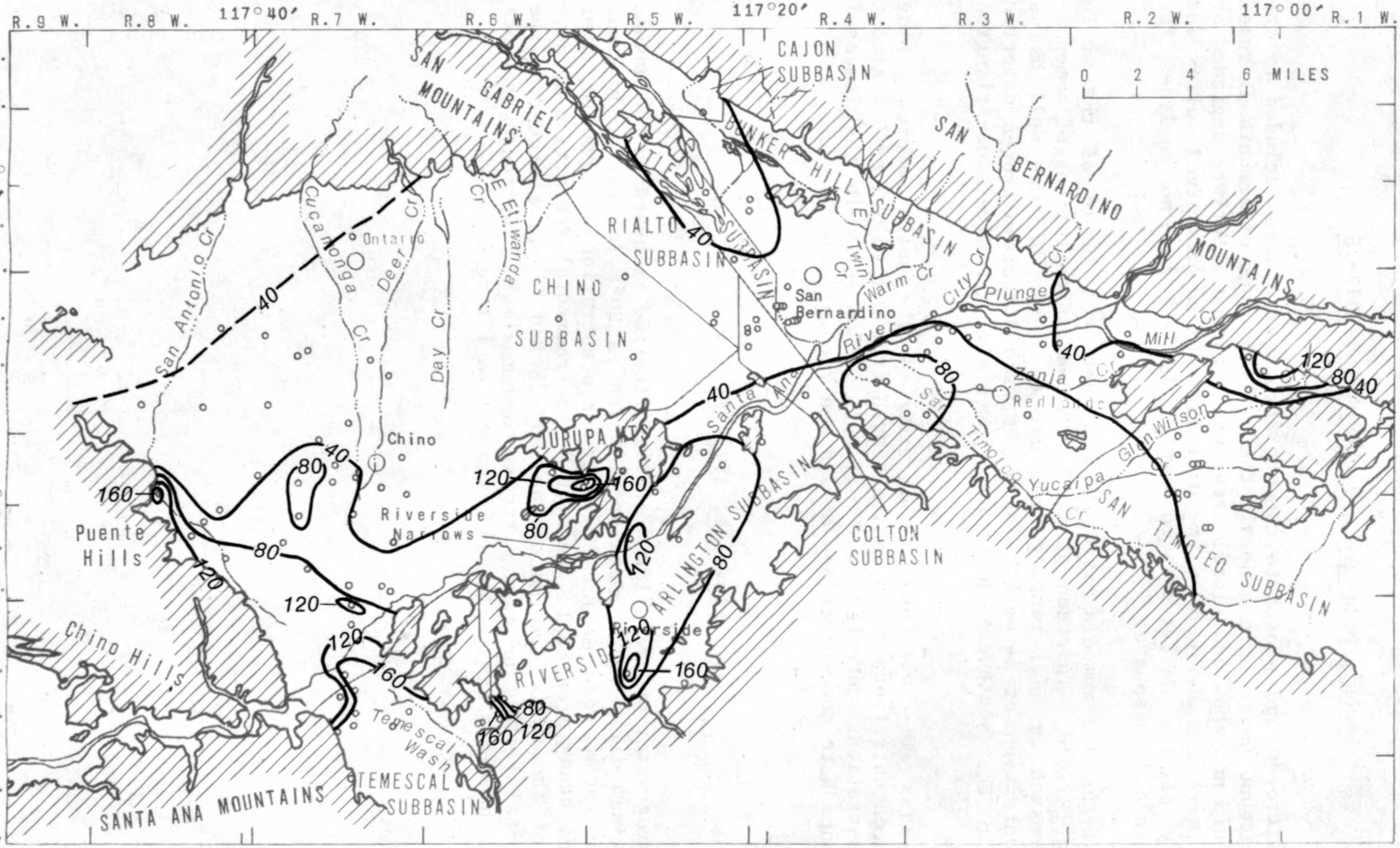
NON-WATER-BEARING ROCK

SUBBASIN BOUNDARY

SAMPLED WELL, 1977-78

—90— LINE OF EQUAL SODIUM CONCENTRATION, 1977-78--
Interval 30 milligrams per liter

FIGURE 11.--Areal distribution of sodium in ground water.



EXPLANATION

NON-WATER-BEARING ROCK

SUBBASIN BOUNDARY

SAMPLED WELL, 1977-78

—40— — LINE OF EQUAL SULFATE CONCENTRATION, 1977-78--
Dashed where doubtful. Interval 40 milligrams per liter

FIGURE 12.--Areal distribution of sulfate in ground water.

Ammonia-Nitrogen and Phosphate, 1977-78

Ammonia-nitrogen and phosphate concentrations were also included in the appraisal of ground water. In general, the distributions of ammonia-nitrogen and phosphate did not show additional areas where ground water was degraded or polluted that were not defined in the distributions of dissolved solids and nitrate. Many of the wells sampled during 1977-78 had no analyses for ammonia-nitrogen and phosphate.

Concentrations of ammonia-nitrogen were detected in 14 of the wells sampled during 1977-78. Thirteen of the wells had concentrations of ammonia-nitrogen (expressed as NH_4) ranging from 0.1 to 1.0 mg/L. One well had a reported concentration of 44 mg/L. The wells with ammonia-nitrogen detected are located in the southwestern Chino, Temescal, and Riverside-Arlington subbasins (fig. 13).

Phosphate (as PO_4) was detected in many of the wells sampled during 1977-78. The concentrations of phosphate ranged from 0.1 to 0.2 mg/L. Almost all the concentrations detected were 0.1 mg/L. Two wells in the Temescal subbasin had phosphate concentrations of 2.8 and 7.6 mg/L.

Fluoride, 1977-78

The drinking water standard for dissolved fluoride is based on the annual average of maximum daily air temperatures, which is 80°F for the study area. Therefore, the recommended maximum fluoride concentration for public water supplies in the study area is 1.4 mg/L (U.S. Environmental Protection Agency, 1977). None of the wells sampled during 1977-78 had fluoride exceeding the U.S. Environmental Protection Agency recommended maximum. The concentrations of fluoride in the wells sampled ranged from 0.1 to 1.1 mg/L.

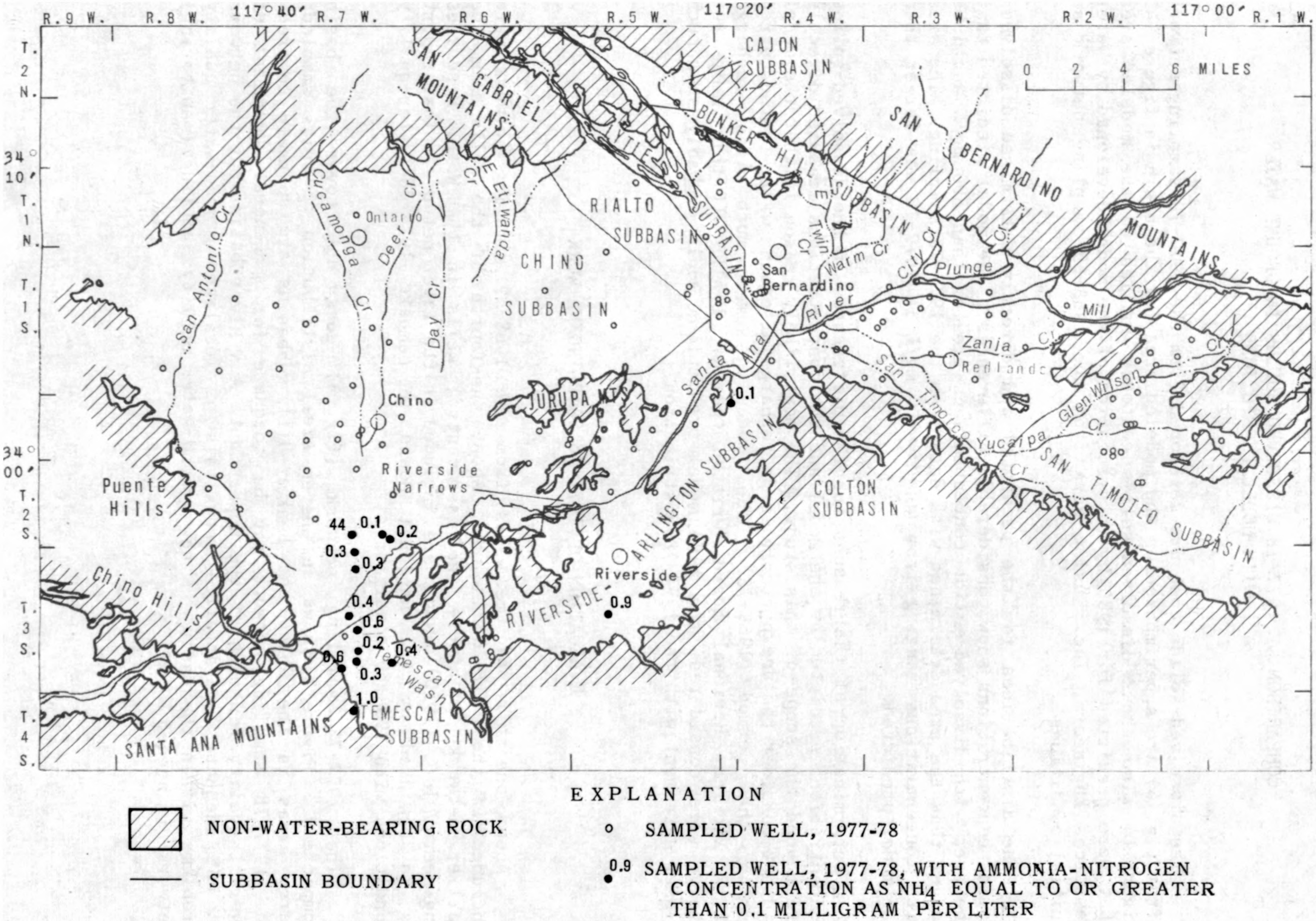


FIGURE 13.--Areal distribution of ammonia-nitrogen in ground water.

COMPARISON OF 1977-78 DISSOLVED SOLIDS IN GROUND WATER WITH MODEL PREDICTIONS

The dissolved-solids contours developed from the 1977-78 sampling network (from fig. 4) are superimposed on the modeled area for the basin in figure 14. Figure 14 also shows dissolved-solids contours applied to the modeled area that were predicted for 1980 by interrogation of the model developed by Water Resources Engineers, Inc., using data from the 1968-69 sampling network as initial conditions.

The distributions for the predicted and directly determined dissolved-solids concentrations show considerable differences. The model predicted that the area with dissolved-solids concentrations greater than 800 mg/L would be larger than the area determined with data from the 1977-78 sampling. The area with concentrations ranging from 400 to 800 mg/L in 1977-78 was larger than the model predicted.

Determination of the reasons for the differences in the dissolved-solids concentrations predicted by the model and the concentrations measured directly are beyond the scope of this study. The most likely reason is that the model did not consider the unexpectedly large recharge of ground water that occurred during the period 1969-78. The model assumed much less recharge (R. R. Nicklen, Regional Board, written commun., 1979). If this large recharge were considered, the 1980 model predictions would probably show much closer agreement with the 1977-78 distribution.

EVALUATION OF 1977-78 SAMPLING NETWORK

About one-third of the wells from the 1968-69 sampling network were included in the 1977-78 network. About one-fourth of the wells from the earlier network that were used as control wells in the Water Resources Engineers, Inc. (1970) report are included in the later network. That report is to be used by the Regional Board to compare 1977-78 water-quality conditions with 1968-69 conditions.

The 1977-78 sampling network (fig. 3) does not cover the basin completely. Figure 3 shows an uneven areal distribution of wells sampled. Large areas in the Chino and Bunker Hill subbasins are sparsely covered. The 1977-78 sampling network may be adequate for a general appraisal of overall quality for much of the upper Santa Ana River basin, but the network is not adequate for detailed appraisals of localized ground-water quality problems within the basin. A new ground-water quality sampling (monitoring) network is needed.

For adequate interpretation of water-quality data, drillers' logs and construction data should be available for the wells used in a sampling network. Few wells in the 1977-78 sampling network have these necessary data available. As many wells as possible from the 1968-69 and 1977-78 sampling networks should be included in a new network. The wells sampled in 1968-69 are listed in table 2. Table 2 also lists the resampled wells that had driller's logs available and the wells used as "control wells" in the 1970 Water Resources Engineers, Inc., study. The wells that were sampled in 1968-69, sampled again in 1977-78, that have drillers' logs available, and were used as control wells in the 1970 study would be the most important wells to include in a new sampling network. The wells that were sampled in 1977-78 and have drillers' logs and construction data available are shown in figure 15. These wells should be included in a new sampling network.

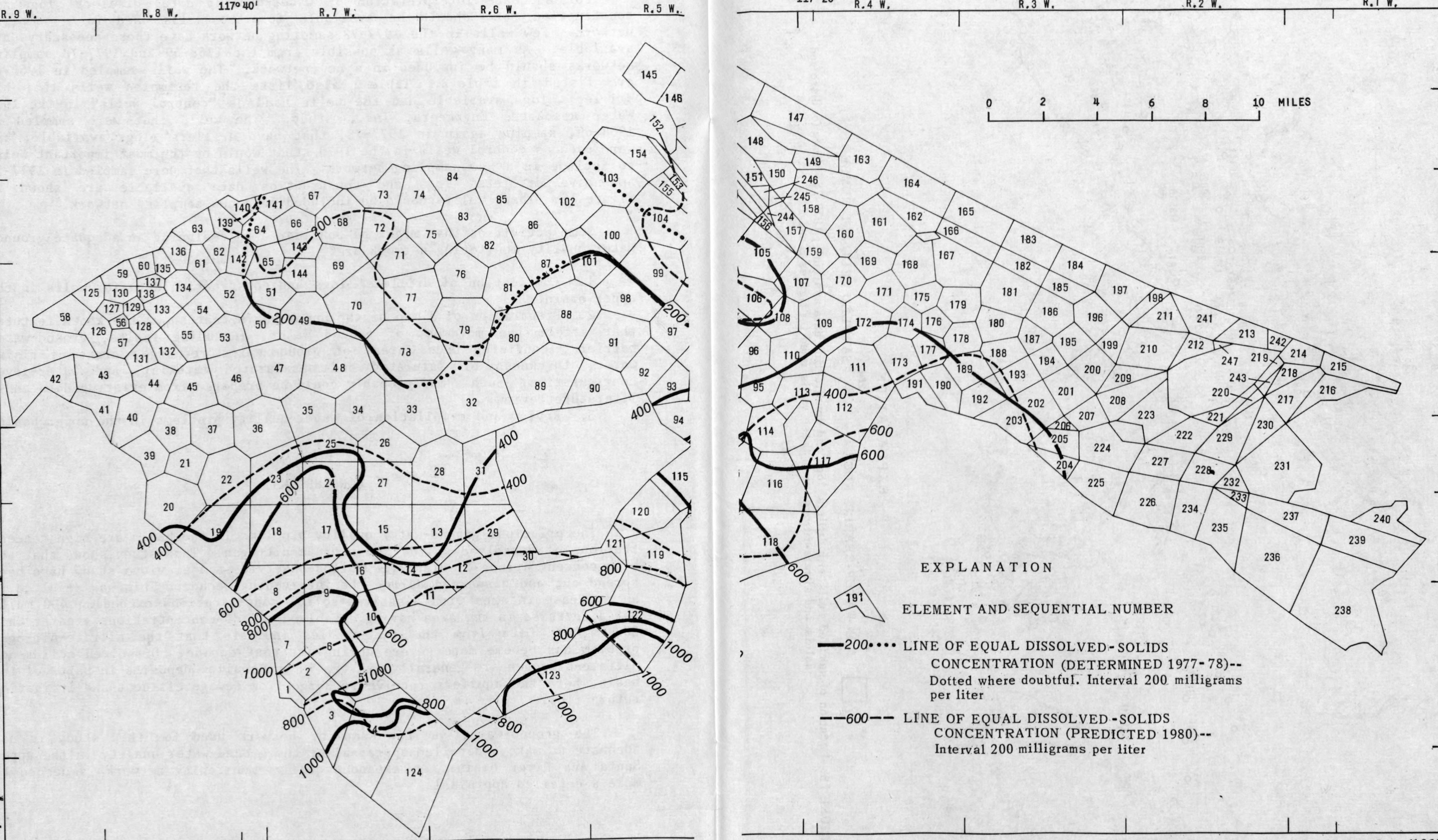
Some activities that might be considered in designing an adequate ground-water quality monitoring network are:

1. Compilation of drillers' logs and construction data for wells in the upper basin.
2. Preparation of a map of the upper basin that shows the known features that affect the movement of ground water, including faults, ground-water barriers, confining beds, areas of ground-water recharge, areas of rising water, thickness of saturated and unsaturated material, and water-level configuration. Such a map probably could be prepared from existing data and a literature review.
3. Review and compilation of water-quality problems in the upper basin.

CONCLUSIONS

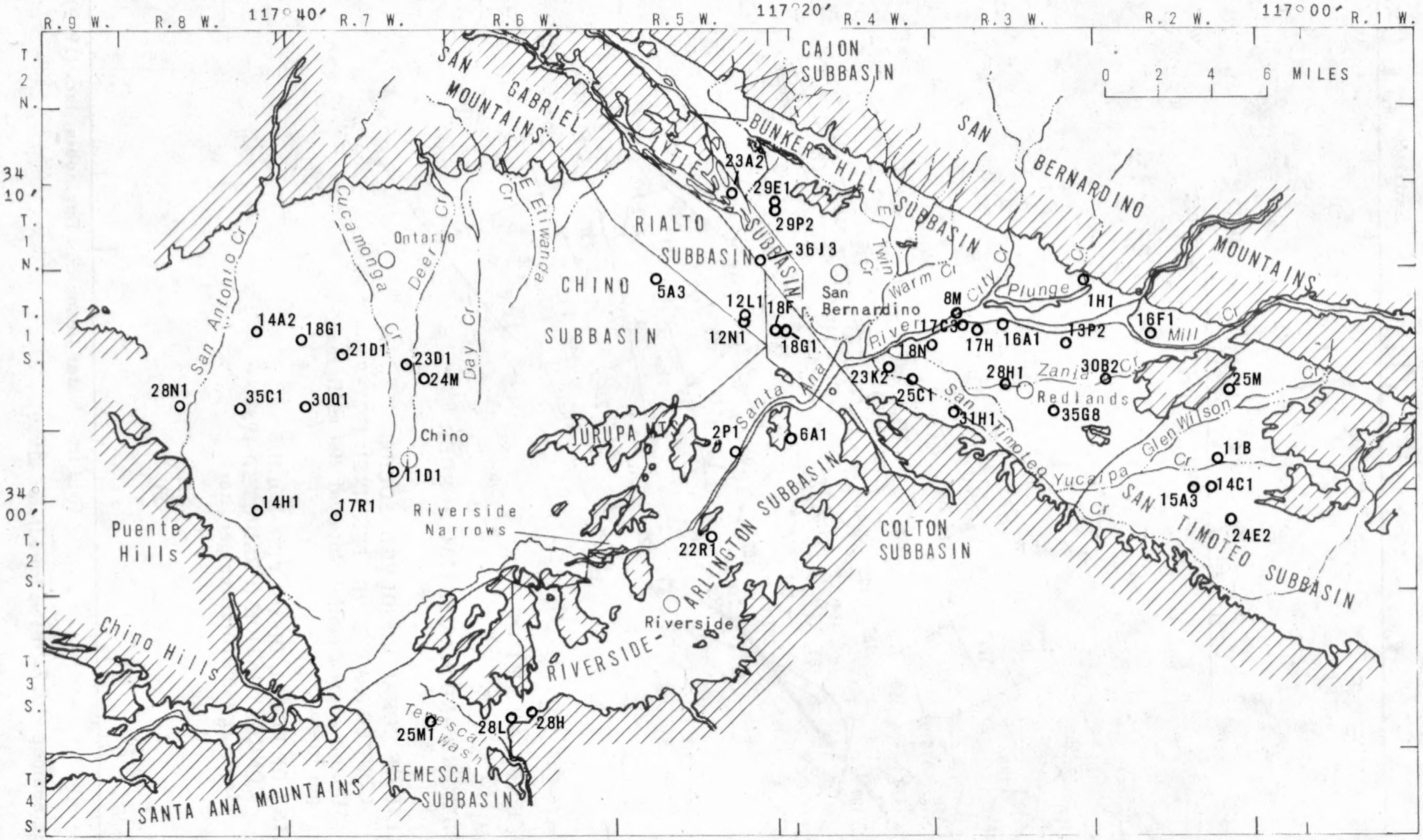
The principal ground-water quality problems in the basin are high concentrations of dissolved solids and nitrate-nitrogen. This study shows that the high concentrations of dissolved solids observed in a previous study have been spread out and dispersed during the intervening decade. This has resulted in an increase in area with dissolved-solids concentrations exceeding 400 mg/L, but a decrease in the area having dissolved-solids concentrations greater than 800 mg/L. Data from the two studies indicate that the nitrate-nitrogen problem has become more severe during the past decade. Dissolved solids and nitrate-nitrogen are generally greater in the shallow deposits in parts of the basin where the aquifers receive recharge from sewage effluent and irrigation return flow.

The ground-water quality sampling network used for this study is not adequate to make a detailed appraisal of the ground-water quality in the upper Santa Ana River basin. An expanded quality-monitoring network is needed to make a detailed appraisal.



Grid from Water Resources Engineers, Inc. (1969)

FIGURE 14.--Areal distribution of dissolved solids in ground water in modeled area, determined (1977-78) and predicted (1980).



EXPLANATION

NON-WATER-BEARING ROCK

28H
SAMPLED WELL AND NUMBER

FIGURE 15.--Location of sampled wells with drillers' logs and construction data available, 1977-78. (Data for dissolved solids and nitrate-nitrogen from these wells used for figures 5 and 7.)

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TABLES

TABLE 1. - Chemical analyses

[Concentrations in milligrams per liter except iron and boron in micrograms per
Edward S. Babcock and Sons, Inc.,

State well number and recordation number	Date of sample	Depth to bottom of sample interval (feet)	Depth to top of sample interval (feet)	Specific conductance	pH	Hardness as calcium carbonate	Calcium	Magnesium	Sodium	Potassium	Bicarbonate
1N/4W-29E1 (3601878)	2-27-78	429		590	7.6	260	82	13	13	4	210
1N/4W-29P2	2-27-78	410	197	570	7.6	250	80	12	16	4	220
1N/5W-2A1	2-28-78			510	7.6	200	58	12	28	3	220
1N/5W-22F1 (3600580)	2-28-78			390	7.8	150	50	6	8	2	160
1N/5W-23A2 (3601500)	2-28-78	433	240	570	7.7	240	74	14	17	4	230
1N/5W-36J3 (3600996)	2-28-78	629	250	390	7.7	180	57	8	8	3	190
1N/7W-27R1 (3600549)	6- -77					160	37	17	27		180
1S/1W-19B2 (3602659)	5-16-77			890	7.4	400	89	22	60		
1S/1W-20M1 (3602662)	5-17-77			890	7.8	320	93	10	80		
1S/1W-30D00 (3601821)	5-17-77			600	7.6	200	59	11	26		
1S/2W-16F1 (3600266)	7-26-77	147	90	630	7.7	300	100	11	11	3	400
1S/2W-21E1	7-26-77			400	7.6	180	55	10	11	5	390
(3601284)	3-21-78			360	7.7	160	50	8	10	4	170
1S/2W-25G00 (3601105)	5-17-77			590	7.7	170	49	10	56		
1S/2W-25M00 (3601857)	5-18-77	506		470	7.8	140	41	8.8	42		
1S/2W-25R00 (3602321)	5-26-77			500	7.9	180	52	12	26		
1S/2W-30B2 (3601642)		228	120	530	7.6	220	65	14	22	2	230
1S/2W-36F00 (3602128)	5-17-77			460	7.7	180	52	13	17		
1S/2W-36N00 (3601853)				480	7.8	180	51	12	27		
1S/3W-1H1 (3600220)	7-26-77	414	250	450	7.1	170	50	12	24	3	390
1S/3W-8M1	5-27-77	148	78	280	7.7	61	21	2	36	3	130
1S/3W-9E2 (3601420)	5-27-77			250	7.4	120	34	7	13	3	120
1S/3W-12F00				310	7.7	130	41	7	14	2	140
1S/3W-13P2	7-26-77	488	265	430	7.7	190	51	15	11	5	410
(3602224)	3-21-78			430	7.8	180	59	8	11	4	190
1S/3W-13R00 (3602112)				470	7.6	210	70	8	17	3	180
1S/3W-15A1 (3602127)	3-21-78			260	7.8	98	30	6	11	3	120
1S/3W-16A1 (3600527)	5-27-77	395	105	310	7.4	110	37	5	21	2	140

[1]Analyses for additional chemical constituents are on file with the California Regional Water Quality Control Board, Santa Ana Region.

of water samples[1]

liter. Concentrations of boron less than 100 micrograms per liter are reported as 0. Analyses by Riverside, Calif.]

Carbonate	Sulfate	Chloride	Fluoride	Silica	Dissolved solids (residue at 180°C)	Nitrate-nitrogen as N	Ammonia-nitrogen as NH_4	Phos-phate	Boron	Iron
0	54	16		20	360	10	0.0	0.0	0	3,000
0	56	12		19	360	7.5	.0	.0	0	900
0	52	14		35	315	1.8	.0	.2	0	180
0	27	5		22	210	1.6	.0	.1	0	
0	69	11		18	340	3.6	.0	.0	0	20
0	28	5		20	225	9	.0	.1	0	0
	42	12	0.4		279	9.8			0	
	110	26	1.1		531	.4				800
	140	15	.7		588	.9				80
	54	18	.6		372	1.8				20
0	56	16	.6	19	380	12			0	
0	29	9	.6		205	27			0	
0	22	5			220	2.5	.0	.0	0	
	59	14	.7		354	1.8				80
	31	21	.7		276	1.4				30
	24	13	.5		294	1.4				60
0	39	7		30	350	10	.0	.2	0	80
	34	12	.6		285	2				30
	31	14	0.6		291	3.2				30
0	40	16	1.1		250	4.8			100	
0	21	11			150	.68	.0	.0	0	50
0	17	9			145	2.9	.0	.1	0	50
0	20	11		17	280	2.9	.0	.0	0	60
0	28	9	.7		245	7.9			0	
0	29	5		10	285	6.8	.0	.1	0	320
0	46	14		20	375	12	.0	.0	0	
0	16	7		15	170	1.6	.0	.1	0	160
0	24	12		25	205	2.7	.0	.0	0	50

TABLE 1. - Chemical analyses

State well number and recordation number	Date of sample	Depth to bottom of sample interval (feet)	Depth to top of sample interval (feet)	Specific conductance	pH	Hardness as calcium carbonate	Calcium	Magnesium	Sodium	Potassium	Bicarbonate
1S/3W-16L00 (3602320)	5-27-77			260	7.4	110	35	6	12	2	130
1S/3W-17C3	5-27-77	225	105	1,030	7.5	460	160	17	42	6	380
1S/3W-17H1 (3600525)	5-27-77	209	79	570	7.6	260	88	8	21	3	190
1S/3W-17L1	6-16-77			660	7.4	280	96	11	23	4	200
(3600524)	3-21-78			400	7.9	160	53	6	12	3	160
1S/3W-18L1 (361750)	5-27-77			630	7.4	280	90	12	22	3	210
1S/3W-18N3 (3601014)	5-27-77	195	145	310	7.7	51	19	1	65	3	140
1S/3W-19A1 (3601748)	5-27-77			400	7.7	110	39	4	43	3	170
1S/3W-19G2	6-20-77			550	7.6	190	66	6	31	4	190
1S/3W-28H1 (3601301)	7-26-77	442	105	630	7.6	210	68	10	43	5	220
1S/3W-31E1	3-21-78			1,000	8.0	320	84	25	92	7	350
1S/3W-31H1 (3600053)	7-26-77	354		1,050	7.7	320	84	28	92	5	400
1S/3W-35G8 (3601291)	3-21-78	546		550	7.8	190	57	12	32	5	210
1S/4W-5R00 (3601252)	9-28-76			390	7.7	180	54	11	14	2.0	220
1S/4W-8F1 (3601254)	9-28-76			490	7.7	240	76	12	14	2.1	220
1S/4W-8F2 (3601257)	9-20-76			450	7.6	220	70	12	13	1.9	220
1S/4W-8F3 (3602405)	9-20-76			390	7.7	190	57	12	12	1.9	200
1S/4W-8R1 (3601250)	9-21-76			370	7.8	190	57	11	12	1.8	220
1S/4W-8R2 (3601251)				350	8.0	180	47	15	16	2.1	220
1S/4W-8R3 (3601253)	9-28-76			460	7.6	230	71	12	14	2.2	230
1S/4W-8R4 (3601258)	9-28-76			350	7.7	160	46	9.6	20	2.1	220
1S/4W-18B00 (3601255)	9-28-76			450	7.7	200	65	8.8	15	1.4	180
1S/4W-18F00 (3601261)	9-28-76			310	7.8	120	33	8.4	18	.8	170
1S/4W-18F1 (3601260)	9-28-76	778	194	415	7.7	210	65	11	14	1.9	220
1S/4W-18G1 (3601259)	9-28-76	534	244	365	7.8	160	47	9.6	15	1.1	170
1S/4W-18N1	3-31-78			450	7.8	200	69	6	12	4	180
1S/4W-23K2 (3600790)	7-26-77	279	84	930	7.6	320	90	23	69	4	410
1S/4W-25C1	7-26-77	200	100	970	7.4	360	94	31	77	5	380
(3602012)	3-21-78	200	100	990	7.7	360	98	28	73	6	380
1S/4W-25D00	3-21-78			440	8.1	34	12	1	75	4	120
1S/4W-28L2	2-28-78			830	7.5	240	78	12	71	6	280
1S/5W-5A3	7-17-76	842		360	7.6	150	45	8.4	15	1.2	180
1S/5W-12L1	3-31-78	590		360	7.9	150	52	5	11	3	170

of water samples--Continued

Carbonate	Sulfate	Chloride	Fluoride	Silica	Dissolved solids (residue at 180°C)	Nitrate-nitrogen as N	Ammonia-nitrogen as NH_4	Phos-phate	Boron	Iron
0	18	9		22	155	1.1	0.0	0.0	0	560
0	100	34		17	730	24	.0	.0	0	180
0	63	14		23	395	18	.0	.0	0	300
0	84	18		25	470	18			700	0
0	26	7		18	270	7.7	.0	.1	0	100
0	63	16		20	430	19	.0	.0	0	50
0	41	28		15	230	.45	.0	.0	0	
0	41	18		18	225	2.7	.0	.0	0	110
0	46	23	1.0	25	335	9.5			0	
0	52	18	.7	22	360	17			0	
0	100	53		13	625	14	.0	.1	0	500
0	100	55	.6	20	615	20			0	
0	42	12		17	345	10	.0	.1	0	40
0	22	8.5	.4		176	.02				780
0	61	12			318	.45				660
0	45	10			296	.25				720
0	30	6			253	.25				910
0	19	10			255	.02				780
0	22	65			253	.04				310
0	50	11	0		309	0				720
0	10	10	.6		243	.59			0	720
0	33	12	.3		273	8.6				660
0	9.5	7			192	.79				660
0	32	9			277	.38				660
0	20	6	.4		228	4.5				720
0	29	11		25	285	10	.0	.1	0	
0	100	44	.7	19	520	13			100	
0	100	48	.7	20	610	13			300	
0	110	44		15	620	12	.0	.1	200	70
6	40	36		10	255	.68			200	490
0	76	59		22	465	5.9	.0	.1	100	20
0	8.5	12	.4		222	4.7	.0	.1	0	160
0	18	7			210	3.8			0	80

TABLE 1. - Chemical analyses

State well number and recordation number	Date of sample	Depth to bottom of sample interval (feet)	Depth to top of sample interval (feet)	Specific conductance	pH	Hardness as calcium carbonate	Calcium	Magnesium	Sodium	Potassium	Bicarbonate
1S/5W-12N1	3-31-78	688		450	7.6	200	67	7	12	3	180
1S/5W-21D1	3-31-78			490	7.7	200	68	7	19	4	190
1S/6W-12P1 (3600572)	3-16-76			415	7.7	150	48	8.4	22	1.1	180
1S/7W-18G1 (3601777)	6- -77	1,204		370	7.5	150	45	9	17	3	180
1S/7W-20A1 (3600375)	6- -77			350	7.5	120	39	6	22	2	150
1S/7W-21D1 (3601772)	6- -77	940		480	7.4	150	42	12	18	2	170
1S/7W-23D1 (3601065)	6- -77	507		390	7.9	160	51	8	20	2	200
1S/7W-24M00 (3602457)	6- -77	1,012		320	7.7	130	39	7	17	3	180
1S/7W-30Q1 (3601773)	6- -77	507		380	7.6	160	49	10	16	2	190
1S/7W-34K1	7-13-77			375	8.2	180	51	13	16	1.5	210
1S/8W-14A2 (3601357)	7-19-77	920		505	7.5	210	60	15	20	8	180
1S/8W-28N1 (1901722)	5-17-77	560	324	445	7.6	230	71	13	14	1.9	180
1S/8W-35C1 (3601617)	1-11-77	453	322	595	8.1	230	72	13	12	.9	190
2S/1W-9G1 (3602655)	5- -78			500	7.8	100	30	8	55		
2S/2W-2D00 (3601997)	5- -78			490	7.8	180	52	11	30		
2S/2W-2N00 (3601852)	5- -78			480	7.9	180	51	9.4	27		
2S/2W-11B1 (3601850)	5- -78	464		450	7.7	140	42	9.2	28		
2S/2W-11B2 (3601998)	5- -78			450	7.9	150	45	9.0	29		
2S/2W-11B3 (3602322)	5- -78			415	7.9	120	36	8.4	31		
2S/2W-14C1	3-31-78	443	205	560	7.6	180	51	12	48	3	240
2S/2W-14D1	3-31-77			550	7.7	190	54	13	40	3	260
2S/2W-14E00	3-31-78			490	8.2	150	41	11	42	3	210
2S/2W-15A3	3-31-78	1,202		650	7.8	160	47	11	73	4	240
2S/2W-24E2 (3602661)	5- -78	800	168	445	8.1	120	29	10	42		
2S/2W-24E3 (3602660)	5- -78			280	8.7	25	7.5	1.2	45		
2S/4W-6A1	4-03-78	372		840	7.4	300	100	12	56	7	310
2S/5W-2P1	4-03-78	100		940	7.7	340	120	8	57	5	260
2S/5W-7N1	2-01-78			1,840	7.6	610	230	10	140	9	480
2S/5W-7N2	2-10-78			1,730	7.5	620	230	10	110	8	360
2S/5W-10G3	2-10-78			940	7.5	340	130	6	52	7	250
2S/5W-12C1	2-10-78			810	7.4	240	92	4	69	8	260
2S/5W-16A3	2-01-78			870	7.7	320	130	2	58	7	300
2S/5W-20R1	2-01-78			870	7.7	360	140	2	42	5	270
2S/5W-22R1	2-02-77	72		680	7.8	280	100	7	28	4	210
2S/6W-12E1	2-01-78			920	7.6	330	130	2	69	5	320
2S/6W-14K1	2-01-78			860	7.6	300	110	4	60	9	260

of water samples--Continued

Carbonate	Sulfate	Chloride	Fluoride	Silica	Dissolved solids (residue at 180°C)	Nitrate-nitrogen as N	Ammonia-nitrogen as NH_4	Phosphate	Boron	Iron
0	31	11		25	285	9	0.0	0.1	0	140
0	23	20		25	290	11	.0	.1	0	560
0	14	15			243	6.8	.0	.0	0	60
0	13	9	0.3		225	4.5			0	20
0	26	11	.3		215	3.0			0	200
0	23	11	.4		205	5.2			0	20
0	13	14	.3		220	5.7			0	20
0	9	7	.2		190	.63			0	30
0	12	12	.2		255	4.1			0	
0	14	10	.1		256	4.3			0	
0	48	9	.4		321	16.8			100	100
0	16	38	.4	21	330	3.3				250
0	24	6	.5		301	15				30
	65	25	1.0		282	.9				20
	26	15	.6		297	4.1				30
	31	12	.6		279	.9				30
	26	25	.6		255	3.2				20
	22	18	.4		264	3.4				30
	19	20	.4		246	3.4				30
0	38	28		25	315	2.7	.0	.1	0	160
0	24	25		25	295	3.4	.0	.1	0	180
9	15	27		25	270	2.9	.0	.1	0	540
0	60	43		25	370	2.7	.0	.1	0	20
	12	28	.6		261	1.8				30
	14	14	.5		165	1.1				60
0	64	66		24	475	4.3	.1	.0	100	460
0	120	57		40	640	15	.0	.1	100	240
0	220	165		73	1,220	18	.0	.1	100	100
0	180	153		80	1,250	51	.0	.1	100	160
0	90	91		43	605	8.9	.0	.0	100	140
0	81	69		40	455	.9	.0	.1	400	190
0	85	69		53	575	7.0	.0	.1	200	1,500
0	140	50		38	585	2.7	.0	.1	0	160
0	100	39		38	450	2.5	.0	.0	0	100
0	87	80		68	610	3.2	.0	.2	400	80
0	87	71		43	565	7.9	.0	.1	0	15,000

TABLE 1. - Chemical analyses

State well number and recordation number	Date of sample	Depth to bottom of sample interval (feet)	Depth to top of sample interval (feet)	Specific conductance	pH	Hardness as calcium carbonate	Calcium	Magnesium	Sodium	Potassium	Bicarbonate
2S/7W-1P00	6-08-78			420	8.0	160	47	10	24	4	200
2S/7W-4B00 (3600616)	7-05-78			250	7.6	93	36	5	15	3	120
2S/7W-7H00 (36020604)	7-05-78			320	7.9	110	37	5	27	4	180
2S/7W-8J00 (3601399)	7-10-78			950	7.6	400	130	18	41	5	320
2S/7W-10D00 (3602096)	7-05-78			980	7.6	440	130	28	37	7	340
2S/7W-10M00 (3600127)	7-10-78			980	7.5	440	130	29	29	6	330
2S/7W-11D00 (3602118)	7-10-78			800	7.6	340	100	19	34	6	320
2S/7W-11D1	---77	363		827	8.1	410	120	29	33	2	340
2S/7W-13J00 (3601320)	7-10-78			360	7.7	140	48	4	19	4	180
2S/7W-14A1 (3602547)	7-10-78			330	7.8	140	46	6	15	3	170
2S/7W-15Q00 (3601064)	7-11-78			510	7.4	220	68	12	28	5	260
2S/7W-17L00 (3600325)	7-11-78			1,020	7.6	420	120	28	30	6	280
2S/7W-17R1	2-01-78	614		920	7.7	370	140	4	45	6	300
2S/7W-20L00 (3602505)	7-11-78			760	7.5	320	94	19	29	6	260
2S/7W-24P00	2-15-78			360	7.7	140	44	7	17	2	190
2S/7W-28N00 (3600557)	7-05-78			1,220	7.6	540	160	34	43	8	380
2S/7W-34K2	2-10-78			1,160	8.0	170	19	28	130	11	410
2S/7W-35J2	2-10-78			770	7.9	300	94	16	46	4	290
2S/7W-36M2	2-10-78			940	7.5	370	120	19	54	4	300
2S/8W-14H1	6-08-78	202		360	8.0	140	44	7	22	4	170
2S/8W-16B1 (3601824)	7-11-78			1,620	7.3	710	220	38	50	9	410
2S/8W-22J00	6-08-78			870	7.8	350	120	12	34	7	300
2S/8W-23C1 (3601911)	7-11-78			340	7.7	150	46	7	16	3	170
2S/8W-25M00	6-08-78			770	7.9	310	100	12	39	7	250
3S/5W-17K2	5-25-78			1,770	7.5	580	150	48	160	14	340
3S/5W-23D1	2-02-78			1,280	6.6	390	80	46	80	12	20
3S/6W-22L2	2-02-78			590	7.7	230	80	7	30	5	200
3S/6W-28H00	2-08-78			1,410	7.3	480	130	36	100	9	330
3S/6W-28H1	2-08-78	218	45	1,370	7.6	490	130	41	84	9	340
3S/6W-28L1	2-14-78	203	40	1,480	7.8	500	150	30	100	10	340
3S/6W-28L3	2-03-78			1,500	7.8	500	150	30	100	10	340
3S/7W-3A2	2-10-78			1,330	7.5	640	220	24	57	5	450
3S/7W-3R2	2-10-78			1,020	7.6	450	140	24	46	4	390
3S/7W-15Q3	2-22-78			2,040	7.4	630	240	10	170	11	350
3S/7W-22H1	2-22-78			1,710	7.6	410	140	13	180	19	350
3S/7W-22L1	2-22-78			3,090	8.3	290	92	14	140	40	1,060
3S/7W-25H00	2-24-78			2,350	7.2	760	220	50	180	13	490
3S/7W-25M1	2-22-78	167	93	1,440	7.5	510	170	19	84	6	300
3S/7W-27A1	2-10-78			1,040	7.4	480	130	34	46	4	500
3S/7W-27J00	2-09-78			2,130	7.3	770	240	41	150	12	500
3S/7W-27N1	2-09-78			1,460	7.7	580	160	43	69	5	320
4S/7W-3F1	2-24-78			1,780	7.6	760	170	82	62	5	350

of water samples--Continued

Carbonate	Sulfate	Chloride	Fluoride	Silica	Dissolved solids (residue at 180°C)	Nitrate-nitrogen as N	Ammonia-nitrogen as NH_4	Phos-phate	Boron	Iron
0	6	23	0.2	30	235	4.7	0.0	0.1	0	0
0	8	7	.4	30	155	3.9	.0	.2	0	20
0	17	7	.4	25	200	2.7	.0	.0	0	100
0	100	59	.4	11	680	7.7	.0	.0	0	40
0	58	78	.2	30	595	25	.0	.1	400	50
0	72	98	.2	13	795	7.7	.0	.1	100	120
0	56	59	.2	14	610	7	.0	.1	100	20
0	63	63	.2		564	16			180	
0	7	18	.2	12	240	1.4	.0	.1	0	260
0	7	18	.2	12	240	1.4	.0	.1	0	40
0	17	28	.1	12	345	2.7	.0	.0	0	200
0	54	60	.2	11	750	32	.0	.0	0	980
0	94	64		43	605	11	.0	.0	100	0
0	64	52	.2	11	505	6.1	.0	.0	0	260
0	8	11		29	260	2.3	.0	.1	0	0
0	120	69	.2	25	680	31.8	.0	.1	0	80
0	10	176		15	735	.45	34	.0	0	28,000
0	46	57		30	445	11	.1	.2	0	220
0	47	101		27	545	13	.2	.0	0	40
0	19	9	.2	23	210	5.9	.0	.0	0	0
0	340	76	.2	12	1,120	4.3	.0	.0	0	160
0	120	5	.2	25	565	14	.0	.0	0	1,800
0	20	14	.4	8	205	3.2	.0	.1	0	360
0	98	41	.2	25	490	12	.0	.0	0	60
0	280	227	.4	38	1,160	12	.7	.1	0	2,100
0	50	359		250	1,040	.68	.0	.0	0	47,000
0	73	27		38	380	2.5	.0	.0	100	180
0	170	122		38	920	25	.0	.1	200	600
0	170	112		38	875	24	.0	.0	300	400
0	190	124		50	925	26	.0	.1	100	320
0	190	124		45	995	26	.0	.1	200	60
0	140	98		27	895	31	.2	.1	0	60
0	64	69		30	615	17	.2	.1	0	140
0	220	302		27	1,200	10	.3	.1	400	0
0	210	188		24	985	14	.5	7.6	800	3,300
30	100	249		19		.9		2.8	500	1,540
0	240	341		20	1,560	24	.0		300	100
0	210	124		27	860	16	.3	.2	100	0
0	40	51		32	620	14	.2	.1	0	40
0	280	284		33	1,350	3.6	.2	.1	800	320
0	280	99		25	885	12	.5	.0	100	13,000
0	400	89		15	1,160	15	.7	.0	100	0

TABLE 2.--Wells sampled in 1968-69 and 1977-78, well construction data availability, and wells suitable for a permanent monitoring network

State well number	Sampled 1968-69	Sampled 1977-78	Well construction data available[1]: Perforated interval	Well construction data available[1]: Depth of well only	Control well[2]	Recommended for monitoring network
2N/5W-33Q2	X	--	--	--	--	--
1N/4W-29E1	X	X	--	X	X	X
1N/4W-29P2	X	X	X	--	X	X
1N/5W-2A1	X	X	--	--	--	--
1N/5W-22F1	X	X	--	--	--	--
1N/5W-23A2	X	X	X	--	--	X
1N/5W-36J3	X	X	X	--	--	X
1N/6W-19A1	X	--	--	--	--	--
1N/6W-25K1	X	--	--	--	--	--
1N/7W-27Q1	X	--	--	--	X	--
1N/7W-27R1	--	X	--	--	--	--
1N/7W-29E1	X	--	--	--	X	--
1N/7W-29E2	X	--	--	--	--	--
1N/8W-24L1	X	--	--	--	X	--
1N/8W-34N1	X	--	--	--	--	--
1S/1W-19B2	--	X	--	--	--	--
1S/1W-20M1	--	X	--	--	--	--
1S/1W-30D00	--	X	--	--	--	--
1S/1W-30E1	X	--	--	--	X	--
1S/1W-31H1	X	--	--	--	--	--
1S/2W-9P1	X	--	--	--	--	--
1S/2W-14L1	X	--	--	--	--	--
1S/2W-16F1	X	X	X	--	--	X
1S/2W-21E1	X	X	--	--	--	--
1S/2W-25G00	--	X	--	--	--	--
1S/2W-25K1	X	--	--	--	--	--
1S/2W-25M00	--	X	--	X	--	X
1S/2W-25R00	--	X	--	--	--	--
1S/2W-30B2	X	X	X	--	--	X
1S/2W-32C1	X	--	--	--	--	--
1S/2W-36F00	--	X	--	--	--	--
1S/2W-36N00	--	X	--	--	--	--
1S/3W-1H1	--	X	X	--	--	X
1S/3W-3Q1	X	--	--	--	X	--
1S/3W-8M1	--	X	X	--	--	X

See footnotes at end of table.

TABLE 2.--Wells sampled in 1968-69 and 1977-78, well construction data availability, and wells suitable for a permanent monitoring network--Continued

State well number	Sampled 1968-69	Sampled 1977-78	Well construction data available[1]		Control well[2]	Recommended for monitoring network
			Perforated interval	Depth of well only		
1S/3W-9E2	--	X	--	--	--	--
1S/3W-9F2	X	--	--	--	--	--
1S/3W-12F00	--	X	--	--	--	--
1S/3W-13P2	X	X	X	--	--	X
1S/3W-13R00	--	X	--	--	--	--
1S/3W-15A1	X	X	--	--	--	--
1S/3W-16A1	X	X	X	--	--	X
1S/3W-16L00	--	X	--	--	--	--
1S/3W-17C3	X	X	X	--	--	X
1S/3W-17H1	--	X	X	--	--	X
1S/3W-17L1	X	X	--	--	--	--
1S/3W-18L1	X	X	--	--	X	--
1S/3W-18N3	--	X	--	--	--	--
1S/3W-19A1	--	X	--	--	--	--
1S/3W-19G2	X	X	--	--	X	--
1S/3W-20R2	X	--	--	--	X	--
1S/3W-28E2	X	--	--	--	--	--
1S/3W-28H1	X	X	X	--	X	X
1S/3W-31E1	--	X	--	--	--	--
1S/3W-31H1	X	X	--	X	X	X
1S/3W-35G8	X	X	--	X	--	X
1S/4W-3H2	X	--	--	--	--	--
1S/4W-5R00	--	X	--	--	--	--
1S/4W-8F1	--	X	--	--	--	--
1S/4W-8F2	--	X	--	--	--	--
1S/4W-8F3	--	X	--	--	--	--
1S/4W-8F7	X	--	--	--	--	--
1S/4W-8R1	--	X	--	--	--	--
1S/4W-8R2	--	X	--	--	--	--
1S/4W-8R3	--	X	--	--	--	--
1S/4W-8R4	--	X	--	--	--	--
1S/4W-13H1	X	--	--	--	--	--
1S/4W-13N5	X	--	--	--	--	--
1S/4W-18B00	--	X	--	--	--	--
1S/4W-18F00	--	X	--	--	--	--

See footnotes at end of table.

TABLE 2.--Wells sampled in 1968-69 and 1977-78, well construction data availability, and wells suitable for a permanent monitoring network--Continued

State well number	Sampled 1968-69	Sampled 1977-78	Well construction data available[1]		Control well[2]	Recommended for monitoring network
			Perforated interval	Depth of well only		
1S/4W-18F1	--	X	X	--	--	X
1S/4W-18G1	--	X	X	--	--	X
1S/4W-18N1	X	X	--	--	--	--
1S/4W-21N1	X	--	--	--	--	--
1S/4W-23K2	X	X	X	--	X	X
1S/4W-25C1	X	X	X	--	X	X
1S/4W-25D00	X	X	--	--	--	--
1S/4W-28L2	--	X	--	--	--	--
1S/4W-28N1	X	--	--	--	--	--
1S/4W-29E1	X	--	--	--	--	--
1S/4W-30D1	X	--	--	--	--	--
1S/4W-31A2	X	--	--	--	--	--
1S/5W-2C1	X	--	--	--	--	--
1S/5W-2K1	X	--	--	--	X	--
1S/5W-5A3	X	X	--	X	--	X
1S/5W-6D1	X	--	--	--	X	--
1S/5W-7N1	X	--	--	--	X	--
1S/5W-12L1	X	X	--	X	--	X
1S/5W-12N1	X	X	--	X	--	X
1S/5W-15G1	X	--	--	--	X	--
1S/5W-16J1	X	--	--	--	X	--
1S/5W-20D1	X	--	--	--	--	--
1S/5W-21B1	X	--	--	--	--	--
1S/5W-21D1	X	X	--	--	--	--
1S/5W-25B2	X	--	--	--	--	--
1S/5W-25R5	X	--	--	--	--	--
1S/5W-33A2	X	--	--	--	--	--
1S/5W-34B2	X	--	--	--	--	--
1S/5W-34D1	X	--	--	--	--	--
1S/6W-11B1	X	--	--	--	X	--
1S/6W-11N1	X	--	--	--	X	--
1S/6W-12P1	--	X	--	--	--	--
1S/6W-12P2	X	--	--	--	--	--
1S/6W-32E00	X	--	--	--	--	--
1S/7W-4B2	X	--	--	--	--	--

See footnotes at end of table.

TABLE 2.--Wells sampled in 1968-69 and 1977-78, well construction data availability, and wells suitable for a permanent monitoring network--Continued

State well number	Sampled 1968-69	Sampled 1977-78	Well construction data available[1]		Control well[2]	Recommended for monitoring network
			Perforated interval	Depth of well only		
1S/7W-4B3	X	--	--	--	--	--
1S/7W-8N1	X	--	--	--	X	--
1S/7W-18G1	--	X	--	X	--	X
1S/7W-18H00	X	--	--	--	--	--
1S/7W-20A1	X	X	--	--	X	--
1S/7W-21D1	X	X	--	X	X	X
1S/7W-23D1	X	X	--	X	--	X
1S/7W-24E00	X	--	--	--	--	--
1S/7W-24M00	--	X	--	X	--	X
1S/7W-30Q1	X	X	--	X	X	X
1S/7W-34K1	X	X	--	--	--	--
1S/8W-3A1	X	--	--	--	--	--
1S/8W-3F3	X	--	--	--	--	--
1S/8W-10N1	X	--	--	--	--	--
1S/8W-14A1	X	--	--	--	--	--
1S/8W-14A2	--	X	--	X	--	X
1S/8W-16B1	X	--	--	--	--	--
1S/8W-28N1	X	X	X	--	X	X
1S/8W-30J1	X	--	--	--	--	--
1S/8W-35C1	X	X	X	--	X	X
1S/8W-35C2	X	--	--	--	--	--
2S/1W-1E1	X	--	--	--	--	--
2S/1W-2J1	X	--	--	--	--	--
2S/1W-2K5	X	--	--	--	--	--
2S/1W-9G1	--	X	--	--	--	--
2S/1W-22H1	X	--	--	--	--	--
2S/1W-27B1	X	--	--	--	--	--
2S/1W-30E1	X	--	--	--	--	--
2S/1W-34Q1	X	--	--	--	--	--
2S/2W-2D00	--	X	--	--	--	--
2S/2W-2N00	--	X	--	--	--	--
2S/2W-4L1	X	--	--	--	X	--
2S/2W-8K1	X	--	--	--	--	--
2S/2W-8K2	X	--	--	--	--	--
2S/2W-11B1	--	X	--	X	--	X

See footnotes at end of table.

TABLE 2.--Wells sampled in 1968-69 and 1977-78, well construction data availability, and wells suitable for a permanent monitoring network--Continued

State well number	Sampled 1968-69	Sampled 1977-78	Well construction data available[1]		Control well[2]	Recommended for monitoring network
			Perforated interval	Depth of well only		
2S/2W-11B2	--	X	--	--	--	--
2S/2W-11B3	--	X	--	--	--	--
2S/2W-11F1	X	--	--	--	--	--
2S/2W-12M1	X	--	--	--	X	--
2S/2W-14C1	X	X	X	--	--	X
2S/2W-14D1	X	X	--	--	--	--
2S/2W-14E00	X	X	--	--	--	--
2S/2W-15A3	X	X	--	X	--	X
2S/2W-15B00	X	--	--	--	--	--
2S/2W-15B1	X	--	--	--	--	--
2S/2W-24E2	X	X	X	--	--	X
2S/2W-24E3	--	X	--	--	--	--
2S/2W-25D1	X	--	--	--	--	--
2S/2W-35D1	X	--	--	--	--	--
2S/4W-6A1	X	X	--	X	--	X
2S/5W-2P1	X	X	--	X	--	X
2S/5W-7N1	X	X	--	--	--	--
2S/5W-7N2	X	X	--	--	--	--
2S/5W-8D1	X	--	--	--	--	--
2S/5W-10C1	X	--	--	--	--	--
2S/5W-10G3	X	X	--	--	--	--
2S/5W-12C1	X	X	--	--	--	--
2S/5W-14D1	X	--	--	--	--	--
2S/5W-16A3	X	X	--	--	--	--
2S/5W-17R1	X	--	--	--	--	--
2S/5W-20R1	X	X	--	--	--	--
2S/5W-22R1	X	X	--	X	--	X
2S/5W-26F1	X	--	--	--	X	--
2S/6W-12E1	X	X	--	--	--	--
2S/6W-14K1	X	X	--	--	--	--
2S/6W-30Q1	X	--	--	--	--	--
2S/6W-31C1	X	--	--	--	--	--
2S/7W-1P00	--	X	--	--	--	--
2S/7W-4B00	--	X	--	--	--	--
2S/7W-4B1	X	--	--	--	--	--

See footnotes at end of table.

TABLE 2.--Wells sampled in 1968-69 and 1977-78, well construction data availability, and wells suitable for a permanent monitoring network--Continued

State well number	Sampled 1968-69	Sampled 1977-78	Well construction data available[1]		Control well[2]	Recommended for monitoring network
			Perforated interval	Depth of well only		
2S/7W-6J2	X	--	--	--	--	--
2S/7W-7H00	--	X	--	--	--	--
2S/7W-8J00	--	X	--	--	--	--
2S/7W-10C1	X	--	--	--	--	--
2S/7W-10D00	--	X	--	--	--	--
2S/7W-10H1	X	--	--	--	--	--
2S/7W-10M00	--	X	--	--	--	--
2S/7W-10M1	X	--	--	--	--	--
2S/7W-11D00	--	X	--	--	--	--
2S/7W-11D1	X	X	--	X	--	X
2S/7W-13J00	--	X	--	--	--	--
2S/7W-14A1	--	X	--	--	--	--
2S/7W-15A2	X	--	--	--	--	--
2S/7W-15Q00	--	X	--	--	--	--
2S/7W-15Q1	X	--	--	--	X	--
2S/7W-17D1	X	--	--	--	--	--
2S/7W-17D2	X	--	--	--	--	--
2S/7W-17L00	--	X	--	--	--	--
2S/7W-17L1	X	--	--	--	X	--
2S/7W-17R1	--	X	--	X	--	X
2S/7W-20L00	--	X	--	--	--	--
2S/7W-21K1	X	--	--	--	--	--
2S/7W-21L1	X	--	--	--	X	--
2S/7W-22K1	X	--	--	--	--	--
2S/7W-23E1	X	--	--	--	X	--
2S/7W-24P00	--	X	--	--	--	--
2S/7W-25L1	X	--	--	--	--	--
2S/7W-27A1	X	--	--	--	X	--
2S/7W-28N00	--	X	--	--	--	--
2S/7W-31E1	X	--	--	--	--	--
2S/7W-31E4	X	--	--	--	--	--
2S/7W-32F1	X	--	--	--	X	--
2S/7W-34K2	X	X	--	--	X	--
2S/7W-35J2	X	X	--	--	--	--
2S/7W-36M2	X	X	--	--	--	--

See footnotes at end of table.

TABLE 2.--Wells sampled in 1968-69 and 1977-78, well construction data availability, and wells suitable for a permanent monitoring network--Continued

State well number	Sampled 1968-69	Sampled 1977-78	Well construction data available[1]		Control well[2]	Recommended for monitoring network
			Perforated interval	Depth of well only		
2S/8W-14B1	X	--	--	--	--	--
2S/8W-14H1	X	X	--	X	X	X
2S/8W-15F1	X	--	--	--	--	--
2S/8W-15K1	X	--	--	--	--	--
2S/8W-16B1	--	X	--	--	--	--
2S/8W-22B1	X	--	--	--	X	--
2S/8W-23C1	--	X	--	--	--	--
2S/8W-25L1	X	--	--	--	X	--
2S/8W-25M00	--	X	--	--	--	--
2S/8W-25M1	X	--	--	--	--	--
2S/8W-26K1	X	--	--	--	--	--
2S/8W-26L1	X	--	--	--	--	--
3S/1W-5Q00	X	--	--	--	X	--
3S/1W-9Q1	X	--	--	--	--	--
3S/5W-9L1	X	--	--	--	--	--
3S/5W-15A1	X	--	--	--	--	--
3S/5W-17K2	X	X	--	--	--	--
3S/5W-18R1	X	--	--	--	--	--
3S/5W-23D1	X	X	--	--	--	--
3S/6W-13M1	X	--	--	--	--	--
3S/6W-15R1	X	--	--	--	--	--
3S/6W-22L2	X	X	--	--	--	--
3S/6W-27H2	X	--	--	--	--	--
3S/6W-28H00	--	X	--	--	--	--
3S/6W-28H1	--	X	X	--	--	X
3S/6W-28L00	X	--	--	--	--	--
3S/6W-28L1	X	X	X	--	--	X
3S/6W-28L3	--	X	--	--	--	--
3S/7W-3A2	--	X	--	--	--	--
3S/7W-3A3	X	--	--	--	--	--
3S/7W-3R2	X	X	--	--	--	--
3S/7W-4A2	X	--	--	--	--	--
3S/7W-4B2	X	--	--	--	--	--
3S/7W-4D1	X	--	--	--	--	--
3S/7W-4H1	X	--	--	--	X	--

See footnotes at end of table.

TABLE 2.--Wells sampled in 1968-69 and 1977-78, well construction data availability, and wells suitable for a permanent monitoring network--Continued

State well number	Sampled 1968-69	Sampled 1977-78	Well construction data available[1]		Control well[2]	Recommended for monitoring network
			Perforated interval	Depth of well only		
3S/7W-10C1	X	--	--	--	X	--
3S/7W-15Q3	X	X	--	--	--	--
3S/7W-21N1	X	--	--	--	--	--
3S/7W-22H1	X	X	--	--	--	--
3S/7W-22L1	X	X	--	X	--	X
3S/7W-24E1	X	--	--	--	--	--
3S/7W-25A3	X	--	--	--	--	--
3S/7W-25H00	--	X	--	--	--	--
3S/7W-25M1	X	X	X	--	X	X
3S/7W-26C1	X	--	--	--	--	--
3S/7W-27A1	--	X	--	--	--	--
3S/7W-27H2	X	--	--	--	--	--
3S/7W-27J00	--	X	--	--	--	--
3S/7W-27N1	--	X	--	--	--	--
3S/7W-35L1	X	--	--	--	--	--
4S/6W-8H1	X	--	--	--	--	--
4S/6W-10C1	X	--	--	--	--	--
4S/6W-16R2	X	--	--	--	--	--
4S/6W-21J1	X	--	--	--	--	--
4S/7W-3F1	X	X	--	--	--	--

[1]Source of data is drillers' logs provided by the Regional Board or on file with the U.S. Geological Survey.

[2]Identified as "control well" in 1970 study by Water Resources Engineers, Inc.

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