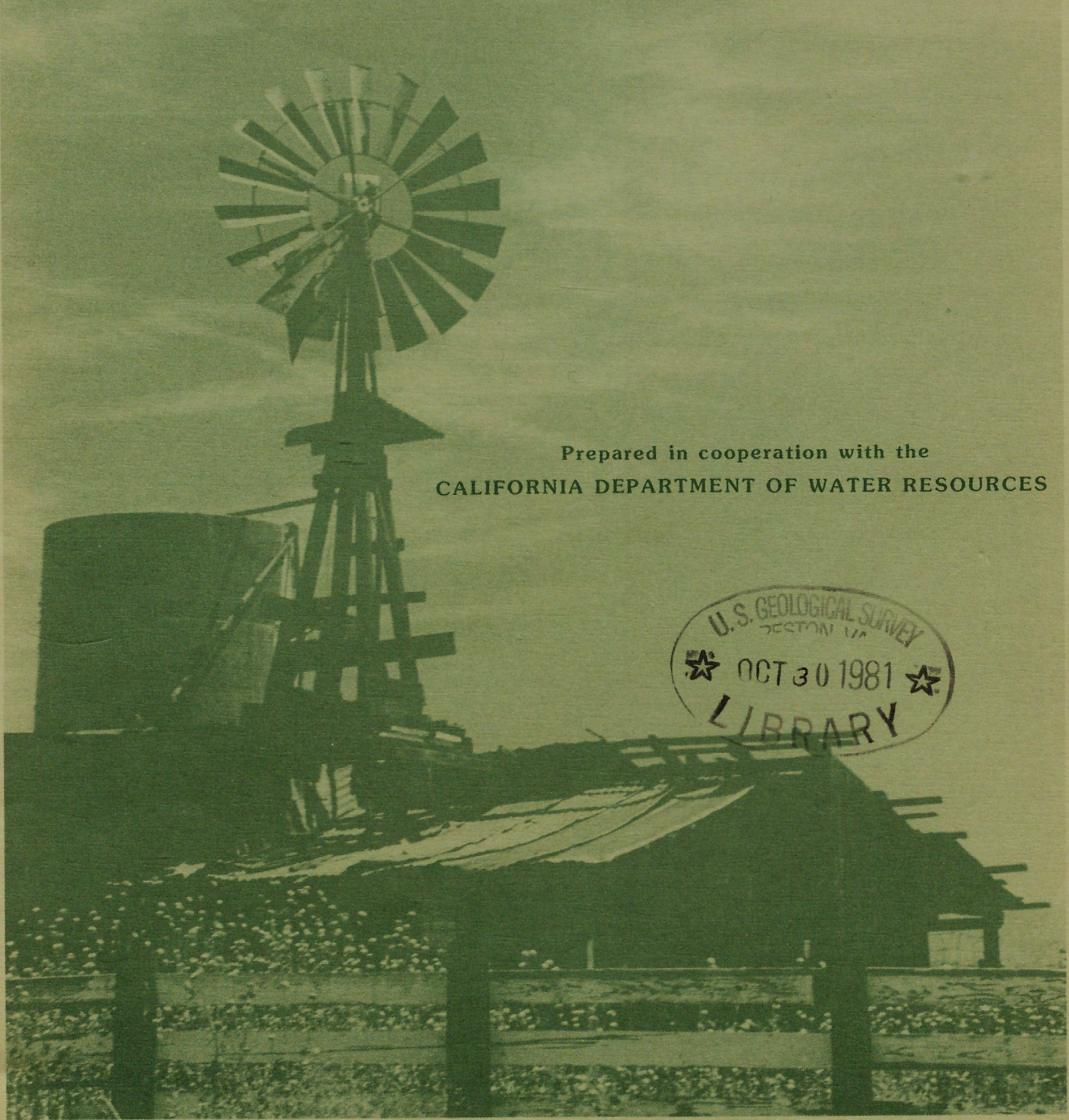
CHEMICAL QUALITY OF GROUND WATER IN SAN JOAQUIN AND PART OF CONTRA COSTA COUNTIES, CALIFORNIA



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By Stephen K. Sorenson

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UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Doyle G. Frederick, Acting Director

For additional information write to:

District Chief
Water Resources Division
U.S. Geological Survey
345 Middlefield Road
Menlo Park, Calif. 94025

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CONVERSION FACTORS

For readers who prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To Obtain
acres	4047	m^2 (square meters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
µmho (micromhos)	1	µS (microsiemens)

Degree Fahrenheit is converted to degree Celsius by using the formula:

$$°C = (°F-32)/1.8$$

<u>Additional abbreviations</u>:

mg/L	(milligrams per liter)
meq/L	(milliequivalents per liter)
µmho/cm	(micromhos per centimeter)

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ABSTRACT

Chemical water-quality conditions were investigated in San Joaquin and part of Contra Costa Counties by canvassing available wells and sampling water from 324 representative wells. Chemical water types varied, with 73 percent of the wells sampled containing either calcium-magnesium bicarbonate, or calcium-sodium bicarbonate type water. Substantial areas contain ground water exceeding water-quality standards for boron, manganese, and nitrate. Trace elements, with the exception of boron and manganese, were present in negligible amounts.

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INTRODUCTION

Location and General Features

The study area consists of San Joaquin County and the eastern valley areas of Contra Costa County (fig. 1). This area occupies the northern end of the San Joaquin Valley in California's Central Valley and covers approximately 1,600 mi^2. Agriculture is the principal economic base of the study area, with a wide variety of field crops, orchards, and vineyards dominating the industry. Stockton is the major metropolitan center, with a 1979 population of approximately 131,100. Secondary centers of population are Lodi, Tracy, and Manteca.

Ground water supplies most of the area's municipal, industrial, and agricultural water needs. Other sources of water include the San Joaquin, Stanislaus, and Mokelumne Rivers and various canals. Increased demand for ground water, caused by expanding agriculture, urbanization, and industrialization, has created overdraft problems in some areas near Stockton (California Department of Water Resources, 1967).

Previous Studies

This report is the fourth in a series prepared in cooperation with the California Department of Water Resources. Previous reports described chemical quality of ground water in the Tehama-Colusa Canal service area of the Sacramento Valley (Bertoldi, 1976), the central part of the Sacramento Valley (Fogelman, 1977), and the eastern part of the Sacramento Valley (Fogelman, 1978).

Purpose and Scope

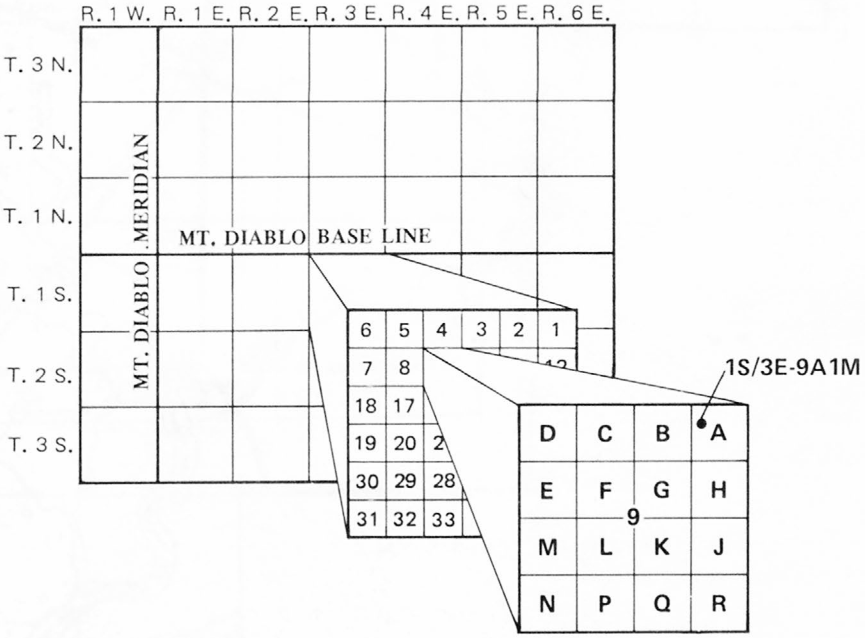
The purpose of this report is to document the chemical character of ground water in the study area as of 1979. The scope of the study included (1) collection of lithological and construction data for existing wells, mostly from drillers reports; (2) a selective field canvass of wells chosen from the gathered data; (3) collection and analysis of water samples from wells selected as representative of the ground water in the study area; (4) classification of water into chemical types; and (5) detection of areas or well sites where specific chemical constituents in the ground water exceed recommended criteria, or standards for agricultural or domestic uses. Parts 1, 2, and 3 were accomplished in 1978 and 1979, and the results were reported by Keeter (1980), who also describes the methods used for inventory, canvass, and field sampling.

Geology and Ground-Water Hydrology

Clay-rich delta deposits and alluvium from the Coast Ranges underlie the study area. The surface and subsurface geology and subsurface hydrology of San Joaquin County are described in detail in California Department of Water Resources Bulletin 146 (1967). Data on water levels are available in semi-annual reports on the ground-water measurements and ground-water quality from the San Joaquin County Flood Control and Water Conservation District (1972 through 1979).

Well-Numbering System

Wells are identified according to their location in the rectangular system for the subdivision of public lands. The identification consists of the township number, north or south; the range number, east or west; and the section number. Each section is further divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with A in the northeast corner of the section and progressing in a sinusoidal manner to R in the southeast corner. Within the 40-acre tract, wells are sequentially numbered in the order they are inventoried. The final letter refers to the base line and meridian. Because all wells in the study area are referenced to the Mount Diablo base line and meridian (M), the final letter is omitted. The diagram below shows how the well number 1S/3E-9A1M is derived.



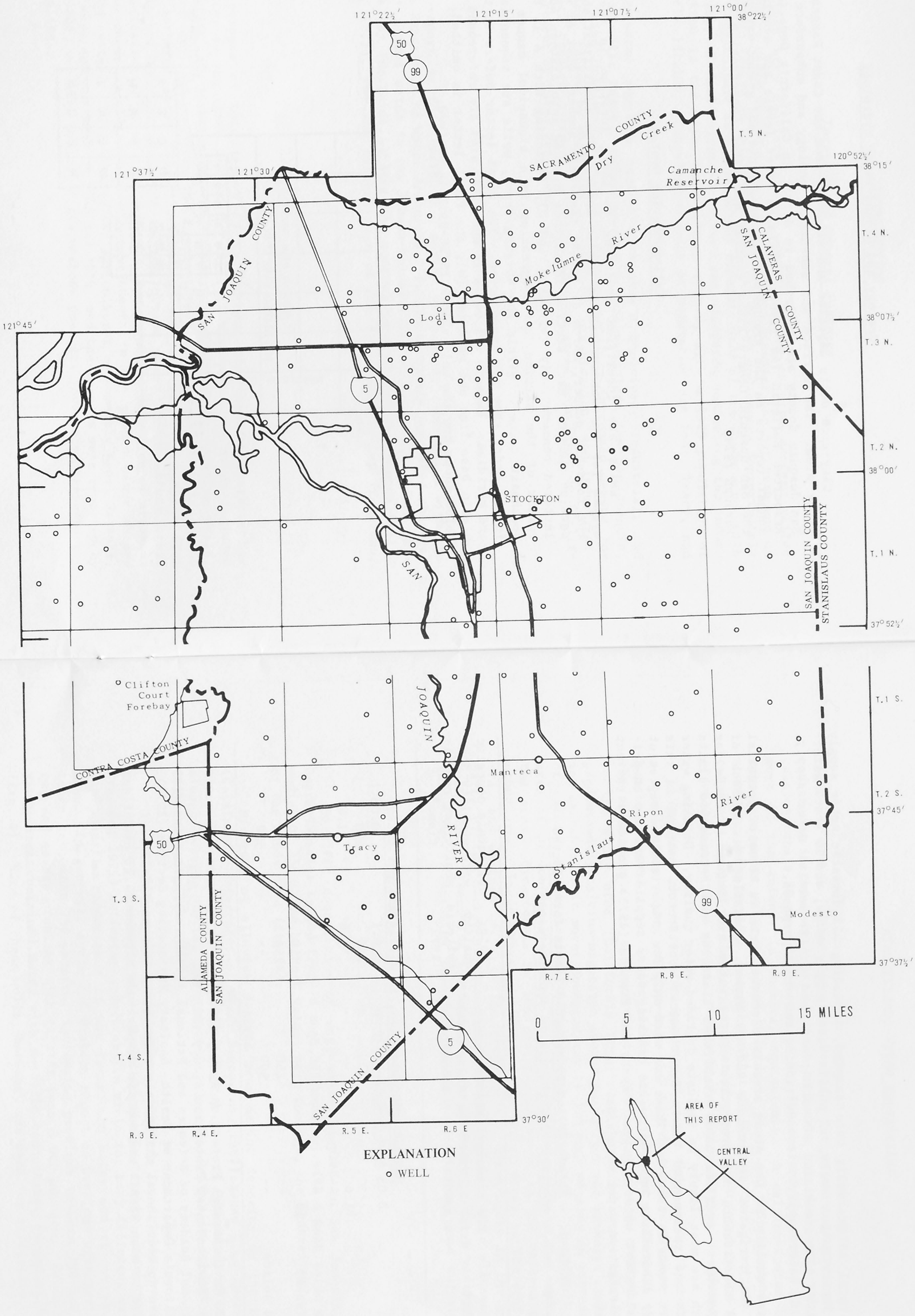


FIGURE 1.--Study area and sample well locations.

A total of 324 wells were sampled, including 253 domestic water supply wells, 39 irrigation wells, 12 public water supply wells, and 10 stock watering wells. The remaining 10 wells were used for commercial water supply, industrial water supply, air conditioning and other purposes.

Water quality in the study area is discussed here in terms of potential effects on irrigated agriculture and on humans. Detailed discussions of chemical constituents and properties of the water are limited to those for which government agencies have established standards and recommended limits and which are most likely to indicate degraded water quality. Drinking water standards and recommended limits for chemical constituents sampled in this study are shown in table 1. These are used only for comparison and represent statutory limitations only on public drinking water supplies and not on private residential water sources. Ayers and Branson (1975) provide a current list of irrigation water standards.

TABLE 1. - Standards and recommended limits for selected chemical constituents in drinking water

Constituent	EPA primary drinking water standard[1]	EPA secondary drinking water standard[2]	Water quality criteria 1972[3]	California domestic water-quality and monitoring regulations[4]
	Maximum concentration, in milligrams per liter			
Arsenic	0.05	--	0.1	0.05
Chloride	--	250	250	250
Fluoride	[5]1.6	--	[6]1.6	[6]1.6
Iron	--	.3	.3	.3
Manganese	--	.05	.05	.05
Nitrate (as N)	10	--	10	10
Sulfate	--	250	250	250
Dissolved solids	--	500	--	500

[1]U.S. Environmental Protection Agency (1975).
[2]U.S. Environmental Protection Agency (1979).
[3]National Academy of Sciences and National Academy of Engineering (1973).
[4]California Department of Health, Sanitary Engineering Section (1977).
[5]Based on mean annual maximum air temperature between 72°-79°F.
[6]Based on mean annual maximum air temperature between 70.7°-79.2°F.

Water Types

Areal distribution of water types in the ground water is presented in figures 2 and 3. Water types are based on the relative percentage of cations and anions in the water. A calcium bicarbonate type designates water in which calcium totals 50 percent or more of the cations and bicarbonate 50 percent or more of the anions, in chemical equivalents. A calcium-sodium bicarbonate type designates water in which calcium is first and sodium second in order of abundance among cations, but neither totals greater than 50 percent of all the cations. Because of the large number of water types found in the study area, discussion sometimes refers to anionic and cationic types of water separately.

Analyses showed a wide variety of water types with 73 percent of the sampled waters either calcium-magnesium bicarbonate, or calcium-sodium bicarbonate. Ground water in the eastern area is similar in chemical character to the surface water in the east-side rivers, which provide most of the recharge to the study area (California Department of Water Resources, 1967). The predominantly calcium-magnesium ground water from the recharge areas undergoes ion exchange as it moves downgradient to the west causing an increasing amount of calcium and magnesium to be replaced with sodium. The result is a large area of predominantly sodium or calcium-sodium water in the western half of the area. Bicarbonate is the predominant anion in the eastern part of the study area. Large areas of chloride type water occur in the central, southern, and western parts of the study area. These areas in the river-slough parts of the Sacramento-San Joaquin Delta are roughly in alinement with the San Joaquin River. The southwestern area near Tracy has a variety of anionic water types including chloride, chloride-bicarbonate, and sulfate-chloride.

Specific Conductance

Specific conductance of well water sampled in San Joaquin and Contra Costa Counties ranged from 78 to 5,390 μmho/cm, with a mean value of 685 and a median of 356. The highest values were found in the central and western parts of the study area (fig. 4).

Minerals of alluvium derived from marine deposits in the Coast Ranges (California Department of Water Resources, 1967) cause high specific conductance in the western part. The central part of the study area (river and slough section of the Sacramento-San Joaquin Delta) is subject to seasonal seawater intrusion.

There are no specific conductance standards for drinking water. A report published by the University of California Cooperative Extension (Ayers and Branson, 1975) estimates reductions in yield for many different crops based on the specific conductance of the irrigation water and the water in the root zone. In general, Ayers and Branson report no problems with specific conductance less than 750 μmho/cm, increasing problems between 750 and 3,000 μmho/cm, and severe problems with greater than 3,000 μmho/cm. Seven wells in the study area contained water with specific conductance exceeding 3,000 μmho/cm (fig. 4). None of these wells, however, was used for irrigation.

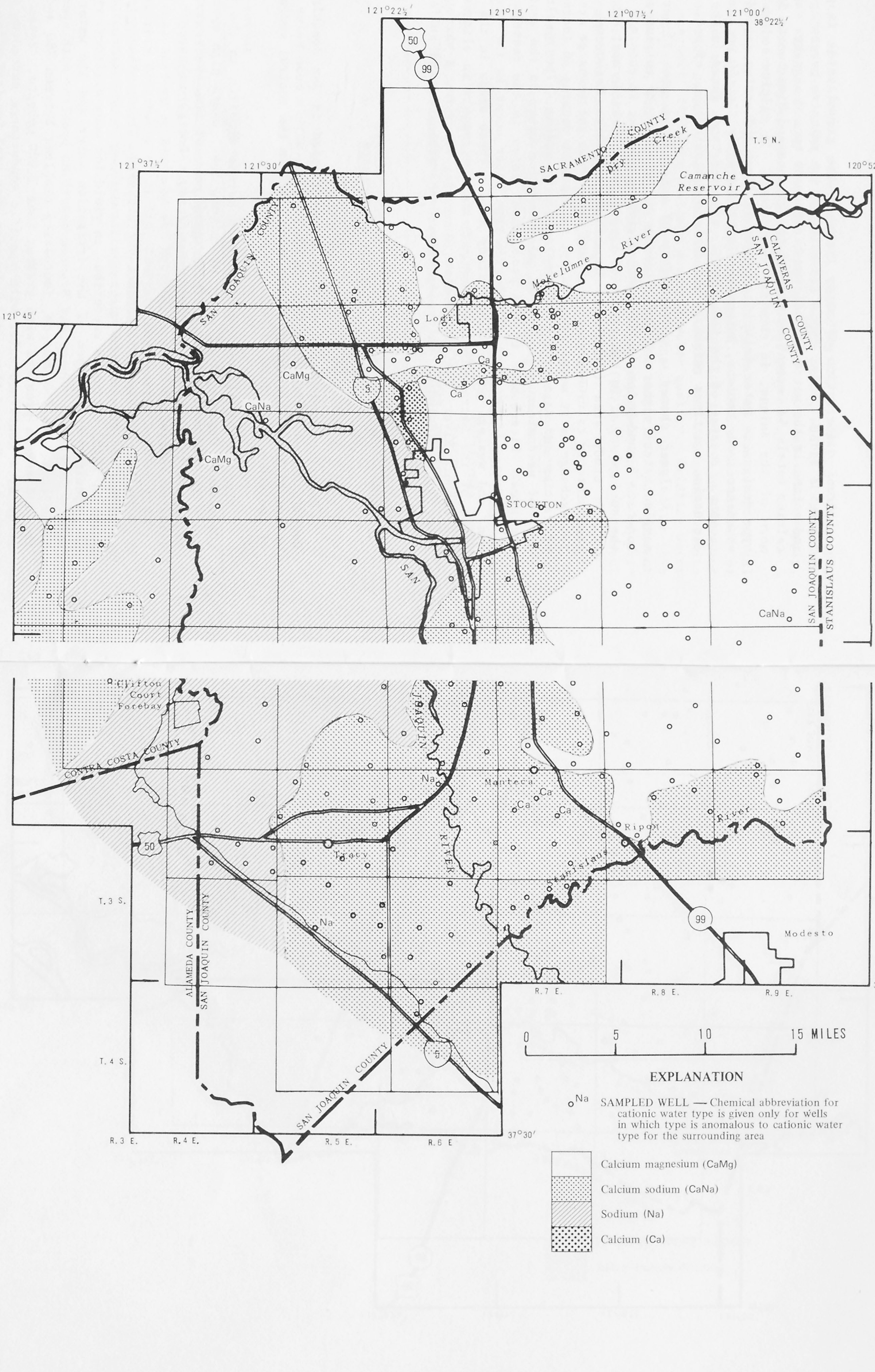


FIGURE 2.--Areal distribution of major cations in ground water.

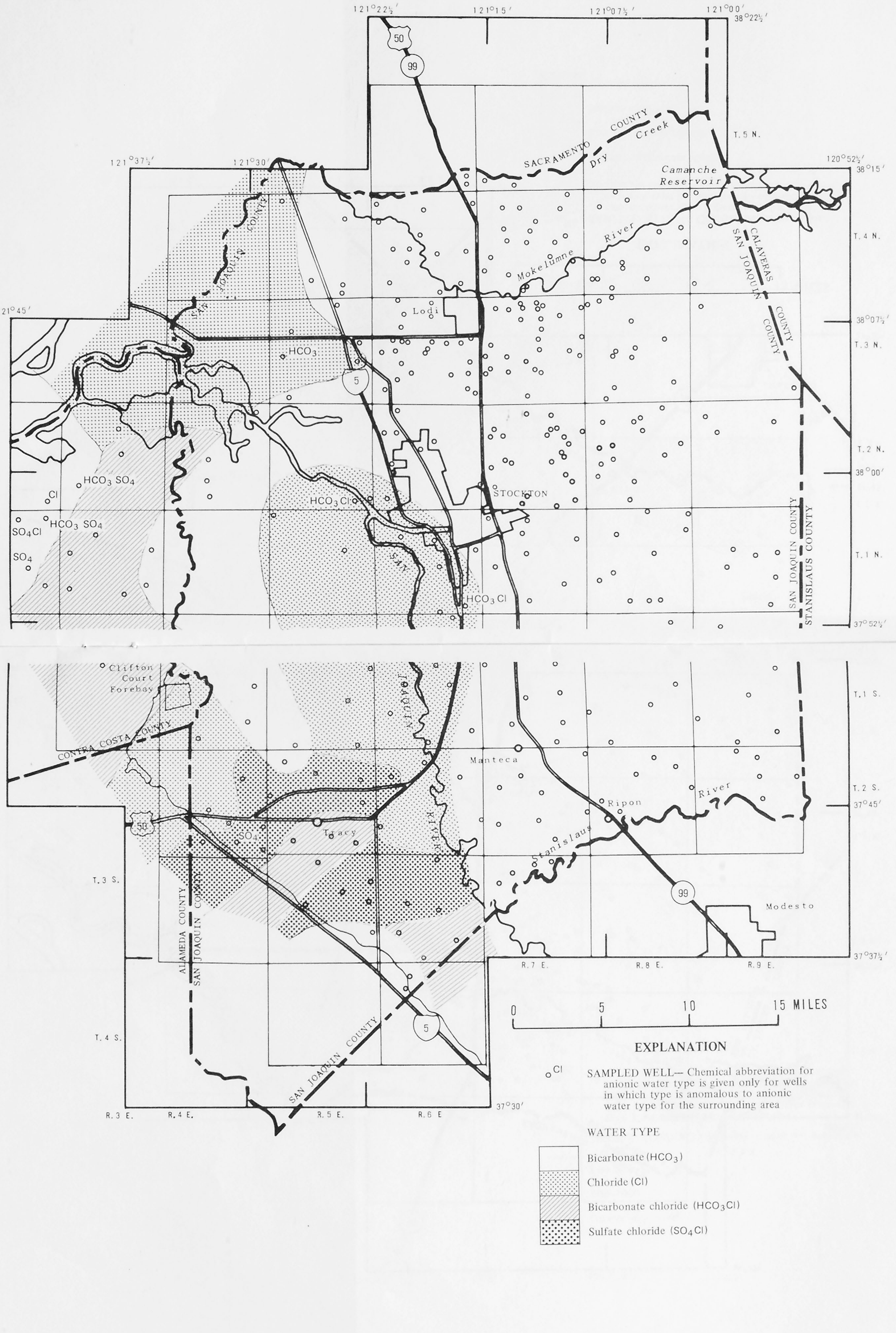


FIGURE 3.--Areal distribution of major anions in ground water.

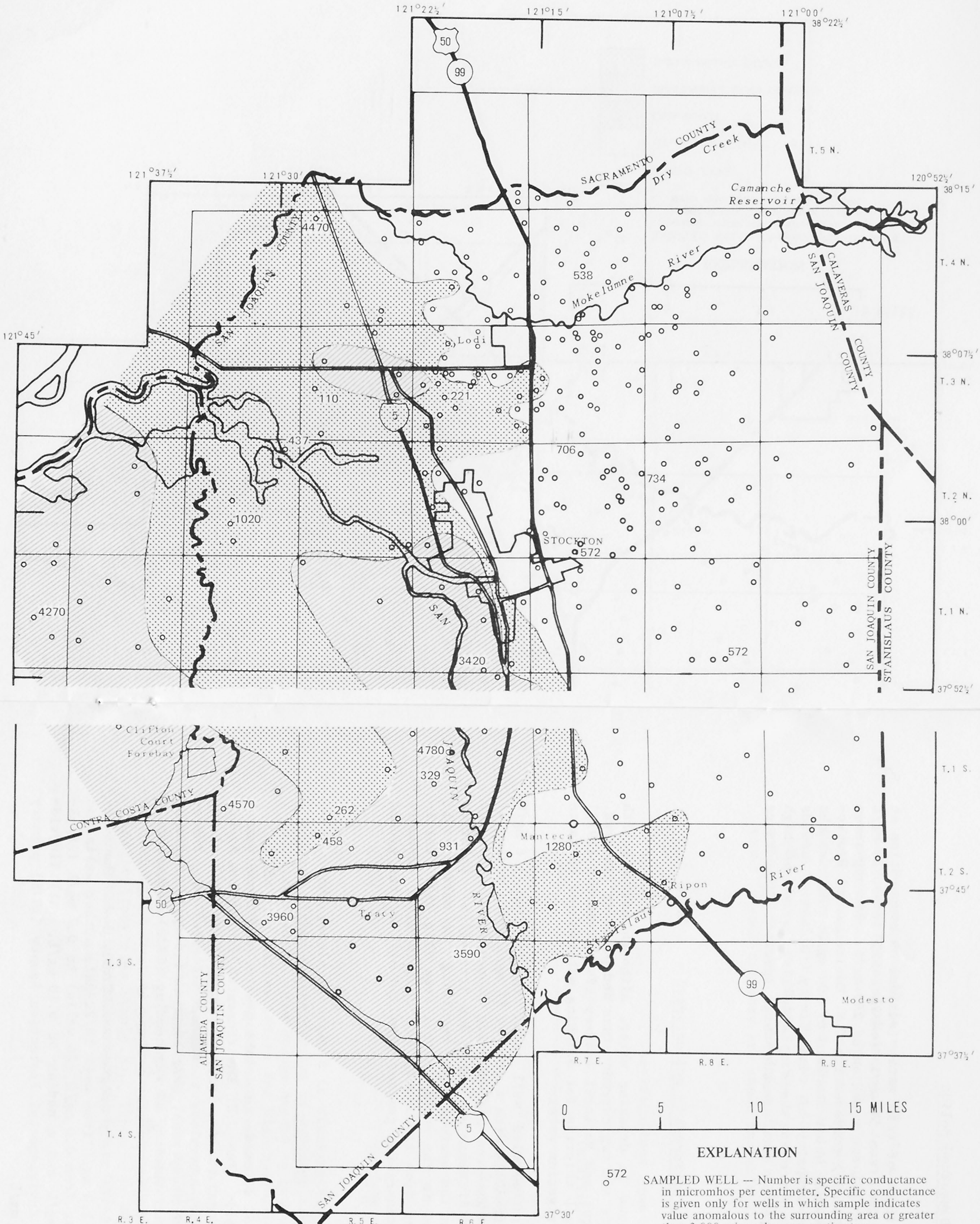


FIGURE 4.--Areal distribution of specific conductance in ground water.

Dissolved Solids

Dissolved-solids concentrations of well water (residue on evaporation at 180°C) in the study area ranged from 50 mg/L (4N/7E-24N2) to 3,520 mg/L (1N/2E-23N1), with a mean of 463 mg/L and a median of 269 mg/L. Seventy-seven of the 317 wells sampled (24 percent) exceeded the U.S. Environmental Protection Agency (1979) secondary drinking water standard of 500 mg/L. Because the dissolved solids determine the property of conductivity (dissolved solids average 0.77 of specific conductance in the sampled wells), areas of high dissolved solids correspond directly with areas of high specific conductance (fig. 4).

Chloride

High chloride concentrations in drinking water, although not a health hazard, cause objectionable taste and can corrode pipes and plumbing fixtures. The National Academy of Sciences and National Academy of Engineering (1973) recommended a maximum of 250 mg/L chloride for drinking water based on taste preference, and 700 mg/L for irrigation water.

Chloride concentrations of sampled well water ranged from 1.8 mg/L (4N/6E-31H3) to 1,500 mg/L (1S/6E-17L1) with a mean of 87 mg/L and a median of 16 mg/L. Five wells in the study area had chloride concentrations greater than 700 mg/L (fig. 5). None of these was used for irrigation. Chloride concentrations were greatest in the western area, resulting from marine sediments of the Coast Ranges, and in the south central area (fig. 5). Infiltration of high chloride water from the nearby San Joaquin River probably accounts for the chloride concentration greater than 250 mg/L of the ground water in the central area.

Fluoride

Excessive concentrations of fluoride in drinking water can cause dental fluorosis (mottled tooth enamel). The U.S. Environmental Protection Agency (1975) primary drinking water standards for fluoride vary with mean annual air temperatures because temperature determines the amount of water and, therefore, fluoride consumed. In the study area, this limit is 1.6 mg/L. National Academy of Sciences and National Academy of Engineering (1973) recommends a maximum of 1.0 mg/L for continuous use for irrigation.

Fluoride concentrations in the study area were uniformly low. The highest concentration sampled was 1.2 mg/L from well 1N/2E-3K1. Other wells had fluoride concentrations ranging from 0.0 mg/L (24 wells) to 0.7 mg/L (2S/4E-33B1), with a mean of 0.16 mg/L and a median of 0.10 mg/L. All fluoride concentrations were below the Environmental Protection Agency (1975) primary drinking water standard of 1.6 mg/L.

Hardness

Water hardness in excess of 180 mg/L (as $CaCO_3$) may be objectionable to some users because of increased soap consumption, scaling of utensils, and incrustation of water pipes (Fogelman, 1978). Because the amount of hardness that is tolerable in a water supply varies with its intended use, no EPA guidelines have been set. Hardness of well water within the study area ranged from 20 mg/L (4N/7E-33G3) to 1,500 mg/L (4N/5E-6J1), with a mean of 210 mg/L and a median of 130 mg/L. The highest concentrations occurred in the southern and western areas. A hardness classification and the percentage of the wells found in each category are shown in table 2.

TABLE 2. - Distribution of hardness classes among waters sampled

[Classifications from Hem, 1970]

Hardness range (mg/L)	Classification	Distribution (percent)
<60	Soft	10
60-120	Moderately hard	39
121-180	Hard	16
>180	Very hard	35

Sulfate

When people accustomed to drinking low sulfate water consume water containing higher concentrations of sulfate, they may suffer minor gastrointestinal disturbances. The dosage needed to produce these disturbances is so large and the acclimatization to the high sulfate water is so rapid that sulfate is not usually considered a hazard to humans.

Sulfate concentrations of sampled well water were generally below the 250 mg/L Environmental Protection Agency (1979) secondary drinking water standard, with values ranging from 0.0 mg/L (2N/6E-20M2 and 31H1) to 1,600 mg/L (1N/2E-23N1). The mean sulfate concentration was 58 mg/L with a median of 10 mg/L. Most of the wells that exceeded the 250 mg/L standard are located in the Tracy area (table 3). These high sulfate concentrations are probably associated with alluvium from marine sediments in that vicinity.

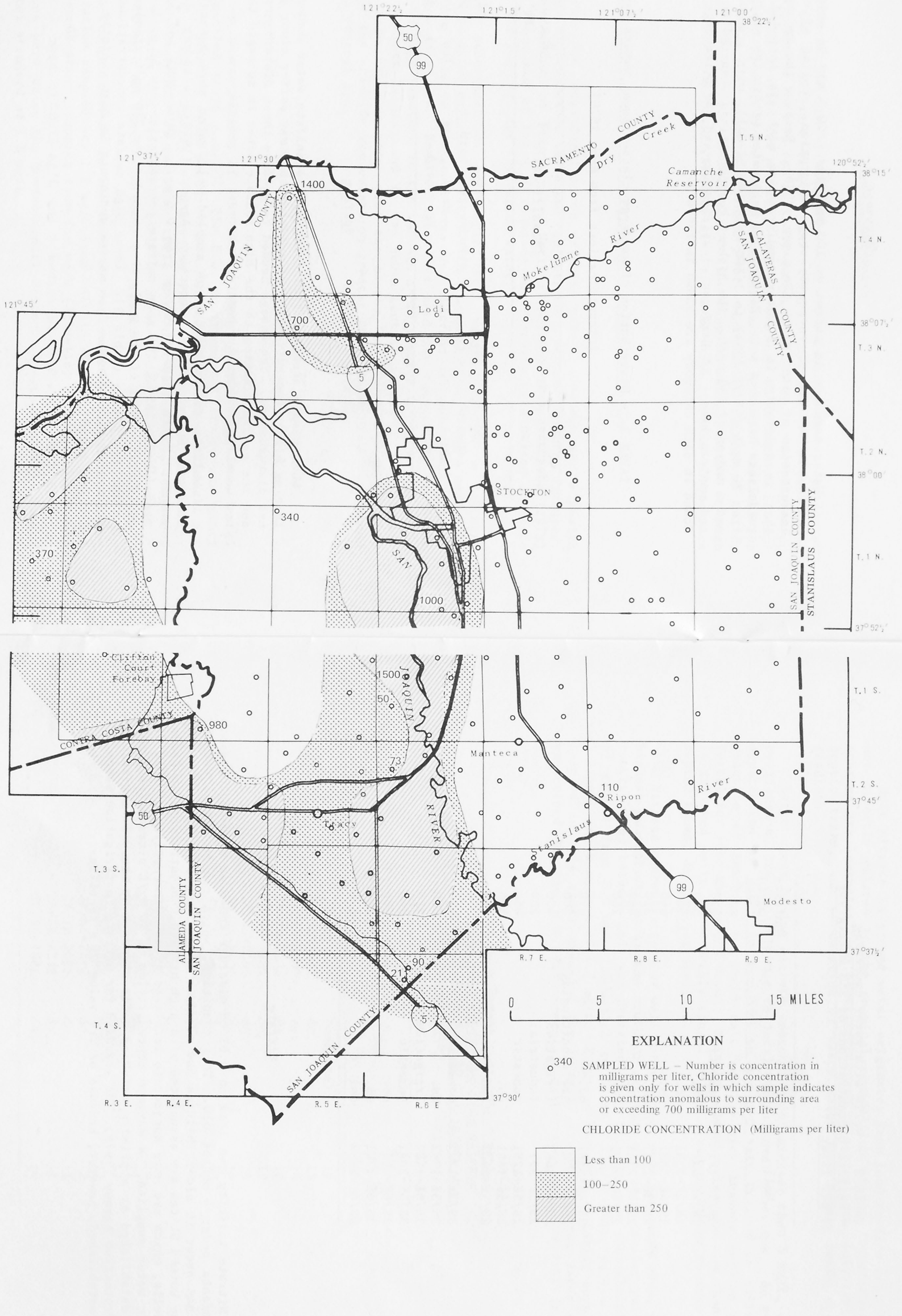


FIGURE 5.--Areal distribution of chloride concentrations in ground water.

TABLE 3. - Wells with water exceeding sulfate concentrations of 250 milligrams per liter

Well	Use	Sulfate (mg/L)
1N/2E-1F1	Domestic	270
1N/2E-3K1	do.	540
1N/2E-23N1	do.	1,600
1S/4E-33M1	do.	640
2N/3E-29M1	do.	310
2S/4E-25H1	do.	680
2S/4E-26D1	do.	260
2S/4E-33B1	do.	470
2S/4E-35H1	Air conditioning	1,300
2S/4E-36R3	Irrigation	400
2S/5E-9J1	Industrial	280
2S/5E-12N1	Domestic	460
2S/5E-18N1	do.	390
2S/5E-24C2	Industrial	350
3S/5E-12J2	Domestic	470
3S/5E-13R2	do.	660
3S/5E-14D2	Irrigation	310
3S/5E-20A1	Domestic	340
3S/6E-3F1	do.	760
3S/6E-17Q1	do.	260
3S/6E-22C2	do.	270

Nitrate

Nitrate toxicity can lead to a blood disorder known as methemoglobinemia in infants under 4 months old. This condition, which can be fatal, usually does not occur in older children and adults. Most cases of nitrate toxicity in the United States are associated with high nitrate concentrations in domestic wells, which are more subject to localized ground-water pollution than are public water supplies. A maximum concentration of 10 mg/L nitrate (as N) has been established as a primary drinking water standard by the U.S. Environmental Protection Agency (1975). No standard for nitrate in irrigation water has been established, however, because of its value as a fertilizer.

Most nitrate in ground water originates from land surface sources and is not directly related to the chemical composition of the formation. Common sources are leachates from fertilizers used in agriculture, infiltration from septic tanks, and percolation of waste water from sewage ponds and cattle feedlots.

Large areas having nitrate concentrations greater than 5 mg/L, as shown by figure 6, are probably due to local agricultural practices. An excessive application of water is required to prevent salt buildup in soils. This practice of leaching to avoid salt buildup also leaches applied nitrogen fertilizer into the ground water. Nitrate concentrations greater than 10 mg/L in isolated wells are probably caused by localized pollution sources such as septic tanks, dairies, or feedlots.

Nitrate concentrations of well water varied over the study area, with the highest concentrations in the southern sections and in a smaller part of the central area between Lodi and Stockton (fig. 6). Nitrate concentrations (as N) ranged from 0.0 mg/L (26 wells) to 63 mg/L (2S/7E-9N4), with a mean of 3.4 mg/L and a median of 1.7 mg/L. Eighteen domestic or public supply wells sampled in this study exceeded the 10 mg/L primary drinking water standard prescribed by the U.S. Environmental Protection Agency (1975) (table 4).

TABLE 4. - Domestic or public supply wells with water exceeding nitrate concentrations of 10 milligrams per liter (as nitrate)

Well	Use	Nitrate (as N) (mg/L)
1N/3E-30L1	Domestic	12
1N/8E-15J1	do.	15
1S/4E-33M1	do.	14
2N/7E-12J2	do.	12
2S/4E-21H1	do.	19
2S/4E-25H1	do.	20
2S/4E-26D1	do.	19
2S/7E-9N4	do.	63
2S/7E-18A1	do.	11
2S/7E-24R2	do.	15
2S/8E-9R1	do.	14
2S/8E-19C1	do.	21
2S/9E-4B1	Public supply	19
3N/6E-22C3	Domestic	12
3N/6E-26F2	do.	12
3N/7E-30F5	do.	11
3S/5E-12J2	do.	11
3S/5E-13R2	do.	24

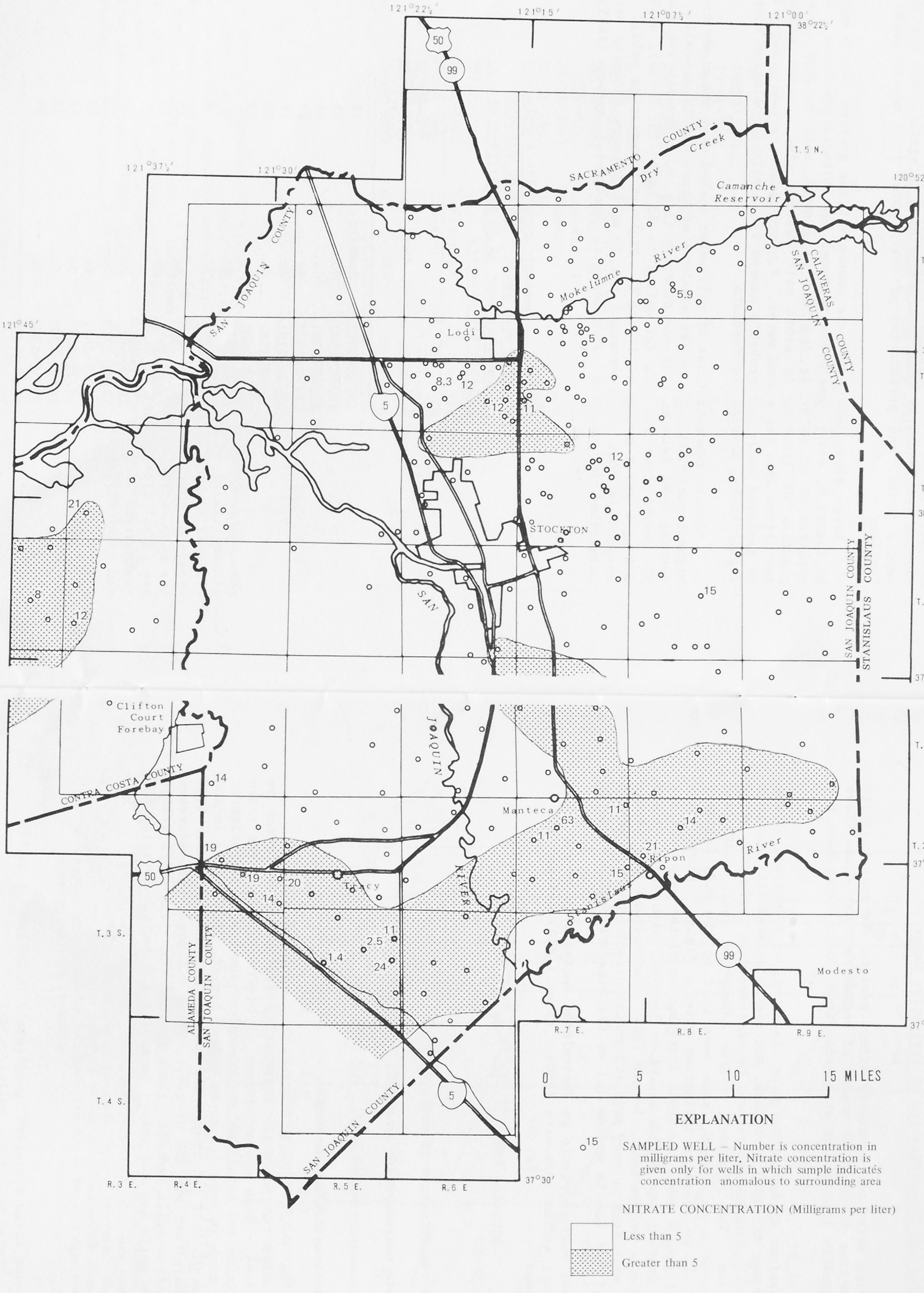


FIGURE 6.--Areal distribution of nitrate concentrations in ground water.

Sodium and Classification of Irrigation Water

Sodium in drinking water can adversely affect persons who must maintain low-sodium or sodium-free diets. The amount of sodium that can cause these effects varies so greatly that sodium standards for drinking water have not been established.

Sodium concentrations of irrigation water in excess of 50 percent of the total cations can change the soil structure, decreasing permeability and root penetrability. Several characteristics must be considered in evaluating water for use in irrigation. Two of these, sodium adsorption ratio (SAR) and dissolved-solids concentration hazard, have been used by the U.S. Salinity Laboratory Staff (1954) to classify irrigation water. Figure 7 shows these classifications and figure 8 shows the areal distribution of the water classes in the study area. Overall the sodium hazard is low (S1) with areas in and around Stockton having a medium sodium hazard (S2). The western half of the study area has water with high to very high (C3 or C4) dissolved-solids hazard and the eastern half has low to medium (C1 or C2) dissolved-solids hazard.

Another important characteristic in determining suitability of water for irrigation is residual sodium carbonate (RSC). Eaton (1950) defined RSC by the following equation:

$$RSC=(CO_3^{-2}+HCO_3^{-1})-(Ca^{+2}+Mg^{+2})$$

where

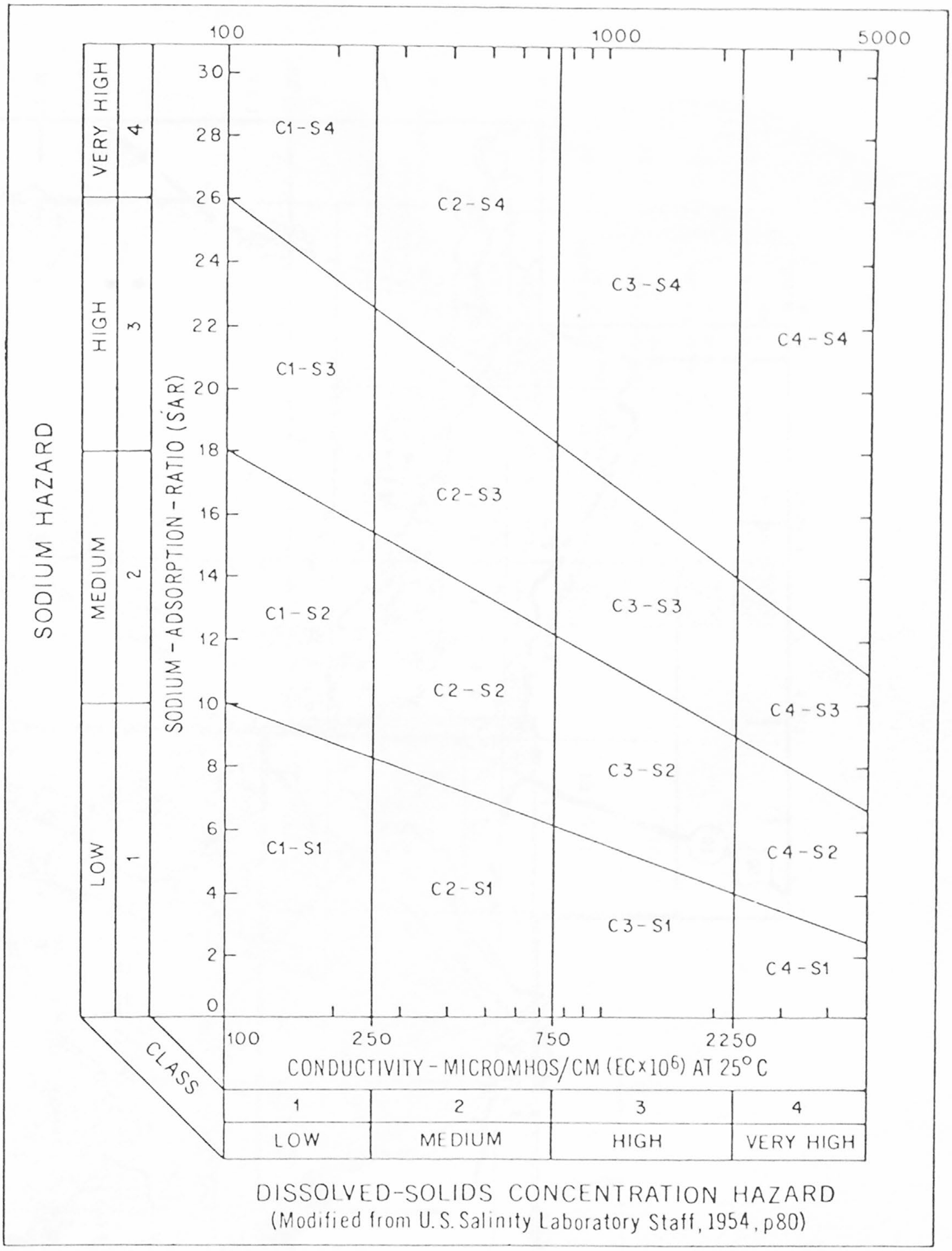
CO_3^{-2}=carbonate concentration in meq/L,

HCO_3^{-1}=bicarbonate concentration in meq/L,

Ca^{+2}=calcium concentration in meq/L, and

Mg^{+2}=magnesium concentration in meq/L.

The RSC value estimates the potential increase in sodium hazard caused by excess bicarbonate ions. High concentrations of bicarbonate ions can cause precipitation of calcium and magnesium as carbonates, increasing the relative percent of sodium, which in turn increases sodium hazard. Generally, an RSC of less than 1.25 meq/L will not change SAR values, RSC values between 1.25 and 2.5 meq/L are marginal, and RSC of greater than 2.5 meq/L will increase sodium hazard. Eighteen wells had RSC values greater than 1.25 meq/L (table 5). Eight of these wells had RSC values exceeding 2.5 meq/L. Overall, the mean RSC was -0.833.



Classification of water samples

Letters designate the type of hazard: C = *dissolved-solids concentration;* S = *sodium. Numbers, which range from* 1 - 4, *indicate from low to very high, respectively, the degree of potential hazard to crops. The* C2 - S2 *classification designates water of medium dissolved-solids concentration and medium sodium hazard. Water so classified can be used on most crops without requiring special cultural practices*

FIGURE 7.--Method of classifying irrigation water based on dissolved-solids concentration and sodium hazard.

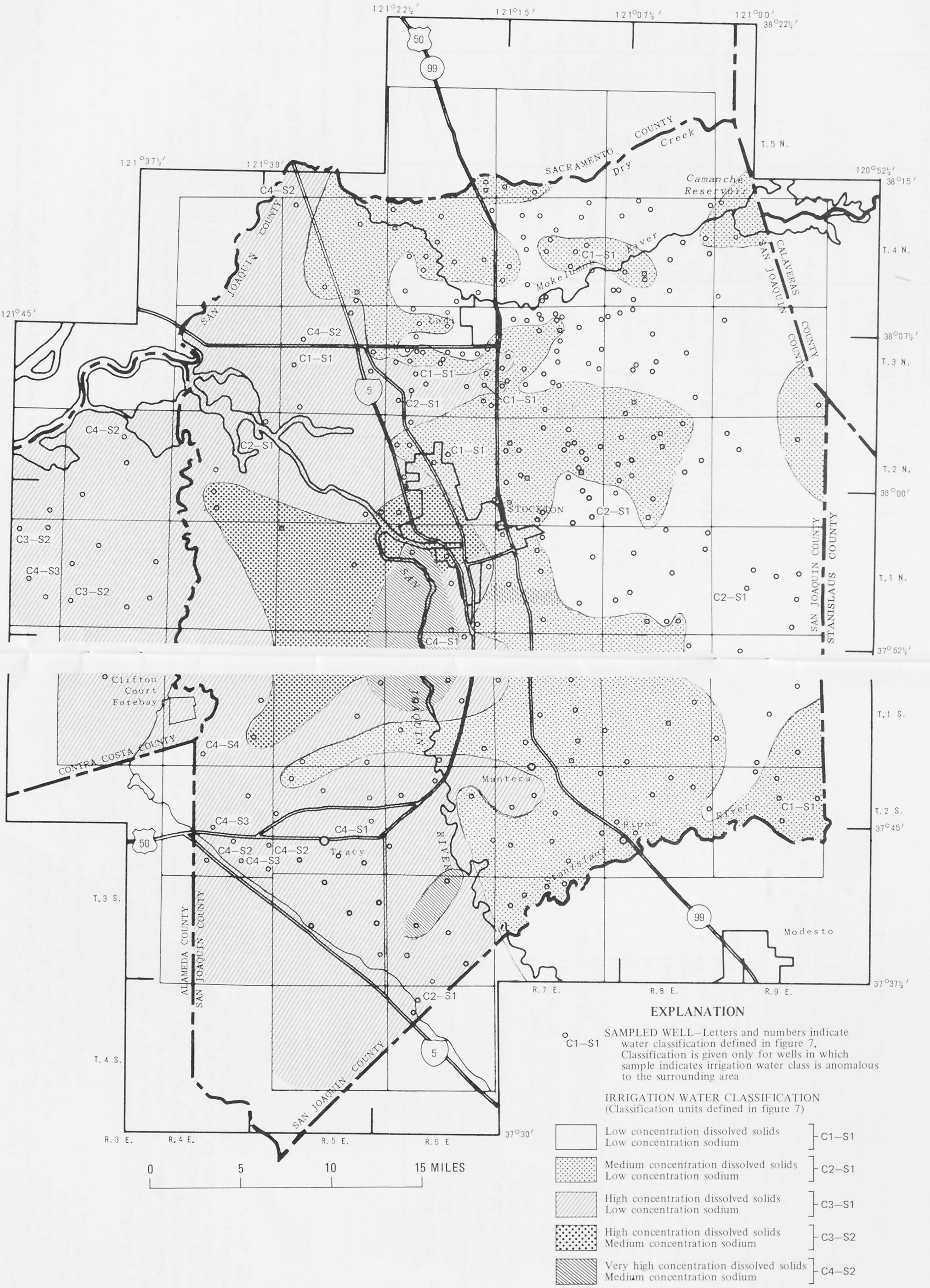


FIGURE 8.--Areal distribution of irrigation classes.

TABLE 5. - Wells with water exceeding 1.25 milliequivalents per liter residual sodium carbonate

Well	Residual sodium carbonate (meq/L)
1N/3E-13C1	2.69
1N/3E-25C1	1.69
1N/5E-6E2	1.86
1N/7E-4F1	1.55
1N/7E-16L1	2.31
1S/4E-13K3	2.46
1S/4E-25D1	3.26
1S/7E-7E2	2.13
1S/7E-21L1	1.37
2N/4E-21G1	3.15
2N/4E-28G1	5.82
2N/4E-33G2	4.68
2N/5E-36K1	5.03
2N/6E-20M2	3.37
2N/7E-11M1	1.39
3N/5E-32N1	1.86
3N/7E-33K3	4.32
4N/5E-35P2	2.37

Trace Elements

Arsenic

Arsenic in water can be acutely or chronically toxic to humans and plants. As a result, the U.S. Environmental Protection Agency (1975) has established 0.05 mg/L as the primary drinking water standard. National Academy of Sciences and National Academy of Engineering (1973) recommended 0.1 mg/L as the maximum concentration for irrigation and 0.2 mg/L as the maximum concentration for livestock watering. None of the wells sampled exceeded these established criteria. Concentrations in the study area ranged from 0.000 mg/L (4 wells) to 0.042 mg/L (1N/6E-10Q9), with a mean of 0.005 mg/L and a median of 0.003 mg/L.

Boron

Boron is toxic to plants in high concentrations. Crops vary considerably in their tolerance, however, and have been classified into tolerant, semi-tolerant, and sensitive groups (Ayers and Branson, 1975)(table 6). No standards have been set for boron concentrations of drinking water. Boron concentrations of sampled well water ranged from 0.00 mg/L (197 wells) to 10 mg/L (1S/4E-33M1), with a mean of 0.35 mg/L and a median of 0.00 mg/L. Greatest concentrations of boron were found in the southern and western parts of the study area (fig. 9). The likely source of the higher boron concentrations is the marine sediments in the Coast Ranges from which the alluvial fan deposits in the southern and western parts of the study area are derived (California Department of Water Resources, 1967).

TABLE 6. - Relative tolerance to boron of major crops grown in San Joaquin County

[Partial list from U.S. Salinity Laboratory Staff, 1954]

Tolerant (>2.0 mg/L)	Semitolerant (1.0-2.0 mg/L)	Sensitive (<1.0 mg/L)
Asparagus	Barley	Apricot
Sugar beet	Corn	Almond
Alfalfa	Bell pepper	Cherry
Onion	Potato	Peach
	Tomato	Grape
	Wheat	

Manganese

Manganese is objectionable in public water supplies because of its taste, staining of plumbing fixtures, spotting of laundered clothes, and accumulation of oxide deposits in distribution systems. National Academy of Sciences and National Academy of Engineering (1973) recommended a maximum manganese concentration of 0.05 mg/L for public water supplies and a maximum manganese concentration of 0.2 mg/L for continuous irrigation use.

Manganese concentrations were low over most of the study area. Concentrations ranged from 0.00 mg/L (73 wells) to 3.1 mg/L (1N/5E-14P1 and 3N/5E-8R1) with a mean of 0.09 mg/L and a median of 0.005 mg/L. Several wells with manganese concentrations above the 0.05 mg/L drinking water criteria were located in the central part of the area near Stockton and Lodi. All wells that exceeded 0.05 mg/L manganese concentration are shown in table 7.

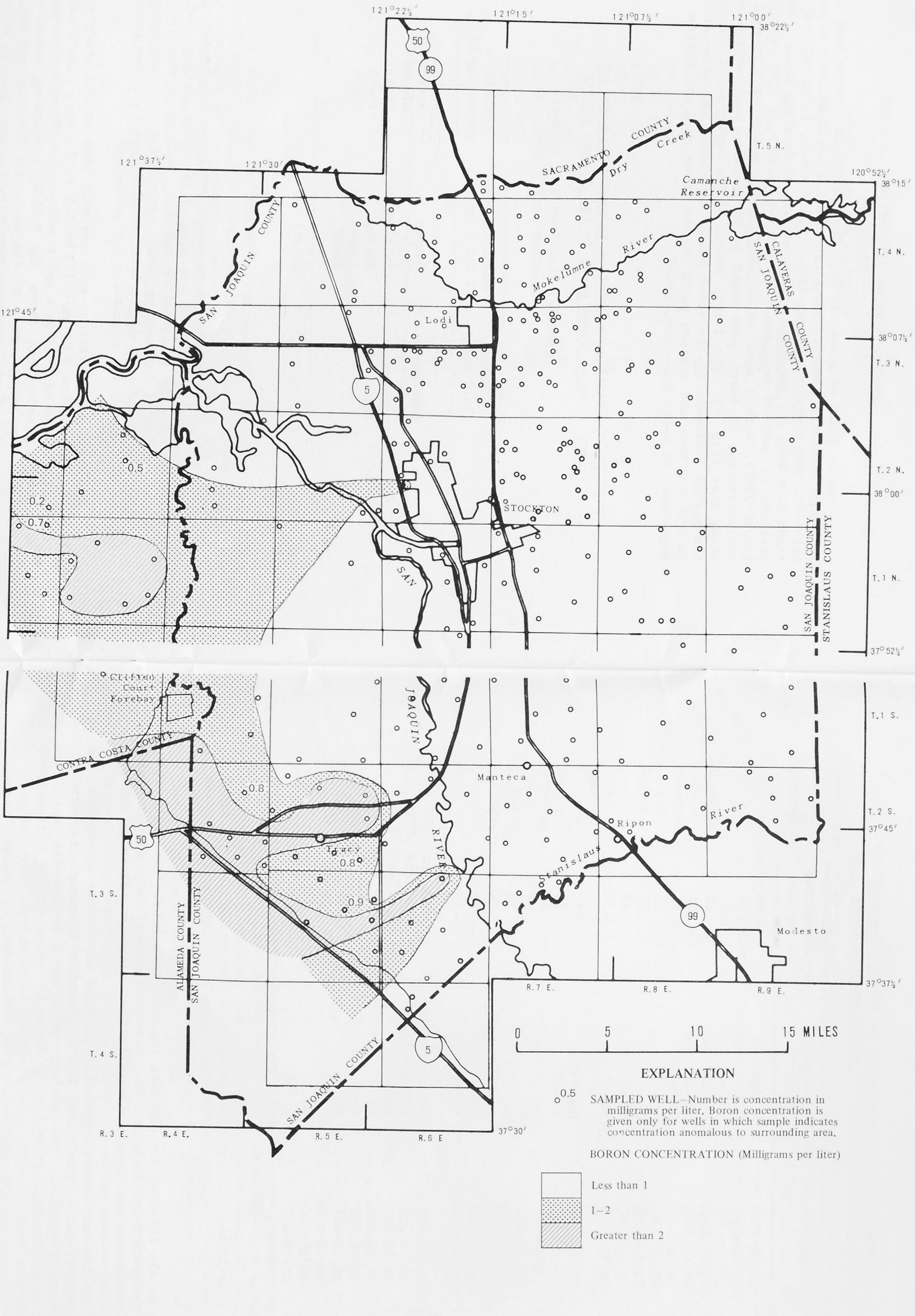


FIGURE 9.--Areal distribution of boron concentrations in ground water.

TABLE 7. - Wells with water exceeding manganese concentrations of 0.05 milligrams per liter

Well	Use	Manganese (mg/L)
1N/2E-25F1	Irrigation	0.14
1N/3E-25C1	Public supply	.14
1N/5E-14P1	Domestic	3.1
1N/6E-10Q9	Industrial	.60
1N/6E-22K1	Irrigation	.36
1N/6E-34P1	Domestic	1.2
1S/4E-25D1	do.	.15
1S/5E-32R1	do.	.09
1S/6E-14P1	Stock	.45
1S/6E-10L1	do.	.48
2N/3E-10D1	Domestic	.32
2N/3E-29M1	do.	.30
2N/4E-2R1	do.	.46
2N/4E-28G1	do.	.21
2N/5E-36E3	do.	.12
2N/6E-16R1	Public supply	.09
2N/6E-31H1	Domestic	.28
2N/7E-22H2	Irrigation	.11
2S/6E-7P1	Public supply	.08
2S/6E-25H1	Irrigation	.07
3N/5E-8R1	Domestic	3.1
3N/5E-32N1	do.	1.6
3N/6E-8K6	do.	.08
3S/7E-8C1	do.	.36
4N/7E-17C3	do.	.08
4N/8E-34G2	do.	.11
5N/7E-33N1	Stock	.06

Trace Metals

Trace metals selected for sampling included some metals for which standards for irrigation and drinking water have been established. The standards for these metals and the observed concentration ranges are shown in table 8.

Iron was the only trace metal that exceeded any of the standards. The U.S Environmental Protection Agency (1975) secondary drinking water standard for iron was exceeded at two wells: 1N/6E-34P1, a domestic well, and 2S/5E-9J1, an industrial well.

TABLE 8. - Standards and recommended limits and observed range for selected trace metals in irrigation and drinking water

Element	Recommended limit for continuous use on all soils[1]	EPA primary drinking water[2]	EPA secondary drinking water[3]	Concen- tration range	Number of wells sampled
	Maximum concentration, in milligrams per liter				
Aluminum	5.0	-	-	0.000 -0.200	159
Cadmium	.01	-	-	.000 - .002	8
Chromium	.1	-	-	.000 - .010	8
Cobalt	.05	-	-	.000 - .001	8
Copper	.2	-	1.0	.000 - .003	8
Iron	5.0	-	.3	.000 - .670	158
Lead	5.0	0.05	-	.001 - .006	8
Lithium	2.5	-	-	.000 - .000	8
Mercury	-	.002	-	.0000- .0001	8
Molybdenum	.01	-	-	.000 - .002	8
Nickel	.2	1.0	-	.000 - .001	8
Selenium	.02	.01	-	.000 - .001	8
Vanadium	.1	-	-	.003 - .022	7
Zinc	2.0	-	5.0	.001 - .690	8

[1]National Academy of Sciences and National Academy of Engineering (1973).
[2]U.S. Environmental Protection Agency (1975).
[3]U.S. Environmental Protection Agency (1979).

CONCLUSIONS

Analysis of water samples from 324 wells in San Joaquin and Contra Costa Counties showed water ranging from excellent quality--low in dissolved solids and potentially harmful trace constituents--to marginal quality--high in dissolved solids and (or) approaching or exceeding established standards for several constituents. In general better quality water was found in the northern and eastern parts of the study area, with poorer quality water in the central, southern, and western parts.

Water quality is related to the origin and composition of the alluvium from which the water is pumped. Better quality water was found in alluvial deposits from the Sierra Nevada, which are mostly igneous in origin. Poorer quality water--high in dissolved solids and boron--was found in alluvium derived from marine sediments in the Coast Ranges. Surface-water characteristics influenced ground-water quality; relatively high concentrations of dissolved solids occur in areas of saltwater intrusion and along the San Joaquin River. Agricultural practices also appear to have affected the ground-water quality as demonstrated by greater-than-average concentrations of nitrate and dissolved solids in some areas.

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