DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

HYDROLOGIC INVESTIGATIONS
ATLAS HA–651

INTRODUCTION

The Sacramento Valley comprises about 6,000 square miles of the northern third of the Central Valley of California. As of 1975, about 44 percent of the Sacramento Valley was irrigated, about 18 percent of it by ground water (California Department of Water Resources, 1978, p. 11). The 2 million acre-feet of ground water used in 1975 was considered to be of good quality for irrigation, domestic, and most other uses.

As part of the Central Valley Aquifer Project, this atlas is the second of three reports concerning the quality of ground water in the Sacramento Valley. It is intended to be a general guide for what the ground-water user might expect to find in terms of chemical quality. The first report was an atlas showing the distribution of dissolved-solids concentrations (Fogelman, 1981). The third, in preparation, is a more detailed report on the geochemistry of ground water.

WATER TYPES

The general chemical character of water can be described by use of a classification system based on the relative proportions of major ions, as in the following examples: a "calcium bicarbonate" type water designates water in which calcium amounts to 50 percent or more of the cations and bicarbonate to 50 percent or more of the anions, in chemical equivalents; "sodium calcium bicarbonate" designates water in which the sodium and calcium are first and second, respectively, in order of abundance among the cations but neither amounts to 50 percent of all the cations; "sodium sulfate bicarbonate" designates water in which the sulfate and bicarbonate are first and second in order of abundance among the anions (Piper, Garrett, and others, 1953, p. 26).

Several types of water occur in the Sacramento Valley (fig. 1). Calcium magnesium bicarbonate and magnesium calcium bicarbonate are the predominant water types in ground water from the Holocene alluvium in the northern part of the valley. Calcium bicarbonate water occurs near Orland in a distinct area that coincides with the radial path of ground-water flow away from Stony Creek. Water in Stony Creek is a calcium bicarbonate type, and, because Stony Creek is a losing stream, the ionic composition of the ground water is influenced by recharge from the creek.

In the Marysville-Gridley area, along the Feather River in the central part of the valley, magnesium bicarbonate is the predominant water type in the ground water. Recharge to this area is from the Feather River and Honcut Creek, which flow through the pre-Tertiary basement complex of the Sierra Nevada.

The southwestern part of the Sacramento Valley, from near Colusa southward, shows a more complex distribution of water types. In general, concentrations of sodium, chloride, and sulfate are greater in ground water in this area than in the northern or central areas. Ground-water recharge is from the Rumsey Hills and the Coast Ranges, which contain Cretaceous marine sediments of the Chico Formation and Lower Cretaceous rocks formerly called the Shasta Series (now an obsolete term). These rocks have low permeability and contain connate saline water (Olmsted and Davis, 1961, p. 37, 43). The source area also is characterized by many mineral springs and seeps. Kirby (1943) reported flowing saline water from exploratory gas and oil wells drilled 40 to 60 years ago. There is a large area of sodium bicarbonate type ground water adjacent to Salt Creek (near Williams) and along the Sacramento River from Colusa to near Grimes. The sodium cation is probably derived from saline water in the Cretaceous formations drained by Salt Creek.

On the western edge of the valley from Williams south to near Dunnigan, most of the ground water is dominated by bicarbonate among the anions with varying proportions of the cations sodium, calcium, and magnesium. Streams from the Rumsey Hills, including Salt Creek (near Arbuckle) and Petroleum Creek, are a source of ground-water recharge and many of them flow through the Chico Formation and the Pliocene Tehama Formation in the lower Rumsey Hills. The Tehama Formation, derived from the Coast Ranges, contains silt, sand, gravel, and clay, locally cemented (Olmsted and Davis, 1961, p. 36). This may account for the increased presence of the calcium and magnesium as cations in combination with the sodium. Magnesium bicarbonate water occurs in a small area near Dunnigan. The source of recharge to this area is the Dunnigan Hills that are predominantly composed of the Tehama Formation.

Sutter Buttes, erosional remnants of a volcano probably formed during Pliocene time, may also be the source of the high concentrations of sodium and chloride in the Sutter Basin and lower Colusa Basin. Saline water may rise from the edges of the core of the Buttes, since depths to the base of fresh water around the Buttes have been shown by Berkstresser (1973) to be shallower than in other parts of the valley. In the area south of the Sutter Buttes, chloride and sulfate are major anions, either singly or in combination with bicarbonate. This is the only area in the Sacramento Valley where bicarbonate is not the single major anion in solution.

POTENTIAL PROBLEM AREAS

Ground-water samples were analyzed for inorganic constituents and, along with water-quality data furnished by other agencies for the period 1974–79, were used to delineate potential problem areas (fig. 2). The analyses were classified by using either California Domestic Water Quality and Monitoring Regulations (California Department of Health, 1977), which are based on National Interim Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 1975), or, when classifying the suitability of water for irrigation, criteria suggested by the National Academy of Sciences and National Academy of Engineering (1973).

The following discussions relate measured concentrations of nitrate and boron to recognized, suggested, or recommended limits. Some concentrations exceeded the recommended limits in the particular area and others only approached that limit; hence the designation, "potential problem area."

Nitrate

Usually, nitrate toxicity does not affect adults and older children, but it may cause a temporary blood disorder known as methemoglobinemia in infants. Occasionally, methemoglobinemia is fatal, but the incidence of fatality is low in the United States where public water supplies are used. Most cases of nitrate toxicity are associated with water from domestic wells with high nitrate concentrations caused by surface contaminants and inadequate sealing of supplying aquifers. The recommended maximum concentration of nitrate as nitrogen (NO_3-N) in drinking water is 10 mg/L (milligrams per liter) (National Academy of Sciences and National Academy of Engineering, 1973, p. 73). Ten mg/L nitrate as nitrogen is roughly equivalent to the maximum contaminant level of 45 mg/L nitrate as NO_3 prescribed by California Domestic Water Quality and Monitoring Regulations (California Department of Health, 1977, p. 11).

For most agricultural purposes, nitrate in irrigation water is considered an asset because of its nutrient value. There is little evidence indicating that it will accumulate to toxic levels in irrigated plants consumed by animals; therefore no limit has been established for nitrate in irrigation water (National Academy of Sciences and National Academy of Engineering, 1973, p. 329).

Three areas in the Sacramento Valley are potential problem areas with respect to nitrate concentrations affecting human consumers. In the Chico-Corning area in the northern part of the valley, water from 40 wells, 32 of which are domestic wells, had nitrate-nitrogen concentrations of 5.5 mg/L or more. Water in 10 of these 40 wells exceeded the recommended maximum of 10 mg/L for drinking water. The main cause of the nitrate problem here may be surface contamination, as the average depth of these wells, or depth where water can enter the well, is only 62 feet.

On the east side of the valley, water from 21 wells in the Marysville-Gridley area had nitrate-nitrogen concentrations of 5.5 mg/L or more, and seven of these exceeded the recommended maximum of 10 mg/L for drinking water. As the average depth of these wells is only 78 feet, the higher nitrate concentrations may also be a result of surface contamination.

Nitrate concentrations are high also in ground water in the Knights Landing-Arbuckle area in the southwestern part of the valley. Of the wells sampled in this area, four had nitrate-nitrogen concentrations greater than the 10 mg/L limit, and 10 wells exceeded 5.5 mg/L. As the average depth of these wells is 159 feet, contamination from the surface seems less likely than in the other two problem areas. This area of high nitrate concentration coincides with the area where the distribution of water types is complex.

The potential sources of excess nitrate in the Sacramento Valley are leaching of applied nitrate-rich fertilizers, urban waste-treatment facilities or farmstead septic systems, and natural resources.

Natural sources of nitrate can be ruled out in the Sacramento Valley. Oxidation of ammonia from tuffaceous deposits has been suggested as a source of nitrate in ground water in Arizona (Silver and Fielden, 1980). Most tuffaceous deposits in the valley are located at depth and would affect deeper rather than shallower wells. Also, the scattering of nitrate concentrations is evidence against this, as the process should give more uniform concentrations across the valley. A source external from the valley is unlikely, as excessive nitrate concentrations have not been observed in surface water entering the valley.

Pollution from sewage effluent in populated areas can explain some of the observed high nitrate concentrations. Sewage waste from septic tanks is capable of supplying excessive concentrations of nitrate to ground water (Klein and Bradford, 1979) and could account for the irregular distribution of wells having higher nitrate concentrations. The higher concentrations found mostly in shallower wells, the nonuniform concentrations, and the increase in the dissolved chemical species would also be expected if the source were sewage effluent. Sodium, however, should also increase from sewage wastes, but does not do so in the waters studied. The concentration of excessive-nitrate wells in urban areas can be explained by this source; however, the farm sources should be randomly distributed with perhaps an excess for farmsteads. Although septic-tank effluent may explain the random occurrence of high nitrate concentrations, it is unlikely that it can be considered the explanation for the large areal distribution as shown on the map.

Leaching of fertilizers applied to croplands is another possible source of excessive nitrate. This source also can explain the occurrence of excessive nitrate in shallower wells scattered throughout the valley. If leaching from croplands in general is considered, the distribution among farm-related land use would be random. The concentration of excessive-nitrate wells in orchard areas suggests that the nitrate problem is related to the use or large quantities of high-nitrate fertilizer in orchards.

Boron

The Federal Drinking Water Standards Technical Review Committee, established in 1971, set aside the limit of 1.0 mg/L for boron in drinking water previously set by the Federal Water Pollution Control Administration (1968), until conclusive evidence could be established of adverse physiological effects on humans. Therefore, no current Federal standards exist for boron in drinking water.

Boron toxicity, its occurrence in foods and feeds, and its role in animal nutrition have been studied; there is no evidence that boron is required by animals or that boron accumulates to any great extent in body tissues. Therefore, to offer a large margin of safety, the National Academy of Sciences and National Academy of Engineering (1973, p. 310) recommended a limit of 5.0 mg/L of boron in water for livestock.

The preponderance of technical and scientific work on boron in water has been directed toward its effects on plants. In concentrations up to 0.5 mg/L in irrigation water, boron is an essential plant micronutrient, however, effects on plant tissue can be detrimental to boron-sensitive plants when concentrations in irrigation water are greater than 0.75 mg/L. Damage to crops by boron concentrations greater than 0.5 mg/L also varies with differences in soil drainage and climate. In general, sensitive crops (table 1) will show some damage when boron levels in irrigation water are between 0.5 and 1.0 mg/L; semitolerant crops show damage at concentrations between 1.0 and 2.0 mg/L; and tolerant crops show damage at concentrations between 2.0 and 4.0 mg/L.

Recommended maximum concentrations of boron in irrigation water used continuously on all types of soils are: sensitive crops, 0.75 mg/L; semitolerant crops, 1.0 mg/L; and tolerant crops, 2.0 mg/L (National Academy of Sciences and National Academy of Engineering, 1973, p. 341).

A potential boron problem area in the southwestern part of the Sacramento Valley coincides with part of the potential nitrate problem area. Boron concentrations in samples from 50 wells exceeded 0.75 mg/L; in 12 of these wells, boron concentrations were at least 2.0 mg/L. This boron may be derived from rocks in the recharge area in the Coast Ranges. The many springs and seeps in that area probably contribute boron from the marine deposits of the Chico Formation and Lower Cretaceous rocks formerly called the Shasta Series, as mentioned earlier.

There is another potential boron problem area in the extreme northern part of the valley. Recharge to this area is from the Cascade Range to the east. Salt Creek (near Red Bluff) is one of the main drainages with headwaters in the Pliocene Tuscan Formation, which, according to Olmsted and Davis (1961, p. 36, 67) contains volcanic breccia and tuff breccia, volcanic sandstone, and conglomerate, coarse- to fine-grained tuff, tuffaceous silt and clay, and, locally, basalt flows. In addition, boron-rich mineral springs are common to the area.

USE OF THIS ATLAS

This map is intended to present a general guide for what the ground-water user might expect to find in terms of chemical quality in the Sacramento Valley. Specifically, farmers may use the boron information to aid in planning conjunctive use of boron-rich ground water with boron-free surface water to produce maximum crop yield. Irrigated agriculture in the Sacramento Valley is rapidly expanding into areas that were previously dry-farmed, leading to the reasonable expectation that there will be corresponding increased use of chemical fertilizers, herbicides, and pesticides. Also, populated areas are experiencing sprawling suburban and exurban development, forewarning of increased industrial wastes and sewage effluent.

For these reasons, continued monitoring of ground-water quality would serve as a measure of the effect of man's activities on the ground water. Those concerned with management of ground water will find this atlas and a companion atlas (Fogelman, 1981) a valuable base for determining water-quality trends.

SELECTED REFERENCES

Berkstresser, C. F., Jr., 1973, Base of fresh ground water, approximately 3,000 micromhos, in the Sacramento Valley and Sacramento-San Joaquin Delta, California: Menlo Park, Calif., U.S. Geological Survey Water-Resources Investigations 40–73, 1 sheet.

Bertoldi, G. L., 1976, Chemical quality of ground water in the Tehama-Colusa Canal Service area, Sacramento Valley, Calif.: Menlo Park, Calif., U.S. Geological Survey Water-Resources Investigations 76–92, 44 p.

California Department of Health, 1977, California domestic water quality and monitoring regulations: California Department of Health, Title 22, sections 64401–64501, California Administrative Code, p. 1701–1722.

California Department of Water Resources, 1978, Evaluation of ground water resources: Sacramento Valley: California Department of Water Resources Bulletin 118–6, 136 p.

Chapman, H. D., 1968, Mineral nutrition in citrus, *in* The citrus industry: University of California, Division of Agricultural Science, v. 2, p. 127–289.

Federal Water Pollution Control Administration, 1968, Water-quality criteria—Report of the National Technical Advisory Committee to the Secretary of the Interior: Washington, D.C., U.S. Government Printing Office, 234 p.

Fogelman, R. P., 1975, Descriptions and chemical analyses for selected wells in the Tehama-Colusa Canal Service Area, Sacramento Valley, California: U.S. Geological Survey open-file report, 52 p.

________ 1976, Descriptions and chemical analyses for selected wells in the central Sacramento Valley, California: U.S. Geological Survey Open-File Report 76–472, 71 p.

________ 1978, Chemical quality of ground water in the central Sacramento Valley, California: Menlo Park, Calif., U.S. Geological Survey Water-Resources Investigations 77–133, 54 p.

________ 1979, Chemical quality of ground water in the eastern Sacramento Valley, California: Menlo Park, Calif., U.S. Geological Survey Water-Resources Investigations 78–124, 45 p.

________ 1981, Dissolved-solids concentrations of ground water in the Sacramento Valley, California: U.S. Geological Survey Hydrologic Investigations Atlas HA–645, scale 1:250,000.

Fogelman, R. P., and Rockwell, G. L., 1977, Descriptions and chemical analyses for selected wells in the eastern Sacramento Valley, California: U.S. Geological Survey Open-File Report 77–486, 82 p.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water, [2d edition]: U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Kirby, J. M., 1943, Rumsey Hills area, *in* Geologic formations and economic development of the oil and gas fields of California: California Division of Mines Bulletin 118, p. 601–605.

Klein, J. M., and Bradford, W. L., 1979, Distribution of nitrate and related nitrogen species in the unsaturated zone, Redlands and vicinity, San Bernardino County, California: Menlo Park, Calif., U.S. Geological Survey Water-Resources Investigations 79–60, 81 p.

National Academy of Sciences and National Academy of Engineering, 1973 [1974], Water quality criteria, 1972: U.S. Environmental Protection Agency, EPA R3–73–033, 594 p.

Olmsted, F. H., and Davis, G. H., 1961, Geologic features and ground water storage capacity of the Sacramento Valley, California: U.S. Geological Survey Water-Supply Paper 1497, 241 p.

Piper, A. M., Garrett, A. A., and others, 1953, Native and contaminated ground water in the Long Beach-Santa Ana area, California: U.S. Geological Survey Water-Supply Paper 1136, 320 p.

Silver, B. A., and Fielden, J. R., 1980, Distribution and probable source of nitrate in ground water of Paradise Valley, Arizona: Ground Water, v. 18, no. 3, p. 244–251.

U.S. Environmental Protection Agency, 1975, National interim primary drinking water regulations: Federal Register, v. 40, no. 248, p. 59566–59587.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Department of Agriculture Handbook 60, 160 p.

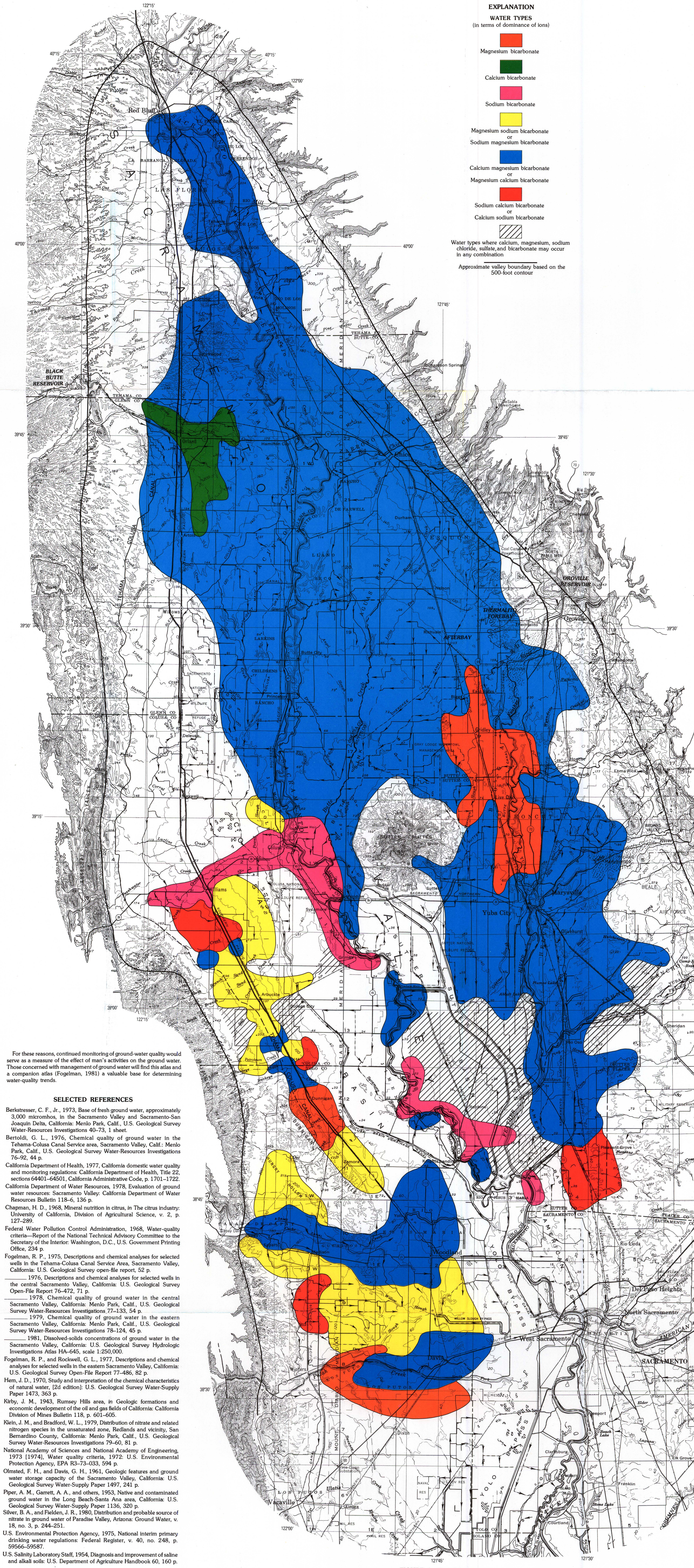


FIGURE 1.—*Distribution of water types.*

Base from U.S. Geological Survey Central Valley, California 1:250,000, North area and Delta area, 1958. Roads and reservoirs as of 1979

SCALE 1:250,000
1 INCH EQUALS APPROXIMATELY 4 MILES

CONTOUR INTERVAL 100 FEET
CONTOURS AT 20 FOOT INTERVALS ARE SHOWN IN VALLEY AREA WHERE SPACE PERMITS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

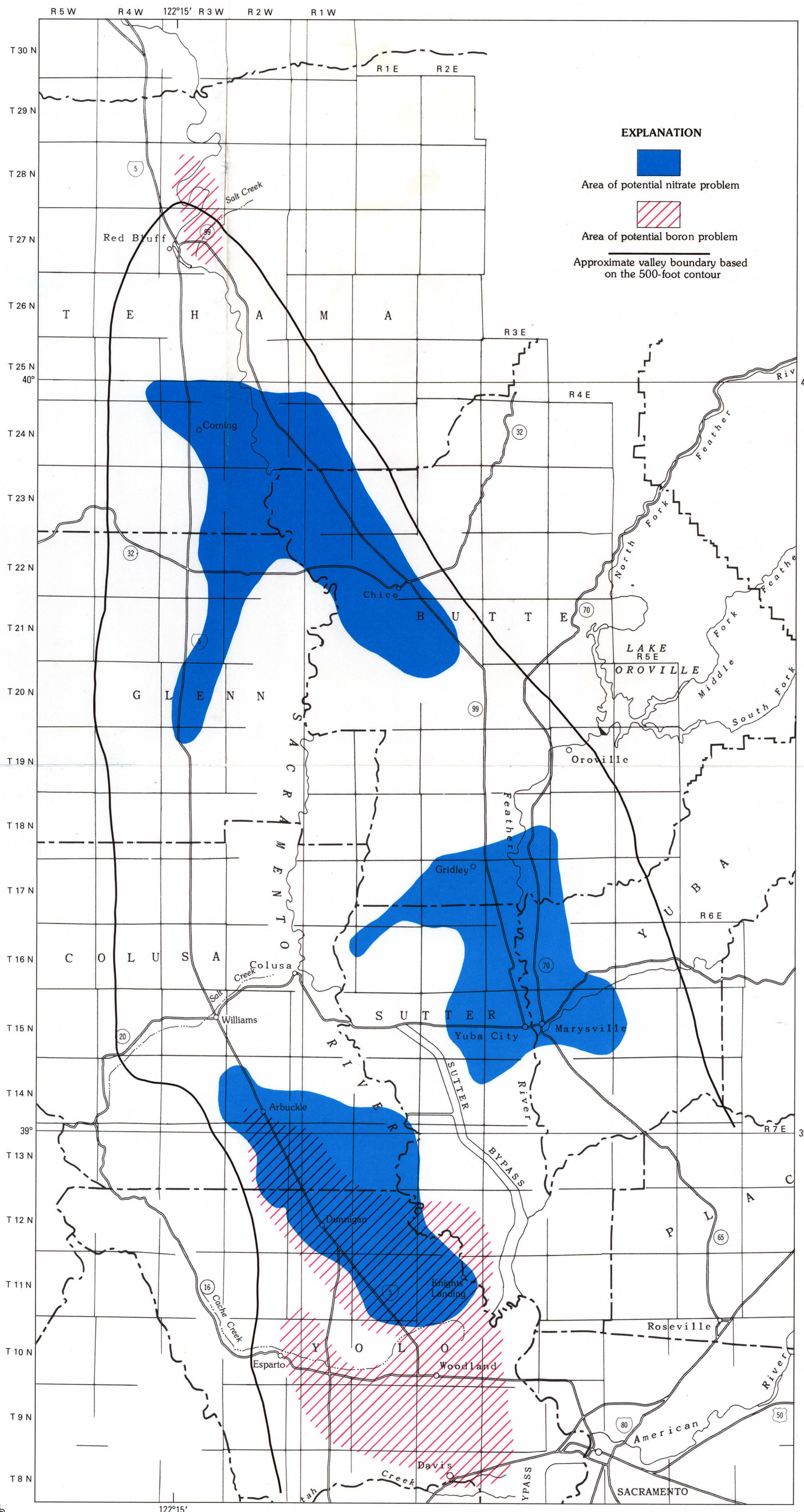


FIGURE 2.—*Potential nitrate and boron problem areas.*

TABLE 1.—*Relative tolerance of some plants to boron*

[Partial list from U.S. Salinity Laboratory Staff (1954). Crops named first in each column are more tolerant; crops named last, more sensitive]

Tolerant	Semitolerant	Sensitive
Athel (Tamarix asphylla)	Sunflower[1]	Pecan
Asparagus	Potato	Black walnut[1]
Palm	Cotton	English Walnut[1]
Date Palm	Tomato[1]	Plum[1]
Sugar beet[1]	Radish	Prune[1]
Garden beet	Pea	Pear[1]
Alfalfa[1]	Olive[1]	Apple
Broadbean	Barley[1]	Cherry
Onion	Wheat[1]	Peach[1]
Turnip	Corn[1]	Apricot
Cabbage	Milo[1]	Almond[1]
Lettuce	Oat[1]	Orange[1]
Carrot	Pumpkin[1]	Avocado
	Bell pepper	Grapefruit
	Sweet potato	Lemon
	Lima bean	

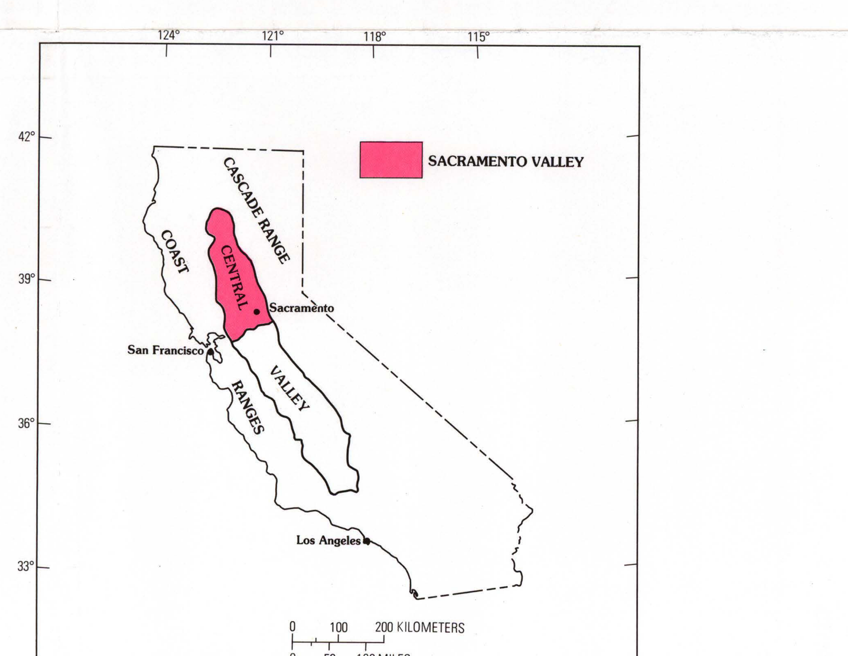
[1]Commonly grown commercially in the Sacramento Valley.

CONVERSION FACTORS

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

Multiply	By	To obtain
acre-feet	0.001233	cubic hectometers
feet	0.3048	meters
square miles	2.590	square kilometers

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.



INDEX MAP OF CALIFORNIA

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1983—W81245

GROUND-WATER QUALITY IN THE SACRAMENTO VALLEY, CALIFORNIA—WATER TYPES AND POTENTIAL NITRATE AND BORON PROBLEM AREAS

By
Ronald P. Fogelman
1983

For sale by Branch of Distribution, U.S. Geological Survey Box 25286, Federal Center, Denver, CO 80225