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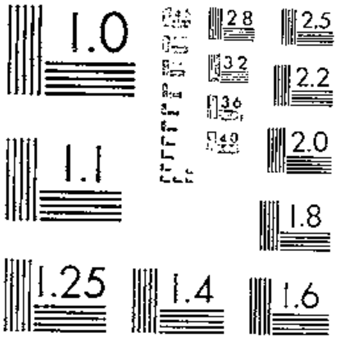
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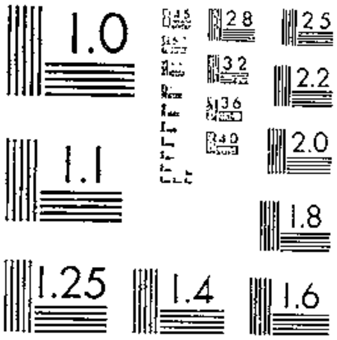
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BORON IN SOILS AND IRRIGATION WATERS AND ITS EFFECT ON PLANTS

WITH PARTICULAR REFERENCE TO THE SAN JOAQUIN VALLEY OF CALIFORNIA

By

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United States Department of Agriculture, Washington, D.C.

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WASHINGTON, D.C.

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By FRANK M. EATON

Associate physiologist, Division of Western Irrigation Agriculture, Bureau of Plant Industry[1]

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INTRODUCTION

NATURAL OCCURRENCE

Boron, the element that characterizes such familiar compounds as boric acid (H_3BO_3) and borax ($Na_2B_4O_7.10H_2O$), is of agricultural importance for two reasons, namely: (1) Some of it is essential to the growth of many if not all plants; (2) it is extremely toxic to a large number of plants if present in the soil solution in concentrations above a few parts per million.

In nature, boron is never found in the uncombined or elemental state, but occurs in the form of boric acid or more commonly as borates, especially in regions that are or have been volcanic. It is not a rare element, as it is widely distributed in small amounts; but

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[1] Throughout the investigation much valuable assistance and cordial support were rendered both by individuals and organizations engaged in the development and utilization of irrigation water. There is also to be especially acknowledged the cooperation of the University of California and members of the extension service. The cooperation offered by all is sincerely appreciated. The writer is further indebted to his associates in the boron investigations not only for their counsel but for many direct contributions to the investigations reported.

workable deposits of boron minerals are uncommon. According to Clarke and Washington (*10*),[2] the igneous rocks that constitute 95 percent of the 10-mile crust of the earth contain possibly 0.001 percent, or 10 parts per million, of boron. The present known boron deposits in the United States are located principally in the semiarid regions of the West. Schaller (*31*) has provided a list of "all the known boron minerals" (1929), which includes 56 names with corresponding chemical formulas. Many of these minerals are soluble in water, but the list includes 20 borosilicates, some of which are known to be practically insoluble, and the others, if soluble in the ordinary sense, are only slightly so.

In connection with the agricultural significance of this element, Kellerman (*21*) in 1920 made the suggestion that toxic concentrations of boron were likely to be found here and there in soils and irrigation waters of the southwestern United States. He pointed out that large deposits of borax and other boron minerals occur not only in several places in California and Nevada but that analyses had shown small amounts of boron in various lakes and streams.

BORON IN SOUTHERN CALIFORNIA

In 1926 and 1927 Kelley and Brown (*22*) established the fact that boron occurring as a natural constituent of irrigation water was responsible for the poor condition of certain citrus and walnut groves in southern California. The peculiar symptoms exhibited by the foliage of affected trees in Ventura County had been an object of inquiry for a number of years, and the nature of the cause was determined when citrus trees elsewhere developed similar symptoms after having been irrigated with water accidentally contaminated with the waste from packing houses in which borax was used in washing fruit. Kelley and Brown found the leaves of the Ventura County trees, as well as those adjacent to these packing houses, to contain more boron than the leaves of healthy trees. Boron occurring as a soil constituent was suspected in the Ventura County injury, and it was found that the soils of the affected groves were high in boron; but further investigation showed that in each of the several larger areas examined the boron was traceable to the irrigation water.

Investigations by the Bureau of Plant Industry following those of Kelley and Brown have confirmed their observations and have shown that boron injury was more widespread than was at first suspected. Scofield and Wilcox (*33*) have reported on the boron situation in southern California, and in addition to discussing general aspects of the problem they further described the effects of boron on citrus and walnuts. As reported by them, instances of injurious effects resulting from toxic concentrations of boron in irrigation waters occur in the following southern California localities: (1) The valley of the Santa Clara River, in Ventura County, where boron is brought in chiefly by Piru and Sespe Creeks; (2) the Simi Valley, also in Ventura County, where the boron occurs in underground waters that are pumped for irrigation; (3) the San Fernando Valley, in Los Angeles County, where boron occurs in the waters brought in through the Los Angeles Aqueduct from Owens River; (4) the vicinity of San Bernardino, where boron occurs in the waters of Arrowhead Hot Springs and in a few wells; and (5) the coastal plain in southern Orange County,

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[2] Italic numbers in parentheses refer to Literature Cited, p. 120.

where boron occurs in some of the underground waters pumped for irrigation. Boron is likewise now known to occur in injurious concentrations in wells in a number of other locations in the area south of the Tehachapi Mountains.

BORON ELSEWHERE IN THE WEST

Significant concentrations of boron are quite commonly found in the underground and surface waters of that portion of the San Joaquin Valley lying west of the valley axis, and in a number of small areas near Bakersfield. Injurious concentrations are likewise found in some of the wells and streams draining to the westward in the coastal mountains and valleys, and these mountains presumably have been, in part at least, the source of the boron found along the western side of the San Joaquin Valley. The principal instance of injury to the west of the San Joaquin Valley is in the vicinity of Hollister, where high concentrations of boron are sometimes found in well waters. Boron has been found in irrigation waters in the western Sacramento Valley in an area about and below Cache Creek. It occurs also in water supplies in and about the Death Valley area and occasionally southward in the Mojave Desert. It is also found in many domestic wells in the Newlands Reclamation Project of Nevada. Other isolated instances of boron injury have been found, and it may be suspected wherever irrigation water is used if symptoms of the boron type develop.

All irrigation waters examined during the course of the investigations by the Bureau of Plant Industry have contained at least a trace of boron. Higher concentrations of boron can normally be expected in both surface and underground waters, as well as in the soil solutions, in the western arid portions of the United States than in eastern more humid regions, by reason of the higher precipitation in the eastern regions.

NATURE OF THE BORON PROBLEM

The fact that boron is now looked upon as essential to the growth of many plants furnishes fairly conclusive evidence of its widespread distribution in agricultural soils. While it is with boron as a toxic element that this bulletin is principally concerned, the boron requirements of crop plants constitutes an important aspect of the relation of the element to agriculture. Some plants are known to be benefited by concentrations of boron sufficiently high to injure others. The spread between beneficial and toxic concentrations is for some plants narrow; in fact, concentrations that stimulate vegetative development may at the same time be sufficient to produce mild evidence of injury as the older leaves mature. The variation in boron requirements and the differential toxicity of this element even to closely related plants causes the two phases of its effects on plant life to be closely allied. It is highly probable that numerous plants are found at their best only on particular soils or in particular localities because of the narrow range of boron concentrations to which they are adapted. In some localities only plants relatively tolerant to boron are successfully produced, though their selection has been by a process of trial and error without knowledge of the reason for their adaptability. As knowledge of the function in growth and mode of injury of boron is amplified by additional information and more becomes known of its distribution in nature, changes in the choice of economic plants for certain areas are almost certain to follow. The concentration of boron required for normal plant growth and the concentrations that cause injury are of a distinctly lower order than are those of many nutritive elements and the common toxic salts.

If soils are high in naturally occurring boron and for that reason are unsuitable for certain types of agriculture, a recognition of the fact should become possible before extensive development of such lands has taken place. The concentrations of boron in the irrigation waters in the area under consideration in the San Joaquin Valley are for the most part not sufficiently high to be directly toxic to many plants, but their continued use has frequently resulted in depressed yields and in the appearance of leaf symptoms characteristic of the injury. This development of toxic effects results from the concentration of boron in the soil solution by transpiration and evaporation.

Boron applied in irrigation water tends to accumulate in the soil, and ill effects may appear only after a number of seasons and after investments have been made in permanent plantings or in the installation of expensive pumping equipment and irrigation systems. In one instance an investment reported to have been in excess of $5,000,000 was made in the development of a fruit ranch which during its first years gave promise of success. These fruit plantings were later abandoned, and the present known facts indicate that the failure is attributable to unsatisfactory irrigation water, high in boron and with sodium as the predominating base. Other examples of this sort are also to be found in which failure might have been avoided if information concerning the distribution and toxicity of boron had been available. The boron content of irrigation water has come to be regarded as having greater economic significance than the initial boron content of soils. Over much of the area considered, water of suitable quality is far more limited than are arable soils.

EFFECTS OF BORON ON PLANT GROWTH

CHARACTERISTICS OF BORON DEFICIENCY

The evidence available as to the role of boron in plant nutrition has shown that this element, at least in very low concentrations, is as essential to the development of many plants as are calcium, magnesium, potassium, nitrogen, phosphorus, sulphur, or iron. The requirement of plants for boron is in some instances so small that enough or nearly enough is supplied in the form of impurities in the so-called chemically pure salts used in making up culture solutions. Work by the writer and his associates now in progress at the Rubidoux Laboratory, Riverside, Calif., is showing that the growth and production of a number of common plants is increased by boron concentrations sufficiently high to injure other species of plants that are particularly sensitive to it.

When boron is highly deficient, the younger leaves and growing points of plants are usually affected first. The apices may die back, or the terminal buds, if not killed, may become dormant. This may be followed by the development of numerous branches which in turn may make only limited growth. As is illustrated in plate 1, the leaves of boron-deficient grapes are reduced in size and become irregularly chlorotic, with the subsequent development of small areas of dead tissue followed by premature abscission. In some plants an arrested or retarded development of the veins takes place, resulting in a buckling of the mesophyll and in irregularities in the shape of the leaves. In citrus plants, as was first shown by Haas (*16*), the leaf veins become conspicuous and split open and there is a subsequent protrusion of corky tissue. In the writer's experiments, the apical portions of the roots are often enlarged and stubby and fail to elongate normally. Sommer and Sorokin (*37*) have shown that boron deficiency in other plants results in a deformed or lacking root cap and in a marked hyperplasia of the sterome and a hypertrophy of the surrounding periblem tissue. Warington (*40*) found the cells of the cambium to be adversely affected, this condition being followed by degeneration and disintegration of surrounding tissue. A number of investigators (*7, 20, 25, 26, 36, 39*), have demonstrated that various plants require boron and have described the plant reactions when the supply was deficient.

The symptoms of boron deficiency nearly always make their appearance only when the available boron is considerably below the concentration required for the best growth of the plants. In other words, the absence of deficiency symptoms does not provide evidence that the plant is obtaining as much boron as might be used beneficially. Some plants develop deficiency symptoms only when special precautions have been taken to reduce the boron supply to a minimum by the use of boron-free culture vessels and repurified chemicals.

It may be recalled that during and following the World War boron toxicity became a problem of economic concern in certain Eastern and Southern States as a result of the use of fertilizers containing borax as an impurity. Investigations of borax injury resulting from fertilizers, by the United States Department of Agriculture and a number of State experiment stations (*8, 28, 34*), showed that injurious effects sometimes followed field applications of the equivalent of 10 pounds or less of anhydrous borax per acre. Smaller applications did not generally result in notable or clear-cut increases in yield. The lack of evidence of beneficial results from smaller applications does not, however, warrant the conclusion that the use of borax as a fertilizer, on particular soils or for particular crops, might not be profitable. In the experiments just mentioned the borax was applied in or broadcast above the drill rows at or near the time of planting, and borax thus concentrated in restricted portions of the root zone would be expected to produce injurious rather than beneficial results until it had become more uniformly distributed through the soil. Certain crops, such as figs, cotton, grapes, alfalfa, beets, and asparagus in the experiments at Riverside, Calif., by the Bureau of Plant Industry, have shown definite requirements for boron in excess of concentrations ordinarily designated as traces.

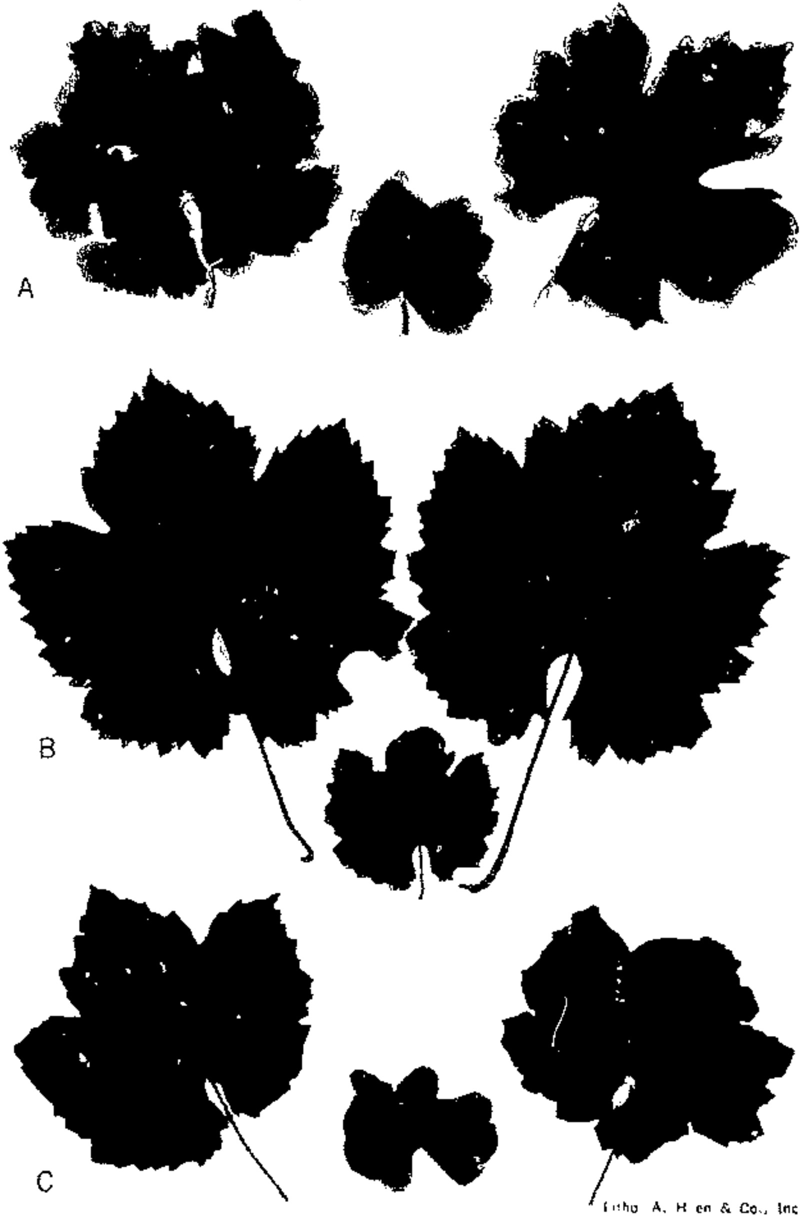
CHARACTERISTICS OF BORON INJURY

The toxic effect of boron on plants was observed and recorded as early as 1876 by Peligot (*29*), who mentions that the leaves of beans yellowed and fell from plants prematurely. Hotter (*19*), in 1890, called attention to the spotting and yellowing of leaves caused by boron. Subsequent investigations by Agulhon (*1*), Brenchley (*6*), Haselhoff (*17*), Warington (*39*), Collings (*11*), and others have all demonstrated the highly toxic character of the element to many species of plants and have added to the fund of knowledge on the subject.

The injury produced by boron, as contrasted with the injury produced by other substances, is distinctive in its effects upon plant foliage. The typical boron symptoms are at once striking and in many cases clearly distinguishable from those normal to maturation processes or resulting from excesses of other elements of the soil solution. The fact that an excessive amount of boron in the soil solution is indicated by leaf characteristics of numerous plants, particularly during the late summer and autumn, makes it possible to arrive at fairly accurate conclusions concerning such occurrence in advance of chemical analyses of the soil, the irrigation water, or plant foliage. Wherever dooryard plants are grown, the indications afforded by their foliage are a great aid in the location of the general boundaries of boron-contaminated areas; and if the boron originates in water from wells, plant symptoms are an aid in the selection of samples for the determination of the water sources or strata most heavily impregnated. The presence of boron in toxic concentrations in certain areas of the San Joaquin Valley was originally discovered by noting plant symptoms. The fact that these symptoms are absent in extensive areas of the San Joaquin Valley has made unnecessary the collection, in such sections, of other than occasional samples of waters which have verified the plant evidence.

There is a tendency for plants to concentrate boron in their leaves, and these organs are typically the first to exhibit its injurious effects. Some variability is shown by different plants, in the character of both the initial and the later symptoms; but usually the apical margins of the leaves first turn yellow, and the yellowing then extends between the lateral veins toward the midveins. The chlorophyll of tissue towards the center and base of the leaves and adjacent to the veins is usually retained until the leaves have dropped from the plants. Areas of dead tissue develop as yellowing progresses. In some plants the dead tissue is confined to the margins of the leaves, while in others, such as walnut, sycamore, cotton, and bean, dead spots develop between the lateral veins either with or without notable yellowing in advance. These dead areas are largest and may coalesce near the periphery of the leaf (pls. 1 and 2).

In citrus and some other plants the injurious effects of boron do not make their appearance until the leaves have approached or attained full size, and the configuration of such leaves is therefore not changed. The injury to some other plants, such as grapes, tomatoes, beets, persimmons, and beans, may become apparent while the leaves are young. Such leaves do not attain a normal size, and, either with or without marked yellowing and drying, they sometimes become cupped owing to a cessation of marginal growth in advance of that of the more central portions. The older leaves are usually the first to show injury, and they abscise sooner than leaves of similar age on uninjured plants. Some of the variations of the form of injury to grapes are shown in group *C* of plate 1. The leaf on the left shows the common marginal injury with dark, discolored areas between the leaf veins. The young leaf in the center, which was spread out for the photograph, was deeply cupped, whereas the leaf at the right showed both cupping and marginal injury. All these leaves were taken from the same plant on the same day.



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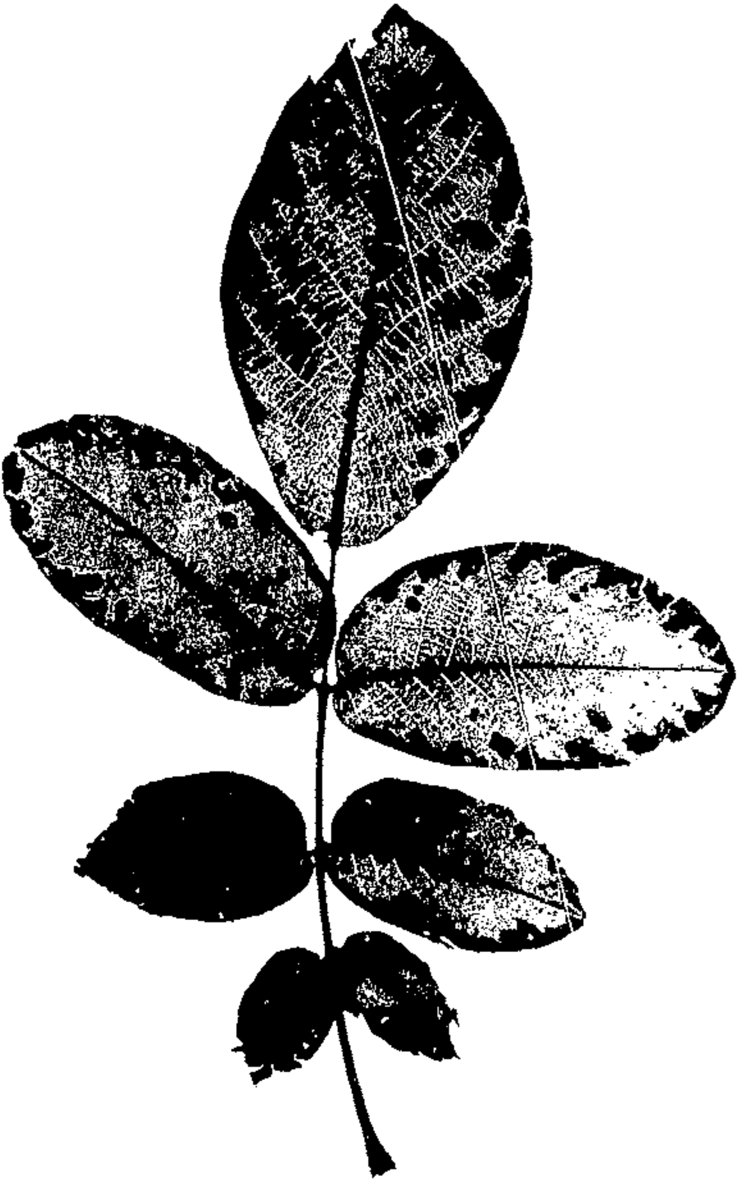
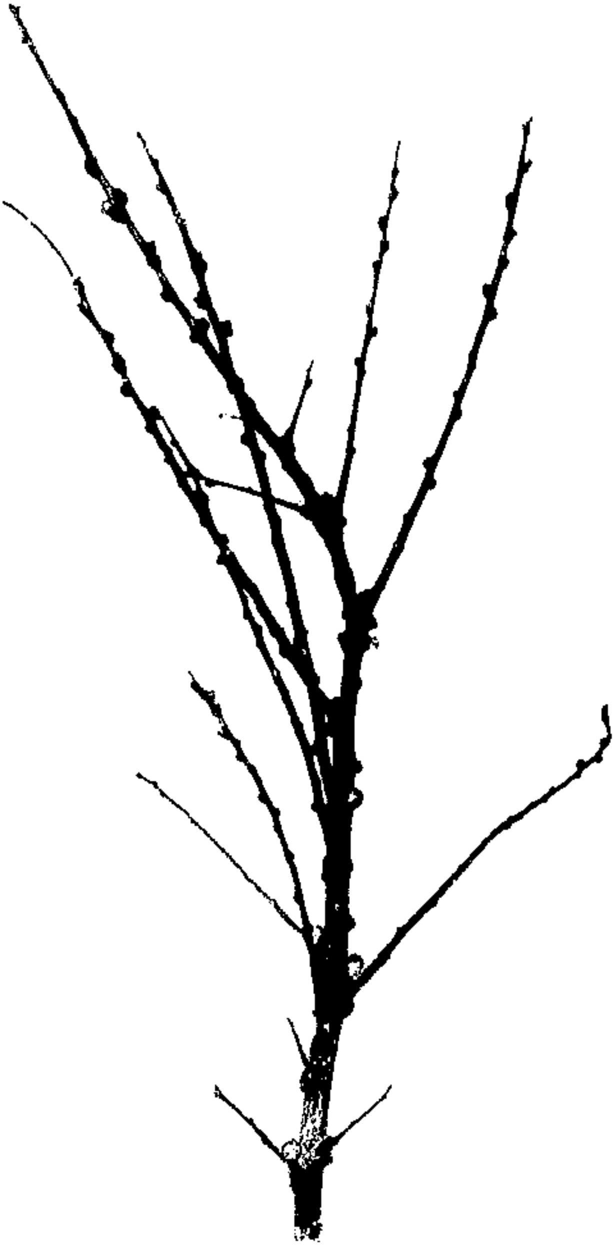
Leaves of Sultanina (Thompson Seedless) Grapes from Rubidoux Experiment 11 (1930), Grown in Sand Supplied with Nutrient Solution.

A, Boron-deficiency symptoms in leaves from plants supplied with solution having 0.05 p.p.m. of boron derived from impurities; *B*, normal leaves from plants supplied with solution containing 1 p.p.m. of boron; *C*, injured leaves from a plant supplied with solution containing 5 p.p.m. of boron.



LEAVES OF PERSIAN (ENGLISH) WALNUT SHOWING TYPE OF BORON INJURY TYPICAL OF THIS PLANT AND MANY OTHERS.



BRANCH OF AN APRICOT TREE SEVERELY INJURED BY BORON

Note enlarged nodes and gumming

TWIGS FROM A PRUNE TREE INJURED BY BORON.

The gumming and enlarged nodes of the twig on the right are to be noted. The bark has been removed from the other twig to show the excessive growth of wood at the nodes.

Cereals and other monocotyledonous plants show pronounced abnormalities when supplied with toxic concentrations of boron, but the symptoms, unless they are severe, cannot be differentiated with certainty from effects attributable to other causes, such as salt and normal maturation. The tips of those leaves turn yellow or brown and die back, and in corn the older leaf blades may develop yellow stripes. Barley leaves not uncommonly develop yellow and dead spots back of the burned areas. The tips of onions likewise burn, as do those of some other plants grown from bulbs. Gladiolus and palms show similar symptoms.

The stone fruits, as well as apples and pears, are sensitive to boron, but these plants do not develop in other than exceptional cases the type of symptoms that in many plants is so nearly specific. Not only are the characteristic leaf markings commonly absent, but repeated analyses have consistently shown the boron content of the leaves to be much lower than the concentrations that are built up in the leaves of such plants as walnuts and lemons.

Prunes and apricots under high-boron conditions sometimes develop growth abnormalities which, while not as specific as is the typical boron leaf injury, are nevertheless highly indicative and when taken together provide a fairly reliable basis for field diagnosis. The most outstanding of these characteristics is a peculiar enlargement of the bark of the smaller branches just below the nodes (pl. 3). The wood at the nodes is likewise found to be enlarged when the bark is scraped away (pl. 4). Accompanying this hypertrophy at the nodes there is commonly an extrusion of gum above the axes of the twigs and leaves. Both with and without these symptoms the tips of twigs often die back, and not infrequently the terminal leaves, instead of attaining normal size, remain small and often cupped, and some of them may abscise leaving vacant nodes. Another effect of boron, which has been seen in young prunes, is a tendency for the tips of the main stem and important branches to become enlarged by the formation of many closely set and poorly developed scale-bearing nodes. Late in the season short and similarly multiple-budded branches may be pushed out from these. Boron-affected apricot, and to a lesser extent prune, orchards present the general aspect of being wilted, owing to a tendency for the leaves to droop. The leaves of these trees thicken considerably when injured and, if folded and pressed lightly between the thumb and forefinger, tend to crack open at the fold.

Symptoms adequate for the field diagnosis of boron injury of peaches have not as yet been found, but in experimental cultures and in a few cases of advanced field injury a tendency for the bark of twigs above some of the leaf axes to turn brown and split open, either with or without the extrusion of gum, has been noted. Often the bark injury encircles the twig and causes death of the growth above. When injury is sufficiently severe in peaches the leaves may die irregularly along a narrow margin with an accompanying or preceding cupping of the leaf. The breaking of the restricted margins gives such leaves a ragged appearance.

Symptoms on pear and apple adequate for field diagnosis are not known.

In all of the stone fruits growth is depressed by boron concentrations below those required for the development of clearly defined symptoms.

Smith and Thomas (*35*) designate as exanthema a growth abnormality of prunes near Santa Cruz, which was remedied by applications of copper sulphate. Enlarged nodes not wholly unlike those here illustrated were among the symptoms, but the general aspect of the affected trees was very different from that produced by boron.

RELATIVE TOLERANCE OF CROPS

A wide variability exists in respect to the amount of boron that different crop plants are able to withstand, and, as was previously noted, some are benefited by boron concentrations high enough to injure the more sensitive plants. A large body of information on comparative plant tolerance is now at hand at the Rubidoux Laboratory. A detailed presentation of these data cannot be attempted in this bulletin, but it is nevertheless desirable that the subject should be dealt with briefly. An irrigation water relatively high in boron may sometimes be used profitably for tolerant crops and be entirely unsuited for crops that are sensitive. In fact, farmers using water high in boron have in some instances found, by trial and error and without knowledge of the cause, that certain crops were more suitable to their particular conditions than others.

In undertaking to determine in a careful way the boron requirements and the relative boron tolerances of some of the more common field, garden, and dooryard plants, it was considered essential that the methods employed should assure the greatest comparability in the conditions under which the test plants were grown. Soils are not only capable of absorbing boron salts or rendering them partially insoluble, but under field conditions soils are notably variable, not only from place to place but in their different horizons. For these reasons pure quartz sand was used in place of soil in this experimental work. The sand was placed in large metal beds (*13*) so arranged that it could be flooded and drained daily with solutions containing all essential plant-food elements, and for the several beds different concentrations of boron. The used solutions were replaced by new solutions at frequent intervals, and a portion of the transpiration loss was made up daily by adding water to the nutrient solution to maintain the initial boron concentrations. These procedures insured that all plant varieties grown together in any bed were subjected to like conditions with respect to the boron content of the nutrient solution with which they were supplied and that the desired boron concentrations were maintained in the different beds. The nutrient solution employed is one that supports a vigorous vegetative growth when boron is applied in sufficient but low concentrations. This experiment will be subsequently referred to as "experiment 11."

Certain plants have been found to be particularly sensitive to boron, some to be semitolerant, and others to be highly tolerant (table 1). The plants that withstand only relatively low boron concentrations have been designated in this table as sensitive, those that show only a small or moderate decrease in growth at relatively high concentrations as tolerant, and intermediate plants as semitolerant. This division of plants into three groups serves the purpose of convenience in classifying plants, but between the groups there is no sharp line of demarcation, and frequently uncertainty exists as to whether a plant should be placed near the bottom of one group or near the top of the next. Within the groups the aim has been to name the more sensitive plants first. In some cases the difference between successive plants of the list has been quite sharp, whereas in other cases the differences were too small or the data insufficient for final conclusions. The continuation of this work will add new plants to the list and will undoubtedly result in certain rearrangements in the order.

TABLE 1.—*Tolerance of various cultivated plants to boron, Rubidoux Laboratory, experiment 11*

[In each group the plants first named are considered as being more sensitive and the last named more tolerant]

Sensitive	Semitolerant	Tolerant
Lemon	Lima bean	Carrot.
Grapefruit	Sweetpotato	Lettuce.
Avocado	Bell pepper	Cabbage.
Orange	Tomato	Turnip.
Thornless blackberry	Pumpkin	Onion.
Apricot	Zinnia	Broad bean.
Peach	Oat	Gladiolus.
Cherry	Milo	Alfalfa.
Persimmon	Corn	Garden beet.
Kadota fig	Wheat	Mangel.
Grape (Sultanina and Malaga)	Barley	Sugar beet.
Apple	Olive	Palm (*Phoenix canariensis*).
Pear	Ragged Robin rose	Date palm (*Phoenix dactylifera*).
Plum	Field pea	Asparagus.
American elm	Radish	Athel (*Tamarix aphylla*).
Navy bean	Sweet pea	
Jerusalem artichoke	Pima cotton	
Persian (English) walnut	Acala cotton	
Black walnut	Potato	
Pecan	Sunflower (native)	

Climatic conditions have an important bearing on the concentration of boron that a plant will withstand. Many plants, including the stone fruits, grown at Riverside, Calif., withstood more boron during the cooler, more humid summer of 1929 than they did during the hotter and drier summer of 1930. A number of the garden vegetables and cover-crop plants listed, when grown during the winter months to which they are best suited, have shown higher tolerance than when planted in the spring.

There are also differences in the reactions of plants to toxic concentrations of boron. Walnuts, for example, show mild late-season leaf injury at boron concentrations so low that a question may properly exist as to whether there is actually an associated injury to the plant as a whole, and yet walnuts survive in higher concentrations than the stone fruits.

The only fig tested as yet has been the Kadota. Mission figs have been observed to grow under field conditions in situations where some of the semitolerant plants showed severe injury. It now seems probable that some of the other varieties of figs are considerably more tolerant than the Kadota.

OCCURRENCE OF BORON IN PLANTS

Agulhon's review (*1*) of the early literature on the occurrence of boron in plants records an identification of this element as early as 1857 in the seeds of a *Primula*. The next reference to similar work is recorded for the year 1879, after which there were a number of papers relating principally to the occurrence of the element in grapes and wines. Agulhon determined by quantitative methods the concentration of boron in the ash of 27 plant species distributed through 15 families, including annual and perennial Angiosperms, Gymnosperms, Cryptogams, and marine algae. His values, when expressed as boron in the dry plant material, show a range of from 7 to 14 p.p.m. of boron, respectively, in the stems and leaves of fir trees to 79 p.p.m. in the leaves of figs. *Fucus* from the English Channel contained 168 p.p.m. of boron. Agulhon conducted a number of plant experiments both with nutrient solutions and in the field, but in only one instance did he report the effects of the treatments on the boron content of plants grown experimentally. As reported by Scofield and Wilcox (*33*), the boron content of leaf samples of citrus plants collected in Florida ranged from 31 to 161 p.p.m. and at Silver Hill, Ala., from 55 to 132. Leaves of post oak, sassafras, and wild grape from Maryland contained 35, 59, and 51 p.p.m. of boron, respectively. A range from 61 to 177 p.p.m. was found in the boron content of 6 samples of citrus leaves from the valley of the lower Rio Grande at Weslaco, Tex. The results taken collectively constitute evidence that boron at least in small amounts is widely distributed and is probably a constituent of all agricultural soils.

The boron content of 127 scattered samples (*33, table 2*) of citrus and walnut leaves collected in southern California ranged from 35 to 1,522 p.p.m. The boron content of the mature leaves of these plants when no injury was apparent was generally less than 300 p.p.m., and when definitely injured, in excess of 400 or 500; concentrations between 300 and 500 p.p.m. are of uncertain significance. Instances of boron concentrations in the leaves of both citrus and walnut trees in excess of 1,000 p.p.m. on the dry-weight basis have been encountered a number of times. Notwithstanding the lack of outstanding difference in the extent of boron accumulation in the different commercial citrus varieties in California, the lemon is definitely more sensitive to boron than the orange, and the grapefruit occupies an intermediate position. Nearly all instances of high concentration of boron in the leaves of these plants in southern California have been associated with irrigation waters also relatively high in boron.

A marked diversity exists in the extent to which different plants grown under comparable conditions accumulate boron in their foliage. A few plants are known that accumulate more boron than the lemon and the walnut, but there are many that accumulate less. As an illustration of this diversity, reference is made to table 2, in which are listed the boron contents of a series of leaves collected from a small mixed orchard on a ranch southwest of Mendota, Calif. This orchard had been irrigated since it was planted from a deep well which, when sampled, contained 1.39 p.p.m. of boron. The water was somewhat saline, having a total salt content in the order of 1,300 p.p.m. Sodium was the dominant base in this water, and as a result the soil had become hard and relatively impervious. The table is not presented for the purpose of drawing conclusions as to the relative tolerance of the different trees, since factors in addition to boron in all probability were operating in the determination of adaptability. There were open places in the orchard indicating that some had already died out, and others were in poor condition; also certain of them may have been younger than others as a result of replanting.

TABLE 2.—*Boron content of leaves in a mixed orchard planting in western Fresno County, Calif.*

[Samples collected Sept. 1, 1931. Boron expressed in parts per million on dry-weight basis]

Sample no.	Variety	Boron content	Sample no.	Variety	Boron content
		Parts per million			*Parts per million*
1059	Lemon	962	1067	Loquat	60
1060	Peach	132	1068	Plum	77
1061	Persimmon	913	1069	Nectarine	143
1062	Cherry	119	1070	Apple	86
1063	Quince	50	1071	Almond	82
1064	Grape	924	1072	Pomegranate	33
1065	Fig	2,222	1073	Olive	77
1066	Cottonwood	2,018			

The fact that plants growing in or adjacent to the same plot of ground may vary to such a remarkable degree in the extent to which they accumulate boron in their leaf tissues clearly indicates outstanding physiological differences which parallel in interest the outstanding differences in the tolerances that different plants show to high boron concentrations. Lemon trees grown in nutrient solutions containing 6 p.p.m. of boron have died, whereas alfalfa, asparagus, and tamarix have been grown in solutions with 100 p.p.m. and certain native plants have been observed to grow in a soil watered by a flowing well containing 161 p.p.m. of boron.

Among the plant characteristics that might be expected to fall in the front rank of importance in the determination of tolerance are those governing either boron absorption by the plant as a whole or the accumulation of boron in particular organs. Evidence is at hand which suffices to show that the relationships in this regard are not simple, and no general criteria are known upon which to judge the tolerance of a plant variety other than by experimental tests and field observations.

In table 1 there was presented a list of plants arranged in what is believed to represent the order of their relative tolerances. Many of these plants have been grown in the sand beds for more than one season. During different seasons the relative tolerances have been found to be essentially the same when reasonable allowances are made for the variability that must necessarily accompany small populations and differences in season. Boron determinations have been made on all these plants, sometimes on composite samples of entire plants, sometimes on the roots, stems, leaves, and grain, and sometimes on the leaves only. Owing to climatic factors, the time of harvest, or the stage of growth at which the plants were harvested, the boron content of each variety has been found to vary to a moderate extent in the different plantings. Leaving the detailed discussion of these effects to another time, it is of interest to examine, among different plants, the extent of the relationship between boron tolerances and the boron concentrations built up by plants in their tissues. For the purpose of illustrating what has been found, a list of representative plants selected from experiment 11 are presented in table 3 in the order of their tolerance of boron. The plants in this experiment were all planted in a series of culture solution concentrations ranging from "0 boron"[3] to 25 p.p.m., but only the boron concentrations found in the plants of the 5 p.p.m. cultures are shown here.

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[3] See p. 16

TABLE 3.—*Boron content of plants grown in sand culture supplied with nutrient solution containing 5 p.p.m. of boron, Rubidoux Laboratory, experiment 11*

[Boron in plants expressed in parts per million on dry-weight basis]

Sample no.	Plant		Boron content	Sample no.	Plant		Boron content
	Variety	Portion			Variety	Portion	
	SENSITIVE PLANTS						
			P.p.m.				*P.p.m.*
1338	Lemon	Leaves	1,232	974	Sultanina grape	Leaves	1,046
1330	do	Stems and roots	54	496	Apple	do	143
494	Avocado	Leaves	569	498	Pear	do	120
929	Blackberry	do	717	817	Plum	do	92
487	Apricot	do	99	867	American elm	do	943
829	Cherry	do	182	871	do	Stem	22
484	Persimmon	do	997	781	Navy bean	Entire	648
805	Kadota fig	do	722				
	SEMITOLERANT PLANTS						
			P.p.m.				*P.p.m.*
775	Lima bean	Entire	515	916	Ragged Robin rose	Leaves	220
331	Tomato	do	160	920	do	Stems	29
268	Pumpkin	do	291	628	Field pea	Entire	207
360	Sweetpotato	Tops	218	1143	Sweet pea	Leaves	520
315	Milo	Tops and roots	102		do	Entire	210
320	do	Heads	22	956	Acala cotton	Leaves	306
325	Corn	Tops and roots	60	962	do	Stems and roots	32
330	do	Grain	16	529	do	Entire	123
380	Wheat	Entire	453	635	Potato	Tops	179
405	Barley	do	447				
977	Olive	Leaves	215				
	TOLERANT PLANTS						
			P.p.m.				*P.p.m.*
680	Carrot	Entire	69	374	Gladiolus	Tops	253
1233	do	Leaves	124	355	Alfalfa	Entire	139
618	Lettuce	Entire	261	660	Garden beet	do	144
350	Cabbage	do	142	757	Sugar beet	Leaves	177
664	Turnip	do	245	763	do	Roots	28
1408	Onion	Tops	242	364	Asparagus	Entire	120
1202	do	Bulbs	165	959	Palm	Pinnae	279
524	Broad bean	Entire	244				

It is customary in the field to select for boron determinations only mature leaves, whereas in table 3 where the boron content of leaves is given the sample represents all leaves, both young and old, on the plants at the time of harvest. Boron concentrations usually increase in leaves as they grow older, but the boron concentrations in entire plants taken from the same crops at different stages of maturity may either increase or decrease as the plant becomes older. This is so since the woody parts of the plant as well as the roots, seed, and fruit, which contain much less boron than the leaves, constitute larger proportions of the weight of old plants than of young ones.

Table 3 indicates a strong tendency for the boron-sensitive plants to accumulate more boron in their leaves than those of either the semitolerant or the tolerant group. The same tendency applies in comparisons between the boron content of entire plants in the two latter groups. The exceptions to this tendency, however, are too numerous and some are of too great magnitude to provide on this single basis a general or adequate explanation for tolerance. Some of the notable exceptions to the tendency are among the sensitive plants. Apples, pears, and the stone fruits are found to have relatively little boron in their leaves, whereas leaves of the lemon, blackberry, fig, grape, and elm are high in boron. In the semitolerant group the lima bean has more than twice as much boron as the sweetpotato, and yet their tolerances are considered as being approximately the same. Of the cereals, milo and corn have much less boron than wheat and barley, but they withstand approximately the same boron concentrations. The leaves of cotton have about 40 percent more boron at this concentration than do leaves of either the olive or the Ragged Robin rose, but cotton is more tolerant than either. In the tolerant group none of the plants so far examined are high in boron, which fact is noteworthy.

It is shown incidentally in table 3, and also previously mentioned, that boron is not uniformly distributed throughout the plant in the different organs or parts. Rooted lemon cuttings grown in experiment 11 had 1,232 p.p.m. of boron in their leaves, which varied in age from young to those ready to abscise, and only 54 p.p.m. in the trunk, stems, and roots. Similarly, young elms had 943 p.p.m. in the leaves, 22 p.p.m. in the main stem and branches, and 18 p.p.m. in the roots. Sugar beets had 177 p.p.m. in the leaves and 28 p.p.m. in the fleshy roots.

The uneven distribution of boron throughout the plant does not stop with particular parts or organs, but is carried to the different portions of the same organ. In describing boron symptoms it was observed for some plants that as injury became evident the margins of the leaves first yellowed, particularly the apical margins, and that the yellowing then progressed along the margins toward the base of the leaf and inward toward the midvein, the veins and the tissue adjacent to them remaining green for a longer time. As injury becomes pronounced, some of the tissue first yellowed commonly dies, the dead tissue remaining in place as a part of the leaf.

For the purpose of determining whether this pattern of injury was associated with the accumulation of boron respectively in the uninjured portions, the yellowed portions, and the dead portions, 150 leaves were collected from a boron-treated Eureka lemon tree at the Rubidoux Laboratory. The different portions of the leaves enumerated were carefully separated with a scalpel and dried for boron determinations. The boundary between the yellow and green areas is infrequently sharp, and there was, therefore, a little admixture of both in the yellow and green samples, but the whole of each leaf was included in one or another of each of four samples reported in table 4.

TABLE 4.—*Boron content of several portions of 150 boron-injured Eureka lemon leaves*

[Collected and dissected in December 1930. Boron expressed in parts per million on dry-weight basis]

Portion of leaves	Dry weight	Boron
	Grams	*P.p.m.*
Midveins and petioles	6.9	47
Green portions	22.6	438
Yellowed portions	7.1	1,060
Dead portions of apices and margins	4.5	1,722
Weighted mean of entire leaves		620

The differences found in the boron content of the different leaf fractions are definite and of outstanding magnitude. They indicate an intimate relationship between the injury that had taken place and the boron concentrations in the corresponding tissues.

The form in which boron occurs in the plant has not been established, and it is not known that all of it is in solution. Presumably, however, it exists in one or more of several reasonably soluble forms. Assuming that all the water[4] of these leaves acted as a solvent (a significant percentage of it does not) and that the boron was all in solution, the concentration of boron in the sap of the yellow tissues where the chlorophyll had largely disappeared was about 800 p.p.m., and the concentration in the sap of the dead tissue before death must have been about 1,300 p.p.m. The latter corresponds to the concentration of boron in a boric-acid solution 17.2 percent saturated at 20° C.

The distribution of boron in the leaves of lemon shown in table 4, conforming as it does with the pattern of injury, supports the view that boron is carried by the transpiration stream into the leaves, and that the movement of water through the cells of the leaves with the transpiration stream tends to carry it to leaf tissues farthest removed from the water vessels of the leaf veins. The distribution of boron in the various parts of the plant, as shown by the boron content of seeds, fruit, and roots (note especially the roots of the beet, table 3, in which extensive storage takes place), further indicates that little boron is translocated from the leaves with organic products in plants of this class, but tends to remain and accumulate in the leaf cells. The fact that the greatest injury occurs to tissue at points of highest boron concentration does not point to the formation or occurrence of appreciable concentrations of nontoxic or insoluble forms of boron in the plant. Boron has an affinity for certain sugars and polyhydric alcohols, and a reaction with one of the latter, mannitol, by which a hydrogen ion is liberated for each molecule of boric acid present, is the basis for the method used in boron determination. Since boron and certain of the carbohydrates are known to combine to form esters, it is quite probable that similar compounds may form in the plant, but if such is the case they are not as extensively translocated as are the uncombined photosynthetic products.

The distribution of boron in the stone fruits is quite different from that in the lemon, and the manner of injury is likewise different. Boron does not accumulate in the leaves of these to the extent that it does in many boron-sensitive plants, and, as has been stated, stone fruits rarely develop leaf symptoms characteristic of boron injury. The stone fruits may, however, develop growth abnormalities at their nodes (pls. 3 and 4) in the form of hypertrophy of both the bark and the wood, or, as in peaches, the cortex may break down. For the purpose of determining whether this overgrowth of the cortex and of the wood at the nodes was in any way associated with an accumulation of boron at these points, the separations of tissue shown in table 5 were made for boron determinations.

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[4] According to results privately communicated by F. F. Halma, of the California Agricultural Experiment Station, lemon leaves normally contain 57 percent of moisture in December.

TABLE 5.—*Distribution of boron in prune and apricot twigs collected near Hollister, Calif., October 15, 1932, and, for comparison, boron in lemon twigs collected from boron-treated trees at Riverside, Calif., January 22, 1932*

[Boron expressed in parts per million on dry-weight basis]

Sample no.	Species and condition	Boron content		
		Leaves	Bark	Wood
		P.p.m.	*P.p.m.*	*P.p.m.*
1119-1121	Prune, injured	176	412	171
1125-1127	Prune, uninjured	33	36	11
1122-1124	Apricot, injured	82	206	82
1076-1078	Apricot, uninjured	52	38	23
1533-1535	Lemon, slightly injured	410	42	9

Table 5 shows boron to have accumulated in the bark and to a lesser extent in the wood of injured prune and apricot twigs and to be relatively low in the same tissues of unaffected twigs. Boron did not accumulate in the twigs and cortex of injured lemon trees. Twigs collected from other boron-injured prune trees in the same orchard in January had 388 p.p.m. of boron in the buds, 244 p.p.m. in the bark adjacent to the buds, 136 and 133 p.p.m., respectively, in the outer and inner bark of the internodes, and 46 p.p.m. in the wood. The buds from twigs of injured pears contained 183 p.p.m. of boron, the adjacent bark 143 p.p.m., the internode cortex 139 p.p.m., and the wood 122 p.p.m. The results provide a means of accounting for the high toxicity of boron to stone fruits in the absence of abnormal leaf characteristics. Studies of the nature of associated anatomical abnormalities are now in progress. The overgrowth at the nodes has clearly indicated their existence, as does the large amount of gum extruded. An examination of the extruded gum for boron showed very low concentrations.

The orchard from which the prune twigs were collected had been observed by pathologists and others prior to the recognition that boron was the cause of its poor condition, and one section of the orchard had been pulled out. Prior to 1931 the orchard was irrigated principally from a well, and a bailed sample from it contained, in September 1931, 3.98 p.p.m. of boron. During 1931 a new well carrying in excess of 15 p.p.m. was used. The conclusion that boron might be the cause of the disorder was arrived at by W. R. Schoonover, of the California station, on the basis of the appearance of adjacent walnuts. Leaves of these walnuts collected by him in August 1931 contained 1,033 p.p.m. of boron, some of the walnut trees were dying, and the others were in poor condition.

TOXICITY OF BORON

In the preceding sections it has not been directly shown that as the boron concentration of the soil solution is increased there follows an increase in the boron content of the plant tissue, nor has it been shown that with an increased concentration of boron in the plant tissue there is an accompanying effect upon the growth of the plant. Both of these effects are illustrated in table 6 with data taken from experiment 11, previously described.

TABLE 6.—*Growth and boron content of plants in sand beds supplied with nutrient solutions, experiment 11*

DRY WEIGHT OF ENTIRE PLANTS

Plant	Period of growth or part of plant	Grown with nutrient solution containing boron of indicated concentration (p.p.m.)					
		"0"	1	5	10	15	25
		Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Malaga grape[1]	Apr. 19 to Nov. 14, 1930	149	379	74	18	15	--------
Kadota fig[1]	Apr. 2 to Nov. 12, 1930	169	456	136	10	--------	--------
Dwarf milo	May 22 to Sept. 19, 1929	678	--------	617	419	394	204
Acala cotton	June 5 to Dec. 9, 1929	114	--------	149	177	153	83
Sugar beet	Apr. 22 to Sept. 8, 1930	75	390	444	375	434	379
Palm[2]	May 1929 to Nov. 1930	150	--------	382	420	402	401

BORON CONTENT OF INDICATED PART OF PLANT (ON DRY-WEIGHT BASIS)

Plant	Period of growth or part of plant	"0"	1	5	10	15	25
		P.p.m.	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Malaga grape	Leaves	38	250	926	1,774	--------	--------
Kadota fig	Do	15	404	722	1,296	--------	--------
Dwarf milo	Less heads	17	--------	102	208	292	427
Acala cotton	Less seed cotton	12	--------	123	312	361	536
Sugar beet	Tops	20	89	177	262	304	592
Date palm	Pinnae	9	--------	279	601	959	1,980

[1] From 1-year-old rooted cuttings pruned back.
[2] *Phoenix canariensis*, 1928 seedlings.

The culture solution designated as "0 boron" contained only such boron as was introduced as an impurity with the ordinary chemically pure chemicals used in making up the base nutrient solution, that derived from the apparatus and the quartz sand, or that resulting from free exposure out of doors. Repeated analyses of the "0" culture solutions both before and after use showed that for the most part these solutions contained approximately 0.05 p.p.m. of boron. The concentration of boron in the solution supplying the other beds was maintained at or near the designated initial concentration by the daily addition of appropriate quantities of water to the culture solution to offset the concentrating effects of transpiration and evaporation. The 1-p.p.m. concentration was not included in the 1929 experiments.

All plants tested have shown higher boron concentrations in their tissues when the boron concentration of the nutrient solution was higher. The examples of table 6 are taken to illustrate plants of contrasting boron requirements and boron tolerances. The optimum range for the Malaga grape and the Kadota fig is narrow. Both respond to boron and both are sensitive. Dwarf milo has not shown definite benefits from added boron, but the plants in the "0" bed have tended to produce a greater number of tillers late in the season and to remain green after the plants supplied with boron matured. Acala cotton, both in the total weight of the plants and in the number of bolls produced, had a higher boron requirement for maximum growth than any other plant as yet studied, but cotton plants were injured by the 15- and 25-p.p.m. concentrations. Sugar beets in the "0" solution produced undersized roots with zones of disintegrated tissue; the leaves were reduced in size, with large areas of the tissues broken down, and judged by taste there was little sugar present in the pulp. The leaves of sugar beets in the higher concentrations showed some cupping and burning, but the yield was not significantly reduced. Like the sugar beet, alfalfa is benefited when some boron is added to the culture solution, and the growth is only moderately reduced at higher concentrations. The palm (*Phoenix canariensis*) was apparently benefited by 5 p.p.m. of boron. The plant in the 25-p.p.m. culture was more compact and the pinnae were burned back about 2 inches, but no reduction in weight occurred.

Nearly all of the annual crops have shown a retarded germination rate and reduced seedling vigor in the higher concentrations of boron.

BORON IN SOILS

The relatively small number of boron determinations that have been made on soils, whether irrigated or not, have in each instance shown boron to be present. In a few cases in the San Joaquin Valley the analyses show that the boron contained in unirrigated soils has been sufficient to have an adverse effect upon crop growth or so high as to hasten the injurious effects following irrigation with water high in boron. Notwithstanding evidence of the occasional occurrence of unirrigated soils containing appreciable concentrations of soluble boron in the San Joaquin Valley, the general inference to be drawn from the appearance of crops grown under irrigation leads to the conclusion that such depression in yield or growth as may be caused by boron is attributable for the most part to boron carried by the water applied.

Boron as found in soils does not appear to be very soluble, and for that reason boron that has accumulated in the root zone is not as easily removed by leaching as are chlorides and soluble sulphates. Several lemon trees growing at the Rubidoux Laboratory at Riverside, Calif., on a soil with a moisture equivalent of about 10 percent have been irrigated by the University of California in basins since March 1926. During the period from March 1926 to May 1927 boron was added to these basins at the time of each irrigation in such quantities as to produce a concentration of 5.0 p.p.m. in the water used (*22*). In 1934 these trees still show some adverse effects of the treatment—this notwithstanding continued irrigation in the basins, subsequent to May 1927, with water containing less than 0.15 p.p.m. of boron.

The behavior of boron, or more correctly of boron compounds, in soils constitutes an important problem. It is no longer difficult to determine accurately very small quantities of boron in aqueous solution, but each method of extracting a series of test soils for such determinations has yielded different values which bear little relation one to another. Extractions with water at high temperatures yield several times as much boron as extractions at low temperatures, and variations of the water-soil ratio used for extraction give different results; also, digestions with acid materially increase the boron obtained. Almost from the beginning of the boron investigations it has been recognized that an equilibrium exists between the undissolved boron in the soil and the boron in the soil solution, and the need of suitable methods for the determination of potentially soluble boron in soils has been appreciated as essential for a full understanding of the effects of boron in irrigation waters. Irrigation waters of similar quality, for example, have been observed to produce varying degrees of injury on different soils, and the time elapsing between the first use of a contaminated water and the first appearance of crop injury likewise varies with different soils. With heavy soils the onset of crop injury is apt to be retarded as compared with light soils. Not only do adverse effects usually become apparent sooner on light soils than on heavy soils, but when good water is substituted improvement is more rapid in the light soil.

The relationship between the boron-fixing power of soils and their texture is only a general one. It is believed that the colloidal matter of soils is the most active constituent, and heavy soils are usually higher in colloidal matter than light soils. The boron-fixing power of 4 San Fernando Valley soils has recently been examined by adding to each from 2 to 25 p.p.m. of boron as boric acid. Each of the 4 soils was wetted with three-fourths of its saturation percentage of moisture and set aside for 30 days. Two of these soils, with moisture equivalents of 5.3 and 15.1 percent, removed approximately 25 percent of the added boron from solution and 2 of them, with moisture equivalents of 13.5 and 24.6, removed approximately 50 percent of the added boron.

The factors that determine the equilibrium between the undissolved boron in the soil and the concentration of boron in the soil solution are not known, but it is recognized on limited evidence that they may be diverse. There is evidence to support the view that the solubilities and rates of formation of an undetermined series of mixed boron compounds may be of primary importance, and that soil colloids, possibly those active in base exchange, take up and render unavailable indefinite quantities of boron. Some boron minerals are highly insoluble. For example, plants grown by the writer in a tourmaline mineral (Al, Cr, Fe, B_2SiO_5) powdered to pass a 100-mesh screen developed no symptoms of boron injury.

Some soils near Hollister, Calif., show remarkable boron-fixing powers. The crops on a few have not shown conspicuous injury even when irrigated with waters containing up to 10 p.p.m. of boron for a number of years. Omund Lilleland, of the University of California, has applied as much as 60 pounds of boric acid to a heavy soil at Davis without producing injury to the prune tree that the soil supported. This amount of boric acid would be roughly equivalent to 60 p.p.m. of elemental boron in terms of the dry weight of the soil. Four ounces of boric acid, if absorbed by one of these large trees, would undoubtedly have produced serious injury. As a further illustration of the marked variability in the capacity of different soils to absorb boron, cotton was grown on a heavy soil at the United States Cotton Breeding Field Station at Greenville, Tex., which had been treated at the rate of 2,000 pounds of borax per acre, and according to Homer C. McNamara no adverse symptoms developed the first season and only a few plants showed injury during the second. But as has been noted, drill-row applications of not more than 10 pounds of anhydrous borax per acre greatly reduced cotton yields on light soils in the Southeastern States.

Evidence of the distinction that exists between the behavior of boron compounds and such ions as chlorides and readily soluble sulphates is illustrated by the data of table 7. The 10 soils there represented were chosen on the basis of soil types and field conditions. The crops grown on some showed marked boron injury, and on others evidence of boron injury was entirely absent. The diversity of soil character is represented in part by the reported moisture equivalents. It may be noted from the boron content of the first three percolates in this table that there are marked differences in the rate at which boron is liberated from different soils to the percolating solution. Significant amounts of boron were in all cases found in the third percolates, whereas nearly all of the chlorides and sulphates were removed by the first two percolates. Sulphates persisted in the percolates of soils 9 and 10, since gypsum in excess of its solubility in the water used for leaching had been added to each. Some boron was obtained in the twentieth percolate from each soil.

TABLE 7.—*Comparison of retention of boron and of chlorides and sulphates in 10 soils when 2 kilograms of each was placed in duplicate percolator tubes and leached 3 successive times with the saturation percentage of water*

Soil, percolate, and extract	Moisture equivalent	Saturation percentage	Volume leaching solution per kilo of soil	Constituents		
				B	Cl	SO_4
				P.p.m.[1]	[2]	[2]
Soil 1	8.4	20.1	201			
Percolate:						
First				0.09	0.42	0.66
Second				.04	.03	.05
Third				.05	.03	T[3]
Twentieth				.003		
Total of 20				.51		
1:5-S extract[4]				.20	.65	.01
Soil 2	11.9	31.3	313			
Percolate:						
First				2.01	1.08	1.37
Second				.81	.03	.12
Third				.67	.03	T
Twentieth				.08		
Total of 20				5.80		
1:5-S extracts[4]				2.83	1.10	1.55
Soil 3	14.1	30.2	302			
Percolate:						
First				.22	.36	1.52
Second				.20	.03	.07
Third				.17	.07	.02
Twentieth				.02		
Total of 20				1.35		
1:5-S extracts[4]				.53	.30	1.53
Soil 4	11.5	28.3	283			
Percolate:						
First				.80	.47	.94
Second				.40	.03	.07
Third				.21	.06	.01
Twentieth				.01		
Total of 20				2.46		
1:5-S extracts[4]				1.22	.71	1.13
Soil 5	21.2	41.9	419			
Percolate:						
First				.29	.69	2.33
Second				.33	.06	.10
Third				.30	.09	T
Twentieth				.02		
Total of 20				1.81		
1:5-S extracts[4]				.69	.84	2.34

[1] Boron determinations referenced to dry weight of soil.
[2] Milligram equivalents per kilogram of dry soil.
[3] T=trace.
[4] 1 part of soil to 5 times saturation percentage of water.

TABLE 7.—*Comparison of retention of boron and of chlorides and sulphates in 10 soils when 2 kilograms of each was placed in duplicate percolator tubes and leached 3 successive times with the saturation percentage of water*—Continued

Soil, percolate, and extract	Moisture equivalent	Saturation percentage	Volume leaching solution per kilo of soil	Constituents		
				B	Cl	SO_4
				P.p.m.[1]	([2])	([2])
Soil 6	12.2	32.9	320			
Percolate:						
First				0.24	.44	1.87
Second				.20	.06	.11
Third				.19	.06	.03
Twentieth				.03		
Total of 20				1.36		
1:5-S extracts [3]				.50	.74	1.50
Soil 7	22.5	40.8	408			
Percolate:						
First				.28	1.24	9.27
Second				.35	.13	.72
Third				.39	.04	T[4]
Twentieth				.01		
Total of 20				2.15		
1:5-S extracts [3]				.87	1.52	9.13
Soil 8	22.3	40.5	465			
Percolate:						
First				.29	1.31	4.58
Second				.29	.07	.27
Third				.23	.07	.13
Twentieth				.01		
Total of 20				1.81		
1:5-S extracts [3]				.49	1.03	5.02
Soil 9 [5]	17.4	35.7	357			
Percolate:						
First				.19	2.89	20.63
Second				.14	.14	16.21
Third				.18	.02	15.04
Twentieth				.01		
Total of 20				1.46		
1:5-S extracts [3]				.62	3.03	65.28
Soil 10 [5]	21.3	44.3	443			
Percolate:						
First				3.82	4.93	56.12
Second				2.78	.08	26.56
Third				1.87	.04	19.68
Twentieth				.11		
Total of 20				14.42		
1:5-S extracts [3]				5.76	5.09	117.75

[1] Boron determinations referenced to dry weight of soil.
[2] Milligram equivalents per kilogram of dry soil.
[3] 1 part of soil to 5 times saturation percentage of water.
[4] T=trace.
[5] 50 and 250 milligram equivalents of $CaSO_4$ per kilo were mixed respectively with soils 9 and 10 before filling the percolation tubes and before making the 1 to 5-S extracts.

If soils are leached with water to which boron has been added, the extract obtained may be either higher or lower in boron than the leaching solution. If a considerable part of the soluble boron has been removed from a soil by leaching with boron-free water, or if a soil is initially relatively free of boron and a water with several parts per million of boron is then used, many successive leachings may be required before equilibrium results and the solutions recovered attain substantially the concentration of boron used in the leaching solution. In other words, the concentration of boron in a leaching water and in the soil, and the soil characteristics that determine the equilibrium concentration, may cause boron to be either absorbed from or released to percolating water. When land is irrigated with boron-contaminated water the soil may remove boron from the water used and for a time maintain a soil solution with less boron than the irrigation water. On the other hand, when toxic concentrations have been reached in the soil solution it may be necessary to pass large quantities of good water through the root zone to reduce substantially the soil-solution concentration.

Two distinct measures of the boron in soils are recognized as desirable. To describe adequately the boron conditions in a soil one should be able to set forth (1) the total amount of boron looked upon as water soluble or potentially injurious and (2) the concentration of boron in the soil solution. Some doubt is entertained as to whether it will be possible to work out an entirely satisfactory method for determining the first of these values. The nature of this problem has already been made evident in the foregoing discussion of the solubilities of boron compounds and the effect of acids and temperature upon their solubilities. It is possible, however, to arrive at satisfactory values for the concentration of boron in the soil solution, and it is this concentration that is most directly reflected by crop conditions. The procedure for displacing the soil solution, nevertheless, is a difficult one and requires considerable experience. The details of the method must be varied to suit different soils, and not uncommonly retrials with variations in moisture content, degree of packing, etc., are necessary. For practical purposes recourse is now taken to what is designated as three-fourths saturation percentage extracts. This method is direct and involves little difficulty. Also much less soil is required. These extracts are obtained by wetting 500 or 1,000 g of soil with three-fourths of the saturation percentage of water and then extracting a portion of this water with air pressure after the soils have been wetted for several days. The concentrations found in the three-fourths saturation extracts are ordinarily a little lower than in displaced soil solutions. The concentrations of boron found in three-fourths saturation extracts of the 10 soils listed in table 7 were on the average 88 percent as high as in corresponding displaced soil solutions. Good correlations have been found between these values and crop conditions.

In undertaking the culture of plants in the experimental sand beds for the determination of boron tolerance, it was assumed that their reactions to the boron of the nutrient solutions held by the sand would be essentially the same as those of plants grown in soils with soil solutions of like concentrations. To the extent that it has yet been possible to make comparisons between the reactions of the plants grown in culture solutions of known boron concentrations with field plants grown on soils of determined soil solution concentrations, this assumption has been substantially verified. It is recognized nevertheless that some discrepancy must result from such factors as nitrate differences between culture and soil solutions and from soil variability.

Boron occurring naturally in toxic concentrations in unirrigated soils is not uncommonly found in small areas surrounded by productive land. The topography or the appearance of such land frequently provides no index as to either the condition or its cause, and yet the boron content of the soil of such areas may differ to the extent of more than 20 to 1 from that of adjacent land. One such area is shown by figure 1 in a peach orchard south of Tracy, Calif. Soil 10 of table 7 was taken in the foreground area, in which both the original and the replanted peach trees either died or made little growth. Soil 9 of table 7 was taken from among healthy trees shown in the background.

COUNTERACTION OF BORON AND THE USE OF BORON-CONTAMINATED WATER

It has frequently been asked whether it is possible to remove boron from irrigation water. For practical purposes it is necessary to answer in the negative. Methods have been proposed, and in the laboratory it may be possible to render a part of the boron in a solution insoluble, but no feasible method applicable to irrigation water is known. To precipitate the few parts per million of boron in irrigation water, excessive concentrations of reactive salts would be necessary and might in themselves prove toxic. The only recommendations that can now be made are the substitution of another water, dilution by blending with better water, or the cultivation of less sensitive crops.

FIGURE 1.—A small area of boron-impregnated, unproductive soil surrounded by fertile land. (Field 7, SE. ¼ sec. 31, T. 3 S., R. 7 E. July 9, 1931.)

It has likewise been asked whether something could not be applied to the soil to reduce the toxicity of boron. Well-cared-for and well-fertilized orchards not uncommonly show less marked boron symptoms than do partly neglected groves irrigated with the same water. It has been found that the severity of the boron injury shown by lemons and grapefruit in controlled experiments both in sand and in water cultures is materially reduced when the concentration of the nitrogen supplied is increased. Field observations have likewise indicated that the liberal use of nitrogenous fertilizers reduces the severity of boron injury in citrus plantings. Potassium and sodium supplied in relatively high concentrations have been found to modify the character but not the intensity of leaf injury caused by boron. The concentrations of chlorides, sulphates, and phosphates have not been found to affect materially the severity of boron symptoms.

When an irrigation water is high in chloride or sulphate it ought to be used in sufficient abundance to displace the soil solution by leaching as it becomes concentrated by transpiration and evaporation. The situation with respect to boron, however, is not so simple; unlike chloride, a part of the boron applied with water, instead of remaining in solution, may accumulate in the soil in an undissolved but potentially available form, and for this reason the same considerations cannot be applied to the use of saline and high-boron waters. Unfortunately, many of the high-boron waters in the San Joaquin Valley also contain high concentrations of the more common salts. Considering boron independently, and assuming the soil to be initially relatively free from this element, the abundant use of water high in boron to promote a systematic leaching of the root zone is not to be recommended until boron symptoms become pronounced. Such symptoms indicate unfavorable root-zone concentrations. When boron symptoms have become pronounced, the advantage will probably lie on the side of abundant use of water to prevent further increases in the soil and soil-solution concentrations; in other words, the methods used should result in some leaching of the root zone.

WATER SUPPLY OF THE SAN JOAQUIN VALLEY

SOURCES AND GENERAL CHARACTER

Agriculture in the southwestern part of the United States is controlled by the distribution of rainfall, the character of the soils, and the possibility of supplementing precipitation by irrigation. In the San Joaquin Valley the rainfall increases gradually from less than 5 inches in the vicinity of Bakersfield to 16 inches or more in the vicinity of Stockton.

The intensive agricultural development of the valley has followed the utilization of water obtained from wells drilled in the valley floor or in the alluvial fans, and the diversion and use for power and irrigation of water derived from the streams that rise in the mountains to the east. Streams originating in the Sierra Nevada, which rise to great heights above the eastern side of the valley, furnish either directly or indirectly by far the greatest proportion of the water that enters the valley. The remarkably rapid growth of agricultural enterprise in the valley is to be attributed not only to the fertility of the soil and the suitability of climatic conditions for crops but also to the fact that the water furnished by the Sierra Nevada watershed is unusually free from dissolved mineral matter. Those areas along the eastern side of the valley most abundantly supplied with good water are the most intensively cultivated. The supply of water derived directly from rivers of the Sierra or that can be pumped from their alluvial fans is limited, however, and along the eastern side of the valley there has been recently little extension of the irrigated area; rather it has been necessary to deepen existing wells and to install larger pumps in order to maintain the present area.

In addition to the rivers that flow from the high Sierra on the east, there are a number of creeks rising in the Tehachapi and San Emigdio Mountains, which form the southern boundary, and from the coastal mountains, which form the western boundary of the valley. Principal among these creeks or "washes" are Caliente, Grapevine, San Emigdio, Los Gatos, Cantua, Big Panoche, Little Panoche, Los Banos, San Luis, and Orestimba. All of these are relatively short, and except at flood time their waters are lost in alluvial cones before reaching the axis of the valley. These streams nevertheless are of considerable importance in the present connection, since they are generally considered to have been the source of the underground water supply tapped by wells over a portion of the southern end and the western side of the valley, in which areas irrigation waters contaminated with boron are most frequently found. The water brought in by these creeks likewise carries a much larger amount of dissolved mineral matter than water derived from the high Sierra.

In some sections of the Southwest the contamination of an irrigation water by boron can be traced to some particular spring or group of springs heavily charged with boron but contributing only a minor portion of the stream flow, or to exposed borax or colemanite deposits in a limited portion of a watershed. In the San Joaquin Valley tracing out the sources of boron contamination is generally difficult. In those portions of the valley in which boron occurs in agriculturally significant amounts, the water supplies for the most part are derived from wells, many of which are of great depth and far removed from the streams that now presumably supply or have in the past supplied water to the underground strata. In fact, over a considerable portion of the western side of the valley some of the water now brought to the surface from the deeper wells may be of an age comparable with that of the upper alluvium depositions of the valley itself.

As has been stated by Mendenhall, Dole, and Stabler (*27*):

> The belief that there is little movement in the subsurface waters of the lower San Joaquin is strengthened by a consideration of their chemical characteristics. Some of the ground waters of the upper deltas of the east side are among the purest waters of this type known, while those from the shallow (formerly) flowing wells of the bottom of Tulare Lake and from the deeper wells of the north end of the valley are so heavily charged with mineral matter as not to be potable or suitable for irrigation purposes. Ground waters dissolve the soluble minerals from the rock fragments—the clay, sand or gravel particles with which they are in contact. The amount thus dissolved depends upon the chemical combinations in which the minerals exist, some being much more soluble than others, and upon the length of time during which the waters are in contact with them. In general, the alkalies in the sands and gravels of the east side are in the most resistant form, the silicates of the granitic debris from the Sierra; the alkalies of the sands and gravels of the west side are in less resistant form, the sulphates and carbonates of the Cretaceous and Tertiary shales and sandstones; hence the ground waters of the high parts of the east slopes and the valley, which move with comparative rapidity, are much purer than the waters from similar situations on the west side. Furthermore, the volume of water poured out upon the east-side fans is many times greater than that discharged upon the west side, so that the alkalies dissolved are greatly diluted. But down in the trough of the valley, especially near its north end, the ground waters contain a much larger percentage of salts, even than those of the west side. If there were rapid circulation of ground waters here, this condition should not exist, for the dissolved salts should be gradually carried out. The fact that the waters are highly mineralized is regarded then as additional evidence of sluggish circulation, or perhaps practical stagnation.

GEOGRAPHICAL AND GEOLOGICAL CHARACTERISTICS OF THE VALLEY

The quality of the ground waters as well as that of the streams entering the valley is related to the topography and geology of the valley and its surrounding mountains and foothills. The alluvium derived from the hard granitic rocks of the Sierra and supplied by water from streams rising in these mountains yields water distinct in composition from that derived from the alluvium of the west side, which has been brought down and deposited in the valley from the more soluble, softer, and often gypsiferous sedimentaries of the Coast Range. The waters derived from the two sides of the valley are in general distinct one from another, but all are highly variable in the concentrations and proportions of their constituents, and both of these waters have contributed to the large body of ground water which extends to great depths beneath the valley. Not only are these underground waters derived from various sources in unknown proportions, but some have been subject to concentration by evaporation and to changes resulting from biological processes. Since the movement of ground water in the valley floor is at most very slow, these waters have long been in contact with the many stratifications of the alluvium of which the valley floor is built, and such contact has served to modify further their quality.

It is because the geographical and geological characteristics of the valley have such a pronounced bearing on the quality of both the surface and ground waters that it has seemed desirable to include in this report a descriptive statement of these features. Mendenhall, Dole, and Stabler (*27, pp. 15–22*) availed themselves of an unpublished manuscript by H. R. Johnson to supply a similar need, and the statement that follows has been taken from their publication almost without change except for the omission of matter of only slightly lesser interest. The contribution by Johnson begins at the third paragraph below:

> The Great Valley of California exhibits little diversity in its physical aspect. Such differences as exist between its north and south ends are climatic, or, if physical, are directly due to climatic differences. Among local physical features based upon climatic differences may be mentioned the Tulare Basin at the south end of the San Joaquin Valley. The basin is due to the aridity of the region and the consequent extensive development of alluvial fans. Two of these, extending from Kings River on the east and Los Gatos Creek on the west side of the valley, have coalesced in a low ridge south of which lie the Tulare Lake and Kern Lake depressions * * *. The southern, more arid third of the depression, extending from Kings River delta to Tehachapi Mountains, has no surface outlet under normal conditions, and the surplus surface waters accumulate in the Tulare Lake depression and Buena Vista reservoir. Originally Kern Lake received a portion of the excess from Kern River, but through the protection afforded by a restraining dike water is kept out of it except when unusual floods break the restraining dam. The original lake bottoms have in part now become valuable wheat lands.
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> * * * the valley floor has been built up by the alluvial material eroded by the streams from the mountains east and west of the depression and deposited in it. The larger and more active streams build flatter but more extensive alluvial fans—the type that makes up the east-side slopes; the more erratic and torrential streams of smaller volume build the steeper and less extensive fans that constitute the west-side slopes.
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> In simplest outline the geology of the eastern border of the San Joaquin Valley consists of the "Bedrock series" of granites and metamorphic sedimentary and igneous masses of pre-Cretaceous age, overlain at the north and south ends of the valley in an interrupted band occupying a zone of low relief between the Sierra proper and the valley proper by a series of Tertiary sediments, entirely unaltered and including beds as old as the Eocene, although the great body of the material seems to be Miocene or Pliocene in age. * * *
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> The geology of the western margin of the valley contrasts in many ways with that of the eastern border. The oldest rocks of the Mount Diablo Range—the easternmost of the coast ranges—comprise a series of altered igneous and sedimentary rocks of Jurassic (?) age known as the Franciscan formation, which

extends along the axis of the range from a point southwest of Coalinga to San Francisco Bay. Overlying them on the valley side, but not continuously, is a series of sandstones, shales, and conglomerates of Cretaceous and earliest Tertiary (Eocene) age. Succeeding these in turn is a variable series, locally of great thickness and usually but not always present in some of its members, representing the middle and upper Tertiary. * * * Toward the top of the series are beds that clearly represent fresh water or subaerial deposition, undoubtedly much like that which is now taking place in Tulare Lake and in the west-side alluvial fans. * * *

The valley as a whole is a great structural trough and appears to have been such a basin since well back in Tertiary time. Since it assumed its general troughlike form, gradual subsidence, perhaps interrupted by periods of uplift, has continued and has been accompanied by deposition alternating at least along what is now its western border with intervals of erosion. This interrupted but on the whole continuous deposition seems to have been marine during the early and middle Tertiary; but during the later Tertiary and Pleistocene, when presumably the valley had been at least roughly outlined by the growth of the Coast Ranges, fresh-water and terrestrial conditions became more and more predominant, until the relations of land and sea, of rivers and lakes, of coast line and interior, of mountain and valley, as they now exist, were gradually evolved. As these conditions developed, the ancestors of the present rivers probably brought to the salt and fresh water bodies that occupied the present site of the valley and its borders, or, in the latest phases of the development, to the land surface itself, the clays, sands, gravels, and alluvium that subsequently consolidated into the shales, sandstones, and conglomerates of the late Tertiary and Pleistocene series, just as the present rivers are supplying the alluvium that is even now accumulating over the valley floor.

The very latest of these accumulations are the sand and silt and gravel beds penetrated by the driller in his explorations for water throughout the valley. They are like the early folded sandstones, shales, and conglomerates exposed along the flanks of the valley, except that they are generally finer, and are not yet consolidated or disturbed. The greater part, perhaps all of them, accumulated as stream wash on the valley surface or in interior lakes like the former Tulare Lake, but a proportion of the older sediment that is greater as we delve farther back into the geologic past accumulated in the sea or in salt bays having free connection with the sea. It is these very latest geologic deposits, saturated below the ground-water level by the fresh water supplied chiefly by the Sierran streams, that constitute the reservoirs drawn upon by the wells, whether flowing or pumped, throughout the valley.

The chemical composition of the ground waters, as well as their occurrence and accessibility, is related to the geology. Where the valley alluvium is derived from the Cretaceous and Tertiary beds of the coast ranges, rich in gypsum and other readily soluble minerals, the ground waters [generally] contain large quantities of these salts. Where, on the other hand, the alluvium is derived from the granites and metamorphic rocks of the Sierra, whose potassium, sodium, and calcium compounds are in the form of difficultly soluble silicates, the ground waters under ordinary conditions contain very little of these salts.

Obviously if the sands and gravels through which the ground waters percolate were deposited under such conditions that salts were deposited with them, as in the salt water of the sea or of bays like San Francisco Bay, or in interior lakes that are saline through evaporation, as is true of Tulare Lake, then the ground waters themselves become saline, although when they leave the mountains as surface waters, before their absorption by the alluvial fans, they may be as pure natural waters as are known in the world.

The lowland through the heart of California known as the Great Valley, whose origin as a depression appears to date well back into Tertiary time, owes its actual surface to more recent action and to more obvious agents. That surface is, in brief, a combination of the surfaces of a great number of alluvial fans, originating at the mouths of the canyons through which the tributary streams discharge from the mountains into the valley.

* * *

The essential fact as to the present valley surface is that it is a direct result of stream action. It has everywhere been built up by deposition from the streams or from the fluctuating lakes that are themselves dependent upon the streams; and it is formed of materials brought by the streams from the mountainous portions of their drainage basins where they are eroding instead of depositing. Throughout the south end of the valley its surface is a combination of alluvial fan surfaces; at the north end of the valley these fans, less strikingly and typically developed because of the greater precipitation there, still predominate along the valley borders, while the center of the valley is a flood plain of the usual type.

* * *

The west-side streams, draining mountains practically free from granitic and similar rocks but with soft serpentines, shales, and sandstones, deposit fragments of those rocks in their alluvial fans, and the result is a soil type entirely different from that of the east side and south end of the valley. These shale, clay, serpentine, and sandstone fragments disintegrate much more quickly than the granitic sands that contain large proportions of such resistant minerals as quartz and feldspar, and the result is the mellow, loamy soil with its fragments of siliceous shale that makes much of the west slope of the valley and is so productive whenever water can be applied to it.

FIRST OBSERVATIONS OF BORON INJURY IN THE VALLEY

As early as 1922 W. S. Ballard, of the Bureau of Plant Industry, noted a similarity between the symptoms shown by certain plants in the vicinity of the Rock Pile School, southeast of Bakersfield, and the symptoms that had been illustrated as resulting from the application of borax with fertilizers in Eastern States. Ballard encountered difficulties with analytical methods and with experimental plants and made no published comment on his observations. He called the conditions in the Rock Pile area to the attention of C. S. Scofield, in charge of Western Irrigation Agriculture, Bureau of Plant Industry, in 1929. About the same time A. R. C. Haas, of the California Agricultural Experiment Station, called attention to boron symptoms that he had observed in citrus near the Weed Patch store, also southeast of Bakersfield. Boron determinations on samples collected by Scofield established the cause of the crop injury in the Rock Pile area and at Weed Patch. A water sample sent in from Lemoore was likewise found to contain an injurious concentration of boron.

Observations of the symptoms exhibited by plants and the analyses of a few scattered water samples collected by the writer in the valley in June of the same year resulted in the conclusion that injurious concentrations of boron were possibly common to many of the well waters along the west side of the valley. No evidence of boron injury was observed in plantings east of the valley axis north of Kern County. These observations pointed to the desirability of the investigations in the San Joaquin Valley which are reported in this bulletin.

QUALITY OF IRRIGATION WATER

INJURIOUS CONCENTRATIONS OF BORON

Before attempting to attach significance to particular concentration ranges of the boron found in irrigation water it is desirable to review a number of the factors that are known or believed to influence the evidence of injury and the accumulation of boron in soils as produced by boron-contaminated water.

The tolerance of the crop or crops grown is in the front rank of importance; alfalfa and sugar beets will do well with boron concentrations in the soil solutions to which cotton and cereals show depressed yields and at which the profitable culture of grapes and many of the deciduous fruits would be out of the question.

A heavy soil initially low in boron will usually remain productive for a longer time than a light soil when water high in boron is used, but after injurious concentrations have been built up in soils the light soil will respond quicker to the substitution of a good water. The existence of marked differences in the boron-fixing powers of both light and heavy soils is appreciated, but little is known of the chemical character of the reactive constituents.

The initial boron content of the soil is of obvious significance, since upon this there is dependent the delay in the onset of adverse symptoms when water high in boron is used.

Boron injury is accentuated by climatic conditions causing high transpiration rates.

The annual quantity of water applied is of significance. Boron will be added to the soil more rapidly when water is supplied in quantities required for such crops as alfalfa and cotton than when lesser quantities are used, as for cereals.

The amount of rainfall is of special significance, since this reduces the amount required by irrigation. Rain water, being free of boron, constitutes an effective agent in leaching boron from the root zone. Highly undesirable boron concentrations in irrigation water in arid localities may have little significance in regions of heavier rainfall.

The effects of boron are similar to those of other toxic elements on plants, in that above certain minima a decrease in plant growth results from any increase in the concentration of the toxic substance. The point of diminished growth selected as critical from an agricultural viewpoint must be chosen somewhat arbitrarily and is certainly contingent not only on plant growth but on economic factors such as the cost of crop production and market values. It is obvious that neither the concentration at which injury first appears nor the concentration that kills the plant is as useful a criterion as some intermediate point of diminished yield. The conditions in the soil solution resulting from the use of a given water are in general not stationary but vary with time as the toxic substances are concentrated in the soil by transpiration and evaporation, become insoluble by soil reactions, or are leached away by water penetrating beyond the root zone.

With the foregoing considerations in mind it should be apparent that any statement of what constitutes dangerous concentration of boron in an irrigation water must be phrased only in the most general terms. This is particularly true in an area as extensive as the San Joaquin Valley with its diversity in quality of irrigation waters, soil types, crops, and climatic conditions.

In terms of suitability of water for those plants listed as being sensitive to boron, a most conservative statement for the southern portion of San Joaquin Valley would be that above a concentration of 0.3 p.p.m. the less boron in an irrigation water the better. In Ventura County, to the south, where rainfall is 10 inches or more and where both the temperature and the humidity are affected by the Pacific Ocean, a water containing much more than 0.5 p.p.m. of boron is considered as being of doubtful quality for the irrigation of lemons and walnuts. In the latter area higher concentrations have been used without appreciable injury under some conditions, but in at least one instance the prolonged use of a water with only slightly more than 0.4 p.p.m. of boron has injured the foliage of lemon trees. In the more arid portions of the San Joaquin Valley, where the annual rainfall is about 5 inches and the transpiration rate is high, injury may result to plants of the sensitive group with water containing 0.5 p.p.m. of boron, or, under favorable conditions, the more tolerant of the sensitive crops may make a fair or even profitable growth for a period of years with water containing as much as 1 p.p.m. of boron.

In the arid parts of the valley the growth of plants of the semitolerant group may be adversely affected by as little as 0.5 p.p.m. of boron in irrigation water in localities where appreciable boron occurs as a native constituent of the soil or where conditions are such that excessive concentration takes place in the root zone. Under more favorable conditions and with soils that remain open to leaching, reasonably satisfactory growth can be expected from semitolerant plants with water containing from 1 up to 2 p.p.m. of boron. When the boron concentrations exceed 1.5 or 2 p.p.m. the best results can ordinarily be expected only with plants of the tolerant group.

The effects of boron are less severe in those parts of the valley with higher rainfall. Where the water is supplied nearly equally by rain and irrigation only about half the injury experienced in the more arid portions of the valley is found.

In all considerations of toxicity the standard of injury or of reduced yields is of great importance. The family of a dry-land farmer southeast of Bakersfield has recurrently endeavored to grow a little garden as well as ornamental plants and dooryard trees with well water containing 7 p.p.m. of boron. It is true that many plants have been found entirely unsuited and that the condition of the perennial plants grown is far from satisfactory, and yet there is no question that the efforts to maintain a little home garden and a few trees are worth while. A water containing 5 p.p.m. of boron in Lost Hills was used for a short time but was found to be unsatisfactory even for a lawn, and cottonwood trees and other plants at this place bore marked evidence of injury. Tamarisk trees grow fairly well with water containing 15 p.p.m. of boron, and a number of other plants have been grown with such water when placed in pots or boxes to permit of the drainage necessary for copious irrigation.

SIGNIFICANCE OF OTHER CONSTITUENTS OF IRRIGATION WATERS

It has been found essential in these investigations to determine the concentrations of constituents other than boron in the irrigation waters examined. Though no general relationship has been found to exist between the concentration of boron and the concentration of any other constituent, there is a marked tendency nevertheless toward higher boron concentrations in the more highly mineralized waters. In some of the San Joaquin Valley waters boron is the only dangerous constituent, but more commonly when boron is high other ions are also high, and there are many saline waters that contain very little boron.

The injurious effect of boron is modified to some extent by other constituents of irrigation waters; and since the ill effects of the various constituents are in a measure interrelated and additive, it is clear that the significance of one characteristic of the salt complex cannot be properly evaluated independently of a knowledge of the others.

In the previous section a number of factors were enumerated which modify the rate at which boron accumulates in soil and influence the effects that follow the use of boron-contaminated water. A variety of factors likewise influence the effect of higher concentrations of the other toxic ions, and for that reason it is not possible to indicate critical concentrations of these ions in other than general terms.

The ill effects that follow the accumulation of toxic substances in the soil are due less commonly to direct injury to plant roots than to effects upon foliar and other tissue after these substances have been absorbed and concentrated within the plant. Climatic factors and the balance of ions in the soil solution may affect absorption rates, but the concentration of salt constituents presented to roots by the soil solution stands out as a predominating factor in the determination of the concentration built up within the plant tissue and the injury that results. The high osmotic force of the soil solution when it has become concentrated has sometimes been pointed to as a deterrent to the free absorption of water from the soil by the plant; but in other than rather unusual cases, as when the soil solution concentration may have been suddenly increased by the application of water more saline than customarily used, or by the washing of surface salt into the root zone, this relationship is of secondary importance. It has been shown elsewhere by the writer (*12*) that plants maintain osmotic concentrations in their tissues which exceed those of the soil, the concentration within the plant being higher when the salinity of the soil is higher Within the limits of tolerance, a tendency toward a uniform difference between the plant and soil concentrations is indicated in soils of varied salinity, but this gradient would be expected to vary for each variety and habitat.

It is well known that plants differ to marked degrees in their tolerance of the different salt constituents, but information comparable to that presented in table 1 for boron is not available. Hilgard (*18*) has published a table of plant tolerances compiled by R. H. Loughridge which sets forth the highest concentrations of sulphate, carbonate, chloride, and "total alkalis" found in soils supporting uninjured plants. The work upon which this table was based was done long ago, and it is still recognized as a valuable and comprehensive source of information, but in the terms of present-day knowledge its limitations are manifest. The plant habitats investigated were undoubtedly limited in number and variety, and conclusions as to whether plants were or were not affected would seem now to be almost impossible except by comparison with similar plants grown on nonsaline or nonalkaline soils. The growth of many plants may be materially reduced by sulphate and chloride ions without the development of symptoms indicating that fact. Hilgard's table reports the tolerances of different plants to each of three, independently considered, soil ingredients, but he recognized that the proportions of these ingredients found in nature were extremely variable. It is likewise to be recognized that the salt concentrations in the different horizons of the root zone may vary widely. A question therefore arises as to which soil layer was or is to be taken as a criterion of tolerance, or what significance is to be attached to composite samples from several different horizons. In the table cited account was taken only of the acid radicals, but it is now known that different proportions and concentrations of the bases, calcium, magnesium, potassium, and sodium, greatly affect plant growth and soil characteristics; these bases, collectively, are always present in concentrations equal to those of the acid radicals. The point here made is that we do not know for any one set of conditions the comparative tolerances of the various agricultural plants to the common ions nor the extent to which plant growth is depressed by the various combinations and concentrations.

The difficulties encountered in attempting to assign critical or toxic limits for these irrigation-water constituents, however, do not end at this point. It is the concentration of salt in the soil solution, and not the concentration in the irrigation water, which determines plant reactions. The concentration of the different salt constituents in the soil solution may exceed by many times that in the water applied. Cultural practices as well as climatic factors and the kind of crops grown are all of importance, and there is to be stressed also the permeability of the soil as it affects the removal of salts from the root zone by leaching and the abundance with which water is used to accomplish this. Waters sufficiently high in toxic constituents to be directly injurious to plants are seldom used for irrigation. Transpiration by the plant and evaporation from the soil both serve to increase the concentration of the soil solution above the concentration of the water applied. On the other hand, water, either irrigation or rain, when in sufficient abundance, displaces in part the soil solution, which, being removed downward, carries salt beyond the root zone. In addition to the salt removal by leaching, small quantities are absorbed by plants, the quantities thus removed being dependent upon the type of plant, the portions of the plant removed from the land, and the concentration of the different constituents of the soil solution presented to the roots.

Plants may absorb the individual constituents of the soil solution either in a greater or lesser proportion than they absorb water, but under the usual conditions in irrigated regions the soil solution is left more concentrated in chlorides and sulphates as a result of plant transpiration. It is not to be assumed that the absorption of salt constituents is determined wholly by plant needs. A plant may absorb such salt constituents as chlorides and sulphates to an extent that certain of its growth processes are impaired as a result of chemical effects. Yet it is obvious that if the growth processes are to be carried on the plant must absorb water from the soil solution, and insofar as this absorption depends upon osmosis it is obvious that the osmotic concentration of the plant sap must be higher than that of the soil solution.

In sand cultures of mixed deciduous fruits and grapes maintained with a nutrient solution containing 1 p.p.m. of boron, the solution removed by the plants over a 21-day period was only 14 percent as concentrated in boron as that presented to the roots. In cultures maintained with a 6 p.p.m. boron nutrient solution the absorbed solution was 15 percent as concentrated as that presented. These same solutions each contained initially 3 millimoles per liter of magnesium sulphate, and a known amount was added with the water used to replace a part of the transpiration loss. In the low-boron and high-boron treatments cited, the solutions taken up by the plants were respectively 5 and 7 percent as concentrated in sulphates as were the solutions presented. In a culture with 9 p.p.m. of boron in which the grape was the predominating plant, the solution removed was 32 percent as concentrated in boron and 21 percent as concentrated in sulphate as that presented to the roots. With other solutions and other plants different percentages have been obtained, but those given are illustrative. The concentrations of the solutions removed by the plants were estimated from the known initial and end concentrations of the culture solutions and the quantity of water transpired.

The preceding discussion has been presented for the primary purpose of showing why it is not possible to set definite limits for the critical concentration of any of the common constituents of irrigation waters. Not only do the tolerances of different plants vary, but no fixed relationship can exist between irrigation-water concentrations and soil-solution concentrations, and it is the latter rather than the former which determines plant behavior. Notwithstanding these limitations, standards of reference are desirable, and when properly interpreted they are of value.

Chlorides in a water supply ordinarily cannot be expected to produce injurious effects of material consequence below a concentration of 4 or 5 milligram equivalents per liter, whereas some injury is generally certain above 8 or 10 m.e. Toxic effects from sulphates cannot ordinarily be expected from water containing less than 7 or 8 m.e., but they are highly probable above 20 m.e. The effects of chlorides and sulphates between these limits are relative to conditions and crops, and the limits are of only moderate significance, since outstanding exceptions might be noted. In view of the uncertainties occasioned by varied conditions, it is preferable to think of the quality of waters with respect to chlorides as being better as the chloride concentrations drop below 7 m.e. and poorer as they exceed it. For sulphates, 12 m.e. provides an equally suitable base.

The concentration of bicarbonate (HCO_3) in irrigation water is of secondary importance, and for practical purposes it may ordinarily be omitted from quality-of-water considerations. At one time bicarbonate was supposed to be as toxic as chloride or sulphate, but that view is not now generally held.

It is customary to regard the basic constituents of irrigation waters, i.e., the calcium, magnesium, potassium, and sodium, first in the light of their potential effects upon the physical character of soils. Different proportions and concentrations of these ions in the soil solution have effects also upon plant growth, but the information now available does not lend itself to field interpretation in terms of the quality of irrigation water, and for that reason the subject cannot be satisfactorily dealt with.

The ratio of alkali bases, i.e., sodium and potassium, to the alkaline earth bases, calcium and magnesium, is of particular significance, since upon this ratio the maintenance of permeability of soils to irrigation water is many times dependent. An impermeable soil not only provides an unsatisfactory seed bed and prevents good aeration but it takes water slowly and does not leach freely. An irrigation water of given salinity used in sufficient abundance may be entirely satisfactory on a permeable soil and yet render unproductive other soils that may not be adequately leached.

When sodium constitutes a large proportion of the bases of an irrigation water, similar relationships must ultimately exist in the soil (*32*). The rapidity with which such changes are brought about is contingent not only upon the proportion of sodium in the water and its concentration but likewise upon the proportions and amounts of replaceable calcium and magnesium and sodium in the exchange complex of the soil. In one section of the area here dealt with, where sodium is the predominant base in the irrigation waters, farmers recognize that such profit as is to be obtained from their land must be obtained during the first few years of irrigation. Yields of 30 sacks of barley the first year are followed by yields of 12 to 15 sacks the third year, and it is then necessary to let the land lie fallow for a year before it can be brought into sufficiently good tilth for a seed bed for a fourth crop.

Just as it was indicated as hazardous to set up well-defined limits of tolerance for salts in irrigation waters, so it is not yet possible to assign definite limits for sodium as a percentage of total bases in irrigation waters.

For each of the water analyses to be reported the alkali bases (sodium and potassium) are presented both in terms of concentration and also as percentages of total bases. Inasmuch as the analyses are set forth in milligram equivalents, it is largely immaterial whether these percentages are read as sodium as percentage of total bases or sodium salts as percentage of total salts. The inaccuracy occasioned by considering the total alkali bases as being sodium is not of great consequence, because the effect of potassium, which is rarely present in high concentrations, is regarded as being like that of sodium. Calcium and magnesium may be considered as nearly alike in their effects upon the soil. Waters carrying sodium to the extent of 65 percent of the total bases are looked upon as being of doubtful quality, waters with less than 50 percent as being wholly satisfactory in this regard, and those with more than 65 percent of sodium as presenting a progressively greater hazard as the percentage increases. But with this interpretation it must be recognized that water very low in total salinity, even though sodium predominated, might be used for many years on a soil high in calcium carbonate or in adsorbed calcium and magnesium.

Gypsum, sulphur, or the salts of iron and aluminum (*24*) are sometimes used successfully for the improvement of soil structure and for promoting reclamation where impermeability is serious. The gypsum equivalent of 1 m.e. of calcium per liter is 234 pounds per acre-foot of water. If water with 69.2 percent of sodium has, for example, 4 m.e. of calcium and magnesium combined and 9 m.e. of alkali bases, the difference in the sums of the alkali bases and the alkaline earth bases is 5 m.e. per liter. To give equal proportions of alkali bases and alkaline earth bases in such water it would be necessary to add to each acre-foot of water 1,170 (5×234) pounds of gypsum. To reduce the alkali-base concentration to 60 percent of total bases 468 (2×234) pounds of gypsum would be required. If the alkaline earth bases exceed the alkali bases, the gypsum equivalent of the excess calcium and magnesium can be computed in a similar manner.

Apprehension exists in the minds of a few growers and agricultural advisers that gypsum taken from deposits in regions where the waters have been found to carry substantial concentrations of boron might likewise be contaminated. Boron determinations have been made on 8 samples of gypsum, 5 of which were collected near Panoche Creek southwest of Mendota, 2 from Lost Hills, and 1 from Imperial Valley. One of these samples showed no boron, 2 had 22 p.p.m., and the average of the 8 was 8.4 p.p.m. The results obtained from the 8 samples do not constitute evidence that boron compounds are never deposited with gypsum, but indicate that there is no particular reason for suspecting such contamination. Ten tons of gypsum containing 22 p.p.m. of boron would add to the soil but 0.4 pound of boron, or approximately the amount added by 1 acre-foot of water containing 0.16 p.p.m. of boron.

The specific electrical conductance, $K \times 10^5$ at 25° C., as given for each of the water analyses, provides an index of the total salinity of the water comparable to that provided by total solids, but neither measurement indicates the nature of the ions present. Waters with conductances below 75 will not ordinarily contain a sufficient concentration of any of the common ions to produce injurious effects, but between conductances of 75 and 150 uncertainty must exist in the absence of chemical analysis. An electrical conductance above 200 is definitely significant of a poor water, although sulphate waters high in calcium and magnesium with conductances above 300 have been used profitably for long periods.

INTERPRETATION OF ANALYSES OF IRRIGATION WATERS

The common mineral constituents of natural waters may be divided into two groups, namely, those existing in ionic forms with definite chemical affinities for other constituents, and those held in suspension as molecular aggregates possibly in the colloidal state. The latter group probably includes a portion of the silica, and oxides of iron and aluminum. Natural waters contain in addition dissolved gases, chiefly oxygen, nitrogen, carbon dioxide, and not infrequently hydrogen sulphide or sometimes hydrocarbons. The concentrations of these colloidal and gaseous constituents have been determined in this work in only a few instances, and these determinations are not given in the analyses that follow in this bulletin. The constituents of the other group, the ionic group, are of two kinds, (1) the positively charged bases, principally calcium, magnesium, sodium, and potassium, and (2) the negatively charged acid radicals, principally carbonate, bicarbonate, chloride, sulphate, and nitrate. The several constituents of each kind have different but definite capacities for reacting with or holding in solution the constituents of the other kind. The two kinds of constituents in a water are always in chemical equilibrium; that is, the sum of the milligram equivalents (or reacting values) of the positive radicals is always equal to the sum of the milligram equivalents of the negative radicals.

An analysis that includes only the ions mentioned is never complete, for in practically all natural waters other chemical substances are present. These other elements, or radicals, which may be of widely varied character, are usually present in low concentrations, and their identification and accurate estimation is often difficult or may require special apparatus, and they are not determined in the ordinary chemical analysis. Boron belongs among these secondary substances. Formerly it was rarely included in an analysis of agricultural water or soil, since its agricultural significance was not appreciated. Only recently have accurate analytical methods for the estimation of boron in very low concentrations been developed.

ANALYSES OF WATERS OF THE SAN JOAQUIN VALLEY

In the following pages are reported the analyses of approximately 450 water samples from streams and wells of the San Joaquin Valley. The samples were collected and analyzed primarily to determine to what extent boron occurs as a natural constituent of the surface and underground waters in the area. The waters examined were for the most part irrigation waters. Some other waters not then used for irrigation but which had been used and abandoned or which might at some time be developed for agricultural use were also collected, and some additional samples were examined, particularly those of foothill streams, wells, or springs, because of the implications afforded with respect to the quality and source of valley waters.

Within the area drained by the San Joaquin River and its tributaries there are 2,405,308 acres of irrigated land (approximately one-half of the total irrigated acreage of California) and an additional 1,157,322 acres which are reported as of 1929 as capable of being supplied with water by existing irrigation enterprises (*38*). Extensive areas underlain with water-bearing sands have been developed only in part.

Boron occurs in higher concentrations in the waters of some regions than in others. It was anticipated that the data resulting from the survey would serve a general purpose by indicating in which portions of the valley boron should receive particular attention in extending agricultural developments and to what extent agricultural problems in developed portions of the valley were attributable to high boron concentrations. The analyses here presented are limited in number and are expected therefore to serve only as guides in these matters, and this function was in view when the work was undertaken. Insofar as the results may direct attention to the importance of boron as a potentially toxic constituent of irrigation waters and so stress the desirability of examining waters for this constituent, the work will have accomplished an additional purpose. Such constituents as chlorides and sulphates have long received serious consideration in the utilization of irrigation waters, but only recently has attention been directed toward the frequent occurrence of boron in irrigation waters and the highly toxic effects upon plants that result from relatively small concentrations.

Boron has been found to be present in each of some 4,000 surface and underground waters so far examined by the Division of Western Irrigation Agriculture in the western portion of the United States. In some of these waters its concentration has been sufficiently high to inhibit the growth of irrigated plants, and in others so low that its presence was demonstrated only by special methods.

The analyses of the San Joaquin Valley waters were not limited to boron determinations but included also determinations of bicarbonate, chloride, sulphate, calcium, magnesium, and alkali bases.

Following the analytical tables and sample descriptions the general characteristics of the waters of different portions of the valley are briefly discussed. For each of the smaller geographical units into which the valley was subdivided for purposes of presentation a more detailed description of the water supplies has been undertaken.

In the preceding pages it has been emphasized that attention should be given to the percentage of sodium in irrigation waters. In the last column of each table of analyses the sodium percentage in each of the samples has been calculated, and the significance of these figures cannot be overemphasized. Their calculation and inclusion in reports of water analyses represent a new departure which it is believed should be generally adopted. The writer has found the concept to be one of great importance in the area studied.

COLLECTION OF SAMPLES

Not all of the water supplies sampled in the area covered by this report have contained appreciable concentrations of boron, and relatively few samples have been collected east of the trough of the valley. The east side of the valley is the most highly developed and is of the greatest agricultural importance for the reason that the quantity of water derived from the Sierra greatly exceeds that derived from the eastern watershed of the coastal mountains. The west side of the valley has received the greater attention in this work, since both preliminary and later observations and collections indicated that boron occurred in appreciable amounts in many of the west-side wells, whereas except for areas in the south end of the valley, little or no evidence of boron injury resulting from the use of water from streams or wells east of the valley trough has been found.

In undertaking the work a general rather than a detailed survey was contemplated, and an effort was made to collect representative samples over the entire west-side area. Nevertheless, more samples were collected in areas where boron contamination was thought to be local and where marked differences were indicated in the quality of the water of neighboring wells or in the different water-bearing strata. More numerous samples were sometimes collected at the solicitation and with the cooperation of property owners when the problem of water quality was thought to be of immediate economic concern.

It has been possible for the writer to collect personally the greater number of the samples, but when any were collected by others the name of the collector is given. For the most part and insofar as practicable, sample collections were confined to the summer or early fall, for it is during the latter part of the season that the effect of boron in irrigation water upon crops is most clearly indicated. Detailed notes on plant reactions for comparison with the subsequent analytical results were regularly taken. The interpretations of the significance of boron concentrations in irrigation water in the different parts of the valley (p. 27) were based upon these observations and upon the severity of symptoms and associated reduction in growth of plants grown experimentally at the Rubidoux Laboratory.

EXPRESSION OF ANALYTICAL RESULTS

At one time nearly all water analyses in other than purely chemical papers were reported as grains per gallon. Parts per million later came to be the more popular unit and is still ordinarily used. In this work it has been elected that the analyses should be reported in milligram equivalents per liter, the reason being that concentrations so expressed more clearly portray the chemical composition of a water, and the analyses so reported most readily lend themselves to agricultural interpretation.

Parts per million is a gravimetric expression which sets forth the weight of a given constituent in a given weight of water, whereas by milligram equivalents a statement is made of the number of ions of each constituent present. The essential difference between the two forms of expression may be simply illustrated by assuming an aquarium containing various kinds of fish. If it is stated that there are so many pounds of each kind of fish in a million pounds of water, the analysis of the population has been expressed in parts per million.

By stating that there are so many of each kind of fish in a given volume of the aquarium, a form of census is adopted which is comparable to that used when the concentrations of the various ions in a water are expressed in milligram equivalents. In other words, the one form of expression concerns itself with the mass of the different constituents and the other with the number of chemical units.

In chemical terms a solution containing 1 milligram equivalent per liter of any ion is one one-thousandth normal with respect to that ion. If water is added to 1 gram of sodium chloride (common salt) to make a liter of solution, that solution contains 393.4 p.p.m. of sodium and 606.6 p.p.m. of chloride. This same solution contains 17.1 m.e. per liter each of sodium and chloride.

If gypsum is added to a water, the numbers of calcium and sulphate ions are increased equally, but gravimetrically the concentrations are increased in the proportion of 20 p.p.m. of calcium and 48 p.p.m. of sulphate. Likewise in base exchange considerations, if sodium of a water exchanges places with calcium of the soil it does so equivalent for equivalent, but gravimetrically expressed in the proportion of 23 p.p.m. of sodium for 20 p.p.m. of calcium.

Boron is expressed in parts per million because its concentration is normally too low to require consideration in the balancing of ions, and the nature of the ion or ions in which it occurs is not known; also, if boron concentrations were expressed in milligram equivalents the concentrations frequently found would lie in the third decimal place, which would make verbal discussion awkward.

The concentration of any ion expressed in milligram equivalents per liter may be converted to parts per million by multiplying by the factor that results when the atomic weight of the ion is divided by its valence. The factors for a number of the common ions are as follows:

Ion	*To convert milligram equivalents to parts per million multiply by—*
Bicarbonate (HCO_3)	61.0
Chloride (Cl)	35.5
Sulphate (SO_4)	48.0
Nitrate (NO_3)	62.0
Calcium (Ca)	20.0
Magnesium (Mg)	12.2
Alkali bases (by difference, as sodium)	23.0
Total hardness (as $CaCO_3$), take sum of calcium and magnesium and multiply by	50.0

To convert parts per million to grains per gallon, multiply by 0.0584; or to convert grains per gallon to parts per million, multiply by 17.12. To convert parts per million to pounds per acre-foot of water, multiply by 2.72.

The specific electrical conductance (K) is the reciprocal of the resistance in ohms offered by a water to the passage of electricity between two electrodes of standard dimensions and spacing. For convenience of expression the decimal is moved five places to the right; thus, $K \times 10^5 = 129$ is the same as $K = 0.00129$. Electrical conductivity, being a function of the number and nature of ions in solution, is more directly related to the sum of ions expressed in milligram equivalents than are values for total solids which represent the weight of all ions in a given volume of solution. The electrical conductance of a solution increases with temperature, and for that reason the temperature at which a conductance measurement is made must be stated. In this work all conductance determinations have been reported as at 25° C. The total salt content in parts per million of some ordinary waters can be estimated approximately from conductance values by multiplying the conductance by 6 if it is less than 100 or if chlorides predominate, and by 7 if the conductance is over 100 or if sulphates predominate. A conductance of 100 is roughly equivalent to 1 ton of salt per acre-foot of water.

The boron concentration is expressed as parts per million of elemental boron in the solution. Two places to the right of the decimal are reported, but full confidence in the second of these is not implied. The titrating solution used in the Wilcox modification (*41*) of the Chapin method was of such concentration that 0.05 milliliter of it was equal to 0.01 p.p.m. of boron in aliquots of the size used. While the error of such a burette reading is not great, there are other sources of error in the process of analysis.

Carbonate and bicarbonates (CO_3 and HCO_3) are reported together in the analyses because very few water samples contain appreciable amounts of normal carbonate and the equilibrium between carbonates and bicarbonates is influenced both by temperature and aeration either before or after sampling.

The alkali bases are assumed to include sodium and potassium, but neither of these elements has been directly determined in the greater number of analyses. The values reported in the tables were obtained by the customary procedure of adding together the milligram equivalents of bicarbonate, chloride, and sulphate and from that sum subtracting the sum of calcium and magnesium. In nearly all waters sodium greatly exceeds potassium, and for all practical purposes the quantity of alkali bases reported can be interpreted as sodium.

The percentage of alkali bases (sodium principally) of the total of all bases (calcium, magnesium, sodium, potassium) has been calculated for each analysis and is designated in the final column of the tables as "percent sodium".

METHODS OF ANALYSIS

The chemical analyses herein reported were made by L. V. Wilcox, Vladimir Sokoloff, and Francis C. Scofield, all of the Division of Western Irrigation Agriculture of the Bureau of Plant Industry. The procedures in brief were as follows:

Conductance.—The specific electrical conductances were determined at 25° ± 0.1° C. by the conventional procedure and with the usual apparatus, which in this case consisted of a Wheatstone bridge of the slide wire type, batteries, 1,000-cycle microphone hummer, and suitable electrode vessels either of the pipette or the immersion type. The pipette electrode had a cell factor of about 0.30 and the immersion type about 1.30. The electrode vessel was standardized each time of use and always rinsed with a duplicate sample at the same temperature before each reading.

Boron.—Up to and including sample no. 4500, the boron determinations were made by the Wilcox modification (*41*) of the Chapin method. Subsequent to that number the determinations were made by the electrometric titration method (*42*).

Carbonate and bicarbonate.—The carbonate and bicarbonate ions were titrated with 0.05 normal sulphuric acid, phenolphthalein indicator being used for the carbonate ion and methyl orange indicator for the bicarbonate ion (*2, p. 93*). Aliquots of 50 milliliter were titrated with 0.05 normal acid, so that a burette reading of 0.05 corresponded to 0.05 milligram equivalents.

Chloride.—To the neutral solution resulting from the carbonate-bicarbonate titration, 1 cc of potassium chromate indicator was added. Chloride was then titrated with 0.05 normal silver nitrate solution. This is the official method.

Sulphate.—Sulphate was determined gravimetrically as barium sulphate from a 200-cc aliquot. The official method was followed except that silica was not removed prior to the precipitation of the barium sulphate. The relatively small amount of silica does not interfere so long as the volume is not evaporated below 75 to 100 ml. The calcium sulphate, anhydrous, equivalent of the sulphate ion may be computed in parts per million by multiplying the sulphate concentration by 68.

Calcium.—The calcium ion in all samples bearing numbers above 767 was precipitated as calcium oxalate and titrated with permanganate (*5*). Calcium and magnesium, in the few samples carrying serial numbers of 767 or below, were separated and determined by the Winkler modification of the Clark soap method, as reported by Grittner (*15, p. 347*).

Magnesium.—Through sample no. 2300, magnesium was determined by the soap method (see calcium). Subsequent to sample 2300, magnesium was determined by precipitation as magnesium ammonium phosphate, which was ignited and weighed as the pyrophosphate.

Alkali bases.—The amount of alkali bases, sodium and potassium, was estimated in nearly all of the analyses without direct determination by subtracting the sum of the calcium and magnesium ions from the sum of the acid radicals.

Sodium percentage.—The expression "percent sodium" takes into account the ratio of the sodium content to the sum of the calcium, magnesium, and the alkali bases, the concentrations of all three constituents being expressed in terms of milligram equivalents. In other words, the percentage of sodium is obtained by dividing the sum of the milligram equivalents of calcium, magnesium, and alkali bases (*AB*) into the figure for the alkali bases and pointing off two places to the left, according to the following formula:

$$\text{“Percent sodium”} = \frac{AB \times 100}{\mathrm{Ca} + \mathrm{Mg} + AB}$$

METHOD OF PRESENTING ANALYTICAL DATA

For the presentation of the analytical data of this report and the orderly arrangement of office records the area here dealt with has been subdivided into quadrangles of uniform size. Each of these quadrangles embraces an area 18 miles wide in an east and west direction by 24 miles long from north to south and includes therefore 12 townships. Except for portions of the valley floor adjacent to the Sierra Nevada, all of the San Joaquin Valley is included in one or another of 35 of these quadrangles. A sketch map of each quadrangle has been prepared. Where a representative number of samples were collected in any one, the map has been reproduced facing or adjacent to the corresponding table of analyses. The locations of the sources of the samples are shown on the maps by numerals which appear also in the first column in the tables of analyses. Samples representing surface waters are identified by a letter S placed adjacent to the location number on the quadrangle maps and following the location number in the tables of analyses. Following each table of analyses there is given a brief description of each of the samples.

A key map (fig. 2) is provided, which designates by township and range as well as by number the respective locations in the valley of the area embraced in each quadrangle. Townships and ranges of quadrangles 1 to 32, inclusive, are referenced to the Mount Diablo meridian and base line, and those of quadrangles 33 to 35 to the San Bernardino meridian and base line.

The quadrangle maps show with a fair degree of accuracy the locations of the important towns and streams and a little of the locations of lines of foothills; they are intended, however, to be diagrammatic rather than precise, and all are drawn on a common base sketch of townships and sections. A part of the area is unsurveyed, and where surveyed the sections and townships are frequently not of regular shape. Certain samples were taken in unsurveyed territory, and these are located on the maps in terms of section, township, and range by projecting township and section lines into unsurveyed territory; but inaccuracies necessarily accompany such procedure.

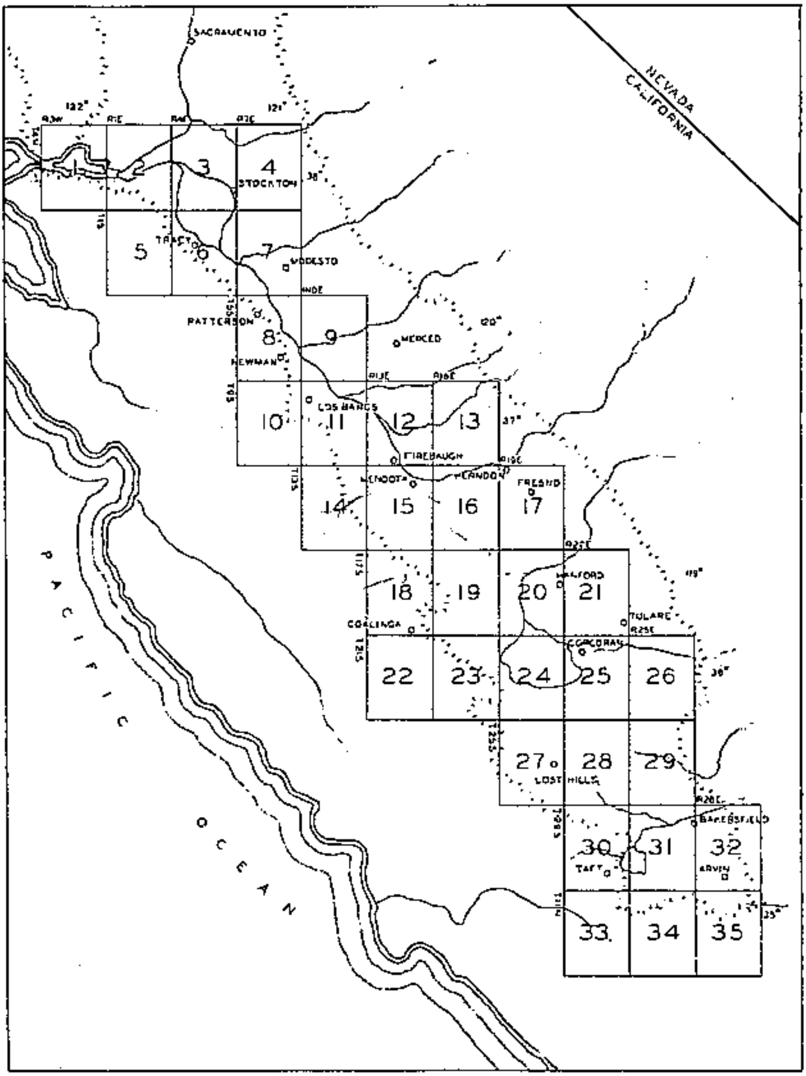

FIGURE 2.—Key map showing locations of areas embraced in the numbered quadrangle maps and the corresponding tables.

Where many samples are reported from areas as large as the 432-section quadrangles here used, it is difficult for the reader to visualize conditions by transposing the data of the tables of analyses and location descriptions to their map positions. A detailed chemical analysis is essential to the adequate description of a water supply, but in the economic application of such analyses certain features are of greater importance than others. In formulating general conclusions with respect to the quality of water in an area it is convenient to adopt a system of group classification in order to clarify the major features. For the purposes here to be served, use is made of a trinomial exponent placed adjacent to each of the location numbers. Each of the figures of this trinomial exponent refers to a characteristic of the water sample. The first figure refers to the specific electrical conductance, the second to the concentration of boron, and the third to the percentage of sodium. The actual concentrations of these constituents are not represented, but instead a group classification is made on the basis of a scale of 1 to 5 for each of the three characteristics. The scale used for each is shown in table 8.

TABLE 8.—*Key to group classification of water samples with regard to specific electrical conductance, boron content, and sodium percentage, as represented by trinomial exponents shown on quadrangle maps*

Class	Conductance ($K \times 10^5$ at 25° C.)	Boron	"Percent sodium"
		P.p.m.	
1	Less than 25	Less than 0.25.	Less than 20.
2	25 to 74.9	0.25 to 0.74	20 to 39.
3	75 to 149.	0.75 to 1.49	40 to 59.
4	150 to 299.	1.50 to 2.99	60 to 79.
5	300 and above	3.00 and above	80 and above.

A water having, for example, a conductance of 36, a boron content of 1.80 p.p.m., and a sodium percentage of 19 would be designated as 241. The classification is in part arbitrary, but it is clear that a water designated as 111 would be regarded as excellent, whereas a water designated 555 would be unsuitable for agricultural use. A water designated 533 might be used profitably under some conditions, whereas a 355 water would be expected in the end to cause the soil to become hard and impermeable with a tendency to accumulate toxic concentrations of salt in the soil solution.

If conductances are high, waters high in sodium are preferred for industrial or domestic use to those high in calcium and magnesium; but for agricultural use it is important that the sodium should be low relative to calcium and magnesium. For practically all purposes a water of low conductance, i.e., low total salinity, is preferable to one of high conductance. Boron concentrations too high for agricultural purposes may have little or no significance in waters used for domestic purposes, since there is no evidence that either people or animals would be adversely affected by the boron concentrations such as were found in the waters of the San Joaquin Valley.

ANALYTICAL DATA

The analytical data are presented in tables 9 to 39 and in the accompanying descriptions of samples, all arranged by quadrangles corresponding to the maps (figs. 3 to 32).

TABLE 9.—*Quality of water in quadrangle 1, Tps. 1, 2, 3, and 4 N., Rs. 1, 2, and 3 W. (fig. 3)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium" [1]
					CO_3+ HCO_3	Cl	SO_4	Ca	Mg	Alkali bases [1]	
				P.p.m.							
1	5062	Oct. 21, 1931	818	53.3	11.30	68.95	0.39	11.60	8.64	60.40	86
2	4571	July 10, 1931	89.9	.46	4.90	3.10	.72	3.26	3.61	2.15	24
3	4572	do	78.9	.33	5.10	1.45	2.03	3.62	1.37	3.60	42
4	4570	do	84.7	.22	4.65	2.10	1.22	2.87	3.60	1.95	23
5	6232	May 17, 1932	136	2.36	9.00	3.10	1.67	.33	.37	13.07	95
6	6230	do	78.4	3.93	6.05	1.30	.24	2.45	4.24	1.82	21
7	6231	do	80.4	1.62	4.50	2.40	1.55	2.14	3.13	3.22	38
8	6213	May 20, 1932	93.9	1.30	6.70	1.55	.81	3.63	3.26	2.89	30
Miscellaneous [2]	6230	May 18, 1932	44.0	.65	3.06	1.25	T [3]	1.14	.98	2.26	52
Do	6235	May 17, 1932	71.8	.66	6.55	.75	.44	3.19	2.72	1.83	24

[1] For method of computation see p. 39.

[2] Outside of quadrangle; included for convenience.

[3] T=trace.

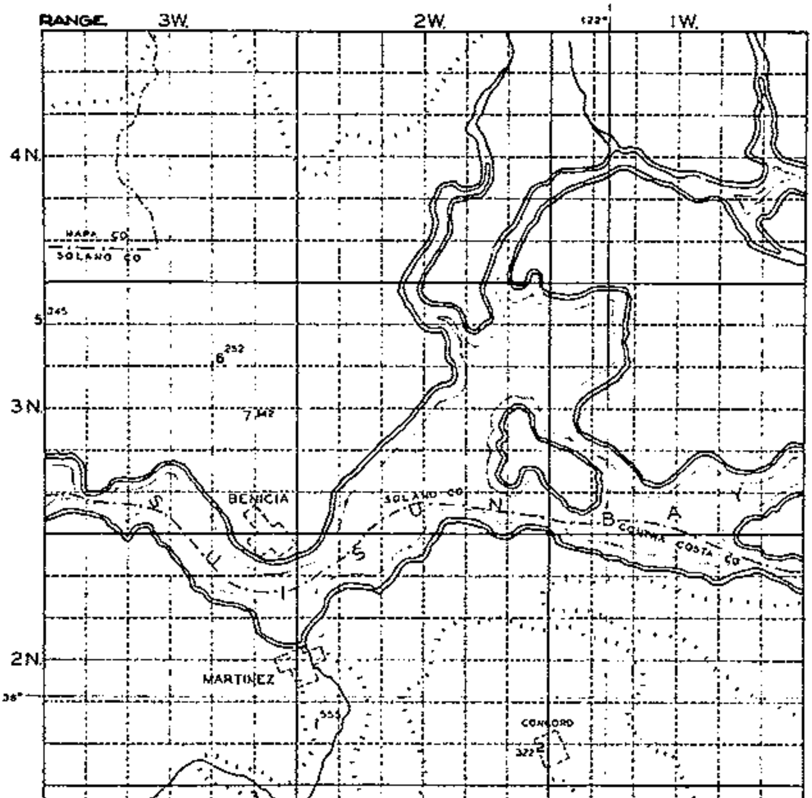

FIGURE 3.—Quadrangle 1, showing locations of samples reported in table 9.

DESCRIPTIONS OF SAMPLES OF QUADRANGLE 1 (TABLE 9 AND FIG. 3)

Location 1, sample 5062. F. W. Haag ranch, Martinez. Location corresponds to NE corner of SW¼ sec. 30, T. 2 N., R. 2 W. Depth about 40 feet. Collected by F. W. Herbert.

Location 2, sample 4571. Concord. Mrs. Amanda Smith, domestic well. Depth, 120 feet; static level, 80 feet.

Location 3, sample 4572. Alhambra Springs. Location corresponds to NW¼ sec. 1, T. 1 N., R. 3 W. Four springs discharging 10,000 gallons per day. Temperature, 60° F.

Location 4, sample 4570. Clayton. A. C. Trette well. NE¼ sec. 14, T. 1 N., R. 1 W. Depth, 70 feet.

Location 5, sample 6232. A. Garibaldi irrigation well. SE¼ sec. 1, T. 3 N., R. 4 W. An old oil well drilled to 2,700 feet, now partly caved in. Casing diameter, 3 inches; discharge, 0.04 cubic foot per second; temperature, 72° F.; some gas. Collected by V. W. De Tar.

Location 6, sample 6230. Sulphur Spring at mouth of Hastings Mine. SW¼ sec. 11, T. 3 N., R. 3 W. Discharge, 0.22 cubic foot per second; temperature, 73° F.; slight odor; discharge flows into Lake Herman, from which Benicia municipal supply is drawn. Collected by V. W. De Tar.

Location 7, sample 6231. Lake Herman. NE¼ sec. 23, T. 3 N., R. 3 W. Benicia municipal supply, with minor use for irrigation. In part from above-mentioned sulphur spring. Collected by V. W. De Tar.

Location 8, sample 6213. Bancroft ranch well, Ygnacio Valley. Approximately 3¾ miles south of Concord and 1 mile southwest of Whitman. Collected by R. E. Goble.

Miscellaneous sample 6239. Ralph Mason irrigation well. NE¼ sec. 35, T. 5 N., R. 3 W. 10-inch casing; depth, 134 feet; upper perforations, 20 feet; discharge, 0.7 cubic foot per second. Bailed sample, motor not operating. Collected by V. W. De Tar.

Miscellaneous sample 6235. J. B. Danielson irrigation well. NE¼ sec. 32, T. 5 N., R. 2 W. Depth, 180 feet; discharge, 0.33 cubic foot per second; temperature, 63° F. Collected by V. W. De Tar.

TABLE 10.—*Quality of water in quadrangle 2, Tps. 1, 2, 3, and 4 N., Rs. 1, 2, and 3 E. (fig. 4)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"[1]
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases[1]	
				P.p.m.							
1	4568	July 10, 1931	74.5	1.50	5.45	1.15	1.20	0.31	0.32	7.17	92
2	4565	....do........	40.0	.24	2.05	1.20	.21	.59	.71	2.76	68
	4566	....do........	297	1.44	4.00	23.40	.10	3.77	4.40	10.33	70
	4564	....do........	160	1.24	4.85	9.75	.43	1.56	2.06	11.41	76
3	4560	....do........	212	.81	6.50	4.30	12.97	6.12	5.22	12.40	52
4	2051	June 24, 1930	122	.43	5.50	1.85	5.61	3.56	3.34	6.05	47
5	2050	....do........	233	.39	6.75	5.30	13.62	4.04	7.38	14.25	50
6	2049	....do........	92.1	1.12	4.60	2.20	2.56	3.04	2.34	3.08	43
7	6202	May 20, 1932	84.1	.54	2.90	3.75	1.43	2.92	2.00	3.21	39
8	6204	....do........	113	1.48	4.50	4.55	2.39	3.79	2.81	4.90	43
9	6206	....do........	146	2.65	6.30	5.20	3.52	4.40	3.52	7.30	48
10	6203	....do........	103	1.29	5.10	3.15	2.34	3.83	3.05	3.67	36
11	6205	....do........	83.2	1.01	3.05	3.00	.97	2.93	1.02	3.14	39
12	6209	May 24, 1932	130	2.36	5.75	5.40	3.05	4.30	3.73	6.31	44
13	6208	....do........	141	2.20	5.60	5.55	3.38	4.27	3.73	6.59	45
	6210	May 27, 1932	136	2.34	5.40	5.35	3.33	3.92	3.74	6.42	46
14	5327	Oct. 28, 1931	114	2.16	5.68	3.90	2.17	3.90	2.90	5.06	43
15	5328	....do........	130	2.43	5.47	5.30	3.02	4.21	3.77	6.05	43
16-S	6212	Apr. 29, 1932	32.0	.34	1.30	1.15	.59	.57	.87	1.30	43
17	6207	May 20, 1932	141	3.27	5.45	5.55	3.34	3.72	3.59	7.07	49

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[1] For method of computation see p. 38.

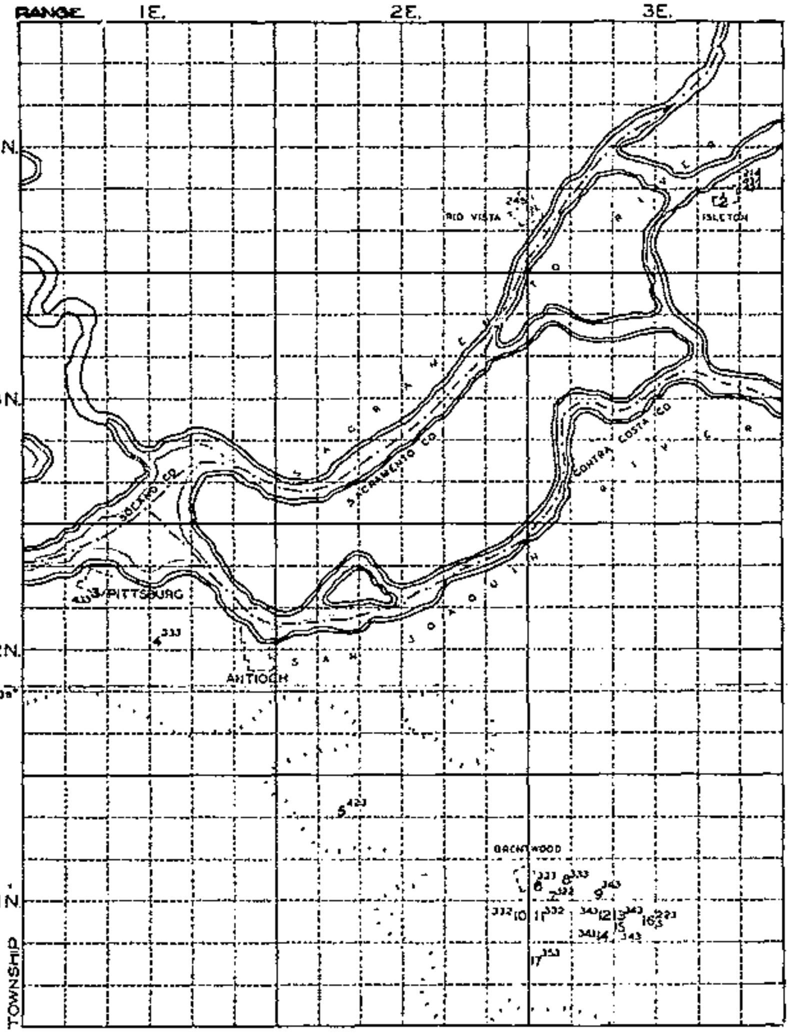

FIGURE 4.—Quadrangle 2, showing locations of samples reported in table 10.

DESCRIPTION OF SAMPLES OF QUADRANGLE 2 (TABLE 10 AND FIG. 4)

Location 1, sample 4568. Rio Fista municipal well; L. P. Gardiner, owner. Depth, approximately 250 feet.

Location 2, sample 4565. Isleton municipal, for fire emergency. Depth, 130 feet; 4-inch casing not perforated; water stands at 10 feet.

Location 2, sample 4566. Isleton municipal; L. P. Gardiner, owner. Seldom used because of sanding. Depth, 211 feet; 12-inch casing not perforated; water stands at 40 feet.

Location 2, sample 4564. Isleton municipal; L. P. Gardiner, owner. Depth, 615 feet; 10-inch casing not perforated; water stands at 60 to 70 feet. Approximately 70 feet from Sacramento River.

Location 3, sample 4569. Pittsburg municipal plant. Three wells 250 feet deep, perforated below 60 feet.

Location 4, sample 2951. Los Medanos Station, Standard Oil Co. Composite of three wells 157 to 171 feet deep, all perforated below about 140 feet.

Location 5, sample 2950. J. G. Pewetter, section 5, stock well. Center S½ sec. 5, T. 1 N., R. 2 E. Depth, about 30 feet.

Location 6, sample 2949. Brentwood municipal well. Depth, 180 feet.

Location 7, sample 6202. Balfour Guthrie Co. well. SW¼ sec. 18, T. 1 N., R. 3 E. Depth, 127 feet; static level, 45 feet; draws down to 93 feet; 12-inch casing perforated entire length. Collected by R. E. Goble.

Location 8, sample 6204. East Contra Costa Irrigation District. Drainage well on lateral 4. SW¼ sec. 19, T. 1 N., R. 3 E. Depth, 50 feet; static level, 12 feet; 16-inch casing. Collected by R. E. Goble.

Location 9, sample 6206. W. W. Collis well. SE¼ sec. 17, T. 1 N., R. 3 E., on Balfour Road. Depth, 48 feet; static level, 15 feet; casing diameter, 8 inches. collected by R. E. Goble.

Location 10, sample 6203. Balfour Guthrie Co. well. Brentwood irrigated farms, lot 50. NE¼ sec. 24, T. 1 N., R. 2 E. Depth, 116 feet; static level, 46 feet; draws down to 18 feet; irrigates 90 acres. Collected by R. E. Goble.

Location 11, sample 6205. R. B. Crawford well. Brentwood irrigated farms, lot 5. NW¼ sec. 19, T. 1 N., R. 3 E. Collected by R. E. Goble.

Location 12, samples 6209 and 6211. East Contra Costa Irrigation District, drainage well. SW¼ sec. 21, T. 1 N., R. 3 E. Collected by R. E. Goble.

Location 13, samples 6208 and 6210. East Contra Costa Irrigation District. Drainage well on main canal. SW¼ sec. 21, T. 1 N., R. 3 E. Collected by R. E. Goble.

Location 14, sample 5327. Andrew Davis, Jr., domestic well. Center south line SE¼ sec. 20, T. 1 N., R. 3 E. Depth, 50 feet; static level, 10.5 feet; draws down to 16 feet; discharge, 0.15 cubic foot per second. Casing extends through clay stratum excluding surface water and is not perforated. Collected by R. E. Goble.

Location 15, sample 5328. Andrew Davis, Jr., drainage well. Near NW corner SW¼ sec. 21, T. 1 N., R. 3 E. Depth, 35 feet; discharge, 1.5 cubic feet per second.

Location 16, sample 6212. East Contra Costa Irrigation District, main canal. Near W¼ corner sec. 21, T. 1 N., R. 3 E. Collected by R. E. Goble.

Location 17, sample 6207. H. P. Garin Co. well no. 5. Near SW corner NW¼ sec. 30, T. 1 N., R. 3 E. Depth, 600 feet; static level, 125 feet. Collected by R. E. Goble.

TABLE 11.—*Quality of water in quadrangle 3, Tps. 1, 2, 3, and 4 N., Rs. 4, 5, and 6 E. (fig. 5)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	4562	July 10, 1931	45.8	1.06	4.45	0.45	T [1]	0.79	0.35	3.76	77
2-S	4560	do	6.41	.06	.55	.05	0.03	.30	.11	.22	35
3	4559	do	28.2	.08	2.15	.30	.20	1.09	1.08	.51	19
4	3416	Oct. 13, 1930	176	.12	1.05	14.35	T	4.06	2.13	9.21	60
5	4543	July 8, 1931	32.2	.10	2.80	.36	.21	1.17	.80	1.40	42
6	4544	do	39.4	.16	2.70	.55	.42	1.80	1.26	.84	21
7	4542	do	35.5	.06	3.15	.55	.03	.32	.17	3.24	87
8	4539	do	971	2.40	1.65	92.50	T	26.11	13.01	55.03	58
9	2914	June 24, 1930	24.9	.20	2.20	.20	.12	.38	.44	1.70	67
	3454	Oct. 21, 1930	22.7	.05	1.75	.05	.01	.57	.51	.73	40
	3692	Jan. 19, 1931	23.7	.07	1.90	.20	.03	.50	.31	1.32	62
	4540	July 8, 1931	23.9	.14	2.30	.25	.04	.48	.40	1.71	66
	3417	Oct. 13, 1930	27.2	.36	2.70	.25	.06	.22	.24	2.55	85
	3529	Nov. 4, 1930	27.5	.37	2.55	.25	.05	.77	.25	1.83	64
10	4545	July 8, 1931	1,258	2.58	1.15	121.50	.04	43.42	11.72	67.55	55
11	4546	do	140	1.18	3.35	9.35	.01	1.82	1.60	9.30	73
12	4541	do	62.0	.83	3.45	2.80	.08	1.15	.88	4.31	68
13	4547	do	72.0	.38	3.00	3.90	.06	2.14	1.25	3.60	52
Miscellaneous [2]	4563	July 10, 1931	47.8	.95	4.00	.40	T	.35	T	4.05	93

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[1] T=trace.

[2] Outside of quadrangle; included for convenience.

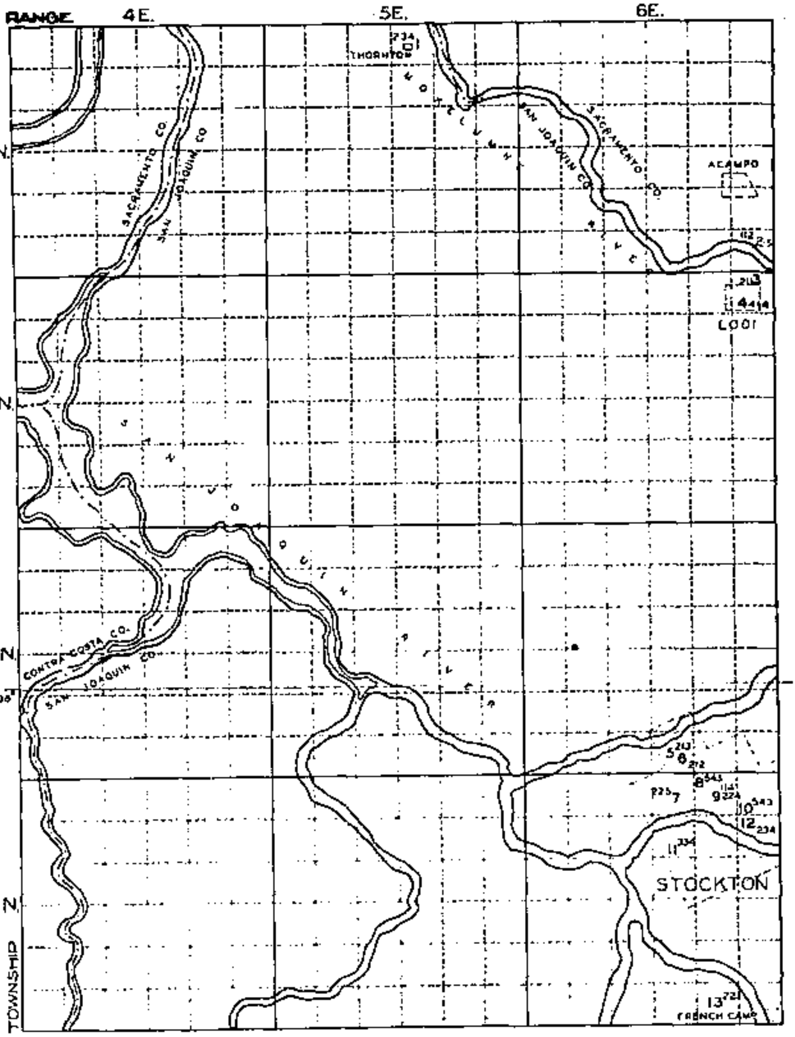

FIGURE 5.—Quadrangle 3, showing locations of samples reported in table 11.

DESCRIPTION OF SAMPLES OF QUADRANGLE 3 (TABLE 11 AND FIG. 5)

Location 1, sample 4562. Western Pacific depot, Thornton. Depth, 280 feet; 14-inch casing.

Location 2 S, sample 4560. Mokelumne River, near Lodi.

Location 3, sample 4559. Vita Fruit Products Co. well, approximately 1 mile north of Lodi. Depth, 150 feet.

Location 4, sample 3416. Lodi municipal well. Used for bath house. Depth, 1,000 feet; temperature, 68° F.; high gas content; formerly flowing, now operated by small pump. Collected by C. S. Scofield.

Location 5, sample 4543. Stockton municipal. California Water Service Co. plant no. 4, at Ellis Street, two blocks west of North Center Street. Depth, 533 feet.

Location 6, sample 4544. Shallow domestic well. East Geary and North Center Streets; near sample 4543. Depth, 101 feet; static level about 75 feet.

Location 7, sample 4542. Stockton municipal. California Water Service Co., plant no. 2, at Monroe and Poplar Streets. Composite of three wells, each about 700 feet deep.

Location 8, sample 4539. Gas well at Hunter Street and Harding Way. Pacific Gas & Electric Co. Water supplies high-school plunge. An old well drilled to 2,900 feet. Temperature, 88° F.

Location 9, samples 2944, 3454, 3692, 4540. Stockton State Hospital, 1,000 block, North California Street. Depth, 594 feet; discharge, 1,000 gallons per minute; temperature, 64° F.

Location 9, samples 3417, 3529. Stockton State Hospital, new well. Depth, 624 feet; discharge, 2 cubic feet per second.

Location 10, sample 4545. Gas well, Wilson Way and Minor Avenue. Depth, 3,300 feet; temperature, 96° F. Serves Olympic Baths.

Location 11, sample 4546. Fibreboard Products, Inc., Stockton, West Church Street, one-quarter mile west of Lincoln Street. Well no. 2. Depth, 1,040 feet; perforated below 233 feet; water stands at 21 feet.

Location 12, sample 4541. Stockton municipal. California Water Service Co., plant no. 1, at East Sonora Street and Wilson Way. Composite of eight wells; depth, 670 to 1,070 feet; none perforated above 200 feet; discharge, each, 2.2 cubic feet per second.

Location 13, sample 4547. San Joaquin County Hospital, one-half mile west of French Camp. Depth, 228 feet; perforated below 185 feet; water stands at 17 feet.

Miscellaneous sample 4563. Walnut Grove. Well at Alexander Brown Hotel, T. 5 N., R. 5 E. Depth, 189 feet.

TABLE 12.—*Quality of water in quadrangle 4, Tps. 1, 2, 3, and 4 N., Rs. 7, 8, and 9 E. (fig. 6)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1-S	4560	July 10, 1931	6.41	0.06	0.55	0.05	0.03	0.30	0.11	0.22	35
2	4556	July 9, 1931	65.6	.07	3.00	2.05	.24	2.03	2.28	1.75	29
3	4558	July 10, 1931	60.1	.10	3.20	1.15	.21	2.77	2.16	1.08	18
4	4557	July 9, 1931	32.4	.08	2.70	.20	.26	1.38	1.35	.47	15
5	4555	July 10, 1931	25.2	.00	2.45	.10	.09	1.22	.93	.54	20
6	4554	do	20.0	.04	1.50	.25	.00	.76	.71	.51	26

DESCRIPTION OF SAMPLES OF QUADRANGLE 4 (TABLE 12 AND FIG. 6)

Location 1, sample 4560. Mokelumne River near Lodi.

Location 2, sample 4556. Clements municipal water.

Location 3, sample 4558. George Messner well. NW¼ sec. 31, T. 3 N., R. 7 E. Depth, 108 feet; stands 40 feet.

Location 4, sample 4557. W. B. Parker well. S½ sec. 35, T. 3 N., R. 7 E. Depth, 265 feet; perforated at all strata.

Location 5, sample 4555. F. W. Moznett well, Linden. SE¼ sec. 15, T. 2 N., R. 8 E. Depth, 288 feet; perforated below 30 feet; water stands at 46 feet.

Location 6, sample 4554. Toda Bros. well. SE¼ sec. 16, T. 1 N., R. 9 E. Depth, 180 feet, not perforated.

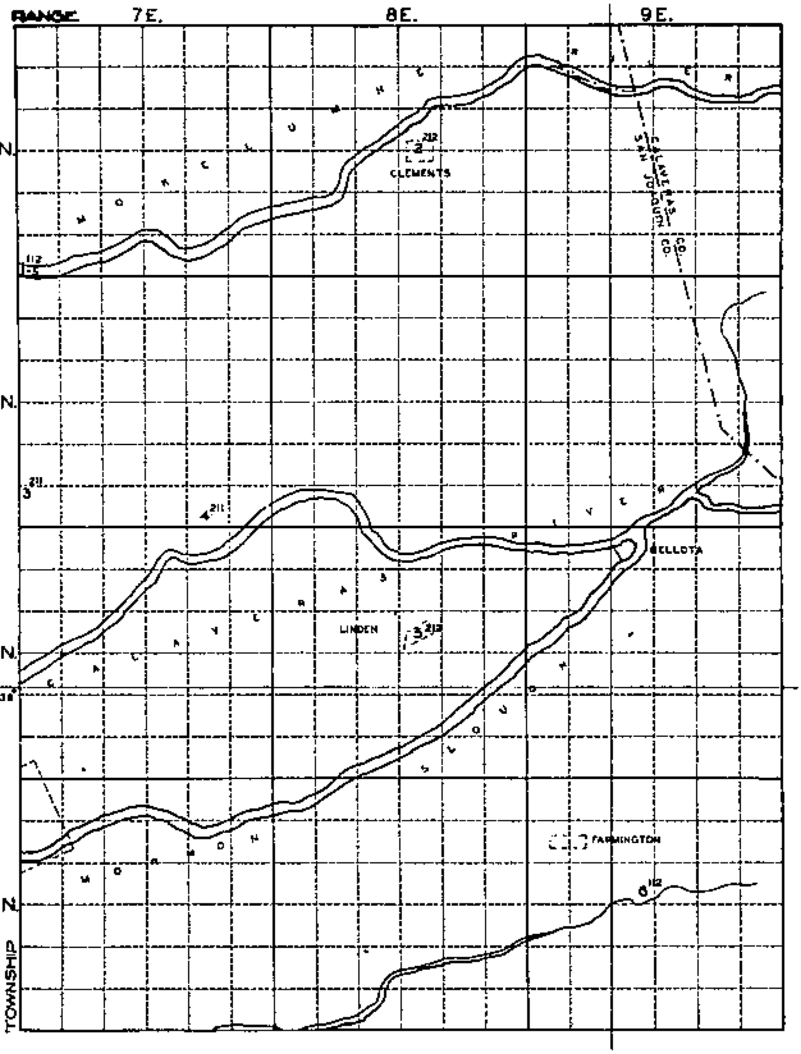

FIGURE 6.—Quadrangle 4, showing locations of samples reported in table 12.

TABLE 13.—*Quality of water in quadrangle 5, Tps. 1, 2, 3, and 4 S., Rs. 1, 2, and 3 E. (fig. 7)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	2948	June 24, 1930	121	2.06	6.95	3.60	2.06	3.43	3.10	5.98	48
2	2947	do	177	5.24	8.85	9.10	2.14	1.42	1.09	17.58	88
3	6350	June 22, 1932	164	1.90	6.70	7.65	1.01	3.80	3.22	9.63	58
4	6349	do	401	20.5	8.50	29.90	T[1]	.70	.42	37.20	97
5	6352	do	51.1	.21	4.15	.65	.61	2.55	2.13	.87	16
6	6351	do	65.3	.32	5.05	.95	.81	2.20	4.18	1.51	19
7-S	6353	do	22.1	.11	1.75	.20	.20	1.16	.75	.27	12

[1] T = trace.

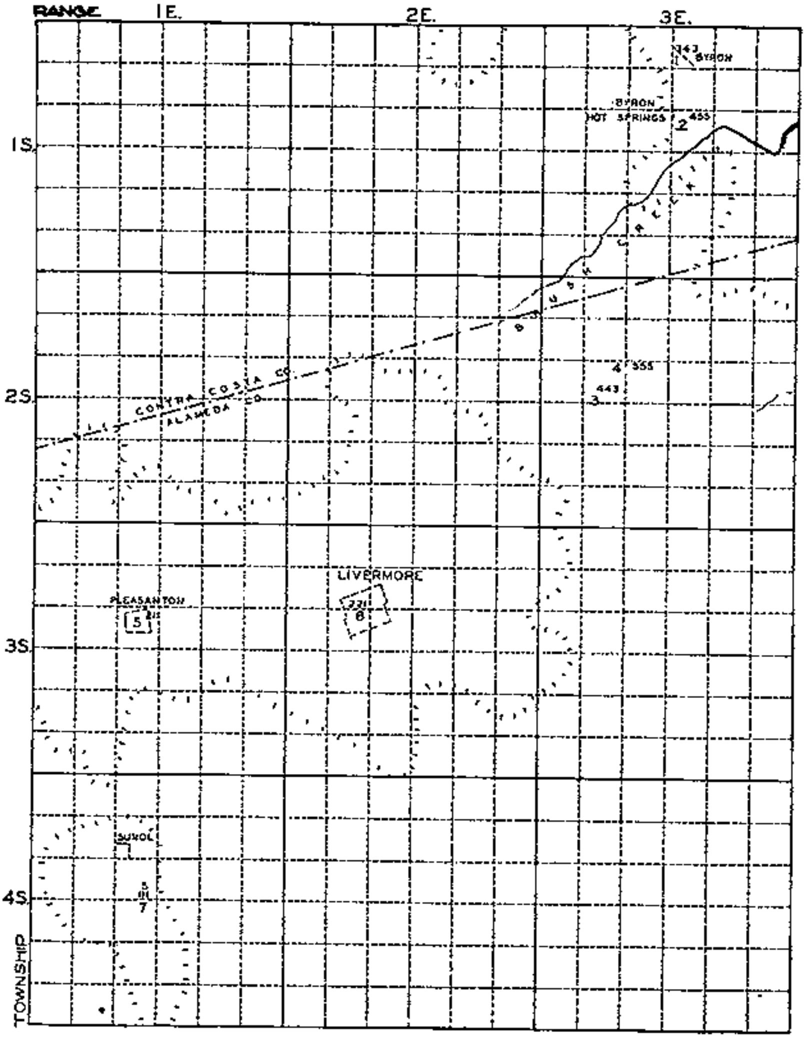

FIGURE 7.—Quadrangle 5, showing locations of samples reported in table 13.

DESCRIPTION OF SAMPLES OF QUADRANGLE 5 (TABLE 13 AND FIG. 7)

Location 1, sample 2948. Byron, Southern Pacific depot. Depth, 40 feet; water stands at 10 feet.

Location 2, sample 2947. Byron Hot Springs, "white sulphur spring." Temperature 81° F. Free H_2S reported as 16.7 cc per liter.

Location 3, sample 6350. Southern Pacific depot, Altamont, from well three-fourths mile west. Near center south line SW¼ sec. 17, T. 2 S., R. 3 E. Depth not known; static level, 15 feet; agent believes water drawn from 125-foot level. Cool, without odor or gas. Used sparingly in locomotives.

Location 4, sample 6349. Summit Garage, Altamont (Tesla quadrangle). Near SE corner NE¼ sec. 17, T. 2 S., R. 3 E. Old oil well drilled by Standard Oil Co. Original depth, 1,190 feet, possibly partly filled in now. Outer casing 12 inches; water-pump casing 1½ inches extending to 250 feet; static level, 175 feet; windmill pump. Water cold, slight odor with CO_2 and possibly other gases.

Location 5, sample 6352. Pleasanton municipal. From San Francisco city wells located in Pleasanton just north of Arroyo Del Valle bridge. A battery of wells, some perhaps 1,000 feet deep. Static level less than 28 feet.

Location 6, sample 6351. Livermore municipal, California Water Service Co. Sample from tap; composite of two wells within city limits, first on North Livermore Avenue, second near P. G. & E. substation. Depth, each, about 600 feet, with upper perforations below 100 feet.

Location 7–S, sample 6353. Alameda Creek, approximately 1 mile south of Sunol, at highway bridge. Location corresponds to NW¼ sec. 21, T. 4 S., R. 1 E. Discharge unknown but small.

TABLE 14.—*Quality of water in quadrangle 6, Tps. 1, 2, 3, and 4 S., Rs. 4, 5, and 6 E.* (*fig. 8*)

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	4552	July 9, 1931	41.5	0.18	2.70	1.15	0.19	1.61	0.88	1.04	40
2	2945	June 24, 1930	380	5.52	5.45	14.85	18.09	6.19	7.16	26.02	68
3	2946	do	68.0	1.12	3.05	1.30	2.45	2.45	1.39	2.90	44
4	4550	July 9, 1931	98.8	.89	2.35	2.25	4.89	3.60	2.32	4.25	42
5	4551	do	89.8	.82	2.70	1.80	4.37	1.59	1.61	5.75	64
6	3419	Oct. 13, 1930	102	.79	2.45	3.70	3.73	3.54	2.61	3.73	38
7	4549	July 9, 1931	66.9	.62	3.85	.55	1.72	2.41	1.30	2.75	43
8	3294	Sept. 10, 1930	59.5	.37	3.45	1.09	2.20	2.78	1.55	2.32	35
9	6348	June 22, 1932	207	3.02	6.00	0.65	5.72	3.10	5.01	12.80	60

DESCRIPTIONS OF SAMPLES OF QUADRANGLE 6 (TABLE 14 AND FIG. 8)

Location 1, sample 4552. Southern Pacific depot, Lathrop. Depth, 160 feet; 7-inch casing; drilled in 1896.

Location 2, sample 2945. Fabian flowing well. SE¼ sec. 33, T. 2 S., R. 4 E. Depth, about 2,000 feet; 14-inch casing; discharge, about 0.1 cubic foot per second; temperature, [illegible], 86°F. Water not used.

Location 3, sample 2946. Tracy municipal well. Depth, 215 feet; 8-inch casing, perforated below [illegible] feet; water stands at 21 feet.

Location 4, sample 4550. J. C. Casselman, domestic well. Near SE corner sec. 25, T. 2 S., R. 5 E. Depth, 90 feet.

Location 5, sample 4551. California Irrigated Farms, Inc., well no. 1. Near NW corner sec. 18, T. 2 S., R. 6 E. Depth, 654 feet; perforated below 618 feet; flows, pumped to increase discharge. Temperature, 71°F.

Location 6, sample 3419. Lou Dedini, domestic well. Sec. 2, T. 3 S., R. 5 E. Depth, 145 feet. Collected by C. S. Scofield.

Location 7, sample 4549. Standard Oil Co., Vernalis pumping plant well no. 2. West center SW¼ sec. 35, T. 3 S., R. 6 E. Depth, 270 feet; perforated below 100 feet; stands at 76 feet; draws down to 98 feet; 8-inch casing.

Location 8, sample 3294. El Solyo Ranch, plant no. 2. Near SW corner sec. 1, T. 4 S., R. 6 E. Depth, 129 feet; stands 57 feet; discharge, 0.4 cubic foot per second.

Location 9, sample 6348. Mountain House well. Near center S½ sec. 18, T. 2 S., R. 4 E. A shallow well with brick casing; static level, about 12 feet. Supplies service station.

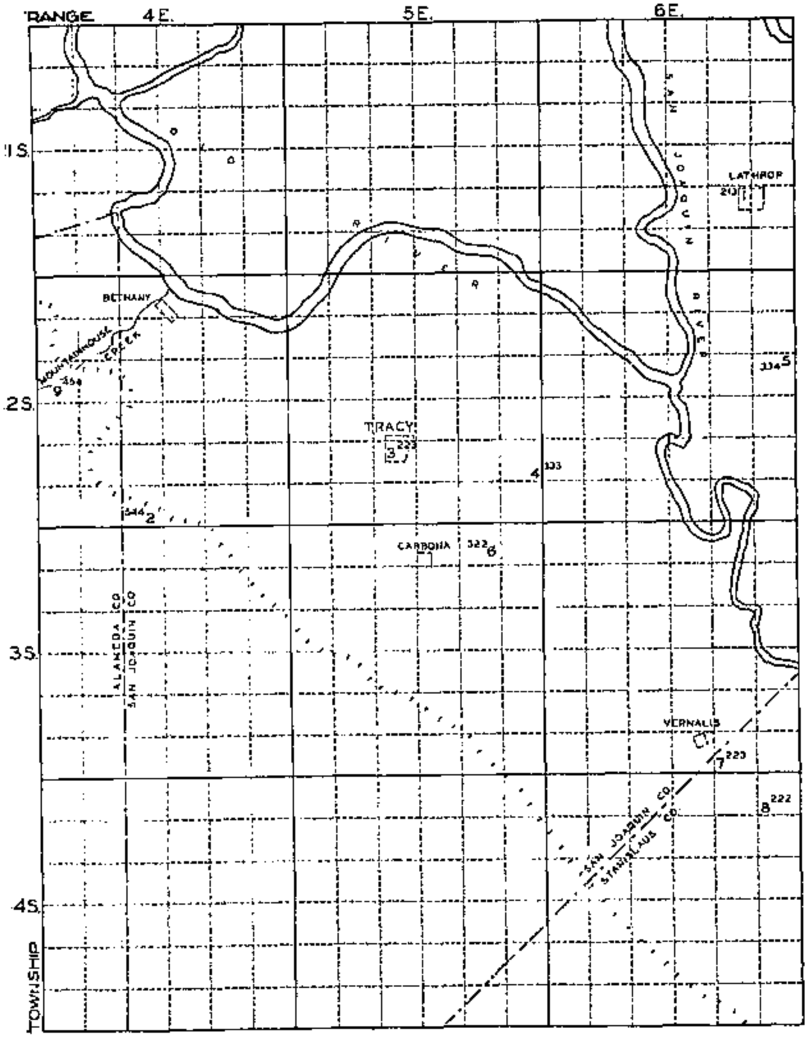

Figure 8.—Quadrangle 6, showing locations of samples reported in table 14.

TABLE 15.—*Quality of water in quadrangle 7, Tps. 1, 2, 3, and 4 S., Rs. 7, 8, and 9 E. (fig. 9)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	4538	July 7, 1931	34.5	0.12	2.55	0.45	0.16	1.72	1.03	0.65	19
2	4553	July 10, 1931	44.0	.08	3.60	.40	.35	1.88	1.62	1.30	28
3	4537	July 7, 1931	43.8	.15	2.65	.70	.18	1.67	.91	1.66	39
4-S	4536	do	23.0	.06	1.95	.15	.04	1.05	.75	.41	19
5-S[1]	1367	June 21, 1929	65.3	.18	2.16	2.64	1.55	1.87	1.54	2.94	40
	3206	Sept. 19, 1930	36.0	.03	1.80	1.80	.42	1.02	1.06	1.94	48
	4579	July 16, 1931	68.3	.23	2.45	3.40	.37	1.89	1.41	2.97	47
	4780	Aug. 1, 1931	72.3	.12	2.05	3.90	.27	1.94	1.47	3.44	50
	4827	Sept. 1, 1931	58.6	.13	2.45	2.80	.32	1.58	.90	3.33	58
	4966	Oct. 1, 1931	50.4	.09	2.45	2.60	.42	1.69	1.41	2.63	40
	5129	Nov. 2, 1931	78.3	.22	2.25	3.65	.74	1.93	1.72	3.03	45
	5329	Dec. 1, 1931	78.6	.21	2.28	3.70	1.46	1.96	1.86	3.64	49
	5387	Jan. 1, 1932	21.7	.11	.80	.50	.21	.64	.78	.24	14
	5602	Feb. 1, 1932	19.1	.07	.95	.50	.21	.67	.40	.59	52
	5773	Mar. 1, 1932	22.3	.03	1.15	.60	.08	.70	.62	1.16	47
	5883	Apr. 1, 1932	38.4	.09	1.30	1.60	.70	1.11	.96	1.59	43
	6099	May 2, 1932	27.0	.23	1.05	1.05	.45	.75	.93	.93	36
	6220	June 1, 1932	11.3	.03	.50	.30	.18	.41	.54	.04	4
	6479	July 1, 1932	11.8	.03	.75	.30	.11	.32	.21	.66	55
	6539	Aug. 1, 1932	70.5	.21	2.15	3.40	1.19	1.77	1.65	3.32	49
6	3420	Oct. 14, 1930	71.0	.60	3.20	1.25	2.75	2.02	1.91	3.27	45
7	4535	July 7, 1931	36.0	.14	2.20	1.00	.02	1.52	.76	1.05	32
8	3293	Sept. 19, 1930	75.6	.70	3.60	2.05	2.30	2.41	1.77	3.77	47
9	3349	July 27, 1930	232	3.60	4.10	4.25	17.52	7.79	5.90	12.09	47
10	2942	June 23, 1930	90.6	1.25	3.70	2.35	3.15	2.73	2.31	4.11	45
11	2943	do	341	3.22	1.85	10.50	22.69	8.14	10.22	16.68	48
	4826	Sept. 8, 1931	328	4.60	4.70	10.20	21.57	6.94	10.00	19.71	54
	5114	Nov. 2, 1931	319	4.49	4.80	9.85	20.71	6.97	9.51	19.04	54
12-S	4750	Aug. 1, 1931	138	.45	3.50	5.05	4.19	3.22	3.51	6.04	51
13	2940	June 23, 1930	106	.53	3.90	3.20	3.51	2.37	5.53	2.71	26
14	6347	June 22, 1932	88.1	.27	7.75	1.60	T[2]	2.21	1.04	8.31	66
15	6660	Sept. 1, 1932	93.5	.40	4.85	1.15	.30	1.01	1.27	3.41	52

[1] Discharges of San Joaquin River at El Solyo diversion, below the mouth of the Tuolumne River, as estimated by W. F. Wooley at time of sampling:

Sample no.:	*Cubic feet per second*	Sample no.:	*Cubic feet per second*
4579	300	5773	2,000
4780	135	5883	1,000
4827	150	6099	5,000
4966	250	6220	15,000
5329	700	6479	15,000
5387	3,000	6539	800
5602	3,500		

[2] T=trace.

DESCRIPTION OF SAMPLES OF QUADRANGLE 7 (TABLE 15 AND FIG. 9)

Location 1, sample 4538. Manteca municipal wells. Composite of three wells; depth, 140 to 150 feet; water stands at 6 feet.

Location 2, sample 4553. Escalon municipal wells. Composite of two wells; depth, 150 and 250 feet; water stands at 10 feet.

Location 3, sample 4537. Ripon municipal well. Ripon Water Co. Depth, 186 feet; stands 18 feet; not perforated.

Location 4-S, sample 4536. Stanislaus River, south of Ripon.

Location 5-S, samples 1367 and following. San Joaquin River at El Solyo Ranch diversion, below mouth of Tuolumne River. Collected by Leonard Petersen.

Location 6, sample 2420. El Solyo Ranch, Brigham Place, domestic well. Collected by C. S. Scofield.

Location 7, sample 4535. Modesto municipal water. Tap at Ninth and I Streets.

Location 8, sample 3293. El Solyo Ranch well at Camp 2. Depth, 165 feet; stands at 28 feet.

Location 9, sample 3349. El Solyo Ranch well at old Camp 1. Collected by R. M. Pike.

Location 10, sample 2942. El Solyo Ranch well at Oaklea headquarters. Depth, 115 feet.

Location 11, samples 2943, 4826, and 5114. El Solyo Ranch well at dairy. Depth, 115 feet.

Location 12-S, sample 4750. San Joaquin River, Laird's Slough, 1 mile above mouth of Tuolumne. At the time of this sample the water was largely if not entirely return flow and drainage from irrigated lands above. Discharge, 35 cubic feet per second.

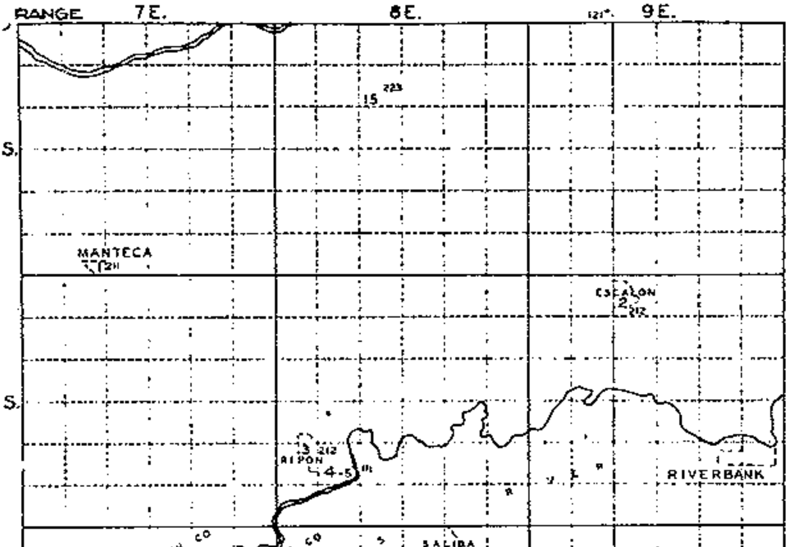

FIGURE 9.—Quadrangle 7, showing locations of samples reported in table 15.

Location 13, sample 2940. Westley, well at Benson Garage. Depth, 73 feet.

Location 14, sample 6347. F. C. Roberts, domestic and garden well. S½SE¼-NW¼ sec. 27, T. 4 S., R. 8 E. Depth, 125 feet; upper perforations, 100 feet; casing diameter, 7 inches; temperature, 64°F.; water clear, no odor.

Location 15, sample 6660. P. G. Poynor spring. SW¼ sec. 9, T. 1 S., R. 8 E. Spring issues into pond 150 feet in diameter. Water cool and clear; used for stock. Spring runs low during summer months but always flows. Collected by W. J. Murphy.

TABLE 16.—*Quality of water in quadrangle 8, Tps. 5, 6, 7, and 8 S., Rs. 7, 8, and 9 E. (fig. 10)*

Location no.	Sample no.	Date	K × 10⁵ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	2941	June 23, 1930	137	0.53	4.65	6.00	3.85	2.75	7.16	4.59	32
2	2787	May 23, 1930	80.7	.47	2.70	2.70	2.10	1.69	3.04	2.77	37
3	2786	do	177	.66	2.35	2.10	14.63	3.88	5.97	9.23	48
	2785	do	73.4	.47	3.20	.45	3.51	1.81	2.61	2.74	38
4	2784	do	139	.67	3.30	3.00	7.79	5.01	4.66	4.42	31
5	2788	do	63.0	.29	3.05	.35	2.09	2.37	1.18	2.86	45
6	2783	do	96.6	.52	7.60	1.60	.95	3.00	2.61	4.54	45
7	3292	Sept. 18, 1930	101	.46	3.90	3.40	3.02	3.17	2.91	4.24	41
	1955	Oct. 8, 1929	112	.08	3.00	5.95	1.85	1.74	1.80	7.26	67
8	1954	do	68.0	.46	3.55	1.05	2.41	2.50	1.67	2.84	41
	2782	May 23, 1930	80.4	.38	3.25	1.40	3.89	2.21	2.16	4.17	49
9	1956	Oct. 8, 1929	112	.04	6.90	2.25	2.06	4.91	1.73	5.49	45
10	2781	May 23, 1930	131	.54	5.65	2.95	3.62	5.57	2.52	4.13	34
11	3291	Sept. 18, 1930	115	1.08	3.50	5.90	2.07	1.63	1.78	8.00	70
12-S	3428	Oct. 1, 1930	84.8	.17	2.50	4.25	1.04	1.80	1.62	4.01	59

DESCRIPTION OF SAMPLES OF QUADRANGLE 8 (TABLE 16 AND FIG. 10)

Location 1, sample 2941. Signoretti well, El Pascadero Grant. Location corresponds to SW¼ sec. 1, T. 5 S., R. 7 E. Depth, 369 feet; perforated at seven water-bearing strata.

Location 2, sample 2787. L. W. Johnson well. W½ sec. 19, T. 5 S., R. 8 E. Depth, 60 feet.

Location 3, sample 2786. Emerald Station, well 3, Standard Oil Co. Depth, 240 feet.

Location 3, sample 2785. Emerald Station, well 4, Standard Oil Co. Depth, 370 feet.

Location 4, sample 2784. F. T. McGinnis well, Crows Landing. Depth, 208 feet; not perforated.

Location 5, sample 2788. Walter Isman, irrigation well. Near S¼ corner, sec. 3, T. 7 S., R. 8 E. Depth, 260 feet.

Location 6, sample 2783. Well near center NW¼ sec. 18, T. 7 S., R. 9 E. Depth, 40 feet.

Location 7, sample 3292. Newman municipal wells. Collected from tap at P Street Grammar School.

Location 7, sample 1955. Golden State milk plant well, Newman. Depth, 425 feet; not perforated.

Location 8, sample 1954. Gustine municipal, new well. Depth, 150 feet.

Location 8, sample 2782. Gustine Creamery well. Depth, 225 feet; not perforated.

Location 9, sample 1956 W. K. McBride well. W½ sec. 17, T. 8 S., R. 9 E. Depth, 35 feet.

Location 10, sample 2781. Shallow domestic well, near center NE¼ sec. 30, T. 8 S., R. 9 E.

Location 11, sample 3291. Lenora Station, Associated Pipe Line Co. NE¼-SE¼ sec. 28, T. 8 S., R. 9 E. Depth, 450 feet; water stands at 12 feet.

Location 12-S, sample 3428. San Joaquin River, Patterson Water Co., main diversion canal. SW¼ sec. 15, T. 5 S., R. 8 E. Collected by R. Schmidt.

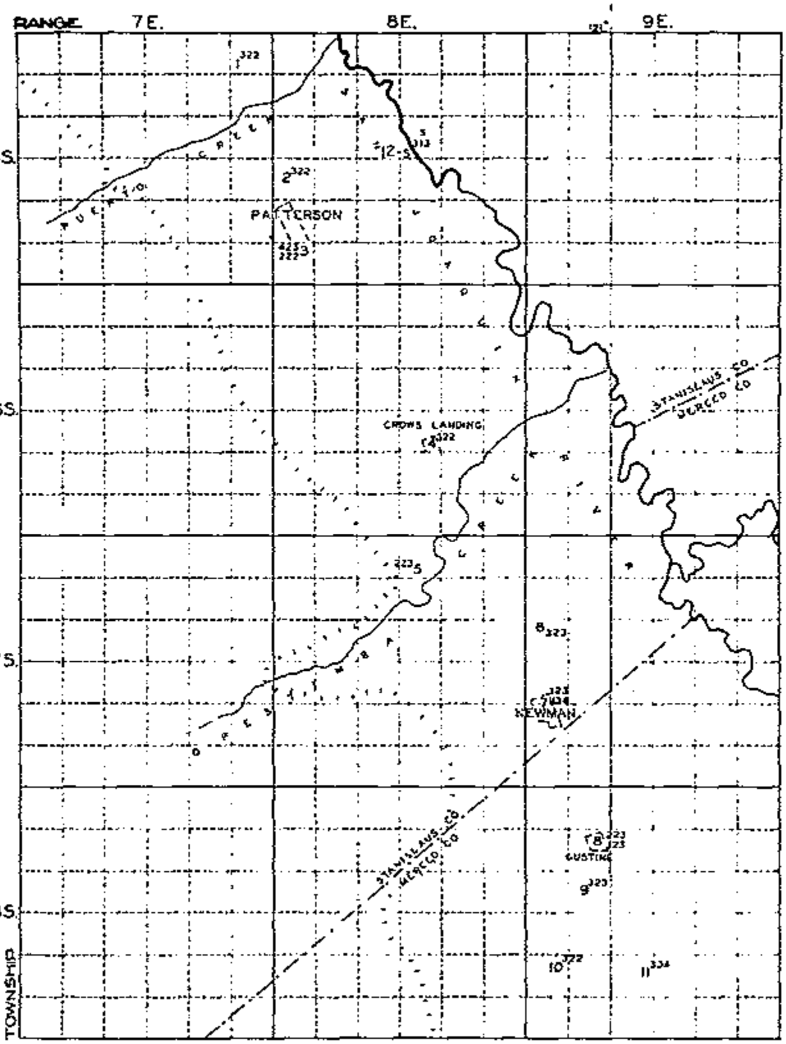

FIGURE 10.—Quadrangle 8, showing locations of samples reported in table 16.

TABLE 17.—*Quality of water in quadrangle 9, Tps. 5, 6, 7, and 8 S., Rs. 10, 11, and 12 E.* (*fig. 11*)

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m							
1	4534	July 7, 1931	44.0	0.13	3.55	0.40	0.20	2.34	1.26	1.03	22
2	2937	June 23, 1930	273	2.04	2.45	12.00	10.95	3.30	.96	22.04	84
3	2938	do	234	(1)	2.65	9.75	10.50	3.43	1.14	18.33	80
	2939	do	270	2.73	2.55	12.95	10.80	3.88	1.03	21.45	81
4	1369	June 21, 1929	24.0	.14	1.37	.31	.20	.90	.38	.60	32
5	1370	do	5.0	.02	.33	.36	.08	.16	.03	.58	75
6–S	1371	do	16.2	.08	1.22	.15	.16	.61	.22	.70	40
7	4533	July 7, 1931	27.3	.02	1.65	.40	.12	.90	.57	1.10	44
8	2936	June 23, 1930	440	.70	1.50	37.50	1.48	9.30	2.05	29.13	72
9	2935	do	20.3	.15	1.80	.20	.34	1.19	.34	.81	35
10	2933	do	47.6	.07	3.80	1.05	.30	.45	.15	4.64	89
11	6159	May 24, 1932	27.0	.05	1.85	.25	.14	.72	.52	1.46	54
	6160	do	17.1	.03	1.55	.25	.00	.49	.29	1.11	50
	6161	do	32.4	.07	2.05	.55	.20	1.02	.60	1.02	49
12	6634	Aug. 24, 1932	86.5	.26	6.20	2.40	.33	.50	.68	7.06	87

[1] Lost.

DESCRIPTION OF SAMPLES OF QUADRANGLE 9 (TABLE 17 AND FIG. 11)

Location 1, sample 4534. Turlock municipal wells. Marshall Street plant, seven wells. Depth, 40 to 300 feet; water stands at 14 feet.

Location 2, sample 2937. Old Stevinson well (Reed). SE¼ sec. 31, T. 6 S., R. 10 E. One of two adjacent wells which formerly flowed, now pumped. Depth not known.

Location 3, sample 2938. Richards well. NE¼ sec. 36, T. 7 S., R. 9 E. Depth 356 feet; flowing.

Location 3, sample 2939. Beckworth well; 250 feet east of sample 2938. Depth, 300 feet.

Location 4, sample 1369. Drainage well, Delhi Settlement, Turlock Irrigation District. In or adjacent to sec. 2, T. 6 S., R. 11 E. Water stands at 20 feet.

Location 5, sample 1370. Canal, Delhi Settlement. Opposite sample 1369.

Location 6–S, sample 1371. Merced River, near Livingston.

Location 7, sample 4533. Livingston municipal wells; 2 wells. Depth, 157 feet; perforated casings; water stands at 16 feet.

Location 8, sample 2936. Old deep well (Rosa). NW corner sec. 2, T. 7 S., R. 10 E. Formerly flowed; casing badly rusted; water stands at 12 feet; sample obtained from 2-inch pipe extending into old casing.

Location 9, sample 2935. J. F. Rhodes, Stevinson. NE¼ sec. 15, T. 7 S., R. 10 E. Domestic well. Depth, 45 feet.

Location 10, sample 2933. Charles Lyons Gun Club. NE¼ sec. 28, T. 7 S., R. 10 E. Depth, 265 feet; flowing.

Location 11, sample 6159. Vern Hammatt, house well. NE¼ sec. 25, T. 6 S., R. 11 E. Depth, 60 feet; 7-inch casing; static level, 10 feet. Collected by R. V. Wright.

Location 11, sample 6160. Vern Hammatt, grove pump. Depth, 47 feet; 12-inch casing; 6-inch discharge; static level, 7 feet; draws down to 15 feet. Collected by R. V. Wright.

Location 11, sample 6161. Vern Hammatt, electric pump. Depth, 70 feet; 12-inch casing; 6-inch discharge; static level, 15 feet; draws down to 27 feet. Collected by R. V. Wright.

Location 12, sample 6634. L. T. Marx ranch well. NE¼NE¼ sec. 21, T. 7 S., R. 10 E. Depth, 24 feet; 3-inch pump. Collected by Wallace Sullivan.

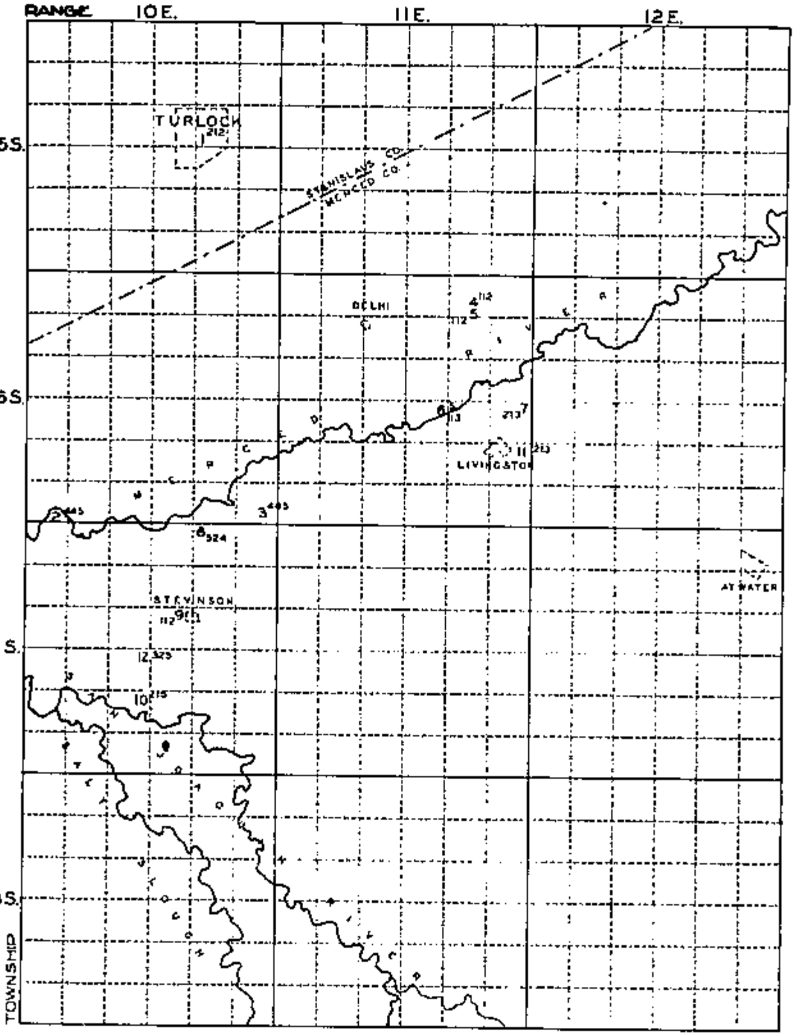

FIGURE 11.—Quadrangle 9, showing locations of samples reported in table 17.

TABLE 18.—*Quality of water in quadrangle, 10, Tps. 9, 10, 11, and 12 S., Rs. 7, 8, and 9 E. (fig. 12)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m							
1	1953	Oct. 8, 1929	515	2.74	3.30	6.75	58.07	15.40	21.73	28.99	43
2	3280	Sept. 18, 1930	190	1.48	4.55	4.50	4.07	2.87	4.49	5.76	44
3	3290	do	202	1.09	3.10	10.80	0.71	4.40	3.89	12.20	50
4	2789	May 23, 1930	54.2	.37	4.45	.50	.30	1.09	1.66	1.89	32
5-S	2791	do	99.7	.55	4.00	4.15	1.14	2.51	2.79	4.59	45
6	2780	do	132	.06	4.60	6.50	1.85	2.68	3.70	6.57	51
7	2770	do	52.3	.47	3.30	1.00	.85	1.50	1.37	2.28	44
8	2790	do	254	.09	3.05	6.70	17.84	6.40	8.23	12.96	47

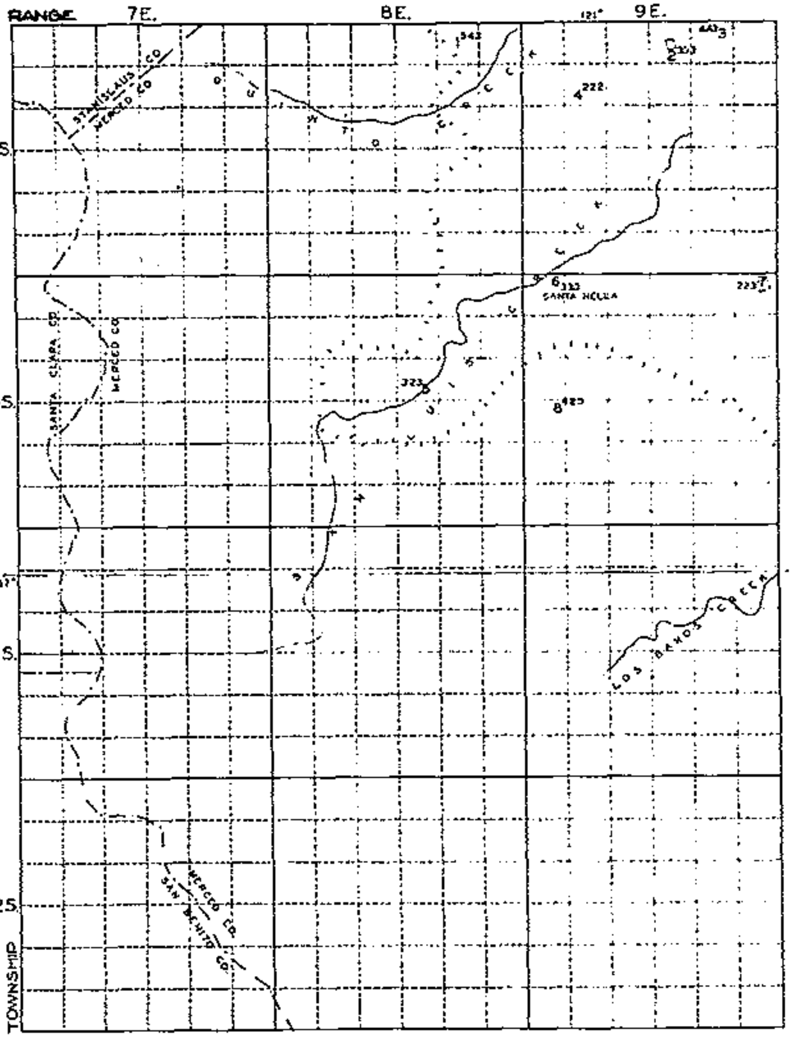

FIGURE 12.—Quadrangle 10, showing locations of samples reported in table 18.

DESCRIPTION OF SAMPLES OF QUADRANGLE 10 (TABLE 18 AND FIG. 12)

Location 1, sample 1953. Allen Ranch. Stock well at mouth of an arroyo near center sec. 2, T. 9 S., R. 8 E. Depth, 360 feet; flows with very small stream to supply trough.

Location 2, sample 3289. Ingomar section house, domestic well. Depth, 90 feet; perforated below 80 feet; stands at 8 feet.

Location 3, sample 3290. Salinas Gun Club. NE¼ sec. 2, T. 9 S., R. 9 E. New flowing well; depth, 550 feet; upper 100 feet of casing is 16-inch, remainder 12-inch; upper perforations, 420 feet; ground water encountered at 9 feet.

Location 4, sample 2789. Shallow domestic well, Quinto Creek delta. SW¼ sec. 8, T. 9 S., R. 9 E.

Location 5–8, sample 2791. San Luis Creek at Pacheco Pass highway crossing. SE¼ sec. 15, T. 10 S., R. 8 E. Discharge, 0.02 cubic foot per second.

Location 6, sample 2780. Santa Nella, domestic well. NE corner sec. 6, T. 10 S., R. 9 E. Depth, 90 feet; water-bearing gravel reported only at 52 feet; casing not perforated elsewhere.

Location 7, sample 2779. Joe Vallado, domestic well. Opposite Volta depot, NE¼ sec. 1, T. 10 S., R. 9 E. Depth, 200 feet; flows during winter months.

Location 8, sample 2790. Pacheco Pass Junction well. NE corner sec. 19, T. 10 S., R. 9 E. Depth, 150 feet.

TABLE 19.—*Quality of water in quadrangle 11, Tps. 9, 10, 11, and 12 S., Rs. 10, 11, and 12 E. (fig. 13)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	1952	Oct. 8, 1929	109	1.13	6.40	2.45	3.05	3.23	4.01	4.63	39
2	2776	May 22, 1930	67.4	.65	4.40	1.30	.03	1.68	1.56	3.09	47
3	2777	do	30.8	.31	2.45	.35	.53	1.20	1.13	.91	27
4-S	1879	Sept. 27, 1929	6.23	.04	.40	.20	.56	.49	.38	.29	25
5	1957	Oct. 8, 1929	139	2.73	3.05	1.85	8.80	1.71	.04	11.95	84
6	2869	June 10, 1930	117	.14	1.40	8.40	.98	3.73	2.02	4.13	38
7	2867	do	71.9	.34	3.10	1.75	2.05	2.62	1.71	2.57	37
8	2778	May 23, 1930	241	2.06	3.25	8.80	11.19	3.97	3.91	15.33	68
9	2871	June 10, 1930	6305	90.00	8.95	335.50	702.88	20.79	213.85	902.69	79
10	2870	do	131	.40	2.10	8.55	1.99	4.21	4.05	4.35	34
11	2775	May 22, 1930	32.5	.10	1.30	1.30	.36	1.25	.71	.97	33
	2868	June 10, 1930	30.8	.11	1.30	1.35	.32	1.20	.77	1.00	31
12	2774	May 22, 1930	252	.18	1.40	22.25	1.93	11.46	7.04	6.18	24
13	2872	June 10, 1930	102	.14	1.05	6.15	1.13	2.21	1.91	4.18	50
14	2772	May 22, 1930	238	3.26	3.45	9.35	11.75	5.74	4.76	14.05	57
15	2771	do	107	2.50	3.10	2.75	16.68	3.70	2.08	15.78	70
16	6965	Dec. 9, 1932	303	2.40	2.35	19.50	7.84	6.24	6.14	17.32	58

DESCRIPTION OF SAMPLES OF QUADRANGLE 11 (TABLE 19 AND FIG. 13)

Location 1, sample 1952. Ben Orogen, domestic well. SE¼ sec. 15, T. 10 S. R. 10 E. Depth, 25 feet.

Location 2, sample 2776. M. B. Miranda, domestic well. Corner Fourth and P Streets, Los Banos. Depth, 33 feet.

Location 3, sample 2777. Los Banos municipal well. NW corner sec. 23, T. 10 S., R. 10 E. Depth, 122 feet; perforated below 116 feet; water stands at 10 feet.

Location 4-S, sample 1879. Santa Fe Canal at highway crossing, 3 miles east of Los Banos. San Joaquin River water diverted at Mendota.

Location 5, sample 1957. Big Water well; flowing well in slough. NW¼ sec. 27, T. 10 S., R. 11 E. Drilled to 385 feet; cased to clay at 305 feet; present discharge small.

Location 6, sample 2869. Drainage well. Near SE corner sec. 4, T. 10 S., R. 12 E. Left bank of branch of Colony Canal. Collected under direction of T. C. Mott.

Location 7, sample 2867. Drainage well, south side SW¼ sec. 2, T. 10 S., R. 12 E. North side of road at west end of Santa Rita Slough. Collected under direction of T. C. Mott.

Location 8, sample 2778. M. T. Avelar well. SW corner sec. 23, T. 11 S., R. 10 E. Depth, 235 feet; lowest water stratum, 93 feet; 8-inch discharge pipe.

Location 9, sample 2871. Miller & Lux, abandoned hole. West side of NE¼ sec. 5, T. 11 S., R. 12 E. Abandoned hole drilled to about 500 feet. Collected under direction of T. C. Mott.

Location 10, sample 2870. Drainage well. SW¼ sec. 4, T. 11 S., R. 12 E. Left bank of Laguna Canal. Collected under direction of T. C. Mott.

Location 11, samples 2775 and 2868. Drainage well. West side SE¼ sec. 2, T. 11 S., R. 12 E. Right bank of canal. Sample 2868 collected under direction of T. C. Mott.

Location 12, sample 2774. A. B. Neese well. NE¼ sec. 11, T. 11 S., R. 12 E. Depth, 12 feet.

Location 13, sample 2872. Drainage well. East side of SW¼ sec. 12, T. 11 S., R. 12 E. Right bank of Colony main canal. Collected under direction of T. C. Mott.

Location 14, sample 2772. Ora Loma Mutual well. Near NW corner sec. 23, T. 12 S., R. 11 E. New well drilled to 1,260 feet.

Location 15, sample 2771. Ora Loma Mutual well no. 24. NW¼ sec. 19, T. 12 S., R. 12 E. Depth not ascertained.

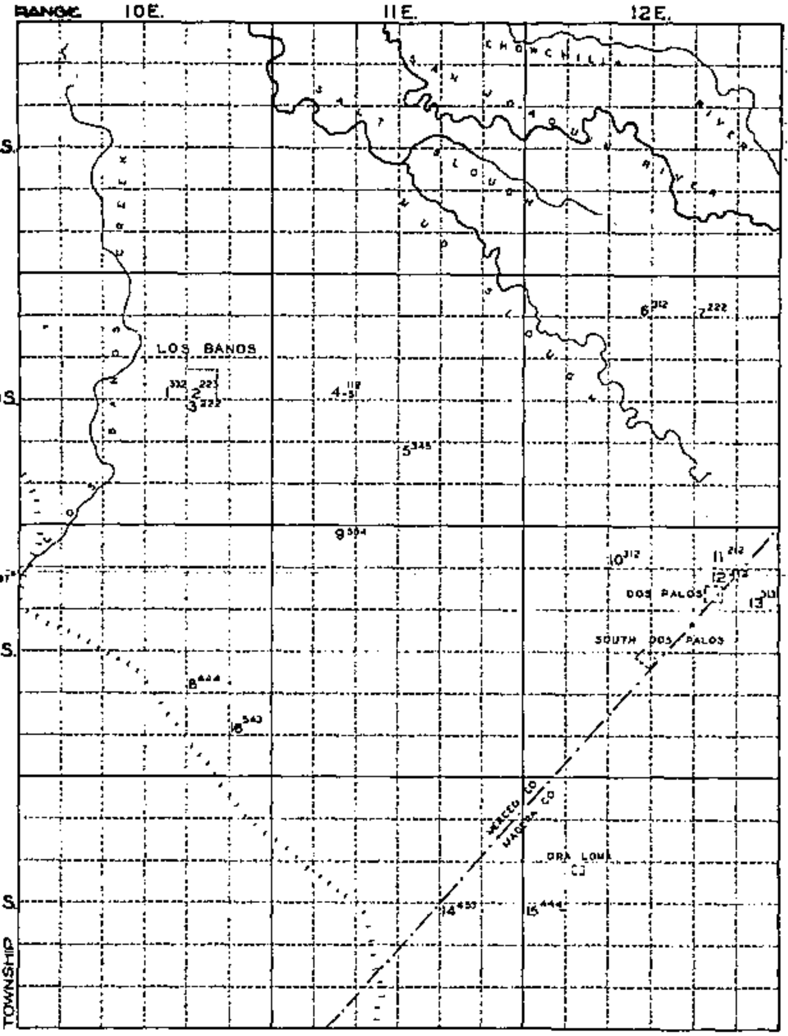

FIGURE 13.—Quadrangle 11, showing locations of samples reported in table 19.

Location 16, sample 6965. W. E. Whittington well; 7 miles south of Los Banos on Mercy Springs Road. SW¼ sec. 25, T. 11 S., R. 10 E. Depth, 608 feet; 60 feet to water; 30-foot draw-down; 12-inch casing. Collected by R. V. Wright.

TABLE 20.—*Quality of water in quadrangle 12, Tps. 9, 10, 11, and 12 S., Rs. 13, 14, and 15 E.*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	2773	May 22, 1930	71.9	0.15	1.80	4.40	0.54	2.37	0.42	3.95	59
2	3288	Sept. 17, 1930	269	.47	3.90	12.15	11.16	2.34	.65	24.22	89

DESCRIPTION OF SAMPLES OF QUADRANGLE 12 (TABLE 20)

(Quadrangle map not shown)

Location 1, sample 2773. Durham farm, flowing well. West of center of sec. 6, T. 11 S., R. 13 E. Depth could not be determined.

Location 2, sample 3288. Silaxo Station, Associated Pipe Line Co. SW¼ sec. 11, T. 12 S., R. 13 E. Depth, 465 feet; water stands at 15 feet; lower 86 feet of casing perforated.

TABLE 21.—*Quality of water in quadrangle 13, Tps. 9, 10, 11, and 12 S., Rs. 16, 17, and 18 E.*

Location no.	Sample no.	Date	K×10⁵ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	4531	July 7, 1931	25.1	0.05	1.95	0.55	0.07	1.25	0.66	0.72	27
2	5294	Nov. 25, 1931	29.0	.03	2.05	.70	.02	1.42	.75	.77	26
3	4530	July 7, 1931	21.0	.08	1.30	.50	.06	.79	.15	.68	35
Miscellaneous[1]	4532	do	30.1	.02	2.30	.25	.05	1.20	.96	.73	25
Do.	7114	Feb. 27, 1933	28.5	.02	2.10	.48	.11	1.09	1.03	.86	35
Do.	7115	do	26.8	.02	1.85	.62	.22	.90	.91	1.15	37

[1] Outside of quadrangle; included for convenience.

DESCRIPTION OF SAMPLES OF QUADRANGLE 13 (TABLE 21)

(Quadrangle map not shown)

Location 1, sample 4531. Chowchilla municipal well no. 2. Depth 104 feet; 12-inch casing, perforated below 60 feet.

Location 2, sample 5294. Stanley Yeeney ranch well. Lot 7, block 7, sec. 6, T. 10 S., R. 16 E. Discharge, 0.89 cubic foot per second. Collected by E. L. Garthewaite.

Location 3, sample 4530. Madera municipal water. Sampled at tower plant. Depth of six scattered wells, 220 to 400 feet.

Miscellaneous sample 4532. Merced municipal water. From tap at Sixteenth and Main Streets.

Miscellaneous sample 7114. San Joaquin Light & Power substation well. NW¼NW¼ sec. 6, T. 8 S., R. 16 E.; 4 miles east of Athlone. Discharge, 0.04 cubic foot per second; depth, 162 feet; 12-inch casing; water clear. Collected by W. H. Alison, Jr.

Miscellaneous sample 7115. E. S. Porter well. NW¼NW¼ sec. 6, T. 8 S., R. 16 E.; 4 miles east of Athlone. One-quarter mile east of sample 7114. Depth 72 feet; water clear. Irrigation and domestic. Collected by W. H. Alison, Jr.

TABLE 22.—*Quality of water in quadrangle 14, Tps. 13, 14, 15, and 16 S., Rs. 10, 11, and 12 E. (fig. 14)*

Location no.	Sample no.	Date	K×10⁵ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1-S	2770	May 22, 1930	650	18.60	5.45	50.95	9.46	13.89	12.00	39.07	61
2	1877	Sept. 27, 1929	130	1.97	3.20	1.80	8.65	1.35	.09	11.40	84
3	2769	May 22, 1930	418	13.10	1.75	36.80	.26	2.24	.36	36.21	93
4	2768	do	129	1.54	3.75	1.05	8.81	5.13	3.56	4.02	30
5-S	2767	do	279	4.80	5.20	4.85	22.25	7.11	9.38	15.83	49
	4833	Sept. 9, 1931	259	6.52	5.10	5.70	22.21	5.59	9.01	18.38	56
6-S	2766	May 22, 1930	806	8.78	5.70	14.00	88.82	10.51	42.37	47.54	43
	4832	Sept. 9, 1931	927	12.7	4.75	25.00	108.78	10.83	40.68	78.94	57
7	6073	Aug. 3, 1932	616	7.44	5.65	5.50	71.10	24.21	10.69	38.42	47

DESCRIPTION OF SAMPLES OF QUADRANGLE 14 (TABLE 22 AND FIG. 14)

Location 1-S, sample 2770. Little Panoche Creek. Near SE corner sec. 19, T. 13 S., R. 11 E. Flow of creek about 0.02 cubic foot per second at this point, but dry at Mercy School, above, although there were a few pools; dry or nearly so below. The bed of Salt Canyon entering just above sampling point was damp.

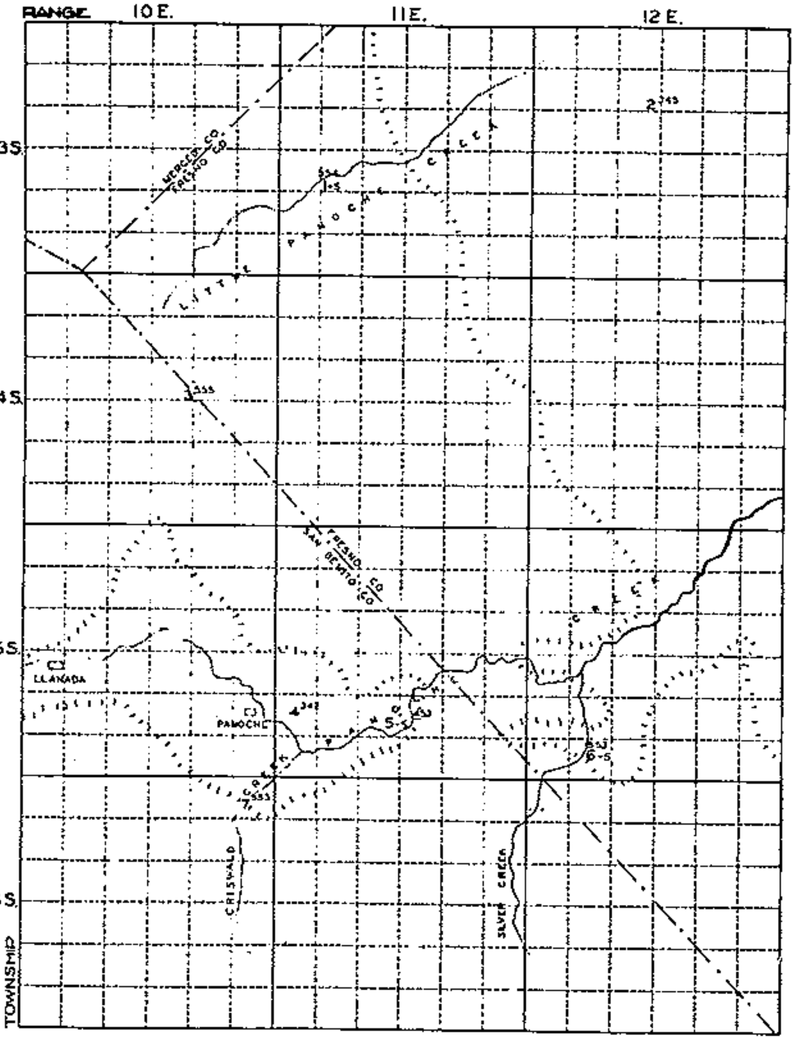

FIGURE 14.—Quadrangle 14, showing locations of samples reported in table 22.

Location 2, sample 1877. Irrigation well near SE corner sec. 9, T. 13 S., R. 12 E. Temperature, 82° F. Probably a deep well.

Location 3, sample 2769. Mercy Hot Springs. Discharge, 0.03 cubic foot per second; temperature, 120° F.

Location 4, sample 2768. Irrigation well near center sec. 30, T. 15 S., R. 11 E. Small centrifugal pump in 30-foot pit.

Location 5-S, samples 2767 and 4833. Panoche Creek. Near center W½ sec. 27, T. 15 S., R. 11 E. Discharge at time of each sample approximately 2 cubic feet per second.

Location 6-S, samples 2766 and 4832. Silver Creek. NW¼ sec. 32, T. 15 S., R 12 E. At P. G. & E. gas line crossing. Discharge at time of each sample approximately 0.03 cubic foot per second.

Location 7, sample 6673. J. H. Morgan well, domestic and irrigation. On Griswold Creek. NE¼SW¼ sec. 1, T. 16 S., R. 10 E. Dug well; depth 20 feet. Collected by R. D. McCallum.

TABLE 23.—*Quality of water in quadrangle 15, Tps. 13, 14, 15, and 16 S., Rs. 13, 14, and 15 E. (fig. 15)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	1876	Sept. 27, 1929	480	2.13	2.40	35.20	11.59	3.69	1.44	37.84	88
2	2932	June 22, 1930	203	1.20	2.95	5.50	11.40	1.17	.27	18.47	93
3	2761	May 22, 1930	329	1.00	3.33	10.70	9.02	4.04	2.00	26.01	81
4	2762	do	145	1.54	4.20	1.50	9.88	2.88	2.46	10.24	66
5-S	1949	Oct. 7, 1929	5.55	.07	.30	.05	.09	.30	.00	.14	32
6-S	1948	do	5.29	.11	.30	.15	.08	.32	.09	.12	23
7	1871	Sept. 27, 1929	108	1.23	2.40	2.30	11.40	1.01	.19	14.90	93
8	1875	do	380	1.02	2.70	26.70	9.29	4.51	3.05	31.13	80
	2760	May 22, 1930	387	.91	2.80	25.25	11.95	4.39	2.06	33.55	84
9	2763	do	146	1.58	3.85	1.30	9.13	2.68	2.05	9.55	67
10	2759	do	219	1.62	3.45	7.80	9.27	2.54	2.05	15.93	78
11	1874	Sept. 27, 1929	140	1.57	4.00	1.50	10.59	3.01	5.50	7.95	48
12	1372	June 22, 1929	580	1.47	1.75	44.60	15.18	10.80	6.41	44.22	72
13	1873	Sept. 27, 1929	189	1.39	3.20	6.20	9.33	1.59	T [1]	17.14	92
14	1872	do	155	1.23	3.00	2.50	9.97	1.53	1.48	12.46	81
15	2764	May 22, 1930	103	1.80	4.80	1.90	10.66	2.79	2.25	12.32	71
16	2765	do	154	1.43	2.80	2.50	9.33	1.16	.37	13.10	90
17-S	1947	Oct. 7, 1929	9.93	.02	.80	.10	.15	.40	.13	.52	50
18	2768	May 21, 1930	302	2.99	3.55	4.50	30.40	9.13	13.30	16.02	42
19	2767	do	127	1.18	2.70	2.00	7.69	2.48	.58	9.33	75
20	1373	June 22, 1929	140	1.88	1.39	1.30	10.99	2.02	.13	11.53	84

[1] T = trace.

DESCRIPTION OF SAMPLES OF QUADRANGLE 15 (TABLE 23 AND FIG. 15)

Location 1, sample 1876. Sellers well no. 19. S¼ corner sec. 9, T. 13 S., R. 13 E. Depth, 1,400 feet; perforated below 580 feet; discharge, 2.6 cubic feet per second; temperature, 91° F.

Location 2, sample 2932. Associated Pipe Line Co., Arbios station. NW¼ sec. 25, T. 13 S., R. 14 E. Depth, 400 feet. Reported as becoming less desirable for drinking.

Location 3, sample 2761. Irrigation well. W¼ corner sec. 31, T. 13 S., R. 14 E. Depth, 1,400 feet; stands at 165 feet.

Location 4, sample 2762. Irrigation well. SW corner SE¼ sec. 32, T. 13 S., R. 14 E. Depth, 1,400 feet; discharge, 2.9 cubic feet per second.

Location 5-S, sample 1949. San Joaquin River below Mendota Dam. This sample contains little if any storage water from Fresno Slough.

Location 6-S, sample 1948. Columbia Canal; diverted from San Joaquin above mouth of Fresno Slough.

Location 7, sample 1871. Mendota municipal well. Depth, 506 feet; lower 50 feet perforated; water stands at 67 feet. Water strata encountered after drilling through 350 or 400 feet of "blue muck", above which the water was reported to be saline.

Location 8, samples 1875 and 2760. Irrigation well. NW corner sec. 6, T. 14 S., R. 14 E. Depth, about 1,400 feet; water stands 165 feet; casing perforated at about 400 feet and below.

Location 9, sample 2763. Irrigation well. SW corner NW¼ sec. 4, T. 14 S., R. 14 E.

Location 10, sample 2759. Wayland no. 2. NW¼ sec. 7, T. 14 S., R. 14 E. Depth, 1,300 feet; stands at 180 feet; casing perforated below 400 feet; discharge, 2.7 cubic feet per second.

Location 11, sample 1874. Victoria Ranch well. SW corner sec. 8, T. 14 S., R. 14 E. Depth, 1,400 feet; stands at 167 feet.

Location 12, sample 1372. F. M. Heim, Inc., irrigation well. SW corner sec. 17, T. 14 S., R. 14 E. Depth, 1,500 feet; discharge, 2 cubic feet per second.

Location 13, sample 1873. Ensher & Alexander well no. 1. SW corner sec. 15, T. 14 S., R. 14 E. Depth, 1,250 feet; perforated below 600 feet; discharge, 2.2 cubic feet per second; temperature, 84° F.; no odor.

Location 14, sample 1872. Irrigation well. SW corner sec. 13, T. 14 S., R. 14 E.

Location 15, sample 2764. SW corner NW¼ sec. 21, T. 14 S., R. 14 E.

Location 16, sample 2765. Irrigation well. NW corner sec. 35, T. 14 S., R. 14 E. Depth, 1,400 feet.

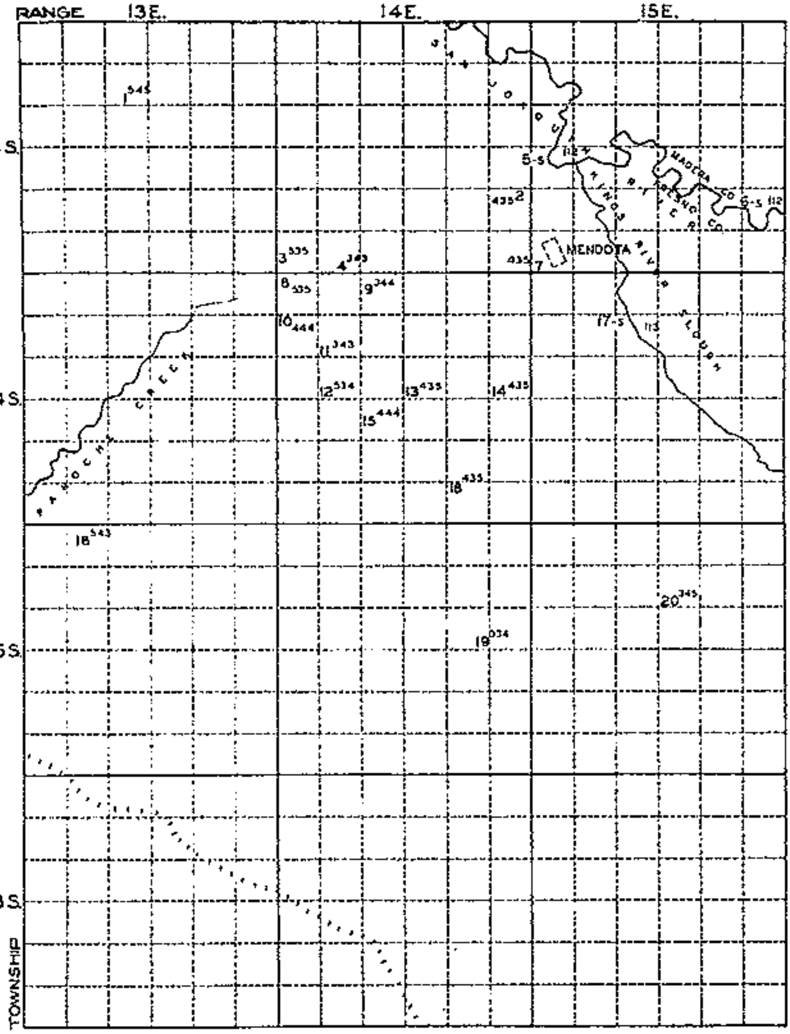

FIGURE 15.—Quadrangle 15, showing locations of samples reported in table 23.

Location 17–S, sample 1947. Kings River Slough at White's Bridge, sec. 4, T. 14 S., R. 15 E. This slough serves as a storage reservoir for San Joaquin River water before diversion at Mendota Dam.

Location 18, sample 2758. Chaney Ranch irrigation well. South center of N½ sec. 5, T. 15 S., R. 13 E. Depth, about 1,000 feet; 8-inch casing; running lift, 300 feet.

Location 19, sample 2757. Levis Pump Station, Associated Pipe Line Co. Near center east line SE¼ sec. 14, T. 15 S., R. 14 E. Depth, 1,008 feet; now stands at 94.8 feet. Reported that when drilled in 1917 the water stood 18 feet from surface.

Location 20, sample 1373. Englebreck Ranch irrigation well. Near SW corner sec. 10, T. 16 S., R. 15 E. Depth, 1,500 feet; stands at 100 feet.

TABLE 24.—*Quality of water in quadrangle 16, Tps. 13, 14, 15, and 16 S., Rs. 16, 17, and 18 E. (fig. 16)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	2931	June 22, 1930	31.5	0.09	2.30	1.00	0.05	0.34	0.11	2.90	87
2	2930	do	376	1.47	3.80	20.00	.38	2.71	.03	50.74	90
	3549	Nov. 28, 1930	281	1.08	2.55	22.05	1.15	1.90	.42	23.43	91
3	1869	Sept. 26, 1929	21.0	.04	1.60	.30	.20	1.05	.45	.69	32
4	1867	do	118	.93	1.00	1.30	7.50	1.05	.03	9.02	90
	1868	do	112	.97	2.20	1.20	6.70	1.00	T [1]	9.01	80
5	1866	do	72.4	.80	3.60	2.00	2.25	.67	.00	7.18	91
6	1865	do	125	.78	3.00	1.30	7.74	1.40	T [1]	10.65	88
7	2929	June 22, 1930	18.0	.03	2.30	.30	.28	1.19	.90	.79	27
8	3287	Sept. 17, 1930	58.5	.21	3.10	1.90	.96	1.07	.47	4.42	74
9	3286	do	88.7	1.00	5.40	2.80	.08	.68	.40	8.10	89
10	1864	Sept. 26, 1929	111	1.29	4.50	4.60	1.74	.75	.03	10.06	93

[1] T=trace.

DESCRIPTION OF SAMPLES OF QUADRANGLE 16 (TABLE 24 AND FIG. 16)

Location 1, sample 2931. Jameson, Southern Pacific Railroad section-house domestic well. Near NE corner sec. 15, T. 14 S., R. 16 E. A shallow well operated with hand pump.

Location 2, samples 2930 and 3549. Associated Pipe Line Co., Jameson station. Near NW¼ corner sec. 14, T. 14 S., R. 16 E. Depth, 600 feet; perforated from 250 feet down.

Location 3, sample 1869. Ed. Nunes service station. Probably N. line sec. 7, T. 14 S., R. 17 E. Depth, 70 feet; casing not perforated and reported to exclude three upper water-bearing strata.

Location 4, sample 1867. Tranquillity municipal well. Depth, 1,000 feet; casing not perforated; water cool.

Location 4, sample 1868. Tranquillity Creamery well. Depth, 993 feet; casing not perforated; water cool.

Location 5, sample 1866. James Irrigation District, well 29–G. Near S¼ corner sec. 22, T. 15 S., R. 16 E. Temperature, 94° F.; strong sulphur odor; formerly a flowing well.

Location 6, sample 1865. San Joaquin municipal well. Depth, 1,700 feet.

Location 7, sample 2929. James Irrigation District. Composite of discharge of the majority of a series of some 20 wells, spaced about one-third mile apart along Coalinga Road, southwest from McMullin toward Helm. Sampled from canal at SW corner sec. 30, T. 15 S., R. 18 E. Depths, 214 to 300 feet.

Location 8, sample 3287. Stinson Irrigation District. Well at SE corner sec. 10, T. 16 S., R. 17 E. Depth, 1,000 feet; perforated at all strata.

Location 9, sample 3286. Stinson Irrigation District. Well at SW corner sec. 23, T. 16 S., R. 17 E. Depth, 750 feet; 12-inch discharge pipe.

Location 10, sample 1864. Irrigation well. SW corner sec. 36, T. 16 S., R. 18 E.; 12-inch discharge pipe, flowing into open ditch.

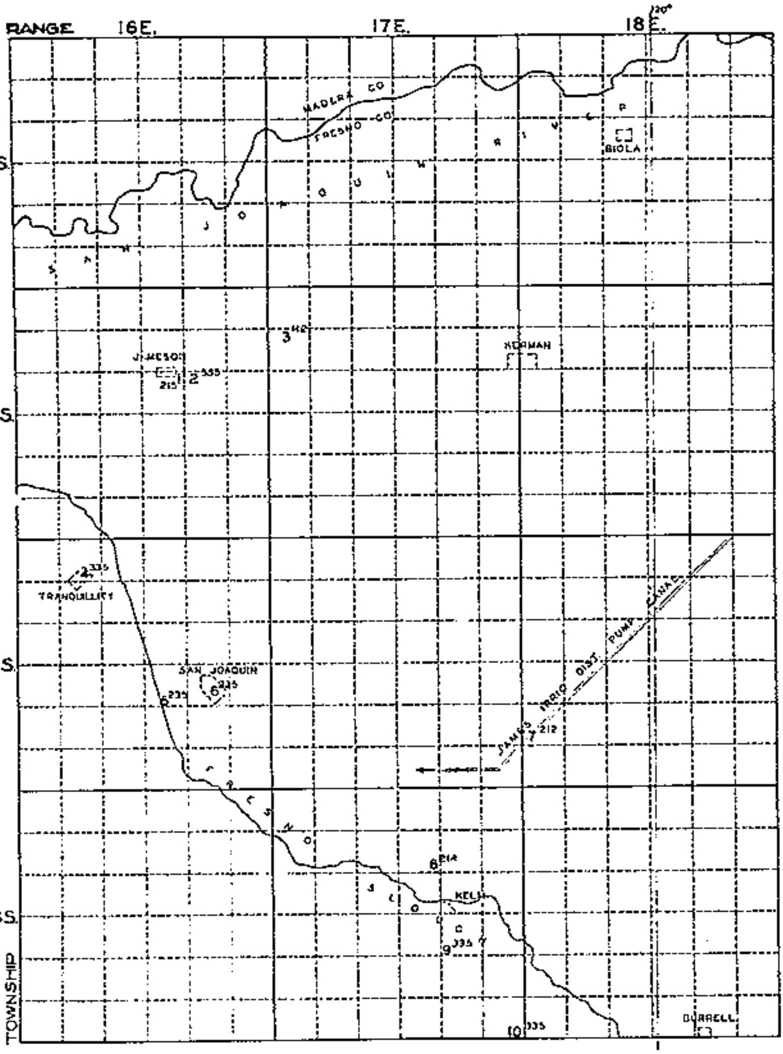

FIGURE 16.—Quadrangle 16, showing locations of samples reported in table 24.

TABLE 25.—*Quality of water in quadrangle 17, Tps. 13, 14, 15, and 16 S., Rs. 19, 20, and 21 E. (fig. 17)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Per cent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1-S	1366	June 16, 1929	5.9	0.08	0.32	0.13	0.12	0.24	T[1]	0.33	58
2	1870	Sept. 27, 1929	30.3	.01	2.50	.70	.36	1.63	1.22	.65	19
	2028	June 22, 1930	13.5	T[1]	1.10	.10	.13	.48	.55	.30	23
	4529	July 7, 1931	42.5	.04	2.85	.09	.12	1.64	1.28	1.29	31
3	5205	Nov. 14, 1931	10.7	.01	1.40	.20	.10	.59	.57	.58	33
4	2023	June 21, 1930	35.2	T[1]	2.05	.09	.18	1.80	.60	.73	23
5	4528	July 7, 1931	24.0	.08	1.45	.55	.06	1.01	.40	.78	3(
6	2022	June 21, 1930	16.0	.02	1.50	.10	.15	.76	.21	.78	46
7	2021	do	15.4	T[1]	1.45	.10	.13	.71	.18	.79	47

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[1] T=trace.

DESCRIPTION OF SAMPLES OF QUADRANGLE 17 (TABLE 25 AND FIG. 17)

Location 1–S, sample 1366. San Joaquin River, Herndon.

Location 2, sample 1870. Fresno municipal water. Tap at E and Fresno Streets.

Location 2, sample 2928. Fresno municipal water. Tap at 1717 Del Mar Avenue.

Location 2, sample 4529. Fresno municipal water. Tap at 1202 Van Ness Street.

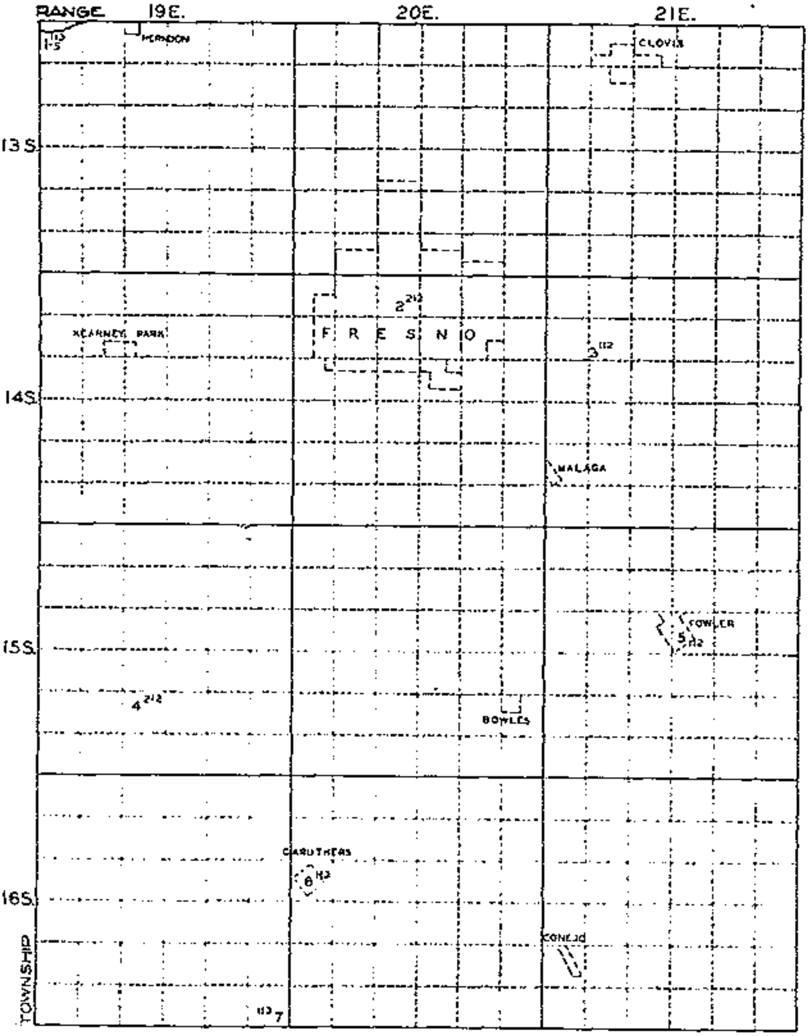

FIGURE 17.—Quadrangle 17, showing locations of samples reported in table 25.

Location 3, sample 5205. Grape experiment station well. Twenty acres at SW corner sec. 8, T. 14 S., R. 21 E. Depth, 90 feet; open bottom; 12-inch casing ending at hardpan layer at 68 feet; discharge, 0.67 cubic foot per second. Collected by E. Snyder.

Location 4, sample 2923. J. M. Long well, Raisin City. SE¼NW¼ sec. 28, T. 15 S., R. 19 E. Depth, 125 feet; water stands at 25 feet; 5-inch casing, perforated below 105 feet.

Location 5, sample 4528. Fowler municipal water. Composite of two wells; depths, 145 and 175 feet; water stands at 127 feet; casings perforated at all strata.

Location 6, sample 2922. Caruthers municipal well. Depth, 170 feet.

Location 7, sample 2921. J. T. Carreia well. SE¼ sec. 36, T. 16 S., R. 19 E. Depth, 186 feet; water stands at 20 feet.

TABLE 26.—*Quality of water in quadrangle 18, Tps. 17, 18, 19, and 20 S., Rs. 13, 14, and 15 E. (fig. 18)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Per cent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	2756	May 21, 1930	178	0.60	3.95	2.45	14.78	5.67	10.26	5.25	25
2	4848	Sept. 10, 1931	64.2	7.70	3.10	1.90	1.03	.17	.09	5.77	96
3	2755	May 21, 1930	208	1.08	5.95	3.75	13.88	2.61	9.81	11.16	47
4	2752	do	254	2.03	2.65	5.00	18.88	5.30	3.84	17.39	66
	2753	do	262	2.28	4.60	2.80	20.31	5.59	11.47	10.65	38

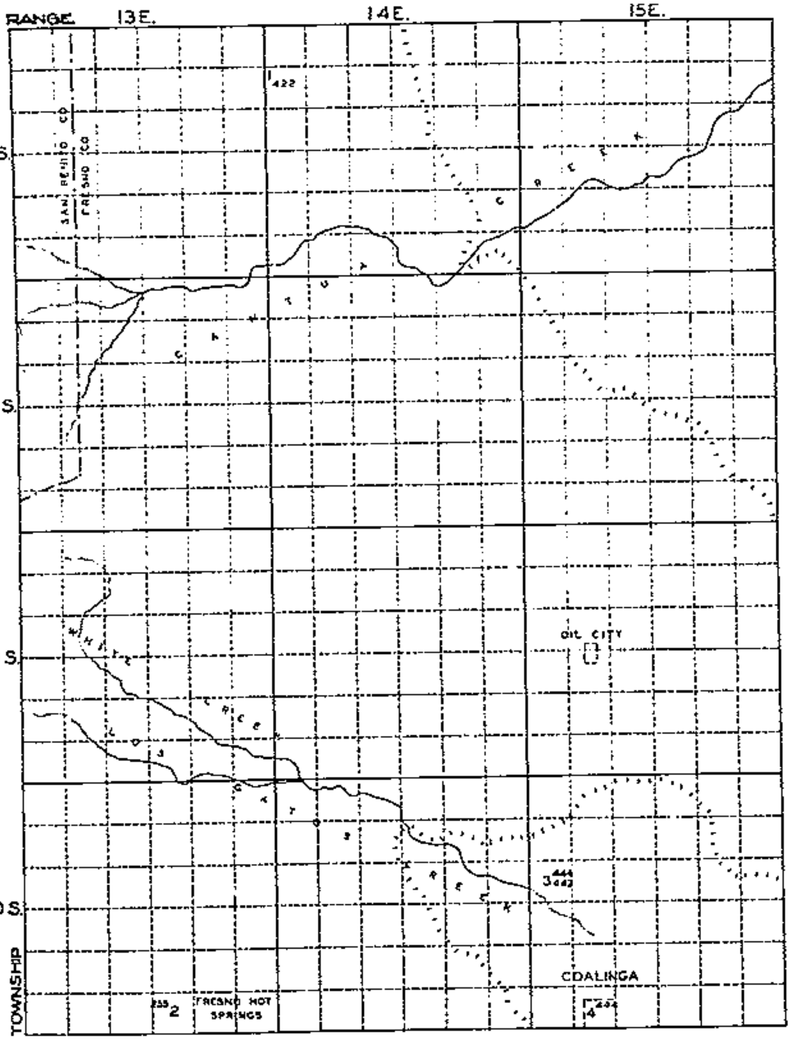

FIGURE 18.—Quadrangle 18, showing locations of samples reported in table 26.

DESCRIPTION OF SAMPLES OF QUADRANGLE 18 (TABLE 26 AND FIG. 18)

Location 1, sample 2756. Halfway Station well, Associated Pipe Line Co. Near NW corner sec. 7, T. 17 S., R. 14 E. Depth, 700 feet; 295 feet to water.

Location 2, sample 4848. Fresno (Coalinga) Hot Springs. Composite of 6 of the 15 springs at this location. Temperature, 108° F.; discharge, 0.05 cubic foot per second.

Location 3, sample 2755. Associated Oil Co., shallow domestic well. Los Gatos Creek delta; probably sec. 18, T. 20 S., R. 15 E.

Location 4, sample 2752. Coalinga municipal well no. 1. Depth, 1,410 feet; stands at 70 feet; casing perforated below 250 feet; discharge, 1.8 cubic feet per second; temperature, 91° F.

Location 4, sample 2753. Coalinga municipal well at gas plant. Depth, 1,402 feet; casing not perforated; discharge, 0.6 cubic foot per second.

TABLE 27.—*Quality of water in quadrangle 19, Tps. 17, 18, 19, and 20 S., Rs. 16, 17, and 18 E. (fig. 19)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	3099	July 22, 1930	92.1	1.06	1.10	0.70	6.55	1.35	0.42	6.58	79
2	3100	do	102	.62	2.20	1.60	6.34	1.99	.06	6.50	69
3	1858	Sept. 25, 1929	98.4	.95	1.10	.90	7.31	1.47	T [1]	7.84	84
4	3285	Sept. 17, 1930	60.1	.08	5.50	.50	.47	1.60	.42	4.45	69
5	1863	Sept. 26, 1929	94.8	1.30	7.10	2.60	.70	1.07	T [1]	9.33	90
6	1861	do	58.0	.89	4.60	1.50	.34	.61	0	5.83	91
7	3098	July 22, 1930	330	1.06	1.90	4.25	31.23	12.61	12.11	12.76	34
8	1857	Sept. 25, 1929	105	1.19	1.50	2.10	6.69	1.63	.03	7.73	75
9	1856	do	182	1.74	2.50	9.80	5.12	1.45	.56	15.41	87
	3097	July 22, 1930	169	1.30	2.30	8.55	5.26	1.74	.90	13.41	83
	4847	Sept. 11, 1931	176	1.62	2.40	8.60	5.82	1.47	.54	14.81	88
10	4844	do	247	.09	1.90	3.40	23.58	8.16	8.44	12.50	43
	4845	Apr. 19, 1931	193	.89	1.70	2.40	16.92	5.50	4.06	10.70	51
	4846	Sept. 11, 1931	433	1.63	2.75	8.56	41.74	12.37	16.71	27.39	49
11	3096	July 22, 1930	144	1.14	1.75	2.70	9.60	1.82	2.61	9.65	68
12	3094	do	86.6	1.01	1.80	.65	5.86	1.68	.26	6.37	77
	3095	do	87.2	.39	3.10	.05	4.02	2.57	1.20	4.54	54
13	1374	June 22, 1929	95.6	1.00	2.13	.79	6.42	1.28	T [1]	8.08	86
	1555	Sept. 25, 1929	96.3	1.10	2.10	.70	6.35	1.59	.32	7.24	79

[1] T=trace.

DESCRIPTION OF SAMPLES OF QUADRANGLE 19 (TABLE 27 AND FIG. 19)

Location 1, sample 3099. Irrigation well; T. L. Sims, tenant. Near S¼ corner sec. 14, T. 17 S., R. 16 E. Depth, 1,600 feet.

Location 2, sample 3100. Towne pump station, Standard Oil Co. Near N¼ corner sec. 8, T. 17 S., R. 17 E. Depth, 1,100 feet; water stands between 65 and 70 feet.

Location 3, sample 1858. Kings County Development Co., ranch no. 1. Irrigation well near SW corner sec. 33, T. 17 S., R. 17 E. Depth, 1,800 feet; casing perforated below 900 feet; discharge, 2.0 cubic feet per second; temperature, 86° F.

Location 4, sample 3285. W. R. Jones, irrigation well. NW¼NE¼ sec. 1, T. 17 S., R. 18 E. Depth, 80 feet; stands at 26 feet.

Location 5, sample 1863. Stinson Irrigation District well no. 7. W¼ corner sec. 9, T. 17 S., R. 18 E. Depth, about 800 feet.

Location 6, sample 1861. Tony Fatado, irrigation well. Near NE corner sec. 25, T. 17 S., R. 18 E. Depth, 408 feet; casing perforated below 150 feet.

Location 7, sample 3098. F. G. Ladd, irrigation well. NW¼ sec. 12, T. 18 S., R. 16 E. Depth, 150 feet.

Location 8, sample 1857. Kings County Development Co., ranch no. 2. Irrigation well near SW corner sec. 5, T. 18 S., R. 17 E. Depth, 1,800 feet; perforated below 900 feet; discharge, 1.8 cubic feet per second; temperature, 89° F.

Location 9, samples 1856, 3097, and 4847. Kings County Development Co., ranch no. 3. Near SW corner sec. 7, T. 18 S., R. 17 E. Depth, 1,700 feet;

perforated below 900 feet; water stands at 150 feet; discharge, 2.0 cubic feet per second; temperature, 91° F.

Location 10, sample 4844. Peter L. Ferry, irrigation well. Near center sec. 10, T. 18 S., R. 17 E. Depth, 650 feet; stands at 70 feet; draws down to 140 feet; casing perforated below 170 feet; upper 250 feet of casing 13-inch, with 10-inch casing below; discharge, 1.89 cubic feet per second. Log shows 15 sand strata alternating with clay strata.

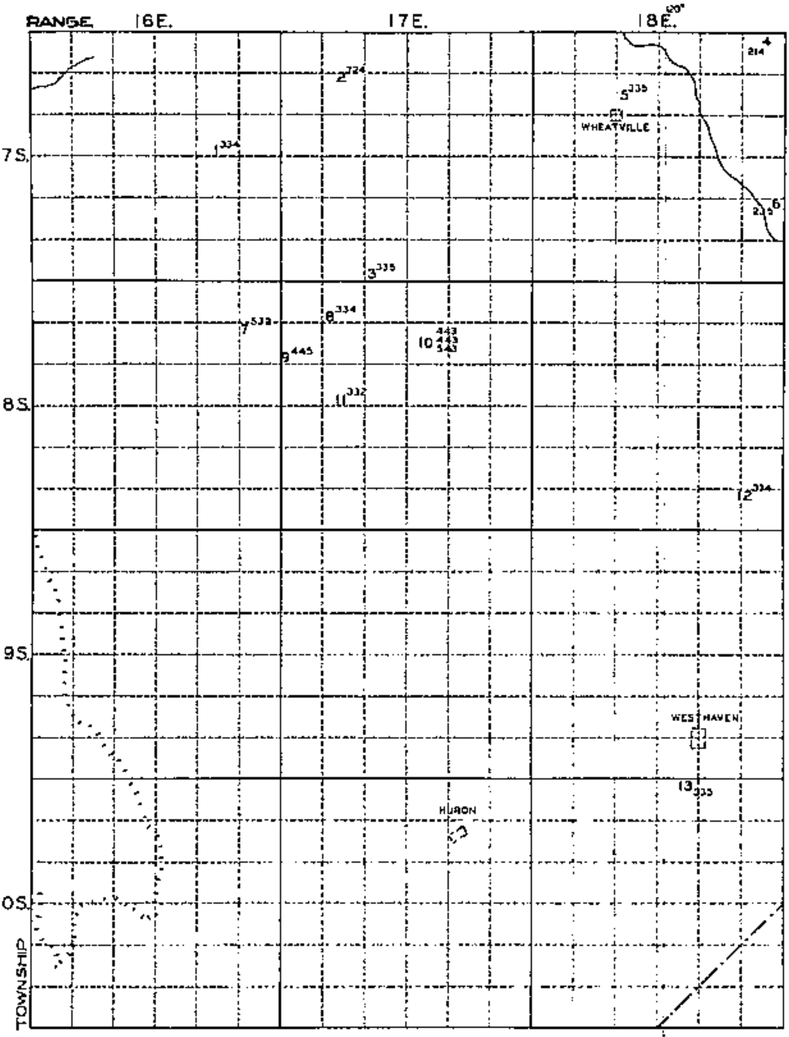

FIGURE 10.—Quadrangle 10, showing locations of samples reported in table 27.

Location 10, sample 4845. Peter L. Ferry, abandoned irrigation well. Adjacent to well represented by sample 4844. Drilled to 467 feet; perforated at 70 feet and below. Sampled in April by cooperator when pump was operating. Sample held in bottle till September.

Location 10, sample 4846. Well described under 4845. This sample represents water entering casing at 70 feet when the operation of well 4844 caused draw down in water level.

Location 11, sample 3096. Citizens National Bank of Los Angeles, irrigation well. Near SW corner of SE¼ sec. 17, T. 18 S., R. 17 E. Depth, about 1,800 feet; perforated below 900 feet.

Location 12, sample 3094. Lethant pump station, well no. 2, Standard Oil Co. Near NW corner sec. 36, T. 18 S., R. 18 E. Depth, 600 feet.

Location 12, sample 3095. Lethant station, well no. 3. Depth, 1,000 feet.

Location 13, samples 1374 and 1855. Boston Land Co., well no. 1. Near NE corner sec. 3, T. 20 S., R. 18 E. A very deep well. Log not ascertained.

TABLE 28.—*Quality of water in quadrangle 20, Tps. 17, 18, 19, and 20 S., Rs. 19, 20, and 21 E. (fig. 20)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	1862	Sept. 26, 1929	80.1	1.30	5.30	2.80	0.85	0.53	T[1]	8.42	95
2	2920	June 21, 1930	38.6	.57	3.35	1.00	.11	.22	.19	4.25	91
3	2919	do	33.0	.55	2.90	.55	.10	.28	.22	3.05	86
4-S	1377	June 22, 1929	5.4	.05	.30	.05	.06	.25	.00	.16	39
5	2918	June 21, 1930	13.5	T[1]	1.35	.10	.12	1.05	.24	.38	23
6	3075	July 22, 1930	38.0	.37	2.10	1.50	.06	.38	.21	3.07	84
7	1860	Sept. 26, 1929	27.5	.13	2.60	.20	.33	.75	T[1]	2.38	76
8	1859	do	44.8	.66	1.80	2.30	.35	.61	.00	3.84	86
9	1117	May 24, 1929	76.8	.78	4.70	2.94	.44	.44	.32	7.38	91
	1375	June 22, 1929	77.0	.07	4.64	2.88	.00	.16	T[1]	7.30	98
	1376	do	90.6	.31	7.20	1.75	.44	3.05	2.31	4.03	43
10	3074	July 21, 1930	111	1.03	3.80	.75	5.80	1.50	.44	8.47	81
11	3073	do	125	1.06	4.10	1.20	6.84	.85	.61	10.68	88
12	3072	do	109	.09	5.00	.70	5.03	.90	.40	9.43	88

[1] T=trace.

DESCRIPTION OF SAMPLES OF QUADRANGLE 20 (TABLE 28 AND FIG. 20)

Location 1, sample 1862. Henry Kapling, irrigation well. NE¼ sec. 30, T. 17 S., R. 19 E. Depth, 195 feet; casing perforated all the way down; running lift, 50 feet; 7-inch discharge pipe; water cool, but with a rather strong sulphur odor.

Location 2, sample 2920. Riverdale Cooperative Creamery Co., Riverdale. NW¼ sec. 25, T. 17 S., R. 19 E. Depth, 210 feet; casing not perforated.

Location 3, sample 2919. G. G. Rogers, domestic well. Near NW corner sec. 30, T. 17 S., R. 20 E. Depth, 200 feet; static level, 28 feet.

Location 4–S, sample 1377. Irrigation canal from Kings River. Lemoore-Hanford highway.

Location 5, sample 2918. Lucern Vineyard. Near center sec. 10, T. 18 S., R. 21 E. Depth, 120 feet; static level, 15 feet; discharge, 3.2 cubic feet per second.

Location 6, sample 3075. Hanford municipal. California Water Service Corporation, station no. 3 well, West Florinda Street and Hanford Avenue. Depth, 1,100 feet; casing perforated below 600 feet.

Location 7, sample 1860. Hanford municipal. California Water Service Corporation, station no. 2 well, Harris and Water Streets. Depth, 1,500 feet; casing perforated below 600 feet; static level, 38 feet; draws down to about 60 feet.

Location 8, sample 1859. Hanford municipal. California Water Service Corporation, station no. 1 well, 131 West Fifth Street. Depth, 900 feet; casing perforated below 600 feet; static level, 45 feet; draws down to about 60 feet.

Location 9, samples 1117 and 1375. Lemoore municipal. A deep well. Sample 1117 collected by F. E. Smith.

Location 9, sample 1376. Lemoore. A shallow well at old high school.

Location 10, sample 3074. A. E. Blakeley, irrigation well. NE¼ sec. 13, T. 20 S., R. 19 E. Depth, 860 feet; draws down to 91 feet; casing perforated below 400 feet.

Location 11, sample 3073. Stratford municipal water. Well one-half mile west of town. Depth, about 1,100 feet.

Location 12, sample 3072. C. H. Meyer, irrigation well. Near NE corner sec. 29, T. 20 S., R. 20 E. Depth, 1,095 feet; temperature, 81° F.

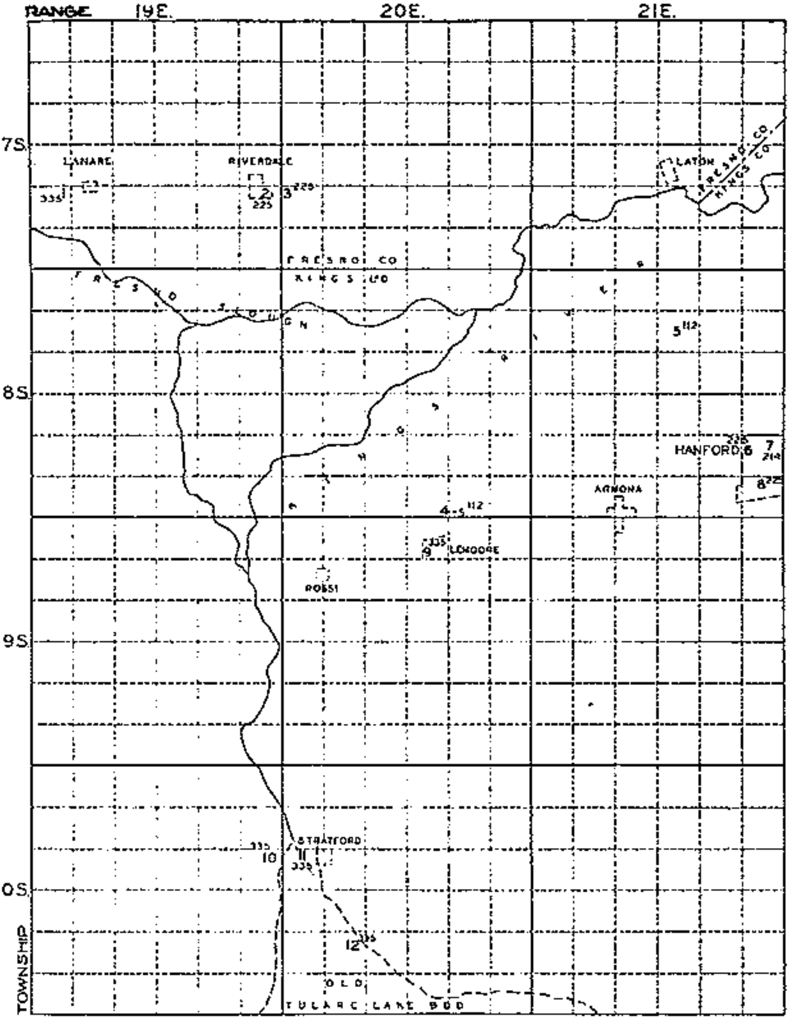

FIGURE 20.—Quadrangle 20, showing locations of samples reported in table 28.

TABLE 29.—*Quality of water in quadrangle 21, Tps. 17, 18, 19, and 20 S., Rs. 22, 23, and 24 E. (fig. 21)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	1305	June 16, 1929	7.2	0.03	0.47	0.05	0.14	0.33	0.03	0.30	45
	1046	Oct. 6, 1929	14.8	T[1]	1.10	.15	.18	.68	.09	.66	46
2	3076	July 22, 1930	23.8	.14	1.95	.30	.06	.20	.32	1.79	77
3	4526	July 7, 1931	20.1	.12	1.38	.20	.02	.82	.16	.58	37
4	2910	June 21, 1930	35.1	.29	2.80	1.30	.21	.33	.11	3.87	90
5	2912	do	10.2	.18	1.80	.20	.15	.49	.14	1.52	71
6	2917	do	214	.48	10.00	9.25	2.69	4.19	2.01	15.71	72
7	4525	July 7, 1931	16.9	.04	1.60	.15	.07	.33	.07	1.46	78
Miscellaneous[2]	3046	July 11, 1930	61.1	.10	4.30	1.25	.67	3.03	2.33	.86	14

[1] T=trace.

[2] Outside of quadrangle; included for convenience.

DESCRIPTION OF SAMPLES OF QUADRANGLE 21 (TABLE 29 AND FIG. 21)

Location 1–S, samples 1365 and 1946. Kings River, between Traver and Kingsburg. (See also sample 1377, location 4, quadrangle 20.)

Location 2, sample 3076. Hanford municipal, California Water Service Corporation, station no. 4 well. East County Road at Eleventh Street. Depth, 500 feet; casing perforated below 200 feet.

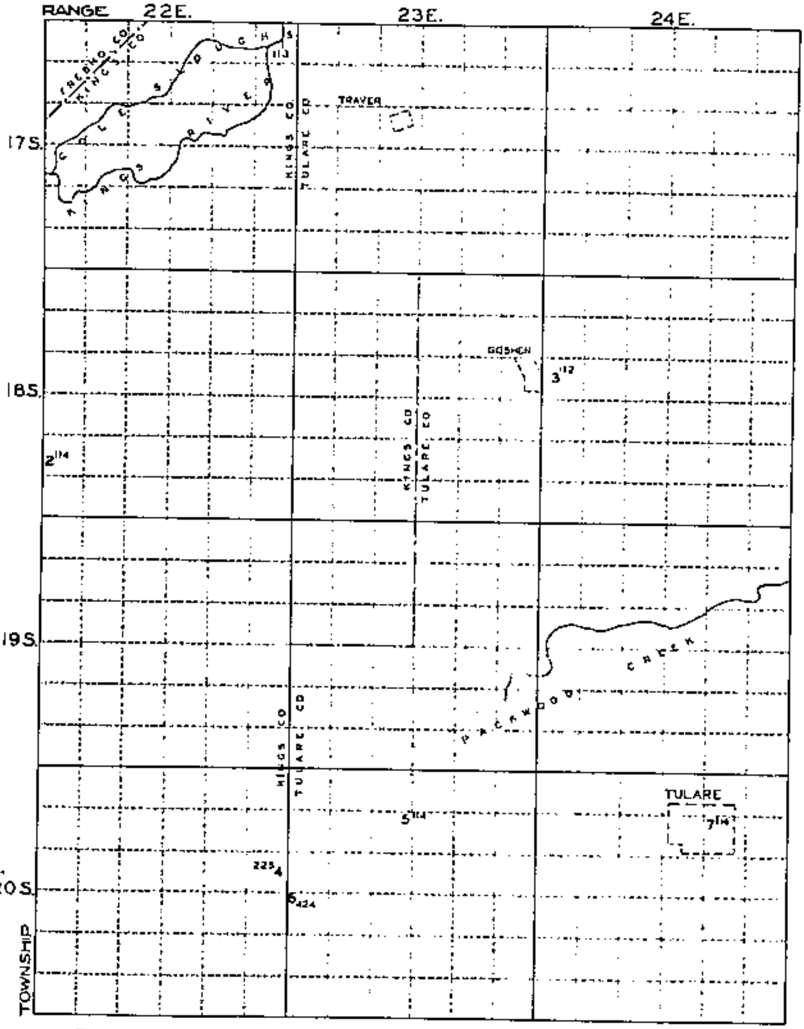

FIGURE 21.—Quadrangle 21, showing locations of samples reported in table 29.

Location 3, sample 4526. Goshen Junction. Southern Pacific depot well. Depth, about 300 feet.

Location 4, sample 2916. C. V. Wreden, irrigation well no. 1. SE¼ sec. 13, T. 20 S., R. 22 E. Depth, 2,100 feet; casing perforated from 600 feet down.

Location 5, sample 2912. Tagus Ranch, James Thomas, irrigation well. Near NE corner sec. 9, T. 20 S., R. 23 E. Depth, 563 feet.

Location 6, sample 2917. C. V. Wreden. NW¼ sec. 19, T. 20 S., R. 23 E. Depth, about 100 feet.

Location 7, sample 4525. Tulare municipal well. Composite of two wells at O Street plant. Depths, 669 and 770 feet; casings perforated below 300 feet; combined discharges, 5.6 cubic feet per second.

Miscellaneous sample 3048. Minnehaha Orchards. Approximately 5 miles northwest of Woodlake. Composite sample of battery of 19 wells. Collected by E. R. Parker.

TABLE 30.—*Quality of water in quadrangle 22, Tps. 21, 22, 23, and 24 S., Rs. 13, 14, and 15 E.*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	2754	May 21, 1930	506	4.20	6.20	14.20	41.30	13.33	7.25	41.18	66
2	2751	May 20, 1930	278	.80	2.90	5.10	24.85	8.33	9.54	14.08	46

DESCRIPTION OF SAMPLES OF QUADRANGLE 22 (TABLE 30)

(Quadrangle map not shown)

Location 1, sample 2754. Crescent Meat Co. Shallow well near Waltham Creek. Near center W½ sec. 8, T. 21 S., R. 15 E.

Location 2, sample 2751. T. Curvi. Shallow domestic well beside Jacalitos Creek. Sec. 14, T. 21 S., R. 15 E. Depth, 15 feet.

TABLE 31.—*Quality of water in quadrangle 23, Tps. 21, 22, 23, and 24 S., Rs. 16, 17, and 18 E. (fig. 22)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	3210	Aug. 22, 1930	154	0.50	2.30	1.00	12.67	5.84	5.34	5.89	35
2	2877	June 12, 1930	165	.52	2.45	1.50	13.66	6.07	6.00	5.84	33
3	1854	Sept. 25, 1929	93.3	.38	1.50	1.20	6.34	2.19	.38	6.47	72
4	1852	do	100	.38	1.40	1.10	7.22	2.80	1.15	5.68	58
5	1853	do	98.5	.40	1.50	1.20	6.86	2.55	.87	6.14	64
6	2876	June 19, 1930	359	.23	5.00	1.65	42.46	21.85	17.71	9.55	19
7	2750	May 20, 1930	235	.66	0.80	1.40	19.75	7.95	8.70	11.30	40
8	2875	June 12, 1930	169	.25	4.15	.60	14.83	5.45	7.32	6.81	35
9	2749	May 20, 1930	200	.32	1.90	1.20	16.23	6.06	8.15	7.12	33
10	2748	do	296	1.28	2.05	6.05	23.40	9.16	7.47	14.87	47

DESCRIPTION OF SAMPLES OF QUADRANGLE 23 (TABLE 31 AND FIG. 22)

Location 1, sample 3210. Hayes Ranch. SW¼ sec. 1, T. 21 S., R. 16 E. Depth 165 feet; casing perforated below 105 feet. Collected by W. T. Hayes.

Location 2, sample 2877. Talvodero Ranch, stock well. NE¼ sec. 22, T. 21 S., R. 16 E. Depth, 100 feet. Collected by Theodore Kreyenhagen.

Location 3, sample 1854. G. M. Gifford & Sons, irrigation well. About 1,500 feet north of SW corner sec. 14, T. 21 S., R. 18 E. Depth, 1,000 feet; casing perforated below 500 feet; static level, 112 feet; discharge, 1 cubic foot per second; cool.

Location 4, sample 1852. Kings County Packing Co. well. Near NW corner sec. 15, T. 21 S., R. 18 E. Depth, 1,700 feet; discharge, 1.8 cubic feet per second.

Location 5, sample 1853. Kings County Packing Co. N¼ corner sec. 23, T. 21 S., R. 18 E. Depth, 1,400 feet; casing perforated below 500 feet; temperature, 82° F.

Location 6, sample 2876. Well near Zapata Creek, drilled to supply rotary oil rig. NE¼ sec. 18, T. 22 S., R. 16 E. Depth, 512 feet. Collected by Theodore Kreyenhagen.

Location 7, sample 2750. Theodore Kreyenhagen, domestic well. Near center sec. 9, T. 22 S., R. 16 E. Depth, 20 feet.

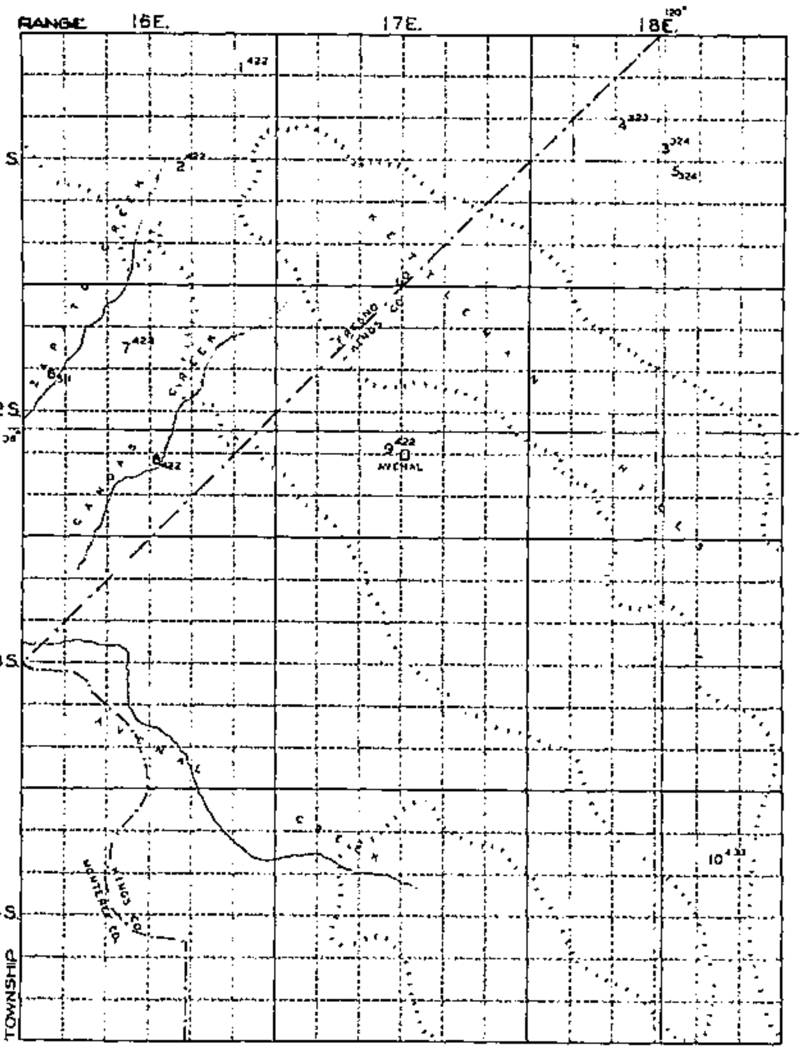

FIGURE 22.—Quadrangle 23, showing locations of samples reported in table 31.

Location 8, sample 2875. Stock well near Canoas Creek. NW¼ sec. 27, T. 22 S., R. 16 E. Depth, 100 feet. Collected by Theodore Kreyenhagen.

Location 9, sample 2749. Avenal. Collected from tap supplied by a well 500 feet deep in sec. 21, T. 22 S., R. 17 E.

Location 10, sample 2748. Dudley pump station, Union Oil Co. Piped from wells several miles away, presumably in sec. 11, T. 24 S., R. 18 E. Well in operation; reported to be 119 feet deep with static level of 32 feet.

TABLE 32.—*Quality of water in quadrangle 24, Tps. 21, 22, 23, and 24 S., Rs. 19, 20, and 21 E.* (*fig. 23*)

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	1851	Sept. 25, 1929	145	[1]	7.30	7.00	0.40	1.15	1.60	11.95	81
2	3093	July 22, 1930	155	0.70	7.40	7.55	.40	1.58	1.16	12.61	82
3	1850	Sept. 25, 1929	171	.87	10.60	7.60	.09	1.77	1.20	15.32	84
4	3092	July 22, 1930	137	.47	6.30	7.35	T [2]	1.54	1.03	11.08	81
5	3071	July 21, 1930	112	.40	5.30	5.40	T [2]	1.28	.81	8.61	80
6	1849	Sept. 25, 1929	243	.91	10.00	14.60	.15	2.31	1.28	21.16	85
7	1848	do	124	.46	5.60	6.70	.02	1.43	.48	10.41	85
8	3251	Aug. 29, 1930	40.3	.22	3.95	1.00	.21	.76	2.96	1.44	28
9	3162	Aug. 15, 1930	126	.62	7.20	5.25	.14	1.57	1.60	9.42	75
10	3252	Aug. 29, 1930	73.9	.65	3.10	4.20	.05	.90	1.02	5.43	74
11	1845	Sept. 25, 1929	92.3	.48	6.40	.50	.05	1.29	.96	4.70	68
12	3163	Aug. 15, 1930	94.0	.30	4.65	4.60	.01	1.26	.51	7.49	81
13	3091	July 22, 1930	348	.37	6.05	25.90	T [2]	4.56	6.78	21.51	65
14	1846	Sept. 25, 1929	108	.40	4.60	5.00	.06	1.27	.32	8.07	85
15	1847	do	144	.27	6.90	7.30	.05	2.49	1.20	10.56	74
	3160	July 22, 1930	145	.25	7.00	7.10	.04	2.38	2.19	9.57	68
16	3090	do	109	.20	5.80	4.75	T [2]	2.00	1.45	7.10	67
17	3089	do	220	.26	8.30	12.80	T [2]	3.49	4.34	13.27	63
18	3070	July 21, 1930	524	2.20	37.00	22.15	2.14	5.00	13.30	42.99	69

[1] Lost.
[2] T = trace

DESCRIPTION OF SAMPLES OF QUADRANGLE 24 (TABLE 32 AND FIG. 23)

Location 1, sample 1851. Missouri State Life Insurance Co. well. Near NW corner sec. 1, T. 21 S., R. 19 E. Depth, between 1,700 and 1,800 feet.

Location 2, sample 3093. Kings County Development Co. well. Near NW corner sec. 7, T. 21 S., R. 20 E. Depth, about 1,800 feet; warm and gas.

Location 3, sample 1850. Kings County Development Co. well. Near NW corner sec. 18, T. 21 S., R. 20 E. Depth 1,800 feet; running lift, 160 feet; temperature, 90° F.

Location 4, sample 3092. Kings County Development Co. well. Near NE corner sec. 18, T. 21 S., R. 20 E. Depth, 2,100 feet; casing perforated below 1,200 feet; running lift, 200 feet; discharge, 4.5 cubic feet per second; warm and gas.

Location 5, sample 3071. Nick Weis well. Near center sec. 23, T. 21 S., R. 20 E. Depth, 1,951 feet; perforated below 955 feet.

Location 6, sample 1849. Kings County Development Co. well. Near NW corner sec. 30, T. 21 S., R. 20 E. Depth, 1,950 feet; discharge, 4 cubic feet per second; temperature, 99° F.

Location 7, sample 1848. A. H. Wolfsen well. North center sec. 36, T. 21 S., R. 20 E. Depth, 1,800 feet; discharge, 3.6 cubic feet per second; temperature, 91° F.

Location 8, sample 3251. Charles Slaybaugh well. Near E¼ corner sec. 12, T. 21 S., R. 21 E. Depth, about 1,500 feet.

Location 9, sample 3162. Gilky Bros. well. E½ sec. 19, T. 21 S., R. 21 E. A deep well. Collected by H. E. Hite.

Location 10, sample 3252. Tulare Lake Land Co. well. N¼ corner sec. 22, T. 21 S., R. 21 E. Depth, about 1,800 feet; casing perforated below 850 feet; temperature not high; considerable gas.

Location 11, sample 1845. Frank Helm well. Near NE corner sec. 24, T. 21 S., R. 21 E. Depth, 1,425 feet; water stands at about 50 feet.

Location 12, sample 3163. W. A. Crockett well. E½ sec. 33, T. 21 S., R. 21 E. A deep well. Collected by H. E. Hite.

Location 13, sample 3091. Kings County Development Co. well. Near SE corner sec. 5, T. 22 S., R. 21 E. Depth 2,100 feet; casing perforated below 1,400 feet; discharge, 4.5 cubic feet per second; running lift, 200 feet. Water warm; gas present.

Location 14, sample 1846. El Rico Land Co. well. Near SE corner NE¼ sec. 1, T. 22 S., R. 21 E. Depth, 1,800 feet; temperature, 90° F.; considerable gas.

Location 15, samples 1847 and 3169. Kings County Development Co. well. SE corner sec. 8, T. 22 S., R. 21 E. Depth, 1,970 feet; temperature, 93° F.; casing perforated below 1,400 feet; discharge, 3.3 cubic feet per second. Well produces considerable gas; when ignited a flame several feet high burns above discharge pipe.

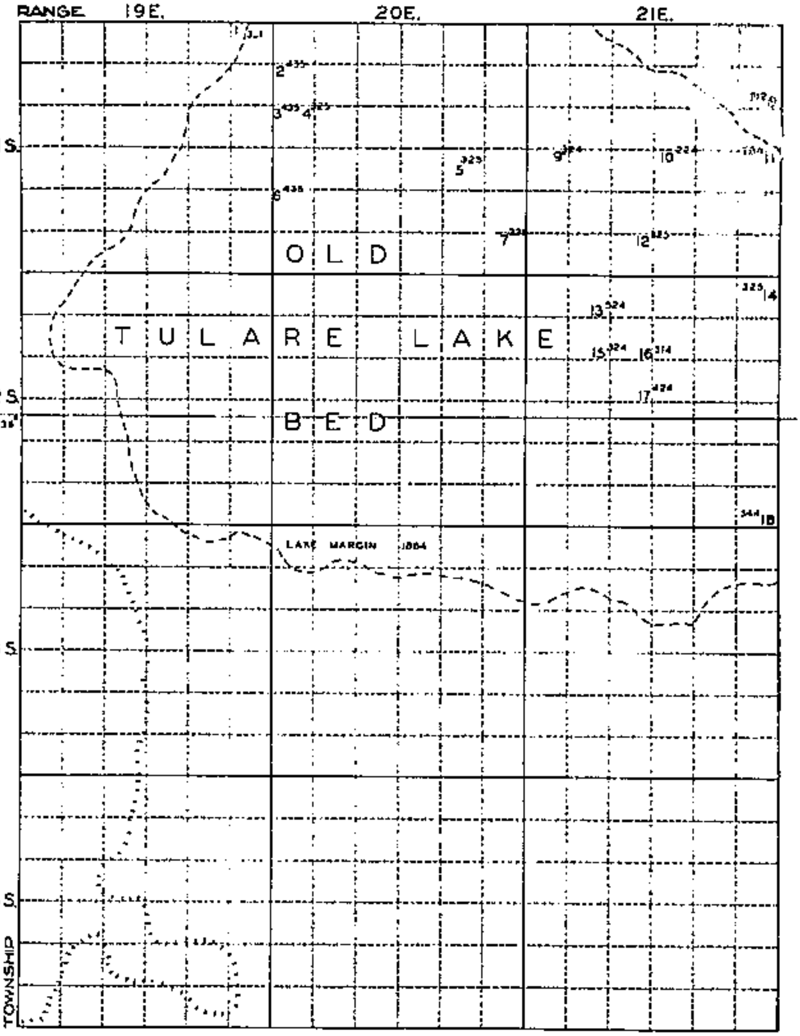

FIGURE 23.—Quadrangle 24, showing locations of samples reported in table 32.

Location 16, sample 3090. Kings County Development Co. well. Near SE corner sec. 9, T. 22 S., R. 21 E. Depth, 1,970 feet; casing perforated below 1,400 feet; static level, 75 feet; running lift, 160 feet; temperature, 91° F.

Location 17, sample 3089. Kings County Development Co. well. Near SE corner sec. 16, T. 22 S., R. 21 E. Depth, 1,800 feet; running lift, 185 feet; discharge, 3.7 cubic feet per second; warm water and considerable gas.

Location 18, sample 3070. Gates Ranch, shallow well. Near SE corner sec. 36, T. 22 S., R. 21 E. Depth, about 150 feet; water used only for washing, etc. Gas from the well is trapped and used for gas ranges.

TABLE 33.—*Quality of water in quadrangle 25, Tps. 21, 22, 23, and 24 S., Rs. 22, 23, and 24 E. (fig. 24)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Per cent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	1844	Sept. 24, 1929	134	0.86	9.50	2.00	2.93	1.67	0.40	12.36	86
2	1843	do	18.2	.15	1.50	.20	.13	.61	.00	1.22	67
	2915	June 24, 1930	19.6	.11	2.00	.20	.11	.52	.12	1.68	72
3	2914	do	492	1.98	36.90	17.00	2.78	2.39	2.18	52.11	92
4	2913	do	18.3	.03	1.50	.15	.31	.71	.14	1.11	57
5	3068	July 21, 1930	92.4	.49	4.40	4.55	T[1]	.97	.56	7.42	83
	3069	do	92.6	.27	5.80	3.40	T[1]	1.36	1.54	6.30	68
6	3066	do	164	.90	11.70	4.10	2.17	1.57	1.80	14.30	80
7	3067	do	72.2	.37	6.35	1.20	T[1]	1.30	.98	5.27	70
	3065	do	42.3	.19	3.80	.45	.20	.74	.55	3.20	72
9	1841	Sept. 24, 1929	34.0	.11	1.80	.90	.63	1.03	.71	1.59	48
	1842	do	20.0	.07	1.60	.20	.17	.45	T[1]	1.52	77
10	1839	do	23.0	.09	1.50	.50	.41	.49	.00	1.92	80
11	1840	do	34.4	.15	2.40	.90	.14	.59	.51	2.34	68
12	3284	Sept. 10, 1930	1,055	5.97	28.10	85.00	.29	3.65	12.90	96.84	85
13	5940	Apr. 10, 1932	82.8	.58	5.40	2.05	T[1]	.63	.68	7.01	84
14	5945	do	69.3	.43	5.80	1.35	.01	1.47	.94	4.75	66

[1] T=trace.

DESCRIPTIONS OF SAMPLES OF QUADRANGLE 25 (TABLE 33 AND FIG. 24)

Location 1, sample 1844. Slaybaugh and Boswell, shallow domestic well. Near W¼ corner sec. 6, T. 21 S., R. 21 E.

Location 2, samples 1843 and 2915. Corcoran municipal. Two wells, 1 mile northeast of Corcoran, probably in SW¼ sec. 12, T. 21 S., R. 22 E. Depths, 400 and 460 feet, 12-inch casings perforated below 200 feet; discharge, 1.8 and 2.0 cubic feet per second.

Location 3, sample 2914. Fred Long service station well, 1 mile west of Corcoran on south side of highway. Probably SW¼ sec. 15, T. 21 S., R. 22 E. Depth, 60 feet; static level, 26 feet; 4-inch discharge pipe.

Location 4, sample 2913. Cord Uptbrove, irrigation well. Probably NW¼ sec. 5, T. 21 S., R. 23 E. Depth 198 feet; casing not perforated.

Location 5, sample 3068. Post Card Ranch, well no. 1. Near NE corner sec. 21, T. 22 S., R. 22 E. Depth, 2,300 feet; casing perforated below 1,500 feet; report water produced by stratum at 1,800 feet; temperature, 90° F.

Location 5, sample 3069. Post Card Ranch, well no. 4. Near well no. 1. Depth, 1,900 feet; casing perforated below 1,400 feet; temperature, 83° F.

Location 6, sample 3066. W. J. Smith well. Near NE corner NW¼ sec. 24, T. 22 S., R. 22 E. Depth, 470 feet; temperature, 70° F.

Location 7, sample 3067. Forrest Riley, irrigation well. Near NE corner SE¼ sec. 24, T. 22 S., R. 22 E. Depth, 2,000 feet; casing perforated below 900 feet; static level, 90 feet; 10-inch discharge pipe; temperature, 78° F.; gas.

Location 8, sample 3065. A. V. Taylor, irrigation well. NE¼ sec. 20, T. 22 S., R. 23 E. (1 mile west of A., T., & S. F. Ry.) Depth, 460 feet; 10-inch discharge pipe; temperature, 69° F.

Location 9, sample 1841. C. W. Bryson ranch, domestic well. Near NE corner sec. 28, T. 22 S., R. 23 E. Depth, 75 feet; 2-inch casing.

Location 9, sample 1842. C. W. Bryson ranch, irrigation well no. 4. Depth, between 350 and 400 feet; 7-inch discharge pipe.

Location 10, sample 1839. Alpaugh Irrigation District canal. Sampled in sec. 33, T. 23 S., R. 23 E. The sample represents water principally if not entirely from a group of 21 wells located near Smyrna. These wells are reported to vary in depth from "shallow" to 1,000 feet. Analysis reported also under quadrangle 28.

Location 11, sample 1840. Alpaugh municipal water, from several wells 1 to 3 miles west of Alpaugh. Depth reported to be about 1,000 feet.

Location 12, sample 3284. Deep well west of La Hacienda Ranch. SW¼ sec. 19, T. 24 S., R. 22 E. Depth, 835 feet; static level, 12 feet; 12-inch casing;

perforations thought by stockman to be below 500 feet; operated by small rotary pump to supply cattle; drilled in 1929.

Location 13, sample 5946. La Hacienda Ranch, well, headquarters. Near center sec. 17, T. 24 S., R. 22 E. Depth, 830 feet; upper perforations at 400 feet; 9⅝-inch casing. Used for stock and domestic purposes. Collected by Roy Filcher.

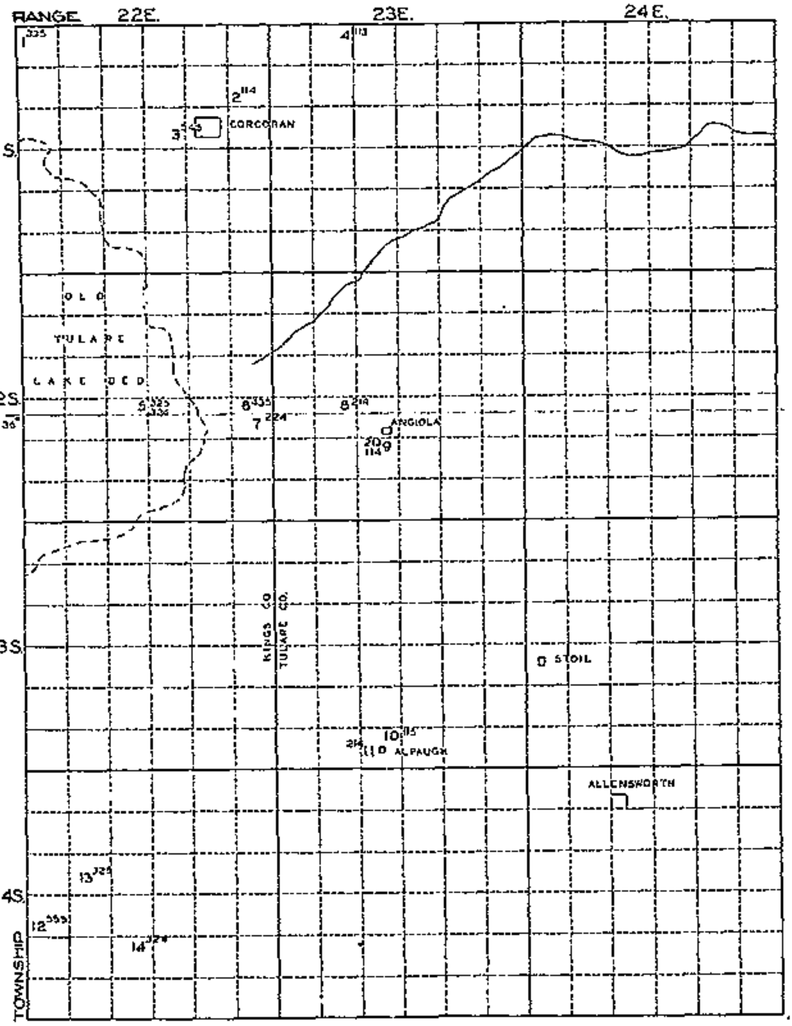

FIGURE 24.—Quadrangle 25, showing locations of samples reported in table 33.

Location 14, sample 5945. La Hacienda Ranch, well no. 7. NE¼ sec. 28, T. 24 S., R. 22 E. Depth, 990 feet; upper perforations at about 400 feet; 14-inch casing to 150 feet, then 12-inch; discharge, 2 cubic feet per second. Collected by Roy Filcher.

TABLE 34.—*Quality of water in quadrangle 26, Tps. 21, 22, 23, and 24 S., Rs. 25, 26, and 27 E.*

Location no.	Sample no.	Date	$K\times10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	4524	July 7, 1931	20.1	0.09	1.65	0.20	0.07	0.06	0.06	1.80	94
2	4523	do	30.1	.05	2.20	.45	.34	1.35	.48	1.70	48

DESCRIPTION OF SAMPLES OF QUADRANGLE 26 (TABLE 34)

(Quadrangle map not shown)

Location 1, sample 4524. Pixley municipal well. Depth, 1,180 feet; static level, 64 feet; discharge, 0.12 cubic foot per second. An old well which at one time flowed.

Location 2, sample 4523. Jorgensen vineyard. SE¼ sec. 34, T. 24 S., R. 25 E.

TABLE 35.—*Quality of water in quadrangle 27, Tps. 25, 26, 27, and 28 S., Rs. 19, 20, and 21 E. (fig. 25)*

Location no.	Sample no.	Date	$K\times10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	2747	May 20, 1930.	456	3.94	4.85	13.05	35.22	8.30	18.42	20.34	50
2	2746	do	303	1.15	3.35	17.10	18.40	9.93	9.35	19.57	50
3	2745	do	545	3.31	3.05	21.60	36.96	14.07	13.67	33.87	55
4	3281	Sept. 16, 1930.	610	5.23	1.40	15.30	50.38	24.30	7.24	44.55	59

DESCRIPTION OF SAMPLES OF QUADRANGLE 27 (TABLE 35 AND FIG. 25)

Location 1, sample 2747. Temblor pump station, Associated Pipe Line Co. Sec. 20, T. 25 S., R. 19 E. Depth, 501 feet; static level, 120 feet; report water stratum encountered at 300 feet with other strata about 3 feet thick to shale at 500 feet.

Location 2, sample 2746. S. & G. Gump property, sheep well. Sec. 25, T. 26 S., R. 19 E. Depth, 363 feet; static level at 357 feet.

Location 3, sample 2745. Chris. Trisslman ranch, sheep well. Sec. 9, T. 27 S., R. 20 E. Depth, 500 feet; "lift", 260 feet; 2½-inch casing.

Location 4, sample 3281. State highway station, Lost Hills, near NE corner sec. 3, T. 27 S., R. 21 E. Depth, 300 feet; casing perforated for three strata. Well runs dry a few minutes after starting and water is hauled both for the lawn and for drinking.

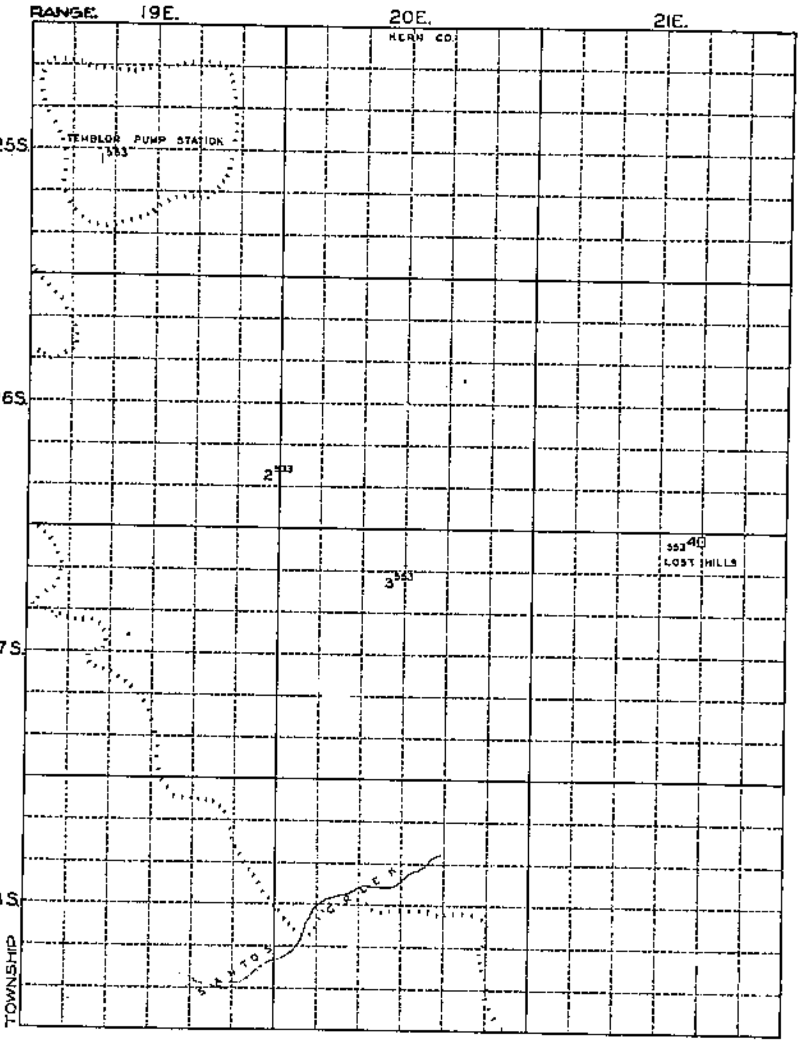

FIGURE 25.—Quadrangle 27, showing locations of samples reported in table 35.

TABLE 36.—*Quality of water in quadrangle 28, Tps. 25, 26, 27, and 28 S., Rs. 22, 23, and 24 E. (fig. 26)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	3283	Sept. 16, 1930	19.7	0.14	1.90	0.20	0.14	0.27	0.28	1.69	75
2	1839	Sept. 24, 1929	23.6	.09	1.50	.50	.41	.49	.00	1.92	80
3	3282	Sept. 16, 1930	40.8	.32	1.80	1.65	1.49	.25	.33	4.36	88
4	3280	do	133	.40	1.70	10.30	T[1]	1.76	.28	9.96	83
5	2744	May 20, 1930	20.8	.10	1.90	.40	.26	.40	.19	1.97	77
6	4831	Sept. 7, 1931	155	.34	1.30	7.20	6.77	7.32	.20	7.82	51

[1] T=trace.

DESCRIPTION OF SAMPLES OF QUADRANGLE 28 (TABLE 36 AND FIG. 26)

Location 1, sample 3283. Old Fowler ranch well. Sec. 10, T. 25 S., R. 22 E. Depth, 700 feet; static level, 18 feet. A very old well which formerly flowed.

Location 2, sample 1839. Alpaugh Irrigation District canal, as sampled in quadrangle 25. Supplied principally if not entirely from wells at Smyrna. Wells reported to vary in depth from shallow to 1,000 feet.

Location 3, sample 3282. Gilbreath ranch. Near SE corner sec. 10, T. 26 S., R. 22 E. Depth, 800 feet; casing perforated below 600 feet; static level, 18 feet.

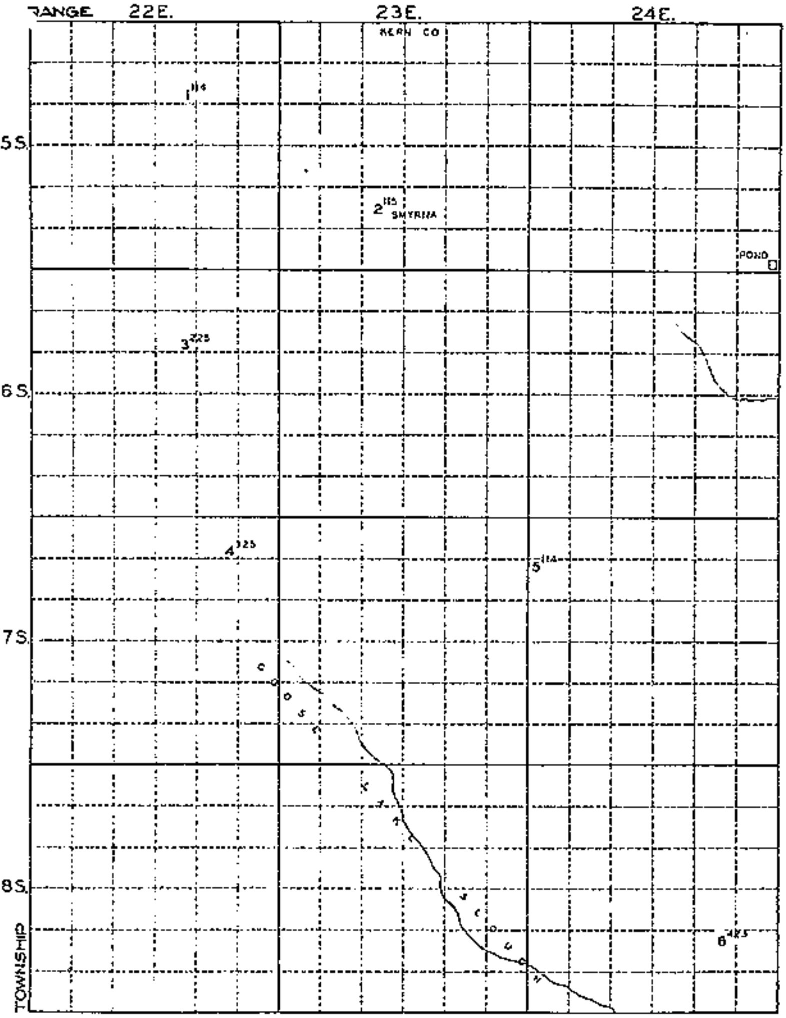

FIGURE 26.—Quadrangle 28, showing locations of samples reported in table 36.

Location 4, sample 3280. E. A. Meyer chicken ranch well. Near SE corner sec. 2, T. 27 S., R. 22 E. Depth, 170 feet; casing not perforated; static level, 50 feet.

Location 5, sample 2744. Semitropic wells supplying General Petroleum pump station at Belridge. Depth not ascertained.

Location 6, sample 4831. C. P. Morgan, irrigation well. Sec. 26, T. 28 S., R. 24 E. Depth, 112 feet; casing perforated at several strata. Reported that the domestic well of similar depth but with an unperforated casing produced a softer water. The boron symptoms were pronounced on dooryard plants irrigated from the domestic well.

TABLE 37.—*Quality of water in quadrangle 29, Tps. 25, 26, 27, and 28 S., Rs. 25 26, and 27 E. (fig. 27)*

Location no.	Sample no.	Date	$K\times10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	4522	July 7, 1931	41.5	0.03	1.90	0.80	1.05	1.53	0.98	1.60	39
2	4520	do	10.2	.03	1.70	.15	.12	.86	.10	1.05	52
3	624	Feb. 5, 1929	40.5	.14	3.50	.30	.60	2.83	1.13	.53	12
4	4521	July 7, 1931	25.4	.01	2.15	.10	.43	1.42	.47	.85	31
5-S	2911	June 21, 1930	7.71	.03	.70	.10	.31	.37	.16	.58	52
6	3279	Sept. 10, 1930	78.3	.19	2.00	2.05	3.20	2.55	.43	4.27	59
7	3232	Aug. 28, 1930	140	.06	1.00	0.95	4.08	0.60	1.01	5.02	40
8	3233	do	248	.05	1.70	16.30	5.45	13.17	2.08	8.23	35
9	2910	June 21, 1930	44.3	.02	1.60	1.20	.48	.33	.15	2.80	85
10	3236	Aug. 28, 1930	46.6	.04	1.40	2.25	1.02	.53	.13	4.01	86
	3235	do	126	.30	1.70	4.20	6.95	2.88	.69	8.28	70
11	3231	do	433	.17	3.10	21.20	23.51	26.60	4.01	17.20	36
12	3230	do	236	.17	1.95	9.60	13.05	12.21	.94	11.35	46
13	3229	do	205	.20	2.60	8.05	10.66	11.40	9.08	.83	4
14	3422	Oct. 16, 1930	359	.30	2.40	15.80	20.13	17.60	2.24	18.40	48
15	3423	do	285	1.01	4.15	9.50	16.16	11.02	1.68	17.11	57
16	3421	do	214	.83	3.95	6.60	13.04	9.37	2.36	11.86	50
17	2909	June 21, 1930	444	2.02	4.95	18.00	25.93	18.05	2.99	27.84	57
18	3234	Aug. 28, 1930	46.7	.03	1.30	2.25	.86	.40	.11	3.54	86
19	3239	do	191	.79	3.50	6.20	10.66	7.85	.91	11.60	54
20	3237	do	166	1.26	3.45	3.60	9.27	3.44	.57	12.31	75
21	3238	do	184	1.60	4.00	8.25	10.92	5.06	.98	13.03	68
Miscellaneous[1]	9346	June 21, 1932	32.3	.11	1.20	1.70	T[2]	.27	.16	2.48	85

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[1] Outside of quadrangle; included for convenience.

[2] T=trace.

DESCRIPTION OF SAMPLES OF QUADRANGLE 29 (TABLE 37 AND FIG. 27)

Location 1, sample 4522. Delano municipal well. Drilled to 1,100 feet; filled to 600 feet because of sanding; casing perforated below 300 feet; static level, 100 feet. Deeper water reported to have had sulphur odor.

Location 2, sample 4520. Wasco municipal. Two adjacent wells; depth, 600 feet; static level, 110 feet; casing not perforated.

Location 3, sample 624. United States Cotton Field Station, Shafter. SE¼ sec. 33, T. 27 S., R. 25 E. The older of two wells. Depth, 165 feet; static level, 72 feet in May, 1927; discharge 1.2 cubic feet per second. Collected by C. S. Scofield.

Location 4, sample 4521. Southern Pacific depot well at Famosa. Depth, about 200 feet; static level, 140 feet.

Location 5–S, sample 2911. Kern River, as sampled from Beardsley Canal, opposite Lerdo.

Location 6, sample 3279. Dow station, Associated Pipe Line Co. Depth not ascertained; engineer reported they were drawing water from about 130 feet.

Location 7, sample 3232. Lerdo Land Co., well no. 4. Near SE corner NW¼ sec. 15, T. 28 S., R. 26 E. Depth, 275 feet; casing perforated below 100 feet.

Location 8, sample 3233. Lerdo School. Near NE corner SW¼ sec. 14, T. 28 S., R. 26 E. Depth, 250 feet; casing perforated below 160 feet.

Location 9, sample 2910. Lerdo Land Co., well no. 17. NE¼ sec. 14, T. 28 S., R. 26 E. Depth, 441 feet; static level, 131 feet; perforated in "hot sand" at 285 feet and below 375 feet; discharge, 2.8 cubic feet per second; mild sulphur odor.

Location 10, sample 3236. Lerdo Mutual well no. 1-B. SE¼ sec. 24, T. 28 S., R. 26 E. Depth, 470 feet; casing perforated below 100 feet.

Location 10, sample 3235. Lerdo Mutual well no. 1. SE¼ sec. 24, T. 28 S., R. 26 E. Depth, 555 feet; casing perforated below 100 feet.

Location 11, sample 3231. N. N. Brown, irrigation well. E½NW¼ sec. 22, T. 28 S., R. 26 E. Depth, 250 feet.

Location 12, sample 3230. Lerdo Land Co., well no. 10. Near NE corner sec. 22, T. 28 S., R. 26 E. Depth, 535 feet; casing perforated at several strata, upper about 105 feet.

Location 13, sample 3229. Lerdo Land Co., well no. 19. Near center sec. 22, T. 28 S., R. 26 E. Depth, 170 feet; perforated below 100 feet.

Location 14, sample 3422. Ben Arkalian ranch. East center sec. 23, T. 28 S., R. 26 E. Collected by C. S. Scofield.

Location 15, sample 3423. W. K. Lee ranch no. 2. Sec. 25, T. 28 S., R. 26 E. Depth, 425 feet; discharge, 5.4 cubic feet per second. Collected by C. S. Scofield.

Location 16, sample 3421. Ben Arkalian ranch. North center sec. 26, T. 28 S., R. 26 E. Collected by C. S. Scofield.

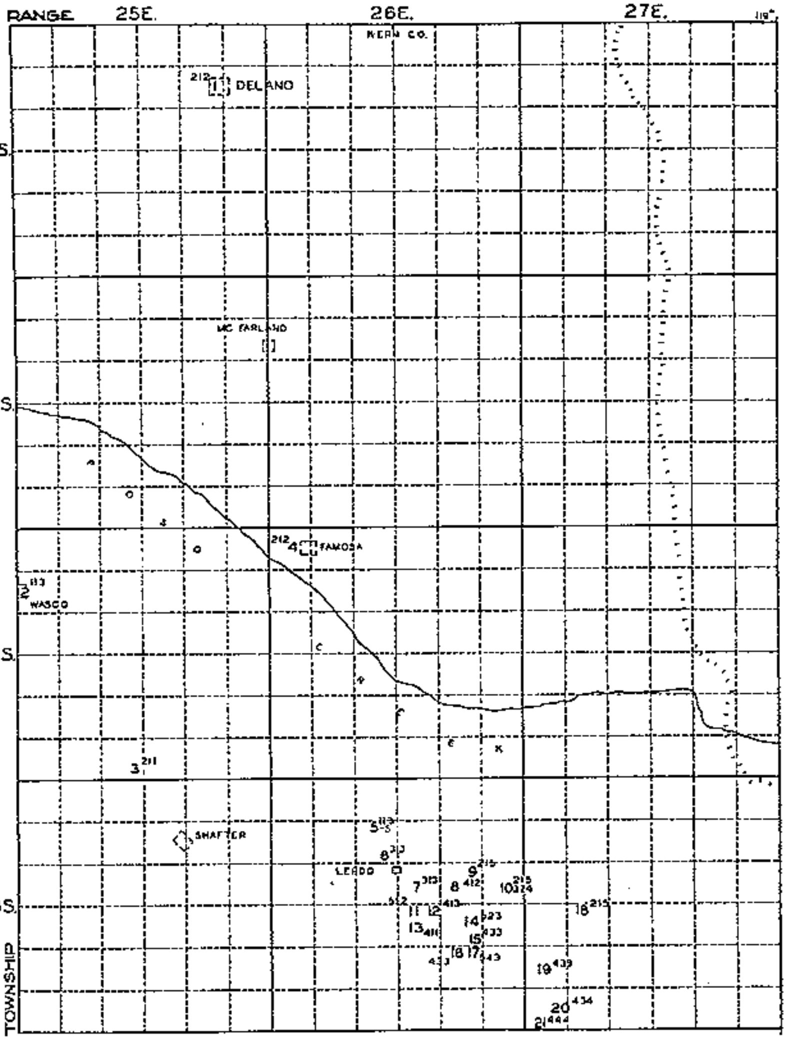

FIGURE 27.—Quadrangle 20, showing locations of samples reported in table 37.

Location 17, sample 2909. Lerdo Land Co., well no. 9–A. NE¼ sec. 26, T. 28 S., R. 26 E. Depth, 135 feet; casing perforated only near bottom; static level, 72 feet; discharge, 1.3 cubic feet per second.

Location 18, sample 3234. C. L. Clafflin, irrigation well. SW¼ sec. 20, T. 28 S., R. 27 E. Depth, 500 feet; upper casing perforations at 160 feet; static level, 160 feet. Sulphur odor, with considerable gas.

Location 19, sample 3239. W. K. Lee, irrigation well. Near NE corner SW¼ sec. 30, T. 28 S., R. 27 E. Depth, 274 feet; upper perforations at 100 feet.

Location 20, sample 3237. L. P. Sorenson, irrigation well. Near NE corner SE ¼ sec. 31, T. 28 S., R. 27 E. Depth, 247 feet.

Location 21, sample 3238. Lerdo Land Co., well no. 20. Near SE corner SW¼ sec. 31, T. 28 S., R. 27 E. Depth, 440 feet; casing perforated below 110 feet.

Miscellaneous sample 6346. Lerdo Mutual Water Co., new no. 9 well, located near and northwest of packing house, near center SW¼ sec. 24, T. 28 S., R. 26 E. Drilled in August 1932. Depth, 765 feet; perforated below 500 feet; draws down to 121 feet. Water slightly warm, with sulphur odor and some gas. Water from this well replaces water from the now abandoned well at location 17.

TABLE 38.—*Quality of water in quadrangle 30, Tps. 29, 30, 31, and 32 S., Rs. 22, 23, and 24 E. (fig. 28)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	2743	May 20, 1930	91.6	0.47	5.55	0.75	4.15	4.37	1.30	4.60	45
2-S	2741	do	18.0	.19	1.45	.30	.70	.99	.30	1.22	49
3	2742	do	91.4	.38	5.25	.60	3.91	3.44	1.03	5.49	55
4	6906	Nov. 17, 1932	483	4.14	3.10	16.08	40.67	20.01	12.95	20.48	45
Miscellaneous [1]	2740	May 20, 1930	87.2	.23	5.55	1.60	1.03	3.96	4.18	.04	5

[1] Outside of quadrangle; included for convenience.

DESCRIPTION OF SAMPLES OF QUADRANGLE 30 (TABLE 38 AND FIG. 28)

Location 1, sample 2743. Andrew Gregg, irrigation well. SE¼ sec. 5, T. 29 S., R. 23 E. Depth, 230 feet; casing perforated below 100 feet; static level, 10 feet.

Location 2-S, sample 2741. Buttonwillow Irrigation Canal, known as Eighty-foot Canal. Sampled at highway crossing near S¼ corner sec. 15, T. 29 S., R. 23 E. Kern River gravity water.

Location 3, sample 2742. Buttonwillow municipal well. Depth, approximately 220 feet; static level, 14 feet.

Location 4, sample 6906. Southern California Gas Co. well. Near center SW¼ sec. 23, T. 32 S., R. 24 E. Depth, 730 feet; upper perforations unknown (drilled 1912 or 1913); 11⅝ inches inside casing; static level, 120 feet; temperature, approximately 60° F. Water passed through 600 feet of 2-inch tubing by means of high-pressure natural gas before sample. Collected by N. D. Hudson.

Miscellaneous sample 2740. McKittrick. Water from Associated Oil Co. wells in Little Santa Maria Valley, sec. 15, T. 30 S., R. 21 E. Composite of three wells drilled to 500 feet; casing perforated below 200 feet; static level in one at 300 feet and in another at 126 feet.

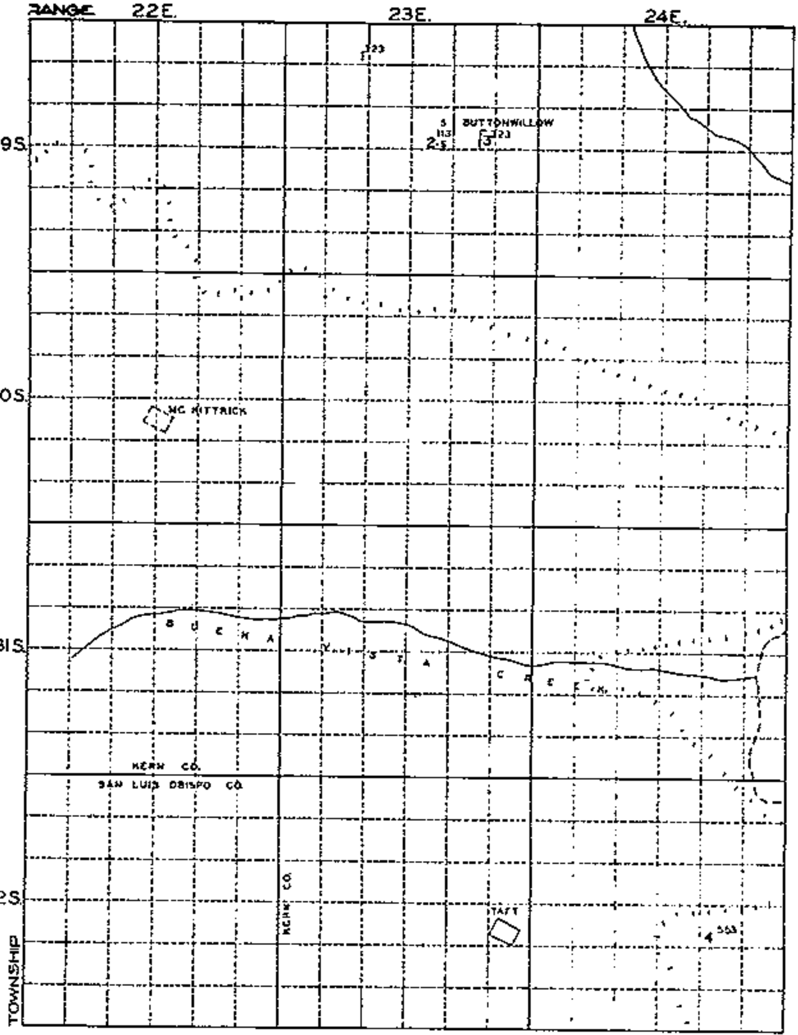

FIGURE 28.—Quadrangle 30, showing locations of samples reported in table 38.

TABLE 39.—*Quality of water in quadrangle 31, Tps. 29, 30, 31, and 32 S., Rs. 25, 26, and 27 E. (fig. 29)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	3760	Feb. 6, 1931	84.8	0.86	5.65	0.50	2.93	1.34	0.48	0.66	79
2	3758	do	133	.18	2.05	4.50	7.03	8.17	1.02	4.39	32
	3268	Sept. 23, 1930	202	.64	2.95	5.95	11.40	6.91	1.82	11.57	57
	3759	Feb. 6, 1931	63.9	.14	1.85	1.55	3.15	3.34	.48	2.73	42
3	2739	May 20, 1930	22.8	.18	1.45	.40	.80	.83	.16	1.66	63
4	2908	June 20, 1930	160	.61	2.80	.95	15.33	9.75	3.34	5.09	31
5	6810	Sept. 14, 1932	56.4	.39	2.20	.40	2.08	1.30	.49	3.40	64
6	6812	do	68.7	.44	2.90	.65	3.64	2.77	.81	3.55	60
7	6811	do	193	.57	3.25	.50	10.81	15.76	1.65	6.10	26
	6820	do	54.0	.43	1.65	.65	2.72	1.21	.42	3.04	66
Miscellaneous [1]	3827	Feb. 17, 1931	275	2.67	5.50	12.95	8.62	5.22	2.54	10.31	71

[1] Outside of quadrangle; included for convenience.

DESCRIPTION OF SAMPLES OF QUADRANGLE 31 (TABLE 30 AND FIG. 20)

Location 1, sample 3760. Oberlander well. NW¼SE¼ sec. 9, T. 29 S., R. 27 E. N½ of lot 18. Depth not ascertained. Collected by W. B. Robb.

Location 2, sample 3758. W. B. Robb, home well. NW¼NW¼ sec. 10, T. 29 S., R. 27 E. Depth not more than 145 feet. Collected by W. B. Robb.

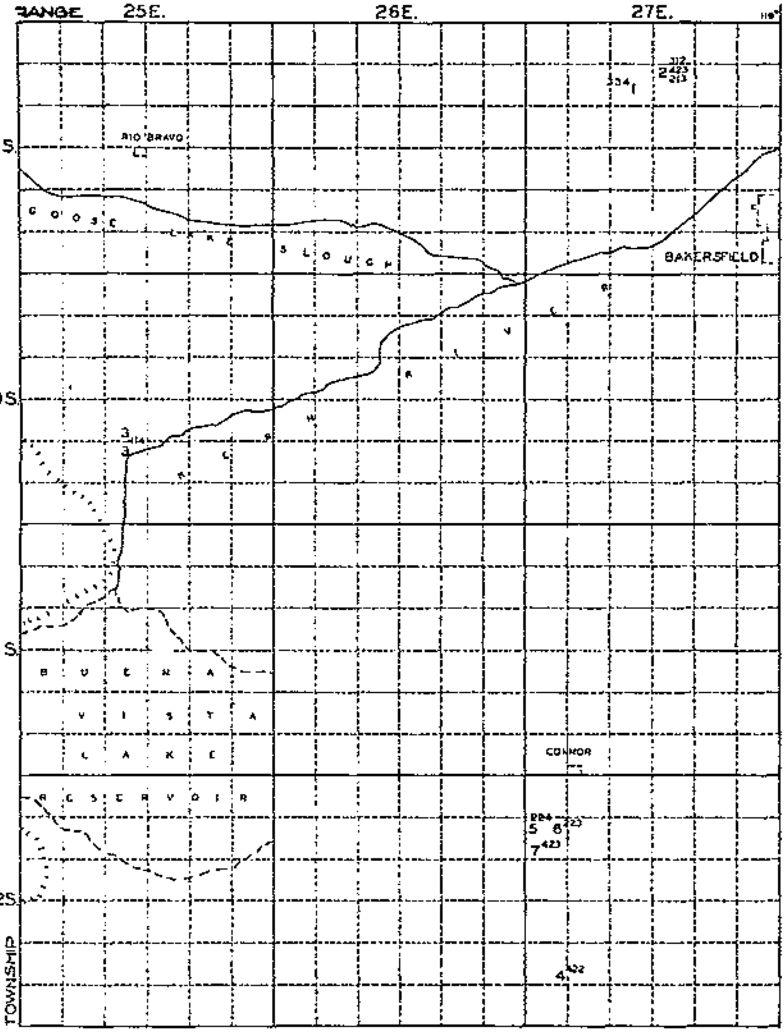

FIGURE 20.—Quadrangle 31, showing locations of samples reported in table 30.

Location 2, sample 3268. W. B. Robb well. NE¼NW¼ sec. 10, T. 29 S., R. 27 E., west of and adjacent to Southern Pacific tracks. Casing perforated from 50 to 310 feet.

Location 2, sample 3759. W. B. Robb well. Near NE corner NW¼ sec. 10, T. 29 S., R. 27 E. East of Southern Pacific tracks and highway. Depth not more than 145 feet. Collected by W. B. Robb.

Location 3, sample 2739. Taft municipal. From Western Water Works wells in sections 21 and 28, T. 30 S., R. 25 E. Depth, 280 to 450 feet; surface elevation at wells, 300 feet; Taft elevation; 1,000 feet.

Location 4, sample 2908. John H. Balbach well. E½SE¼ sec. 30, T. 32 S., R. 27 E. Depth, not less than 210 feet; static level, 14 feet.

Location 5, sample 6810. Symons Bros. Development Co., well no. 1. Kern County, NE¼ sec. 7, T. 32 S., R. 27 E.; 100 yards from north side, in center. Depth, 800 feet; 16-inch casing; discharge, 2.2 cubic feet per second; flowing well; draws down to 85 feet; temperature, 55° or 60° F.; sulphur odor; no gas; clear. Irrigates 160 to 200 acres. Collected by R. L. Sanders.

Location 6, sample 6812. Symons Bros. Development Co., well no. 3. Kern County, NE¼ sec. 7, T. 32 S., R. 27 E., 200 yards from north section line, 200 yards from center section line. Depth, 600 feet; all perforated; 18-inch casing; discharge, 3.6 cubic feet per second; static level, 12 feet; draws down to 45 feet; temperature, 55° or 60° F. Collected by R. L. Sanders.

Location 7, sample 6811. Symons Bros. Development Co., well no. 2. Kern County, SW¼ sec. 7, T. 32 S., R. 27 E., 150 yards from NE corner. Depth, 237 feet; all perforated; 14-inch casing; discharge, 2.8 cubic feet per second; static level, 12 feet; draws down to 45 feet; temperature, 55° or 60° F. Collected by R. L. Sanders.

Location 7, sample 6820. Symons Bros. Development Co., flowing domestic well. Kern County, SW¼ sec. 7, T. 32 S., R. 27 E., in corner of quarter. Depth, 800 feet; 10-inch casing. Collected by R. L. Sanders.

Miscellaneous sample 3827. Kern River County Park well. SE¼ sec. 36, T. 28, S., R. 28 E. Depth, 755 feet; temperature, 90° F. An artesian well with flowing discharge of 0.5 cubic foot per second. Collected by N. D. Hudson.

TABLE 40.—*Quality of water in quadrangle 32, Tps. 29, 30, 31, and 32 S., Rs. 28, 29, and 30 E.* (*fig. 30*)

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Percent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1-S	952	Apr. 26, 1929	15.9	0.35	1.20	0.30	0.20	0.72	0.03	0.05	56
	1360	June 23, 1929	11.1	.17	.57			.43	.00		
	2011	June 21, 1930	7.71	.03	.70	.10	.31	.37	.16	.58	52
	6345	June 21, 1932	7.51	.05	.60	.05	T[1]	.41	.23	.18	22
2	1958	Oct. 8, 1929	27.7	.23	1.60	.35	.57	1.27	.00	1.39	51
	3424	Oct. 17, 1930	22.1	.15	1.30	.35	.38	.95	.33	.75	37
	4519	July 9, 1931	16.4	.10	1.45	.20	.17	.85	.29	.08	37
3	920	Feb. 6, 1929	67.6	.27	4.00	1.05	1.18	3.69	.45	2.09	33
4	930	Apr. 24, 1929	92.8	.43							
5	946	Apr. 25, 1929	118	.21	4.00	.90	8.00	6.62	1.56	4.72	37
6	945	do	47.0	.28	3.70	.70	.56	1.82	.00	3.14	63
7	944	Apr. 24, 1929	47.0	.82	4.01	.65	.02	.20	.00	4.48	96
8	810	Apr. 5, 1929	81.0	6.60	2.39	2.53	2.03	.28	.03	7.24	93
	1370	June 23, 1929	81.8	6.68	2.26	2.49	2.64	.28	.00	7.11	96
9	943	Apr. 24, 1929	53.8	7.51	3.36	1.70	.24	.44	.00	4.86	92
10	1945	Oct. 6, 1929	47.7	.21	3.00	.05	1.21	2.33	.16	2.37	49
11	931	Apr. 24, 1929	66.6	.20	4.15	.86	1.35	3.14	1.31	1.91	30
12	1400	June 24, 1929	62.9	.31	4.42	.05	1.42	3.24	.06	2.20	35
13	948	Apr. 25, 1929	63.2	.40	4.50	.90	1.43	3.19	.90	2.74	33
14	949	do	63.5	.61	3.80	1.00	1.59	2.92	.58	2.89	45
15	932	Apr. 24, 1929	65.2	.26	3.90	.80	1.50	3.01	1.81	1.38	22
16	925	Feb. 6, 1929	91.1	.60	5.70	1.20	2.97	4.65	1.07	4.15	43
17	1381	June 24, 1929	55.5	.47	3.70	.68	1.20	2.51	.20	2.87	51
18	1399	do	48.1	.51	2.59	.05	1.01	1.07	.20	1.99	47
19	1384	do	32.6	.24	1.92	.28	.54	.98	T[1]	1.76	64
20	813	Apr. 5, 1929	52.5	.40	3.23	.74	1.16	2.38	.28	2.47	48
21	1398	June 24, 1929	32.2	.29	2.48	.37	.60	1.27	.01	2.17	63
22	941	Apr. 24, 1929	101	1.61	5.25	2.11	2.13	4.46	1.31	3.72	39
	1397	June 24, 1929	90.9	1.89	3.36	2.08	2.75	4.57	1.36	2.26	28
23	1396	do	74.9	2.37	2.88	1.59	1.34	2.91	1.03	1.87	32
24	805	Apr. 5, 1929	78.5	4.51	2.26	1.08	1.14	2.30	.38	2.70	50
	938	Apr. 24, 1929	55.0	4.43	2.50	1.50	.63	1.28	.25	3.10	67
	1378	June 23, 1929	53.5	4.63	2.46	1.3[illegible]	.71	1.20	.18	3.13	70
	1838	Sept. 23, 1929	83.4	4.63	2.40	2.10	1.49	2.67	.35	2.77	46
25	815	Apr. 5, 1929	61.0	1.94	2.94	1.38	.75	2.23	.50	2.34	46
	1395	June 24, 1929	64.9	2.18	2.98	1.45	1.11	2.30	.4[illegible]	2.60	48
26	940	Apr. 24, 1929	51.1	1.01	3.60	1.10	.20	1.40	.33	3.08	63
	1394	June 24, 1929	51.1	1.31	3.35	1.06	.24	1.61	.42	2.61	56
27	806	Apr. 5, 1929	53.2	.62	2.69	1.02	1.21	2.02	.38	2.52	41
28	1382	June 24, 1929	50.2	.28	3.04	.68	1.17	1.77	T[1]	3.12	64
29	1383	do	47.4	.60	2.70	1.59	.00	1.21	T[1]	3.08	77
30	1385	do	30.9	.21	2.47	.60	.27	1.49	.13	1.72	51
31	5817	Mar. 21, 1932	37.8	.08	2.75	.35	.20	1.54	.65	1.31	37
32	1386	June 24, 1929	31.5	.14	2.60	.27	.32	.13	1.28	1.78	56
33	5823	Mar. 22, 1932	32.1	.00	2.85	.40	.30	1.66	.63	1.34	37

[1] T=Trace.

TABLE 40.—*Quality of water in quadrangle 32, Tps. 29, 30, 31, and 32 S., Rs. 28, 29, and 30 E.* (*fig. 30*)—Continued

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						Percent sodium
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
34	935	Apr. 24, 1929	51.0	.12	2.82	1.15	0.72	2.34	0.49	1.86	40
35	936	do	34.8	.16	2.70	.40	.36	1.25	.25	1.96	57
36	937	do	104	.18	3.10	3.20	3.17	4.39	1.48	3.60	38
37	947	Apr. 25, 1929	64.7	.31	4.30	.90	1.62	2.98	1.40	2.44	36
38	950	do	138.7	7.12							
39	811	Apr. 5, 1929	46.0	6.90	2.23	1.54	.40	.09	.06	4.11	96
	812	do	46.9	7.30	2.15	1.53	.67	.07	.03	4.25	98
40	933	Apr. 24, 1929	64.0	.33	4.42	.79	1.64	3.55	1.64	1.66	24
41	814	Apr. 5, 1929	66.4	.54	4.00	.82	1.65	3.21	1.42	1.93	29
	804	do	63.0	.33	4.39	.71	1.44	3.12	1.42	2.00	31
	3278	Sept. 15, 1930	62.9	.30	4.60	.60	1.35	3.07	1.52	1.96	30
42	942	Apr. 24, 1929	46.9	7.24	2.17	1.80	.40	.57	.00	3.80	87
43	808	Apr. 5, 1929	41.3	4.64	2.64	1.27	.34	.95	.41	2.76	67
44	1393	June 24, 1929	41.5	1.13	2.93	.77	.32	1.02	.09	2.91	72
45	939	Apr. 24, 1929	40.0	.31	3.30	.90	.30	1.57	.33	2.69	59
	1392	June 24, 1929	53.6	.45	3.72	.72	.55	2.06	.77	2.16	43
46	934	Apr. 24, 1929	51.2	3.52	2.80	1.40	.42	1.87	.49	2.26	49
47	807	Apr. 5, 1929	41.8	.06	2.73	.88	.50	.81	.28	3.02	73
48	1391	June 24, 1929	43.1	.19	2.83	.42	.67	1.87	.10	1.89	48
49	3014	Apr. 1, 1931	31.4	.04	2.45	.46	.27	1.65	.82	.70	22
50	1387	June 24, 1929	30.1	.21	2.94	.37	.22	2.00	.71	.82	23
51	2907	June 20, 1930	40.3	.19	3.30	.50	1.44	1.80	.83	2.61	50
52	1390	June 24, 1929	50.6	.55	1.63	1.26	1.25	1.11	.00	2.93	73
53	1389	do	55.6	.56	1.50	2.07	1.31	.98	.00	3.90	80
54	1388	do	39.0	1.60	3.05	.62	.40	.09	.00	4.07	98
55	5908	Apr. 14, 1932	73.1	.17	2.25	2.05	2.32	4.40	1.61	1.60	23
Miscellaneous[1]	928	Apr. 23, 1929	134	.87	5.69	1.92	7.33	4.98	5.66	4.30	29
	929	do	113	.25	5.11	1.65	5.31	5.42	3.38	3.27	27
	3915	Apr. 1, 1931	69.4	.71	4.85	.35	1.85	2.04	1.42	3.59	51
	6827	Oct. 17, 1932	49.0	.13	1.25	2.45	.70	.78	.18	3.65	78
	6828	do	75.2	.33	1.05	4.13	1.15	2.46	.47	4.05	58

[1] Outside of quadrangle; included for convenience.

DESCRIPTION OF SAMPLES OF QUADRANGLE 32 (TABLE 40 AND FIG. 30)

Location 1–S, samples 952 and 1380. Kern River, Bakersfield. Sampled at heading of East Side Canal.

Location 1–S, sample 2911. Kern River, Beardsley Canal. Sampled opposite Lerdo.

Location 1–S, sample 6345. Kern River at Bakersfield. River was high at time of sampling.

Location 2, sample 1958. Bakersfield municipal. Sampled at service station opposite tower. Well source unknown. There are a large number of scattered pumping stations which pump directly into Bakersfield municipal water mains.

Location 2, sample 3424. Bakersfield municipal, tap at Seventeenth and Chester Streets. Collected by C. S. Scofield.

Location 2, sample 4519. Bakersfield municipal, tap at Seventeenth and Center Streets. Collected by C. S. Scofield.

Location 3, sample 626. Edison domestic supply well. Depth, 160 feet. Collected by C. S. Scofield.

Location 4, sample 930. Goff well, near NE corner SE¼ sec. 33, T. 30 S., R. 29 E. Depth, 400 feet; static level, 85 feet; approximate water table elevation, 390 feet; draws down 45 feet.

Location 5, sample 946. A. Brown Co. well. SE¼SE¼ sec. 5, T. 30 S., R. 30 E. Depth, 565 feet; static level, 375 feet; water table elevation, 690 feet; discharge, 0.2 cubic foot per second; temperature, 79° F.

Location 6, sample 945. Jack Bowman, domestic well. SE¼ sec. 8, T. 30 S., R. 30 E. Depth, 355 feet; static level, 160 feet; approximate water table elevation, 740 feet.

Location 7, sample 944. Deemer abandoned irrigation well. Near center sec. 17, T. 30 S., R. 30 E., in Caliente Wash. Depth not ascertained; static level, 134 feet; approximate elevation of water table, 636 feet.

Location 8, samples 810 and 1379. M. F. Newmarkel well. Near SE corner sec. 20, T. 30 S., R. 30 E. Depth, 387 feet; static level, 126 feet; approximate elevation of water table, 664 feet. Sample 810 collected by C. S. Scofield.

Location 9, sample 943. Shallow well at location sometimes known as "Deemer Spring." NE¼ sec. 33, T. 30 S., R. 30 E. Bailed sample. Surface elevation approximately 720 feet; water table several feet below.

Location 10, sample 1945. Ed Joiner service station well. Near SE corner sec. 18, T. 31 S., R. 28 E. Depth, 41 feet.

Location 11, sample 931. Earl Fruit Co. well. NE corner sec. 4, T. 31 S., R. 29 E. Static level, 120 feet; water table elevation, 355 feet.

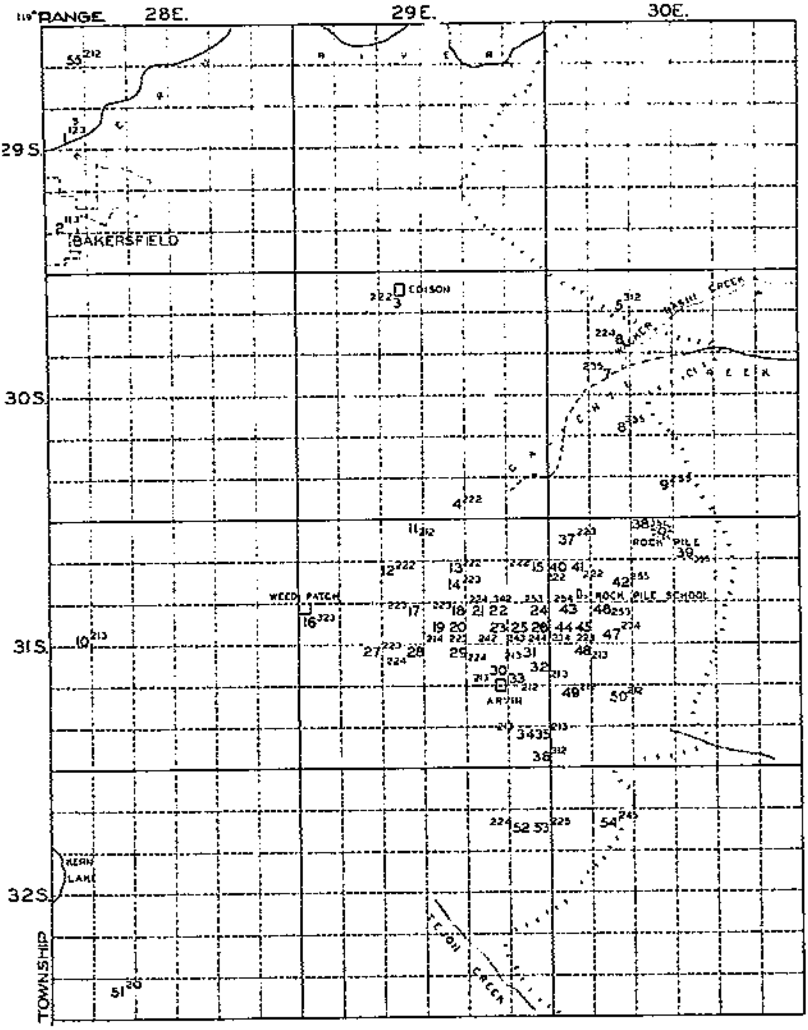

FIGURE 30.—Quadrangle 32, showing locations of samples reported in table 40.

Location 12, sample 1400. Irrigation well. Near NW corner sec. 9, T. 31 S., R. 29 E. Characteristics of well not ascertained.

Location 13, sample 948. Earl Fruit Co. well. Near NE corner sec. 10, T. 31 S., R. 29 E., just west of the edge of old Caliente Wash.

Location 14, sample 949. Earl Fruit Co., irrigation well. NE corner SE¼ sec. 10, T. 31 S., R. 29 E.

Location 15, sample 932. Earl Fruit Co., irrigation well. NE corner sec. 12, T. 31 S., R. 29 E. Depth, 424 feet; static level, 185 feet; approximate water table elevation, 360 feet; draws down 19 feet; discharge, 6.7 cubic feet per second.

Location 16, sample 625. Hoover well. NW¼ sec. 18, T. 31 S., R. 29 E. Static level, 50 to 60 feet. Collected by C. S. Scofield.

Location 17, sample 1381. H. S. Jewett well. Near NE corner sec. 16, T. 31 S., R. 29 E. Depth, 635 feet; static level, 110 feet; draws down 25 feet; discharge, 2.5 cubic feet per second.

Location 18, sample 1399. P. H. Greene Co. well. NE corner sec. 15, T. 31 S., R. 29 E. Depth, 407 feet; static level, 150 feet; discharge, 3.0 cubic feet per second.

Location 19, sample 1384. H. S. Jewett well. Near NE corner SW¼ sec. 15, T. 31 S., R. 29 E. Depth, 700 feet; static level, 110 feet; draws down 50 feet; discharge, 2.0 cubic feet per second.

Location 20, sample 813. C. Yanssey well. Near E¼ corner sec. 15, T. 31 S., R. 29 E. Static level, 105 feet; approximate elevation of water table, 360 feet. Collected by C. S. Scofield.

Location 21, sample 1398. P. H. Greene Co. well. Near N¼ corner sec. 14, T. 31 S., R. 29 E. Depth, 550 feet; discharge, 3.0 cubic feet per second. This well perforates a clay stratum in which sample 1399 ended.

Location 22, samples 941 and 1397. Hannon well. NE corner sec. 14, T. 31 S., R. 29 E. Depth, 320 feet; static level, 140 feet; approximate elevation of water table, 355 feet; discharge, 2.7 cubic feet per second.

Location 23, sample 1396. Irrigation well. NE corner SE¼ sec. 14, T. 31 S., R. 29 E.

Location 24, samples 805, 938, 1378, and 1838. Earl Fruit Co. well no. 2. NE corner sec. 13, T. 31 S., R. 29 E. Depth, 240 feet; static level, 142 feet; draws down 27 feet; discharge, 5.7 cubic feet per second; warm. This well has sulphur odor, is now capped, and is adjacent to a previously capped well, 450 feet deep, with a perforated casing.

Location 25, samples 815 and 1395. Edmundson well. NW corner SW¼ sec. 13, T. 31 S., R. 29 E. Static level, 135 feet; elevation of water table, approximately 355 feet. Sample 815 collected by C. S. Scofield.

Location 26, samples 940 and 1394. Daly well. NW corner NE¼SE¼ sec. 13, T. 31 S., R. 29 E. Static level, 113 feet; elevation of water table, 377 feet; discharge, 2.9 cubic feet per second.

Location 27, sample 806. Brewster well no. 3. NE corner sec. 20, T. 31 S., R. 29 E. Static level, 155 feet; elevation of water table, approximately 260 feet. Collected by C. S. Scofield.

Location 28, sample 1382. Irrigation well. Near NE corner sec. 21, T. 31 S., R. 29 E. Well operating; characteristics not ascertained.

Location 29, sample 1383. Richards, Pauley & Krauter well. NE corner sec. 22, T. 31 S., R. 29 E. Well operating; characteristics not determined.

Location 30, sample 1385. Stenderup-Jewett well. NE corner SE¼ sec. 23, T. 31 S., R. 29 E. Depth, 390 feet; static level, 100 feet; draws down 40 feet.

Location 31, sample 5817. Bear Mountain Orange Co. north well; 1,000 feet west of NE corner sec. 24, T. 31 S., R. 29 E. Collected by H. G. Clardy.

Location 32, sample 1386. Bear Mountain Orange Co., NE corner SE¼ sec. 24, T. 31 S., R. 29 E.

Location 33, sample 5823. H. G. Clardy well. Bear Mountain subdivision, 337 feet west of NE corner of S½SW¼ sec. 24, T. 31 S., R. 29 E. Depth, 519 feet; casing perforated from 300 to 500 feet; principal gravel stratum, 450 to 500 feet; discharge, 2 cubic feet per second. Collected by H. G. Clardy.

Location 34, sample 935. Earl Fruit Co. NW corner NE¼ sec. 36, T. 31 S., R. 29 E. Depth, 525 feet; static level, 60 feet; elevation of water table, approximately 360 feet; discharge, 0.7 cubic foot per second.

Location 35, sample 936. Earl Fruit Co. NE corner sec. 36, T. 31 S., R. 29 E. Depth, 400 feet; static level, 60 feet; discharge, 0.7 cubic foot per second.

Location 36, sample 937. Earl Fruit Co. SE corner NE¼ sec. 36, T. 31 S., R. 29 E. Depth, 385 feet; static level, 40 feet; approximate elevation of water table, 375 feet; discharge, 3.6 cubic feet per second.

Location 37, sample 947. Earl Fruit Co. NE corner SW¼ sec. 6, T. 31 S., R. 30 E. Static level, 190 feet; elevation of water table, approximately 375 feet.

Location 38, sample 950. Abandoned well. NW corner sec. 4, T. 31 S., R. 30 E. Static level, 255 feet; elevation of water table, as measured in casing when bailed, was 360 feet, but sound in the well indicated that water from a higher water table was running into casing through a crack or through higher perforations. Sample too small for complete analysis. It is probable that the bailed sample represented an upper stratum.

Location 39, sample 811. Tejon Spring, El Tejon Rancho. SW¼ sec. 3, T. 31 S., R. 30 E. Discharge, 0.04 cubic foot per second; temperature, 100° F. Elevation approximately 600 feet. Sample collected by C. S. Scofield. Sample 812. Reservoir supplied by Tejon Spring. Collected by C. S. Scofield.

Location 40, sample 933. Earl Fruit Co. NE corner NW¼ sec. 7, T. 31 S., R. 30 E. Elevation of water table, 360 feet; discharge, 4 cubic feet per second.

Location 41, sample 814. Earl Fruit Co. NE¼ sec. 7, T. 31 S., R. 30 E., 1,800 feet west of NE corner. Depth, 430 feet; static level, 184 feet; elevation of water table, 366 feet. Collected by C. S. Scofield.

Location 41, samples 804 and 3278. Lewis well. NE corner sec. 7, T. 31 S., R. 30 E. Discharge, 3.6 cubic feet per second. Collected by C. S. Scofield.

Location 42, sample 942. Valley Farms Co. abandoned well. NE corner SE¼ sec. 8, T. 31 S., R. 30 E. Static level, about 170 feet; elevation of water table, about 360 feet.

Location 43, sample 808. Small well. Near center north line sec. 18, T. 31 S., R. 30 E. Depth, 385 feet; static level, 135 feet; elevation of water table, 365 feet; discharge, 2.0 cubic feet per second. Collected by C. S. Scofield.

Location 44, sample 1393. Irrigation well. SW corner NE¼ sec. 18, T. 31 S., R. 30 E.

Location 45, samples 939 and 1392. Dan Moore well. Near NW corner NE¼SE¼ sec. 18, T. 31 S., R. 30 E. Depth, 400 feet; static level, 145 feet; elevation of water table, 355 feet; discharge, 2 cubic feet per second.

Location 46, sample 934. Giffen well, abandoned. NW corner sec. 17, T. 31 S., R. 30 E. Drilled in 1920; depth, 460 feet; static level, 178 feet; approximate elevation of water table, 337 feet; discharge, 1.8 cubic feet per second.

Location 47, sample 807. McCowan irrigation well. Near center sec. 17, T. 31 S., R. 30 E. Static level, 140 feet; approximate elevation of water table, 360 feet; discharge, 3.8 cubic feet per second; temperature, 82° F. Collected by C. S. Scofield.

Location 48, sample 1391. Aaron Neff well. North of center NE¼ sec. 19, T. 31 S., R. 30 E. Depth, 383 feet; static level, 127 feet; draws down 23 feet; elevation of water table, about 350 feet.

Location 49, sample 3914. Irrigation well, drilled in 1930. North of center sec. 30, T. 31 S., R. 30 E. Depth, 800 feet. Collected by C. S. Scofield.

Location 50, sample 1387. Kern Oil Co. stock well. North of center NE¼ sec. 29, T. 31 S., R. 30 E. Depth, 350 feet; static level, 125 feet; approximate elevation of water table, 355 feet.

Location 51, sample 2907. Mary Dickas well. Sec. 32, T. 32 S., R. 28 E. Small domestic pump attached to well drilled to depth of 815 feet; casing perforated below 182 feet; static level, 22 feet.

Location 52, sample 1390. E. W. Smith well. SE corner NW¼ sec. 12, T. 32 S., R. 29 E. Depth, 500 feet; static level, 62 feet; elevation of water table, about 418 feet.

Location 53, sample 1389. J. H. Alward well. Near center south line NE¼ sec. 12, T. 32 S., R. 29 E. Depth, 700 feet; static level, 80 feet; elevation of water table, about 418 feet.

Location 54, sample 1388. Spring in Little Sycamore Canyon. NW¼ sec. 8, T. 32 S., R. 30 E. Sampled from pipe outlet at Tejon Rancho stock reservoir.

Location 55, sample 5908. Union Oil Co., irrigation well, Oildale. SE¼ sec. 6, T. 29 S., R. 28 E. Depth, 450 feet; 12-inch casing; operated by compressed air; static level, 107 feet; operating level, 117 feet. Collected by N. D. Hudson.

Miscellaneous sample 928. Caliente Creek. Sample taken from stream 1 mile east of Caliente Station. Discharge, 0.3 cubic foot per second.

Miscellaneous sample 926. Tehachapi Creek. Sample taken near SE corner sec. 17, T. 31 S., R. 32 E., approximately one-half mile north of Keene post office. Discharge, 2 cubic feet per second.

Miscellaneous sample 3915. Ranch well, operated by windmill. East of gravel pit on south side of Tehachapi-Mojave highway, about 2½ miles east of Monolith. Sec. 28, T. 32 S., R. 34 E. Collected by C. S. Scofield.

Miscellaneous sample 6827. E. O. Mitchell well no. 1. Middle of north line, sec. 22, T. 31 S., R. 29 E. Pumped with 50-hp. motor; 10-inch discharge pipe, half full. Collected by N. D. Hudson.

Miscellaneous sample 6828. E. O. Mitchell well no. 2. NE corner SW 80 acres sec. 22, T. 31 S., R. 29 E. Pumped with 50-hp. motor; 10-inch discharge pipe; discharge, 2.4 cubic feet per second. Collected by N. D. Hudson.

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TABLE 41.—*Quality of water in quadrangle 33, Tps. 11, 10, 9, and 8 N., Rs. 26, 25, and 24 W.*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Per-cent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1	2738	May 19, 1930	2,076	49.80	64.85	166.00	0.26	4.32	9.76	216.63	94
2	2736	do	184	.23	3.30	.35	17.81	2.21	7.31	1.94	9
Miscellaneous[1]	2737	do	49.6	.23	3.20	.60	.03	2.33	.93	1.17	26

[1] Outside of quadrangle; included for convenience.

DESCRIPTION OF SAMPLES OF QUADRANGLE 33 (TABLE 41)

(Quadrangle map not shown)

Location 1, sample 2738. Northern Oil Co. Water brought up with oil from 12 wells drilled to 1,000 feet. NW¼ sec. 1, T. 11 N., R. 24 W.

Location 2, sample 2736. Cuyama Ranch. Cuyama no. 2 grant. Location corresponds to sec. 2, T. 10 N., R. 26 W. Reservoir composite of water from stream bed sand and 14 springs. Some springs reported as warm and with sulphur odor.

Miscellaneous sample 2737. Springs at Ozena. Sec. 19, T. 7 N., R. 23 W., San Bernardino base and meridian. Sample from water piped to Maricopa. Ozena is near head of Cuyama River.

TABLE 42.—*Quality of water in quadrangle 34, Tps. 11, 10, 9, and 8 N., Rs. 23, 22, and 21 W. (fig. 31)*

Location no.	Sample no.	Date	$K \times 10^5$ at 25° C.	Boron	Milligram equivalents						"Per-cent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1-S	2710	Apr. 27, 1930	192	0.93	4.95	1.50	15.73	11.00	7.92	3.26	15
2	2706	do	188	.02	4.10	1.55	16.67	9.45	8.37	4.50	20
3-S	2707	do	190	90	5.20	1.35	16.21	9.62	7.66	5.48	24
4-S	2708	do	167	1.17	4.95	1.30	15.23	9.34	7.35	4.79	22
5-S	2709	do	105	.64	5.25	.35	7.33	4.85	5.42	2.66	21

DESCRIPTION OF SAMPLES OF QUADRANGLE 34 (TABLE 42 AND FIG. 31)

Location 1-S, sample 2710. San Emigdio Creek as diverted at San Emigdio Ranch. SW¼ sec. 36, T. 11 N., R. 22 W., San Bernardino base and meridian. Discharge, 0.3 cubic foot per second. Collected by V. G. Ryland.

Location 2, sample 2706. Adobe Spring, San Emigdio Creek. In unsurveyed area; position corresponds to SW corner sec. 1, T. 10 N., R. 22 W. Discharge, 0.15 cubic foot per second. Collected by V. G. Ryland.

Location 3-S, sample 2707. San Emigdio Creek. Corresponds to E¼ corner sec. 12, T. 10 N., R. 22 W. Discharge, 0.4 cubic foot per second. Collected by V. G. Ryland.

Location 4-S, sample 2708. San Emigdio Creek, Berley Flats. Corresponds to SW corner sec. 13, T. 10 N., R. 22 W. Discharge, 0.5 cubic foot per second. Collected by V. G. Ryland.

Location 5-S, sample 2709. San Emigdio Creek, Douglas Place. SE¼ sec. 5, T. 9 N., R. 21 W. Discharge, 0.36 cubic foot per second. Collected by V. G. Ryland.

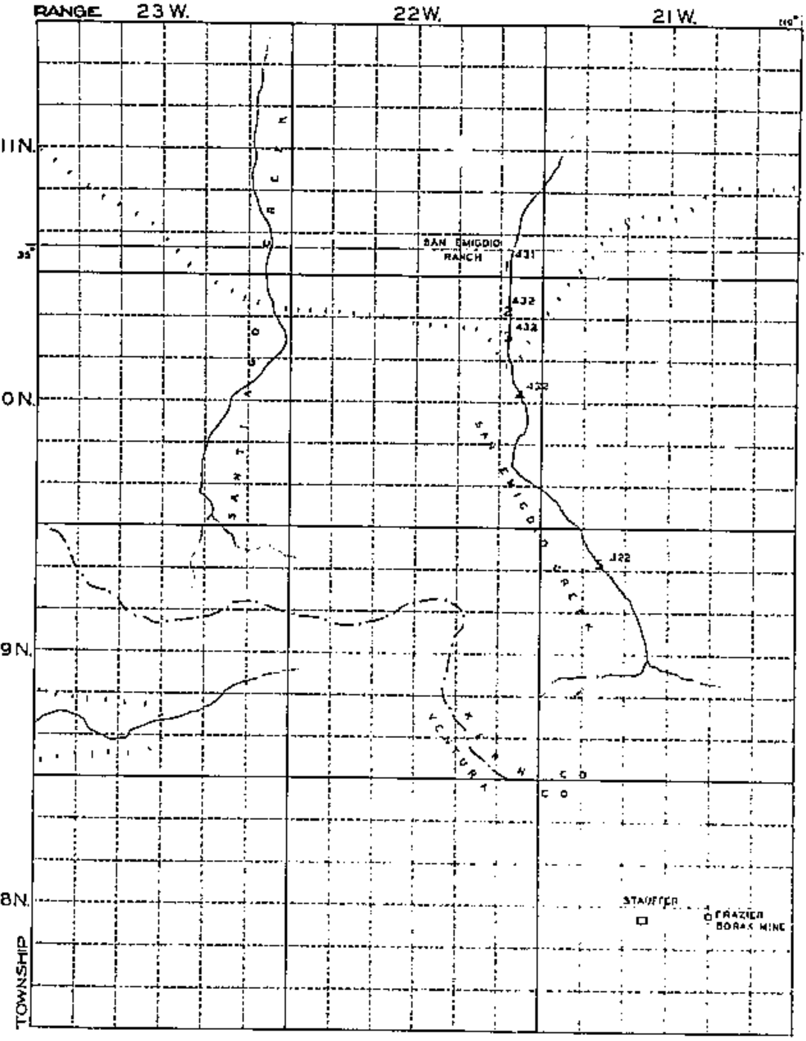

FIGURE 31.—Quadrangle 34, showing locations of samples reported in table 42.

TABLE 43.—*Quality of water in quadrangle 35, Tps. 11, 10, 9, and 8 N., Rs. 20, 19, and 18 E. (fig. 32)*

Location no.	Sample no.	Date	$K\times10^5$ at 25° C.	Boron	Milligram equivalents						"Per-cent sodium"
					CO_3+HCO_3	Cl	SO_4	Ca	Mg	Alkali bases	
				P.p.m.							
1-S	5005	Oct. 16, 1931	47.5	0.40	4.40	0.35	0.79	3.12	2.17	0.25	5
2	1837	Sept. 23, 1929	101	.92	6.00	.60	4.90	1.03	5.90	4.57	37
3-S	1944	Oct. 6, 1929	105	.92	7.10	.85	3.89	2.03	5.37	4.44	38
4	2018	Apr. 18, 1930	138	.92	11.00	1.40	3.46	3.65	1.53	10.68	67
5	1943	Oct. 6, 1929	81.2	.60	5.60	.45	2.98	3.30	3.13	2.60	29
6	2905	June 20, 1930	80.7	.35	5.80	.50	2.78	3.37	2.51	3.20	35
7	2906	do	74.1	.51	5.30	.50	2.45	3.25	2.17	2.83	34
8-S	2619	Apr. 18, 1930	7,919	20.90	56.25	368.00	883.53	1.80	28.06	1,277.92	98
9-S	383	Nov. 11, 1928	83	.20	5.90	.70	2.18	5.00		3.78	43
10-S	380	do	60.5	5.00	3.00	.20	2.96	4.60		1.56	25
11-S	381	do	71.3	2.00	3.40	.10	4.66	5.60		2.56	31
Miscellaneous[1]	5006	Oct. 16, 1931	85.2	.15	6.85	.80	2.45	4.80	2.92	2.30	24

[1] Outside of quadrangle; included for convenience.

DESCRIPTION OF SAMPLES OF QUADRANGLE 35 (TABLE 43 AND FIG. 32)

Location 1–S, sample 5005. El Paso Creek, near El Tejon Ranch headquarters. Location corresponds to NW¼ sec. 25, T. 11 N., R. 18 W., San Bernardino base and meridian. Discharge, 0.2 cubic foot per second.

Location 2, sample 1837. Well at foot of Grapevine grade. T. 10 N., R. 19 W. Depth, 780 feet; formerly flowing. On this date, water stands 2 feet below ground surface. Section location of well not known definitely. Sampled from highway tank. Information supplied by George Brunk, highway foreman.

Location 3–S, sample 1944. Grapevine Creek. Sampled at foot of grade. Sec. 29, T. 10 N., R. 19 W. Discharge, 15 cubic feet per second.

Location 4, sample 2018. Mud Spring, Castaic Lake. Location corresponds to sec. 25, T. 9 N., R. 19 W. One of numerous small springs in the bed of Castaic Lake.

Location 5, sample 1943. Lebec village wells, sec. 35, T. 9 N., R. 19 W. Depth, 150 to 175 feet.

Location 6, sample 2905. John J. Peters, Lebec, well no. 2. NE¼ sec. 35, T. 9 N., R. 19 W. Depth, 139 feet; casing perforated at all strata.

Location 7, sample 2906. John J. Peters, Lebec, well no. 3 (800 feet south of no. 2), NE¼ sec. 35, T. 9 N., R. 19 W. Depth, 250 feet; casing perforated below 118 feet.

Location 8–S, sample 2619. Castaic Lake. Location corresponds to center sec. 25, T. 9 N., R. 19 W. Lake receding rapidly and was dry later in the summer.

Location 9–S, sample 383. Cuddy Creek, below Cuddy Ranch. SE¼ sec. 33, T. 9 N., R. 20 W. Discharge, 0.2 cubic foot per second. Small sample collected by C. S. Scofield. The boron determination is by the semiquantitative tumeric method.

Location 10–S, sample 380. Seymour Creek, one-fourth mile north of old Griffen post office. Sec. 31, T. 8 N., R. 20 W. Discharge, 1 cubic foot per second. Small sample collected by C. S. Scofield. This sample and the sample (381) from Lockwood Creek are of water tributary to Piru Creek and the Santa Clara River. Boron determination is by the semiquantitative tumeric method.

Location 11–S, sample 381. Lockwood Creek, above junction of Seymour Creek. Discharge, 2 cubic feet per second. Small sample collected by C. S. Scofield. The boron determination is by the semiquantitative tumeric method.

Miscellaneous sample 5006. Tejon Creek; sampled near location corresponding to SE corner sec. 14, T. 11 N., R. 17 W. Discharge, 0.3 cubic foot per second.

DISCUSSION OF SAN JOAQUIN VALLEY WATERS

QUADRANGLES 1 TO 4

The area embraced by quadrangles numbered 1 to 4 includes the drainage contiguous to Suisun Bay and that of the lower portions of both the San Joaquin and Sacramento Rivers.

The ground waters of this area, insofar as these may be represented by the samples collected, were found for the most part to be higher in bicarbonate than in chloride, and higher in chloride than in sulphate. The calcium and magnesium concentrations were usually about equal. Except for waters from a number of relatively deep wells, sodium constituted less than 50 percent of the bases.

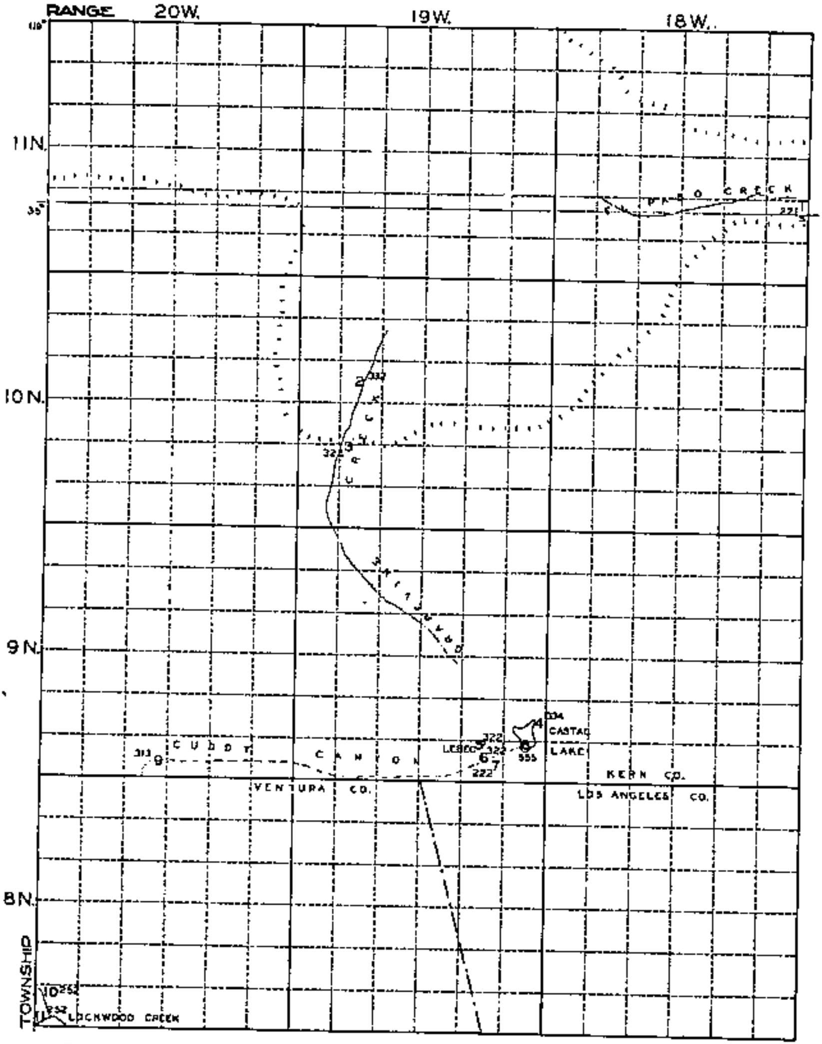

FIGURE 32.—Quadrangle 35, showing locations of samples reported in table 43.

In quadrangles 1 and 2 the greater number of the waters sampled were moderately saline. Conductances of about 80 were found for 7 of the 10 samples from quadrangle 1, and conductances usually above 100, sometimes above 200, were found for the samples from quadrangle 2. The greater number of the samples from quadrangle 3 were collected near Stockton, and most of these had conductances lower than 50. None of the 5 widely scattered samples collected in quadrangle 4 were saline.

The boron concentrations were found to be highly variable in each of these quadrangles; 3 of the 10 samples from quadrangle 1 had less than 0.5 p.p.m., and 5 had more than 1.0 p.p.m.; 4 of the 20 samples from quadrangle 2 had less than 0.5 p.p.m., and 14 had more than 1.0 p.p.m.; 12 of the 19 samples from quadrangle 3 had less than 0.5 p.p.m., and 4 had in excess of 1.0 p.p.m. No sample from quadrangle 4 had more than 0.1 p.p.m. of boron.

Water from the municipal well at Rio Vista contained 1.50 p.p.m. of boron; 3 samples from Isleton contained 0.24, 1.44, and 1.24 p.p.m.; a sample from Walnut Grove (quadrangle 3, miscellaneous) contained 0.06 p.p.m., and a sample from Thornton contained 1.06 p.p.m. These samples, representing as they do ground waters in part north of the San Joaquin River drainage, provide evidence that appreciable concentrations of boron may occur as a normal constituent in many of the ground waters of the lower Sacramento River Valley.

QUADRANGLE 1

(Tps. 1, 2, 3, and 4 N., Rs. 1, 2, and 3 W.)

The well sample from the Haag ranch south of Martinez, location 1, must be looked upon as distinctly nontypical. It was sent to the laboratory for analysis because of the adverse effects that followed immediately it's use on a garden. This water, derived from a shallow well, had a conductance of 818 and contained 53.3 p.p.m. of boron. It is not possible to conclude whether the stratum tapped was once a part of a saline lagoon or whether boron and chloride had been deposited here by a once active fumarole. The magmatic gases emanating from fumaroles are commonly high in both chlorides and boron.

Like many warm springs, the water of Sulphur Spring at location 6, north of Suisun Bay, carries several parts per million of boron. Appreciable concentrations of boron are not always found in natural hot waters, but such is commonly the case. Hot springs frequently occur along fault lines, which may provide either outlets for deep-seated waters or access for subsurface waters to underlying magma or the hot gaseous emissions from them.

Samples from a few irrigation wells immediately north of this quadrangle have been found to carry several parts per million of boron. Sample 6232 at location 5 is from an old oil well, and, like many deep wells in the San Joaquin Valley, its boron content is significantly high and sodium is the principal base.

QUADRANGLE 2

(Tps. 1, 2, 3, and 4 N., Rs. 1, 2, and 3 E.)

The three Isleton samples were from wells adjacent to the Sacramento River. The first of these, from a 130-foot well, had low salinity, conductance 40.0, and little boron, 0.24 p.p.m.; that from the 211-foot well was saline, conductance 297, 23.40 milligram equivalents of chloride, and 1.44 p.p.m. of boron; it would not be suitable for most agricultural purposes. The water from the 615-foot well was of somewhat better quality (conductance 160 and boron 1.24), and it is this water that is used principally for municipal purposes. Boron symptoms on plants were pronounced in Isleton, and the effects of high percentage of sodium on the permeability of the soil were evident.

The Pittsburg municipal water, location 3, had sufficient boron, 0.81 p.p.m., to produce mild but characteristic leaf injury. Two wells at locations 4 and 5 southeast of Pittsburg produced water with less than 0.50 p.p.m. of boron.

Boron symptoms are in evidence in and around Brentwood, and the well samples obtained in the area contained, with one exception, in excess of 1 p.p.m. of boron. Where continued use is made of certain of these well waters boron injury can be expected. The irrigation water used in this area is for the most part that diverted from the San Joaquin River, and this water has not been found to carry injurious boron concentrations. (See sample at location 16, collected in April, and the series of samples from the river below the mouth of the Tuolumne at location 5 of quadrangle 7.) The water from drainage wells installed to lower the water table has been found to be injuriously high in boron, and except as this water can be judiciously combined with large volumes of water low in boron, its reuse should be avoided. Boron injury is and has been experienced when the water table has been allowed to rise into the root zone.

Notwithstanding some variation in the depths of the different wells in the Brentwood area, the waters produced are all of the same general type; calcium and magnesium concentrations are in excess of sodium, bicarbonate exceeds chloride, and the chloride exceeds the sulphate.

QUADRANGLE 3

(Tps. 1, 2, 3, and 4 N., Rs. 4, 5, and 6 E.)

Several types of water are represented by the samples collected in Stockton. The waters produced by the deep wells, locations 8 and 10, are warm, very saline, carry a great deal of chloride and some boron, and, as in the Lodi well, sulphates are low. The absence of sulphate and the presence of gas suggest sulphate reduction by anaerobic bacteria (p. 122). The 1,040-foot well at the fiberboard plant, location 11, is relatively high in both sodium and chloride, conductance was 140, and the 1.18 p.p.m. of boron had been sufficient to produce characteristic symptoms on ornamental plantings. Boron symptoms are in evidence on many of the street and dooryard plantings in Stockton, but in general they are not of severe intensity. The water from the wells at East Sonora Street and Wilson Way, location 12, with depths from 670 to 1,070 feet, had a conductance of 62 and 0.83 p.p.m. of boron, which are both greater than found in the water from the two pump stations to the north at locations 5 and 7. The conductances of these, the Ellis Street 533-foot well and the three 700-foot wells on Monroe Street, were 32.2 and 35.5 and the boron concentrations were 0.10 and 0.66. The water from a shallow domestic well at location 6 had a conductance of 39.4 and 0.16 p.p.m. of boron. The State Hospital wells, location 9, with depths of about 600 feet, are both relatively low in solutes of all kinds. The samples collected in Stockton indicate that water of low salinity and low boron content is generally available to a depth of about 700 feet. The percentage of sodium tends to increase with depth.

QUADRANGLE 4

(Tps. 1, 2, 3, and 4 N., Rs. 7, 8, and 9 E.)

The 6 scattered samples collected in quadrangle 4, including sample 4560 repeated from quadrangle 3, are significant in the fact that in no instance did boron occur in excess of 0.10 p.p.m. The conductances of the samples and the percentages of sodium (alkali bases) were low in each instance, and in all samples the sums of chloride and sulphate were less than the bicarbonate.

QUADRANGLES 5 TO 13

The San Joaquin Valley waters grouped for consideration in quadrangles 5 to 13 include those along the valley axis and those to the east and to the west of the valley axis northwestward from Herndon and Firebaugh to the Mount Diablo base line.

Samples, either from streams or wells, collected east of the lowlands adjacent to the San Joaquin River carried little mineral matter. Poyner Spring, which is 7 miles northeast of Manteca, had a conductance of 63.5, and the conductances of all others were less than 45. Evidences of boron injury were nowhere observed in this area east of the valley axis, and with the exception of Poyner Spring, which had 0.40 p.p.m. of boron, none of the waters sampled contained more than 0.15 p.p.m. Bicarbonate concentrations in all samples exceeded chloride concentrations and were usually 3 to 4 times as high. Chloride concentrations in all samples exceeded sulphate concentrations and were usually much higher than the sulphate. Calcium concentrations in all instances exceeded magnesium concentrations. Sodium constituted less than 50 percent of the bases in all except Poyner Spring and one other source with a very low conductance.

The ground waters west of the San Joaquin River are highly variable in quality but as a class are clearly differentiated from the ground waters east of the river. Few ground waters west of the river, as represented by 53 samples, had conductances less than 50, and many had conductances greater than 100. Conductances less than 50 were obtained only in the instances of two drainage wells near Dos Palos and a well in Los Banos. A considerable number of these ground-water samples contained less than 0.5 p.p.m. of boron, but only in four drainage wells, a shallow domestic well, and the flowing well on the Durham farm, all near Dos Palos, did any of the samples contain less than 0.25 p.p.m. of boron. Numerous samples contained in excess of 2 p.p.m. of boron.

Sulphate was present in appreciable concentrations in nearly all of the wells sampled west of the river, but only a few more than half of the samples contained higher concentrations of sulphate than of chloride. Bicarbonate concentrations commonly exceeded the chloride and sulphate concentrations.

In this portion of the west side of the valley the concentration of sodium was in most instances less than the sum of the calcium and magnesium concentrations, but there were a number of marked exceptions. In approximately one-third of the samples the magnesium concentrations exceeded the calcium concentrations.

Something of the character of the ground waters along the axis of the valley to the east of the San Joaquin River but closer to the river than those discussed is illustrated in part by samples at locations 1 and 5 of quadrangle 6, location 14 of quadrangle 7, and locations 3, 8, 9, 10, and 12 of quadrangle 9. None of the wells west of the river are included as axial waters, but some of them might properly be considered as such. In this central area there were at one time many flowing wells, and some of those here represented still flow. The samples are too few in number to permit of generalizations, but it is indicated that boron may occur to the extent of 2 or more p.p.m. in waters at depths of several hundred feet, and that such waters may be saline; but one sample from a flowing well 265 feet deep carried only 0.07 p.p.m. of boron and had a conductance below 50. Two shallow wells near Stevinson had little boron and were not saline.

QUADRANGLE 5

(Tps. 1, 2, 3, and 4 S., Rs. 1, 2, and 3 E.)

The upper ground water in the vicinity of Byron, location 1, insofar as it may be represented by the shallow well at the depot, is like that from the wells in the vicinity of Brentwood, quadrangle 2.

At Byron Hot Springs only one of the several springs was sampled. Analyses from other sources have shown the water from certain of these springs to possess distinctly different characteristics. The "white sulphur spring" is characterized by free hydrogen sulphide gas, a temperature of 90° F., and high concentrations of boron, bicarbonate, chloride, and alkali bases.

Two samples, locations 3 and 4, were obtained near Altamont. The first of these is from the Southern Pacific Railroad well in the creek bottom about one-half mile southwest of the depot. It carries sufficient boron, 1.90 p.p.m., to produce marked symptoms on all the plantings in the station park. These plants receive excellent care and many of them make a good showing notwithstanding boron injury. The second sample from Altamont, location 4, is of water produced by an abandoned oil well. This water, which is unsuited for gardens or other agricultural use, had 20.1 p.p.m. of boron and only a trace of sulphate.

The samples from Pleasanton, Livermore, and Alameda Creek, locations 5, 6, and 7, are not related to the San Joaquin Valley except as they are derived from the coastal mountains. All are low in conductance, boron, chloride, and alkali bases.

QUADRANGLE 6

(Tps. 1, 2, 3, and 4 S., Rs. 4, 5, and 6 E.)

The Lathrop sample, location 1, had the lowest conductance, boron, and sulphate content of the wells sampled in quadrangle 6, and this relatively shallow well is east of the San Joaquin River. The water was much like those sampled in quadrangle 7 to the east. The California Irrigated Farms well at location 5, also east of the river, drilled to 654 feet and perforated only below 618 feet, had a conductance of 89.8, carried 0.82 p.p.m. of boron, and sodium constituted 64 percent of the bases.

Two relatively poor waters are represented by the samples from foothill wells at locations 2 and 9. The first was from the now abandoned Fabian flowing well, which was drilled to a depth of about 2,000 feet, presumably in search of oil. This warm and highly mineralized water had 5.52 p.p.m. of boron and a conductance of 380. The second sample mentioned was from a brick-cased well with a static level at about 12 feet beside Mountainhouse Creek; this water, which is used at an automobile service station, doubtless represents creek underflow. It had a conductance of 206 and a boron concentration of 3.02 p.p.m.

The five wells sampled between the foothills and the San Joaquin River, locations 3, 4, 6, 7, and 8, all produced water higher in sulphates than in chlorides, with the concentration of alkali bases less than the sum of calcium and magnesium. In four of the wells the boron concentrations were sufficiently high to affect boron-sensitive plants.

QUADRANGLE 7

(Tps. 1, 2, 3, and 4 S., Rs. 4, 5, and 6 E.)

Of the 7 scattered samples collected east of the San Joaquin River, those at locations 1, 2, 3, 4, and 7 all had conductances less than 45, boron concentrations below 0.15 p.p.m., and sulphate concentrations of 0.35 milligram equivalents or less. The percentages of sodium (alkali bases) were less than 40. The well at location 14 in comparatively low land near the river had a conductance of 88.1, 0.27 p.p.m. of boron, and 66 percent of alkali bases. The Poyner Spring, location 15, long used as a watering place for stock, had more boron (0.40 p.p.m.) than has been found elsewhere in the lower portion of the valley so far east of the valley axis. In all of these samples the salinity was low, and in each bicarbonates exceeded chlorides and chlorides exceeded sulphates.

Six wells were sampled west of the San Joaquin River. In two of these, locations 9 and 11, the boron concentrations exceeded 3.00 p.p.m., and both were relatively saline. The other four, locations 6, 8, 10, and 13, did not carry injurious concentrations of salt, and the boron concentrations ranged from 0.53 to 1.25 p.p.m. In all of the 6 wells the sum of calcium and magnesium exceeded sodium, and sulphates exceeded chlorides.

In a portion of this quadrangle west of the river there are a number of small areas of unproductive land such as is illustrated in figure 1 (p. 22). Soils from these places have shown abnormally high concentrations of boron, and orchard plantings made in them have either died or remained unthrifty, with the development of marked boron symptoms. It had been concluded that the boron in these spots was of local origin, since the land was irrigated with San Joaquin River water. In a healthy vineyard where no evidence of boron injury had previously been observed, a few groups of vines made little new growth in the spring of 1932 and developed outstanding evidence of boron injury. The upper ground-water table in the area lies at depths of from 5 to 12 feet and in the winter of 1932 showed a tendency to rise. A sample was taken from the water table immediately below one of these injured vines in June and was found to contain 25.6 p.p.m. of boron, whereas 2 years previously a similar sample from a healthy vineyard across the roadway had contained but 0.5 p.p.m. of boron. It is assumed that underlying water had been in contact either with soils very high in boron or with soluble boron minerals, and that this underlying water had been forced upward into the root zone of the grapes as a result of an increase in its hydrostatic pressure. This interpretation may also provide an explanation for the occurrence of boron in the older spots discussed.

Under location 5 (table 15) there are given a series of analyses of samples collected from the San Joaquin River at the El Solyo Ranch diversion below the mouth of the Tuolumne. In the table footnote the corresponding river discharges are reported. As represented by these determinations the quality of the San Joaquin River at this point is different from its quality at Mendota, quadrangle 15, location 5. During parts of the year most of the river flow is from the Tuolumne and the remainder represents return flow to the San Joaquin from drainage. On August 1, 1931, the river discharge at the El Solyo diversion was 135 cubic feet per second and above the mouth of the Tuolumne, location 12, the discharge was 35 cubic feet per second. The latter water, from Lairds Slough, was twice as saline as that at the El Solyo diversion and 25 times as saline as that of the river at Mendota. It is to be observed that none of the 16 samples from the San Joaquin River at the El Solyo diversion, location 5, had conductances above 80, and that the concentrations of boron, chloride, and sulphate and the percentages of sodium were well within the limits of safety.

Samples of grape leaves collected west of the river in this quadrangle varied from 45 to 754 p.p.m. in their boron content. Those showing injury either were irrigated by well waters high in boron or were collected from the areas of boron-contaminated soils. Other than in localized areas such as have been mentioned, plantings irrigated by San Joaquin River water have not shown evidence of boron injury.

QUADRANGLE 8

(Tps. 5, 6, 7, and 8 S., Rs. 7, 8, and 9 E.)

The greater part of quadrangle 8 lies west of the San Joaquin River, and nearly all of the wells sampled were moderately saline but with a few exceptions not injuriously so. The boron concentrations in the wells ranged from 0.26 to 1.08 p.p.m.; in 6 of the 12 samples chlorides exceeded sulphates, and in 3 the concentration of sodium exceeded the sum of calcium and magnesium.

Boron symptoms were evident here and there in this area, and in the southeast portion these symptoms appeared to be related, in part at least, to the quality of the subsoil water, which in some places is high. Particularly were boron symptoms outstanding in Gustine, where the new municipal well had only 0.46 p.p.m. of boron; but this well had recently replaced an older well, a sample of which could not be obtained. The water table in Gustine is normally high, and at the time of the sample it was reported as being about 4 feet below the soil surface.

Three samples of walnut leaves showing evidence of moderate boron injury were collected in the vicinity of Gustine on October 8, 1929. One of them (no. 307) was from an old grove in the southeast corner of sec. 36, T. 8, R. 9 E. These leaves contained 628 p.p.m. of boron. The trees were large and previous to 1928 had been irrigated with water diverted from the San Joaquin River. Subsequently the grove was unirrigated. The ground water was reported as being at about 5 feet. The second sample of walnut leaves (no. 308) was taken from the grove irrigated by the well at location 9; this sample contained 400 p.p.m. of boron; the trees were from 4 to 6 years old. The third sample (no. 310) was from trees in a grove of the same age immediately to the south but irrigated from the Outside Canal. This leaf sample contained 379 p.p.m. of boron, and the water table was reported as varying between 7 and 14 feet. An adjacent canal-irrigated old grove, likewise showing some evidence of mild boron injury, was reported as producing about 1 ton of walnuts per acre per year.

Canals diverting water from the San Joaquin River at and below Mendota supply irrigation water as far north as Crows Landing, but in the upper portion of the area served, ample supplies of water are not always available.

The San Joaquin River at Mendota carries remarkably pure water; it is very low in total salinity even as late as October, and the concentration of boron is negligible. (See analyses under locations 5 and 6, quadrangle 15, table 23.) The greater part and at times all of the river water is diverted at Mendota to canals supplying lands west of the river. During the late summer the water carried by the San Joaquin above the mouth of the Tuolumne is largely if not entirely return flow from irrigated lands. A comparison of the difference in the return flow water and the river water at Mendota is afforded by the samples at Mendota of October 1929, which had conductances of less than 6, and by the sample of October 1930 of the river as diverted at Patterson, location 12, which had a conductance of 84.8.

QUADRANGLE 9

(Tps. 5, 6, 7, and 8 S., Rs. 10, 11, and 12 E.)

Two classes of water are represented by the samples in quadrangle 9. The four flowing, or formerly flowing, deep wells at locations 2, 3, and 8, near the Merced River north of Stevinson, had conductances of 273, 234, 270, and 440, relatively high concentrations of chlorides, and in two at least high concentrations of boron. In each sodium was the predominating base. In the first two of these wells sulphates were abundant, while in the latter, which had 35 milligram equivalents of chloride, there was little sulphate. The sample from the old flowing well at the Charles Lyon Gun Club, location 10, had a high percentage of sodium, but the conductance of this water was but 47.6, and boron was present only to the extent of 0.07 p.p.m., clearly indicating an origin quite distinct from the other deep waters.

The examples of the water from shallower wells (locations 1, 4, 7, 9, and 11) and the surface waters from the Merced River (location 6) and from the canal at Delhi (location 5) are all of excellent quality, typical of the drainage from the Sierra Nevada.

Leaf samples of walnut and peach, collected June 22, 1929, in the Delhi settlement adjacent to location 4, had respectively 47 and 32 p.p.m. of boron.

QUADRANGLE 10

(Tps. 9, 10, 11, and 12 S., Rs. 7, 8, and 9 E.)

The deeper water underlying that portion of quadrangle 10 within the valley is represented by samples from flowing wells at locations 1 and 3 about 6 miles respectively southwest and southeast of Gustine. These samples had conductances of 515 and 202 and boron concentrations of 2.74 and 1.99 p.p.m., respectively. The first, the Allen Ranch stock well, located near the mouth of an arroyo, is remarkably high in magnesium and sodium sulphates, whereas water from the new well of the Salinas Gun Club, 7 miles east in the valley floor, carried more chloride but less than one-eighth as much sulphate. The water of a third deep flowing well between Los Banos and Dos Palos, quadrangle 11, location 7, did not resemble either of these.

San Luis Creek, sampled at location 5, presumably has made a material contribution to the subsurface waters of its delta, and the proportion of ions in the well at Santa Nella, location 6, is similar, though the concentrations of all ions excepting calcium and bicarbonate are materially higher. The samples collected at locations 2 and 4 to the north did not resemble that collected at 6 and were different one from the other.

QUADRANGLE 11

(Tps. 9, 10, 11, and 12 S., Rs. 10, 11, and 12 E.)

Samples from locations 1 and 2 are of shallow domestic wells in and near Los Banos. Under both wells, as is the case elsewhere here and there in the vicinity of Los Banos, typical boron symptoms were in evidence; these waters carried 1.13 and 0.65 p.p.m. of boron respectively. Sample 2774 at location 12 is from a shallow well in the vicinity of Dos Palos; the boron concentration was 0.18 p.p.m., and there was no evidence of boron injury.

The drainage wells at locations 6, 7, 10, 11, and 13 are all adjacent to irrigation canals and most of them had been operated for a sufficient time to lower the water table in their vicinity. The water produced by these wells is markedly variable in total concentration and in the proportions of the different ions; in all, the concentration of boron was insufficient to be considered agriculturally significant.

Samples at 8, 14, 15, and 16 are ground waters from wells on land adjacent to the foothills above irrigation canals south of Los Banos and Dos Palos. Independent of other characteristics, the boron concentrations were too high for use in the production of other than boron-tolerant crops. In each the concentrations of chloride or sulphate or both were high, and the percentage of sodium in each was sufficiently high to raise a question as to the effect of prolonged use of these waters on the physical character of the soil.

Sample 2871, location 9, was bailed from a 500-foot hole drilled to supply irrigation water. A pump was never installed in this well, and the concentrations of boron, chlorides, and sulphates were the highest encountered in well waters during the investigations. The chloride concentration was 63 percent as high as sea water and the sodium (alkali bases) concentration exceeded that of sea water by 1.9 times.

QUADRANGLE 12

(Tps. 9, 10, 11, and 12 S., Rs. 13, 14, and 15 E. Quadrangle map not shown.)

The flat area east of the San Joaquin River embraced by quadrangle 12 is not cultivated extensively. Some water from the river is used for irrigation both east and west of Firebaugh, but a large part of the bottom lands east of the river are grazed.

The concentrations of chlorides and sulphates in the deep well sampled west of the river, location 2, in common with many of the wells in quadrangle 15 to the south, are relatively high, and as in many of those wells, sodium is the predominant base, but as compared with the quadrangle 15 wells the boron content of this well, 0.47 p.p.m., is relatively low. The relatively good water represented by the sample from location 1 is from the old flowing well on the Durham farm east of Dos Palos.

QUADRANGLE 13

(Tps. 9, 10, 11, and 12 S., Rs. 16, 17, and 18 E. Quadrangle map not shown.)

The 3 samples in quadrangle 13 together with the 1 from Merced and 2 from sec. 6, T. 8 S., R. 16 E., are believed to be typical of the ground waters in this east-side area. All are of low salinity, have little boron, the chlorides exceed the sulphates, and the alkaline earth bases exceed the alkali bases.

QUADRANGLES 14 TO 26

The area embraced by the group of quadrangles numbered from 14 to 26 includes that portion of the San Joaquin Valley southward from Herndon and Firebaugh to the northern boundary of Kern County. The bed of Tulare Lake is situated in the center of the southern portion of this area and has in the past overflowed through Kings River Slough to the San Joaquin River near Mendota. The Kings River water which reaches the axis of the valley normally discharges into the slough, which likewise receives some water backed up by the dam across the San Joaquin River at Mendota. At times of excessive run-off the Kings River discharges into Tulare Lake through canals constructed to carry the water to a portion of the lake bed surrounded by levees. These levees and canals were constructed to protect the farm lands of the lake bed from flood waters.

The ground waters east of the broad low-lying area adjacent to Kings River Slough and Tulare Lake are for the most part of excellent quality and similar in general character to those encountered east and north of the San Joaquin River. Only one of the few scattered samples collected in quadrangles 17, 21, and 26 was saline, and similarly good waters are represented by some of the samples in quadrangles 16, 20, and 25. The concentration of boron in certain of these samples was remarkably low. As in the area east of the San Joaquin River to the north, the bicarbonate concentrations tended to be materially higher than the chloride concentrations and the chloride concentrations higher than sulphate. In some samples sodium constituted in excess of 50 percent of the bases, but where the conductances were in the order of 25 or less the percentage of sodium is of only secondary significance.

The surface and ground waters in the area west of the central or axial portion of this section of the valley tend to be saline and to contain sufficient boron to constitute a factor of agricultural consequence. The conductances of the samples obtained were in nearly all instances in excess of 100, with conductances above 250 quite common. The boron concentration in one of the water samples was as low as 0.20 p.p.m., but concentrations of 1 part per million or more were common to the greater number of the samples; though in quadrangle 23, which includes Kettleman Hills and drainage from mountains and foothills to the west, only 1 of 10 samples contained as much as 1 p.p.m.

The bicarbonate concentrations in these waters west of the valley axis were mostly higher than in the waters east of the valley axis but were usually exceeded by either chloride or sulphate. In this area as a whole nearly 80 percent of the waters carried more sulphate than chloride. Nearly all of them carried substantial quantities of calcium and magnesium, but in considerably over half of the samples the sum of calcium and magnesium was exceeded by sodium.

The ground waters of the central or axial portion of the valley are of such character and variability that the analyses lend themselves better to detailed study than to generalization. These waters nevertheless tended to have higher conductances and higher boron concentrations than were found in representative samples east of the valley axis. In some of the axial waters the sulphate concentrations were particularly low, and in these there was marked tendency toward high sodium percentages.

QUADRANGLE 14

(Tps. 13, 14, 15, and 16 S., Rs. 10, 11, and 12 E.)

Sample 2770, location 1, was taken from one of a number of almost stagnant pools along the then mostly dry bed of Little Panoche Creek below Mercy School. It contained 18.60 p.p.m. of boron, and the conductance and sodium concentrations were both high. Unlike the Mercy Springs water, location 3, with 13.0 p.p.m. of boron and little else than sodium chloride, the creek sample was high in sulphate, calcium, and magnesium. Plantings watered from a farm well above Mercy School showed marked boron symptoms.

The irrigation well at location 2, 6 miles east and a little north of where Little Panoche Creek wash leaves the foothills, produces water very unlike the creek sample; but wells at locations 14 and 15 of quadrangle 11, 6 miles north and 1 and 3 miles east of the wash, produce water less saline but having a proportion of ions and a salinity which suggest that Little Panoche Creek run-off has there contributed to the ground water. The salinity of Little Panoche Creek as sampled is unquestionably higher than would be the case during run-off after rains.

Panoche Creek and Silver Creek, its tributary, were sampled in May 1930 and again in September 1931. The Panoche Creek samples, location 5, were taken about 5 miles above the junction with Silver Creek. The Panoche Creek samples had conductances of 279 and 289, whereas those of Silver Creek were 806 and 927. The boron concentrations in each were high, but Panoche Creek with 4.89 and 6.52 p.p.m. had only about half as much as Silver Creek with 8.78 and 12.7 p.p.m. In each the alkali base content was approximately equivalent to the sum of calcium and magnesium.

Panoche Creek underflow above Griswold Creek may be represented by the well sample at location 4, and Griswold Creek underflow is probably represented by the sample from a well at location 7. If this is the case, a major portion of the boron and a major portion of the salinity represented in Panoche Creek is derived respectively from Silver and Griswold Creeks. The conductance of the water at location 4 was 129, and that from location 7 was 618. The corresponding boron concentrations were 1.54 and 7.44.

QUADRANGLE 15

(Tps. 13, 14, 15, and 16 S., Rs. 13, 14, and 15 E.)

High prices for cereals and cotton were immediately responsible for the deep-well agricultural development in the Panoche Creek delta area southwest of Mendota, though some of the acreage is devoted to other crops such as grapes, figs, and asparagus. Wells with discharges up to 3 cubic feet per second were drilled to depths of 1,400 feet to tap water-bearing sands interspersed with blue clay below 600 feet. Water-bearing sands occur at high levels, but the casings were not ordinarily perforated for them, as the upper water was known to be more saline. Under certain cropping systems individual wells in this area serve a section of land.

The irrigation waters used in this quadrangle are in many instances saline. The conductances of the well samples collected ranged from 127 to 580, corresponding with total solids of from 900 to 3,800 p.p.m. The boron concentrations in the same samples varied from 0.91 to 2.99 p.p.m., the average being 1.55; sodium (alkali bases) constituted from 42 to 93 percent of the total bases; chlorides varied from 1.30 to 44.50 m.e.; and sulphates, which tended to be of more uniform concentration, varied from 7.69 to an outstanding concentration in the Chaney Ranch well of 30.40 m.e. Chlorides exceeded sulphates in 6 of the 16 samples, but in no instances were sulphates low.

General indications of a directional trend in the characteristics of the water produced by the wells in the Panoche Creek delta are lacking. Wells at locations 1, 3, 8, and 9 were all high in chlorides, and these wells are in the northwest portion of the area sampled; but the well at location 4, which is adjacent to those at 8 and 9, was low in chlorides. The well at location 12 was highest of all in chlorides, and it is adjacent to wells at 11 and 15, which were low in chlorides.

The water from the Chaney Ranch well, location 18, had a higher proportion of calcium and magnesium and higher concentration of sulphate than the wells farther out on the delta, and in these respects it is not unlike that of Panoche Creek with the contribution made by Silver Creek taken into account. As judged by the quality of water, it seems improbable that Panoche Creek has made a material contribution, however, to the deeper water-bearing strata underlying the lower part of the delta fan. The surface elevation at the Chaney Ranch is 140 feet higher than that at the nearest of the wells of the lower group, and the Chaney Ranch well was drilled to but 1,000 feet, whereas the wells farther out on the delta were drilled to 1,400 feet and the casings perforated only below 600 feet.

The uniform depths of wells and depths of perforation and the evenness of the delta-plain topography cause the variability shown in the quality of water obtained from these deep wells to become noteworthy. With the lower 800 feet of the well casings perforated, waters from many strata must contribute to the discharge of each. It is to be assumed that the water-bearing strata tapped are in the form of lenses, or uneven and limited layers of successively deposited permeable material. To explain the variation in the quality of water of neighboring wells it appears necessary to assume that there is now little movement in this ground water, and that the water of different strata has come in during different periods, with associated though unknown variations in source.

The waters from many of these wells are not suited to permanent agriculture, and the agricultural experience of the area bears out experience with such waters elsewhere. A number of the operators have recognized that the fertility of this initially productive land is of short duration when the waters from certain wells are used, and that such profit as was to be obtained must be derived during the first few years of cultivation. The profitable utilization of waters from such wells as those at locations 4, 9, 10, and possibly 15 and 19, however, might extend over many years, particularly if gypsum or sulphur is used to offset the effects of the high percentages of sodium.

The analyses reported under locations 5, 6, and 17 are of samples from the San Joaquin River, which, in contrast with the well waters of this quadrangle, is remarkably pure. The location 5 sample, with a conductance of 5.55, was from the river below the Mendota Dam; the location 6 sample, with a conductance of 5.29, was from Columbia Canal as diverted several miles up stream; and the location 17 sample, with a conductance of 9.93, was from Fresno Slough at White's Bridge. These same samples contained respectively 0.07, 0.11, and 0.02 p.p.m. of boron.

QUADRANGLE 16

(Tps. 13, 14, 15, and 16 S., Rs. 16, 17, and 18 E.)

The eight samples collected along the axis of the valley in the southwest portion of quadrangle 16, locations 4, 5, 6, 8, 9, and 10, were from wells that were relatively deep; the well in San Joaquin, believed to be the deepest, was reported as having been drilled to 1,700 feet. The waters produced by these wells had, with one exception, about 1 p.p.m. of boron. None of them contained injurious concentrations of either chloride or sulphate, but all were sufficiently high in percentage of sodium to render them unsatisfactory for prolonged agricultural use. The conductances of these wells varied between 58.5 and 125.

Water of very different character is produced by a series of some 21 wells discharging into a James Irrigation District canal extending to the northeast at a right angle with the valley axis. This canal and the series of wells, spaced about three to a mile, extends diagonally across T. 15 S., R. 18 E. These wells have depths of 214 to 300 feet. The water produced by them, as represented by a composite sample taken from the canal at location 7 at a time when most of the wells were operating, had a conductance of only 28.9, contained but 0.03 p.p.m. of boron, and sodium constituted but 27 percent of the bases.

Two wells were sampled at Jameson. The shallow well at the Southern Pacific Railroad section house, location 1, produced water low in mineral matter and boron, whereas two samples from the 600-foot well supplying water for the boilers of the Associated Pipe Line Co., location 2, had conductances of 376 and 281 and were unusually high in sodium chloride. Sodium constituted 90 percent of the bases, and there was in excess of 1 p.p.m. of boron.

The water from the 70-foot well at location 3, east of Jameson, was very similar to that produced by the series of wells along the canal.

QUADRANGLE 17

(Tps. 13, 14, 15, and 16 S., Rs. 19, 20, and 21 E.)

The well waters sampled in quadrangle 17 are believed to be generally representative of the area, and they are noteworthy for their low concentrations of salt; none of the wells had conductances above 50, and in none did the boron concentration exceed 0.10 p.p.m. In most of the well samples calcium was the predominating base, and in all the percentage of sodium was less than 50. The San Joaquin River near Herndon carried sodium to the extent of 58 percent of its bases, but this has little or no significance, since the water had a conductance of but 5.9.

Ground waters with as little boron as is represented in these wells at least suggest that the boron concentrations in the soil solutions may likewise be low. It is not improbable that boron might be beneficially applied here and there in the area as a fertilizer for crops having high-boron requirements. Such crops as beets, cotton, grapes, and asparagus would be most apt to show response.

QUADRANGLE 18

(Tps. 17, 18, 19, and 20 S., Rs. 13, 14, and 15 E.)

The sample at location 2 from the Fresno Hot Springs, 10 miles west of Coalinga, was not highly mineralized. It had a conductance of 64.2, the principal salt being sodium bicarbonate, and relative to numerous well samples the concentration of this was low. The concentration of boron, 7.76 p.p.m., was relatively high, as is the case in many hot springs.

Sample 2756, location 1, at the Halfway Station of the Associated Pipe Line north of Cantua Creek, may or may not reflect Cantua Creek run-off or underflow. The well is drilled to 700 feet, and the static level was 295 feet below the surface. The conductance was 178; the boron concentration (0.60 p.p.m.) was not as high as in wells in the quadrangle to the east, and the percentage of sodium is much lower. This water, which is fairly high in magnesium sulphate, is not used for drinking. The shallow well at location 3, with a conductance of 208 and 1.68 p.p.m. of boron, probably represents Los Gatos Creek underflow.

The two deep wells in Coalinga, location 4, were both drilled to 1,400 feet; the casing of the first (sample 2752) is perforated below 250 feet, whereas the casing of the second (sample 2753) is not perforated. If it is assumed that the deeper waters tapped by each are alike, then the upper strata waters must be low in bicarbonate and magnesium and high in chloride and sodium, with the boron, sulphate, and calcium concentrations substantially the same in both the upper and lower strata. Coalinga drinking water is brought in from elsewhere.

QUADRANGLE 19

(Tps. 17, 18, 19, and 20 S., Rs. 16, 17, and 18 E.)

The major portion of the irrigation water utilized in quadrangle 19 is obtained from relatively deep wells. Nine wells with depths of 800 feet or more were sampled, and these waters, with some exceptions, had conductances of about 100, boron concentrations of about 1 p.p.m., and sodium percentages between 70 and 90. The ranges for all nine of these wells were: Conductances from 87 to 182, boron concentrations from 0.39 to 1.74 p.p.m., and sodium percentages between 54 and 90. The waters from wells with depths of less than 800 feet were more diverse. Those sampled had conductances between 58 and 433, boron concentrations between 0.08 and 1.63 p.p.m., and sodium percentages between 34 and 91.

In some instances boron was believed to be present in significant concentrations as a natural constituent of the soil, and under certain of the wells evidence of injury to the more sensitive plants was marked. Under the well at location 13, boron symptoms were pronounced, and grape leaves collected in September 1929 contained 1,019 p.p.m. of boron.

The general tendency toward high percentages of sodium in the deeper waters of this quadrangle deserves perhaps more serious consideration in the culture of semitolerant or tolerant crops than the boron concentrations. As an illustration of the importance of the sodium percentage, the shallow well at location 7 produces water with a conductance of 330, and yet it has been used for 15 years without indications of declining yields or tightening of the soil. The sulphate concentration of this water was 31.23 m.e., but the concentration of calcium and magnesium together was approximately twice as great as the sodium concentration. Nearby soils irrigated with water with a similar concentration of sodium but with very little calcium and magnesium have become hard, and alfalfa has been abandoned after 9 years. Where upper-strata waters are high in calcium and magnesium and low in sodium in this area, owners should give consideration to the possibility of decreasing the percentage of sodium by perforating deep-well casings to admit water from the upper strata. The water from the location 7 well carried calcium and magnesium in excess of sodium equivalent to 3,238 pounds of gypsum per acre-foot of water.

At location 10, sample 4846, water from a stratum at 70 feet, while high in calcium and magnesium (12.37 and 16.71 milligram equivalents respectively), was also proportionately high in sodium (27.39 milligram equivalents). At this location a 650-foot well perforated below 170 feet produced water (sample 4844) with a conductance of 247 and a sodium percentage of 43. Such water, while not highly satisfactory, would nevertheless be preferred over a long period to a water such as that from location 11, or possibly from 3 or 8; and certainly it would give better results than the water from the well at location 9, the casings of which are perforated only below 900 feet.

QUADRANGLE 20

(Tps. 17, 18, 19, and 20 S., Rs. 19, 20, and 21 E.)

Sodium was the predominating base in all samples from wells in quadrangle 20 that had depths of 195 feet or more (locations 1, 2, 3, 6, 7, 8, 9, 10, 11, and 12). The boron concentrations in the same wells were variable; three of them had more than 1 p.p.m. of boron, and three located in Hanford had less than 0.5 p.p.m.

The water from the three deep wells near Stratford (locations 10, 11, and 12) differed from the other waters sampled in this quadrangle in that the conductances exceeded 100 and the sulphate materially exceeded the chloride.

The Kings River water, as sampled from a canal near Lemoore (location 4), carried very little salt, and similar water was obtained from the 120-foot well on the Lucern Vineyard property 4 miles northwest of Hanford at location 5.

QUADRANGLE 21

(Tps. 17, 18, 19, and 20 S., Rs. 22, 23, and 24 E.)

A number of the ground waters sampled in quadrangle 21 had high percentages of sodium, but only one was saline. The saline water was from a 100-foot well 6 miles north of Corcoran at location 6. A second well on the same property, location 4, drilled to 2,100 feet, produced water with a conductance of 35.1. The latter water is not unlike the Hanford waters, one of which is represented by the sample at location 2.

Kings River, here represented by two samples at location 1 and in quadrangle 20 by a canal sample at location 4, was found to have a conductance below 15 and very little boron on each of the three sampling dates.

QUADRANGLE 22

(Tps. 21, 22, 23, and 24 S., Rs. 13, 14, and 15 E. Quadrangle map not shown.)

The two samples collected in quadrangle 22, locations 1 and 2, are from shallow wells adjacent respectively to Waltham and Jacelitos Creeks. The conductances were 506 and 278 and the boron concentrations 4.29 and 0.80 respectively. Both were sulphate waters; the first, with 41.36 m.e. of sulphate, had 41.18 m.e. of alkaline bases.

QUADRANGLE 23

(Tps 21, 22, 23, and 24 S., Rs. 19, 20, and 21 E.)

A sample from the Dudley pump-station well west of Kettleman Hills in the southeastern portion of the quadrangle, location 10, had 1.28 p.p.m. of boron. None of the other 9 well samples contained more than 0.66 p.p.m. of boron. The conductances of all the samples west of Kettleman Hills were relatively high, but in none did sodium constitute more than 47 percent of the bases. In each of these waters the sulphate concentration exceeded that of any other ion.

The group of three irrigation wells northeast of Kettleman Hills, locations 3, 4, and 5, produced water of much lower salinity than the waters more closely associated with coast range drainage as sampled to the west and south of these hills, but the percentages of sodium were 72, 58, and 64, respectively. A tendency for the soils irrigated to become hard was in evidence. Grapes, plums, walnuts, pears, apricots, melons, and cottonwoods all showed typical boron injury under the location 3 well. Walnut and orange leaves collected September 25, 1929, under a well on the corner west of the location 5 well, carried, respectively, 597 and 431 p.p.m. of boron, and fig leaves under the location 5 well contained 767 p.p.m. of boron. Though these concentrations are not particularly high, they afford indications of appreciable concentrations of boron in the soils upon which the trees were grown. It is probable that at least some of this boron is present as a natural constituent of the soil, since none of the three waters contained more than 0.40 p.p.m.

QUADRANGLE 24

(Tps. 21, 22, 23, and 24 S., Rs., 19, 20, and 21 E.)

The Tulare Lake bed is now dry and farmed extensively, but lake waters at one time or another in the past not only occupied a considerable part of this quadrangle but extended into portions of quadrangles 20, 21, 25, 27, and 28. The lake bottom has an elevation of 180 feet above sea level, and it was only at an elevation of approximately 220 feet that an outlet became available through Kings River Slough to the San Joaquin River. The margin shown, as of 1884, corresponds to an elevation of about 194 feet. The available records on lake levels have been summarized by Dole (*27*), and according to his summary the lake previous to 1884 had not been recorded as being below 192 feet as far back as 1853; but the general impression exists that the lake has probably been recurrently filled and dried out in the past; this view, the writer is informed, is supported by Indian legends.

The irrigation wells known to the writer in the old Tulare Lake bed within the 1884 margin are deep. The depths of the wells sampled ranged from 1,400 to 2,100 feet. One shallow well, location 18, not used for irrigation, was also sampled. In drilling these deep wells many successive strata of heavy clay are reported to have been encountered, the occurrence of which permits a question as to whether these deep waters, in some instances not highly mineralized, have been derived or replenished from the lake during periods when the lake has been filled, or whether the source has been more remote in time or place. This question naturally is not peculiar to the deep-well waters underlying the lake bed, since the time and place of origin of the deeper waters of the valley floor as a whole are uncertain. The waters underlying the lake bed are nevertheless subject to special consideration for the reason that they have been found to be uniformly low in their sulphate content for fresh water of such salinity. Of the 17 deep wells sampled, only 2 contained as much as 0.40 m.e. per liter of sulphate, and 6 contained less than 0.01 m.e. Other deep-well waters to the north, south, and east were also examined and likewise found to contain very little sulphate and yet their total salinity was well above that of the fresh waters derived from the Sierra. As is discussed later in this bulletin, it is the writer's belief that the low sulphate concentrations of waters underlying this area reflect anaerobic bacterial reduction of sulphate.

Normal carbonates were not found in any of these waters; bicarbonate and chloride tended to be present in somewhat similar concentrations; and in all but one of the samples alkali bases exceeded calcium and magnesium. In these deep-well waters no boron concentration exceeded 1 p.p.m., and in one the concentration was as low as 0.20 p.p.m.

It is not believed that the boron concentrations occurring in most of these irrigation waters are sufficiently high to affect materially the cereals and cotton grown in the lake bed. Boron may occur naturally in a part of the lake bottom, and there is evidence in some sections that with continued irrigation and utilization of the land, yields have decreased, but this is not necessarily general. Where reduced yields occur in successive crops consideration should be given to the abundance with which the irrigation water is used.

Boron determinations seem never to have been a part of the early Tulare Lake water analyses, but it is nevertheless not improbable that it may have been an important constituent, particularly at low stages. The subsoil at variable depths is probably impregnated with the salts residual to the evaporated lake waters. Various plants under the well at location 14, which had 0.49 p.p.m. of boron, showed symptoms of mild boron injury; leaves of string bean (sample no. 298) contained 247 p.p.m. of boron, and leaves of cottonwood 657 p.p.m. when sampled September 25, 1929. Three samples of milo leaves (nos. 739, 740, and 741) collected August 29, 1930, from different sections contained respectively 578, 1,040, and 144 p.p.m. of boron. The water used to irrigate the milo represented by samples 739 and 740 had slightly less than 0.5 p.p.m. of boron, and that used on sample 741 had 0.65 p.p.m. Samples 739 and 740 were from different sections of land cultivated respectively for 2 and 5 years.

Water from the shallow well at location 18 was unsuitable for agricultural use, and the upper waters in this region are generally recognized as being saline.

QUADRANGLE 25

(Tps. 21, 22, 23, and 24 S., Rs. 22, 23, and 24 E.)

The wells west of Angiola at locations 5 and 7 in quadrangle 25, with depths of 1,900 feet or more, are like the deep-well waters of the Tulare Lake bed in that they contain little sulphate and the predominating base is sodium. The wells at locations 6 and 8, also west of Angiola, are 470 and 460 feet deep; the former has 4.10 m.e. of sulphate and a higher conductance than any of the deep lake-bed wells.

Waters of low salinity and similar characteristics are obtained from the 400- and 460-foot Corcoran municipal wells (location 2) and the 350-foot Bryson Ranch irrigation well at Angiola (location 9). A shallow well just west of Corcoran (location 3) was saline and had 1.98 p.p.m. of boron, whereas a shallow well on the Bryson Ranch produced water of good quality. The canal sample at location 10, derived from wells near Smyrna, and the Alpaugh municipal water from 1,000-foot wells at location 11 are much like the Corcoran municipal and Bryson Ranch irrigation-well samples. All had low conductances, 35 or less; low boron concentration, 0.15 p.p.m. or less; low chlorides, and low sulphate concentrations. The alkali bases were twice as concentrated as the alkaline earth bases. Other than for the sodium percentages, all of these waters resemble those characteristic of the east side of the valley.

The wells at locations 12, 13, and 14 in T. 24 S., R. 22 E., about 14 miles north of Lost Hills, are, respectively, 825, 830, and 990 feet in depth; they are within a 2-mile radius, and the upper ground waters are excluded. All are very low in sulphate. The first-mentioned well is extremely saline, having a conductance of 1055, 85 m.e. of chloride, and 5.97 p.p.m. of boron. The other two wells each have less than 1 p.p.m. of boron and conductances below 100. The latter waters, like those from locations 5 and 7, are in the class of the deep Tulare Lake wells.

QUADRANGLE 26

(Tps. 21, 22, 23, and 24 S., Rs. 25, 26, and 27 E.)

The two samples collected in quadrangle 26 had 0.09 and 0.05 p.p.m. of boron, and boron symptoms have not been observed in the area. The well at Pixley, location 1, which formerly flowed, was drilled to a depth of 1,180 feet. The water had a conductance of 20.1 and contained little else than sodium bicarbonate. If sulphate was at one time present in the water tapped by this well it has now largely disappeared, as the sulphate concentration was 0.07 m.e.

The well at location 2, 2 miles north of Delano, serves a vineyard of Sultanina grapes on a light soil. Leaves collected from these grapes on September 20, 1929, contained 245 p.p.m. of boron. This concentration in grape leaves is greater than has resulted in cultures of Sultanina without added boron at the Rubidoux Laboratory, but less than the concentrations produced when solutions with 1 p.p.m. of boron have been applied.

QUADRANGLES 27 TO 35

The group of quadrangles numbered from 27 to 35 constitutes the southern portion of the San Joaquin Valley in Kern County. The greater part of the water available for irrigation is derived either directly or indirectly from the Kern River. Caliente Creek makes a material contribution to the ground waters in the vicinity of Arvin, and some additional water is likewise contributed by small creeks and washes from the mountains enclosing the southern end of the valley on three sides; but in proportion to the supply afforded by the Kern River, all of these are of secondary importance. Kern River water is widely distributed by canals and some is stored in Buena Vista Lake Reservoir, from which lower-lying lands north of the lake are irrigated.

During cycles of wet years previous to the present extensive development of irrigation agriculture there has been at times a water connection between the Kern River and Tulare Lake; but water movement, either surface or underground, out of the southern portion of the valley is now believed to be negligible. Though Kern River water is relatively pure, it carries and has brought to the floor of the valley in the past an appreciable quantity of salt, and some is also brought into the valley by the creeks and washes referred to. The surface slope between Buena Vista and Tulare Lake bottoms averages less than 2 feet to the mile. Between Bakersfield and the depression marked by Kern Lake, Buena Vista Lake Reservoir, and Buena Vista Slough at the outer margin of the Kern River delta the slope is less than 5 feet per mile. There is a difference in elevation of only 13 feet between the Kern Lake depression, 15 miles south of Bakersfield, and Buttonwillow, 30 miles west of Bakersfield. In this low flat area and its northern extension there are fertile lands, but also there are many acres of nonproductive, unreclaimed, salt-impregnated waste land. In much of this land the water table is relatively near the surface.

Kern River water carries very little boron and little other mineral matter, and the wells sampled in the Kern River delta generally have been found to be of good quality. In the northern part of Kern County, wells sampled west of Buena Vista Slough were saline and high in boron. None of the wells sampled in the central part of the valley had more than 0.50 p.p.m. of boron and the deep wells relatively little mineral matter, but the percentages of sodium were high. Wells sampled in the eastern part of the area in or near Delano, Wasco, Shafter, and Famosa produced good agricultural water. The underground water situation near Lerdo is complex; certain of the deeper wells carry very little boron or other mineral matter, but the wells less than 500 feet in depth are sometimes both saline and high in boron. The waters below Caliente Creek in the Arvin section are mostly good, but there is an important area of boron contamination near the Rock Pile School. High concentrations of boron were found in a perched water table east of Caliente Wash. The water of Grapevine and San Emigdio Creeks had in the order of 1 p.p.m. of boron.

QUADRANGLE 27

(Tps. 25, 26, 27, and 28 S., Rs. 19, 20, and 21 E.)

There is almost no agriculture and there are very few wells in quadrangle 27, which lies to the west of Lost Hills. The static water levels in the four wells sampled, locations 1, 2, 3, and 4, were at depths of approximately 120, 357, 260, and 300 feet, respectively. Each of the four waters was highly saline, the conductances ranging from 363 to 610; each carried appreciable concentrations of boron, 1.15 to 5.23

p.p.m.; in each the sulphates exceeded the chlorides, but in all the chloride concentrations were high; each of the waters was hard, being high both in calcium and magnesium, but in each the sodium (alkali base) concentration was equal to or higher than the sum of calcium and magnesium. None of these waters would be suitable for agriculture.

QUADRANGLE 28

(Tps. 25, 26, 27, and 28 S., Rs. 22, 23, and 24 E.)

Samples were collected along the axis of the valley between Buena Vista and Tulare Lakes from wells at Smyrna, a well 6 miles southwest and one about the same distance northwest of Smyrna, which were relatively deep and at one time flowing. These wells, together with the wells at Semitropic, location 5, produced water with conductances between 19.7 and 49.8 and with 0.32 p.p.m. or less of boron; in each the percentage of sodium was relatively high.

The waters from a 170-foot well 7 miles west of Semitropic, location 4, and from a 112-foot well in the southeast corner of the quadrangle, location 6, had conductances of 133 and 155 respectively, boron concentrations of 0.40 and 0.34 p.p.m., and sodium percentages of 83 and 51.

QUADRANGLE 29

(Tps. 25, 26, 27, and 28 S., Rs. 25, 26, and 27 E.)

The four samples collected at locations 1, 2, 3, and 4 respectively at Delano, Wasco, Shafter (U.S. Cotton Field Station), and Famosa from wells of depths of 1,100, 600, 165, and 140 feet are typical of the good irrigation waters along the east side of the valley; the conductances were all less than 50, and the boron concentrations were 0.14 p.p.m. or less. A sample of Kern River water taken from Beardsley Canal is shown under location 5.

The other samples taken in the quadrangle are from wells in T. 28 S., Rs. 26 and 27 E. Some of the ground waters in this area are of inferior quality, and the group of samples as a whole affords an outstanding example of the variability that may be encountered in the quality of ground waters in a relatively small area. The conductances ranged from 32.3 to 444, the boron concentrations from 0.02 to 2.02 p.p.m., and the alkali base percentages varied from 4 to 86. The poorest of the waters, location 17, was from a well (now abandoned) drilled to 138 feet. The best of these waters, miscellaneous sample 6346, is from a new 765-foot well the casing of which was not perforated above 500 feet. This is the deepest well of the group, and its water now replaces for irrigation that from the location 17 well. Evidence afforded by the analyses of the samples first collected in the area pointed to the possibility of obtaining better water from deeper strata and also indicated the desirability of leaving casings unperforated at the higher strata.

The response of vineyards on rather light soil to the water represented by sample 6346 when it was substituted for water from the well at location 17 and a similar water was noteworthy in the rapidity with which improvement took place. After installing the pump on the new well, one half of a vineyard was given an irrigation in August 1931, and at the same time the other half was irrigated from the old wells. A month later a marked and unmistakable difference in growth was in evidence.

A well-cared-for vineyard irrigated from the well at location 16 is located across a roadway from a vineyard irrigated until September 1931 from the location 17 well. Both were in poor condition in 1931, but the latter was poorer. One year's irrigation with the no. 6346 water doubled the new growth on the later vineyard, whereas no evidence of improvement was shown in the location 16 vineyard. The location 16 water is much better than the location 17 water, but poorer than the new well water, both in total salinity and in the concentration of boron.

Sultanina grapes irrigated with water from the well at location 17 were observed in 1931 to have ripened properly, but the fruit was small and too round. Some of these vines were heavily fruited and others practically barren. Duplicate leaf samples collected September 16, 1930, from heavily fruited vines contained 1,048 and 1,093 p.p.m. of boron, and duplicate samples from immediately adjacent lightly fruited vines contained 1,231 and 1,230 p.p.m. The lightly fruited vines exhibited typical boron leaf injury. An inch or more of the leaf margins of the heavily fruited vines were dead, but the condition was not one that could be attributed directly to boron, since the same effect has been observed in heavily fruited vineyards irrigated with nonboron waters.

Ten ounces of anhydrous borax was applied by F. W. Herbert to a basin-irrigated Salwey peach tree on a light soil in a border row adjacent to cotton at the United States Cotton Field Station at Shafter, location 3, in May 1930. A leaf sample collected from the tree on October 30 of the same year contained 87 p.p.m. of boron, whereas the leaves of an untreated Muir peach contained 46 p.p.m. A year later pronounced boron symptoms were shown by the treated tree, and these were more marked on the side next to a roadway than on the side next to the irrigated cotton, into the soil of which roots of the tree undoubtedly extended. Leaves from the roadway side of the tree contained 165 p.p.m. of boron, and many leaves had been shed. Leaves from the cotton side contained 101 p.p.m. of boron. The leaves of the untreated Muir peach at the same time contained 47 p.p.m. of boron. The boron applied was equivalent to that which would have been applied by 48 acre-inches of water containing 1.9 p.p.m. of boron.

QUADRANGLE 30

(Tps. 29, 30, 31, and 32 S., Rs. 22, 23, and 24 E.)

Sample 2743 under location 2 in quadrangle 30 represents Kern River water as diverted through Buena Vista Lake Reservoir by canal. Other analyses of Kern River water are shown under location 1 of quadrangle 32.

Wells at locations 1 and 3, near and in Buttonwillow, were drilled to 230 and 220 feet, and the static levels were 10 and 14 feet. The two waters were essentially alike, having conductances of 91.6 and 91.4, boron concentrations of 0.47 and 0.38, and sodium percentages of 45 and 55. The chloride concentrations of each of these waters was much less than either bicarbonate or sulphate.

The water from the 730-foot Southern California Gas Co. well in T. 32 S., R. 24 E, with a conductance of 483 and a boron content of 4.14 p.p.m., is comparable in quality and in the proportions of ions to the poor waters found in quadrangle 27 to the northwest.

QUADRANGLE 31

(Tps. 29, 30, 31, and 32 S., Rs. 25, 26, and 27 E.)

The samples from locations 1 and 2 in quadrangle 31 represent waters which geographically and in quality are associated with those of T. 28 S., Rs. 26 and 27 E., of quadrangle 29.

The wells at location 3 near the Kern River north of Buena Vista Lake supply Taft with domestic water. Though this water had a conductance a little higher than any of the Kern River samples, its source is evident.

In a study of oil-field waters Rogers (*30*) has reported analyses of some samples in this quadrangle and many in quadrangle 30 to the west. He provides an extensive discussion of the ground-water situation in the latter area, but determinations of the boron concentrations were not made. According to Rogers' report the composition of a composite sample from shallow wells of the Western Water Co. in sec. 5, T. 31 S., R. 25 E., was as follows:

	Milligram equivalent per liter
$CO_3 + HCO_3$	1.69
Cl	9.43
SO_4	3.45
Ca	1.56
Mg	.49
Alkali bases	11.02

The Balbach well, location 4, lies below San Emigdio Creek, of which samples are reported under quadrangle 34. San Emigdio Creek is the probable source of this water, and the sulphate concentration, 15.33 m.e. is comparable with San Emigdio water as sampled April 27, 1930, but the concentrations of several other constituents are quite different; magnesium, for example, being present in the well to the extent of 33.4 m.e. and in the stream as diverted to the extent of 7.92 m.e.

Samples were obtained from four wells in section 7, 3 to 4 miles north of the location 4 well. One of these wells, sample 6811, was 237 feet deep, and the water, with a conductance of 193, had a composition not unlike San Emigdio Creek and that from the Balbach well. The other three wells, samples 6810, 6812, and 6820, were respectively 800, 600, and 800 feet in depth, two being reported as flowing. These wells, with conductances of 56.4, 68.7, and 54.0, were distinct in composition from the shallow well. The shallow well had a sodium percentage of 26, whereas the sodium percentages in the deep wells were 64, 50, and 69.

QUADRANGLE 32

(Tps. 29, 30, 31, and 32 S., Rs. 28, 29, and 30 E.)

Boron occurs in relatively high concentrations in the waters from a number of wells in the Caliente Creek delta near the Rock Pile School. The wells, at locations 22, 23, 24, 25, 26, 38, 42, 43, 44, 46, and 47 had upward from 0.96 to 7.24 p.p.m. of boron, and all were located in sections 12 and 13, T. 31 S., R. 29 E., and secs. 17 and 18, T. 31 S., R. 30 E. The conductances of these waters ranged from 41.3 to 138. Other wells nearby, locations 4, 14, 16, 18, 20, 27, 29, 41, 45, 52, and 53, some of which were in the sections enumerated, produced water containing boron in concentrations between 0.31 and 0.61 p.p.m. Other wells among those bordering the center of contamination and wells farther removed therefrom (locations 11, 12, 13, 15, 19, 21, 28, 30, 31, 32, 33, 34, 35, 36, 37, 48, 49, and 50) produced water with 0.40 p.p.m. of boron or less, and a number contained less than 0.10 p.p.m. The conductances of the latter series of samples varied from 30.9 to 104.

The preponderant number of the foregoing wells varied in depth from 400 to 600 feet, and the elevation of the water table at the time of the work was for the most part between 350 and 375 feet above sea level.

Immediately east and north of the center of boron contamination near the Rock Pile School there is a second body of ground water at an appreciably higher elevation. This perched water table is separated from that of the lower plain by some underground barrier, marked possibly by the rocky outcrop known as the Rock Pile. The water of this upper table, as sampled from a 387-foot well on the Newmarkel Ranch (location 8), a shallow well known as Deemer Spring (location 9), and Tejon Spring (location 39), had an elevation between 600 and 710 feet above sea level. The boron concentrations in samples from each of the three locations were in the order of 7 p.p.m. The location 8 water had a somewhat higher conductance and more sulphate than the water at 9, but otherwise the proportion of ions was such as to suggest that these three samples represented substantially the same water. In one respect other than boron this perched water is clearly different from that of the lower plane, namely, sodium is the predominant base, the percentages being 93, 92, and 96, respectively. The percentages of sodium in the samples of the delta water table varied from 22 to 87 percent, the average being 50 percent.

Farmers recognized in the early years of the agricultural development of this section, in which many of the soils are highly productive, that deciduous fruits could not be successfully grown with the waters from certain wells. It was also recognized that while some of the annual crops were injured, they withstood these waters better than grapes and deciduous trees. In one instance peach trees were observed to have shown marked improvement following a few irrigations with water from a new well. Prior to the investigations here reported boron determinations had been made on none of these well waters.

With the establishment of the fact that boron occurred in appreciable concentrations in certain of the well waters that had caused difficulty and that the concentrations were relatively low in other wells that were being used successfully, there were numerous solicitations by owners to have their well waters analyzed. The Kern River Water Storage District by well measurements had shown increasing elevations in the water levels from beyond the portion of the lower plane in which boron contamination was found toward the mouth of Caliente Creek. This fact indicated that at least during recent years and possibly over a long period Caliente Creek has made the principal contribution to ground waters of the area. Numerous well samples were collected and analyzed for the purpose of determining the extent of boron contamination, to enable the growers to adjust their water sources and choice of crops to the existing conditions. Some additional samples were collected and analyzed to throw light if possible on the source of the boron in the underground waters or the source of the waters found to be high in this element. The evidence that it was possible to obtain for the latter purpose proved insufficient for general conclusions, but some of it is nevertheless worthy of brief discussion.

In one of the eastern lower-plane wells, location 42, the boron concentration was as high as in the perched water table, and in this well sodium constituted 87 percent of the bases. No other lower-plane water contained more than 77 percent of sodium, and most of them, though variable, were much lower. This well is the closest of any, the well at location 38 excepted, to a perched-water sample, and the concentrations of bicarbonate, chloride, and sulphate are essentially the same as in the location 39 sample from Tejon Spring of the perched table group. By these observations it seems to be indicated that water from the upper plane has to a limited extent found its way into a portion of the lower plane, possibly overflowing or passing through a fissure in the barrier.

A sample was bailed from an abandoned well at location 38, which is about 1½ miles northwest of Tejon Spring. The water elevation in this well corresponded with that of the lower plane, but sound in the well indicated that water was entering the casing in appreciable volume from a higher elevation. The sample obtained is believed to have represented the water entering the casing from above, but it was too small for other than conductance and boron determinations. The boron content, 6.90 p.p.m., corresponded with the concentrations found in the upper plane waters, but the conductance was far higher than that found elsewhere in either body. The observations afforded by this well are believed to indicate that at this point the perched water table overlies that of the lower plane, but that here the perched water is locally more saline.

An abandoned well in Caliente Wash, location 7, had a water elevation of 636 feet (134 feet below the surface of the wash), corresponding roughly with that of the perched table, but the boron concentration was less than 1 p.p.m. The stream-bed elevation and the elevation of the water in this well suggest a source of water, at least during freshets, for the perched table, but the low concentration of boron in the Caliente Wash well shows that if the water of the perched table is derived from Caliente Creek the boron is otherwise derived. The fact that the boron concentrations in the several samples from the three upper table locations and from the associated waters at locations 42 and 38 were all so nearly the same (6.66, 6.58, 7.51, 6.90, 7.24, and 7.12 p.p.m.) may indicate that somewhere this water has been in contact with boron minerals whose solubility was sufficient to produce an equilibrium concentration in the water of about 7 p.p.m.

The water-table elevations of the two wells north of Caliente Creek, locations 5 and 6, are comparable with the perched table south of the creek. These waters contained 0.21 and 0.28 p.p.m. of boron.

In the lower plane the well at location 24, now abandoned, was sampled four successive times in 1929 before it was capped. The boron concentration was essentially the same in each of the samples (4.51, 4.43, 4.63, 4.63), but the conductances varied as follows: 78.5, 55.0, 53.5, 83.4. There was a marked downward and a subsequen upward shift in the concentration of all ions except bicarbonate and sodium during the period. The sodium percentages, on the contrary, first increased and then dropped (50, 67, 70, and 46). These changes in the concentrations of all ions except boron would suggest either a local release of boron by deep gaseous emanations in the vicinity of the well or deposits of boron minerals sufficiently soluble to produce boron concentrations of about 4.5 p.p.m. in the ground water. The characteristics of this water and the shifts in ionic concentrations with boron remaining practically constant would seem to eliminate the perched water table as a source of this local contamination.

Successive samples from wells at locations 22, 25, and 26 showed variations in boron concentrations which were not accompanied by variations of corresponding magnitude in conductances or ionic concentrations.

In Bakersfield a number of wells are pumped to supply municipal water, and the three samples obtained there show only moderate variations in the characteristics of the water on three dates. The total salinity of the samples was low, and the alkaline earth bases tended to exceed the alkali bases. The boron concentration in each of the samples was below 0.25 p.p.m. Mild boron symptoms are in evidence late in the season in the leaves of boron-sensitive plants along the streets and in parkings in Bakersfield.

Miscellaneous sample 928 is from Caliente Creek above Caliente Station, and sample 926 is from Tehachapi Creek above Keene. Caliente Creek, with a discharge of but 0.3 cubic feet per second on the date sampled, carried 0.87 p.p.m. of boron, and the location 7 well in the bed of Caliente Wash below carried 0.82 p.p.m. The conductance of the creek water as sampled in April was nearly three times as great as that of the well.

Sample 3915 from a shallow well east of Monolith represents foothill drainage on the Mojave Basin side of the Tehachapi Mountains.

The scattered samples from locations 3, 10, and 51 are all low in salinity and boron.

Leaf samples of various plants have been collected at one time and another in this quadrangle, and insofar as the boron-absorption characteristics of the different plants are known, the boron concentrations found have been indicative of the quality of water used for irrigation. Sycamore leaves from trees 18 miles south of Bakersfield along the highway to the Grapevine grade, watered from a well at location 2 of quadrangle 35 with 0.92 p.p.m. of boron, contained 1,843 p.p.m. of boron. Leaves of cottonwood from trees watered from the well at location 22, with 1.51 and 1.81 p.p.m. of boron by two analyses, contained 1,428 p.p.m. of boron. Under the well at location 24, with 4.63 p.p.m. of boron, grape leaves contained 1,155 p.p.m. of boron, persimmon leaves 847 p.p.m., and dooryard alfalfa (entire plants) 199 p.p.m. Cotton leaves under the well at location 46, with 3.52 p.p.m. of boron, contained 1,229 p.p.m. of boron. Fig leaves under the well at location 8, with 6.66 p.p.m. of boron, contained 1,853 p.p.m. The foregoing samples were all collected on September 23, 1929. Under the latter well other leaf samples were collected in June 1929, and the following was found: Tomatoes, 840 p.p.m.; Swiss chard, 85 p.p.m.; grapes of wild type, 1,120 p.p.m.; grapes, 722 p.p.m.; figs, 1,294 p.p.m.; olives, 87 p.p.m.; cannas, 1,483 p.p.m. On the same date grape leaves under the well at location 46, unirrigated that spring, had 930 p.p.m. of boron. Leaves of fig and walnut under the well at location 29 with 0.50 p.p.m. of boron contained respectively 500 and 656 p.p.m. of boron in October 1932.

Orange leaves from then unirrigated trees under the well at location 16, with 0.60 p.p.m. of boron, had 558 p.p.m. of boron. Leaves of eucalyptus trees near the well at location 43, with 4.64 p.p.m. of boron, contained 1,000 p.p.m.

QUADRANGLE 33

(Tps. 8, 9, 10, and 11 N., Rs. 24, 25, and 26 E. Quadrangle map not shown.)

Water piped to Maricopa from Ozena, which is near the head of Cuyama River, miscellaneous sample 2637, had a conductance of 49.6 and 0.23 p.p.m. of boron.

Numerous springs discharge near location 2 into Cuyama River, and these springs, together with water obtained from the stream bed, are diverted into a reservoir for irrigation on the Cuyama Ranch. Some of these springs are warm and produce sulphide gas. The concentration of boron in the reservoir sample was 0.23 p.p.m., which is the same as found in the Ozena water; but the reservoir water was very different in other respects and had a conductance of 184.

Sample 2738, at location 1, represents water brought to the surface with oil by Northern Oil Co. wells at Maricopa, which are drilled to a depth of about 1,000 feet. Like oil-well waters generally the chloride in this sample was high, and likewise the sodium. Subsequent analyses of oil-well waters elsewhere have shown the boron concentrations as well as chloride and sodium to be correspondingly high.

QUADRANGLE 34

(Tps. 8, 9, 10, and 11 N., Rs. 21, 22, and 23 W.)

San Emigdio Creek water is diverted at location 1 for irrigation on the San Emigdio Ranch. This water when used on oranges had not been satisfactory. Both the sulphate and boron concentrations were undesirably high. The series of samples here reported were collected to determine whether water of better quality could be obtained at some higher point on the creek. The analyses show that a considerable proportion of both the boron and sulphates are accumulated below location 5, which is 7 miles above the present diversion.

QUADRANGLE 35

(Tps. 8, 9, 10, and 11 N., Rs. 18, 19, and 20 W.)

El Paso Creek as sampled at location 1, where it is diverted for domestic, garden and orchard use at the El Tejon Ranch headquarters, had a conductivity of 47.5. This water, which is low in sodium, contained 0.40 p.p.m. of boron, which was just sufficient to produce mild but characteristic boron symptoms in lemons. Tejon Creek, miscellaneous sample 5006, from sec. 14, T. 11 N., R. 17 W., had a conductance of 85.2 and 0.15 p.p.m. of boron, and sodium constituted 15 percent of the bases.

Grapevine Creek and a well near the foot of the grade locations 2 and 3, which supply water for highway trees have slightly less than 1 p.p.m. of boron, and this concentration has been sufficient to produce outstanding injury to many of the roadside plantings. Sycamore leaves collected from highway trees 18 miles south of Bakersfield in September 1929 contained 1,843 p.p.m. of boron.

A sample of water from Castac Lake, sample 2619, location 8, taken at a time when the lake was low and the margins heavily encrusted with salt, had a conductance of 7,919 and contained 299 p.p.m. of boron. The salts contributing to this high conductance were principally sodium chloride and sulphate. A spring in the mud flat immediately east of the lake margin produced water with a conductance of 138 and a boron concentration of 0.92 p.p.m. This spring water is different from Grapevine Creek water in its proportions of both magnesium and alkali bases. Wells west of the lake at locations 5, 6, and 7 contained 0.60, 0.35, and 0.51 p.p.m. of boron. Mild boron injury was noted on ornamental plantings around the hotel irrigated with the location 5 well and also on irrigated crops served by the other two wells. The injury was most pronounced on the field plantings grown on lower-lying portions of the fields closest to the lake. Leaves collected September 11, 1931, from a large oak tree at the end of the lane and outside of the cattle gate below Castac Lake contained 148 p.p.m. of boron.

Seymour Creek and Lockwood Creek, locations 10 and 11, which are in the vicinity of the Frazier borax mine, are tributary to Piru Creek. At the time of sampling in 1928 these creeks carried about 5 and 2 p.p.m. of boron, respectively, as determined by the semiquantitative turmeric method. The same method was used for the determination of boron in the Cuddy Creek sample.

BACTERIAL REDUCTION OF SULPHATES

Attention has already been directed in the discussion of quadrangle 24 to the fact that the sulphate concentrations are remarkably low in the waters from deep wells in the bed of old Tulare Lake. These Tulare Lake bed irrigation wells are drilled to depths of 1,400 to 2,100 feet. One of them (location 13, quadrangle 24) had a conductance of 348, and yet in this water there was only a trace of sulphate. Of the 17 deep-well waters collected in the quadrangle, 6 contained 0.01 m.e. or less of sulphate, and the remaining 11 contained 0.40 or less m.e. per liter. Along the valley axis, north and south of the lake bed, and also to the east, there are other deep wells of moderate to high salinity in which the sulphate concentrations were likewise particularly low. Sulphates are practically absent in the warm and saline waters from the deep Stockton gas wells and from the gas well at Lodi. Waters examined west of the lake uniformly contained sulphate in excess of 1 m.e. per liter, and most of them contained much more than this amount. A group of three wells approximately 1,000 feet deep near the mouth of Kings River at the northern extremity of the lake margin of 1884 (locations 10, 11, and 12, quadrangle 20) contained about 6 m.e. of sulphate.

A demonstration that these low-sulphate, deep waters could not have been derived from the Sierra with as little sulphate as some now contain is scarcely necessary, as a certain amount of run-off from the coastal mountains at flood time reaches the valley axis and this water characteristically contains much sulphate. That waters with less sulphate entered the valley at an earlier period seems unlikely, since with the continued weathering of the softer mantle formations of the Sierra any changes in the quality of the run-off from the watersheds should be in the direction of lower salinity. The varied character of the waters underlying the area once occupied to fluctuating depths by Tulare Lake clearly indicates that a common source for all these waters cannot be assumed except as some of them may have been altered by the formations with which they are or have been in contact. Inasmuch as the lower half of the well casings are commonly perforated, the water from any well is a mixture of that from many horizons. The composition of the lake waters during recent times does not provide information as to the source of these deep waters, but it does furnish evidence that recently and probably in the distant past waters accumulating along the valley axis were much more concentrated with respect to sulphates than the deep waters in question. Analyses made of the lake waters in 1880 and 1889 by the agricultural experiment station of the University of California and recomputed in parts per million from hypothetical combinations by Dole (*27*) show the compositions given in table 44, when expressed in milligram equivalents per liter.

TABLE 44.—*Chemical composition of the water of Tulare Lake*[1]

Constituent	Milligram equivalents per liter		
	Sample 1[2]	Sample 2[3]	Sample 3[4]
Carbonate	0	0	0
Bicarbonate	12.04	12.37	31.88
Chloride	6.65	5.91	28.00
Sulphate	4.79	4.23	21.25
Calcium	1.00	.85	.70
Magnesium	1.96	1.72	1.07
Alkali bases	20.55	20.00	79.59
	Parts per million		
Total solids	1,400	1,401	5,188
Organic and volatile	39	76	276

[1] Analyses here reported in milligram equivalents were taken by Dole (*27, pp. 95, 281*) from the California University Agricultural Experiment Station report for 1890, appendix, and recomputed by him from hypothetical combinations to parts per million.

[2] Collected in January 1880.

[3] Collected in the spring of 1880. Lake elevation of samples 1 and 2 probably about 200 feet above sea level.

[4] Collected in February 1889. For the period 1883-97 the lake level was reported as fluctuating and generally low.

The evidence at hand strongly indicates that many of the deep waters underlying this portion of the valley have lost sulphates. In the presence of organic matter such loss is possible through the action of anaerobic bacteria, but insofar as the writer knows, sulphate reduction in fresh water of deep wells has not been demonstrated.

Sulphate reduction in natural waters by anaerobic micro-organisms has been demonstrated in the instance of the bottom waters of the Black Sea, as the classic example, and in river muds, brackish canal muds, sewage, soils, lake sands, springs, and dune sands. The presence of organic matter is essential to this reaction, and as a part of the reaction carbonate and sulphide are formed. Three species of sulphate-reducing bacteria have been described (*14*), and in one instance the reaction is attributed also to algae. More recently Rogers (*30*) attributed the low sulphate content of saline oil-associated waters of the Midway-Sunset oil field of the San Joaquin Valley to reactions with petroleum without the aid of living organisms. It was Rogers' belief that living bacteria could not exist in such situations. Bastin and his collaborators (*3*) took issue with Rogers' view and undertook to show that the sulphate-petroleum reaction could take place only at very high temperatures. To determine if bacteria were not responsible for Rogers' phenomenon, these investigators first examined waters of Illinois oil sands and subsequently waters from the Sunset-Midway and Coalinga oil fields of California. Evidence of sulphate-reducing bacteria was found in all but 2 of the 30 Illinois oil-field waters examined, and the organism was isolated in pure cultures. Sulphate-reducing bacteria were found at depths of 760 and 3,090 feet in many but not all of the California low-sulphate oil-field waters. Bastin and Greer (*4*) later examined 8 fresh-water well samples and 1 river sample in the neighborhood of the Illinois oil fields. Negative results were obtained from the well waters, but sulphate-reducing bacteria were indicated as sparingly present in the river sample, which had some drainage from oil fields.

The following equations (*4*) are of the type of those that have been postulated to explain the results of these reactions:

1-a. $CaSO_4+CH_4 \rightarrow CaS+CO_2+2H_2O$
1-b. $CaS+CO_2+H_2O \rightarrow CaCO_3+H_2S$
2-a. $Na_2SO_4+CH_4 \rightarrow Na_2S+CO_2+2H_2O$
2-b. $Na_2S+CO_2+H_2O \rightarrow Na_2CO_3+H_2S$
3. $CaSO_4+2C \rightarrow CaS+2CO_2$
4. $MgSO_4+2C \rightarrow MgS+2CO_2$
5. $Na_2SO_4+2C \rightarrow Na_2S+2CO_2$

Should the presence of living sulphate-reducing bacteria in the deep-well waters in and about Tulare Lake and in the Stockton and Lodi gas wells be demonstrated by the appropriate bacteriological procedures, this would provide satisfactory evidence of the cause of the low sulphate concentrations here reported; but negative results from such tests would scarcely seem to disprove bacteria as the cause. There is reason to believe that these deep waters, lying as they do far below sea level, are practically stagnant and have been impounded for many years. The changes that brought about their present chemical make-up may have occurred at a much earlier time, and it is possible that the bacteria if once active might no longer be present. The writer cannot recall that combustible gases were present in any of the sulphate waters from wells west of the lake, but such gases (possibly methane) are of common occurrence in the lake waters. In one instance (location 15, quadrangle 24) a well emitted sufficient gas to support a flame several feet in height above a discharge pipe, and on still days it is sometimes dangerous to light matches near certain of these wells. The hydrocarbon requisite for the reaction is therefore present. The shallow well at location 18 emits much gas, but the water contained 2.18 m.e. of sulphate, which is less than that shown in the lake-water analyses. In this well active reduction may be in process, and living bacteria should be found here if anywhere.

As indicated by the literature and the postulated equations, free hydrogen sulphide is a common product of the reaction; but it does not follow that it should always be found in waters where the reaction has taken place. Should it not escape from the water, its precipitation as the sulphide of heavy metals is possible. The writer cannot recall that any of these wells produced water with a notable sulphide odor. Small amounts of the gas might, however, have escaped attention both in the field and in the laboratory, particularly in the wells that were producing other gas so freely. That sulphates could have been otherwise removed from the waters, as by precipitation with naturally occurring barium, seems improbable; barium was not present in significant amounts, as no sample showed cloudiness when the bicarbonates were titrated with H_2SO_4.

Dole (27) has reported analyses and field "assays" of the ground waters of the San Joaquin Valley, and on the basis of his data and their interpretation he was led to conclude that the quality of these waters, specifically their sulphate content, provided an index to the source of the alluvium from which they were drawn. It was his contention that ground waters low in sulphate were from alluvium derived from the Sierra, whereas when considerable sulphate occurred in other than isolated instances that fact was believed to indicate that the alluvium had been derived from the coastal mountains. In its broader scope this interpretation is one of great interest and convenience in accounting for the varied character of the ground waters along the two sides of the valley, but its applicability to the axial waters may be open to question. In the writer's opinion the view becomes necessary that some of the valley waters have been altered by the action of organisms to the extent that their origin and the origin of the alluvium from which they are drawn is highly uncertain.

SUMMARY

Boron, the element that characterizes in part some 50 named minerals and such familiar compounds as boric acid and borax, is of agricultural importance by reason of its being essential to the growth of many if not all plants and also because it is highly toxic to many plants when present in the soil solution in concentrations of more than a few parts per million.

Boron has been found to be present in each of some 4,000 surface and underground waters so far examined in the western portion of the United States. In some of these waters its concentration has been sufficiently high to inhibit the growth of irrigated plants and in others so low that its presence was demonstrated only by special methods. This bulletin deals with the natural occurrence and the effects of boron particularly in reference to the agriculture of the San Joaquin Valley of California.

The spread between beneficial and toxic boron concentrations for some plants is narrow; in fact, concentrations that stimulate vegetative growth during the early development of the plant may be sufficient to produce mild evidence of injury as the older leaves mature. Boron concentrations found beneficial to some plants have prevented the growth of others. The differences in boron requirements and the differences in boron tolerance of even closely related plants cause the two phases of its effects on plant life to be closely allied. In some localities only crop plants relatively tolerant to boron have been found to grow successfully, though their selection had been by trial and error without knowledge of the cause of failures.

Boron applied in irrigation water tends to accumulate in the soil, and ill effects may appear only after a number of seasons and after investments have been made in permanent plantings or in the installation of expensive pumping equipment and irrigation systems.

Boron deficiency symptoms may be of varied character, but usually the younger leaves and growing points of plants are affected first. The apices may die back, or the terminal buds, if not killed, may remain dormant. The leaves of boron-deficient plants may be reduced in size, become irregularly chlorotic, dead areas may appear, and they may abscise prematurely. In some plants an arrested development of the veins takes place, resulting in a buckling of the mesophyll and irregularities in shape. The apical portions of the roots are often enlarged and stubby and fail to elongate normally. The symptoms of boron deficiency have been found to appear only when the boron available was considerably below the concentration required for the best growth of the plant.

Cotton, figs, grapes, alfalfa, beets, asparagus, and a number of other crops have shown increased growth when supplied with boron in concentrations above those that might be designated as traces.

Evidence of boron injury is manifested in the foliage of many plants by the yellowing and subsequent death of the marginal tissue. These effects normally appear first at the tips of the leaves and as more of the margin is affected progress toward the midvein or leaf base. Chlorophyll is retained longer in tissues near leaf veins. Leaves become cupped when marginal injury occurs in advance of full development. Affected leaves are abscised prematurely. The injury produced by boron may often be clearly differentiated from that produced by other causes.

The stone fruits, which rarely have leaf symptoms indicative of boron injury, are otherwise affected. The bark immediately below the nodes of prunes and apricots becomes thickened, and with the overgrowth of underlying wood the structures at the bases of leaves and twigs become enlarged. The bark above the leaf and twig insertions of peaches and prunes often breaks down and splits open. Gumming frequently accompanies these abnormalities. Death of the terminal growth late in the summer or over winter is a common effect. Some stone fruits may make little growth or die without the development of marked symptoms. In pear and apple, symptoms adequate for field diagnosis are not known, yet these plants are sensitive to boron.

The growth of lemons, grapefruit, and avocados is sharply reduced in sand cultures supplied with nutrient solutions containing 3 p.p.m. of boron; such plants as the stone fruits and pears in cultures supplied with 6 to 9 p.p.m.; cereals, olives, and cotton in cultures with 15 p.p.m.; carrots, onions, and beets with 25 or more p.p.m.; whereas date palms, asparagus, and athel withstand up to 100 p.p.m. Fifty-four plants are listed in the order of their relative tolerances.

All varieties of plants examined have been found to contain boron in their tissue, though marked differences exist in the concentrations in the different varieties when grown under similar conditions. Marked differences likewise have been found in the concentrations in different parts of plants and in different portions of tissues. The fact that boron in some quantity has always been found in plants irrespective of where they were collected provides evidence of the widespread distribution of the element.

In sand cultures supplied with nutrient solutions containing 5 p.p.m. of boron, the leaves of various plants contained boron in parts per million on a dry-weight basis as follows: Lemon, 1,232; avocado, 569; apricot, 99; Kadota fig, 722; grape, 1,046; apple, 143; elm, 943; olive, 215; sweet pea, 520; cotton, 306; carrot, 124; sugar beet, 177; palm (pinnae), 279. These plants are listed in the order of their relative tolerance. The stems and roots of plants contain less boron than the leaves. Those of lemon, elm, rose, and sugar beet contained respectively 54, 22, 29, and 28 p.p.m. The boron concentrations in different parts of other plants are reported.

The midveins, green portions, yellow portions, and dead portions of injured lemon leaves contained respectively 47, 438, 1,060, and 1,722 p.p.m. of boron.

Boron accumulates in the bark of certain of the stone-fruit trees, particularly at the nodes; and these plants, which develop wood and bark abnormalities, do not accumulate as high concentrations of boron in their leaves as do many other plants. Injured prunes contained in their leaves, bark, and wood respectively 176, 412, and 171 p.p.m. of boron, whereas uninjured prunes contained in the same parts 33, 36, and 11 p.p.m., and injured lemon twigs contained 410, 42, and 9 p.p.m.

Notwithstanding evidence of the occasional occurrence of appreciable concentrations of boron in unirrigated soils in the San Joaquin Valley, the general inference to be drawn from the appearance of crops is that the boron carried by irrigation water is for the most part responsible for such depressions in yield and such crop injury as have occurred.

Much of the boron found in soils, whether irrigated or not, is not very soluble. Soils are capable, in varying degrees, of removing from solution some of the boron applied by irrigation waters. A few or many irrigations may be applied before the soil-solution concentrations equal or exceed the concentrations of boron in the water used. Injury to plants results sooner on light soils than on heavy soils, and sooner on some heavy soils than on others, when boron-contaminated irrigation waters are used. The productivity of light soils may be restored more rapidly than that of heavy soils when leached with good water, but removal of boron from light soils is often slow.

The nature and quantity of soluble or slightly soluble boron compounds in the soil determine soil-solution concentrations, and it is the latter concentrations that affect plant growth.

Under the usual conditions in irrigated regions, plants withdraw a greater proportion of the water than of the salt from the soil solution and the soil solution, as a result of transpiration, is left more concentrated. Few irrigation waters of the San Joaquin Valley were found to contain concentrations of boron or other salt constituents sufficiently high to be directly injurious to plants. Injury has resulted from the continued use of many of these waters because transpiration and evaporation increase the concentration of these elements in the soil solution. Mixed deciduous fruits were grown in sand cultures with nutrient solutions containing 1 and 6 p.p.m. of boron. The solutions taken up by these trees were respectively 14 and 16 percent as concentrated in boron and 5 and 7 percent as concentrated in sulphate as the culture solution supplied to the roots. In a culture supplied with 9 p.p.m. of boron in which the grape was the predominating plant the solution taken up was 32 percent as concentrated in boron and 21 percent as concentrated in sulphate as was that supplied.

Practical methods of removing the boron from irrigation water have not been found, nor have practical methods been found for counteracting the toxic effects of boron in soils. Citrus plants withstand boron a little better when nitrates are applied in abundance.

Where satisfactory waters cannot be had, the diversity in crop tolerances provides recourse in the substitution of crops of suitable tolerances to boron injury. A table of crop tolerances is presented.

The San Joaquin Valley, which is a great structural trough, has a rainfall of about 5 inches toward the southern or upper end and about 15 inches at the northern end. The principal supplies of surface water and the underground water of the east side of the valley are derived from streams arising in the granitic, metamorphic, sedimentary, and igneous formations of pre-Cretaceous age of the high Sierra Nevada. The water of these streams carries little boron or other mineral matter. Smaller streams enter the valley from the Tehachapi and San Emigdio Mountains, which form the southern boundary of the valley, and from the coastal mountains that form the western boundary of the valley. All of the latter streams are short and except after heavy rains bring little water to the valley. These waters, draining mountains practically free from granitic and similar rocks but with soft serpentines, shales, and sandstones of Cretaceous and Tertiary age, are more highly mineralized than water from the Sierra and commonly contain appreciable concentrations of boron. In their chemical characteristics the ground waters in the different portions of the valley reflect their source or the source of the alluvial material from which they are drawn.

Boron concentrations as low as 0.5 p.p.m. in irrigation waters of the more arid portion of the valley have been found injurious to boron-sensitive crops, but under favorable conditions the more tolerant of the sensitive crops may be grown with only moderate reductions in yield with as much as 1 p.p.m. of boron in the irrigation water. When boron concentrations exceed 1.5 or 2 p.p.m. the best results have been found to follow when tolerant crops were cultivated.

The effects of boron in irrigation water are less severe in those parts of the valley with higher rainfall. Where water is supplied nearly equally by rain and irrigation, only about half the injury experienced in the more arid portions of the valley has been found. Soil characteristics, cultural practices, and length of use influence the rate at which boron accumulates in the soil solution and the accompanying effect upon crops.

Though no general relationship has been found to exist between the concentration of boron and the concentration of any other constituents of irrigation water, there is a marked tendency in the San Joaquin Valley toward higher boron concentrations in the more highly mineralized waters.

The ill effects of boron and of other salt constituents are in a measure interrelated and additive. In these investigations the concentrations of carbonate, bicarbonate, chloride, sulphate, calcium, magnesium, and alkali bases in the irrigation waters have been determined. A discussion of the significance of these other constituents of irrigation water is included.

Some San Joaquin Valley irrigation waters contain more sodium than calcium and magnesium. High percentages of sodium have an adverse effect upon the physical condition of soils by causing them to become hard and relatively impervious to water. Irrigation water that penetrates beyond the root zone carries with it a portion of the salts residual from transpiration and evaporation. Without adequate leaching the concentration of the soil solution may become sufficiently high to depress plant growth even when relatively pure irrigation water is used. Emphasis is placed on the importance of the sodium percentage as a useful criterion of water quality, and in reporting the analyses of 450 San Joaquin Valley waters the percentage of sodium in each sample is given. The calculation and inclusion of these percentages represent a new departure, which is recommended for general adoption in reporting water analyses. Water with less than 50 percent sodium should not cause trouble in hardening the soil. Trouble is likely to result when the percentage exceeds 60.

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