



Issued March 16, 1914.

U. S. DEPARTMENT OF AGRICULTURE.  
BUREAU OF SOILS—MILTON WHITNEY, Chief.

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# SOIL SURVEY OF THE FRESNO AREA, CALIFORNIA.

BY

A. T. STRAHORN, J. W. NELSON, L. C. HOLMES,  
AND E. C. ECKMANN.

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MACY H. LAPHAM, INSPECTOR IN CHARGE WESTERN DIVISION.

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[Advance Sheets—Field Operations of the Bureau of Soils, 1912.]



WASHINGTON:  
GOVERNMENT PRINTING OFFICE.  
1914.

**BUREAU OF SOILS.**

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## LETTER OF TRANSMITTAL

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U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF SOILS,  
*Washington, D. C., June 18, 1913.*

SIR: In the extension of the soil survey in the State of California work was undertaken in the Fresno area. This survey was completed during the field season of 1912.

I have the honor to transmit herewith the manuscript report and maps covering this work, and to recommend their publication as advance sheets of Field Operations of the Bureau of Soils for 1912, as authorized by law.

Respectfully,

MILTON WHITNEY,  
*Chief of Bureau.*

Hon. D. F. HOUSTON,  
*Secretary of Agriculture.*

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to slightly less than 300 feet at Buena Vista Lake, in its upper or southern extremity. Fresno County occupies a central position, not only in the State, but also in the San Joaquin Valley, and extends from the summit of the Sierra Nevada Mountains southwesterly across the floor of the valley and into the Coast Range of Mountains. The area of the county is about 5,500 square miles, nearly one-half of which is mountainous or too hilly to be classed as agricultural land.

The present survey includes all of the agricultural lands in this county lying between the axial line of the valley on the west and the lower slopes of the Sierra Nevada Mountains on the east. The total area within these limits is 1,356 square miles, or 867,840 acres. With the exception of a small area of soils lying on the west side of Fresno Slough and the San Joaquin River, this survey comprises all of the agriculturally developed lands in Fresno County. A part of this area had previously been covered by soil surveys,<sup>1</sup> but the reports covering these areas had become exhausted, and constant and urgent demands for information concerning this part of the Interior Valley made it desirable to make a new survey of the county.

The northern two-thirds of the San Joaquin Valley is drained by the San Joaquin River, which, rising in the Sierra Nevada Mountains, pursues a southwesterly course along the northern border of Fresno County from the mountains to the axial line of the valley, where it turns abruptly to the northwest and follows the valley for a distance of 120 miles to Suisun Bay. A number of important tributaries, rising in the Sierra Nevada Mountains, enter the San Joaquin Valley from the east. Owing to the lower arid character of the ridges of the Coast Range, no perennial streams enter the San Joaquin from the west side of the valley. Kings River, the first important stream entering the valley south of the San Joaquin, originally discharged its waters into Tulare Lake, a low, flat depression in the valley trough, and it was only in time of flood that any of its waters found their way into the main drainage by a course through Bogg and Fresno Sloughs into the San Joaquin River. The construction of ditches, artificial flood-water channels, and levees for purposes of irrigation and of protecting the lands in the basin of Tulare Lake from overflow has, however, largely diverted the water of this stream from its natural course and into the San Joaquin drainage. South of the San Joaquin River none of the streams tributary to the valley, with this exception, have any connection with the main drainage system, but flow into a series of shallow basins, from which the water is removed by evaporation.

Little and Big Dry Creeks, Dog, Red Bank, Fancher, Holland, and Wah-To-Ke Creeks are all small, intermittent streams, each

<sup>1</sup> Soil Survey of the Fresno Area, by Thomas H. Means and T. Garnett Holmes, 1900, and Soil Survey of the Hanford Area, by Macy H. Lapham and W. H. Helleman, 1901.

draining a small area in the lower mountains and foothills in the eastern part of the area. Little Dry Creek flows into the San Joaquin River a few miles below Friant, and Wah-To-Ke Creek flows into Kings River just west of the town of Reedley. None of the other creeks mentioned have any permanent connection with the drainage systems of the area, as their flow has not been sufficient to maintain an open channel across the loose, porous soils of the valley.

In the extreme western part of the area Bogg and Fresno Sloughs afford means of outlet for the waste irrigation waters from the higher lands and for any water which may come down the numerous channels of Kings River. During the late spring and early summer months, when the larger streams are at flood stage, a considerable area of land along these sloughs is subject to annual overflow. The extent of the country inundated varies from season to season, depending upon the volume of water, but is greatest when the floods occur simultaneously in both streams. In Fresno County the area of such land amounts to 133,275 acres.

In the eastern part of the area the foothills of the Sierra Nevada Mountains rise from the floor of the valley, either as relatively low, rounded hills of gentle, uniform slope, or as steep rocky elevations of several hundred feet elevation. The rest of the area is a plain sloping westward. Part of its surface, mainly the western part, is so smooth to the eye that it is essentially featureless. In the eastern part the surface is marked by numerous low mounds and basins, known as "hog wallows." The elevation of the mounds above the bottoms of the hog wallows reaches a maximum of 3 or 4 feet. Remnants of former stream channels occur in places on the smooth parts of the plain.

The larger streams which flow across the valley from the foothills on the east to the axial belt have well-defined valleys cut into the main valley plain. Where they leave the foothills their valleys are deepest, ranging up to about 100 feet as a maximum. The streams have a rapid current, and are usually bordered by a narrow flood plain. Westward the floor of the plain slopes at a more rapid rate than the slope of the river beds. The valleys become shallower downstream, therefore, until they reach the axial line or join the axial stream. This has a channel in the surface of the plain, but no continuous and easily discernible valley.

Near the foothills the rivers are bordered by well-defined elevated terraces. They are narrow at first, but downstream they widen rapidly and by the time half the distance to the axial stream has been traversed the terraces from adjacent streams have coalesced into one smooth plain which stretches thence westward to the axial stream. That part of the valley plain lying above these terraces or the plain

into which they coalesce rises gradually from where it seems to emerge from the plain at the coalescence of adjacent terraces to a maximum of somewhat less than 100 feet along the foothills.

In the western part of the area the elevation is about 180 feet above sea level. At Fresno it is about 300 feet, and the 500-foot contour passes along the hills in the eastern part of the area.

Prior to the settlement and irrigation of this area the floor of the valley was entirely treeless. In the slightly more moist soils of the foothills there were extensive growths of oak, while at higher elevations were pine and similar trees. Along the rivers in the well-watered bottoms sycamore, cottonwood, willow, and oak thrived, and, with the accompanying underbrush and vines, the growth was often so thick as to form dense jungles. The Kings River Delta country, a portion of which is included within the southern part of the survey, is well watered, and here there was a heavy growth of trees almost dense enough to form true forest. Cottonwood, sycamore, and willow grew close to the streamways, while the intervening lands carried groves of gigantic oaks and a carpet of waving grasses. The combination of feed, shade, and water made this an ideal stock country, and for many years it was devoted entirely to grazing.

At the present time the developed portion of the area is well provided with trees (exclusive of orchard trees), but the nonirrigated portions are still as barren as before the settlement of the country. The roadways are commonly bordered by lines of fig or olive trees, which not only afford a pleasant shade during the long, hot summer, but yield a revenue to the owner as well. Eucalyptus and palms are a common occurrence, and some magnificent specimens of these trees are to be found in various parts of the area.

The population of the area is cosmopolitan and the influx of foreigners has been so large that fairly well-defined colonies of various nationalities are common both in the towns and in the country. The first settlements made by Americans were along the margin of the foothills at Centerville and Millerton. In the early days both these towns were stage stations and points of supply for cattlemen on the plains and the miners in the mountains. Centerville was not only a commercial center, but near it was developed the first irrigated and cultivated land in the area. Until the building of the Southern Pacific Railroad through the valley in the early seventies Millerton was the county seat and the principal business center of Fresno County. A town site was laid out by the railroad company on the present site of the city of Fresno, and shortly afterwards Millerton was abandoned and the county seat moved to this place. A small settlement still exists at Centerville.

For many years after settlers had begun to drift into this part of the valley the increase in population was slow, and it was not until

after the irrigation of the plains was taken up that the real growth of the county began. Some irrigation was attempted as early as 1868, but the principal development did not take place until nearly 1880. From that time to the present there has been a steady increase in both rural and city population. The population of Fresno County in 1880 was 9,478; in 1890, 32,026; in 1900, 37,862; and in 1910, 75,657.

The most densely settled portions of the county are those south and east of the city of Fresno, where irrigation has been practiced for the longest time. As the canals were extended to cover the higher soils the population began spreading to the north and west. In the nonirrigated districts of the area, where dry farming is the only method of agriculture, the population averages less than one to the square mile.

The type of agriculture which prevailed before the construction of the irrigation systems tended toward large individual holdings of land, and these large holdings still persist in those sections not yet reached by any of the canals. For several years there has been a gradual extension of the canals, with the result that the number of farms in the area has been increased, the larger holdings being divided and sold.

Fresno, the county seat of Fresno County, is the principal town of the area, and the metropolis of the San Joaquin Valley. It is the center of the seeded raisin industry of the country. In addition to this, it has the distinction of being in the exact center of the State, a monument indicating that point being located within the city limits. The population of the city has risen from 1,112 in 1880 to 24,892 in 1910.

Fowler, Selma, Kingsburg, Reedley, Sanger, Kerman, Clovis, and Laton are important towns in various parts of the area along some of the different lines of railroad. All of these towns, excepting Kerman and Laton, were founded after the construction of the Southern Pacific Railroad through the county and are surrounded by more or less extensive areas of highly developed vineyard and orchard land. Kerman, formerly known as Collis, has been a station for many years at the junction of the West Side and Hanford branches of the Southern Pacific Railroad. Its development as the center of an irrigated district dates from five or six years ago, when lands to the north and east, which had been devoted to grain farming, were placed on the market and sold in small tracts. Laton, a small town in the southern part of the area, along the Atchison, Topeka & Santa Fe Railway, has a similar history. For many years the lands to the west of this place were held by a few individuals and the development of the country has been retarded by this condition,

but recently these lands have been placed on the market and the population of this section is increasing rapidly.

Ormus and Caruthers, on the Hanford Branch of the Southern Pacific, have long been grain-shipping points for the surrounding country. Lying somewhat beyond the supply of irrigation water in the canals, the development in these sections has been slow, but now that it has been demonstrated that water for irrigation may be obtained by pumping from wells, the development of the adjacent areas is progressing rapidly.

Friant, formerly known as Pollasky, is a small town at the terminus of a branch of the Southern Pacific Railroad in the northern part of the survey and is a supply point for extensive power, mining, and cattle industries in the adjacent mountains.

The main transcontinental line of the Atchison, Topeka & Santa Fe Railway passes through the area from north to south, and the principal valley lines of the Southern Pacific Co. have a parallel course through the country. Branches of these lines reach to all of the towns in the area, and afford an outlet for products to distant markets. A partly constructed line of railroad—the Hanford & Summit Lake—traverses the western part of the area and affords transportation facilities for this section of the county. The Laton & Western Railroad, which is operated by the Santa Fe, extends several miles west of Laton into the developing lands of the Kings River Delta district.

#### CLIMATE.

The climate of this part of California is characterized by two principal seasons, winter and summer, or, viewed from the distribution of the rainfall, a wet and a dry season. With normal conditions the wet season may be regarded as extending from the 1st of October to the 1st of April, as within that time about 83 per cent of the seasonal precipitation is received. Ninety-five per cent of the normal rainfall occurs between the 1st of October and the 1st of June. During the rest of the year, or the dry season, the rainfall is very slight, and the larger part of this comes near the beginning or closing of the winter season. During the dry season over 100 consecutive days may occur without a trace of rain.

The distribution of the rainfall is responsible for the type of dry farming carried on in this valley, the winter growing of grain, and the amount and distribution of the rainfall during the winter period is of the greatest importance to the grain farmer. This has led to the practice of showing the rainfall according to the season rather than by the calendar year. When the results are expressed in this way for a long period of years the final average will be practically the same as that obtained by calculating the annual rainfall

for the same period, but in any single year there may be differences of nearly 100 per cent between the two methods.

Below is given the seasonal and annual precipitation at Fresno for a series of years. The differences referred to above are evident here, and it can be seen of how little value the statement of the annual rainfall may be.

*Seasonal and annual precipitation at Fresno, 1887-1911.*

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Seasonal.	Annual.	
														Year.	Total.
1887-88.....			0.49	0.15	0.32	1.16	1.75	0.13	1.95	0.22	0.56	T.	6.73	1888	8.76
1888-89....	T.	T.	.06	.00	2.68	1.71	.34	.32	2.07	.54	.57	0.00	7.99	1889	12.27
1889-90.....		T.	.00	3.17	1.39	3.87	2.12	.80	1.04	.17	.45	.00	13.01	1890	8.36
1890-91....		T.	1.26	.00	.22	2.30	.88	2.24	.81	.49	.03	.02	8.25	1891	8.94
1891-92.....			.27	.00	.21	3.99	.48	1.00	1.69	.79	1.44	.06	9.93	1892	8.75
1892-93.....		T.	.34	.39	2.56	1.04	2.21	4.22	.34	T.	.10	1.16	11.10	1893	9.40
1893-94....	T.		.001	.02	.16	1.40	4.09	2.02	.29	.34	1.16	1.16	8.59	1894	12.48
1894-95....	T.	T.	.75	.37	.27	4.09	4.14	1.70	1.84	.99	.52	.00	14.67	1895	10.39
1895-96....	T.	T.	.07	.16	.19	.78	2.89	.06	1.21	2.82	.02	.00	8.20	1896	11.02
1896-97....	0.07	0.15	.06	1.28	1.46	1.00	1.93	2.65	1.64	.30	.00	T.	10.54	1897	8.41
1897-98....		T.	T.	1.19	.22	.48	.42	1.15	.71	.00	.79	.00	4.96	1898	4.99
1898-99....			1.12	.03	.34	.43	1.92	.02	2.90	.36	.06	.66	7.84	1899	10.54
1899-1900..				2.01	1.52	1.09	1.52	.08	.88	1.21	1.97	T.	10.28	1900	11.09
1900-1.....	T.		.16	.33	4.61	.33	2.16	2.35	.34	.55	.50	T.	6.87	1901	8.07
1901-2.....	T.	T.	.59	.56	.86	.16	.41	2.44	1.14	.70	.01	T.	11.33	1902	7.91
1902-3.....		T.	.00	.42	2.35	.54	1.86	.65	2.28	.50	T.	T.	8.50	1903	6.19
1903-4.....	.00	.00	.00	.00	.68	.22	.57	2.49	2.75	1.21	.12	.00	8.04	1904	13.33
1904-5.....	.00	.00	1.78	3.21	.08	1.12	.93	.90	2.04	.45	1.58	.00	12.09	1905	7.27
1905-6.....	.00	.00	T.	.00	.96	.41	2.05	2.20	4.12	.92	2.88	T.	13.54	1906	16.06
1906-7.....	T.	.00	T.	.00	.73	3.16	3.34	.94	1.74	.69	T.	.24	10.84	1907	9.00
1907-8.....	.00	T.	T.	1.08	.00	.97	1.78	1.75	.71	.80	.63	.00	7.72	1908	7.08
1908-9.....	.01	.00	.15	.02	.66	.57	4.44	2.76	1.18	T.	.00	.08	9.87	1909	16.47
1909-10....	.00	.00	.00	.72	2.79	4.50	1.22	.21	1.28	.27	T.	T.	10.99	1910	4.88
1910-11....	T.	.00	1.00	.45	.24	.21	4.23	1.14	3.38	1.03	.22	T.	11.82	1911	11.25
Mean....	.00	.01	.29	.65	.99	1.60	1.76	1.36	1.69	.63	.58	.10	9.65	.....	9.70

The annual rainfall for Fresno may be taken as a fair average for the entire area, but there is a noticeable difference in the amount which falls in the different sections. Mendota and Huron are two small towns just outside the limits of this survey, the former lying west of Whites Bridge, near the northwestern extremity of the area, and the latter a short distance south of the southwest corner of the area. At Mendota the average precipitation is 8.48 inches, while at Huron it is 4.35 inches. Fresno's average annual precipitation is 9.70 inches, and as the foothills are approached the amount increases, being 10.06 inches at Friant.

Snow is so rare as to be a curiosity, having fallen but twice since the establishment of the local office of the Weather Bureau in 1887.

Hailstorms are as much of a rarity as snow and there is seldom more than one thunderstorm in a year. During the winter season the stormy days are not continuous, but the rainy periods are broken by many clear, sunshiny days, when the temperature frequently rises to near 60° F.

During the winter months fogs are of common occurrence, becoming heavier and more frequent as the trough of the valley is approached. They usually occur on the mornings of clearing days following periods of rain, and, as a rule, disappear before noon, though they sometimes last throughout the day. They rarely occur along the foothills.

During the winter months frosts may be expected at any time between December 3 and February 23, these being the average dates of the first killing frost in the fall and the last in the spring. Killing frosts have occurred as early as October 23 and as late as April 29, but such a condition is extremely rare. There is not a very great difference in the daily range of temperature in different parts of the area, but there is a marked difference in the minimum temperatures between the eastern and western parts. In the foothill region light frosts are common, but ice is unknown, and the lowest temperatures do not affect the successful production of citrus fruits. To the westward the minimum temperatures are much more severe, making the growing of citrus fruits impossible and the winter growing of vegetables very uncertain.

During the summer season the temperature is high and most of the days are sunshiny.

According to the records of the Weather Bureau at Fresno, the mean annual temperature of Fresno County is 63° F., the absolute maximum 114°, and the absolute minimum 20°.

Owing to the low humidity the high temperature of the summer months is not oppressive and prostrations from heat are practically unknown. The average relative humidity at Fresno during the summer months is 35°; during the hottest days of summer in the afternoons it is much lower and has been as low as 6. During the winter the relative humidity is high, and the cold is felt more here than in sections where the atmosphere contains but little moisture.

The total annual wind movement is low, and only in the spring are there any winds of sufficient velocity to be particularly noticeable. This is a distinct advantage, as no damage ever results to the fruits or other crops from the winds. There is more wind in the western part of the area than along the foothills.

The maximum velocity of wind recorded at Fresno since the establishment of the local office of the Weather Bureau is 38 miles per hour.

## AGRICULTURE.

With the exception of the few people who made up the early population at Millerton and Centerville, the activities of the early settlers were concerned with stock raising and mining. During the winter and spring months the plains supported a luxuriant growth of native grasses, and from the time the grass made its appearance in the fall until it dried up in the spring cattle and sheep grazed on the valley floor from the Sierras to the Coast Range. As the grass died down the herds were slowly driven toward the mountain meadows, where they grazed until the winter snow forced a descent into the valley.

The beginning of irrigation and the construction of the Southern Pacific Railroad through the valley, both occurring at about the same time, put a check upon the activities of the cattlemen, and although a large number of cattle are still raised in the county the continued extension of the irrigated area is restricting the valley range more each year. The principal ranges now are in the alkali lands in the western part of the area and in the foothill section in the eastern part. The raising of sheep is still of some importance, but this industry is largely confined to the western part of the valley.

The first agricultural operations were carried on in the Centerville Bottoms, where the early settlers grew vegetables, fruits, and forage for home use, for the itinerant stockmen, and for the miners. On the plains the first agricultural development was the production of grain under an extensive system of dry farming. This increased slowly until the advent of the railroads, when it grew rapidly, and practically the entire area of plains soils was given over to the production of wheat. The history of this method of farming in the Fresno area is a repetition of what has occurred in other sections of the valley, namely, high yields and prosperity for the large land-owners, succeeded by constantly decreasing yields, and finally, for many who persisted in the practice, by bankruptcy.

Wheat was practically the only cereal sown at first, but as the soil became impoverished and the crops often failed to mature before suffering from lack of moisture, this grain was largely supplanted by barley, which matures earlier and sets the grain before the drought of the summer begins. Conditions became gradually worse, and it was impossible to mature a crop each year; so the practice of leaving the land idle in alternate years was developed, and this is the method used to-day.

With the soil conditions which now exist the stubble stands until the fall rains set in, when the land is given a shallow plowing. It may or may not receive a plowing in the spring. As soon as moisture conditions are favorable the next fall the land is plowed, seeded, and harrowed, all operations being carried on at the same time, the

implements being fastened one behind the other and dragged by a string of mules or by a tractor engine. The grain begins to ripen in May and is allowed to stand in the field until dead ripe, when it is harvested with a combined harvester, a machine which cuts, thrashes, sacks the grain, and dumps the filled sacks onto the ground. It is then usually hauled directly to the warehouses, which are located along the lines of railroad.

In the early history of the grain industry binders and headers were used to harvest the crop, and the grain was thrashed by a stationary separator at some central point in the field. A shortage of labor and decreased yields demanded a more rapid and economical method of harvesting, and this demand led to the development of the combined harvester. Although this machine has probably reduced the cost of harvesting the crop to the lowest possible figure, its use has been responsible for other troubles. Under the old system all plants were gathered and removed from the fields and weeds and weed seeds were largely destroyed by the later burning of the straw. With the combined harvester the straw, weed seeds, and chaff are left upon the ground, and although attempts are made to keep the fields clear by burning the stubble, yet in many cases they have become so foul with weeds that they have been abandoned.

The steady decrease in the grain yields led the Government and the State to investigate the situation and to seek means for restoring, in some measure at least, the former yields, and for improving the quality of the grain. These investigations have not been completed, but the results obtained show that conditions may be much improved by practicing better methods of cultivation, the selection of better varieties of grain, the farming of smaller holdings, and the use of manure crops. A full discussion of the conditions and the methods of improvement is given in a Government publication<sup>1</sup> and it will not be necessary to go further into detail here.

With the extension of irrigation there has been a steady decline in the acreage of dry-farmed grain in the area, and although there are a few sections where the soil is better adapted to grain than to any other crop, the acreage devoted to it will continue to decrease for some time with the increase in population and the development of facilities for irrigation. The development which is now going on in the vicinity of Kerman, Ormus, and Caruthers illustrates this changing condition.

In the older irrigated portions of the area the development was at first entirely in the growing of grapes and deciduous fruits, and although these are still the principal crops of the area the dairy and allied industries have been developed in recent years, and the growing

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<sup>1</sup> Bulletin No. 178, B. P. I., U. S. Dept. of Agr. "Improvement of the Wheat Crop in California."

of nuts, oranges, lemons, and other fruits has reached an important stage of development.

In the early development of the county the light-colored soils of the Fresno series were regarded as the only soils that were adapted to fruit, the red San Joaquin and the brown Madera soils being considered as second-class soils. The development of orchards and vineyards was very rapid on the so-called "white-ash" lands of the Fresno series wherever water was available, but the rise of the level of underground water and the appearance of alkali in many sections wrought complete destruction to hundreds of acres of trees and vines, and the movement in the extension of agriculture toward the red lands was practically a forced one. On a portion of the more level land of the Madera series east of Fresno there had been a slow development for several years, and the true hog-wallow lands, typically developed in the soils of the San Joaquin series, had already been tried. The result of the planting of vines and trees on these soils was a pleasant surprise to the pioneers of the movement, for where proper treatment was given to the crops the yields were practically as high as upon the "white-ash" soils, completely disproving the prevailing theories.

The destruction of the trees and vines in portions of the area south of Fresno affected by accumulations of alkali salts forced the owners either to sell their land or adopt a different system of agriculture. Many of them moved to the higher and better-drained soils, while others turned their attention to the growing of alfalfa and to dairying. When the alkali conditions became intolerable for alfalfa the land was given over to Bermuda and salt grass pastures, and in the most seriously affected locations these have disappeared, leaving fields devoid of vegetation or supporting only the most resistant weeds.

These and other local and general conditions caused the beginning of the development of the dairy industry. There has since been a steady increase in the acreage of alfalfa in the area as a whole, as well as in the number of dairy herds. During the last five or six years persistent efforts have been made to persuade settlers to devote at least a part of the land which they purchase to alfalfa and to keep as many cows as the size of the fields warrants.

In the growing of grapes for the table and for making wine and raisins, the vines are planted on the rectangular system. Wine grapevines are very commonly planted 8 by 8 feet, leaving out every twenty-fifth row for a lane through the vineyard. Raisin grapevines, on the other hand, are set at distances varying from 8 by 8 to 6 by 12 feet, with the wider rows running from east to west. For table grapes 8 by 10 feet is a common distance, with the wide rows running from north to south. The subsequent treatment of the vines de-

pends upon the variety. Such varieties as the Sultanina, Emperor, Tokay, and Cornichon are grown with long canes, which are tied to stakes or to a wire trellis stretched along the rows. Other varieties are commonly headed very low and have the canes cut back to one or two buds each spring. (Pl. 1, fig. 1.)

The vineyards are usually plowed in the spring and cultivated two or three times before the growth of the canes prevents further operations. Early varieties, such as the Muscat, Malaga, and Sultana, ripen about August 1, and from then on until October there is a constant supply of ripened fruit. The earliest varieties are usually converted into raisins.

It is generally considered that the cost of a pound of raisins delivered to the packing and seeding houses is about 2 cents. It is said that for a number of years the average price paid by the California Raisin Growers Association has been about \$66 per ton. In 1909 the price in the sweat box ranged from  $1\frac{3}{4}$  to  $2\frac{3}{4}$  cents per pound, and in 1910 from  $2\frac{1}{4}$  to  $3\frac{1}{4}$  cents.

The yield of raisins is about 1 ton to the acre, and this represents an average yield of from 2 to 3 tons of grapes to the acre.

In 1909 the raisin production of California was about 140,000,000 pounds, of which Fresno County produced about 83,400,000 pounds, or close to 60 per cent of the total.

The price of wine grapes has varied considerably, ranging from \$5 to \$14 a ton, with an average price of about \$10 per ton, and many growers have contracts with the wineries for the crop at that price for several years.

The wines produced in this area are largely of the sweet type, the production of which in 1909 was about 5,950,000 gallons, while only about 150,000 gallons of dry wines were made. In addition to these there was produced about 750,000 gallons of brandy, which is obtained from the distillation of juice from the second pressing of the grapes.

With the exception of the olive and fig, the grape has a wider soil adaptation than any other crop grown in the area. It is not very tolerant of alkali, and the crops from alkali sections are inferior to those grown upon the better soils, particularly for wine making. Irrigation is necessary, except where the ground water is within reach of the plant roots. Excepting the alkali soils, there are no soils in the area which are not well adapted to some of the varieties of grapes. Little attention is paid to the type of soil except in the case of the Tokay, which is confined very largely to soils of the San Joaquin series. The extent to which this variety may be planted therefore seems to depend not only upon the demand, but also upon the area of the San Joaquin soils that may be profitably irrigated.

In total yield by weight grapes are far ahead of any other fruit crop. Peaches, however, are second in importance, with a high yield,



FIG. 1.—VINEYARD OF MUSCAT GRAPES.

[Grown mainly on sand and sandy loam types of the Fresno and Madera series. This vineyard has just been pruned.]

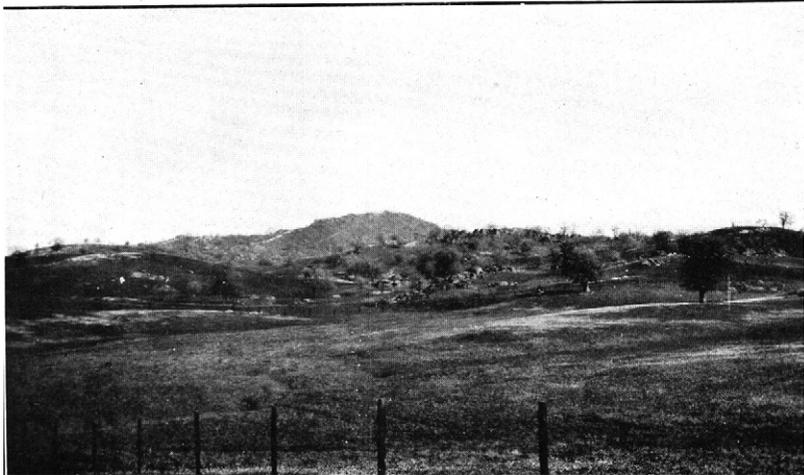


FIG. 2.—TYPICAL LANDSCAPE IN THE AREA OF RESIDUAL SOILS.

[Holland coarse sandy loam in the foreground. Rough stony land in the background.]



and figs stand third in quantity of yield. The three crops stand in this respect approximately in the proportions of 15, 180, and 620 for figs, peaches, and grapes, respectively. Peach growing is at present confined mainly to the lighter soils of the Fresno and Madera series. Of the San Joaquin series only the sandy loam is adapted to this fruit, and this only when the soil is more than 4 feet deep or when the hardpan has been broken by blasting. The peach requires a well-drained, moderately loose-textured soil, and should not be planted on soils with a heavy subsoil or where the water table approaches within 4 feet of the surface. Alkali, even in small quantities, is detrimental, and soils showing traces of harmful salts should be avoided.

The future development of peach growing may be expected to take place most extensively on the sandy soils in the vicinity of Caruthers, Ormus, and Kerman, and to some extent in the area occupied by the soils of the San Joaquin series north of Fresno.

In 1909 over 11,000 tons of green and canned peaches and over 8,000 tons of dried were shipped. The price for the dried product has ranged from 2 to 10 cents a pound, while the fresh fruit for canning or shipping green has varied from \$13 to \$30 a ton.

The yields vary greatly, depending upon the soil conditions, the variety and age of the trees, and the care given the orchards.

The planting of figs and olives is going steadily forward both as border trees around fields of other crops, along the roadways, and as solid blocks of trees in newly developed sections. In a number of cases old peach orchards and unsatisfactory vineyards are being removed and replaced by these fruits. In the case of the fig there has developed a greater consumption of the ordinary varieties, and the successful development of the Smyrna (Calimyrna) fig in this section has given the growers an opportunity to supply the domestic markets with a product heretofore imported from foreign countries. The olive has enjoyed a similar prosperity for several seasons.

At the present time the most of the fig trees in the area occur in single rows bordering either fields or roadways, and the returns from these trees represent no small part of the income from the land, most of them bearing two crops each season. In the orchards the trees are planted on the square system at distances of 25 to 40 feet apart. Owing to the great spread of the trees the best authorities favor the greater distance, so as to allow plenty of room for their development. If the soil conditions are favorable interplanting of grapes or peaches may be made, and these can safely remain for a number of years, furnishing an income until the figs come into full bearing.

The Adriatics, or mule figs, bear either one or two crops, according to variety. Where only one crop is produced the ripening season is in August, and when two crops are matured the first usually ripens

in June and the second in the latter part of August and early September. In growing the Smyrna fig the planting of a number of Capri figs is necessary, as these trees furnish the pollen for the fertilization of the Smyrna and a home for the small wasp which carries the pollen to the latter.

In growing figs the ground is plowed in the spring, and a number of shallow cultivations are given during the summer, usually after irrigations. Where the trees are planted as borders their cultivation is the same as that given to the adjacent trees or vines.

The fig is adapted to practically any soil where there is room for root development and a supply of moisture. It will succeed under some unfavorable conditions, where a number of other fruits do not yield profitable returns, as in soils containing a moderate amount of alkali, in shallow and poorly drained soils, or in soils where the moisture may be slightly deficient. Such soils should not be planted to the fig if a better soil can be secured, as the returns will be in proportion to the quality of the soil.

The olive, like the fig, is commonly planted as a border tree, but in the acreage of orchard plantings it probably exceeds that fruit. The olive requires a longer time to come into full bearing than the other fruits grown in the area. Plantings are commonly made at 25-foot intervals, the square system being used, and unless the trees are kept within bounds by vigorous pruning they will fill the intervening space and necessitate the removal of the alternate trees. The cultivation is similar to that given the fig.

The olive is not surpassed by any tree in its ability to withstand adverse soil, water, and climatic conditions. The olive tree will survive in soils which contain considerable quantities of alkali and where the level of the underground water comes close to the surface. In this and in other portions of the Interior Valley olive trees may be found on the plains and in the foothill region around abandoned ranch houses, where, in spite of absolute neglect and the injuries received from cattle, they thrive, and if the moisture conditions are favorable fruit heavily.

Commercial plantings of the olive are not advised in the poorer soils, even though the trees will survive, as the returns will be in proportion to the nature of the soil and the care given the orchards. Under proper conditions the olive will mature heavy yields of fruit in this section, and the growing demand for the fruit and oil makes it a crop not to be slighted.

As nearly as can be determined, there are about 14,000 acres in olive orchards in the area, a little over one-half of which is in bearing. In 1910 the olive crop of Fresno County was about 43,000 gallons of pickled fruit and about 11,000 gallons of oil. An acre will produce

from 2 to 4 tons of fruit, and the price ranges from \$40 to \$80 a ton, depending upon the variety.

Oranges, principally of the navel type, have been grown in a small way for many years in this area, but until recently increase in the acreage planted has been slow. This is not because the adaptability of the soils has not been appreciated, but because facilities for irrigating much of the land are lacking and because packing houses and transportation facilities have not been available. During the last four or five years there has been a much more rapid extension of the planted area, and the number of orchards will probably continue to increase until all of the higher lands suitable for planting and susceptible of irrigation have been utilized.

The principal development along this line of agriculture has been in the Campbell Mountain section and in the district just north of Kings River, in the vicinity of Centerville. In the first-named section the development has been on the San Joaquin clay loam and the Portersville clay adobe. A part of the area of the San Joaquin clay loam is below the line of the canal supplying this district with water for irrigation and can be irrigated from this, but the remainder of the type and all the Portersville clay adobe lie above the level of the gravity supply and must be irrigated by the use of pumping plants. All the area occupied by these soils may be profitably irrigated in this way, although the cost will in some cases be rather high. The extent to which groves may be planted upon the Portersville clay adobe is governed by the amount of lime in the subsoil more than by any other factor. All of the soils of the San Joaquin series must have the hardpan removed or broken before the trees can be safely planted.

Where the surface slope is not too pronounced and the soil is of sufficient depth and irrigation is practicable by pumps, the soils of the Holland, Sierra, and Aiken series are well adapted to citrus fruit, although none has as yet been planted on them.

In general, the foothill soils in this area are similar to those occurring in other parts of the valley, where there are large and successful citrus orchards, and there seems to be no reason why they should not be fully as profitable.

Apricots, plums, prunes, and pears practically complete the list of tree fruits in the area. A few hundred tons of these fruits are shipped each year, but they are of less importance than the fruits previously mentioned.

Small fruits are grown to a small extent, and with the exception of the early supply, which comes from warmer sections of the State, there is no reason why the entire demand of the local markets should not be met by home-grown products and a surplus produced to ship to outside points. Irrigation and alkali-free soils are the two requi-

sites. With these supplied the small fruits will thrive best upon the moderately heavy textured soils.

The trucking industry is well developed, and with the exception of the early vegetables, which are shipped on from the southern part of the State, and a few that do not find the hot, dry climate of the valley congenial, the local demand is supplied by the local gardeners. Potatoes, beets, and onions are supplied almost entirely from outside sources. Sweet potatoes could be profitably grown upon the lighter soils of the Fresno series. Irish potatoes would do fairly well on the lighter-textured phases of the Merced silt loam where alkali is not present, and there are but few soils on which the farmers could not grow the home supply.

Alfalfa is grown on practically every type of soil in the area where irrigation water is available. In localities where the ground water is close to the surface or where alkali is present there is now practically no increase in the area planted, and many of the older fields are being abandoned to Bermuda and salt grass. Quite a number of the older peach orchards and vineyards have been grubbed out in recent years and the land planted to alfalfa. The greatest extension of this crop is taking place in the vicinity of Caruthers, Ormus, and Kerman, where lands are being opened for settlement, and irrigation water is supplied either from canals or by wells. If a permanent stand of alfalfa is to be secured, it should not be seeded where the hardpan is within 3 feet of the surface, or where there is any alkali present or any reason to fear that it will accumulate. With a shallow soil it is a difficult matter to avoid either the drowning or burning out of the plants, and if alkali is present the yield may be reduced below the point of profit. For the efficient irrigation of the field the checks must be perfectly level, and for this reason land with as level a surface as possible should be chosen. The more uneven the surface the greater the cost of preparing the checks, the more land taken up by the ridges between the checks, and the greater the difficulty of all cultural and harvesting operations. The yields of alfalfa range from less than 1 ton to 7 tons or more to the acre, depending upon the soil conditions and the care given the field. The average yield per acre is not far from  $3\frac{1}{2}$  tons, and the price averages about \$7 a ton. When baled the hay brings from \$8 to \$12 a ton, depending upon the state of the market.

Dairy farming supported largely by alfalfa has had a steady and healthy growth, and a large expansion of the industry is still possible. In 1900 the production of butter in Fresno County was 609,676 pounds. In 1910, according to the census, the production had decreased to 514,946 pounds. The milk is usually separated on the farms and the cream sold to one of the near-by creameries, the manufactured product being consumed locally or shipped to some of the

larger cities of the State. The price paid to the dairymen for butter fat has ranged from 32 to 38 cents a pound, depending upon the quality of the cream and the season of the year.

Within the older irrigated section of the area there are a number of individual or company holdings of land in excess of a section, but the larger number of farms contain less than 80 acres, and 10 to 20 acre orchards and vineyards are very common. On lands not reached by any of the canal systems the individual holdings run into the hundreds and not uncommonly into thousands of acres. Many of these large holdings must remain intact for an indefinite time, as the land is nonagricultural and of value only for grazing, but wherever the soil is adapted to cultivated crops, these large tracts will eventually be subdivided.

#### SOILS.

The Interior Valley, comprising the Sacramento and San Joaquin Valleys, is geologically a great structural trough formerly occupied by a large body of water. Streams from the Sierras and from the Coast Ranges carried a large amount of rock material into the basin, where it was spread out over the floor, forming deposits of great though undetermined thickness.

The early deposits, which are of subaqueous character, were laid down during early and middle Tertiary time and are probably marine. During late Tertiary and Pleistocene time the marine deposits were covered by others laid down in succeeding bodies of fresh water or by alluvial deposits distributed over the older deposits which had been exposed by elevation. After the last of these deposits were laid down and the basin drained either by uplift of the land or depression of the sea the agencies of erosion and stream deposition began their work. This apparently did not take place over the whole width of the basin at once. The emergence of the basin occurred along its higher portions first, the axial belt being the last. In fact a small area of it is now submerged around the mouth of the San Joaquin River.

The coalescing terraces referred to above became in fact essentially the same as coalescing alluvial fans. These constitute, as has been stated, the surface deposits of the western half of the eastern side of the valley. It is difficult in some places to separate these alluvial-fan or stream-laid deposits from the earlier deposits of the basin, and it is uncertain in some cases whether the soil material was deposited in the waters of the inclosed basin or whether it is essentially old alluvial-fan deposits similar to those of more recent date. The alluvial fans slope gently to the west. They are so low, broad, and extensive that their character is not evident in the field, but it is brought out by an inspection of a contour map of the valley. Some of the

alluvial-fan deposits are very recent and still in process of formation. Most of the recent stream-laid soil material is of this character. In the eastern part of the area surveyed, however, the larger streams having their sources in the Sierra Nevada Mountains are confined to quite deeply entrenched stream valleys eroded in the older material of the valley floor and the materials laid down by this stream have more the nature of flood-plains than of alluvial-fan deposits. Aside from broad topographic features, they are, however, similar to the recent alluvial-fan deposits and have not been separated in the soil classification.

Some of the alluvial material of recent date carried into the valley has been deposited in slack water in the vicinity of the valley where conditions favor overflow during certain periods of the year. Such material has been modified by the prevailing swampy conditions and has acquired much of the characteristics of lake-laid material.

The eastern part of the area is occupied by a belt of residual soils derived by disintegration or weathering of granitic and of quartz-free metamorphic rocks upon which the valley sediments lie.

Bordering the residual soils of the foothills, and lying between them and the sediments of the valley, occur in places areas of soil-forming material, the basal part of which is largely of residual origin, but the surface material of which consists predominantly, or at least in part, of alluvial and colluvial material washed from the higher slopes and deposited over the more gentle slopes by sheet water or by minor intermittent streams.

There are thus essential differences in the character of the material from which the soils of the region have been derived and in the processes which have changed these raw materials into the soils as found to-day. These interacting factors have resulted in a large number of distinct types of soil, which have been grouped in a number of series, each comprising types alike in certain essential features, such as color, topography, origin, and mode of formation, but differing in texture, which is determined by the proportion of particles of different sizes which compose the soil. A complete soil series thus includes a group of closely related soil types ranging in texture from coarse sand to clay.

A brief summary of the general characteristics of the several series recognized in the survey follows.

#### RESIDUAL AND COLLUVIAL SOILS OF THE FOOTHILLS.

The foothills in the eastern part of the area rise abruptly from the floor of the valley. The soils here are of variable color and texture and predominantly residual in origin, i. e., formed in place by the decomposition of the underlying rocks. Small areas on the lower slopes are colluvial and along small, intermittent stream ways some

alluvial deposits occur, but the smallness and irregularity of most such bodies renders them of little agricultural importance, and they have not been mapped separately.

From Friant the residual soils of the foothills extend southeastward in a continuous body, interrupted only by the narrow bottoms along Kings River, to the southeastern corner of the area. The western boundary of this belt is exceedingly irregular, and is governed very largely by the position of the underlying rocks. The eastern boundary is determined by the eastern limits of the survey. In a number of places along the lower margin of the foothills masses of half-buried rock rise above the soils of the valley floor, and the slopes of these elevations are covered with a mantle of residual soils of varying thickness.

The surface of the residual soil varies from gently sloping at the base of the hills to irregular and steeply sloping at higher elevations. It is broken by rock outcrop and by occasional eroded areas. The agricultural areas of this belt seldom pass over the crests of the hills or ridges, as the elevated areas are marked by outcropping rock and are unfit for cultivation. (Pl. I, fig. 2.) The value of several soils is not so much a matter of texture as of varying physical conditions, such as depth of soil, abundance of rock outcrop, character of slope, etc. The soils in this general region have been classified with the Holland, Sheridan, Sierra, Aiken, and Portersville series. Some of the area is mapped as Rough stony land. In this survey only one type is found in each of the series.

The Holland and Sheridan soils are derived predominantly from the weathering of quartz-bearing or granitic rocks. They are, however, in the field separated from the soil material derived from adjacent quartz-free rock with some difficulty and as mapped include a relatively small amount of material from such sources. They are underlain by a bedrock substratum which often closely approaches the surface or outcrops. In the Holland series the soil and subsoil material is typically of light-brown to reddish-brown color, while in the Sheridan series the material is of dark-gray to black color owing to a larger proportion of dark-colored minerals and of organic matter.

The soils of the Sierra series are red and are generally underlain by deeper red subsoils of heavier texture and more compact structure, resting upon bedrock in many places at comparatively shallow depths, the rock often outcropping. The soils are derived typically from granitic rocks, but in this area the representative of the series includes an undetermined amount of undifferentiated material derived from quartz-free metamorphic rocks. In this respect it is not typical of the Sierra series.

The soils of the Aiken and the Portersville series are derived in the main from weathered material of quartz-free metamorphic rocks which are the predominating formations of the foothills. The soil and subsoil material, as mapped, however, includes in certain localities an unimportant admixture of undifferentiated material derived from quartz-bearing rocks. In the Portersville series as typically developed the superficial material consists predominantly of colluvial deposits. In this area, however, it includes a large proportion of residual material and the subsoil and substratum are predominantly derived in place through decomposition of the underlying rock. The soils of the Aiken series are of red to reddish-brown color and underlain by deep-red to dark reddish brown subsoils resting on the bedrock, often at shallow depths. The soils and subsoils of the Portersville series are of dark reddish brown or chocolate to black color and are underlain by a substratum of light-colored calcareous or marly material. They occupy gentle to rather steep slopes and are sometimes broken by rock outcrop. They are generally well drained, but retentive of moisture. The agricultural value of the soils of this series is determined to a great extent by the thickness of and depth to the calcareous stratum.

Rough stony land includes areas where the topography is so rough and the amount of rock fragments or rock outcrop so great as to render the soil worthless for cultivation. Such areas predominate in the foothill part of the area surveyed and constitute a continuous belt lying along its northeastern margin. (Pl. I, fig. 2.)

#### SOILS DERIVED FROM OLDER VALLEY-FILLING MATERIAL.

The most extensive soils derived from the older valley-filling material are included in the San Joaquin series. The soils of this series are of yellowish-red or brownish-red to deep-red color and are generally underlain by red to dark-red, heavy, compact subsoils, which are marked by the occurrence of a substratum of dense, impervious hardpan, cemented by iron solutions, and of red to red mottled with gray or brown color.

These soils occupy large areas of the valley floor and of the slopes adjacent to the foothills upon the east. On the west they are bounded by types derived from the valley trough or by stream-laid deposits of the alluvial-fan deltas. Detached areas which represent portions of the original formation which have withstood the agencies of erosion occur to the west of the main bodies. These outlying bodies often form knolls and ridges rising above the adjacent soils of other series.

The San Joaquin soils usually form nearly level to gently sloping treeless plains, marked by minor mounds and depressions which give

rise to characteristic hummocky areas locally known as "hog-wallow" lands. In the vicinity of foothills the surface is undulating.

With the exception to Wah-To-Ke, Fancher, and Big Dry Creeks no drainage courses pass through these soils. All of the other drainage courses from the foothills drain only restricted areas and flow but a short distance, when they disappear upon the plains. On account of this lack of surface drainage and because of the ever-present hardpan in the subsoil, the drainage of these soils during the rainy season is very deficient. Two types of the San Joaquin series, the sandy loam and clay loam, are found in the Fresno area.

Lying within the main areas of the soils of the San Joaquin series and adjacent to the soils of the foothills upon the east there occur a few inextensive bodies of dark reddish brown to nearly black soils, which are underlain by the same red hardpan that lies beneath the San Joaquin soils. These areas represent the clay adobe member of the Alamo series, of which but this one type occurs in the present survey. The Alamo series is related to and probably derived from the material of the San Joaquin series, but has been so modified by conditions of deficient drainage, the result of insufficient slope, restricted subdrainage, or accumulation of seepage waters from adjacent foothill slopes that it warrants distinct classification. Like the soils of the San Joaquin series the Alamo clay adobe occupies sloping to undulating treeless plains. The "hog-wallow" feature may or may not be developed. Surface drainage is usually rather poorly established and underdrainage is restricted.

The characteristic features of the San Joaquin soils are due to the changes which have been brought about since the deposition of the material, such as drainage and oxidation, rather than any characteristic difference between the San Joaquin material and that of the other soil series occurring in the area. The original basin-filling material came from the Sierra Nevada Mountains. The more recent flood-plain and alluvial-fan material is derived from the same source. The San Joaquin soil material has been subjected to weathering and oxidation under well-drained conditions through a long period of time. The series differentiation of the soils of the valley plain is based mainly on the color of the soil and subsoil and on the occurrence and character of hardpan. Study on the ground indicates that these features merely express the stage that has been reached in the cycle of changes that are brought about by weathering under the conditions existing in that region. The San Joaquin soil represents the most advanced stage reached by any of the soils. The Madera series is an intermediate stage, one in which the red color has not yet been developed except as a faint suggestion. The development of hog-wallow topography has just begun. The soil is brown also, having passed from the original gray or brownish-gray

color to a darker and more uniform brown with a faint tinge of red. The red hardpan substratum characteristic of the San Joaquin series is always present, save in some of the lighter textured soils, but usually occurs at greater depths than beneath the San Joaquin, and instead of being a uniform, compact mass the upper sections usually show a somewhat shaly structure, with thin coatings of calcareous material in the cleavage fissures.

The hog-wallow feature of the topography is developed in some of these soils, but in the lighter members it is so slightly developed as to be hardly noticeable. Surface and subdrainage are generally imperfectly developed.

The heavier members of the Madera series occupy treeless, sloping lands of the same general level as the floor of the valley, but the lighter textured members commonly occur as low, broad ridges and as such may extend for several miles. This feature of the topography is conspicuously developed in a ridge which runs westward from the southern part of the city of Fresno.

The Fresno, Hanford, and Merced series are derived from more recent deposits and have therefore reached the least advanced stage of all in their weathering. These soils are at times inclined to be slightly micaceous, and this tendency is most evident in places where they seem to have undergone some modification by alluvial agencies.

#### SOILS OF THE RIVER FLOOD PLAINS AND RECENT VALLEY DEPOSITS.

The soils of the river flood plains and recent valley deposits are composed of water-laid materials generally of comparatively recent origin. They occur along the flood plains of the rivers which traverse the valley as recent alluvial deposits and in large, fan-shaped areas and belts confined mainly to the western half of the valley. They occur in that part of the valley that is made up entirely of the coalescing fans deposited by the rivers after the higher parts of the valley had been raised above stream grade and were being subjected to erosion and weathering. The same physiographic area includes the Madera soils also, though these soils occur on the higher and better drained situations. Occasional low ridges traverse the region. They may in a few cases represent fragments of the older series of deposits, such as are elsewhere converted into the San Joaquin soils, that are almost buried and in other cases they are probably natural levees of former distributaries of some of the large streams. The Madera series occurs on such ridges and in other localities where the natural drainage is good and oxidation has made considerable progress.

The fans within this area seem from their distribution and the trend lines of the soils developed on them to have been built by Kings River rather than by the San Joaquin. The latter stream probably

spread its fan material northward and westward. The Kings River seems to have flowed from a point near Sanger westward across the valley to beyond Fresno, and then northward toward the present course of the San Joaquin River. Extensive but unknown areas of the older sedimentary material were removed and its place taken by the fine gray material which now enters largely into the formation of the Fresno series. After a period the stream acquired its present course and there was left on the plain numerous depressions and long, sinuous swales marking the former channels. At the present time these swales are seldom of any great length, nor are they continuous, but by their uniformity of direction it is often possible to trace the earlier course of the stream for several miles.

Excepting the swales just referred to and certain undulations due probably to wind deposition the topography is smooth. To the eye it seems flat, but the westward slope is sufficient to give a good current to the rivers. The soils of this group are the Fresno, the Hanford, and the Centerville.

After these soils had been laid down changes within the soil mass resulted in the formation of a cemented layer in the subsoil. This hardpan is of a calcareous nature, gray or bluish gray in color, and of a varying degree of hardness and thickness. As a general rule, it is nearer the surface in the heavy than in the light soils of the series, and the nearer the surface the more impervious it becomes.

In the areas of heavier soils drainage is poorly developed. The lighter members are generally well drained, except where seepage waters from excessive irrigation accumulate.

Alkali may or may not be present in these soils in dangerous quantities, but a large proportion of their area is worthless for cultivated crops because of the presence of excessive amounts.

The soil and subsoil of the Fresno series are gray to light brown in color. The areas have a uniform, sloping surface, or are marked by swales and depressions and in some sections by indistinct "hog wallows." The sand, sandy loam, and fine sandy loam of the series were encountered in this survey.

The more recent soils of the river flood plains and alluvial fans occupy the present stream-valley bottoms and alluvial-fan deltas of Kings and San Joaquin Rivers. The deposition and distribution of the parent material is still taking place, except where interfered with by the construction of dikes to prevent overflow. These recent alluvial deposits, exclusive of Riverwash, have given rise to the soils of the Hanford series, the soil and subsoil of which are of light-gray to grayish-brown color. No hardpan occurs in this series.

Along the upper courses of the streams traversing the area and issuing from the Sierra Nevada Mountains it occupies flood plains in the stream valleys here incised in the material of the valley plains.

Along the lower courses of these streams it occupies low, broad, nearly flat alluvial fans or delta cones, the material of which has been superimposed over the material of the plains.

The most extensive and uniform development of the Hanford soils is in the Centerville Bottoms, east of Sanger, and in the Kings River Delta country, west of Laton. In these two sections the soils would be subject to annual overflow and to more or less alteration were the waters of that stream not confined by levees.

The surface of these soils may be uniform, but is more commonly slightly uneven, and old, abandoned stream ways, sloughs and indistinct depressions are characteristic features.

A large proportion of these soils carry alkali salts, and although the amounts are not always large, they are usually sufficient to affect materially the agricultural value of the soil. The Hanford gravelly sand, fine sand, sand, sandy loam, and fine sandy loam occur in the Fresno area.

A short distance north of Centerville there is a single body of soil covering several square miles which has been classified as the Centerville clay adobe. This type is the only representative of the Centerville series encountered and its occurrence is limited to this one soil body. It has a dark-brown to dark chocolate brown color and is underlain by a substratum of stratified gravel.

While of alluvial origin, the material forms high river terrace and is of much earlier deposition than the materials in this group already described. Aside from its topographic position and mode of distribution, this soil series is very similar to that giving the Portersville series; in fact, the area mapped includes considerable undifferentiated material of the Portersville series. Unlike the latter soils, however, surface quartzite gravel of unknown origin is of common occurrence.

The surface is generally that of a gently sloping plain, treeless, and elevated above much of the adjacent valley plains.

Riverwash includes a few inextensive areas of recent deposits of sand and gravel occupying or lying adjacent to stream channels. It is covered by water during floods and is of no agricultural value.

#### SEDIMENTARY SOILS OF THE VALLEY TROUGH.

Adjacent to Bogg and Fresno Sloughs and extending along the valley trough across the entire western end of the area there is a body of soil material which has been laid down in quiet or slowly moving water occupying extensive overflow basins. The material is thus rather more closely associated with lacustrine or lake-laid than with stream-laid deposits. The soils composed of this material are dark brown to black and underlain by reddish-brown to yellowish-brown subsoils, and are classified under the Merced series. The

material is frequently calcareous, and from the junction of Fresno Slough and the San Joaquin River southward for several miles there is usually a soft, calcareous hardpan between the soil and subsoil.

The silt loam, silty clay loam, and clay adobe have been mapped in the present survey.

The surface of these soils has but little slope, and, except for the presence of a number of deep-cut sloughs and water courses, is very uniform.

West of Lanare and Riverdale drainage has been very deficient and a considerable area is covered with overflow water for several months at a time. As a result, growths of tules and other water-loving plants have sprung up, and a well-defined area of swampy country has developed, which extends for some distance outside the limits of the present survey. Alkali is frequently present in the heavier members of this series in considerable quantities, rendering the soil barren of any plants but the most resistant weeds and grasses. The better drained areas, lying adjacent to the larger streams, often support a rather heavy forest growth.

The following table gives the names and extent of the several soils found in the survey:

*Areas of different soils.*

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Fresno sandy loam.....	192,256	22.2	Holland coarse sandy loam.....	8,448	0.9
Fresno sand.....	130,304	15.0	Merced clay adobe.....	8,256	.9
San Joaquin sandy loam.....	109,312	12.6	Madera fine sandy loam.....	6,016	.7
Fresno fine sandy loam.....	93,632	10.8	Hanford fine sand.....	5,312	.6
Madera sandy loam.....	76,032	8.8	Centerville clay adobe.....	5,248	.6
Merced silt loam.....	51,328	5.9	Sierra loam.....	4,160	.5
Rough stony land.....	48,192	5.5	Sheridan sandy loam.....	3,392	.4
Hanford fine sandy loam.....	25,024	2.9	Hanford gravelly sand.....	2,688	.3
Madera sand.....	23,232	2.8	Alamo clay adobe.....	2,624	.3
San Joaquin clay loam.....	17,984	2.0	Hanford sand.....	1,664	.2
Merced silty clay loam.....	16,768	1.9	Madera loam.....	640	.1
Hanford sandy loam.....	10,560	1.6	Riverwash.....	384	.1
Terrace phase.....	3,840				
Aiken clay loam.....	11,904	1.4	Total.....	867,840	.....
Portersville clay adobe.....	8,640	1.0			

DESCRIPTION OF THE INDIVIDUAL SOIL TYPES.

HOLLAND COARSE SANDY LOAM.

The Holland coarse sandy loam consists of a light-brown to light reddish brown coarse sandy loam. The subsoil is of the same color, structure, and texture and is underlain by a substratum of more or less decomposed bedrock. This often closely approaches the surface. Rock outcrop and boulders are not uncommon, and fine subangular gravel and coarse sand are conspicuous in the soil and subsoil mate-

rial. The soil is from 12 inches to 6 feet or more deep, the depth varying greatly within short distances. The soil is easily handled, but it is deficient in organic matter and in its native condition becomes very compact during the dry season.

The Holland coarse sandy loam occurs in irregular areas in the foothills. It lies upon the lower slopes of the higher elevations and frequently extends over the crests of the lower knolls and ridges. A large area occurs a short distance southeast of Friant. Others occupy a considerable proportion of the lower marginal foothill lands extending southeast from Academy to a short distance below Kings River. One small body lies about  $3\frac{1}{2}$  miles northwest of Letcher. The surface of the soil is generally uniform and the slope moderate. (Pl. I, fig. 2.)

The greater part of the soil material is derived from weathering in place of granite rocks. It includes, however, local areas in which the surface material consists mainly of colluvial or alluvial foot-slope material washed from higher adjacent slopes.

Drainage is usually well established and sometimes excessive. Although excessive amounts of alkali salts sometimes occur, in very narrow areas along some of the intermittent stream ways where the drainage is deficient and the water-soluble materials from the decomposition of adjacent rocks accumulate their distribution is so limited that they are of but little importance.

The larger areas of this type are treeless, although in places where the moisture conditions are favorable there is a scattering growth of foothill oak and occasional patches of brush.

The areas of this type lie above the level of the canal systems of the area, and, on account of the rolling topography, only a small part of the soil could be irrigated even were water available. The future agricultural development of this soil will depend not only upon the depth of the soil, but upon the development of a supply of underground water that can profitably be brought to the surface by means of pumps. Under irrigation the areas of deeper soil are adapted to citrus fruits, olives, figs, and grapes, but it is doubtful whether the latter fruits would justify the expenditure necessary to supply irrigation water. The type is at present utilized for grazing or for dry-farmed grain, with low average yields.

The following table shows the average results of mechanical analyses of samples of the soil of the Holland coarse sandy loam:

*Mechanical analyses of Holland coarse sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572546, 572548.....	Soil.....	11.7	17.9	12.1	18.7	11.4	18.5	9.8

## SIERRA LOAM.

The soil of the Sierra loam consists predominantly of a red compact loam, in places approximating a fine sandy loam in texture. The subsoil is usually a darker red loam to clay loam, also of compact structure. Bedrock occurs at depths ranging from 6 inches to 6 feet or more. Rock fragments and rock outcrop are very common, and it is frequently a difficult matter to distinguish between this soil and Rough stony land. Under favorable conditions of drainage, moisture content, and cultivation the soil is friable. As mapped it includes some undifferentiated bodies of soils of reddish-brown color.

The Sierra loam occurs in the foothills of the eastern part of the area and is most extensively developed east of Round Mountain and north of Clovis. It is predominantly of residual origin, but includes considerable areas of colluvial and alluvial material distributed by sheet water or by the drainage of poorly defined watercourses over the lower slopes. This soil is typically derived from quartz-bearing granitic rocks, but in this area includes bodies in which some of the material has been derived from quartz-free metamorphic rocks.

The lower-lying areas of this soil are treeless, but along the narrow, intermittent stream ways oaks, vines, and brush are common. The surface slope is moderate to very pronounced, and drainage is generally thorough and in some places excessive.

This soil can be irrigated only by pumping, and its use will be restricted to crops that justify the expense of taking water from an underground source. It is possible that where the soil can be irrigated citrus fruits, olives, and figs may be successfully grown. The type is at present utilized for grazing and for the production of grain without irrigation, the average yields being low.

## AIKEN CLAY LOAM.

The Aiken clay loam consists of a dark reddish brown to dark-red sticky, compact, adobelike clay loam, underlain by a subsoil of similar or slightly heavier texture and of a deep-red or dark reddish brown color. In places the subsoil is underlain at less than 6 feet by bedrock, which is a variety of fine-grained metamorphic rock. Both soil and subsoil are deficient in organic matter and contain small, angular rock fragments. Rock outcrop and detached, boulderlike masses of rock also occur frequently.

The type is derived mainly from quartz-free schists or other quartz-free metamorphic rocks, but minor local areas exist in which there has been included a slight admixture of material from quartz-bearing granitic and gneissic rocks.

Areas of this soil occupy foothill slopes in the northeastern part of the area, and, while considered predominantly of residual origin, the

type includes undifferentiated areas of colluvial and alluvial material washed from the residual mantle of the higher slopes. Surface drainage is generally thorough and on the steeper slopes excessive. Owing to the heavy, compact structure of the material, however, underdrainage is deficient. The type is of minor importance in the area and a considerable part of it has no agricultural value. It is devoted mainly to grazing, small areas are used for dry-farmed grains, of which low average yields are secured. In small areas, where the slopes are not too pronounced and the soil has good depth, and where water may be obtained by pumping from an underground source, citrus fruits, olives, and figs may possibly be grown.

The following table gives the results of a mechanical analysis of a sample of soil:

*Mechanical analysis of Aiken clay loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572550.....	Soil.....	4.3	9.6	7.7	17.9	17.1	21.0	22.5

SHERIDAN SANDY LOAM.

The surface soil of the Sheridan sandy loam is a dark-gray to nearly black sandy loam, compact when dry, usually micaceous, and seldom carrying noticeable quantities of rock fragments. The subsoil is a friable, sticky sandy loam to heavy loam, of dark-gray to yellowish-brown color. Bedrock frequently lies within 6 feet of the surface, and rock outcrop is not uncommon.

This type is predominantly residual in origin, being derived from the decomposition of the underlying granitic rocks, but also includes some undifferentiated areas of colluvial origin. It occupies irregular areas in the foothill section, from near Kings River southward to the Tulare County line.

The surface slope is steep to moderate. Drainage is well established and along the more pronounced slopes excessive.

The Sheridan sandy loam is used entirely for grazing and dry farming, and although much of it lies in a suitable location for growing citrus fruits, it will probably not be extensively used for that purpose, owing to the difficulty of obtaining water for irrigation.

ROUGH STONY LAND.

Rough stony land includes the stony hills and lower mountain slopes. These areas lie above the level of the agricultural soils of the area. The soil and subsoil material is very shallow and varies in texture from a coarse sandy loam to heavy clay loam adobe. It is

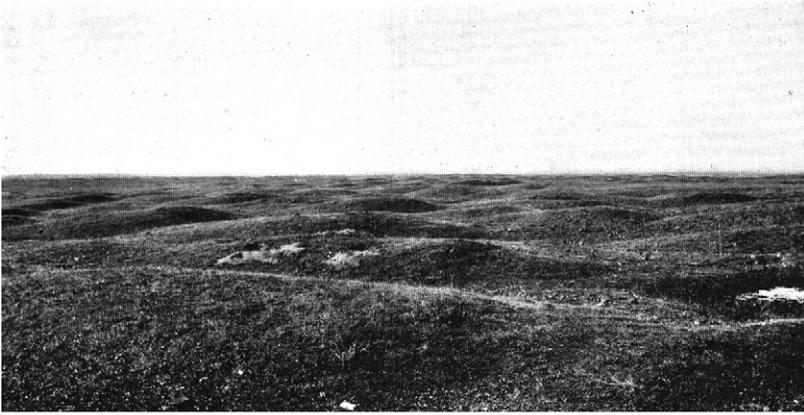


FIG. 1.—“HOG WALLOWS” ON SAN JOAQUIN SANDY LOAM.  
[A characteristic feature of the surface of soils of the San Joaquin series.]



FIG. 2.—SCENE IN THE ALKALI BELT SOUTH OF FRESNO.  
[Formerly a Muscat vineyard, now a field of Bermuda grass. Characteristic of alkali areas on Fresno sandy loam and fine sandy loam.]



red to grayish or reddish brown in color, and the surface is badly broken by rock outcrop and large masses and smaller fragments of rock. The material is largely residual in origin, although in part colluvial on the more gentle slopes. It is derived from both granitic and quartz-free metamorphic rocks.

The land is thinly forested, excessively drained, nonirrigable, and, aside from furnishing some spring grazing for cattle and sheep, has no agricultural value. (Pl. I, fig. 2.)

#### PORTERSVILLE CLAY ADOBE.

The surface soil of the Portersville clay adobe consists of a dark reddish brown or chocolate-brown sticky clay with a pronounced adobe structure. The upper subsoil, extending to a depth of 18 inches to 6 feet or more, is similar to the surface material, and is usually underlain by a highly calcareous or marly substratum of light-gray color. As mapped in this area, however, the type includes areas in which the calcareous substratum is absent and the subsoil material is underlain directly by bedrock. This rock outcrops in places along the higher elevations, but, as a rule, it does not occur within 6 feet of the surface. Varying quantities of loose rock fragments are found in the soil and subsoil.

There are extensive bodies of this type where the soil and subsoil materials are identical to a depth of more than 6 feet, and there are others nearly as large in which the calcareous substratum lies within 6 feet of the surface. In a few extreme cases it is reached a foot below the surface. The calcareous layer is either brownish or grayish in color. The larger the percentage of lime the lighter the color becomes. Where this marly stratum is strongly developed the texture of the material is a sticky loam of a rather crumbly structure. Occasionally it is slightly cemented.

The Portersville clay adobe occurs at intervals along the foothill slopes in the eastern part of the area, from the southern boundary northward to a short distance beyond Kings River, and in a few small bodies upon the lower slopes of a number of outlying elevations rising above the soils of the valley floor. It is encountered most extensively in the vicinity of Campbell Mountain, about 7 miles east of Sanger.

The greater part of the soil material consists of colluvial and alluvial material washed from the higher slopes by sheet water or by intermittent streams. Locally, however, considerable areas are included with the type as mapped, in which the soil material contains a large proportion of residual material derived from weathering of the underlying rocks, and much of the subsoil material probably consists mainly of residual material. The parent rocks are mainly metamorphic formations, such as serpentine, schists, amphibolite, and

magnesite. Under favorable conditions all of these rocks break down into heavy soils high in lime.

None of the usual alkali salts are evident in this soil either before or after irrigation and cultivation, but the excessive quantities of lime and magnesia which are frequently present in the subsoil injuriously affect orchard trees, and there are considerable areas which are for this reason of little value for cultivated crops.

The surface is devoid of minor irregularities, such as hog wallows or erosions, and the areas lie in long, gentle slopes rising from the level of the plains and terminating in the broken, rocky slopes of the Rough stony land.

The surface drainage is good, and were it not for the heavy texture of the soil and subsoil, which possess a high water-holding capacity, the type would be excessively drained.

Until a few years ago this type had been used entirely for grazing and dry farming, but recently, as the value of the soil for high-class crops has become known, considerable citrus fruit has been grown. There still remain several thousand acres of the type that are capable of successfully producing these fruits. The extension of groves will be controlled by two conditions, the practicability of securing water for irrigation and the presence of the marly subsoil. Nearly all of this type lies above the level of the canals, but for citrus fruits the expenditure of considerable sums of money to obtain water is justified. On the steeper slopes it will probably often be found impossible to obtain wells that will furnish sufficient water for irrigation, but under the more nearly level land an abundant supply of underground water usually exists. Citrus trees should not be planted where there is evidence that the subsoil carries excessive quantities of lime within 4 feet of the surface. Even with the stratum at this depth the trees may eventually be injured or killed by the lime.

Unimproved areas of this type are held at figures ranging from \$75 to \$125 an acre, depending upon location. Improved land ranges from \$150 an acre upward, depending upon the nature of the improvements and the age of the orchards.

The following table shows the average results of mechanical analyses of samples of the soil and subsoil of the Portersville clay adobe:

*Mechanical analyses of Portersville clay adobe.*

Number.	Description	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572554, 572558.....	Soil.....	0.1	1.0	1.6	7.5	12.6	35.9	41.2
572555, 572559.....	Subsoil.....	3.1	8.1	5.7	15.3	12.1	26.9	28.8

## SAN JOAQUIN SANDY LOAM.

The San Joaquin sandy loam is a yellowish-red to light brownish red sandy loam containing a relatively large proportion of fine sand, very fine sand, and silt. The coarser particles are, however, sharp and angular, causing the soil to appear coarser in texture than it really is.

The subsoil is usually similar in color, texture, and structure to the surface material. At an average depth of 30 inches below the surface there is a layer of red, impervious hardpan from a few inches to several feet in thickness. There may occur between the hardpan and the upper subsoil a thin stratum of a reddish clay loam. The depth at which the hardpan lies varies widely and at short distances. It may occur within 18 inches of the surface or not within the 6-foot profile. This hardpan is composed of a mass of soil grains firmly cemented by iron salts and it is so dense that it can only be broken up by blasting. (See Pl. III.) The texture of the material underlying the hardpan is commonly sandy loam.

The physical condition of the soil varies remarkably with the changing moisture conditions. It has a low humus content and during the dry season the uncultivated soil bakes into a hard mass. During the rainy season it becomes very sticky and boggy. When cultivated under favorable moisture conditions the soil works up easily and it is not difficult to keep it in good tilth. The type contains no alkali.

The San Joaquin sandy loam is derived from older sedimentary deposits laid down in the waters formerly covering the valley basin.

The type is extensively developed in the eastern and north-central parts of the area. It occurs in bodies of varying extent, east of Kings River, and in the extensive plains area between that stream and the San Joaquin River. In the vicinity of Reedley, and north of Sanger, relatively small bodies are found surrounded by soils of the same or of other series. The most extensive development is found east and west of Clovis.

This soil forms areas of gently sloping to nearly level surface and is poorly drained. In its virgin condition the San Joaquin sandy loam was treeless except for a scattering growth along the streams, and the only vegetation consisted of grasses and wild oats.

Where the land has not been plowed and leveled for irrigation it is covered by low, rounded mounds ("hog wallows"), from 1 to 3 feet in height and from 20 to 50 feet in diameter. Plate II, figure 1, gives a very good idea of the appearance of the surface of this soil type.

The soil is utilized mainly for dry farming and for pasture. No very extensive additions to the present irrigated area can be looked

for, as the supply of water is hardly more than sufficient to serve the lands now under the canal systems. If at some future time it is found practicable to store the flood waters of Kings River at some point in the lower mountains, the canals may be made to cover a wider range of the country. It is probable, however, that an extension of the cultivated area of this soil will come with the development of the underground-water supply. The supply is probably ample for the irrigation of all the type and, with minor exceptions, will probably be found close enough to the surface to justify its use in growing orchard fruits.

Where the hardpan is more than 30 inches below the surface the soil is admirably suited to the production of grapes, and where it is 4 feet or more below the surface to a number of deciduous fruits, olives, figs, and almonds. Whenever the hardpan is closer than this it will be necessary to fracture it by blasting. The open structure of the material below the hardpan is a condition favoring internal drainage once the hardpan is broken.

During recent years there has been a growing inclination to extend the planting of oranges to this soil, and it seems probable that this may be carried to excess. Such planting should be confined to the more eastern parts of the type, where the elevation is sufficient to insure reasonable immunity from frosts.

For unimproved and unirrigated land of this type the prices range from about \$40 to \$125 an acre. Improved land brings from \$125 to \$400 an acre, depending upon location and improvements.

The following table gives the results of a mechanical analysis of a sample of soil of the San Joaquin sandy loam:

*Mechanical analysis of San Joaquin sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572524.....	Soil.....	5.0	11.7	8.5	20.4	14.0	28.9	11.2

**SAN JOAQUIN CLAY LOAM.**

The San Joaquin clay loam consists of 12 inches to 4 feet of red to reddish-brown clay loam, of low humus content and compact structure, underlain either by dense, red hardpan from a few inches to several feet in thickness or by a stratum of red or reddish-brown clay above the hardpan. Where present this stratum may occur at any depth below 12 inches.

The texture of the surface soil varies considerably within the type and along the line of contact with adjacent soils, into which this soil often merges by indefinite degrees. The hog-wallow knolls are

sometimes a sandy loam in texture, while the intervening depressions may contain a heavy silty loam, occasionally showing an adobe structure. The boundary between this soil and the foothill soils is usually definite, but between it and the other soils of the plains the lines have been drawn more or less arbitrarily, except where there is a distinct change in color.

The most extensive and characteristic areas of the San Joaquin clay loam lie east of Kings River, occurring as irregular and broken bodies extending from near Reedley eastward to the county line and northward to the lower slopes of the foothills and mountains. North of Kings River only a few small bodies of the type exist. These are found east of Clovis.

San Joaquin clay loam is a sedimentary soil, derived from older marine or lacustrine deposits. The materials of which it is composed are derived from a wide variety of quartz-bearing and quartz-free rocks. The soil carries no alkali.

In topography it is similar to the San Joaquin sandy loam, i. e., a sloping plain dotted with innumerable hog-wallow mounds. Considerable leveling is required to prepare the land for irrigation. The underlying hardpan, when occurring near the surface, sometimes interferes with this and seriously reduces the depth of soil material upon portions of the leveled surface previously occupied by the mounds or hummocks.

Grasses constitute the larger part of the native vegetation, and trees occur only in places along some of the streams where the soil has a somewhat greater depth and the moisture conditions are favorable.

The areas of this type north of Kings River are used only for the production of dry-farmed grains. East of Kings River this type was also at one time used entirely for this purpose, but with the construction of irrigation canals a part of the area was given to grapes and deciduous tree fruits. The area occupied by these crops has been slowly increasing since the introduction of pumping plants.

This type is not so well adapted to the production of peaches and almonds as are some of the lighter textured soils in the area, but is well adapted to other deciduous fruits, including the fig, and to the olive. Grapes, particularly the Tokay, Zinfandel, and Mission, do very well on this type, and where the hardpan is 30 inches or more below the surface this fruit may be successfully grown without blasting. Where the hardpan occurs within 4 feet of the surface it must be broken up by blasting before the land will be fit for orchards.

Citrus fruits are being extensively planted on parts of this type. Such plantings should be confined to the vicinity of the foothills, where the winter temperatures are less severe than farther out on

the plains. Any considerable extension of the cultivated area of this soil must depend largely upon the development of a supply of underground water, as the existing canal provides a supply hardly sufficient for the lands now served.

Land values are governed largely by location and improvements and range from \$50 to \$200 or more an acre.

The following table shows the average results of mechanical analyses of samples of the soil and a single analysis of the subsoil of the San Joaquin clay loam:

*Mechanical analyses of San Joaquin clay loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572523, 572533.....	Soil.....	1.6	5.1	6.1	17.5	18.7	26.9	24.0
572534.....	Subsoil.....	.9	6.0	5.6	15.8	10.0	22.8	38.7

ALAMO CLAY ADOBE.

The Alamo clay adobe is similar to the soils of the San Joaquin series in origin, but later processes, resulting probably from long-continued subjection to flooding or to poor drainage conditions, have so altered the color of the soil material that it is recognized as a member of a distinct soil series.

The Alamo clay adobe is composed of a dark reddish brown to nearly black clay adobe, underlain at depths of 1 to 4 feet by a red hardpan stratum of variable thickness and similar to that underlying the soils of the San Joaquin series.

Only a few small bodies of this soil exist. They are found just below the margin of the foothills in the eastern part of the area surveyed. Three small bodies occur east of Clovis, while another quite prominent area occurs in the vicinity of Campbell Mountain, east of Sanger. The type ranks as one of the relatively unimportant soils of the area.

The soil is devoted entirely to the dry farming of grains. It is of an extremely stiff, heavy, refractory character and requires a heavy farming equipment, deep plowing, and thorough cultivation. It is very sticky when wet; upon subsequent exposure uncultivated areas bake hard and crack deeply. Owing to its tendency to assume a crumbly structure, the soil is capable of being maintained in a favorable condition of tilth by proper cultural methods. It carries a more abundant supply of humus than the soils of the San Joaquin series, has the power to retain much moisture, and in seasons when the rainfall is well distributed yields slightly better crops than the adjacent soils. The type occupies treeless, sloping to undulating

plains. It is marked by hog wallows, but the mounds are not so prominent as on the San Joaquin series. Leveling is usually necessary, however, in preparing the land for irrigation. Drainage is deficient.

Two requisites to the use of this soil for more intensive crops are irrigation and drainage. Water for irrigation must be obtained by sinking wells and installing pumping plants, as these bodies of soil lie above the present canal. The deficient drainage is due largely to obstructed subdrainage and may be materially improved by blasting the underlying hardpan.

On account of its heavy nature, this soil is not well adapted to the deciduous fruits usually grown in this area, but it is believed that olives, figs, and certain varieties of grapes would do well on it.

The following table shows the average results of mechanical analyses of samples of the soil of Alamo clay adobe:

*Mechanical analyses of Alamo clay adobe.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572535, 572549.....	Soil.....	0.4	3.0	3.9	10.3	9.8	31.2	41.1

#### MADERA SAND.

The Madera sand is a light reddish brown to light-brown sand, resting on a subsoil similar in color and character to the surface soil, and extending to a depth of 6 feet or more. With minor exceptions near the contact with other types there appears to be no change in the texture or structure of the material to a depth of 20 feet or more. From 12 to 15 feet is believed to be a fair average depth, and at this point there is usually a stratum of compact, tenacious red clay loam. This stratum is not cemented, as is the red hardpan typical of this and the related series, but is sufficiently compact to retard the downward movement of the subsoil waters. The light reddish brown color of the soil is developed where the type approaches a loamy sand, or as it grades over into heavier types of this or of the San Joaquin series. In certain localities the surface color tends to a light gray, but this color is not typical of Madera soils. Both the soil and subsoil are low in organic matter and have a rather low moisture-retaining power. The type requires frequent irrigation and intensive cultivation to get the best results.

The Madera sand is most typically developed in the north-central part of the area. It occurs as elongated bodies with a general north-easterly to southwesterly trend in the valley plains. A number of such bodies are found in the vicinity of Clovis, between Clovis and

the city of Fresno, and south and west of the latter place. Smaller and less extensive areas are also found on the plains east of Fresno and in the vicinity of Reedley.

The surface is gently sloping and treeless, and while usually somewhat irregular or undulating it is quite easily leveled and prepared for irrigation. The typical areas of this soil have a slightly greater elevation than surrounding soils, but many of the smaller areas are not marked by any noticeable change in elevation of the surface, and as the texture changes slowly from one type to another, the Madera sand merging gradually into the adjacent types, it is commonly difficult to decide where the boundary line is to be placed.

The soil is free from alkali, and drainage conditions are always good and sometimes excessive.

Practically all of this soil, with the exception of that which occurs within the city of Fresno, is under cultivation, being largely devoted to grapes and peaches. All deciduous fruits, grapes, alfalfa, and truck crops will do well, providing there is sufficient water for irrigation.

This soil is valued at \$100 an acre and upward, depending largely upon the nature and extent of the improvements.

#### MADERA SANDY LOAM.

As mapped in this area the surface soil of the Madera sandy loam is a reddish-brown sandy loam, of a medium to rather coarse texture and carrying some mica. The subsoil is similar in color, texture, and structure to the surface soil. In irregularity of depth of the soil material, which ranges from 18 inches to 6 feet or more, this soil is similar to the San Joaquin sandy loam, there being numerous small areas, both detached and occurring in bodies of the type of large extent, where the depth of the soil and subsoil varies greatly. Like the latter type it is also underlain by a dense, impenetrable, red hardpan, which varies in thickness from a few inches to several feet, but the Madera sandy loam differs from the San Joaquin sandy loam mainly in that there are considerable areas where the hardpan occurs at a depth of more than 6 feet, and usually when within less than 6 feet of the surface it lies at a rather uniform depth. As a general rule it will be found that the depth of the soil and subsoil is most variable in the vicinity of areas of the San Joaquin series, and the greater the distance from the latter the more uniform, and the greater the depth of the material overlying the hardpan. The average depth is about 5 feet. The position of the hardpan in this soil makes it more desirable for the deeper rooted irrigated crops. The material underlying the hardpan is usually similar to the soil and upper subsoil.

The uncultivated areas of this soil have a tendency to become compact upon drying, and when the hardpan is close to the surface sub-drainage is restricted and the soil becomes boggy during the rainy season. Under favorable conditions of drainage and tillage, however, it is of friable structure and readily maintained in good tilth.

Within the main bodies of this soil there are no marked departures from the normal color and structure, but along the margins of the areas variations are not uncommon, and in the field the boundary between it and the adjacent soils is not always distinct. For example, as this soil passes into the sand of the same series the color gradually becomes lighter, the texture of both soil and subsoil becomes coarser, the surface more uniform, the depth to hardpan greater, and it is impossible to place a line on the soil map that will show exactly the point of change from one type to the other. Similar variations occur as this type passes into heavier members of the same series or into types of other related series.

The Madera sandy loam occurs throughout the eastern and north-central parts of the area, and although it does not cover so great an extent of territory as some of the other types its agricultural importance makes it one of the leading soils in the area surveyed. With the exception of a few small, isolated bodies south of Selma, this type is closely associated with the soils of the San Joaquin series, occurring within areas of these soils and as more or less extensive bodies intervening between them and soils of the Hanford and Fresno series. The largest continuous body of this soil lies upon the sloping, treeless plains in the vicinity of Fresno and extending northward and eastward. This body reaches from the bluff along the San Joaquin, east of Lanes Bridge, southward nearly to the town of Sanger, and a number of extensions of it occur as far west as Kearney Park.

Like the other members of the Madera series this soil is mainly or entirely alluvial in origin. It occurs on terraces and in other areas of old alluvium, such as the older and higher alluvial fans. There is no characteristic of the soil, however, that would prevent it from being derived from any of the younger alluvium in which drainage conditions have permitted weathering and oxidation to have reached the Madera stage. On the other hand there seems to be no characteristic of the series that could not be provided for by a retarded rate of weathering in the material that ordinarily has developed into the San Joaquin soils. Such retarded development would be expected to occur on low smooth areas where drainage has been rather poor. The Madera soils represent, therefore, an intermediate stage in the weathering cycle, lying between the advanced San Joaquin on the one hand and the Fresno and Merced on the other.

The stage in the cycle is a function of the drainage, and only incidentally of the age of the material.

The surface of this type is characterized by hog wallows, although they are not so prominently developed as on the San Joaquin sandy loam. A striking feature of the topography of that part of the area south of Selma is the occurrence of low, rounded or elongated knolls or ridges rising slightly above the general level of the plain. These are elevations of the Madera sandy loam, standing several miles distant from the principal bodies of that type, and indicate the former wider distribution of the material of which the type is formed.

South of Friant, where the soils lie above the river bottom and on the same general level as the soils of the plains, there is an area of this soil which has undergone extensive erosion. A number of intermittent stream courses from the higher lands have cut narrow, tortuous passages, sometimes to a depth of 40 feet, leaving the larger part of the surface of the plain in its original condition. The result is that a considerable area of soil has been removed and the remaining portions stand as semiisolated plateaus.

Except in the eroded section just referred to, surface drainage is very poorly developed. Prior to the construction of the present dike systems a number of the foothill streams, including Fancher, Red Bank, and Dog Creeks, overflowed or discharged their waters on areas of the type. At present these creeks flow into the canals east and north of Fresno and overflow of the lower-lying lands is largely prevented.

Over the greater part of this type the level of the ground water is at a depth of several feet, but in places there has been a marked rise in the level of the water table, and in one or two instances where an outlet was available open-drainage ditches have been constructed to prevent the conditions from becoming more serious. This condition has developed in a minor degree in some areas of this soil south and west of Fresno, but it is thought that the ground water has reached about its maximum height and that there will be no farther extension of the affected area.

In a number of places south of Fresno there has been some accumulation of alkali salts in the soil. These areas arise not from the alkali salts contained in the original soil, but from the movement of subsoil water from bodies of adjacent soils in which excessive quantities of soluble salts are present. It is very probable that there is no more alkali present in the soil now than there has been for a number of years past, and there need be no apprehension of the spread of alkali to the areas of this type now free from it.

All of this soil is under cultivation either to grain by the usual dry-farming method or to some of the many crops grown under irrigation. Water is available to probably 80 per cent of this soil,

and the larger part of it is devoted to the production of fruits or alfalfa. With the present flow of Kings River so fully utilized, and with the difficulties attendant upon obtaining water from the San Joaquin River, there can be little or no increase in the area irrigated by the gravity systems. The extension of the irrigated area will come through development of water pumped from an underground source, and this development is slowly going on at the present time. With the exception of the shallower areas the soil is well adapted to irrigation, although some leveling is usually necessary.

In this area the Madera sandy loam constitutes a good general-purpose type. It is not meant by this that it is the best type for each and all of the crops found in the area, but, with the exception of the citrus fruits, it is well adapted to the crops suited to the climatic conditions which exist in this valley. All varieties of deciduous fruits and grapes thrive, providing the hardpan is fractured by blasting where it occurs close enough to the surface to interfere with proper root development. Alfalfa does well on this soil, yielding from 4 to 6 tons to the acre annually, depending upon the attention given the fields. Vegetables and truck crops do well on the lighter phases, while the olive and the fig need only a favorable depth of soil and a supply of irrigation water.

Well-developed orchards and vineyards are valued at figures ranging from \$200 to \$500 an acre, depending upon location and the nature of the crop. Unimproved property is held at \$25 to \$150 an acre, depending upon the location and facilities for irrigation.

The following table shows the results of a mechanical analysis of a sample of soil of this type:

*Mechanical analysis of Madera sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572518.....	Soil.....	2.5	13.3	12.6	26.9	11.0	21.3	12.0

MADERA FINE SANDY LOAM.

The surface soil of the Madera fine sandy loam is a rather smooth, sticky fine sandy loam of compact structure and brown or reddish-brown to dark reddish-brown color. The subsoil is in general similar to the surface soil to a depth of 4 feet or more, though in some places it is of somewhat heavier texture. It is underlain by the usual hardpan formation of the Madera series which rests upon material of a sandy loam texture. The hardpan varies in thickness. As in the case of the sandy loam of this series, the boundary between this and related types is often rather indefinite, and adjacent to other types

there are minor variations in color, texture, structure, and depth of material. In places the texture approaches that of a sandy loam, and the type as mapped probably includes some undifferentiated material of the Madera sandy loam.

A large and uniform body of the Madera fine sandy loam lies in the vicinity of Kearney Park, 6 miles west of Fresno. With this exception, it occurs as small areas scattered throughout that part of the area east of Fresno and is associated with other types of the same series.

In origin and mode of formation it is similar to the sandy loam of the same series.

The type occupies portions of the gently sloping or nearly level valley plains of smooth to slightly undulating surface. It is well adapted to irrigation and the cost of leveling and preparing the land for the distribution and application of water is not excessive. Hog wallows occur in a few places, but are never very conspicuous.

Surface drainage and subdrainage are not quite so good as in the lighter textured members of this series, the soil being of more compact structure and higher moisture-holding capacity, and cultural operations are generally begun later in the spring.

In the vicinity of Kearney Park small quantities of alkali have been carried in from the adjoining soils of the Fresno series by subsoil waters, but no excessive quantities of alkali can originate within this type, as there are not sufficient soluble minerals in the soil to cause such concentration. It is not probable that the affected area will be extended. Even in areas now carrying alkali the content (always less than 200 parts per 100,000 of dry soil) is not sufficient to render the soil worthless, though it has resulted in causing a few barren spots and in materially reducing the productiveness of the land.

All of this type is within the irrigated section of the area and it is all under cultivation. Grapes are the principal crop, while alfalfa and peaches are also grown to some extent. Vines do exceptionally well on this soil, and alfalfa is remunerative, except where there is too great an accumulation of alkali.

On account of the development which has taken place upon this type, the land values are high. It is seldom that any property changes hands for less than \$250 an acre, and higher prices are common.

#### MADERA LOAM.

The surface soil of the Madera loam consists of a sticky, brown to dark-brown loam, usually of a reddish shade. The upper subsoil is similar to the surface material, but usually assumes a somewhat darker color, heavier texture, and more compact structure with in-

creasing depth. It is underlain by the red hardpan of the Madera series at varying depths below 24 inches. The average depth of the soil and subsoil material is about 36 inches. No opportunity was found for determining the thickness of the hardpan, but it is probably about the same as in the other types of this and the associated series in the area.

In origin and mode of formation this type is similar to the other members of the Madera series.

In this area the Madera loam is confined to a few small bodies in the district east of Fresno along or near some of the intermittent stream courses. The surface is level to gently sloping and of smooth to occasionally hummocky configuration. The type usually lies somewhat lower than the surrounding soils, which, with the shallow depth of the soil and subsoil material and its high water-holding capacity, renders drainage deficient. Some leveling would probably be necessary in preparing the land for irrigation.

Owing to its small extent and rather deficient drainage, the Madera loam is one of the least important soil types in the area. If drainage can be effected to a sufficient depth, it will be fairly well adapted to certain varieties of grapes and olives; figs and alfalfa should give profitable yields.

The following table shows the results of a mechanical analysis of a sample of the Madera loam:

*Mechanical analysis of Madera loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572521.....	Soil.....	0.9	5.1	6.3	21.7	16.2	31.8	18.0

FRESNO SAND.

The surface soil of the Fresno sand is a sand of medium to rather coarse texture, grayish brown or light brown in color. It has a low organic-matter content, is incoherent, and usually carries small quantities of mica. Excepting in the vicinity of other types, where textural changes are to be expected, the subsoil is similar in color and character to the surface soil and extends to a depth of 6 feet or more. The grayish or bluish-gray calcareous hardpan characteristic of the Fresno soils does not appear within 6 feet of the surface of this type, save near the margins of the areas, and is commonly found at depths ranging from 10 to 15 feet below the surface. It is usually from 6 inches to 2 feet in thickness. It consists mainly of silt and clay particles cemented by calcium carbonate, and while impervious to water and of sufficiently dense structure to interfere with the

development of plant roots, it softens somewhat under irrigation and is of much less refractory character than the red ferruginous hardpan of the San Joaquin and Madera series.

This and other types of the Fresno series grade into one another so imperceptibly that in the construction of the soil map the boundaries between them are more or less arbitrary. On this account, the field work was carried on with the fact in mind that the typically developed sand has practically no coherence, while the other soils will form clods when plowed, and when the texture was so indefinite as to lead to any uncertainty the division between the types was based on that fact.

No bodies of Fresno sand are found in that part of the area east of Kings River. West of that stream scattering bodies appear in larger bodies of the Fresno sandy loam. To the south and west the areas increase in number and extent, gradually merging into larger areas, until in the vicinity of Fowler, Selma, Caruthers, and Ormus the type constitutes the predominant type of the plains, often extending in unbroken bodies for mile after mile across the valley. It is also found north and east of Kerman, but not in bodies of as great extent as those noted above.

This type occupies gently sloping or undulating, treeless valley plains, occurring as low, broad alluvial fans or deltalike areas. In the case of the smaller bodies there is commonly a slight elevation of the surface above the surrounding soils, but the difference is not pronounced. In the large areas the only minor irregularities of surface are numerous swales and circular depressions, and the general topography of the country is that of a rolling plain, the ridges extending for miles, at times hardly noticeable and again rising to such a height as to form more or less conspicuous landmarks. The swales are common to all portions of the type, with the exception of a few of the western bodies, and, with minor exceptions, they represent partially obliterated channels of former streams. These swales and depressions are shown on the soil map by means of a symbol. They are partially filled with seepage water during the irrigation season.

Prior to the construction of the irrigation systems in this area these depressions were dry and unless the slopes were too steep were dry farmed to grain with the rest of the soil. With the rise in the level of the ground water due to the collection of seepage waters from irrigation the larger number of these were partially filled with water for a greater part of the year. At the present time many are filled with water during the entire year. Practically all of them carry dense growths of tule, and willow usually grows around the edge of the water. West of the Hanford Branch of the Southern Pacific Railroad water has not yet made its appearance in the depressions,

but with the extension of irrigation in that part of the area the deeper depressions may be expected to contain water for a part of the year at least.

The material of this soil owes its distribution to the action of the streams referred to above, which deposited their load of sand on the plains, where the velocity of the water was diminished by the more gradual slope of the country. Since the deposition of the soil material the only changes have been local ones, some of the minor undulations of surface having been caused by drifting of the soil. Channels and depressions have been either wholly or partly obliterated by the blowing in of sand and a number of the smaller circular depressions seem to have been caused by the same agency. In a few cases in this and in other parts of the area characteristic dunes of a moderately coarse sand have been formed. These have not been differentiated in the present survey from the typical Fresno sand.

With the exception of the water-logged depressions, the drainage of the type is good, and over the greater part there is no danger of a serious rise in the level of the water table.

With the exception of the depressions, into which alkali has been carried by the seepage water, the soil is free from excessive quantities of alkali to a depth of 6 feet or more. West of Caruthers and Raisin the immediate surface soil frequently carries traces of alkali, but the quantity is so small that a season's irrigation should remove practically all of it. The white hardpan, which is invariably found at some depth, always carries alkali salts, but the depth of this formation and the loose, porous structure of the soil are an assurance that the soluble salts will not accumulate at the surface and render the soil worthless for cultivated crops.

In the southern part of the area from Bowles and Conejo westward there is in the aggregate a considerable area of this type not devoted to intensive farming, but given over to grazing or dry farming. Throughout this section a rapid development is taking place, vineyards, orchards, and fields of alfalfa appearing on every hand, and at the present rate of progress it will be but a short time until practically all of the type in that section is devoted to some line of intensive agriculture. The remainder of this type is very thoroughly developed, orchards and vineyards often extending in unbroken bodies over the country for mile after mile.

The Fresno sand is well covered by the present irrigation systems about as far west as the Hanford Branch of the Southern Pacific Railroad. In the vicinity of Ormus and Caruthers the land is either not reached by canals or if the canals are found the quantity of water is insufficient to supply all the land. Here areas are being rapidly placed under irrigation by the installation of pumping

plants. Some surface leveling is usually necessary in preparing the land for irrigation. The cost of this, however, is not excessive.

In its virgin condition the Fresno sand is of very loose structure and when water is applied for the first time the soil undergoes considerable settling, with the result that the surface often sinks a foot or more in patches from a few feet to several feet in diameter. Ordinarily one heavy irrigation will bring the surface to about its permanent level, but in some instances it has been necessary to irrigate and level the land two or three times before a stable condition could be obtained.

The larger part of this soil is planted to peaches, grapes ranking second in acreage, and alfalfa third. In addition to these, apricots, nectarines, and figs have been planted to some extent. The olive, fig, and English walnut are very often set as border trees around property lines and along the country roads. During the earlier development of the area this soil was devoted almost exclusively to the production of peaches, as it was not considered a very desirable soil for grapes. Although it is true that other soils in the area are better adapted to grapes, in recent years the planting of vines has been extended until this type is an important factor in the raisin production of the area.

Alfalfa is grown successfully if the soil is carefully prepared before seeding the crop and given the proper care and attention afterwards. Owing to lack of care, the average yield is less than it should be. In addition to these crops the soil is well adapted to truck crops. The soil possesses a low moisture-holding capacity and requires rather frequent irrigation and cultivation for the maintenance of a favorable moisture condition.

Owing to its wide extent and high state of development, the Fresno sand is probably the most important soil in the area. Undeveloped areas of this soil are now bringing from \$75 to \$125 an acre, depending upon the location. Developed orchards and vineyards range from \$125 to \$300 an acre or more, depending upon location, age and productiveness of the trees or vines, and the nature of other improvements.

#### FRESNO SANDY LOAM.

The Fresno sandy loam is a grayish-brown or light-brown sandy loam, with a low content of organic matter and a loose, porous structure. The surface soil and subsoil are identical. The underlying grayish hardpan of the Fresno series is always to be expected within 6 feet of the surface, except where this type grades into the Fresno sand, and although it is not commonly the case, it may occur at a depth of a foot or so. Hardpan as near the surface as this is confined to the bottoms of the swales and depressions, which are numerous in this soil. Under a part of the area south of Sanger red hardpan of



CANAL ACROSS SOILS OF THE SAN JOAQUIN SERIES, SHOWING HARDPAN.



the San Joaquin series is found, commonly at greater depths than 6 feet. It was not practicable to determine the extent of this occurrence and such areas were not differentiated in the map but included with the typical areas.

In the agriculturally developed portions of the areas of this soil type extending from Kerman eastward to Sanger the average depth of the soil and subsoil is not far from 4 feet. In this section the sandy loam texture commonly extends downward to the hardpan, but in the larger bodies west of Kerman, Ormus, and Caruthers a substratum of silty clay loam is usually found above the hardpan, and this heavier portion may come within a foot of the surface.

The texture of the surface soil is subject to considerable variation and ranges from a very light-textured sandy loam to a sticky, fine-textured sandy loam, which merges into the fine sandy loam of the series. The latter condition exists largely in that part of the area between Fresno and McMullin, where these types are closely associated. South and west of Kerman the soil sometimes assumes a reddish shade.

East of Kings River the type is confined to a narrow strip running through Reedley. West of the river it occurs in bodies of varying extent from near Sanger westward throughout the entire southern and western portions of the area. The general northern limit of these bodies is marked by a line running westward from Sanger to a point southwest of Fresno, near Kearney Park, and then northward to the San Joaquin River. The most extensive area extends from just west of Kerman to a point west of Jamesan, forming an unbroken body of about 60,000 acres. In the south-central and eastern parts of the survey the areas of this type are much smaller, usually long, and relatively narrow.

The Fresno sandy loam owes its origin largely to former alluvial agencies which brought vast quantities of material from the Sierra Nevada Mountains.

The "white ash lands" in the Fresno series are popularly thought to owe their character to a derivation from volcanic ash. No studies were made in the progress of this survey to demonstrate this, so it is not known whether it is true or not.

In all of the areas of this type where agricultural development has gone forward the topography is very similar to that of the Fresno sand, save that the depressions are relatively fewer in number and the ridges are not so prominent. Outside of these sections the surface breaks into a series of more or less connected ridges, 5 to 10 feet in height, with intervening flat-bottomed depressions. This feature, together with the accompanying hardpan and alkali, renders the larger part of the soil in such places of little value for cultivated crops. Over this type the topography is a very

good indication of the value of the soil, the more level areas being, as a rule, fair to good, and the more uneven areas being less desirable in proportion to the extent of their unevenness.

The drainage is good to deficient, the better conditions maintaining east of Ormus and Caruthers, toward Kings River. Just south of Fresno defective subdrainage has resulted in the destruction of thousands of acres of orchards and vineyards, and the level of the ground water is slowly rising in the newly developed portion of the area adjacent to Kerman. In this latter section damage from a rise in the level of the water table can be prevented, and steps to this end are now being taken by the owners controlling the larger part of the land in that section. The reclamation of the damaged areas south of Fresno would be profitable, but it has not yet been found possible to secure the unity of action necessary to carry on such work, and this spot remains an eyesore amid thousands of acres of thriving orchards and vineyards.

The proportion of alkali salts in the Fresno sandy loam varies from none to over 1,000 parts per 100,000 of dry soil. Extensive bodies of this soil in the western part of the area are at present unproductive and entirely unsuited to crops, because of the high alkali content, while all of the waterlogged areas of the type south of Fresno contain sufficient quantities to render production either impossible or extremely hazardous. The more eastern bodies of the type have been under cultivation and irrigation for many years, and as alkali has so far not appeared, excepting along the margins of some of the depressions, there is no need at this late date to fear its appearance.

With the exception of some undeveloped land in the vicinity of Kerman and Ormus, where the settlement of the land is progressing rapidly, all of the alkali-free portions of this soil are under cultivation. It is of friable character, and is easily maintained in a good condition of tilth. The surface material does not, however, possess a high water-holding capacity, and rather frequent irrigation and cultivation are necessary to maintain a satisfactory moisture content.

The Fresno sandy loam has as wide a range of crop adaptation as the Madera sandy loam. Excepting the citrus fruits, all fruits grown in the valley will, under favorable conditions, give remunerative returns, while alfalfa, berries, melons, truck crops, and vegetables can be successfully grown.

Land values range from \$15 an acre upward. The lowest value is placed on the soil in the western part of the area, which is used only for grazing. Good unimproved land without water ranges from \$80 to \$120 an acre, and the addition of a water right adds from \$40 to \$50 an acre to that price. Improved property ranges from \$200 to

\$500 an acre, and sometimes more, depending upon location and the nature of the improvements.

The following table shows the results of a mechanical analysis of a sample of the Fresno sandy loam:

*Mechanical analysis of Fresno sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572515.....	Soil.....	2.2	21.0	14.4	20.4	16.0	22.2	3.5

FRESNO FINE SANDY LOAM.

The soil of the Fresno fine sandy loam consists of 6 inches or more of fine sandy loam, containing a large amount of very fine sand and silt, and varying from light gray to light brown in color. In the eastern and north-central parts of the area, where small bodies of this soil occur, the surface soil rests directly upon the grayish, calcareous hardpan characteristic of the soils of this series or is separated from the hardpan by a subsoil similar to the surface material, while from McMullin southward and westward the surface soil is seldom over 12 inches in depth and is underlain by a grayish to light-brown, compact silty clay loam, which rests upon the hardpan.

The hardpan underlying this type varies in thickness from a few inches to 2 or 3 feet, is firmly cemented, and seldom penetrable with the ordinary soil auger. In the other soils of the series the hardpan is less dense and hard. The average depth to hardpan in the Fresno fine sandy loam is about 24 inches, and it is only in a few of the smaller bodies in the eastern part of the area surveyed that the depth is as much as 4 feet. In the western part of the area the hardpan is never very far below the surface and there are extensive areas where the average depth is less than 1 foot. The usual texture of the subsoil below the hardpan is that of a sandy loam.

The principal areas of this type occur south of the San Joaquin River west of Herndon and to the southwest, in the overflow lands near Fresno Slough. Near McMullin one arm of the larger body extends eastward to within a short distance of Fresno and a number of extensions of the main body are developed as far as the course of the old Enterprise Canal. Other less extensive bodies lie in the vicinity of Cando and north of Laton. With the exception of the large areas, the occurrence of this soil is as small, irregular areas, associated with extensive areas of the Fresno sand and sandy loam.

The soil material of this type is of alluvial origin, derived from the deposits laid down by waters flowing across the present plains.

The extent of the smaller bodies of this soil is rarely sufficient to allow of any great surface irregularities, but in the larger, western bodies the surface is subject to considerable variation. It ranges from slightly rolling to very uneven, areas being dotted with low mounds and sinuous ridges rising above small playalike depressions. With this type, as with the Fresno sandy loam, there is generally a close relationship between the topography of the soil and its agricultural value, the average depth to hardpan being less, the content of alkali larger, and the cost of preparing the land for irrigation greater as the surface becomes more uneven. The extensive area of alkali lands south of Fresno must be excepted from this rule.

In the smaller areas of the type associated with soils of lighter texture the drainage is fair, occasionally good, but over the rest of the type the surface and subdrainage are decidedly deficient and the water table is close to the surface.

Alkali salts, including both white and black alkali, are commonly present in this type, except in the most northern and eastern parts of the survey. The percentage of salts is usually excessive, and the surface in many places is bare of vegetation, or supports but a scanty growth of the most resistant alkali weeds.

A part of this type south of Fresno was one of the first areas developed to agriculture under irrigation, and it was regarded as one of the most desirable soils for grapes and peaches. Excessive irrigation brought about the rise of the ground water and an accumulation of alkali, with the result that hundreds of acres of orchards and vineyards were killed. This land has now either been abandoned or is used to pasture dairy cows. On many of the better portions of this type where development is going on the level of the underground water is slowly rising, and unless some means are taken to check it the value of the land will be very much impaired. At the present time practically all of the arable areas are under cultivation either to peaches, grapes, or alfalfa. Where favorable soil and water conditions exist the Fresno fine sandy loam is adapted to all of the deciduous fruits grown in this area and to alfalfa and olives. The nonagricultural portions are devoted largely to grazing, the only purpose for which they are of value at present. Such lands are commonly held in large tracts.

The prices asked for land of the Fresno fine sandy loam type range from \$15 to \$300 or more an acre, depending upon the fitness of the soil for cultivation, the nature of the improvements, and the location.

The following table shows the average results of mechanical analyses of samples of the Fresno fine sandy loam:

*Mechanical analyses of Fresno fine sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572502, 572504.....	Soil.....	0.4	5.3	6.6	23.9	26.3	30.2	6.7

HANFORD GRAVELLY SAND.

The Hanford gravelly sand as recognized in this survey departs in certain features to quite an extent from the soils of the Hanford series as typically developed. It was, however, thought best, considering its limited extent and its association with the Hanford series, to include the areas mapped with the Hanford series in the broader classification of the soils of the area surveyed, recognizing that the results of further study may justify recognition of the material under a distinct series head.

The surface soil of the type as here developed is a light-brown to slightly reddish-brown gravelly sand, carrying a large proportion of coarse sand, somewhat micaceous, and of a loose, porous structure. The subsoil to a depth of 6 feet or more is usually similar in color, texture, and structure to the surface soil, but in a few of the western bodies a compact yellowish-brown sand of rather coarse texture may be found at varying depths below 4 feet. This deeper subsoil commonly occurs at depths much below 6 feet and is sometimes so compact as to have the appearance of being cemented.

The gravel in this type is moderately fine, always well rounded, and usually consists of metamorphic and volcanic rocks. In places the quantity is small and in others it represents a very large proportion of the soil mass. The finer material of the type appears to have been derived mainly from granitic rocks.

The Hanford gravelly sand occurs only within the valley entrenched in the material of the plains by the San Joaquin River along its upper course in the area, and usually occurs as a terrace elevated from 6 to 50 feet above the soils of the stream bottoms. In this respect it differs from the adjacent bodies of more nearly typical Hanford soils.

The contact between areas of this type and the adjacent higher-lying soils of the valley plains is usually marked by a well-defined bluff or terrace slope. The surface is moderately sloping, smooth to slightly undulating, and crossed here and there by the courses of intermittent streams. The drainage is well established, and, owing

to the porous soil, in some places excessive. The areas are not overflowed or subject to erosion.

The type is of alluvial formation and occurs as a remnant of higher-lying deposits of the San Joaquin River, laid down when that stream occupied a higher level than at the present time.

A part of the Hanford gravelly sand is devoted to the production of deciduous fruits and alfalfa, but the larger part of it is used only for the growing of grain without irrigation. The slower development of agriculture on this type as compared with that of the other soils of the area is due partly to its location and partly to a lack of irrigation water.

The soil is deficient in humus and of low moisture-holding capacity. These conditions may be improved by the use of green manures. Rather frequent irrigation and cultivation are required to maintain a favorable moisture content. The soil is free from alkali salts and under favorable conditions of irrigation and culture is well adapted to many of the deciduous fruits, to grapes and to alfalfa. Land of this type ranges in value from \$75 to \$400 an acre, depending upon location, improvements, and the supply of irrigation water.

The following table shows the results of mechanical analyses of samples of the soil and subsoil of the Hanford gravelly sand:

*Mechanical analyses of Hanford gravelly sand.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572505.....	Soil.....	10.2	29.9	13.9	17.3	11.1	14.4	3.1
572506.....	Subsoil.....	10.5	20.2	10.3	22.3	20.1	11.7	4.8

HANFORD SAND.

The soil and subsoil material of the Hanford sand is a buff-colored, micaceous sand of low organic-matter content, porous structure, usually 6 feet or more in depth. In small areas it carries some fine waterworn gravel. Areas of slight extent depart from the general characteristics of the type in being underlain at a depth of 4 to 6 feet by a substratum of stream-laid gravel.

The type is not of extensive occurrence in this area. It is confined to the belt of alluvial soils along Kings and San Joaquin Rivers and is usually developed in small areas. The largest and most prominent lies east of Kings River and about 6 miles east of Sanger. The soil consists of alluvial deposits and generally occupies stream-valley bottoms and fans. As mapped in this survey, however, undifferentiated areas of stream-terrace materials are included.

The surface of the type is smooth to slightly rolling, and it generally lies higher than the adjacent types of soil. It is frequently

marked by the occurrence of former drainage depressions. Leveling is sometimes necessary in preparing the land for irrigation, but is usually not difficult or expensive.

Both surface drainage and subdrainage are usually adequate. Owing to the occurrence of the type in or adjacent to the stream bottoms, however, some of the unprotected areas are subject to occasional overflow.

The soil is usually free from injurious accumulations of alkali salts, though traces may sometimes appear in the surface materials.

With the exception of the one or two small areas in the vicinity of Laton, practically all of this type is in vineyards. While this is not an important type of the area, owing to its small extent, it is well adapted, under irrigation, to grapes, early stone fruits, alfalfa, and truck crops. Portions of the type support a native growth of trees and underbrush.

#### HANFORD FINE SAND.

The soil of the Hanford fine sand is a very light grayish brown or buff-colored fine sand, usually with but little organic matter, of a loose, porous structure, and carrying varying quantities of fine mica, sometimes sufficient to give the soil a distinctly greasy feel and appearance. The upper subsoil, to a depth ranging from 24 inches to more than 6 feet, is similar to the surface material and is underlain by fine to coarse alluvial material, occurring in no regular order of stratification and subject to extensive variation within short distances.

Like the other members of the Hanford series, the material of this type is of alluvial origin. In this area it occurs mainly as bottom lands within the valleys entrenched below the level of the plains along the upper courses of the streams. Some of the smaller bodies, however, occur along the stream courses not confined to stream valleys and represent alluvial-fan deposits, the usual source of the Hanford soils.

The most extensive and typical areas are developed along Kings River, in the Centerville Bottoms, where the stream shifting in its numerous channels has laid down, first, the coarser material of the subsoil, and later the surface covering of fine sand. The type is also encountered along the San Joaquin River as occasional narrow, inextensive areas adjacent to or but slightly removed from the present course of the stream.

The surface of the Hanford fine sand is traversed by a number of abandoned stream channels and old sloughs, and these give much of the type an uneven or rolling topography. The rest of the type is fairly smooth and requires but little leveling to prepare it for irrigation. Drainage is usually well established, but some unprotected areas are subject to periodical overflows.

The level of the underground water is usually within 6 feet of the surface, and owing to favorable moisture conditions the areas were originally covered with a dense growth of trees and underbrush. The larger part of this has been removed to make way for cultivated crops, but along the deeper swales and the main stream channels fringes of trees still remain, affording a supply of fuel of considerable value.

The soil requires frequent irrigation and cultivation and the incorporation of humus by the use of green manures or stable manure for the best results. Traces of alkali salts appear at the surface in places, but the areas are free from excessive or injurious accumulations of salts.

Some fruits are grown upon this type, but the larger part of the soil is used for pasture or is sown to alfalfa. Grapes and many of the deciduous fruits will do well, but apricots and almonds will do better if confined to higher soils, where there is less danger from low temperatures in the spring of the year.

There is very little transfer of property in the parts of the area where this type occurs, and it is hardly possible to make a definite statement regarding the values of these lands. Probably \$75 an acre would be a fair value for unimproved areas, while the improved lots would command from \$300 an acre upward.

#### HANFORD SANDY LOAM.

The soil of the Hanford sandy loam is a medium-textured sandy loam, micaceous, of friable, porous structure, and buff or light-brown color. The subsoil material is similar to the surface soil in color and character and generally extends to a depth of 6 feet or more. In the vicinity of other types of soil and in a very few bodies of this type which lie close to the level of the streams minor variations in the texture of the subsoil are common, and in some cases it assumes a slightly darker color than the surface material, but in the main bodies the texture and structure are uniform to a depth of several feet. Fine, dark-colored waterworn gravel is present in some places, and in one or two instances it occurs in sufficient quantities to give the soil a gravelly texture. These areas are small and of little importance and for this reason have not been differentiated as a distinct type of soil.

In the Kings River Delta country, near Laton, there are a number of more or less extensive, irregular bodies of this type, and just east of the Centerville Bottoms, east of Sanger, there is one body covering several square miles in extent. A comparatively extensive area also occurs in the extreme northwestern part of the survey east of Whites Bridge. These areas make up the greater part of this type. A few additional areas of small extent occur near the San Joaquin River.

Like the other members of the Hanford series, the Hanford sandy loam is an alluvial soil, having been formed by the deposition of sediment suspended in the waters of the adjacent streams.

The surface of this type is smooth to slightly undulating and frequently marked by shallow, abandoned watercourses and irregular depressions. A growth of brush and trees frequently occurs in the vicinity of stream channels. The area east of the Centerville Bottoms has a fairly uniform surface and occupies a more or less prominent terrace above the more recent stream bottoms occupied by soils of the Hanford series. This body departs in its topographic position from the usual occurrence of the type and is indicated upon the soil map as a terrace phase.

Drainage is fair to good, depending upon the elevation of the surface and the depth to standing water. Some of the areas are subject to overflow.

With the exception of the body of this type east of the Centerville Bottoms, the larger part of the soil contains some alkali, the quantity seldom exceeding 400 parts per 100,000 of the dry soil. The usual proportion is somewhat less than 200 parts per 100,000, but as this is concentrated largely in the upper 24 inches of the soil material it has a marked influence upon the value of the land.

Where alkali conditions are not too serious a considerable part of the type has been under cultivation for many years, being used for the production of alfalfa and deciduous fruits. It is adapted to these crops. The distribution of alkali salts in the soil and subsoil will govern the further extension of agriculture on this type.

The prices of land composed of this soil have about the same range as those for the fine sandy loam of this series.

The following table shows the results of a mechanical analysis of a sample of the Hanford sandy loam:

*Mechanical analysis of Hanford sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
572540.....	Soil.....	<i>Per cent.</i> 6.6	<i>Per cent.</i> 22.6	<i>Per cent.</i> 8.7	<i>Per cent.</i> 14.7	<i>Per cent.</i> 20.2	<i>Per cent.</i> 22.3	<i>Per cent.</i> 5.0

HANFORD FINE SANDY LOAM.

The soil of the Hanford fine sandy loam consists of a buff to light-brown fine sandy loam, often of light texture and approaching a fine sand, very micaceous, and free from gravel. The texture of the soil is rather uniform throughout its depth. The upper subsoil is similar in color, texture, structure, and composition to the surface

material. At depths below 4 feet this is underlain by a sandy loam of varying texture, containing fine gravel.

A few small bodies of this soil are found in the bottoms along the San Joaquin River, but the larger and typical areas occur along Kings River bottoms, near Sanger, Centerville, and Reedley. Extensive areas also occupy low, broad alluvial fans in the Kings River Delta lands west of Laton.

This soil is of alluvial origin, having been deposited by the streams along which it lies. The drainage is good to fair, depending upon the elevation of the surface. Some of the areas are subject to overflow when not protected.

In the Kings River Delta the surface of the type is seldom sufficiently uneven to call for very extensive leveling in preparing the land for irrigation, yet as a whole it can be regarded as quite undulating, being traversed by low, broad ridges which run in every direction. The soils in this part of the area are reached by irrigation canals. To cover as great an extent of country as possible the canals are carried along the crests of the ridges, and a glance at the very irregular course of these canals shows the diversity of direction which the ridges have. In the Centerville Bottoms the surface irregularities consist largely of abandoned stream ways and sloughs.

Not a great deal of the type carries alkali in excessive quantities, but in places concentration in the surface soil is sufficient to affect materially the productiveness of the lands.

This soil is of friable structure and easily cultivated, and adapted to a wide range of deciduous fruits and to alfalfa. A considerable area is planted to these crops. It is somewhat more retentive of moisture than the lighter members of the Hanford series and is better adapted to the general farm crops. In the Kings River Delta region a part of its area has been held in a single large tract for many years, and here there has been but little development. Recently this tract has been broken up and placed upon the market, and is being rapidly disposed of to new settlers. Prices for this soil range from \$75 an acre upward, depending upon the location and improvements.

The following table shows the results of a mechanical analysis of a sample of the Hanford fine sandy loam:

*Mechanical analysis of Hanford fine sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572543.....	Soil.....	0.4	1.1	1.4	35.4	38.7	19.9	3.2

## MERCED SILT LOAM.

The soil of the Merced silt loam consists of a dark grayish brown to drab, smooth-textured silt loam, often calcareous, of rather low silt and high clay content for a silt loam and approaching a clay loam in texture. When wet the soil frequently assumes a black color. The surface soil is from 6 inches to 4 feet in depth and is underlain by a yellowish-brown or yellowish-gray, compact, somewhat micaceous, and frequently calcareous sandy loam or fine sandy loam. The organic content of the soil is moderate to high, being greatest in that part of the area south of the West Side branch of the Southern Pacific Railroad. The sandy loam subsoil occurs at the shallower depth in the extreme southern part of the area and gradually increases in depth to the northward. The soil is of rather compact structure and is sticky when wet but friable under favorable moisture conditions and capable of being maintained in good tilth.

This soil is one of the important types found in the extreme western part of the area. The largest area extends from the Kings County line northwestward in an unbroken body more than halfway across the survey. Two other areas occur, the more extensive of which covers several square miles near the junction of Fresno Slough and the San Joaquin River, in the extreme northwestern part of the survey.

In origin this soil is essentially the same as the other series derived from the younger and less weathered deposits of the valley.

In the extreme southern part of its development the surface is slightly undulating. Elsewhere it is broken only by numerous deep-cut sloughs and watercourses. With few minor exceptions, the surface of this soil is noticeably lower than that of the soils which border it on the east, and before the floods in the adjacent stream were confined by levees all of the type was subject to overflow, the lowest portions being under water for the greater part of the year. As a result of this continuous flooding, extensive growths of tule and other water-loving vegetation flourished over large areas. By their decay small areas exist where the soil is of a decidedly peaty structure. On the soil map the irregular, swampy area shown by swamp symbol in the southwestern corner of the survey indicates portions of this soil which are either without protection from overflow by levees or else are so low that water stands there for a part of the year.

The northern area of this type may carry small quantities of alkali, but not sufficient to do much damage. In the northern extension of the main area of the type there are a few small areas where alkali occurs in dangerous quantities, but there the trouble is largely due to the presence of black alkali, which is sometimes present to the extent of 200 parts per 100,000 of dry soil. In the southern part of the area traces of alkali appear only in the vicinity of alkali-laden soils of other series.

Owing to periodical overflows, and to the fact that the larger part of the land has been in large holdings, its development has been greatly retarded. It has been used only for grazing or the production of dry-farmed grains. In late years considerable work has been done to confine the flood waters, and at least one of the larger holdings has been subdivided and placed on the market. The ultimate development of this soil will depend upon the extent of the alkali and the rapidity with which the large holdings are offered for sale. The parts which are affected by alkali will doubtless be used only for grazing for years to come. Other areas will probably be utilized for the production of alfalfa in connection with dairying. Certain varieties of grapes and deciduous fruits will do well, but probably not give as large returns as upon some of the other soils in the area.

The following table shows the results of mechanical analyses of samples of the soil and subsoil of the Merced silt loam:

*Mechanical analyses of Merced silt loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572528.....	Soil.....	0.2	2.5	3.0	9.4	16.9	50.7	17.4
572529.....	Subsoil.....	.2	5.5	9.2	24.3	18.4	28.6	13.8

MERCED SILTY CLAY LOAM.

The surface soil of the Merced silty clay loam consists of a heavy, sticky, compact, dark-gray or drab to black silty clay loam, which extends, with but little variation in character, to a depth of 30 inches to 6 feet or more. Beneath this material is found a yellowish or reddish-brown, sticky sandy loam, somewhat micaceous and very compact, in places partially cemented into a soft hardpan. The soil and subsoil may carry whitish fragments or nodules of a calcareous nature, and at the zone of contact between the soil and subsoil a thin layer or crust of light-colored, calcareous material frequently occurs. This is not sufficiently dense, however, to interfere with the development of plant roots.

This type covers extensive areas in the western part of the survey, extending as a nearly continuous body of soil from the mouth of Fresno Slough southward nearly to the road which runs southwest-erly from McMullin.

In origin and formation the type is similar to the silt loam of this series. The surface is either very smooth or else is eroded by over-flow channels from the San Joaquin River. It is also traversed by a number of deep-cut drainage ways.

The larger part of this soil is subject to overflow; and as the surface drainage and subdrainage are rather sluggish and the soil possesses a high water-holding capacity, it dries out slowly. Where the drainage is poorest growths of tule have sprung up. Such areas are indicated upon the soil map by the usual swamp symbol.

The southern extensions of this type are free from alkali, but to the north alkali is present in increasing quantities, rendering some parts of the land unfit for cultivated crops in its present condition.

Aside from grazing, the only use to which this soil has been put is the production of dry-farmed grains, and upon the better drained areas good average yields have been maintained for many years. With protection from overflow and with irrigation this soil would be better adapted to alfalfa than to any other crop. The land comprising this type is held in large tracts and is not as yet being developed for agriculture.

While the soil is of a tenacious, compact structure and requires a heavy farming equipment, under favorable conditions of moisture content and cultivation it assumes a friable condition and may be maintained in good tilth.

The following table shows the results of mechanical analyses of samples of the soil and subsoil of the Merced silty clay loam:

*Mechanical analyses of Merced silty clay loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572507.....	Soil.....	1.6	6.4	3.1	5.7	10.6	49.8	22.5
572508.....	Subsoil.....	5.4	19.2	9.4	15.1	16.3	27.2	7.7

MERCED CLAY ADOBE.

The soil of this type consists of a dark-drab to black, sticky clay with a well-developed adobe structure. When wet it is exceedingly tenacious and bakes and checks deeply upon exposure during dry periods. While requiring a heavy farming equipment, careful management, and thorough cultivation for the maintenance of good tilth, it assumes a fairly friable structure when in a favorable condition as regards moisture content. The upper subsoil is similar in color and character to the surface soil and extends to a depth of 2 to 6 feet or more below the surface. The deeper subsoil, occurring at varying depths below 24 inches, is a heavy sandy loam of dark-gray to yellowish-brown color and similar to that underlying the silty clay loam of this series. Both the soil and subsoil are usually noticeably calcareous, and the upper sections of the latter are frequently cemented into a soft hardpan.

In origin and mode of formation the Merced clay adobe is similar to the Merced silty clay loam.

Only two bodies of the type occur within this area. These lie in the extreme western part of the area adjacent to Fresno Slough. The surface is nearly level, very uniform, and is unbroken except for a few drainage channels. The drainage conditions are much the same as in the silty clay loam of this series, and the soil is overflowed unless protected by levees.

No alkali is found in the southern body of this type, and it is largely used for grain farming. The northern body invariably contains large quantities of alkali and is of little value even for grazing.

Under favorable conditions, including irrigation, freedom from alkali, drainage, and protection from overflow, the type could be profitably utilized for the production of alfalfa and other general farm crops.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of this type:

*Mechanical analyses of Merced clay adobe.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572510.....	Soil.....	3.2	8.2	8.0	16.0	7.0	23.6	34.3
572511.....	Subsoil.....	4.3	16.2	14.2	29.3	8.9	15.3	11.8

CENTERVILLE CLAY ADOBE.

The Centerville clay adobe occurs upon a conspicuous mesa or elevated terrace to the north of Centerville. The soil is a dark reddish brown to dark chocolate brown clay adobe, similar in structure, texture, and appearance to the Portersville clay adobe, excepting that it carries some large waterworn, rounded gravel and small cobbles, which are largely made up of jasper and quartzite. The upper subsoil, extending to a depth of 2 to 6 feet or more, is similar in color and character to the surface material. It is underlain by a heavy, sticky loam carrying excessive quantities of lime, forming a calcareous marl, which occurs within the 6-foot soil profile only in limited areas, and is by no means as common in this type as in the Portersville clay adobe. Adjacent to the foothill slopes the type as mapped includes undifferentiated areas of the Portersville clay adobe.

The Centerville clay adobe seems to have been derived largely from the material giving rise to the Portersville clay adobe and the material deposited by Kings River over earlier deposits of sand and gravel. Some of the gravel and boulders undoubtedly come from

the same source, but a part of them came from more distant sources, as no quartzite has been found in the typical Portersville soils.

Usually the surface of the type is moderately smooth and gently sloping. The areas lie some 30 to 60 feet above the adjacent soils of the valley plains upon the one hand and grade into the soils of the foothills upon the other. In certain localities the original surface has been modified to some extent by erosion subsequent to deposition of the material. Where the surface has undergone but little change, gravel and cobbles are not particularly noticeable, but on slopes and in depressions gravel is frequently so plentiful as practically to form a pavement over the surface.

The larger part of the area covered by this soil lies above the present irrigation canals and is used for grain farming or grazing, but here and there small citrus orchards are being developed. The extent to which it may be utilized for citrus fruits will depend mainly upon the supply of underground water. It is probable that practically all of the type can be irrigated by pumping from wells, but in the case of the areas farthest from the river the alluvial substratum is probably replaced by bedrock and it will be necessary to sink a well some distance away and convey the water to the desired locations by means of flumes, pipes, or canals. On account of the cost of obtaining water, only crops of high market value, such as citrus fruits, can be profitably grown upon this soil under irrigation. The adaptation of soil of this character to such fruits has been demonstrated. In this area the position of the type is such as to give comparative freedom from temperatures low enough to injure the trees.

The following table shows the average results of mechanical analyses of samples of the soil of this type:

*Mechanical analyses of Centerville clay adobe.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
572544, 572545.....	Soil.....	2.3	5.1	3.0	6.7	7.4	34.1	41.4

RIVERWASH.

Riverwash is a nonagricultural type consisting of gravel and sand, extensive areas of which lie along the channels of the Kings and San Joaquin Rivers. This deposit lies but little above the low-water stage of the streams and is subject to overflow for several months in each year.

The usual appearance of this material is that of beds of glistening sand streaked with deposits of gravel. In a very few places it supports a thin growth of willow where it comes in contact with other soil types.

## ALKALI.

Alkali salts in quantities sufficient to prevent utilization of the land for ordinary crops or seriously to impair its productiveness are found in certain soils of the area. This fact has been pointed out in the descriptions of the several soils, but in order to give a comprehensive view of the extent and distribution of alkali two maps have been constructed. Upon one of these maps is shown the total quantity of alkali salts in the soil and the extent and distribution of land at varying degrees of concentration. The other map (see Pl. A) shows in a similar manner the facts as regards black alkali.

Alkali lands have been mapped in several grades, based upon the average quantity of alkali in the dry soil to a depth of 6 feet or where impenetrable hardpan occurs to the depth to which the soil could be sampled. In determining the total quantity of alkali in the soil each foot of soil is tested separately by the electrolytic bridge method and the amounts added and averaged by dividing the sum by the depth of the boring.

In the black alkali map the figures given represent the quantity of black alkali in the surface foot of the soil as determined by titration.

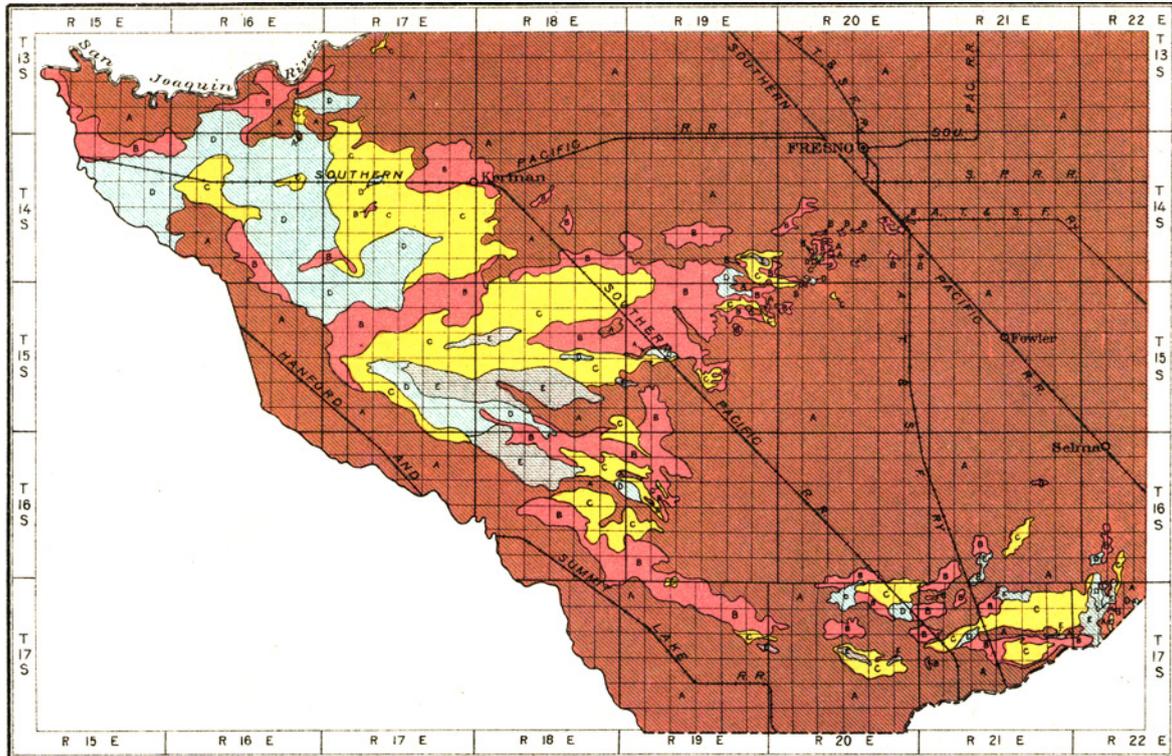
The following table gives the different grades of alkali land indicated upon the total alkali map:

Grade.	Total amount of alkali in the soil.
A	Less than 200 parts of alkali salts per 100,000 of dry soil. Blank areas indicate areas free from injurious amounts of alkali. Cross-lined areas indicate areas in which injurious surface accumulations or affected spots occur. The average concentration of salts in the cross-lined areas ranges from 50 to 200 parts of salts per 100,000 of dry soil.
B	More than 200, but less than 400, parts per 100,000 of dry soil.
C	More than 400, but less than 600, parts per 100,000 of dry soil.
D	More than 600, but less than 1,000, parts per 100,000 of dry soil.
E	More than 1,000 parts of alkali per 100,000 of dry soil.

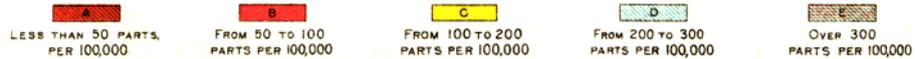
The various concentrations of grades of black alkali in the surface foot of the soil as represented upon the black alkali map are as follow:

Grade.	Amount of black alkali in the surface foot of soil.
A	Less than 50 parts per 100,000 of dry soil.
B	More than 50, but less than 100, parts per 100,000 of dry soil.
C	More than 100, but less than 200, parts per 100,000 of dry soil.
D	More than 200, but less than 300, parts per 100,000 of dry soil.
E	More than 300 parts per 100,000 of dry soil.

With the exception of a number of very small, widely scattered areas, the alkali lands occur principally west of the main valley line



BLACK ALKALI MAP, FRESNO SHEET





of the Southern Pacific Railroad and are confined, with minor exceptions, to soils of the Fresno, Hanford, and Merced series.

A large continuous body of alkali land lies in the western part of the survey, extending from the junction of Fresno Slough and the San Joaquin River southwesterly to its southern limits east of Laton. The larger part of this extensive body lies west of the Hanford Branch of the Southern Pacific Railroad and west of a line running northwest from Kerman. In this section of the area the land available for agricultural purposes is confined to comparatively narrow strips along the principal water courses, and for mile after mile the only vegetation consists of growths of weeds and grasses which thrive in alkali soils. East of the Hanford Branch there are large arms of the body of alkali land which extend for several miles eastward. (Pl. II, fig. 2.) Another prominent extension in the southern part of the area extends from around Cando eastward to the county line, near Kingsburg. In addition to this main body, there are a large number of detached areas of alkali scattered throughout the soils lying between the extensions referred to, and in the aggregate a considerable area of soil has been injured through accumulation of the salts.

In addition to the areas of alkali occurring in the soils of the plains, small areas are sometimes found in the residual and colluvial soils of the foothill region. With the exception of one body, which occurs northeast of Centerville, none of these areas are of sufficient extent to be of any importance and are not shown on the alkali map.

When the first survey of the soils around Fresno was made in 1900 the quantities of alkali in the soils were expressed in terms of percentage rather than as parts per 100,000 of the dry soil. The limits or grades of concentration were, however, the same as in the present survey, with the exception that in the earlier survey no distinction was made between the soils which were practically free from alkali and those which contained small quantities of soluble salts under 200 parts per 100,000 of dry soil. In the present survey it was noted that although the average alkali content to the depth of 6 feet might fall below 200 parts per 100,000, the minimum limit usually recognized as constituting an injurious concentration, this condition was frequently accompanied by injurious concentrations of salts in the surface foot, associated with the presence of barren unproductive spots. For this reason in the present survey the soils which carry less than 200 parts per 100,000 of alkali have been divided into two subgrades. One includes all of the soils in which there is no surface appearance of alkali and in which the proportion of soluble salts is less than 50 parts per 100,000. The other includes areas usually marked by the occurrence of unproductive alkali spots,

and where the amount of alkali is more than 50 and less than 200 parts per 100,000.

As a distinction of this kind was not made in the earlier work, no conclusions as to the changes in the extent and concentration of salts that may have taken place within the last 10 or 12 years in this grade of land can be drawn. With this exception the grades of concentration indicated upon the maps of the two surveys are similar, and a direct comparison is impossible. Changes since the former determinations have been slight, though, as a rule, there is a little less alkali in the soils now than formerly. In a few cases there has been an accumulation of soluble salts, but such increases have not taken place over extensive areas. The most noticeable decrease in the amount of alkali occurs in the affected belt extending westward from Malaga. Where there were formerly hundreds of acres having an alkali content of 400 to 600 parts per 100,000, now the content has generally dropped below 400 parts per 100,000, and quite a noticeable proportion of the soil now contains less than 200 parts per 100,000. A similar change has taken place in the southern part of the area, a part of which is included in the Hanford area, north and west of Laton, surveyed in 1901. The change in this section has not been so pronounced and is less evident, as the high level of the underground water has been nearly as much of a deterrent factor in the matter of crop production as has the alkali.

From the above statement the inference might be drawn that in time the injurious accumulations of alkali will disappear by natural processes and that there will be a return of the prosperity formerly enjoyed by some of these sections. Such a thing may happen, but it would be a matter of many generations, and even with the disappearance of the alkali there would still be the high level of the underground water to contend with. Without artificial aid in removing the latter about the only improvement would probably be in extending the area which may be used as Bermuda and salt-grass pastures.

Before the irrigation of the soil was begun the larger part of the alkali was contained in the subsoil, both within the hardpan of the Fresno series and in the soil just above that formation, and in the section south of Fresno there was no visible evidence of the occurrence of the salts. In the western body of the alkali areas indicated upon the map and in many of the alluvial soils the alkali was plainly evident both by the nature of the vegetation and by the presence of crusts of salts on the surface of the soil. At the present time it is impossible to find a place where one can be sure that the original distribution of the alkali salts has not been disturbed by the irrigation of the soils, but at the time of the former survey around

Fresno a number of tests were made where in all probability the alkali had not been disturbed. These tests were made in foot sections to depths ranging from 6 to 10 feet, and in every case in soils of the Fresno series the largest percentage of soluble salts was in the hardpan, or just above it and below it.

The depth to which the alkali extends is uncertain, but probably varies with the texture of the soil. From the fact that a good quality of domestic water is obtainable at depths of 40 to 50 feet it would seem that the most of the alkali occurs above these depths.

Under the natural conditions of rainfall and drainage the alkali was retained in the subsoil, but when the excessive irrigation of the soils took place the natural drainage of the plains was insufficient to remove the load of excess subsoil water, and with the rise in the level of the water table evaporation from the surface went on from year to year, the amount of salts deposited gradually increasing until fruit trees and vines were killed and extensive acreages of choice orchards and vineyards completely ruined.

Many persons not conversant with the concentration of the alkali in the subsoils believe that it has been brought to the land by the irrigation water. The water from Kings River, constituting the most important source of supply, is of exceptional purity, and even had all the water applied to these soils been removed by evaporation there would not yet have accumulated the quantity of alkali which is now present. Upon the other hand, past and present conditions indicate the present distribution of the salts to have been due to translocation of large quantities of the salts from the subsoils to the upper portion of the soil section through rise of the water table and surface evaporation. Not only do the analyses show that the hardpan and subsoil of the Fresno soils contain excessive quantities of alkali, but the alkaline nature of the formation is evident wherever the hardpan crops out along the bluffs of either the Kings or San Joaquin Rivers. Here the soluble salts may be seen in the dry season crystallized on the face of the bluffs, and alkali seeps at the base of the bluffs are not uncommon.

In the area included within the survey black alkali is to be expected whenever there are more than 200 parts per 100,000 of total salts present in the dry soil. Exceptions to this exist, as may be seen in comparing the two alkali maps, but they are not so general or extensive as materially to modify the rule.

As a large number of analyses of the alkali soils of this area were made at the time of the former survey, no samples were taken in the prosecution of the recent work. Below are given the results of the analyses of a number of samples of alkali collected in 1900:<sup>1</sup>

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<sup>1</sup> Soil survey around Fresno, Field Operations of the Bureau of Soils, 1900.

*Chemical analyses of alkali salts.*

Constituent.	I.	II.	III.	IV.	V.	VI.	VII.
Ions:	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Ca.....	12.59	Trace.	3.65	3.52	0.20	1.75	0.04
Mg.....	5.26	Trace.	1.99	Trace.	.....	.42	.....
Na.....	15.56	33.78	23.80	28.74	34.90	30.66	41.85
K.....	1.15	1.86	10.86	.59	1.15	9.87	1.26
SO <sub>4</sub> .....	1.60	11.97	10.20	3.81	17.09	9.80	2.35
Cl.....	60.40	29.92	39.64	4.99	2.50	15.75	1.15
CO <sub>3</sub> .....	.....	3.19	9.87	16.71	23.56	31.71	52.79
HCO <sub>3</sub> .....	3.44	19.28	.....	41.64	20.60	.....	.56
PO <sub>4</sub> .....	.....	Trace.	.....	.....	.....	.....	.....
Conventional combinations:	.....	.....	.....	.....	.....	.....	.....
CaSO <sub>4</sub> .....	2.28	.....	12.36	5.28	.67	5.88	.10
CaCl <sub>2</sub> .....	34.61	.....	.....	<sup>1</sup> 8.21	.....	.....	.....
MgSO <sub>4</sub> .....	.....	.....	1.82	.....	.....	2.03	.....
MgCl <sub>2</sub> .....	20.49	.....	6.46	.....	.....	.....	.....
K <sub>2</sub> SO <sub>4</sub> .....	.....	.....	.....	.....	.....	7.35	.....
KCl.....	2.05	3.46	20.65	1.17	2.19	12.67	2.41
Na <sub>2</sub> SO <sub>4</sub> .....	.....	17.69	.....	.....	24.69	.....	3.36
NaCl.....	35.77	46.68	41.30	7.04	2.39	16.03	.....
Na <sub>2</sub> CO <sub>3</sub> .....	.....	5.72	17.42	29.62	41.67	56.06	93.35
NaHCO <sub>3</sub> .....	4.79	26.45	.....	48.68	38.39	.....	.77
PO <sub>4</sub> .....	.....	.....	.....	.....	.....	.....	.....
Per cent sol.....	.87	1.50	2.41	.68	28.22	2.86	54.24

<sup>1</sup> Ca(HCO<sub>3</sub>)<sub>2</sub>.

As has been stated, the quantities of alkali in the soil are expressed in parts per 100,000, representing the average content to a depth of 6 feet, or to hardpan, in places where that formation occurs. Land at the lowest grade of concentration—less than 200 parts per 100,000 of dry soil—is indicated upon the map by the absence of any color, but includes areas shown by cross lines, where there are alkali spots and an average concentration of more than 50 parts of alkali salts per 100,000. The latter areas are more or less impaired for the production of cultivated crops, not only by the quantity of total salts, but by the presence of the more harmful black alkali and by the high level of the underground water. These three conditions are so closely related that it is not always possible to say which of them is responsible for the damage to crops. Sickly appearing fruit trees, stunted grapevines, and patchy fields of alfalfa represent about the average condition on this grade of alkali, the health and vigor of the plants being in inverse proportion to the quantities of salts present or condition of the subdrainage. Where the surface accumulation of salts is unusually high the surface of the soil may be entirely bare of vegetation or support but a scanty growth of the alkali grasses. In uncultivated soils the vegetation is commonly salt grass or Bermuda grass, and alkali weeds, which are associated with large quantities of alkali, are often present.

To show the vertical distribution of the alkali in lands where an average of less than 200 parts of alkali per 100,000 of soil is found to the depth of 6 feet the result of field tests have been averaged and stated in the table below :

*Distribution of total salts in the soil of lands grading less than 200 parts per 100,000.*

[Parts per 100,000.]

First foot.	Second foot.	Third foot.	Fourth foot.	Fifth foot.	Sixth foot.	Average for 6 feet.
160	150	160	160	170	150	160

Least amount of alkali observed in the surface foot, 40 parts per 100,000.  
Greatest amount of alkali in the surface foot, 260 parts per 100,000.

The quantity of black alkali in the surface soil associated with the above concentrations varies from 0 to 150 parts per 100,000, over 50 per cent of the tests showing no black alkali, or the presence of quantities too small to be satisfactorily determined.

The alkali field work was carried on in the spring, following the wet season, and the salts were well distributed throughout the soil. Had the tests been made late in the summer or early fall the results would show somewhat more alkali in the surface foot and less in the subsoil. The average alkali content of the soil is not excessive, and, provided the level of the ground water were several feet below the surface, these soils could be devoted to all crops excepting those which are most easily affected. Barley and oats would do well, but beans, rye, and wheat would, under the conditions existing, probably hardly be profitable. Grapes, olives, and figs will withstand these quantities of alkali, where the proportion of black alkali is not over 50 parts per 100,000, and the subsoil is not waterlogged. The growth of peaches, almonds, and apricots will be stunted in the presence of concentrations around the upper limit of this grade, and their cultivation should be confined to better soils. Young alfalfa is very susceptible to small quantities of alkali, and a stand can be secured on these soils only after the surface foot of soil has been well flooded to drive the alkali down beyond the reach of young plants. When once established alfalfa will easily do well in soils of this grade of concentration, providing the level of the ground water is not too close to the surface. Eucalyptus of several years growth will flourish in these soils, although some difficulty will be found in starting some of the species where the content of black alkali is as high as 50 parts per 100,000 in the surface foot of the soil.

In the next grade of alkali (200 to 400 parts per 100,000), the uncultivated soils support either dense growths of salt and Bermuda grasses or various alkali weeds, or the surface may be entirely bare

of vegetation. Salt grass is very typical of this grade, and the bare soil occurs in but a few instances where the proportion of salts concentrated in the surface foot is about 1,000 parts per 100,000. Practically none of this soil is being used successfully for fruit production, and existing fields of alfalfa are inferior. The limiting condition here is not only the amount of alkali but also the level of the underground water, which is too close to the surface to permit the development of the roots of the plants.

Combining and averaging the results of field tests that fall within the limits of this grade of concentration, the quantities of alkali in the various foot sections of the soil and the average amount in the soil down to a depth of 6 feet are as follows:

*Distribution of total salts in the soil of land grading 200 to 400 parts per 100,000.*

[Parts per 100,000.]

First foot.	Second foot.	Third foot.	Fourth foot.	Fifth foot.	Sixth foot.	Average for 6 feet.
270	240	240	210	180	140	213

Average amount of black alkali in the surface foot of soils, 120 parts per 100,000.

Greatest amount of total alkali observed in the surface foot of soil, 1,300 parts per 100,000.

Least amount of total alkali observed in the surface foot of soil, 140 parts per 100,000.

Barley and oats are the only cereals successfully grown upon soils of this grade, and these suffer when the upper limit is approached or when the amount of black alkali is close to 100 parts per 100,000. The successful production of deciduous fruits and vines is eliminated from areas of this concentration, for while these fruits will do reasonably well in the lower limits of this grade the presence of a high water table in these soils prevents their development. Figs, olives, pears, alfalfa, beets, and onions will do fairly well provided the quantity of salts in the surface soil is not too large during their early growth and the soil is reasonably well drained.

Combining and averaging the results of all of the tests which come within the next grade (400 to 600 parts per 100,000) the following results are obtained:

*Distribution of total salts in the soil of lands grading 400 to 600 per 100,000.*

[Parts per 100,000.]

First foot.	Second foot.	Third foot.	Fourth foot.	Fifth foot.	Sixth foot.	Average for 6 feet.
530	530	400	370	370	320	420

Greatest amount of total alkali observed in the surface foot, 1,300 parts per 100,000.

Least amount of total alkali observed in the surface foot, 170 parts per 100,000.

Average amount of black alkali in the surface foot, 190 parts per 100,000.

The surface of uncultivated areas of soils carrying this grade of concentration of alkali may support heavy growths of salt grass, but

commonly this plant is absent and only the more resistant alkali weeds make up the usual vegetation. This grade of soil is worthless for fruit culture, cereals will not grow, and alfalfa will seldom prove profitable. Some of the sorghums will produce a little forage, and salt grass can be used to a limited extent for grazing.

In the next grade, where the soil contains from 600 to 1,000 parts

In the next grade, where the soil contains from 600 to 1,000 parts per 100,000 of alkali, the averaging of the tests gives the following results:

*Distribution of total salts in the soil of land grading 1,000 parts per 100,000.*

[Parts per 100,000.]

First foot.	Second foot.	Third foot.	Fourth foot.	Fifth foot.	Sixth foot.	Average for 6 feet.
760	790	630	660	510	450	630

Average amount of black alkali in the surface foot, 210 parts per 100,000.

Greatest amount of alkali observed in the surface foot, 1,900 parts per 100,000.

Least amount of alkali observed in the surface foot, 170 parts per 100,000.

This grade of soils is worthless for cultivated crops. Salt grass will continue to make good growth, except in the presence of higher amounts of salts, but Bermuda grass shows distress even in the lower grades. The plant growth is commonly restricted to a variety of alkali weeds and not uncommonly the surface soil is barren. In the bodies of least concentration this land will furnish a little pasture during the spring months.

When the soil contains over 1,000 parts per 100,000 of alkali it is of no value for cultivation and of little value even for grazing. Averaging of the tests on this grade of soil shows the following results:

*Distribution of alkali in the soil of land grading more than 1,000 parts per 100,000.*

[Parts per 100,000.]

First foot.	Second foot.	Third foot.	Fourth foot.	Fifth foot.	Sixth foot.	Average for 6 feet.
1,640	1,750	1,300	1,070	1,330	1,240	1,390

The only way in which the alkali conditions may be effectively and permanently improved is by drainage, combined with more or less flooding of the surface, which will dissolve the alkali salts and leach them from the soils into the drainage waters. Other measures to counteract the injurious effect of the alkali may be used, but they are rarely of any permanent benefit, and as long as the alkali is still in the soil there is always the probability that crops will be damaged or destroyed. Among the measures sometimes resorted to for improving or utilizing alkali lands are the introduction of alkali-resistant crops, the use of surface mulches to prevent evaporation,

application of gypsum to correct black alkali, and cultivation and flooding without drainage improvement. In the discussion of the concentration and distribution of alkali mention was made of the crops which could be expected to thrive on the soils of the several grades, and by the selection of these crops it will be possible to derive some revenue from the affected land except in case of high concentration. When the content of alkali is not large, but occurs mostly in the surface foot of the soil, the use of heavy mulches of manure, straw, etc., coupled with irrigation, will tend to transfer the alkali to the subsoils and prevent its return until the plants have made considerable growth and are able to endure larger quantities.

When freed from surface concentrations some crops, such as alfalfa, which keeps the surface of the soil well shaded, aid in preventing the return of the alkali to the surface, and under favorable conditions profitable crops may be obtained from the land for several years.

Gypsum is a chemical corrective for black alkali, transforming the sodium carbonate into a less harmful white alkali compound. If there are but small quantities of both white and black alkali in the soil the use of gypsum may prove economical and efficient, but where large quantities of salts are present the application of gypsum will be costly and will be of little permanent benefit, as it would only increase the total amount of alkali in the soil. Black alkali tends to alter the structure of the soil, making it compact and retarding the passage of water. Where land is being reclaimed an application of gypsum will usually improve the structure and render the material more porous and more readily drained.

Surface cultivation and flooding as agents in the reclamation of alkali soils are effective only when there is a good depth of porous subsoil, so that the water may move freely downward and carry the alkali beyond the reach of the plant roots. Such means of reclamation are applicable only to a small area of the soils of this area, as under the greater proportion of the lands the subsoil is already overburdened with water.

The reclamation of the lands affected with alkali is considered in a succeeding chapter which deals with the improvement of soils affected with alkali and an excess of seepage or subsoil waters.

#### IRRIGATION.

Much of the data in this chapter regarding volume and fluctuation of stream flow, character of drainage basins, extent and development of the present sources of gravity distributed waters, etc., is taken from Water Supply Papers Nos. 17, 18, 19, 213, and 222, United States Geological Survey, to which the reader is referred for further information and a more extensive treatment of the subject.

At the present time the principal supply of water for the irrigation of the lands in this area is drawn from the flow of Kings River. The drainage area of Kings River lies in the high Sierra Nevada Mountains, to the east of the area, where the precipitation is largely in the form of snow. Under normal conditions this snow is very compact and melts slowly, and the flow of the river is highest during the spring and early summer months, subsiding abruptly following the disappearance of the snow. During the rest of the year there is no marked variation in the discharge. The average annual discharge of this stream is given by Mendenhall<sup>1</sup> as 1,790,187 acre-feet. The highest stage of the water is reached in June, when the mean discharge is 17,100 second-feet, and the minimum flow comes in October and November, when the mean flow is but little more than 400 second-feet.<sup>2</sup> The result is that during the period from March to July, inclusive, when there is the greatest need of water there is a large flow available for irrigation. During a considerable part of this period the flow is greater than the capacity of the canals and a considerable part of the water passes westward into Fresno Slough and the San Joaquin River. During the remainder of the year the discharge of the stream is not sufficient to supply the canals with all the water that is needed, and canals which have inferior water rights are compelled to go without water during the late summer and fall months.

The water from the San Joaquin River irrigates but a small area of soil in the northwestern corner of this survey but its proximity to much of the land in the northern part of the area and the possibilities contained in its flow entitle it to some consideration. This stream, which is the largest watercourse in the San Joaquin Valley, has its watershed in the high Sierras, draining portions of both Fresno and Madera Counties. The precipitation is largely in the form of snow, and the nature of the discharge of the stream is very similar to that of Kings River. The average annual discharge is stated by Mendenhall to be 1,972,145 acre-feet. At various points below Skaggs Bridge the waters of this stream are diverted for the irrigation of grass lands, alfalfa, grain, and other crops, and during the late summer months the flow of the stream is not sufficient to satisfy the present water rights. It is believed that there are available reservoir sites along the river above Friant, and the storage of water at such points would not only insure a supply of water for existing rights, but would make a supply available for nonirrigated sections in this and in the adjoining county to the north.

Big Dry Creek is a possible source of a small supply of irrigation water. Under the conditions of flow which exist in this stream the

<sup>1</sup> Water Supply Paper 222, U. S. Geological Survey.

<sup>2</sup> Water Supply Paper 213, U. S. Geological Survey.

greatest amount of water comes at a time when the canals are usually full, and the volume of water sent down by the creek is often a serious strain upon the capacity of the canals. If this flow could be stored in the lower foothills by means of reservoirs the water could be used for the irrigation of some of the soils in the vicinity of Academy and westward.

Fresno Slough affords a supply of water for the lands in the western part of the area. As this watercourse occupies the lowest part of the area, it not only receives the water which comes down the various channels of Kings River, but also more or less from the sloughs and canals in the Kings River Delta country lying to the south, and it is only in exceptionally dry years that the supply of water is insufficient. A number of canals have been constructed along this slough, but there is only one within the area. This is located in one of the large holdings in the western part of the area.

Under existing conditions the area in Fresno County irrigated by the gravity canals has practically reached its maximum development, and further extension must come either by the storage of the flood waters of the streams or by the development of a supply of underground water. Although it is by no means impossible to augment greatly the supply of surface water by the construction of storage works on the streams in and adjacent to the area, the difficulties, which are principally of a legal nature, are so great that there is but little chance that there will be any development along this line for many years. There is no doubt as to the immense volume of water which underlies the surface soils of the area. The area that may be irrigated practically from this source depends upon the depth to the water, and the nature of the soil. It is generally held that with a lift of 50 feet or less all the crops grown in this area, with the exception of grain, may be profitably irrigated by pumping, but when the lift goes beyond that figure the cost of pumping increases rapidly and only very remunerative crops will justify the expense.

In the northeastern part of the area, north, east, and west of Clovis, the level of the ground water is about 80 feet below the surface, and sometimes deeper, and the development of pumping plants in this section will be confined to soils adapted to citrus fruits or products of similarly high market value, and to restricted areas where the ground water is somewhat closer to the surface. It is possible that in that part of the area between Clovis and the line of the Santa Fe Railroad there will be a gradual rise in the level of the ground water within the next few years, and should this occur there is considerable idle land that could be profitably developed.

Along the line of the foothills and in the small foothill valleys the ground water is usually at considerable depths, and, with minor exceptions, the pumping of water for these soils will only be justified

by the returns commonly received from citrus fruits or other products of high value.

Throughout the remainder of the area the ground water is close to the surface, and its use is increasing rapidly, as alfalfa and all fruits can be easily irrigated from this source. In the developed portions of the area, where the canals have inferior water rights and there is not sufficient water during the summer and fall months, there is an increasing use of the subsoil water to make up the shortage and insure the maximum returns from the crops.

Particularly rapid progress in the sinking of wells and the installation of pumping plants is taking place in the vicinity of Ormus and Caruthers, where there is either a lack of gravity-distributed water, or else a supply too small and irregular to be of much value. This is being remedied by pumping, and as the lift is seldom over 35 feet the condition which controls the ultimate extension of this method is the extent of alkali-free soil. A study of the alkali map shows that Ormus lies near the southern and eastern boundaries of a vast body of alkali soil, which extends southward for several miles, with traces of alkali as far east as Caruthers. Under the alkali, hardpan, and topographic conditions existing in this belt of country all of the land which contains 400 parts per 100,000 or more of alkali is unsuited for cultivation and irrigation, and much of the soil which carries between 200 and 400 parts of alkali per 100,000 or more of dry soil is nearly as undesirable. The extension of the area irrigated by pumping too far in this direction is certain to result in loss and disappointment to those attempting it.

Along the trough of the valley there is a belt of country of varying width underlain by a body of artesian water, where a number of wells have been developed. The eastern limit of this belt practically coincides with the line of the Hanford Branch of the Southern Pacific, while the western boundary lies some distance west of the axis of the valley. In the southern part of the area the depth of the wells is about 1,000 feet, while farther north flows have been obtained at depths ranging from 500 to 800 feet. Up to the present time these wells have been bored to secure a supply of water for stock, and owing to their cost, the uncertainty as to the flow that may be secured, the alkalinity of much of the soil in that part of the area, and the quantity of soluble mineral material carried by the water it is not likely that they will ever be much of a factor in the irrigation of the soils of the area.

The waters flowing from the slopes of the Sierra Nevada Mountains and in the channels of the Kings and the San Joaquin Rivers are of exceptional purity, as they are derived from melting snow, come from a region of excellent drainage, and have no opportunity of taking up large quantities of dissolved salts. These waters seldom

carry more than eight parts of dissolved material in 100,000 parts of water, and when the flow in the streams is near the maximum the proportion is still less.

In Fresno Slough the water is good, but the amount of salts is somewhat larger than that carried by the waters of Kings River.

The immediate surface water in this area usually carries rather large quantities of dissolved material (sometimes more than 190 parts in 100,000 parts of water) and is seldom used for irrigation. To overcome this the wells are sunk with a casing to depths of 75 to 125 feet. The casing is seated in a stratum of bluish clay, which is usually encountered within these depths, and the drill run through into the underlying soil. The water then rises to within 20 to 40 feet of the surface and is of very good quality for irrigation purposes.

Much of the artesian water carries a little more than 100 parts of dissolved salts. While such water could be safely used on soils that were well drained and free from alkali, its use on other soils might be dangerous. In that part of the area adjacent to Fresno Slough, where the quantity of alkali in the soil is very small, a good supply of artesian water would be a valuable asset.

As a result of past troubles over the water-right question, the canal systems have been consolidated, so that at the present time there are practically only two diversions of water for the irrigation of the soil of this area, and these diversions are managed by one corporation. East of Kings River the irrigable lands are covered by the "76" Canal and its branches. On the north bank of Kings River the principal diversions are the Fresno and the Consolidated Canals, which divert water some little distance above Centerville, and by a network of canals cover practically all of the irrigated lands westward to beyond Kerman and from a short distance north of Clovis southward to the Kings River Delta country. The canal system which covers the larger part of the delta country is controlled by the same corporation. The remainder of the land is served by a number of small ditches which take water from Murphy Slough.

An attempt was made at one time to divert water from the San Joaquin River to irrigate lands in the northern part of the area by the construction of a dam in the river at a point near Friant and a line of canal along the river bluffs to near Herndon, but legal and engineering troubles caused the abandonment of the project.

The Fresno and Consolidated systems own no land, and the right to the use of the canal water has been perfected by the sale of water rights to those who desired the use of the water. The water right is based on a flow of one second-foot of water to every 160 acres, but in practice the right is for a proportionate flow of the canal. So-called second-class water rights are sold, but the purchasers of these

are not given a definite quantity of water but only the use of water not taken out by the holders of first-class rights.

The cost of a water right under the Fresno system is \$10 an acre, and under the Consolidated system it is \$4 an acre. These rights are sold for specified tracts of land and are transferrable only when the owner relinquishes his right, when it may again be sold by the canal company. By a provision of the State law the annual charge for the water is determined by the board of supervisors of the county. At the present time the cost under the Fresno system is 62½ cents an acre per year and under the Consolidated system 75 cents an acre. A large part of the water carried by these systems is sold to the owners of party ditches which have been constructed by the farmers, and the maintenance of the canals and the distribution of the water is controlled by them.

The "76" Canal, which has a diversion on the south bank of the Kings River a short distance above the intake of the Fresno system, was constructed in 1882 to cover the lands in this and other counties to the south. The water rights of this canal are subject to a number of priorities, with the result that there is seldom any water available for it after the 1st of July, so that it is dry at a time when water is badly needed.

During the earlier development of irrigation in this area the check system was the approved method of applying water to all crops except vegetables, but for all crops except alfalfa this has been superseded to a large extent by the furrow system, the advantages of which are many. Both rectangular and contour checks are used in this area, depending upon the regularity of the surface of the soil. The former method is to be recommended, even if the cost of preparing the land is more than it would be for the latter method. The rectangular checks are more easily kept in repair, irrigation is facilitated, cutting and removing the crop is less troublesome, and the disking of the field can be more thoroughly done and with less damage to the ridges. The usual size of the checks in this area is about one-fourth of an acre, the size varying somewhat according to individual ideas, nature of the soil, and the size of the irrigation stream. The cost of leveling and checking the land, including boxes in the lateral ditches, varies with the nature of the surface of the soil from \$5 to \$35 an acre. For furrow irrigation the surface of the soil is not usually so carefully leveled, as it is only necessary to secure a fairly uniform slope in one direction, and the average cost is somewhat less than for the check system.

Alfalfa is usually irrigated once in the spring, once after each cutting, and once in the fall before the rains have set in, making from five to seven irrigations a year. This practice is followed when there is a supply of water available throughout the summer. In case there

is a shortage the yields suffer accordingly. A few of the growers irrigate a short time before cutting the crop, claiming that there is less danger of scalding the crowns of the plants than by the other method. Fruits and vines receive from one to six or seven applications of water, depending principally upon the supply of water and the drainage of the soil. Where water is available the usual number of irrigations is about four. In some portions of the area, where the level of the ground water is high, a heavy irrigation is given in the spring, and during the remainder of the season the underground water is counted on to supply the needs of the plants.

#### DRAINAGE.

Prior to the development of irrigation in this area the surface waters stood at a depth of 50 feet or more under all of the land, excepting in the extreme west and southwest, where the level of the streams was close to the surface and the natural drainage very poor. Water for domestic purposes was obtainable in the vicinity of Fresno only at a depth of 60 feet or more, east of Fresno at a depth of 50 to 100 feet, and in the vicinity of the towns south of Fresno at 30 to 80 feet below the surface. These levels varied somewhat from season to season, depending upon the volume of the water in Kings River.

The source of this body of subterranean water was the surface streams, and it represented that portion of the flow which percolated downward through the sand and gravel of the stream beds. Once in the soil substratum its movement was along the lines of the country drainage, and, although this movement was slow, the fall of the valley was sufficient to prevent an undue accumulation of water, except in the sections noted. The spreading of the enormous volume of water over the surface of the soil year after year following the development of the irrigation systems threw a burden upon the regional drainage facilities which could not be handled and the level of the ground water moved steadily nearer the surface.

Although some irrigation was practiced in this area as early as 1865 it was not until about 10 years later that the irrigation of the plains became general. Within the next five or six years a pronounced rise in the level of the underground water became noticeable, not only by the rise of the water in the wells but by its appearance in the early summer at the bottom of many of the deeper depressions, where it remained until after the water had been shut out of the canals in the fall. Each succeeding year saw a steady rise in the level of the ground water and an increase in the number of intermittent ponds. Vines and fruit trees began to show signs of distress, salt grass—associated with alkali—made its appearance and alkali crusts

appeared in various parts of the area. Conditions grew worse with each year and finally thousands of acres of highly productive land, once intensively cultivated to orchards and vineyards, were abandoned to Bermuda and salt grass, affording scanty pasturage for dairy cattle. (Pl. II, fig. 2.) During the irrigating season the level of the underground water in such areas fluctuates between 2 and 3 feet below the surface, or less, and after the close of the irrigating season it drops to 6 to 10 feet below the surface.

The close approach of the ground water to the surface was first noticeable in the belt country lying between Fresno and Easton and extending from Malaga westward into the extensive alkali flat in the vicinity of McMullin, and it is in this belt that the greatest damage has resulted. As the water continued to rise the extent of this body increased and intermittent ponds made their appearance over the entire southern half of the area. Within the last 8 or 10 years the rise in the water table to a dangerous level has manifested itself in various parts of the area east of Fresno.

Reference to both the soil and alkali maps accompanying this report will give a very fair idea of the extent of soil which has suffered from the rise of the water table. Upon the soil map there is indicated by swamp symbols occurrences of standing water or where water stands above the surface for a part of each year, while on the total alkali map the extent of soil damaged by an excess of soluble salts is indicated by colors. Excluding all of the land west of the Hanford Branch of the Southern Pacific Railroad which has always been alkaline and not under cultivation, the area of soil which is now damaged by a high water table includes all portions where there is any alkali present and where the swamp symbols appear upon the soil map.

With regard to the older irrigated portions of the area it is a significant fact that the territory damaged by the high water table has increased but little since 1900, when the first survey was made around Fresno. This would indicate that at that time the level of the water had reached its maximum height and that a natural balance has been established between the subsoil drainage and the surface of the subsoil water, so that the fall in the level of the water each winter is sufficient to make room for the excess of water which will be poured onto the land during the next season.

In the northern and more recently developed part of the area the conditions are not stable and, in the absence of any artificial drainage, will in the future depend upon the extent of country irrigated and the quantity of irrigation water available. From Fancher Creek westward to about 3 miles west of the main line of the Southern Pacific Railroad the fall of the surface of the land is more pronounced than it is west of the latter point, and the movement of any surplus water

in the soil will be relatively rapid. West of here the subsoil drainage is not so good, and since the settlement and irrigation of lands north and east of Kerman there has been a gradual rise in the level of the underground water. The damage at the present time is hardly evident by surface indications, but unless some remedy is applied the water will continue to rise and the unproductive conditions which have arisen in the irrigated sections south of Fresno will be repeated in this section.

The importance of the removal of this excess of subsoil water and the prevention of its rise in heretofore unaffected sections of the county is generally appreciated, but up to the present time there has been no progress made in the actual development of a project to accomplish this. Attempts have been made, from time to time, to organize a drainage district for the reclamation of these lands, but such attempts have been fruitless, mainly on account of difficulty in perfecting the organization of a large number of small land holders. In order to demonstrate the feasibility of the project, steps were taken several years ago by the Fresno Chamber of Commerce to prove that such lands could be profitably reclaimed and brought back to their former state of fertility. The work was finally taken over by the Bureau of Soils. The principal idea was to demonstrate that alkali could be removed by the use of tile drains, but as a high water table and the presence of alkali in the soil are concurrent in this area, the one demonstration served for the correction of both evils. A tract of land was tiled and drained and the soil brought into excellent condition. At a somewhat later date the Office of Experiment Stations of this department conducted drainage demonstrations upon two tracts of land south of the city of Fresno and the results confirmed and strengthened those obtained by the Bureau of Soils.<sup>1</sup>

No further field operations have followed these demonstrations, but a tentative drainage district has been outlined which embraces over 200,000 acres in the country around Fresno. The cost of reclaiming this land has been roughly estimated at about \$10 an acre, and even were the final cost twice that amount it would be very small compared with the returns from the land and the increased valuation of the property.

In a few places in the area more or less successful attempts have been made by individual land owners to keep down the level of the underground water, either by the installation of tile drains or the construction of open ditches, but the lack of drainage outlets will deter any extensive area from being reclaimed in this way.

In the section north, east, and west of Kerman steps are being taken to protect the land from the encroachment of the ground water by the

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<sup>1</sup> Bul. No. 42, Bureau of Soils, U. S. Department of Agriculture; Bul. No. 217, Office of Experiment Stations, U. S. Department of Agriculture.

development of a series of wells and pumping plants, by means of which it is proposed to pump the water into flumes and convey it into the San Joaquin River.

#### SUMMARY.

The Fresno area embraces 1,356 square miles, or 867,840 acres, and includes practically all of the agriculturally developed portions of Fresno County. The portion of the county surveyed includes all of the region extending from the axis of the valley eastward to and including some of the lower slopes of the foothills of the Sierra Nevada Mountains.

The surface of the area slopes to the southwest and with the exception of a number of rocky elevations in the eastern part the slope is usually gentle.

Fresno is the principal city and the county seat of Fresno County. Other towns are Fowler, Selma, Kingsburg, Reedley, Sanger, Kerman, Clovis, Ormus, and Caruthers.

The climate is arid, the annual rainfall being in the neighborhood of 9 inches. The larger part of the rain falls between November and February and during the rest of the year the precipitation is usually so small as to be of little aid to crops. The winters are moderate, the minimum temperature seldom going below 30° F., and the summers are hot, there being on an average about three months when the temperature rises above 90° F., and from May to October temperatures above 100° F. are to be expected. The low relative humidity renders the heat less noticeable than in many sections having lower temperatures and materially assists in the drying of the various fruits. Winds do no damage to crops, snow is almost unknown, and thunderstorms and hail very rare.

A wide variety of deciduous fruits and grapes thrive in this area under irrigation and are extensively planted. Fresno County produces over 60 per cent of the raisins produced in the State of California. Peaches are the principal deciduous fruit, followed by apricots, plums, prunes, almonds, and figs. The olive is also an important product. Alfalfa does well on the majority of the soils and the acreage is steadily increasing. Small fruits and truck crops are produced in considerable quantities, but there are opportunities for planting more of these. Citrus fruits are grown to a limited extent along the foothills and there is a considerable area of soil that is well adapted to these fruits.

The utilization of the area covered by the irrigation systems of the county is nearly complete and the future extension of the planted area depends upon the utilization of the subsoil water by means of wells and pumping plants. Such development is going on in a number of places in the area.

The soils vary widely in origin, color, texture, and adaptation to crops, but except where unfavorable alkali conditions exist the majority of them are well adapted to some of the crops which flourish under the existing climatic conditions.

The water for the irrigation of the soil is derived from the flow of Kings River. The San Joaquin River, which borders the county on the north, supplies no water to the soils of this area excepting to a small area in the northwestern part of the survey. The flow of Kings River is not sufficient for the existing water rights and any further increase in the supply of this stream can only come through the storage of the flood waters. Legal difficulties prevent the use of water from the San Joaquin River.

A large percentage of the soils contain too much alkali to be of much value for cultivated crops. The amount of alkali has apparently not increased within recent years and with the exception of a portion of the area now undergoing development there is little cause to fear the appearance of alkali in soils which are now free from it.

The level of the ground water is dangerously high in a larger part of the area and is still rising in some portions of the irrigated sections. Drainage would remove this danger and aid in the removal of the alkali, but no concerted movement has been made for the correction of these evils.



[PUBLIC RESOLUTION—No 9.]

JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled,* That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided,* That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]

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