HILGARDIA

A Journal of Agricultural Science Published by the California Agricultural Experiment Station

VOLUME 33 NOVEMBER, 1962 NUMBER 5

A SOIL-DRAINAGE STUDY IN SOUTHWESTERN FRESNO COUNTY

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This study describes the conditions associated with a developing drainage problem in southwestern Fresno County, where irrigation water is to be furnished from the joint state and federal San Luis Project.

In a 7½-square-mile study area southeast of the town of Cantua Creek, where no drainage problem has been suspected until recently, a semiperched water table has risen into the crop-root zone. This water is perched on an extensive layer of heavy-textured sediments 100 feet below ground surface. The thickness and limited permeability of this layer have resulted in the accumulation of considerable depths of perched water. The perched water in the study area is part of a groundwater ridge that extends at least 10 miles south of that area and is maintained by deep percolation from irrigation, even though irrigation has been greatly limited by dwindling groundwater supplies. The soluble-salt content of this water has built up the salinity of the surface soils where the water table has risen into the root zone.

Scattered stratigraphic and water-table observations indicate that similar drainage problems could develop over a broad area of southwestern Fresno County when irrigation is intensified with imported water.

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A SOIL-DRAINAGE STUDY IN SOUTHWESTERN FRESNO COUNTY[1]

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SOIL DRAINAGE is not at present considered a problem in southwestern Fresno County. Current rates of use are depleting the groundwater that supplies this region, and the acreage of irrigated crops is limited.

Surface water from the joint state and federal San Luis Project will supply this region in the near future and will lead to a more intensive irrigated agriculture and an increased acreage of irrigated field crops. The present study gives a preliminary indication of the changes in soil-drainage conditions that can be expected to ensue.

REGION STUDIED

The region, of which the study area is a representative part, is shown in figure 1. Irrigation water is pumped from two distinct aquifer zones, separated by a 30- to 50-foot-thick bed of diatomaceous clay 500 to 700 feet below the ground surface. The lower, confined aquifer is the major source of irrigation water pumped, and wells more than 2,000 feet deep, with 400-foot pumping lifts, are common. The semiconfined portion of the upper zone, just above the clay layer, is utilized in the vicinity of Five Points, but in most of the region very few wells are perforated above the diatomaceous clay.

Water is distributed from pump to field in unlined ditches; furrow and border irrigation methods predominate. However, the cost of deep wells, pumping plants, power, and maintenance has justified large capital outlays by farm operators for sprinkler equipment, to irrigate more efficiently in fields previously graded for surface irrigation.

Above the thick bed of clay that separates the deep aquifers, there are heavy-textured perching layers of varying thicknesses, about 100 feet below the ground surface. Under conditions described below, a mound of groundwater perched on any of these shallow layers may produce a very high water table.

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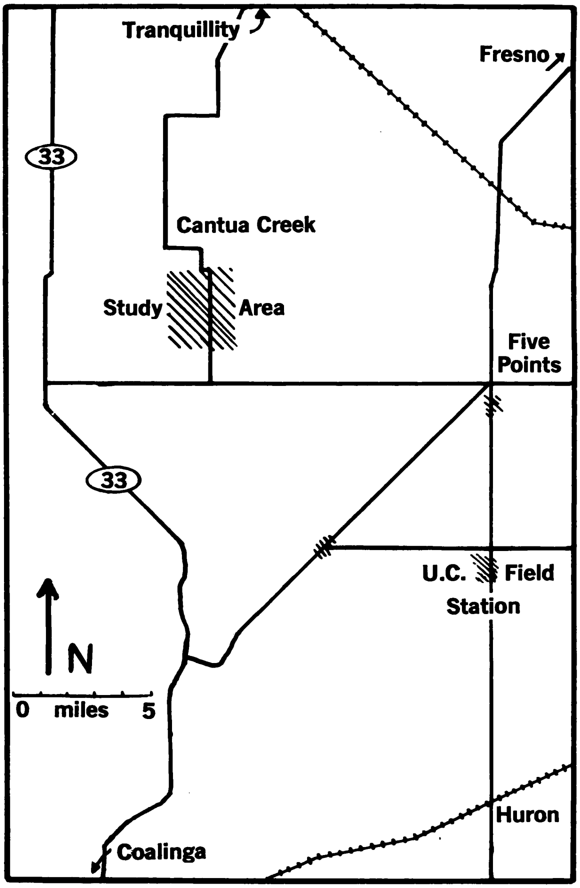

Fig. 1. General map of southwestern Fresno County, showing observation areas (shaded).

Experimental Area. Detailed water-table observations were made in an area of 7½ square miles in sections 4, 5, 6, 7, 8, 9, 16, 17, and 18 of Township 17 South, Range 16 East, just south and east of the town of Cantua Creek. This study area is part of the alluvial fan of Cantua Creek. The parent materials, chiefly fine-grained sedimentary deposits of the Coast Range, have produced surface soils of the Panoche series, uniform in texture and ranging from sandy loams to silty clays. Here the fan has an average slope of 18 feet per mile. The soil profiles are deep and permeable. Soils in the Five Points and Huron areas are similar and are also classed as recent alluvial-fan and flood-plain soils (Harradine, 1950).

Cotton is the primary row crop irrigated in the region, but cantaloupe and sugar beets have appeared in rotations. Either barley or safflower follows cotton. Both require preirrigation and usually an additional irrigation later in the season. A field is generally left fallow the third year.

FIELD METHODS AND OBSERVATIONS

The Cantua Creek study area was gridded with piezometers, distributed as shown in figure 2. The jetting method of installation (Pillsbury and Christiansen, 1947) utilizes a high-pressure stream of water directed through a ⅜-inch pipe. The pipe is forced into the soil as the water washes a hole ahead of it. The materials washed from the hole, the amount of circulation, and the

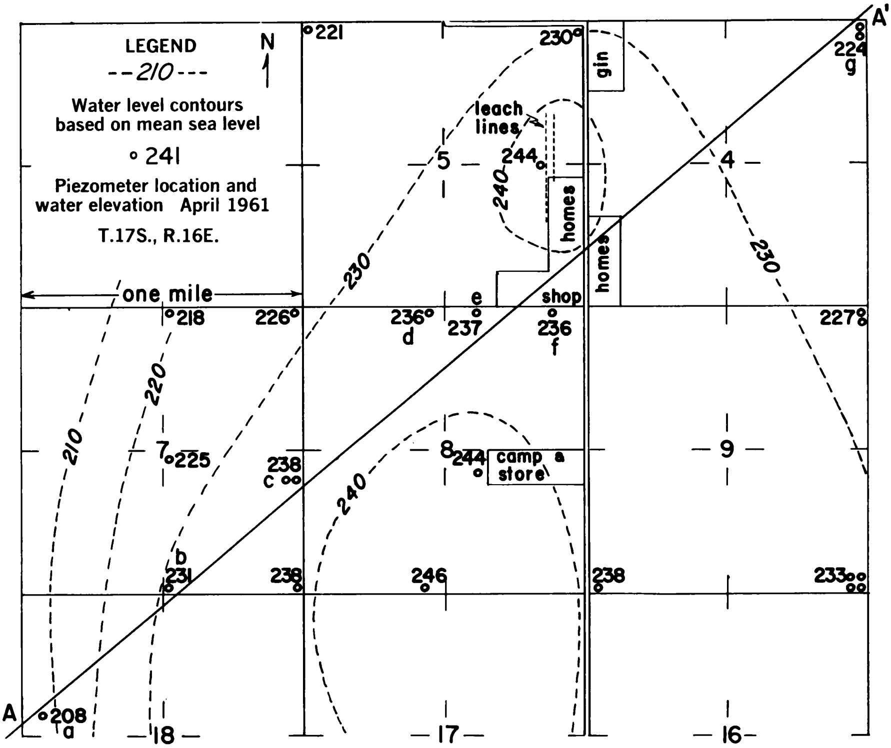

Fig. 2. Map of the study area near Cantua Creek, showing water-level contours and piezometer locations.

force required to puncture soil layers indicate the gross characteristics of the soil profile. When equilibrium is reached, the elevation of water in the pipe shows the static head in the water table at the lower end of the pipe. To assure equilibrium at the time of reading, two or three days were allowed after installation. Readings of the water levels in these piezometers were taken over a two-month period, starting in April, 1961.

Groundwater Mound. The contours in figure 2, plotted from piezometer readings made in April, 1961, show the elevation above sea level of the water table in the study area. A cross section (fig. 3) along line A–A′ in figure 2 shows the relation of the water table to the ground surface. The breadth and flatness of the mound suggest that the major source of recharge water is not localized. However, seepage from the septic-tank leach lines has caused

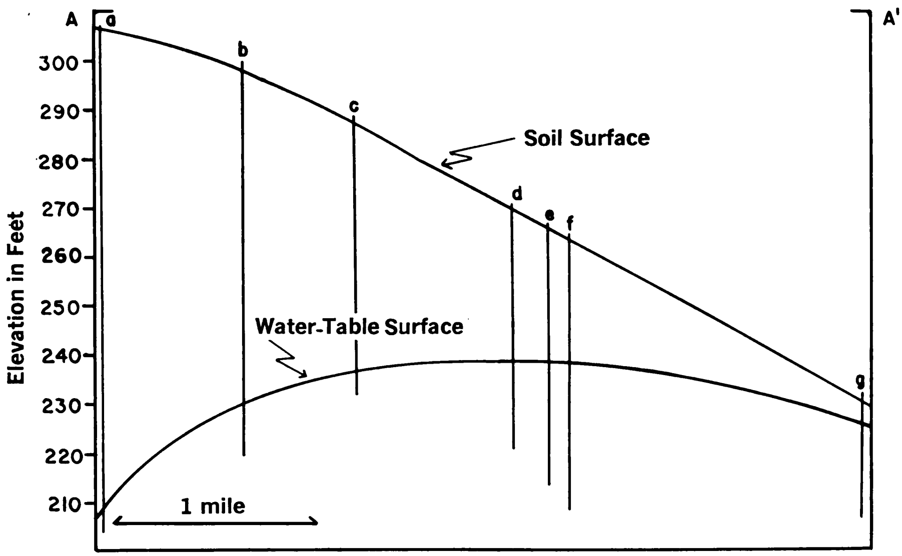

Fig. 3. Cross section along line A–A′ of figure 2, showing the depth of the groundwater mound in the study area.

higher contours, which close in locally around the homes and the labor camp.

Scattered piezometer readings extending 10 miles south of the study area show that contours 210 to 230 (fig. 2) do not close and that the mound is part of a groundwater ridge extending at least 10 miles to the south.

Vertical Movement of Water. Paired piezometers, one 40 feet deeper in the water table than the other, showed vertical movement of water. A pair of piezometers was located at point *c* in section 7, another at point *g* in section 4, and a third in the northeast corner of section 9. In each pair, a downward gradient of 0.2 to 0.3 foot through the upper 40 feet of the saturated profile indicated a small vertical leakage through a deeper layer.

Perching Layer. Readings (table 1) from a group of four piezometers set

TABLE 1

DATA FROM DEEP PIEZOMETERS IN SECTION 9*

Depth	Water elevation†	Head loss between depths‡
feet	*feet*	*feet*
21	232.51	
		0.05
63	232.46	
		12.66
136	219.80	
		6.22
200	213.58	

* Ground-surface elevation 241.43 feet above mean sea level. Depth to water 8.97 feet.

† Average of seven observations, May 19, 1961, to June 27, 1962.

‡ These values are of only qualitative significance, as the jetting method influences head measurements where vertical gradients are of this magnitude.

at different depths in the southeast corner of section 9 showed a sharp head loss between the 63-foot and the 136-foot levels. This part of the profile contains a 30-foot layer of heavy-textured sediments, extending from a depth of 90 feet to 120 feet, which limits vertical movement and results in the semiperched water table.

The perching layer becomes discontinuous on the west side of the study area, where the water table drops sharply (profile at *a* in fig. 3). A test hole drilled at point *a* in section 18 showed that the 100-foot-deep perching layer is only 2 to 3 feet thick in that area. Increased leakage through the limiting

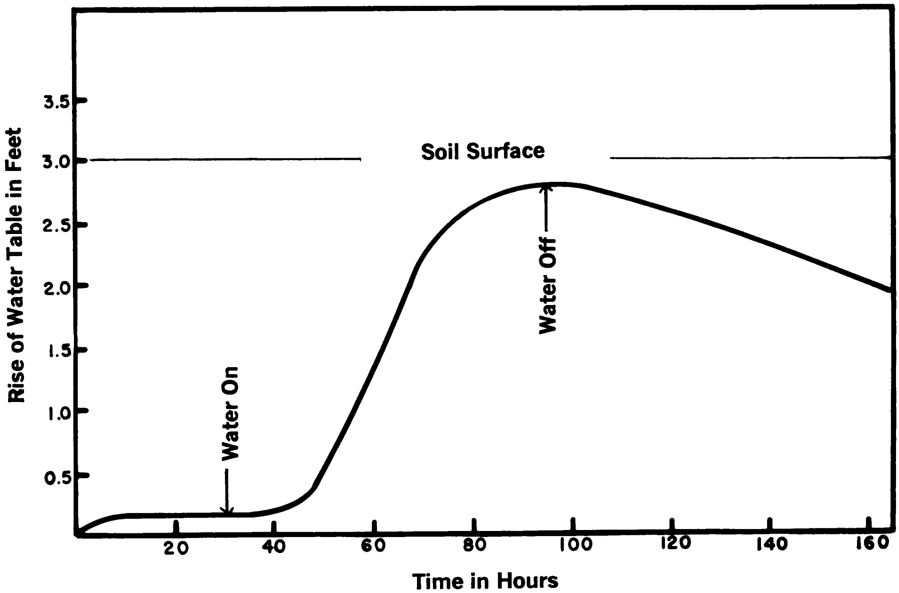

Fig. 4. Fluctuations in high water table caused by irrigation of cotton.

layer as it thins out toward the edge increases both the horizontal flow in the mound and the horizontal head loss.

Overirrigation. To measure the effects of overirrigation, a 6-inch-diameter observation well with a water-stage recorder was established in a cotton field in section 4 near piezometer *g*, where the water table was 3 feet from the ground surface. Figure 4 is the graph made by the recorder during the week of the first postemergence furrow irrigation. The first part of the curve shows the newly dug well coming into equilibrium with the water table. Irrigation was started at 30 hours, and the water table began to rise at 40 hours. Enough water was applied to saturate about 3 feet of the soil profile. At 95 hours, when the water table came to within 0.4 foot of the soil surface, irrigation water was shut off and the water table began to decline. Water in excess of field capacity was dissipated to the groundwater mound.[5] As the season pro-

[5] Hydraulic conductivity of the surface soil on the plot, measured by the auger-hole method, was 2.0 to 2.5 ft/day. This is comparable to values for the Panoche series in the Mendota-Firebaugh area (Johnston and Pillsbury, 1961).

TABLE 2

CHEMICAL ANALYSIS OF WATER SAMPLES FROM THE STUDY AREA

Location	Depth to water	Constituent ions										pH	Electrical conductivity
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$SO_4^{=}$	Cl^{-}	$CO_3^{=}$	HCO_3^{-}	NO_3^{-}	Boron		EC × 10^3
	feet	*meq/liter*									*ppm*		*mmhos/cm*
g, Sec. 4	3	7.94	3.64	29.2	0.16	28.0	5.66	0	7.40	1.12	3.45	7.80	3.48
c, Sec. 7	48	18.3	12.38	14.5	0.11	41.1	2.86	0	2.27	0.41	1.45	7.97	3.26
a, Sec. 18	98	15.0	19.25	14.2	0.77	32.3	6.85	0	9.20	0.80	0.96	7.90	3.63
Irrigation well No. 3, Sec. 4		1.38	0.16	8.51	0.10	7.22	1.46	0	1.58	0.0	1.40	8.45	1.10

gressed and the cotton root systems developed, the plants used more of the soil moisture between irrigations; irrigation efficiency increased and the response of the water table to irrigation diminished.

Seepage from unlined field-distribution ditches also contributes to the maintenance of the water table. Where the water table was no deeper than 30 or 40 feet, there was a correlation between the heads in piezometers and the presence of water in the ditches.

Salinity of Soil and Water. A chemical analysis of water samples from the perched water table is shown in table 2. Considering field variability, the data on chloride concentration and on electrical conductivity indicate some homogeneity in salt concentration. The higher level of sodium in the shallow water table in section 4 reflects accumulations from the irrigation water obtained from well 3. The water of the groundwater mound is of such high salinity that reuse of any drainage water would require dilution with water of much lower salt concentration.

Analyses of surface soils in the study area show salt accumulation where the water table has risen into the root zone. Soil samples were taken from two different locations: (1) near piezometer *g* in the cotton field in section 4, where the recorder-well showed water-table fluctuations from the surface to a depth of 5 feet, and (2) near piezometer *a* in section 18, where drainage has not been restricted and the water table is nearly 100 feet below the ground surface. Near point *g*, six samples—each a composite from the surface to a depth of 20 inches—had an average saturated-extract conductivity ($EC_e \times 10^3$) of 3.64 mmhos/cm (range 3.33 to 6.02) and an average sodium-absorption ratio (SAR) of 15.8 (range 15.5 to 16.3). On the other hand, near piezometer *a*, nine composite samples from the same depths had an average conductivity of 1.31 mmhos/cm (range 0.93 to 2.06) and an average SAR value of 10.2 (range 9.21 to 11.8). The average soluble-salt content in the top 20 inches of soil is now 0.26 per cent near point *g*, where surface soils and subsoils had less than 0.20 per cent before 1943 (Harradine, 1950). At *a* the salinity has not increased, and the soluble-salt content is 0.09 per cent.

DISCUSSION

Extensive perching layers within 90 to 150 feet of the ground surface are characteristic of the sedimentation that has occurred in southwestern Fresno County. Scattered observations (see shaded areas in fig. 1) showed a perched water table 6 feet below ground surface near Five Points, 25 to 35 feet at the University of California West Side Field Station, and 38 to 42 feet 5 miles west of the Field Station. In the vicinity of Huron there is an intermittent perched water table at 120 feet.

The water table in the Cantua Creek study area where soil-drainage problems exist is part of a groundwater ridge. The area of maximum overdraft from the deep, confined aquifers—the area most densely covered by pumping wells—coincides (Davis and Poland, 1957) with this groundwater ridge. The overdraft indicates a history of irrigation and attendant deep percolation, which has caused the rise of perched water tables. Data from the U.S. Geological Survey (Davis *et al.*, 1957) indicate that in 1952 the free water table in the study area and in the area five miles west of the Field Station was 30 to 40 feet below its current elevation. This significant change in water-table elevation can be attributed directly to deep percolation from overirrigation, for no other significant change has occurred recently in the water regime of the area.

At present, the portion of southwestern Fresno County affected by high water table is very small because deep percolation due to overirrigation is limited each year to one third of the area potentially available for row-crop irrigation. However, importation of water from the San Luis Project will expand the area of intensive irrigation at least two- to threefold. This will increase the quantity of deep percolation, the area of the perched water tables, and the areas where the water table rises into the root zone.

Efforts are being made to extend the limited water supply by a more general use of sprinklers. In the light of this study, it is important that the threat of drainage problems motivate further efforts toward maximizing irrigation efficiencies, especially after a firm supply of surface water reaches the region. If such action is taken, the areas requiring artificial drainage will be kept at a minimum.

ACKNOWLEDGMENTS

We are grateful to Mr. K. L. Dyer for the analyses of soils and of water quality and to Professor A. F. Pillsbury for his critical review of the work. The study was supported in part by the California State Department of Water Resources.

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4*m*-11,'62(D1857)JT 141

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