Estimated Permeabilities for Soils in the Sacramento Valley California

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May 1974

UNITED STATES DEPARTMENT OF THE INTERIOR

Rogers C. B. Morton, Secretary

GEOLOGICAL SURVEY

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ESTIMATED PERMEABILITIES FOR SOILS IN THE SACRAMENTO VALLEY, CALIFORNIA

By Gilbert L. Bertoldi

ABSTRACT

Analysis of engineering and hydrologic data from 15 previous soil studies, analysis of particle-size distribution, and analysis of descriptions of soil profiles show that 50 percent of the Sacramento Valley area has soils having permeabilities characterized by infiltration rates of less than 2 feet per day (0.6 meter per day). Consolidated barriers that could impede vertical flow were found in 30 percent of the area.

INTRODUCTION

Location and General Features

The Sacramento Valley is a broad structural trough occupying the northern one-third of the Great Central Valley of California (fig. 1). Boundaries for the valley are defined differently by several authors (Bryan, 1923; Olmsted and Davis, 1961; and Hinds, 1952). In this report, the boundaries are defined as the Sierra Nevada on the east, the Cascade Range on the northeast, the Coast Ranges on the west, Iron Canyon (north of Red Bluff) on the north, and a sinuous line formed by the Sacramento and Mokelumne Rivers on the south.

Within the valley, the most extensive physiographic features are: (1) The low alluvial plains and fans west of the Sierra Nevada, (2) the low alluvial plains and fans on the west side of the valley, (3) the dissected alluvial uplands west of the Sierra Nevada, (4) the low hills and dissected uplands, (5) flood basins, and (6) the river flood plains (Olmsted and Davis, 1961, pl. 1). The only prominent topographic feature on the valley floor is Sutter Buttes (fig. 2), a circular mass of intrusive volcanic rocks that is the erosional remnant of a volcano.

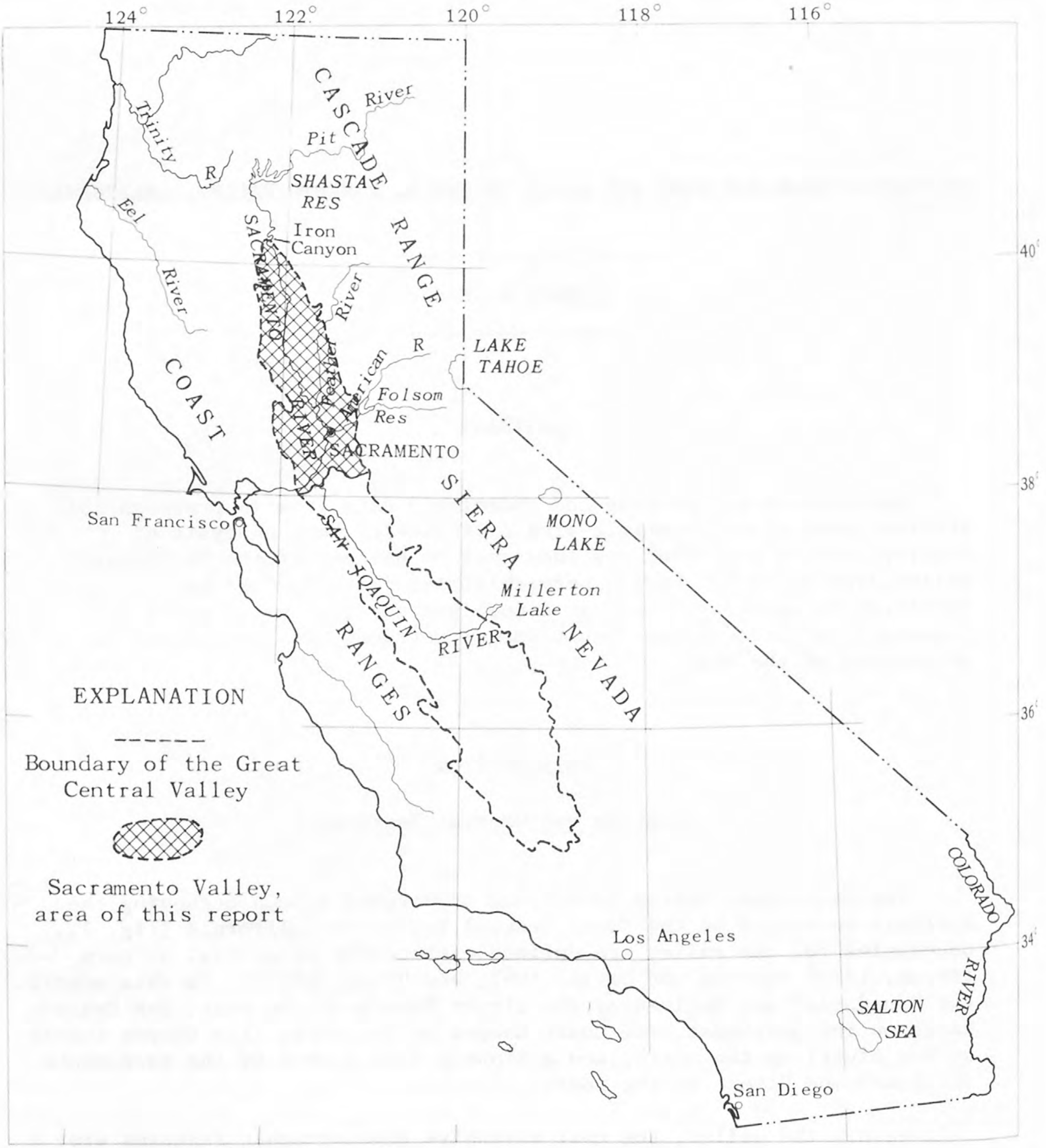

FIGURE 1.--Index map.

20 0 20 40 60 80 MILES
50 0 50 100 KILOMETERS

Purpose and Scope

The purpose of this study is to develop knowledge of a part of the hydrologic system of the Sacramento Valley. Data and conclusions from the study may be used to make water-resources management and planning decisions. At present (1973) maps and data from this project will be used to help conceptualize a digital model of the ground-water system in the Sacramento Valley being developed by R. M. Bloyd. Recharge and discharge areas and the relative magnitudes of recharge and discharge as shown in the model will be compared to the areal distribution of infiltration rates shown on maps from this study to determine if the model values are reasonable.

The scope of the study includes: (1) Preparing a soil permeability map of the Sacramento Valley, and (2) preparing a map of soils containing barriers or clays that may reduce the vertical flow of water.

METHOD OF STUDY AND RESULTS

Most of the data for this study were obtained from 15 published reports (all listed in the selected references) of the U.S. Department of Agriculture or the University of California Agricultural Extension Service.

In general, these reports consist of (1) a detailed description of the soil mapping units (soil series), (2) agricultural ratings of each series, (3) maps showing the areal distribution of each series, and (4) appendixes of physical and chemical properties of each series. Specific physical properties that were useful in this study were particle-size distribution, textural classification, shrink-swell potential, and permeability. In addition, most descriptions of the soil profile of a series indicated the presence or absence of hardpans, cemented alluvium, sandstone, or bedrock. Uniformity among the 15 reports was controlled by guidelines established in Handbook 18 (Soil Survey Staff, 1951).

The following terms are defined as used in this report.

Soil is the collection of natural bodies upon the Earth's surface in which plants grow. The thickness of soils considered herein is generally less than 15 feet (4.6 meters).[1/]

Soil consistence is a term that expresses, by degree and kind, cohesion, adhesion, and resistance to deformation of a soil mass (Soil Survey Staff, 1951).

Soil horizon (zone) is a layer of soil distinguishable from adjacent zones by distinct physical properties.

1/ To convert feet to meters, multiply feet by 0.3048.

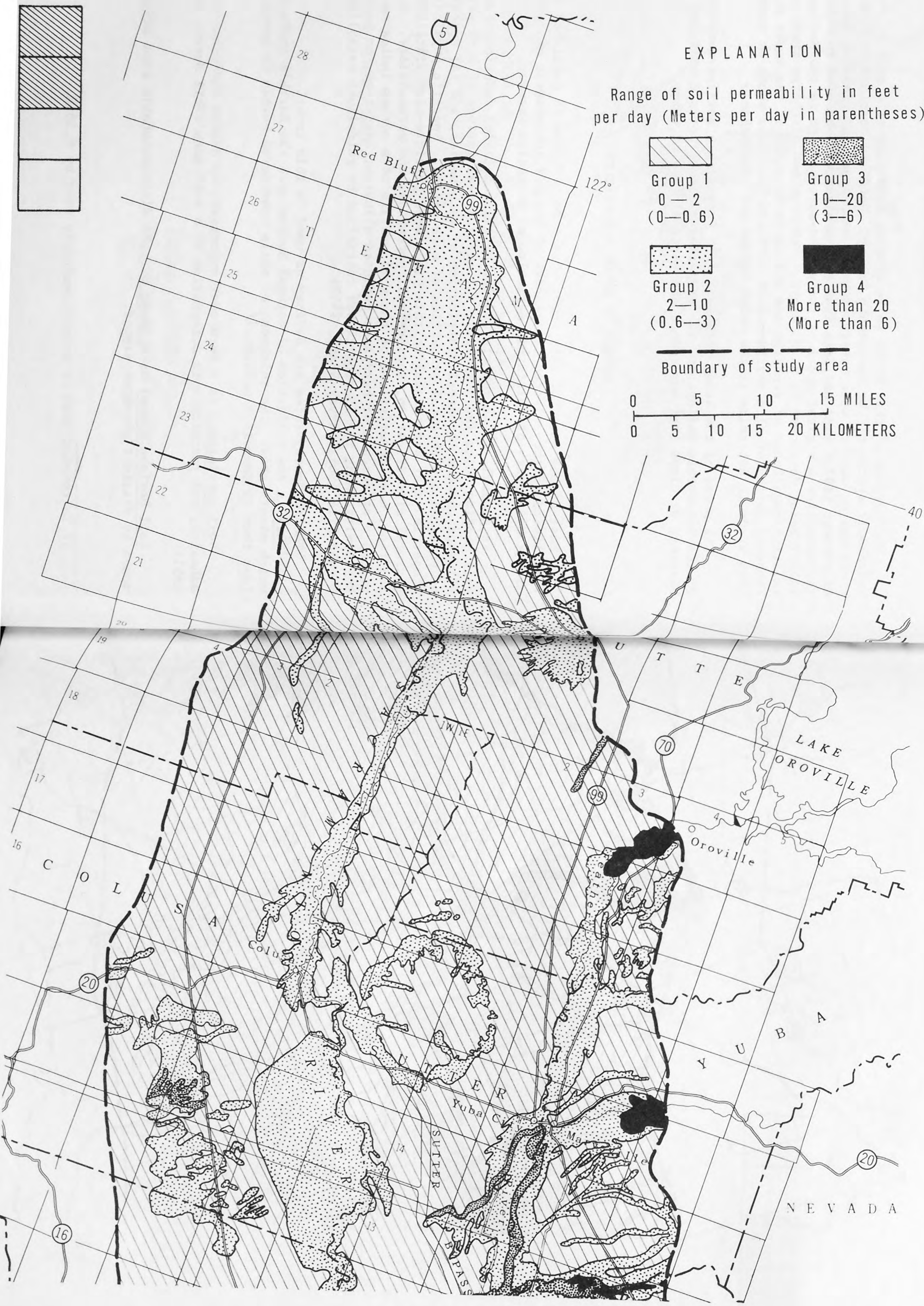

FIGURE 2.--continued on following pages

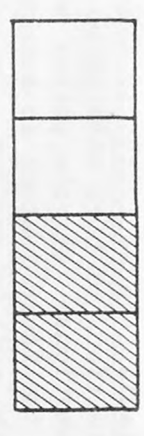

FIGURE 2.--Permeability of soils.

Soil permeability as here used is the quality of a soil that enables it to transmit water. In general the ease of root penetration may be used as a qualitative description of soil permeability. Quantitatively, a soil-permeability coefficient is measured in terms of rate of flow of water through a unit cross section of presaturated soil in unit time, under specified temperature and hydraulic conditions. Soil-permeability coefficients are reported in ft day^{-1} (feet per day) and m day^{-1} (meters per day). Another term that is frequently used in reports of the U.S. Geological Survey, hydraulic conductivity, is synonymous with soil permeability. Implicit in the definitions of both soil permeability and hydraulic conductivity are three assumptions: (1) the porous medium through which water is moving is isotropic, (2) the fluid (water) is homogeneous, and (3) saturated flow conditions exist in the soil or aquifer. Unfortunately these assumptions do not always prevail in soils under field conditions, yet most published permeability data for soils of Sacramento Valley were laboratory-determined using saturated-sample techniques. Therefore, the soil-permeability figures used in this report represent a maximum possible rate of infiltration under saturated soil conditions.

Soil profile is a vertical section of a soil displaying all its horizons (zones) and the material from which the soil was formed (parent material).

Soil series is the basic (most specific) unit in the taxonomy of soils. A series is made up of a soil or group of soils that has horizons (zones) of similar physical character and arrangement in the soil profile.

Soil structure is the aggregation of primary soil particles into compound particles, or clusters of primary particles, that are separated from adjacent aggregates by surfaces of weakness (Soil Survey Staff, 1951).

With the above definitions in mind, figure 2 was made in the following manner.

1. Estimates of hydraulic conductivity for each soil horizon in a soil profile representative of a soil series were made from published data.

2. Maximum and minimum hydraulic conductivity for the entire profile were computed according to a method given by De Wiest (1965, p. 231-233), using the following equations:

$$K_{max} = \frac{\Sigma_H K_h t_h}{\Sigma_H t_h}, \quad \text{and} \quad K_{min} = \frac{\Sigma_H t_h}{\Sigma_H \frac{t_h}{K_h}}$$

in which:

K_{max} is the maximum hydraulic conductivity for the entire profile (where flow is parallel to bedding),

K_{min} is the minimum hydraulic conductivity for the entire profile (where flow is across bedding),

Σ_H is the summation of the indicated arithmetic operation(s) over the entire profile,

K_h is the estimated hydraulic conductivity for a single horizon, and

t_h is the thickness of a single horizon corresponding to K_h.

3. A value for effective hydraulic conductivity for each soil profile (within the computed maximum-minimum range) was determined, depending upon the degree of profile development and substratum consistence and structure.

4. Using the value determined in (3) above, each soil series was assigned to a soil permeability group (table 1).

Table 1.--*Soil permeability groups*[1/]

Group	Range of permeability ft day^{-1}	Qualitative term[2/]
1	0- 2	Very slow, slow, moderately slow
2	2-10	Moderate, moderately rapid
3	10-20	Rapid
4	20	Very rapid

1. Modified after Soil Survey Staff (1951, p. 168).
2. Many soil scientists prefer to use qualitative terms, which are included here because many of the soil reports give qualitative terms only.

5. Areal distribution of soil permeability groups was plotted on published soil series maps and transferred to figure 2.

As a numerical example of how the method works, take the case of the Zamora Soil series profile, in Yolo County; described by Anderson (1972, p. 42 and table 5) as having the following engineering properties:

Horizon (zone)	Thickness (ft)	Range of hydraulic conductivities (ft day^{-1})	Average hydraulic conductivity (ft day^{-1})
A	0.83	1.26 - 4.00	2.60
B	1.50	.40 - 1.26	.80
C	1.67	1.26 - 4.00	2.60

Substituting the values above into the equations for K_{max} and K_{min}, the corresponding hydraulic conductivities are:

$$K_{max} = \frac{(2.60 \cdot 0.83)+(0.80 \cdot 2.50)+(2.60 \cdot 1.67)}{5} \simeq 1.70 \text{ ft day}^{-1} \text{ } (0.52 \text{ m day}^{-1})$$

and

$$K_{min} = \frac{5}{\left(\frac{0.83}{2.60}\right)+\left(\frac{2.50}{0.80}\right)+\left(\frac{1.67}{2.60}\right)} \simeq 1.22 \text{ ft day}^{-1} \text{ } (0.37 \text{ m day}^{-1}).$$

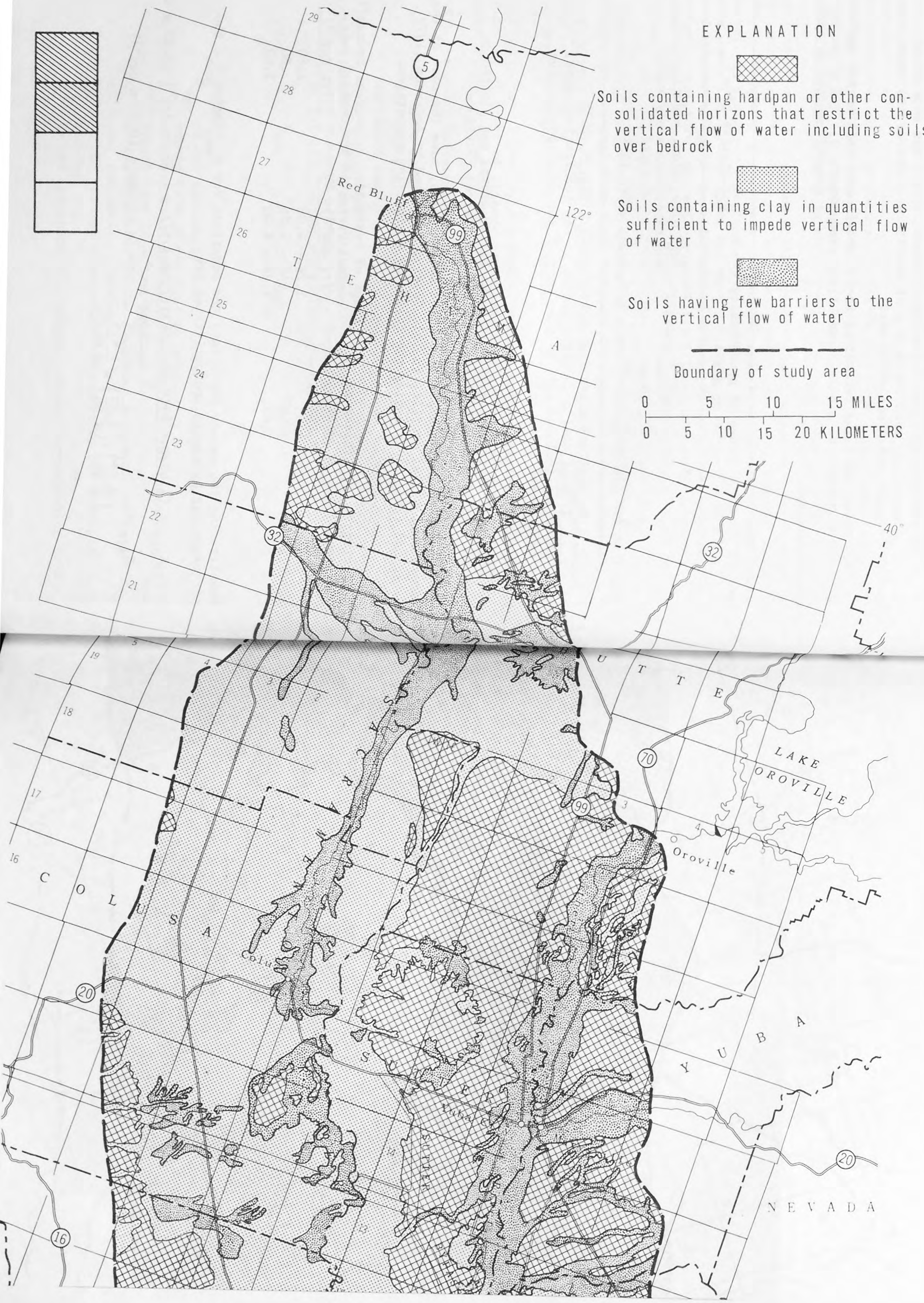

FIGURE 3.--continued on following pages

FIGURE 3.--Barriers to vertical flow of water in soils.

Because the computed range of hydraulic conductivities falls entirely within group I (table 1) soil permeabilities, no further adjustments need be made. If K_{max} had been (for illustration purposes) equal to 5.75 ft day^{-1} (1.75 m day^{-1}), then strong profile development (distinct differences and boundaries among the horizons), the stratified nature of the substratum, the presence of plastic varieties of clay, and a moderately large shrink-swell potential reduce the maximum calculated hydraulic conductivity. Considering these profile characteristics, the effective vertical hydraulic conductivity would be closer to the minimum calculated hydraulic conductivity, and the entire profile should be classified in group 1 (table 1).

Many of the coarser textured soils in the valley, such as the Tujunga Sand, and Sutter Sandy Loam, have little or no stratification or bedding and very weak profile development; therefore, the effective hydraulic conductivity was practically the same as K_{max}.

Figure 3 was made from information gathered to make figure 2. Figures 2 and 3 indicate that a rather small part of the study area has soils that are free from clay or barriers of some type. About 50 percent of the area is covered by soils with more than 2 ft day^{-1} (0.6 m day^{-1}) permeability. Soils having the highest permeability are found along streambeds, flood plains subject to frequent inundation, and recent alluvial fans where strong profile development has not had time to occur. In general the soils with greater permeability are also free of hardpan, claypan, or other cemented layers. Three exceptions to this are: (1) the group 2 soils of the dissected uplands and foothill areas where many of these rest directly on bedrock; (2) dredger tailings (group 4 permeability) along the Yuba and American Rivers that rest on hardpan soils; and (3) peat and muck soils (shown as group 4 soils in fig. 2) in southeastern Solano and southwestern Sacramento Counties. Typically peat and muck soils are 6 to 10 feet thick and have developed as the result of partly decomposed organic materials intermixing with sediments brought in by floodwater. Although very permeable and rather thick, they are underlain by shallow, flat basins that have poor drainage.

In the central part of the valley, mainly on the older alluvium (fans) and on the infrequently flooded part of river flood plains, soils containing large quantities of clay and silt (generally more than 40 percent of the total soil material) are found. These heavy soils locally contain hardpan. Thickness and depth of the hardpan horizon are highly variable. Cemented volcanic tuffs replace hardpans in many of the soils developed on the alluvial plains and fans west of the Cascade Range.

SELECTED REFERENCES

Anderson, W. F., 1972, Soil survey of Yolo County, California: U.S. Dept. Agriculture, 180 p.

Baldwin, Mark, Kellogg, C. E., and Thorp, James, 1938, Soil classification: Soils and men--U.S. Dept. Agriculture, Yearbook of Agriculture, 1938, p. 979-1001.

Begg, E. L., 1968, Soil survey--Glenn County, California: U.S. Dept. Agriculture, 198 p.

Bryan, Kirk, 1923, Geology and ground-water resources of Sacramento Valley, California: U.S. Geol. Survey Water-Supply Paper 495, 285 p.

Carpenter, E. J., and Cosby, S. W., 1930, Soil survey of the Suisun area, California: U.S. Dept. Agriculture soil ser. 1930, no. 18, 60 p.

Carpenter, E. J., Strahorn, A. T., Glassey, T. W., and Storie, R. E., 1930, Soil survey of the Oroville area, California: U.S. Dept. Agriculture soil ser. 1926, no. 4, 63 p.

Cole, R. C., Stromberg, L. K., Bartholomew, O. F., and Retzer, J. L., 1954, Soil survey of the Sacramento area: U.S. Dept. Agriculture soil ser. 1941, no. 11, 101 p.

Cosby, S. W., 1941, Soil survey--The Sacramento-San Joaquin Delta area, California: U.S. Dept. Agriculture soil ser. 1935, no. 21, 48 p.

Cosby, S. W., and Carpenter, E. J., 1933, Soil survey of the Dixon area, California: U.S. Dept. Agriculture soil ser. 1931, no. 7, 47 p.

Cosby, S. W., Watson, E. B., and Harper, W. G., 1928, Soil survey--Auburn area, California: U.S. Dept. Agriculture soil ser. 1924, no. 15, 38 p.

De Wiest, R. J. M., 1965, Geohydrology: New York, John Wiley and Sons, 366 p.

Gowens, K. D., 1967, Soil survey--Tehama County, California: U.S. Dept. Agriculture, 124 p.

Gowens, K. D., and Lindt, J. H., Jr., 1965, Reconnaissance soil survey of Sutter County: California Univ. Agricultural Ext. Service, 32 p.

Harradine, F. F., 1948, Soils of Colusa County: California Univ. Berkeley Experimental Sta., 140 p.

Herbert, F. W., Jr., and Begg, E. L., 1969, Soils of the Yuba area, California: Davis California Univ., Dept. Soils and Plant Nutrition, 170 p.

Hinds, N. E., 1952, Evolution of the California landscape: California Div. Mines Bull. 158, 240 p.

Holmes, L. C., and Nelson, J. W., 1915, Reconnaissance soil survey of the Sacramento Valley, California: U.S. Dept. Agriculture, 148 p.

Johnson, A. I., 1963, Application of laboratory permeability data: U.S. Geol. Survey open-file rept., 34 p.

Lohman, S. W., and others, 1972, Definitions of selected ground-water terms--revisions and conceptual refinements: U.S. Geol. Survey Water-Supply Paper 1988, 21 p.

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

Shetchley, H. R., 1965, Soil survey--Amador area, California: U.S. Dept. Agriculture soil ser. 1961, no. 26, 167 p.

Soil Survey Staff, 1951, Soil survey manual: U.S. Dept. Agriculture Handb. no. 18, 503 p.

Watson, E. B., Glassey, T. W., Storie, R. E., and Cosby, S. W., 1929, Soil survey of the Chico area, California: U.S. Dept. Agriculture soil ser. 1925, no. 4, 48 p.

APPENDIX

Soil Series Used in Study

Aiken
Alamo
Altamont
Amador
Anita
Antioch
Antone
Arbuckle
Artois
Auburn
Ayar
Bear Creek
Berrendos
Burns
Burrus
Capay
Castro
Chamisal
Chualar
Childs
Chummy
Clear Lake
Cohasset
Columbia
Colusa
Cone
Conejo
Contra Costa
Corning
Correra Peat
Cortina
Denverton
Dibble
Dobbins
Dorado
Dubkella
Dunnigan
East Park
Egbert
Elam
Esparto
Exchequer
Farwell
Forgeus
Forward
Freeport
Genevra
Glann
Goulding
Gridley
Grimes
Guenoc
Hanford
Harrington
Henneke
Hildreth
Hillgate
Hohman
Holland
Honcut
Hugo
Hulls
Inks
Inkskip
Iron Mountain
Jacinto
Jiggs
Josephine
Kimball
Keefers
Landlow
Laniger
Las Posas
Leesville
Lodo
Los Gatos
Los Osos
Los Robles
Lyonsville
Manton
Marcuse
Marvin
Masterson
Maymen
Maywood
McCarthy
Millrace
Millsap
Millsholm
Moda
Molinos
Montara
Montezuma
Morman
Myers
Nicimientos
Nanny
Neuns
Newville
Nicolaus
Nord
Oakly
Olcott
Orland
Pardee
Parrish
Pentz
Perkins
Peters
Placentia
Plaza
Pleasanton
Piper
Polebar
Porterville
Ramada
Romona
Red Bluff
Redding
Rincon
Riverwash
Riz
Rumsey
Rydberg
Ryde
Ryer
Sacramento
San Joaquin
Sehorn
Sheed
Sheet Iron
Siskiyou

Soil Series Used in Study--Continued

Sites	Tehama	Whiterock
Snelling	Toomes	Whitney
Sobrante	Tujunga	Willows
Solano	Tuscan	Windy
Stockton	Tyndall	Wyman
Stonyford	Tyson	Wyo
Staten	Upland	Yokohl
Sunnyvale	Valdez	Yollabolly
Sutter	Venado	Yolo
Supan	Venice	Yorkville
Sycamore	Vina	Zamora

In addition, the following soils that have limited areal distribution or no specific soil profile were used in this study:

Colluvium	Rock Land
Gravel Pits	Rock Outcrops
Kitchen Midden	Rubble Land
Made Land	Slickens
Mixed Alluvium	Tailings
Placer Diggings	Unstructured Peat and Muck soils

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SSOLVED SOLIDS···WATER QUALITY···TEMPERATURE···STAGE-
IC···FLOODFLOW···PERCOLATION···CONFINING BED···METEORIC
CABLEWAY···TOTAL KJELDAHL NITROGEN···RUNOFF···PRECIPIT
TOMATIC ANALYZER···TURBIDITY···BIODEGRADATION···E. COL
ONE OF SATURATION···BASE OF FRESH WATER···DEPOSITION
CTRICAL LOGS···SAFE YIELD···EFFECTIVE PRECIPITATION···
SCHARGE···SALTWATER INTRUSION···HYDROGRAPHS···CONE OF
···HYDROLOGIC BUDGET···LIMNOLOGY···AQUICLUDE···WATER Y
OROSITY···LAKES···DRAINAGE DIVIDE···RESERVOIRS···CANALS
OUGHNESS COEFFICIENT···GLACIER···SNOWMELT···PARTICLE S
···HEAD DECLINE···EUTROPHICATION···MOISTURE EQUIVALENT··
CORDER···SEDIMENT TRANSPORT···DYE TRACER···STREAM GAG
ISSOLVED OXYGEN···SODIUM ADSORPTION···BIOCHEMICAL OXYG
OTENTIOMETRIC SURFACE···INFILTRATION···HEAD···ACRE-FEET
EVE SIZE···STREAMS···TOTAL NITROGEN···GRAIN SIZE···G
···CUBIC FEET PER SECOND···SLOPE-AREA METHOD···DRAINAG
GANIC POLLUTION···SPECIFIC CONDUCTANCE···TOTAL ORGANIC
ATER TABLE···HYDROLOGY···SUBSURFACE GEOLOGY···DIVERSI
OOD PLAIN···COMPUTER READOUT···NO-FLOW BOUNDARY···AQU
···EVAPOTRANSPIRATION···RECHARGE···VELOCITY···STREAM P