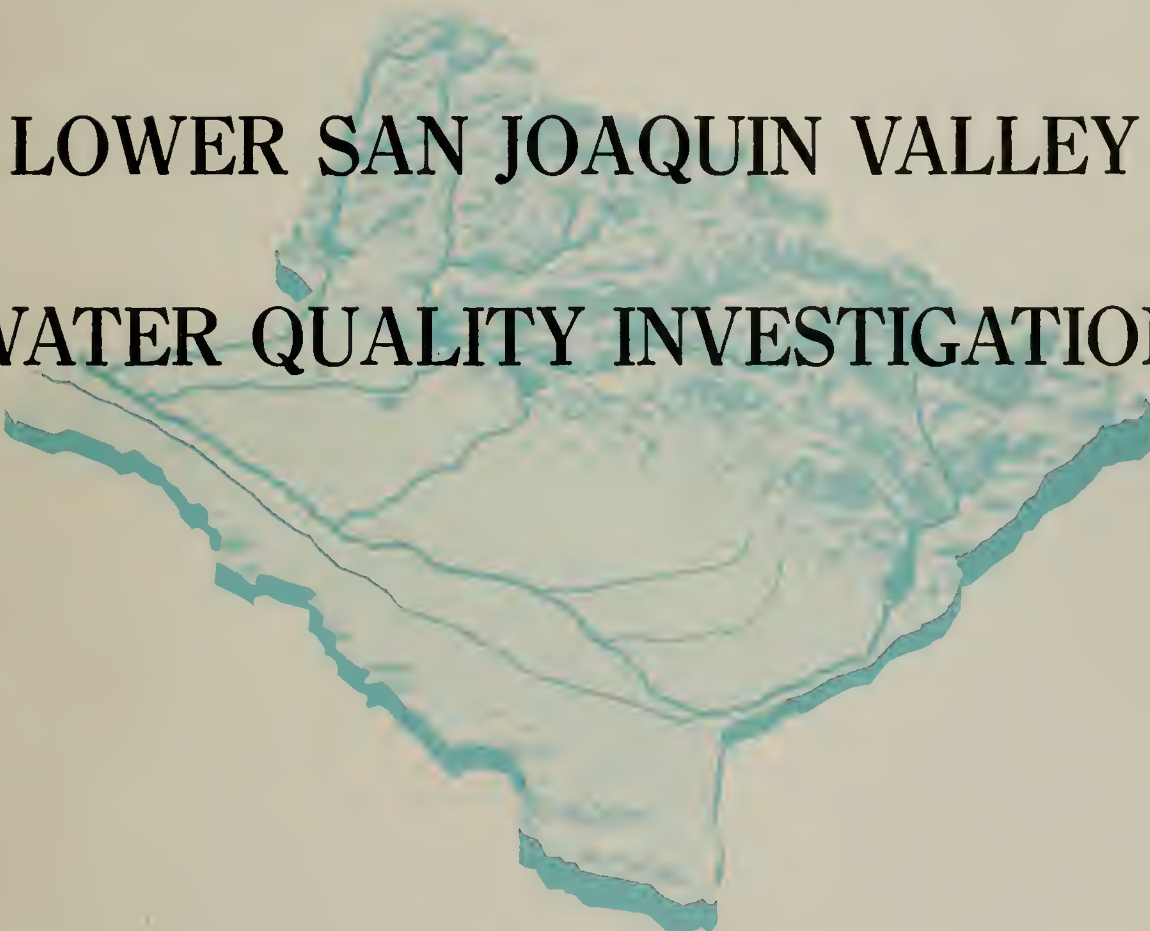
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

BULLETIN NO. 89

LOWER SAN JOAQUIN VALLEY WATER QUALITY INVESTIGATION



EDMUND G. BROWN
Governor

HARVEY O. BANKS
Director of Water Resources

DECEMBER 1960

La Grange Dam on the Tuolumne River
Constructed in 1893, this dam is owned and operated by the Modesto and Turlock Irrigation Districts

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STATE OF CALIFORNIA

Department of Water Resources

SACRAMENTO

December 9, 1960

Honorable Edmund G. Brown, Governor, and
Members of the Legislature of the
State of California

Chairman, Board of Directors of the
Banta-Carbona Irrigation District,
West Stanislaus Irrigation District,
Patterson Water District, and
El Solyo Water District

Gentlemen:

I have the honor to transmit herewith Bulletin No. 89, of the State Department of Water Resources, entitled "Lower San Joaquin Valley Water Quality Investigation". The investigation was financed cooperatively by the Banta-Carbona Irrigation District, West Stanislaus Irrigation District, Patterson Water District, El Solyo Water District, and the State of California, as authorized by Section 229 of the Water Code.

This bulletin summarizes data regarding the past and present quality of the waters in the Lower San Joaquin Valley, and includes an evaluation of the factors influencing water quality. A discussion of the existing water quality problem, associated hydrologic problems, and an estimate of the probable future quality of water in the lower San Joaquin River are presented. It has been concluded that the future quality of the water available in the river will be essentially similar to that existing at present, provided the master drainage system for the San Joaquin Valley, as authorized under the State Water Resources Development System, is put into operation at an early date.

The information presented in the bulletin should serve as a guide to the cooperating agencies, as well as other users of water from the lower San Joaquin River, in appraising the present and future adequacy of their supply. The information will also be of value in planning the further development of the water resources of the San Joaquin River and its tributaries.

Very truly yours,

Harvey O. Banks

HARVEY O. BANKS
Director

ACKNOWLEDGMENT

Valuable assistance and data used in the report and in the conduct of this investigation were furnished by the following agencies:

United States Bureau of Reclamation, Region 2
(Fresno, Sacramento, and Tracy offices)
United States Geological Survey, Ground Water
Branch and Quality of Water Branch
United States Soil Conservation Service

California Department of Natural Resources,
Division of Mines
California State Reclamation Board
Central Valley Regional Pollution Control
Board (No. 5)
University of California at Davis, Department
of Irrigation

Central California Irrigation District
City and County of San Francisco, Public Utilities
Commission, Hetch Hetchy Water Supply
Dos Palos Drainage District
Gustine Drainage District
Madera County
Madera Irrigation District
Merced County
Merced Irrigation District
Modesto Irrigation District
Oakdale Irrigation District
San Joaquin County
South San Joaquin Irrigation District
Stanislaus County
Stevinson Water District
Turlock Irrigation District

Information and assistance furnished by the foregoing agencies is deeply appreciated.

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CHAPTER I. INTRODUCTION

The ever increasing demands upon the water supplies available to the Lower San Joaquin Valley has required continued development of the water resources of the entire San Joaquin River drainage basin. Coincident with this development, there has been an increase in the mineral content of water available for diversion from the lower San Joaquin River, especially during periods of low flow. Concern has been aroused regarding the continued suitability of the San Joaquin River as a source of water supply for irrigation use.

Authorization for Investigation

As a result of widespread concern regarding the present and future quality of their water supply, the Board of Directors of the Banta-Carbona Irrigation District, following a meeting held on March 25, 1955, requested the State Division (now Department) of Water Resources to conduct an investigation of the quality of water in the San Joaquin River. On April 25, 1955, the Board of Directors of the West Stanislaus Irrigation District; and on April 26, 1955, the Boards of Directors of the Banta-Carbona Irrigation District and Patterson Water Company (now Patterson Water District), adopted resolutions requesting the then State Water Resources Board to undertake an investigation of the quality of water in the San Joaquin River.

As a result of these requests, the State Engineer recommended, and the State Water Resources Board, on May 13, 1955, approved, an investigation of water quality in the lower reaches of the San Joaquin River. On June 28, 1955, a cooperative agreement was consummated among and between the State Water Resources Board; the Banta-Carbona Irrigation District, acting for itself and the West Stanislaus Irrigation District, Patterson Water Company, such other agencies and individuals diverting water from the San Joaquin River as may contribute financially; and the Department of Public Works. This agreement provided that the Department of Public Works, acting through the State Engineer, with the cooperation, financial and otherwise, of the interested local agencies, would make the necessary investigation and prepare a report incorporating the results of the study.

Generally, the program of investigation provided for (1) a complete review of reports of prior investigations of the water resources of the San Joaquin River and contributory watersheds; (2) a compilation and evaluation of data now (1955) available and preparation of an interim report evaluating the following as well as may be possible with such data; (3) determination of effects of quality of waters in lower reaches of San Joaquin River on lands and crops served therefrom; (4) evaluation of quality of waters in lower reaches of San Joaquin River as existing and in the future as they may be affected by present and proposed water development projects on, and utilization of, waters from the San Joaquin River and its tributaries; (5) determination of effect on quality of return water in lower reaches of San Joaquin River of further economic development in San Joaquin Valley; and (6) preparation of a final report evaluating the foregoing items using data to be obtained in the course of the investigation in addition to that now (1955) available.

It was contemplated that the investigation would require five years to complete, principally because of the necessity of securing sufficient continuing field measurements and laboratory analyses of water samples to enable the proper interpretation of data and the formulation of sound conclusions. An interim report regarding the investigation was issued in October 1956, with a final report to be prepared as soon as possible after the conclusion of the field collection of data. The program of field collection of data was concluded on December 31, 1959.

The agreement between the cooperating agencies provided that the State of California, on the one hand, and the combined signatory districts and other agencies, on the other hand, would contribute annually one-half of the cost of investigation. The estimated cost to complete the investigation was $90,600, and the annual cost to be borne by each party is set forth in the following tabulation.

Fiscal year	Estimated share of cost to State of California	Estimated share of cost to Participating agencies	Total
1955-56	$ 12,500	$ 12,500	$ 25,000
1956-57	7,600	7,600	15,200
1957-58	7,600	7,600	15,200
1958-59	7,600	7,600	15,200
1959-60	10,000	10,000	20,000
TOTALS	$ 45,300	$ 45,300	$ 90,600

Due to increased costs encountered during the period of investigation, funds appropriated to the Department of Water Resources for work authorized by Section 229 of the Water Code were used to supplement the funds provided under the contractual agreement. In addition, valuable data contributing to the successful completion of this work were made available as a result of other concurrent investigations and statutory programs of the department. A copy of the basic agreement, and of subsidiary agreements between participating agencies, is included as Appendix A of this report.

Subsequent to the consummation of the agreement, the El Solyo Ranch Company (now El Solyo Water District) joined the aforementioned districts as a participant in accordance with the procedure outlined in the agreement. The term "cooperating districts", as used in this report, includes the El Solyo Water District.

Area of Investigation

The area of investigation is generally rectangular, extending westerly from the crest of the Sierra Nevada to the crest of the Coast Ranges, and southerly from the Sacramento-San Joaquin Delta to near Mendota on the San Joaquin River. The entire area is approximately 120 miles long and 100 miles wide, with the valley floor portion being about 100 miles long and 50 miles wide, as shown on Plate 1.

Drainage Basins

The area of investigation is traversed by several major San Joaquin Valley streams. In order, from south to north, these are the San Joaquin, Fresno, Chowchilla, Merced, Tuolumne, and

Stanislaus Rivers. Table 1 lists the various drainage basins together with their areas divided in accordance with topography.

TABLE 1

AREAS OF DRAINAGE BASINS, LOWER SAN JOAQUIN VALLEY AREA

(In square miles)

Stream or stream group basin	Drainage areas: Mountain and foothills	Valley	Total
San Joaquin River above Friant Dam	1,633	0	1,633
Fresno River above gage near Daulton	266	4	270
Chowchilla River above gage at Buchanan Dam site	238	0	238
Merced River above gage at Exchequer	1,035	0	1,035
Tuolumne River above gage near La Grange	1,540	0	1,540
Stanislaus River above gage near Knights Ferry	983	0	983
Minor streams above valley floor (east side) from San Joaquin River drainage to Stanislaus River drainage	1,053	56	1,109
Total area above valley floor (east side) tributary to San Joaquin River	6,748	60	6,808
Total area above valley floor (west side) tributary to San Joaquin River	1,245	65	1,310
Valley floor area tributary to San Joaquin River	0	3,674	3,674
Total area tributary to San Joaquin River	7,993	3,799	11,792

Elevations of peaks in the tributary drainage area range up to 10,000 feet above sea level with a few as high as 13,000 feet. Multipurpose water conservation projects have been constructed in most of the east side drainage basins. The topography, even in the foothills, is quite rough and rugged; consequently, extensive cultivated valleys are not generally found in these basins and existing projects are located near the valley floor.

In contrast to the east side basins, no conservation works for impoundment of runoff have been built in the west side foothill area tributary to the San Joaquin River. This area encompasses the eastern slopes of the Coast Ranges, where the total precipitation is comparatively minor in amount. Precipitation in this area generally does not produce substantial stream flow, since it is absorbed by the dry, non-vegetative and often porous soils. Elevations in this portion of the tributary drainage area range from about 500 to 4,000 feet, with one peak over 5,000 feet in elevation.

The valley floor area extends from the south bank of the San Joaquin River on the east, and from the Panoche Creek drainage system on the west, northward to the drainage divide north of the Stanislaus River, and is bounded by the Coast Range foothills on the west and the Sierra Nevada on the east. Elevations range from near sea level at the north end to about 250 feet at the south end. A portion of the valley floor south of the present San Joaquin River drainage formerly drained to the Delta. An outlet to the San Joaquin River is still maintained through Fresno Slough Bypass (also known as James Bypass). This channel carries flow only at times of excessive runoff in the Kings River Basin.

Climate

The climate of the northern San Joaquin Valley area ranges from the warm two-season climate of the Central Valley to the cold four-season climate of the rugged Sierra Nevada.

In the valley, about 90 percent of the seasonal rainfall occurs from November to April, inclusive, while the summers are hot and dry. Mean seasonal rainfall on the east side varies from 14 inches at Stockton to 9.5 inches at Fresno, and on the west side from 9.5 inches at Tracy to 6.5 inches at Mendota. Rainfall on the Coast Ranges generally is greater than on the valley floor, averaging about 20 inches in the higher elevations, and decreasing both in elevation and in a southerly direction. The effect of elevation can be seen in comparing the seasonal rainfall at Idria, elevation 3,000 feet, of 15 inches; and that at Mercy Hot Springs at elevation 1,200 feet, only 8 inches. Snowfall is light in the Coast Ranges, even at the higher elevations. The evaporation is high, both on the valley floor and on the western hills and mountains.

In the upper basins of the Sierra Nevada, summers are mild and short, and the winters cold and long. There is heavy snow at higher elevations, changing to rain at lower elevations. Precipitation varies from 28 inches at Melones and 29 inches at Mariposa, at lower elevations to 38 inches at Strawberry Dam, 35 inches at Yosemite, and 30 inches at Huntington Lake, in the higher elevations. Although precipitation is heavier in the upper basins, the precipitation season is comparable to that in the valley, with about 90 percent falling in the months of November to April, inclusive.

Geology

The area of investigation includes portions of the Sierra Nevada, Coast Ranges, and Great Valley geomorphic provinces. A great diversification in age, structure, and composition is found in the geologic formations of the area. The geologic units range in age from pre-Cretaceous to Recent and include rocks of sedimentary, metamorphic, and igneous origin. Rocks of the Sierra Nevada are, for the most part, the nonwater-bearing crystalline rocks that comprise the Sierran batholith and associated remnants of older metamorphics. Overlying these units are small areas of Tertiary sediments and fairly widespread volcanic cappings on the higher ridges in the northeastern part of the area.

Jurassic and Cretaceous sandstone and shale are dominant in the Coast Ranges. However, the Franciscan formation of Jurassic-Cretaceous age also includes intrusions of greenstone, diabase, and serpentine. Flanking the Jurassic and Cretaceous formations is a series of Tertiary and Pleistocene sediments which form a narrow band of outcrops for almost the entire length of the west side of the San Joaquin Valley and underlie its western portion.

The upper Tertiary and Quaternary sediments of the San Joaquin Valley contain fresh water to a depth, in some places, of approximately 2,000 feet. The Corcoran clay member of the Tulare formation, a widespread diatomaceous lacustrine deposit of late Pliocene or Pleistocene age, forms an impermeable body which confines the lower water-bearing zone in most of the area of investigation. Hydrologically, this clay is one of the most important features of the area as it divides the upper water-bearing zone from the lower zone, allows significant differences in water quality to develop, and prevents direct percolation of applied water to the lower water-bearing zone over most of the valley. Much of the San Joaquin Valley is underlain at depth by formations containing saline, connate waters.

Soils

Soils of the San Joaquin Valley vary in their chemical and physical properties in accordance with differences in parent material, drainage, and degree of development. The soils of the area have been divided into three permeability groups on the basis of the land forms on which they occur, their extent of development, and their parent material. These groups are:

1. soils which occur on young alluvial fans and along the basin rim and are permeable to moderately permeable;
2. soils on the old alluvial fans which are moderately to poorly permeable; and
3. soils that have developed on basin deposits which are poorly permeable to nearly impermeable.

Present Development

Part of the great Central Valley of California, the Lower San Joaquin Valley area has developed into one of the major agricultural areas of the State. The adjacent Sierra Nevada mountains have a considerable recreational value, a factor which brings tourists to and through the valley and contributes to the commercial economy of the area.

The several large and many small communities distributed throughout the valley are centers of commercial development. The larger cities are found on the east side of the valley and the smaller on the west side. On the east side, from north to south, the principal communities are Oakdale, Modesto, Turlock, Merced, Chowchilla, and Madera; and on the west side, Tracy, Patterson, Newman, Gustine, and Los Banos. In addition, there are many smaller communities throughout the area. Stockton is adjacent to the area of investigation on the north and Fresno on the south. These two cities are the largest cities in the San Joaquin Valley.

Table 2 lists population of the principal cities and towns in the Lower San Joaquin Valley area, including the adjacent cities of Stockton and Fresno. Continued agricultural expansion and its accompanying industrial growth has resulted in substantial increases in population since 1940.

Suburban growth has been phenomenal since 1940 in most cities of the area. Suburbs of the City of Modesto quadrupled in population in the years between 1940 and 1950. Table 3 lists the populations of principal urban centers in the region for 1940 and 1950, showing total population both within city limits and in metropolitan areas.

Irrigated agriculture is the chief economic activity throughout the valley area, while allied industries make up the bulk of the remaining enterprises. Leading crops are alfalfa, grapes, tomatoes, cotton, beans, sugar beets, deciduous fruits, and nuts. Olives, vegetables, and melons are also grown. The production of alfalfa and pasturage is principally practiced as an adjunct to the livestock industry which includes the raising of both beef and dairy cattle. Poultry production, especially the raising of turkeys, is significant.

The dominant industrial activity is found in food processing, including the packing, canning, and freezing of fruits, vegetables, meats, and dairy and poultry products. Other industries in the area include wine making, and the manufacture of farm equipment, concrete pipe, fertilizer and agricultural chemicals, animal feeds, sheet metal products, and fibre boxes and containers. As an example of industrial expansion in recent years, payrolls for industry in Stanislaus County increased 154 percent, and in Merced County 110 percent, during the period 1947 to 1956.

TABLE 2

POPULATION OF PRINCIPAL COMMUNITIES IN AND ADJACENT TO THE LOWER SAN JOAQUIN VALLEY AREA

Community	County	Population 1940	1950	1960*
		East Side		
Atwater	Merced	1,235	2,856	7,259
Chowchilla	Madera	1,957	3,893	4,486
Fresno	Fresno	60,685	91,669	133,929
Madera	Madera	6,457	10,497	10,497
Merced	Merced	10,135	15,278	19,998
Modesto	Stanislaus	16,379	17,389	36,099
Oakdale	Stanislaus	2,592	4,064	4,943
Riverbank	Stanislaus	1,130	2,662	2,789
Stockton	San Joaquin	54,714	70,853	85,452
Turlock	Stanislaus	4,839	6,235	9,056
		West Side		
Gustine	Merced	1,355	1,984	2,276
Los Banos	Merced	2,214	3,868	5,163
Newman	Stanislaus	1,214	1,815	2,127
Patterson	Stanislaus	1,109	1,343	2,229
Tracy	San Joaquin	4,056	8,410	11,175

* Preliminary figures from U. S. Bureau of the Census

Two major railroads, several major highways and excellent county road systems serve the valley area. The main line of the Atchinson, Topeka, and Santa Fe Railroad lies in the east side of the valley, while the Southern Pacific Railroad operates lines on both the east and west sides of the valley. In addition to the main lines, the Southern Pacific operates several smaller branches

TABLE 3

POPULATION OF PRINCIPAL URBAN CENTERS
IN AND ADJACENT TO LOWER SAN JOAQUIN VALLEY AREA

City	1940		1950	
	Within city limits	Metropolitan area	Within city limits	Metropolitan area
Fresno	60,700	82,800	91,700	130,600
Merced	10,100	13,400	15,300	23,400
Modesto	16,400	22,100	17,400	42,400
Stockton	54,700	68,900	70,800	112,800

and other smaller rail lines also serve portions of the area. The most important highway is United States Route 99, traversing the east side of the valley. This highway is the primary inland route in California, extending throughout the length of the State. State Route 33, an excellent two-lane highway, serves the west side. Numerous highways cross the valley at various points, connecting the cities of the east side with those west of the San Joaquin River. The most important of these are United States Highway 50, providing access to the San Francisco Bay area, and State Route 152, the Pacheco Pass Highway, which leads to the Monterey Bay and Salinas Valley areas.

In the upper basins, cities and towns are smaller and fewer in number. Sonora and Mariposa are the largest communities in the upper area. The most important industries are lumbering, mining, and recreation. Irrigated agriculture, principally pasture, is of modest proportions. There are large resources of timber and minerals, not all of which have been exploited. Lumbering is the largest industry, utilizing various species of fir, pine, and cedar. Mining is quite extensive, including the production of such resources as lime, stone, and a variety of other minerals. Gold mining, formerly important, now constitutes only a minor portion of the total mineral production. The mining of pumice for use in cement is of particular importance in Madera County, where the annual production is the greatest of any county in the State. Agriculture is principally based on the use of abundant pasture and range land for livestock.

Recreational opportunities in the area are extensive and a source of appreciable income to commercial enterprises. Camping, fishing, hiking, hunting, winter sports, and sightseeing attract thousands of visitors. Areas of leading interest are Yosemite National Park and the Mother Lode Country. These areas are served by excellent highways. About one million persons visit Yosemite National Park each year, and many thousands visit the scenes of the gold mining days.

Related Investigations and Reports

Prior investigations and reports reviewed in connection with this investigation are listed in Appendix B, in alphabetical order by author. In addition, the documents are numbered so that convenient reference may be made in the text. For example, the interim report on this investigation is listed as item 21.

The Department of Water Resources is presently conducting the San Joaquin Valley Drainage Investigation. This investigation includes the area which is particularly the subject of this report, as well as the remainder of the San Joaquin Valley. The objective of this latter study, scheduled for completion in June 1963, is to define the present and potential drainage problems in the valley and to propose a feasible means of coping with them.

Two other programs of the department are related to this investigation. These are monitoring programs concerned with the collection and evaluation of data regarding the quality of surface and ground waters of the State. The surface water quality monitoring program involves collection of data on the quality of surface waters in major streams in California and publication of monthly and annual reports. Twenty key locations on streams in the area of investigation are included in this program. The ground water quality monitoring constitutes a parallel program and relevant data are collected, evaluated, and published annually.

Information gathered in connection with these and other programs of investigation has been utilized in this investigation where applicable.

Statement of the Problem

In recent years, there has been a noticeable increase in the mineral content of waters available for diversion from the downstream reach of the San Joaquin River, between Fremont Ford and Mossdale. A substantial portion of waters available for diversion from this section of the river during the irrigation season are return flows from upstream irrigation use. Water users have become concerned regarding possible increases in the salinity of waters from lower reaches of the San Joaquin River stemming from the continuing upstream development of the water resources tributary to the area.

A companion source of concern stems from the physical consequences of the application of poor quality waters to irrigated crops resulting in an accumulation of salts in the soil. Continued increase in salinization of soils can bring eventual destruction to the productivity of agricultural lands. The severity of the problem is dependent not only on the quality of the applied water, but also on the type of soil, soil drainage, and irrigation practices, such as provisions for leaching. Adequate corrective measures must be employed in order to preserve the crop-producing characteristics of the agricultural lands and counteract the destructive effects of salinization. Spring flood flows from the watersheds of the east side streams during the early months of the irrigation season afford a source of good quality water which can be used to flush the salts accumulated in the soil during prior irrigation seasons. Increased upstream conservation of flood waters will reduce the magnitude of the spring flows, and this reduction, if great enough, could tend to accelerate the development of adverse salinity conditions.

In addition to their influence on the salinity of the soil, poor quality applied waters can have detrimental effects on crops. These effects result not only from the overall salt concentration in the water, but often are aggravated by the concentration of particular constituents. At times, it is difficult to determine whether the water alone, or the effect of the water on the soil, is the cause of trouble.

Scope of Investigation and Report

The objective of the Lower San Joaquin Valley Water Quality Investigation is to determine the factors affecting the quality of waters in the San Joaquin River, from the mouth of the Merced River to the Delta, and to suggest possible solutions to problems encountered, particularly with respect to quality as related to agricultural use of water.

As provided in the agreement, the objective for the first year of the investigation was to compile and evaluate data available previous to 1955, and to initiate a comprehensive field program for the collection of information needed to evaluate various factors influencing the quality of water in the lower reaches of the San Joaquin River. Historical data such as mineral analyses of surface, ground, and return waters, well logs, and stream flow were collected from many private and public agencies. From these data, an interim report was prepared in 1956.

During the three intervening years (1956-59), a field program, including sampling of surface, ground, and return waters, inspection and measurement of return waters, and collection of data from other agencies, was continued. A study of the effect of water quality on soils and crop response was made. Study and analysis of all data collected was a continuing function throughout the period of investigation.

Summaries of available data collected during this investigation are included in this report. Comprehensive tabulations of all data collected are available for reference in the files of the department.

Field Investigation

A varied program of data collection was begun in July 1955, and was continued until October 31, 1959, approximately the close of the irrigation season. In addition to the routine sampling of surface, ground, and return waters, special effort was made to obtain information on certain important factors affecting water quality at specific locations.

The need for detailed information on the quality of water diverted by the cooperating agencies was apparent. Consequently, these waters were sampled at the point of diversion with a greater frequency than called for by the routine monitoring programs. Samples were taken daily in 1955 and 1956, and weekly in 1957, 1958, and 1959. In addition, salinometers were placed in operation at the intake of each cooperating district to obtain a continuous record of the salt content in the water supply.

A detailed program of measurement of quantity of return flow, and identification as to source, was undertaken in 1956. This included inspection of return flow channels tributary to the San Joaquin River and other streams, and measurement and sampling of flows in those channels carrying significant quantities of return flow.

In order to provide additional information on the variation in quality of the San Joaquin River, imported waters, and return waters, the United States Geological Survey operated three daily sampling stations under cooperative agreement with the department. The locations of these stations were selected to supplement other continuing sampling stations.

A cooperative agreement was entered into with the Department of Irrigation, University of California at Davis, to make a study of the effect of the quality of water diverted from the lower reaches of the San Joaquin River on irrigated soils, as well as the resultant effect on crops.

Laboratory Work

Mineral analyses of water samples collected for this investigation were made by laboratories of the Quality of Water Branch, United States Geological Survey and the Department of Water Resources. Both laboratories are located in the Sacramento metropolitan area.

Analyses of soil samples were made at the laboratory of the Department of Irrigation, University of California at Davis. Soil-water-crop response studies also were made on the Davis campus.

Location Numbering System

The numbering system used in the investigation for the location of wells, sampling stations, and land features utilizes the township, range, and section subdivisions of the federal land survey. The same system is used in all ground water investigations made by the United States Geological Survey in California and by the Department of Water Resources. In assigning numerical designations, each section of land is divided into 40-acre plots lettered in accordance with the following diagram.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Wells, or other features, are numbered within each of the 16 lettered plots of each section, according to the order in which they are located. For example, a well having the number 4S/8E-29A1, MDB&M, would be in Township 4 South, Range 8 East, Section 29, and would be the first well located in plot A. Likewise, other features, such as stream sampling points or stream gaging stations can be located with a fair degree of accuracy. For example, a statement that Panoche Creek was sampled southwest of Mendota would be further defined by use of the number 15S/12E-16N, MDB&M, which would place it in a specific reach of the stream lying in the 40-acre subdivision lettered N, in Township 15 South, Range 12 East, Section 16. In this report, all location and well numbers are referenced to the Mount Diablo Base and Meredian, therefore, no supplementary designation to the basic number is necessary. For reports covering large areas, such as the entire state, a final letter is added to the number in order to define the appropriate base and meredian.

CHAPTER II. WATER SUPPLY

The water supplies available for use in the Lower San Joaquin Valley area are derived from numerous sources. Information and data concerning precipitation and runoff is presented in considerable detail in State Water Resources Board Bulletin No. 1, "Water Resources of California", 1951 (35). Much of the following discussion of water supply is general in scope; however, selected data which would clarify or help to define the water problems in the Lower San Joaquin Valley are presented herein. Particular attention has been given to stream runoff, probably one of the most significant factors related to this investigation.

Precipitation

Precipitation in the area varies from a seasonal average of about 10 inches on the valley floor to a maximum of around 70 inches in the higher elevations of the Sierra Nevada. After depositing some precipitation on the western slope of the Coast Ranges, storms generally move easterly across the valley, with the quantity of precipitation remaining fairly constant. Precipitation again increases with ascending elevations on the western slopes of the Sierra Nevada.

Within the area, there are 56 precipitation stations having records of ten years or longer. Table 4 lists selected stations in the Lower San Joaquin Valley area, with the maximum and minimum seasonal precipitation of record and the computed or recorded seasonal mean. It is evident that there is a considerable variation of precipitation from season to season.

TABLE 4

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION
AT SELECTED STATIONS IN THE LOWER SAN JOAQUIN VALLEY AREA

Station	Elevation, in feet	Period of record	Mean for period 1897-1947, in inches	Maximum and minimum precipitation: Season	Maximum and minimum precipitation: Inches depth
Firebaugh	175	1873-74 1946-47	8.45	1885-86 1875-77	18.24 2.24
Fresno	287	1878-79 1946-47	9.41	1940-41 1933-34	17.03 4.43
Idria	2,650	1918-19 1946-47	15.64	1940-41 1919-20	35.74 6.46
Merced	170	1872-73 1946-47	11.68	1883-84 1876-77	22.08 3.20
Newman	91	1889-90 1946-47	10.02	1889-90 1923-24	23.67 4.16
Sonora	1,830	1887-88 1946-47	32.00	1889-90 1923-24	67.39 13.67
Stockton	15	1867-68 1946-47	14.10	1906-07 1923-24	22.49 6.81
Yosemite	3,985	1904-05 1946-47	33.97	1937-38 1923-24	58.64 14.77

Plate 2 shows the geographical distribution of mean seasonal precipitation in the area, for the period 1897-1947, by means of isohyets representing the depth of precipitation in inches.

Runoff

Major streams tributary to the Lower San Joaquin Valley are, from north to south, the Stanislaus, Tuolumne, Merced, and San Joaquin Rivers. These four rivers contribute the major portion of the surface inflow to the valley, and have a combined estimated mean seasonal natural runoff of 5,953,000 acre-feet. Between

1923 and 1947, conservation works were constructed on these streams to provide 1,570,000 acre-feet of storage and regulation of water to meet requirements of the presently developed area. Minor streams on the east side of the valley are the Fresno and Chowchilla Rivers and Bear, Mariposa, and Owens Creeks. Panoche, Little Panoche, Los Banos, San Luis, Orestimba, and Del Puerto Creeks comprise the minor streams on the west side. Numerous other small foothill channels carry water only during intense storms. Runoff from all streams in the Lower San Joaquin Valley is tributary to the San Joaquin River, which flows northerly to the Sacramento-San Joaquin Delta.

Stream Gaging Stations and Records

Flow records for streams in the Lower San Joaquin Valley are numerous and many cover long periods of time. Stream gaging stations in the valley are maintained and operated by the following agencies:

- United States Department of the Army, Corps of Engineers
- United States Department of the Interior, Bureau of Reclamation, and Geological Survey
- California Department of Water Resources
- Central California Irrigation District (formerly San Joaquin Canal Company)
- Merced Irrigation District
- Modesto Irrigation District
- Oakdale Irrigation District
- South San Joaquin Irrigation District
- Turlock Irrigation District
- City and County of San Francisco

Many of these stations are jointly maintained by two or more agencies. The locations of stream gaging stations are shown on Plate 3.

Runoff Characteristics

Surface runoff from any watershed may be considered under one of the two general classifications -- either "natural flow" or "impaired flow". The term "natural flow" refers to the flow of a stream as it would be if unaltered by upstream diversion, storage, import, export, or change in upstream consumptive use caused by development. The term "impaired flow" refers to the actual flow of a stream at any given stage of upstream development and, in the case of past flows, constitutes the historical record.

Regulation and development of the runoff in the Lower San Joaquin Valley streams during the last fifty years, together with substantial imports and exports of water, have greatly altered the regimen of the natural outflow from the valley. Flows in the major tributary streams generally are regulated to a considerable extent and releases from reservoirs are controlled to such a degree that little or no natural flow appears in the lower reaches of stream channels during the summer months. The many diversions of water from the San Joaquin River and its tributaries have reduced summer flows to the extent that during the late summer months many diverters are forced to build small diversion dams across the main channel of the lower San Joaquin River in order to direct the available water supplies to their pumping plants.

The pattern of runoff in minor streams and on the valley floor somewhat parallels the distribution of rainfall throughout the year. However, at the higher elevations, watershed areas tributary to the major streams experience a delay in immediate runoff due to the accumulated snow pack in the Sierra Nevada. As a result of this delay, the major portion of the seasonal runoff occurs during the snowmelt period in the late spring and early summer months.

The wide seasonal variations in runoff of the San Joaquin River are exemplified by the records of flow at three key stations on the river. These stations, near Friant, Dos Palos, and Vernalis, are, respectively, at the edge of the Sierra Nevada foothills; at a point of minimum flow midway between the foothills and the Delta; and adjacent to the Delta, just upstream from the influence of tidal action. Recorded seasonal (October 1 - September 30) runoff at these stations is shown graphically on Plate 4.

Since completion of Friant Dam in 1947, stream flow near Friant has been substantially controlled, so that the regimen of flow has little relation to that occurring in the years preceding construction. Considerable regulation of the stream was effected between 1944 and 1947, during construction of the dam; consequently flow as it existed prior to this stage of impairment, ended in 1943. The regulation accomplished by Friant Dam has resulted in the reduction of the wide variations in flow previously experienced at this station. Peak flows are reduced in volume and lesser flows almost completely conserved so that the amount of water passing the dam during the winter and spring periods is considerably reduced.

The Dos Palos gaging station, located approximately midway between the Mendota Pool and the confluence of the San Joaquin and Merced Rivers, is of particular significance in the study of stream flow in the San Joaquin River. In almost every year, a portion of the river between the Dos Palos gaging station and Fremont Ford Bridge, 56 miles downstream, is dry for many months. This condition has been prevalent for many years and is a result of the diversion of the entire flow of the river between Mendota Pool and the Dos Palos gaging station. The last point of diversion, just above the Dos Palos station, is frequently referred to as the Temple Slough diversion.

The coordinated operation of the Delta-Mendota Canal (importing water to the area) and Friant Reservoir, coupled with the magnitude of diversions to areas served from the Mendota Pool, will undoubtedly continue to affect flow in the river to the extent that only a minimum amount of water will pass the Dos Palos gaging station. In addition to the effect of diversions above Dos Palos, historical records provide evidence that even while flows passed the Dos Palos station, the channel at Santa Rita Bridge eight miles downstream from the gaging station was frequently observed to be dry.

Records obtained from the gaging station on the San Joaquin River near Vernalis (known locally as Durham Ferry Bridge) are considered to represent the surface outflow from the San Joaquin Valley, as that valley is delineated in this report. Runoff at this station is affected by flow in all tributaries and by all upstream diversions and return flows. Consequently, seasonal runoff near Vernalis is quite variable, and for the 29-year period, 1929-58, ranged from 677,000 acre-feet in 1930-31, to 10,837,000 acre-feet in 1937-38.

<u>Quantity of Runoff</u>

Estimated values of mean seasonal natural runoff of streams in the area for the 53-year mean period 1894-1947 are shown in Table 5 (35).

TABLE 5

ESTIMATED MEAN SEASONAL NATURAL RUNOFF FROM WATERSHEDS TRIBUTARY TO LOWER SAN JOAQUIN VALLEY

Stream	Drainage area, in square miles	Runoff, in acre-feet
San Joaquin River above Friant Dam	1,633	1,816,000
Fresno River near Daulton	270	103,000
Chowchilla River at Buchanan Dam site	238	91,300
Merced River at Exchequer	1,035	1,027,000
Tuolumne River near La Grange	1,540	1,900,000
Stanislaus River near Knights Ferry	898	1,210,000
East side minor streams above valley floor		180,000
West side minor streams above valley floor		58,500
TOTAL MEAN SEASONAL NATURAL RUNOFF		6,385,800

Records of inflow to, and outflow from, the Lower San Joaquin Valley are published in United States Geological Survey Water Supply Papers and in reports of the Department of Water Resources. All major sources of inflow to the valley floor are measured, together with the flow of the San Joaquin River near Vernalis, the latter constituting the entire outflow from the valley.

Imported and Exported Water

Imports of water to, and exports from, the area of investigation, though few in number, have considerable bearing on the regimen of the San Joaquin River and its tributaries. There is one import and one natural inflow to the area of investigation.

The import is from the Sacramento River, via the Delta-Mendota Canal, and the natural inflow is the overflow from the Kings River via Fresno Slough (James Bypass). For the purpose of consistency in discussion, this latter flow is also considered to be an importation of water since the quantity has no ascertainable relationship to runoff of the Kings River.

There are four major exports of water from the area: Stanislaus River water via the North Main Canal to the Oakdale and South San Joaquin Irrigation Districts; Tuolumne River water via the Hetch Hetchy Aqueduct to the City of San Francisco; San Joaquin River water via Friant-Kern Canal to the Tulare Lake basin in the southern San Joaquin Valley; and water from the Mendota Pool, via Fresno Slough, to the area adjacent to that slough. Each water transfer is discussed separately in the following paragraphs except for the inflow to, and export from, the Lower San Joaquin Valley, via Fresno Slough, which are discussed together.

Table 6 lists imports of water to the Lower San Joaquin Valley area for the runoff seasons (October 1 - September 30) since the season of 1944-45. Table 7 lists exports from the area for the same period.

Delta-Mendota Canal

The importation of water diverted from the Sacramento-San Joaquin Delta through the Delta-Mendota Canal, is a part of the overall operation of the Central Valley Project, constructed by the United States Bureau of Reclamation. Water, principally from the Sacramento River, enters the Delta Cross Channel, then passes through natural channels to the southern edge of the Sacramento-San Joaquin Delta where it is lifted almost 200 feet

TABLE 6

SEASONAL IMPORTATION OF WATER TO
LOWER SAN JOAQUIN VALLEY AREA

(In acre-feet)

Season[a]	Delta-Mendota Canal, at Tracy	Fresno Slough	Total
1944-45		264,200	264,200
1945-46		93,600	93,600
1946-47		26,600	26,600
1947-48		2,600	2,600
1948-49		400	400
1949-50		2,000	2,000
1950-51	163,700[b]	71,900	235,600
1951-52	166,900	436,500	603,400
1952-53	787,500	3,900	791,400
1953-54	1,004,200	0	1,004,200
1954-55	1,130,500	0	1,130,500
1955-56	725,900	93,400	819,300
1956-57	1,181,500	0	1,181,500
1957-58	663,300	212,800	876,100
Seasonal average	808,500	86,300	895,000

a/ Period October 1 - September 30

b/ Started June 11, 1951

into the Delta-Mendota Canal at the Tracy pumping plant near Bethany. The water is then conveyed southerly about 118 miles to the Mendota Pool on the San Joaquin River. Throughout the length of the canal there are many water service diversions, four wasteways, and many inlets intercepting return and storm waters from

TABLE 7

SEASONAL EXPORTATION OF WATER FROM LOWER SAN JOAQUIN VALLEY AREA

(In acre-feet)

Season[a]	Oakdale-South San Joaquin Diversion	Hetch Hetchy Aqueduct	Friant-Kern Canal	Fresno Slough	Total
1944-45	353,400	54,800		19,300	427,500
1945-46	293,900	57,500		44,000	395,400
1946-47	284,800	69,500		49,400	403,700
1947-48	278,600	69,100		42,600	390,300
1948-49	292,700	68,500	45,100[c]	67,300	473,600
1949-50	357,400	62,500	195,400	41,100	656,400
1950-51	310,900	69,500[b]	368,200	41,800	790,400
1951-52	349,200	69,500[b]	462,000	26,000	906,700
1952-53	361,800	90,800[b]	740,600	69,200	1,262,400
1953-54	317,100	102,100	811,300	72,900	1,303,400
1954-55	312,000	116,300	804,700	55,100	1,288,100
1955-56	346,400	98,500	1,322,200	61,600	1,828,700
1956-57	314,000	112,100	990,400	68,400	1,484,900
1957-58	397,900	90,700	1,144,900	54,200	1,687,700
Seasonal average	326,400	80,800	760,000	50,900	1,220,000

a/ Period October 1 - September 30; except Hetch Hetchy Aqueduct, for which the period July 1 - June 30 is used
b/ Estimated
c/ Started July 19, 1949

local areas. The canal capacity at the pumping plant is 4,600 second-feet, decreasing to 3,200 second-feet at the point of discharge to the Mendota Pool. Operation of the canal was begun in June 1951.

Fresno Slough

Fresno Slough, or James Bypass, serves the dual purpose of providing a relief channel for excess runoff from the Kings River and also provides a conveyance channel for irrigation water diverted southerly from the Mendota Pool. In the first instance, water is imported to the investigation area; in the latter, water is exported from the area. Seasonal runoff entering Fresno Slough from the Kings River has always been subject to great variation in quantity and, since 1944, has varied from no flow in 1953-54, 1954-55, and 1956-57 to 436,500 acre-feet in 1951-52. The frequency of inflow via Fresno Slough is expected to be reduced considerably through operation of Pine Flat Dam for flood control on the Kings River. This dam, completed in 1954, has a storage capacity of 1,000,000 acre-feet.

During the irrigation season, flow in Fresno Slough moves in the reverse direction, i.e., from the San Joaquin River at the Mendota Pool to the various points of diversion along the slough. The average seasonal diversion from Fresno Slough for the period 1944-58 was 50,900 acre-feet.

Stanislaus River Diversion

The boundary for this investigation is such that the South San Joaquin Irrigation District and the portion of the Oakdale Irrigation District lying north of the Stanislaus River are outside the area of investigation. Consequently, water diverted from the Stanislaus River for use in these outlying areas is considered an export. The average seasonal export, for the 1944-58 period, has been 326,400 acre-feet.

Hetch Hetchy Aqueduct

A source of water supply for the City of San Francisco and adjacent peninsular communities is provided by the Hetch Hetchy system, diverting water from the Tuolumne River and its tributaries. The Hetch Hetchy system is the result of planning initiated as early as 1882. The present system consists of three impounding reservoirs, powerplants, regulatory reservoirs, tunnels, and the 103-mile Hetch Hetchy Aqueduct. Water is diverted at Moccasin Reservoir into the aqueduct which consists of a tunnel through the Sierra Nevada foothills, a double pipeline across the San Joaquin Valley, a tunnel through the Coast Ranges, and pipelines to its terminus, Crystal Springs Reservoir, on the San Francisco Peninsula.

After many years of planning, construction, and solution of legal problems, diversion to the aqueduct began on October 18, 1934. The average seasonal diversion for the 1944-58 period has been about 80,800 acre-feet and, since demands have increased with a rapidly growing population, the seasonal diversion has increased in recent years and the system expanded in accordance with original plans.

The present capacity of the aqueduct across the valley floor is 163,000,000 gallons per day or about 183,000 acre-feet per year. The capacity of the present Coast Range tunnel portion of the aqueduct is 200,000,000 gallons per day or about 224,000 acre-feet per year. Ultimately, it is planned that the Hetch Hetchy system will provide a firm supply of 400,000,000 gallons per day or about 448,000 acre-feet per year to the coastal area. This will require additional storage and a parallel aqueduct, including a second Coast Range tunnel.

Friant-Kern Canal

The Friant-Kern Canal diverts water to the south of the area of investigation from Millerton Lake, the reservoir formed by Friant Dam, on the San Joaquin River. The facilities are operated by the U. S. Bureau of Reclamation as part of the Central Valley Project. The operation of this reservoir, Friant-Kern Canal, and Madera Canal, which diverts north into the area of investigation, required construction of the Delta-Mendota Canal and importation of Sacramento River water to replace San Joaquin water exported from the area. Under the Exchange Contract of July 27, 1937, diverters between Mendota and Newman were entitled to imported water equivalent in quantity and quality to that which they would have diverted from the San Joaquin River under former conditions. This contract has been superseded by the Amended Exchange Contract of March 17, 1956, providing that the annual substitute supply of water will be 855,000 acre-feet, except during critical dry years, and that the quality of such water, as determined by total dissolved solids, will not exceed the following weighted mean values:

Time interval	Total dissolved solids (in ppm)
Daily	800
Monthly	600
Annually	450
Five years	400

Ground Water Hydrology

Three distinct bodies of ground water underlie most of the northern portion of the San Joaquin Valley. From the surface downward, these are: (1) a body of unconfined and semi-confined water found in alluvial deposits of Recent and Pleistocene age;

these deposits overlie the Corcoran clay member, a widespread diatomaceous lacustrine deposit of late Pliocene or Pleistocene age; (2) a body of confined ground water, lying below the Corcoran clay member in alluvial and lake deposits of Pleistocene and late Pliocene age; since the Corcoran clay member is not found along the eastern margin of the valley, the water-bearing deposits in this area are a continuation of those described in (1) above; and (3) a zone of saline connate water found in the predominantly marine formations of middle Pliocene and earlier age which underlie the confined ground water body.

The term "free ground water", as used in this report, refers to a body of ground water not overlain by impervious materials, and in which the movement of water is under the influence of gravity and controlled by the hydraulic gradient. "Confined ground water" refers to a body of ground water overlain by relatively impervious material, movement of water to regions of discharge being controlled by the difference in head between the area of recharge and area of discharge. In areas of free ground water, the storage capacity available in the ground water basin provides the regulatory storage required to reduce the magnitude of fluctuations in available water supplies, and change in the quantity of ground water in storage is indicated by changes in ground water levels. A free ground water body may also constitute an area of recharge for a confined ground water zone as well as providing a certain amount of regulatory storage for such recharge.

Ground Water Geology

Ground water occurring in the northern portion of San Joaquin Valley was divided, for the purpose of discussion in this report, into three zones, selected on the basis of water quality, hydrologic characteristics of the included aquifers, and location. These are the free ground water zone, pressure or confined ground water zone, and saline water zone. Each of these zones includes a number of individual aquifers and basins.

Free Ground Water Zone. The free ground water zone occurs throughout the entire San Joaquin Valley and usually overlies the pressure zone, from which it is separated by the Corcoran clay member.

The free ground water is contained in unconsolidated deposits of gravel, sand, silt, and clay, of Quaternary age, deposited in river channels, alluvial fans, flood plains, and lake beds (lacustrine deposits). The river channel deposits consist of discontinuous, lenticular, and commonly elongated bodies of sand and gravel, sand, and silt. The alluvial fan deposits usually comprise poorly-sorted gravel, sand, and silt in discontinuous lenticular bodies. In flood plain deposits, silt and clay are the predominant lithologic types; sediments are discontinuous, although some beds occur in sheet-like bodies. The lacustrine sediments are well-sorted silts and clays which were deposited in ancient lakes and swamps; included in this group are well-sorted sands deposited in still water near the mouths of streams which fed the lakes.

In general, the more permeable materials are found in the eastern portion of the valley, grading westerly into finer-grained lacustrine and flood plain deposits in the axial trough of the valley. The fan deposits of the western margin have been deposited by streams which drain small areas of relatively low rainfall. However, these streams are subject to occasional flood flows which cause deposition of poorly-sorted silt, fine sand, clay, and locally, considerable gravel.

The total thickness of the continental sediments, which includes both free and confined ground water zones, is variable throughout the San Joaquin Valley due to the differential down-warping of the valley floor which occurred periodically during the deposition of sediments. Generally, the portion of the continental sediments which contain fresh water varies from less than 1,000 feet in thickness in portions of the northerly and easterly segments to at least 3,500 feet in the southwesterly portion of the area of investigation.

The source of fresh ground water in the San Joaquin Valley is from precipitation in the form of rain on the valley floor and foothills and is snow in the higher elevations. Replenishment of the free ground water body may occur either by deep penetration of rainfall, by percolation from streams or stream underflow into the valley at its margins, or by deep percolation from irrigation ditches and from irrigation water applied in excess of plant requirements.

Deep percolation of rainfall occurs only when there is no soil moisture deficiency in the upper soil horizons. The average precipitation over most of the valley floor is in the order of 12 inches per season or less. This quantity is the approximate lower limit of precipitation below which occurs little or no deep percolation of rainfall. Thus, deep percolation of rainfall is likely to be a major source of ground water recharge only in the northeastern sector of the valley where the seasonal precipitation is greater in amount or, in other portions of the valley during occasional years of high rainfall.

Percolation from streams which flow across the valley is appreciable in quantity and it is probable that much of this water reaches the main body of ground water in storage. Except during high flood periods, flows in west side streams seldom reach the channel of the San Joaquin River. Rivers on the east side of the valley contribute many thousands of acre-feet per year to ground water. This is evidenced by comparison of flow measurements on the valley floor with those made as the streams enter the valley.

Confined Ground Water Zone. The confined ground water zone beneath the Corcoran clay member forms an essentially continuous ground water reservoir throughout much of the San Joaquin Valley. A large portion of the eastern part of the valley, especially in the areas underlain by the alluvial fans of the major rivers, is outside the area influenced by the Corcoran clay member and, consequently, water under pressure is not present in such locations. Since the confined and unconfined ground water zones blend imperceptibly into one essentially unconfined zone at the edge of such areas, the actual margin of the pressure zone is difficult to locate.

Recharge to the confined zone is chiefly from the unconfined and semiconfined ground water bodies along the valley margins in the areas not underlain by the Corcoran clay member. It is possible that some minor part of the recharge is gained by extremely slow percolation of water through the Corcoran clay from the overlying unconfined and semiconfined zones.

Saline Zone. In marine sediments underlying the confined zone, a body of connate water of poor quality containing high concentrations of various salts, of which sodium chloride is the most abundant, is found. These waters were entrapped in the marine sediments at the time of deposition. Excessive drawdown in fresh water zones tends, in many instances, to induce upward or lateral intrusion of these saline waters into fresh ground water bodies.

Ground Water Levels

Periodic measurements of ground water levels in the Lower San Joaquin Valley area are made by many agencies and are compiled and published by the United States Bureau of Reclamation, United States Geological Survey, and the Department of Water Resources. The most recent comprehensive publication on ground water levels in the area is a report by the United States Geological Survey, entitled "Ground Water Conditions and Storage Capacity in the San Joaquin Valley, California", 1957 (76). As a part of the Geological Survey investigation, field measurements of ground water levels over the area included in the Lower San Joaquin Valley investigation were made in 1952 and these data have been made available to the Department of Water Resources.

Ground water levels in the spring of 1952, based upon the data collected by the Geological Survey, are depicted on Plate 5. Ground water levels in the unconfined zone are generally high, with depths to water varying from 5 to 50 feet. In areas served by surface water, free ground water levels generally are higher than in areas of ground water pumpage. In addition to the data mentioned above, other studies of ground water hydrology in the area, dealing with various subareas or specific problems, have been of assistance in this investigation.

Ground Water Storage Capacity

The term "specific yield", as used in connection with ground water, refers to the ratio of the quantity of water a given volume of a saturated soil will yield by gravity to its own volume, and is commonly expressed as a percentage. Estimated ground water storage capacity is the product of the specific yield and the volume of material, contained in the depth intervals considered, in a specific area.

Ground water storage capacities, as computed for the storage units underlying the San Joaquin Valley, were taken from the report (76) previously cited. For those units not lying wholly within the area of investigation, ground water storage capacity was apportioned on the basis of surface area within and without the investigation area. In estimating the total ground water storage capacity, an area of about 600 square miles, mostly in the valley trough, and subject to overflow from the San Joaquin River and its tributaries, was excluded. These lands have soils with very low permeabilities, excessive accumulations of harmful salts, and are subject to periodic flooding.

The estimated ground water storage capacity of the basins lying within the area of investigation is about 7,300,000 acre-feet for the depth zone from 10 to 50 feet below the surface; 9,000,000 acre-feet from 50 to 100 feet; 16,000,000 acre-feet from 100 to 200 feet; and approximately 32,000,000 acre-feet for the total depth between 10 and 200 feet.

Movement of Ground Water

Lines of equal elevation on the surface of the free ground water body in the San Joaquin Valley for the spring of 1952 indicate that the ground water gradient generally slopes away from the valley margins toward the central trough. The hydraulic gradient on the east side of the valley ranges from 5 to as much as 18 feet per mile, and in any given direction, exhibits a fairly regular pattern.

A number of ground water mounds have been formed in the free ground water zones along the west side of the valley underlying organized irrigation districts. The occurrence of these mounds is attributable to the large amount of applied irrigation water derived from surface sources. There is very little draft on ground water in this area by large irrigation wells and the probable low transmissibility of soils and underlying sediments inhibits rapid dissipation of accumulated ground water mounds. A small ground water mound also exists south of Riverbank on the east side of the valley. Several depressions in the free ground water surface have developed as a result of heavy irrigation pumping. These are found principally northwest of Madera in the vicinity of Ash and Berenda Slough on the east side of the valley; and in the area between Mendota and Tranquility, west of Fresno Slough and south of the San Joaquin River.

Percolation, or seepage, of water into the free ground water zone is subject to wide variations because of seasonal and cyclical fluctuations in the flow of the San Joaquin River and its tributaries. Plate 5, consequently, does not reflect conditions which might occur in a drier and more nearly normal year in the areas immediately adjacent to major streams. The lines shown thereon indicate that the San Joaquin River was contributing appreciable amounts to the ground water in storage. Generally, measurements at the San Joaquin River gaging stations show that the flows are augmented by rising ground water in the reach between Dos Palos and Vernalis. It is not possible, with available data, to estimate the portion of the accretions in this reach due to seepage from ground water. It is probable, however, especially in years of low stream flow, that considerable quantities of water seep into the San Joaquin River from the upper ground water zone.

Movement of ground water in the confined zone is more difficult to analyze because of the lack of adequate data covering any area other than the western margin of the valley. In general, however, it is thought that the gradient in the confined zone is such as to cause movement from areas of recharge on the east side into areas of heavy pumpage along the western margin, at least in the southwestern portion of the area of investigation.

Further studies of the movement of ground water by the Department of Water Resources and other agencies indicate that Plate 5 generally depicts the normal aspect of ground water slope and movement, with the exception that ground water generally contributes to flow in the San Joaquin River downstream from Dos Palos.

Subsurface Inflow and Outflow

The southern boundary of the area of investigation has been established along the crest of the existing ground water divide underlying the San Joaquin River. The boundary extends westerly through the center of the pumping depression in the confined ground water zone on the west side of the San Joaquin Valley.

It is apparent from a study of ground water levels in the area that in the spring of 1952, there was little or no subsurface inflow or outflow across the southern boundary.

The northern boundary is not so well defined, and while there apparently is an unknown quantity of subsurface outflow into the Sacramento-San Joaquin Delta from the northwestern part of the area, the magnitude of this outflow is probably not great because of the relatively flat gradient of the ground water mound across which the boundary was established. The easterly segment of the northern boundary has been established along the crest of a ground water ridge north of the Stanislaus River and there apparently was no subsurface outflow or inflow across this portion in the spring of 1952.

Areas of High Water Table

High water table conditions prevail over considerable portions of the northern San Joaquin Valley. These areas are largely confined to the central trough of the valley and to the areas where surface water supplies most of the irrigation demands. In the spring of 1952, the water table was within 10 feet of the ground surface over an area of about 1,200 square miles.

In the area around Merced, the water table has been within one foot of the surface on several occasions in the past and has not been lower than eight feet from the surface within the last 25 years. Drainage wells have been used in an effort to maintain the water table below the root zone of the crops. In addition, other areas, principally around Turlock and Modesto, have had similar difficulties with high water table conditions in the past. However, in these areas, drainage wells have been installed and are now maintaining the water table at an average depth of seven feet. High water table conditions in the areas discussed above are mainly attributable to unfavorable drainage characteristics of the alluvial flood plain deposit and basin soils and subsoils.

Between United States Highway 33 and the San Joaquin River, in an area of a few square miles lying east of Patterson, ground water occurs within five feet of the surface. Several conditions apparently contribute to the problem in this area. Application of irrigation water from surface sources, along with seepage of water from canals and lateral distribution systems, are primary sources of excessive ground water infiltration. Additional water is derived through the natural movement of ground water into the area from the southwest. The high water table condition occurs in an area underlain by recent alluvial fan deposits, bounded on the east near the San Joaquin River by less permeable, older alluvial fan and basin deposits. Movement of ground water from the high water table area toward the San Joaquin River is consequently restricted and has resulted in the rising water levels near Patterson. Another contributing factor is that the pumpage in the high water table area is limited to minor domestic uses and, consequently, no effective drainage from it is accomplished by withdrawals.

A large high water table area, with some swamps and marshes, occurs in the vicinity of Gustine, Los Banos, and Dos Palos. High water table conditions in this area are maintained by excessive amounts of applied surface water and canal seepage, accompanied by lower permeabilities in the soils and substrata.

A detailed report on high water table as it occurs in the entire San Joaquin Valley has been published by the University of California (78). The particular problems of the above-mentioned areas are discussed in detail in that report. In addition, several reports on high water table conditions in various subareas are available (2) (30) (43) (53) (60).

CHAPTER III. WATER UTILIZATION

The term "water utilization" is used in a broad sense to include any employment of water by nature or man, either consumptive or nonconsumptive, as well as those irrecoverable losses of water incidental to such employment, and is synonymous with the term "water use".

A schematic representation of the means by which the present supply and utilization of water in the Lower San Joaquin Valley area occurs is shown on Plate 6.

Water Supply Development

Development of streams for irrigation in the Lower San Joaquin Valley began in the 1870's and has progressed steadily since that time. Construction of major water conservation and storage works for irrigation, municipal, power, and flood control purposes did not begin until after 1920. Progress of construction was rapid and, by 1930, a major dam had been erected on each of the three principal tributaries to the San Joaquin River. Since that date, additional works have been completed on the San Joaquin River and tributary streams. Further development is contemplated. Chronological development of the surface water resources in the San Joaquin River Basin, in 20-year periods since 1860, is depicted schematically on Plate 7, and works presently being considered for possible future construction are also shown.

Present Development

Existing conservation works in the Lower San Joaquin Valley, shown on Plate 1, are owned and operated by municipalities, irrigation districts, the federal government, and private utility companies. Many of these works are operated independently but all of them, either directly or indirectly, tend to regulate and control the flow in the San Joaquin River. General information on all major works (over 10,000 acre-feet of storage capacity) is presented in Table 8.

Since the initiation of this investigation in July 1955, three additional projects have been completed and placed in operation. These are the Cherry Valley (1956), the Tri-Dam (1957), and the Mammoth Pool (1960) Projects.

The Cherry Valley Project is owned and operated by the City of San Francisco for municipal supply, flood control, and power purposes, as a part of the city's Hetch Hetchy water supply system. It is located on Cherry Creek, a tributary of the Tuolumne River.

The Tri-Dam Project includes Tulloch, Donnells, and Beardsley Dams on the Stanislaus River, owned and operated by the Oakdale and South San Joaquin Irrigation Districts, for irrigation and power purposes.

The Mammoth Pool Project is owned and operated by the Southern California Edison Company, a privately financed public electric utility. The project is an integral part of the company's hydroelectric power generating complex on the San Joaquin River.

Future Development

Although water conservation works exist on all principal streams in the Lower San Joaquin Valley, the resources of these streams are not yet completely developed. This is emphasized by

TABLE 8

MAJOR EXISTING AND PROPOSED WATER CONSERVATION DEVELOPMENTS IN THE LOWER SAN JOAQUIN VALLEY AREA

Name of dam	Location, MDB&M	Type of dam	Use	Year of completion	Storage capacity, in acre-feet
		Stanislaus River Basin			
Melones	1N/13E-11	Arch	Irrigation, Power	1926	112,500
New Melones	1N/13E-11		Flood Control, Irrigation, Power	(Proposed)	2,400,000
Main Strawberry	4N/18E-15	Rockfill	Power	1916	18,600
Relief	5N/20E-13	Rockfill	Power	1910	15,100
Tulloch	1S/12E-1	Gravity	Irrigation, Power	1957	68,400
Donnells	6N/18E-35	Arch	Irrigation, Power	1957	64,500
Beardsley	4N/17E-14	Earth	Irrigation, Power	1957	97,500
Woodward	1S/10E-9	Hydraulic fill	Irrigation	1918	35,000
		Tuolumne River Basin			
Don Pedro	2S/14E-35	Gravity-curved	Irrigation, Power	1923	289,000
New Don Pedro	2S/14E-35		Flood Control, Irrigation, Power	(Proposed)	1,950,000
Owen	3S/13E-31	Earth	Irrigation	1915	49,000
Dallas-Warner	3S/12E-20	Earth	Irrigation	1911	27,000
Lake Eleanor	1N/19E-3	Multiple Arch	Municipal, Power	1918	27,800

TABLE 8

MAJOR EXISTING AND PROPOSED WATER CONSERVATION DEVELOPMENTS IN THE LOWER SAN JOAQUIN VALLEY AREA (continued)

Name of dam	Location, MDB&M	Type of dam	Use	Year of completion	Storage capacity, in acre-feet
			Tuolumne River Basin (continued)		
Hetch Hetchy	1N/20E-16	Gravity-curved	Municipal, Power	1923	360,000
Cherry Valley	1N/17E-5	Earth-rock	Municipal, Flood Control, Power	1956	268,000
			Merced River Basin		
Exchequer	4S/15E-13	Gravity-curved	Irrigation, Power, Flood Control	1926	289,000
New Exchequer	4S/15E-13		Irrigation, Power, Flood Control	(Proposed)	1,000,000
Bagby	4S/17E-6		Irrigation, Power, Flood Control	(Proposed)	415,000
Snelling	5S/15E-7		Irrigation, Power, Flood Control	(Proposed)	190,000
			Mariposa Creek Basin		
Mariposa	7S/17E-30	Earth	Flood Control	1948	15,000
			San Joaquin River Basin		
Friant	11S/21E-5	Gravity-straight	Flood Control, Irrigation	1947	520,000
Shaver Lake	9S/24E-13	Gravity-curved	Power	1927	135,300
Thomas A. Edison	6S/27E-25	Earth	Domestic, Power	1954	125,000

TABLE 8

MAJOR EXISTING AND PROPOSED WATER CONSERVATION DEVELOPMENTS IN THE LOWER SAN JOAQUIN VALLEY AREA (continued)

Name of dam	Location, MDB&M	Type of dam	Use	Year of completion	Storage capacity, in acre-feet
		San Joaquin River Basin (continued)			
Huntington Lake	8S/25E-14	Gravity-curved	Power	1917	88,800
Florence Lake	7S/27E-36	Multiple Arch	Power	1926	64,400
Crane Valley Storage (Bass Lake)	7S/22E-25	Earth-rock	Power	1910	45,400
Big Creek #7	9S/23E-15	Gravity-straight	Power	1951	35,000
Mammoth Pool	7S/24E-14	Earth-fill	Power	1960	123,000
		Chowchilla River Basin			
Buchanan	8S/18E-22		Irrigation, Flood Control	(Proposed)	150,000
		Fresno River Basin			
Hidden	9S/19E-34		Irrigation, Flood Control	(Proposed)	75,000
Windy Gap	7S/20E-2		Irrigation, Flood Control	(Proposed)	32,000
		San Luis Creek Basin			
San Luis	10S/8E-15		Irrigation and Domestic regulatory storage	(Proposed)	2,100,000

the occurrence of severe floods, such as those of December 1955, and April 1958; by years of water deficiency such as occurred in 1947 and 1959; by the observable uncontrolled discharge of water to San Francisco Bay during the winter and spring months; and by the existing need for augmented water supplies in local areas. Consequently, a continuous program of planning for further development has been carried on by federal, state, and local agencies.

The California Water Plan. A comprehensive plan for development of the waters of the State, designated The California Water Plan (23), has been prepared by the Department of Water Resources. This plan has been adopted by the Legislature as a master plan to guide all agencies concerned in the future development of the water resources of California. The plan envisions the statewide transfer of surplus waters from areas of surplus to areas of deficiency. The principal features of The California Water Plan pertinent to the Lower San Joaquin Valley area include:

1. Major water conservation works on tributaries of the San Joaquin River;
2. Importation of surplus waters via the Delta-Mendota Canal, the San Joaquin Valley-Southern California Aqueduct, and the East Side Canal;
3. San Luis Reservoir to store and regulate imported waters from areas of surplus; and
4. The San Joaquin Valley Master Drainage Conduit.

Details of these features, as shown in Bulletin No. 3, "The California Water Plan", 1957 (23) are subject to change as necessary or desirable, as a result of further intensive planning effort. Generalized locations of The California Water Plan features in the Lower San Joaquin Valley are shown diagrammatically on Plate 7.

Other Projects Plans. There are plans for further developments on the Merced and Tuolumne Rivers under active consideration, and proposed projects on the Stanislaus, Chowchilla, and Fresno Rivers. The contemplated developments are shown on Plates 1 and 7, and information relative to them is presented in Table 8.

On the Merced River, a project consisting of three dams and associated works is planned for early implementation by the Merced Irrigation District. This project would stabilize presently available water supplies, develop additional power, and provide additional flood protection for the lower reaches of the Merced and San Joaquin Rivers.

On the Tuolumne River, construction of the New Don Pedro Dam is being planned jointly by the Modesto and Turlock Irrigation Districts. Water supply, power, and flood control benefits would be derived from the project.

Construction of New Melones Dam on the Stanislaus River is under consideration as a joint project by the United States Corps of Engineers and Bureau of Reclamation. This project would provide additional flood protection for the lower reaches of the Stanislaus and San Joaquin Rivers, as well as additional irrigation and power benefits.

On the Chowchilla and Fresno Rivers the United States Corps of Engineers is planning the projected Buchanan and Hidden Dams, respectively. These developments would be multipurpose projects, although their principal benefit would be flood control.

The United States Bureau of Reclamation is currently studying the possible benefits which could be derived from a proposed East Side Canal, primarily diverting water to the south from the American River and the Sacramento-San Joaquin Delta. It is expected that a feasibility report on this project will be available by July 1961.

<u>Water Service Agencies</u>

Water for irrigation in the Lower San Joaquin Valley prior to 1950 was supplied principally from surface water diversion by water service agencies. The increase in the irrigated area since 1950 has apparently been made possible by development of ground water supplies on an individual basis. A total of about 1,200,000 acres is served by these agencies. The geographical areas included in the principal water service agencies are shown on Plate 8. Additional information on agencies organized as irrigation districts may be found in reports on the operations of irrigation and water storage districts in California, issued periodically by the Department of Water Resources (13) (26).

Water for municipal and industrial use in the area is furnished by numerous water service agencies obtaining their water supply principally from ground water.

The agencies supplying irrigation water have been divided into four groups according to their principal source of supply. Table 9 lists the agencies in each group, together with their location and service areas.

Water service agencies in the East Side group obtain water from the Stanislaus, Tuolumne, Merced, and Upper San Joaquin Rivers by means of storage in upstream reservoirs, supplemented by

TABLE 9

WATER SERVICE AGENCIES IN THE
LOWER SAN JOAQUIN VALLEY AREA

Agency	Location (at or near)	Service area, in acres
East Side Group		
Chowchilla Water District	Chowchilla	62,574
El Nido Irrigation District	El Nido	7,295
Gravelly Ford Water Association	Madera	2,500
Madera Irrigation District	Madera	88,688
Merced Irrigation District	Merced	145,348
Modesto Irrigation District	Modesto	70,038
Oakdale Irrigation District	Oakdale	56,918
South San Joaquin Irrigation District	Manteca	63,842
Turlock Irrigation District	Turlock	163,735
Waterford Irrigation District	Waterford	6,700
San Joaquin River Group		
West Side of River		
Banta-Carbona Irrigation District	Carbona	15,919
Blewitt Mutual Water Company	Vernalis	1,064
El Solyo Water Company	Vernalis	4,277
Patterson Water District	Patterson	14,100
Twin Oaks Irrigation Company	Patterson	2,400
West Stanislaus Irrigation District	Westley	22,429
White Lake Mutual Water Company	Westley	2,258
Reclamation District 1602	Patterson	1,495

TABLE 9

WATER SERVICE AGENCIES IN THE
LOWER SAN JOAQUIN VALLEY AREA (continued)

Agency	Location (at or near)	Service area, in acres
San Joaquin River Group (continued)		
East Side of River		
East Side Canal and Irrigation Company	Stevinson	5,935
Stevinson Water District	Stevinson	20,000
Reclamation District 1604	Patterson	3,960
Reclamation District 2031	Vernalis	3,000
Reclamation District 2063	Crows Landing	1,752
Reclamation District 2064	Manteca	3,000
Reclamation District 2075	Ripon	2,773
Mendota Pool Group		
Central California Irrigation District	Los Banos	132,436
Columbia Canal Company	Firebaugh	16,560
Dos Palos Drainage District	Dos Palos	9,552[a]
Firebaugh Canal Company	Firebaugh	23,675
Grasslands Water District	Los Banos	47,084
Gustine Drainage District	Gustine	20,321[a]
San Luis Canal Company	Los Banos	42,979
Delta-Mendota Canal Group		
Broadview Water District	Mendota	9,661
Davis Water District	Newman	2,249
Del Puerto Water District	Patterson	3,650
Eagle Field Water District	South Dos Palos	1,789

TABLE 9

WATER SERVICE AGENCIES IN THE
LOWER SAN JOAQUIN VALLEY AREA (continued)

Agency	Location (at or near)	Service area, in acres
Delta-Mendota Canal Group (continued)		
Foothill Water District	Newman	1,965
Hospital Water District	Westley	7,862
Kern Canyon Water District	Westley	2,934
Mercy Springs Water District	Dos Palos	2,652
Mustang Water District	Gustine	3,671
Ora Loma Water District	South Dos Palos	1,131
Orestimba Water District	Crows Landing	5,135
Pacheco Water District	South Dos Palos	999
Panoche Water District	Dos Palos	38,240
Plainview Water District	Tracy	5,419
Quinto Water District	Gustine	2,173
Romero Water District	Volta	1,354
Salado Water District	Patterson	2,860
San Luis Water District	Los Banos	51,325
Sunflower Water District	Crows Landing	2,871
Widren Water User's Association	Firebaugh	1,363

a/ Drainage area

direct pumped diversions from these streams and from wells in the irrigated areas.

Agencies in the San Joaquin River group obtain water primarily by pumping directly from the San Joaquin River downstream from Fremont Ford Bridge and from the three main tributaries near their confluence with the San Joaquin River. The group is subdivided into those agencies west of the San Joaquin River and those east of the river. Included in this group are the four agencies cooperating in this investigation.

In the years following completion of the San Joaquin and Kings River Canal (1872), temporary brush dams were erected across the San Joaquin River channel near Mendota, during the irrigation season, to back up the waters in the river channel so that they could be diverted into the canal. Eventually, a permanent diversion structure was erected, causing water to back up into the channels of the San Joaquin River and Fresno Slough. With the passage of time, the shallow reservoir came to be known as the "Mendota Pool". Agencies obtaining water supply principally from the operation of this artificial lake are referred to herein as the Mendota Pool group. The group consists almost wholly of the Affiliated Canal Companies, so identified because they were the primary participants involved in the exchange of water in the San Joaquin River for water supplied by the Delta-Mendota Canal. These agencies are the Central California Irrigation District (formerly the area served by the San Joaquin Canal Company), the San Luis Canal Company, the Firebaugh Canal Company, and the Columbia Canal Company.

Between 1930 and 1940, two drainage districts in the vicinity of Dos Palos and Gustine were formed to serve areas affected by high ground water. Their boundaries coincide with certain portions of the present Central California Irrigation District, formed in 1954. Water from wells operated by these districts is spilled into the canal system of the Central California Irrigation District or is discharged to minor tributaries of the San Joaquin River.

Agencies of the Delta-Mendota Canal Group were organized primarily for the purpose of utilizing the canal as their main source of supply. Water is supplied to these agencies by diversion from the canal or via the facilities of other agencies in the Mendota Pool group. Should the proposed San Luis Project be constructed, two of the water districts listed, Panoche and San Luis, will be able to obtain additional water from that source.

Land Use

Irrigated agriculture constitutes the largest and most important use of land within the Lower San Joaquin Valley. At present, over 1,000,000 acres are devoted to alfalfa, cotton, hay and grain, truck crops, vineyards, pasture, orchards, and rice. In State Water Resources Board Bulletin No. 2, "Water Utilization and Requirements of California", 1955 (36), it is estimated that within the area of investigation, the total ultimate irrigated acreage on the valley floor will be about 1,700,000 acres, with urban and suburban areas utilizing about 25,000 acres.

Data regarding the growth of irrigated agriculture in the area is presented to provide a means of evaluating significant changes in irrigated land use. Detailed studies of trends and variations in land use are beyond the scope of this investigation. These data have been obtained from surveys of irrigated lands made by the Department of Water Resources in 1948-50 and during 1957 and 1958. Results of these surveys are listed in Table 10, divided into data pertaining to lands west and east of the San Joaquin River and separated by principal crop classes. Although a portion of the service areas of the Oakdale and the South San Joaquin Irrigation Districts is outside the area covered by this investigation, no deduction for this irrigated acreage was made for Table 10.

Comparison of the results of these surveys, conducted approximately ten years apart, shows that the area irrigated on the west side, in 1957, was about 110,000 acres greater than in 1948-50; and on the east side, in 1958, was about 130,000 acres greater than in 1948. The increase in irrigated acreage on the west side can be attributed to the completion of the Delta-Mendota Canal in 1951 and further development of ground water. Growth on the east side is a result of increased ground water development and of a firmer water supply provided by water conservation works placed in service during the intervening period.

With a rapidly growing population, the demand for agricultural products increases; which, in turn, brings about conversion of agriculture from the practice of dry farming to the more profitable production of irrigated crops. Thus, the overall growth within the area of investigation probably can be attributed to the rising economy of the state and nation.

Further examination of the data indicates that on the west side, the area irrigated in 1957 was about 38 percent greater

TABLE 10

AREAS OF IRRIGATED LANDS IN THE
LOWER SAN JOAQUIN VALLEY AREA

(In acres)

Crop	West side of valley		East side of valley	
	Year		Year	
	1948-50	1957	1948	1958
Alfalfa	102,000	115,000	125,000	116,000
Pasture	19,500	64,600	217,000	280,000
Orchard	6,900	15,800	76,300	119,000
Vineyard	200	0	76,000	72,000
Truck crops	25,400	38,500	26,700	36,000
Rice	9,600	15,400	7,700	11,400
Cotton	30,000	43,200	79,500	58,600
Hay and grain	68,100	50,500	86,700	22,000
Miscellaneous field crops	31,100	59,000	33,700	146,000
TOTALS	292,800	402,000	728,600	861,000

than in 1948-50, with one-third of the increase occurring on lands served by the Delta-Mendota Canal group of water service agencies; one-third on lands served by the Mendota Pool group; and one-third on individually served lands not included within the area of organized agencies. East of the San Joaquin River, most of the increase appears to have taken place in Merced and Madera Counties on lands outside the areas served by organized agencies.

Beneficial Use of Water

The major use of water within the Lower San Joaquin Valley area is for irrigation. Surface water is the main source of supply. Municipalities utilize ground water almost exclusively as their source of supply. The relatively small amounts of water used by industry are supplied largely by municipalities.

Consumptive Use of Water

The term, consumptive use of water, refers to water consumed by vegetative growth in transpiration and building of plant tissue, and to water evaporated from adjacent soil, from water surfaces, and from foliage. It also refers to water similarly consumed and evaporated by urban and nonvegetative types of land use.

Estimates of the consumptive use of water in the Lower San Joaquin Valley are presented in Bulletin No. 2 (36). Supplemental consumptive use studies are presently under way. In Bulletin No. 2 (36), the mean seasonal consumptive use of water on irrigated lands in the area was estimated to be about 3,000,000 acre-feet. The total can be divided into that portion derived from applied water, 2,000,000 acre-feet; and that from precipitation, slightly less than 1,000,000 acre-feet. The mean seasonal consumptive use of applied water on farm lots, urban and suburban lands, and unclassified land areas was estimated at 12,000, 15,000, and 25,300 acre-feet, respectively.

Agricultural Use

Surface water is available to satisfy the requirements of most of the agricultural lands in the area, with ground water used as a supplemental supply. In certain locations, however, ground water is the only available source of irrigation water. In those areas underlain by high ground water tables, much of the water pumped for control of the water is subsequently mixed with the available surface supply.

Water users on the east side of the valley generally are assured of a reliable supply of water of excellent mineral quality; those served from the Mendota Pool are usually assured of a reliable supply, although of variable mineral quality; while those served from the San Joaquin River have, at times, a variable supply of water of doubtful quality for agricultural use.

Data on the quantity of surface water diverted by individuals and districts, from the various streams or stream reaches, are published in other reports of the Department of Water Resources (12). Accordingly, only the total overall diversions of surface water for agriculture and the details of certain specific diversions are presented in this report.

Table 11 lists the gross diversion of surface water for irrigation in the Lower San Joaquin Valley area for the calendar years 1930 to 1958. Waters exported from the area, particularly diversions via the Friant-Kern Canal and Fresno Slough and minor diversions from the San Joaquin River, between Friant Dam and Mendota Dam, have been excluded. To enable comparison of irrigated areas, as given in Table 10, with the gross diversion of surface water for irrigation, water exported via the Oakdale-South San Joaquin diversion is included in the total diversion. Diversion from surface water supplies for irrigation increased from 2,500,000 acre-feet, in 1930, to 3,500,000 acre-feet in 1958. Diversions have been in excess of 3,000,000 acre-feet annually since 1949. This is an overall increase, not confined to any particular subbasin or source of supply, although a substantial portion of the increase can be attributed to development of features of the Central Valley Project, i.e., Friant Reservoir and the Delta-Mendota and Madera Canals.

Distribution of the total diversion between sources of supply is depicted in Figures 1 and 2. Figure 1 shows the average

TABLE 11

ANNUAL GROSS DIVERSION OF SURFACE WATER SUPPLIES
FOR IRRIGATION USE IN THE
LOWER SAN JOAQUIN VALLEY FOR THE PERIOD 1930-58

(In thousands of acre-feet)

Calendar year	Total diversion	Calendar year	Total diversion
1930	2,530	1945	3,230
1931	1,590	1946	3,250
1932	3,000	1947	2,860
1933	2,590	1948	2,840
1934	2,160	1949	3,070
1935	2,570	1950	3,170
1936	2,590	1951	3,170
1937	2,550	1952	3,310
1938	2,640	1953	3,500
1939	2,550	1954	3,480
1940	2,750	1955	3,390
1941	2,650	1956	3,750
1942	2,830	1957	3,610
1943	2,840	1958	3,440
1944	2,980		

distribution of diversions occurring between the location of the present Friant Dam and Mossdale for the period from 1930-50. Figure 2 represents the average distribution for the 1951-58 period and shows the effect of the importation of water through the Delta-Mendota Canal commencing in 1951.

As can be seen, diversions from the Tuolumne River and the Mendota Pool constitute 60 percent of the total diversion effected prior to 1950 and about 51 percent after that date. The difference, however, is more apparent than real, since the average total diversion prior to 1951 was about 2,730,000 acre-feet, and after that date was about 3,460,000 acre-feet. For the years preceding the importation of water via the Delta-Mendota Canal, the

Upper San Joaquin River (Mendota Pool and the Madera Diversion) and the three principal tributaries supplied 94 percent of the water diverted.

The average distribution of diversions from the San Joaquin River between Fremont Ford and Mossdale, according to using agency, for the years 1951-58 is shown by Figure 3. This figure is, consequently, an expansion of the quantity (about 7 percent of the total diversions) shown in Figure 2 for the section of the San Joaquin River between these two stations.

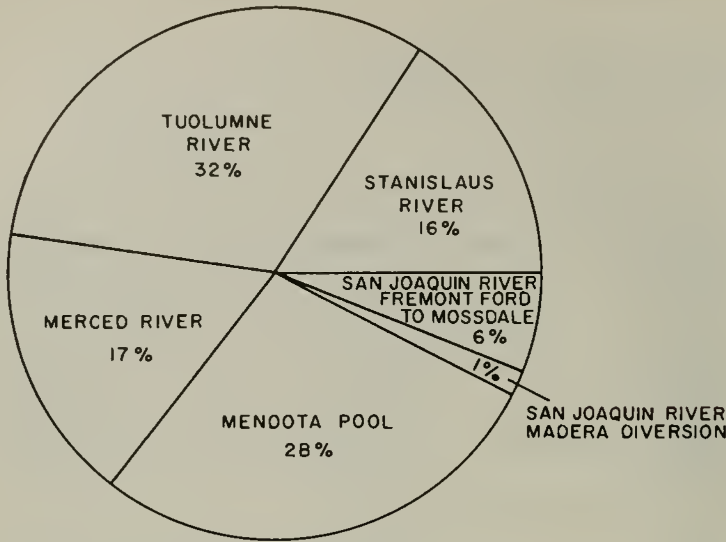
Domestic and Municipal Use

Ground water in the area affords a supply of relatively good quality water for domestic and municipal uses without the necessity for expensive treatment. In addition to the use in municipalities, ground water is the source of water for domestic use outside urban areas.

Dos Palos and Los Banos are the major exceptions to the exclusive use of ground water for municipal purposes. Dos Palos obtains most of its required water supply from the San Joaquin River at Mendota Pool via facilities of the Central California Irrigation District. Los Banos secures somewhat less than one-half of the quantity of water needed for municipal demand from the same source. Both cities pump from ground water to supplement the surface diversions.

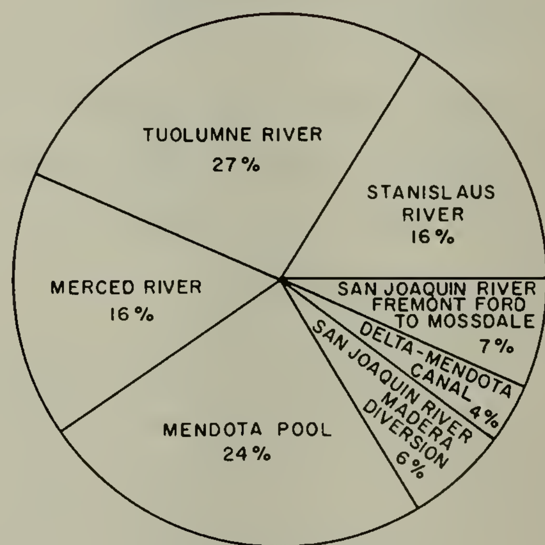
Industrial Use

Industrial water uses mainly occur within municipal water service areas. Although some of the major industrial establishments operate their own wells, the majority obtain water from



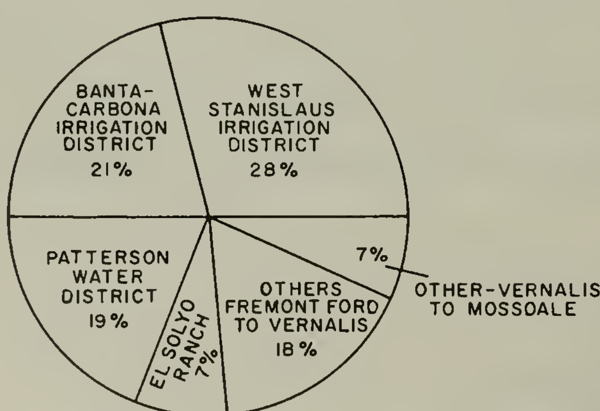
AVERAGE DIVERSIONS
IN AREA BETWEEN
MILLERTON LAKE AND MOSSDALE
1930-1950

FIGURE 1



AVERAGE DIVERSIONS
IN AREA BETWEEN
MILLERTON LAKE AND MOSSDALE
1951 - 1958

FIGURE 2



AVERAGE DIVERSION FROM
SAN JOAQUIN RIVER BETWEEN
FREMONT FORD AND MOSSDALE
1951 - 1958

FIGURE 3

NOTE: OPERATION OF THE DELTA-MANDOTA CANAL BEGAN IN 1951.

established water service agencies. The bulk of the required water is used in the food processing industry.

Hydroelectric Power Generation

The use of water for the generation of power is confined to streams on the east side of the valley. The present capacity is in excess of 800,000 kilowatts installed in 25 hydroelectric powerplants on the Stanislaus, Tuolumne, Merced, and San Joaquin Rivers. From consideration of the plans proposed in Bulletin No. 3 (23), it is estimated that an additional 600,000-kilowatt capacity can be developed by further regulation in these streams.

Fish and Wildlife Uses

The use of water for the preservation and propagation of fish and wildlife is of special importance among the employments of water for recreational purposes. The availability of water for this use in the Lower San Joaquin Valley area is affected by the operation of the numerous reservoirs controlling the water resources of the region. Stream fishing on the valley floor, consequently, generally is limited in extent. However, an excellent fishery is found in the mountain portions of the tributary drainage area and many of the existing reservoirs are stocked with catchables by the California Department of Fish and Game.

Hunting of wildfowl is of prime significance on the valley floor as the investigation area lies athwart the major Pacific Flyway route. At the close of the irrigation season, large acreages of the grasslands are flooded to provide nesting places for waterfowl flying to the south. The Los Banos Waterfowl and Management Area, operated by the Department of Fish and Game, and hunting areas owned by private clubs, occupy thousands of acres on the valley floor.

Much of this activity is centered in the grasslands area of Merced County, which, for many years, has led the counties in California in number of ducks bagged and contains almost 300 private and commercial duck clubs. Soils in the grasslands area are generally saline-alkaline in composition and therefore are limited to raising of salt tolerant grasses used as forage for cattle. For the present, the grasslands appear to have more value as hunting lands than as cropped agricultural lands.

Recreational Use

Recreational uses of water in the Lower San Joaquin Valley area, in addition to fish and hunting, include swimming, boating, and the aesthetic benefits derived from the protection of areas of natural beauty and through the development of conservation works. The area of investigation contains Yosemite National Park and eight state parks; one of which is undeveloped. Over 1,000,000 persons visit Yosemite National Park each year. In 1957, slightly less than 1,000,000 persons used the facilities provided in the seven developed state parks, representing a 50 percent increase over the attendance registered in 1954.

Flood Control

The control of floods is a major problem in the Lower San Joaquin Valley. At present, each of the existing major water conservation facilities is operated to provide a measure of flood protection for downstream areas; however, additional facilities are needed for adequate protection against disaster.

Within the area of investigation, there are four dams built for the primary purpose of control of flood waters. These dams, and associated reservoirs, are Bear, Burns, Owens, and Mariposa, located on streams of the same name. For purposes of reference, these streams are often designated the Merced Stream Group.

There are two San Joaquin River flood control projects now under construction. One of these consists of the construction of a complete levee system for the San Joaquin River, from the mouth of the Merced River south to Gravelly Ford Canal. This levee system is being built by the Department of Water Resources for the State Reclamation Board. The project consists of levees along the San Joaquin River, three bypass channels, and a retention basin near the mouth of the Fresno River. The second project, being built by the United States Corps of Engineers, is the construction of a levee system on the San Joaquin River, from the mouth of the Merced River north to Mossdale Bridge.

Accretions

Accretions to stream flow in the San Joaquin River channel originate in five ways, which for simplicity are referred to as sources. These sources are: spillage, drainage, effluent ground water, ground water pumped for water table control, and sewage and industrial wastes. Many of the individual return flow channels carry waters stemming from a combination of these sources. The proportions of these combinations are constantly varying, making it impossible to determine exactly how much water from each source is contained in a drainage channel at a particular time. Most of the tributary channels with wide fluctuations in contributions from the various sources enter the San Joaquin River from the east.

As a result of development of lands within a productive agricultural basin, accretions generally increase as the quantities of applied water increase. Such flows may be either beneficial or detrimental, as illustrated by conditions in the lower San Joaquin River. Due to an increase in concentration of mineral constituents caused by consumptive use, leaching, and other factors, accretions tend to degrade the better quality waters with which they are mixed. On the other hand accretions, in which mineral concentrations are not excessive, supplement the flows available to meet the demands of downstream users.

Existing stream channels, sloughs, drains, and canals are utilized for the disposal of return water. Some return water is disposed of directly to the main streams, but reuse of such water from drainage channels before it reaches a stream is common.

During summer and fall months, and in other months during dry years, stream flow in the San Joaquin River below Fremont Ford is largely return flow, as are flows in the downstream reaches of the principal tributaries. This condition is not a recent development but has existed for many years.

Location of Accretions

The drainage system of the Lower San Joaquin Valley is extensive and complex; consequently, no attempt has been made to provide a detailed description in this report. Of significance to users of waters of the lower San Joaquin River are the location of, and flows derived from, tributary channels debouching to the river. The quantity of such accretions is discussed subsequently.

During the course of the investigation, about 70 channels tributary to the San Joaquin River between Mossdale and Santa Rita Bridge, and 30 channels tributary to the Merced, Tuolumne, and

Stanislaus Rivers were observed and inspected. Further study was made of the more significant drainage channels.

Table 12 lists the tributary surface accretions found, and the location and type of outlet. The location of outlets tributary to the San Joaquin River are shown on Plate 3, as are many of those tributary to the Merced, Tuolumne, and Stanislaus Rivers.

A few of the channels listed in Table 12 carry local runoff during the winter months, and some of the channels are utilized for the collection and disposal of seepage waters, which generally occur during high stages of flow in the lower reaches of the rivers. Where the use of pumps is noted, the drainage channels usually receive seepage waters, since the majority of lands subject to seepage lie below the elevation of high water stages in the adjacent stream channels.

Quantity of Accretions

Accreting water is present in the San Joaquin River and its principal tributaries throughout the year. Obviously, during winter months when runoff due to rainfall dilutes or obliterates the identity of such waters, and when minor amounts of surface water are diverted for irrigation, the quantity is much smaller, of little import, and difficult to measure. Of most interest to this investigation, however, are the flows which occur during the irrigation season, roughly from March through October. During the spring months, runoff due to rainfall and snowmelt is present in predominant amounts and, consequently, accretion quantities are a small proportion of the total flow. In dry years, such as 1959, or in the early spring months of years when runoff due to rainfall

TABLE 12

LOCATION OF SURFACE ACCRETIONS TO THE SAN JOAQUIN RIVER AND ITS PRINCIPAL TRIBUTARIES

Name	Reference number, Plate 3	Location of outlet	Bank[a]	Type of outlet[b]
San Joaquin River - Mossdale Bridge to Durham Ferry Bridge				
Walthall Slough (tributary to Wetherbee Lake)	1	2S/6E-10R	R	G
South San Joaquin Irrigation District Lateral No. 11 (to Wetherbee Lake)[c]	2	2S/6E-23B	R	G
Paradise Mutual Water Co. Drain (tributary to Paradise Cut)	3	2S/6E-16D	L	P
Dethlefson Drain Pump (tributary to Paradise Cut)	4	2S/6E-16L	L	P
Drain Pump	5	2S/6E-22B	R	P
Drain Pump	6	2S/6E-22H	R	P
Drain Pump	7	2S/6E-27F	L	P
Kasson Drain Pump	8	2S/6E-34R	L	P
Drain Pump	9	2S/6E-35A	R	P
Drain Pump	10	3S/6E-1D	R	P
San Joaquin River - Durham Ferry Bridge to Hetch Hetchy Crossing				
West Stanislaus Irrigation District Drain	11	3S/6E-24J	L	G
Drain Pump	12	3S/6E-24J	L	P
Blewitt Drain	13	3S/7E-29N	L	G
West Stanislaus Irrigation District - El Solyo Drain	14	3S/7E-29N	L	G
El Solyo Drain	15	3S/7E-29N	L	M
San Joaquin River - Hetch Hetchy Crossing to Grayson				
El Solyo Drain	16	3S/7E-32J	L	M
Hospital Creek (tributary to Burkhardt Drain)	17	4S/7E-4L	L	G
Burkhardt Drain	18	4S/7E-4G	L	G
Sarmento Drain Pumps	19	4S/7E-4J	L	P
Modesto Irrigation District Lateral No. 4 (extended)	20	3S/7E-34L	R	G
West Stanislaus Irrigation District Drain[d]	21	4S/7E-14E	L	G
Field Drain	22	4S/7E-13R	R	G
Field Drain	23	4S/7E-23H	L	G
West Stanislaus Irrigation District Drain[d]	24	4S/7E-23N	L	G
West Stanislaus Irrigation District Drain[d]	25	4S/7E-26D	L	G

TABLE 12

LOCATION OF SURFACE ACCRETIONS TO THE SAN JOAQUIN RIVER AND ITS PRINCIPAL TRIBUTARIES (continued)

Name	Reference number, Plate 3	Location of outlet	Bank[a]	Type of outlet[b]
San Joaquin River - Hetch Hetchy Crossing to Grayson (continued)				
Wesley Wasteway[d]	26	4S/7E-26K	L	G
West Stanislaus Irrigation District Drain[d]	27	4S/7E-26J	L	G
San Joaquin River - Grayson to Newman (Hills Ferry Bridge)				
Turlock Irrigation District Lateral No. 2	28	4S/7E-25G	R	G
West Stanislaus Irrigation District Drain	29	4S/8E-30K	L	G
Turlock Irrigation District Westport Drain	30	4S/8E-32F	R	G
Del Puerto Creek	31	4S/8E-32N	L	G
Chase Ranch Drain Pump	32	4S/8E-32R	R	M
Patterson Water District Lateral A	33	5S/8E-5F	L	G
Salado Creek	34	5S/8E-16B	L	G
Patterson Sewage Outfall	35	5S/8E-16H	L	G
Patterson Water District Tile Drains	36	5S/8E-15M	L	G
Lake Ramona	37	5S/8E-22R	L	G
Levee Drain	38	5S/8E-24N	R	G
Turlock Irrigation District Lateral No. 5	39	5S/8E-25R	R	G
Patterson Water District Lateral G	40	6S/8E-1Q	L	G
Patterson Water District Drain	41	6S/8E-1R	L	G
Vivian Slough	42	6S/9E-8D	R	M
Orestimba Creek	43	6S/9E-8Q	L	G
Field Drain	44	6S/9E-17E	L	G
Unnamed Drain	45	6S/9E-17K	L	G
Field Drain	46	6S/9E-21D	L	G
Turlock Irrigation District Lateral Nos. 6-7	47	6S/9E-21B	R	G
Unnamed Drain	48	6S/9E-28M	L	G
San Joaquin River - Newman to Fremont Ford Bridge				
Newman Wasteway	49	7S/9E-10L	L	G
Unnamed Drain	50	7S/9E-11R	R	G
Los Banos Creek	51	7S/9E-26G	L	G
Mud Slough	52	7S/9E-26G	L	G

TABLE 12

LOCATION OF SURFACE ACCRETIONS TO THE
SAN JOAQUIN RIVER AND ITS PRINCIPAL TRIBUTARIES (continued)

Name	Reference number, Plate 3	Location of outlet	Bank[a]	Type of outlet[b]
San Joaquin River - Fremont Ford Bridge to Santa Rita Bridge				
Stevinson Water District Spill	53	7S/10E-20P	R	G
Salt Slough	54	7S/10E-29L	L	G
Unnamed Drain	55	7S/10E-26G	R	G
Bear Creek	56	7S/10E-36L	R	G
Mariposa Slough	57	8S/11E-34D	R	G
Unnamed Canal	58	9S/11E-4J	L	G
Field Drain	59	9S/11E-10P	L	G
Field Drain	60	9S/11E-14F	L	G
San Luis Canal Co. Spill	61	9S/11E-13E	L	G
Unnamed Drain	62	9S/12E-18N	L	G
Unnamed Drain	63	9S/12E-18K	L	G
Unnamed Drain	64	9S/12E-16M	L	G
Unnamed Drain	65	9S/12E-25M	R	G
Riverside Canal Spill	66	9S/13E-31B	L	G
Unnamed Spill	67	10S/13E-16C	L	G
Stanislaus River - Mouth to Gaging Station				
Faith Ranch Drain	68	3S/7E-19J	L	M
Faith Ranch Drain	69	3S/7E-17Q	L	M
Stanislaus River - above Gaging Station				
Bret Harte Drain	70	3S/7E-4Q	R	G
Modesto Irrigation District Lateral Nos.-6-8	71	3S/7E-1E	L	G
South San Joaquin Irrigation District Spill	72	2S/7E-35H	R	G
South San Joaquin Irrigation District Spill	73	2S/8E-20Q	R	G
Modesto Irrigation District Main Canal	74	2S/8E-28F	L	G
South San Joaquin Irrigation District Escalon Spill	75	2S/9E-17J	R	G
Tuolumne River - Mouth to Tuolumne City				
Drain Pumps	76	4S/7E-11J	L	P
Unnamed Drain	77	4S/7E-2H	R	G
Modesto Irrigation District Lateral No. 5	78	4S/7E-1K	R	G

TABLE 12

LOCATION OF SURFACE ACCRETIONS TO THE
SAN JOAQUIN RIVER AND ITS PRINCIPAL TRIBUTARIES (continued)

Name	Reference number, Plate 3	Location of outlet	Bank[a]	Type of outlet[b]
Tuolumne River - Above Tuolumne City				
Modesto Irrigation District Spill	79	4S/8E-7G	R	G
Turlock Irrigation District Lateral No. 1	80	4S/8E-14C	L	G
Modesto Sewage Outfall	81	4S/9E-7D	R	G
Dry Creek	82	3S/9E-33K	R	G
Modesto Irrigation District Spill	83	4S/9E-3A	R	G
Gas Well	84	4S/9E-2C	L	G
Gas Well	85	4S/9E-2G	L	G
Gas Well	86	4S/9E-2J	L	G
Beard Tract Sewage	87	4S/9E-1C	R	G
Turlock Irrigation District Spill	88	4S/10E-6N	L	G
Waterford Irrigation District Spill	89	3S/11E-32J	R	G
Gas Well	90	3S/11E-34D	R	G
Gas Well	91	3S/11E-34C	R	G
Turlock Irrigation District Hickman Spill	92	3S/11E-35D	L	G
Merced River - Mouth to Stevinson				
Stevinson Water District Spill	93	7S/9E-2M	L	G
Merced River - Above Stevinson				
Turlock Irrigation District Stevinson Lateral	94	6S/9E-36G	R	G
Turlock Irrigation District Highline Canal Spill	95	6S/11E-30C	R	G
Merced Irrigation District Livingston Spill	96	6S/11E-14K	L	G

a/ L - Left bank, R - Right bank (facing downstream)
b/ Type of outlet: G - Gravity, P - Pump, M - Combination gravity and pump
c/ Alignment change has made this channel tributary to Walthall Slough
d/ Tributary to old channel of San Joaquin River

or snowmelt is deficient in quantity, the quantity of drainage water during the early part of the irrigation season is important.

The period of primary concern, in addition to the above-mentioned dry year flows, is during the summer months of July, August, and September, when natural runoff is ordinarily at a minimum and diversions, particularly for agricultural use, are substantial. The fact that flow in the lower reaches of the San Joaquin River and its tributaries during summer months consists largely of return water has been acknowledged for many years. The first measurements to determine the quantities of accretion were made under the direction of Consulting Engineer Thomas H. Means during the years 1914 to 1919. Between 1920 and 1927, predecessor agencies of the Department of Water Resources made similar measurements along the course of the San Joaquin River and its tributaries. In 1928, eight gaging stations were established on these streams and, in conjunction with existing stations of other agencies, greatly facilitated the determination of the quantity of accretions during the summer months. These gaging stations, plus others later found to be desirable, were eventually placed in continuous operation.

Accretions to the San Joaquin River and its tributaries, irrespective of source, for summer months during the years 1954 through 1958, are listed in Table 13. All accretions occurring downstream from the lowermost gaging station established on each of the three principal tributaries are included in the quantities of accretion given for the respective reaches of the San Joaquin River.

Because of the effect of tidal action on stream flow in the reach between Vernalis and Mossdale Bridge, downstream

TABLE 13

ACCRETIONS TO FLOW IN LOWER SAN JOAQUIN RIVER
AND PRINCIPAL TRIBUTARIES
FOR PERIOD JULY 1 TO SEPTEMBER 30

(In cubic feet per second)

Reach	Length of reach, in miles	Average accretions				
		1954	1955	1956	1957	1958
San Joaquin River						
Near Dos Palos to Fremont Ford	56	132	129	227	169	394
Fremont Ford to Near Newman	7	28	13	22	32	90
Near Newman to Near Grayson	29	229	233	408	284	569
Near Grayson to Hetch Hetchy Crossing	11	164	106	301	228	303
Hetch Hetchy Crossing to Near Vernalis	6	38	63	160	80	125
Merced River						
Below Snelling to Near Stevinson	37	202	180	352	222	337
Tuolumne River						
La Grange to Tuolumne City	47	294	251	382	297	538
Stanislaus River						
Orange Blossom Bridge to Near Mouth	45	183	166	262	248	395

from Vernalis, derivation of accretions to this reach is impractical. Surface flows tributary to this reach were measured during the irrigation season (March through October) in 1955 and 1956 to facilitate other studies of the Sacramento River and the Delta currently being made by the Department of Water Resources. The measured summer flows were 3,780 acre-feet in 1955, and 3,930 in 1956.

In a previous paragraph, it has been pointed out that there frequently are other periods than the summer months of July, August, and September, when accretions are of importance. From the standpoint of users of water from the lower San Joaquin River and its tributaries, these periods would be the spring months of March, April, May, and June. The quantity of accretions available during these months is particularly important in drought years, or in dry months of other years. At such times, runoff due to precipitation and snowmelt is generally significantly deficient. Inspection of records of stream flow in the San Joaquin River near Newman, Grayson, and Vernalis indicates spring periods in the past when such conditions occurred.

Upstream from the junction with the Tuolumne River, accretions in the spring months are generally of importance in practically all years due to diminished main stream flows stemming from the operation of conservation storage. This condition has occurred somewhat regularly since 1947 as well as in known drought years prior to that date. However, in 1952, 1956, and 1958, years of abnormal runoff, spill from the upstream storage works combined with local runoff, provided ample quantities of main stream flow for dilution of local drainage. Tuolumne and Stanislaus Rivers often provide ample quantities of water for beneficial uses in the portion of the area downstream from Grayson, even in years when the water supply in the region between Grayson and Dos Palos is deficient in quantity.

The establishment of additional stream gaging stations, providing the more complete geographical coverage of the area, has resulted in the conclusion that between 1945 and 1958, low flow conditions in the entire stream system existed only during five years; 1947, 1948, 1953, 1955, and 1957. Prior to 1945, the known drought years were 1930, 1931, 1933, 1934, and 1939.

CHAPTER IV. WATER QUALITY

The mineral quality of surface and ground waters in the Lower San Joaquin Valley area varies considerably from place to place and time to time, but generally is suitable for most beneficial uses. However, poor quality ground waters occur in certain areas and surface water quality is degraded at times when natural runoff is less than required for dilution of return waters containing higher concentrations of salts.

Water Quality Criteria

In all activities dealing with measurement and observation of physical data, there must be a yardstick or standard by which the observer, planner, and user can judge or classify the information gathered. With regard to water quality, the problem becomes one of determining whether or not the water is suitable for the anticipated use. This investigation is concerned primarily with the use of water for irrigation.

Criteria for the mineral quality of irrigation water have been developed at the University of California at Davis and at the Regional Salinity Laboratory of the United States Department of Agriculture. Because of diverse climatological conditions and the variation in crops and soils in California, only general limits of quality for irrigation waters, as given in the following tabulation, can be suggested.

QUALITATIVE CLASSIFICATION OF IRRIGATION WATERS

Chemical properties	Class 1 excellent to good	Class 2 good to injurious	Class 3 injurious to unsatisfactory
Specific electrical conductance, in micromhos at 25°C	Less than 1000	1000 - 3000	More than 3000
Total dissolved solids, in ppm	Less than 700	700 - 2000	More than 2000
Chlorides, in ppm	Less than 175	175 - 350	More than 350
Sodium, in percent of base constituents	Less than 60	60 - 75	More than 75
Boron, in ppm	Less than 0.5	0.5 - 2.0	More than 2.0

These criteria are subject to limitations in actual practice. In many instances a water may be wholly unsuitable for irrigation under certain conditions of use, and yet be satisfactory under other circumstances. Additional physical factors such as soil permeability, drainage, temperature, humidity, rainfall, and other similar conditions can alter materially the response of a crop to a particular quality of water.

Specific electrical conductance (denoted in Tables 14-27 as $ECx10^6$) is a chemical property of a given water providing an approximate measure of the quantity of total dissolved solids (TDS) in solutions containing mineral matter. This determination is simple and inexpensive and the measured values of electrical conductance are a very useful index to the classification of water supplies. Throughout the investigational area, total dissolved solids, expressed in parts per million, usually range from 55 to 70 percent of the "conductivity" (as it is often referred to) expressed in micromhos.

Chlorides (Cl) are considered to be among the most troublesome anions found in irrigation water supplies. At certain levels of concentration, chlorides are toxic to most plants and therefore are an important consideration in classifying waters for use in irrigation. The determination of the quantity of chlorides contained in a water supply is relatively simple and accurate in modern laboratory practice.

For many years, leading agricultural experts have used the measure known as "percent sodium" (% Na) to identify waters which might induce the undesirable characteristics associated with alkali soils. When irrigation water containing an overabundance of sodium ions is applied to soils containing exchangeable calcium and magnesium ions, these ions tend to be replaced by the sodium. Continued application of such water could cause the soil to be impaired in both tilth and permeability. The effects indicated by the percent sodium, the percentage relationship of the sodium concentration to the total cation concentration, are generally minor until the percentage rises considerably above 50 percent.

Boron (B) is found in almost all waters used for irrigation in this area. While minute traces of boron are essential for plant growth, many plants are very sensitive to boron and even small concentrations, barely in excess of the tolerance level, may produce plant injury. Plants vary in their sensitivity to boron, and in classifying waters according to their boron content, the tolerance of the crop to which the water is to be applied should be considered.

General objectives of the collection of water quality data during this investigation were: (1) the determination of quality of surface inflow to, and outflow from, the Lower San Joaquin Valley; (2) determination of the effect of the quality of water on lands served; and (3) the evaluation of factors affecting water quality. To these ends, discussion of the mineral quality of water supplies in the area is presented under three headings covering surface water, ground water, and sewage and industrial wastes. Tabular data on water quality, as given herein, are generally arithmetical average values for the location considered. Detailed data concerning the quality of water supplies in this area are available in the files of the department. Other records of surface water analyses may be found in reports by the Department of Water Resources (12) (22) (25) and the United States Bureau of Reclamation (62).

Surface Water

Monthly records of water quality of streams in the valley floor portion of the investigation area are available for most streams since 1938. Occasional analyses were made prior to that time. The quality of water entering the valley floor from the mountain drainage area has been, since 1951, measured monthly on the major streams, except for the Stanislaus River, on which sampling began in 1956. Data for minor streams has been obtained at irregular intervals for many years. The locations of water quality sampling points used in the investigation are shown on Plate 3.

To assist in visualizing the variation in quality and stream flow in the San Joaquin River channel, schematic drawings of these conditions are presented as Plates 9 and 10. The quality of water is shown on the plates in two forms: (1) as total dissolved solids in parts per million, defined by the width of the color band, and (2) as total tonnage of salts at significant points. These plates are pictorial in nature and only relative quantitative values are shown. Exact values and mathematical equalities at or between particular points cannot be attained through scaling since quantities of return water and minor diversions could not be shown, although their aggregate effect is evident.

These schematic drawings are included in this report to illustrate quality conditions under two general types of flow as they have occurred in recent years, that is, conditions during a summer month in a relatively dry year, and conditions during a spring month in an above-normal year. The months selected for the purposes of illustration were July 1955 and April 1956.

For purposes of discussion, the quality of surface waters has been separated into six categories: east side streams, west side streams above the valley floor, imported surface waters, valley floor tributaries, the main stream of the San Joaquin River, and waters diverted for use in the cooperating districts.

East Side Streams

Waters of streams on the east side of the valley are a calcium bicarbonate type, with low total solids and boron concentrations. There has been little industrial or agricultural water utilization in the upper watersheds to alter the mineral quality of water in these streams at the points where they enter the valley floor. As the streams cross the valley floor, the waters are degraded by return flows to a greater or lesser degree. A summary of the average quality of water in these streams, together with the maximum and minimum observed mineral content, is presented in Table 14 for three time periods. These periods include, respectively, all available records prior to 1951 (generally the 1938-1950 period), 1951 through 1954, and 1955 through 1959. These periods were selected for several reasons: (1) prior to 1951 there was no systematic collection of records of quality of inflow, as well as outflow, to and from the valley floor; (2) the period 1951-54 represents the years of adjustment to the present status of water conservation development; and (3) the period 1955-59, the years covered by the investigation, represents present conditions of water supply and use.

Stanislaus River. Records of the quality of Stanislaus River inflow to the valley floor are available since June 1956. These, plus occasional samples taken prior to that time, show the water to be of excellent quality.

Quality of water in the Stanislaus River at the mouth is slightly degraded due to return waters. The average quality at the mouth during the period 1951 through 1954 was slightly better than that of the period 1946-50 while the average for the period 1955-59 was poorer than for either of the preceding periods. Although the flow of the Stanislaus River at the mouth during the summer consists essentially of return water, the quality lies within Class 1. Winter floods and spring snowmelt flows show little degradation in crossing the valley.

Tuolumne River. Inflow to the valley floor has been sampled once a month since 1951. There is no substantial difference in average quality of water for the periods before and after the close of 1954. Samples collected throughout 1906 by the

TABLE 14

MINERAL QUALITY OF WATERS IN
PRINCIPAL EAST SIDE TRIBUTARIES
OF THE SAN JOAQUIN RIVER

Station	Prior to 1951				1951-1954				1955-1959			
	EC	Parts per million			EC	Parts per million			EC	Parts per million		
	x 10^6	TDS	Cl	B	x 10^6	TDS	Cl	B	x 10^6	TDS	Cl	B
Stanislaus River												
At Tulloch Dam												
Average									82	58	1.6	0.04
Maximum									249	175	7.0	0.30
Minimum									37	27	0	0.00
Near Mouth												
Average	---	125	7.3	---	185	109	4.8	0.06	205	143	6.3	0.03
Maximum	---	220	17	---	281	200	22	0.37	310	196	14	0.17
Minimum	---	32	0.3	---	50	35	0	0.00	47	40	0	0.00
Tuolumne River												
At Don Pedro Dam												
Average					41	23	1.3	0.03	38	26	0.9	0.02
Maximum					154	27	10	0.18	69	44	2.5	0.17
Minimum					18	20	0	0.00	14	15	0	0.00
At Tuolumne City												
Average	326	224	72	0.11	406	233	75	0.08	470	297	92	0.07
Maximum	716	525	160	0.30	880	530	180	0.36	1,030	571	238	0.20
Minimum	55	34	3.2	0.00	54	38	5	0.00	75	50	3	0.00
Merced River												
At Exchequer Dam												
Average					81	41	4.1	0.07	75	43	2.2	0.02
Maximum					162	81	5.2	0.24	242	77	7	0.06
Minimum					25	25	0	0.00	20	22	0	0.00

TABLE 14

MINERAL QUALITY OF WATERS IN
PRINCIPAL EAST SIDE TRIBUTARIES
OF THE SAN JOAQUIN RIVER (continued)

Station	Prior to 1951				1951-1954				1955-1959			
	EC	Parts per million			EC	Parts per million			EC	Parts per million		
	$x\ 10^6$	TDS	Cl	B	$x\ 10^6$	TDS	Cl	B	$x\ 10^6$	TDS	Cl	B
Merced River (continued)												
Near Stevinson												
Average	---	142	21	0.03	229	131	21	0.05	229	161	16	0.04
Maximum	---	343	76	0.06	366	217	52	0.31	385	248	38	0.24
Minimum	---	22	0.4	0.00	51	40	1.8	0.00	34	45	0	0.00
Chowchilla River												
At Buchanan Dam Site												
Average									335	176	60	0.05
Maximum									783	309	190	0.21
Minimum									57	38	5	0.00
Fresno River												
Near Daulton												
Average									153	89	21	0.03
Maximum									336	142	70	0.30
Minimum									72	55	4	0.00

United States Geological Survey, indicate that total dissolved solids averaged 74 parts per million, three times the average concentration since 1951. No apparent reason for this discrepancy can be ascertained.

Records of quality at the mouth of the Tuolumne River are available since 1938. Though the quality at the foothill line is better than that of the Stanislaus and Merced Rivers, this difference is reversed at the mouth of the Tuolumne River. In comparing the averages presented in Table 14 for the three streams at their mouths it is noted that, for each period, the total dissolved solids concentration in the waters of the Tuolumne River is about twice that of the others.

The average chloride concentration at the mouth of the Tuolumne River is over three times the average concentration in the Merced River for the period prior to 1951 and between 1951-54, and over five times the average for the period 1955-59. As compared to the Stanislaus River, the chloride concentration is ten times the average prior to 1951 and fifteen times the average since 1951.

From Table 14 it is also noted that the average concentrations of total dissolved solids at the mouth increase in each successive time period. An exception to this general condition is the average boron concentration, which is quite small and well within acceptable limits.

Comparison of quality records secured at an intermediate station located near Waterford, above most of the developed area for the periods 1951-54 and 1955-59, indicates that the quality of water during the latter period is slightly improved over that of the former. The conclusion resulting from this condition is that the continuing decrease in quality is occurring downstream from Waterford. Since 1953, waters at the mouth have been more frequently in Class 2 during the irrigation months.

Merced River. Quality of water records for inflow to the valley floor from the Merced River have been collected once a month since 1951. Little change is noted in the averages for the periods before and after December 1954, and the quality has been excellent at all times.

Records of quality at the mouth of the Merced River are available since 1938. Comparison of the values presented in Table 14 indicate that the quality improved during the 1951-1954 period, but subsequent increases in concentration have resulted in a slightly poorer average quality of water. However, waters of Merced River remain in Class 1 for irrigation.

Chowchilla and Fresno Rivers. Continuous records of quality in these streams have been obtained monthly since January 1958, at points above the valley floor. Only flood flows from these streams reach the San Joaquin River and, in the late summer months of many years, significant flow is absent in the upper reaches of the streams. During the irrigation season, portions of the reaches in the valley floor serve as conveyance channels for waters supplied from the Madera Canal. This water is either diverted for use or percolates to ground water and no flow exists in the lower reaches adjacent to the San Joaquin River. The quality of waters in both streams is generally within the limits of Class 1.

Minor East Side Streams Above the Valley Floor. There are only a few analyses available of waters from minor east side streams. These streams are Bear, Owens, Burns, Mariposa, and Little Dry Creeks. Single samples show the first four to be calcium-magnesium bicarbonate waters with total dissolved solids less than 310 parts per million, low chlorides, and almost no boron. A sample from Little Dry Creek near Friant, taken in March 1958, showed it to be a bicarbonate water with about equal concentration of the calcium, magnesium, and sodium ions. Total dissolved solids were 204 parts per million and boron 0.14 parts per million. Flow in these streams is dependent almost entirely on rainfall.

West Side Streams Above the Valley Floor

The quality of water on the west side of the Lower San Joaquin Valley varies from stream to stream and with stream stage. The west side streams are generally intermittent and natural flows occur only during the rainy months. No continuous records of quality exist, but sufficient analyses are available to indicate the prevailing quality in all but the smallest streams. Table 15 lists these streams, together with average values for the principal constituents indicative of water quality. Variations of the quality of water in these streams are discussed in the following paragraphs.

Corral Hollow Creek. This stream is intermittent and flows reach the San Joaquin River only during extremely high flood stages. The significant quality characteristic is the high boron content (3.2 parts per million). Because of the boron content, the average quality of water in this stream lies in Class 3 for agricultural use. A sample collected in February 1957 indicated a boron content of 7.2 parts per million.

Del Puerto Creek. Del Puerto Creek is one of the few west side streams with a channel actually extending from the foothills to the San Joaquin River. Natural flow beyond the foothills usually ceases before the irrigation season. The quality of native water in Del Puerto Creek is Class 2, because of its boron content (1.0 parts per million). During the summer months, flow in the reach between the crossing with the Delta-Mendota Canal and the creek mouth is entirely comprised of irrigation return water.

Orestimba Creek. This is the largest of the west side streams and the only one in which natural flow is continuously gaged. The water is mainly calcium-magnesium bicarbonate in type. During high stages, the quality is such that the waters are Class 1 for agricultural use. Higher concentrations of total dissolved solids and boron reduce the quality to Class 2 at times of low flow. Summer flow between the foothills and the mouth, east of Crows Landing, is comprised of irrigation return water.

Garzas Creek. Only five analyses of water from Garzas Creek are available. The water of this stream is mainly calcium-magnesium bicarbonate in type and is in Class 1 for irrigation use.

Quinto Creek. Waters of Quinto Creek have about an equal balance of calcium, magnesium, and sodium. Bicarbonates are the predominant anions with an approximate balance between sulfates and chlorides. During flood stages, the quality is Class 1, but as the flow decreases the quality frequently is lowered as far as Class 3 because of higher concentrations of boron.

Romero Creek. Analyses of the few available samples of the waters of Romero Creek at the foothill line indicate that they are Class 2 in quality at low creek stages. Analyses of a sample

TABLE 15

AVERAGE MINERAL QUALITY OF WATER
IN WEST SIDE STREAMS ABOVE THE VALLEY FLOOR
IN THE LOWER SAN JOAQUIN VALLEY

Stream	EC x 10^6	Parts per million TDS	Cl	B	SO_4[a]	% Na
Corral Hollow Creek	1,245	822	93	3.2	289	44
Del Puerto Creek	975	613	31	1.0	156	24
Orestimba Creek	581	364	19	0.56	101	23
Garzas Creek	569	349	26	0.34	82	28
Quinto Creek	896	548	89	1.64	86	33
San Luis Creek	495	293	48	0.28	38	36
Los Banos Creek	489	330	41	0.57	46	32
Little Panoche Creek	3,155	1,850	779	9.0	245	58
Panoche Creek	4,216	3,320	240	5.0	1,890	44

a/ Sulfate

taken at the headwaters indicated a chloride concentration of 355 parts per million and a boron concentration of 3.4 parts per million which would place these waters in Class 3.

San Luis Creek. Mineral analyses of the waters show the quality to be in Class 1. The water has about an equal balance of calcium, magnesium, and sodium, with bicarbonate as the predominant anion and chlorides and sulfates approximately balanced. The total dissolved solid concentrations are moderate, chlorides low, and boron less than 0.5 part per million.

Los Banos Creek. Waters in Los Banos Creek are generally within the limits of Class 1. Calcium, magnesium, and sodium are approximately equal in concentration with bicarbonate the predominant anion. Total dissolved solids concentrations are moderate, chlorides are low, and boron generally is less than 1.0 part per million, except under conditions of very low flow, when boron concentrations as high as 2.2 parts per million have been reported.

Little Panoche Creek. Waters of this creek are poor and generally unfit for irrigation use at low flows. Analyses of the waters when flow is about 10 second-feet indicate that the quality improves as the discharge increases. Records secured during 1930, and since 1952, show that total dissolved solids, chlorides, and boron generally are excessive in amount. Maximum concentrations have been 3,820, 1,770, and 17 parts per million, respectively. Percent sodium and sulfate concentrations are also high.

Panoche Creek. Records secured during 1930, and since 1952, indicate that this water generally is unfit for irrigation use at low flows and lies in Class 2 at flows of five second-feet or more. Maximum recorded concentrations are: total dissolved solids, 7,320 parts per million; chlorides, 720 parts per million; and boron, 13 parts per million. Sulfate is the dominating anion and sodium the predominant cation. The sulfate concentration has been reported as high as 4,050 parts per million.

Imported Surface Waters

As stated in Chapter II, there are two major imports of water to the area of investigation. One of these is water entering the area via Fresno Slough, and the other is water brought into the area via the Delta-Mendota Canal. A minor import enters the area from the south through Panoche Drain.

Fresno Slough. No analyses of water entering the area through Fresno Slough are available. However, only extreme floods bring water into Fresno Slough and since this flood water stems from the Kings River, which contains excellent quality water at flood stages, it can be assumed that the quality of waters imported via Fresno Slough approximates that of the Kings River. Flows occurring since 1944 in Fresno Slough are listed in Table 6 of Chapter II.

Delta-Mendota Canal. As described in Chapter II of this report, the greater portion of water in this canal is used to replace San Joaquin River water which formerly supplied diversions made from the Mendota Pool. A smaller portion of the water is delivered to users along the length of canal. Because of the significance of this canal as a source of water supply, a quality sampling station was established at the head of the canal, adjacent to the Tracy Pumping Plant, on July 1, 1955, and operated daily until October 31, 1959. In addition, the quality of water diverted to the canal was sampled monthly at the intake to Tracy Pumping Plant and at the terminus since July 1952. Table 16 lists average, maximum, and minimum quality values for these locations both before and after December 1954.

From the data in Table 16, it appears that quality differences between the mean values for each of the periods shown are small. However, about six times the number of analyses are available for the latter period than for the earlier period and a greater weight should be given to the 1955-59 values. Most of the maximum values listed are from samples taken during winter months when no regular diversion from the Sacramento-San Joaquin

TABLE 16

MINERAL QUALITY OF WATER IMPORTED TO THE LOWER SAN JOAQUIN VALLEY BY THE DELTA-MENDOTA CANAL

Station	July 1952 - December 1954					1955-1959				
	EC x 10^6	Parts per million			%	EC x 10^6	Parts per million			%
		TDS	Cl	B	Na		TDS	Cl	B	Na
Near Tracy										
Average	548	284	89	0.20	50	522	300	85	0.22	48
Maximum	878	459	153	0.52	60	1,110	643	258	1.10	67
Minimum	223	100	24	0.01	39	132	81	16	0.00	37
Near Mendota										
Average	688	325	94	0.26	51	604	343	89	0.18	50
Maximum	1,630	452	165	0.71	62	1,220	654	245	0.82	67
Minimum	207	150	22	0.00	38	62	144	2	0.00	30

Delta is taking place. The 1952-54 maximum values near Tracy are from waters in the intake channel connecting the Delta with the pumping plant. Maximum values, except for boron, for the period 1955-59, at the head of the canal near Tracy, occurred during the summer of 1959 when diversions were substantial. The maximum value for boron was obtained in January 1958, near Tracy, and in February 1955, near Mendota.

The quality of water at the terminus of the canal, near Mendota, appears to be degraded slightly as compared to that at the point of diversion. The addition of irrigation return waters to the canal, increased concentrations resulting from evaporation from the 113-mile length of water surface, and probable effluent ground water seepage in unlined canal sections may account for the increase in mineral concentration in discharge to the Mendota

Pool. This increase is substantiated by continuous records of mean daily total dissolved solids available for both the head and the terminus of the canal.

Quality of water at both stations generally has been within the limits of Class 1 during the irrigation season; however, during the 1959 season the quality fell to Class 2 for portions of July, August, and September. During the fall and winter months, the quality has generally been within either Class 1 or 2. The percent sodium as measured at each station has been, with few exceptions, below 60. Again, the exceptions occurred in the summer of 1959 and during the fall and winter months.

A detailed graphical presentation of the daily variation in quality at the head and terminus of the Delta-Mendota Canal, since June 1951, may be found in "Reports of Operations, Division of Irrigation and Power", Region 2, United States Bureau of Reclamation (62). These graphs, compiled from salinometer records, depict the total dissolved solid concentrations.

Panoche Drain. The Delta-Mendota Canal, and the Main and Outside canals of the Central California Irrigation District, have served as barriers to drainage of return waters from areas to the south. In 1958, an outlet from the Panoche area, generally called the "Panoche Drain", into the upper (southern) grasslands area, was completed.

Waters draining from the Panoche area are highly concentrated from a quality standpoint and are unusable for beneficial purposes. Samples of the water in Panoche Drain have been taken with increasing frequency since March 1957; average and maximum values of the principal chemical properties of the water are listed below:

	Average value	Maximum value
Specific conductance, EC x 10^6	4,683	8,110
Total dissolved solids, ppm	3,615	6,367
Chlorides, ppm	926	1,979
Boron, ppm	8.3	12.8
Sulfates, ppm	1,268	2,058
Percent sodium	62	65

There are a few analyses of other drainage waters in the Panoche area available. These analyses indicate that most of the drainage waters in this area are of similar poor quality.

For the purposes of this investigation, these waters are considered as "imported" waters, since they drain into the investigation area. Only a small quantity of water is involved and, considering the complex and flat drainage system, the great distance which the water must travel, and the high rate of evaporation prevalent in the area, it is doubtful that this drainage water reaches the San Joaquin River in identifiable form.

Valley Floor Tributaries

Accretions of flow to the major streams from valley floor drainage occur at many points. The channels containing runoff and return flows are primarily those listed in Table 12 (Chapter III). The locations of the stream channels are shown on Plate 3.

Records of the quality of these waters prior to 1955, are, for the most part, fragmentary, since most analyses were made as the situation required. Records up to and including the fall of 1959, are available in the files of the department. The locations of points sampled are shown on Plate 3.

Most analyses are for samples of waters entering the lower San Joaquin River directly. Outside the area served by waters diverted from the Mendota Pool, only a few samples of waters tributary to other streams on the valley floor have been taken. The primary reason for the paucity of data is that there has been little concern about these waters other than their influence on the quality of water in the San Joaquin River below Dos Palos. Accordingly, discussion of the quality of valley tributary flows is confined, for the most part, to flows entering the main channel of the San Joaquin River and to drainage from the area south of Los Banos and west of Mendota. Since the quality of these waters is more significant with regard to the major stream, or stream reach, to which they are tributary, rather than on an individual basis, they are discussed in this manner in the following paragraphs.

Tributaries of the Stanislaus, Tuolumne, and Merced Rivers. Flows tributary to the three principal streams, with the exception of flows in three drainage channels entering the Tuolumne River have not been sampled or analyzed for quality characteristics. Drainage waters entering these three streams below the lowermost gaging station have, for purposes of computation, been included in reaches of the San Joaquin River.

Of the three flows tributary to the Tuolumne River above the gaging station at Tuolumne City, for which analyses are available, one is classed as sewage and is discussed in the final section of this chapter. The second is Dry Creek, a tributary entering at the City of Modesto. Available analyses of Dry Creek show the waters to be of good quality.

The third flow consists of saline waters spilled to the Tuolumne River from gas wells in the vicinity of Modesto and Waterford. These waters have been discharged to the Tuolumne River for more than ten years. A number of samples have been taken of these waters since 1955, and all analyses show them to be in Class 3. For the most part, these flows are unsuitable for irrigation use because of excessive chloride concentrations, ranging from 484 to 10,400 parts per million. Discussion of the effect of these discharges on the Tuolumne River is contained in the following chapter.

San Joaquin River-Dos Palos to Fremont Ford. Continuous records of the quality of the largest streams tributary to this reach, Salt Slough and Bear Creek, are available since 1947. Table 17 lists average, maximum, and minimum values for selected constituents of these streams for the periods 1948-1950, 1951-1954, and 1955-1959. Included in the figures are analyses of winter flows which can consist of drainage, effluent ground water, runoff, or a mixture from all three sources.

From inspection of Table 17, it can be noted that the average quality of water in Salt Slough is generally Class 2. The quality varies throughout the year in a rather definite pattern. During the spring and summer months, quality generally ranges from Class 1 to Class 2; while in the fall and winter months, when there is no flood runoff, the quality is usually Class 2, but occasionally deteriorates to Class 3. Since the channel drains a large saline and alkaline area (the "Grasslands"), which has a high water table, the quality of water naturally reflects the influence of salts leached from these lands.

TABLE 17

MINERAL QUALITY OF WATER IN
SALT SLOUGH AND BEAR CREEK,
LOWER SAN JOAQUIN VALLEY

Channel	1948-1950				1951-1954				1955-1959			
	EC x 10^6	Parts per million			EC x 10^6	Parts per million			EC x 10^6	Parts per million		
		TDS	Cl	B		TDS	Cl	B		TDS	Cl	B
Salt Slough near Los Banos												
Average	--	684	192	--	983	597	161	--	1,286	798	223	0.74
Maximum	--	2,100	490	--	2,000	1,200	430	--	2,786	1,716	540	2.20
Minimum	--	175	31	--	140	120	13	--	314	230	48	0.27
Bear Creek near Stevinson												
Average	--	269	33	--	529	236	58	0.10	543	350	71	0.12
Maximum	--	600	120	--	3,350	451	785	0.49	1,710	799	311	0.36
Minimum	--	84	3	--	81	91	4	0.00	98	86	4	0.00

When irrigation of agricultural lands in the Central California Irrigation District and San Luis Canal Company service areas takes place, a considerable volume of drainage water flows into Salt Slough and dilutes the existing effluent ground water. Additionally, in the fall, when these lands are flooded for use as nesting areas for wildfowl, water used to flood the land washes the surface salts into the slough. There appears to be no great difference in average quality between the periods 1948-1950, and 1951-1954, although data for the latter period indicates a slight improvement in quality. The quality for the period 1955-1959, however, definitely is poorer than during the preceding periods, although there is no immediately apparent reason for the decrease in quality.

The quality of the waters in Bear Creek at its mouth is somewhat better than those from Salt Slough and generally falls in Class 1 throughout the period of record, with little change in quality during the twelve-year span. Flows stem mainly from the Merced Irrigation District, and consist of drainage derived from Merced River waters applied for irrigation. Consequently, the average quality is quite good. The occasional high values shown in Table 17 do not originate in waters from the district service area. Like Salt Slough, the channel of Bear Creek, after leaving the Merced area, passes through a saline-alkaline area and, at times of low flow, carries drainage and effluent ground waters from these lands. This generally occurs in the late summer and fall.

A third stream tributary to this reach is the Stevinson Water District Spill. Water in this drain has been sampled regularly during the irrigation season since 1955. Data are not available, however, for the remainder of the year as no flow is carried in the channel. The quality of water in this drain, while degraded in comparison to its source, the Merced River, is quite good. Average irrigation season water quality values are specific conductance, 210 micromhos; total dissolved solids, 145 parts per million; chlorides, 6 parts per million; and boron, 0.06 part per million.

Data on the quality of flows in other and smaller channels are meager. However, it is doubtful that water from those drains upstream from Bear Creek reaches the San Joaquin River below Fremont Ford in significant or measurable quantities.

San Joaquin River-Fremont Ford to Newman. The only significant tributary channel in this reach is the Newman Wasteway of the Delta-Mendota Canal. The major portion of the flow discharged from the wasteway is effluent ground water, with high concentrations of sulfate and boron, characteristic of shallow west side ground waters. Maximum concentrations found were sulfate, 556 parts per million and boron, 1.5 parts per million. Average quality of the waters is specific conductance, 1,700 micromhos; total dissolved solids, 1,100 parts per million; chlorides, 180 parts per million; and boron, 1.0 part per million.

San Joaquin River-Newman to Grayson. Tributary waters in this reach have been sampled and analyzed since 1933, but with greater regularity since 1945. The number of analyses available are sufficient to evaluate long term trends in quality, although occasional periods occurred when samples were not collected. The quality of water in the principal tributary streams is listed in Table 18. Table 19 presents data on water quality in the minor tributaries.

Waters spilled from the Turlock Irrigation District laterals account for between 30 and 50 percent of the flow entering this reach. This water stems from return flows from surface diversions, ground water pumpage for drainage control and, in the case of Lateral 5, sewage from the City of Turlock. The quantity from each source varies considerably in magnitude. Consequently, the quality of water at the mouths of the Turlock Laterals is subject to large variations with time. To account for this variation, daily sampling stations were established on two of these canals at various times during the investigation. The first station was at the Turlock Lateral 6 and 7 Drain, and was operated between July 1, 1955, and November 17, 1956. A second station was established at the mouth of Turlock Lateral 5 for the period March 1, 1959, to October 31, 1959. In addition, samples were taken from each tributary canal during the irrigation season throughout the period of investigation.

Irrespective of the frequency of sampling, the general quality characteristics of these waters are the same as for other tributary channels in which flow occurs beyond the irrigation season, i.e., the best quality of water occurs in the spring, and the poorest quality occurs in the late fall and winter.

With the exception of the period from 1951 to 1954 for Lateral 2, the water in the Turlock Canals has been sampled since 1933. Again, with exception of Lateral 2, there has been

TABLE 18

MINERAL QUALITY OF PRINCIPAL VALLEY FLOOR STREAMS
TRIBUTARY TO THE SAN JOAQUIN RIVER
BETWEEN NEWMAN AND GRAYSON

Channel and location[a]	Prior to 1951				1951-1954				1955-1959			
	EC $\times 10^6$	Parts per million			EC $\times 10^6$	Parts per million			EC $\times 10^6$	Parts per million		
		TDS	Cl	B		TDS	Cl	B		TDS	Cl	B
East Side												
Turlock Irrigation District												
Lateral 6 and 7 (47)												
Average	678	352	104	0.12	680	299	89	0.03	634	400	90	0.17
Maximum	1,700	910	240	0.25	930	317	140	0.04	1,660	987	277	1.40
Minimum	300	190	42	0.07	460	266	67	0.01	346	202	52	0.00
Lateral 5 (39)												
Average	770	367	96	0.11	823	316	114	0.04	655	402	97	0.09
Maximum	1,310	830	350	0.45	1,700	408	330	0.06	1,040	620	176	0.30
Minimum	280	150	23	0.05	430	164	32	0.01	302	168	40	0.00
Westport Drain (30)												
Average	630	360	68	0.11					568	331	66	0.08
Maximum	730	463	97	0.20					744	475	80	0.20
Minimum	440	230	41	0.05					542	148	26	0.00
Lateral 2 (28)												
Average	565	282	75	--					223	179	30	0.12
Maximum	1,500	770	280	--					529	321	92	0.30
Minimum	200	64	2	--					123	99	14	0.00
Vivian Slough (42)												
Average	--	686	242	--	1,596	708	247	--	1,204	706	235	0.32
Maximum	--	2,100	920	--	2,000	1,540	530	--	2,620	1,160	682	0.44
Minimum	--	196	35	--	780	322	69	--	802	582	147	0.10

TABLE 18

MINERAL QUALITY OF PRINCIPAL VALLEY FLOOR STREAMS
TRIBUTARY TO THE SAN JOAQUIN RIVER
BETWEEN NEWMAN AND GRAYSON (continued)

Channel and location[a]	Prior to 1951				1951-1954				1955-1959			
	EC x 10^6	Parts per million			EC x 10^6	Parts per million			EC x 10^6	Parts per million		
		TDS	Cl	B		TDS	Cl	B		TDS	Cl	B
West Side												
Orestimba Creek (43)												
Average									770	484	97	0.41
Maximum									1,140	654	202	0.64
Minimum									579	343	49	0.20
Patterson Water District Tile Drain Channel (36)												
Average									3,830	2,481	544	1.90
Maximum									5,620	3,010	715	2.70
Minimum									2,150	1,480	262	0.90
Del Puerto Creek (31)												
Average	975	404	134	--					797	438	126	0.29
Maximum	1,600	730	310	--					1,610	755	330	0.78
Minimum	490	150	20	--					277	172	22	0.00

a/ Location indicated by number in parenthesis (see Table 12 and Plate 3) essentially no change in quality of water throughout the 27-year period 1933-1959. Records of Lateral 2 for the period 1955-1959 indicate a quality of water which is better than that which existed before 1951. The quality of water in the four canals draining to the river has been in Class 1 during the irrigation season. Occasionally, in the late fall, the quality of water has fallen as low as Class 2.

Water in Vivian Slough has been sampled since 1948, with no significant change in quality being noted over the years. This water is typical of the return flow emanating from the saline-alkaline lands west of the Turlock Irrigation District. As a result of contact with these soils, the quality of water in Vivian Slough is, on the average, in Class 2 and occasionally in Class 3. The waters are characterized by higher concentrations of total salts and chlorides than other similar return flows.

The Turlock Garden Drain originates in the same saline-alkaline land as Vivian Slough and was sampled frequently between 1943 and 1951. During this period, the average quality of water fell in Class 3 because of high chloride content (420 parts per million). The drain was sampled twice in 1956, at which time specific conductances were found to be 2,470 and 1,940 micromhos; and the chloride concentration was 634 and 475 parts per million, respectively.

West of the river, the quality of tributary flows ranges from Class 1 to Class 3. The largest tributary, Del Puerto Creek, was sampled frequently between 1945 and 1951, and regularly between 1956 and 1959. The average quality of water at the mouth for both periods was in Class 1. A few samples taken in both

TABLE 19

AVERAGE MINERAL QUALITY OF MINOR VALLEY FLOOR STREAMS TRIBUTARY TO SAN JOAQUIN RIVER BETWEEN NEWMAN AND GRAYSON

Channel and location[a]	Period of record	$ECx10^6$	Parts per million TDS	Cl	B
	East Side				
Levee Drain (38)	1942-51	993	688	153	--
Turlock Garden Drain (32)	1943-51	1,771	1,313	421	--
	West Side				
Unnamed Drain (45)	1956	846	--	100	--
Patterson Water District Drain (40)	1945-51	1,538	980	189	--
	1956-57	834	--	116	--
	1958-59	931	551	131	0.36
Patterson Water District Drain (41)	1958-59	746	--	88	0.48
Lake Ramona (37)	1948-50	--	1,360	175	--
	1951-53	2,236	1,228	211	--
	1956	1,545	--	215	0.57
West Stanislaus Irrigation District Drain (29)	1956	1,152	--	171	--

a/ Location indicated by number in parenthesis (see Table 12 and Plate 3)

periods indicated that the water occasionally deteriorated to Class 2.

Valley floor flow in Orestimba Creek during the irrigation season was intermittent before 1957 and consisted mainly of spill from the Main Canal of the Central California Irrigation District. Since 1957, irrigation return water has flowed continuously in this channel as the result of the development of better drainage facilities for tributary lands. The quality of water in Orestimba Creek at its mouth is in Class 1.

In January 1957, the Patterson Water District completed construction of a tile drain system to alleviate high water table conditions in a portion of the district. Flow from the channel to which the tile system discharges has been sampled since March 1957. These waters, as would be expected, are highly concentrated and are in Class 3 because of chloride content. Although percent sodium is less than 50, sulfates range from 449 to 1,290 parts per million. The high sulfate concentration is indicative of the soil through which the water passes. Occasionally, the water is diluted by other surface drainage and, at those times, becomes Class 2 water. While the salt concentration in this water is excessive, the flow only approximates 60 acre-feet per month, considerably less than one percent of the total flow in the San Joaquin River.

The quality of other minor return flows in this reach, as listed in Table 19, is generally in Class 1, or ranges between Class 1 and Class 2 for agricultural water supplies. Water flowing from an older tile drain in the Patterson Water District is usually in Class 3. However, dilution with other waters occurs prior to reaching the San Joaquin River through Lake Ramona.

<u>San Joaquin River-Grayson to Hetch Hetchy Crossing</u>. With certain exceptions, the quality of tributary flows entering this reach falls in Class 1 or in the lower range for Class 2. Records before 1955 are sparse and almost all of these are 30-year-old analyses of samples of drainage waters from the El Solyo Ranch. Table 20 presents data on the quality of water in the principal channels tributary to this reach and Table 21 lists the average quality in minor streams.

TABLE 20

MINERAL QUALITY OF PRINCIPAL VALLEY FLOOR STREAMS TRIBUTARY TO SAN JOAQUIN RIVER BETWEEN GRAYSON AND HETCH HETCHY CROSSING FOR THE PERIOD 1955-1959

Channel and location[a]	$ECx10^6$	Parts per million		
		TDS	Cl	B
East Side				
Modesto Irrigation District Lateral 5 (78)				
Average	305	193	42	0.07
Maximum	775	434	126	0.17
Minimum	48	38	1	0.00
West Side				
Westley Wasteway (26)				
Average	839	508	134	0.30
Maximum	1,370	783	255	0.55
Minimum	275	258	36	0.00
Sarmento Drain (19)				
Average	1,962	1,120	294	1.28
Maximum	3,880	1,720	580	2.20
Minimum	1,000	750	73	0.20
Burkhardt Drain (18)				
Average	983	572	149	0.77
Maximum	1,600	740	239	1.60
Minimum	429	408	48	0.00
Hospital Creek (tributary to Burkhardt Drain)				
Average	658	585	92	0.56
Maximum	1,200	759	184	1.20
Minimum	235	496	31	0.00

a/ Location indicated by number in parenthesis (see Table 12 and Plate 3)

TABLE 21

AVERAGE MINERAL QUALITY OF MINOR STREAMS TRIBUTARY TO SAN JOAQUIN RIVER BETWEEN GRAYSON AND HETCH HETCHY CROSSING FROM THE WEST FOR THE PERIOD 1955-1959

Channel and location[a]	Period of record	$ECx10^6$	Parts per million TDS	Cl	B
West Stanislaus Irrigation District Drain (27)	1956-59	1,070		159	0.38
West Stanislaus Irrigation District Drain (25)	1956	1,144		171	
West Stanislaus Irrigation District Drain (24)	1956	1,091		169	
West Stanislaus Irrigation District Drain (21)	1956	1,181		149	
El Solyo Drain (16)	1956-57	1,135		182	

a/ Location indicated by number in parenthesis (see Table 12 and Plate 3)

The most significant tributary channel from the east is Modesto Irrigation District Lateral 5. As was the case with the Turlock laterals, the quality of water in this canal is constantly varying. This variation in concentration is dependent on the number of wells, used to control the water table, spilling to the lateral at a particular time; which of the wells are spilling; and the quantity of water diverted above the mouth. The initial quality of the water in the lateral, supplied by Tuolumne River water diverted at La Grange is, of course, excellent.

As in the case of the Turlock laterals, a daily station was established at the mouth of the Lateral 5 to determine the significance of the variation in quality. The station was in operation from March 26 to October 10, 1957, and between April 16 and September 20, 1958. The quality of water remained in Class 1 at all times. At the close of the irrigation season, the canal is emptied. While the canal spills to the Tuolumne River about two miles above its confluence with the San Joaquin River, it is tributary within the reach defined by the gaging stations near Grayson and at Hetch Hetchy Crossing on the San Joaquin River, and Tuolumne City on the Tuolumne River.

Return flow in the Westley Wasteway of the Delta-Mendota Canal, as well as that in the four West Stanislaus Irrigation District drains listed in Table 21, discharges into the old channel of the San Joaquin River near Grayson. This channel is connected with the present river channel (Laird Slough) only during flood stages. Consequently, it is doubtful that water from this group of streams reaches the San Joaquin River through surface channels. The quality of waters in this channel is in Class 1 and occasionally in Class 2. Waters of the four West Stanislaus drains are in Class 2.

Sarmento Drain serves an area in which the soil is saline-alkaline in character. Drainage from the area is pooled in a sump, permitting some concentrations of minerals by evaporation before the water is pumped into an old river channel. The average quality of the drainage water is Class 2 and occasionally falls as low as Class 3.

The average quality of water in Burkhardt Drain, the largest return flow tributary from the west, is in Class 1. Occasionally, the quality deteriorates to Class 2, primarily resulting from ground water pumped for control of the water table in the area immediately to the south and west of the drain. The ground water, pumped continuously from five drainage wells, is undiluted by better quality water during the nonirrigation season unless storm runoff is present.

Burkhardt Drain, above its confluence with Hospital Creek, was sampled five times in the period 1928-30 and weekly during the summer months of 1956-58. On the basis of chloride and sulfate determinations for both periods, it appears that the present quality is poorer than that in the former period. Hospital Creek was sampled during the same periods, and also in 1949. On the basis of concentrations of chlorides and sulfates, there appears to have been no noticeable change in water quality. The average quality is in Class 1.

The quality of water in the El Solyo Ranch Drain, listed in Table 21, is in Class 2. The point selected for sampling during this investigation, in 1956 and 1957, is downstream from two tributaries which were sampled in 1928-30. On the basis of the chlorides and sulfates in the samples taken in each period, it appears that the present quality of water is better than that formerly experienced. Chloride content in some of the earlier water samples, the highest being 1,225 parts per million, reduced the water to a Class 3 supply.

<u>San Joaquin River-Hetch Hetchy Crossing to Vernalis</u>. The quantity of accretions entering this reach is quite small in comparison with that entering the two previous reaches of the San Joaquin and, consequently, has little effect on the quality of water in the river. The average quality of the few existing

drains which spill to the San Joaquin River in this reach is presented in Table 22. Excepting the most northerly West Stanislaus Irrigation District Drain, in which the quality of water is Class 2, the quality in general, is in Class 1. There are no available records of water quality prior to 1955.

San Joaquin River-Vernalis to Mossdale Bridge. As in the previous reach, there are no records prior to 1955 of the water quality of tributary streams entering the reach. A few samples of surface waters tributary to the reach were taken between 1955 and 1959. On the east side, the average quality characteristics were determined to be specific conductance, 570 micromhos; and chlorides, 40 parts per million, placing these waters in Class 1. On the west side, there is an average specific conductance of 1,300 micromhos and chlorides, 250 parts per million. All of the western and most of the eastern drainage in this reach is collected in sumps and pumped through levees to the river.

The west side drainage waters are of poorer quality than the wastes from the east side. The main reason for this is that the source of water on the west side, a mixture of San Joaquin River water and ground water, contains several times the salt concentration of the east side supply from the Stanislaus River. Some of the drainage water on the west side was in Class 3, while the average quality of water was Class 2.

Minor Streams in the Mendota Pool Service Area. There are numerous analyses of return water from the area generally lying between the Delta-Mendota Canal and Los Banos, supplied by the Mendota Pool. Some of the return waters find their way to Salt Slough. Most, however, drain to, and mix with, the service area

TABLE 22

AVERAGE MINERAL QUALITY OF VALLEY FLOOR STREAMS TRIBUTARY TO SAN JOAQUIN RIVER BETWEEN HETCH HETCHY CROSSING AND VERNALIS FOR THE PERIOD 1955-1959

Channel and location[a]	Period of record	$ECx10^6$	Parts per million TDS	Cl	B
East Side					
Faith Ranch Drain (68)	1955-59	480	--	19	--
Faith Ranch Drain (69)	1956-59	919	--	--	--
West Side					
West Stanislaus Irrigation District Drain (14)	1956-59	787	--	123	--
Blewitt Drain (13)	1956-59	735	--	110	--
West Stanislaus Irrigation District Drain (11)	1956-59	1,085	626	158	0.41

a/ Location indicated by number in parenthesis (see Table 12 and Plate 3)

supply system and are used again in diluted form. The sampling points are scattered over the area and, except at three locations, available records are sparse. Quality of water varies greatly but most drainage waters are in Class 1 or 2. A few contain high concentrations of sulfates.

Water draining to the head of the Firebaugh Wasteway of the Delta-Mendota Canal, sampled regularly in 1959, had the following average quality values: specific conductance, 1,500 micromhos; total dissolved solids, 900 parts per million; chlorides, 150 parts per million; and boron, 1.3 parts per million. The quality was Class 2.

The quality of water in the Helm Ranch Drain at the Firebaugh Wasteway, also sampled in 1959, was in Class 2. Average values were: specific conductance, 600 micromhos; total dissolved solids, 340 parts per million; and chloride, 90 parts per million. Boron averaged 0.3 part per million and percent sodium averaged 66. The higher sodium percentage places the water in Class 2.

Many analyses are available for a channel known locally as the Old Main Drain, at its intersection with Camp 13 Slough (location number 11S/11E-27P). Water from the Old Main Drain usually is mixed with water in the Main Canal, to which it is parallel, of the Central California Irrigation District. The average quality of water in the drain is Class 2. Average quality values are total dissolved solids, 1,400 parts per million; chlorides 240 parts per million; and boron 1.6 parts per million. Percent sodium averages 63 and sulfates average 530 parts per million. Occasionally, chloride and boron concentrations have been sufficiently high to place water in Class 3. However, the total concentration is reduced considerably through dilution with a large volume of Class 1 water from the Main Canal. The quality of the resultant mixture remains in Class 1.

San Joaquin River

Since the San Joaquin River is influenced by all other waters in the valley, including imported and return waters (Plate 9), the quality of water is discussed with reference to the principal points of sampling. These points are the terminii of river reaches about which the general discussion in this report is centered.

Table 23 lists average, maximum, and minimum values for quality at the principal points along the San Joaquin River between Friant Dam and Mossdale Bridge for the three periods used previously in this chapter.

Average and extreme values compiled from existing data are sometimes misleading and this is demonstrated in Table 23. The average and maximum values listed for the Newman station (Hills Ferry Bridge) during the period 1955-1959 are higher than those at Grayson, the next downstream station. However, this is true only because the quality during the nonirrigation season, especially during very dry years, overbalances the better quality values obtained from samples taken during the irrigation season. The significant fact here is that the quality of water at Newman during the irrigation season is better than at Grayson. This can be substantiated by examining values obtained during 1959, the year when all of the maximum values occurred. For the months January, February, October, November, and December, the quality at Newman was the poorer of the two. Between March and September, the quality at Grayson was poorest. The quality at Newman is dependent on the volume of good quality diluting water entering the San Joaquin River immediately above that station.

Plate 11 is a graphic comparison of the variation in total dissolved solids at three key points on the San Joaquin River for the period from July 1, 1955, through October 31, 1959. These points are Biola, Fremont Ford, and Vernalis. Quality at these points essentially represents the quality of the San Joaquin River (1) prior to mixture with imported waters, (2) at the point of maximum concentration, and (3) at the point of discharge to the

TABLE 23

MINERAL QUALITY OF WATER IN THE
SAN JOAQUIN RIVER AT SELECTED STATIONS

Station	1938-1951				1951-1954				1955-1959			
	EC x 10^6	Parts per million			EC x 10^6	Parts per million			EC x 10^6	Parts per million		
		TDS	Cl	B		TDS	Cl	B		TDS	Cl	B
Near Friant												
Average	--	37	3.4	--	50	31	2.8	0.06	44	35	3.2	0.03
Maximum	--	75	6.4	--	203	120	11.0	0.34	72	45	7.5	0.17
Minimum	--	19	0.2	--	21	22	0.0	0.00	25	27	0.0	0.00
At Mendota												
Average	--	44	3.4	--	188	100	27	0.10	419	291	65	0.15
Maximum	--	99	5.7	--	808	385	134	0.29	1,030	472	235	0.40
Minimum	--	19	0.7	--	31	18	0.4	0.00	35	43	1	0.00
At Fremont Ford												
Average	--	434	123	--	1,080	597	190	0.32	1,205	691	232	0.41
Maximum	--	1,940	670	--	2,400	1,500	510	0.36	5,440	3,350	1,330	1.60
Minimum	--	49	4	--	81	74	3	0.20	103	67	6	0.00
Near Newman (Hills Ferry Bridge)												
Average	--	356	83	--	525	549	121	--	1,000	622	169	0.39
Maximum	--	970	300	--	1,000	1,300	320	--	2,160	1,320	445	1.30
Minimum	--	51	4	--	82	168	10	--	100	67	6	0.00
Near Grayson												
Average	666	399	104	0.18	814	534	107	0.25	934	520	142	0.33
Maximum	1,390	1,001	272	0.42	1,500	910	255	0.78	1,660	913	280	0.80
Minimum	83	60	6	0.00	97	61	6	0.02	113	72	12	0.00
At Maze Road Bridge												
Average	490	294	82	0.12	613	416	103	0.21	701	435	119	0.20
Maximum	1,060	740	240	0.29	1,110	651	246	0.80	1,300	720	295	0.43
Minimum	86	26	2	0.01	97	70	5	0.00	145	89	10	0.00

TABLE 23

MINERAL QUALITY OF WATER IN THE
SAN JOAQUIN RIVER AT SELECTED STATIONS (continued)

Station	1938-1951				1951-1954				1955-1959			
	EC $\times 10^6$	Parts per million			EC $\times 10^6$	Parts per million			EC $\times 10^6$	Parts per million		
		TDS	Cl	B		TDS	Cl	B		TDS	Cl	B
Near Vernalis (Durham Ferry Bridge)												
Average	--	297	76	--	477	317	78	0.16	586	332	100	0.17
Maximum	--	890	180	--	991	633	198	0.38	1,260	740	290	0.50
Minimum	--	53	5	--	92	54	0.20	0.01	96	62	8	0.00
At Mossdale												
Average	--	240	61	--	544	335	91	0.17	648	461	112	0.18
Maximum	--	539	170	--	1,054	656	283	0.46	1,150	646	232	0.40
Minimum	--	38	4	--	79	58	10	0.01	135	93	9	0.00

Sacramento-San Joaquin Delta. At each of these locations, the United States Geological Survey has maintained a daily water quality sampling station. The station at Biola, thirty miles below Friant and midway between Friant and Mendota, was operated between October 1954 and September 1958. The station at Fremont Ford was operated for this investigation from July 1, 1955, to October 31, 1959. The station near Vernalis commenced operation in March 1951, and will be indefinitely continued.

In the irrigation seasons occurring during this investigation, the San Joaquin River was sampled a number of times on a "profile" basis. This consisted of taking samples at principal points on the river, over a short period of time, proceeding in a downstream direction in order to observe the variation in quality with location. The periods of measurement extended from one to three days, depending on the length of stream selected for sampling. At the same time, principal contributing waters were sampled. The specific conductances obtained in five of these profile samplings, one for each year in the period 1955-1959, are presented graphically on Plate 12.

At Friant. Available records since 1938 show the quality of waters in the San Joaquin River at the point of inflow to the valley floor has been excellent. No significant changes have taken place over the years; however, it is noted that the greatest concentration of salts occurred in the period 1951-1954.

At Mendota. A marked difference is apparent in the quality of water at Mendota before and after December 1950. Substitution of Delta-Mendota Canal water for San Joaquin River water, which began in 1951, accounts for this change in quality.

Thus, the data prior to 1951 is for San Joaquin River water, while the data for the later periods represents a mixture of waters, dominated for the most part by imported water. An increase in mineral concentration for the period 1955-59 over the preceding period is noted and probably is due to the greater proportion of Delta-Mendota Canal water. During extreme flood stages the Delta-Mendota Canal is not in operation, and the quality at Mendota is, therefore, that of the San Joaquin River.

At Fremont Ford. Since all summer flows of the San Joaquin River are diverted between Mendota and Temple Slough, flows at Fremont Ford during this time consist entirely of return waters. At this point, waters of the San Joaquin River contain the highest concentrations of salts to be found anywhere throughout its length. During the period 1938-50, the quality of water was generally Class 1, although at times it became Class 2 or 3. Since 1950, the average quality has been that of Class 2 and often as low as Class 3. Occasionally the quality has lowered to the point of the water being unusable. During flood stages, the quality is usually in Class 1 and is represented by the minimum values listed in Table 23. The maximum daily value of specific conductance at this station, since July 1955, was 7,730 micromhos and the percent sodium frequently has been between 60 and 62.

Since this station is located at what is essentially the head of the lower San Joaquin River, it is of considerable importance. Because of this, a daily sampling station was established here for the period of investigation. The water passing this station is now being sampled monthly as a part of the statewide surface water monitoring program and installation of a salinometer is planned for the near future.

Near Newman (Hills Ferry Bridge). An improvement in the average quality of the San Joaquin River is noted at this point as a result of dilution by Merced River water, particularly during the summer months (see Plate 9). The total salt concentration of the Merced River is about one-fourth that of the San Joaquin River. Although the improvement of quality at this section as compared to Fremont Ford is apparent throughout the period of record, an increase in average concentration occurred after 1950. The quality generally falls in Class 1 during the irrigation season but often is Class 2 during the remaining months of the year.

Near Grayson. As noted in an earlier paragraph, the quality at this point during the irrigation season is poorer than at Newman, although the average values shown in Table 23 do not make this apparent. Some degradation in the average quality has occurred since 1950. While the average quality lies in Class 1, it often falls to Class 2 during summer months. The percent sodium at this station since 1950 remained within tolerable limits, less than 60, with but one exception; a value of 61 percent was measured in February 1959.

At Maze Road Bridge. Analyses used to arrive at average quality values for this station include those for samples taken at the El Solyo Water District intake and the gaging station at Hetch Hetchy Crossing, both located within a half-mile of the Maze Road Bridge. A further improvement in quality of water in the San Joaquin River occurs here as a result of dilution by waters of the Tuolumne River. The total salt concentration of the Tuolumne River at its mouth ranges from one-half to two-thirds that of the San Joaquin River at this point. A comparison of the quality values listed for the three periods in Table 23 indicates that continued degradation has occurred in the river at this station though the degree of increase is smaller between the two later periods.

Near Vernalis (Durham Ferry Bridge). Since the station near Vernalis marks the point of outflow from the San Joaquin Valley, it is of considerable importance. Continuous records are available since 1938 and the United States Geological Survey has maintained a daily sampling station here since March 1951.

Inflow of Stanislaus River water of excellent quality results in a decrease in total salt concentration as the concentration in the Stanislaus River in the summer is about one-third of the average for the San Joaquin River near Vernalis. Snowmelt runoff, generally occurring at the beginning of the irrigation season, results in a substantial quality improvement in San Joaquin River waters at this point as well as at all other points below Fremont Ford, during the spring of each year.

While the average quality near Vernalis is in Class 1, summer flows occasionally have been in Class 2. During 1959, however, the quality of water was almost continuously in Class 2 from May through September. Since 1950, the percent sodium always has been below 60.

At Mossdale. The station at this point is influenced by tidal action and stream flow is not measured. However, the flow is basically dependent on the San Joaquin River, and the quality of water is of significance to water users between Mossdale and Vernalis.

As is the case with the upstream stations, averages for the three periods indicate that the quality of water at this station has deteriorated over the years. It is interesting to note that the maximum values for the period 1955-59 are less than those measured near Vernalis.

During the years 1906 and 1908, samples were taken regularly at this point by the United Stated Geological Survey. Values of total dissolved solids at that time were as follows:

Total Dissolved Solids, in Parts Per Million

	Average	Maximum	Minimum
1906	161	358	60
1908	205	416	52

These values are less than those obtained since 1938, indicating a long-continued trend toward higher concentrations, probably due to expanded agricultural use.

Diverted Waters

Of primary interest to water users in the lower reaches of the San Joaquin River is the quality of the water supplies which they divert for irrigation. The principal diverters are the agencies cooperating in this investigation who, together, use about 75 percent of the total diversion from the San Joaquin River between Fremont Ford and Mossdale Bridge. A number of samples were taken at or near the points of diversion before 1955; however, no regular sampling program had been undertaken prior to this study to evaluate specifically the quality of diverted water supplies.

During the irrigation season of each year of the investigation, a systematic examination of the quality of water diverted by the cooperators was made covering the portion of the season when quality was of greatest concern. The frequency and type of sampling was governed by hydrologic conditions and the type of data required.

Discussion of the quality of water diverted at each intake, particularly since 1954, is presented in the following sections. It is noted that each district, with the exception of the El Solyo Water District, receives supplemental water supplies from the Delta-Mendota Canal. The quality of imported water supplies in that service facility was presented earlier in this report under the heading "Imported Water".

Patterson Water District Intake. The intake is situated on the left (west) bank of the San Joaquin River at the old Patterson Bridge, about 20 miles below the mouth of the Merced River. Flow and quality of the San Joaquin River at this point is considerably influenced by the Merced River, as well as by return waters entering above the intake. Because this location is readily accessible, a considerable number of water samples have been collected at this point in earlier years. Analyses of water samples are available since 1938, excepting during 1946 and 1947. Table 24 lists quality values for the periods prior to 1955. As at other points on the San Joaquin River, the average concentration for the period 1951-54 was higher than for the period before 1951. The maximum values of total dissolved solids, and of chlorides, occurred in February 1948 at a time when the district was not diverting water supplies from the river.

The quality of water diverted by the Patterson Water District since 1955 is presented in Table 25. The first portion of the table lists values obtained from regular sampling at the head end of the main canal, while the second portion lists values

TABLE 24

MINERAL QUALITY OF WATER IN THE
SAN JOAQUIN RIVER AT THE PATTERSON
WATER DISTRICT INTAKE PRIOR TO 1955

Constituent or characteristic	Prior to 1951			1951-1954		
	Average	Maximum	Minimum	Average	Maximum	Minimum
Specific conductance, as $ECx10^6$	---	---	---	778	1,400	95
Total dissolved solids, in ppm	362	1,100	66	524	890	105
Chlorides, in ppm	91	330	7	120	240	10
Percent sodium	55	60	52	52	60	38

recorded by the salinometer located at the same point. These data show that the diverted water was in Class 1 and occasionally Class 2 in 1956, 1957, and 1958; and was in Class 2 in 1955 and 1959. On August 3, 1959, the quality fell to Class 3 when a chloride content of 353 parts per million was measured.

Samples for which other constituents were analyzed during the investigation show boron generally to be less than 0.5 part per million, excepting during 1959 when boron attained a value of 0.6 part per million. Percent sodium ranged between 52 and 59, the maximum occurring in 1959.

Specific conductance values obtained through sampling for the years 1955-59 are presented graphically on Plate 13.

West Stanislaus Irrigation District Intake. The pumping station is two miles west of the San Joaquin River and is connected with the river by an intake channel excavated in 1929. This channel is located about one-half mile above the mouth of the Tuolumne River and flow at the intake may be affected by the Tuolumne River discharge under certain river stage conditions.

TABLE 25

MINERAL QUALITY OF WATER DIVERTED BY PATTERSON WATER DISTRICT FROM THE SAN JOAQUIN RIVER DURING THE 1955-1959 PERIOD

A. Summary of Sampling Records

Constituent or characteristic	1955 Aug. 5 to Sept. 30	1956 May 1 to Oct. 4	1957 May 3 to Sept. 30	1958 May 6 to Oct. 2	1959 April 2 to Sept. 14
Specific conductance as $ECx10^6$					
Average	1,029	519	713	544	1,283
Maximum	1,542	1,190	1,120	1,050	1,710
Minimum	723	90	166	118	864
Chlorides, in ppm					
Average	---	79	112	81	232
Maximum	---	205	193	170	353
Minimum	---	7	11	10	128

TABLE 25

MINERAL QUALITY OF WATER DIVERTED BY PATTERSON WATER DISTRICT FROM THE SAN JOAQUIN RIVER DURING THE 1955-1959 PERIOD (continued)

B. Average Monthly Salinometer Records

Month	1956			1957			1958			1959[1/]		
	July 2 - Oct. 6			May 3 - Oct. 4			May 6 - Sept. 30			April 2 - Oct. 4		
	Mean daily											
	$ECx10^6$	TDS, in ppm	Salt load, in tons	$ECx10^6$	TDS, in ppm	Salt load, in tons	$ECx10^6$	TDS, in ppm	Salt load, in tons	$ECx10^6$	TDS, in ppm	Salt load, in tons
April										965	552	235
May				708	399	98	145	81	21	1,143	654	221
June				421	238	80	168	94	25	1,192	680	286
July	805	462	165	943	532	200	663	372	122	---	---	---
August	862	495	160	852	481	169	933	523	174	---	---	---
September	705	405	81	823	464	98	665	373	76	---	---	---
October	726	417	59	696	392	55				---	---	---

1/ Records for July-October period are of doubtful reliability. Data may be secured from Department of Water Resources.

Samples have been taken at both the junction of the canal and river, and at the first pumping station, and there appears to be no significant difference in quality between the two points. Records are available since 1948, with the exception of most of 1953 and all of 1954. For the period 1948-50, average quality characteristics were total dissolved solids, 600 parts per million; and chloride concentration, 150 parts per million. Maximum values of 1,120 parts per million for total dissolved solids and 270 parts per million of chlorides occurred in January 1950. For the period from January 1951 to January 1953, sampling was irregular, except for chloride determinations, average quality of water values were specific conductance, 530 micromhos; total dissolved solids, 460 parts per million; and chlorides, 100 parts per million. An indication of the quality of water in the San Joaquin River, available to the West Stanislaus Irrigation District for the years prior to 1955, may be obtained by referring to the discussion of the quality at Grayson and at Maze Road as previously given in this chapter. These stations are located 5.4 miles above, and 6.0 miles below the intake, respectively.

The quality of water diverted by West Stanislaus Irrigation District from the San Joaquin River during the period of investigation is presented in Table 26. Data are tabulated in the same manner as for the Patterson district. The quality of water was generally in Class 1 and occasionally in Class 2 in 1956, 1957, and 1958, and was in Class 2 in 1955 and 1959. As at Patterson, a high chloride content of 366 parts per million, on August 3, 1959, placed the water in Class 3.

TABLE 26

MINERAL QUALITY OF WATER DIVERTED BY WEST STANISLAUS IRRIGATION DISTRICT FROM THE SAN JOAQUIN RIVER DURING THE 1955-1959 PERIOD

A. Summary of Sampling Records

Constituent or characteristic	1955 Aug. 7 to Sept. 30	1956 May 1 to Oct. 4	1957 May 3 to Sept. 25	1958 May 6 to Sept. 27	1959 March 31 to Sept. 14
Specific conductance as $ECx10^6$					
Average	1,142	612	795	681	1,283
Maximum	1,460	1,230	1,040	1,050	1,690
Minimum	908	123	188	196	860
Chloride, in ppm					
Average	---	94	124	109	226
Maximum	---	204	182	176	366
Minimum	---	13	24	24	129

TABLE 26

MINERAL QUALITY OF WATER DIVERTED BY WEST STANISLAUS IRRIGATION DISTRICT FROM THE SAN JOAQUIN RIVER DURING THE 1955-1959 PERIOD (continued)

B. Average Monthly Salinometer Records

Month	1956			1957			1958			1959		
	July 3 - Oct. 17			May 3 - Oct. 9			May 6 - Sept. 30			April 2 - Oct. 7		
	Mean daily											
	$ECx10^6$	TDS, in ppm	Salt load, in tons	$ECx10^6$	TDS, in ppm	Salt load, in tons	$ECx10^6$	TDS, in ppm	Salt load, in tons	$ECx10^6$	TDS, in ppm	Salt load, in tons
April										1,310	747	411
May				748	423	186	305	177	94	1,176	670	308
June				485	274	153	263	152	81	1,317	751	323
July	892	503	296	1,019	577	312	650	376	183	1,444	823	412
August	955	550	234	976	552	234	952	551	129	1,437	819	319
September	880	507	107	890	504	154	781	452	107	1,345	767	77
October	957	551	30	848	480	10				1,201	685	27

All the quality values listed in the first portion of the table exceed those pertinent to the Patterson Water District, with the exception of values for 1959, although it may be noted that the 1959 differences are small and generally less than 5 percent. This further substantiates the conclusion that during the irrigation season, the quality of waters of the San Joaquin River in the vicinity of Grayson is poorer than at Newman.

Since 1954, the boron content in these waters has been less than 0.5 part per million except in 1959, when it reached 0.6 part per million; and percent sodium has been less than 56.

Plate 14 shows graphically the variation in specific conductance during the years 1955 through 1959.

El Solyo Water District Intake. The intake is situated on the left (west) bank of the San Joaquin River a short distance upstream from Maze Road Bridge and about one-fourth mile below the gaging station at Hetch Hetchy Crossing. Routine sampling stations have been maintained at the intake, bridge, and gaging station by the department and other agencies since 1938. Because of the proximity of these three points and since the available data is abundant, no samples of water diverted at the intake were taken specifically for this investigation. The results of sampling at the Maze Road Bridge were discussed in the previous section.

As previously stated, continued degradation has occurred in the quality of water in the river at Maze Road. This degradation is further substantiated by comparison of the data gathered since 1938 with a series of samples collected monthly at the intake during the period July 1931 - August 1932 by the United States Department of Agriculture (58). Values obtained during that period of time are tabulated below. It is noted that the average and maximum values listed are less than any of those listed in Table 23 for the Maze Road Bridge station.

	Average	Maximum	Minimum
Specific conductance $EC \times 10^6$	455	786	113
Chlorides, ppm	72	138	11
Boron, ppm	0.13	0.23	0.03

The quality of water available for diversion at the El Solyo Water District intake during the irrigation season was in Class 1 during 1956, 1957, and 1958, and in Class 2 during 1955 and 1959.

Banta-Carbona Irrigation District Intake. The pumping station for this diversion is one mile west of the San Joaquin River and is connected with the river by a channel dredged in 1925. The entrance to the channel is 11 miles below the mouth of the Stanislaus River and midway between Durham Ferry Bridge, the site of the gaging station near Vernalis, and Mossdale Bridge. At this location, flow in the San Joaquin River is affected by tidal action with a daily fluctuation in water stage of as much as three feet.

As is the case at West Stanislaus, samples have been taken at both the entrance of the channel and at the first pumping station. Again, there appears to be no significant difference in quality of water at the two points. Previously, samples were taken at the entrance of the channel from 1948 through 1952. For this period, the total dissolved solids averaged 340 parts per million and chloride content averaged 80 parts per million. A maximum of 210 parts per million chlorides was obtained in February 1948.

The quality of water at the intake, since 1954, is presented in Table 27. In similarity to that at the Patterson

TABLE 27

MINERAL QUALITY OF WATER DIVERTED BY BANTA-CARBONA IRRIGATION DISTRICT FROM THE SAN JOAQUIN RIVER FOR THE 1955-1959 PERIOD

A. Summary of Sampling Records

Constituent or characteristic	1955 Aug. 3 to Oct. 10	1956 May 1 to Oct. 4	1957 May 3 to Oct. 7	1958 May 6 to Oct. 1	1959 March 31 to Oct. 3
Specific conductance - $EC \times 10^6$					
Average	992	388	704	484	1,119
Maximum	1,260	912	972	795	1,640
Minimum	895	81	119	107	802
Chloride - ppm					
Average	--	60	123	76	238
Maximum	--	171	185	140	416
Minimum	--	5	12	9	135

TABLE 27

MINERAL QUALITY OF WATER DIVERTED BY BANTA-CARBONA IRRIGATION DISTRICT FROM THE SAN JOAQUIN RIVER FOR THE 1955-1959 PERIOD (continued)

B. Average Monthly Salinometer Records

Month	1955			1956			1957			1958			1959		
	Sept. 1 - Oct. 16			Aug. 2 - Oct. 6			May 3 - Oct. 11			May 6 - Sept. 30			April 1 - Oct. 7		
	Mean daily														
	$ECx10^6$	TDS, in ppm	Salt load, in tons	$ECx10^6$	TDS, in ppm	Salt load, in tons	$ECx10^6$	TDS, in ppm	Salt load, in tons	$ECx10^6$	TDS, in ppm	Salt load, in tons	$ECx10^6$	TDS, in ppm	Salt load, in tons
April													997	568	247
May							703	405	128	134	77	28	992	566	179
June							506	291	106	151	87	27	1,095	624	222
July							880	507	214	504	291	105	1,213	692	269
August				620	352	98	909	523	166	774	446	132	1,188	677	210
September	961	549	119	610	347	35	829	478	73	613	354	66	1,062	605	96
October	1,030	588	54	667	379	26	699	403	28				1,005	573	42

Water District, West Stanislaus Irrigation District, and El Solyo Water District intakes, the quality of water at this diversion was in Class 1 during 1956, 1957, and 1958, and in Class 2 in 1955 and 1959. On August 3 and 4, 1959, chloride values of 416 and 376 parts per million were obtained, placing the quality for those two days in Class 3. During this period, boron never exceeded 0.4 part per million and percent sodium always remained below 54.

A good correlation exists between the quality at the Banta-Carbona intake and the quality of the San Joaquin River near Vernalis. This is to be expected since there is a relatively small change in flow between Vernalis and the entrance to the intake channel, and both diversions and accretions are small. The water quality values obtained at the Banta-Carbona intake are slightly greater than those at the Vernalis station. This correlation is of considerable value, since there is an abundance of data available for the Vernalis station.

Variation in water quality at the Banta-Carbona intake, as indicated by determination of specific conductance, is shown graphically on Plate 15 for the irrigation seasons of 1955 through 1959.

Ground Water

About 1,300 analyses of ground water, collected during the period from 1937 through the spring of 1959, were obtained from public and private agencies. These analyses represent the available data on ground water quality, and most are as yet unpublished. In the area between the City of Merced and the Chowchilla River, extending westerly to Salt Slough, the coverage of available analyses is somewhat sparse. All of the analyses collected during this investigation are on file with, and available from, the department. These data have not been differentiated with reference to the ground water zone represented, since correlating well data are not available. Many of the data collected consist of analyses of water pumped for control of the water table and for drainage purposes.

Plate 16 depicts the general overall quality of ground water in the Lower San Joaquin Valley area with relation to the quality classification standards for agricultural water supplies.

Ground waters on the east side of the San Joaquin Valley are generally of good quality. However, some wells adjacent to the river, between Turner Island Bridge and the Tuolumne River, show high concentrations of chlorides and total dissolved solids. Ground waters west of the San Joaquin River vary greatly in quality. Many of these waters have high total dissolved solids, attributed to concentration by evaporation in high water table areas, to intrusion of connate brines, and to recharge from highly mineralized west side stream waters. West side ground waters are characterized by significant concentrations of boron and sulfate, and such concentrations are considerably higher than in waters found on the east side of the river.

In the following paragraphs, the quality of ground water in various parts of the valley is summarized. In general, the areas are described and bounded by surface features only and are not necessarily hydrologic subdivisions of the San Joaquin Valley ground water basin.

East Side-North of Stanislaus River

Ground waters in the area just north of the Stanislaus River are, with few exceptions, of excellent quality, with total dissolved solids averaging 230 parts per million; chlorides, 20 parts per million; and boron, 0.05 part per million. Although only a few analyses of water from this area were available prior to 1955, recent data indicates that no significant change in the average quality of ground water has occurred in this area.

East Side-Stanislaus River to Tuolumne River

With the exception of water from deep wells along the Tuolumne River east of Modesto, ground waters in this area are excellent to good in quality. Average water quality values are 340 parts per million total dissolved solids; 50 parts per million chlorides; and 0.08 part per million boron.

Waters from deep wells adjacent to the Tuolumne River yield water of poor quality. Most of these wells, which are from 400 to 2.000 feet in depth, are gas wells. Waste water from these wells averages about 4,000 parts per million of total dissolved solids and 2,400 parts per million of chlorides. Prior records indicate that no change in the average quality of ground waters in this area has occurred in recent years.

East Side-Tuolumne River to Merced River

In this area, the quality of ground water is excellent in the portion east of United States Highway 99, and ranges from good to poor west of the highway. The poorest quality water is found in wells located within a few miles of the San Joaquin River, on poorly drained lands. Soils in this area are saline-alkaline, which accounts, to some extent, for the poor quality of ground waters. Ground water in the area east of the highway averages 300 parts per million total dissolved solids; 40 parts per million chlorides; and 0.1 part per million boron. The areal distribution of water samples before 1955 was not as complete as in subsequent years; however, comparison of analyses reveals no significant change in quality over the years.

An improvement in quality during the period 1955-58, over that prevalent in the years prior to 1955, is indicated for the area adjacent to the San Joaquin River. Since 1955, the average quality characteristics have been 870 parts per million total dissolved solids; 380 parts per million chloride; and 0.1 part per million boron. For the period 1943-54, the average total dissolved solids were in the neighborhood of 1,000 parts per million. There was no apparent change in the average for chlorides and boron between early and recent periods.

East Side-Merced River to Chowchilla River

The quality of ground water in this area is classed as excellent to good, except for that yielded by a few wells adjacent to the San Joaquin River. The average quality characteristics are 300 parts per million total dissolved solids; 60 parts per million chlorides; and 0.2 part per million boron. Since there were few analyses in the years preceding 1955, no comparison of water quality for recent and prior years can be made.

East Side-Chowchilla River to San Joaquin River

The quality of ground water in this area is excellent to good, with the exception of that from some wells adjacent to the San Joaquin River. The average quality characteristics are 280 parts per million total dissolved solids; 40 parts per million chlorides, and 0.1 part per million boron. No changes in quality over the years before and since 1955 have been noted.

West Side-Banta-Carbona Area

Except for wells adjacent to the foothills of the Coast Range, the quality of ground water in this area is generally in Class 2 for irrigation use. Water from the foothill wells generally contains concentrations of boron greater than the limits given for Class 2 water supplies. The quality of water since 1955 has been somewhat poorer than in previous years. Average quality values are: 830 parts per million total dissolved solids; 170 parts per million chlorides; and 1.0 part per million boron.

West Side-West Stanislaus and El Solyo Water District Area

The quality of ground water in this area, essentially the service area of the West Stanislaus Irrigation District and the El Solyo Water District is, with few exceptions, Class 2. The small number of analyses available for the years prior to 1955 provides little basis for comparison with those made since; however, it appears that no significant changes in quality have taken place. The average quality values are: 770 parts per million total dissolved solids; 160 parts per million chlorides; and 0.9 part per million boron.

West Side-Patterson Area

Most of the wells in the Patterson Water District service area are shallow wells. A few wells over 200 feet in depth are used for municipal, industrial, and irrigation purposes. The shallow waters generally fall in Class 3 for irrigation uses and average 1,900 parts per million total dissolved solids; 400 parts per million chlorides; and 1.3 parts per million boron. Waters from the deep wells are in Class 2 and average 1,000 parts per million total dissolved solids; 90 parts per million chlorides; and 0.7 part per million boron. Sulfates also are excessive and average 450 parts per million for deeper wells and 650 parts per million for the shallow wells. Analyses of ground waters in the area before 1955 are few in number. Comparison of these with samples taken since 1955, however, reveals no significant differences in quality.

West Side-Orestimba Creek to the Delta-Mendota Canal

The quality of ground water in this area varies considerably from place to place. For this reason, the area has been divided into six subareas from north to south and average qualities computed for each. Table 28 lists the average quality of ground water in these areas. Certain quality characteristics in four of the areas are discussed in the following paragraphs.

In the Salt Slough-Los Banos Creek subarea, available analyses of shallow ground waters indicate that they are very poor in quality. Shallow water analyses, however, were not included in the analyses used to compute the average quality values presented in Table 28, as there appears to be a complete differential between

TABLE 28

AVERAGE MINERAL QUALITY OF GROUND WATER IN THE WEST SIDE AREA FROM ORESTIMBA CREEK TO THE DELTA-MENDOTA CANAL, LOWER SAN JOAQUIN VALLEY

Subarea	Parts per million				%
	TDS	Cl	B	SO_4 1/	Na
Crows Landing-Newman Area	877	78	0.50	283	35
Gustine Area	533	55	0.45	101	41
Salt Slough-Los Banos Creek Area	1,268	425	2.4	457	78
Los Banos Area	498	97	0.38	85	49
Dos Palos Area	801	355	0.33	79	55
Firebaugh Area	368	91	0.15	53	67

1/ Sulfates

shallow and deep ground water in this area. Average values for the shallow waters are: chlorides, 1,600 parts per million; boron 4.3 parts per million; sulfates 1,600 parts per million; and percent sodium 77.

The Firebaugh subarea comprises a narrow band of land adjacent to the San Joaquin River, extending from the vicinity of Dos Palos south to Mendota Dam. Ground water in this strip of land is much less mineralized than in the other subareas listed, however, its high percent sodium value places it in Class 2 for irrigation uses.

In the Gustine subarea the average concentration of total dissolved solids subsequent to 1954 is about 100 parts per million greater than that existing between 1937 and 1954; and in the Dos Palos subarea a similar increase amounts to about 200 parts per million. The increase, however, has not effected a change in the classification of the waters for agricultural use. These are, for the Gustine subarea, Class 1; and for the Dos Palos subarea, Class 3. It is noted that relatively small changes occurred in chloride, sulfate, and boron concentrations.

West Side-South of Delta-Mendota Canal

The portion of the west side area included in this investigation is a small part of the larger Mendota-Huron area (75), where depths to ground water are great and the available ground water is being mined from storage. The water is of poor quality, with average concentrations of 1,700 parts per million total dissolved solids; 350 parts per million chlorides, and 1.9 parts per million boron. Sulfate concentrations are also high and average 730 parts per million. Percent sodium averages 67 percent and often exceeds 75 percent. The quality of water in recent years is slightly poorer than that pumped in the years prior to this investigation. In spite of the general poor quality, ground water in this area has been found usable for a limited number of salt tolerant crops because of existing favorable soil and drainage conditions.

Sewage and Industrial Wastes

The most common method of disposal of domestic and industrial wastes in the area of investigation is by ponding the effluent, resulting in evaporation to the atmosphere and percolation to ground water. Some disposal systems are known to discharge the effluent after primary treatment into the main streams through tributary drains. Other systems dispose of wastes to main streams only during flood periods and operate percolation ponds for the remainder of the year. The wastes are not highly mineralized and available analyses indicate that they average less than 500 parts per million of total dissolved solids. During the canning season, however, industrial wastes sometimes increase the total dissolved solid content to 1,200 parts per million. Municipal sewage disposal methods for the various communities in the area of investigation are listed in Table 29. These facilities presently serve a population of about 150,000.

From the standpoint of users of surface water in the lower reaches of the San Joaquin River, only two disposal system effluents which discharge directly into the stream system are significant.

The first of these is the waste disposed by the City of Turlock to Lateral No. 5 of the Turlock Irrigation District. The quality of water in Lateral No. 5, even after receiving this discharge, is in Class 1, as previously discussed, and no apparent adverse problem is presented.

The second waste discharge is that spilled to the Tuolumne River by the City of Modesto. Analyses of the summer effluent since 1955 show the quality to fall principally in Class 1, and occasionally Class 2, for irrigation use. However, it is not believed to significantly lower the quality of water supplies available to downstream users.

TABLE 29

MUNICIPAL WASTE DISPOSAL METHODS IN THE LOWER SAN JOAQUIN VALLEY AREA

City	Method or point of waste disposal
Atwater	Irrigation
Ceres	Percolation ponds, overflow to Gilstrap Lake
Chowchilla	Disposal upon grassland
Dos Palos	Percolation ponds
Firebaugh	Land disposal
Gustine	Overland to San Joaquin River
Livingston	Percolation ponds
Los Banos	Ponding, overflow to San Joaquin River
Madera	Disposal upon grassland
Mendota	Percolation ponds
Merced	Ponding, overflow to minor streams
Modesto	Ponding, overflow to Tuolumne River
Newman	Indirect discharge to San Joaquin River
Oakdale	Percolation ponds
Patterson	Ponding; discharged to San Joaquin River during floods
Ripon	Land spreading and lagoons
Riverbank	Disposal upon land
Tracy	Ponding
Turlock	Lateral Drain No. 5 of Turlock Irrigation District thence to San Joaquin River

CHAPTER V. QUALITY PROBLEMS, EFFECTS, AND CONTROL

The quality of both surface and ground waters in the area of investigation varies widely from place to place and from time to time. In some instances, the native waters are of poor quality; in others, there has been a progressive deterioration in quality resulting from cultural development and water utilization. In areas where the quality has, or probably may, become unsuitable for general or specific uses, a water quality problem exists.

The primary objective of the current investigation was to determine whether the quality of waters available in the lower San Joaquin River is, or will be, a problem to using agencies and individuals. To satisfy this objective, a number of lesser objectives must be attained. These are identification of sources and causes of degradation, identification of associated problems, and determination of the effects of degradation of water supplies with reference to proposed uses. A discussion of water quality and associated problems, together with an outline of possible remedial measures is presented in this chapter.

Deep-Seated Brines

Geologic exploration has indicated that a major part of the San Joaquin Valley is underlain at varying depths by saline waters. It is believed that, in many cases, these waters will migrate into fresh water deposits by reason of underlying gas pressure, excessive pumpage from fresh water zones, and movement due to hydraulic pressure. The present depth to the surface of these waters increases from north to south, and is between 400 and

500 feet below the surface near Modesto, increasing to 1,000 feet or greater between Madera and Mendota (76).

In water pumped from a number of wells in the Modesto area and the Turlock Irrigation District area, a trend of increasing chloride content has been noted over the period of record. For the period 1939 to 1951, chlorides at one well, owned by the City of Modesto, increased from 179 to 381 parts per million; at another the increase was from 104 to 248 parts per million. Samples from five wells in the Turlock Irrigation District, for which five or more years of consecutive record since 1950 are available, have consistently contained high concentrations of chlorides. These wells are 200 to 300 feet deep and chloride concentrations ranged between 162 and 762 parts per million.

In a report on water quality in eastern Stanislaus and Merced Counties (40), it was shown that the chloride content in ground water from depths of 150 feet to the top of the Mehrten formation (at a depth of about 700 feet in the vicinity of Modesto and Turlock) is over 200 parts per million west of Modesto and over 100 parts per million west of Turlock. It was also shown that the chloride content of ground water progressively increases in a southwesterly direction, generally parallel to the San Joaquin River.

In the area near Waterford, samples from wells 300 to 1,000 feet deep show chlorides ranging from 330 to 2,070 parts per million. These waters are calcium-sodium chloride waters and the percent sodium ranges from 50 to 60. The quality indicated by these samples is identical in chemical composition to the water pumped from the Modesto-Waterford gas wells in the same area. The depths of these latter range up to 2,000 feet and the chloride content ranges between 480 and 10,400 parts per million. Comparison of samples taken from nine gas wells and eight water wells indicates that the concentrations increase with depth. In contrast, chlorides in wells of similar depth located immediately north of this area, in the service area of the Oakdale Irrigation District, are quite low.

A third region in which evidence of brines is apparent is the area west of Firebaugh and Mendota. In examining samples from wells 800 to 2,000 feet deep, a wide range in values for various constituents was found. However, only a small number of wells produced water of a quality which would fall in the lower concentration ranges. Ranges for principal constituents are listed below:

Total dissolved solids	790-5,740 ppm
Chlorides	61-1,840 ppm
Sulfates	261-2,690 ppm
Boron	0.5- 11 ppm
Percent sodium	38- 89

The average quality of ground water in this area, including that from a few wells shallower than 800 feet in depth, is discussed in Chapter IV of this report. As there stated, this area is a portion of the larger Mendota-Huron area, where the mining of ground water probably accounts for the intrusion of the deep-seated brines into usable ground water zone (75).

Runoff From West Side Streams

The quality of water in west side streams varies from stream to stream and from time to time, the concentration of dissolved solids generally increasing as the flow decreases.

Waters of Panoche Creek and its tributaries are high in sulfates, probably dissolved from gypsum deposits. The waters of most of the other streams are high in bicarbonates. In Little Panoche Creek and other streams, chlorides are high, probably because of water flowing from saline springs. Nearly all of the west side waters are high in boron content, especially those of Corral Hollow, Quinto, Little Panoche, and Panoche Creeks. Though few samples were taken prior to 1951, it has been recognized for some time that the quality of water in the west side streams is generally poor.

None of these waters are impounded, and because of the sporadic flow, only small amounts are diverted directly for use. The streams discharge into the San Joaquin River only at times of high flow, when the concentrations in the streams themselves are least, and the dilution capacity of the river is large.

The significant problem resulting from the poor quality water in the west side streams is its effect on the underlying ground water. Information on ground water quality, summarized in Table 30, indicates that the water is markedly similar to that of the surface streams.

Drainage Facilities

While the quality of water used in irrigation may in itself be a problem, other problems can result in conjunction with the use of such waters. Generally these problems are both physical and chemical in nature. A primary problem in the Lower San Joaquin Valley is drainage as related to the use of the land.

TABLE 30

COMPARISON OF CONSTITUENTS IN WATER
FROM SELECTED WELLS AND ADJACENT STREAMS
IN THE WEST SIDE AREA OF THE LOWER SAN JOAQUIN VALLEY

Well number	Date sampled	Depth, in feet	Primary anion in ground water	Adjacent influencing stream	Primary anion in stream
13S/14E-7N1	8/15/51	825	Sulfate	Panoche	Sulfate
12S/11E-25Q1	8/14/51	1,050	Chloride-sulfate	Little Panoche	Chloride
10S/10E-28D1	7/5/57	250	Bicarbonate	Los Banos	Bicarbonate
9S/9E-17B1	4/9/56	100	Bicarbonate	San Luis	Bicarbonate
9S/9E-5B1	8/4/58	102	Bicarbonate	Quinto	Bicarbonate
8S/9E-16E1	8/4/58	105	Bicarbonate-sulfate	Garzas	Sulfate
6S/9E-18F1	7/4/57	620	Bicarbonate-sulfate	Orestimba	Bicarbonate
5S/7E-15E1	7/21/47	---	Bicarbonate-sulfate	Del Puerto	Bicarbonate
3S/5E-17A1	7/21/53	168	Bicarbonate-sulfate	Corral Hollow	Bicarbonate-sulfate

Historically, the introduction of irrigated agriculture in an area always has created a need for the natural or artificial removal of water not used consumptively. A portion of the unconsumed water usually drains on the surface, while the remainder passes through the soil to the water table. The removal of surface water is primarily a mechanical problem, but the disposal of infiltrating water is more complex. If the water table is but a short distance below the ground surface, or if the soil does not readily permit the passage of water and the volume of applied water is considerable, a high ground water table develops. The resultant effect is frequently twofold; crops are either destroyed or the productivity of the land is retarded by the shallow water and by salt accumulation in the root zone of the soil. These effects are commonly referred to as "drowning" and "salt-burn".

In portions of the presently irrigated area in the Lower San Joaquin Valley, the occurrence of high ground water conditions followed the introduction of surface irrigation. In some areas, drainage water has been removed effectively, while in others the lack of adequate drainage remains a current problem.

Only a small quantity of minerals are utilized by plants in promoting growth. Consequently, unconsumed water will contain higher mineral concentrations than the water applied in the practice of irrigation. It follows that removal of unconsumed water by drainage systems will likewise remove a considerable portion of the dissolved minerals. One means of controlling the elevation of the water table in an area of existing or threatened high ground water is through the use of open or tile drains. This results in an outflow of water which otherwise would be consumed and evaporated in wet areas and, by so doing, reduces the accumulation of salts in the soil.

The installation and pumping of drainage wells also may be utilized to control the water table elevation. In some areas drainage districts are formed to provide facilities of this type and in other areas the water supply agency provides the means of disposal for unconsumed water. In the Turlock, Modesto, and Merced Irrigation Districts, water is pumped from drainage wells into the district canals during the irrigation season and re-used.

The Dos Palos and Gustine Drainage Districts similarly dispose of pumped water into the canal system of the Central California Irrigation District.

In the Patterson Water District, wells and tile drains are used although the wells apparently have not been as effective as desired. In a few instances, the district drilled wells interconnecting the upper and lower aquifers. In these wells, the upper zone poor quality waters are able to drain into lower water-bearing zones. These wells are in the process of abandonment after sealing.

In the Banta-Carbona and West Stanislaus Irrigation Districts, the use of wells to control the water table is necessary only in minor problem areas. The absence of a widespread high water table problem in these two districts is probably due to the large number of irrigation wells in and adjacent to the area. These wells, as may be expected, are effective in maintaining the water table at an acceptable elevation. In all of the abovementioned districts, wells and tile drains were installed to supplement previously constructed, or natural, surface drainage channels.

In areas without the benefit of adequate natural or artificial drainage facilities, lands tend to become saline-alkaline in nature. This is the case with certain lands adjacent to the San Joaquin River between Turner Island Bridge and the Stanislaus River. These lands constitute a natural source of quality degradation in the San Joaquin River because of the discharge of poor quality water. According to available earlier studies, these lands have always been saline-alkaline, and have been underlain by poor quality ground water. In the "Tenth Annual Report of the State Mineralogist", published in 1890 (32), saline water and the saline-alkaline lands in this area were described. This is substantiated by data, including mineral analyses of ground waters in the area, gathered in 1906 by the United States Geological Survey (52). Historically, these lands probably extended over a larger area of the valley floor. Through reclamation, the areal extent of the poorer lands has been reduced until, at present, they are contained in two fairly definite units.

The largest of these units is adjacent to the San Joaquin River between Turner Island Bridge and Hills Ferry Bridge. West of the river, the lands are termed the "grasslands" and their extent generally conforms to the boundaries of the Grasslands Water District (Plate 8). On the east side, the lands extend from one-half to five miles from the river. As stated previously in this report, lands in this unit, because of their saline-alkaline nature, are at present limited in their suitability for agricultural use; however, they are valued as nesting areas for waterfowl. A high water table underlies the area and the quality of the shallow ground water is very poor. This saline-alkaline area is drained chiefly by Salt Slough on the west, and Bear Creek on the east. The high salt content of waters in Salt Slough and Bear Creek, in the absence of rainfall during the nonirrigation months, indicates the effect of these lands on the quality of water.

The other unit of saline-alkaline land, two to five miles in width, lies east of the San Joaquin River and parallel to it, from the mouth of the Stanislaus River to Hills Ferry Bridge. A large portion of the land in this unit is devoted to irrigated pasture, and other crops are being introduced. Despite this development, the quality of drainage and effluent ground waters emitting from the area is poor. This is typified by the quality of waters in Vivian Slough and the Turlock Garden Drain, the principal return flow channels. The average quality of ground water in the area is Class 3.

Return Waters

One of the principal factors affecting the quality of waters in streams of the Lower San Joaquin Valley has been, and will continue to be, return water from agricultural areas. The importance of these waters is emphasized by the fact that available water in the lower reaches of the rivers draining the area during the last half of the irrigation season is primarily return water from upstream lands.

Each time crops are irrigated, water is consumed and evaporated but little, if any, of the salt content is removed. Fertilizers increase the salt content of the water, as do the soluable minerals in many of the soils. With repeated use, the accumulation of salts may be such as to render ground water and the effluent seepage unsuitable for further use. To avoid this, the combined outflow of ground water and surface drainage must be sufficient to carry out of the area a quantity of salts equal to that brought in, plus any additives within the area, without the concentration of salts rendering the water unfit for downstream use. Although the entire demand for water may be supplied from surface sources, similar problems arise when drainage water is re-used before it enters a stream.

A significant alteration in land use, in turn, will result in a change in the quality, as well as the volume, of return water. However, to bring about a measurable difference, such a change would necessarily be of considerable magnitude. Whether a change of this degree has occurred in the Lower San Joaquin Valley in recent years is not apparent, though a substantial increase in the area irrigated has occurred. A 25 percent increase in irrigated acreage over an approximate 10-year span (1948-50 to 1957-58) is shown in Table 10. The volume of summer accretions from return waters for the same period does not show a similar increase but fluctuates according to climatic conditions and available water supplies. At the same time, an increase in salt concentration is evident at key points on the San Joaquin River (Table 23).

Further reclamation of the saline-alkaline areas, described earlier, would affect the quality of the water in the San Joaquin River through addition of salts removed from the soil by leaching, and would increase the quantity of return water through the introduction of more adequate drainage facilities. After areawide reclamation and leaching of saline soils has been accomplished, it may be anticipated that the average quality of return flows would be improved.

Although, in the general case, return waters contribute to the degradation of streamflow, in the Lower San Joaquin Valley, some return flows actually tend to improve the quality of the water supplies otherwise available. This is especially true during the latter part of the irrigation season. At that time, surface return flows from the east side agricultural area, with the exception of those waters draining from saline-alkaline areas, are derived from abundant supplies of good water. Consequently, the mixture of such flows with drainage and ground waters of poorer quality tends, if anything, to upgrade the available late season water supplies.

Conversely, west side return waters are derived from surface water supplies with salt concentrations generally in the range of Class 1 or 2, and ground waters principally in Class 2 and occasionally in Class 3. The salinity of these waters is increased two or more times by use, and invariably results in the discharge of highly concentrated return waters.

The importation of return waters from outside the investigation area, as results from the operation of Panoche Drain, poses serious water quality problems. As pointed out in the previous chapter, the quality of return water from areas south of the Delta-Mendota Canal, so far as is known, is very poor. Further increase in the area irrigated in this vicinity will ultimately create a problem of disposal of such return waters. Such waters, if they enter the San Joaquin River, can become a significant source of degradation. Recognizing this problem, the Department of Water Resources, in June 1957, commenced a comprehensive investigation of the drainage problem in the San Joaquin Valley with the objective of formulating a detailed master drainage plan for the entire valley. Preliminary findings resulting from this investigation are discussed subsequently in this chapter.

Agricultural Chemicals

The use of fertilizers and insecticides in agricultural operations, for the purpose of promoting crop production, has continued to increase in California. A portion of the minerals contained in these additions eventually enters surface and ground water supplies as a result of solution in water applied to agricultural lands. No studies have been made to determine the types and quantities of chemical constituents entering the State's waters from fertilizers and insecticides. Consequently, the degrading effects of salts from fertilizers and insecticides are uncertain; however, the presence of salts probably deriving from these additives is noted in many water analyses, and is indicated in determinations for the various compounds of nitrogen and phosphorus.

Estimates of the use of fertilizing materials in the various counties of California were made in 1954 by the United States Department of Commerce, Bureau of the Census. To date, this remains the only available detailed compilation of this type. It was found that the counties of Madera, Merced, and Stanislaus, as a group, used about seven percent of the total tonnage of commercial fertilizers used in California in 1954. This quantity amounted to about 54,000 tons. Other important soil additives, such as gypsum, were not included in the above estimate. Since the statewide sale of commercial fertilizers has increased six-fold in the last 20 years and agricultural minerals (primarily gypsum) twenty-fold in the same period, it is reasonable to expect that a proportionate increase in use has occurred in the area of investigation.

Sewage and Industrial Wastes

Waste waters derived from the domestic, commercial, and industrial uses of water are also sources of degradation. As discussed earlier in this report, there are only three such wastes significantly affecting waters of the Lower San Joaquin Valley. These are sewage from the City of Turlock which enters the San Joaquin River via Turlock Lateral No. 5, sewage from the City of Modesto discharged to the Tuolumne River, and waste water from eight natural gas wells adjacent to the Tuolumne River above Modesto. This latter waste is the more significant of the three in its effect on water quality.

The wastes discharged from the gas wells are unsuitable for all ordinary consumptive uses and directly increase the salt concentration in the river downstream from the point of discharge. The wastes have a high concentration of chlorides, and records of chloride concentrations at Don Pedro Dam and at the Hickman-Waterford Bridge indicate that the tonnage of chlorides contributed by these wells is comparable in magnitude to the increase in such tonnage between the two stations. The chlorides discharged from these wells represents an increment of 28 parts per million in the average flow of the Tuolumne River at Modesto.

In a report on water quality of eastern Stanislaus and Merced Counties (40), it was similarly concluded that the gas wells discussed above directly contributed to the increase in chloride concentration found in the Tuolumne River below Waterford.

Effect of Quality of Water on Soils and Crop Response

One of the objectives of this investigation has been to determine the effect of the quality of applied irrigation water on soils of the area and on crops produced. This objective was limited to water diverted from the San Joaquin River by the cooperating districts for use on typical soils native to their service areas.

To accomplish this objective an agreement was made with the Department of Irrigation, University of California at Davis, to study water quality in relation to soil and crop production. The work done by the university is summarized briefly in this section. A detailed report of field examinations and laboratory studies is contained in Appendix C.

Field Investigation

During the four years between 1955 and 1958, soil samples were taken at 67 sites in the Banta-Carbona, West Stanislaus, and Patterson service areas and adjacent lands. Many of the samples were taken in cooperation with the Agricultural Extension Service of the University of California in San Joaquin and Stanislaus Counties. Sites selected included unirrigated lands, representative irrigated fields, and lands reportedly presenting problems stemming from salt accumulation. The selection of unirrigated lands provided a means for comparison between those salts native to the soils and the salt concentration in the soil after the land had been irrigated. About half the samples were taken in the Patterson Water District service area, where the problems of salt accumulation, high water table, and restricted soil drainage appear to be more widespread. A few samples were taken south of the Patterson area around Crow's Landing, and the remaining samples came from the Banta-Carbona and West Stanislaus areas. Physical and chemical analyses of the soil samples were made in the laboratory for each foot of depth of soil at the point of sampling. The information sought determined the type of analyses to which the soil samples were subjected.

Considerable variation in salt accumulation, even in groups of soil samples from similar land classes, is to be expected since many diverse factors govern conditions at each site. This is true, regardless of the care used in selection of the site locations. These factors include soil type, condition of the soil, past and present irrigation history, methods of cultivation, etc. However, sufficient field data were obtained so that the basic causes of salt accumulation in the soils of the area, and the relationship between applied water, the soil, and crop production could be evaluated. Data gathered in the field, including a discussion of conditions at each site, are presented according to individual sample location in Appendix C. These sites are shown on Plate 3.

Laboratory Studies

Under field conditions, the status of salt accumulation in the soil can be altered through leaching resulting from excessive precipitation and changes in irrigation practice, such as the application of substantial supplies of water for this purpose. Successful leaching permits the use of a lesser quality water, since salt accumulation is prevented or reduced thereby. As changes in climate and irrigation practice influence the accumulation of salt under existing conditions, studies of the process and effect of salt accumulation in soils of the area and of the effect of leaching were made under laboratory conditions where the principal factors could be controlled.

The laboratory studies consisted of the application of waters of various qualities to test cylinders filled with soils native to the investigation area. In a number of cylinders, leaching was permitted, while in others the process of irrigation continued until the crop wilted as a result of salinity in the soil.

The soils selected for study were Sorrento loam and Ambrose clay, typical of the soils in the service areas of the cooperating districts. A total of 42 six-foot test cylinders were prepared for laboratory use and experimentation. In addition to the use of Sorrento and Ambrose soils for these tests, Pleasanton gravelly clay loam was used in auxiliary studies of leaching. The Pleasanton soils were placed in cylinders three feet in length.

Four test waters, each more concentrated than the other, prepared by the addition of various combinations of chemicals, were used to irrigate the test cylinders. The quality of the least concentrated water represented the quality of San Joaquin River water prior to 1950; the next highest concentrated water approached the present quality of water of San Joaquin River; and the two most concentrated waters represented further degrees of degradation, projected from present analyses and trends in occurrence of types of salt.

Sunflowers were raised in the test cylinders. This crop was selected because it is deep rooted and deficiencies in both quantity and quality of water supplies may be readily detected by observation of the foliage.

The various test procedures and results of the laboratory studies are presented in detail in Appendix C.

Conclusions Derived from the Laboratory Studies

Following are the conclusions obtained from the studies:

"1. The application of San Joaquin River water, even though considered of good quality before 1950, over a period of many years on certain soils, together with past irrigation practice, has resulted in increasing soil salinity to such an extent that it is harmful to salt-sensitive plants.

"2. Factors responsible for accumulation of soil salines are:

a. The mean seasonal precipitation is too low to properly leach the soil.

b. The type of soil, especially fine-textured soil of low permeability, may retard the infiltration of water through the soil thus curtailing the process of leaching.

c. Over-efficient use of irrigation water where less than 30 inches is applied per season. The raising of perennial crops, such as orchards and alfalfa, induces efficient use of water. With few exceptions, lands on which annual crops were grown showed little accumulation.

d. High water tables. In such cases, evaporation and transpiration concentrate salt in the soil.

"3. The concentration and type of salt in the irrigation water will influence the soil properties and the accumulated salines.

a. Chloride is not the predominating ion, but its accumulation in the soil indicates a need for leaching.

b. Future deterioration of irrigation water, with increasing concentrations of sodium will disperse the soil, reduce infiltration, and cause injury to salt-sensitive plants.

c. Accumulation of the bicarbonate ion will result in increased exchangeable sodium. This can occur when waters of the type found in the San Joaquin River at present and in the past are used.

"4. Present and past quality of water diverted from the San Joaquin River is not responsible for existing low infiltration rates; these are due to poor soil structure or compact, high volume-weight, soils. This is important in leaching for when infiltration rates are low leaching can be difficult.

"5. In most of the area, soils are relatively free of accumulated salts and little advantage would be gained from the application of more water. However, additional water should be applied for leaching in fields where salts have accumulated."

Remedial Measures

Since the quality of waters available in the lower San Joaquin River is such that special care may be required in accomplishing agricultural operations, users are concerned about possible measures to maintain or improve the quality of the water which they divert.

While there is need for collective efforts to improve existing conditions, it is the individual irrigator who is affected most directly by the quality problems. In many instances, problems resulting from the complex relationship between water, soil, and irrigation practices are confined to relatively small areas. Solutions to these problems are beyond the scope of this investigation. However, individual farmers should keep informed of the quality characteristics of their water supply and of soil conditions, and apply corrective measures when necessary. Such measures include changes in irrigation practices as well as, or in addition to, the use of chemical and mechanical aids to crop cultivation and production. An additional, or alternative, step which might be taken by the farm operator is the selection of crops which can produce satisfactory yields under adverse salinity conditions. The solution of individual problems generally requires the advice of qualified personnel, such as soil conservation specialists or local farm advisors.

Beyond the individual farm, the collection and disposal of surface and subsurface drainage generally becomes the responsibility of agencies organized for this purpose. The need for additional drainage facilities is evidenced by high water table conditions in many areas of the Lower San Joaquin Valley, and by the apparent inadequacy of existing facilities in certain areas. Correction of these drainage problems will assist in the removal of the salts which have accumulated in the soil over the course of time. Both individuals and water service agencies in the area have long recognized, and particularly so during recent years, that positive action for improvement of drainage conditions is required at an early date in order to maintain the agricultural production of this region.

Of particular interest in this regard is a plan prepared by the Soil Conservation Service for drainage of the "grasslands" and tributary areas (60). This area lies entirely west of the San Joaquin River and Salt Slough, and extends from the mouth of Salt Slough to near the boundary between Townships 13 and 14 South, MDB&M, roughly eight miles south of the Delta-Mendota Canal. The plan would provide drainage facilities serving approximately 119,000 acres. Briefly, it is proposed to drain the higher (southern) areas and transfer the effluent to lower areas where it could be used on pasture lands and for the maintaince of wild fowl nesting areas. It is further proposed that drainage waters in excess of these requirements be retained in surface storage for later release to the San Joaquin River during the winter flood period or discharged into a San Joaquin Valley master drain.

A part of The California Water Plan for the San Joaquin Valley is a drainage facility, designated in Bulletin No. 3 as the San Joaquin Valley Waste Conduit. The inclusion of the drain in the plan followed from recognition that provision of drainage is vital to the continuity of agricultural productivity in the valley. Subsequent to publication of Bulletin No. 3 in 1957, hearings concerned with the drainage problems in the valley were held by the Joint Committee on Water Problems of the California Legislature. As a result of the recommendations of this committee, the Department of Water Resources, in 1957, initiated the San Joaquin Valley Drainage Investigation.

This investigation, programmed to be completed over a six-year period, had two broad objectives: (1) formulation of a comprehensive master drainage plan for the entire San Joaquin Valley, and (2) intensive study of areas in present urgent need of drainage, including evaluation of the problem, design of needed facilities, and other studies necessary to determine the feasibility of construction of the proposed works.

Two solutions to the problem appear to be available, insofar as collection and conveyance of poor quality drainage water from the San Joaquin Valley is concerned. Each solution would affect the quality of water available in the Lower San Joaquin River. These possible solutions are: (1) abandonment of the San Joaquin River channel for conveyance of usable water supplies in favor of its use as a drainage channel, and (2) construction of a separate channel to convey poor quality waters to a locality where discharge to saline waters of the San Francisco Bay system might be accomplished.

The first solution would necessitate provision of an alternate source of water supply for present diverters. The most likely sources of such substitute water supplies would be either the Delta-Mendota Canal or the proposed San Joaquin Valley-Southern California Aqueduct of the State Water Facilities. The cooperating districts divert about three-fourths of the total water diverted from the San Joaquin River below Fremont Ford. The remaining one-fourth is diverted and used by smaller agencies and individuals. It would appear that extension of the service areas of the larger agencies to provide water to meet requirements of the minority group of water users would be feasible of accomplishment. A distinct advantage would be that the quality of the substitute water supply, as evidenced by the present quality of water in the Delta-Mendota Canal, would be better on the average than that now diverted from the San Joaquin River.

The second solution, providing for the disposal by removal from the area of both local poor quality drainage waters and saline effluent ground waters, could enhance the quality of water now available in the San Joaquin River by permitting only better quality return flows to enter the river. Thus, selective disposal of return water could effect an improvement in the future quality of water in the San Joaquin River. However, the use of substitute sources of water as a supplemental supply might be needed in conjunction with the operation of a separate waste channel.

CHAPTER VI. FUTURE WATER QUALITY CONDITIONS

One of the primary objectives of this investigation was evaluation of the effect of future water resources development on the quality of waters available for beneficial use in the lower reaches of the San Joaquin River. To accomplish this, a salt-routing study of the San Joaquin River was made. A salt-routing study is a mathematical procedure used to estimate and forecast salt concentrations anticipated to occur under various conditions of watershed development, and to determine the salt balance condition resulting from the predicted conditions.

The relationship between the input and output of salts, contained in the water supplied to and discharged from a given service area may be favorable or unfavorable, depending on circumstances peculiar to the area or body of water under consideration. This relationship is termed "salt balance". It is axiomatic that, to achieve a favorable salt balance, the quantity of salt leaving an area must be equal to or greater than the quantity of salt which enters. The reverse condition is termed an unfavorable salt balance because it results in the accumulation of salt in the area.

Salt Balance Considerations

In developing plans for conducting the salt-routing study, the objectives and scope of the investigation, as well as the availability of data, were taken into consideration. In addition, certain assumptions were necessary. The principal assumptions used in making this study are discussed in the following paragraphs.

Critical Period

It has been found that the critical period for maintenance of water quality coincides with the period of minimum flow, since maximum mineral concentrations will occur during such periods. Therefore, in order to forecast the most critical quality conditions that might occur in the lower reaches of the San Joaquin River, runoff and flows measured during the historical drought period from 1927 to 1934 were assumed to recur in the future.

New Projects

New water conservation projects were assumed to be in existence on the Stanislaus, Tuolumne, and Merced Rivers and to be of sufficient capacity to accomplish nearly full control of the flow. The new projects assumed to be in operation were New Melones Dam on the Stanislaus River, as proposed by the United States Corps of Engineers; New Don Pedro Dam on the Tuolumne River, as proposed by the Turlock and Modesto Irrigation Districts; and the Merced River Development Project, as proposed by the Merced Irrigation District.

Plans for proposed projects are generally subject to extensive revision, and often entirely new projects are conceived.

thus voiding older plans. Consequently, it is emphasized that assumed operating schedules used in making the salt-routing study are such as to approximate future developments of a forseeable magnitude.

It is evident that additional studies could be made incorporating a completely different visualization of the future physical development. An example of this would be the inclusion of the recently proposed East Side Canal, presently being studied by the United States Bureau of Reclamation. An extension of the Central Valley Project, the plan envisions the transfer of surplus waters from the Delta, and from Nimbus Reservoir on the American River, southerly along the east side of the San Joaquin Valley. The plan includes a dam and reservoir at the site of the New Melones development on the Stanislaus River, with a storage capacity about double that of the facilities proposed by the United States Corps of Engineers. The inclusion of this development, and consequent exclusion of other developments considered would, of course, change the computed result of the salt-routing study made for this investigation.

Existing Projects

It was assumed that existing projects would continue to function under established operation criteria. These projects include Friant Dam and Reservoir on the San Joaquin River, and the Delta-Mendota Canal. They are governed by operation criteria of the Central Valley Project, including the Exchange Agreement, described in Chapter II of this report.

Imported Return Water

An important aspect of future development considered involves the disposal of drainage from the area south of the Delta-Mendota Canal. For purposes of this study, it was assumed that such water would be intercepted before reaching the San Joaquin River and transported to the north without mixture with the water supplies of the area of investigation.

Methodology

While the entire stream system of the San Joaquin River basin was considered in making the salt-routing study for this investigation, mathematical computations were confined to the portion of the San Joaquin River between the Dos Palos gaging station and the Vernalis gaging station, and to the valley reaches of the three principal tributaries. Reasons for limiting computations to this expanse of the stream system were:

(1) Examination of stream flow records at Dos Palos and the diversion and operation criteria affecting stream flow at this point indicates that the natural flow of the San Joaquin River would be totally depleted at Dos Palos during the period assumed for the study. Therefore, all water supplies available below this point would consist of tributary inflow and drainage and return flow and, consequently, quality considerations become of primary importance.

(2) With regard to the principal tributaries, relatively insignificant changes in quality take place as flow proceeds from their sources to the foothill reservoirs, so that consideration of quality above the reservoirs was unnecessary.

The period of study covered the eight-year critical drought which occurred between 1927 and 1934, since this period imposed the most stringent limiting conditions for both supply and quality.

To facilitate computations, the San Joaquin River was divided into four reaches. These reaches were established so as to terminate each reach at or near the diversion point of each of the four cooperating agencies. A salt-routing equation was developed for each reach, as well as for the principal tributaries, taking into account the various factors of inflow and outflow affecting flow and quality in the reach. Each equation was solved and the results transferred to the adjoining downstream reach where the process was repeated. Factors considered included such sources of inflow as minor tributaries, valley floor tributaries (runoff, drainage, spillage, etc.), unmeasured runoff from precipitation, effluent ground water, and outflows such as seepage losses, diversions, and channel evaporation.

Values of flow in lesser streams were obtained from existing records or were estimated using standard methods of hydrologic correlation. Existing records provided the necessary precipitation and evaporation data. Minor correlation studies were made to estimate the less tangible, but important, quantities of effluent ground water and seepage losses. Since lands irrigated by direct diversion from the lower portions of the San Joaquin River and the valley sections of the three principal tributaries are essentially fully developed, the quantities of water diverted to them were assumed to be equal to recent rates of diversion.

Quality values were obtained principally through correlation of existing flow and quality records, and occasionally by calculation of probable chemical composition. In a few instances involving minor flows, reasonable values for quality had to be assumed.

Each of the four stream reaches used for the study, and individual factors considered to affect each reach are discussed in the following paragraphs.

Patterson Reach

This reach of the river extends from the Dos Palos gaging station to the Patterson Water District diversion. Principal sources of surface inflow include the Merced River, Salt Slough, Turlock Lateral 5, and Turlock Lateral 6 and 7. The Fresno and Chowchilla Rivers are tributary to this reach, but examination of stream flow records indicated that flow from these streams would reach the San Joaquin River in only two months of the eight-year period. A separate salt-routing study was made for the Merced River, based on the assumed operation of the Merced River Development Project, and the results incorporated into the computation for the reach. Calculations for the reach were considered to be indicative of the quality of water available to the Patterson Water District.

West Stanislaus Reach

This reach extends from the Patterson Water District diversion to just below the confluence of the Tuolumne and San Joaquin Rivers. The Tuolumne River is the principal inflow to this reach. In addition, there is also a number of small surface return flows, as well as effluent ground water. The primary purpose of the study in this reach was the determination of quality of water at the West Stanislaus Irrigation District diversion, just upstream from the mouth of the Tuolumne River. These quality values were computed by correlation with quality data calculated for the Grayson gaging station.

El Solyo Reach

This reach is relatively short, extending from below the confluence of the Tuolumne and San Joaquin Rivers to the El Solyo Water District diversion, a distance of about 10 miles. The largest sources of inflow are Burkhardt Drain and effluent ground water. Calculations for the reach resulted in the estimated quality of water in the San Joaquin River available to the El Solyo Water District at the point of diversion.

Banta-Carbona Reach

This reach extends from the El Solyo Water District diversion to the San Joaquin River gaging station near Vernalis. The most influential factor in the reach is the inflow from the Stanislaus River, as other inflows and outflows are quite small.

As stated in Chapter IV, an excellent correlation exists between the quality of water in the San Joaquin River at Vernalis and at the Banta-Carbona Irrigation District point of diversion. Consequently, the future quality at the Banta-Carbona Irrigation District intake was derived from qualities calculated for the Vernalis station.

Predicted Future Water Quality

It is emphasized that the results of the study presented herein are based on presently available data. Because of errors inherent in prognosticating future conditions they are subject to considerable revision, and are only indicative of probable future water quality. For these reasons, detailed numerical values obtained from the study are not included in this report. Instead, the probable range in quality, at the intakes of the cooperating districts and at Vernalis, are presented in Table 31. This table presents monthly mean values derived for an eight-year drought period, and the values should not be construed as instantaneous or daily mean values for water quality at these locations.

Comparison of Table 31 with Tables 23 through 27 of Chapter IV results in the following conclusions regarding salt balance:

1. The future quality of water available in the San Joaquin River, under the assumed conditions, would be similar to that existing at present.

2. The average future quality of water at each of the five locations would place the available supplies in Class 1 for agricultural use.

Although the maximum values of total dissolved solids and chlorides, as listed in Table 31, are in Class 2 for irrigation water, the unfavorable aspects of this condition are not serious as the length of time during the irrigation season when the quality would be poorer than Class 1 would be of short duration.

TABLE 31

ESTIMATED MONTHLY MEAN VALUES OF FUTURE MINERAL QUALITY OF WATER IN SAN JOAQUIN RIVER AT SELECTED LOCATIONS FOR ASSUMED EIGHT-YEAR DROUGHT PERIOD

(In parts per million)

Location	Total dissolved solids			Chlorides		
	Average	Maximum	Minimum	Average	Maximum	Minimum
At Patterson Water District Diversion	450	800	140	130	270	10
At West Stanislaus Irrigation District Diversion	520	900	130	140	260	10
At El Solyo Water District Diversion	470	630	160	150	230	30
At Vernalis	410	540	180	110	180	20
At Banta-Carbona Irrigation District Diversion	430	580	190	120	190	20

Values appearing in the above table assume the following projects to be in existence:

1. New Melones Dam on the Stanislaus River. Storage capacity 1.2 million acre-feet. Operation study dated 1953.
2. New Don Pedro Dam on the Tuolumne River. Storage capacity 1.8 million acre-feet. Operation study dated 1954.
3. Merced River Development Project. Three reservoirs with a combined storage capacity of 1.6 million acre-feet. Operation study dated January 1959.
4. Drainage water conveyed around the area by the proposed San Joaquin Valley Waste Conduit.

In general, late irrigation season flows below the mouth of the Tuolumne River are expected to be in the lower ranges of Class 2 agricultural supplies, and thus, not too detrimental for the proposed beneficial uses. Upstream from the Tuolumne River the quality should be somewhat poorer, but is expected to be within the range of Class 2 supplies, although tending toward the upper limits for such waters.

In summary, it was concluded that additional water conservation projects on streams tributary to the Lower San Joaquin Valley probably will not materially alter the quality of water available in the lower reaches of the river under the assumed conditions.

CHAPTER VII. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Continued development of water resources throughout the San Joaquin River drainage basin has brought about a high degree of water utilization in the Lower San Joaquin Valley area, especially during the latter part of the irrigation season. Coincident with this development, there has been an increase in the mineral content of water available for diversion from the lower San Joaquin River, especially during low flow periods.

Concern regarding the maintenance of usable quality of such waters prompted the Banta-Carbona and West Stanislaus Irrigation Districts and the Patterson Water Company to enter into an agreement with the State Water Resources Board for a study of factors affecting the quality of their available water supplies. The purpose of the investigation was the study of factors affecting the quantity and quality of water in the San Joaquin River, from the mouth of the Merced River to the Delta, and to suggest possible solutions to water quality problems.

The area covered by this investigation lies between the divides of the Sierra Nevada and the Coast Ranges, and includes the San Joaquin River drainage on the south and the Stanislaus River drainage on the north.

Water Supply

Seasonal precipitation in the area varies from about 10 inches on the valley floor to a maximum of around 70 inches per year, principally in the form of snow, on the higher elevations of the Sierra Nevada.

Major streams are the Stanislaus, Tuolumne, Merced, and San Joaquin Rivers. These four streams contribute the bulk of surface inflow to the valley and have an estimated mean natural runoff of 5,953,000 acre-feet per season. Regulation and development of these rivers has greatly altered the regimen of natural inflow to the valley. The major portion of the flow in the major streams generally is stored, except during periods of extreme flood stage, and releases from the reservoirs are controlled so that little natural flow occurs at the mouth of the east side streams during summer months. The water resources available in the San Joaquin River have been utilized to such a degree that, even prior to the construction of Friant Dam, a portion of the San Joaquin River channel below the gaging station near Dos Palos was dry from August through November in practically all years.

Water is imported to this area through the Delta-Mendota Canal and Fresno Slough. There are four existing exports of water: Hetch Hetchy Aqueduct, Friant-Kern Canal, North Main Canal of the Oakdale and South San Joaquin Irrigation Districts, and diversions via Fresno Slough. These imports and exports of water have altered the regimen of flow in streams in the valley.

Three distinct zones of bodies of ground water underlie the area of investigation. They are, in order of occurrence from the surface downward, the free ground water zone, the confined ground water zone, and the saline zone. Estimated ground water storage capacity for the total depth between 10 and 200 feet is about 32,000,000 acre-feet. High water table conditions prevail over considerable portions of the central trough of the valley and in areas where surface water supplies most of the irrigation demand.

Water Utilization

Development of streams in the Lower San Joaquin Valley for irrigation, power, and flood control purposes has progressed steadily since the 1920's. Further development of water resources is contemplated.

The major use of water is for irrigation. Requirements are met, mainly by diversion from surface water, by water service agencies serving about 1,200,000 acres. The gross diversion of surface water for irrigation uses increased from about 2,500,000 acre-feet in 1930 to about 3,500,000 acre-feet in 1958. Municipalities within the area utilize ground water almost exclusively as a source of supply. Relatively small amounts of water, derived largely from municipal sources, are used by industry.

During summer and fall months, and in other months during dry years, stream flow in the San Joaquin River below Dos Palos is largely return flow, as are flows in the downstream reaches of the principal tributaries. This condition is not a recent development but has existed for many years.

Water Quality

Monthly records of water quality for the larger streams are available since 1938. Waters of east side streams are a calcium bicarbonate type with low total solids and boron concentrations, whereas waters of west side streams display great variations in water quality and the total dissolved solids content ranges from low to very high.

The quality of water in the Stanislaus, Tuolumne, and Merced Rivers as they enter the valley floor is excellent; but as they cross the valley floor degradation by return waters occurs.

Little change is noted in the average quality of water at the mouth of the Stanislaus and Merced Rivers for the period of record. On the other hand, the salt concentration at the mouth of the Tuolumne River has increased significantly.

The quality of water in valley floor streams tributary to the San Joaquin River varies from excellent to very poor, or even unusable, for agricultural purposes. With certain limited exceptions, east side waters are of considerably better quality than west side waters.

The quality of water imported through the Delta-Mendota Canal is, with few exceptions, Class 1 during the irrigation season. The quality of water which could be made available through this facility during winter months is variable.

Since the San Joaquin River is influenced by all other sources of water in the investigation area, including imported and return waters, there is considerable variation in the quality of its waters downstream from the point where the river enters the valley floor. The quality of water in the San Joaquin River is degraded by return flows and is poorest at Fremont Ford. As flow proceeds further downstream, the overall salt concentration decreases due to dilution from better quality tributary east side waters. However, during the irrigation season a second increase in mineral concentration is noted at Grayson. The quality of water diverted from the San Joaquin River by the cooperating districts fell in Class 1 in 1956, 1957, and 1958, and in Class 2 in 1955 and 1959.

Ground waters on the east side of San Joaquin Valley are generally of good quality. Exceptions, however, occur in certain small areas adjacent to the San Joaquin River and in water from deep wells near the Tuolumne River above Modesto. Ground water west of the San Joaquin River varies greatly in quality.

Quality Problems, Effects, and Control

The quality of both surface and ground waters in the area of investigation varies widely from place to place and from time to time. In some instances, the water is naturally of poor quality; in others, there has been a progressive deterioration in quality resulting from cultural development. In areas where the quality has, or probably may, become unsuitable for general or specific uses, a water quality problem exists. Degradation of the quality of water in the Lower San Joaquin Valley may be attributed to both natural sources and cultural development.

There is a large body of saline water of marine origin underlying the entire San Joaquin Valley ground water basin. This body of water is found at a depth of 400 to 500 feet near Modesto, and 1,000 feet or greater between Madera and Mendota. Intrusion of the saline water into usable ground waters is apparent in the Modesto-Turlock-Waterford area and in the area west of Firebaugh and Mendota. Analyses of water from deep wells in these areas show high chlorides and high percent sodium. The possibility of increased intrusion from saline waters in these areas, or of intrusion in other areas, is dependent upon the magnitude and location of ground water development.

Although the quality of water used for irrigation may constitute a problem, other problems can result in conjunction with the irrigation of land. Drainage is such a problem in the Lower San Joaquin Valley. Historically, the introduction of irrigated agriculture in an area creates a need for the natural or artificial removal of water not used consumptively. The lack of effective subsurface drainage frequently has a twofold effect; crops are either destroyed, or the productivity of the land is retarded by the shallow water table and by salt accumulation in the root zone of the soil. In portions of the presently irrigated area of the Lower San Joaquin Valley, the occurrence of high ground water conditions followed the introduction of surface irrigation. In some areas, drainage has prevented the accumulation of salts in the upper soil horizons, while in others the lack of adequate drainage remains a current problem.

In areas without the benefit of adequate natural or artificial drainage facilities, lands have become saline-alkaline in nature. These areas constitute a probable source of degradation because of the poor quality of drainage water discharged. The effect of such lands on water quality may be judged from laboratory analyses of ground waters and return waters derived from the two such areas which lie adjacent to the San Joaquin River.

One of the principal factors affecting the quality of water in streams of the Lower San Joaquin Valley has been, and will continue to be, return waters. The importance of these waters is emphasized by the fact that available water in the lower reaches of the river during the latter part of the irrigation season is primarily return water.

Return water is generally of lesser quality than natural flow as a result of its use in irrigation. A significant alteration in land use will, in turn, result in a change in the quality as well as the return flows. Whether significant changes in return flows have occurred in the Lower San Joaquin Valley in recent years is not apparent, although a substantial increase in the area irrigated is evident. At the same time, an increase in salt concentration has been found at key points on the San Joaquin River.

While return waters from lands irrigated on the west side of the San Joaquin Valley contribute to the degradation of streams in the Lower San Joaquin Valley, a paradox exists in that some return flows from lands irrigated on the east side of the valley actually tend to improve the quality of the receiving waters. This results from the fact that the original supply to east side lands is abundant and of such good quality that the quality of the drainage water is better than that of the receiving water.

Conversely, west side return waters are derived from water supplies with salt concentrations ranging from Class 1 or 2 for surface waters to Class 2 and occasionally Class 3 for ground waters. The use and reuse of these waters in certain areas generally result in return waters with high mineral concentrations.

Waste waters derived from the domestic, commercial, and industrial uses of water are also sources of degradation. Of the wastes which significantly affect waters of the Lower San Joaquin Valley, those stemming from natural gas wells adjacent to the Tuolumne River above Modesto are the more degrading.

To determine the effect of the quality of irrigation water on soils and crops of the area, the Department of Irrigation of the University of California at Davis made a study of water quality in relation to soil and crop production. Field investigations in the area of the cooperating districts were made to determine the presence and quantity of salts in soils of the area. Laboratory studies were made to determine the process and effect of salt accumulation in the soils of the area under varying conditions of water supply and quality.

Many of the problems associated with the quality of water used in agriculture are confined to small areas, or even individual farms, and are generally associated with soil and drainage conditions. These problems are best solved through individual effort supplemented by specialized advice.

There are, however, large areas of valley floor lands in which the problem of drainage and disposal of return flows is predominant. Organized governmental agencies, federal, state, and local, are in the best position to deal effectively with this type of problem. Current efforts in this regard are being made by the Soil Conservation Service in planning for the drainage of about 120,000 acres in the southerly portion of the investigation area, and by the Department of Water Resources which is studying plans for a San Joaquin Valley master drain.

There appear to be two principal means of removing drainage and return waters from the San Joaquin Valley. These, broadly, are (1) the use of the San Joaquin River channel as a conveyance conduit, and (2) the construction of a separate drainage facility to deliver poor quality water to a point of discharge to tidewater. With either alternative method of disposal, however, a supplemental or substitute supply of good quality water may be required to maintain and expand the agricultural economy of the area. Such supplies could be made available from either the Delta-Mendota Canal or the state-constructed and -operated San Joaquin Valley-Southern California Aqueduct.

Future Water Quality Conditions

One of the primary objectives of this investigation was evaluation of the effects of future water resources development, on streams tributary to the area, on the quality of waters in the lower reaches of the San Joaquin River. To accomplish this, a salt routing study of the San Joaquin River was made.

In making this study it was assumed that (1) the historical drought period from 1927 to 1934 would recur; (2) New Melones Dam on the Stanislaus River with a storage capacity of 1.2 million acre-feet, New Don Pedro Dam on the Tuolumne River with a storage capacity of 1.8 million acre-feet, and the Merced River Development Project consisting of three reservoirs with a combined storage capacity of 1.6 million acre-feet, would be in existence; (3) existing projects would continue to function under presently established operation criteria; (4) imported drainage water would be conveyed through the area via the master drainage system for the San Joaquin Valley as authorized under the State Water Resources Development System. The effect of the East Side Division of the Central Valley Project, as proposed by the United States Bureau of Reclamation, was not considered.

The operation studies used in the current investigation were those made for New Melones Dam by the United States Corps of Engineers, in 1953, for New Don Pedro Dam by the Department of Water Resources in 1954, and for the Merced River Development Project by the Merced Irrigation District in January 1959. The San Joaquin River was divided into four reaches, each terminating at or near the intakes of the cooperating districts. The various factors affecting flow and quality of water in the San Joaquin River and the three principal tributaries were evaluated and parameters leading directly to the determination of results were considered. It was found that the future quality of water available at the intakes of the four cooperating districts probably would not vary greatly from that existing at present.

Conclusions

1. Water is imported to the area of investigation through the Delta-Mendota Canal and Fresno Slough while the principal exports are effected by the Friant-Kern Canal and the Oakdale-South San Joaquin Irrigation District diversion on the Stanislaus River. The total export of water, excluding natural outflow, has exceeded the import in recent years, often by a ratio of as much as two to one.

2. In almost every year, a portion of the San Joaquin River channel between the Dos Palos gaging station and Fremont Ford Bridge, 56 miles downstream, is dry during the months of August through November. This condition is not of recent origin, but has been prevalent for many years.

3. Waters in the Stanislaus and Merced Rivers at their confluence with the San Joaquin River are of excellent quality during both summer and winter months, and tend to improve the quality of water in the San Joaquin River. The salt content of water of the Tuolumne River at its confluence with the San Joaquin River, although less than that in the San Joaquin River, is twice that of either the Stanislaus or Merced Rivers.

4. The quality of waters in west side streams above the valley floor varies seasonally, and during periods of low flow the waters are generally unsuitable for irrigation uses.

5. The highest concentrations of salts in the waters of the San Joaquin River are found in the vicinity of Fremont Ford Bridge. The salinity from Fremont Ford to Mossdale is decreased by dilution with waters from the Merced, Tuolumne, and Stanislaus Rivers and by the relatively high quality return flows in this reach.

6. The average quality of waters in the San Joaquin River at all points below Mendota has undergone a continuous deterioration since December 1950.

7. Return waters from the area west of the San Joaquin River are generally of a poorer quality than return waters from the east side areas.

8. Increased use of ground water from the zone beneath the Corcoran clay member has resulted in the pumping of waters which contain saline connate water from wells in several local areas.

9. Poor quality ground water on the west side of the San Joaquin River results from recharge of the aquifers by highly mineralized west side streams.

10. While the quality of water of the Tuolumne River at, and for some distance below, Waterford remains in Class 1 for irrigation, its mineral content is increased by saline waste waters discharged to the river from gas and artesian wells east of Modesto.

11. The irrigation application of San Joaquin River water over a period of many years on certain soils, together with the effects of past irrigation practice, has resulted in increasing soil salinity to such an extent that it is now harmful to salt-sensitive plants.

12. Factors responsible for accumulation of soil salines in the area are: (a) the low mean seasonal precipitation is insufficient to properly leach the upper soil layers, (b) the type of soil, especially fine-textured soil of low permeability may retard the percolation of water through the soil thus curtailing the process of leaching, (c) excessively stringent economy in the application of irrigation water, and (d) high water tables.

13. Results of a salt routing study indicate that, under the assumed conditions additional water conservation projects on streams of the Lower San Joaquin Valley probably will not alter materially the average quality of water in the lower reaches of the river, in comparison to the present quality conditions. The assumed conditions were: (a) the historical drought period from 1927 to 1934 would recur; (b) New Melones Dam on the Stanislaus River with a storage capacity of 1.2 million acre-feet, New Don Pedro Dam on the Tuolumne River with a storage capacity of 1.8 million acre-feet, and the Merced

River Development Project consisting of three reservoirs with a combined storage capacity of 1.6 million acre-feet, would be in existence; (c) existing projects would continue to function under presently established operation criteria; and (d) imported drainage water would be conveyed through the area via the master drainage system for the San Joaquin Valley as authorized under the State Water Resources Development System.

Recommendations

1. Continued surveillance of the quality of water in the lower reaches of the San Joaquin River and of the status of salt accumulation in the soil should be maintained by both concerned individuals and water service agencies in the area.

2. Drainage districts or similar agencies empowered to plan, construct, and operate facilities for the drainage of high water table lands or for the disposal of return waters, should be organized by local governmental bodies and by responsible agricultural interests in the area.

3. Responsible agriculturists representing irrigated or irrigable areas not presently contained within the boundaries of an organized water service agency competent to contract for imported supplies of good quality water should give consideration to the advisability of organizing such additional agencies as may be required for such purpose.

APPENDIX A

AGREEMENTS

APPENDIX A

AGREEMENTS

CONTENTS

AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD,
THE BANTA-CARBONA IRRIGATION DISTRICT, ACTING FOR ITSELF
AND THE WEST STANISLAUS IRRIGATION DISTRICT,
THE PATTERSON WATER COMPANY, ET AL,
AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quintuplicate, entered into as of June 28, 1955, by and between the State Water Resources Board, hereinafter referred to as the "Board", the Banta-Carbona Irrigation District, hereinafter referred to as the "District", acting for itself and the West Stanislaus Irrigation District, the Patterson Water Company, and such other agencies and individuals diverting water from the San Joaquin River as may contribute financially, and the Department of Public Works, State of California, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer".

W I T N E S S E T H

WHEREAS, by the State Water Resources Act of 1945, as amended, the Board is authorized to conduct investigations of the water resources of the State, formulate plans for the control, conservation, protection, and utilization of such water resources, including solutions for the water problems of each portion of the State as deemed expedient and economically feasible, and may render reports thereon; and

WHEREAS, by said act, and by Chapter 1552, Statutes of 1949, the State Engineer is authorized to cooperate with any county, city, state agency, or public district on flood control and other water problems including problems of water quality, and when requested by any thereof may enter into a cooperative agreement to expend money on behalf of any thereof to accomplish the purposes of said acts; and

WHEREAS, the District has requested the Board and the State Engineer to enter into a cooperative agreement to conduct a comprehensive investigation of all factors that are known or believed to influence quantity and quality of return flow in the lower reaches of the San Joaquin River, and to prepare a report of such investigations with recommendations as to possible solution of the problems involved; and

WHEREAS, the Board on May 13, 1955, adopted a report from the State Engineer stating a need for such investigation in the lower reaches of the San Joaquin River, such investigation to extend over a period of five years at a total cost of Ninety Thousand Six Hundred Dollars ($90,600).

NOW, THEREFORE, in consideration of the premises and of the several promises to be performed by each as hereinafter set forth, the Board, the District, and the State Engineer do hereby mutually agree as follows:

ARTICLE I - WORK TO BE PERFORMED:

The work to be performed under this agreement shall consist of (1) a complete review of reports of prior investigations of the water resources of the San Joaquin River and contributory watershed; (2) a compilation and evaluation of data now available and preparation of an interim report evaluating the following as well as may be possible with such data; (3) determination of effects of quality of waters in lower reaches of San Joaquin River on lands and crops served therefrom; (4) evaluation of quality of waters in lower reaches of San Joaquin River at present and in the future as they may be affected by present and proposed water development projects on, and utilization of, waters from the San Joaquin River and its tributaries; (5) determination of effect on quality of return water in lower reaches of San Joaquin River of further economic development in San Joaquin Valley; and (6) preparation of a final report evaluating the foregoing items using data to be obtained in the course of the investigation in addition to that now available.

The Board by this agreement authorizes and directs the State Engineer to cooperate by conducting said investigation and preparing said report and by otherwise advising and assisting in formulating solutions to the water problems of the District.

During the progress of said investigation, all maps, plans, information, data, and records pertaining thereto which are in the possession of any party hereto, shall be made fully available to any other party hereto for the due and proper accomplishments of the objectives hereof.

The work to be done under this agreement shall be diligently prosecuted with the objective of completing the interim report by June 30, 1956, or as nearly thereafter as possible, and to completing the investigation and report thereon by June 30, 1960, or as nearly thereafter as possible.

ARTICLE II - FUNDS:

On execution of this agreement, the District shall transmit the sum of Twelve Thousand Five Hundred Dollars ($12,500) to the State Engineer for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury, for expenditure by the State Engineer in performance of the work provided for in this agreement.

Execution of this agreement shall also be contingent upon approval by the Director of Finance of the transfer, prior to June 30, 1955, of the sum of Seven Thousand Five Hundred Dollars ($7,500) from funds appropriated to the Board by Item 259 of the Budget Act of 1954, and the sum of Five Thousand Dollars ($5,000) from funds appropriated to the State Division of Water Resources by Item 247 of the Budget Act of 1954, to the said Water Resources Revolving Fund for expenditure by the State Engineer in performance of work provided for in this agreement.

It is understood by and between the parties hereto the sum of Twenty Five Thousand Dollars ($25,000) to be made available as hereinbefore provided is adequate to perform that portion of the above specified work during the first year of said five-year investigation. It is further understood that the District will make a further sum of Seven Thousand Six Hundred Dollars ($7,600) available at the commencement of each of the second, the third, and the fourth years of said investigation which will be subject to a matching or contribution in an equal sum by the Board to defray expenses incurred during the second, third, and fourth years thereof, and will make a further sum of Ten Thousand Dollars ($10,000) available at the commencement of the fifth year of said investigation which will be subject to a matching or contribution in an equal sum by the Board for the completion of said investigation and report, contingent upon availability of District and Board funds for such purposes.

It is understood by and between the parties hereto that the sum of Ninety Thousand Six Hundred Dollars ($90,600) to be made available as hereinbefore provided, is adequate for laboratory charges, salaries and expenses of engineers and geologists engaged directly in the investigation. The State Engineer in accordance with statutory responsibilities under Section 229 of the Water Code, will contribute to the investigation to the extent of furnishing supervision, clerical and drafting services, and printing the reports.

Notwithstanding anything contained in this agreement contrary hereto or in conflict herewith, this agreement is made contingent upon the funds being deposited in or transferred to the Water Resources Revolving Fund as provided herein for expenditure by the State Engineer in performance of the work provided for in this agreement. In the event any of the funds are not transferred to the Water Resources Revolving Fund by the Director of Finance as provided for herein, this agreement shall terminate and the unexpended balance of any funds deposited by the District shall be returned, provided that neither the Board nor the State Engineer shall be obligated to the District for any portion of the funds already expended.

The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the funds made available hereunder.

A statement of expenditures for each fiscal year beginning July 1 and ending June 30 shall be furnished the District by the State Engineer as soon as practicable after the close of the fiscal year.

Upon completion and final payment for the work provided for in this agreement, the State Engineer shall furnish to the Board and to the District a statement of all expenditures made under this agreement. One-half of the total amount of all said expenditures shall be deducted from the sum advanced from funds appropriated to the Board and one-half of the total amount of all said expenditures shall be deducted from the sum advanced by the District and any balance which may remain shall be returned to the Board and to the District in equal amounts.

Notwithstanding anything herein contained to the contrary, this agreement may be terminated and the provisions of this agreement may be altered, changed, or amended, by mutual consent of the parties hereto.

IN WITNESS WHEREOF, the parties hereunto have executed this agreement as of the date first herein written.

Approved as to Form and Procedure

Rutherford, Jacobs, Cavalero
& Dietrich

S
E
A
L

By /s/ Philip Cavalero
Attorney

BANTA-CARBONA IRRIGATION DISTRICT

By /s/ A. R. Lehman
Chairman, Board of Directors

Approved as to Form and Procedure

/s/ Elvera Draper
Secretary, Board of Directors

/s/ Henry Holsinger
Attorney for Division of Water Resources

STATE WATER RESOURCES BOARD

By /s/ Clair A. Hill
Chairman

APPROVED AS TO FUNDS

/s/ E. R. Higgins
Comptroller

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

FRANK B. DURKEE

Director of Public Works

Approved as to Form and Procedure

By /s/ A. H. Henderson
A. H. Henderson
Deputy Director of Public Works
June 30, 1955

Attorney, Department of Public Works

/s/ A. D. Edmonston
A. D. Edmonston
State Engineer

APPROVED BY DEPARTMENT OF FINANCE:

S.H.Y.	L.F.H.		
Form	Budget	Value	Descript.

DEPARTMENT OF FINANCE
A P P R O V E D
Jul 25 1955

JOHN M. PEIRCE, Director
By /s/ Louis J. Heinzer

Administrative Adviser

THIS AGREEMENT, made and entered into as of June 20, 1955, by and between BANTA-CARBONA IRRIGATION DISTRICT, a state agency of the State of California, hereinafter referred to as "Banta-Carbona", WEST STANISLAUS IRRIGATION DISTRICT, a state agency of the State of California, hereinafter referred to as "West Stanislaus", and PATTERSON WATER COMPANY, a mutual water company, hereinafter referred to as "Patterson",

W-I-T-N-E-S-S-E-S T-H-A-T :

WHEREAS, Banta-Carbona, West Stanislaus, and Patterson mutually desire that a comprehensive investigation be made of all factors that are known or believed to influence quantity or quality of return flow in the lower reaches of the San Joaquin River and that a report of such investigation with recommendations as to possible solution of the problems involved, if any, be prepared; and

WHEREAS, there are existing state agencies of the State of California that have qualified personnel and facilities to undertake such a study and investigation; and

WHEREAS, said agencies of the State of California have been contacted and the desired study and investigation can be made pursuant to the terms of that certain Agreement attached hereto, marked Exhibit "A", and by this reference thereto incorporated herein as though fully set forth herein, which said Agreement shall hereinafter be referred to as the "Survey Agreement"; and

WHEREAS, pursuant to said Survey Agreement, the state agencies of the State of California involved require that Banta-Carbona, therein referred to as "District", act as the contracting agency for all of the parties herein; and

WHEREAS, Banta-Carbona, West Stanislaus, and Patterson wish to proceed as in said Survey Agreement set forth and wish to have a written agreement among themselves relative to their respective responsibilities, contributions, and benefits in this regard;

NOW, THEREFORE, IT IS AGREED AS FOLLOWS:

1. Banta-Carbona, as the contracting agency representing Banta-Carbona, West Stanislaus, and Patterson, is hereby authorized and directed by Banta-Carbona, West Stanislaus, and Patterson to execute, for and on behalf of each of the parties hereto, said Survey Agreement, and each of the parties hereto agrees to be bound by the terms of said Survey Agreement and to indemnify and hold harmless Banta-Carbona from any liability or responsibility other than its appropriate proportionate liability and responsibility herein set forth.

2. It is agreed that all cash contributions to be made by Banta-Carbona, West Stanislaus, and Patterson for the purpose of paying for their respective portion of the amount to be paid for the work to be done pursuant to said Survey Agreement shall be shared among them or a per acreage basis, and that for all purposes of this agreement, the acreage of each of the three contracting parties shall be the following:

Banta-Carbona	15,680 acres
West Stanislaus	21,695 acres
Patterson	14,088 acres
Total	51,463 acres

From the foregoing, it is agreed that each of the contracting parties hereto shall pay and be responsible for the following percentage, respectively, of any payment to be made, to wit:

Banta-Carbona	30.47 percent
West Stanislaus	42.16 percent
Patterson	27.37 percent

3. The contracting parties hereto expect that other landholders and agencies, both public and private, similarly situated will join the cooperative effort contemplated hereby, and in this regard it is agreed that such other participants as may join this cooperative effort at a later date will be asked to contribute on a per acreage basis in an equitable manner. To the extent that the contributions of any additional participants will serve to meet the obligations of the contracting parties hereto incurred by the execution of the Survey Agreement, the amount required to be contributed by the parties hereto shall be reduced on a prorata basis.

4. The contribution of each of the parties hereto, and of any additional participant who may join this enterprise at a later date, shall be deposited in a special fund in the American Trust Company bank at Tracy, California. Said fund shall be known and designated as the "San Joaquin River Water Quality Survey Fund". Checks drawn upon said fund shall bear three (3) signatures, to wit, that of the respective Secretary of each of the contracting parties hereto.

5. Upon the completion of the prupose contemplated by this agreement, or upon any eariler agreed termination thereof, any unexpended funds remaining on deposit in the account of the

contracting parties shall be returned to the contracting parties and to any other participants who may have advanced funds subsequent hereto in the proportion that the amount of each particular participant's contribution bears to the total contribution made for the entire enterprise.

6. This agreement contemplates the highest good faith between the parties hereto, and each of the parties hereto pledges itself to exert its best effort to the end that the objectives of this agreement may be finally accomplished.

IN WITNESS WHEREOF, each of the parties,hereto, by and through its officers thereunto duly authorized, has exceuted this Agreement, in triplicate, as of the day and year first hereinabove written.

S E A L

BANTA CARBONA IRRIGATION DISTRICT

By /s/ A. R. Lehman

By/s/ Elvera Draper
Secretary

S E A L

WEST STANISLAUS IRRIGATION DISTRICT

By /s/ W. W. Cox

By/s/ Lawrence D. Harrison,
Secretary

S E A L

PATTERSON WATER COMPANY

By /s/ Lestor K. Gustafson, Pres.

By /s/ Leora Fink, Sec.

APPENDIX B

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APPENDIX B
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APPENDIX C

WATER QUALITY IN RELATION TO SOIL AND CROP PRODUCTION LOWER SAN JOAQUIN VALLEY

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APPENDIX C

WATER QUALITY IN RELATION TO SOIL AND CROP PRODUCTION

LOWER SAN JOAQUIN VALLEY

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Special recognition is due to the Water Resources Center of the University of California in providing funds for the large number of analyses made at the conclusion of the experiments. These analyses were not contemplated in the beginning, but they added materially to the results obtained and assisted in formulating the final conclusions.

WATER QUALITY IN RELATION TO SOIL AND CROP PRODUCTION
LOWER SAN JOAQUIN VALLEY

Introduction

Research on water quality in relation to soil and crop production in the lower San Joaquin Valley was initiated by an agreement between the Department of Water Resources and the University of California January 30, 1956. The statement of the problem and other general information concerning this area of investigation is given in the report on the "Lower San Joaquin Valley Water Quality Investigation", Department of Water Resources, State of California, to which this is an appendix. The area considered in the studies discussed in this appendix is bounded on the north by U. S. Highway 50; on the east by the San Joaquin River; on the south by Orestimba Creek, and on the west by the Delta-Mendota Canal, and consists essentially of the service areas of the Banta-Carbona Irrigation District, West Stanislaus Irrigation District, and Patterson Water District.

At the beginning of the investigation it was agreed to determine the level of soil salinity by conventional chemical methods, at a series of locations. This was to be done at the initiation and at the end of the project, thereby determining the effects on the soil and crop production for quality of waters now being used.

As money was made available during the period of investigation, additional information was to be secured on salt injury to crops, the effect of salinity on soil structure, and the relationship of irrigation practice to salt balance in the soil profile penetrated by plant roots.

Field Investigations

Soil samples were taken from various locations in the three irrigation districts for salinity analysis. Detailed analytical results are reported by site number in the basic data, bound at the end of this report. A total of 67 sites were sampled.

The soil sampling sites, or locations, were concentrated in areas where there was evidence of salt injury to crops. This was most pronounced in the Patterson Water District, and may be due in part to the fact that land in this district has been irrigated longer than in the other districts.

After a preliminary survey of the area and tentative locations had been selected, the Department of Water Resources collected soil samples for analyses late in the fall of 1955. The 14 sampling sites, the soil type, and the crop grown are given in the basic data portion of this report. In each irrigation district, one dry land, or unirrigated area, was sampled. These are identified as sites 3, 8, and 12 for West Stanislaus, Banta-Carbona, and Patterson Districts, respectively. A number of irrigated fields reasonably close to the dry-land area were sampled in one-foot intervals to a depth of five feet. This allowed a comparison between the natural salt occurring in the unirrigated soil and the salt concentration after the land has been irrigated for a period of years.

To help characterize the soil, the moisture equivalent was determined for each sample (the moisture equivalent is a laboratory measure for the field capacity, or the water-holding capacity of well drained soil). The soils sampled were from two soil series--Sorrento clay loam and Ambrose clay.

Sorrento clay loam is a grayish-brown surface soil free from lime to a depth of about two feet. From two to more than six feet, the subsoil is brown to light brown and contains lime in both the disseminated and mycelial forms. Normally, there is no evidence of profile development. Organic matter is consistently low and this soil group is usually free from injurious concentrations of salts.

Ambrose clay is dark brown in the surface soil, noncalcareous, and contains slight to moderate quantities of organic matter. The soil, when dry, has a blocky structure and forms hard clods. At a depth of 15 to 30 inches, it grades into a brownish-gray calcareous subsoil. This layer becomes somewhat lighter with depth, and grades into the yellowish-brown of the deeper subsoil at 30 to 60 inches. The heavy texture and the dense subsoil offer considerable resistance to penetration of roots and water. Besides the lime in the subsoil, some gypsum may appear. Normally this soil is free from the accumulation of harmful soluble salts, but some exceptions have been noted.

Soluble Salts of the Soil*. The soluble salts of the soil were determined in the saturation extract for each site and depth. The overall soluble salt concentration was estimated by electrical conductivity. The anions -- bicarbonate, chloride, and sulfate, and the cations -- calcium, magnesium, potassium, and sodium, are reported in milliequivalents per liter (Meq./L.) of the saturated extract.

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* Soil analyses for the soluble salts usually include the CO_3, HCO_3, Cl, SO_4, Ca, Mg, K, and Na in the saturation extract of the soil paste. The saturated paste is made by adding sufficient water to a dry soil to saturate it and by stirring to bring it to a pasty consistency. Some of the solution from the soil paste is removed by suction and this solution is termed

the "saturation extract". This is the most recent technique evolved for the estimation of soil salinity and has been suggested by the U. S. Salinity Laboratory as a method for estimating sodium percentage (of the cation exchange).

Electrical conductivity in millimhos/cm ($EC \times 10^3$) is a standard measurement of the electrical conductivity for salt solutions. Conductivity in millimhos ($EC \times 10^3$) may be converted to conductivity in micromhos ($EC \times 10^6$) by multiplying the figures given by 1000. The measurement is an excellent and rapid method for obtaining an estimate of the total salt content of the saturation extract, but does not give the individual salts or ions that may predominate, important in judging the effects of salinity on soil structure and plant growth. Consequently, detailed analyses were made for the cations and anions listed above.

Salinity of a soil is estimated by the electrical conductivity of the saturation extract ($EC \times 10^3$). The salinity by this method has been correlated with plant growth as follows:

$EC \times 10^3$	Crop Response
0 - 4	all crops thrive
4 - 8	yields of many crops restricted
8 - 16	only tolerant crops yield satisfactorily
16+	only a few very tolerant crops yield satisfactorily

Recent developments indicate salt concentrations somewhat below four millimhos may be injurious to sensitive plants, as the almond and apricot.

Sodium percentage (% Na) is the proportion of this element to the total cations when the analysis is expressed in millioquivalents per liter. This relationship is indicated by the following formula:

$$\frac{Na \times 100}{Ca + Mg + K + Na}$$

Sites 1, 2, and 4 in the West Stanislaus Irrigation District indicated some accumulation of salts when compared with the unirrigated land at Site 3. Apricot and almond trees at Sites 1 and 2 showed injury from salt. At Sites 1 and 2, chloride and sulfate ions were of about equal concentration, with the exception of the 4-5-foot depth at Site 2, where sulfate was high. The presence of high sulfates, coupled with the high calcium content and the common ion effect, indicates a saturated gypsum solution with additional gypsum probably present in the soil. The salinity, however, resulted from sodium sulfate and chloride. Low soil salinity was measured at Site 4. In general, sodium was the cation in highest concentration, it being more than 50 percent of the total cations, excepting in the surface foot of soil. However, the sodium percentage in the saturation extract is not considered sufficiently high to cause a deterioration of soil structure.

Samples from the unirrigated area in the Banta-Carbona Irrigation District, Site 8, had the highest salinity in the subsoil when compared to adjacent Sites 5, 6, and 7. The subsoil at Site 8 contained gypsum. According to the soil survey of the Tracy area, salinity is usually not found in this soil except under high water table conditions. However, the adjacent Sites 5, 6, and 7 have been irrigated for many years, and probably the salts had been leached from the surface five feet of soil prior to the date the survey was made. The lowest salt content in this group of Ambrose clays is at Site 7, farmed to annual crops -- this year, beans. Growing of annual crops usually provides leaching of the soil because of irrigation prior to planting the crop, and frequent irrigations when the plants are small. As with the previous soil, the percent sodium of the saturation extracts from the Ambrose clays are probably not sufficiently high to cause deterioration of the soil structure.

Sites 9 through 14 in the Patterson Water District are of the Sorrento series of loam to clay loam. The lowest salt content was found in the unirrigated soil at Site 12. All the irrigated soils showed an appreciable increase in salt in the areas planted to orchards, Sites 10, 13, and 14. Of all the 14 fields sampled throughout the study area, Site 13 had the highest concentration of salt with some gypsum present in the lower depths and with a high accumulation of chlorides. The percent sodium of the saturated extract from the Patterson area is not considered sufficiently high to cause deterioration of soil structure.

Exchangeable Cations (Base Exchange) of the Soil*. This determination was made for all 70 soil samples collected from the first 14 sites; included determination of the cation exchange capacity of the soil and the individual cations of calcium, magnesium, potassium, and sodium. The exchangeable cations were determined by the commonly used ammonium acetate method.

Most of the soil samples contained lime as indicated by the high calcium content, which is often larger than the cation-exchange capacity. Consequently, the total cations extracted in the cation exchange determination included the lime brought into solution and the soluble salts of the saturation

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* Cations absorbed on the soil may be replaced by an equivalent amount of ions from the soil solution. However, the ions of the cation exchange are not soluble and do not influence the total concentration of the soil solution. But, because of the stoichiometrical relationship between the cation exchange and the soil solution, its character may be different than that of the irrigation water. Also, the salts of an irrigation water and their accumulation in the soil solution will influence the kind of cations in the exchange. The cation exchange properties of a soil are sometimes termed the "exchange complex" and consist for the most part of various clay minerals and organic matter.

Cation-exchange capacity is the exchangeable cations a soil can retain and is usually expressed in milliequivalents per 100 grams of soil. Solutions capable of displacing exchangeable cations from soils dissolve most of the soluble salts and significant amounts of calcium and magnesium carbonate. As alkaline soils have from a trace to large amounts of lime or dolomite (calcium-magnesium carbonate) the summation of the cations in the extracting solution is larger than the cation-exchange capacity.

Percent sodium is calculated on the cation-exchange capacity after subtracting the amount of soluble sodium in the saturated extract.

extract. The principal exceptions are the surface foot in the nonirrigated soils, Sites 3, 8, and 12. Apparently, precipitation has been sufficient to leach most of the lime from this depth. In the irrigated soils, some lime may have been deposited from the irrigation water, for example, in the surface foot of Site 1 and 2, where the calcium content is higher than the cation-exchange capacity.

The percent sodium (corrected for the soluble sodium) on the cation exchange is not especially high for any of the soil samples. Under field conditions and type of irrigation water used in the past, probably no dispersal of the soil or deterioration of its structure has taken place.

After the soil samples were collected and analyzed, field studies of some of the problem areas were initiated. This work was conducted with the cooperation of the district managers and the farm advisors for the particular county. It soon became evident that lands within the districts, in general, used a minimum of irrigation water for good production. This was evident particularly from water deliveries and irrigation practice for tree crops. Because of this practice, soils in many orchards were not leached below the depth of rooting for the trees, and salts tended to accumulate. This was evident at Sites 1, 2, 6, 10, 13, and 14. Because of the leaf burn from salts, particularly with almonds and apricots, the University and Farm Advisors office has advised applying extra water to leach the soil. Many growers started this program and within the year some reported an improvement in the appearance of their trees. Consequently, analysis of the soil now and after several years, even with a poorer quality water being used, would show a decrease in salts. Therefore, after consultation with the Department of Water Resources, it was decided, in the summer of 1956, to study salt accumulation, and to a limited extent, leaching requirements in lysimeter-type tanks or columns where the irrigation water could be controlled. In addition, the survey of the salt status of soils throughout the area was to continue as time and opportunity afforded.

The field investigations for 1956, 1957, and 1958 were made in cooperation with the Farm Advisors of the counties located within the area under study. Dr. O. Lilleland of the Department of Pomology has data showing salts below the five-foot depth may contribute to the injury of deciduous fruit trees. Accordingly, soils were sampled to a depth of nine feet for most of the locations. The 53 sampling locations, soil series, and crops grown are listed in the basic data portion of this report as Sites 15 to 67, inclusive. The initial samples taken in 1956 indicated sodium of the exchange complex was not sufficiently high to cause dispersion of the soil or influence infiltration rates. Therefore, the cation exchange was not determined for these samples. They were analyzed only for the cations of the saturation extract. In localities where salinity occurs, the anions usually are a mixture of chloride and sulfate, with the latter often predominating. Accordingly, high concentrations of the chloride ion are frequently associated with salinity. To be certain that chloride was not the predominating ion, samples from seven locations, Sites 15, 16, 17, 18, 19, 66, and 67 were analyzed for chloride. Samples from Sites 66 and 67 were very high in soluble salines, and with only a few exceptions, the chloride ranged from a fifth to a half of the total salt concentration with sodium as the predominant ion. Therefore, to permit the processing of more samples in the laboratory, the major portion of the field investigation was limited to estimating salinity by electrical conductance and making analyses of the cations in the saturated extract.

The apricot orchard at location 18 had evidence of salt injury the previous season (1955) and larger quantities of water were applied during the summer of 1956 with the new growth appearing healthy when the orchard was sampled in the fall. Following this excess application of water, considerable salinity remained in the subsoil below the 5-foot depth. Site 27, in the same orchard as Site 18, but not at the same place, was sampled in 1957. Again, in 1957, an excess quantity of irrigation water was applied to leach the salts. Results indicated a lower salt concentration in the subsoil. A comparison of salinity in the soil profile for the two years is shown on Figure 1A.

Site 28, sampled in 1957, is in the same orchard as Site 15, which was sampled in the previous year and where a number of trees had died. In the intervening period, excess irrigation water had been applied which resulted in a decrease in the salt content of the soil profile, as shown in Figure 1B. At the time the samples were taken, in the fall of 1957, no apparent change in the appearance of the trees was noted. A tile drain has been installed in this area which should lower the water table and allow leaching of the salts.

Laboratory Studies

In previous studies on salt accumulation, its precipitation, and base exchange reaction for various qualities of water, it was found that growing plants in tall cylindrical columns of soil has certain advantages in obtaining basic information. The principal advantage is the large quantity of water used by the plants in relation to the limited area of soil and the ability to utilize sufficient depth to approach field conditions in regard to salt movement and distribution. In the greenhouse, with cylinders of soil four to six inches in diameter and three to four feet in depth, the use of water for annual crops will average four to six times the amount utilized under field conditions.

Salt Accumulation in Six-foot Cylinders

Two soils were selected for this study: Sorrento loam, as typical of the area, and a fine-textured soil -- Ambrose clay (adobe). Detailed descriptions of these soils are given in the soil survey covering this area*. The Sorrento loam was collected from the railroad right of way and was probably never irrigated. The Ambrose clay was from a farmer's field where field and truck crops have been grown. These soils were collected by one-foot increments to a depth of 6 feet; 97.6 pounds of dry soil were packed in cylinders six inches in diameter and six feet four inches high, according to their original depth. The cylinders were too tall for the greenhouse, so they were placed out of doors in a trench. To extend the growing season, the cylinders were covered with clear plastic in the early spring and again in the late fall of 1958. A total of 21 cylinders for each soil were used.

Water Used and Treatments. Four types of water were used in these studies. Water "A" was approximately the concentration and percent sodium of the San Joaquin River water during the forties. Water "B" was approximately the concentration of some of the water used at the present time, while "C" and "D" waters had proportionally higher salt concentrations. Analyses of these waters are given in Table 1.

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* Soil Survey: The Tracy Area of California Series 1938 No. 5, 1943.
The Newman Area of California Series 1938 No. 11, 1948.

TABLE 1

Analyses of waters used in 6-foot cylinder experiment.

Water	Cond. ECx10^3	Milliequivalents per liter							% Na
		Anions			Cations				
		HCO_3	SO_4	Cl	Ca	Mg	Na	Total	Na
A	0.44	1.5	0.4	2.5	1.0	1.1	2.2	4.3	51
B	0.96	2.9	1.4	4.9	2.5	1.7	4.8	9.0	53
C	1.95	3.5	2.1	12.5	3.5	2.5	12.0	18.0	67
D	2.89	3.5	3.1	20.5	3.5	3.5	20.0	27.0	74

The irrigation treatments for Sorrento loam and Ambrose clay were as follows:

Water "A" was used to irrigate three soil cylinders and the salts were allowed to accumulate in the soil profile. This was considered to be the check or control treatment.

Water "B" was used to irrigate six soil cylinders. In three of these cylinders, the salts were allowed to accumulate. In the remaining three cylinders, the salts were removed by leaching.

Water "C" -- the number of cylinders and the treatments used were the same as for Water "B".

Water "D" -- the number of cylinders and the treatments used were the same as for Water "B".

The soils were transported to Davis and packed in the cylinders during the summer of 1956. Field sunflowers were planted on the first day of August after initial wetting of the soil. This crop was used because of its deep rooting habit (under field conditions sunflowers will root to 7-8 feet) and the ease of determining Leaf Wilt, when the readily available water has been utilized. The irrigation schedule was determined by the drooping or wilting of the leaves, which indicated that the soil was at the permanent wilting percentage. Sufficient water was then added to bring the soil to field capacity. By this irrigation procedure, no leaching occurred until the accumulation of soluble salines in the soil solution reached an osmotic concentration sufficiently high to cause wilting of the plants before the permanent wilting percentage was reached.

The Sorrento loam cylinders were covered during the winter of 1956-57 to prevent wetting of the soil by rain, but in the winter of 1957-58, the cylinders were not covered and the dry soil was wet by rainfall. From November to the end of February, the precipitation was 17.4 inches which may have caused some leaching of the soil. The Sorrento loam cylinders were cropped six times during the experiment: one crop was grown in the fall of 1956; two crops were grown in 1957; and with the aid of plastic covering in the early spring and late fall, three crops were grown in 1958.

The Ambrose clay (adobe) was packed into the cylinders at a volume weight of 1.3, which resulted in exceedingly low infiltration rates. Therefore, these cylinders were dismantled during the winter of 1956-57, repacked at a lower volume weight, and the first crop was planted in the spring of 1957. The Ambrose clay cylinders were cropped five times, starting in the spring of 1957.

Original Soil. The moisture equivalent and the permanent wilting percentage for the Sorrento loam and the Ambrose clay are given in Table 2.

TABLE 2

Moisture equivalent (ME) and permanent wilting percentage (P.W.P.) for soils used in 6-foot cylinder experiment.

Depth Ft.	0-1	1-2	2-3	3-4	4-5	5-6	Ave
			Sorrento Loam				
M.E.	23.7	23.7	23.3	21.7	20.2	18.0	21.8
P.W.P.	11.5	12.0	11.6	10.9	9.5	8.4	10.6
Ratio	2.06	1.97	2.01	1.99	2.16	2.14	2.06
Available moisture %	11.2	11.7	11.7	10.8	10.7	9.6	11.2
			Ambrose Clay (Adobe)				
M.E.	33.1	31.4	29.9	27.5	25.1	27.5	29.1
P.W.P.	17.1	15.1	14.5	12.2	12.8	12.1	14.1
Ratio	1.87	2.08	2.06	2.25	1.96	2.27	2.07
Available moisture %	15.4	16.3	15.4	15.3	12.3	15.4	15.0

According to these measurements, the soils had a very uniform profile, except for a slightly lighter phase in the 5-6-foot depth interval of the Sorrento loam and in the 4-5-foot depth interval of the Ambrose clay. The salinity of the original soils is given in Table 3.

TABLE 3

Analyses of the saturation extract of the original soil by depth for 6-foot cylinder experiment.

Depth Feet	$EC \times 10^3$	Milliequivalents per liter									% Na
		Anions				Cations					
		HCO_3	Cl	SO_4	NO_3	Ca	Mg	K	Na	Total	
Sorrento Loam											
0-1	0.6	3.2	0.7	1.1	0.5	3.6	1.8	0.1	0.7	6.2	11
1-2	0.5	2.3	1.0	1.2	0.2	2.7	1.3	0.1	1.1	5.2	21
2-3	0.4	2.4	0.6	1.1	0.2	2.0	1.0	0.1	0.9	3.9	24
3-4	0.4	2.3	0.7	0.7	0.3	1.6	0.8	0.1	2.0	4.5	44
4-5	0.4	2.6	0.7	0.8	0.3	1.6	0.6	0.1	2.5	4.8	52
5-6	0.4	2.6	0.6	0.6	0.2	1.1	0.4	0.1	2.8	4.4	64
Ambrose Clay (Adobe)*											
0-1	1.6	4.6	3.8	7.3	1.6	6.5	3.8	0.4	7.7	18.4	41
2-3	1.8	2.6	5.2	10.8	1.4	8.5	4.6	0.2	7.9	21.2	37
3-4	1.7	2.4	5.0	9.4	1.9	7.0	3.5	0.2	8.6	19.3	44
4-5	1.4	2.7	3.6	7.3	1.1	4.5	1.8	0.2	9.3	15.8	59

*Not sufficient soil for analyses of the 1-2 and 5-6-foot depths.

The soluble salts were low in the Sorrento loam. In the Ambrose clay, where irrigation water has been applied, there is some evidence of salt accumulation, but the percent sodium is relatively low. The exchangeable cations for these soils are given in Table 4.

TABLE 4

Cation exchange in milliequivalents per 100 grams of the original soil for the 6-foot cylinder experiment.

Depth Feet	Cation Exch.Cap.	Cations in milliequivalents Ca	Mg	K	Na	Total	%* Na
				Sorrento Loam			
0-1	22.9	19.8	7.2	0.4	0.2	27.6	1
1-2	20.8	30.9	6.1	0.3	0.3	37.6	1
2-3	19.3	30.6	6.5	0.3	0.3	37.7	1
3-4	17.7	24.5	6.5	0.3	0.5	31.8	3
4-5	15.9	25.3	5.2	0.3	0.5	31.3	2
5-6	14.3	21.2	4.1	0.2	0.6	26.1	4
				Ambrose Clay 1/			
0-1	32.1	20.9	11.0	1.4	1.3	34.6	3
2-3	29.2	28.5	10.7	0.6	1.2	41.0	3
3-4	25.2	24.6	9.0	0.5	1.2	35.3	3
4-5	20.1	23.4	6.0	0.5	1.4	31.3	5

* Corrected for the soluble sodium of the saturated extract.
1/ Not sufficient soil for analyses of the 1-2 and 5-6-foot depths.

The Sorrento loam had only one percent exchangeable sodium in the surface three feet and two to four percent in the subsoil; whereas, Ambrose clay had three percent except in the 4-5-foot depth.

Results with Sorrento Loam Soil. The original soil was packed into the cylinders at a volume weight of 1.3. As the experiment progressed, some settling of the soil in the cylinders was observed, and by the end of the experiment, a volume weight of 1.41 was measured. With the increase in volume weight, a decrease in infiltration rate was noted. This decrease in infiltration does not appear to be associated with any particular water. However, this general observation need not rule out the influence of certain ions.

At the end of the second crop in June 1957, 81.4 inches in depth of irrigation water had been applied to the soil columns. At this time, three cylinders for each irrigation water -- "B", "C", and "D" were progressively leached by their respective waters until the concentration of the effluent was approximately 4 millimhos. The concentration of the effluent and the amount of water required, by depth in inches, to remove the accumulated salines is shown on Figure 2. Approximately 4 inches of leachate for "B", 8 inches for "C", and 13 inches for "D", were required to reduce the salinity of the effluent to 4 millimhos.

With the irrigation schedule employed, where most of the available water in the 6-foot column is used before replenishment, each irrigation constitutes a leaching process in the upper portion of the soil column and a deposition or increased concentration of salines in the lower part of the column. (Evidence of this process will be given later in the report). Consequently, the quantity of water necessary for salt removal is that required to leach the accumulated salts from the lower portion of the soil column.

Figure 3 shows the accumulative removal of salts in milliequivalents*

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* The milliequivalents of salt are estimated from the electrical conductivity of the leachate. For dilute solutions of mixed salts below 2 millimhos, and in the range of many irrigation waters, the relationship of $EC \times 10^3$ to milliequivalents is usually accepted as 1 to 10. However, this relation may be influenced by the predominancy of certain ions. Between 2 and 4 millimhos, the relationship still holds unless the solutions are high in magnesium or calcium sulfate. With increasing concentration above 4 millimhos, a proportionally larger discrepancy is noted between the conductivity and the total milliequivalents per liter. For example: 10 millimhos at ratio of 1 to 10 may represent about 83 percent of the total salts; 20, 77 percent; and 40, 70 percent. (Taken from the U.S.D.A. Handbook No. 60, page 12, conductivity of the saturation extract).

by increments of effluent from cylinders irrigated with Waters "B", "C", and "D". The study of salt balance by conductivity measurement is limited due to the discrepancy between conductance and total concentration at higher salt levels, and the probability that a portion of the calcium bicarbonate may precipitate as carbonate with increased concentration of the soil solution. With these considerations, the quantity of irrigation water added and the amount leached are given in Table 5, and the salt balance for the three waters in Table 6. Of the 81.4 inches of water applied, for the first two crops, the additional amount used for leaching was 8, 11, and 17 percent for "B", "C", and "D", respectively. Of the total salts added, the amount recovered on the leachate was 46, 64, and 82 percent for "B", "C", and "D", respectively. The low recovery of salt in treatment "B" may be due to the high percentage of bicarbonates in this water (the bicarbonates for the Waters "A", "B", "C", and "D", are 35, 32, 19, and 13 percent of the total anions, Table 1), and the large proportion of salt from this low-salinity water remaining in the soil. Although the effluent was reduced to approximately 2 millimhos, the leaching water contained less than one, and the original soil less than one-half millimho. In the case of "D" Water, with a concentration of nearly 3 millimhos and the final leachate of about 4 millimhos, a salt balance is being approached if consideration is given to the discrepancy in the relationship between conductivity measurements and total milliequivalents at higher concentrations. The results with Water "C" fall between "B" and "D" and the salt balance is influenced by the combinations of factors listed for waters "B" and "D".

TABLE 5

Inches depth of irrigation water applied and effluent recovered by leaching (BL, CL, and DL) for Waters "A", "B", "C", and "D".

Crop	Treatment						
	A	B	BL	C	CL	D	DL
Crop 1	57.7	57.7	57.7	57.7	57.7	57.7	57.7
Crop 2	23.7	23.7	23.7	23.7	23.7	23.7	23.7
Crop 3	54.0	54.0	69.0	54.0	72.3	54.0	78.8
Less leachate			-6.7		-9.1		-13.8
Total	135.4	135.4	143.7	135.4	144.6	135.4	146.4

TABLE 6

Salt balance for irrigation waters BL, CL, and DL, as estimated from $ECx10^3$ of 1 to 10 ratio for milliequivalents salt.

Crop	A	B	BL	C	CL	D	DL
Crop 1	115	241	241	481	481	722	722
Crop 2	47	99	99	198	198	297	297
Sum	162	340	340	679	679	1019	1019
Less leachate			-158		-435		-832
Salt remaining			182		244		187
Crop 3	107	225	288	450	603	675	985
Total	269	565	470	1129	847	1694	1172

During the 1958 season, the spring crops received 27.5, the summer 63.6, and the fall 38.9 inches of irrigation water for a total of 130 inches. At the end of the experiment, three cylinders for treatments B, C, and D were dismantled for determination of salt distribution and concentration in the soil profile, and the other three were leached with their respective irrigation waters for salt removal. In the case of treatment A, one cylinder was dismantled for salt distribution and the other two were leached.

The average salt distribution for the three cylinders by foot depths and for the four irrigation waters is given in Figure 4. Saturation extracts from these soil profiles were analyzed for cations and the results are given in milliequivalents per liter rather than electrical conductivity, which may be approximated by dividing the milliequivalents by 10. The first foot of soil had a concentration in the saturation extract approximately equal to the irrigation water applied. For the "A" and "B" Waters, this was the condition at the second foot but the "C" and "D" Waters showed some increase in concentration -- then, the concentration increased with depth, except at the bottom (5-6-foot depth). This probably resulted from the low infiltration rate of some of the cylinders and the high rate of transpiration, or water removal, during the summer months. Consequently, it is doubtful if many of these irrigations penetrated to the bottom of the cylinder. (During this period irrigation water was applied at an average of four-day intervals). For the "D" Water, the salt concentration is proportionally higher in the lower depth of soil than for the other waters, and the $ECx10^3$ is between 8.5 to 9.5 which is sufficiently salty to prevent the extraction of water to the permanent wilting percentage before wilting of the plant occurs. Consequently, this excess water is displaced into the subsoil when sufficient irrigation water is added to bring the entire mass up to field capacity, even though it may not penetrate more than 4-5 feet. This relationship was indicated when the cylinders were dismantled. The last crop was allowed to permanently wilt before it was removed. The cylinders were stored several months before dismantling and no doubt some evaporation took place at the surface of the soil and from the bottom foot where a drainage hole was open to the air. Upon dismantling, moisture samples were taken from each foot of soil and the results are given in Table 7. For the Sorrento loam soil, the columns irrigated with "A" and "B" Waters were at or below the original permanent wilting percentage due to the prolonged wilting of the plants, but with "C" Water the soil moisture was slightly above the wilting percentage in the lower 3 feet, and for Water "D" the moisture was appreciably higher at all depths, being particularly so in the lower 4 feet.

TABLE 7

Soil moisture in percent dry weight soil after permanently wilting the last crop of sunflowers.

Irrig. water	Depth, feet					
	0-1	1-2	2-3	3-4	4-5	5-6
			Sorrento Loam			
A	10.0	11.0	10.0	9.3	8.1	7.3
B	10.6	11.1	9.7	9.4	8.9	7.5
C	11.5	12.3	12.2	12.3	11.1	10.4
D	12.4	13.8	14.8	15.0	12.7	13.5
PWP*	11.5	12.0	11.6	10.9	9.5	8.4
			Ambrose Clay			
A	17.1	15.5	14.5	12.0	12.7	13.2
B	16.5	16.8	15.4	13.9	12.7	13.5
C	16.9	17.8	16.9	16.4	14.8	14.6
D	18.5	19.0	18.5	19.4	20.6	22.7
PWP*	17.7	15.1	14.5	12.2	12.8	12.1

*Permanent wilting percentage of the original soil.

The percent sodium of the total cations in the saturated extract, by depth of column, is given in Figure 4 for each irrigation water used. The sodium percentage is highest in the surface 2 feet where the salinity is the lowest, and decreases to a relatively low level in the last 2 feet as the total concentration of the salts increases. This indicates the base exchange of the surface soil is being increased with sodium at the expense of calcium and magnesium, which are being leached to the lower depths of the column and accumulating as a part of the salines.

The original surface 2 feet of soil (Table 3), contained 1-2 percent sodium in the saturated extract, but this has increased to 65-80 percent, after adding 211 inches of irrigation water containing from 51 to 74 percent sodium.

The 17.4 inch rainfall during the winter of 1957-58 undoubtedly removed most of the accumulated salines in the soil columns. The salts added during the irrigation season of 1958 and the total accounted for by analyses of the saturation extract are given in Table 8. Only in cylinders irrigated with Water "A" can all the salts be accounted for in the saturation extract. At the higher salt levels of soil treatments B, C, and D, all of the salts present, apparently, were not dissolved in the solution of the saturated soil.

TABLE 8

Milliequivalents salts added in the irrigation water and recovered in the saturation extract for 1958.

	Treatments			
	A	B	C	D
Meq. salts added in irrig. water	258	540	1080	1620
Meq. salt recovered in sat. ext.	265	463	862	1395
Meq. salt in the leachate	273	572	997	1546

The effluent from one cylinder, per irrigation water of those leached for removal of salts, was analyzed by aliquots. The depth of water required in inches to reduce the effluent to 4 millimhos or less is given in Figure 5. The relation of millimhos to milliequivalents per liter is given in Figure 6. To reduce the effluent to 4 millimhos concentration required about 5 inches of water for cylinder A, 9 inches for cylinder B, 13 inches for cylinder C, and 23 inches for cylinder D. More water was required than in the first leaching of these cylinders as illustrated in Figure 2. The columns had a higher salinity because 130 inches of irrigation water were added between the winter rains and before leaching started; while, with the first leaching, only 81 inches of water were applied. With this increased salinity, the soil column was being salinized at a higher depth in the column, Figure 4, than for the first leaching when, undoubtedly, most of the salts were in the bottom two feet of the column.

The milliequivalents of salt removed in the leachate are given in Table 9. Slightly more salt was recovered in the effluent from A and B than was added after leaching by the winter rainfall; but for C and D, slightly less was recovered. For practical purposes, most of the salt was removed by leaching with the quantities of water given in Figure 5.

TABLE 9

Salt analyses of composite leachates from 6-foot cylinders of Sorrento loam irrigated with Water "A", "B", "C", and "D".

Irrig. water	A		B		C		D	
Leachate $ECx10^3$	6.1		6.5		10.3		11.5	
	Meq./L	%	Meq./L	%	Meq./L	%	Meq./L	%
CO_3	1.2	4.9	0.7	3.2	0.8	2.3	0.2	1.3
HCO_3	2.6		2.1		3.2		2.4	
Cl	67.7	86.9	73.9	84.3	143.4	84.1	164.5	81.2
SO_4	6.4	8.2	10.9	12.4	23.1	13.5	35.5	17.5
Ca	34.0	44.5	40.0	46.4	81.2	48.4	72.5	35.5
Mg	19.4	25.4	26.0	30.2	47.7	28.4	41.1	20.1
K	0.3	0.4	0.1	0.1	0.3	0.2	0.3	0.2
Na	22.6	29.6	20.1	23.3	38.7	23.0	90.2	44.2
TOTAL	76.3		86.2		167.9		204.1	

The analyses, as percent of total cations and anions for each successive increment of leachate, is diagrammed in Figures 7, 8, 9, and 10, for accumulation of salt from Waters "A", "B", "C", and "D", respectively. Also given is the total concentration of salts in milliequivalents per liter for each increment of leachate. All of the figures show the first several aliquots of effluent contained less than 20 percent sodium, while the irrigation waters contained 57 to 74 percent. This indicates sodium is replacing calcium and magnesium. As leaching progresses and the high salinity of the effluent is reduced, the percent sodium increases to approximately that of the irrigation water, with the exception of B, Figure 8, where the percent sodium is considerably lower. Chloride is the principal anion involved during the early stages of leaching with only traces of sulfate and bicarbonate..

As leaching continues, there is a gradual drop in chloride percentage and by the end of the leaching period, a smaller percent occurred than in the irrigation water. With the decrease in chloride, a corresponding increase in sulfate and bicarbonate occurs. When the concentration of the effluent is reduced to about 100 milliequivalents, or less, a rapid increase in percentage bicarbonate occurs and at this concentration the first appearance of carbonate is noted. In general, the carbonate increases as the concentration of the effluent decreases until it may equal 20 to 25 percent of the bicarbonate ions. The large amount of carbonate and bicarbonate in the effluent near the end of the leaching period indicates the percolating water has absorbed additional carbon dioxide. The effluent is unstable, as equilibrium with the atmosphere is obtained, resulting in precipitation of calcium carbonate. This increased concentration of carbonate-bicarbonate probably indicates some removal of sodium from the cation exchange.

The remaining cylinders of soil were leached until the effluent was reduced to 4 millimhos or less and all the aliquots composited for analyses, Table 9. The analyses of the effluent from leaching compared with the original irrigation water revealed some marked changes in percentage composition. The bicarbonates ranging from 33 percent in Water "A" to 13 in Water "D" have been reduced to 4.9 and 1.3 percent, respectively, while the percentage of chlorides ranging in the irrigation waters from 54 to 74 percent have increased from 81 to 87 percent, with the largest percent increase being in the high bicarbonate waters, "A" and "B". The sulfates show only minor changes, probably within experimental error. The percent sodium of the original water ranged from 57 to 74 percent, while in the effluent the percentage ranged from 23 to 44. Evaluation of these results indicate the bicarbonate ion is precipitating in the soil with a large amount of the sodium being retained on the cation exchange.

Results with Ambrose Clay (Adobe). The original soil was packed to a volume weight of about 1.18, but after settling from wetting and drying during the experiment, the volume weight had increased to 1.31 and this was sufficient to greatly reduce infiltration rates. After repacking 90 pounds of air-dry soil into the cylinders, the first crops were grown in 1957. This soil was not leached during the summer of 1957 as only one crop had been grown on it at this time. At the end of the 1957 growing season, the soil had settled and it was necessary to add an additional 2.5 pounds of soil to each cylinder. This soil grew two crops in 1957 and three in 1958. Some leaching of the salt probably occurred during the winter of 1957-58. This soil has an extremely low infiltration rate and towards the end of the experiment, the irrigation water remained on the soil surface 75 to 80 percent of the time between irrigations. The leaching at the end of the experiment was started in February 1959 and water was ponded more or less continuously for seven months, and by this time most of the effluents from the soil columns were in the range of 4-5 millimhos for the "C" and "D" Waters.

Essentially the same type of data was collected at the end of the experiment as with the Sorrento loam soil, with the exception that individual aliquot analyses were not made during the leaching period.

The accumulation of salts in the profile column, as measured in milliequivalents of the saturation extract, is given in Figure 11. The salts are somewhat higher in the Ambrose clay than in the Sorrento loam although only 112 inches of water were applied in 1958 as compared to 130 inches for the Sorrento soil. The winter rain probably did not effectively leach this soil, also a small amount of salinity was present in the original soil, Table 3. Sodium percentage of the extract shows less variation for the individual waters than for the Sorrento columns (Figure 4), but the same trend is noted; that is, the highest percent sodium occurs in the surface two feet of soil with a decrease in percentage with depth except at the six-foot depth.

After permanently wilting the sunflower plants and upon dismantling the cylinders, the soil moisture was determined by foot depths (Table 7). The soil columns irrigated with Water "D" had a moisture content 10 percent above the permanent wilting percentage of the original soil in the four- to six-foot depths. This would indicate the possibility of some slow drainage from the bottom of the cylinder. However, this is not definite due to the low infiltration rate and the rapid use of water by the plants. The analyses of the effluent, Table 10, would support this thesis due to the slight increase in salt of D effluent over C.

TABLE 10

Salt analyses of composite leachates from 6-foot cylinders of Ambrose clay irrigated with Water "A", "B", "C", and "D".

Irrig. water		A		B		C		D	
Leachate	$ECx10^3$	4.1		9.8		17.7		19.7	
		Meq./L	%	Meq./L	%	Meq./L	%	Meq./L	%
CO_3	Meq./L	0.9	10.8	0.3	2.6	0	0.9	0	0.9
HCO_3	"	4.1		2.5		1.7		1.8	
Cl	"	24.2	52.7	70.4	66.8	156.5	80.2	161.9	79.5
SO_4	"	16.7	36.4	32.2	30.5	37.0	18.9	39.8	19.5
Ca	"	12.5	26.8	34.4	32.6	62.5	33.7	86.0	41.3
Mg	"	9.7	20.8	26.0	24.6	51.5	27.8	49.0	23.5
K	"	0.3	0.6	0.9	0.8	1.7	0.9	1.2	0.6
Na	"	24.1	51.7	44.2	41.9	69.5	37.5	72.0	34.6
Total	"	46.6		105.5		185.2		208.2	

The accumulative effluent by depth in inches to bring its concentration to approximately 4 millimhos is given in Figure 12. More salines were undoubtedly present in these columns than in the Sorrento loam, but less water was required to remove them. This may be a function of the hydraulic conductivity rate for the leaching of salts. With the exception of the cylinders irrigated with Water "A", a large percent of the salines were leached with the first 8-10 inches of water passing through the column. This is considerably less than required for a single displacement of the soil solution.

The analyses of the composite leachate from representative soil columns and the ion percentages are given in Table 10. The decrease in percent bicarbonate when compared to the irrigation water is similar to the results obtained with Sorrento loam soil. In this case, the chloride is only slightly higher than the corresponding water, but the percentage sulfate ion shows a marked increase, particularly for the high bicarbonate waters of "A" and "D". The increase in sulfate is probably from traces of gypsum which may occur in this soil. The percent sodium in the effluent from "A" is similar to the irrigation water, but in comparing the other treatments a decreasing percentage is shown, particularly for "C" and "D". The small amount of gypsum is probably responsible for the low sodium adsorption on the cation exchange for Water "A". However, with increasing amounts of sodium in Waters "B", "C", and "D", the cation exchange is enriched with this ion as the bicarbonates are precipitated.

Salt Accumulation and Leaching Studies

After initiating the field investigation and the experiment for the accumulation of salts in the six-foot soil columns, it became evident that additional information was needed concerning the leaching requirements for the four waters used in the above experiment. Although tall cylinders of soil had been used in the study for salt accumulation, precipitation, and exchangeable cations, no leaching requirements had been determined. Therefore, it was decided to investigate the use of the four waters listed in Table 1 with regard to leaching requirements.

Soil Properties and Proposed Treatments. The soil selected was classified as Pleasanton gravelly clay loam. Surface soil only was used in this experiment and the small amount of gravel present was removed by sieving. The soil is considered somewhat plastic when wet and bakes on the surface when dry. In the field, it tends to pack readily and a plow sole is easily formed.

The soil is non-saline with the following cation exchange properties:

Milliequivalents per 100 grams soil						:	Percent Na*
Exch. Cap.	Ca	Mg	K	Na	Total	:	
18.9	9.8	12.7	0.7	0.4	23.6	:	1.2

* Corrected for soluble sodium.

This soil had a low sodium percentage. The moisture equivalent was 20.3 percent.

Dry soil was collected in the fall of 1956, sieved and packed in 6 by 42-inch cylinders to a depth of 38 inches. This required 53.5 pounds of air-dry soil and the volume weight after packing was approximately 1.3. The soil settled while growing the first crop and three additional pounds were added to each cylinder.

The original plan was to leach a definite percentage of the irrigation water through the soil columns. For example, with Water "D", 10, 20, 30, and 50 percent of the total applied was to be leached with every second irrigation, and with additional columns this same percentage was to be leached with every fifth irrigation. The leaching regimes were in duplicate, including the nonleached check, for a total of 18 soil columns. With the lower salt waters of "A", "B", and "C", the leaching treatments were decreased proportionally to their concentration. Therefore, the number of soil columns for Waters "A", "B", "C", and "D" were 4, 6, 14, and 18, respectively, for a total of 42. The experiment was conducted in the greenhouse.

While growing the first crop, it became evident that the treatments could not be maintained and the original objectives were unattainable. As the irrigation schedule* proceeded, the infiltration rates decreased and became erratic. In some extreme cases, a 5-inch irrigation remained on the soil surface for 36 to 40 hours, and internal drainage of the soil required additional time. With the frequency of irrigation at an average of every three days, the plants used half of the applied water before the last of it had penetrated below the soil surface. In other cylinders, all the water penetrated the soil within five or six hours. However, the rate of infiltration was not consistent from one irrigation to the next.

After somewhat more than half of the water for the first crop had been applied, the leaching regime was inaugurated. From the start, it was impossible to maintain leaching requirements. Soil columns having very slow infiltration rates were given a double irrigation -- that is, the second irrigation followed the first as soon as the water had disappeared from the soil surface. This procedure did not always produce leaching. Throughout the second half of the growth period of the first crop and during the second crop, an endeavor was made to maintain the leaching schedule, but without success. However, considerable information and valuable data were obtained.

Results of Leaching Trials. In 1957, two crops of sunflowers were grown. After adding 99 inches of irrigation water to the soil columns, leaching was started. The amount of effluent and its concentration for this first leaching is given in Table 11. Only a small amount of leachate was

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* The irrigation schedule was the same as in the previous experiment, i.e., when the plants showed signs of wilting, sufficient water was added to bring the entire soil mass from the permanent wilting percentage to field capacity.

obtained, but this initial effluent was very high in salts, EC x 10^3 of 38.5 to 41.1, regardless of the waters used. Effluents from eight of the cylinders were selected for chemical analyses, Table 12.

TABLE 11

Average inches of effluent and its concentration in millimhos after adding 99 inches of irrigation water to the soil columns of Pleasanton clay loam.

Irrigation water	No. cylinders leached	Leachate, inches	ECx10^3
B	4	0.33	40.6
C	11	1.14	38.5
D	16	2.16	41.1

TABLE 12

Analyses of initial effluent from soil columns after adding 99 inches of irrigation water.

Cylinder No.	Leachate inches	ECx10^3	Milliequivalent per liter							% Na
			Anions		Cations					
			HCO_3	Cl	Ca	Mg	K	Na	Total	
B7	0.69	32.2	6.5	225.1	138.0	301.9	1.8	28.3	469.9	6.0
B9	0.10	46.8	8.1	284.0	240.0	459.8	2.8	41.9	744.6	5.6
C14	0.59	42.9	6.0	363.9	180.0	383.8	1.0	35.6	600.5	5.9
C18	1.86	39.6	8.1	351.8	168.0	349.9	1.0	33.7	552.6	6.1
C24	1.94	36.8	7.6	316.1	150.0	329.9	1.4	33.7	515.0	6.5
D29	1.38	41.2	14.1	445.6	162.0	349.9	0.7	61.9	574.5	10.8
D39	2.37	41.2	10.8	448.4	174.0	383.8	0.7	46.6	605.2	7.7
D41	3.33	39.0	11.9	403.9	156.0	349.9	0.7	49.1	555.7	8.8

As noted previously, the initial solutions are very high in calcium and magnesium with 10 percent or less as sodium. The high concentration of the divalent ions may be, in part, the result of leaching the soluble material native to the original soil. Most alkaline soils have soluble salts in a concentration of about one millimho or less, and where sodium is low, as in this soil, these are mainly calcium and magnesium. These native soluble salts are carried to the bottom of the cylinder in the initial wetting of the soil and constitute a part of the first effluent collected. According to the data presented in Table 12, the average electrical conductance measures 69 percent of the analyzed salts.

The plants in the non-leached columns irrigated with "C" and "D" Water, used less water toward the end of the first cropping period when compared to the leached columns. These non-leached columns of soil were removed from the experiment and one for each water was leached for the removal of salts and the other dismantled and analyzed for salt distribution in the soil profile. The results are given in Figure 13 "A" and "B". To reduce the concentration to 4 and 5 millimhos, in columns C11 and D25, respectively, $10\frac{1}{2}$ and 13 inches of effluent were collected (Figure 13 "A"). However, the high concentration of salt, above 10 millimhos, was removed with 4 inches of leachate for C11, and 6 inches for D25, which is 3.3 and 5.5 percent of the total irrigation water added to the columns.

According to the conductance measurements, using the ratio of 1 to 10 for milliequivalents, 68 and 82 percent of the salts added in irrigation water were recovered in the effluent for C11 and D25, respectively. This would indicate most of the accumulated salts had been removed, even though the leachate was giving a reading of 4 to 5 millimhos.

The salt concentration according to the saturation extract is relatively low in the top half of the soil columns irrigated with Waters "C" and "D", but high in the lower part, Figure 13 "B". The top 18 inches of the C12 column has a concentration of the saturated soil nearly equal to that of the irrigation water, while D26 for the same depth is approximately twice that of the irrigation water. Nevertheless, each irrigation is a leaching process for the top portion of the soil column while building up a high accumulation of salines in the lower part.

Of the 988 milliequivalents of salt applied in the irrigation water to soil column C12, 676 milliequivalents can be accounted for by conductance (1 to 10 ratio), or 68 percent. A total of 1,320 milliequivalents of salt were added to cylinder D26 and 1,084 milliequivalents or 82 percent were recorded by conductance.

At the end of the second crop, the salt removed by leaching and its distribution in the columns was evaluated. For each water, the cylinders were grouped according to the amount of leaching obtained. For determination of the saturation extract, a core from the center of the soil column, 3/4 inch in diameter by six-inch increments, was taken to the bottom of each cylinder. These samples were used to determine the salt distribution within the soil column and the results are shown on Figure 14. The soil was wet to field capacity before sampling and represents the salt condition in the profile following an irrigation. Regardless of the water used or the amount of leaching, the salt concentration of the saturation extract in the top half of the soil column is approximately the same, or less, than the concentration of the irrigation water. The accumulation of salt in the bottom of the cylinders is proportional to the amount of leaching.

Table 13 gives the amount of water and salt applied to the soil columns, the percent of the water leached through these columns, its salt content, and the quantity of salt remaining in the soil. Data for salt recovered from the leachate and the saturation extract are estimated from the electrical conductivity measurements. At high conductivity measurements, the estimation of salt is usually 25 to 30 percent low, and it is in this range that most of the leaching occurred. Consequently, the salts recovered in the leachates are considerably higher than indicated in Table 13. From the data presented in this table and Figure 14, it would appear that if 9 percent of the applied Water "D" passed through the soil column, a relatively low salt balance would be maintained in the soil. For Water "C", the highest average leaching percentage was 2.8 percent; however, this is too low, as salt accumulated to 8 millimhos in the lower part of the column. Probably 5-6 percent of the irrigation water should be leached to maintain a salt level below 4 millimhos. For Waters "A" and "B", 1.0 and 1.4 percent, respectively, leached through the columns prevented a high accumulation of salts in the subsoil.

TABLE 13

Salts added in the irrigation water to Pleasanton clay loam and recovered in the leachate and saturation extract.

Water	No. of cyl.	Irrigation water applied			Salts recovered			Salts in leachate	Salts recovered
		Inch	Salt meq.	% leached	Leachate	Salt ext.	Total meq.*	%	%
A	2	181	361	None		343	343		95
A	2	188	375	1.1	129	117	246	52	65
B	1	175	628	0.7	206	298	504	41	80
B	2	189	786	1.4	280	193	473	44	60
C	3	183	1525	1.0	279	660	939	30	62
C	5	185	1541	2.8	804	362	1160	69	76
D	2	186	2323	1.3	1120	628	1748	64	75
D	6	174	2185	3.2	1052	513	1565	67	72
D	5	184	2295	5.2	1274	463	1737	73	76
D	3	190	2385	9.2	1636	355	1991	82	84

* Calculated from the electrical conductivity ($ECx10^3$) using a ratio of 1 to 10.

<u>A Weeping Procedure for the Study of Salt Accumulation and its Effect on Cation Exchange</u>. The studies listed above show that when sufficient irrigation water is added to wet the entire soil, the top portion of the column is relatively low in salt while the lower part accumulates it to a high concentration. As this concentration increases so does the osmotic

pressure of the soil solution which decreases the availability of water to plants* causing them to wilt at a soil moisture content higher than the permanent wilting percentage of the non-saline soil. Then, if the full complement of irrigation water is added, i.e., the quantity required to bring the soil moisture from the permanent wilting percentage to the field capacity, excess or gravitational water will form in the bottom and slowly drain from the cylinders. This slow drainage from the bottom of the cylinders, resulting from the high osmotic pressure of the soil solution and a full complement of irrigation water, has been termed "weeping".

By the end of the second crop grown on Pleasanton clay loam, some of the cylinders irrigated with "C" and "D" Waters, having low infiltration rates, were in the process of weeping. Therefore, the decision was made to change the experiment from one of controlled leaching (which was not accomplished) to one of adding the full complement of irrigation water at each wilting of the plants and allow weeping from the cylinders to proceed at will. The assumption is made that sufficient leaching will take place in the top portion of the soil column to maintain plant growth.

The third crop was grown during the winter of 1957-58 when transpiration was low and only 15-18 inches of water used. Two additional crops were

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* The saturation extract of 10 millimhos has an osmotic pressure of about 4 atmospheres and at 15 atmospheres, the accepted wilting percentage for plants, the concentration is about 35 millimhos. A saturation extract of 4 millimhos, which may produce salt injury to sensitive plants, has an osmotic pressure of about 1.4 atmospheres (Taken from the U.S.D.A. Handbook No. 60, page 15, osmotic pressure of the saturation extract). These measurements are made on the extract from a saturated paste, but the Pleasanton clay loam soil at field capacity is approximately half of the saturation percentage. Therefore, the osmotic values given above would be doubled at the field capacity and increased considerably more as the plants remove the moisture and concentrate the salts.

grown during the summer of 1958 and the cylinders were allowed to weep. At the end of the experiment, the cylinders irrigated with each water were divided into two groups: one for the study of the removal of salts by leaching, and the other group was dismantled for determination of salt in the soil profile, and cation exchange.

Figure 15 shows the exemplary curves obtained for the relationship of effluent concentration and accumulative inches of leachate. For the waters of higher concentration, "C" and "D", the initial part of the curve is flat, indicating, under the weeping technique for salt removal, the accumulation occurs at a greater depth of soil, but at a lower concentration than those intermittently leached, as in Figures 2, 5, and 12. Although Figure 15 was drawn as idealistic composite curves, considerable variation occurred between individual soil columns for any one water (with respect to the concentration of the effluent and the total amount of salts removed by leaching). This relationship is indicated in Figures 16, 17, and 18 when the accumulative salt in milliequivalents per leaching aliquot is related to the accumulated volume of leachate.

The individual leaching aliquots for each soil column were composited and analyzed. The average results of these analyses for each irrigation water are given in Table 14.

TABLE 14

Average analyses for composite leachate of individual cylinders of Pleasanton clay loam.

Water	No. cyl.	$EC \times 10^3$	Milliequivalents per liter: Anions					Cations					%
			CO_3	HCO_3	Cl	SO_4	NO_3	Ca	Mg	K	Na	Total	Na
A	2	4.9	1.4	10.4	27.7	8.2	9.4	8.4	17.5	0.9	30.8	57.6	53
B	4	4.1	0.9	6.9	21.8	8.2	7.4	6.9	11.7	[illegible]	26.9	46.0	59
C	6	6.1	1.2	5.9	43.2	9.5	7.4	6.9	9.7	0.8	49.7	67.1	71
D	8	6.7	1.2	6.1	54.1	10.7	4.9	6.2	7.9	0.9	62.0	77.0	81

The percent sodium of the leachates is as high or higher than the corresponding irrigation water. This may indicate an equilibrium has been established between the accumulating salines, as controlled by weeping, and the cation exchange of the soil. However, this may be questioned, as relatively large amounts of carbonate and bicarbonate occur in the effluent when the concentration of salt decreases, Figures 7, 8, 9, and 10. This indicates lime is being brought into solution, of which calcium will replace the sodium of the cation exchange, thus enriching the effluent with sodium.

The average salt concentration, by depth, for these weeping soil columns is given in Figure 19. The accumulation of salt is more or less in proportion to the concentration of the irrigation water. Of course, this should be reflected in the top part of the soil column where leaching occurs with each irrigation. In the lower portion of the column, apparently the lower salt waters, particularly "A", have not had sufficient time to accumulate a high salinity. This is also indicated by a small amount of weeping from these cylinders. The extreme deviations from the mean salt concentration for the individual soil columns irrigated with "B", "C", and "D" Waters are given in Figures 20, 21, and 22, respectively. These deviations do not mean that a particular soil column had a lower or higher salt content at all depths, but it illustrates the extremes at any one depth of concentration.

A complete analysis was made of the saturation extract for each soil column by depth. Of most interest was the concentration of sodium and chloride which was averaged by depth and plotted in Figure 23. The amount of chloride is less than sodium for each water and at any particular depth. Chloride is easily leached and was moving readily out of the cylinder with the weeping effluent, while sodium has a tendency to accumulate to a higher concentration in the soil, with the exception of the surface 6 inches, where both are nearly the same. The percent sodium of the total cations in the saturation extract is given in Figure 24. There is an increased percentage sodium with depth, as would be expected from the concentration values shown on Figure 19. The difference in percent sodium of the extract is influenced as much by the total salt concentration of the irrigation water as by its sodium percentage.

The results given, in Figures 23 and 24, suggest an increase in sodium of the cation exchange. A soil column irrigated with each water was selected and the percent sodium of the exchange was determined, Figure 25. When compared with 1.2 percent sodium in the original soil, all the waters used resulted in a marked increase in sodium. In general, this increase is proportional to the total salt concentration and percent sodium of the original water. A marked increase in exchangeable sodium, with depth, is closely related to the accumulation of salinity in the soil profile, Figure 19. For Waters "A","B", and "C", the increase of exchangeable sodium from top to bottom of the soil column is about three times, while for Water "D" it is about twice. This increase with depth is probably due to two factors: (1) The increased concentration of the soil solution results in additional sodium on the exchange; (2) upon concentration of the irrigation water as the soil solution, the bicarbonates precipitate with calcium producing a higher percentage of sodium in solution, which in turn increases the sodium of the exchange complex. This is probably the principal reaction in increasing the exchangeable sodium with the low sodium percentage Waters "A" and "B".

The salt balance for the entire experiment on Pleasanton clay loam is given in Table 15.

TABLE 15

The salt balance at the end of the experiment for Pleasanton clay loam.

Water	Inches irrig.	Inches leached	Percent leached	Meq. applied	Salt sat. ext.	Percent* leached
A	302	3.7	1.2	601	122	79.7
B	280	13.0	4.6	1166	171	85.3
C	284	20.5	7.2	2422	255	89.5
D	276	25.8	9.4	3459	326	90.6

* Estimated from total salts added in the irrigation water minus those remaining in the soil at the end of the experiment, as determined by analyses of the saturation extract.

The percent water and salts leached may be influenced to some extent by controlled leaching during the first part of the experiment, particularly for the low salt Waters "A" and "B". For the higher salt Waters "C" and "D", the evidence indicates a balance has been established between the salts added in the irrigation water and the salts removed by weeping from the cylinders. For the last crop, the concentration of the weeping effluent was between 5.5 and 8.0 millimhos, regardless of the irrigation water. This is a lower concentration than previously reported for leaching after a period of salt accumulation, and probably represents about as concentrated a solution as will be tolerated by a moderately salt-tolerant plant. However, in the absence of drainage, or leaching, a successive number of irrigations can build up a high salt concentration in the subsoil, Figures 5 and 12.

After severe wilting of the plants at the end of the experiment, the soil moisture in columns irrigated with "C" and "D" Waters averaged as follows:

Depth of soil, inches	0-6	6-12	12-18	18-24	24-30	30-36
Percent soil moisture	4.9	8.2	9.9	12.7	13.9	15.0

The cylinders remained in the warm greenhouse several months before removal for analyses. Consequently, considerable evaporation took place from the soil surface. However, at the 12-18-inch depth, and below, the moisture is at, or considerably above, the permanent wilting percentage, and at the lowest depth half of the moisture remains in the range between the field capacity and permanent wilting percentage after severe wilting of the plants.

The average volume weight at the end of the experiment was 1.53. This is extremely high for a clay loam soil and is the principal factor contributing to low and erratic infiltration rates. Although the growing of plants in tall cylinders of small diameter is limited to a few soils, experience indicates high volume weights are usually obtained after several crops. These volume weights are considerably higher than found in the field. However, in our experience, few have reached the volume weight attained in the experiments with Ambrose clay and Pleasanton clay loam soils.

Summary

1. San Joaquin River waters, before 1950, were considered of good quality with the salt concentration usually ranging between 300 and 400 parts per million, and a sodium constituting about 50 percent or less of the cations during the irrigation season. Yet these waters, applied over a period of years on certain soils, and used with a high degree of irrigation efficiency, have increased soil salinity sufficiently to be harmful to salt sensitive plants. Some of the factors responsible for the accumulation of soil salines in this area are:

A. The mean seasonal precipitation is approximately 10 inches. Most of the rainfall is distributed over a six-month period and is not sufficient to leach the soil to a depth below the rooting depth of many plants. Measurements show that under a similar rainfall pattern it requires, on an average, about 16 inches of precipitation to wet a clay loam soil to a depth of six feet. The customary practice is to allow the soil to enter the winter, or rainy season, dry to the rooting depth of plants. This is good economy both for water and in farm practice, but it does not assist in the leaching of salts below the rooting zone of the deeper rooted plants, such as alfalfa, sugar beets, tomatoes, trees, etc.

B. Soil type may be a factor in the accumulation of salines. An example is the Ambrose clay (adobe) and related fine-textured soils. These soils usually have a high water-holding capacity and large quantities of irrigation water are required to penetrate into the subsoil. But probably of most importance are the low infiltration rates, which require good irrigation management to effectively leach these soils. Under some conditions, it may be necessary to leach during the winter months, when water can be ponded on the land for long periods of time.

Stratified soils, or soils with clay lenses, or tight, fine-textured subsoil, can be a problem in salt removal due to low permeability. Occasionally these subsoils are so tight they essentially prevent percolation; and when excess water is applied, a perched water table develops, which either "drowns" the crops, or prevents leaching of the soil. This, in turn, accumulates salts in the capillary fringe above the water table and eventually stunts or kills the crop. This condition has been found in one locality; others may develop, particularly in the basin soils near the trough of the valley. Some of these areas already have a high water table and are salty. This high-water-table condition results in part from the restriction of lateral migration of ground water by tight or impermeable subsoils.

C. Efficient use of water may cause the accumulation of salines in the subsoil, i.e., when only sufficient irrigation water is applied to meet the demand of evapotranspiration, without supplemental amounts for leaching. Some evidence of this was found in the deep rooted deciduous trees of the area. The water was usually applied in three to four irrigations for a total of 16-22 inches. These irrigations wet the soil to a depth of 4 to 7 feet. Consequently, the surface 3 or 4 feet are relatively free of salts, due to the leaching with each irrigation, but the accumulation of salt takes place at or near the depth of wetting, 4 to 7 feet. As the roots permeate the soil to 10 feet or more, this deposition of salt is within the root system of the trees. Most of the salt injury in the area has been to almonds and apricots -- two salt sensitive plants. As these plants are also very sensitive to sodium, injury usually occurs before the salt concentration reaches 4 millimhos, often around 2 or less, if the sodium in the soil solution is high in relation to calcium and magnesium.

The 100 per cent irrigation efficiency is commendable for water economy where sufficient rainfall occurs to occasionally leach the soil, but in this low rainfall area some excess water should be added for leaching. For the low salt waters, the amount of leaching need not be large or necessarily repeated every year, as some of the orchards were under this irrigation practice for years before salt injury was noted.

The accumulation of salts from efficient use of water has been limited to deep rooted perennial crops such as orchards and alfalfa. The annual field and truck crops showed little or no salt accumulation, with the exception of the very fine-textured soils. This is due, no doubt, to the increased irrigation frequency for these crops, particularly as a preirrigation, or "irrigating the crop up" and additional irrigations while the crop is small with a low consumptive use.

D. High water tables are recognized as areas of salt accumulation. High concentration of salts occurs in soils from the water surface through the height of the capillary movement. This accumulation is caused by surface evaporation, or the loss of water through transpiration. It has been established that salt problems may occur in areas where the water table was developed originally from very low salinity waters. How this happens is open to question, possibly by the movement of salts from the deeper subsoil, the movement of salts laterally through the soil from an irrigated area at a higher elevation, or probably the decomposition of the young alkaline soil under moist conditions and high temperatures with the liberation of soluble minerals. In any case, these areas will require drainage followed by leaching. The study, as originally designed, did not include consideration of the problem of salt accumulation and its removal under high water table conditions.

2. The concentration and type of salts in the irrigation water will influence the soil properties and the accumulated salines.

A. The chloride content of the water used in the area has been one-half or less of the total anions. This ion is considered a good measure of salinity because it does not react with the soil and is easily leached. Assumption was made that with increasing concentration of the river water, by return and drainage water, the chloride content would increase, because it is soluble with all the cations of the soil, at the expense of the bicarbonate and sulfate.

B. Considerable emphasis was placed on the sodium ion in this study because its role is not as simple as that of chloride. Even with the low salt water of approximately 50 percent sodium, when salines are allowed to accumulate in the soil, some increase in sodium percentage of the base exchange occurs, as illustrated by the saline soil samples in the "Field Investigation" and the experimental "Salt Accumulation and Leaching Studies". However, if the salts of this water are not allowed to accumulate to a high degree of salinity, the sodium of the cation exchange should remain relatively low and the water would be satisfactory for an indefinite period of use.

As the concentration and sodium percentage of the water increase, sodium will be found in increasing amounts of the exchange, as in the case of Waters "C" and "D" used in the soil column experiments. Two factors are involved: (a) as the sodium percentage of the water approaches 60 and higher, increasing amounts of sodium will displace the divalent cations of the exchange, even though accumulation does not occur; (b) as these waters are concentrated, a proportionally larger percent of the exchange will be sodium, as illustrated in the soil column experiments. Some increase in concentration always occurs under normal irrigation practice. For example, if most of the available water is used between irrigations, the water or soil solution will approximately double in concentration. This usually occurs a number of times during the growing season. The soil solution, even with some leaching, usually has a concentration three to eight times that of the irrigation water. To prevent this moderate amount of accumulation would require large amounts of water for leaching -- at least the equivalent to the quantity used in evapotranspiration, or more.

The author's opinion: Growing of salt-sensitive plants, as the almond, is not in the realm of practicability with high sodium-high salt waters.

C. The bicarbonate ion may play an important role in some irrigation waters, but with the high salt waters, "C" and "D", this would be minor due to the relatively small amount in relation to the total salts. However, in the lower salt waters, such as the San Joaquin River, represented by Waters "A" and "B", the bicarbonate constitutes about a third of the anions. If the salts of these waters are allowed to accumulate to a relatively high salinity, the bicarbonates precipitate in the soil as lime, thus removing the divalent ions from solution, which decreases the salinity of the soil solution, but increases the percent sodium. This probably accounts for the small percentage increase in exchangeable sodium found in the "Field Investigation" and the "Soil Column Experiments". However, the amount of calcium and magnesium of the irrigation waters is greater than the bicarbonate, and with a small amount of leaching, the salinity will be maintained at a sufficiently low level to prevent this reaction from playing an important role in exchangeable sodium.

3. Leaching the soil is important when the irrigation water contains salts and rainfall is low. Where infiltration rates are low, as is generally the case in the area under investigation, leaching can be difficult.

A. The irrigation waters often are blamed for these low infiltration rates. There is no indication that present or past waters diverted from the San Joaquin River have been responsible for these low rates. If the water should deteriorate in quality, having a higher salt and sodium content, it is questionable whether it would reduce the permeability of the soil. It is known that as the total salt of the water increases, a larger percent of sodium can be tolerated without reducing infiltration rates.

B. In general, the low infiltration rates are due to poor soil structure or compacted, high volume-weight soils. Much of the compaction occurs from the surface to 18 inches deep, as a result of tillage operations and the use of heavy farm equipment. These soils are easily compacted when tilled in a moist to wet condition. This study, and other investigations in the area, indicate some of these dense, high volume-weight properties are native to the soil and not necessarily man-made. Experimental work indicates some of the soils are weakly aggregated; therefore, the structure is easily destroyed and compaction results. At the present time, there is no evidence to indicate the irrigation water used has been related to this problem.

4. In most of the area, the soil is relatively free from accumulated salts and no advantage would be obtained in applying more water, but many disadvantages may occur. Throughout the area are a number of orchards showing salt or sodium burn, while others are menaced by the salt level in the root zone of the trees. These fields should have additional water applied

for leaching. The data obtained for leaching requirements in the soil columns should not be applied literally to field conditions, as these were small, uniformly-packed columns and leaching was much more efficient than would be obtained under field conditions. Therefore, the data obtained should be used only as a guide for leaching requirements.

Conclusions

1. The application of San Joaquin River water, even though considered of good quality before 1950, over a period of many years on certain soils, together with past irrigation practice has resulted in increasing soil salinity to such an extent that it is harmful to salt sensitive plants.

2. Factors responsible for accumulation of soil salines are:

A. The mean seasonal precipitation is too low to properly leach the soil.

B. The type of soil, especially fine-textured soil of low permeability, may retard the infiltration of water through the soil thus curtailing the process of leaching.

C. Over-efficient use of irrigation water where less than 30 inches is applied per season. The raising of perennial crops, such as orchards and alfalfa, induces efficient use of water. With few exceptions, lands on which annual crops were grown showed little accumulation.

D. High water tables. In such cases, evaporation and transpiration concentrates salts in the soil.

3. The concentration and type of salt in the irrigation water will influence the soil properties and the accumulated salines.

A. Chloride is not the predominating ion, but its accumulation in the soil indicates a need for leaching.

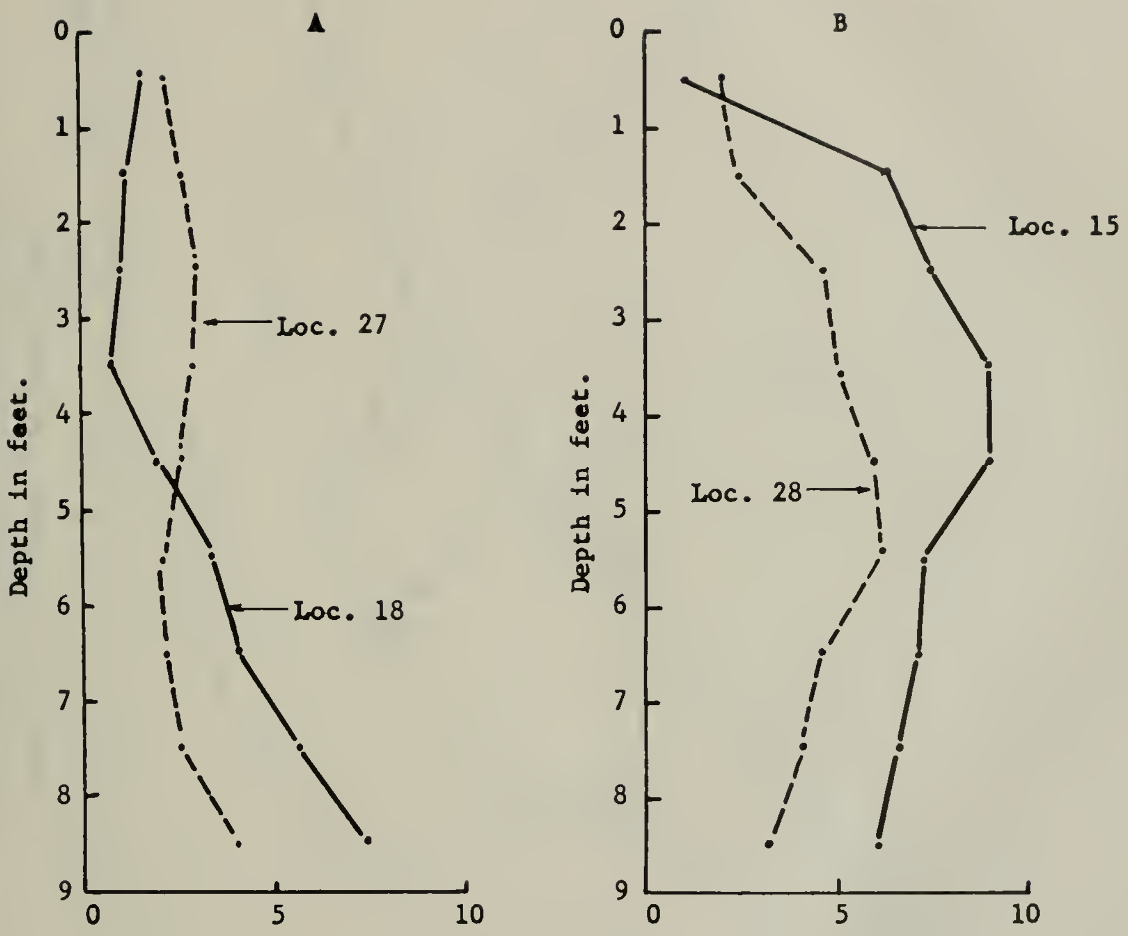
B. Future deterioration of irrigation water, with increasing concentrations of sodium will disperse the soil, reduce infiltration, and cause injury to salt-sensitive plants.

C. Accumulation of the bicarbonate ion will result in increased exchangeable sodium. This can occur when waters of the type found in the San Joaquin River at present and in the past are used.

4. Present and past quality of water diverted from the San Joaquin River is not responsible for existing low infiltration rates; these are due to poor soil structure or compact, high volume-weight, soils. This is important in leaching for when infiltration rates are low, leaching can be difficult.

5. In most of the area, soils are relatively free of accumulated salts and little advantage would be gained from the application of more water. However, additional water should be applied for leaching in fields where salts have accumulated.

FIGURES



EC x 10^3 of the saturation extract.

Figure 1 A comparison of the salinity in the soil profile.

A - for 1956, Loc. 18 and 1957, Loc. 27

B - for 1956, Loc. 15 and 1957, Loc. 28

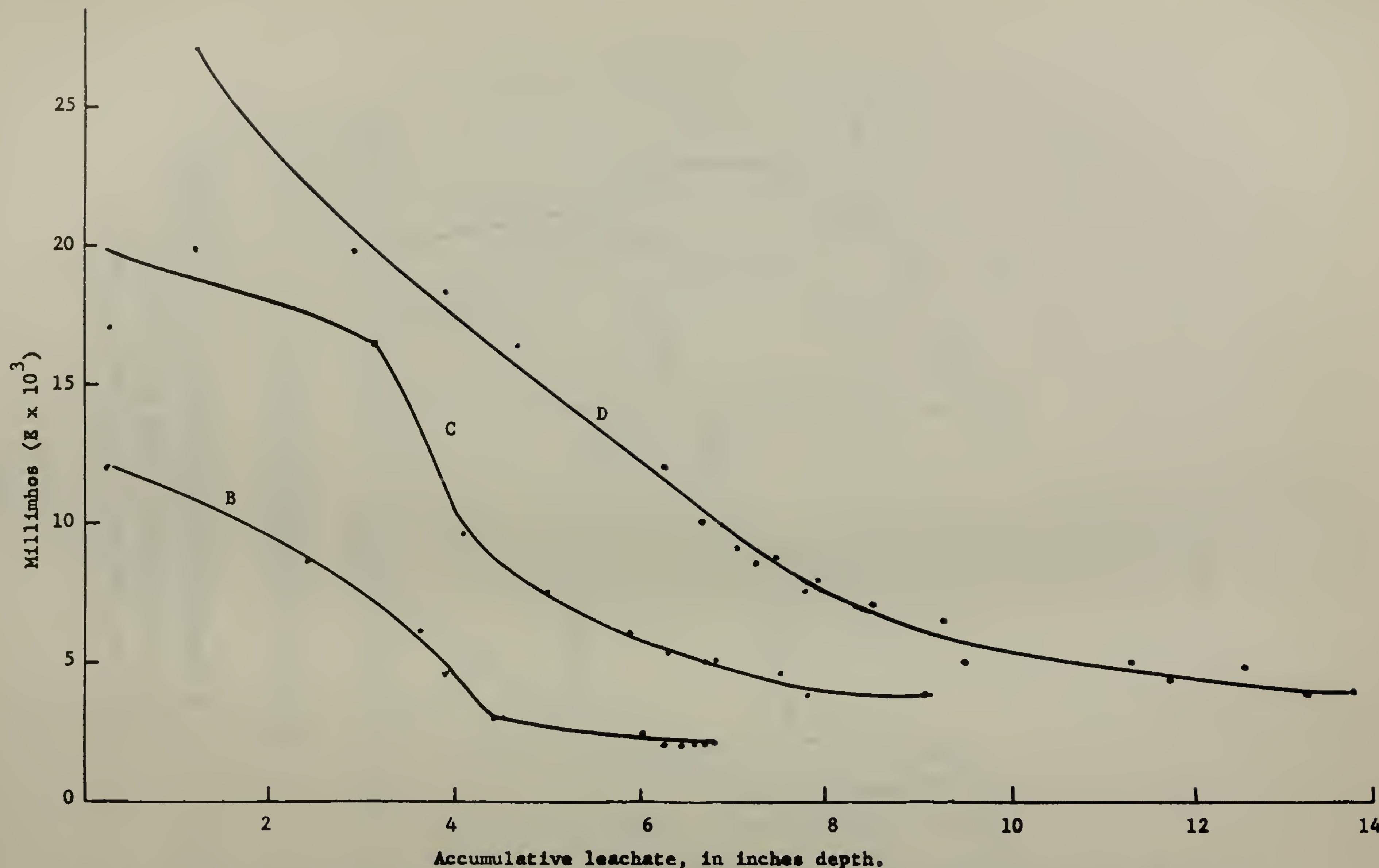


Figure 2 Effluent concentration with progressive leaching from 6-foot cylinders after the second crop and the addition of 81 inches of irrigation waters B, C, and D to Sorrento loam.

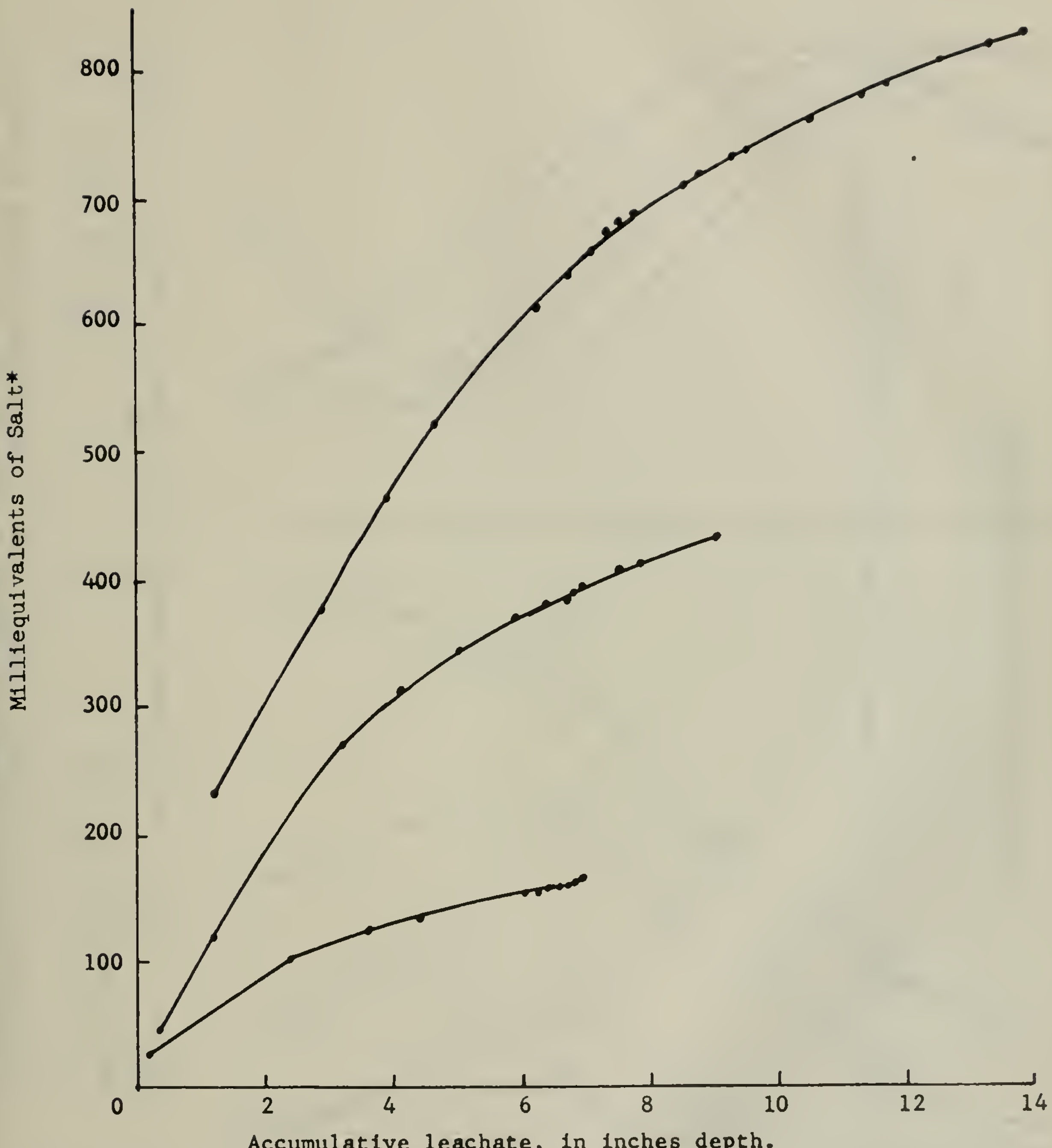


Figure 3 Accumulative salt removal of leaching 6-foot cylinders irrigated with water B, C and D *(see text for estimation of salt).

* from conductivity

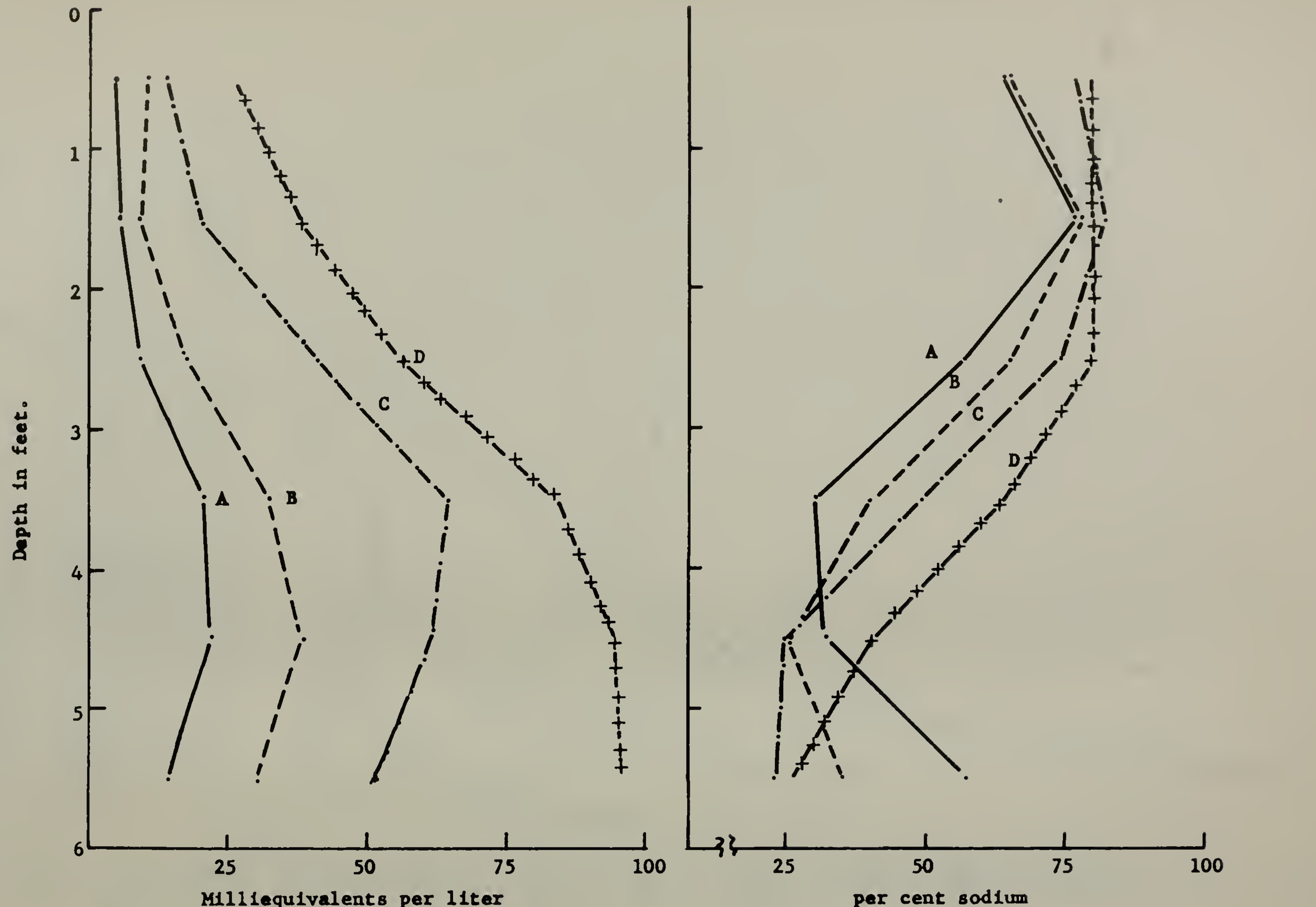


Figure 4 Milliequivalents salt and per cent sodium of the saturate extract by depth for Sorrento loam soil irrigated with waters A, B, C and D.

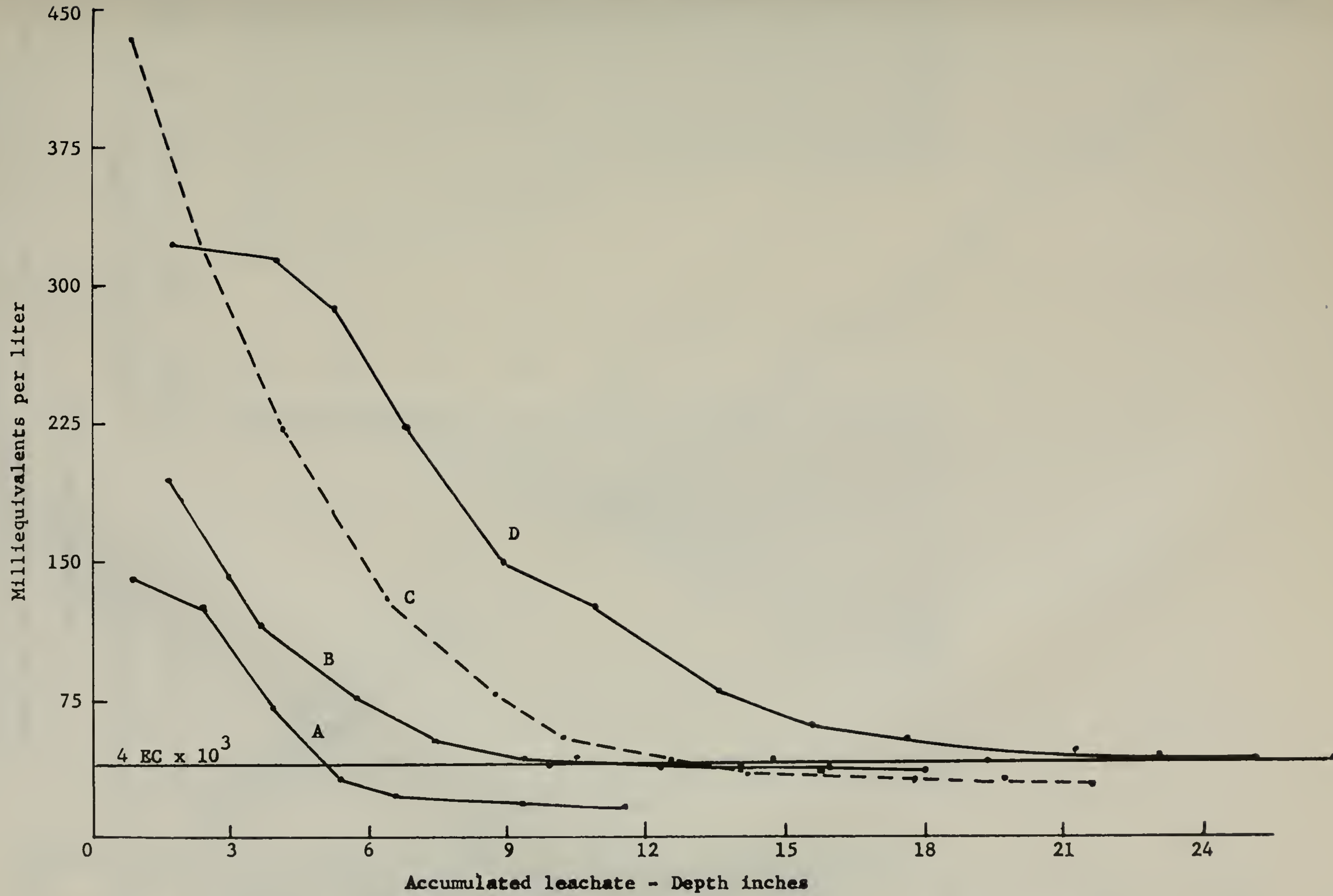


Figure 5 Effluent concentration with progressive leaching from 6-foot cylinders of Sorrento loam irrigated with waters A, B, C and D.

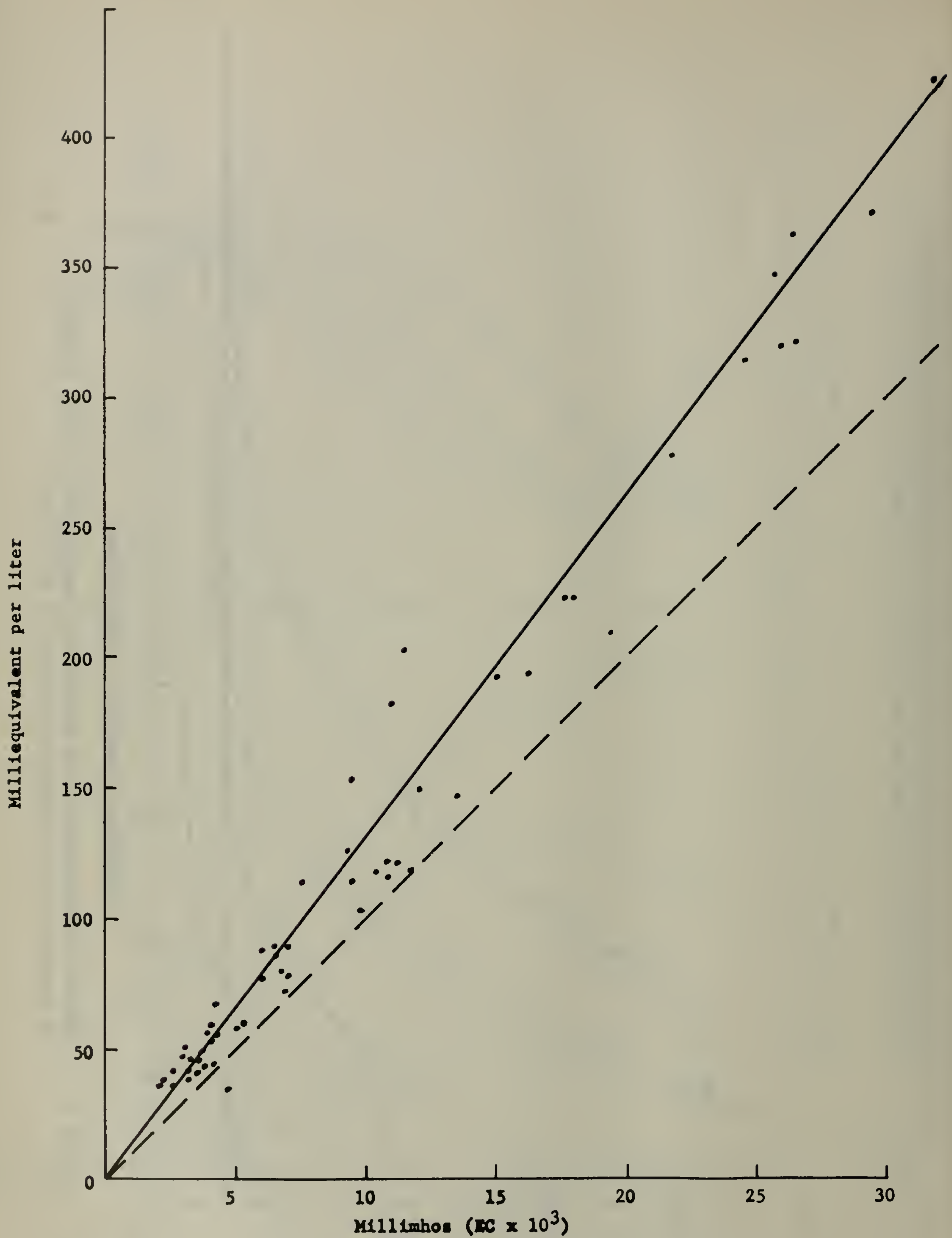


Figure 6 Concentration of leachate from Sorrento loam in milliequivalents per liter as related to electrical conductivity in millimhos.

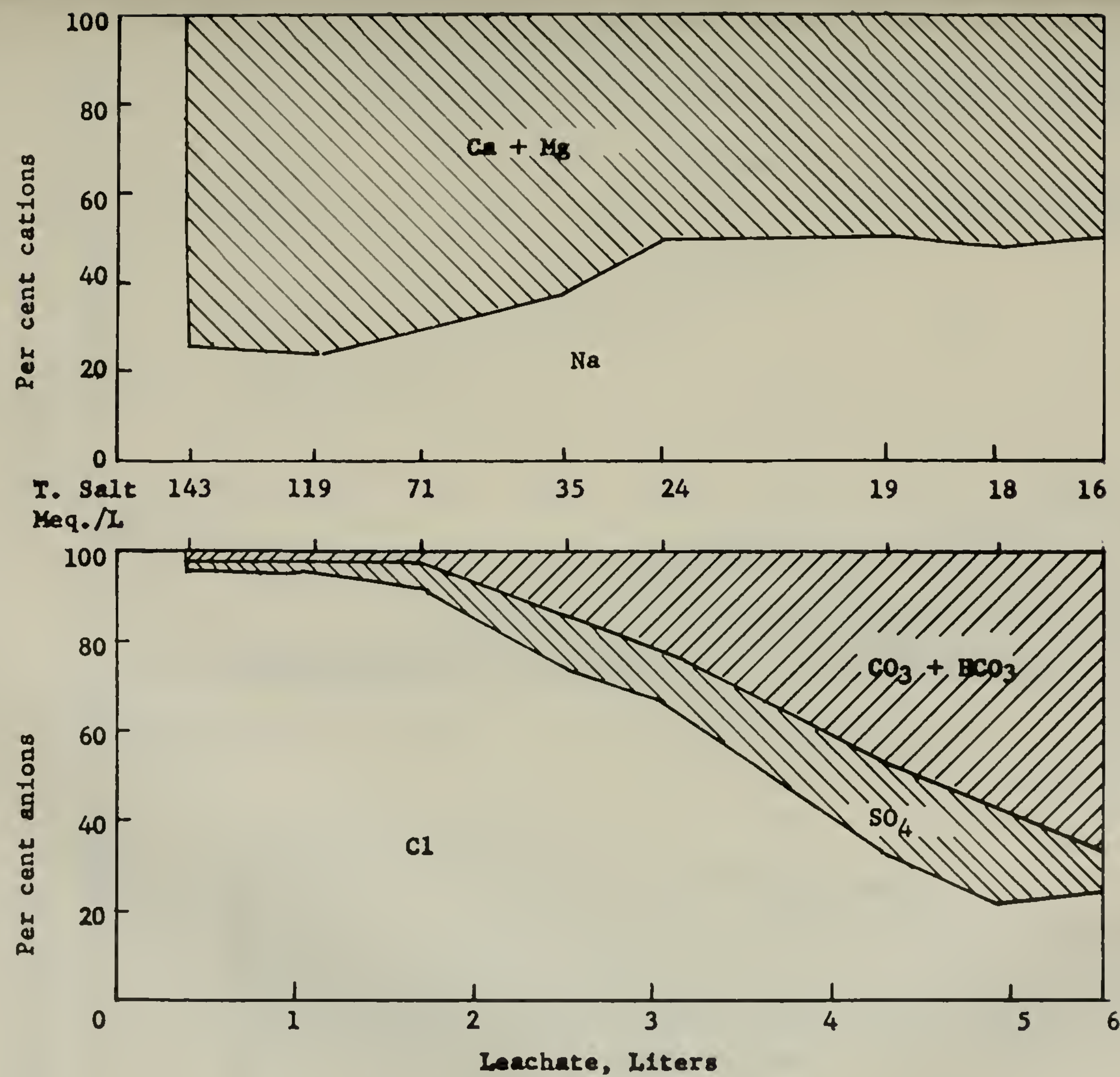


Figure 7 Per cent anions and cations in leachate from 6-foot cylinder of Sorrento loam irrigated with water A (water contained 57% Cl, 9% SO_4, 32% HCO_3 anions; cations, 51% Na, 49% Ca and Mg.)

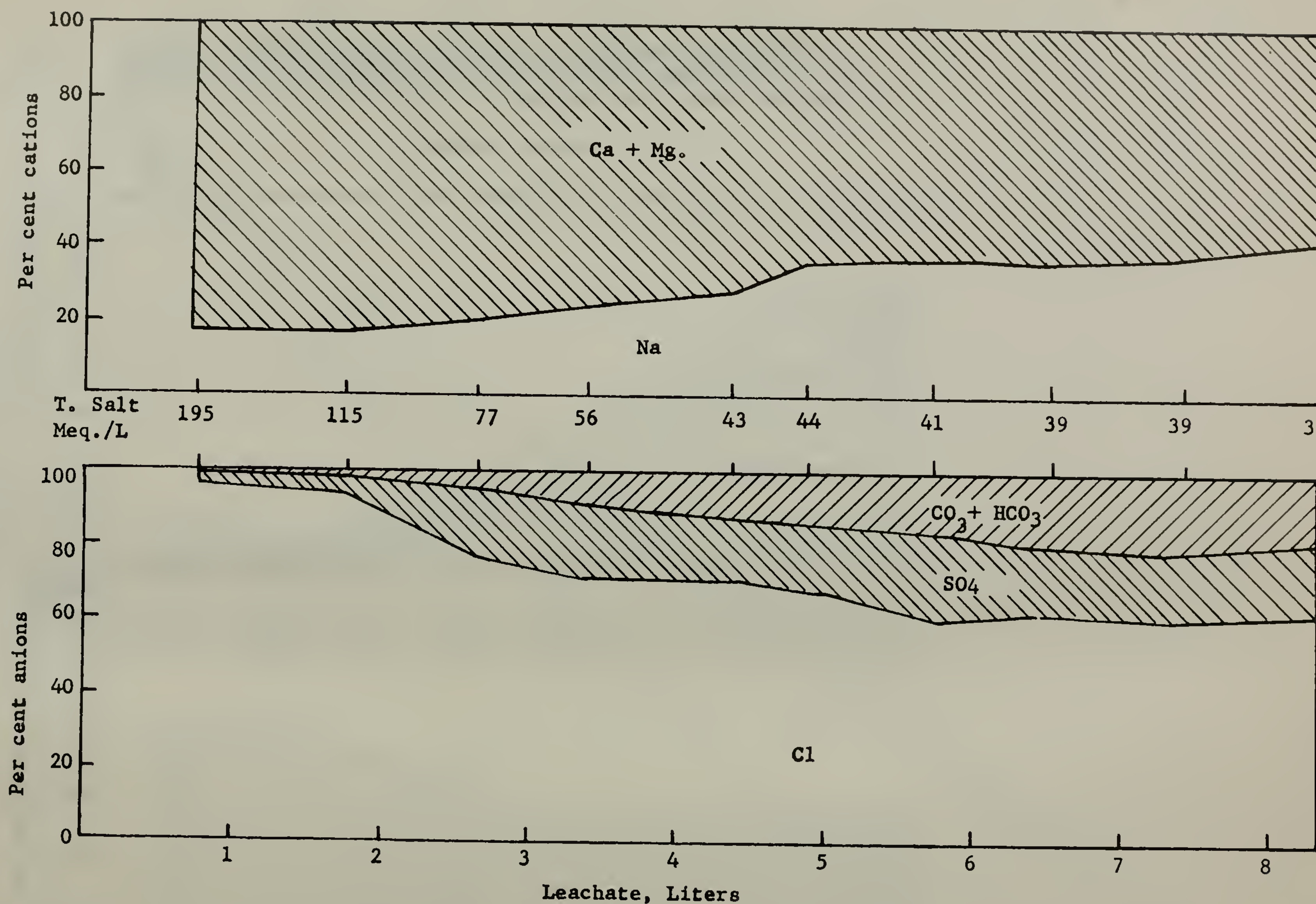


Figure 8 Per cent anions and cations in leachate from 6-foot cylinder of Sorrento loam irrigated with water B (water contained 54% Cl, 14% SO_4, 32% HCO_3 anions; cations, 53% Na, 47% Ca and Mg.)

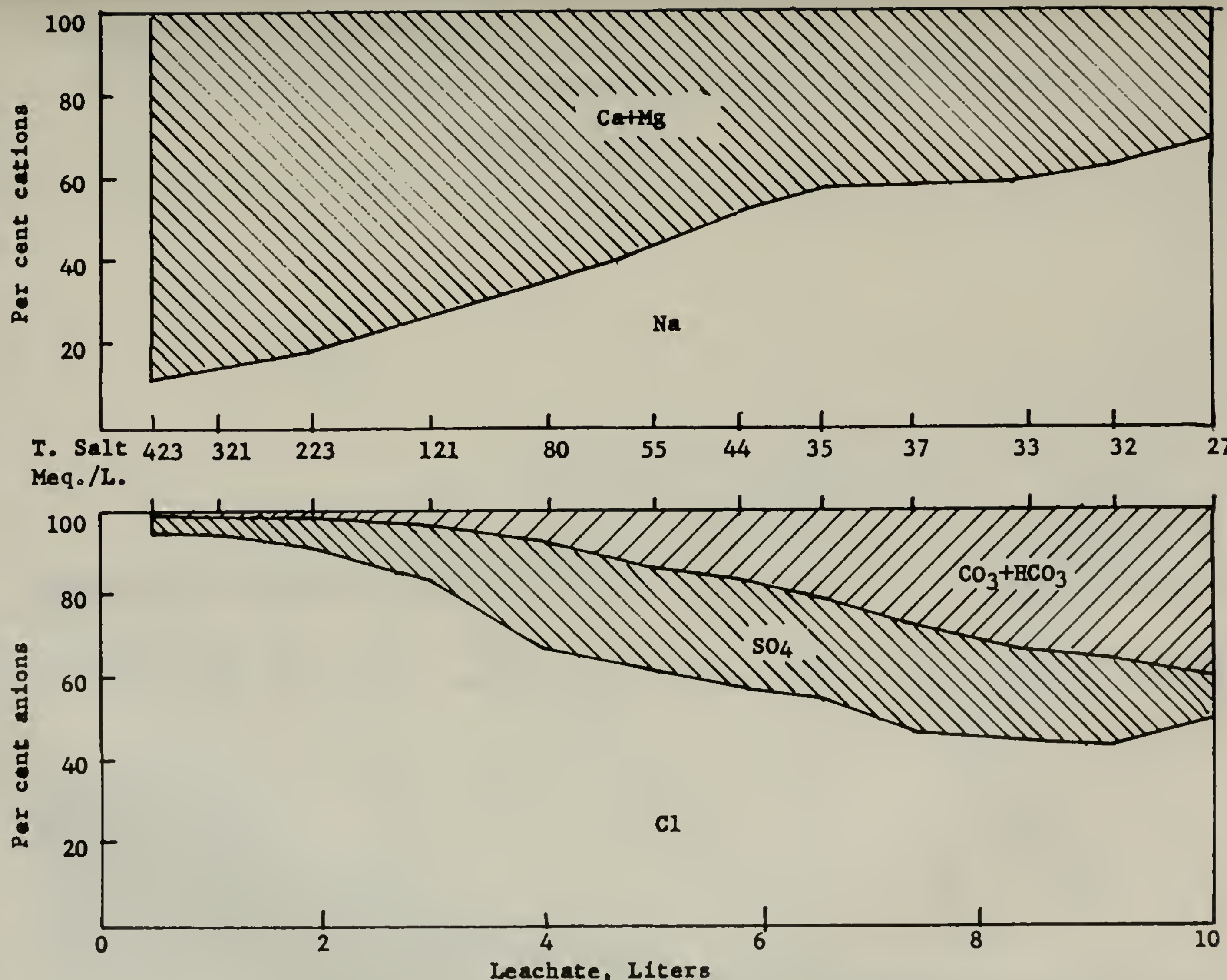


Figure 9 Per cent anions and cations in leachate from 6-foot cylinder of Sorrento loam irrigated with water C (Water contained 69% Cl, 12% SO_4, 19% HCO_3 anions; Cations, 67% Na, 33% Ca and Mg.)

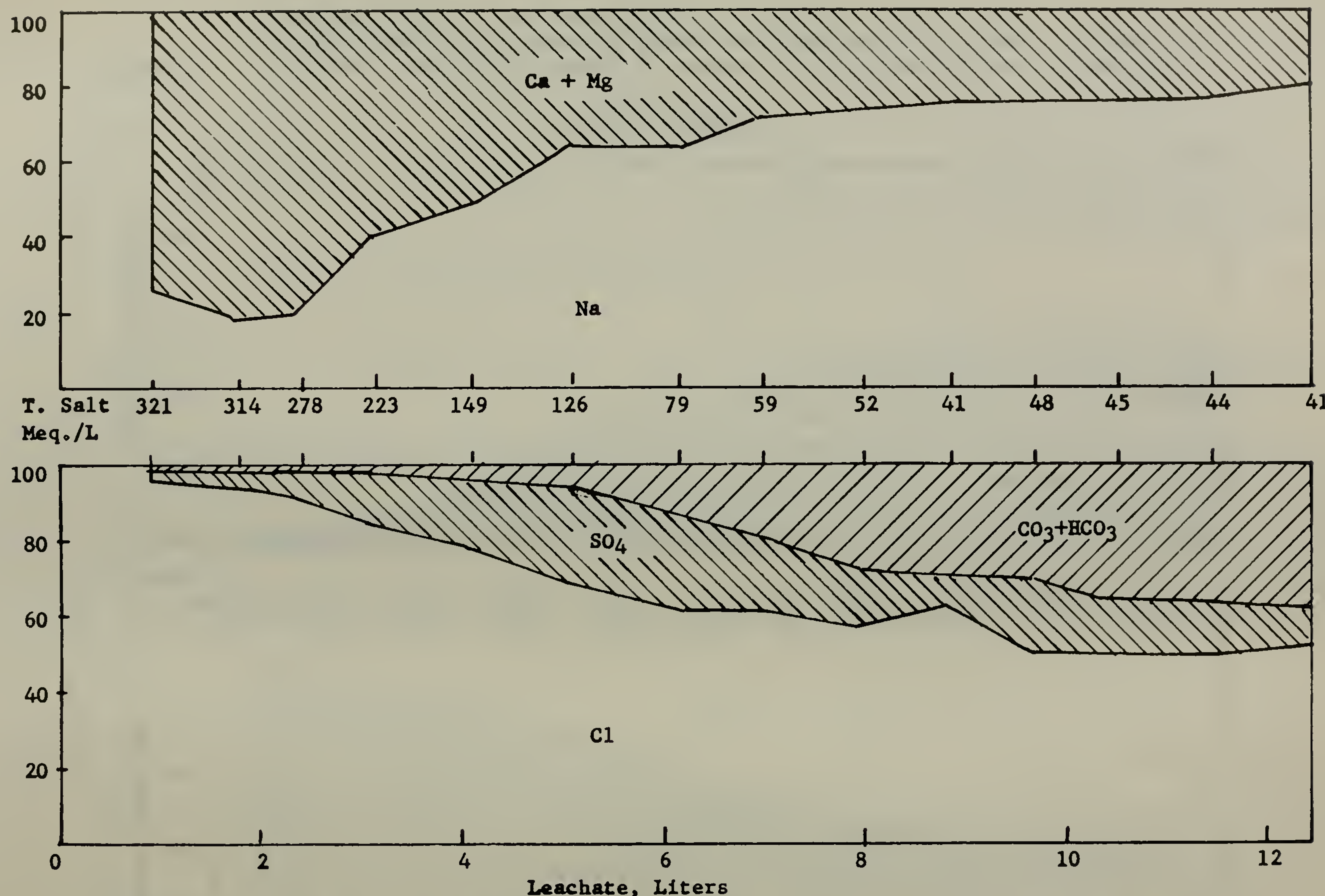


Figure 10 Per cent anions and cations in leachate from 6-foot cylinder of Sorrento loam irrigated with water D (water contained 76% Cl, 11% SO_4, 13% HCO_3, anions; cations 74% Na, 26% Ca and Mg.)

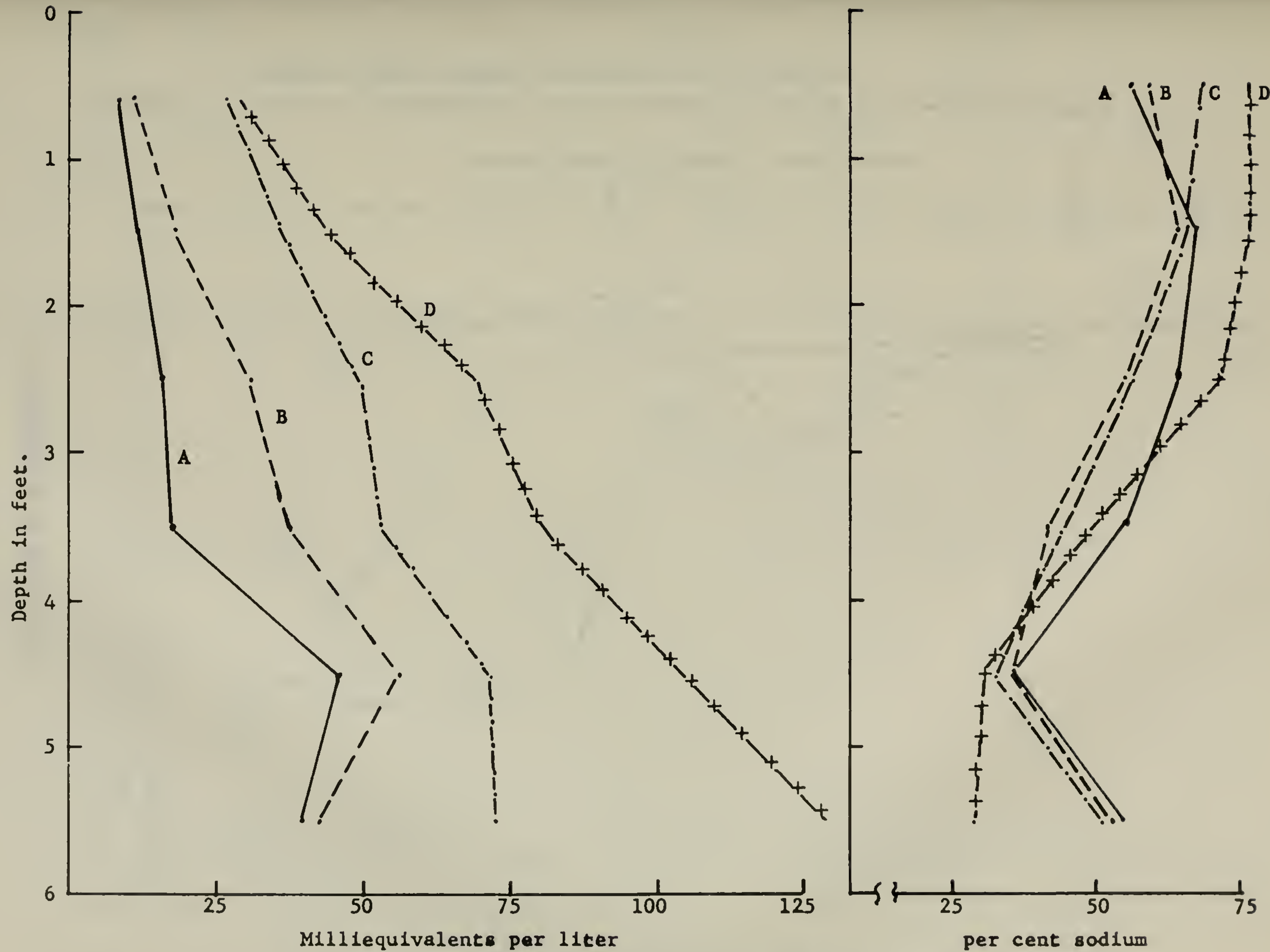


Figure 11 Milliequivalents salt and per cent sodium of the saturated extract by depth for Ambrose clay soil irrigated with waters A, B, C and D.

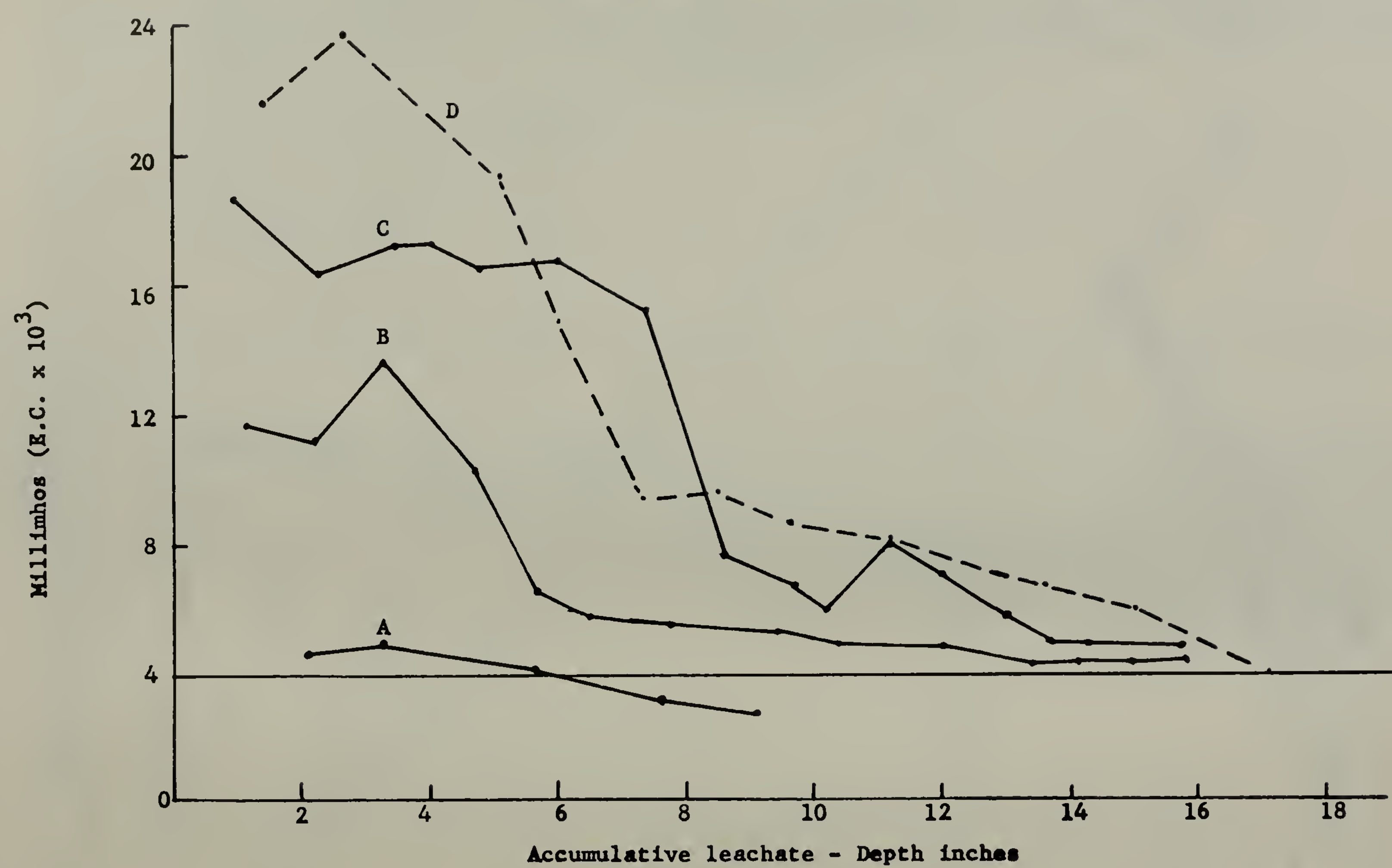


Figure 12 Effluent concentration with progressive leaching from 6-foot cylinders of Ambrose clay irrigated with waters A, B, C and D.

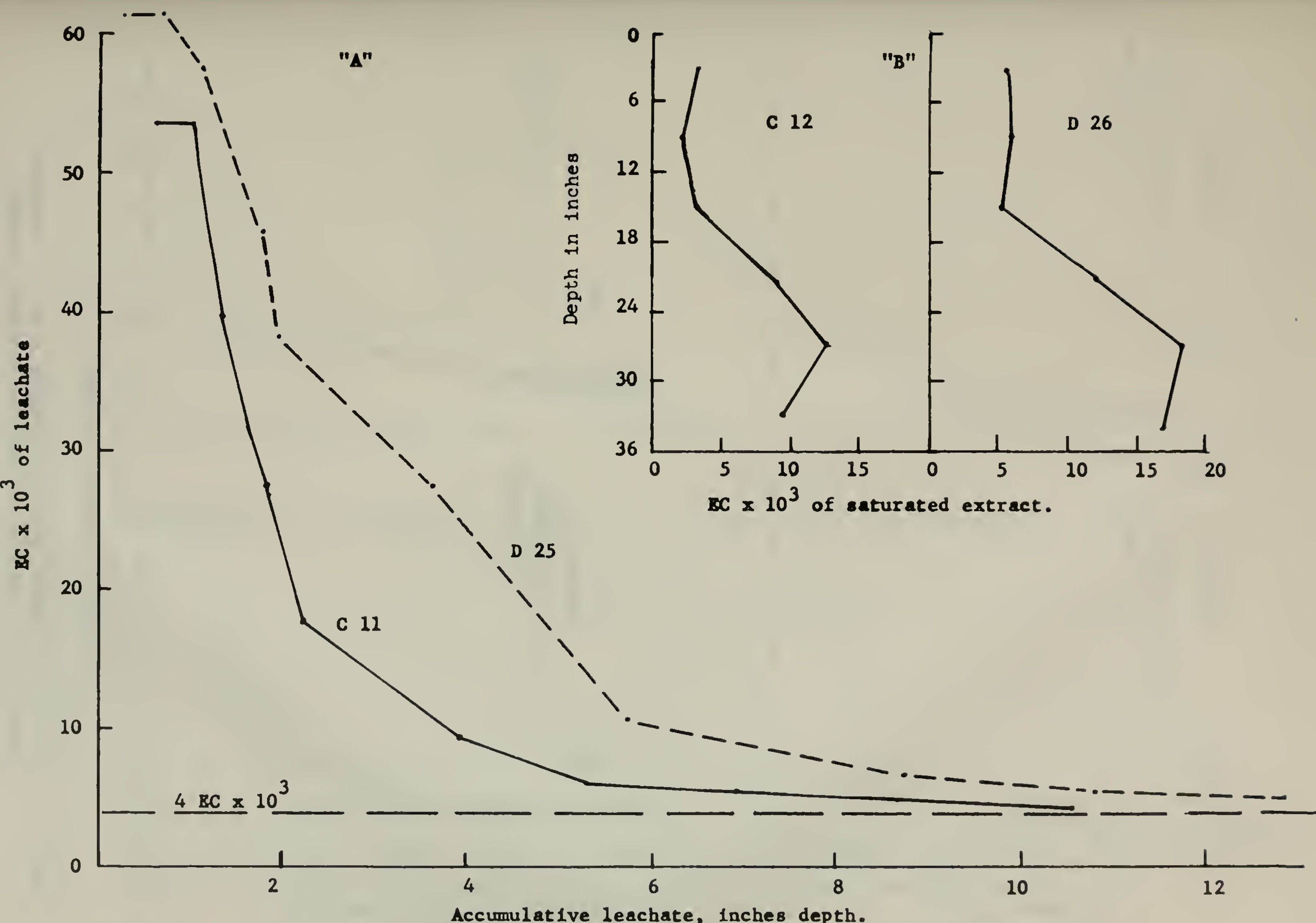


Figure 13 "A" effluent concentration with progressive leaching. "B" concentration of saturation extract by depth. Pleasanton clay loam irrigated with water C and D.

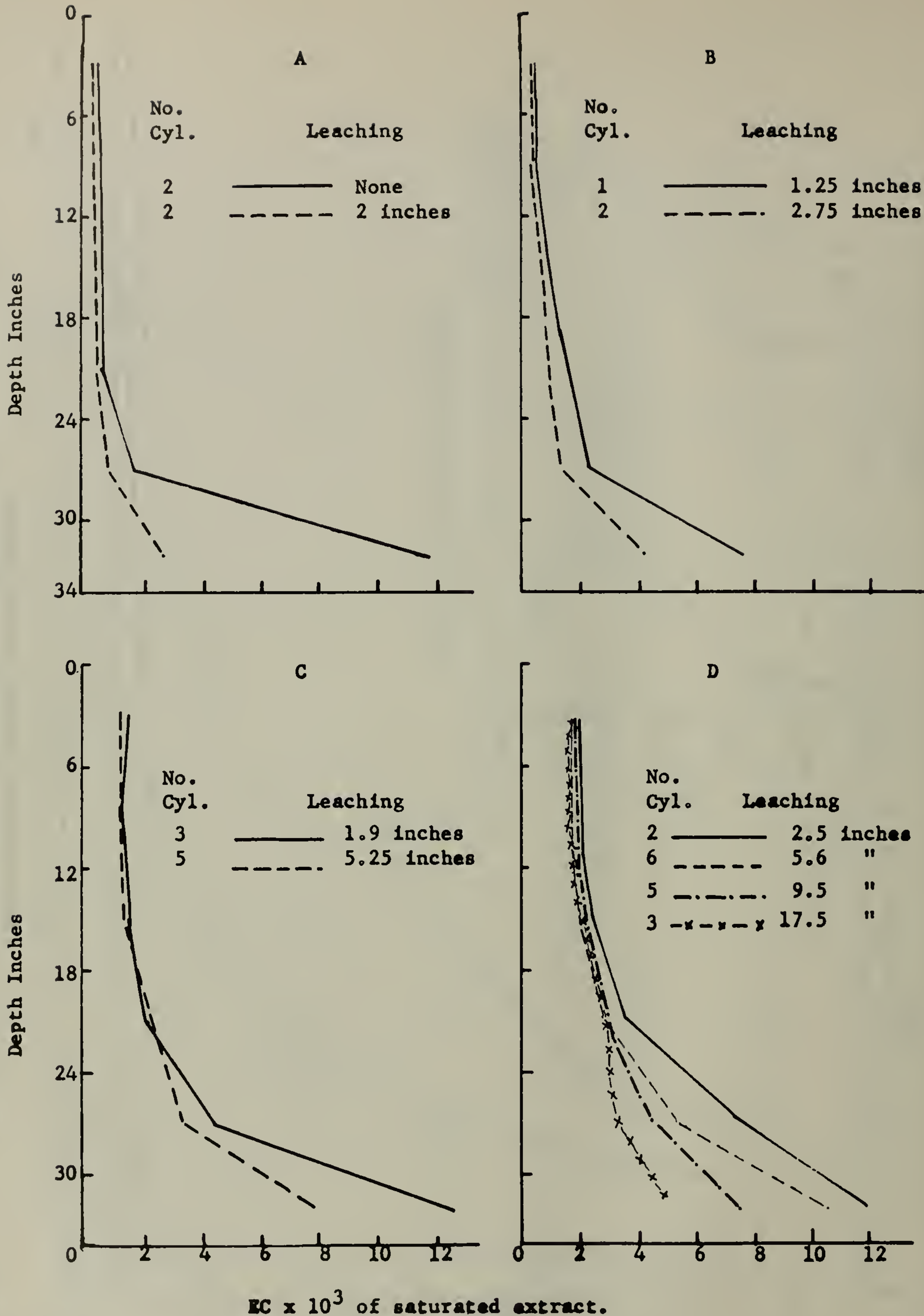


Figure 14 Salt distribution in the soil profile for 4 irrigation waters (A, B, C and D) and various leaching regimes.

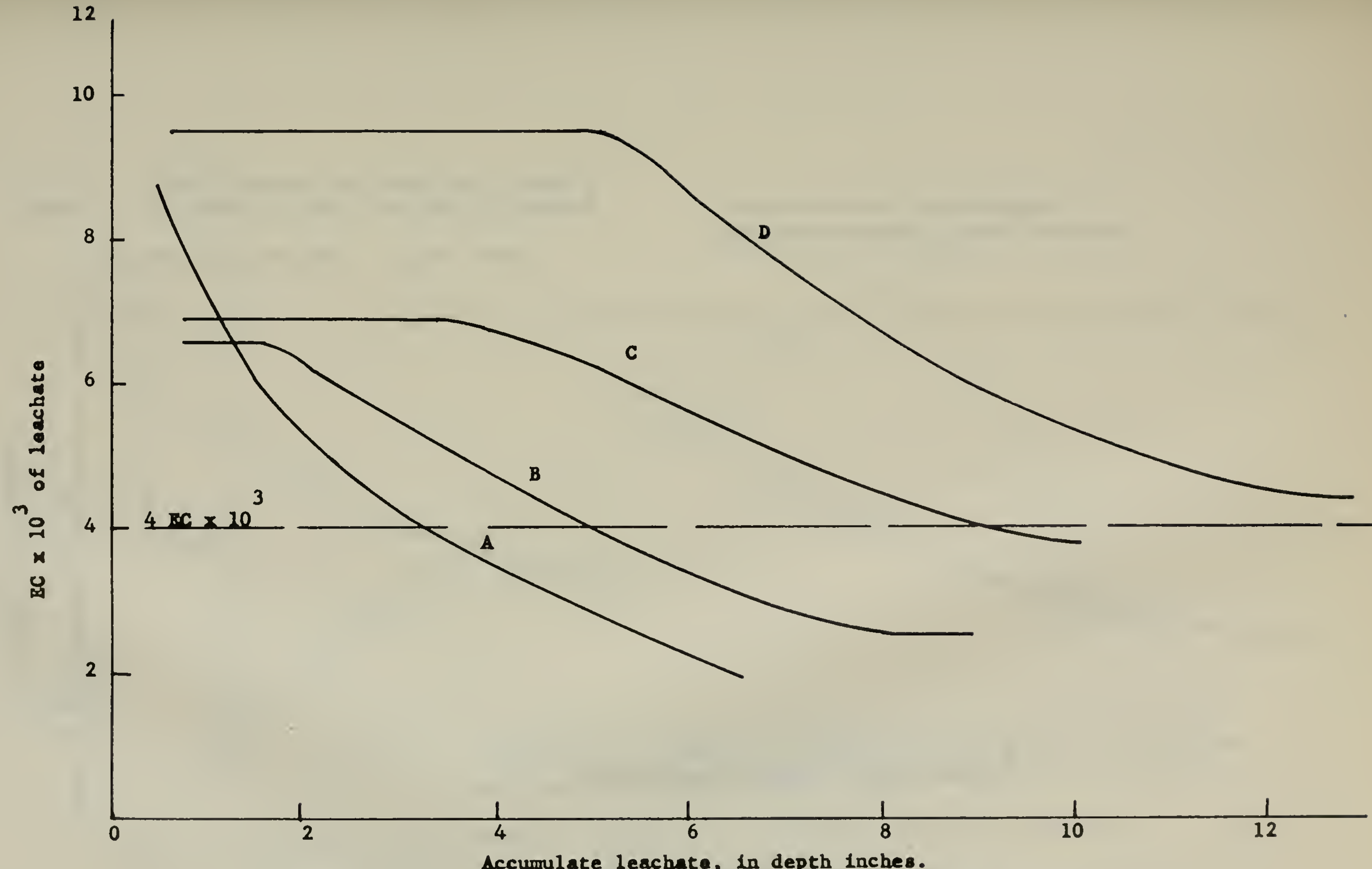
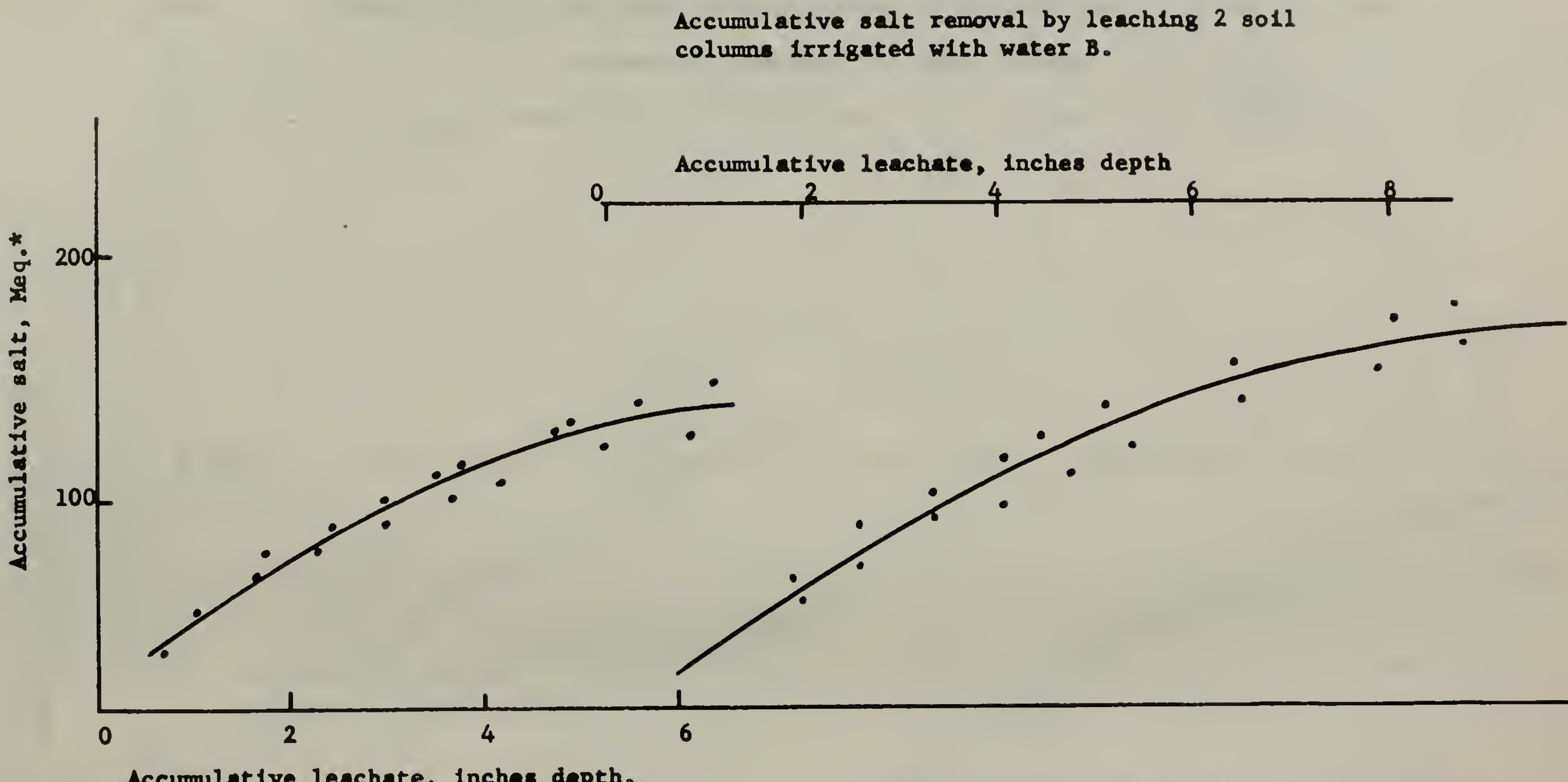


Figure 15 Concentration of the leachate in relation to accumulative leaching for 2 soil columns irrigated with water A, 4 with water B, 6 with water C, and 8 with water D, for Pleasanton clay loam.



*Milliequivalents of salt estimated from electrical conductance

Figure 16 Accumulative salt removal by leaching 2 soil columns irrigated with water A.

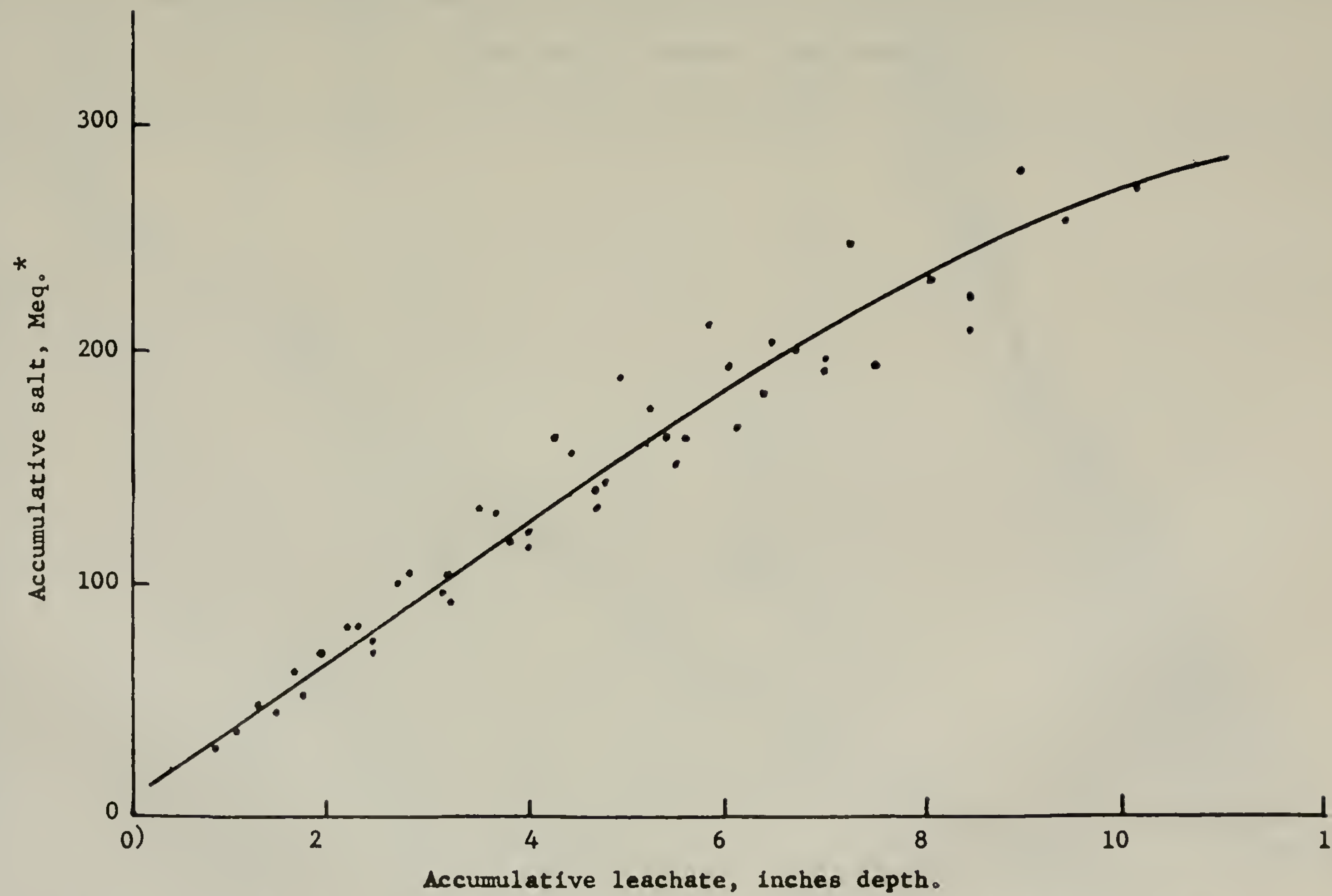


Figure 17 Accumulative salt removal by leaching 5 soil columns irrigated with water C.

*Milliequivalents salt estimated from electrical conductivity.

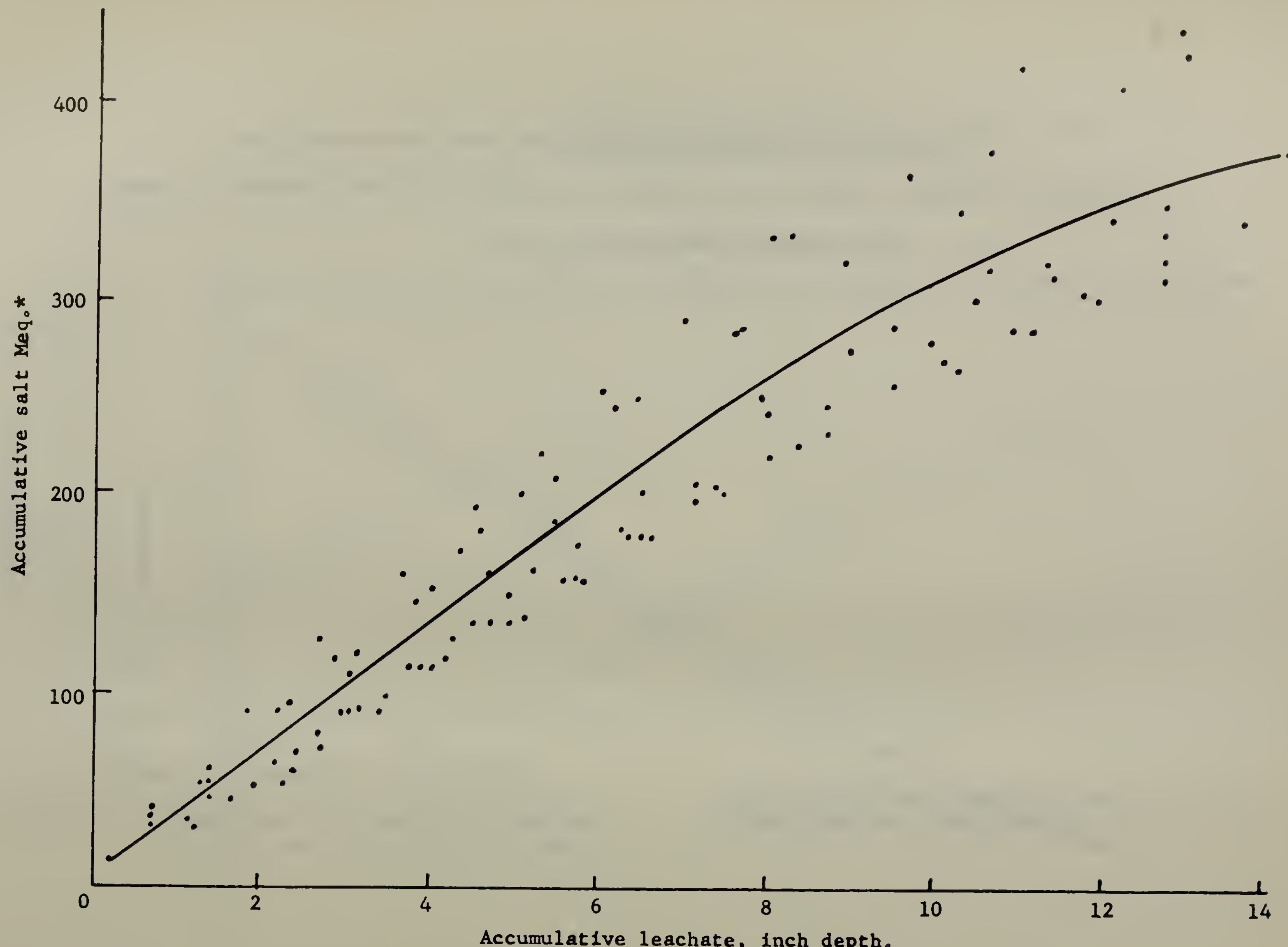


Figure 18 Accumulative salt removal by leaching 9 soil columns irrigated with water D

*Milliequivalents salt estimated from electrical conductivity.

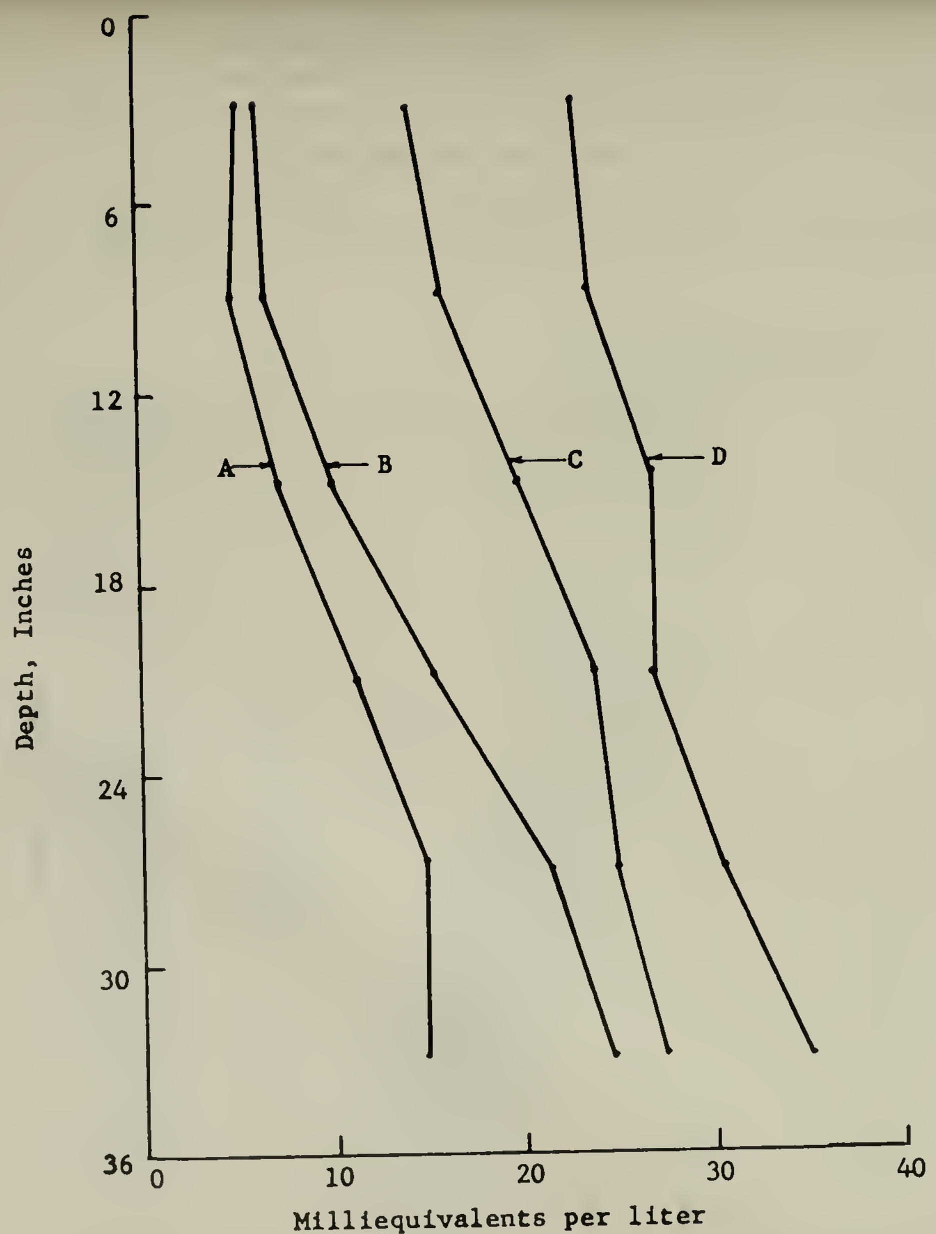


Figure 19 Average concentration of salts in the saturated extract for soil columns irrigated with waters A, B, C and D.

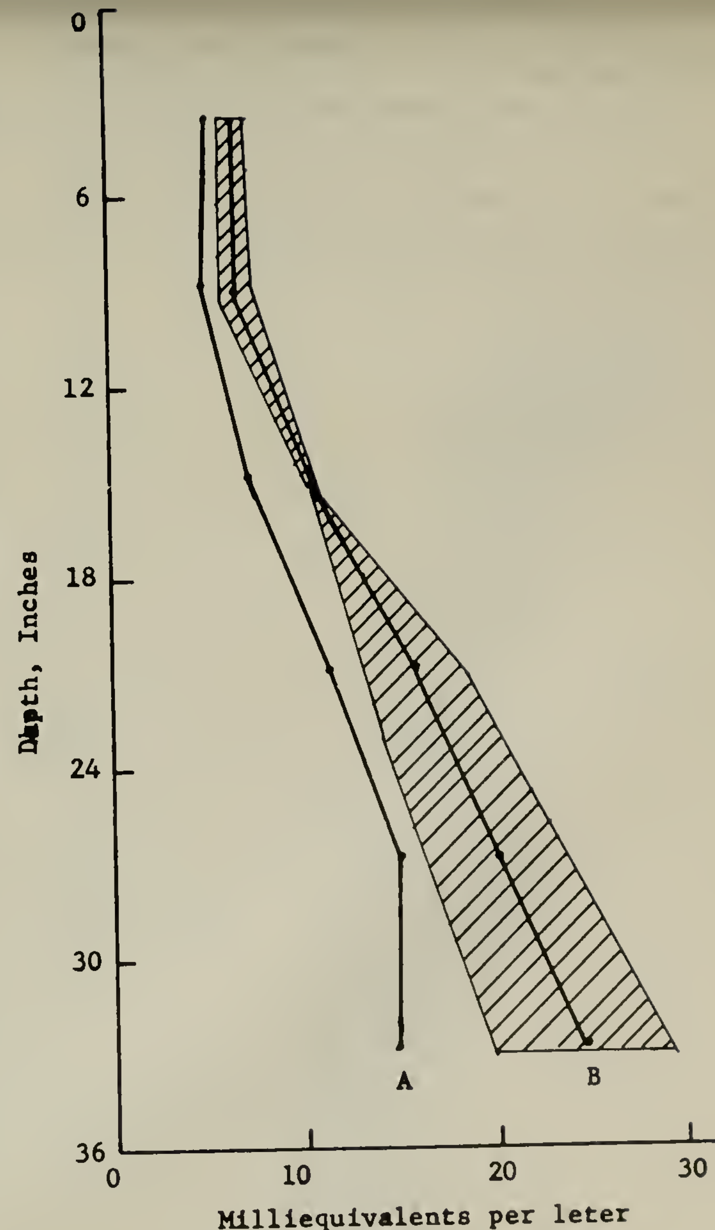


Figure 20 Deviation from the mean of salt in the saturated extract for 2 soil columns irrigated with B water.

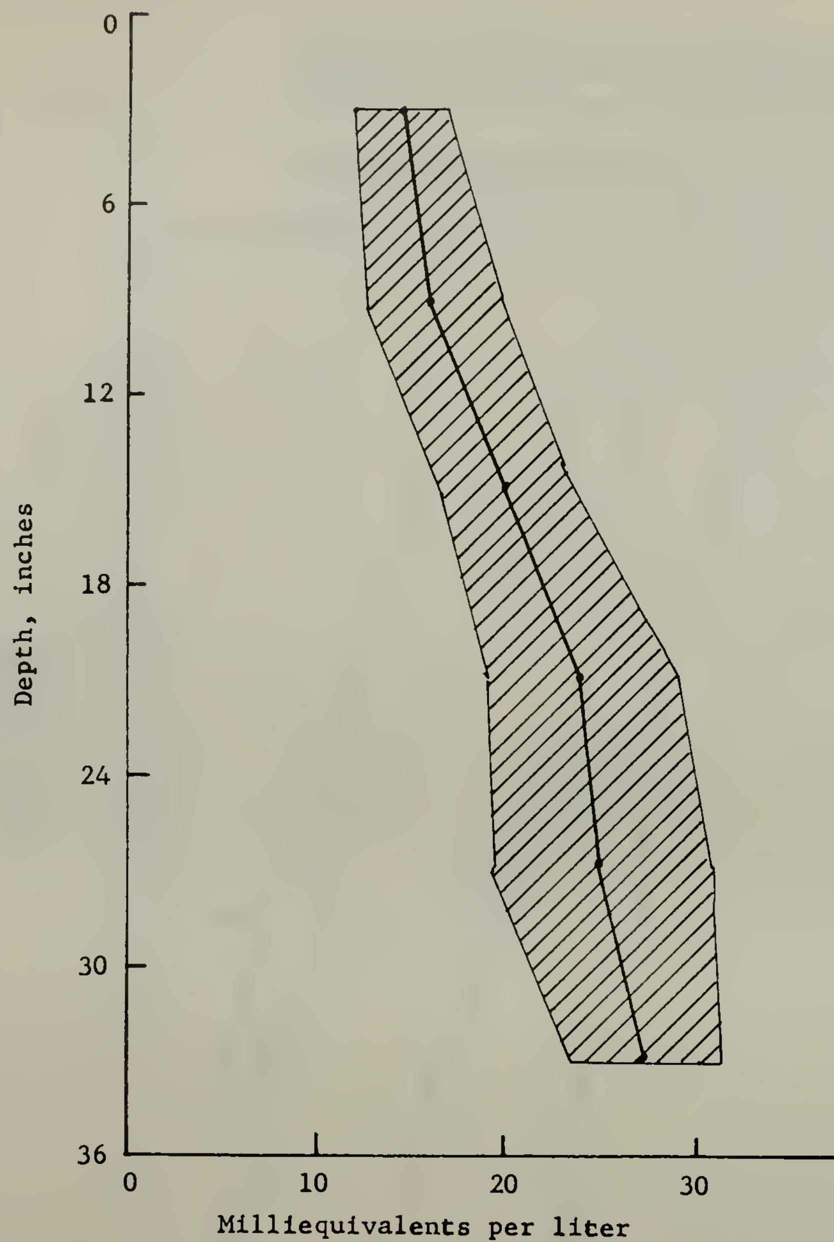


Figure 21 Deviation from the mean of salt in the saturated extract for 6 soil columns irrigated with C water.

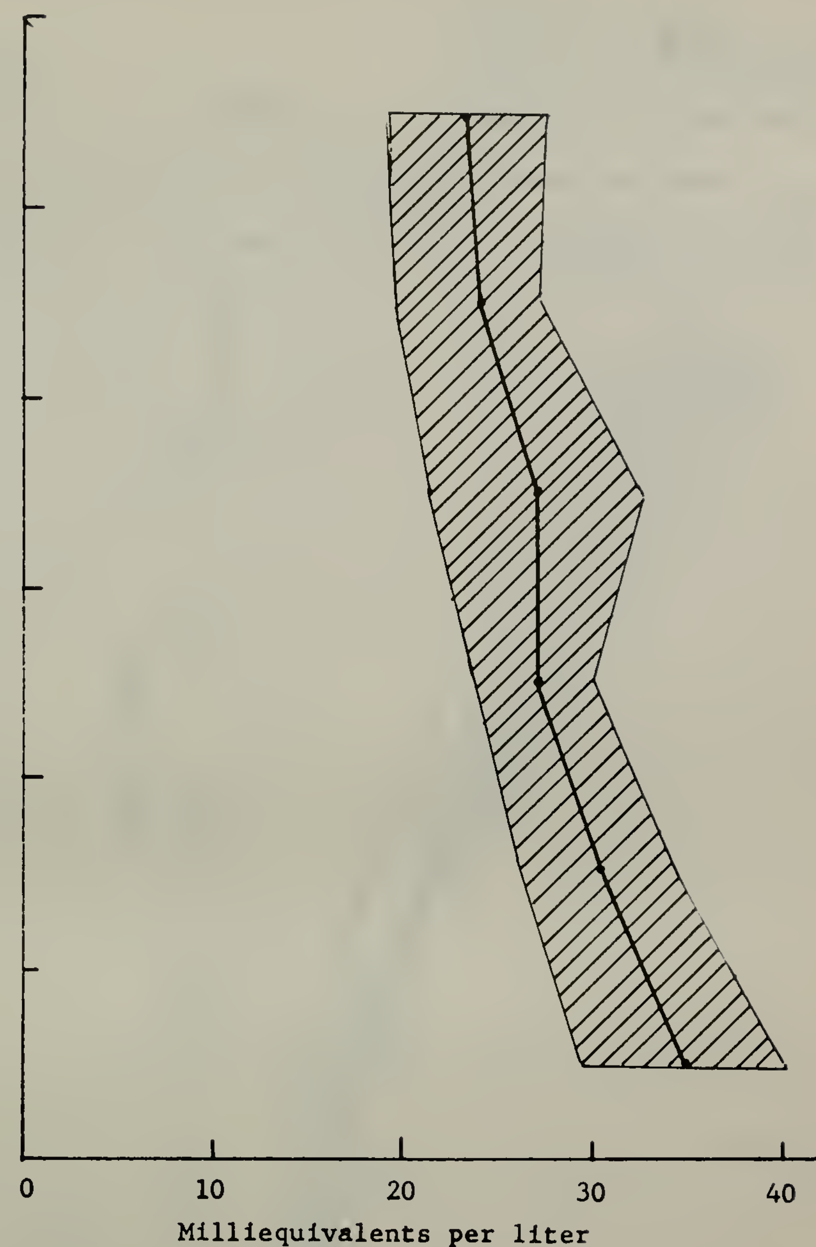


Figure 22 Deviation from the mean of salt in the saturated extract for 8 soil columns irrigated with D water.

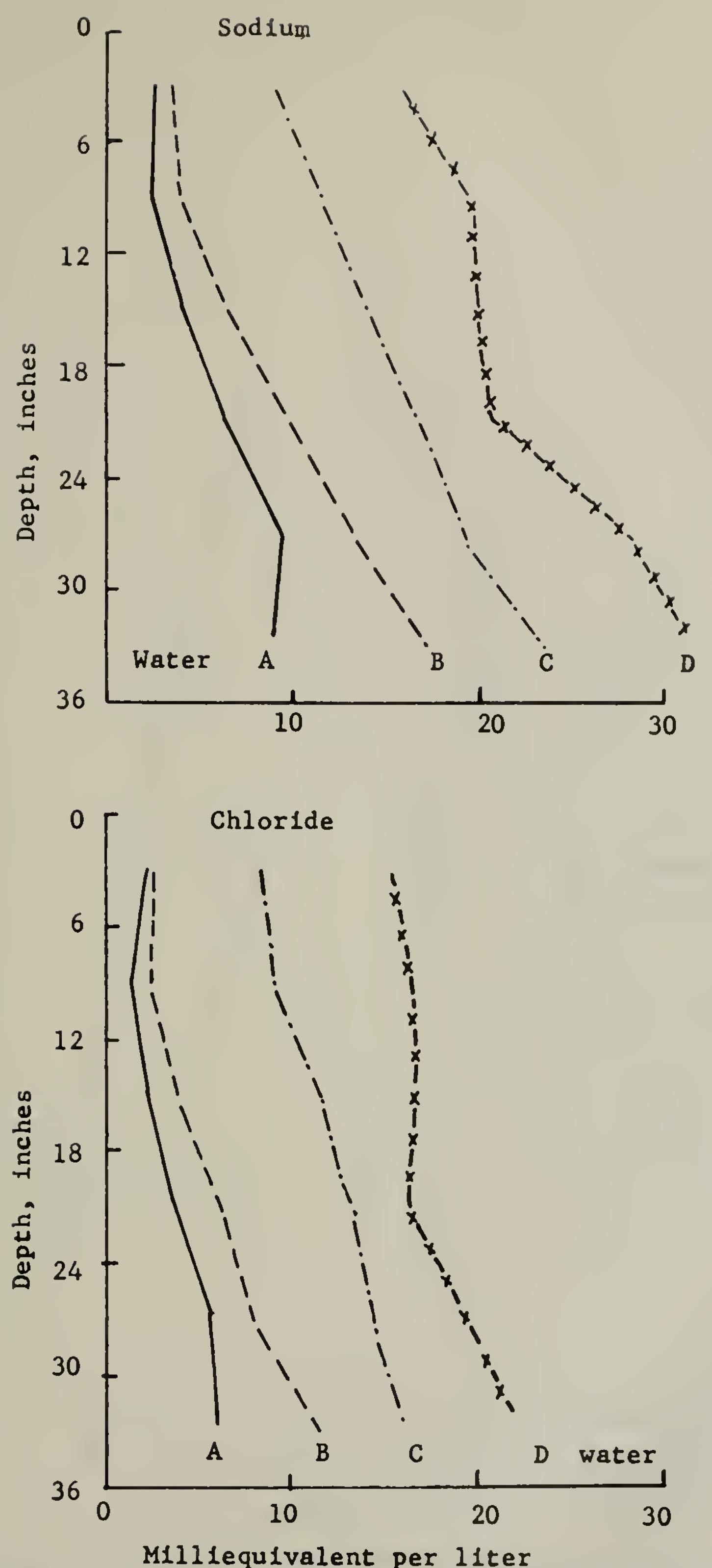


Figure 23 Concentration of sodium and chloride in saturation extract by depth of cylinder irrigated with 4 waters, A, B, C and D.

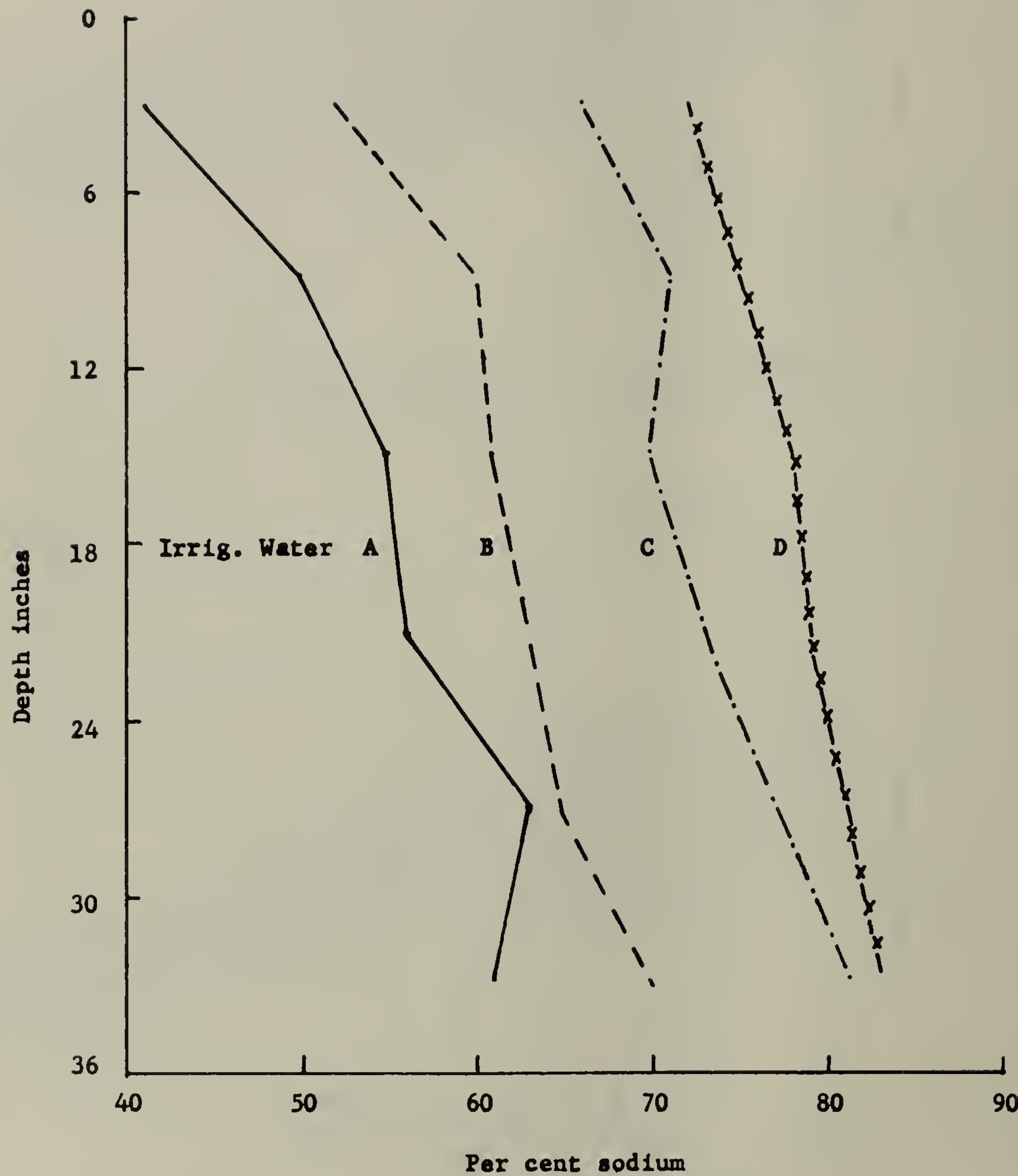


Figure 24 Per cent sodium of the saturation extract by depth of cylinder, irrigated with A, B, C and D waters having 51, 53, 67 and 74 per cent sodium respectively.

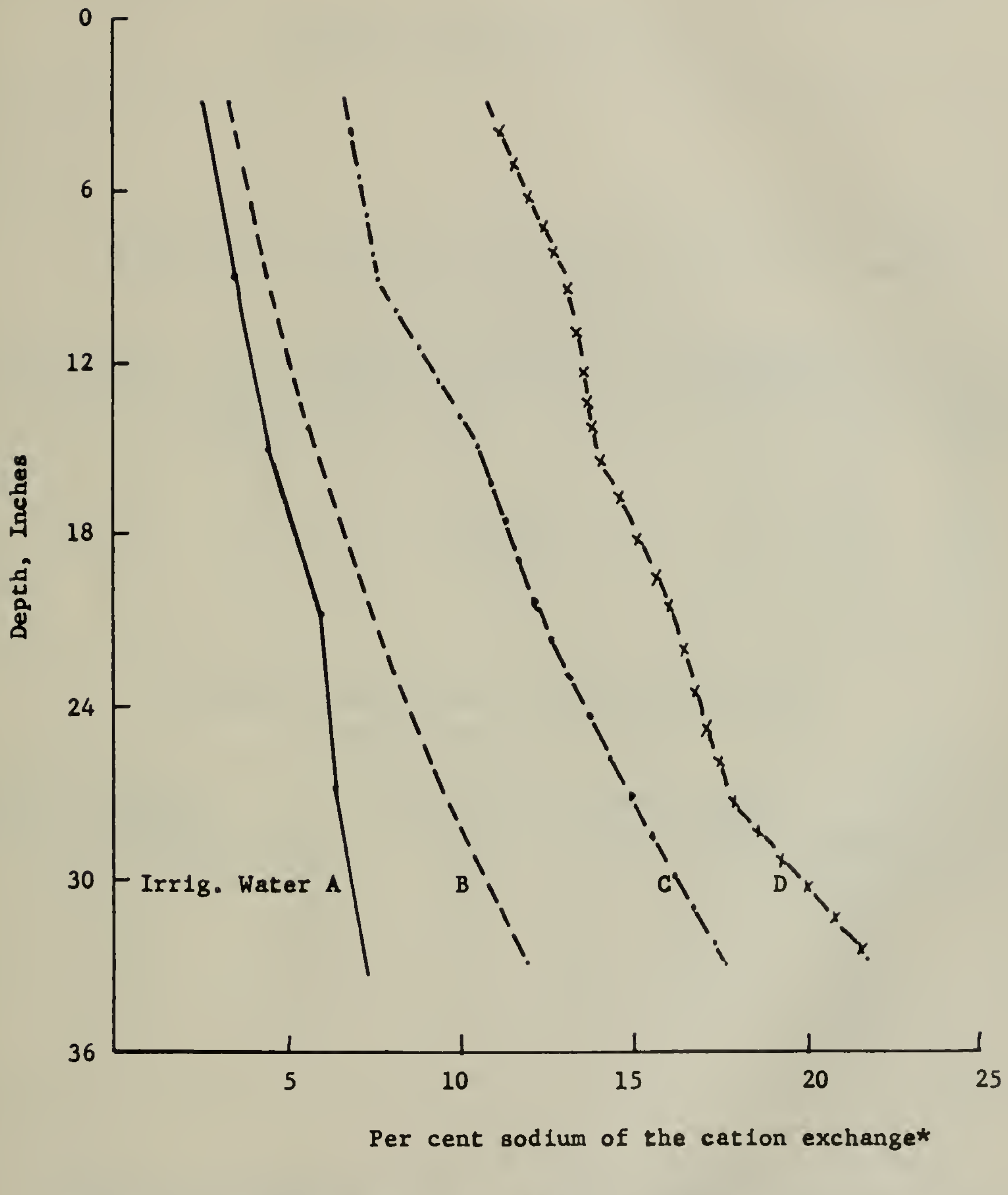


Figure 25 Per cent exchangeable sodium of the soil by depth of cylinder, irrigated with waters A, B, C and D having 51, 53, 67 and 74 per cent sodium respectively.

* Corrected for soluble sodium of the saturation extract.

BASIC DATA

ANALYSES OF SOIL SAMPLES

District: West Stanislaus Irrigation — Site No. 1

Location Number: T4S, R6E, Sec. 12D — Year Sampled: 1955

Soil: Sorrento loam — Crop: Apricots

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	13.1	12.7	7.0	5.1	4.8

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter: Anions			Cations					% Na
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	2.8	2.2	14.1	11.5	10.9	4.0	0.4	12.4	27.7	45
1-2	3.1	1.6	14.8	14.5	10.9	3.7	0.1	16.2	30.9	52
2-3	2.6	1.6	11.7	12.4	8.5	2.7	0.4	14.2	25.7	55
3-4	2.5	1.5	11.3	11.7	8.0	2.5	0.1	13.8	24.5	56
4-5	2.5	1.6	10.7	12.8	8.0	3.7	0.4	13.1	25.1	52

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents: Ca	Mg	K	Na	Total	% Na
0-1	9.4	16.9	2.9	0.2	0.9	21.0	6
1-2	10.1	36.0	3.7	0.2	1.5	41.4	11
2-3	6.6	21.9	2.4	0.1	1.0	25.4	10
3-4	4.5	11.5	1.5	0.1	0.5	13.6	5
4-5	4.7	10.8	1.5	0.1	0.5	13.0	6

Remarks:

Moisture equivalents indicate a sandy type of soil with the 3-4 and 4-5 foot depth containing 20 and 25 per cent rocks respectively.

Salinity of this irrigated soil has increased when compared to nearby dry land site 3. Also increased is the per cent sodium of the cation exchange.

The trees showed some injury from salt.

ANALYSES OF SOIL SAMPLES

District: West Stanislaus Irrigation — Site No. 2

Location Number: T4S, R6E, Sec. 2P — Year Sampled: 1955

Soil: Sorrento clay loam — Crop: Almonds

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	22.8	21.6	14.8	8.9	13.3

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	2.1	4.7	10.0	6.6	7.0	2.9	0.4	11.1	21.4	52
1-2	2.7	1.9	14.8	9.9	9.0	2.7	0.4	14.6	26.6	55
2-3	2.0	1.9	7.1	11.6	6.0	1.7	0.1	12.8	20.6	62
3-4	2.7	1.9	6.3	19.6	7.0	2.7	0.1	18.0	27.8	65
4-5	5.8	1.6	16.9	57.9	20.0	9.2	0.3	47.0	76.4	61

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	13.0	19.6	4.9	0.6	1.3	26.4	6
1-2	15.0	23.4	3.8	0.3	1.7	29.3	7
2-3	10.0	18.4	2.9	0.2	1.1	22.7	8
3-4	6.5	8.9	1.9	0.1	1.0	12.0	10
4-5	8.4	19.6	2.7	0.2	2.3	24.8	12

Remarks:

The 3, 4 and 5 foot depth contained 24, 25, and 10 per cent rock respectively.

The salinity has increased in this irrigated soil particularly in the 5 foot depth when compared to nearby dry land site 3.

Also, increased is the per cent sodium of the cation exchange. Sulfate and calcium are sufficiently high to indicate the presence of gypsum in the 5 foot depth.

The trees showed some injury from salt.

ANALYSES OF SOIL SAMPLES

District: West Stanislaus Irrigation — Site No. 3

Location Number: T4S, R7E, Sec. 20E — Year Sampled: 1955

Soil: Sorrento clay loam — Crop: Dry land

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	27.3	22.3	22.5	2.15	20.5

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	0.4	2.6	0.6	0.8	2.1	0.9	0.1	0.9	4.0	23
1-2	0.3	2.2	0.3	1.0	1.1	0.5	0.1	1.8	3.5	53
2-3	0.4	2.4	0.3	0.8	0.7	0.3	0.1	2.6	3.6	71
3-4	0.4	3.0	0.3	0.8	0.6	0.2	0.1	3.3	4.1	79
4-5	0.6	3.2	0.6	1.3	1.1	0.2	0.1	3.7	5.1	73

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	28.1	21.5	6.6	0.4	0.3	28.7	1
1-2	20.8	40.0	7.8	0.4	0.6	48.8	2
2-3	19.8	39.3	6.6	0.3	1.3	47.5	6
3-4	18.9	18.7	6.4	0.3	1.8	27.2	9
4-5	17.2	26.6	5.2	0.3	1.8	33.9	9

Remarks:

Dry land or unirrigated.

Very low salinity and sodium on the cation exchange.

ANALYSES OF SOIL SAMPLES

District: West Stanislaus Irrigation | Site No. 4

Location Number: T4S, R7E, Sec. 20P | Year Sampled: 1955

Soil: Sorrento clay loam | Crop: Beans

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	19.6	19.2	19.5	22.4	22.2

Electrical Conductivity in Millimhos ($EC \times 10^3$) and analyses of soil saturation extract

Depth, feet	$EC \times 10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	1.4	2.1	4.7	6.6	4.5	2.4	0.1	6.4	13.4	47
1-2	0.9	3.9	2.5	2.9	2.5	1.3	0.1	5.4	9.3	58
2-3	0.8	2.1	3.1	2.3	2.5	0.7	0.1	4.1	7.5	55
3-4	0.9	1.6	3.7	3.4	2.8	0.8	0.1	5.0	8.7	57
4-5	1.0	1.6	4.5	3.3	3.0	1.2	0.1	5.1	9.4	54

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	17.2	12.7	6.4	0.4	1.0	20.5	4
1-2	16.9	12.7	6.2	0.3	1.0	20.2	4
2-3	15.1	38.5	4.6	0.3	0.9	44.4	5
3-4	17.8	41.6	5.8	0.3	1.1	48.9	5
4-5	17.7	54.7	7.3	0.4	1.2	63.6	5

Remarks:

Low soil salinity.

ANALYSES OF SOIL SAMPLES

District: Banta-Carbona Irrigation — Site No. 5

Location Number: T3S, R5E, Sec. 22 — Year Sampled: 1955

Soil: Ambrose clay — Crop: Alfalfa

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	31.2	31.1	34.7	43.4	29.8

Electrical Conductivity in Millimhos (Ec x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter: Anions: HCO_3	Cl	SO_4	Cations: Ca	Mg	K	Na	Total	% Na
0-1	1.1	3.5	5.9	1.9	3.5	1.6	0.1	6.0	11.2	54
1-2	2.1	2.5	11.4	6.7	5.2	2.7	0.2	12.6	20.7	61
2-3	2.0	2.2	9.8	6.4	3.0	1.3	0.1	14.0	18.4	76
3-4	1.6	2.6	6.8	5.3	2.0	0.6	0.1	12.0	14.7	82
4-5	3.0	2.0	12.2	15.1	5.0	1.8	0.1	22.3	29.2	76

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents: Ca	Mg	K	Na	Total	% Na
0-1	28.5	20.0	11.5	0.9	1.8	34.2	5
1-2	29.2	23.1	12.2	0.6	3.2	39.2	8
2-3	28.2	40.9	10.6	0.6	4.6	56.7	13
3-4	26.7	33.9	9.2	0.7	4.3	48.2	13
4-5	24.7	28.9	8.9	0.7	4.7	43.2	14

Remarks:

A slight amount of salt occurs in the profile particularly in the 5-foot depth. The cation exchange contains an appreciable amount of sodium in the lower 3 feet of the soil profile. The salts present are not harmful to the crop - alfalfa, as this is a salt tolerant plant.

ANALYSES OF SOIL SAMPLES

District: Banta-Carbona Irrigation — Site No. 6

Location Number: T3S, R5E, Sec. 22 — Year Sampled: 1955

Soil: Ambrose clay — Crop: Almonds

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	28.4	30.5	31.2	27.6	30.5

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	1.7	1.4	7.9	7.4	5.0	3.6	0.3	7.9	16.7	47
1-2	1.9	2.3	7.9	8.4	3.5	1.7	0.1	13.3	18.6	72
2-3	3.6	1.6	18.9	15.6	8.0	3.2	0.1	24.7	36.1	69
3-4	4.6	0.6	29.6	15.5	11.9	4.0	0.4	29.5	45.7	64
4-5	4.8	1.2	32.0	14.3	12.5	4.2	0.6	30.2	47.5	63

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	28.1	19.3	11.0	1.1	1.8	33.1	1
1-2	29.6	37.0	11.8	0.6	4.1	53.2	3
2-3	28.3	45.4	9.6	0.6	4.5	60.0	3
3-4	23.6	27.4	7.8	0.7	3.9	39.7	10
4-5	24.1	22.7	7.8	0.9	4.3	35.7	10

Remarks:

Orchard showed salt burn of the leaves. Salt accumulation in the subsoil is in the saline range. As indicated by the high chloride concentration leaching of the soil has not been accomplished in this orchard.

ANALYSES OF SOIL SAMPLES

District: Banta-Carbona Irrigation — Site No. 7

Location Number: T3S, R5E, Sec. 24D — Year Sampled: 1955

Soil: Ambrose clay — Crop: Beans

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	32.2	31.4	29.0	32.1	38.1

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	1.1	2.2	1.2	6.9	3.5	1.8	0.2	4.8	10.3	46
1-2	1.2	1.8	1.7	7.0	3.7	2.3	0.1	5.4	11.5	47
2-3	1.2	1.5	1.6	7.7	3.7	1.7	0.1	5.3	10.8	49
3-4	0.9	1.7	1.0	6.0	2.6	0.9	0.1	5.1	8.8	58
4-5	0.8	2.4	0.8	4.8	1.4	0.5	0.1	6.0	8.0	75

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	31.7	23.8	11.9	1.2	1.6	38.5	4
1-2	30.6	21.2	11.0	0.7	1.5	34.5	4
2-3	27.3	36.3	9.9	0.6	1.6	48.4	5
3-4	28.0	25.2	9.2	0.7	1.9	37.0	6
4-5	27.8	28.4	8.4	0.8	2.8	40.5	9

Remarks:

For this soil series the salt is of a relatively low level. Irrigation management and the production of annual crops have probably been responsible for this condition.

ANALYSES OF SOIL SAMPLES

District: Banta-Carbona Irrigation — Site No. 8

Location Number: T3S, R5E, Sec. 14R — Year Sampled: 1955

Soil: Ambrose clay — Crop: Dry land

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	28.9	29.0	25.5	24.1	26.9

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	0.8	2.1	3.6	1.3	1.9	1.1	0.1	3.8	6.9	55
1-2	1.2	1.5	8.4	3.0	2.5	1.1	0.1	8.3	12.0	69
2-3	2.5	1.3	12.2	11.4	5.0	2.0	0.2	17.7	24.9	71
3-4	5.6	1.1	14.5	45.2	22.0	9.2	0.1	29.5	60.8	48
4-5	6.1	1.3	14.8	50.8	25.0	10.9	0.1	30.8	66.8	46

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	30.3	19.6	11.5	1.1	1.5	33.8	4
1-2	32.4	24.5	11.0	0.7	3.4	39.6	9
2-3	24.3	30.7	8.4	0.5	4.4	44.1	14
3-4	19.9	21.5	6.2	0.5	4.5	32.7	16
4-5	23.1	35.9	7.3	0.6	4.3	48.1	12

Remarks:

Dry land, or unirrigated with increasing salinity with depth. The analyses of calcium and sulfate indicate the presence of gypsum. According to the soil survey, salinity usually is not found in this soil except under high watertable conditions. Most Ambrose soil series in this area have been under irrigation for many years and salts could have been leached from the upper 5 feet before the survey was made. However, this unirrigated area may be typical of the salt concentration in the native Ambrose clay soil.

ANALYSES OF SOIL SAMPLES

District: Patterson Water   Site No. 9

Location Number: T5S, R8E, Sec. 7M   Year Sampled: 1955

Soil: Sorrento clay loam   Crop: Alfalfa

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	23.4	23.2	21.9	23.1	24.4

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	1.4	2.4	6.6	3.9	3.0	2.3	0.2	7.5	12.9	58
1-2	1.6	1.3	10.0	3.8	3.5	3.4	0.1	8.1	15.1	54
2-3	1.1	2.5	6.0	2.7	3.0	2.3	0.1	5.8	11.3	52
3-4	1.3	2.4	5.9	4.5	2.7	2.9	0.1	7.1	12.8	55
4-5	1.3	2.5	6.6	4.2	2.2	2.8	0.1	8.1	13.3	61

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	20.6	13.1	8.9	0.5	1.5	24.1	6
1-2	20.6	13.1	8.9	0.4	1.5	23.9	5
2-3	18.3	20.8	8.9	0.3	1.2	31.2	5
3-4	17.1	33.6	9.9	0.3	1.4	45.1	6
4-5	17.6	33.9	13.4	0.3	1.9	49.6	9

Remarks:

Some accumulation of salts when compared to the non-irrigated site 12. For alfalfa or field crops this accumulation would not be considered harmful.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 10

Location Number: T6S, R8E, Sec. 4E — Year Sampled: 1955

Soil: Sorrento clay loam — Crop: Almonds

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	19.9	19.6	18.9	18.5	19.5

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	1.3	2.6	6.1	4.0	3.2	2.6	0.2	6.7	12.7	54
1-2	1.1	0.6	5.9	4.0	2.5	1.7	0.1	6.2	10.6	59
2-3	1.3	0.8	7.1	4.3	3.0	2.1	0.1	7.1	12.2	58
3-4	1.8	0.3	11.4	4.4	3.7	2.7	0.1	9.6	16.1	60
4-5	2.3	0.3	16.5	4.6	5.0	2.9	0.2	13.3	21.3	62

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	18.5	12.0	7.1	0.4	1.1	20.7	5
1-2	17.8	11.6	7.5	0.3	1.3	20.7	6
2-3	17.5	11.6	7.5	0.2	1.5	20.8	7
3-4	16.4	10.8	7.1	0.2	1.7	19.9	8
4-5	15.9	10.8	6. 5	0.2	2.2	19.8	11

Remarks:

Some accumulation of salts has taken place, noticeable in the 4 and 5-foot depth as indicated by the high chloride content. At this level it is questionable whether sufficient salts are present to injure almond tress.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 11

Location Number: T5S, R7E, Sec. 12G — Year Sampled: 1955

Soil: Sorrento loam (or mocho fine sandy loam) — Crop: Beans

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	18.8	18.6	20.6	20.6	19.1

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	0.8	1.6	3.5	2.7	1.8	1.1	0.2	4.7	7.9	60
1-2	0.9	1.8	3.8	3.1	1.9	1.2	0.2	5.3	8.6	61
2-3	0.9	2.1	3.5	2.6	2.0	1.1	0.1	5.0	8.2	60
3-4	0.8	2.3	2.8	2.3	1.5	0.9	0.1	4.8	7.3	66
4-5	1.0	1.6	4.1	4.1	2.1	1.9	0.1	5.6	9.7	57

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	14.6	10.8	5.6	0.6	0.9	17.9	5
1-2	14.5	10.4	5.9	0.4	1.0	17.8	6
2-3	15.1	28.9	7.5	0.3	1.1	37.9	6
3-4	14.5	28.9	8.1	0.3	1.1	38.4	6
4-5	14.2	23.4	8.9	0.2	1.0	33.5	6

Remarks:

The salts are relatively low, indicating some leaching has taken place in the production of annual crops.

ANALYSES OF SOIL SAMPLES

District: Patterson Water | Site No. 12

Location Number: T5S, R8E, Sec. 30G | Year Sampled: 1955

Soil: Sorrento clay loam | Crop: Dry land

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	24.6	25.4	24.8	24.2	22.7

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	0.3	1.2	0.3	1.8	1.4	1.5	0.1	0.4	3.4	12
1-2	0.3	1.3	0.2	1.5	1.5	0.8	--	0.8	3.1	25
2-3	0.3	1.3	0.1	1.7	1.3	0.7	--	1.1	3.1	35
3-4	0.3	1.5	0.1	1.3	0.9	0.4	--	1.6	3.0	55
4-5	0.4	2.4	0.2	1.1	0.8	0.5	--	2.3	3.7	63

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	26.3	18.1	10.6	0.5	0.2	29.4	1
1-2	26.4	21.5	9.9	0.5	0.3	32.3	1
2-3	25.3	22.3	9.9	0.4	0.5	33.1	2
3-4	23.1	27.4	9.6	0.4	0.7	38.0	3
4-5	20.2	36.3	9.2	0.4	0.9	46.9	4

Remarks:

Dry land, or unirrigated with a very low salt content of the soil profile and a low percent sodium on the exchange complex.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 13

Location Number: T5S, R8E, Sec. 33D — Year Sampled: 1955

Soil: Sorrento clay loam — Crop: Apricots

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	23.9	23.7	24.6	25.8	23.8

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter: Anions: HCO_3	Cl	SO_4	Cations: Ca	Mg	K	Na	Total	% Na
0-1	1.0	1.3	4.3	4.9	3.0	1.9	0.1	5.5	10.5	52
1-2	1.6	1.3	7.8	7.0	4.5	2.7	0.1	8.9	16.1	55
2-3	5.8	0.6	38.8	23.2	24.0	12.5	0.4	25.7	62.6	41
3-4	6.6	0.9	39.3	35.5	30.0	16.2	0.4	29.1	75.6	38
4-5	7.0	1.0	33.8	51.0	30.0	20.0	0.4	35.5	85.8	41

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents: Ca	Mg	K	Na	Total	Na
0-1	23.7	16.5	8.1	0.6	1.3	26.5	4
1-2	23.6	17.3	8.9	0.4	1.9	28.5	6
2-3	24.6	19.6	9.6	0.4	3.5	33.1	9
3-4	24.2	25.6	10.3	0.5	3.9	40.3	10
4-5	21.2	31.9	9.9	0.4	4.3	46.6	13

Remarks:

A high concentration of salt has accumulated in the 3-5 foot depths. Leaching has not taken place in this orchard as indicated by the chloride content and the presence of gypsum in the subsoil. The orchard is extremely poor with burning and death of many leaves and death of the young wood.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 14

Location Number: T5S, R8E, Sec. 32D — Year Sampled: 1955

Soil: Sorrento clay loam — Crop: Apricots

Moisture equivalents (M. E.)

Depth, feet	0-1	1-2	2-3	3-4	4-5
M. E.	26.6	26.3	25.0	25.1	27.0

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								%
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	Na
0-1	2.0	2.9	5.5	11.9	8.0	3.1	0.5	8.6	20.2	43
1-2	1.1	1.7	3.9	5.6	3.8	1.9	0.1	5.5	11.3	48
2-3	1.5	1.9	3.7	11.0	6.4	3.5	0.1	6.3	16.3	39
3-4	2.8	1.4	3.5	27.0	11.5	6.4	0.1	14.0	32.0	44
4-5	3.1	1.3	6.1	27.1	11.7	6.9	0.1	15.9	34.6	46

Cation Exchange Capacity in Milliequivalents per 100 grams of soil

Depth, feet	Cation Exchange Capacity	Cations in Milliequivalents					% Na
		Ca	Mg	K	Na	Total	
0-1	26.2	23.4	7.1	1.3	1.9	33.7	5
1-2	26.4	20.0	8.1	0.6	1.5	30.2	5
2-3	25.3	21.5	8.1	0.5	1.3	31.4	4
3-4	23.6	36.0	8.1	0.5	2.3	46.9	7
4-5	25.5	30.7	9.2	0.5	2.9	43.5	8

Remarks:

Some accumulation of salines throughout the soil profile has occurred, notable on the 4 and 5-foot depths, when compared to the non-irrigated site 12. If the salts continue to accumulate they will adversely effect the orchard.

ANALYSES OF SOIL SAMPLES

District: Patterson Water　　　　　　Site No. 15

Location Number: T5S, R8E, 28N*　　　　　　Year Sampled: 1956

Soil: Sorrento clay loam　　　　　　Crop: Apricots

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter: Anion Cl	Cations: Ca	Mg	K	Na	Total	% Na
0-1	1.0	3.6	3.2	1.6	0.1	5.4	10.3	52
1-2	6.3	6.8	19.0	19.2	0	40.4	78.6	51
2-3	7.5	13.7	23.0	25.3	0	50.3	98.6	51
3-4	8.9	29.4	26.0	31.6	0	70.8	128.4	55
4-5	8.8	32.5	26.0	31.6	0	57.8	115.4	50
5-6	7.2	24.8	19.0	22.5	0	47.9	89.4	53
6-7	7.1	30.4	17.0	19.2	0	46.9	83.1	56
7-8	6.6	31.1	18.0	17.5	0	41.5	77.0	54
8-9	6.0	26.9	17.0	17.5	0	36.5	69.0	53
9-10	5.3	21.7	16.5	15.8	0	31.7	64.0	49

Remarks:

Very high salinity in the soil profile with sodium constituting 50 percent or more of the total cations. Analyses indicate the presence of gypsum in the 3-to 5-foot depth.

The water table is estimated to be approximately 4 to 5 feet from the surface.

The trees had died in this area, probably from salt injury due to the poor subsoil drainage.

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* Location determined by projection of section lines.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 16

Location Number: T5S, R8E, Sec. 28L* — Year Sampled: 1956

Soil: Sorrento clay loam — Crop: Virgin

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter — Anion: Cl	Cations: Ca	Mg	K	Na	Total	% Na
0-1	1.6	3.8	5.2	4.6	1.3	5.4	16.5	33
1-2	0.9	2.0	2.4	2.2	0.2	3.9	8.7	45
2-3	1.0	2.8	2.5	2.2	0.4	4.8	9.9	48
3-4	0.6	1.8	1.2	1.1	0.2	3.4	5.9	58
4-5	0.7	1.8	2.0	1.7	0.3	3.6	7.6	47
5-6	0.8	2.4	1.9	1.7	0.3	3.5	7.4	47
6-7	0.7	2.0	1.7	2.0	0.2	3.0	6.9	43
7-8	1.1	4.6	3.2	3.1	0.3	3.9	10.5	37
8-9	3.1	13.3	5.7	9.8	0.4	16.2	32.1	50

Remarks:

Unirrigated native soil. Low in salts except in the 9-foot depth.

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* Location determined by projection of section lines.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 17

Location Number: T5S, R8E, Sec. 31F — Year Sampled: 1956

Soil: Sorrento clay — Crop: Walnuts

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter: Anion: Cl	Cations: Ca	Mg	K	Na	Total	% Na
0-1	0.6	1.7	1.5	1.1	0.1	3.4	6.1	56
1-2	0.6	2.2	1.2	0.6	0	3.5	5.3	66
2-3	0.7	2.5	1.9	0.8	0.1	3.5	6.3	55
3-4	0.8	2.7	2.4	1.1	0	4.5	8.0	56
4-5	0.9	3.4	2.4	1.2	0	4.8	8.4	57
5-6	1.0	4.2	2.5	1.1	0.1	6.2	9.9	63
6-7	1.1	5.3	2.2	1.1	0.1	7.0	10.4	67
7-8	1.2	6.4	2.2	1.0	0.1	7.4	10.7	69
8-9	1.2	5.5	2.2	1.0	0.1	8.3	11.6	71

Remarks:

Soil profile low in salts, indicating sufficient water has been applied to prevent the accumulation of salines.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 18

Location Number: T5S, R8E, Sec. 32E — Year Sampled: 1956

Soil: Sorrento clay loam — Crop: Apricots

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter: Anion: Cl	Cations: Ca	Mg	K	Na	Total	% Na
0-1	1.5	4.8	6.0	3.0	1.3	5.3	15.6	34
1-2	1.1	2.6	3.7	1.6	0.4	5.6	11.3	49
2-3	0.9	1.6	2.6	1.1	0.1	4.8	8.6	56
3-4	1.2	1.2	3.8	1.4	0.1	7.1	12.4	57
4-5	2.0	1.3	7.4	3.3	0.1	10.5	21.3	49
5-6	3.4	7.2	16.5	8.3	0.1	14.8	39.7	37
6-7	4.1	15.1	20.0	10.8	0.1	16.5	47.4	35
7-8	5.6	24.0	31.0	16.7	0	19.7	67.4	29
8-9	7.4	58.9	28.0	16.2	0	35.6	79.8	45

Remarks:

High concentration of salts in the subsoil.

This orchard had considerable evidence of salt injury the previous season and larger quantities of water were applied during the summer. The new growth this year appeared healthy when the orchard was sampled in the fall. Following this excess application of water considerable salinity remained in the subsoil below the 5-foot depth.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 19

Location Number: T6S, R8E, Sec. 5A — Year Sampled: 1956

Soil: Sorrento clay loam — Crop: Alfalfa

Electrical Conductivity in Millimhos ($EC \times 10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter: Anion	Cations					% Na
		Cl	Ca	Mg	K	Na	Total	
0-1	1.0	2.5	2.7	2.0	0.1	4.0	8.8	45
1-2		Too dry for sampling						
2-3		" " " "						
3-4	2.7	11.8	8.5	5.0	0	14.8	28.3	52
4-5	1.7	6.5	5.0	2.2	0	9.9	17.1	58
5-6	2.5	17.2	7.2	5.1	0.1	11.6	24.0	48
6-7	1.2	3.6	4.0	1.1	0	6.6	11.7	56
7-8	2.7	15.3	12.5	5.0	0	14.3	31.8	45
8-9	3.0	20.8	9.2	6.6	0.2	13.5	29.5	46

Remarks:

Some accumulation of salt in the 4- to 9-foot depth, but not in sufficient amounts to affect the growth or yield of alfalfa -- a salt tolerant plant.

The soil very dry to the depth of sampling and the lack of soil moisture was reflected in vegetative growth.

ANALYSES OF SOIL SAMPLES

District: West Stanislaus Irrigation **Site No.** 20

Location Number: T5S, R7E, Sec. 25 **Year Sampled:** 1956

Soil: Sorrento clay loam **Crop:** Almonds

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.2	2.2	1.5	0.1	7.9	11.7	67
1-2	3.0	7.5	7.5	0.1	17.7	32.8	54
2-3	5.2	16.5	22.5	0.2	20.6	59.8	34
3-4	4.9	18.0	29.0	0.2	11.7	58.9	20
4-5	3.5	13.5	20.4	0.2	5.6	39.7	14
5-6	3.5	12.5	19.7	0	5.6	37.8	15
6-7	3.3	10.5	17.5	0.2	7.3	35.5	20
7-8	3.2	10.0	15.9	0.1	7.9	33.9	23
8-9	3.3	10.2	15.4	0.2	8.4	34.2	24

Remarks:

The soil has a salt concentration of 3 millimhos in the 2 foot and 5.2 and 4.9 millimhos in the 3 and 4 foot respectively. Below this depth the soil contains about 3.4 millimhos.

The orchard showed severe salt or sodium injury for the Texas variety (the Texas variety is sensitive to sodium burn). In general, the irrigation practice has been to add only sufficient water to wet the soil 3 to 4 feet in depth. The highest percent sodium occurs in the surface 2 feet of soil, but no doubt the trees obtain most of their moisture from this area due to the shallow penetration of irrigation water.

ANALYSES OF SOIL SAMPLES

District: West Stanislaus Irrigation **Site No.** 21

Location Number: T5S, R7E, Sec. 36 **Year Sampled:** 1956

Soil: Sorrento clay loam **Crop:** Apricots

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	3.2	10.2	15.9	0.2	8.1	34.4	23
1-2	0.7	2.4	1.0	0.3	2.9	6.6	44
2-3	0.9	2.7	1.6	0.1	4.7	9.1	52
3-4	1.0	2.5	1.7	0	5.0	9.2	54
4-5	0.9	2.4	1.7	0	4.8	8.9	54
5-6	0.8	1.7	1.4	0	4.7	7.8	60
6-7	0.8	1.6	1.2	0	4.3	7.1	60
7-8	0.7	1.7	1.2	0	3.9	6.8	57
8-9	0.8	2.1	1.3	0.1	4.4	7.9	56

Remarks:

No salt accumulation is evident in the soil profile. Some salt was found in the surface foot, probably due to surface evaporation.

The trees were dying in this area -- a low part of the orchard where ample leaching has occurred, and death of the trees was due to causes other than salts. The rest of the orchard appeared healthy.

ANALYSES OF SOIL SAMPLES

District: West Stanislaus Irrigation **Site No.** 22

Location Number: T5S, R7E, Sec. 25 **Year Sampled:** 1956

Soil: Sorrento clay loam **Crop:** Apricots

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	0.9	2.0	1.4	0.1	4.7	8.2	57
1-2	0.8	2.5	1.2	0.2	3.5	7.4	47
2-3	1.5	4.2	1.9	0.1	8.5	14.7	58
3-4	3.6	15.0	10.2	0.2	17.7	43.1	41
4-5	3.3	13.0	10.4	0.1	11.4	34.9	33
5-6	4.9	21.0	19.7	0.1	10.2	51.0	20
6-7	1.2	4.2	3.5	0.1	4.1	11.9	34
7-8	1.0	2.6	2.3	0.1	3.5	8.5	41

Remarks:

The surface 3 feet of soil is free of salts, but the next 3 feet have an accumulation ranging from 3.3 to 4.9 millimhos. The last 2 feet show little or no salt deposits. The trees are relatively healthy with a fair amount of new growth being produced during the past year. It is apparent that the water from each irrigation penetrated only to a depth of 3 to 6 feet thus leaching the surface 3 feet and depositing salts in the next 3 feet of soil. If the present practice of irrigation without leaching the subsoil is continued, this orchard will be eventually in serious trouble from salt injury and may be approaching that condition now, as a general healthy appearance of the trees can be deceiving.

ANALYSES OF SOIL SAMPLES

District: Patterson Water **Site No.** 23

Location Number: -- **Year Sampled:** 1956

Soil: -- **Crop:** Weeds

Electrical Conductivity in Millimhos (ECx10^3) and analyses of soil saturation extract

Depth, feet	ECx10^3	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	0.6	2.6	1.2	0.2	1.5	5.5	27
1-2	0.9	2.5	1.2	0.1	4.3	8.1	53
2-3	1.2	3.7	2.1	0.1	5.5	11.4	48
3-4	1.8	6.5	4.6	0.1	7.5	18.7	40
4-5	3.6	15.7	12.0	0.4	14.1	42.2	33
5-6	3.8	13.5	10.8	0.2	16.2	40.7	40
6-7	3.6	9.5	7.7	0.2	17.0	34.4	49
7-8	3.3	8.0	5.9	0.2	17.0	31.1	55

Remarks:

Salt accumulation in the subsoil -- 5 to 8 feet.

This area has not been irrigated in recent years. Whether this build-up in concentration of salt is from earlier irrigations or due to the subbing of water from a canal a short distance away is difficult to determine. At the present time weeds are allowed to grow in this area.

ANALYSES OF SOIL SAMPLES

District: West Stanislaus Irrigation **Site No.** 24

Location Number: T4S, R7E, Sec. 30 **Year Sampled:** 1956

Soil: Sorrento clay loam **Crop:** Apricots

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.0	3.6	2.5	0.1	4.5	10.7	42
1-2	1.2	4.0	1.9	0.1	6.2	12.2	51
2-3	1.2	3.0	1.7	0.1	7.1	11.9	60
3-4	2.8	10.6	9.0	0.1	13.6	33.3	41
4-5	3.7	15.2	14.5	0.2	11.1	41.0	27
5-6	4.0	16.0	15.0	0.2	9.8	41.0	24
6-7	3.3	21.7	10.8	0.2	7.9	31.6	25
7-8	1.9	7.2	5.4	0.2	5.1	17.9	28

Remarks:

Low salts in the surface 3 feet and higher concentration of salts in 4 to 7-foot depth. (A discussion of this condition is given in Site 22).

A decline in vigor of the trees was noted in 1955 and this year (1956) the irrigation schedule was changed from 2 or 3 to 4 or 5 applications per season, which probably moved some of the salts downward.

ANALYSES OF SOIL SAMPLES

District: Patterson Water **Site No.** 25

Location Number: T5S, R8E, Sec. 16 **Year Sampled:** 1956

Soil: Rincon clay **Crop:** Field crops

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.4	4.0	2.2	0.1	8.1	14.4	56
1-2	1.8	4.0	2.7	0.2	10.6	17.5	60
2-3	2.3	6.2	3.5	0.1	13.2	23.0	57
3-4	3.1	7.0	3.9	0.1	18.9	29.9	63
4-5	2.3	4.5	2.2	0.1	14.5	21.3	68

Remarks:

Some accumulation of salines is evident even with good drainage below 5 feet where coarse gravel was encountered.

This soil type is noted for its low permeability.

ANALYSES OF SOIL SAMPLES

District: Patterson Water **Site No.** 26

Location Number: -- **Year Sampled:** 1956

Soil: -- **Crop:** Apricots

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.7	6.2	3.5	0.2	6.1	16.0	38
1-2	1.9	5.5	2.2	0.1	10.9	18.7	58
2-3	1.6	6.2	3.3	0.2	5.5	15.2	36
3-4	2.0	5.0	2.1	0.1	11.1	18.3	61
4-5	3.0	11.7	6.2	0.2	12.9	31.0	42

Remarks:

Some accumulation of salt in the surface 4 feet with increasing concentration in the 5-foot depth.

The trees were dead or dying but the salt concentration was probably not sufficiently high to kill them. The sampling was limited to 5 feet; whether or not the salts of the subsoil killed these trees is problematic.

ANALYSES OF SOIL SAMPLES

District: Patterson Water **Site No.** 27

Location Number: T5S, R8E, Sec. 32E **Year Sampled:** 1957

Soil: Sorrento clay loam **Crop:** Apricots

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	2.2	8.0	5.0	2.6	6.6	22.1	30
1-2	2.7	12.0	7.6	0.4	9.6	29.6	32
2-3	3.0	9.6	6.6	0.3	10.2	26.7	38
3-4	2.9	11.7	6.0	0.2	10.4	28.3	37
4-5	2.6	10.7	5.6	0.2	10.4	26.9	38
5-6	2.1	7.7	4.6	0.2	9.6	22.2	43
6-7	2.2	7.0	4.6	0.2	11.2	23.0	49
7-8	2.6	9.7	5.9	0.2	12.6	28.5	44
8-9	4.1	20.9	14.2	0.4	14.2	49.7	28

Remarks:

This is the same orchard as reported at Site 18, in 1956, but not at the same place. This year, 1957, an excess quantity of irrigation water was applied to leach the salts. The results show a salt concentration in the subsoil. A comparison for the two years is given in Figure 1A. The higher salt content in the surface 4 feet in 1957 is probably due to the different places of sampling for the two years. In 1955, the Farm Advisor found the soil contained a higher concentration of salts in the subsoil and a test for salt removal was conducted by applying excess irrigation water during the 1956 and 1957 season.* In summary, the 1955 results showed the conentration of salt for the 7, 8 and 9-foot depth of soil to be 4.1, 5.8 and 7.5 millimhos, respectively. After leaching, the salt content is below 3 millimos except for the 4.1 in the 8-9 foot depth.

* "Apricot Irrigation Studies", Clyde E. Houston and Jewell L. Meyers, California Agr. 12:9:6, 1958

ANALYSES OF SOIL SAMPLES

District: Patterson Water **Site No.** 28

Location Number: T5S, R8E, Sec. 28N* **Year Sampled:** 1957

Soil: Sorrento clay loam **Crop:** Apricots

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.9	5.7	4.2	0.2	9.4	19.5	48
1-2	2.4	6.5	5.8	0.2	13.1	25.7	51
2-3	4.7	19.9	17.7	0.4	24.6	26.7	39
3-4	5.1	11.0	11.7	0.9	32.6	56.2	58
4-5	6.0	21.0	21.5	0.5	33.5	76.5	44
5-6	6.6	23.9	24.3	0.9	43.6	92.6	47
6-7	4.6	8.6	9.6	0.4	31.4	50.1	63
7-8	4.1	6.9	7.9	0.4	30.0	45.3	66
8-9	3.2	5.2	5.7	0.4	22.6	34.0	66

Remarks:

This is the same orchard as reported at Site 15 in 1956, where a considerable number of trees died. In the meantime excess irrigation water has been applied to this orchard which resulted in a decrease in the salt content of the soil profile, Figure 1B. At the time the samples were taken in the fall of 1957, no apparent change in the appearance of the trees was noted. A tile drain has been installed in this area which should lower the water table and allow leaching of the salt.

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* Location determined by projection of section lines.

ANALYSES OF SOIL SAMPLES

District: West Stanislaus Irrigation | **Site No.** 29

Location Number: T5S, R7E, Sec. 24R | **Year Sampled:** 1957

Soil: Sorrento fine sandy loam | **Crop:** Young Orchard

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	3.0	10.7	9.7	1.0	9.1	30.6	30
1-2	2.8	10.7	8.8	1.2	10.0	30.7	32
2-3	1.9	5.0	4.6	0.6	7.8	18.0	43
3-4	2.1	6.0	5.8	0.3	10.1	22.2	45
4-5	2.4	4.8	4.8	0.2	9.7	19.5	50
5-6	2.4	3.7	4.4	0.2	15.2	23.5	64
6-7	2.0	2.0	2.9	0.2	14.8	19.9	74
7-8	2.1	2.0	3.3	0.2	15.5	21.0	74
8-9	1.8	1.7	3.1	0.2	12.9	18.0	72

Remarks:

Some accumulation of salts has occurred in this profile. Before planting the young orchard the area had been in field crops.

ANALYSES OF SOIL SAMPLES

District: Patterson Water **Site No.** 30

Location Number: T5S, R7E, Sec. 13L **Year Sampled:** 1957

Soil: Sorrento loam **Crop:** Apricots

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.2	2.6	3.1	0.3	6.1	12.1	50
1-2	1.1	2.5	2.9	0.3	5.8	11.5	51
2-3	1.8	4.0	3.6	0.2	9.6	17.4	55
3-4	1.6	3.7	3.3	0.2	8.0	15.3	52
4-5	2.6	5.5	7.5	0.2	12.3	25.6	48
5-6	3.3	5.5	11.2	0.4	17.4	34.5	50
6-7	3.6	6.2	17.2	0.4	16.3	40.2	41
7-8	2.8	4.6	13.4	0.4	11.8	30.2	39
8-9	2.1	4.0	11.2	0.4	6.4	22.0	29

Remarks:

Salt accumulation below 4 feet.

The orchard is 15 years old and considered healthy at present. It is apparent that additional water should be applied for leaching to remove and prevent the accumulation of salts in the subsoil.

By estimation, the farmer applied about 30 inches of irrigation water a year.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 31

Location Number: T5S, R8E, Sec. 33B* — Year Sampled: 1957

Soil: Sorrento clay loam — Crop: Alfalfa

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter: Ca	Mg	K	Na	Total	% Na
0-1	1.6	4.7	3.6	0.4	8.4	17.1	49
1-2	1.6	3.5	2.1	0.2	10.6	16.4	65
2-3	7.0	23.9	15.0	0.9	33.0	72.8	45
3-4	11.5	41.2	31.4	1.3	58.3	132.3	44
4-5	7.7	26.7	19.6	0.9	46.3	93.4	50
5-6	4.3	8.6	6.8	0.4	23.1	39.0	59
6-7	3.3	8.0	6.3	0.2	20.7	35.3	59
7-8	2.6	5.7	4.6	0.2	16.6	27.2	61
8-9	2.2	5.2	3.8	0.2	12.0	21.3	56

Remarks:

A high salt concentration at or just above a water table between 4 and 5 feet.

The alfalfa is growing poorly, which no doubt is due to the 7 to 11.5 millimhos salt concentration in the zone of root activity.

* Location determined by projection of section lines.

ANALYSES OF SOIL SAMPLES

District: Central California Irrigation **Site No.** 32

Location Number: T6S, R8E, Sec. 23J* **Year Sampled:** 1957

Soil: Sorrento loam **Crop:** Walnuts

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.0	3.4	2.9	0.3	3.5	10.1	35
1-2	0.8	2.7	1.7	0.1	3.2	7.9	41
2-3	0.9	2.8	1.5	0.2	3.7	9.2	40
3-4	0.8	2.7	1.7	0.1	3.0	7.4	40
4-5	0.7	2.8	1.8	0.1	2.1	6.9	31
5-6	0.8	3.0	2.0	0.1	1.7	6.7	25
6-7	0.7	3.2	2.1	0.1	1.5	7.0	22
7-8	0.7	2.6	1.9	0.1	1.2	5.8	21
8-9	0.7	3.1	2.1	0.1	1.3	6.6	20

Remarks:

Low salt level in the soil profile.

Considerable burning of the leaves occurred late in the season. Additional soil samples by the Farm Advisor indicated this is not a salt problem. It was evident from the grower's irrigation practice, ample water was being applied to leach the salts.

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* Location determined by projection of section lines.

ANALYSES OF SOIL SAMPLES

District: Banta-Carbona Irrigation **Site No.** 33

Location Number: T3S, R5E, Sec. 13Q **Year Sampled:** 1957

Soil: Ambrose clay **Crop:** Almonds

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.6	5.5	4.1	0.4	5.6	15.6	36
1-2	1.8	5.4	3.7	0.2	10.3	19.6	53
2-3	2.3	3.5	2.7	0.2	16.6	23.1	72
3-4	2.2	2.5	1.7	0.6	17.0	21.8	78
4-5	2.6	4.0	1.5	0.4	19.7	25.7	77
5-6	2.1	3.0	1.1	0.4	14.6	19.2	76

Remarks:

Some salt accumulation in the soil profile with a large amount of sodium.

This almond orchard is 20 years old and sodium burn of the leaves first showed in 1948. This was confirmed by leaf analyses in 1951 by Dr. Lilleland. Since then larger applications of irrigation water have been applied and the severity of the leaf burn has declined. The soil analyses indicate the total salt concentration is not particularly high, averaging slightly more than 2 millimhos but the sodium, 72 to 78 percent, is relatively high in the subsoil when compared to the other sites.

ANALYSES OF SOIL SAMPLES

District: Banta-Carbona Irrigation **Site No.** 34 to 41 inclusive

Location Number: T3S, R6E, Sec. 9 NW$\frac{1}{4}$ **Year Sampled:** 1957

Soil: Rincon clay loam and Rincon clay **Crop:** Field crops

Electrical Conductivity in Millimhos (ECx10^3) and analyses of soil saturation extract

Depth, feet	ECx10^3	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
			Site No. 34				
0-1	2.1	8.0	6.2	0.4	6.3	21.0	30
1-2	0.7	2.1	1.7	0.1	3.3	7.2	45
2-3	0.7	1.7	1.5	0.1	3.4	6.6	51
3-4	0.9	2.4	2.3	0.1	4.2	9.0	47
4-5	0.9	2.7	2.1	0.1	3.9	8.9	44
5-6	0.7	1.8	1.6	0.1	2.5	6.0	41
6-7	0.9	2.2	2.1	0.1	3.3	7.7	43
7-8	0.7	1.8	1.6	0.1	3.1	6.6	47
8-9	0.7	1.9	1.8	0.1	3.2	7.0	46
9-10	0.8	2.0	1.9	0.1	3.4	7.4	46
			Site No. 35				
0-1	0.8	1.6	2.0	0.1	4.0	7.6	52
1-2	0.9	1.6	2.3	0.1	4.5	8.5	53
2-3	1.1	2.3	3.5	0.1	5.4	11.3	48
3-4	0.8	1.5	2.4	0.1	4.2	8.2	51
4-5	0.9	1.7	2.7	0.1	4.2	8.7	48
5-6	0.9	1.8	2.8	0.1	4.3	9.1	48
6-7	1.0	2.0	3.0	0.1	4.5	9.6	47
7-8	0.9	1.8	2.3	0.1	4.2	8.4	50
			Site No. 36				
0-1	3.0	8.2	10.7	0.5	10.1	29.6	34
1-2	1.9	5.0	5.1	0.2	7.6	18.0	42
2-3	3.8	12.8	11.7	0.2	12.8	37.4	34
3-4	9.6	40.7	33.3	0.4	28.3	102.7	27
4-5	6.4	26.4	19.6	0	22.1	68.1	32
5-6	3.6	13.7	10.7	0.2	10.5	35.1	30
6-7	3.6	13.7	11.6	0.2	9.8	35.2	28
7-8	3.9	17.9	15.7	0.2	10.7	44.5	24
8-9	3.3	14.1	8.8	0.2	12.9	36.1	36

ANALYSES OF SOIL SAMPLES

District: Banta-Carbona Irrigation

Site No. 34 to 41 inclusive (continued)

Location Number: T3S, R6E, Sec. 9 $NW\frac{1}{4}$

Year Sampled: 1957

Soil: Rincon clay loam and Rincon clay

Crop: Field crops

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
			Site No. 37				
0-1	1.6	3.9	5.0	0.1	7.2	16.2	44
1-2	1.2	1.7	2.8	0.1	6.8	11.3	60
2-3	1.1	1.2	1.9	0.1	7.0	10.1	69
3-4	1.3	2.0	2.3	0.1	7.6	12.1	63
4-5	1.6	4.2	3.4	0.2	7.5	15.3	49
5-6	1.6	4.3	3.7	0.2	6.7	14.9	45
6-7	1.7	4.3	4.0	0.2	7.1	15.5	45
7-8	1.7	4.8	4.8	0.2	7.0	15.7	44
8-9	3.9	26.1	14.9	0.5	7.9	49.4	16
			Site No. 38				
0-1	2.4	5.5	6.5	0.2	10.8	23.0	47
1-2	3.2	9.6	9.0	0.4	12.6	31.6	40
2-3	2.2	4.3	6.1	0.1	10.5	21.0	50
3-4	1.8	3.5	4.8	0.9	8.7	17.1	51
4-5	1.9	4.2	5.3	0.2	8.7	18.3	47
5-6	2.3	5.0	6.7	0.2	10.3	22.2	46
6-7	1.6	3.5	4.1	0.2	7.3	15.0	48
7-8	1.9	4.3	4.6	0.2	8.0	17.2	47
8-9	2.1	5.4	5.3	0.2	8.6	19.5	44
9-10	1.6	9.3	7.6	0.4	12.4	29.8	42
			Site No. 39				
0-1	4.3	5.7	6.2	0.2	29.9	41.9	71
1-2	4.7	4.2	4.9	0.2	25.6	34.9	73
2-3	2.2	1.8	1.7	0.2	15.8	19.5	81
3-4	1.4	0.9	0.8	0.2	12.1	14.1	86
4-5	1.1	0.9	0.5	0.1	9.2	10.7	86
5-6	1.3	0.9	0.6	0.1	10.0	11.6	86
6-7	1.4	1.0	0.8	0.1	10.7	12.6	85
7-8	1.4	1.0	0.7	0	10.4	12.1	86
8-9	1.4	1.1	0.7	0.1	10.7	12.6	85

ANALYSES OF SOIL SAMPLES

District: Banta-Carbona Irrigation

Site No. 34 to 41 inclusive (continued)

Location Number: T3S, R6E, Sec. 9 NW$\frac{1}{4}$

Year Sampled: 1957

Soil: Rincon clay loam and Rincon clay

Crop: Field crops

Electrical Conductivity in Millimhos (ECx10^3) and analyses of soil saturation extract

Depth, feet	ECx10^3	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
				Site No. 40			
0-1	1.0	2.3	2.3	0.1	4.4	9.2	48
1-2	1.2	2.7	2.7	0.1	6.5	12.0	54
2-3	1.5	2.1	2.7	0.2	8.9	13.9	64
3-4	2.6	3.9	5.1	0.12	18.4	27.6	67
4-5	3.4	5.2	6.8	0.4	24.9	37.3	67
5-6	3.2	5.0	5.8	0.4	22.8	34.1	67
6-7	2.9	4.1	4.6	0.2	20.3	29.2	69
				Site No. 41			
0-1	2.0	4.1	5.1	0.1	9.7	19.0	51
1-2	2.3	4.6	5.0	0.2	13.9	23.6	59
2-3	2.0	3.5	3.9	0.2	12.1	19.8	61
3-4	1.8	5.0	4.2	0.4	7.7	17.3	44
4-5	3.0	14.9	9.9	0.4	8.8	34.0	26
5-6	4.5	28.6	16.7	0.4	8.1	53.7	15
6-7	4.4	29.4	17,4	0.2	8.1	55.1	15
7-8	3.4	18.5	10.4	0.7	9.8	39.3	25
8-9	2.7	5.7	3.5	0.1	5.7	15.0	38

Remarks: (See following page)

Remarks:

The eight sites, 34 to 41, illustrate the variability of soil salinity. These samples were taken in conjunction with a water table investigation by the Agricultural Extension Service, and were obtained on the same quarter section of land, where the water table at the first site for the irrigation section was below 10 and at approximately 7 feet for the latter sites, respectively. The first two sites showed no increase in salts, but No. 36 had a salt concentration of 3 millimhos or above, with the exception of the 2-foot depth,and the highest salinity, 9.6 millimhos, was at the 4-foot depth. Site No. 37 was on the south edge and approximately mid-point of the quarter while No. 8 was in the southeast corner; the water table during the irrigation season was approximately 6 and 10 feet, respectively. Only a slight increase in salt was noted for Site 37, but it was fairly uniform for the entire depth of the profile except at the 9-foot depth. In the southeast corner, No. 38 showed some accumulation of salt with an average concentration for the profile of 2.1 millimhos. Samples from three sites, 39, 40, and 41, were taken from east to west through the center of the quarter. In this area, the water table for the irrigation season was about 6 feet from the surface. All three sites showed a build-up in salinity. At Site No. 39, this occurred in the surface 3 feet, while for the other two locations the highest concentration was found in the subsoil. However, Site No. 41 had a salinity of 2 or more millimhos in the surface 3 feet. The first five sites, 34 through 38, were on the edge of the field and there is some question as to the amount and adequacy of irrigation water. Site 34 was at the high point in the field, and it is questionable whether this spot was ever irrigated, therefore it may be considered as the check, where no salt has accumulated. Since Rincon soils are low in permeability, farming this area to field crops has not prevented some accumulation of salts as indicated at Sites 39, 40 and 41.

ANALYSES OF SOIL SAMPLES

District: Banta-Carbona Irrigation **Site No.** 42

Location Number: T3S, R6E, Sec. 9 NW¼ **Year Sampled:** 1957

Soil: Rincon clay loam and Rincon clay **Crop:** Field crops

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.0	2.2	2.5	0.1	4.9	9.7	51
1-2	2.3	4.6	5.3	0.1	12.8	22.8	56
2-3	5.1	15.2	15.3	0	24.4	55.0	44
3-4	4.2	13.7	11.1	0.5	17.4	42.7	41
4-5	2.4	8.0	4.8	0.2	10.1	73.2	44
5-6	2.2	8.3	4.7	0.2	8.5	21.7	39

Remarks:

Accumulation of salts below the surface foot soil has occurred.

The yield of sugar beets appeared about average and they can tolerate this salt concentration if sufficient irrigation water is applied.

ANALYSES OF SOIL SAMPLES

District: Patterson Water and adjacent lands[a] — Site No. 43 to 61

In cooperation with the Stanislaus County Farm Advisor a general survey was made for salts in field crop soils. Exceptions were at Sites 54 and 56 where the respective crops were rice and alfalfa. Electrical conductivity in Millimhos (EC x 10^3) for the saturated extracts of soil according to location and depth are listed below:

Site	Location	Soil series	Depth feet	$ECx10^3$
43	T5S, R8E, Sec 20P[b]	Sorrento clay loam	0-1.5	0.8
			1.5-6.5	1.6
44	T5S, R8E, Sec 29P[b]	Sorrento clay loam	0-1	1.0
			1-1.5	1.1
45	T5S, R8E, Sec 29K[b]	Sorrento clay loam	0-2.5	1.0
			2.5-4.0	1.0
			4-6	1.5
46	T5S, R8E, Sec 20F[b]	Sorrento clay loam	0-2.5	0.7
			2.5-4.2	0.8
			4.5-6.5	0.7
47	T5S, R8E, Sec 34F[b]	Rincon clay	0-3	3.3
			3-6	7.3
			6-8	1.3
			8-10	1.1
48	T5S, R8E, Sec 6D	Sorrento loam	0-2	0.8
			2-4	0.9
			4-6	0.9
			6-8	0.8
			8-10	0.8
49	T5S, R8E, Sec 34K	Rincon clay	0-2	4.8
			2-4	4.0
			4-6	3.8
			6-8	5.2
			8-10	2.2
50	T6S, R8E, Sec 8D	Sorrento clay loam	0-2	0.8
			2-4	0.9
			4-6	0.8
			6-8	0.7
			8-10	0.7

Site	Location	Soil series	Depth feet	ECx10[3]
51	T6S, R8E, Sec 29D	Sorrento loam	0-2	1.4
			2-4	0.9
			4-6	0.8
			6-8	0.8
			8-10	0.8
52	T6S, R8E, Sec 19A	Ambrose clay (adobe)	0-2	1.5
			2-4	1.7
			4-6	1.4
			6-8	3.5
			8-10	2.9
53	T5S, R8E, Sec 34N[b]	Sorrento clay loam	0-2	1.3
			2-4	1.9
			4-6	1.5
			6-8	1.3
			8-10	1.2
54	T5S, R8E, Sec 35E[b]	Rincon clay	0-2	1.1
			2-4	1.6
			4-6	1.6
			6-8	1.9
			8-10	2.9
55	T6S, R8E, Sec 14E[b]	Sorrento clay loam	0-2	---
			2-4	1.4
			4-6	1.8
			6-8	1.7
			8-10	2.6
56	T6S, R9E, Sec 7E[b]	Sorrento fine-sandy loam	0-2	0.8
			2-4	0.7
			4-6	0.8
			6-8	0.8
			8-10	0.6
57	T6S, R9E, Sec 7G[b]	Orestimba clay loam	0-2	10.0
			2-4	7.5
			4-6	2.4
			6-8	3.9
			8-10	4.1
58	T6S, R8E, Sec 33R	Sorrento clay loam	0-2	0.6
			2-4	0.6
			4-6	1.0
			6-8	1.9
			8-10	1.3

Site	Location	Soil series	Depth feet	$ECx10^3$
59	T6S, R9E, Sec 32G[b]	Sorrento fine sandy loam	0-2	0.6
			2-4	0.8
			4-6	0.8
			6-8	0.6
			8-10	0.6
60	T6S, R9E, Sec 20C[b]	Orestimba clay loam	0-2	5.7
			2-4	8.1
			4-6	0.7
			6-8	5.9
			8-10	4.6
61	T6S, R9E, Sec 20A[b]	Merced clay loam	0-2	3.3
			2-4	3.3
			4-6	4.0
			6-8	3.3
			8-10	3.8

Remarks:

The salts are low except at Sites 47, 49, 57, 60 and 61, which are areas having a high water table and poor drainage. In general, these soils are heavy with a low permeability.

Site 52 is not in a high water table area, but due to its plastic nature and low permeability some salts have accumulated in the subsoil.

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a. Adjacent lands are south of Patterson Water District in the vicinity of Crow's Landing and lie within the following organized districts: Central California Irrigation District (55-57 and 59-61); Orestimba Water District (58); Salado Water District (50); and Sunflower Water District (51,52).

b. Location determined by projection of section lines.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 62

Location Number: T5S, R8E, Sec. 31 — Year Sampled: 1958

Soil: Sorrento loam — Crop: Apricots and Walnuts

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	0.5	3.5	1.8	0.2	1.4	6.9	20
1-2	0.9	4.2	2.5	0.1	3.5	10.3	34
2-3	1.0	4.0	2.2	0	5.6	11.8	48
3-4	1.2	3.7	1.7	0	5.8	11.3	52
4-5	0.8	3.0	1.5	0	4.8	9.2	52
5-6	0.7	3.0	1.3	0	4.3	8.6	50
6-7	0.7	2.0	1.0	0	5.3	8.2	64
7-8	0.8	1.6	1.3	0.1	6.9	9.9	70
8-9	1.2	3.2	1.8	0	8.5	13.6	62

Remarks:

Salts in the soil profile are low.

The' apricot orchard is interplanted with young walnuts.

ANALYSES OF SOIL SAMPLES

District: Patterson Water **Site No.** 63

Location Number: T5S, R8E, Sec. 31 **Year Sampled:** 1958

Soil: Sorrento loam **Crop:** Apricots and walnuts

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	0.6	2.7	1.3	0	2.1	6.2	34
1-2	0.5	2.5	1.0	0	3.2	6.7	48
2-3	0.6	2.2	1.0	0	4.6	7.8	59
3-4	0.5	2.2	1.0	0	4.4	7.7	57
4-5	1.0	3.2	1.5	0	5.1	9.8	52
5-6	0.5	2.5	1.2	0	4.1	7.9	52
6-7	0.7	2.7	1.5	0	4.4	8.6	51
7-8	0.6	2.5	1.2	0	3.6	7.4	49
8-9	0.9	3.2	1.7	0	4.8	9.7	49

Remarks:

Salts in the soil profile are low.

The apricot orchard is interplanted with young walnuts.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 64

Location Number: T5S, R7E, Sec. 12A* — Year Sampled: 1958

Soil: Sorrento loam — Crop: Apricots

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.0	3.7	2.9	0.3	4.4	11.4	39
1-2	0.8	2.2	1.7	0.1	5.1	9.1	54
2-3	0.7	2.5	1.6	0	5.3	9.4	56
3-4	0.9	2.2	1.8	0	6.0	10.1	59
4-5	1.0	3.5	2.3	0	7.0	12.8	54
5-6	0.8	3.0	1.6	0	6.1	10.7	57
6-7	1.0	1.7	1.2	0.1	8.5	11.6	73
7-8	1.2	1.7	1.5	0	10.4	13.6	76
8-9	1.5	2.2	2.5	0.1	12.0	16.8	71
9-10	1.5	2.2	2.3	0	12.3	16.8	73

Remarks:

The soil profile is low in salts.

*Location determined by projection of section lines.

ANALYSES OF SOIL SAMPLES

District: Patterson Water **Site No.** 65

Location Number: T5S, R8E, Sec. 15* **Year Sampled:** 1958

Soil: Dinuba fine sand **Crop:** Alfalfa

Electrical Conductivity in Millimhos ($ECx10^3$) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Cations in Milliequivalents per liter					% Na
		Ca	Mg	K	Na	Total	
0-1	1.2	3.2	3.8	0	6.4	14.5	44
1-2	0.7	1.5	1.2	0	4.4	7.2	62
2-3	0.8	2.2	1.7	0.1	4.2	8.2	52
3-4	1.2	4.2	3.3	0	4.6	12.2	38
4-5	1.3	4.5	5.0	0.1	4.4	14.0	31
5-6	0.9	2.0	3.9	0.1	3.6	9.5	38
6-7	0.8	2.0	1.2	0.1	3.1	8.3	37
7-8	0.7	2.0	2.7	0	3.0	7.7	39
8-9	0.8	1.6	2.2	0.2	3.5	7.5	47
9-10	0.9	1.7	2.7	0.2	4.1	8.6	48

Remarks:

The soil profile is low in salts.

* Location determined by projection of section lines.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No.: 66

Location Number: T5S, R8E, Sec. 21F* — Year Sampled:

Soil: Sorrento clay loam — Crop: Field Crops

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								%
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	Na
0-1	1.0	2.6	3.7	2.0	2.5	1.0	0.1	5.6	9.2	60
1-2	1.5	4.0	3.4	7.0	1.4	0.7	0.2	12.0	14.2	84
2-3	5.1	2.3	9.3	42.0	9.2	6.7	0.5	41.8	58.1	72
3-4	11.4	1.7	45.9	99.5	23.0	18.7	1.1	107.6	150.5	71
4-5	12.9	1.7	78.6	89.2	25.2	20.8	1.1	126.1	173.3	73
5-6	10.7	1.1	54.9	88.4	32.5	20.0	1.1	96.7	150.4	64
6-7	10.5	1.7	54.4	85.8	30.0	18.7	1.1	93.9	143.8	65

Remarks:

The subsoil is very high in salines. This site is close to the trough of the valley and accumulation, no doubt, is due to poor drainage. The analyses indicate the presence of gypsum below the 4-foot depth.

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* Location determined by projection of section lines.

ANALYSES OF SOIL SAMPLES

District: Patterson Water — Site No. 67

Location Number: T5S, R8E, Sec. 22* — Year Sampled: 1958

Soil: Rincon clay — Crop: Alfalfa

Electrical Conductivity in Millimhos (EC x 10^3) and analyses of soil saturation extract

Depth, feet	$ECx10^3$	Milliequivalents per liter								% Na
		Anions			Cations					
		HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total	
0-1	1.1	6.8	2.1	1.2	1.8	1.9	0.1	5.7	9.6	60
1-2	1.0	5.7	1.4	3.6	1.1	1.2	0.1	7.4	10.0	75
2-3	1.1	4.6	0.8	5.7	0.9	0.8	0.1	8.4	10.3	82
3-4	6.0	2.0	3.4	78.9	19.4	33.6	0	35.6	88.6	40
4-5	7.2	1.3	11.8	87.9	25.0	41.6	0.5	46.5	113.6	41
5-6	8.7	1.4	19.6	109.8	25.0	54.1	0.5	60.3	139.9	43
6-7	11.7	1.1	30.7	101.2	27.5	72.9	0	83.7	184.1	45
7-8	12.5	1.7	40.8	154.4	27.5	87.5	0	91.3	206.3	44
8-9	13.2	1.7	44.8	148.4	25.2	90.8	0	91.3	207.4	44
9-10	12.5	1.7	36.1	147.6	27.5	81.7	0	91.3	200.5	45

Remarks:

High salinity in the soil profile below the 4-foot depth. This site is close to the trough of the valley and is probably due to poor drainage. The analyses indicate the presence of gypsum below 5 feet.

The alfalfa is not healthy and spots in the field show leaf burn. The salts are sufficiently high below 3 feet to cause this condition.

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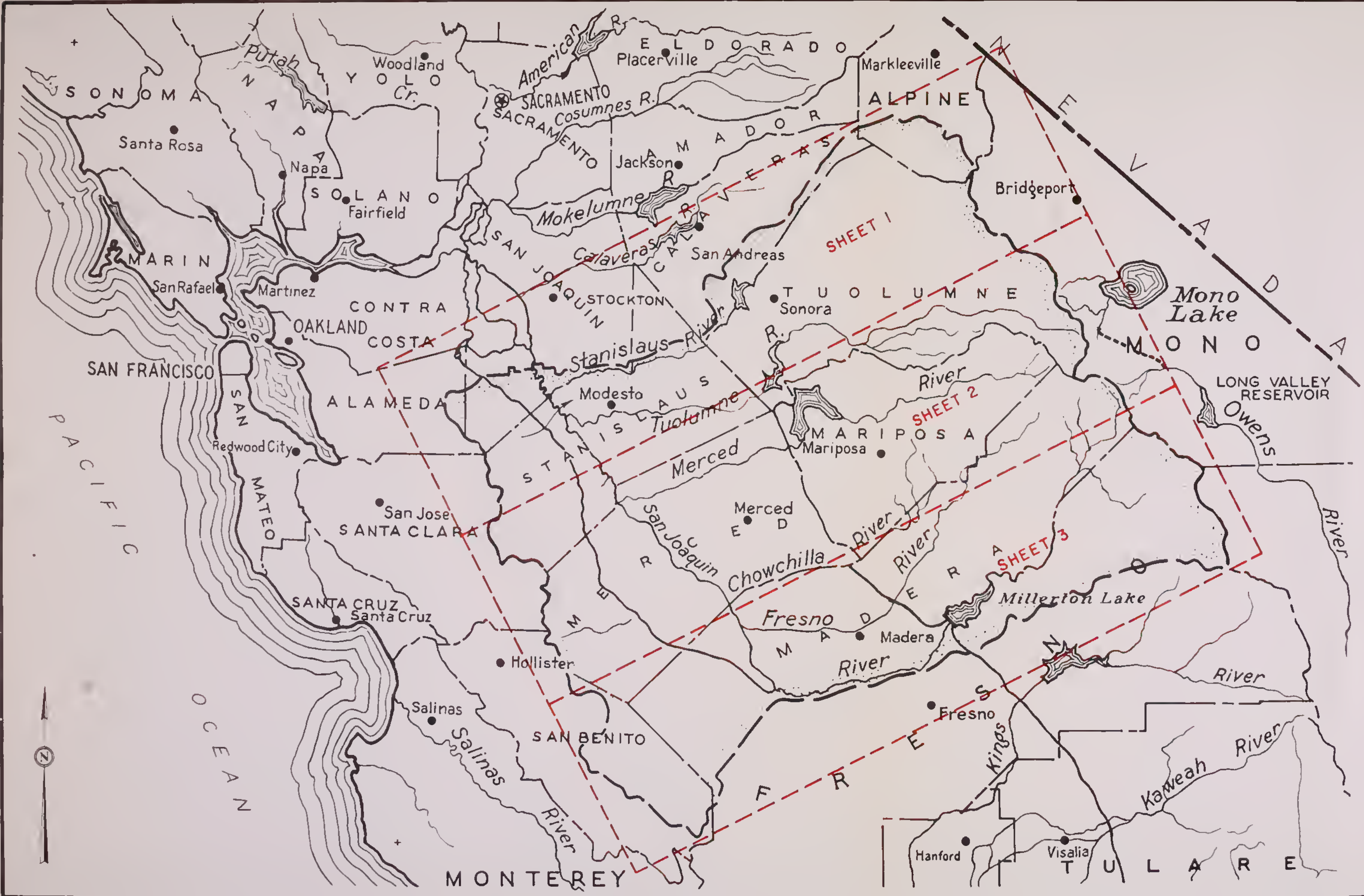
* Location determined by projection of section lines.

29979 12-60 600



LOCATION OF AREA OF INVESTIGATION

LEGEND

BOUNDARY OF INVESTIGATED AREA

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
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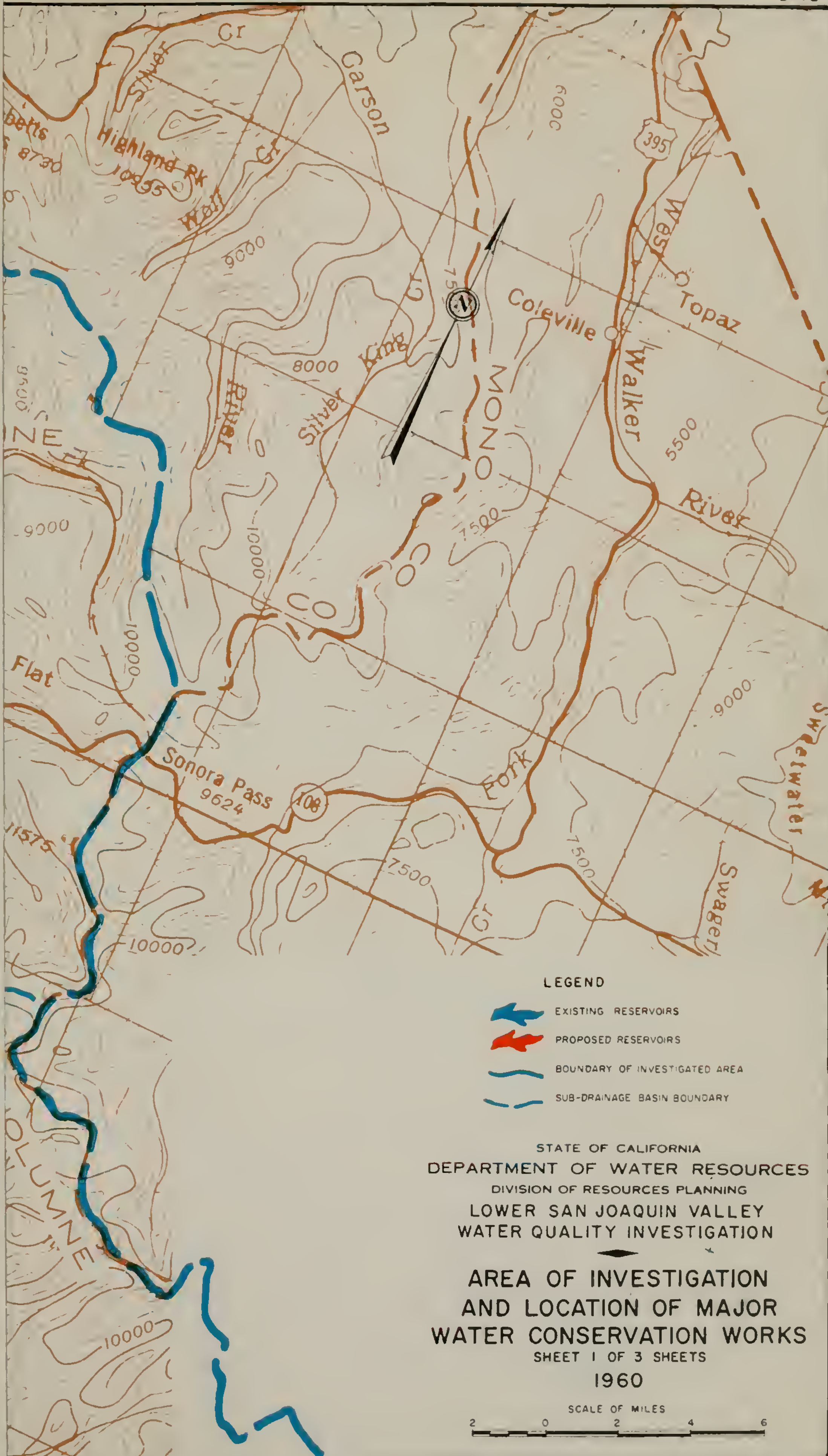
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

AREA OF INVESTIGATION
AND LOCATION OF MAJOR
WATER CONSERVATION WORKS
1960
INDEX TO SHEETS

SCALE OF MILES
10 0 10 20



STATE OF CALIFORNIA
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WATER QUALITY INVESTIGATION

AREA OF INVESTIGATION
AND LOCATION OF MAJOR
WATER CONSERVATION WORKS
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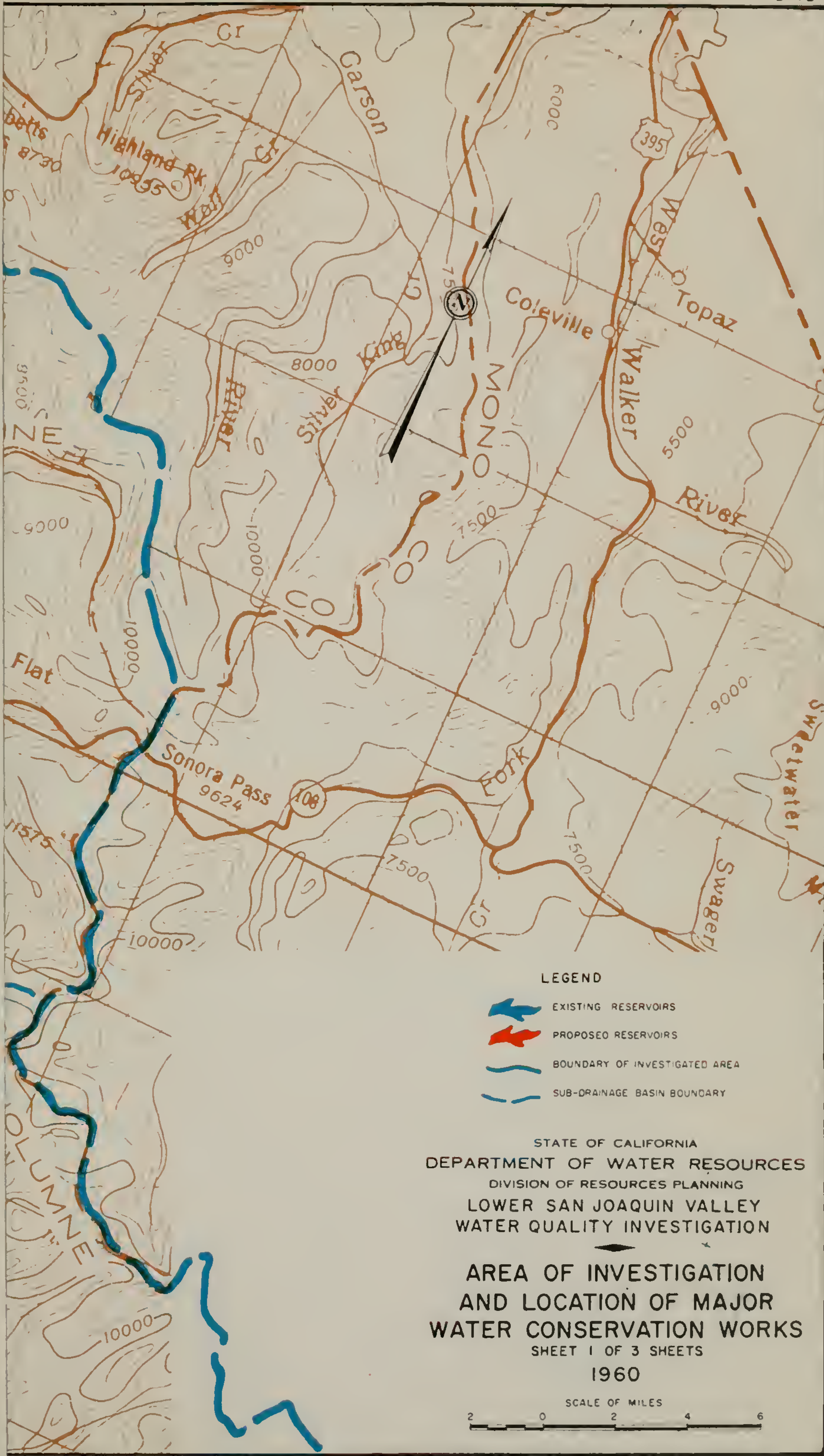
1960

PLATE I



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
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LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

AREA OF INVESTIGATION
AND LOCATION OF MAJOR
WATER CONSERVATION WORKS
SHEET 1 OF 3 SHEETS
1960

CONTRA COSTA CO
ALAMEDA CO
Byron
Holt
MOKELUMNE
Calaveras
Waterloo
STOCKTON
Linden
Bellota
Peters
Valley Spr
Kentucky House
San Andreas
Jenny Lind
River
Bear Mountains
Altamont
Livermore
French Camp
Lathrop
Duck
Littlejohns
Collegeville
Turner
Farmington
Milton
Altaville
Tracy
Banta
Manteca
SAN JOAQUIN
STANISLAUS CO
CALAVERAS CO
Rock
Farmington Res
Copperopolis
Corral
Hollow
Carbona
MENDOTA
DELTA
PACIFIC
SOUTHERN
WESTERN
TIDEWATER
ATCHISON
TOPEKA
Escalon
Eugene
DIABLO
Woodward Res
Valley Home
TULLOCH RES.
Ripon
Salida
Vernalis
Hospital
SAN JOAQUIN
STANISLAUS
CANAL
Riverbank
Oakdale
STANISLAUS
Knights Ferry
Table Mountain
Keystone
HETCH HETCHY AQUEDUCT
Modesto
Empire
TUOLUMNE
Ceres
Hughson
Waterford
Keyes
Westley
Patterson
RIVER
Cooperstown
Dallas Warner Res
Don Pedro Res
Jacksonville
Chinese
SANTA CLARA CO
Cedar Mtn
Valle
Del Puerto
Salado
Gopher Ridge


LEGEND
EXISTING RESERVOIRS
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SCALE OF MILES
STANISLAUS BASIN
TUOLUMNE BASIN
STANISLAUS RIVER
TUOLUMNE RIVER
San Andreas
Mountain Ranch
Sheep Ranch
Altaville
Angels Camp
Vallecito
Murphys
Columbia
Tuttletown
NEW MELONES RES.
Sonora
Jamestown
Standard
Soulsbyville
Tuolumne
Chinese Camp
Jacksonville
Groveland
Moccasin
NEW DON PEDRO RES.
Big Oak Flat
Don Pedro Res.
White Pines
Hathaway Pines
Dorrington
Big Meadows
Bull Run Pk 9489
Ebbetts Pass 8730
Highland Pk 10935
Spicer Meadows Res
DONNELL RES
BEARDSLEY RES
Dardanelle
Douglas Flat
Relief Res
Sonora Pass 9624
Strawberry Res
Pinecrest
Long Barn
Cherry Valley Res
Eleanor Res
Duckwall Mtn 5859
ALPINE CO
MONO CO
CALAVERAS CO
TUOLUMNE CO
Coleville
Topaz
Walker River
BASE LINE

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AREA OF INVESTIGATION
AND LOCATION OF MAJOR
WATER CONSERVATION WORKS
SHEET 2 OF 3 SHEETS
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Mt Stakes 3806
SANTA CLARA CO
Orestimba
Crow
Creek
Garzas
Pacheco
Quinto
Romero
SAN LUIS RES
Pacheco Pass 1386
Bells Sta
Pacheco Pk 2772
Cathedral Pk
SAN BENITO CO
MERCED CO
Los Banos Cr
Fork
DELTA
SOUTHERN PACIFIC
MENDOTA
CANAL
Crows Ldg
Newman
Hills Ferry
Gustine
Volta
Los Banos
STANISLAUS CO
MERCED CO
Turlock
Denair
Montpelier
Hilmar
Irwin
Delhi
MERCED RIVER
Livingston
Cressey
Stevinson
SAN JOAQUIN RIVER
Winton
Atwater
Merced
Bear
Fahrens
Burns Creek Res
Yosemite L
Burns
Tuttle Creek
Owens
Owens Creek Res
Planada
Creek
Deadman
Plainsburg
Athlone
Le Grand
El Nido
Chowchilla River
MADERA CO
MODESTO CANAL
Owen Res
La Grange
Blanchard
Dry Creek
Snelling
SNELLING RES
Merced Falls
Lake McClure
MERCED CO
MARIPOSA CO
Hornitos
Mariposa Creek
Bear Creek

LEGEND
EXISTING RESERVOIRS
PROPOSED RESERVOIRS
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1960
SCALE OF MILES
TUOLUMNE RIVER BASIN
MERCED RIVER BASIN
CHOWCHILLA RIVER BASIN
FRESNO RIVER BASIN
MERCED RIVER PROJECT
TUOLUMNE CO
MARIPOSA CO
MADERA CO
MONO
MONO LAKE
CATHEDRAL RANGE
Hetch Hetchy Res
Don Pedro Res
NEW DON PEDRO RES
NEW EXCHEQUER RES
BAGBY RES
WINDY GAP RES.
Lake McClure
Bear Creek Res
Mariposa Creek Res
Coulterville
Buck Meadow
Mather
Bald Mtn 7338
Tuolumne Meadows
Tioga Pass 9941
Mt Dana 13050
Leevining
Mono Lake
Mt Lyell
El Portal
Incline
Briceburg
Midpines
Mt Bullion
Hornitos
Bear Valley
Bagby
Mariposa
Mormon Bar
Cathay
Schultz Mtn 2287
Usona
Wawona
Fish Camp
Sugar Pine
Nipinnawasee
Ahwahnee
Grubgulch
Ben Hur
Merced Falls
Blanchard

LEGEND

EXISTING RESERVOIRS

PROPOSED RESERVOIRS

BOUNDARY OF INVESTIGATED AREA

SUB-DRAINAGE BASIN BOUNDARY

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

AREA OF INVESTIGATION AND LOCATION OF MAJOR WATER CONSERVATION WORKS

SHEET 3 OF 3 SHEETS

1960

SCALE OF MILES

2 0 2 4 6

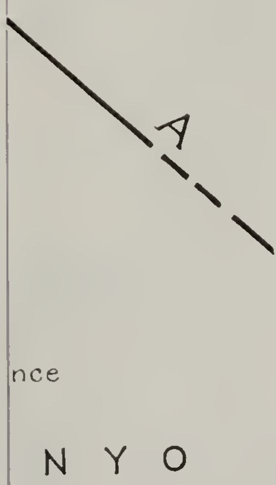
South Dos Palos
Dos Palos
DELTA
MERCED CO
FRESNO CO
Oryguita Pk
MENDOTA
Firebaugh
Lone Willow Slough
Ash
Dairyland
Chowchilla
Chowchilla River
Creek
Fairmead
Sharon
Berenda
Berenda Cr
Daulton
MADERA
Madera
SAN BENITO CO
PANOCHE HILLS
Little Panoche Cr
Panoche Pass
Llanada
Panoche
Panoche Creek
Griswold Hills
San Benito R.
CANAL
Mendota
FRESNO CO.
SAN JOAQUIN
Trigo
Little Dry Cr
SOUTHERN PACIFIC
Jamesan
Tranquillity
Biola
Herndon
Figarden
Kerman
Rolinda
Kearney Park
San Joaquin
Slough
Hernandez
Idria
Lonoak
Arroyo Hondo
Cantua Cr
Calwa

PLATE I

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

AREA OF INVESTIGATION
AND LOCATION OF MAJOR
WATER CONSERVATION WORKS
SHEET 3 OF 3 SHEETS
1960

LOCATION OF AREA OF INVESTIGATION



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
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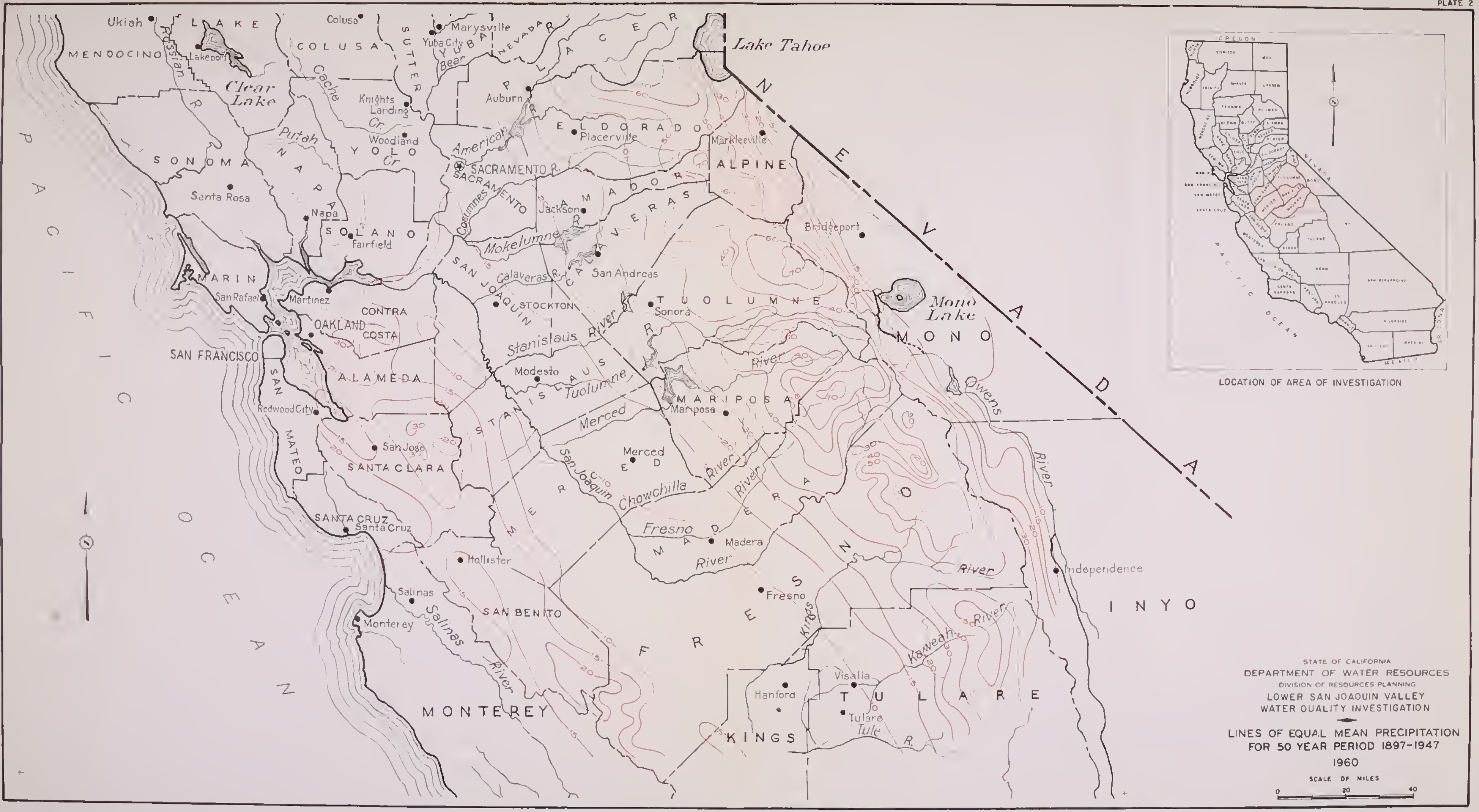
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

LINES OF EQUAL MEAN PRECIPITATION
FOR 50 YEAR PERIOD 1897-1947
1960

SCALE OF MILES
0 20 40

PLATE 2



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
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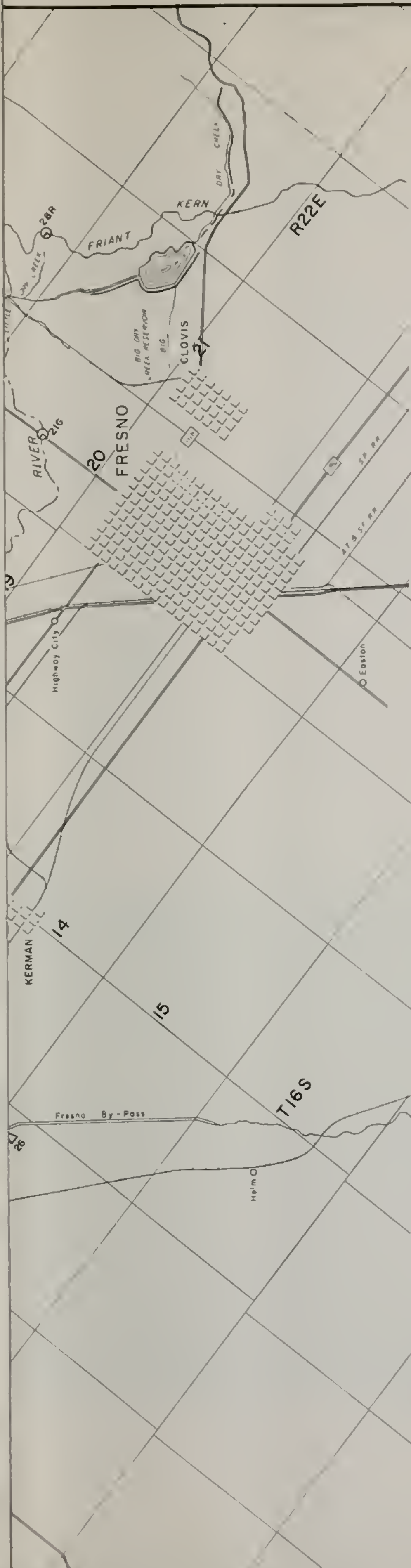
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

LINES OF EQUAL MEAN PRECIPITATION
FOR 50 YEAR PERIOD 1897-1947
1960



NOTE: ANALYSES OF WATER SAMPLES AT STATIONS SHOWN HEREON ARE AVAILABLE IN THE FILES OF THE DEPARTMENT OF WATER RESOURCES.

LEGEND

- ▽ GAGING STATION
- ◔ STREAM SAMPLING STATION
- ○ RETURN FLOW SAMPLING STATION
- (66) SURFACE ACCRETION OUTLET

STATE OF CALIFORNIA
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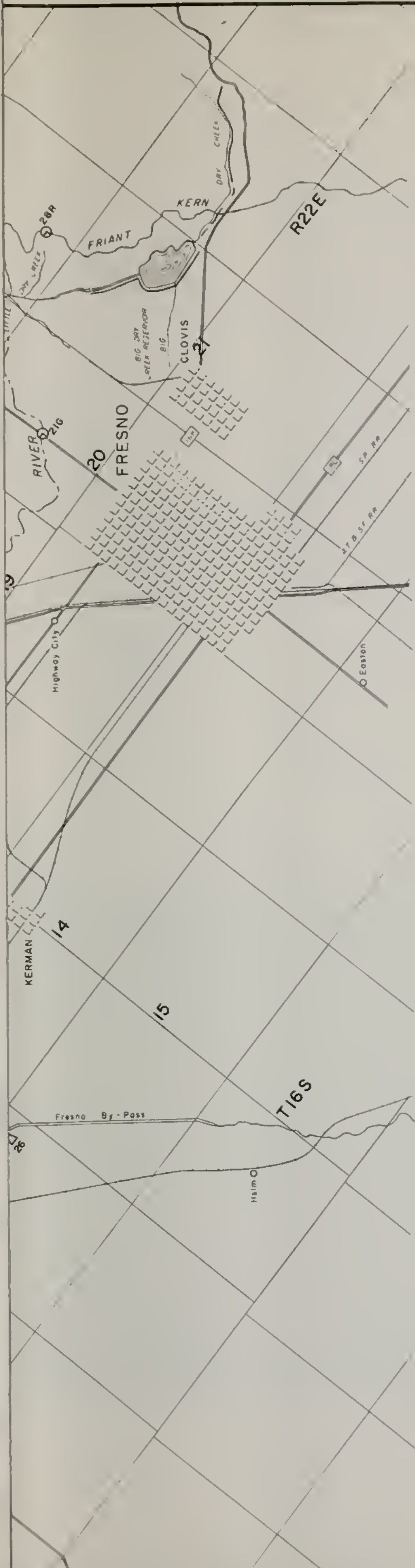
DIVISION OF RESOURCES PLANNING

LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

LOCATION OF STREAM GAGING STATIONS SAMPLING POINTS AND SURFACE ACCRETION OUTLETS
1960

SCALE OF MILES
4 0 4 8



NOTE: ANALYSES OF WATER SAMPLES AT STATIONS SHOWN HEREON ARE AVAILABLE IN THE FILES OF THE DEPARTMENT OF WATER RESOURCES.

LEGEND

- ▽ GAGING STATION
- STREAM SAMPLING STATION
- ○ RETURN FLOW SAMPLING STATION
- (66) SURFACE ACCRETION OUTLET

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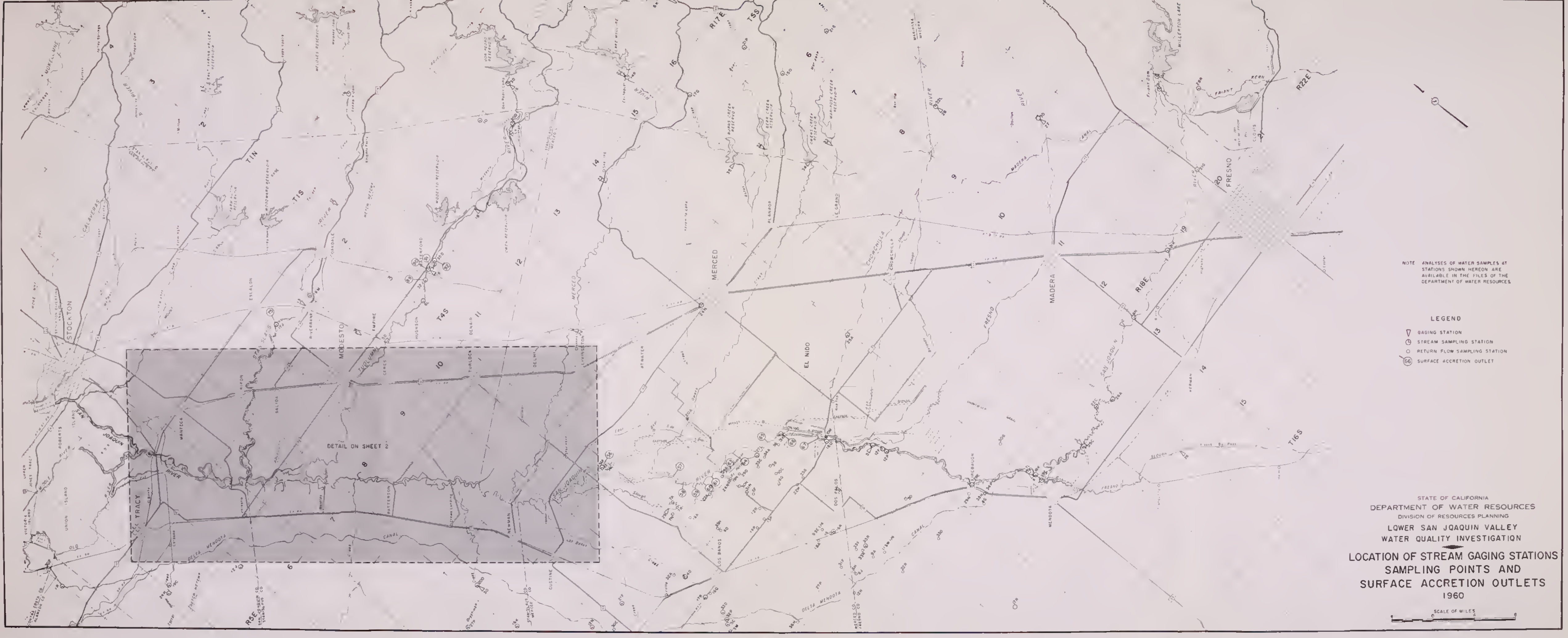
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

LOCATION OF STREAM GAGING STATIONS SAMPLING POINTS AND SURFACE ACCRETION OUTLETS
1960

SCALE OF MILES
4 0 4 8



NOTE ANALYSES OF WATER SAMPLES AT STATIONS SHOWN HEREON ARE AVAILABLE IN THE FILES OF THE DEPARTMENT OF WATER RESOURCES
LEGEND
GAGING STATION
STREAM SAMPLING STATION
RETURN FLOW SAMPLING STATION
66 SURFACE ACCRETION OUTLET
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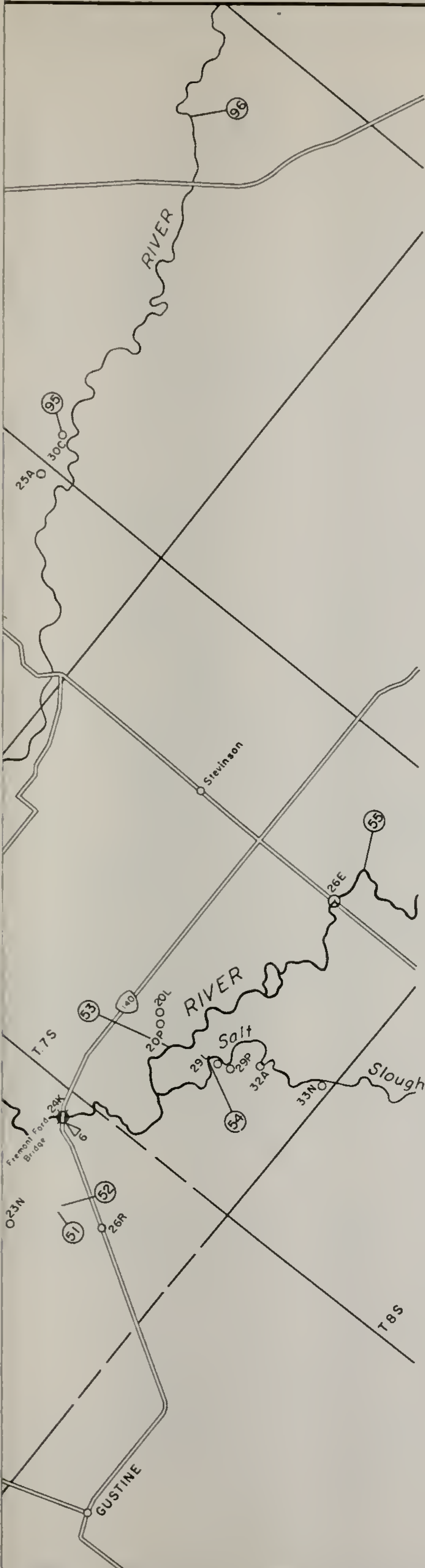
1960
SCALE OF MILES
DETAIL ON SHEET 2
STOCKTON
MODESTO
MERCED
MADERA
FRESNO
TRACY
MANTECA
OAKDALE
TURLOCK
NEWMAN
LOS BANOS
DOS PALOS
EL NIDO
MENDOTA
GUSTINE
LIVINGSTON
ATWATER
DELHI
RIPON
SALIDA
KERMAN
SAN JOAQUIN
RIVER
DELTA MENDOTA CANAL
FRIANT KERN
MILLERTON LAKE
CHOWCHILLA
CALAVERAS
MOKELUMNE
TUOLUMNE
R5E
R17E
R18E
R22E
T1N
T1S
T4S
T5S
T16S



NOTE: ANALYSES OF WATER SAMPLES AT STATIONS SHOWN HEREON ARE AVAILABLE IN THE FILES OF THE DEPARTMENT OF WATER RESOURCES.

LEGEND

- ▽ GAGING STATION
- STREAM SAMPLING STATION
- ○ RETURN FLOW SAMPLING STATION
- (66) SURFACE ACCRETION OUTLET
- x5 SOIL SAMPLING SITES (APPENDIX C)

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

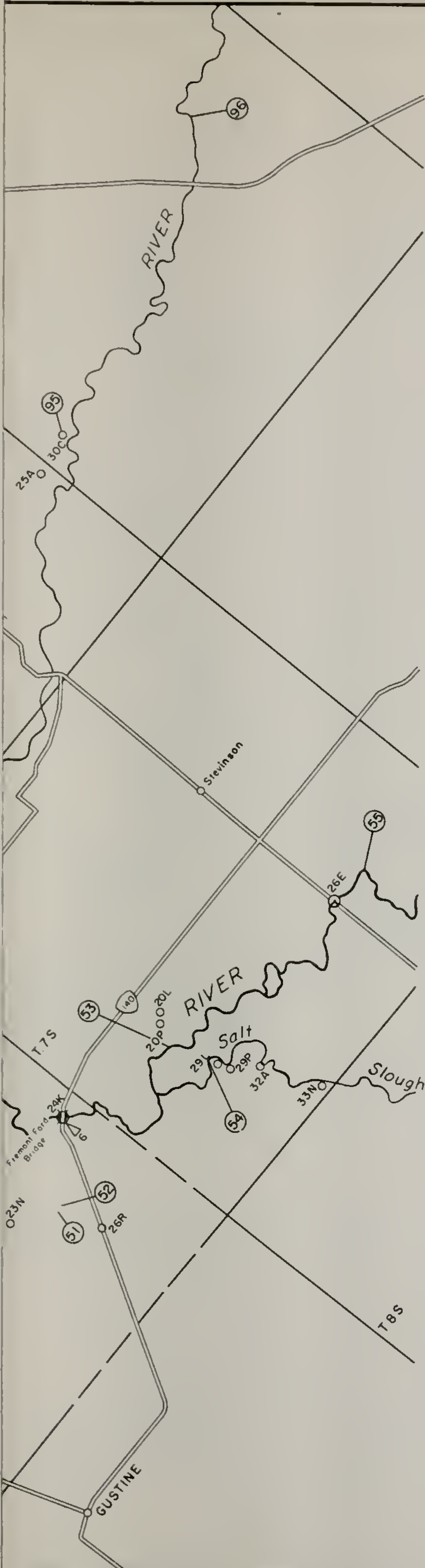
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

LOCATION OF STREAM GAGING STATIONS SAMPLING POINTS AND SURFACE ACCRETION OUTLETS

1960

SCALE OF MILES

1 0 1 2 3



NOTE: ANALYSES OF WATER SAMPLES AT STATIONS SHOWN HEREON ARE AVAILABLE IN THE FILES OF THE DEPARTMENT OF WATER RESOURCES.

LEGEND

- ▽ GAGING STATION
- STREAM SAMPLING STATION
- ○ RETURN FLOW SAMPLING STATION
- (66) SURFACE ACCRETION OUTLET
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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

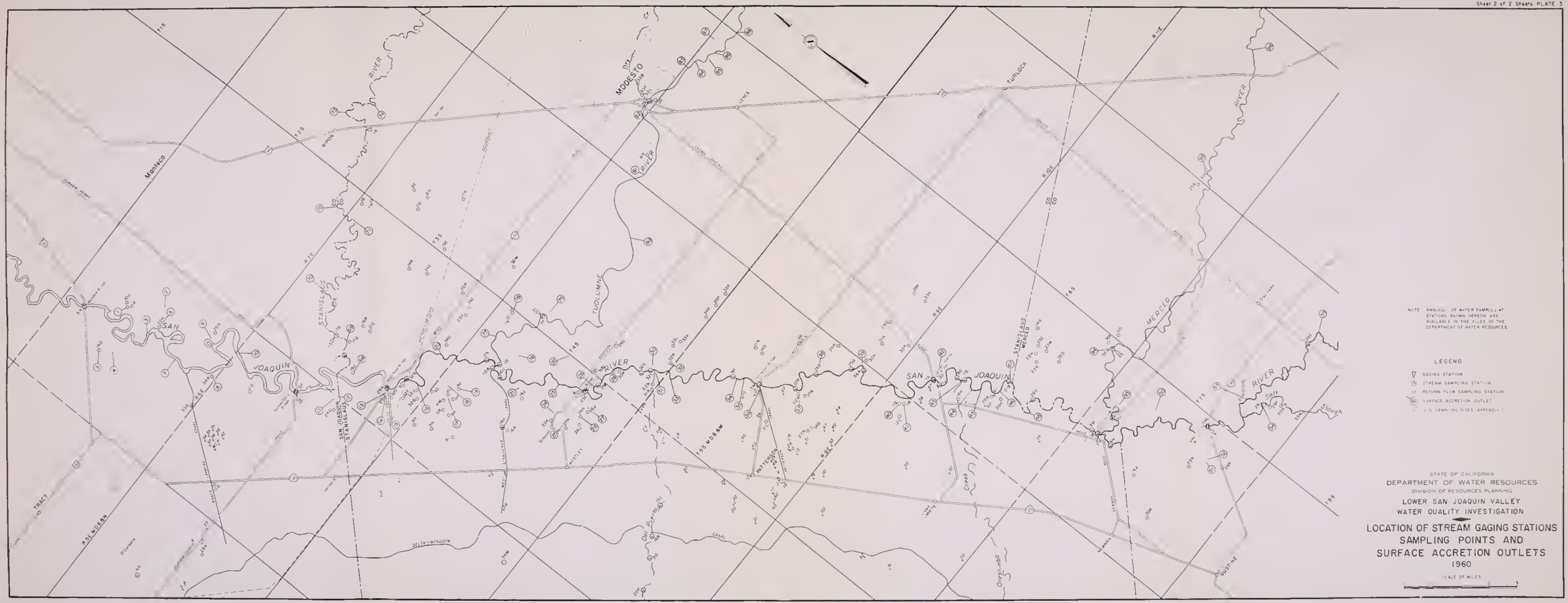
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

LOCATION OF STREAM GAGING STATIONS SAMPLING POINTS AND SURFACE ACCRETION OUTLETS

1960

SCALE OF MILES

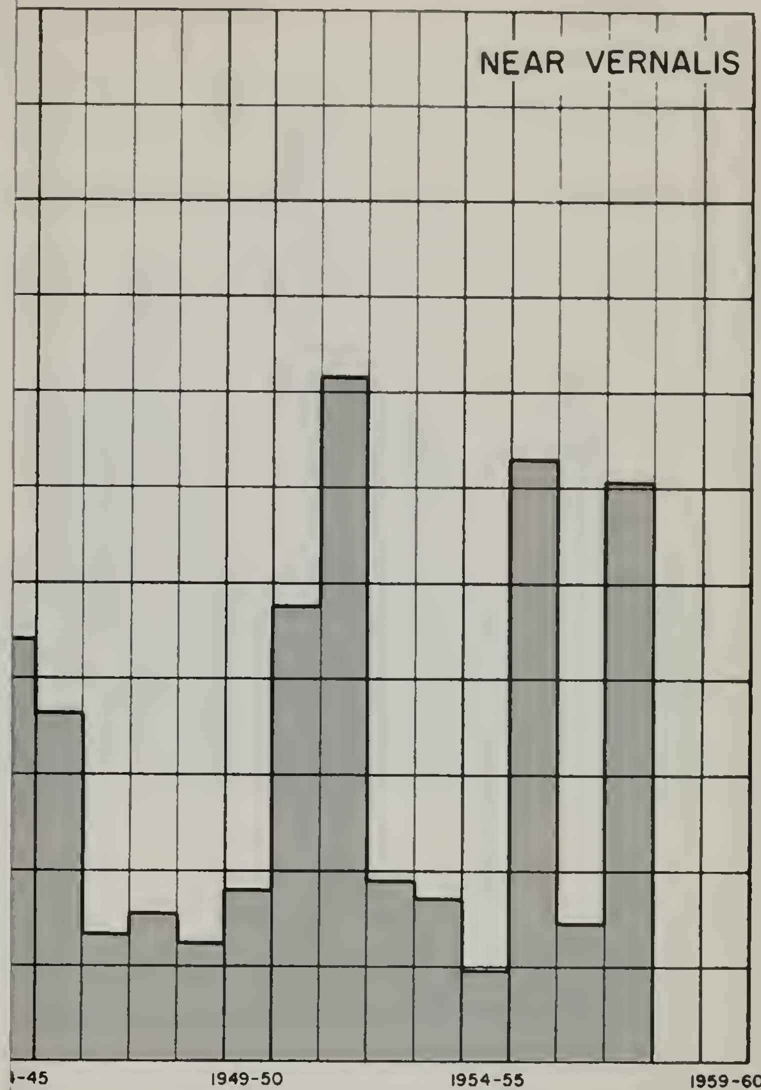
1 0 1 2 3



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

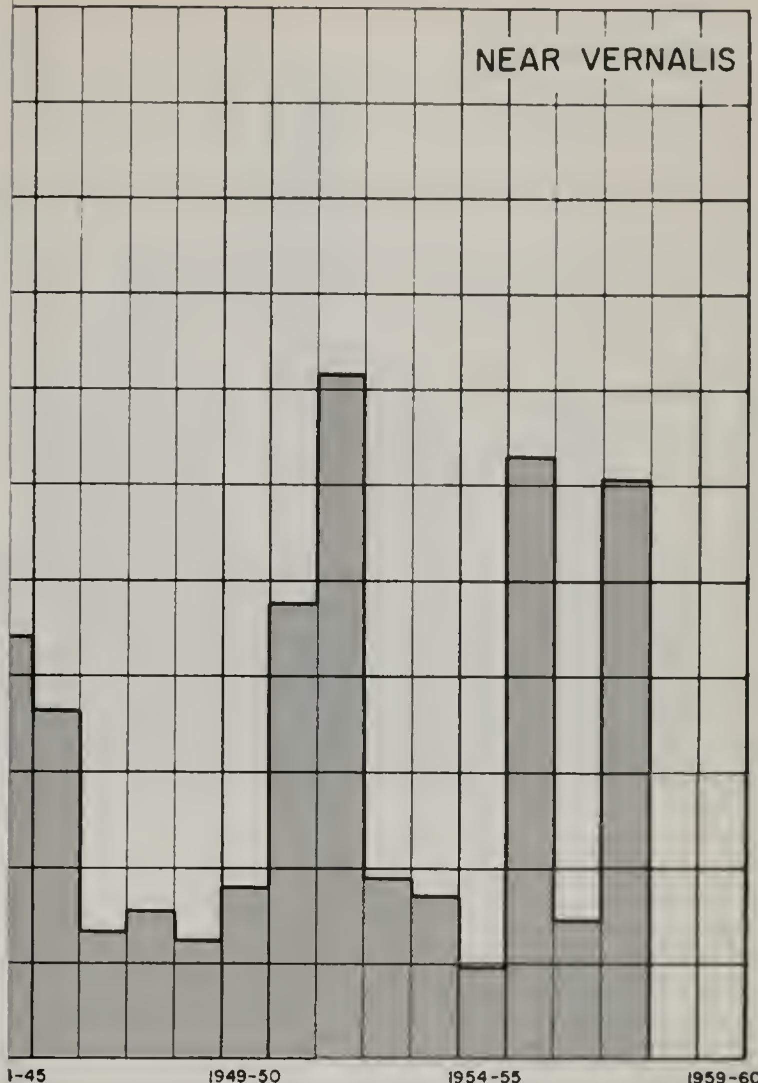
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

LOCATION OF STREAM GAGING STATIONS SAMPLING POINTS AND SURFACE ACCRETION OUTLETS
1960



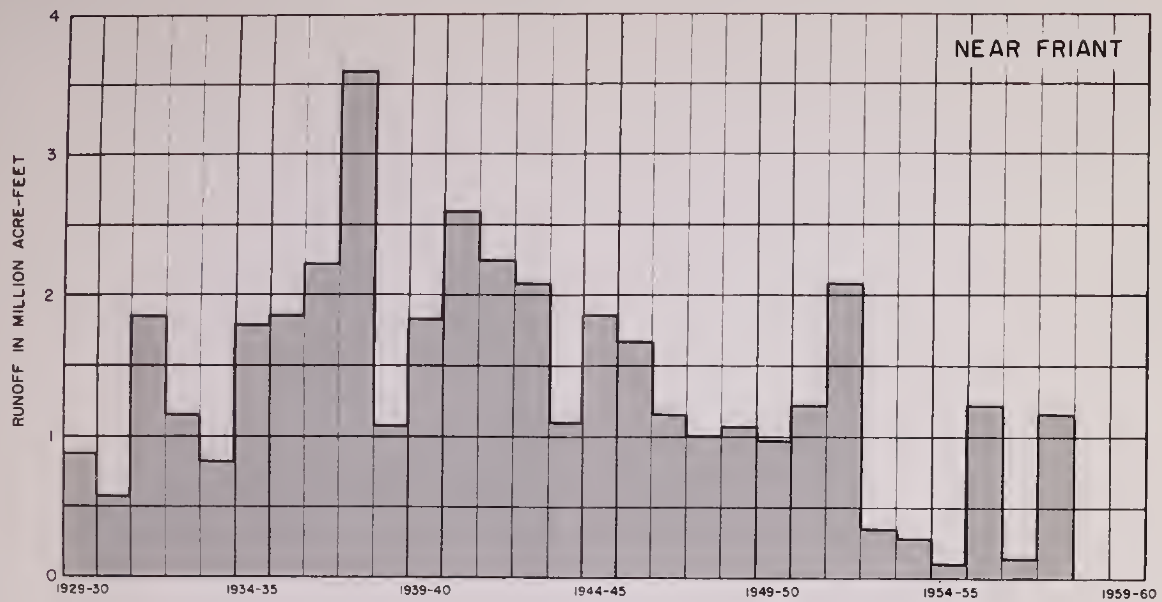
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

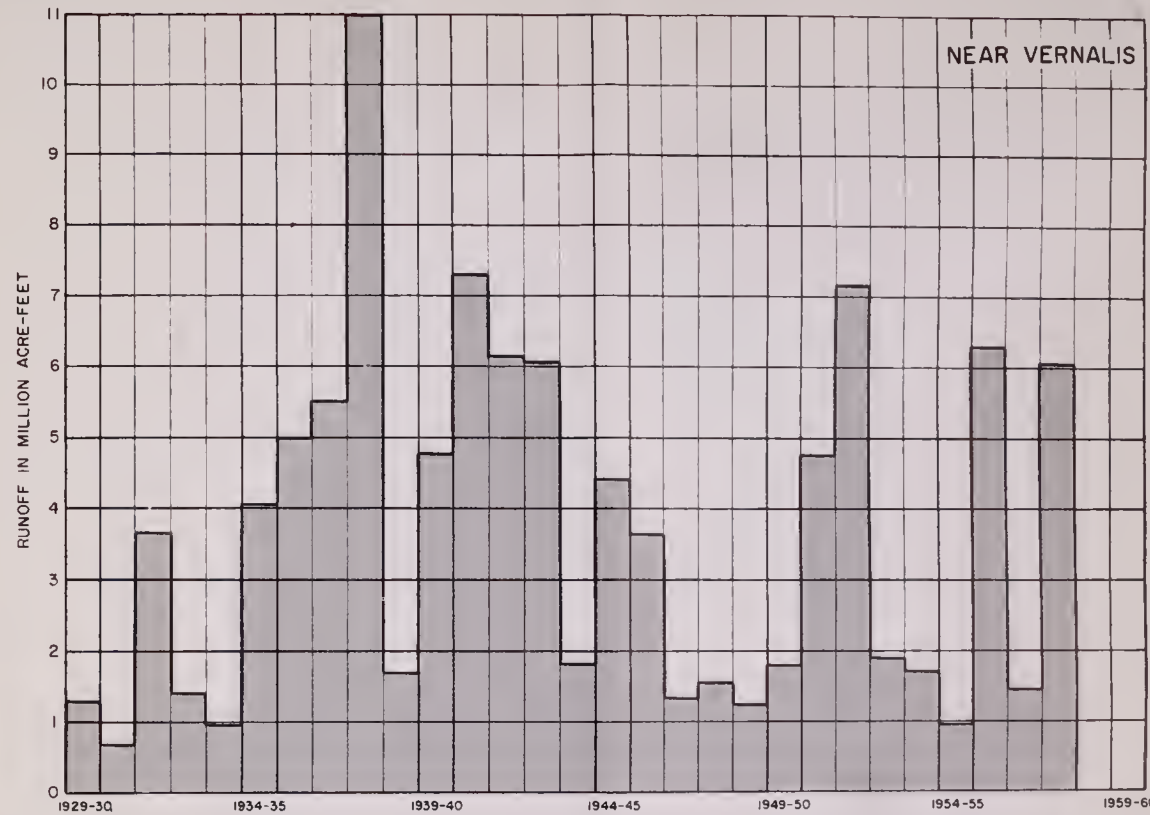
EASONAL RUNOFF OF THE SAN JOAQUIN RIVER
NT, NEAR DOS PALOS AND NEAR VERNALIS
1929 - 1958

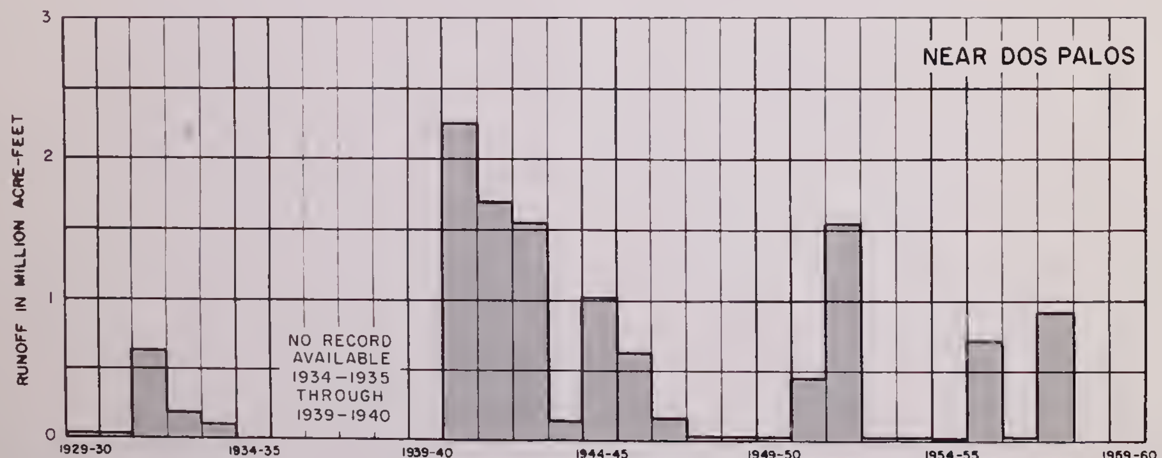


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

EASONAL RUNOFF OF THE SAN JOAQUIN RIVER
NT, NEAR DOS PALOS AND NEAR VERNALIS
1929 - 1958

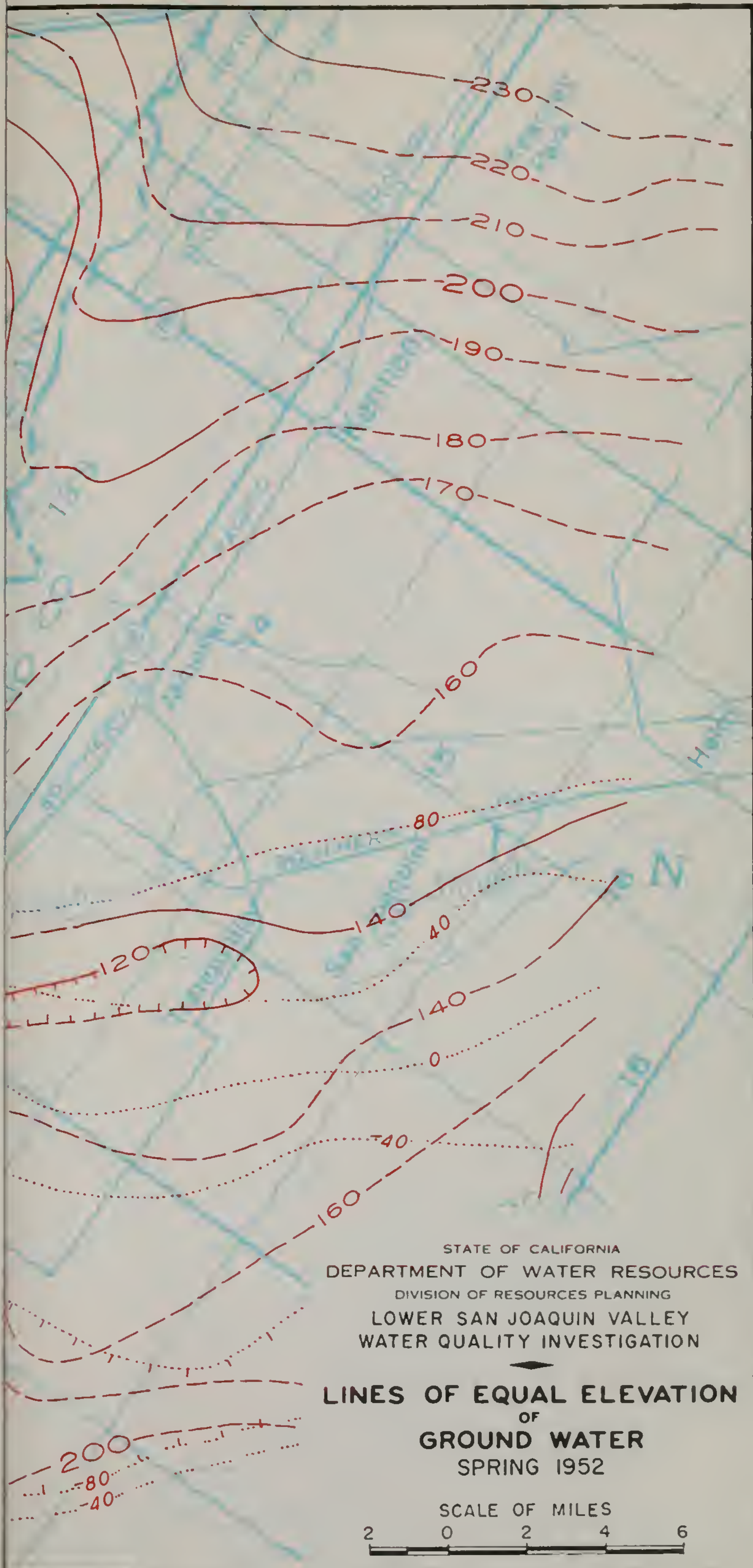






STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

RECORDED SEASONAL RUNOFF OF THE SAN JOAQUIN RIVER
NEAR FRIANT, NEAR DOS PALOS AND NEAR VERNALIS
1929-1958



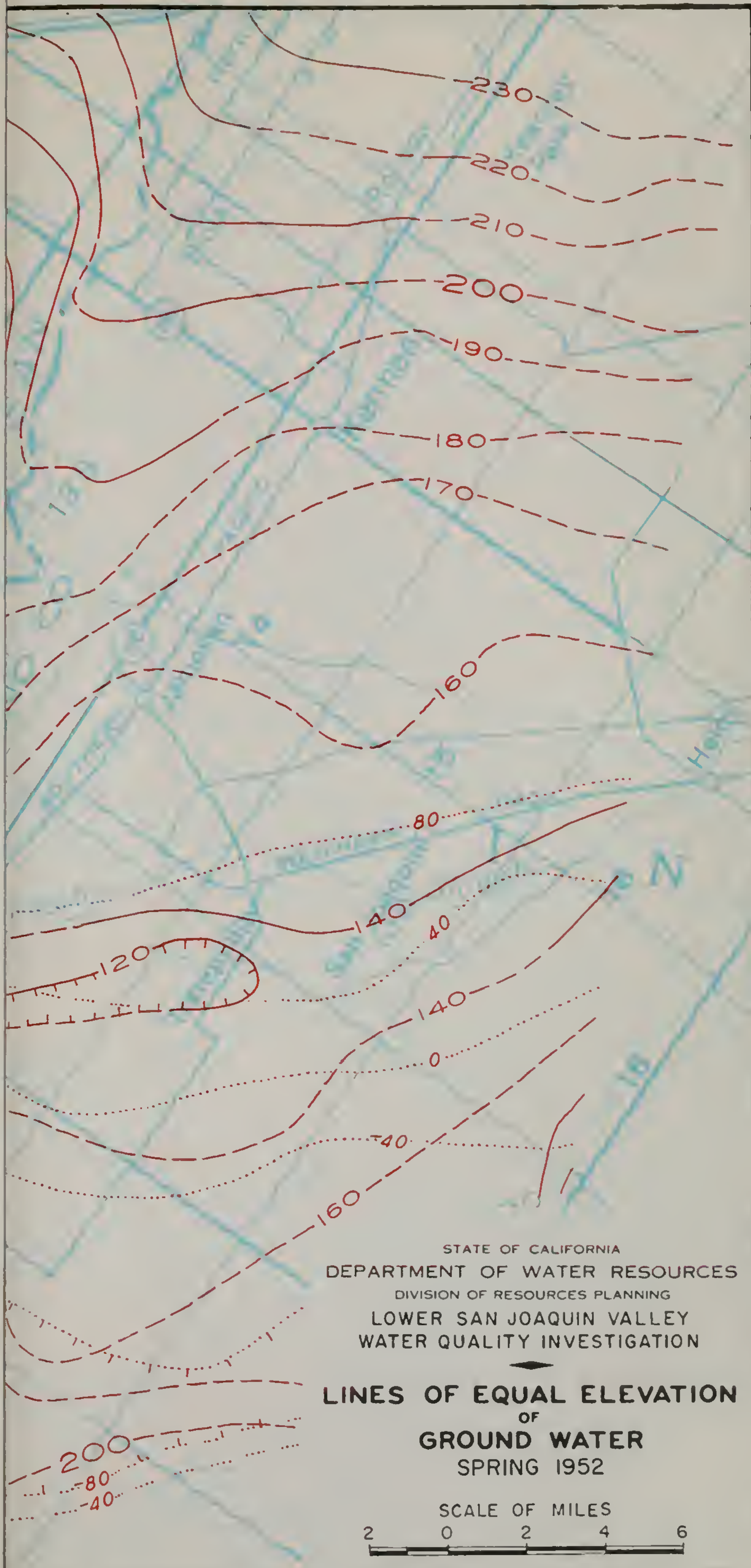
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

LINES OF EQUAL ELEVATION OF GROUND WATER

SPRING 1952

SCALE OF MILES

2 0 2 4 6



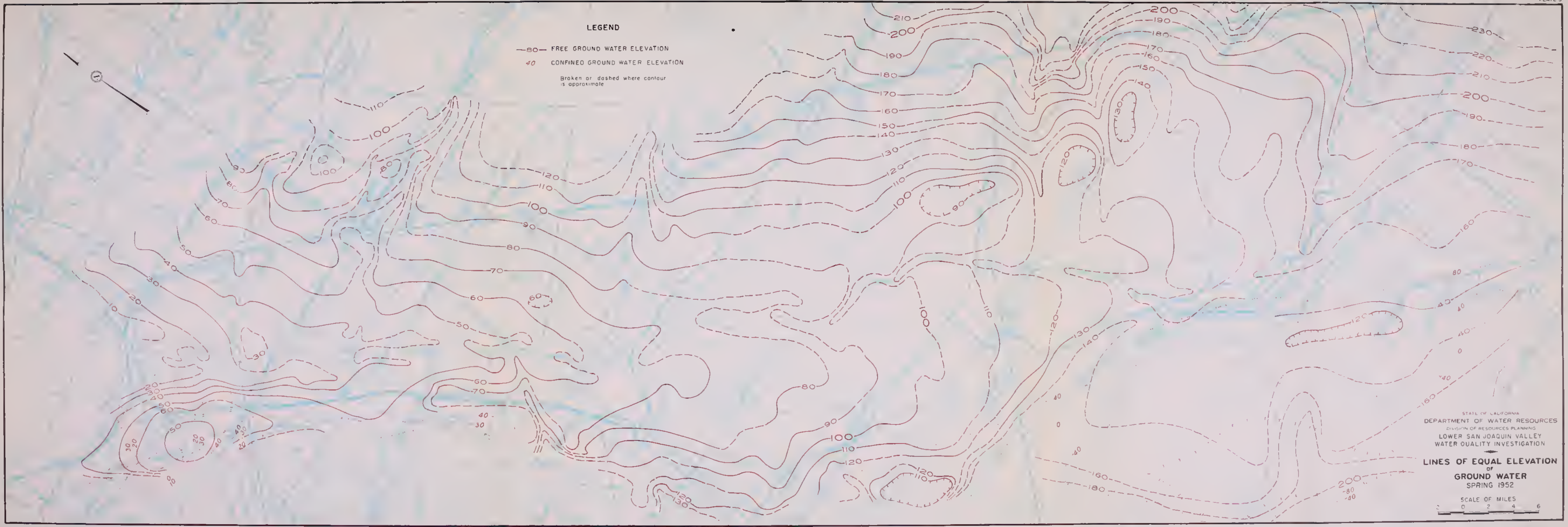
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

LINES OF EQUAL ELEVATION OF GROUND WATER

SPRING 1952

SCALE OF MILES

2 0 2 4 6


LEGEND
—80— FREE GROUND WATER ELEVATION
40 CONFINED GROUND WATER ELEVATION
Broken or dashed where contour is approximate
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION
LINES OF EQUAL ELEVATION OF GROUND WATER
SPRING 1952
SCALE OF MILES
0 2 4 6

LEGEND

EXPORT	SURFACE SUPPLY
IMPORT	RETURN FLOWS
SERVICE AREAS	GROUND WATER

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

DIAGRAMMATIC SKETCH OF WATER SUPPLY AND UTILIZATION

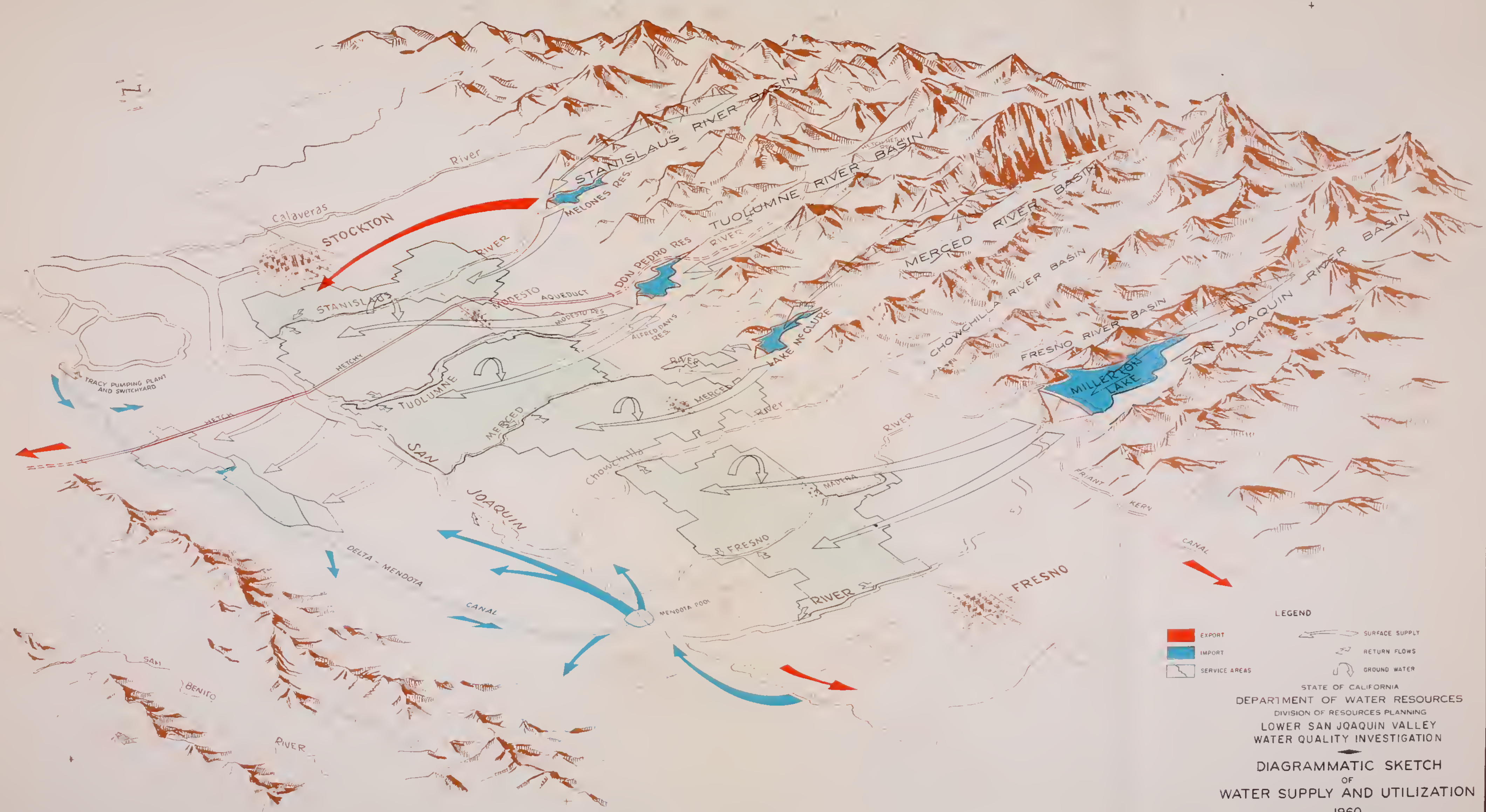
1960

LEGEND

EXPORT
IMPORT
SERVICE AREAS
SURFACE SUPPLY
RETURN FLOWS
GROUND WATER

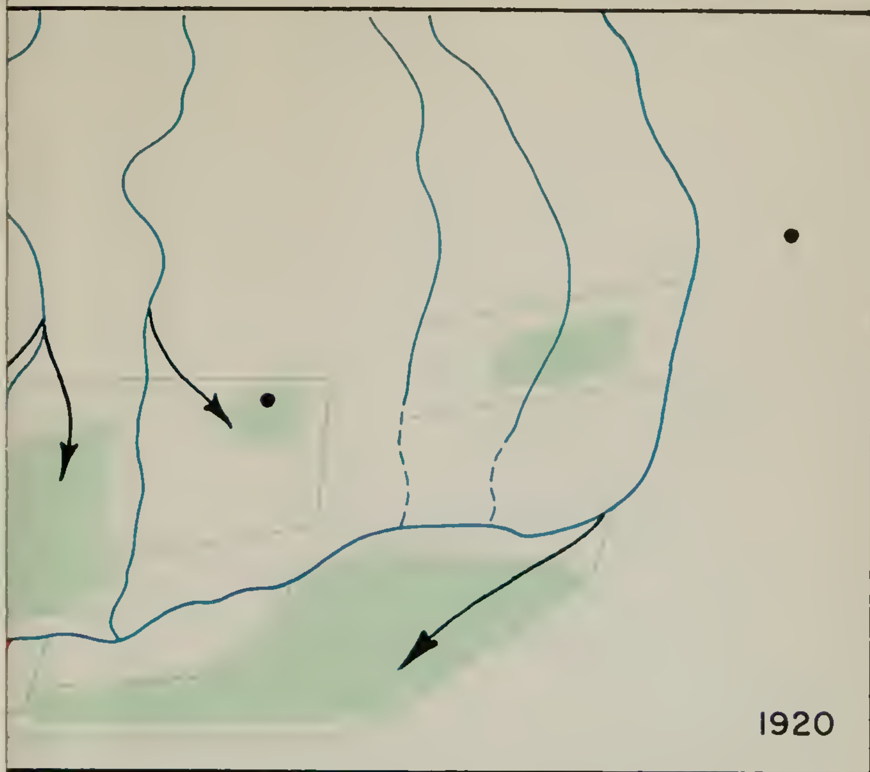
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

DIAGRAMMATIC SKETCH
OF
WATER SUPPLY AND UTILIZATION
1960



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

DIAGRAMMATIC SKETCH
OF
WATER SUPPLY AND UTILIZATION
1960



END

M

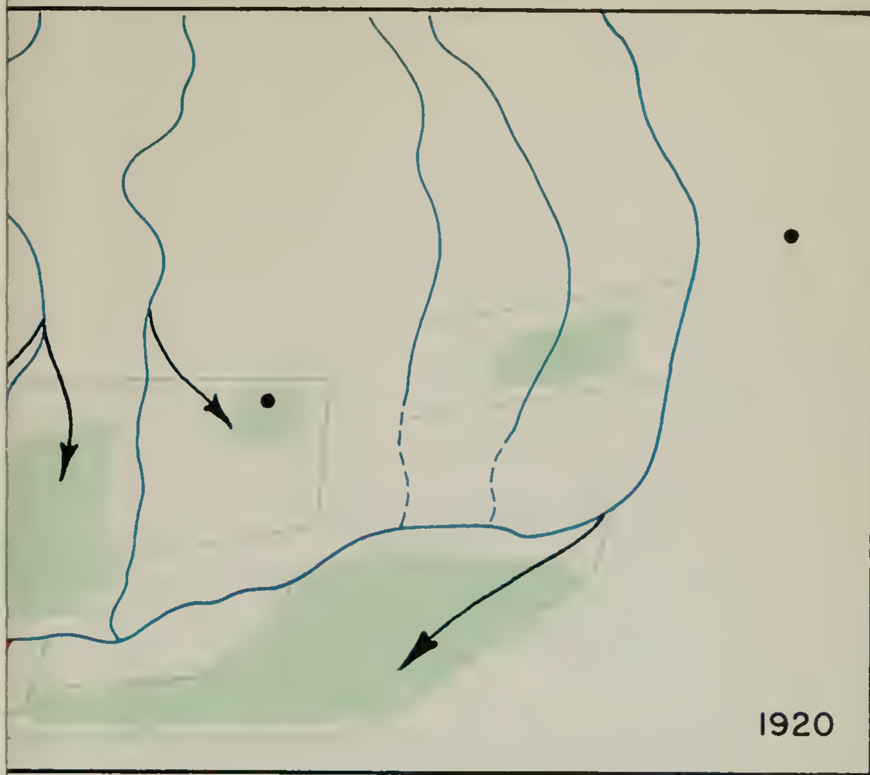
ED IN OPERATION DURING PERIOD

PERATION PRIOR TO PERIOD

ICE AREA OR IRRIGATED AREA

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

CHRONOLOGICAL DEVELOPMENT
OF SURFACE WATER RESOURCES IN THE
SAN JOAQUIN RIVER BASIN
1960
NOT TO SCALE



END

EM

ED IN OPERATION DURING PERIOD

PERATION PRIOR TO PERIOD

ICE AREA OR IRRIGATED AREA

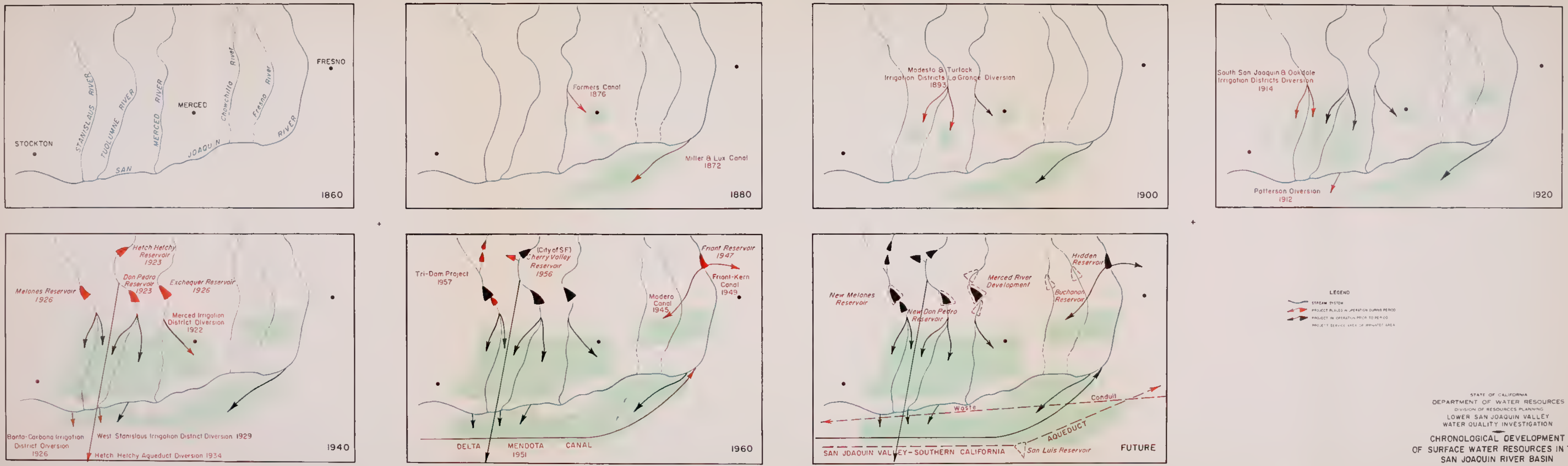
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

CHRONOLOGICAL DEVELOPMENT
OF SURFACE WATER RESOURCES IN THE
SAN JOAQUIN RIVER BASIN

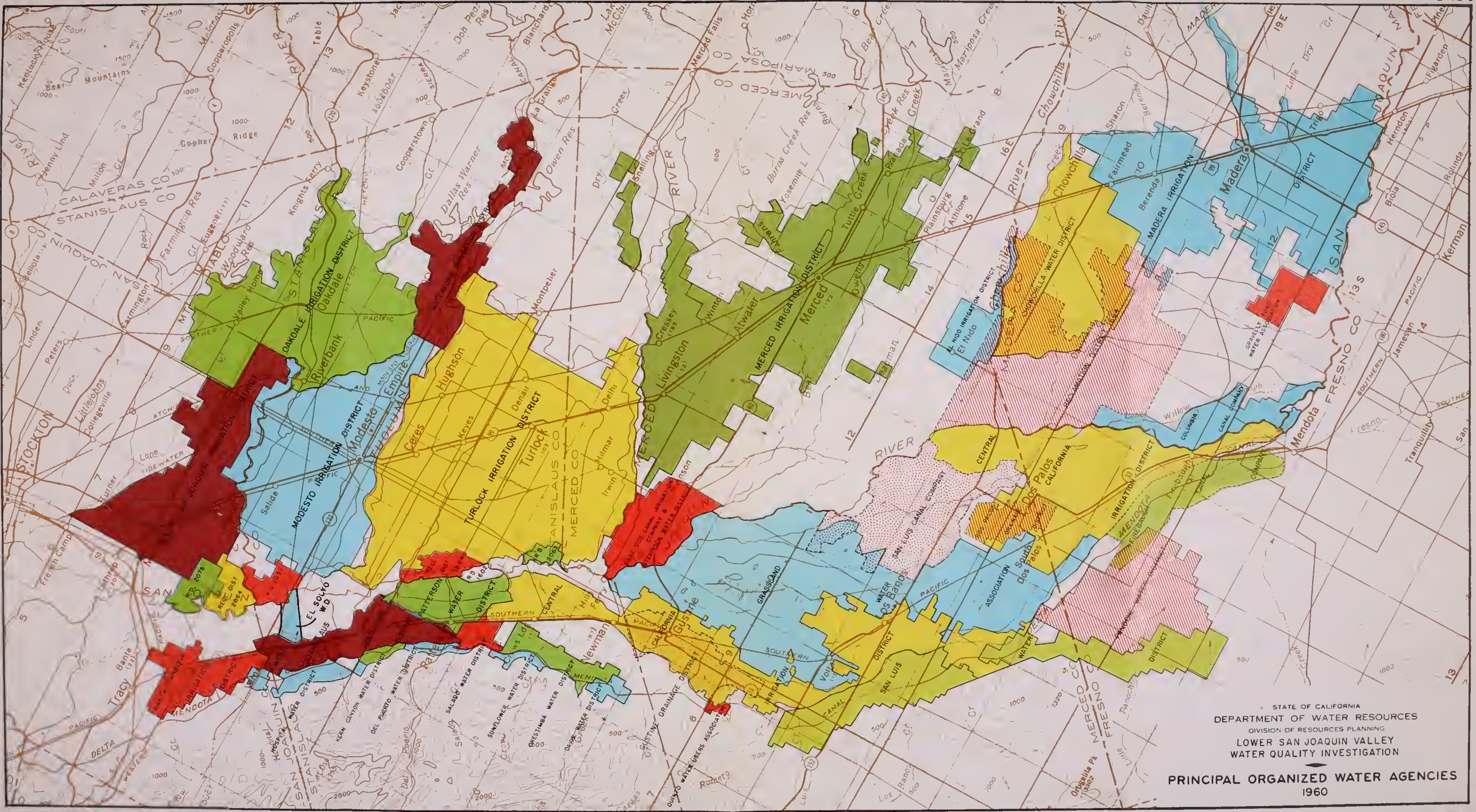
1960

NOT TO SCALE



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

CHRONOLOGICAL DEVELOPMENT OF SURFACE WATER RESOURCES IN THE SAN JOAQUIN RIVER BASIN
1960
NOT TO SCALE



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

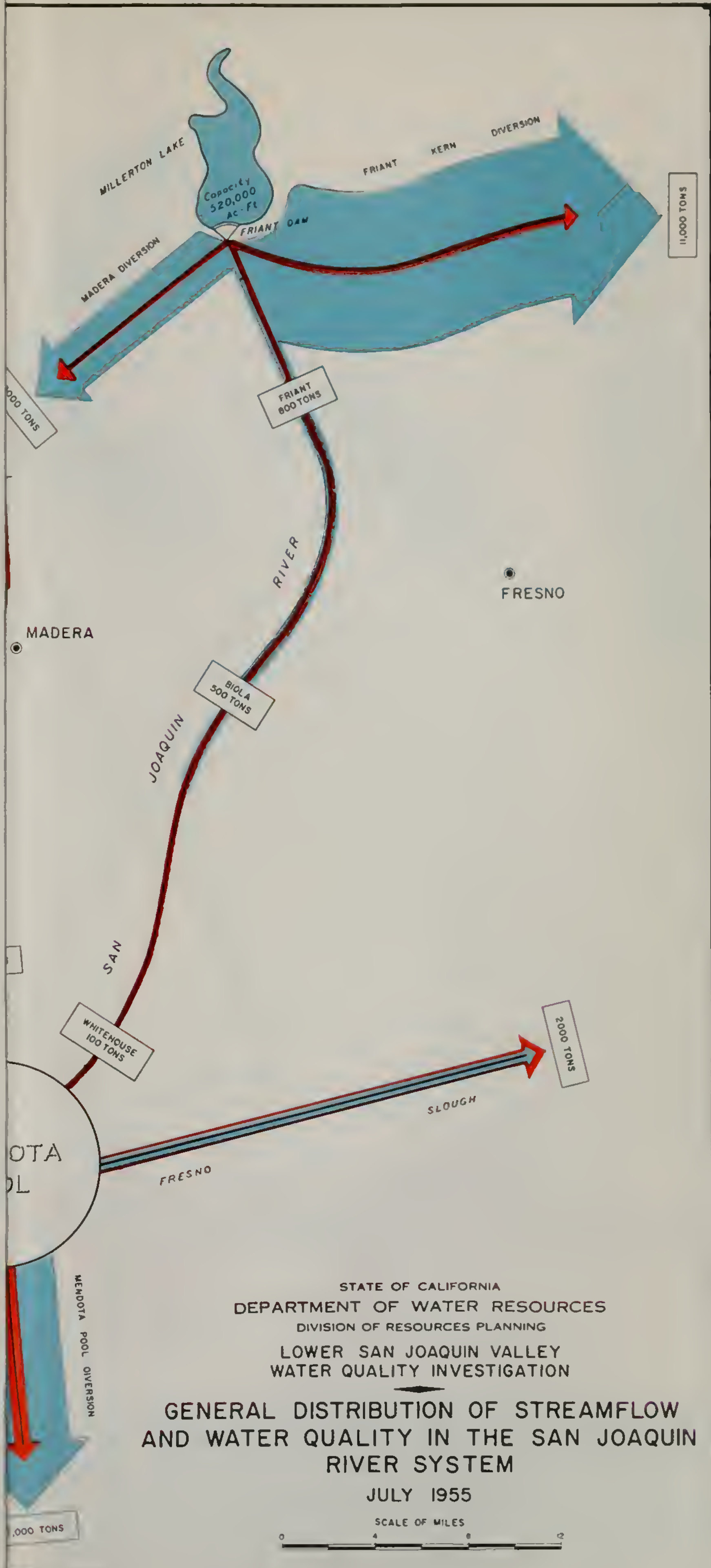
PRINCIPAL ORGANIZED WATER AGENCIES
1960

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

GENERAL DISTRIBUTION OF STREAMFLOW AND WATER QUALITY IN THE SAN JOAQUIN RIVER SYSTEM

JULY 1955

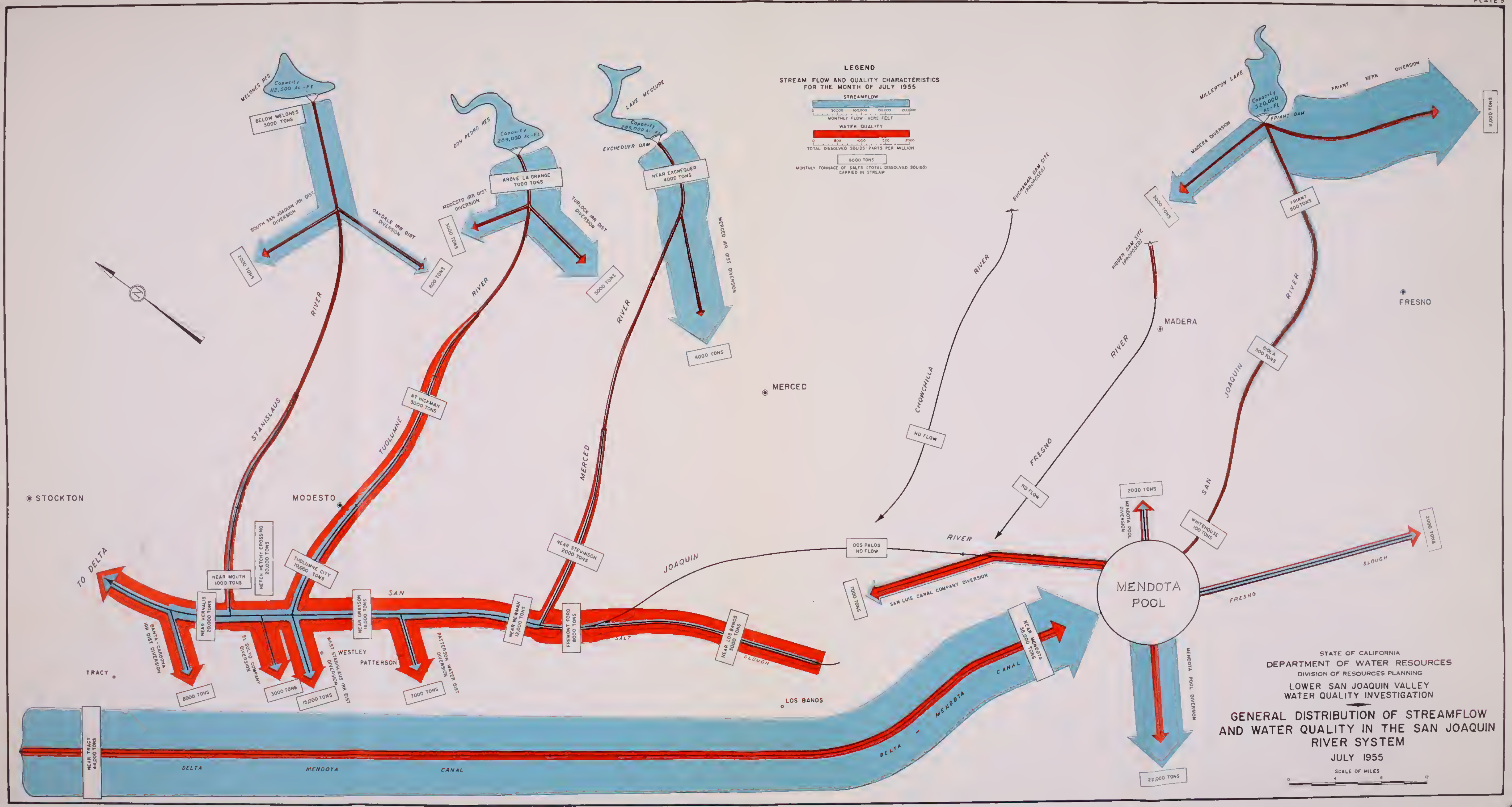


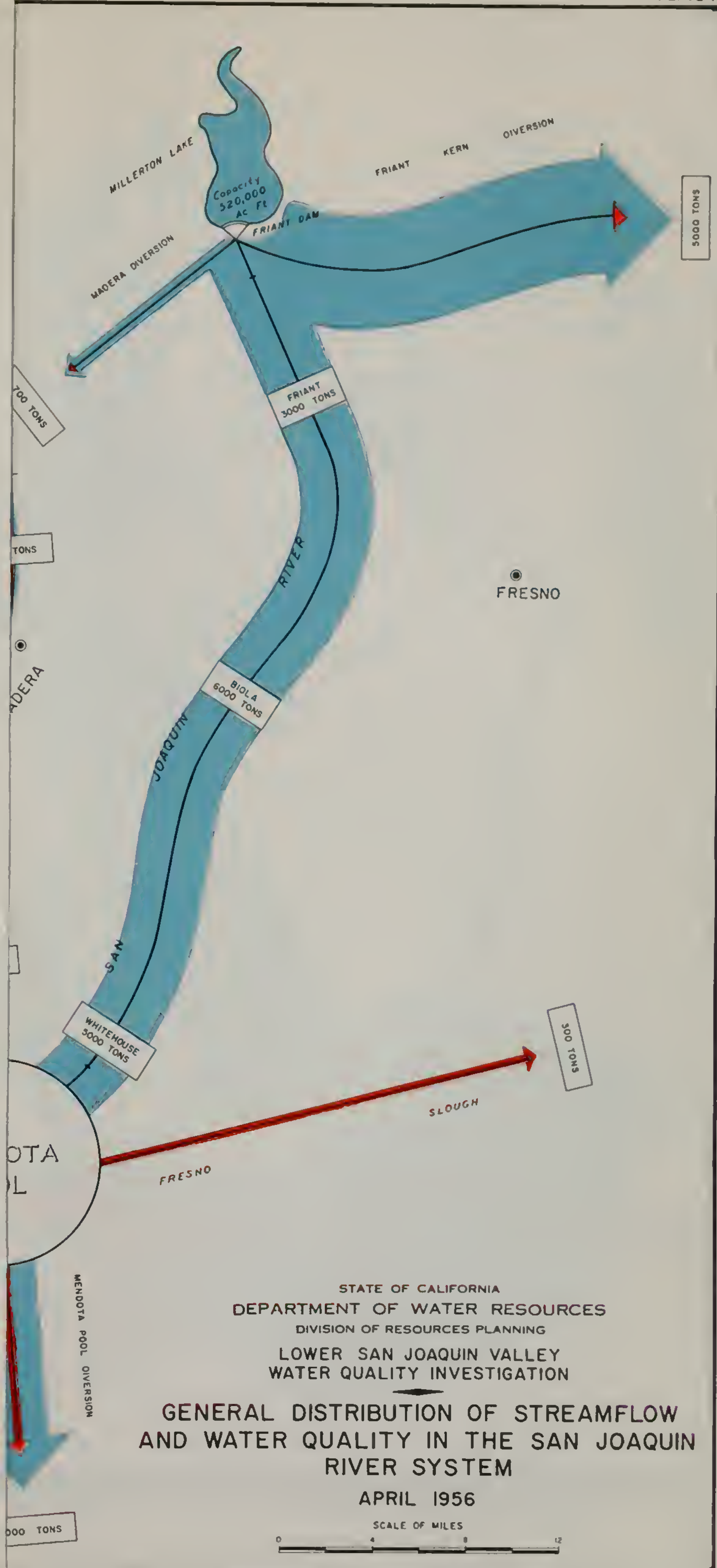
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

GENERAL DISTRIBUTION OF STREAMFLOW AND WATER QUALITY IN THE SAN JOAQUIN RIVER SYSTEM

JULY 1955


LEGEND
STREAM FLOW AND QUALITY CHARACTERISTICS FOR THE MONTH OF JULY 1955
STREAMFLOW
MONTHLY FLOW - ACRE FEET
WATER QUALITY
TOTAL DISSOLVED SOLIDS - PARTS PER MILLION
8000 TONS
MONTHLY TONNAGE OF SALTS (TOTAL DISSOLVED SOLIDS) CARRIED IN STREAM
MELONES RES
Capacity 112,500 Ac-Ft
BELOW MELONES 3000 TONS
SOUTH SAN JOAQUIN IRR DIST DIVERSION
OAKDALE IRR DIST DIVERSION
2000 TONS
800 TONS
STANISLAUS RIVER
DON PEDRO RES
Capacity 289,000 Ac-Ft
ABOVE LA GRANGE 7000 TONS
MODESTO IRR DIST DIVERSION
TURLOCK IRR DIST DIVERSION
3000 TONS
5000 TONS
TUOLUMNE RIVER
AT HICKMAN 3000 TONS
LAKE McCLURE
Capacity 289,000 Ac-Ft
EXCHEQUER DAM
NEAR EXCHEQUER 4000 TONS
MERCED IRR DIST DIVERSION
4000 TONS
MERCED RIVER
MERCED
BUCHANAN DAM SITE (PROPOSED)
CHOWCHILLA RIVER
NO FLOW
HIDDEN DAM SITE (PROPOSED)
FRESNO RIVER
NO FLOW
MADERA
FRESNO
MILLERTON LAKE
Capacity 520,000 Ac-Ft
FRIANT DAM
FRIANT KERN DIVERSION
11,000 TONS
MADERA DIVERSION
3000 TONS
FRIANT 800 TONS
SAN JOAQUIN RIVER
BIOLA 500 TONS
WHITEHOUSE 100 TONS
STOCKTON
MODESTO
TO DELTA
NEAR MOUTH 1000 TONS
HETCH HETCHY CROSSING 20,000 TONS
TUOLUMNE CITY 10,000 TONS
NEAR VERNALIS 20,000 TONS
BANTA-CARBONA IRR DIST DIVERSION
8000 TONS
EL SOLYO COMPANY DIVERSION
3000 TONS
WEST STANISLAUS IRR DIST DIVERSION
15,000 TONS
NEAR GRAYSON 16,000 TONS
PATTERSON WATER DIST DIVERSION
7000 TONS
WESTLEY
PATTERSON
TRACY
NEAR NEWMAN 12,000 TONS
FREMONT FORD 8000 TONS
NEAR STEVINSON 2000 TONS
SALT SLOUGH
NEAR LOS BANOS 5000 TONS
LOS BANOS
DOS PALOS NO FLOW
SAN LUIS CANAL COMPANY DIVERSION
7000 TONS
MENDOTA POOL
2000 TONS
MENDOTA POOL DIVERSION
FRESNO SLOUGH
2000 TONS
NEAR MENDOTA 58,000 TONS
MENDOTA POOL DIVERSION
22,000 TONS
NEAR TRACY 44,000 TONS
DELTA MENDOTA CANAL
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION
GENERAL DISTRIBUTION OF STREAMFLOW AND WATER QUALITY IN THE SAN JOAQUIN RIVER SYSTEM
JULY 1955
SCALE OF MILES

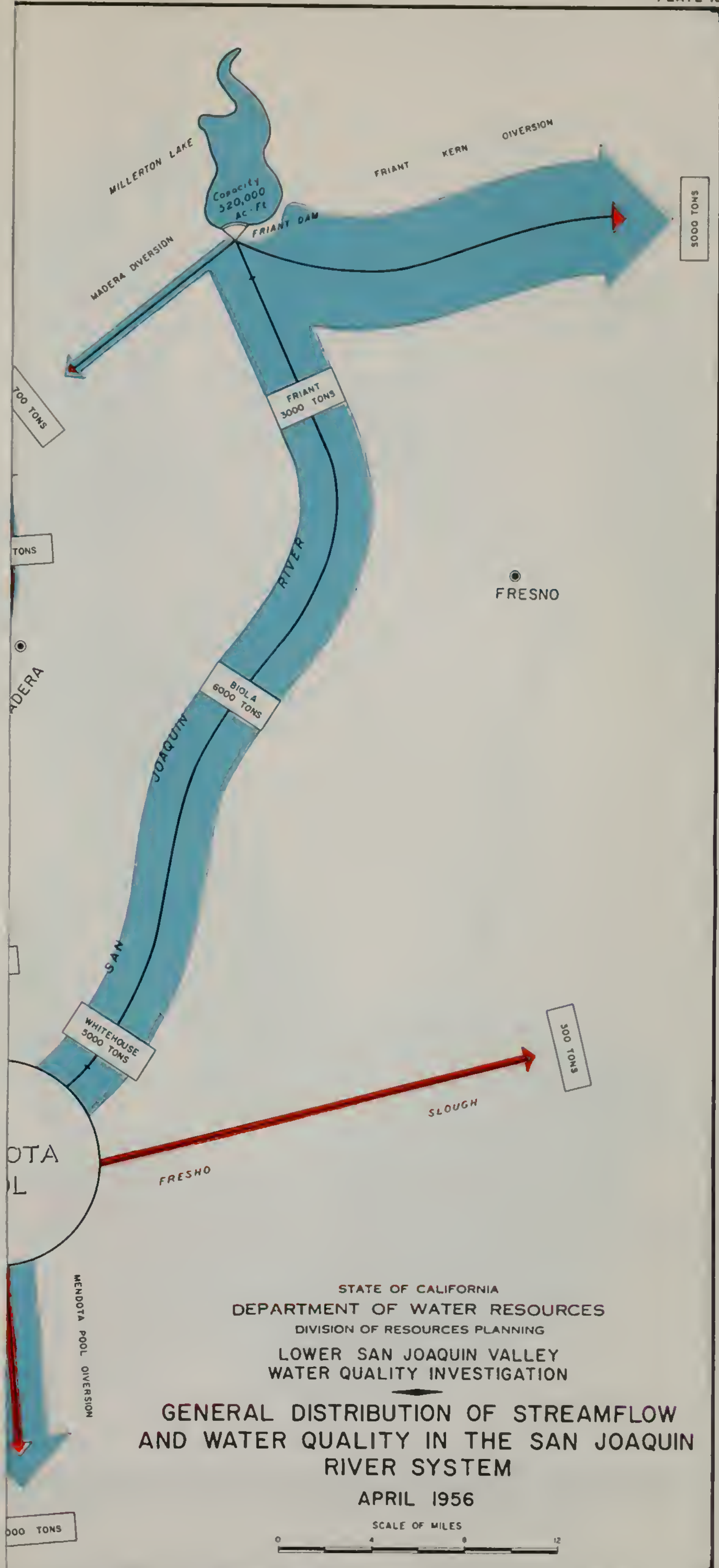


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

GENERAL DISTRIBUTION OF STREAMFLOW AND WATER QUALITY IN THE SAN JOAQUIN RIVER SYSTEM

APRIL 1956

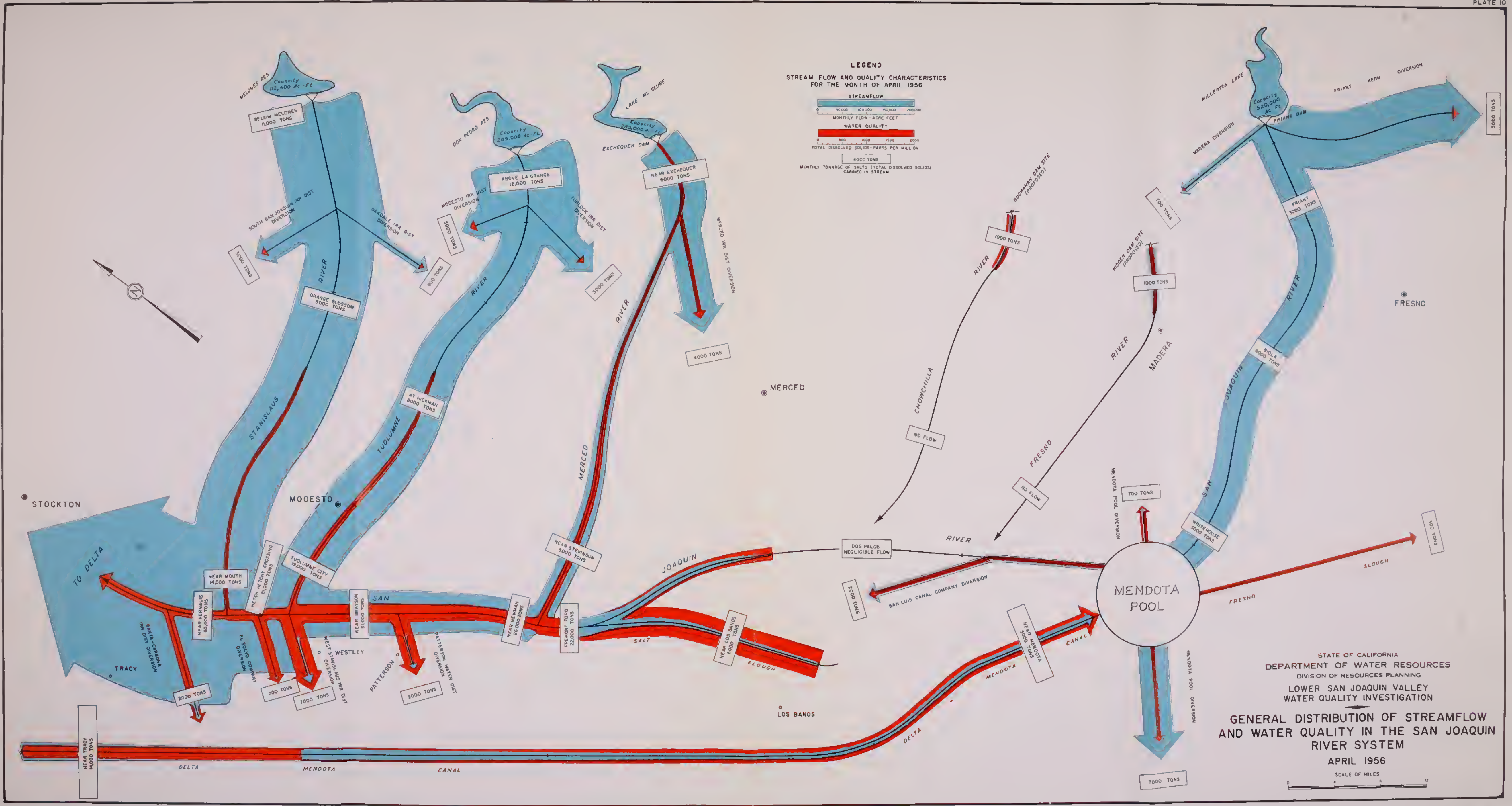


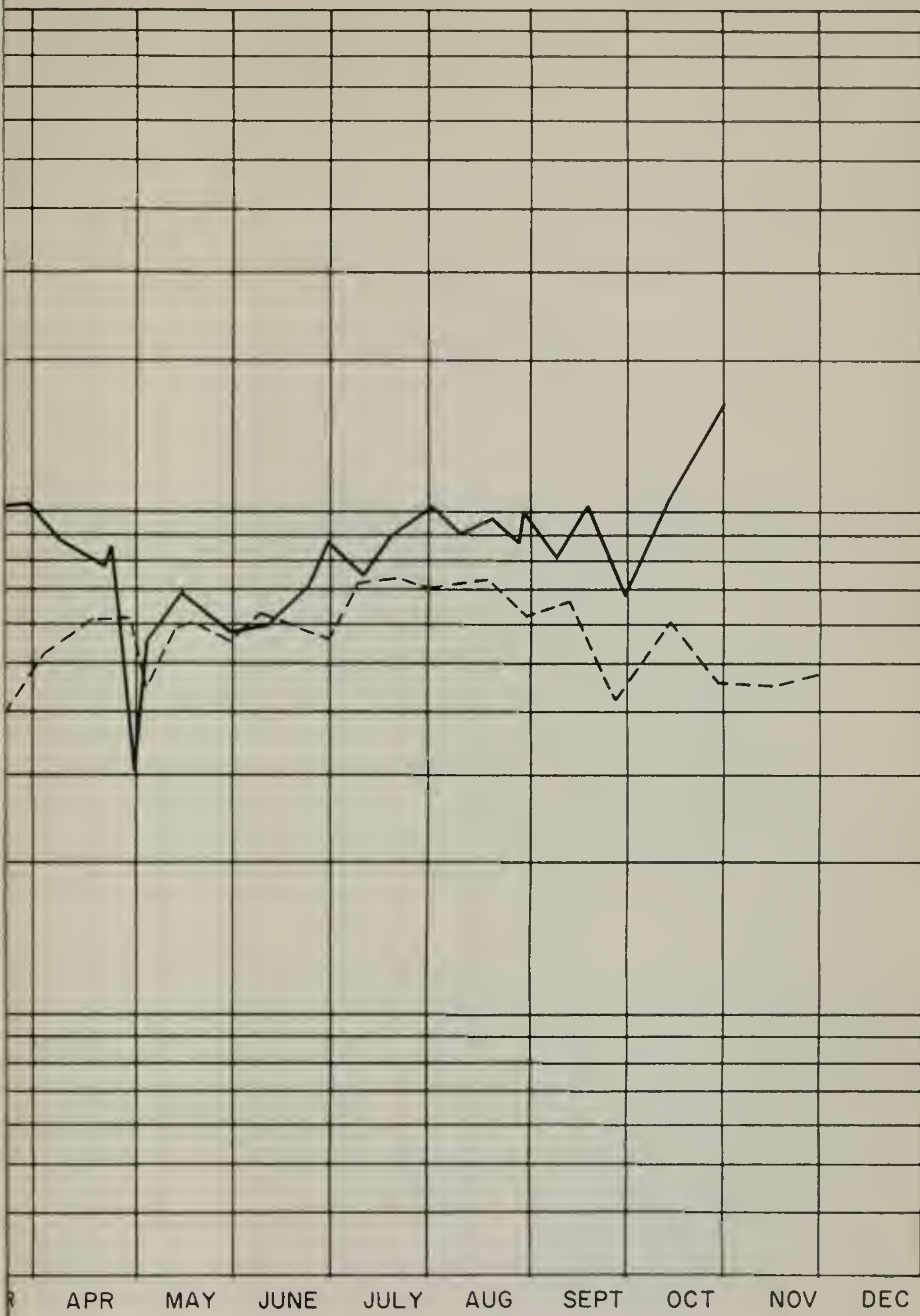
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

GENERAL DISTRIBUTION OF STREAMFLOW AND WATER QUALITY IN THE SAN JOAQUIN RIVER SYSTEM

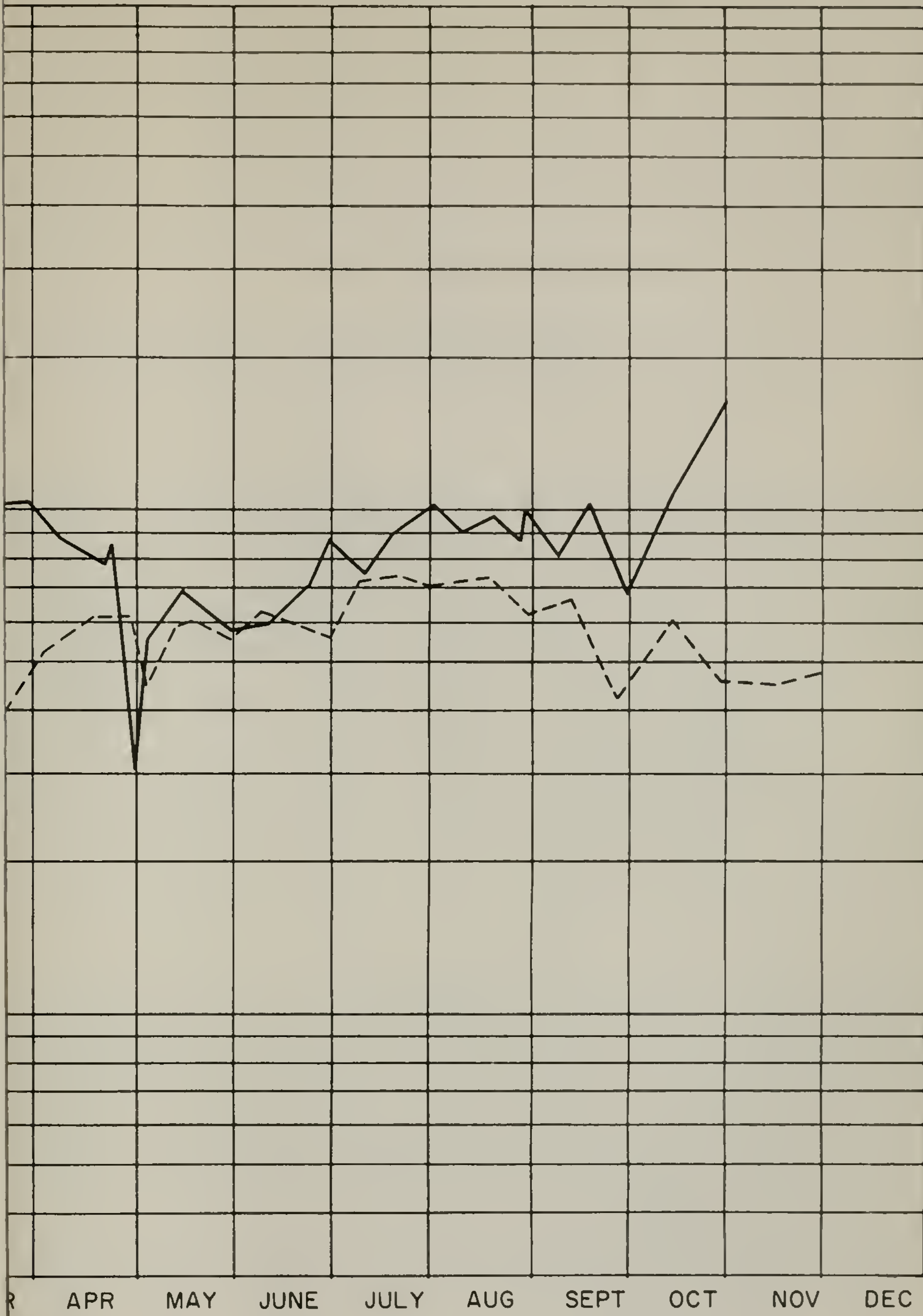
APRIL 1956


LEGEND
STREAM FLOW AND QUALITY CHARACTERISTICS
FOR THE MONTH OF APRIL 1956
STREAMFLOW
MONTHLY FLOW - ACRE FEET
WATER QUALITY
TOTAL DISSOLVED SOLIDS - PARTS PER MILLION
6000 TONS
MONTHLY TONNAGE OF SALTS (TOTAL DISSOLVED SOLIDS) CARRIED IN STREAM
MELONES RES
Capacity 112,500 Ac-Ft
BELOW MELONES 11,000 TONS
SOUTH SAN JOAQUIN IRR DIST DIVERSION
OAKDALE IRR DIST DIVERSION
3000 TONS
900 TONS
ORANGE BLOSSOM 8000 TONS
STANISLAUS
RIVER
DON PEDRO RES
Capacity 289,000 Ac-Ft
ABOVE LA GRANGE 12,000 TONS
MODESTO IRR DIST DIVERSION
TURLOCK IRR DIST DIVERSION
3000 TONS
AT HICKMAN 8000 TONS
TUOLUMNE
LAKE MC CLURE
Capacity 289,000 Ac-Ft
EXCHEQUER DAM
NEAR EXCHEQUER 6000 TONS
MERCED IRR DIST DIVERSION
4000 TONS
MERCED
NEAR STEVINSON 8000 TONS
BUCHANAN DAM SITE (PROPOSED)
1000 TONS
CHOWCHILLA
NO FLOW
HIDDEN DAM SITE (PROPOSED)
1000 TONS
FRESNO
MADERA
MILLERTON LAKE
Capacity 520,000 Ac-Ft
FRIANT DAM
FRIANT KERN DIVERSION
5000 TONS
MADERA DIVERSION
700 TONS
FRIANT 3000 TONS
BIOLA 6000 TONS
SAN JOAQUIN RIVER
WHITEHOUSE 5000 TONS
FRESNO
MERCED
STOCKTON
MODESTO
TO DELTA
NEAR MOUTH 14,000 TONS
HETCH HETCHY CROSSING 81,000 TONS
TUOLUMNE CITY 19,000 TONS
NEAR VERNALIS 85,000 TONS
NEAR GRAYSON 51,000 TONS
NEAR NEWMAN 26,000 TONS
FREMONT FORD 22,000 TONS
JOAQUIN
SAN
SALT SLOUGH
NEAR LOS BANOS 6000 TONS
DOS PALOS NEGLIGIBLE FLOW
RIVER
SAN LUIS CANAL COMPANY DIVERSION
2000 TONS
MENDOTA POOL DIVERSION
700 TONS
MENDOTA POOL
FRESNO SLOUGH
300 TONS
NEAR MENDOTA 5000 TONS
MENDOTA CANAL
DELTA
7000 TONS
BANTA-CARBONA IRR DIST DIVERSION
2000 TONS
EL SOLYO COMPANY DIVERSION
700 TONS
WEST STANISLAUS IRR DIST DIVERSION
7000 TONS
WESTLEY
PATTERSON
PATTERSON WATER DIST DIVERSION
2000 TONS
TRACY
LOS BANOS
NEAR TRACY 14,000 TONS
DELTA MENDOTA CANAL
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION
GENERAL DISTRIBUTION OF STREAMFLOW AND WATER QUALITY IN THE SAN JOAQUIN RIVER SYSTEM
APRIL 1956
SCALE OF MILES



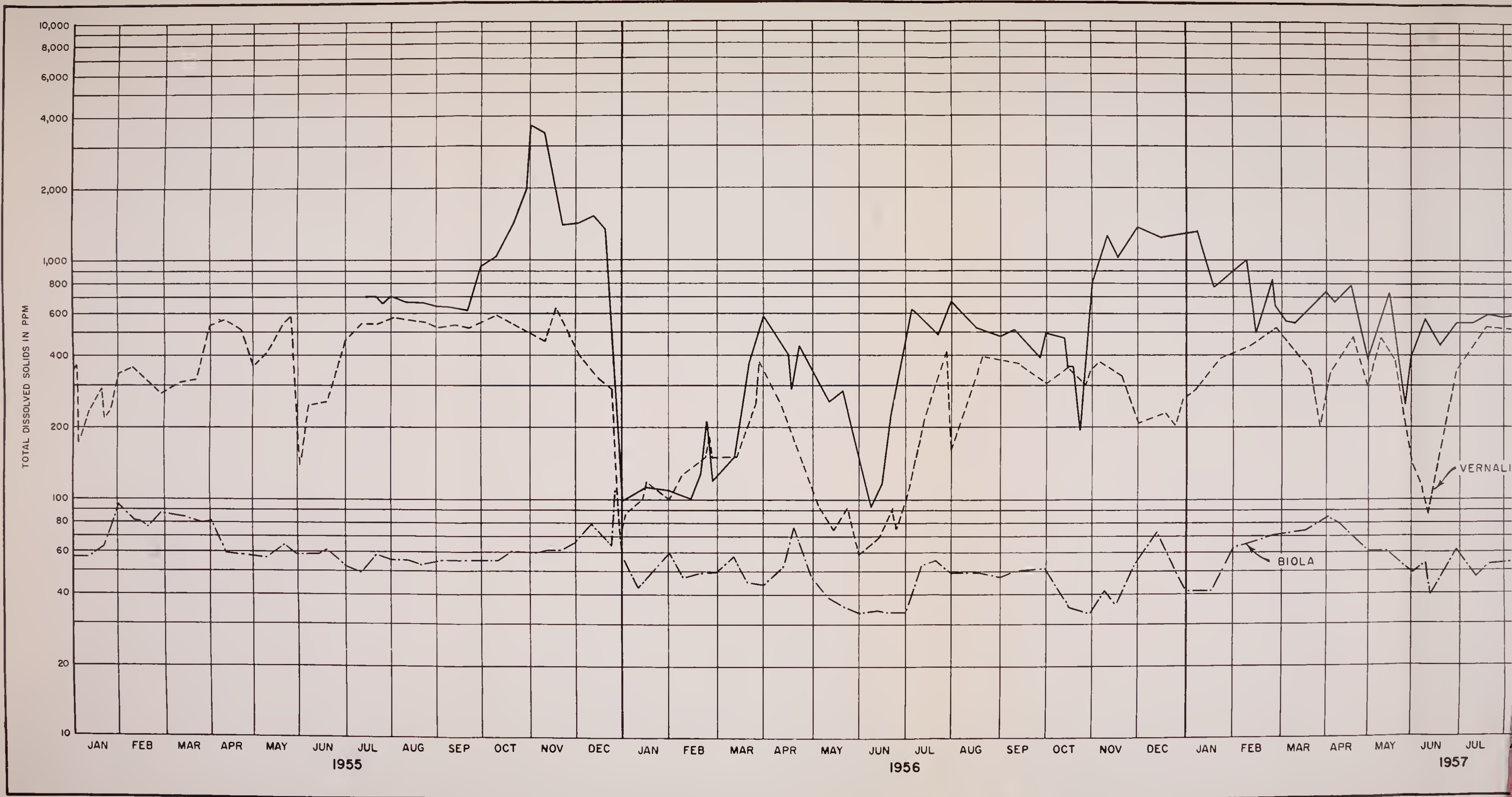
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

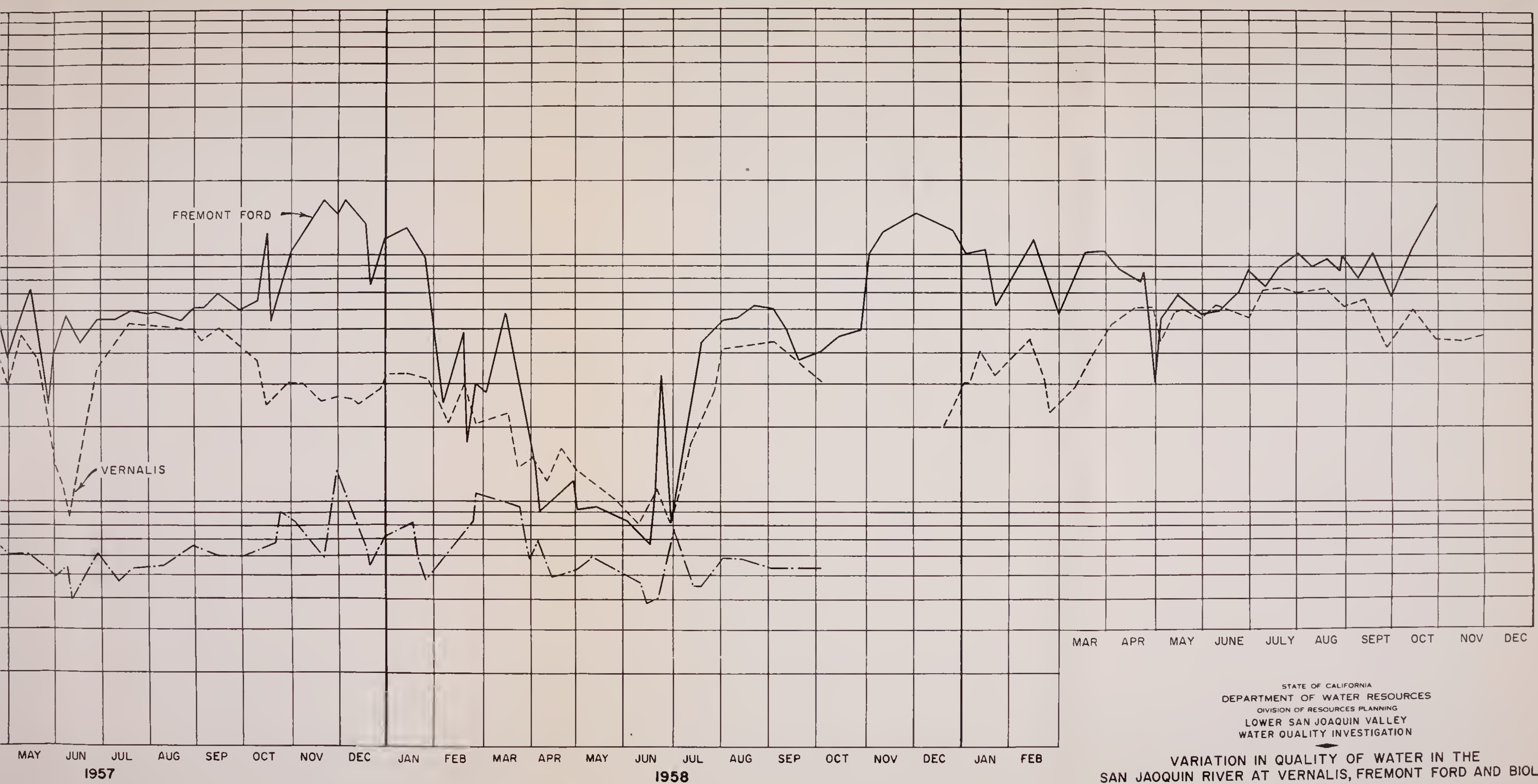
VARIATION IN QUALITY OF WATER IN THE
SAN JAOQUIN RIVER AT VERNALIS, FREMONT FORD AND BIOLA
1955–1959



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

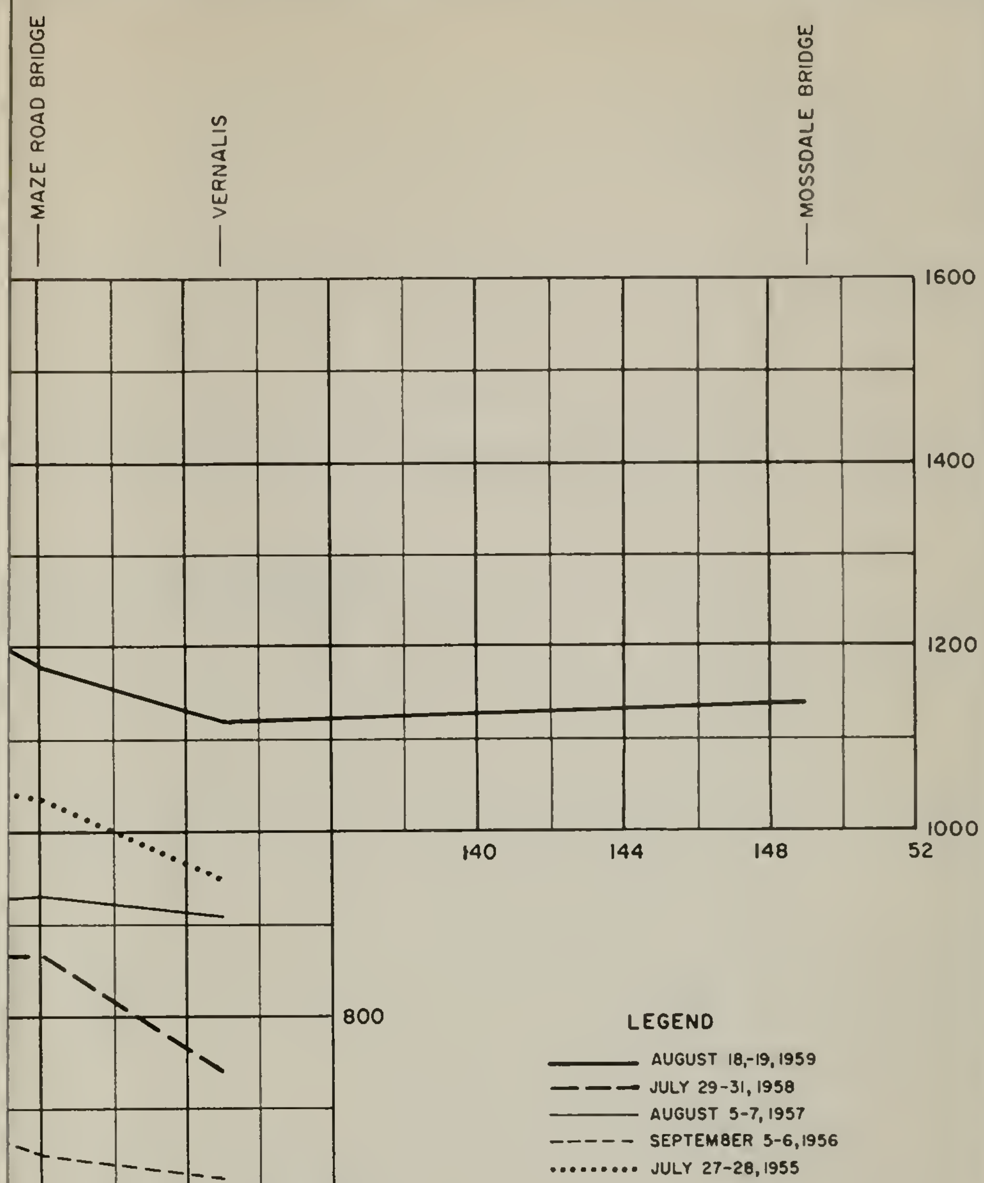
VARIATION IN QUALITY OF WATER IN THE
SAN JAOQUIN RIVER AT VERNALIS, FREMONT FORD AND BIOLA
1955–1959


TOTAL DISSOLVED SOLIDS IN PPM
10,000
8,000
6,000
4,000
2,000
1,000
800
600
400
200
100
80
60
40
20
10
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1955
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1956
JAN FEB MAR APR MAY JUN JUL
1957
VERNALI
BIOLA



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

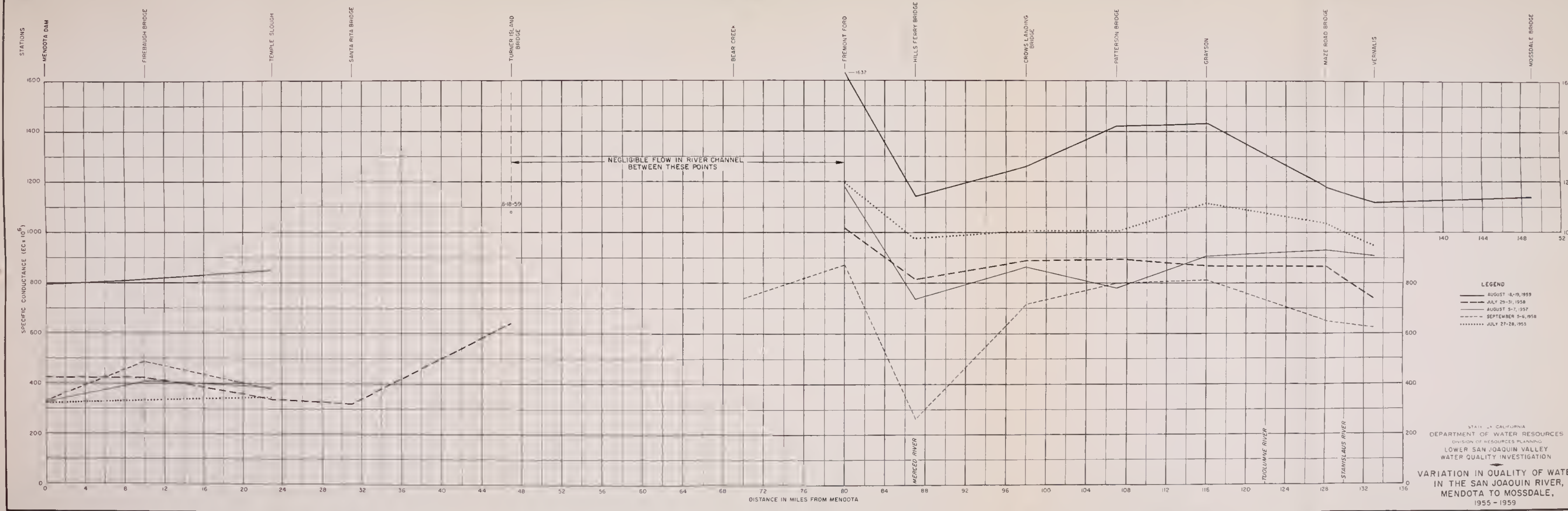
VARIATION IN QUALITY OF WATER IN THE
SAN JAOQUIN RIVER AT VERNALIS, FREMONT FORD AND BIOLA
1955–1959



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

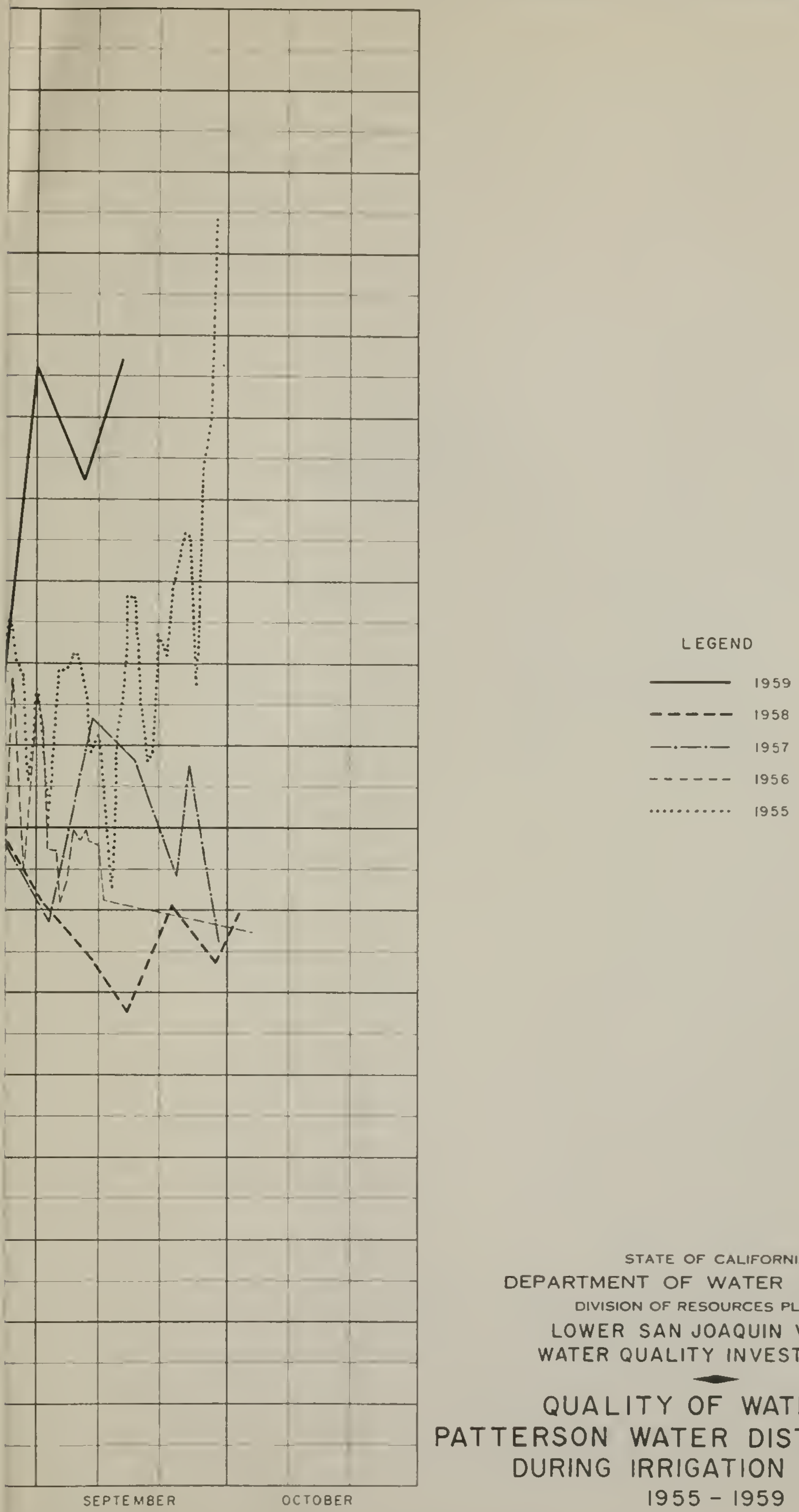
VARIATION IN QUALITY OF WATER
IN THE SAN JOAQUIN RIVER,
MENDOTA TO MOSSDALE,
1955 – 1959

PLATE 12



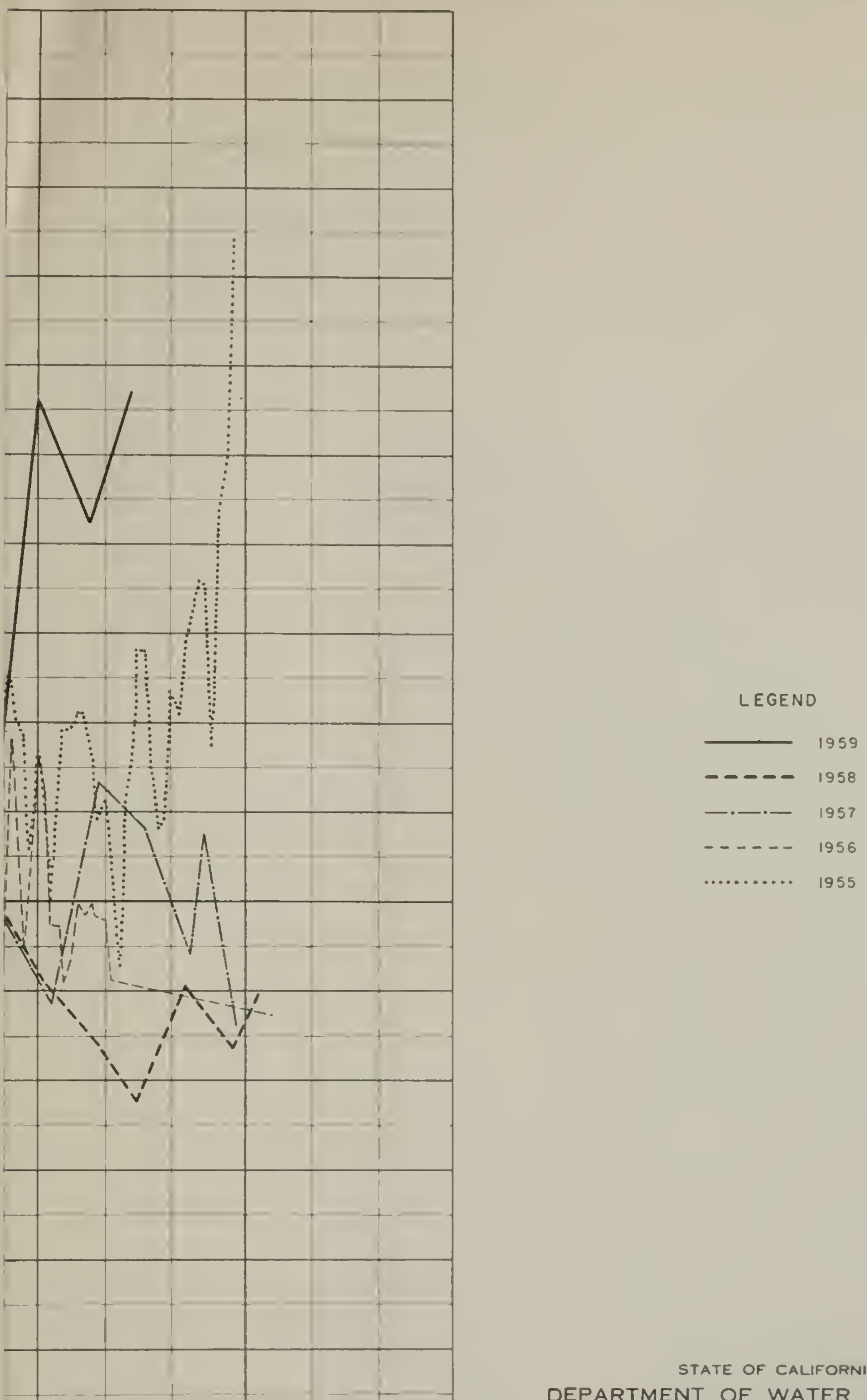
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

VARIATION IN QUALITY OF WATER IN THE SAN JOAQUIN RIVER, MENDOTA TO MOSSDALE, 1955 - 1959



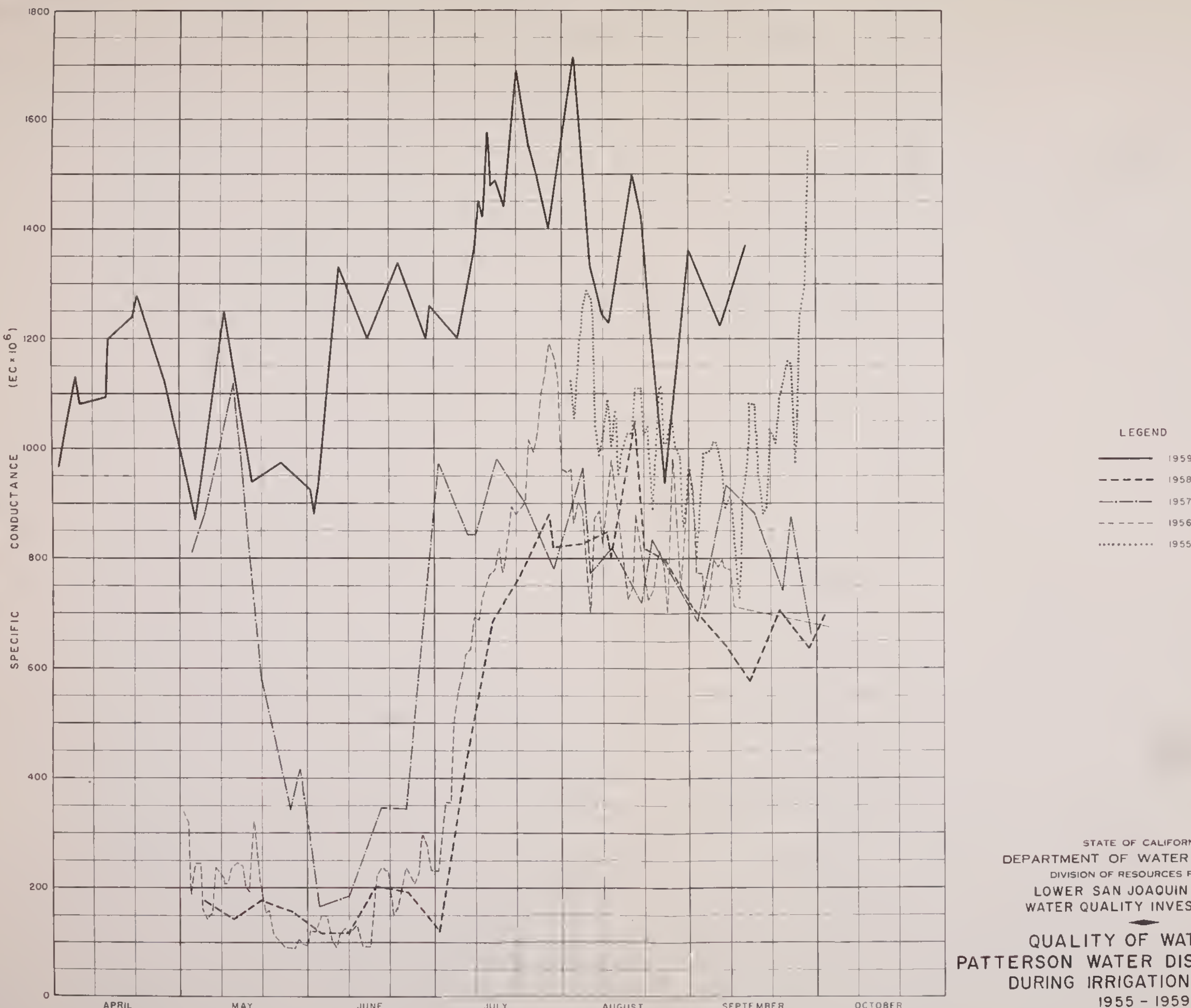
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

QUALITY OF WATER AT PATTERSON WATER DISTRICT INTAKE, DURING IRRIGATION SEASON 1955 - 1959



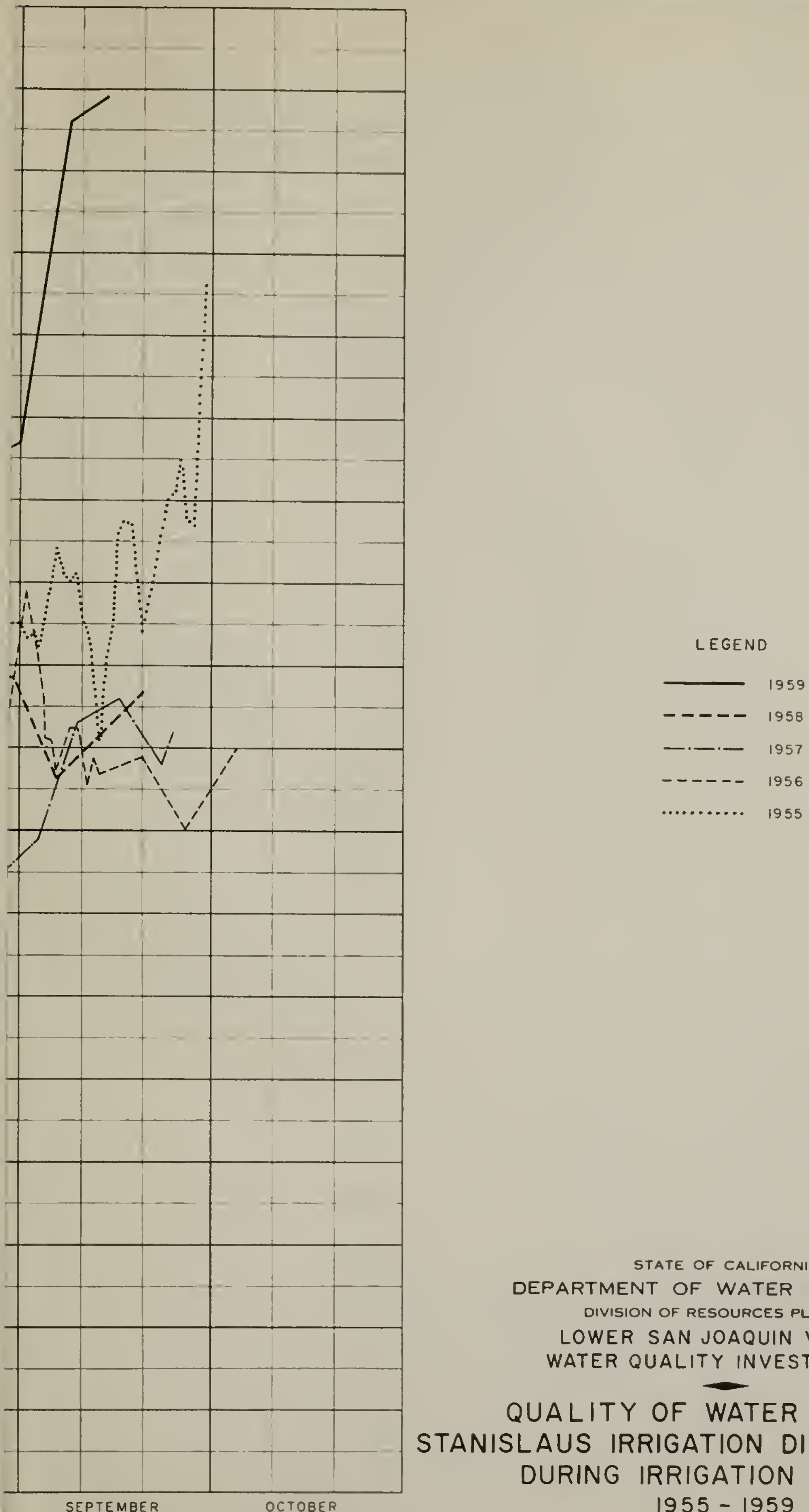
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

QUALITY OF WATER AT
PATTERSON WATER DISTRICT INTAKE,
DURING IRRIGATION SEASON
1955 - 1959



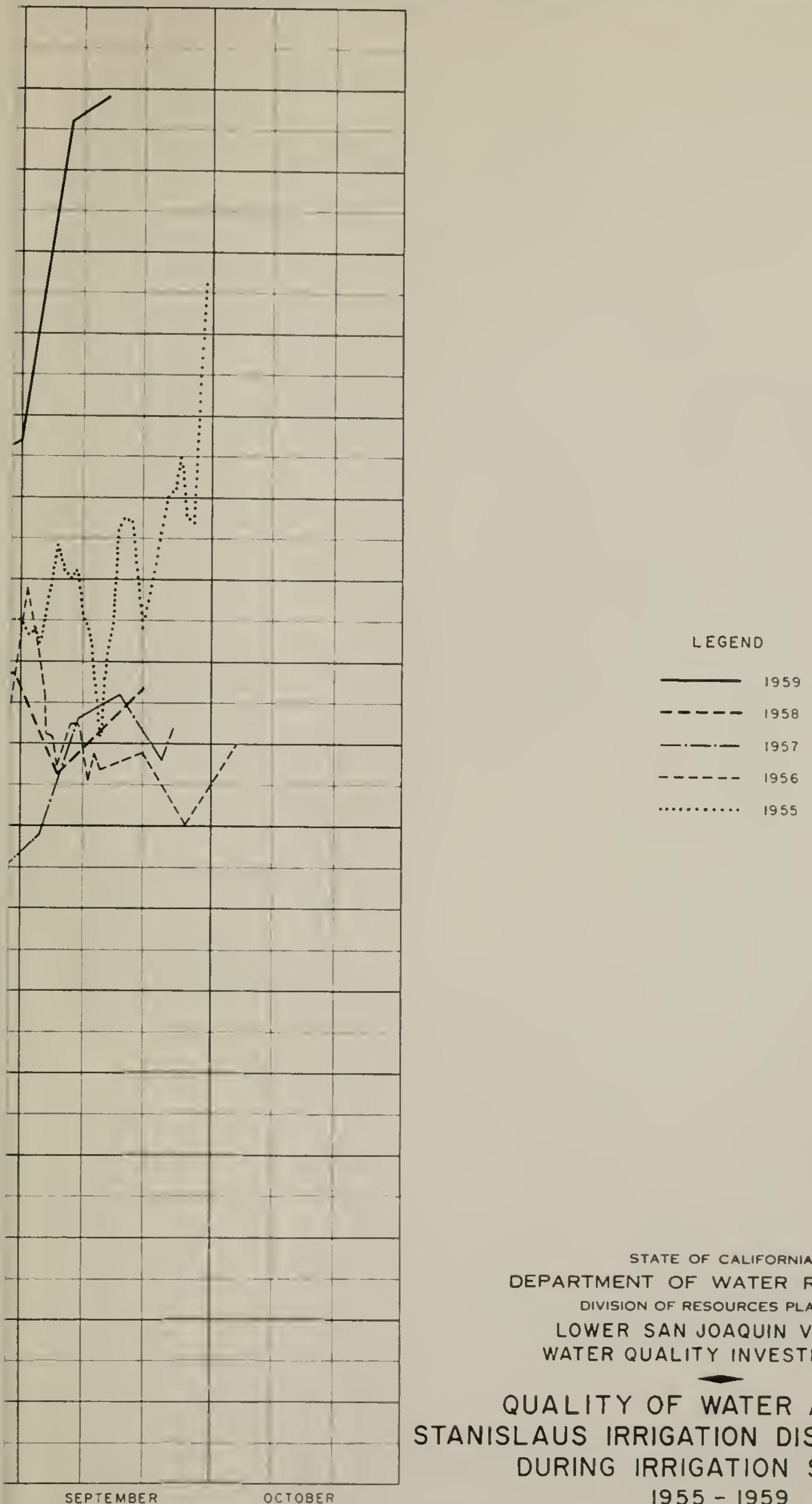
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

QUALITY OF WATER AT PATTERSON WATER DISTRICT INTAKE, DURING IRRIGATION SEASON
1955 - 1959



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

QUALITY OF WATER AT WEST STANISLAUS IRRIGATION DISTRICT INTAKE, DURING IRRIGATION SEASON
1955 - 1959



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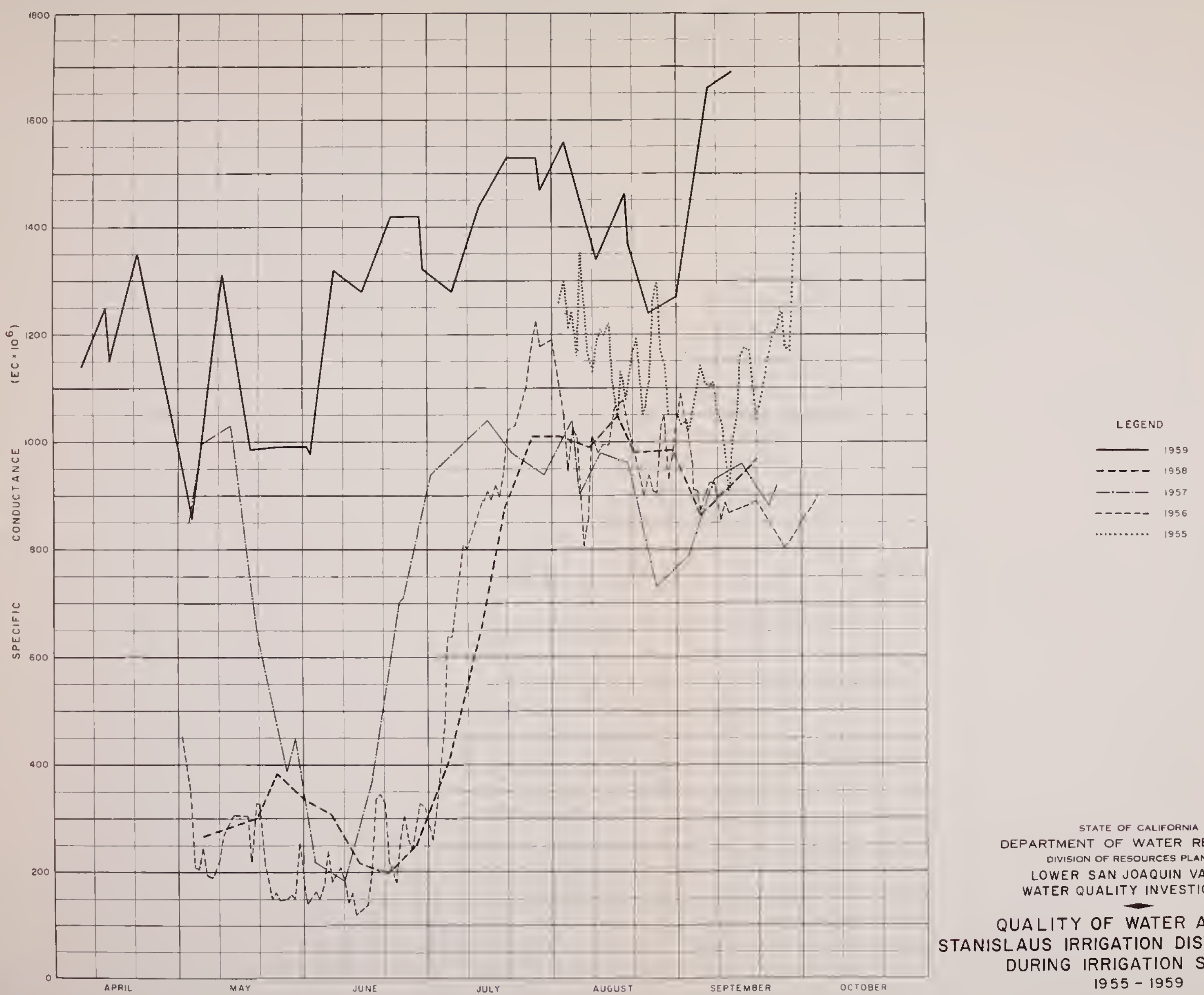
DIVISION OF RESOURCES PLANNING
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION

QUALITY OF WATER AT WEST STANISLAUS IRRIGATION DISTRICT INTAKE, DURING IRRIGATION SEASON
1955 - 1959



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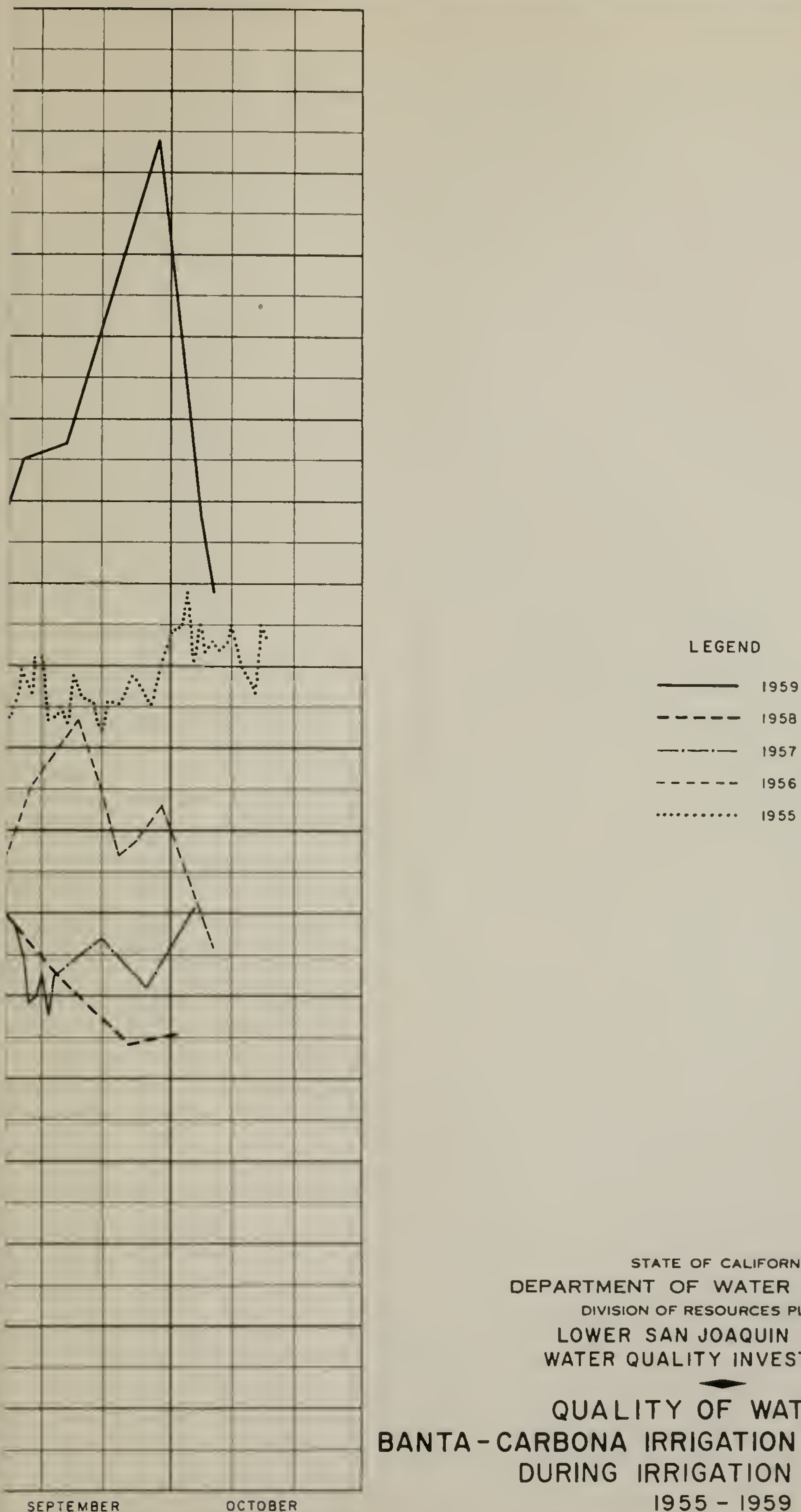
1955 - 1959



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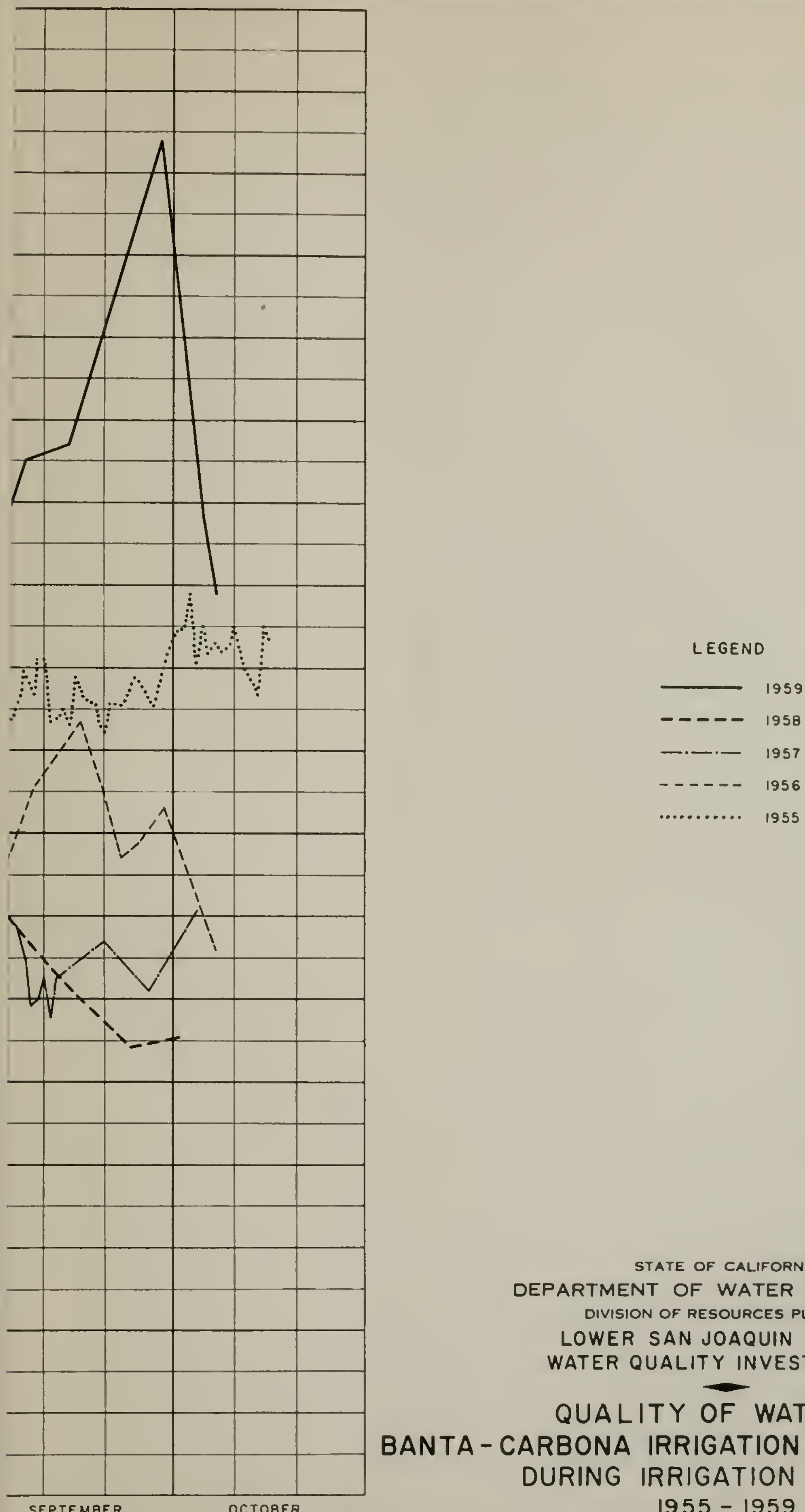
WATER QUALITY INVESTIGATION

QUALITY OF WATER AT
BANTA-CARBONA IRRIGATION DISTRICT INTAKE,
DURING IRRIGATION SEASON
1955 - 1959



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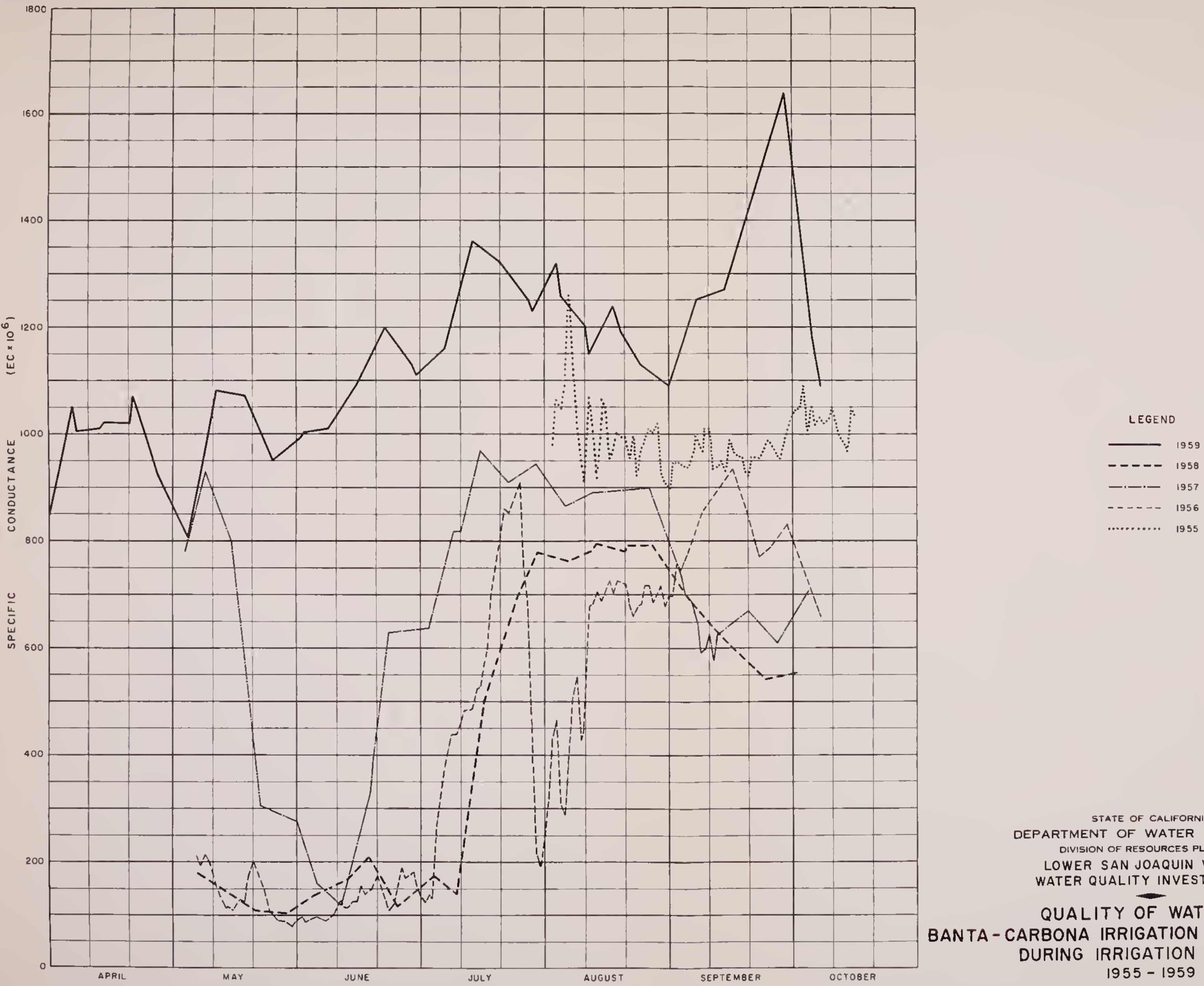
QUALITY OF WATER AT
BANTA-CARBONA IRRIGATION DISTRICT INTAKE,
DURING IRRIGATION SEASON
1955 - 1959



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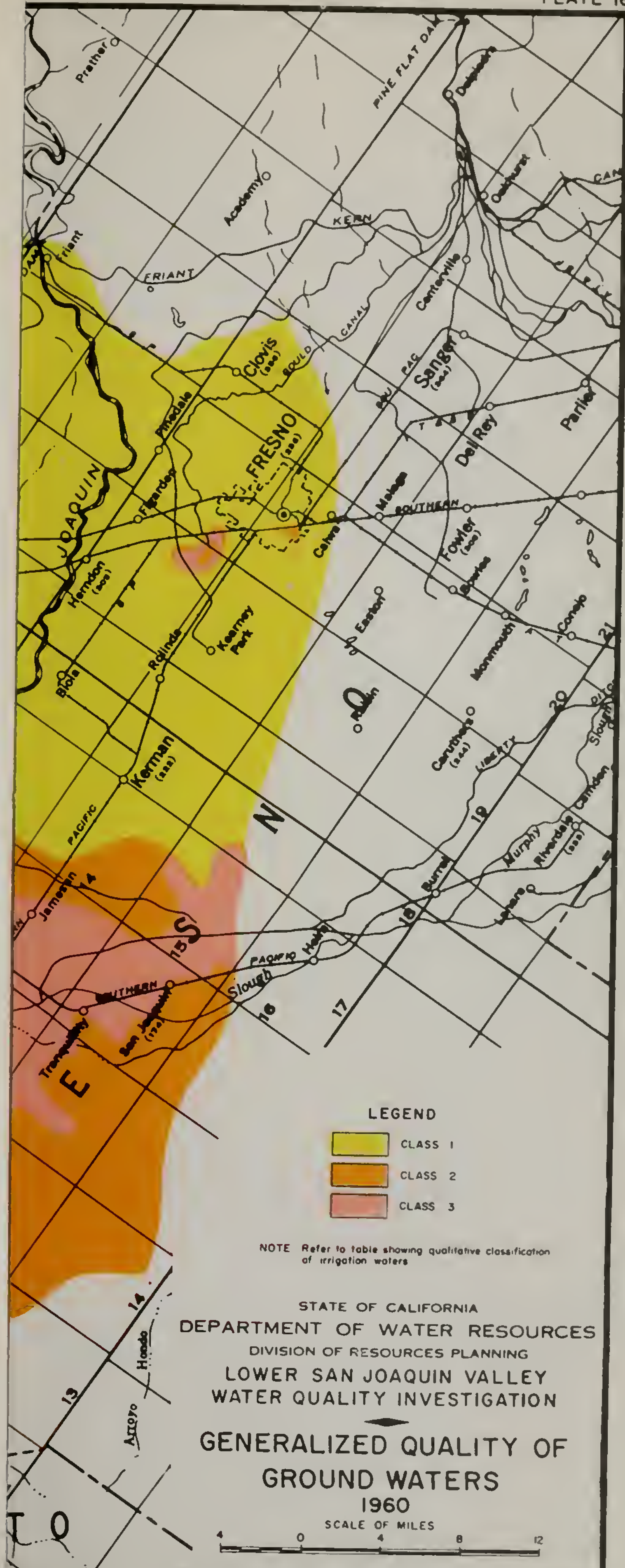
1955 - 1959


LEGEND
CLASS 1
CLASS 2
CLASS 3
NOTE Refer to table showing qualitative classification of irrigation waters
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
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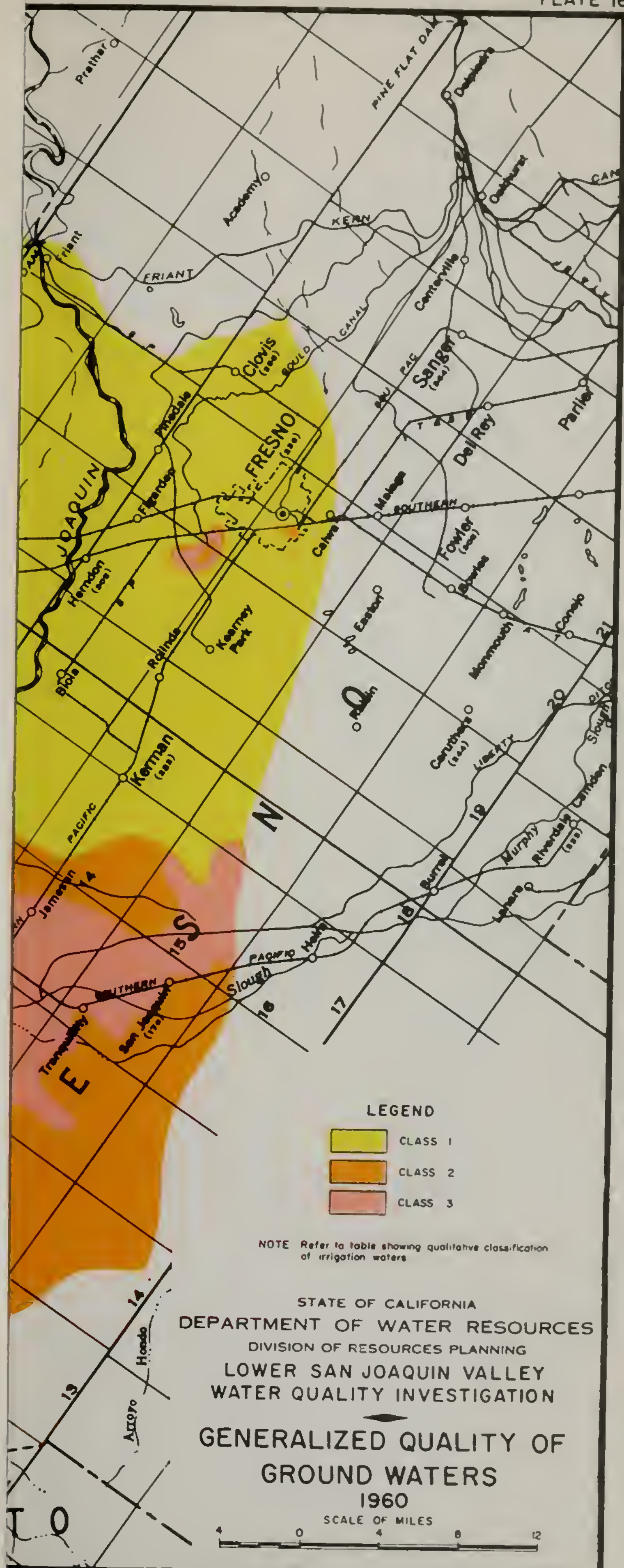
LOWER SAN JOAQUIN VALLEY
WATER QUALITY INVESTIGATION
GENERALIZED QUALITY OF
GROUND WATERS
1960
SCALE OF MILES
4
0
4
8
12
PINE FLAT DAM
Prather
Academy
Friant
FRIANT
KERN
CANAL
GOULD
Centerville
Clovis
Sanger
Parlier
Del Rey
FRESNO
Pinedale
Figarden
Malaga
SOUTHERN
Calwa
Fowler
Herndon
Kearney Park
Easton
Monmouth
Conejo
Rolinda
Biola
Caruthers
LIBERTY
Kerman
PACIFIC
JOAQUIN
Burrel
Murphy
Riverdale
Laton
Jameson
Helm
Slough
Tranquillity
San Joaquin
Hoodo
Arroyo
F
R
E
S
N
O
T O
13
14
15
16
17
18
19
20
21


Prather
PINE FLAT DAM
Dunlap
Academy
KERN
Friant
FRIANT
CANAL
Centerville
Clovis
Sanger
Parlier
Pinedale
FRESNO
Del Rey
JOAQUIN
SOUTHERN
Malaga
Fowler
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Herndon
Kearney Park
Easton
Monmouth
Conejo
Biola
Rolinda
Kerman
Caruthers
LIBERTY
PACIFIC
Riverdale
Laton
N
Jameson
Burrel
Murphy
S
Helm
Lanare
Slough
Tranquillity
San Joaquin
E
LEGEND
CLASS 1
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NOTE Refer to table showing qualitative classification of irrigation waters
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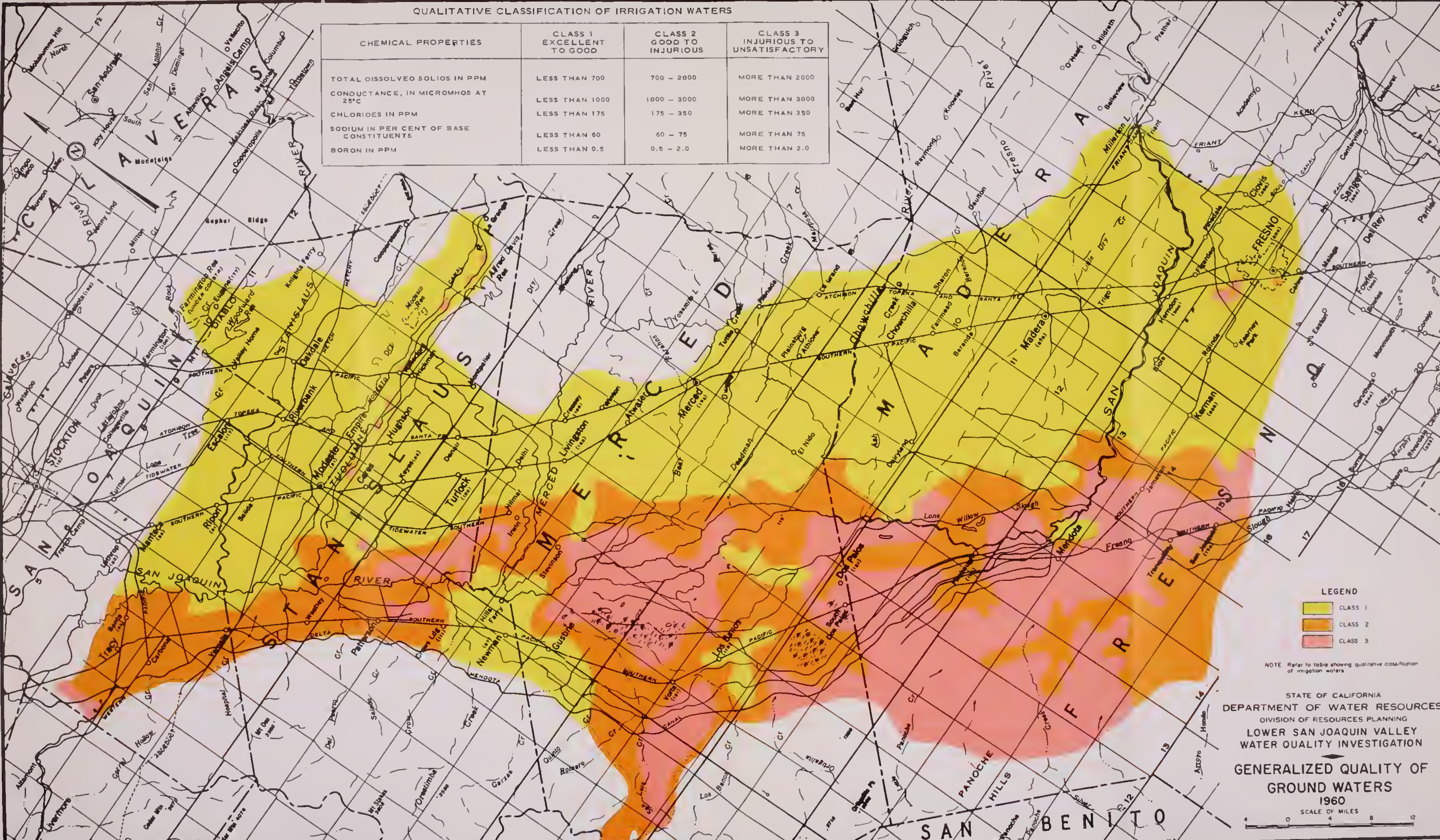
WATER QUALITY INVESTIGATION
GENERALIZED QUALITY OF
GROUND WATERS
1960
SCALE OF MILES
4 0 4 8 12
Hondo
Arroyo
T O

QUALITATIVE CLASSIFICATION OF IRRIGATION WATERS

CHEMICAL PROPERTIES	CLASS 1 EXCELLENT TO GOOD	CLASS 2 GOOD TO INJURIOUS	CLASS 3 INJURIOUS TO UNSATISFACTORY
TOTAL DISSOLVED SOLIDS IN PPM	LESS THAN 700	700 – 2000	MORE THAN 2000
CONDUCTANCE, IN MICROMHOS AT 25°C	LESS THAN 1000	1000 – 3000	MORE THAN 3000
CHLORIDES IN PPM	LESS THAN 175	175 – 350	MORE THAN 350
SODIUM IN PER CENT OF BASE CONSTITUENTS	LESS THAN 60	60 – 75	MORE THAN 75
BORON IN PPM	LESS THAN 0.5	0.5 – 2.0	MORE THAN 2.0



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WATER QUALITY INVESTIGATION

GENERALIZED QUALITY OF GROUND WATERS
1960