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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

PUBLICATIONS OF THE
DIVISION OF WATER RESOURCES
EDWARD HYATT, State Engineer

Reports on State Water Plan Prepared Pursuant to Chapter 832, Statutes of 1929

BULLETIN No. 27

VARIATION AND CONTROL OF SALINITY IN SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY

1931

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ACKNOWLEDGMENT

In carrying out the investigation of salinity in the Sacramento–San Joaquin Delta and San Francisco Bay, valuable assistance has been rendered by many individuals and public and private agencies.

Many have cooperated in the work of obtaining water samples at salinity observation stations. The owners of lands in the delta have contributed the time of their employees for taking water samples without cost to the State. In addition they have cooperated in furnishing basic data as to crop acreages and yields and as to irrigation diversions and drainage pumping operations. Executives and engineers of industries and other agencies have furnished records of salinity.

Valuable cooperation has been received from several departments of the Federal Government, including the Water Resources and Topographic branches of the Geological Survey of the Department of the Interior, the Division of Agricultural Engineering of the Bureau of Public Roads of the Department of Agriculture, and the Coast and Geodetic Survey of the Department of Commerce. The State Division of Highways has cooperated in the testing of salinity samples.

Special commendation is due the engineers on the Advisory Committee of this investigation whose advice and assistance have contributed materially to the successful prosecution and completion of the studies and report presented herein.

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Edward Hyatt ---------------------------------- *State Engineer*

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This investigation was outlined and the report prepared with the advice of and in consultation with the following consulting engineers:

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T. H. Means

FEDERAL AGENCIES COOPERATING IN INVESTIGATION

DEPARTMENT OF THE INTERIOR

Geological Survey, Water Resources Branch

H. D. McGlashan, *District Engineer*

Valuable cooperation was rendered by Mr. McGlashan in furnishing advance information on stream flow entering the delta, and in improving the installations of certain stream gaging stations maintained for this purpose.

Geological Survey, Topographic Branch

Thomas D. Gerdine,* *Division Engineer*

Through cooperative agreement, precise level lines were run in the San Francisco Bay region and delta under the direction of Mr. Gerdine for the purpose of referring the automatic tide gages to a common precise level datum.

DEPARTMENT OF AGRICULTURE

Bureau of Public Roads, Division of Agricultural Engineering

W. W. McLaughlin, *Associate Chief*

Under cooperative agreement, the Division of Agricultural Engineering under the general direction of Mr. McLaughlin and immediate supervision of Major O. V. P. Stout, made detailed measurements of the consumptive use of water by crops and natural vegetation in the Sacramento–San Joaquin Delta, covering a period of over six years.

DEPARTMENT OF COMMERCE

Coast and Geodetic Survey

Thos. J. Maher, *Inspector, San Francisco Field Station*

Commander Maher of the Coast and Geodetic Survey furnished assistance and advice and loaned tide gage equipment in the work of obtaining tidal records in the San Francisco Bay and delta regions.

* Since deceased.

STATE AGENCIES COOPERATING IN INVESTIGATION

DIVISION OF HIGHWAYS

C. H. PURCELL, *State Highway Engineer*

The testing laboratory of the Division of Highways under the direction of Thomas E. Stanton, Materials and Research Engineer, has rendered most valuable assistance in the testing of all water samples for salinity since 1923. Chemical Testing Engineer G. H. P. Lichthardt has been in general charge of the work assisted by Testing Engineer Aids H. M. Aaron and N. T. Austin and Assistant Testing Engineers W. J. Lentz and E. F. Pennock. The expeditious and efficient manner in which the testing of samples was handled has greatly aided the effective prosecution of the investigation. Appendix B contains a brief report prepared by Thomas E. Stanton on "Laboratory Methods for Determination of Salinity."

CHAPTER 832, STATUTES OF 1929

An act making an appropriation for work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development and utilization of the water resources of California including the Santa Ana River, Mojave River and all water resources of southern California.

(I object to the item of $450,000 in section 1 and reduce the amount to $390,000. With this reduction I approve the bill. Dated June 17, 1929. C. C. Young, Governor.)

The people of the State of California do enact as follows:

SECTION 1. Out of any money in the state treasury not otherwise appropriated, the sum of four hundred fifty thousand dollars, or so much thereof as may be necessary, is hereby appropriated to be expended by the state department of public works in accordance with law in conducting work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development and utilization of the water resources of California including the Santa Ana River and its tributaries, the Mojave River and its tributaries, and all other water resources of southern California.

SEC. 2. The department of public works, subject to the other provisions of this act, is empowered to expend any portion of the appropriation herein provided for the purposes of this act, in cooperation with the government of the United States of America or in cooperation with political subdivisions of the State of California; and for the purpose of such cooperation is hereby authorized to draw its claim upon said appropriation in favor of the United States of America, or the appropriate agency thereof for the payment of the cost of such portion of said cooperative work as may be determined by the department of public works.

SEC. 3. Upon the sale of any bonds of this state hereafter authorized to be issued to be expended for any one or more of the purposes for which any part of the appropriation herein provided may have been expended, the amount so expended from the appropriation herein provided shall be returned into the general fund of the state treasury out of the proceeds first derived from the sale of said bonds.

FOREWORD

This report is one of a series of bulletins on the State Water Plan issued by the Division of Water Resources pursuant to Chapter 832, Statutes of 1929, directing further investigations of the water resources of California. The series include Bulletin Nos. 25 to 36, inclusive. Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," is a summary report of the entire investigation.

Prior to the studies carried out under this act, the water resources investigation had been in progress more or less continuously since 1921 under several statutory enactments. The results of the earlier work have been published as Bulletin Nos. 3, 4, 5, 6, 9, 11, 12, 13, 14, 19 and 20 of the former Division of Engineering and Irrigation, Nos. 5, 6 and 7 of the former Division of Water Rights and Nos. 22 and 24 of the Division of Water Resources.

The full series of water resources reports prepared under Chapter 832, twelve in number are:

Bulletin No. 25—"Report to Legislature of 1931 on State Water Plan."

Bulletin No. 26—"Sacramento River Basin."

Bulletin No. 27—"Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay."

Bulletin No. 28—"Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers."

Bulletin No. 29—"San Joaquin River Basin."

Bulletin No. 30—"Pacific Slope of Southern California."

Bulletin No. 31—"Santa Ana River Basin."

Bulletin No. 32—"South Coastal Basin."

Bulletin No. 33—"Rainfall Penetration and Consumptive Use of Water in Santa Ana River Valley and Coastal Plain."

Bulletin No. 34—"Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley."

Bulletin No. 35—"Permissible Economic Rate of Irrigation Development in California."

Bulletin No. 36—"Cost of Irrigation Water in California."

This bulletin presents the results of an intensive study of the occurrence and variation of salinity in the upper San Francisco Bay and Sacramento-San Joaquin Delta channels, and the basic factors of stream flow and tidal action affecting salinity and their relation to its variation. Finally, there is presented a proposed plan for the control of salinity by stream flow to prevent harmful saline invasion into the delta and maintain a dependable and adequate fresh-water supply in the delta channels for the full consumptive demands of the delta; and provide a dependable source for diversion of fresh-water supplies, now or hereafter made available in the delta, for the needs of industrial, municipal and agricultural developments in the upper bay region.

CHAPTER I

INTRODUCTION, SUMMARY AND CONCLUSIONS

The waters of San Francisco Bay are a combination of the salt water of the ocean which enters the bay through the Golden Gate, and the fresh water of the Sacramento and San Joaquin rivers and local streams of the San Francisco Bay Basin which discharge into the bay. The salinity of the water resulting from this combination is extremely variable both geographically and during different periods of the year, and depends upon the amount of fresh water discharged by the streams. The more saline waters are found in the lower bay nearest the ocean, the fresher waters in the upper bays and tidal estuaries and channels through which the fresh water enters, while in between are found gradations from salt to fresh water. When the streams are in flood, the upper bays and channels are often filled with fresh water and, during extreme floods, it is stated that fresh water has been found even as far down as the Golden Gate. When the flow of the streams is small during the summer and fall months, the water in the upper bays and tidal channels up to the lower reaches of the Sacramento and San Joaquin rivers generally becomes saline and remains so until the first floods of the succeeding winter season.

The invasion of saline water into the upper bay as far as the lower end of the Sacramento-San Joaquin Delta is a natural phenomenon which has occurred annually, at least as far back as historical records reveal. Under conditions of natural stream flow before upstream irrigation and storage developments occurred, the extent of saline invasion and the degree of salinity reached was much smaller than during the last ten to fifteen years. However, the evidence of all available information, as presented hereafter, points to the conclusion that saline water from the bay has advanced as far upstream as the vicinity of Collinsville and Antioch, causing a noticeable degree of salinity of ten parts or more of chlorine per 100,000 parts of water at some time each year during the period of low stream flow. In former years before extensive developments in agriculture and industry had been made in the upper bay and delta region, it was of small importance and received little, if any, attention. However, it was known by many of the early inhabitants of the Suisun Bay and lower delta region.

Beginning in 1917, there has been an almost unbroken succession of subnormal years of precipitation and stream flow which, in combination with increased irrigation and storage diversions from the upper Sacramento and San Joaquin River systems, has resulted in a degree and extent of saline invasion greater than has occurred ever before as far as known. These abnormal saline invasions not only have curtailed irrigation diversions and affected crop production and land values in the delta but also have reduced considerably the diversions of fresh-water supplies from the lower river and upper bay channels by the industries in the upper Suisun Bay area, thus increasing the difficulties and cost of obtaining industrial fresh-water supplies. The seriousness of this situation resulted in the initiation of investigations of salinity by the State, leading to the present investigation and report.

Area of Salinity Investigations.

The area in which the investigations of salinity have been made embraces the Sacramento-San Joaquin Delta and Suisun and San Pablo bays. This is shown on Plate I, "Area of Salinity Investigations and Related Water Resources and Developments in California." The more extensive studies have been made within the delta area and Suisun Bay, where the invasion of saline water during recent years has assumed great importance because of the serious effect upon the adjacent industrial and agricultural developments. However, in order to obtain more complete data on variation of salinity and determine the factors controlling the same, the investigation has been extended into San Pablo Bay area. Thus, there is embraced within the area of investigation all of the waters of the upper bay and delta channels in which the cyclic variations of salinity annually occur. It is within this area that the natural phenomenon of annual invasion and retreat of salinity takes place.

The geographical relation of the area of salinity investigations to the physiographical features of the State and, especially, the tributary stream systems is shown on Plate I. The magnitude of water resources naturally tributary to the delta and upper bay region is relatively large. Into this area drains the run-off from 32,000 [1] square miles of mountain and foothill land or 39 per cent of the entire mountain and foothill catchment area of the State. The two great river systems, the Sacramento and San Joaquin, which drain most of this area, flow through a network of channels forming a common delta and finally combine to discharge through a common mouth into the upper or easterly end of Suisun Bay. It is the discharge of these streams that has the most profound effect upon the quality of the waters in upper San Francisco Bay. When these streams are in flood, Suisun Bay is usually made fresh and San Pablo Bay often becomes partly fresh. On the other hand, when these streams have reached their low stage in the summer and fall months each season, the salt waters from the lower bay gradually advance upstream and mix with the fresh-water inflow and there results the annually recurring phenomenon of saline invasion. It is evident that any irrigation or storage developments on these tributary stream systems above the delta, involving a change in regimen of stream flow and, especially, a reduction in flow, directly modify the natural interrelations of salinity and stream flow in the delta and upper bay channels. The existing major storage reservoirs as of 1929 are shown on Plate I. Present irrigation developments diverting water from the Sacramento and San Joaquin rivers are far too numerous and extensive to illustrate properly on this map, but a large area of lands in the Sacramento and San Joaquin valleys is irrigated from these streams, diverting most of the low water flow. Looking to the future development of water resources on these streams, it may be

[1] Does not include Kings River.

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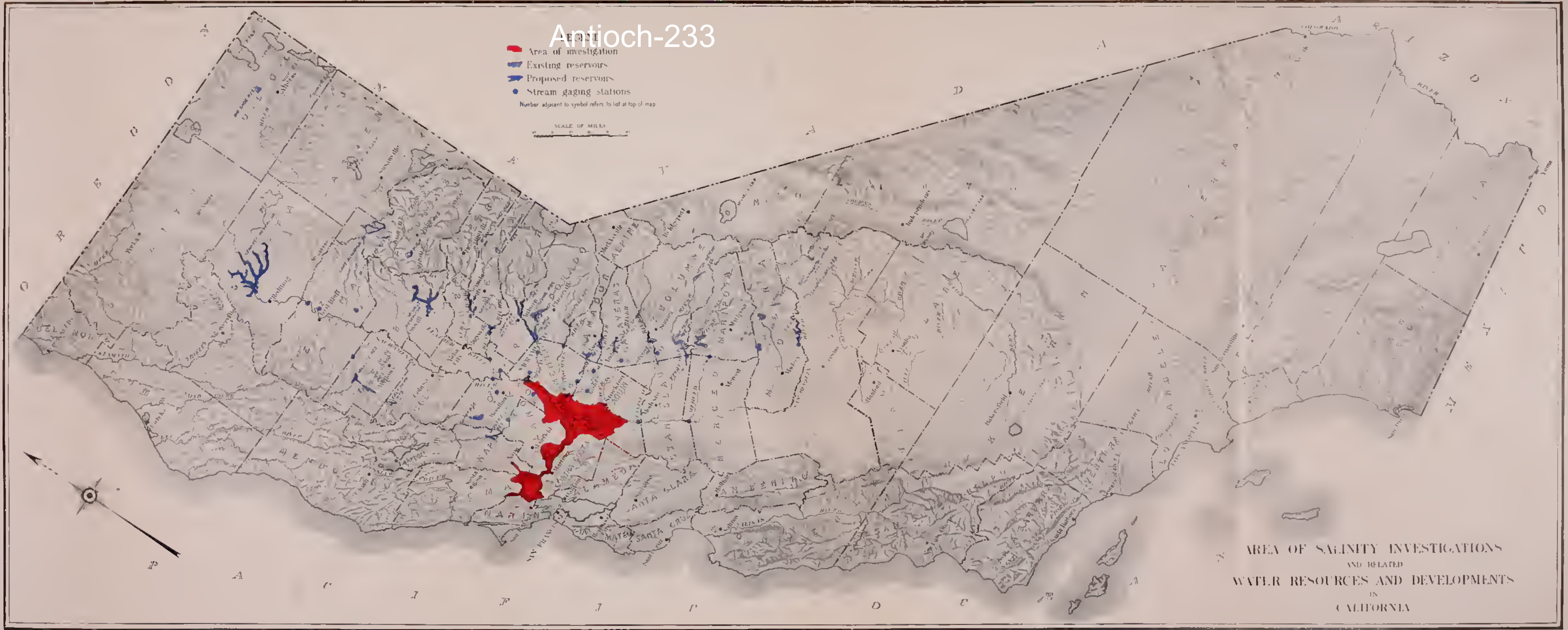
STREAM GAGING STATIONS

1	[illegible] River	[illegible] Jellys Ferry
[illegible]	[illegible] River	near Red Bluff
[illegible]	[illegible] Creek	near Vina
[illegible]	[illegible] River	at Oroville
[illegible]	[illegible]	at Smartsville
[illegible]	[illegible] River	at Van Trent
[illegible]	[illegible] River	at Nicolaus
[illegible]	[illegible] River	at Knights Landing
[illegible]	[illegible] River	at Verona
[illegible]	[illegible]	at Sacramento
[illegible]	[illegible] River	at H St. Bridge near Sacramento
[illegible]	[illegible] River	at Fairoaks
[illegible]	[illegible] River	at Michigan Bar
[illegible]	[illegible] River	near Thornton
[illegible]	[illegible] Creek	near Galt
[illegible]	[illegible] River	at Woodbridge
[illegible]	[illegible] River	near Clements
[illegible]	[illegible] River	at Jenny Lind
[illegible]	[illegible] River	near Knights Ferry
[illegible]	Tuolumne River	near La Grange
[illegible]	San Joaquin River	near Newman
[illegible]	Merced River	near Merced Falls
[illegible]	San Joaquin River	near Friant
[illegible]	San Joaquin River	near Vernalis
25	Yolo By-pass	at Lisbon
[illegible]	Putah Creek	at Winters
[illegible]	Cache Creek	at Yolo
[illegible]	Stony Creek	near Orland



AREA OF SALINITY INVESTIGATIONS
AND RELATED
WATER RESOURCES AND DEVELOPMENTS
IN
CALIFORNIA

expected that additional storage reservoirs and municipal water supply, irrigation and power systems will be constructed as the needs increase with the growth of the State. Plate I shows the major storage reservoirs on these streams as proposed in the State Water Plan.* In addition, there doubtless will be numerous other reservoirs constructed by private and public agencies. The water resources developments in past years have affected salinity conditions in the delta and upper bay region and future developments may be expected to modify them still farther.

The developments and interests affected by saline invasion include the agricultural lands of the Sacramento-San Joaquin Delta and the industries, municipalities, and agricultural lands adjacent to Suisun and San Pablo Bays. The location and extent of these developments are shown on Plate II, "Agricultural and Industrial Developments in the Sacramento-San Joaquin Delta and Upper San Francisco Bay Regions and Related Water Resources and Developments of Northern California." Inasmuch as the investigations of the variation and control of salinity are particularly related to these developments, it is of interest to consider the character and magnitude of their operations and activities, and the physiographical features of the channels and bays adjacent thereto. These are briefly described in the following paragraphs, but a more detailed description of the developments and activities of the upper bay and delta regions is presented in another report.**

Sacramento-San Joaquin Delta—The area known as the Sacramento-San Joaquin Delta is situated in the lowest part of the Great Central Basin of California, midway between the Sacramento and San Joaquin valleys. (See Plates I and II). In its original state of nature, it consisted of swamp and overflow lands gradually built up through the ages by accumulations of decayed vegetation and deposits of silt brought down by the Sacramento and San Joaquin rivers. These swamp lands were covered with various types of aquatic vegetation, trees and grasses. Sycamores, willows and cottonwoods lined the banks of the Sacramento River and its branch channels while the interior of the islands and lower-lying lands of the Sacramento Delta supported a dense growth of tules and other aquatic plants. In the San Joaquin Delta and lower Sacramento Delta where the peat lands are situated, willows occasionally lined the banks of the channels or occurred inland in clumps. Most of the islands in the San Joaquin Delta were covered largely with various grasses and occasional clumps of tules and similar aquatic plants. The Sacramento and San Joaquin rivers, upon reaching the delta, spread out into a network of channels separated by islands in a typical delta formation, and finally discharge their waters through a common mouth into Suisun Bay, which forms the northeasterly arm of San Francisco Bay.

The delta has a gross area of 487,500 acres, roughly 20 miles wide by 50 miles long. It extends up the Sacramento River as far north as the city of Sacramento and up the San Joaquin River as far south as the Mossdale Bridge on the Lincoln Highway near the town of Lathrop.

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* Bulletin No. 25, Report to Legislature of 1931 on State Water Plan, Division of Water Resources, 1930.

** Bulletin No. 28, Economic Aspects of a Salt Water Barrier below Confluence of Sacramento and San Joaquin Rivers, Division of Water Resources, 1931.

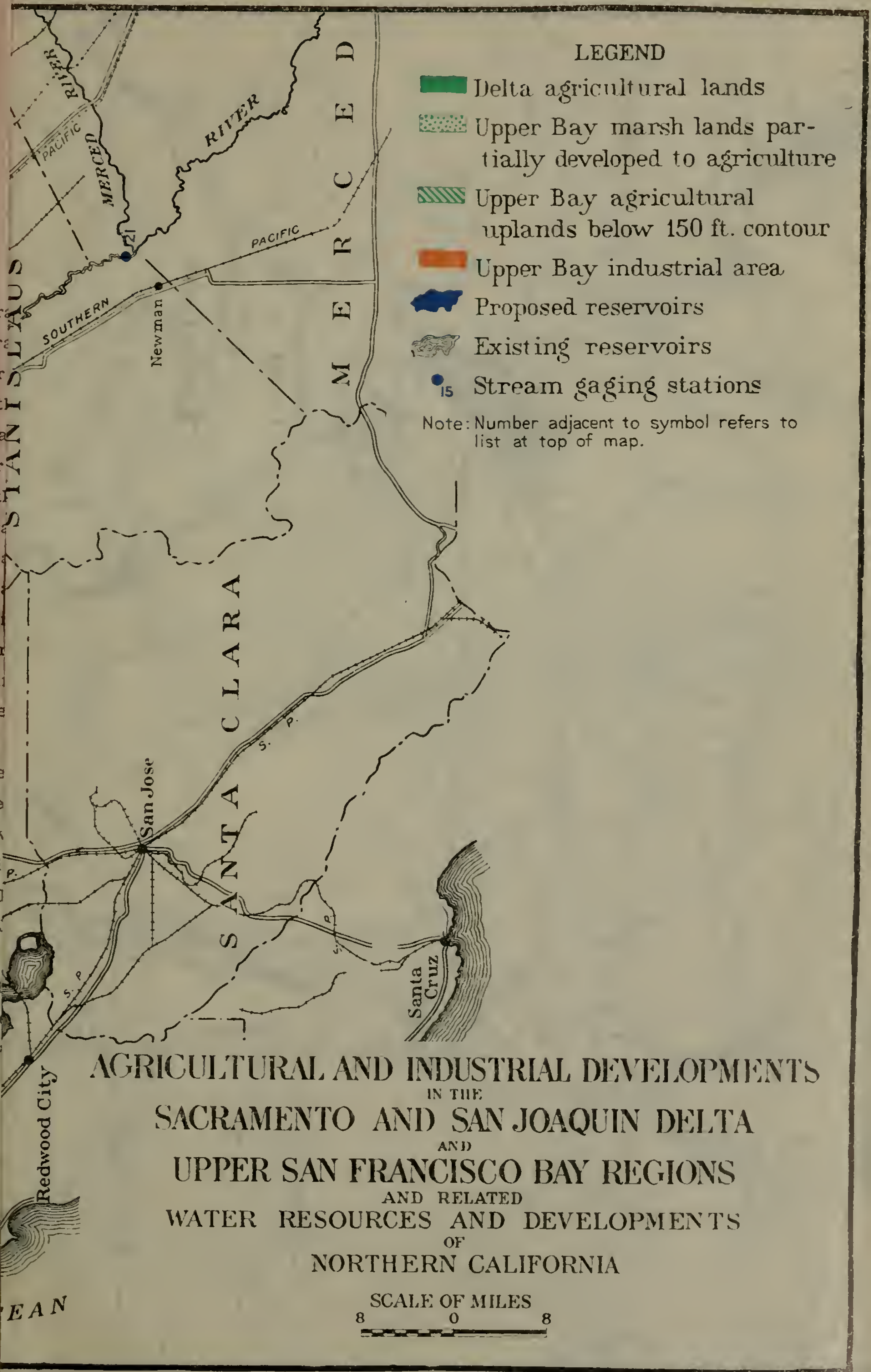
Its easterly boundary skirts the city of Stockton and lies about seven miles west from Lodi and Galt. Its westerly end at the junction of the rivers is near Antioch and Collinsville. A large portion of the land lies at an elevation at or below mean sea level.

Within the delta are 421,000 acres of highly productive agricultural lands, consisting of sediment and peat soils, which have been gradually reclaimed at great cost over a period of 75 years of progressive reclamation development. At the present time probably all lands within the delta which are feasible of reclamation have been fully reclaimed and are now being farmed. In 1929, 350,000 acres of land in the delta were in crops, such as asparagus, corn, potatoes, sugar beets, beans, celery, pears, peaches, alfalfa, wheat and barley. The annual value of crops produced in the delta in 1929 is estimated to have been about $30,000,000. The taxable wealth of the delta area is approximately $45,000,000.

The network of channels which separate the islands in the delta is of great importance to the area. The channels not only are the source of water supply used for irrigation of crops, but they provide efficient and economical water transportation for crops, equipment, materials and supplies. In the case of some of the islands, it is the only form of transportation now available. These channels, which have an aggregate length of about 550 miles and an open water area of about 38,000 acres, are all navigable for river craft, which transport a large part of the freight handled, to and from the nearest railroad loading points, or to and from bay and river points. With the completion of the Stockton Ship Canal, now under construction, it will be possible for deep-draft ocean-going vessels to navigate as far as Stockton.

Suisun Bay Area—Suisun Bay, into which the Sacramento and San Joaquin rivers jointly discharge immediately west of the delta, is a relatively shallow body of water, with two main arms separated by a peninsula and close-lying islands extending out from the north shore. Its southerly arm is practically a continuation of the river, extending along the south shore for about ten miles and varying in width from one to two miles. The southerly arm includes the deeper waters and the main navigation channels. The northerly arm extends in a northeasterly direction from the lower end of Suisun Bay a distance of ten miles and spreads out at its upper end into a broad, shallow basin locally known as Grizzly Bay. The total area of open water in Suisun Bay below the mouth of the rivers is about 30,000 acres. Large quantities of silt and debris brought down by the rivers have been deposited in Suisun Bay and the gradual accumulations through the passage of time have resulted in diminishing the area and depth of the bay. Dredging operations are required from year to year to keep the navigation channels open.

Adjoining the north shore of Suisun Bay is an extensive area of marshlands aggregating 58,700 acres, consisting of numerous islands separated by a network of channels. One of these main channels, known as Montezuma Slough, extends in a circular path for about 20 miles from the upper end of the northerly arm of Suisun Bay to join the Sacramento River just below Collinsville. This channel thus forms a secondary outlet to carry the river discharge into the bay. Suisun Slough is another important channel, which meanders northerly to a dead end near the cities of Suisun and Fairfield.



AGRICULTURAL AND INDUSTRIAL DEVELOPMENTS
IN THE
SACRAMENTO AND SAN JOAQUIN DELTA
AND
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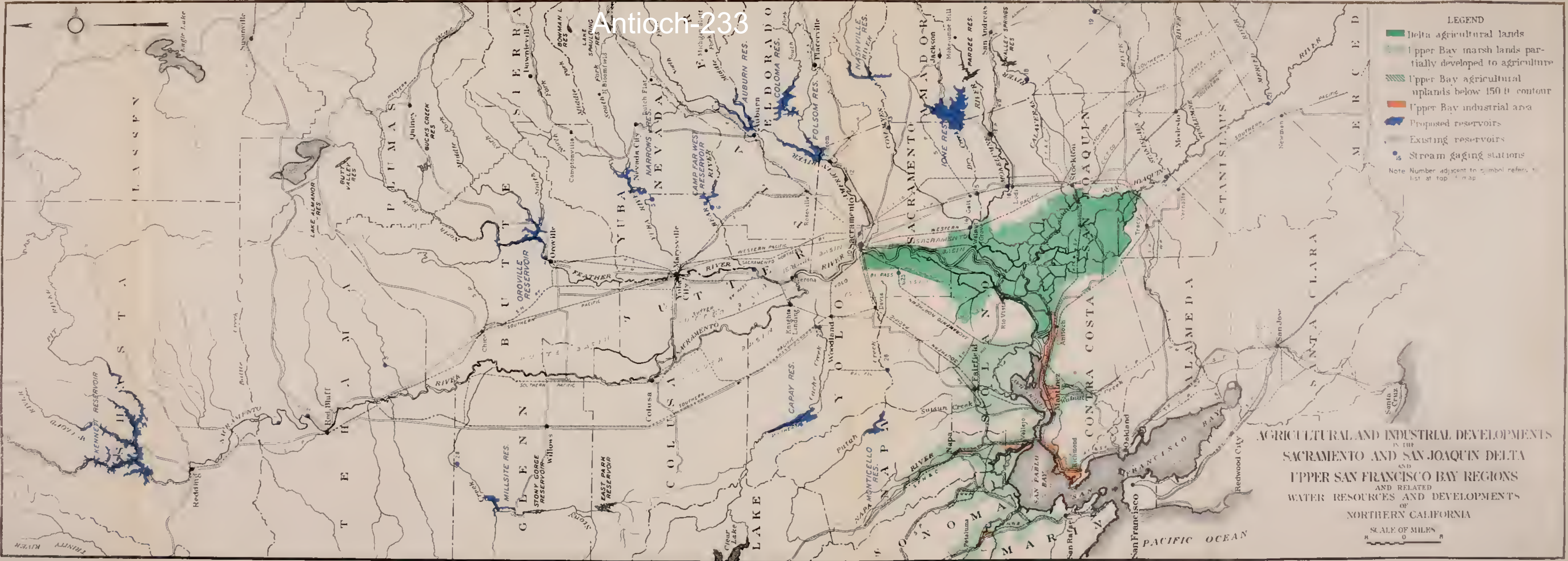
ATIONS

	Jellys Ferry
	r Red Bluff
	ar Vina
	t Oroville
a River	
r River	at Van Trent
ther River	Niclaus
Sacramento River	Knights Landing
Sacramento River	Verona
ramento River	Sacramento
erican River	a H Bridge, near ramento
American River	at Fairoaks
Cosumnes River	at Michigan Bar
elumne River	near Thornton
Creek	near Galt
elumne River	at Woodbridge
elumne River	near Clements
veras River	at Jenny Lind
nislaus River	near Knights Ferry
n Joaquin River	near Newman
an Joaquin River	near Vernalis
By-pass	at Lisbon
tah Creek	at Winters
che Creek	at Yolo
Stony Creek	near Orland



The marshlands north of Suisun Bay have been largely reclaimed by levees, the area within levees aggregating 44,600 acres. However, only a small portion, 5000 acres, of the leveed land is farmed at present. Agricultural development has been largely unsuccessful, due to the salt-marsh character of the soil and the brackish quality of the water supply which predominates during most of each year in the adjacent channels. The leveed lands are now occupied largely by duck hunting preserves.

North of the marshland area of Suisun Bay is an upland agricultural area, comprising hill and valley lands. Of the entire area between the border of the marshlands and the 150-foot contour, about 35 per cent is now cultivated. There is a considerable acreage of orchards and vineyards and larger areas in grain and hay. Much of the orchard area is irrigated from wells. The ground water supplies are generally limited to the valley areas of tributary local streams, and the available supply is practically all utilized on the present irrigated area.

Along the south shore of Suisun Bay, there is a large industrial development extending from Antioch to Martinez. Much of this development centers around the city of Pittsburg, situated at the lower end of New York Slough. Other large industrial plants are scattered at various locations on or near the bay shore from Pittsburg to Martinez. The low-lying marsh areas skirting the shore are for the most part unreclaimed and uncultivated. Hay and grain are grown on most of the higher bordering uplands. The upland area extending from Antioch easterly to Knightsen is largely devoted to orchards and vineyards, with some grain and hay, most of which is dry farmed.

South of Martinez, the Ygnacio and Clayton valleys open out into a broad upland area of comparatively flat land. This area is largely devoted to agriculture, including dry farming and irrigation by wells. Over one-third of the area is in orchards and vineyards and a somewhat smaller area in hay and grain and various field crops. Ground water supplies are limited in quantity and already are being overdrawn.

Carquinez Strait Area—Suisun Bay is joined to the next large bay to the west, San Pablo Bay, by Carquinez Strait. This is a deep channel averaging about three-quarter miles in width and about seven miles long. It extends through a narrow rift in the hills which rise steeply and abruptly from both shore lines for the greater part of its course. The area along the south shore is largely occupied by railroad and industrial developments, with the industrial city of Crockett lying near its westerly end. The area along the north shore is but little developed, except at Benicia which is situated near its easterly end, and at which the United States Arsenal is located.

San Pablo Bay Area—San Pablo Bay is considerably larger in size than Suisun Bay, being roughly ten miles wide by twelve miles long and having an open water area of 73,000 acres. Like Suisun Bay, it is comparatively shallow over most of its area, except for navigation channels which are maintained at desired depths by more or less constant dredging operations. The finer and lighter silts brought down by the river floods and by local streams find their way into San Pablo Bay and their deposits, under the action of tidal movement, have formed large areas of shallow water and mud flats extending out for great distances from the shore line.

The area along the southeasterly shore of San Pablo Bay from Oleum on the north to the city of Richmond on the south includes several large industries and a few small towns. There is some agricultural development, but it is not extensive, consisting mostly of dry farming of grain and hay on the rolling hill lands. Some few small areas of truck gardens irrigated by wells are farmed in the flat valley lands of tributary streams.

North of San Pablo Bay, there is a large area of marshlands aggregating 58,600 acres. Several streams, most important of which are the Napa River, and Sonoma, Petaluma and Novato creeks, discharge their waters through channels extending through these marshlands into the bay. There are numerous connecting channels between the Napa River and Sonoma Creek, which divide the intervening marsh area into several islands. A considerable portion of this marshland area is reclaimed by levees and much of it is farmed. Of 45,400 acres of leveed land, 24,000 acres are now farmed, mostly to hay and grain. Above the marshland areas, the adjacent uplands, especially in Napa, Sonoma, Petaluma and Novato valleys, are largely devoted to agriculture including chiefly, orchards, vineyards and poultry raising. Most of the land is dry farmed and only a small area is now irrigated.

The city of Vallejo is situated at the lower end of the Napa River at the northeast corner of San Pablo Bay. Directly opposite Vallejo is located the United States Navy Yard on Mare Island. The cities of Napa and Petaluma are situated near the upper boundary of the marshland area north of San Pablo Bay. Each of these cities has several industries.

Developments and Interests Affected by Saline Invasion—Only a portion of the developments and interests in the upper bay and delta regions is or has been affected by saline invasion and, especially, by the change in salinity conditions during the last ten to fifteen years. These include the agricultural lands in the Sacramento-San Joaquin Delta and adjacent delta uplands, and, to a minor extent, the marshlands adjacent to Suisun Bay; and some of the industries and public water supply systems in the upper Suisun Bay area. Irrigation supplies for the delta lands and adjacent uplands are obtained from the delta channels. The greater degree and extent of saline invasion in certain years since 1917 have resulted in the curtailment of irrigation diversions for a portion of the delta and adjacent upland area. The marshlands adjacent to Suisun Bay have been affected less adversely by the greater saline invasions of recent years, because, as revealed by available historical information, fresh water was never available in the adjacent channels throughout the irrigation season as it was in the delta channels in former years. However, the period of availability of fresh water in the Suisun Bay channels has been reduced to some extent in recent years, thus curtailing irrigation on the limited area farmed, and increasing the difficulty of removing salt from the marsh soils because of the greater lack of fresh-water supplies for leaching purposes.

The industries using fresh-water supplies from the river to any large extent are mostly confined to the Antioch-Pittsburg district, although some fresh-water supplies have been obtained from the river and bay by industries as far down as Martinez. In 1929 the industries used an average over the year of about seven million gallons per day of fresh water for boiler and process purposes by private diversions from the river. Over 80 per cent of this use was by industries in the Antioch-Pittsburg district. The industries with private diversion works have no storage facilities and hence can not obtain fresh-water supplies from the river or bay for boiler and process uses during saline invasion. Due to the greater degree and duration of saline invasion in recent years, these industries have been curtailed in their use of the river and upper bay channels as a source of fresh-water supply, and have been required to obtain more of their fresh-water supplies than in former years from other sources, entailing greater expense. Considerable supplies have been developed from local underground sources but this source of supply is limited in quantity and of doubtful dependability because of a tendency for the well waters becoming polluted with saline water infiltrating from the adjacent bay and river channels. The California-Hawaiian Sugar Refining Corporation, located at Crockett, formerly obtained a large part of its fresh-water supply by means of barges filled upstream from the plant wherever fresh water was available. Because of the increased distance of travel to obtain fresh water, due to the more extensive saline invasions of recent years, the company obtained water by barge from Marin County beginning in 1920, and more recently (1931) has completed a new private water supply system, developing underground water in the lower end of Napa Valley and piping the same to Crockett, which is expected to supply its fresh-water demands.

A large part of the water used by the industries in the upper bay region is for cooling and condensing purposes. The use of saline water for this purpose is satisfactory and little advantage would be gained if the water were fresh. Salt-resisting equipment is required to prevent abnormal corrosion but the additional cost of such equipment does not greatly increase the expense of cooling water and the cost of cooling water per 1000 gallons is relatively small.

The public water supply systems now using the river as a source of fresh-water supply include those of the city of Antioch and a public utility serving domestic and industrial consumers in upper Contra Costa County. These two public water supply systems are using an average of two to three million gallons per day from the river. Both have storage reservoirs, which are filled when the water in the river is fresh to provide a supply to meet the demands during the period of saline invasion. In former years, Pittsburg obtained its domestic and municipal supply from New York Slough, a branch of the lower river. However, this source of supply was abandoned in 1920 in favor of supplies from wells, because the quality of the water in New York Slough was unsatisfactory due to saline invasion and sewage pollution.

The remaining developments and interests in the upper bay region have not been affected thus far by saline invasion in regard to water supply, because the river and bay channels have not been used as a source of fresh-water supply. However, the studies presented in other reports* show that the ultimate water requirements for industrial,

* Bulletin No. 25, Report to Legislature of 1931 on State Water Plan, Division of Water Resources, 1930.

Bulletin No. 28, Economic Aspects of a Salt Water Barrier below Confluence of Sacramento and San Joaquin rivers, Division of Water Resources, 1931.

municipal and agricultural use in the upper bay region will necessitate the importation of supplies from some suitable source to supplement the local water resources which are capable of economic development. The nearest source of supply would be the lower Sacramento and San Joaquin rivers. The studies of water supply, yield and demand in the operation of the initial and ultimate developments of the State Water Plan show that most of the water supply required to be imported to the upper San Francisco Bay region could be furnished from this source. Therefore, the industrial, municipal and agricultural developments adjacent to Suisun and San Pablo bays are directly interested in the investigation of salinity, and particularly in the determination of a means of controlling saline invasion in such a way that water supplies now available or hereafter made available in the lower Sacramento and San Joaquin rivers would be maintained fresh at all times for diversion to supply the future needs of the upper bay region.

Previous Investigations.

The first investigations of salinity by the State were made in the fall of 1916 when a preliminary study and a few samples and analyses of the water were made by the State Water Commission. At this time, the potential seriousness of the salinity problem began to be recognized. Again in 1918 and 1919 some samples and analyses of the water at Antioch were made by the State Board of Health and the State Water Commission. However, the investigation of salinity in the upper bay and delta channels was not started on any extensive scale until 1920. The dry years of 1917 to 1919, combined with increased upstream irrigation diversions, especially for rice culture in the Sacramento Valley, had already given rise to invasions of salinity into the upper bay and lower delta channels of greater extent and magnitude than had ever been known before. At the beginning of 1920, it was evident that another dry year was impending which might result in serious water shortage and a possibly greater saline invasion. Accordingly, in February 1920, the State Water Commission and the State Engineer in cooperation with an organization of the delta land owners, designated the River Lands Association, arranged a cooperative program for a detailed investigation of the salinity conditions. Funds were provided partly by the State and partly by the River Lands Association. The State Water Commission furnished most of the personnel and equipment. Actual field work was started on May 25, 1920. Salinity observation stations, 28 in number, were established at various points in the delta channels and a regular schedule initiated for sampling of water. The samples were tested for salinity in terms of chlorine content by standard titration methods. The water samples were generally taken about every two days at about the time of high tide. In addition to these regular observation stations, a few special surveys were made to determine the variation of salinity through a tidal cycle and also the variation with depth, but these were not extensive enough to come to any definite conclusions. However, it was discovered that the highest degree of salinity usually occurred about one and one-half to two hours following high-high tide and the minimum salinity about the same time after low-low tide. In addition to the investigations made by the State in 1920, a large amount of additional investigational work was done by engineers employed by the plaintiffs and defendants in the "Antioch" suit.

The Antioch Suit—The "Antioch" suit was the direct result of the impending water shortage of 1920 and the menace to the delta interests of a serious saline invasion. It was preceded by a series of meetings and discussions among the water users of the upper valley and the delta, which failed to reach any agreement as to the conflicting claims for water. The suit, filed on July 2, 1920, was instituted by the city of Antioch under claim of riparian right against the upper irrigation appropriators of the Sacramento Valley, seeking to enjoin their diversions of water. The hearing upon the plaintiff's application for a temporary injunction was started on July 26, 1920, in the Superior Court of Alameda County before Judge A. F. St. Sure, and continued over a period of about three months. The temporary injunction was granted and the defendants appealed from the order therefor and secured its reversal by the Supreme Court. In its decision, the Supreme Court held that Antioch did not have a riparian right to the use of water within the corporate limits of the city but that its rights in the San Joaquin River were those of a diverter and user of water thereof for beneficial purposes and nothing more. It further held that an appropriator or diverter of fresh water from a stream at a point near its outlet to the sea does not, by such appropriation, acquire the right to insist that subsequent appropriators above should leave enough water flowing in the stream to hold the salt water of the incoming tides below his point of diversion.

The actual outcome of the suit and the final decision rendered is not of very great importance to this study, although, at the time, it was considered a great victory for the upper irrigationists and equally a great loss to the city of Antioch, and more particularly to the delta land owners who were in fact the real force behind the initiation and prosecution of the suit. Of greatest importance to the State and all of the interests involved and affected by the salinity conditions is the fact that the filing and prosecution of the Antioch suit forceably called to the attention of the public the seriousness of the salinity problem confronting the upper bay and delta interests. It became evident to all concerned, and especially to the State authorities, that it was necessary and essential that a complete investigation be made of the salinity conditions with the object of finally determining, if possible, remedial measures to control the invasion of salinity. It was realized that it probably would be necessary to continue the gathering of data for several years before there would be sufficient information for a detailed study.

Investigations During Period 1921 to 1929—Following 1920, the investigations of salinity were carried on under the State Water Commission and its successor, the Division of Water Rights, in much the same manner as during 1920. Regular salinity observation stations were maintained and samples taken at regular intervals in accordance with a prearranged schedule. The samples were taken only during the summer and fall months when salinity of magnitude was present in the delta channels. Prior to 1923, the testing of the salinity samples was done by a specially employed chemist in the office of the State Division of Water Rights (formerly the State Water Commission). Beginning with 1923, however, all testing of salinity samples was done by the chemist in the State Highway Testing Laboratory. The years 1921, 1922 and 1923 were fairly normal run-off years and the salinity conditions and extent of saline invasion were not anywhere near as severe as in 1920. However, in the year 1924, following one of the driest seasons of precipitation and run-off on record in California in the last sixty years, the number of observation stations was greatly increased in order to cover in detail the greatly increased area in the delta into which saline water advanced during the summer and fall of that year. Regular salinity samples were being taken at 32 stations by the middle of August.

Beginning with the 1924 season, the salinity investigations were handled by the Sacramento-San Joaquin Water Supervisor. This office of water supervisor was created in 1924 as a result of a series of conferences, beginning in 1923 and participated in by representatives of the delta and the upper irrigationists and business men of the Sacramento Valley, which culminated in the Sacramento River Problems Conference held on January 25 and 26, 1924. This meeting was called by the State Division of Water Rights in cooperation with the Sacramento Chamber of Commerce. As a result of this first Sacramento River Problems Conference, a permanent committee was created, called the "Sacramento River Problems Committee," which has functioned up to the present time. In realizing the impending serious water shortage in 1924, this permanent committee arranged a contract with the State Division of Water Rights whereby the division agreed to carry on necessary work of supervision and collection of records through the agency of a water supervisor. Necessary funds to carry out the program, including detailed measurements of stream flow and diversions, were raised by the committee through voluntary subscription.

In addition to the detailed measurements of stream flow and diversions, the Sacramento-San Joaquin Water Supervisor has been directly in charge of all field work on salinity investigations since 1924. Salinity bulletins giving the detailed records of salinity in the delta have been sent out at periodic intervals during each season to the delta land owners and the information has been of material assistance to them in planning and carrying out their irrigation and agricultural operations. Beginning with 1926, regular salinity observation stations were established at points in Suisun and San Pablo bays and, at the same time, seven of the lower stations were maintained throughout the year. This enlargement of the territory covered by the salinity observations has furnished data of great value in carrying out the present studies. The detailed records of salinity and stream flow and measurements of use of water in the delta, which were gathered from 1924 to 1929, inclusive, comprise the more important physical data for the studies and analyses upon which the present study and report are based.

Scope of 1929 Investigation.

The salinity investigation which was programmed and carried out during the season of 1929 has been by far the most comprehensive and intensive in its scope of any of the preceding years' investigations. The adopted program was designed with the purpose of obtaining all necessary information and data required for the completion of a study and analysis of the variation and control of salinity in the delta and upper bay channels. The scope of the investigation is shown on Plate III, "Sacramento-San Joaquin Delta and Upper San Francisco Bay Region, Showing Main Features of Salinity Investigations." The locations of all stations for regular salinity observations, special salinity surveys and stream gaging, and tide gages are shown on this plate.

The field work and office studies were actually started in May, 1929. Seventy-six (76) regular salinity observation stations were established and maintained throughout the season. Samples of the water at these stations were taken regularly at four day intervals about one and one-half hours after high tide and immediately below the water surface, designated as the surface zone. In practically all cases, local observers were appointed to take the actual samples which were mailed in special bottles and containers to the testing laboratory of the State Division of Highways in Sacramento, where they were analyzed. Observers were instructed to take samples if possible about one and one-half hours after high-high tide, but where impossible or impractical, they were instructed to take the samples at about one and one-half hours after low-high tide. Each observer was furnished with a schedule showing the exact time at which samples were to be taken. The actual time of taking samples was reported by each observer on a tag on the sample bottle sent in. At 22 of these stations, samples were taken for both high-high and low-high tides during a period of four months, and at Antioch, samples for both low-high and high-high tides were taken throughout the season. During periods of variable stream flow into the delta such as occurred in June and again in December, 1929, daily samples were taken throughout the variable flow period at all stations which were affected by the changing flow conditions.

In addition to regular salinity observation stations maintained at points in the bay and delta channels, sampling stations were established on six of the islands for the purpose of determining the salinity of the drainage water discharged from the islands during the season, as compared to the salinity of water in the adjacent channels. Samples were taken of this drainage water at seven stations at four day intervals, generally at the same time that the samples of the water in the adjacent channels were taken at the nearest stations.

Two types of special salinity surveys were made, including "tidal cycle" and "river cross section" salinity surveys. The tidal cycle salinity surveys involved the taking of samples at hourly intervals over a tidal cycle period of about 25 hours, samples being taken at depth intervals of five to ten feet from the surface zone to the stream bed. These tidal cycle salinity surveys were made at several different stations selected in the delta and bay and scheduled to include all variations of salinity, tidal and channel conditions. Each survey included the taking and analysis of from 90 to 317 samples. In all, this type of survey was made at 14 different stations with 90 surveys completed. The purpose of these surveys was to determine the variation of salinity at different depths with the rise and fall of the tide.

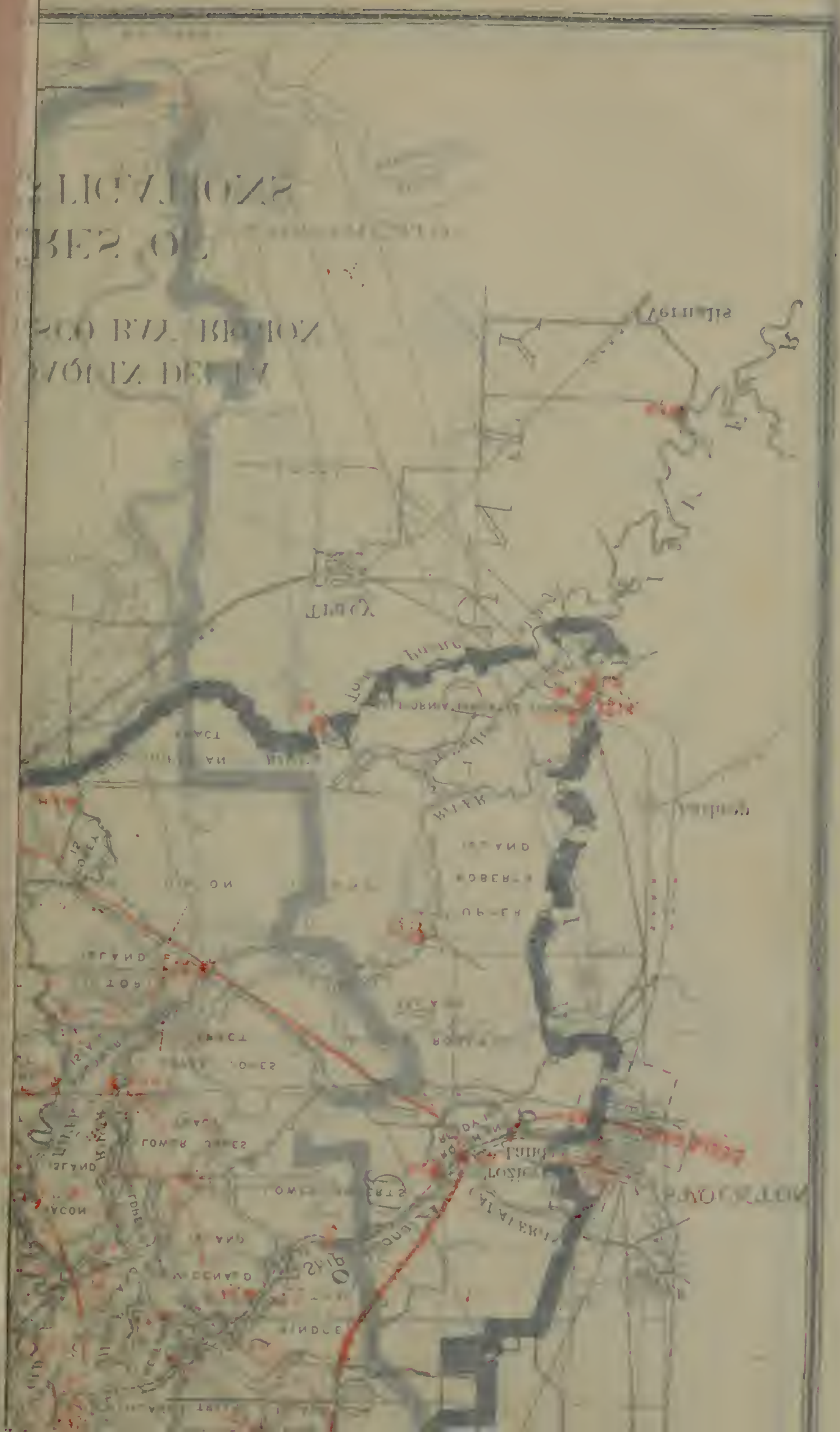
The second type of special surveys, designated as "river cross section" salinity surveys, comprised the taking of samples at various intervals of width and depth throughout a complete channel cross section. Two channel cross sections were selected, one in the San Joaquin River opposite Antioch and one on the Sacramento River directly north of the section on the San Joaquin River. Samples were taken for the most part immediately after high-high tide, but some surveys were taken immediately after low-low tide or other tidal phases. The purpose of these surveys was to determine the lateral variation of salinity through a channel cross section. About 70 samples were taken and analyzed for each survey. In all, 33 separate surveys of this type were made.

A series of more intensive measurements also were carried out at these two river cross sections, which included the taking of water samples and coincident measurements of tidal velocity at hourly intervals throughout a complete tidal cycle period of about 25 hours and at depth intervals of from five to ten feet from surface to bottom, at each of three stations located at fixed points on each of these river sections. These were by far the most complete special salinity surveys attempted, the data obtained showing the related variation of tidal velocity and salinity throughout a complete tidal cycle for an entire river cross section.

All water samples obtained at the regular salinity observation stations and the special salinity surveys were analyzed at the State Division of Highway's testing laboratory in Sacramento. Samples were analyzed for chlorine content, salinity of the water, or degree of salinity, being expressed in number of parts (by weight) of chlorine per 100,000 parts (by volume). The method of analysis used by the State Chemist is known as the Mohr method, which is the more usual standard for analysis of chlorine in water, being rapid and accurate. The method is a so-called "titration" operation, making use of a silver nitrate solution standardized with a known strength of sodium chloride solution, and a potassium chromate solution as an indicator. Silver nitrate of a known strength is added to a sample of the water, to which potassium chromate solution has been added previously, until the color of the chromate changes to a standard color indicating that the reaction is completed. The volume of silver nitrate added as related to the volume of the sample then gives the number of parts of chlorine present. With an experienced chemist, the method is considered to be one of the most accurate of chemical determinations. A more detailed description of the methods used in the laboratory is included in Appendix B of this report.

In addition to the chlorine determinations made on the standard samples, a series of complete chemical analyses of water sampled at different points in the bay and delta channels during different times of the season were made. These complete analyses included the determination of total solids, chlorides, sulphates, carbonates, bicarbonates, sodium, magnesium, lime, silica, iron and alumina and total hardness. The purpose of these complete chemical determinations was to find out if possible the character and source of the salinity and hardness of the water.

An important part of the 1929 field work on salinity investigations was the measurement of flow in the branch channels of the Sacramento



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REGULAR SALINITY STATIONS

1 Point Orient
2 Grand View
3 Lakeville
4 Petaluma
5 Sonoma Creek Bridge
6 McGill
7 Merazo
8 Vallejo
9 Cuttings Wharf
10 Napa
11 Point Davis
12 Carquinez Light Station
13 Crockett
14 Bulls Head Point
15 Bay Point
16 Sprig Club
17 Inveslad Ferry
18 O & A Ferry
19 O & A Bridge
20 Collinsville
21 Mayberry (Prior to Oct 1929)
21a Mayberry
22 Emmaton
23 Three Mile Slough Bridge
24 Three Mile Slough Ferry
25 Rio Vista Bridge
26 Junction Point
27 Ryer Island Ferry
28 Liberty Ferry
29 Jones Landing
30 Cache Slough
31 Grand Island (Steamboat Slough)
31a Grand Island Drain Steamboat Slough
32 Walker Landing
33 Howard Ferry
34 Island Home
35 Sutter Slough
36 Little Holland Ferry
37 Isleton Bridge
38 Ryde
39 Walnut Grove
40 Grand Island Bridge
41 Paintersville Bridge
42 Hood Ferry
43 Freeport Ferry
44 Sacramento
45 Verona
46 Antioch
47 Curtis Landing
48 Sherman Island Ferry
49 Jersey
49a Jersey Drain
50 Blylock Landing
51 Twitchell Island Pump
52 Webb Point
53 Central Landing, Bouldin Island
53a Central Landing, Main
54 Camp 2, Tyler Island
55 Southwest Point, Staten Island
56 Camp 7, Staten Island
57 Tyler Island Ferry
58 Camp 11, Staten Island
58a Camp 11, Staten Island Drain
59 Eagle Tree
60 New Hope Bridge
61 Camp 20, Staten Island
62 Camp 24, Staten Island
63 Camp 25, Staten Island
64 Camp 29, Staten Island
65 Camp 33, Staten Island
66 Camp 35, Staten Island
66a Camp 35, Staten Island Drain
67 Camp 3½, Kings Island
68 Sing Kee Landing
69 Webb Pump
70 Blakes Landing, Venice Island
71 Quimby Pump
72 Ward Landing
73 Medford Island Pump
74 McDonald Pump
74a McDonald Drain
75 Rindge Pump
76 Mandeville Pump
76a Mandeville Drain
76b Bacon Island Drain
77 Holland Pump
78 Palm Tract
79 Orwood Bridge
80 Middle River, Post Office
80a Middle River, Main
81 East Contra Costa Irrigation District
82 Mansion House
83 Zuckerman Pump
84 Wakefield Landing
85 Stockton Country Club
86 Stockton
87 Williams Bridge
88 Drexler Bridge
89 Clifton Court Ferry
90 Whitehall
91 Mossdale, Highway Bridge
92 Western Pacific Railroad Bridge
93 Durham Ferry Bridge

SPECIAL TIDAL CYCLE—DEPTH SALINITY STATIONS

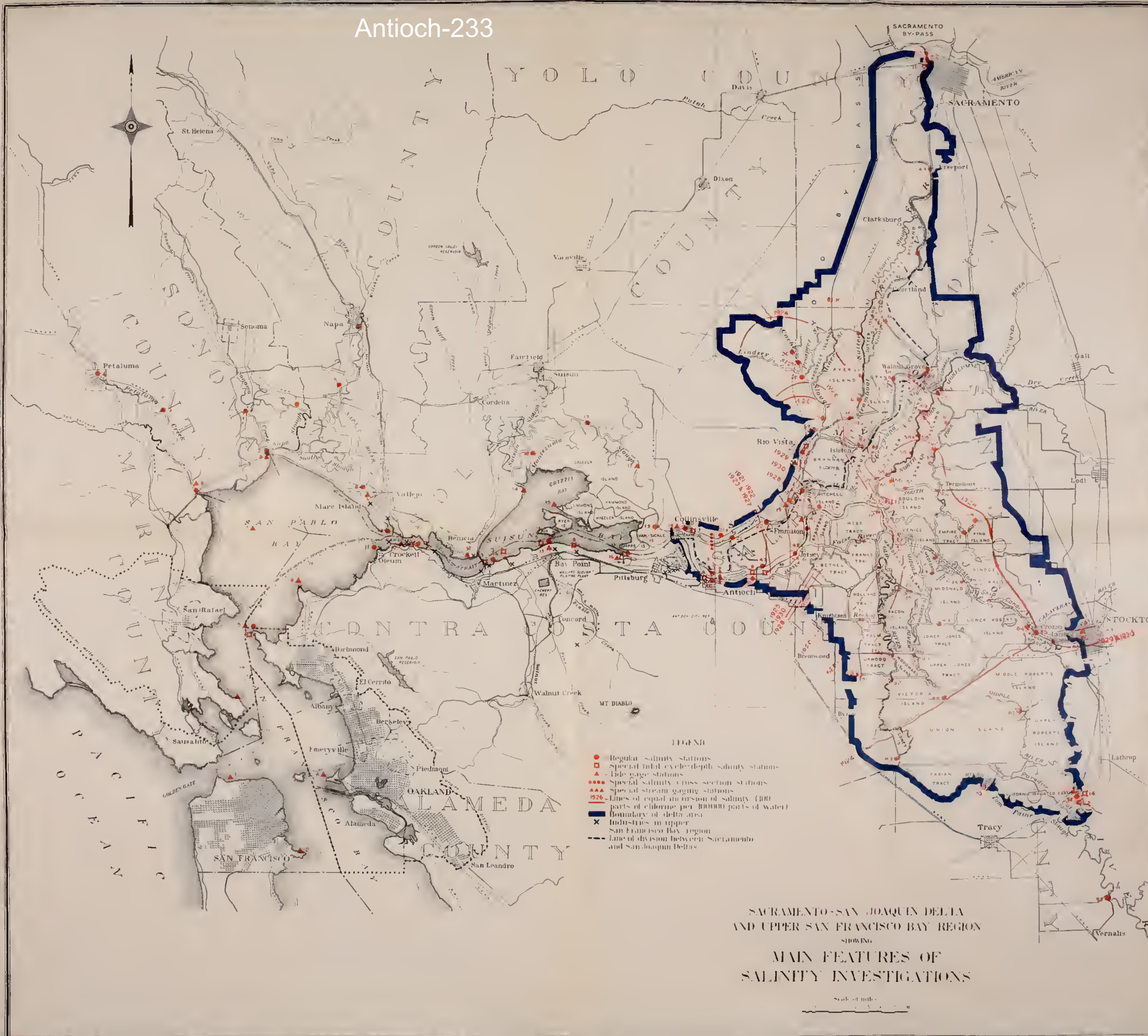
1 Point Orient
2 Crockett
3 Bulls Head Point
4 Avon
5 Bay Point
6 Nicholls (General Chemical Co Wharf)
7 Collinsville
8 Antioch
9 Antioch Bridge
10 Rio Vista Bridge
11 Sacramento (I Street Bridge)
12 Curtis Landing
13 Central Landing, Bouldin Island
14 Mossdale Highway Bridge

SPECIAL STREAM GAGING STATIONS

1 Sutter Slough
2 Steamboat Slough
3 Sacramento River Below Georgiana Slough
4 Georgiana Slough
5 Three Mile Slough

TIDE GAGE STATIONS

1 Presidio
2 Hunters Point
3 Point Bluff
4 Oakland Mole
5 Point Orient
6 Pinole Point
7 Beacon No. 2
8 Sonoma Creek
9 Petaluma Creek
10 Crockett
11 Mare Island
12 Benicia
13 Bay Point
14 Suisun Light
15 Point Buckler
16 Mallard Slough
17 Mains Landing
18 Collinsville
19 Three Mile Slough, Sacramento River End
20 Rio Vista
21 Walnut Grove
22 Sacramento
23 Antioch
24 Three Mile Slough, San Joaquin River End
25 Venice Island
26 Georgiana Slough
27 East Contra Costa County Irr District
28 New Hope Bridge
29 Stockton
30 Mossdale S P R R Bridge



River below Sacramento, including the interconnecting channels between the Sacramento and the San Joaquin rivers, for the purpose of determining the effect of the distribution of flow in these channels on the extent and degree of saline invasion in different parts of the delta. Measurements were made of the flow in Sutter, Steamboat, Georgiana and Three-Mile sloughs and of the Sacramento River below the upper mouth of Georgiana Slough immediately down stream from Walnut Grove. All measurements were made by current meter, with standard methods and equipment employed. Because of the fact that the rate of flow in these channels during the period of low stream flow is not uniform but varies with the rise and fall of the tide, each complete measurement comprised stream gagings at one-hour intervals throughout a complete tidal cycle period of about 25 hours. However, except for the multiplicity of gagings required, the measurements were of the usual standard type of stream gaging operations by current meter.

For the purpose of obtaining comprehensive data on tidal action in the bay and delta channels and determining the effect of tidal action on the variation of salinity, automatic tide gages were established at strategic points in the bay and delta channels. Ten automatic tide gages were already in operation at points in the delta, four by the U. S. Army Engineers, four by the State and two by private agencies. A tide gage was also in operation at the Mare Island Navy Yard and likewise the basic tide gage of San Francisco Bay, maintained by the U. S. Coast and Geodetic Survey at the Presidio near the Golden Gate. Six new tide gages were installed by the State in 1929 and fifteen by the State and U. S. Army Engineers in 1930. All of these tide gages were connected together by precise lines of levels to tie them in to the same datum. In making these level surveys, the U. S. Geological Survey cooperated in running precise level lines from San Francisco to the upper bay region, thus for the first time accurately tying together the level datums from the lower end to the upper end of San Francisco Bay and the delta area. With this system of precise levels connecting all automatic tide gages, it was possible to reduce the tide gage records to the same datum and thus obtain the instantaneous relation of the elevation of the water at all points in the tidal basin.

Measurements of stream flow into the delta from the Sacramento and San Joaquin rivers and their tributaries were continued during the 1929 season as in previous years to determine the source and amount of daily inflow into the delta. Gaging stations were maintained at points on or near the rim of the delta for all streams.

The comprehensive experiments on consumptive use of water in the delta, which have been in progress in cooperation between the State and the U. S. Department of Agriculture since 1924, were virtually brought to completion. These experimental measurements have been directed to a determination of the consumptive use of water for all of the important crops grown in the delta and also for natural vegetation and evaporation. In order to obtain data on consumptive use, it was found necessary to measure the water used by means of tanks specially constructed for the purpose. The details of these several years of experiments are described in another report * and will be further amplified in subsequent reports.

* Bulletin No. 23, Report of Sacramento-San Joaquin Water Supervisor for the period 1924–1928, Division of Water Resources, 1930.

During 1929 from May until the end of the year, over 20,000 water samples were taken and analyzed for salinity. Of these about 5000 samples were taken and analyzed from the regular salinity observation stations and over 15,000 for the special salinity surveys. The compilation and analysis of the large amount of data gathered during 1929 and in previous years have presented a task of no small magnitude. Inasmuch as the study of this salinity problem has involved a field of research in which little if any investigations have previously been made that would assist in the present investigation, the studies have often required a multiplicity of trial analyses before the final procedure as to proper method of analysis was determined.

The results of the investigation of the variation and control of salinity in the Sacramento-San Joaquin Delta and upper San Francisco Bay are briefly summarized in the remaining portion of this Chapter. The detailed presentation of the studies and analyses with graphs and tables in Chapters II to V, inclusive, is essential to a full understanding of the basic relations and conclusions derived from the investigation, and should be consulted for complete information.

Salinity Conditions.

Although actual records of salinity in the upper bay and delta channels are of rather recent date, there is considerable general historical information as to salinity conditions. As early as 1775, a Spanish expedition under command of Don Juan Manuel de Ayola reported saline water in the upper part of Suisun Bay in the summer of that year. In the summer of 1841, the expedition under Commander Ringgold reported the presence of saline water in the San Joaquin River near Antioch. The early settlers on the Suisun Bay marshlands were familiar with the fact that saline water invaded Suisun Bay each year, usually to the upper end thereof. Several of the early residents of the town of Antioch have stated that saline water invaded the lower channels of the delta during many years, as early as the sixties and seventies, to such a degree that the water at Antioch was unsuitable for domestic consumption. A more recent source of information as to salinity conditions is available from the records of water barge travel of the California-Hawaiian Sugar Refining Corporation. This company, whose plant is located at Crockett, has obtained most of its fresh-water supply from 1908 up to the present time (1931) by hauling the same in barges which were filled at points upstream where fresh water was found. The record of the distance traveled above Crockett thus furnishes information as to the dividing line between saline and fresh water throughout this period. The record shows that saline water extended into the lower channels of the delta in varying degree during a period of three to nine months in most every year from 1908 to 1920. Based upon this historical information, it is evident that the invasion of saline water into Suisun Bay with some salinity reaching as far upstream as the lower end of the delta is a natural phenomenon which occurred prior to the time of extensive developments of reclamation, irrigation, and storage works on and bordering the Sacramento and San Joaquin rivers.

The salinity conditions in the upper bay and delta channels during any season are characterized by marked cyclic variations. The maximum retreat of salinity and the farthest downstream advance of fresh water occurs during the flood season of winter and spring. As the stream flow gradually decreases with the approach of summer, saline water gradually advances upstream until the maximum extent of advance and degree of salinity is reached in late summer. After the maximum salinity for the season is reached, it gradually decreases at all points and retreats downstream until it again reaches a point of maximum retreat during the following flood season of winter and spring. Based on the records from 1920 to 1929, saline water generally starts to advance into the channels at the lower end of the delta in the latter part of June, but varying from early May to the latter part of July. The period of saline invasion into the delta channels generally extends from this time until November or December, when the first winter freshets of magnitude occur. During the remaining portion of the year, the water in the entire delta is fresh. Saline water advances into Suisun Bay at a much earlier date and remains during a longer portion of the year. However, in many years, the water of Suisun Bay becomes entirely fresh for a certain period during the winter and spring months. In some years of heavy floods, fresh water extends down into San Pablo Bay for limited intervals of time. In most every year, the salinity of water in Suisun and San Pablo bays is greatly reduced during the winter and spring season. However, under present conditions, during the greater portion of each year, the water of San Pablo Bay has a saline content approaching that of ocean water, while the water in most of Suisun Bay reaches a salinity usually averaging 50 per cent or more of that contained in ocean water.

The salinity conditions in the tidal channels of the Napa River and Suisun and Petaluma creeks are quite similar to those in the channels of upper Suisun Bay and the lower delta. The same type of cyclic variations of salinity occur, characterized by the advance of salinity upstream in the channels starting in the late spring and extending throughout the summer and fall months, and the retreat of salinity downstream with the saline water replaced by fresh water during the winter and spring months.

During certain years of the thirteen-year period, 1917 to 1929, the extent of saline invasion into the Sacramento-San Joaquin Delta has been greater than ever before known to have occurred. In 1924, the waters in the channels of about 50 per cent of the delta area had a salinity content, at the time of maximum extent of invasion, in excess of 100 parts of chlorine per 100,000 parts of water (based upon samples taken in the surface zone usually after high-high tide), or a greater salinity than has been assumed suitable for irrigation use in the delta. In 1920 and 1926, about one-fifth of the delta was similarly affected. In the remaining years of this period, the extent of invasion was not serious, only 3 to 9 per cent of the delta area being similarly affected.*

* Since the preparation of this report, the extremely dry season of 1930–31 has occurred, which resulted in an unprecedented saline invasion into the delta. At the time of its maximum extent, about 70 per cent of the delta had salinity in excess of 100 parts of chlorine per 100,000 parts of water. The saline invasion started into the delta in early April and gradually advanced upstream as far as Courtland on the Sacramento River, above Stockton on the San Joaquin River, above Williams Bridge on Middle River and above Clifton Court Ferry on Old River. The detailed records of salinity for 1931 are tabulated in Appendix C. The saline invasion in 1931 has been far more serious in its magnitude and affect than in any previous year of record. Irrigation diversions were curtailed on a much larger area of delta and for a much longer period of time than in any previous year. The extent of invasion in 1931 is shown on Plate LXXXII.

Based upon records obtained on six typical islands in the delta during 1929, it appears in general that the salinity of drainage water pumped from the islands averages about the same amount as the salinity of water in the adjacent channels during the irrigation season, but becomes somewhat greater on some of the islands during the winter and spring months. In the lower delta where the channels are usually invaded annually with saline water to such an extent that irrigation diversions are discontinued, the salinity of drainage water appears to remain about the same throughout the period of saline invasion as the amount present at the time irrigation diversions ceased, and is apparently unaffected by the presence of large amounts of salinity in the adjacent channels surrounding the islands. The period of invasion of salinity of high degree does not appear to have been long enough, up to 1930, to have caused an increase of salinity in the interior ground water.

Basic Factors Governing Salinity Conditions.

The basic factors governing the extent of saline invasion and retreat and the rate of advance and retreat of salinity are stream flow into the delta and tidal action. The effect of stream flow into the delta is modified by the consumption of water in the delta by crops, vegetation and evaporation. The variation of salinity is the direct result of the relative magnitude of the opposing forces of tidal action and stream flow.

Stream Flow—There are wide variations in the stream flow into the delta as to total amount from season to season, and as to the flow from month to month and day to day in any particular season and for different seasons. The total seasonal stream flow into the delta from the combined Sacramento and San Joaquin River systems averages a little over 31,000,000 acre-feet for the 58-year period, 1871 to 1929, inclusive, and practically the same amount for the forty-year period, 1889 to 1929, inclusive. The corresponding averages for the twenty, ten and five-year periods, to and including 1929 are considerably less, being about 24,000,000 acre-feet for the twenty-year period and about 19,000,000 acre-feet for the ten and five-year periods. The total seasonal stream flow into the delta has varied from a minimum of 18 per cent to a maximum of 261 per cent of the 58-year mean.

Prior to 1917 there was a preponderance of wet years with more than average total seasonal stream flow. Since 1917, however, there has been a preponderance of dry years of less than average total seasonal stream flow. This period includes the driest season of record up to 1930, namely, 1923–24, when the total seasonal flow into the delta was but 18 per cent of the 58-year mean. During the twelve-year period, 1917 to 1929, inclusive, there have been but two seasons of normal stream flow, and, of the balance, there were five seasons with a total seasonal stream flow into the delta of 50 per cent or less of the 58-year mean.

Most of the stream flow occurs during the period January to June, in the winter and spring months, during which over 80 per cent of the total seasonal stream flow occurs on the average. During the five or six summer and fall months, only 10 to 20 per cent of the total seasonal stream flow occurs. Thus, the available stream flow into the delta is a minimum during the period when consumption of water in the delta is a maximum. The variations in daily stream flow into the delta are even more marked. During the period 1919 to 1929, the combined flow of the Sacramento and San Joaquin rivers into the delta has varied from a minimum of about 700 second-feet in August, 1920, to a maximum of 353,000 second-feet in March, 1928. As far as known, this minimum combined flow in August, 1920, is the smallest amount that has ever occurred up to 1930.* It was supplied about equally from the Sacramento and San Joaquin rivers. On the other hand, the maximum daily stream flow into the delta probably has been greater in past years and it is estimated that it might reach a rate of between 700,000 and 800,000 second-feet under future maximum flood conditions. The greater portion of the stream flow into the delta usually comes from the Sacramento River. Hence, under present conditions, the delta is dependent to large extent on the Sacramento River for its irrigation supply.

The stream flow into the delta has been considerably modified, especially in recent years, by irrigation and storage developments on the Sacramento and San Joaquin River systems above the delta. The direct diversions by upstream irrigation developments have resulted in reducing the flow into the delta during the irrigation season. Where storage developments have been made for irrigation purposes, the regimen of stream flow has been modified by their operation in other months of the year as well as the irrigation season. In addition, the operation of storage reservoirs constructed for hydroelectric developments have considerably modified the regimen of stream flow into the delta, although usually in themselves resulting in no material reduction in total flow.

Up to the present time, irrigation has had by far the greatest effect upon the inflow into the delta. From 1910 to 1929, the area irrigated from the combined river systems increased at the rate of over 36,000 acres annually, reaching a total of about 1,317,000 acres in 1929. The growth during the five-year period, 1915 to 1920, was much more rapid, amounting to about 67,000 acres annually, chiefly as a reflection of the development of rice culture in the Sacramento Valley. From 1910 to 1929, the gross annual irrigation diversions increased from less than 3,000,000 to over 5,000,000 acre-feet with an increase of over 1,000,000 acre-feet in the five-year period from 1915 to 1920. These irrigation diversions are chiefly in the period April to October and reach a maximum rate in midsummer when, at the same time, the stream flow naturally available is a minimum. Not all of the water diverted for irrigation is actually consumed by the crops and it is estimated that 35 to 40 per cent or more of the gross diversions is returned to the streams below the irrigated area. However, the return flow is delayed and it is estimated that 75 per cent or less of the total return flow actually becomes available during the irrigation season.

* Since the preparation of this report, the extremely dry season of 1930–31 has occurred, resulting in an unprecedented minimum flow into the delta of less than 500 second-feet from the combined river systems. During a period of about two weeks, there was practically no inflow into the delta from the Sacramento River passing Sacramento, and the only water coming into the delta during this time was return flow from the San Joaquin River and water released from reservoirs on the Mokelumne River.

Storage developments on the Sacramento and San Joaquin River systems have increased from about 350,000 acre-feet total capacity in 1910 to over 4,000,000 acre-feet in 1929. Nearly 3,000,000 acre-feet of this total has come into operation since 1920. Most of the water released from storage, whether primarily for power or irrigation, is used for irrigation during the irrigation season before reaching the delta.

Based upon a study of the combined effect of irrigation diversions and storage operations, taking into account the amount of return water from irrigation, and the period, amount and use of reservoir releases, it is estimated that the stream flow into the delta has been substantially reduced below that which would have naturally occurred in most months of the year, with the possible exception of some of the late fall or early winter months. In this latter period, in some years, the amount of return flow combined with power releases appear to have resulted in actually increasing the flow above that which would have naturally occurred. The reduction of stream flow into the delta, especially during late spring and summer, resulting from these upstream developments, has had a substantial effect in decreasing the force exerted by stream flow against saline invasion, as compared to that which would have prevailed under conditions of natural stream flow before the large increases in diversions and storage of the last 10 or 15 years. This large increase in irrigation and storage developments has been coincident with a period of subnormal precipitation and naturally reduced stream flow, and hence, in the drier years, its proportional effect on the extent and degree of saline invasion has been large.

Consumptive Use of Water in Delta—Based upon observations and experiments for six years as described in Chapter II, the present consumptive use of water in the delta by crops, vegetation and evaporation is estimated to vary from a minimum of about 800 acre-feet per day or 400 second-feet (in midwinter) to a maximum of about 7400 acre-feet per day or 3700 second-feet at the peak of the irrigation season (in midsummer). The estimated total annual consumption on the gross area of the delta of about 488,000 acres amounts to 2.6 acre-feet per acre. The estimated total seasonal consumption on 321,800 acres of irrigated crops alone amounts to 2.1 acre-feet per acre. During several years in the period 1920 to 1929, the inflow into the delta during the summer months has been insufficient to take care of the consumptive requirements. The shortages in supply occurred during periods of one to three months in five years out of ten. These same years have also witnessed the invasions of salinity of greatest degree and extent.

Tidal Action—Tidal action in any tidal basin is evidenced by the rise and fall of the water level and the tidal currents induced by the movement of water into and out of the basin. On the Pacific Coast the tide generally rises and falls twice during a lunar day of 24 to 25 hours, resulting in the occurrence of two high and two low phases of water level. The level actually reached by the high and low tidal phases varies considerably from day to day, and on the same day as well. There are generally two high phases of the tide each day, designated as high-high and low-high tide, and two low phases designated as low-low and high-low tide. The difference in level or the range of the tide between the successive phases thereof varies widely as between different phases on the same day and as between the same successive phases on different days. The mean, average, and maximum ranges of the tide are generally greatest at the lower end of the bay near the Golden Gate, and gradually decrease to minimum amounts at the upstream limits of tidal action in the basin. There is also considerable variation in the average water level or mean tide from day to day during the year and for different years.

The tidal basin of San Francisco Bay has a total area at mean water surface level of about 500 square miles, with a total volume between the limits of maximum tidal range of about 3,000,000 acre-feet. The volume of that portion of the tidal basin in the Sacramento-San Joaquin Delta between the maximum limits of tidal range amounts only to about 250,000 acre-feet, or about 8 per cent of the total tidal basin volume. The water level in the tidal basin is never a continuous plane surface at the same instant, because of the fact that the time of occurrence of identical tidal phases comes at an increasingly later time after their occurrence at the Golden Gate, the farther upstream in the basin. Identical tidal phases occur at upstream points as much as ten hours later than at the Golden Gate. Since successive tidal phases occur on the average about six hours apart, it may be readily seen that the tide may be rising in the lower part of the basin at the same time that it is dropping in the upper part of the basin and vice versa. The actual tidal flow into and out of the tidal basin, or any portion thereof, is therefore considerably less than the total potential volume in the tidal basin, included within either the maximum or average limits of tidal range. The volume of the actual tidal prism between the limits of water surfaces at time of slack water following any two successive phases of the tide at the mouth of the basin is the chief measure of the amount of tidal flow into or out of the basin between these two successive tidal phases. However, the exact measure of tidal flow must be based not only upon the tidal prism volume, but also upon the additions by stream flow and the extractions by consumption into and out of the basin respectively. When the tide rises in what is termed the flood period, stream flow into the basin tends to decrease the magnitude of tidal flow into the basin, whereas consumption of water tends to increase the same. When the tide falls during what is termed the ebb period, stream flow tends to increase the tidal flow out of the basin, whereas consumption tends to decrease the same. Thus, if the consumption in a tidal basin above any point exceeds the stream inflow at any time, it is evident that the tidal flow into the basin will tend to exceed the tidal flow out of the basin, even though the tidal prism volume be the same in ebb and flood. On the other hand, during the occurrence of floods of large magnitude, it is apparent that the stream flow into a tidal basin above any point might be sufficient to eliminate entirely the tidal flow into a basin, thus resulting in a continuous ebb flow.

The amount of tidal flow past any section in the tidal basin is chiefly dependent upon the volume of the tidal prism in the basin above the section, and therefore increases for sections further downstream. During the months of low stream flow, the total amount of tidal flow during a lunar day into and out of the delta tidal basin

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averages about 350,000 acre-feet and, into and out of the tidal basin of Suisun Bay and the delta combined, about 600,000 acre-feet. Of the total tidal flow into and out of the delta, about two-thirds results from that portion of the tidal basin comprising the channels of the San Joaquin River and its tributaries.

The tidal flow into the upper portion of the San Francisco Bay tidal basin comprising Suisun Bay and the delta has been modified in past years by various changes and developments resulting from reclamation, flood control and navigation works; and also from the effects of the movement and deposition of silt and water-borne debris emanating from natural erosion and from hydraulic-mining operations. As far as deposition of debris from hydraulic mining and natural erosion is concerned in the tidal channels of the delta, the effect on tidal flow was temporary and has been mostly removed as a result of natural erosion and dredging operations for reclamation and navigation improvements.

The reclamation of the lands in the delta has removed a portion of the original potential tidal volume within the delta tidal basin. However, because of the rank vegetation growing under natural conditions on the delta lands, and the different rate and character of tidal movement than at present, this larger tidal volume in the delta under natural conditions probably did not result in a much larger tidal flow than at present into and out of the basin. It is probable, however, that the reclamation of lands in the delta has had the effect of decreasing to some extent the tidal flow into and out of the basin past points at or near the lower end of the delta. Similarly, the reclamation of the marshlands lying north of and adjacent to Suisun Bay has had the effect of decreasing to some extent the tidal flow into and out of the basin past the lower end of Suisun Bay and points downstream. The reduction in tidal flow and the decrease in the consumption of water in the delta by the elimination of considerable areas of aquatic vegetation originally present, have tended to reduce the degree and extent of saline invasion which would have occurred in recent years had these lands not been reclaimed. However, since these changes occurred prior to 1920, they have had no direct effect upon variations in salinity during the period 1920 to 1929.

The changes in the tidal basin that have modified tidal flow and hence have directly affected salinity conditions since 1920, include the widening and deepening of Sacramento River from Collinsville to a point above Rio Vista as a part of the Sacramento Flood Control Project, the flooding of the lower end of Sherman Island which accompanied this channel enlargement, and the flooding of a previously reclaimed area lying south of the San Joaquin River and Dutch Slough. It is estimated that the Sacramento River channel enlargement has resulted in an increase of tidal flow into and out of the delta tidal basin of about 30,000 acre-feet per lunar day, and that the flooding of the previously reclaimed lands has resulted in an increase of tidal flow of about equal magnitude. These changes in amount of tidal flow have had an effect on the extent and rate of advance and retreat of salinity during the last decade.

ation of Stream Flow Into Delta to Salinity.

The stream flow into the Sacramento-San Joaquin Delta is one the most important factors governing the advance and retreat of linity in the upper bay and delta channels. The force exerted by tream flow opposes the action of the tides in their tendency to push aline water upstream. Hence, the variations in amount of seasonal stream flow and of monthly and daily stream flow into the delta during any season are directly reflected in the total extent and rate of advance and retreat of salinity in the channels of the upper bay and delta.

The extent of advance and retreat of salinity are approximately related to the total seasonal stream flow into the delta. In general, the records show that the drier the season and the smaller the total seasonal stream flow entering the delta, the greater will be the extent of saline invasion during the summer and the smaller will be the extent of retreat of salinity in the winter and spring. However, the degree and extent of saline invasion in the summer season is more particularly governed by the amount and variation of stream flow into the delta during the summer months. The records show that the smaller the total amount of stream flow into the delta during the summer period of June 15 to September 1, the farther upstream will be the advance and the greater will be the degree of salinity reached at points in the upper bay and delta channels. During the period 1920 to 1929, there were no invasions of salinity of material extent into the delta when the summer stream flow from June 15 to September 1 averaged about 5000 second-feet or more.

The actual occurrence of advance or retreat of salinity in any channel section of the upper bay or delta depends directly upon the rate of stream flow passing the section and the degree of salinity present in the particular channel section at any particular time. This governing flow at any particular section is the net stream flow resulting from the flow into the delta reduced by the actual consumption of water in the basin above the particular section. For any particular degree of salinity at any particular point or channel section, there is a rate of stream flow which will equalize the action of the tides and prevent an advance of salinity. If at any time the rate of flow is less than the required amount to prevent advance of a particular degree of salinity, the salinity will tend to advance to points farther upstream and to increase to greater degrees at the particular point or channel section. If, on the other hand, the rate of flow is greater than that preventing advance, the salinity will tend to retreat to points downstream and to decrease to smaller degrees at the particular point or channel section. At any particular section, the rate of stream flow required to prevent advance of salinity increases as the degree of salinity at the particular point or channel section decreases. For any particular degree of salinity, the rate of flow required to prevent the advance of salinity becomes smaller the farther upstream the point or channel section.

The maximum extent and rate of advance of salinity and the maximum degrees of salinity which are reached in any season at various points in the upper bay and delta channels are directly related to the amount and variation in rate of flow into the delta and the amount and variation of consumptive use of water by crops, natural vegetatio nd evaporation in the basin above the various points. In order to pr t advance of salinity at any point in the upper bay and delta cha m the rate of inflow into the delta must exceed the amount of wate a- sumed above the particular point by an amount sufficient to eq the action of the tide in its tendency to advance salinity upstream. y records show that, in 1921, 1922, 1923, 1925 and 1927 when the st n flow into the delta during the summer months was sufficient to the consumptive demands in the delta, saline invasion into the delta s of small extent and degree, affecting only about 3 per cent of the d area even at the time of maximum extent of invasion during the seas Saline water did not start to advance into the delta until about mid-Ju On the other hand, in years when the stream flow into the delta durin the summer months was insufficient to meet the consumptive demands in the delta, invasions of saline water of considerable extent and degre have occurred. This was especially true in the dry years of 1924, 192 and 1926, when the stream flow was insufficient to meet the consumptiv demands for a considerable period of time. The records show tha salinity at points in the upper bay and delta channels continues to increase after the invasion has started until the stream flow into the delta increases to an amount sufficient not only to meet the consumptive demands, but also an excess amount sufficient to counteract the force exerted by the tides toward pushing saline water upstream, with the particular degree of salinity reached at the particular time.

The rate of flow into the delta at the time of occurrence of maximum salinity for the season is closely related to the maximum degree of salinity reached at typical points in the upper bay and lower delta channels. This relation shows that, at any particular point, the smaller the degree of maximum seasonal salinity reached the greater is the rate of flow into the delta at the time of occurrence of maximum salinity for the season. Thus, at Antioch, the data show that the rate of flow into the delta which prevented salinity from increasing above a mean degree (mean tidal cycle surface zone salinity), in parts of chlorine per 100,000 parts of water, of about 800 was about 3200 second-feet; of 200 parts, about 5400 second-feet, and of 100 parts about 6700 second-feet. Therefore, as an approximation, it is evident that with these flows maintained into the delta, the mean tidal cycle surface zone salinity at Antioch would not increase above those stated above for the respective flows. The relation is approximate, however, and applies only to a particular time during the season, averaging about September 1, when the maximum seasonal salinity usually is reached. Since the actual time of occurrence of maximum salinity in different years has varied from August 15 to September 15, at various points, the element of varying consumption in the delta affects the accuracy of the relation. It is evident that, at other times of the season when the consumption in the delta is different than the consumption at the time of occurrence of maximum salinity averaging about September 1, the flow into the delta related to a maximum salinity of any degree would differ by the amount of difference in the consumption on the two different dates. Therefore, the stream flow related to maximum salinity for an average time of about September 1 would have to be modified, with a correction based upon the difference in amount of consumption, if the relation were applied to any other time of the year. The relation also takes no account of possible differences in magnitude of tidal flow at the time of occurrence of maximum salinity in different years, which might affect the relation to some extent.

It has been pointed out previously that the greater portion of the stream flow into the delta comes from the Sacramento River. In certain periods when there is very little inflow from the San Joaquin River system, the portion of the delta embracing the San Joaquin River and its tributaries is largely dependent for its consumptive requirements on supplies from the Sacramento River. This supply from the Sacramento River to the San Joaquin Delta is limited to the flow which passes through two sloughs; namely, Georgiana and Three Mile Sloughs. Detailed measurements of the division of flow of the Sacramento River in the branch channels below Sacramento show that the flow through Georgiana Slough is directly related to the flow passing Sacramento, whereas the flow through Three Mile Slough bears no relation to the flow passing Sacramento, but results entirely from tidal movement, at least during the period of low stream flow. The percentage of the total flow passing Sacramento which goes through Georgiana Slough varies considerably with the rate of flow in the Sacramento River, varying from a maximum of about $43\frac{1}{2}$ per cent with a flow of 3000 second-feet to a minimum of about 15 per cent for a flow of 40,000 second-feet or greater. The tidal flow through Three Mile Slough results in a net transfer from the Sacramento to the San Joaquin River of about 950 second-feet averaged over a period of about three months, but with extreme variations as measured from no flow to 3700 second-feet.

If the entire consumptive requirements of the delta were required to be furnished from the Sacramento River, a supply of 3700 second-feet passing Sacramento, or the amount required at the time of maximum consumptive demands in the delta, would be distributed through the present connecting channels in about the same proportion as the respective consumptive demands in the Sacramento and San Joaquin deltas. However, with a flow of 7000 second-feet passing Sacramento, or a sufficient supply to meet the maximum consumptive demands in the delta and also the net flow required to control salinity at the lower end of the delta, the division of flow would not be in proportion to these combined requirements of consumptive demand and repulsion of saline invasion in the two deltas. The portion flowing into the San Joaquin Delta through the present connecting channels would not be sufficient for the combined needs of the San Joaquin Delta.

The effect of the proportional distribution of the Sacramento River flow, when there is very little inflow from the San Joaquin River system, is clearly evidenced in the records of salinity during the period 1920 to 1929. The extent of saline invasion has been proportionately greater in the San Joaquin Delta than in the Sacramento Delta. Moreover, salinity tends to remain in the San Joaquin Delta for a considerable period after increased stream flow in the Sacramento River has almost entirely removed salinity from the Sacramento Delta channels. Hence, if, under future conditions, the water requirements for consumption and repulsion of salinity must be furnished almost entirely from the Sacramento River, the present limited channel capacity connecting the Sacramento River with the San Joaquin Delta would not be sufficient to provide the necessary flexibility in distribution and permit the most effective utilization of the water supplies furnished. However, it would be feasible to provide additional channel capacity between the Sacramento River and the San Joaquin Delta which would provide the necessary flexibility and insure the maximum effectiveness of the supplies furnished.

Relation of Tidal Action to Salinity.

Tidal action is a basic factor governing salinity conditions in the upper bay and delta channels that is of equal importance to stream flow. If it were not for the action of the tides, resulting in a movement of saline water from the ocean and lower bay into the upper bay and delta, there would be no salinity problem. The effect of tidal action on the salinity of waters in the upper bay and delta channels is clearly evidenced by the variations of salinity coinciding with the rise and fall of the tide. The salinity at any point in the tidal basin is constantly changing with the rise and fall of the tide. Wide variations occur during a tidal cycle, amounting to as much as 200 per cent above and 80 per cent below a mean value. The maximum salinity during a tidal cycle occurs at time of slack water following high-high tide and the minimum at time of slack water following low-low tide. The salinity at any time during a tidal cycle is directly related to the height of the tide above low-low water, increasing in approximately direct proportion to the height of the tide above its low-low stage.

Salinity increases only slightly with depth. The maximum variation found from surface to bottom was three-tenths per cent increase per foot of depth. The amount of increase is gradually less as the quality of water approaches either that of ocean water or of fresh water. There is little lateral variation in the salinity of water in channels of the delta. The waters in the entire channel were found to be quite uniform in saline content at any particular time, except for some tendency toward increase in salinity at greater depth. There was no evidence found of high concentrations of salt water creeping along either the bottom or sides of any channel.

As the tides rise and fall in flood and ebb, tidal flows occur of varying magnitude, the pulsating action of which cause a mixing and diffusion of the more saline waters from points downstream with the fresher waters upstream. This action of the tides exerts a positive and continuing tendency to push the more saline waters to points farther upstream in the tidal basin. Opposed to this action, stream flow into the basin is at all times exerting a tendency to push the more saline waters to points farther downstream in the tidal basin. It is the relative magnitude of these two opposite and opposing forces which governs the actual occurrence of advance or retreat of salinity at any point in the tidal basin. Unless the stream flow past a particular section is sufficient in magnitude to counteract the force of tidal action in its positive tendency to push saline water upstream, the result will be an increase of salinity at the particular section and an advance of salinity to points farther upstream.

Tidal Diffusion—The magnitude of advance or retreat of salinity during a particular time interval is measured by the volume of water in the channel or channels through which salinity of a particular degree has traveled. This total amount of advance or retreat is due to the combined effect of tidal action and net stream flow at the particular channel section. The effect of tidal action on the advance or retreat of salinity is represented by the difference between the total volume of channel through which advance or retreat takes place in a particular time interval, and the total volume of net stream flow passing the section during the same period of time. It is the result of the pulsating tidal flows, accompanied always by the positive and continuing tendency to mix the generally more saline waters from downstream with the fresher waters upstream, and has been designated as "Tidal Diffusion."

The effect of tidal diffusion during any period of time on the extent of advance or retreat of salinity in any channel section is dependent upon the volume of channel through which diffusion takes place, and upon the amount of net stream flow tending to oppose the same. Tidal diffusion is always directed upstream during both advance and retreat of salinity. However, the net stream flow may be either upstream or downstream in any particular section of the tidal basin, depending at the particular time on the relative magnitude of stream flow into the basin and the consumption of water extracted from the basin above the section.

At any particular channel section in the upper bay or delta, the magnitude of tidal diffusion varies with the degree of salinity, increasing from a minimum approaching zero for relative high salinities to a maximum for low salinities. For the same degree of salinity, the magnitude of tidal diffusion is directly related to the magnitude of tidal flow and increases progressively downstream. Thus, for a mean salinity (mean tidal cycle surface zone salinity) of 100 parts of chlorine per 100.000 parts of water, the tidal diffusion is about 94,000 acre-feet per day at Bulls Head Point, 8600 acre-feet per day at Collinsville and 6000 acre-feet per day at Antioch. This progressive increase downstream in the amount of tidal diffusion for the same degree of salinity is directly due to the progressively increasing amounts of tidal flow for points farther downstream.

It is estimated that the enlargement of the lower Sacramento River channel from Collinsville to a point above Rio Vista and the flooding of the previously reclaimed areas of lower Sherman Island and the area south of the San Joaquin River and Dutch Slough have resulted in an increase of tidal flow passing the mouth of the river and points downstream of about 60,000 acre-feet per day, with an attendant increase in tidal diffusion. The amount of tidal diffusion has been increased not only at the mouth of the river by these changes, but also at points downstream in Suisun Bay. The effect of this increased diffusion at points downstream has been to decrease the time required for salinity of any degree to advance through the Suisun Bay channels up to the lower end of the delta, thus resulting in saline water arriving at the lower end of the delta earlier in the year than would occur if these changes had not been made. On the other hand, the increased volume of channel in the lower delta resulting from these changes has tended to delay the advance of salinity from the lower end of the delta to upstream points. This latter effect has tended to counteract the effect of the earlier arrival of salinity at the lower end of the delta with respect to the arrival of salinity at points on the Sacramento River from Rio Vista upstream. The studies indicate that if lower Sherman Island

and the area south of the San Joaquin River and Dutch Slough were again reclaimed and removed from the tidal basin, the amount of tidal diffusion at Collinsville under present conditions, for a mean salinity of 100 parts of chlorine per 100,000 parts of water, would be reduced by 3200 acre-feet per day.

Control of Salinity.

The primary purpose of the investigation of salinity is the determination of an effective means of controlling salinity and preventing the harmful effects of saline invasion in the upper bay and delta region. This is the objective toward which all the activities and studies of the investigation have been directed. It is recognized that the present conditions brought about by saline invasion are of serious concern. The possibility of more prolonged and more extensive invasions than have heretofore occurred may result in permanent injury to the delta. The saline menace has already had a tendency to depreciate land values in the delta, and has led to expensive water right litigation. The industries in the upper Suisun Bay area have been put to serious difficulties and considerable expense to obtain fresh-water supplies, because of being curtailed in the use of the lower river and upper bay as a source of fresh-water supply. Remedial measures are desirable and necessary to protect the delta and provide adequate and dependable fresh-water supplies for the needs of the delta and upper bay region.

One method for controlling salinity would be the provision of a physical barrier to obstruct the entrance of salt water into the upper bay and delta. The physical and economic aspects of a salt water barrier are presented in other reports.*

An obvious solution of the salinity problem of the upper bay and delta region would be the control and prevention of saline invasion into the delta by means of stream flow. The primary requirement for such a control of salinity would be the furnishing of a sufficient water supply into the delta to fully satisfy the consumptive demands for all purposes therein. After this primary requirement is met, an additional supply flowing into Suisun Bay would be required to repel tidal action and the tidal diffusion of salinity resulting therefrom.

The net stream flow required to prevent the invasion of salinity depends upon the location at which control is sought or desired and the degree of salinity desired to be controlled at the particular location. In order to prevent advance of salinity, the basic essential of control is the provision of a net stream flow downstream equal in magnitude to the amount of tidal diffusion. If the net stream flow downstream past any particular channel section, is equal to the amount of tidal diffusion for any particular degree of salinity, its repelling action will counteract tidal diffusion and prevent any further advance of salinity.

Control Flow—Based upon a careful consideration of the needs of both the upper bay and delta region, it is concluded that the most practical and most desirable control of salinity by stream flow would be a control at Antioch sufficient to limit the increase of mean salinity (mean tidal cycle surface zone salinity) at that point to a degree of not more than

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* Bulletin No. 22, Report on Salt Water Barrier (2 volumes), Division of Water Resources, 1929.

Bulletin No. 28, Economic Aspects of a Salt Water Barrier below Confluence of Sacramento and San Joaquin Rivers, Division of Water Resources, 1931.

100 parts of chlorine per 100,000 parts of water, and lesser degrees of salinity upstream. This could be accomplished by providing a net stream flow in the combined channels of the Sacramento and San Joaquin rivers passing Antioch into Suisun Bay of not less than 3300 second-feet. With this flow maintained at all times as a minimum, the maximum degree of mean tidal cycle surface zone salinity in parts of chlorine per 100,000 parts of water would not exceed 10 to 15 at Emmaton and Jersey, 100 at Antioch, 150 at Collinsville, 225 at Pittsburg, 275 at O. and A. Ferry and 700 at Bay Point. The total gross control flow into the delta to provide for the combined demands of consumptive use in the delta and the proposed control of salinity at Antioch would vary from a minimum of about 3700 second-feet (in midwinter) to a maximum of about 7000 second-feet (in midsummer).

The determination of the rate of flow required for control and the positive effectiveness of control by stream flow do not rest upon theory, but are supported by the observed occurrence of natural control effected by the stream flow during the period 1920 to 1929. The records show that, even though the stream flow into the delta in the summer months was actually as low as 3500 to 5000 second-feet in years like 1921 to 1923, inclusive, and 1927, the maximum extent of harmful saline invasion into the delta did not reach Emmaton, thus affecting less than 5 per cent of the delta in these years. Hence, the proposed control flow positively insures adequate protection of the delta from saline invasion.

Required Supplemental Water Supply for Control—With stream flow into the delta as during the period 1920 to 1929 and with consumption of water in the delta as at present, there would be far more than enough water to meet these requirements during most of the year, with the exception of limited periods in the summer months when the flow would be frequently insufficient. Therefore, additional water supplies to supplement the available flow would have to be furnished during the periods of deficiency. The additional amounts of water supply to supplement those which were available during the period 1920 to 1929 would have averaged 451,000 acre-feet total per year, varying from a minimum of 149,000 acre-feet in a year like 1923 to a maximum of 1,128,000 acre-feet in a year like 1924. These amounts include both those required to supply the shortages in the inflow meeting the consumptive demands in the delta as well as salinity control at the lower end of the delta. Of the total annual amount of required supplemental supply, an average of 67,000 acre-feet would have been required to meet the consumptive demands of the delta alone, due to the shortage between supply and consumption. This shortage by reason of excess of consumption in the delta over inflow reached a maximum of 277,000 acre-feet in 1924 and 225,000 acre-feet in 1920. For salinity control alone, the total annual amount of supplemental water supply would have averaged 384,000 acre-feet, varying from a minimum of 149,000 acre-feet to a maximum of 851,000 acre-feet. The maximum monthly amount of supplemental supply required for salinity control and consumptive demands in the delta would have averaged 212,000 acre-feet, varying between a minimum of 112,000 acre-feet in a year like 1923 to a maximum of 354,000 acre-feet in a year like 1920 and slightly less in 1924.

These supplemental supplies could be furnished by releases from mountain storage reservoirs proposed under the State Water Plan. The studies of water supply, yield and demand in the operation of both the initial and ultimate proposed developments of the State Water Plan * show that, during the period 1920 to 1929, ample supplies would have been available to meet all present and ultimate water requirements in the Great Central Valley, the Sacramento-San Joaquin Delta, upper bay region and also the supplemental supplies required for the proposed control of salinity at the lower end of the delta. Under the operation of both the initial and ultimate developments for these purposes, the studies show that not only would fresh water have been maintained continuously in the channels of the delta, but also that the salinity conditions in Suisun Bay would have been improved as compared to those of recent years, and would have approached practically the equivalent of conditions under a regimen of unimpaired natural stream flow.

Conclusions.

1. The invasion of salinity into Suisun Bay as far as the lower end of the Sacramento-San Joaquin Delta is a natural phenomenon which, in varying degree, has occurred each year as far back as historical records reveal.

2. The extent of saline invasion into the Sacramento-San Joaquin Delta was greater in certain years since 1917 than has occurred before so far as known.

3. The invasions of salinity into the upper bay and delta channels in certain years since 1917 have resulted in curtailment in use and doubtful dependability of water supplies for irrigation in the delta and for municipal and domestic purposes and for boiler and process use by the industries in the upper Suisun Bay area. The marsh lands adjacent to Suisun Bay have been affected to some extent by reason of curtailment of irrigation diversions and the greater lack of availability of fresh water supplies for cattle and for leaching operations to improve the soils for crop production.

4. The abnormal degree and extent of saline invasion into the delta during recent years since 1917 have been due chiefly to: first, subnormal precipitation and run-off with a subnormal amount of stream flow naturally available to the delta, and, second, increased upstream diversions for irrigation and storage on the Sacramento and San Joaquin River systems, reducing the inflow naturally available to the delta. It is probable that the degree of salinity in the lower channels of the delta and the extent of saline invasion above the confluence of the Sacramento and San Joaquin rivers have been about doubled by reason of the second factor.

5. The salinity conditions in the upper San Francisco Bay and Sacramento-San Joaquin Delta channels are characterized by marked cyclic variations. The total extent and rate of advance and retreat of salinity vary with the total amount and distribution of the seasonal stream flow into the delta.

6. The distribution of the flow of the Sacramento River, which generally contributes the greater portion of the total inflow into the

* Bulletin No. 25, Report to Legislature of 1931 on State Water Plan, Division of Water Resources, 1930.

delta, through its various branch channels below Sacramento has a material effect on the variation of salinity in different portions of the delta channels. The San Joaquin Delta and the salinity conditions therein depend to a large extent on the supplies from the Sacramento River which are obtained through two interconnecting sloughs (Georgiana and Three Mile sloughs) of limited capacity.

7. During several years from 1920 to the present, the inflow into the delta during the summer months has been insufficient to take care of the consumptive demands within the delta, which range from a minimum of about 400 second-feet (in mid-winter) to a maximum of about 3700 second-feet at the peak of the irrigation season (in midsummer).

8. The channels of the Sacramento-San Joaquin Delta are a part of the tidal basin of San Francisco Bay and are affected by tidal action, characterized by the rise and fall and coincident flood and ebb, respectively, of the waters therein.

9. The tidal flow passing any section of the tidal basin into and out of the portion of the tidal basin above the section depends upon the change in volume in the tidal basin corresponding to the rise or fall of the water level therein and also the additions thereto by stream flow and the extractions therefrom by water consumption.

10. Tidal action has a direct effect upon the variation of salinity. The salinity at any point in the tidal basin is constantly changing with the rise and fall of the tide. The salinity at any time during a tidal cycle is directly related to the height of the tide above low water, increasing and decreasing respectively with the rise and fall of the tide in approximately direct proportion to the height of the tide above its low-low stage. Salinity increases only slightly with depth and there is little lateral variation in the salinity of water in the delta channels.

11. As the tides rise and fall in flood and ebb, tidal flows of varying magnitude occur, the pulsating action of which exerts a positive and continuing tendency to push upstream and mix the more saline waters from points downstream with the fresher waters upstream in the tidal basin. Opposed to this action, stream flow into the basin tends to push the more saline waters to points farther downstream in the tidal basin. The relative magnitude of these opposite and opposing forces of tidal action and stream flow governs the actual occurrence of advance and retreat of salinity.

12. The effect of tidal action, designated as "tidal diffusion," on advance or retreat of salinity is represented by the difference between the total volume of channel through which advance or retreat takes place and the total volume of net stream flow passing the channel section during a particular time interval. Tidal diffusion is always directed upstream during both advance and retreat of salinity. Advance or retreat of salinity will occur when the net stream flow is respectively less or greater in magnitude than tidal diffusion. If the net stream flow downstream is equal in magnitude to tidal diffusion, there will be no advance or retreat of salinity.

13. The magnitude of tidal diffusion at any section is directly related to the amount of tidal flow passing the section and increases progressively downstream as the tidal flow increases. At any particular section, tidal diffusion varies with the degree of salinity, increasing from

a minimum approaching zero for relative high salinites to a maximum for low salinities.

14. The recent enlargement of the lower Sacramento River channel from Collinsville to a point above Rio Vista and the flooding of the previously reclaimed areas of lower Sherman Island and a tract lying south of the San Joaquin River and Dutch Slough have increased the tidal flow passing the mouth of the river, resulting in an increased tidal diffusion in the channels of the lower delta and upper bay.

15. In order to protect the Sacramento-San Joaquin Delta from saline invasion, it would be necessary, first, to furnish a sufficient water supply flowing into the delta to fully satisfy the consumptive demands of crops together with natural losses by evaporation and transpiration from vegetation in the delta, and, second, to provide an additional flow into the delta, over and above that required for the full consumptive demands therein, sufficient to repel tidal action and prevent invasion of salinity into the delta.

16. The prevention of the invasion of saline water in harmful degree into the delta would require a flow at all times of not less than 3300 second-feet in the combined channels of the Sacramento and San Joaquin rivers past Antioch into Suisun Bay. With this flow maintained past Antioch, the maximum degree of mean tidal cycle surface zone salinity would be limited to 100 parts of chlorine per 100,000 parts of water at Antioch, and to ten parts or less of chlorine per 100,000 parts of water at points in the delta from Emmaton and Jersey upstream.

17. The control of salinity at the lower end of the delta by stream flow, involving the provision of a supply for the full consumptive demands of the delta and the net control flow past Antioch. would require a gross stream flow into the delta varying from about 4000 second-feet in winter and spring to a maximum of 7000 second-feet in midsummer. In addition to this gross control flow, water supplies would have to be furnished to meet all present and future diversions from the delta channels to areas outside the delta.

18. Stream flow into the delta during the past ten years or more has been insufficient in certain summer months to supply the required gross flow for control of salinity. Supplemental water supplies would have been required to meet the deficiencies. The supplemental water supplies required for control of salinity by stream flow could be developed and furnished from mountain storage reservoirs proposed in the State Water Plan.

19. If the required supplemental supplies for control of salinity are to be furnished by releases from storage on the Sacramento River system, additional channel capacity between the Sacramento River and the San Joaquin Delta would be required to provide for complete flexibility in distribution of flow and permit the most effective utilization of water supplies furnished for consumptive demands in the delta and repulsion of saline invasion at the lower end of the delta.

20. The reclamation of lower Sherman Island and the area south of the San Joaquin River and Dutch Slough probably would increase the effectiveness of the proposed control flow and probably would reduce the flow required for the proposed degree of control near Antioch.

21. The control of salinity by the maintenance of the required control stream flow into the delta would adequately protect the delta

from saline invasion and remove the present salinity menace, assure ample and dependable irrigation supplies for the entire delta, provide a source of fresh water supply when available in the delta channels suitable for industrial, municipal and agricultural use in the upper bay region, reduce the salinity of the water in Suisun Bay below that prevailing during the past ten years or more, and bring about salinity conditions approaching the equivalent of those which would have occurred in the same years with natural stream flow unimpaired by upstream irrigation and storage diversions.

CHAPTER II

SALINITY CONDITIONS IN SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY

Actual records of salinity in the upper bay and delta channels are of rather recent date. The first investigations made by the State were in 1916, but the investigation of salinity on any extensive scale was not started until 1920. Since 1920, investigations have been continued each year and regular salinity observation stations maintained up to the present time. The records prior to the last decade are fragmentary and hence of but relatively small value. The studies of variation and control of salinity have been based, therefore, almost entirely upon the records of salinity which have been obtained during the last 10 years. Although there are no known actual records of salinity prior to the last two decades, there is considerable information available as to salinity conditions which existed in the upper bay and delta, extending back for many years.

Historical Records of Salinity Conditions.

The earliest historical information on salinity conditions in the upper bay and delta is given in the report of the Spanish expedition under Commander Don Juan Manuel de Ayola and his pilot Don Jose de Canizares of the packet boat *San Carlos*, who explored San Francisco Bay in the summer of 1775.* In August of that year, Pilot Canizares sailed the *San Carlos* from Angel Island up through San Pablo Bay, Carquinez Strait and finally into Suisun Bay. In describing Suisun Bay, he states in his report that upon entering the bay, it has a "depth of 13 brazos, diminishing to four where some rivers empty and take the saltiness of the water which then becomes sweet, the same as in a lake. The rivers come, one from the east-northeast (this is the largest about 250 yards wide), the other, which has many branches, comes from the northeast through tulares and swamps in very low land."

There appears to be some doubt as to the exact point referred to as the place where fresh water was encountered, although the description implies that it was near the confluence of the Sacramento and San Joaquin rivers. The rough map accompanying the report may indicate, however, that the point described might have been only about midway between the lower end of Suisun Bay and the confluence of the Sacramento and San Joaquin rivers.

The second historical reference to salinity conditions in the upper bay and delta comes from the accounts of Commander Ringgold's explorations in 1841.** In August of that year, this exploration "took

* The March of Portola and the Log of the San Carlos, Zoeth S. Eldridge and E. J. Molera, The California Promotion Committee, San Francisco, 1909.

** U. S. Exploring Expedition, Charles Wilkes, U. S. N., 1845—Chap. 5 of Vol. V.

the southeast arm of the Sacramento River and proceeded up the stream for the distance of three miles, where they encamped, without water, that of the river being still brackish.'' This branch is stated to have ''led immediately into the San Joaquin,'' which indicates that the channel taken was that now known as New York Slough. The point of encampment described is evidently near the present town of Antioch. The winter preceding the summer of 1841 was a dry one with very little rainfall, as it is related that Commander Ringgold encountered difficulties in obtaining water while at anchor at San Francisco ''on account of the drought that had prevailed for several months.'' It is reasonable to assume that the flow of the Sacramento and San Joaquin rivers, especially during the summer months of 1841, was probably considerably below normal.

One of the earliest community settlements of the lower delta region was the town of Antioch, located on the south bank of the San Joaquin River, about four miles above its mouth. This community has from earliest times obtained all or a portion of its water supply from the San Joaquin River offshore from the city. Considerable information as to the quality of the water obtained from the river at Antioch is thus available from the early inhabitants who used the supply. Based upon the testimony which was presented during the trial of the ''Antioch'' case, there appears to be no doubt that the water in the San Joaquin River at Antioch became brackish or salty and unfit for domestic consumption during a part of the late summer or early fall months of most years and certainly during dry years, as far back as the sixties and seventies. It is stated that, because of these conditions, many of the residents had cisterns which they filled with fresh clear water immediately after the freshets in June, so that they would have fresh water for use in the later summer and fall months when the water supply became brackish and unfit for drinking, washing and occasionally even garden irrigation. One witness in the trial of the Antioch suit who resided on Twitchell Island testified that the water became brackish and unfit for drinking for certain periods during the early seventies as far up the San Joaquin River as Larsen Landing on Twitchell Island, or above Three Mile Slough.

Considerable general information of value on salinity conditions in upper Suisun Bay is available from early settlers on the marshlands adjacent to Suisun Bay. It is stated that the first levees for the reclamation of these marshlands were started in the early seventies and the salinity conditions in the channels adjacent to these lands were well known by the individuals who developed and utilized these lands. The annual invasion and retreat of saline waters in upper Suisun Bay were observed from the earliest time of this development. Only in a few years of extremely heavy precipitation and run-off of the Sacramento and San Joaquin rivers did the water remain fresh in the upper part of Suisun Bay during any considerable period of the year.

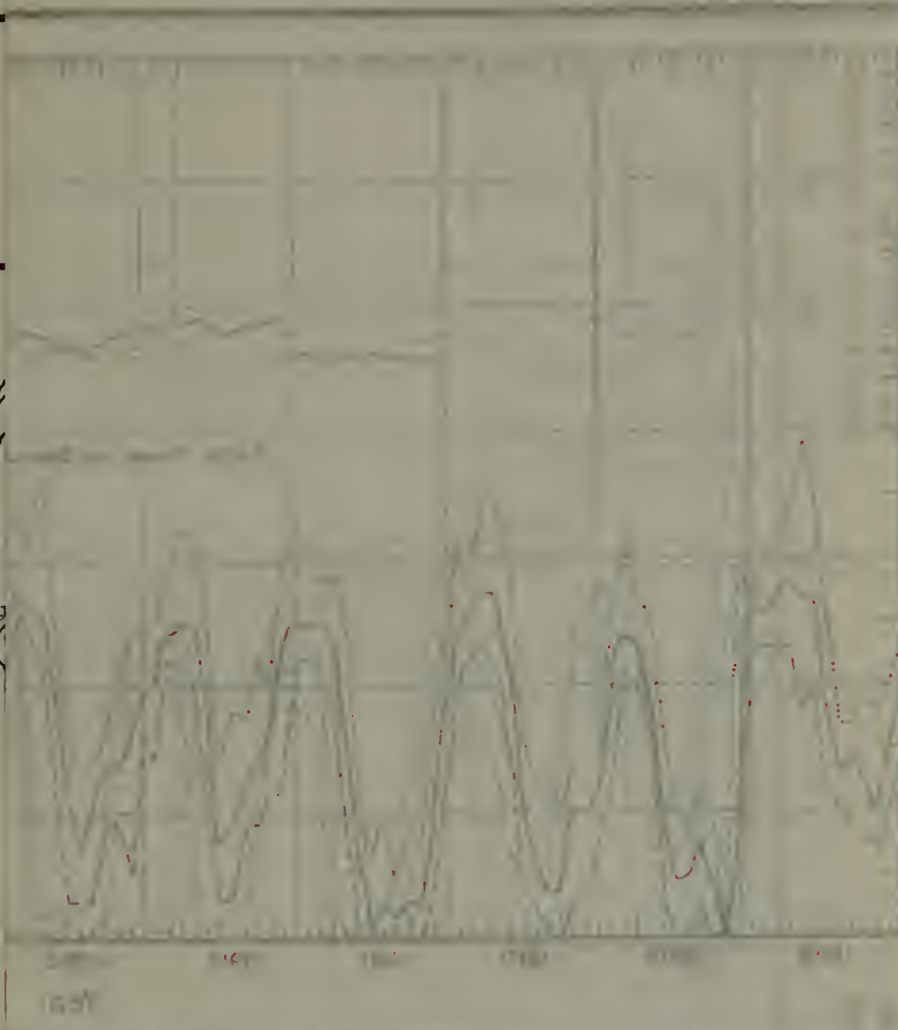
Shortly after 1900 it is reported that a tract of land on the southeasterly portion of Grizzly Island was reclaimed by the construction of drains and the leaching out of the salts by diversion of water from Montezuma Slough at a point about three miles below its confluence with the Sacramento River. The leaching operations were conducted over a period of about five or six years whenever fresh water was available in Montezuma Slough. In order to determine whether the water was fresh enough for this purpose samples of the water were taken and analyzed for saline content. It was usually found that fresh water was available in Montezuma Slough at the point of diversion up to about the first of July or not later than the first of August, at which time the salinity of the water became too great to be used effectively for leaching operations. The water remained saline usually until about November or December when the first winter stream freshets occurred.

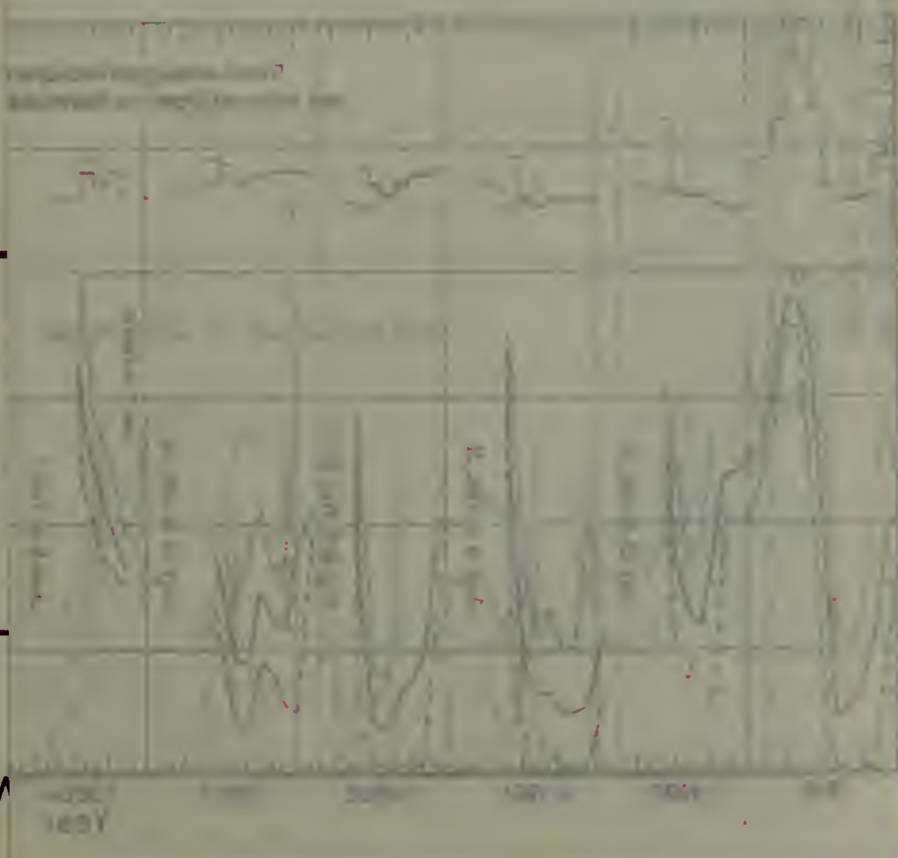
During the last two decades, considerable light is thrown on salinity conditions in the upper bay and delta channels by the records of travel of the water barges operated by the California and Hawaiian Sugar Refining Corporation. This company, whose sugar refinery is located at Crockett, has obtained its fresh-water supply from the river by means of barges since the time of its establishment in 1905. A very pure quality of water containing not to exceed five parts of chlorine per 100,000 parts of water is required for sugar refining purposes. This supply has been obtained by towing specially constructed water barges to points where the desired quality of water was found, where the barges were filled and returned to the plant. It has been the usual practice to make two trips each day, going up on the flood tide and returning on the ebb tide.

The company has kept a careful and accurate record of the travel of the barges each day since 1908. This record is presented graphically on Plate IV, "Barge Travel of California and Hawaiian Sugar Refining Corporation, 1908 to 1929," which shows the maximum, average and minimum distance traveled upstream from their plant at Crockett for each month of each year since 1908, and the saline content of the water obtained. A map is also shown giving the distances in miles along the line of travel. Beginning in 1920 and up to 1929 the company obtained part of its supply from Marin County, and the broken record on the graph during these last 10 years shows the periods during which water was obtained from this source.

These records are of particular interest for the period prior to 1920, when few actual records of salinity are available. As shown on the graph, the distance traveled to obtain water of the purity desired varies from month to month each year, and differs considerably for the same month of different years, thus directly reflecting the changing salinity conditions and the periods of invasion and retreat of salinity. During the 10-year period starting with 1908, the maximum average monthly distance traveled varied from 24 to 28 miles. In each of these years, it was necessary during a period of three to six months to go 20 miles or more. By referring to the map, it is seen that water was obtained for considerable periods of time each year in the vicinity of Antioch and Collinsville or near the confluence of the rivers. Maximum distances traveled during these years varied from 28 to 39 miles or well above Antioch. In the dry years of 1918 and 1919, the maximum average monthly distance traveled was 38 miles and the maximum 65 miles. For a period of nine months in 1919 and early 1920, barges traveled to a point beyond the mouth of the rivers to get fresh water.

It is evident, therefore, that from 1908 to 1920, there have been periods of from three to nine months during each year when all of Suisun Bay up to the lower end of the delta was impregnated by saline water in varying degrees, and that for shorter periods in each year,





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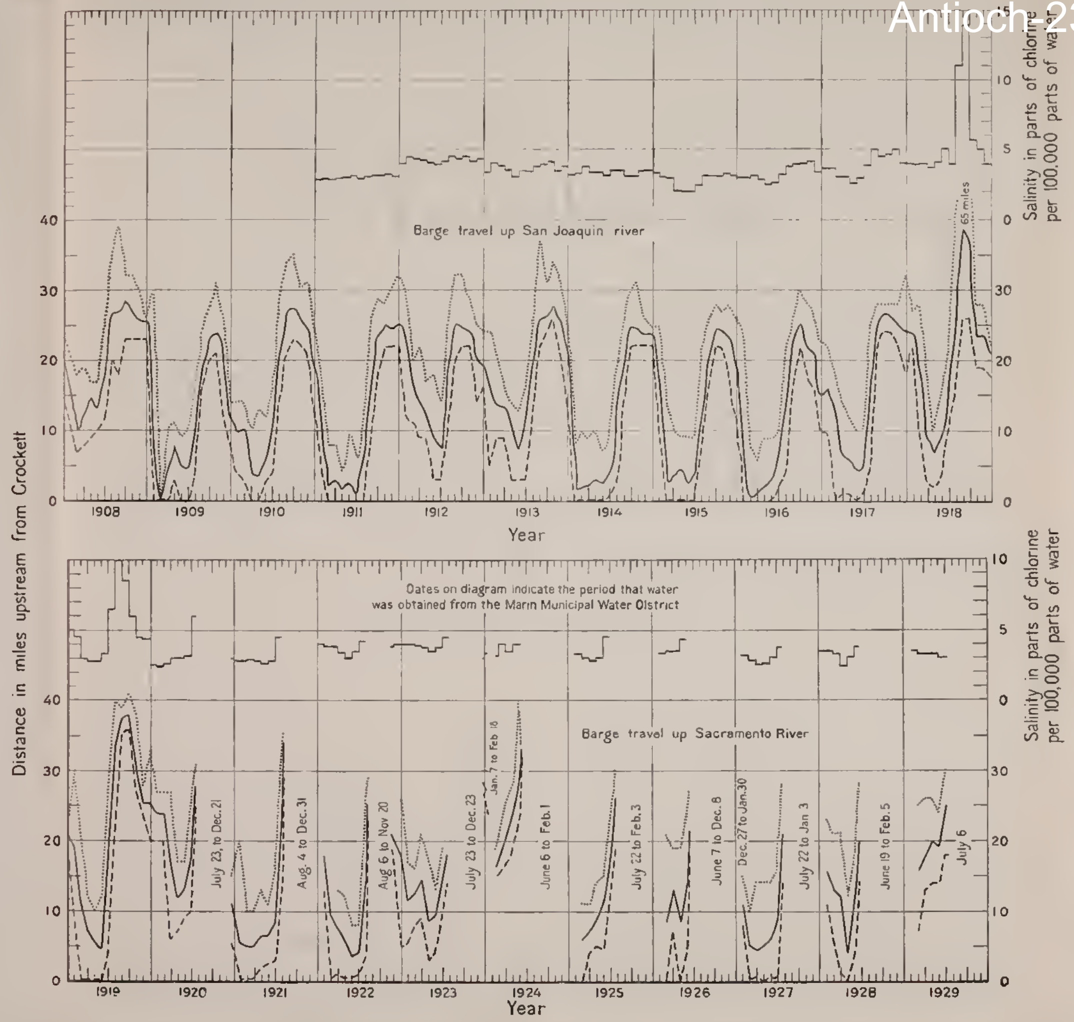
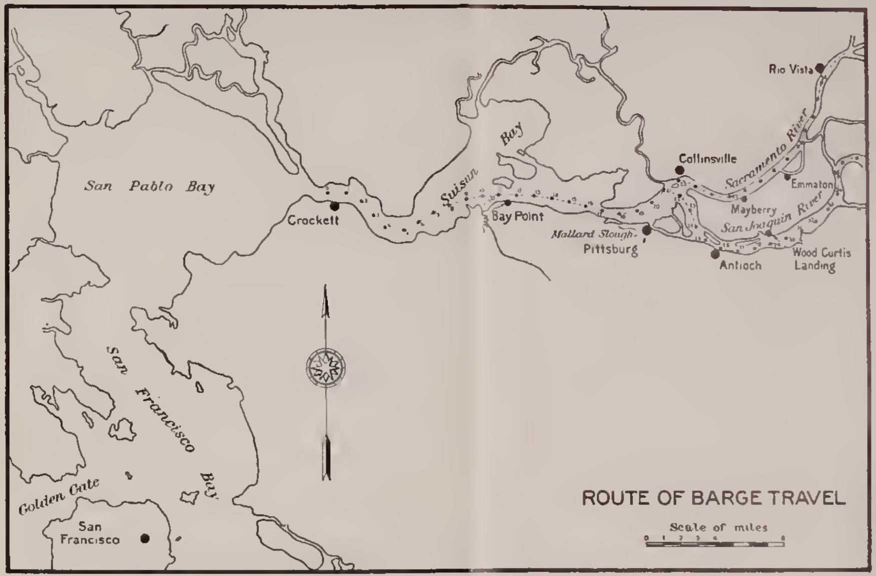




LEGEND
- - - Minimum barge travel
—— Mean " "
······ Maximum " "

BARGE TRAVEL
OF
CALIFORNIA & HAWAIIAN SUGAR REFINING CORPORATION
1908 TO 1929

the invasion of salinity has reached points well above the confluence of the Sacramento and San Joaquin rivers. Even in wet seasons such as 1909, 1911 and 1914 to 1916, inclusive, saline invasion as far as the lower end of the delta has occurred during periods within the above limits.

On the other hand, the record shows that in most years from 1908 to 1929, Suisun Bay has been completely full of fresh water for certain periods, varying from nothing to six months and averaging about two and one-fourth months per year during the 22-year period. Suisun Bay never became entirely fresh in 1908, 1924, or 1929, and was completely fresh for a period of only a few days in 1912, 1913, 1918, 1920, 1923 and 1926. It is interesting to note that all of these years fell during seasons of subnormal rainfall and stream flow. The record also shows that there have been brief periods during several years in which the company was able to obtain fresh water directly in front of their plant at Crockett. This condition occurred in the years 1909, 1910, 1911, 1914, 1915, 1916, 1917, 1919, 1925, 1926, 1927 and 1928. This reflects conditions which occur during periods of heavy flood run-off from the San Joaquin and Sacramento River systems of such magnitude that the saline water is forced downstream as far as San Pablo Bay.

The graphical record of barge travel clearly depicts the location of the dividing line between saline and fresh water and hence pictorially shows the advance and retreat of salinity during the entire period of record. It has been found possible to establish a relation between this record of barge travel and the salinity records during the last decade, from which an estimate has been made of salinity conditions in Suisun Bay and the delta from the record of barge travel prior to 1920. The record of barge travel is, therefore, of unusual value in this study in giving a basis for obtaining closely approximate estimates of the actual salinity that occurred prior to the existence of any available records and at a time before the reduction in stream flow resulting from the rapid growth of irrigation and storage developments on the Sacramento and San Joaquin River systems had affected very materially the natural salinity conditions. The details of the estimates of salinity conditions prior to the period of actual salinity records are presented in Chapter V.

The historical information from the various sources heretofore presented affords a fairly comprehensive picture of actual salinity conditions in the upper bay and delta before the time when there was much development of irrigation, storage and reclamation works, which have tended to modify the natural conditions. It appears evident that, even under natural conditions during the summer and fall months, salt water from the lower bay has advanced upstream to varying extent. Normally, during the summer and fall months, San Francisco Bay and San Pablo Bay have contained salt water and Suisun Bay has been saline in varying degree with the salinity extending usually as far upstream as the lower end of the delta. During the winter and spring, on the other hand, the water in most of Suisun Bay has been fresh for a period of several months; and, in occasional years, such as in 1909 and 1911 when large floods occurred, the water in a portion of San Pablo

Bay has been fresh for limited periods. It is reported that fresh water from the rivers extended down into San Francisco Bay and even outside the Golden Gate during the exceedingly large floods of 1862 and 1878. However, the fresh water in the lower bay at these times is reported to have been only of shallow depth on the surface and overlaying the salt water below.

It is important to note that even before extensive developments of irrigation, storage and reclamation works were made in the Sacramento and San Joaquin valleys, there is ample evidence of the invasion of saline water from the lower bay into Suisun Bay and the lower channels of the delta; that this invasion of salinity has occurred every year during the summer and early fall months when the stream flow of the Sacramento and San Joaquin rivers was at its low stage; that, likewise, the retreat of salinity has occurred each year with the coming of winter freshets forcing the saline water downstream and usually making Suisun Bay fresh and sometimes a portion of San Pablo Bay; and, finally, that the advance and retreat of salinity in the upper bay channels are fundamentally natural phenomena that have occurred annually at least as far back as historical records reveal.

Records of Salinity Observations.

The salinity conditions in the upper bay and delta channels during the last decade since 1920 are generally shown by the actual records of salinity obtained by the investigations of the State during this period. Prior to 1920 a few fragmentary records are also available, some of which were taken by the State and some of which have been obtained from various private sources. In 1906 and 1908, the U. S. Geological Survey determined the salinity of water in the San Joaquin River near Lathrop. From 1910 to 1916 records of salinity of water in New York Slough near Pittsburg were maintained by the Black Diamond Water Company. In 1913 the engineering firm of Haviland, Dozier and Tibbetts obtained several salinity records of the water in the channels of the lower delta from both the San Joaquin and Sacramento rivers in connection with an investigation for a proposed municipal water supply for the city of Richmond and vicinity. The Pacific-Portland Cement Company obtained records of salinity in Suisun Slough at Suisun in 1916. A few scattered records of salinity observations in the San Joaquin River at Antioch taken by that city and the State Board of Health are available from 1916 to 1918. There are also a few records of salinity from observations made by the East Contra Costa Irrigation Company at their intake near the westerly end of Indian Slough north of Byron. In addition to the above there are several other scattered and miscellaneous salinity records from various sources. An effort has been made to obtain all salinity records which have been known to exist and these have been brought together and compiled in Table 34. Some additional miscellaneous records since 1920 from various private agencies are presented in Table 35. The records, although scattered as to place and time of sampling, are nevertheless of some value in the present studies.

The records of salinity observations by the State during the period 1920 to 1931 are summarized in Tables 31, 32 and 33. Table 31 summarizes the descriptions and locations of the salinity observation stations and in addition shows the time of sampling in relation to the occurrence of high tide at the Presidio (Golden Gate). Table 32 shows the period of record for each of the observation stations, while Table 33 summarizes the actual records of salinity observations from 1920 to 1931 inclusive. Plate III shows the location of all salinity observation stations.

Table 36 summarizes the complete chemical analyses of water samples taken at various points in 1929. The purpose of these analyses was to determine, if possible, the source of saline pollution in the waters of the upper bay and delta. It was presumed that, if the source of salinity was ocean water, water polluted or impregnated by invasion of ocean water would contain the saline constituents (in chemical radical form) in about the same percentages of the total chemical constituents as those found in ocean water. This fact is borne out by the results of the analyses. It will be noted that the percentages of the total chemical constituents for various chemical radicals, such as chlorine, sulphates and magnesium, which were found in ocean water, were found also in the water taken at upper bay and delta points affected by saline invasion. On the other hand, the waters at up-river points unaffected by saline invasion and at points in the delta prior to saline invasion, contained entirely different percentages of these constituents, definitely showing that the source of salinity was not ocean water. The differences at Emmaton and Jersey before and after saline invasion are particularly notable. The samples of water taken at Stockton, while showing a similar percentage of chlorine as in ocean water, were different in the amount of magnesium and sulphates, verifying the fact otherwise established that the source of salinity at Stockton in 1929 was not ocean water. The data presented in Table 36 are of importance because they furnish an independent verification of the fact that the source of salinity annually occurring in the upper bay and delta channels is salt water emanating from the ocean.

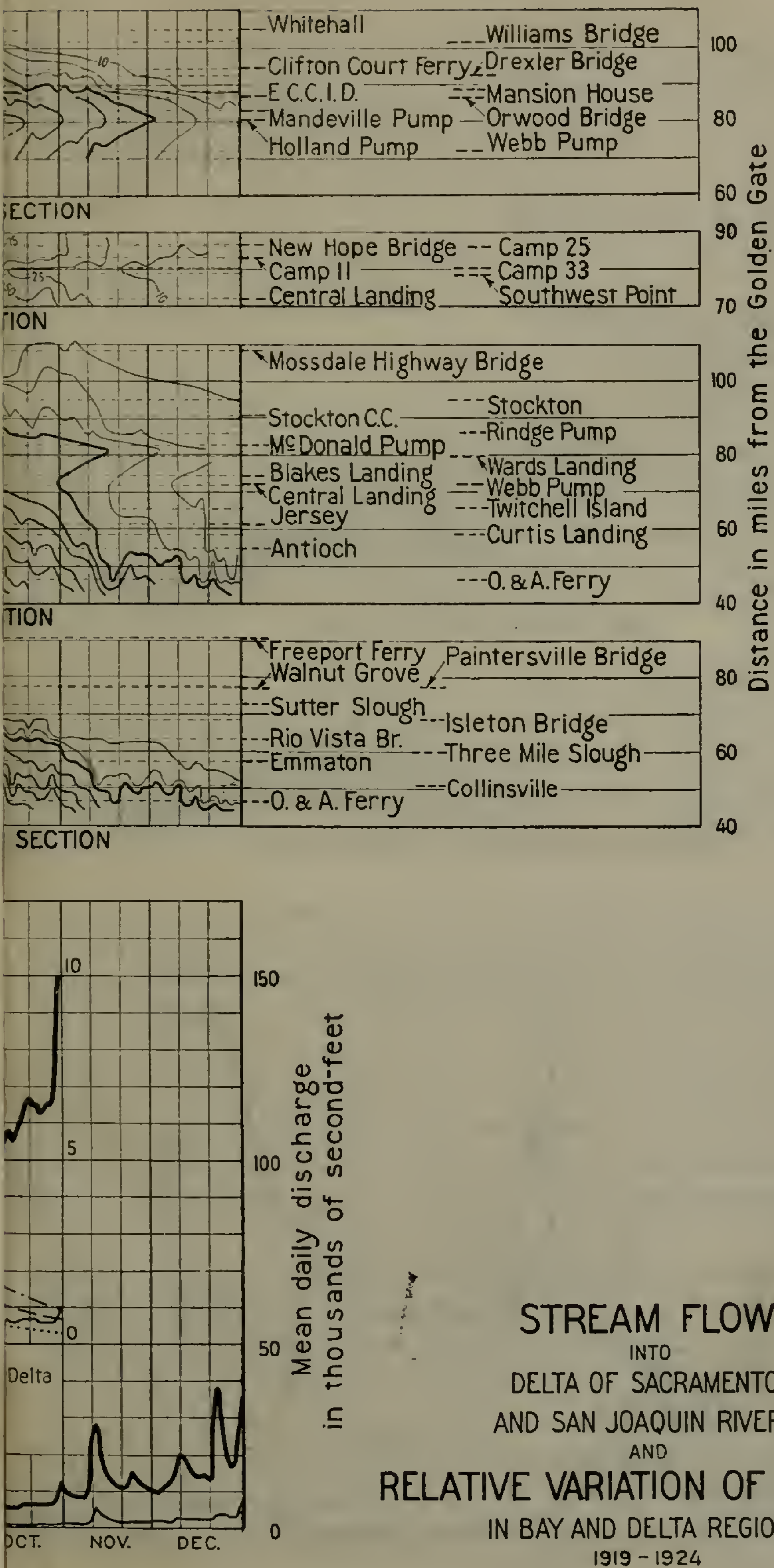
The salinity of water is expressed in number of parts (by weight) of chlorine per 100,000 parts (by volume), this being the standard used throughout the entire period of investigation and in this report. With but few exceptions the salinity expressed in terms of chlorine content represents samples of water taken at time of slack water following high tide. Observers were instructed to take samples if possible at time of slack water following high-high tide, in which case the observed salinity would be the maximum for the tidal cycle occurring on the date of sampling. In cases where samples for some reason were not taken after high-high tide, they were generally taken at time of slack water following low-high tide, thus representing the next highest degree of salinity occurring during the tidal cycle. In a few instances observations were taken at time of low tide, in which case, a special note is attached to the observation. The time of slack water averages about 1½ hours after high or low tide. All salinity samples at regular observation stations have been taken about one foot below the water surface, which is termed the "surface zone." In general, therefore, the salinity records at regular observation stations represent maximum degrees of salinity in the surface zone occurring at the particular points on the dates when the observations were made. It should be clearly understood that the average salinity during the day at these points on the same dates would be less. The relation of these observed values of salinity to the average or mean salinity on the same days and also the relation to the salinity at the low stages of the tide is presented and discussed in detail in Chapter IV.

These records of salinity taken at the regular observation stations comprise the basic information on the variation of salinity in the bay and delta channels for the period of record. They are graphically presented on the upper diagrams of Plate V, "Streamflow into Delta of Sacramento and San Joaquin Rivers and Relative Variation of Salinity in Bay and Delta Regions, 1919–1924," and Plate VI, "Streamflow into Delta of Sacramento and San Joaquin Rivers and Relative Variation of Salinity in Bay and Delta Regions, 1925–1929." These graphs are prepared in such a way that they not only show the variation of salinity from time to time at any point in the upper bay and delta covered by the actual records, but also the relative salinity at different points in the bay and delta at any particular time. The lines on these graphs indicate values of equal salinity in the surface zone after high tide expressed in parts of chlorine per 100,000 parts of water. The abscissa represent time divided into months, days and years. The ordinates represent distance from the Golden Gate measured from the bottom of each graph towards the upper edge of the plate. On the ordinates are shown the location of each of the more important key salinity observation stations. The actual salinity records for each station have been plotted on the horizontal lines representing the location of each station, each recorded salinity being plotted for the day on which it was taken. With these points as a basis, lines of equal salinity were drawn on the graph. The points of intersection of these lines of equal salinity with a horizontal line drawn through the graph, therefore, indicate the variation of the salinity at a point in the basin from day to day through the season. The points of intersection of these lines of equal salinity with a vertical line on the graph indicate the variation of salinity at any particular time at different points in the basin. Thus, for the year 1924 at O. and A. ferry, the graph shows a salinity of about 350 on June 1st, 750 on July 1st, 1100 on August 1st, 1300 on September 1st, 1150 on October 1st, 700 on November 1st and about 100 on November 20th, all in parts of chlorine per 100,000 parts of water. On September 1, 1924, the salinity at O. and A. ferry was about 1300, at Collinsville 1100, at Emmaton 800, at Three Mile Slough 700, at Rio Vista 450, at Isleton 50 and at Walnut Grove 10, all in parts of chlorine per 100,000 parts of water.

Separate graphs are shown of the variation of salinity along the Sacramento River, San Joaquin River, Mokelumne River and Old and Middle rivers. These separate graphs are necessary because of the marked difference in variation along these separate geographical sections of the delta. The variation of salinity for stations in the bay region are shown combined with the diagram of salinity variation along the Sacramento River section. Inasmuch as the salinity observations at stations in the bay region below the delta were not started until 1926, no graphical records of salinity in the bay region are shown prior to that year.

A study of the graphical and tabular records of salinity during the last decade shows that there has been an invasion of saline water into

Antioch-233



STREAM FLOW
INTO
DELTA OF SACRAMENTO
AND SAN JOAQUIN RIVERS
AND
RELATIVE VARIATION OF SALINITY
IN BAY AND DELTA REGIONS
1919 - 1924

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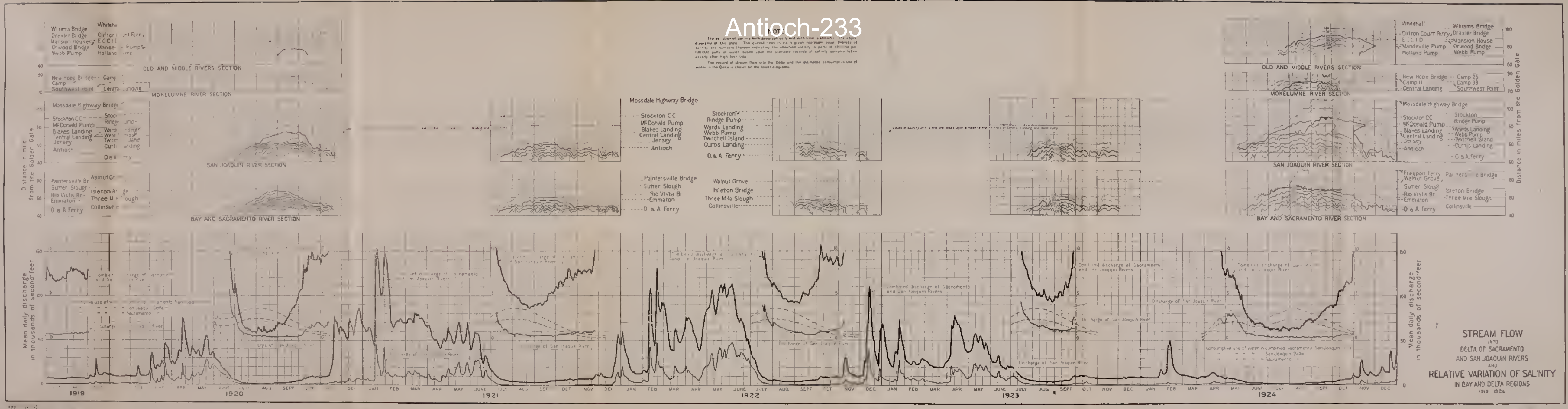


STREAM FLOW INTO DELTA OF SACRAMENTO AND SAN JOAQUIN RIVERS AND RELATIVE VARIATION OF SALINITY IN BAY AND DELTA REGIONS 1919–1924


OLD AND MIDDLE RIVERS SECTION
MOKELUMNE RIVER SECTION
SAN JOAQUIN RIVER SECTION
BAY AND SACRAMENTO RIVER SECTION
Distance in miles from the Golden Gate
Mean daily discharge in thousands of second feet
Combined discharge of Sacramento and San Joaquin Rivers
Discharge of San Joaquin River
267000 Second feet
353000 Second-feet
1925
1926
1927
1928
1929
STREAM FLOW
INTO
DELTA OF SACRAMENTO
AND SAN JOAQUIN RIVERS
AND
RELATIVE VARIATION OF SALINITY
IN BAY AND DELTA REGIONS
1925–1929

the delta each year during the period, but with a considerable variation from year to year as to its degree and extent. The invasion of saline water into the delta, as evidenced by the record at Collinsville, has started from as early as May in 1924 to as late as July 23, in 1923.* After the invasion has started, the salinity usually continues to advance upstream into the delta for a period of about two months, generally reaching its maximum limit of invasion and maximum salinities at various points in the delta channels about the first of September, but varying anywhere from about mid-August to mid-September. After reaching the stage of maximum advance the salinity starts to slowly retreat from the delta channels. This retreat usually continues more or less steadily with the salinity gradually decreasing at all points until about the middle of November to the latter part of December, when the waters in the delta channels down to the lower end generally become fresh again. The actual time at which the delta channels become fresh depends upon the time of the first winter freshets of magnitude. This will be discussed in more detail in Chapter III. It is interesting to note that there appears to be a tendency for saline water to remain in the channels of the San Joaquin Delta later than in the channels immediately connected with the Sacramento River. This is illustrated very clearly by the salinity graphs for the year 1929. It will be noted that, in the month of December, when the salinity at O. and A. Ferry was less than five parts per 100,000 parts of water, the salinity at the same time at many points in the San Joaquin Delta along Old and Middle rivers was in excess of ten parts per 100,000 parts of water. This condition of a considerable degree of salinity remaining pocketed in the San Joaquin Delta occurred similarly in other years in the various branch channels of the San Joaquin River and also in the Mokelumne River. (See Table 33.) It is the result of the lack of a large enough flow from the San Joaquin River to flush out the channels in the San Joaquin Delta. This same condition tends to occur in any channel invaded by salinity during the low water season until there is a flow down through the channel in sufficient amount to flush out the saline water that has previously accumulated therein.

The variation of salinity in the upper bay region is similar to that in the delta as shown by the available records from 1926 to 1929, inclusive. The minimum salinity at points in both Suisun and San Pablo bays is generally reached some time in the months of February, March or April during the floods of the winter and spring. The actual minimum salinity and the maximum retreat of salinity in any year is generally coincident with the maximum flood of substantial duration. After reaching its minimum values and its point of maximum retreat for the season, the salinity gradually advances upstream, continuing until about the first of September. In any particular year, the salinity starts to increase earliest at the farther downstream points and at an increasingly later date at points farther upstream. Thus, in years when salinity retreats below Suisun Bay and the waters of Suisun Bay become fresh in the winter and spring months, the waters in the upper half of Suisun Bay usually remain practically fresh until May or June. Salinity at points farther downstream in the bay frequently closely approaches the seasonal maximum a considerable time before the actual

* In 1931 the invasion into the delta at Collinsville started in early April.

maximum occurs, and the period of high degree of salinity, closely approaching the maximum, is longer than for points in the delta. Sea water has a salinity of about 1800 to 1900 parts of chlorine per 100,000 parts of water. As compared to this, the salinity at Point Orient during the period 1926 to 1929 has varied from a minimum of 350 to a maximum of about 1900 parts. The minimum salinity in each season has varied from 350 to 1350 parts. At Point Davis near the westerly end of Carquinez Strait, the minimum seasonal salinity has varied from about 24 to 540 parts, with a maximum value of about 1850 parts during this period. Similarly, at Bulls Head Point, the minimum seasonal salinity during the period has varied from about 3 to about 240 parts, with a maximum of about 1690 parts during this period. All of these values of salinity are for the regular observations with samples taken in the surface zone after high tide.

In January, 1930, eight additional salinity observation stations were established in the channels on the north side of San Pablo Bay, comprising two on Napa River, three on Sonoma Creek and branch channels and three on Petaluma Creek. These records indicate that, in these channels, salinity conditions are quite similar to those in the delta of the Sacramento and San Joaquin rivers. During the winter period of heavy run-off, these streams and the interconnecting channels generally are filled with fresh water. As stream flow diminishes after the spring, salt water advances upstream into the channels in a similar manner to that in the delta, salinity generally reaching a maximum in August or September. Saline water remains in these channels until winter runoff occurs in sufficient magnitude to push out the saline water.

A very interesting condition as regards salinity exists in the channels in the immediate vicinity of Stockton. It will be noted in the tabular and graphical record for 1929 that salinity in the channel at Stockton averaged about 100 parts all during the low water season. This high salinity affected the salinity in the river channel as far down as McDonald Pump during midsummer. Inasmuch as it was evident that this relatively high salinity in the channels at Stockton was not due to saline invasion from the bay, a special investigation was made for the purpose of determining, if possible, the source of this saline pollution. As a result of this investigation, it was found that the source of the salinity in the channels in the vicinity of Stockton was the saline water discharged from twelve to fifteen natural gas wells operated by a public utility in Stockton. The total amount of water discharged more or less continuously into the Stockton channel from these wells in 1929 amounted to approximately twelve to fifteen second-feet. With practically no fresh water coming in from the San Joaquin or the Calaveras rivers, this discharge of saline water having a chlorine content as high as 400 parts per 100,000 parts of water was sufficient to keep the salinity at about 100 parts in the Stockton channel all season and to affect the salinity to a marked degree at points some distance downstream.

Extent of Saline Invasion—The extent of saline invasion into the delta during each year of the period 1920 to 1930, inclusive, is shown on Plate III. The red lines on this map indicate the upstream limit of saline invasion each year to a degree of 100 parts of chlorine per 100,000 parts of water, and afford a means of visualizing the comparative extent of saline invasion for different years during the period. They also show for each year the maximum extent to which the water in the channels of the delta was affected at some particular time of the season, with a degree of salinity assumed as too high for general irrigation use in the delta.

Whether the application of water with a salinity of 100 parts of chlorine per 100,000 parts of water for the irrigation of crops in the delta would be harmful to crops or land is a question which has not been determined in this investigation. The toxicity of salts to crops depends upon many factors, including the character of the soil, drainage, method of irrigation and the type of crop itself. Some crops are known to be able to withstand more salt than others for any given soil and drainage conditions. Moreover, many crops in the germinating and seedling stages will stand much less salt than the same crops when mature. Although it is difficult to set an exact limit, it has been assumed for average conditions in the delta that water having in excess of 100 parts of chlorine per 100,000 parts of water is not suitable for irrigation use. Hence this degree of salinity was chosen as the basis for the lines on Plate III depicting the maximum extent of saline invasion in different years. However, it should be understood that salinity of lesser degrees advanced to points upstream a considerable distance above the limiting lines of 100 parts shown on Plate III. The degree of salinity reached at points upstream in these different years may be obtained by referring to the tabular and graphical records of salinity. (See Table 33 and Plates V and VI.)

The greatest invasion of salinity during the period 1920 to 1930 occurred in 1924, during or immediately following the driest season (1923–24) of record up to 1930 on the Sacramento and San Joaquin rivers.* In that year at the time of maximum extent of invasion, the water in the channels of about 50 per cent of the delta had a salinity in excess of 100 parts. The dry years of 1920 and 1926 resulted in a smaller extent of invasion, the waters in the channels of less than 20 per cent of the delta being similarly affected. In the years 1928 and 1929 and also 1930, less than 10 per cent of the delta was similarly affected. In five years during the last ten, namely, 1921 to 1923, inclusive, and 1925 and 1927, the portion of the delta similarly affected was small even at the time of maximum invasion, being less than 5 per cent.

It should be noted that the maximum extent of saline invasion usually occurs in late August or September, or in the latter part of the irrigation season. The maximum extent of saline invasion is usually also of short duration except for certain portions of the delta where the salinity becomes pocketed and remains for longer periods because of the lack of a sufficient inflow through these channels to flush out the saline water. The upstream limit of water having a salinity of 100 parts or more of chlorine per 100,000 parts of water gradually advances upstream from the lower end of the delta over a period of two to three months. As a result, irrigation is curtailed on the lower lands of the delta soon after invasion starts, but at an increasingly later date on

* Since the preparation of this report, the extremely dry season of 1930–31 has occurred, which resulted in an unprecedented saline invasion into the delta. At the time of its maximum extent, about 70 per cent of the delta had salinity in excess of 100 parts of chlorine per 100,000 parts of water. The extent of invasion in 1931 is shown on Plate LXXXII.

lands progressively further upstream. Hence, a considerable portion of the delta area finally invaded with water having a salinity of 100 parts or more of chlorine per 100,000 parts of water has had water suitable for irrigation use until the latter part of the irrigation season, even in years of extensive invasion, such as 1924, 1920 and 1926.

The observed maximum salinity for the season during the period 1920 to 1930 has varied between the following limits for typical stations in the upper bay and lower delta:

Station	* *Limits of variation of observed maximum salinity for season in parts of chlorine per 100,000 parts of water, 1920 to 1930*
O. and A. Ferry	510 to 1345
Collinsville	358 to 1150
Antioch	179 to 1085
Jersey	33 to 708
Emmaton	†44 to 802
Three Mile Slough	17 to 730
Rio Vista	4 to 608

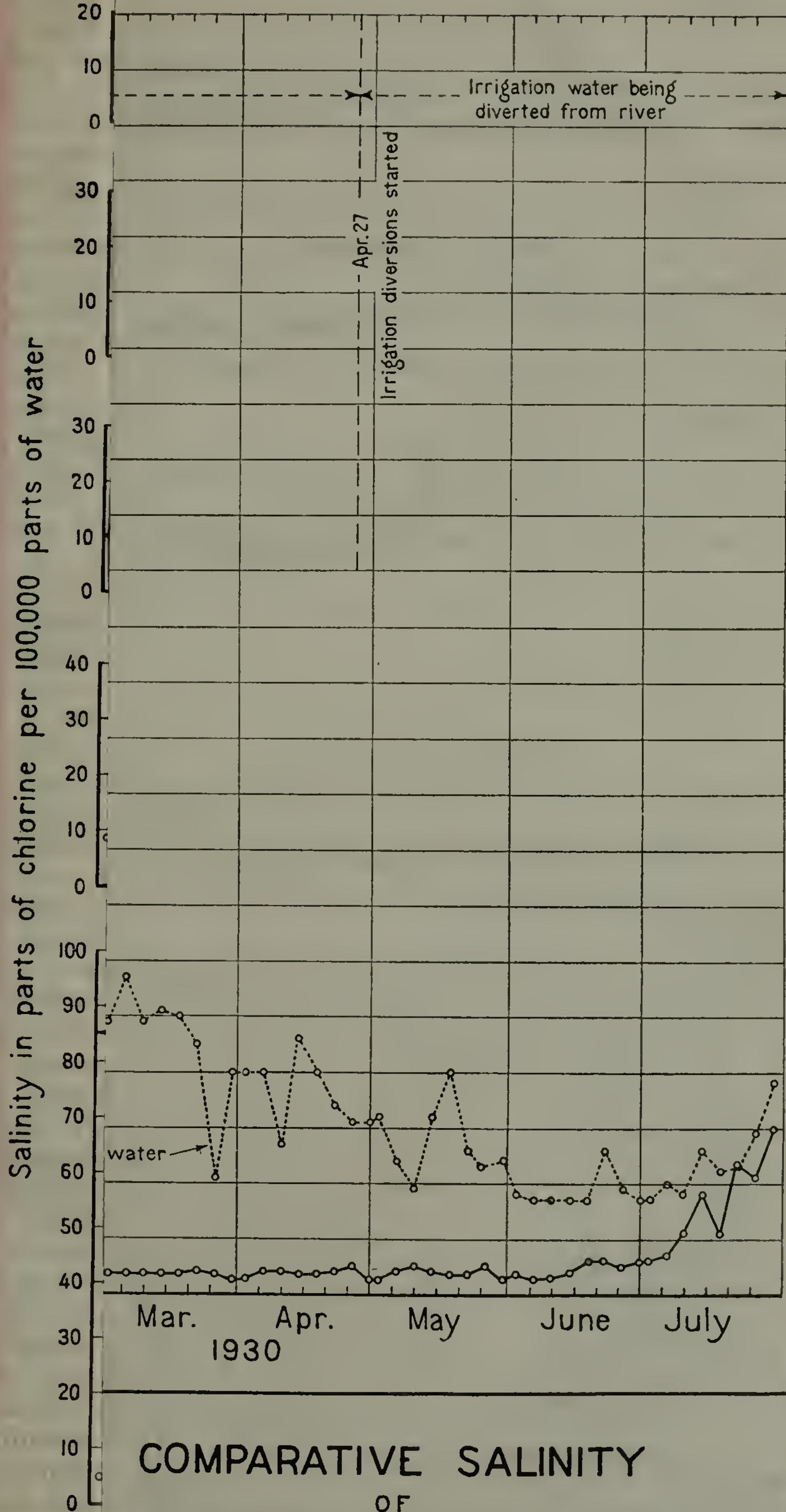
The relation of the extent and degree of saline invasion to stream flow and other factors affecting the same will be fully discussed in a later portion of the report.

Salinity of Drainage Water from Delta Islands—As stated in Chapter I, the program initiated in 1929 included the taking of samples of drainage water on six of the islands in the delta, the points being selected with a view to obtaining conditions which might be representative of the variable conditions of soil and crops in the delta. Staten Island, including stations at Camp 11 and Camp 35, was especially selected because of the fact that there was also the possibility of obtaining complete records of the amount of water diverted for irrigation and drainage water pumped. Other stations were located on Mandeville, McDonald, Bacon and Jersey islands, representing the peat soil conditions in the San Joaquin Delta, and two stations on Grand Island in the Sacramento Delta, representing the silt soil conditions. The salinity records during the seasons 1929 to 1931 are summarized in Table 33.

It is interesting to consider the relative magnitude of the salinity of the drainage water and that of the water in the adjacent river channels from which the supplies of irrigation water for the islands are obtained. For this purpose, Plate VII, "Comparative Salinity of River and Drainage Water," is presented. The records show considerable variation in the relative magnitude of the salinity of river and drainage water. On Staten Island the salinity of the river water in general was somewhat less than that of the drainage water, but the difference in salinity varied considerably during the season. In the months of July, August and September, 1929, the salinity was about the same. Following September and continuing during the winter months, the salinity of the drainage water increased while that of the river water decreased slightly. On Mandeville, McDonald and Bacon

* Maximum salinities for 1931 were: O. and A. Ferry—1390, Collinsville—1230, Antioch—1240, Jersey—1170, Emmaton—1000, Three Mile Slough—860, Rio Vista—740.

† Estimated. No record.



COMPARATIVE SALINITY
OF
IVER AND DRAINAGE WATER

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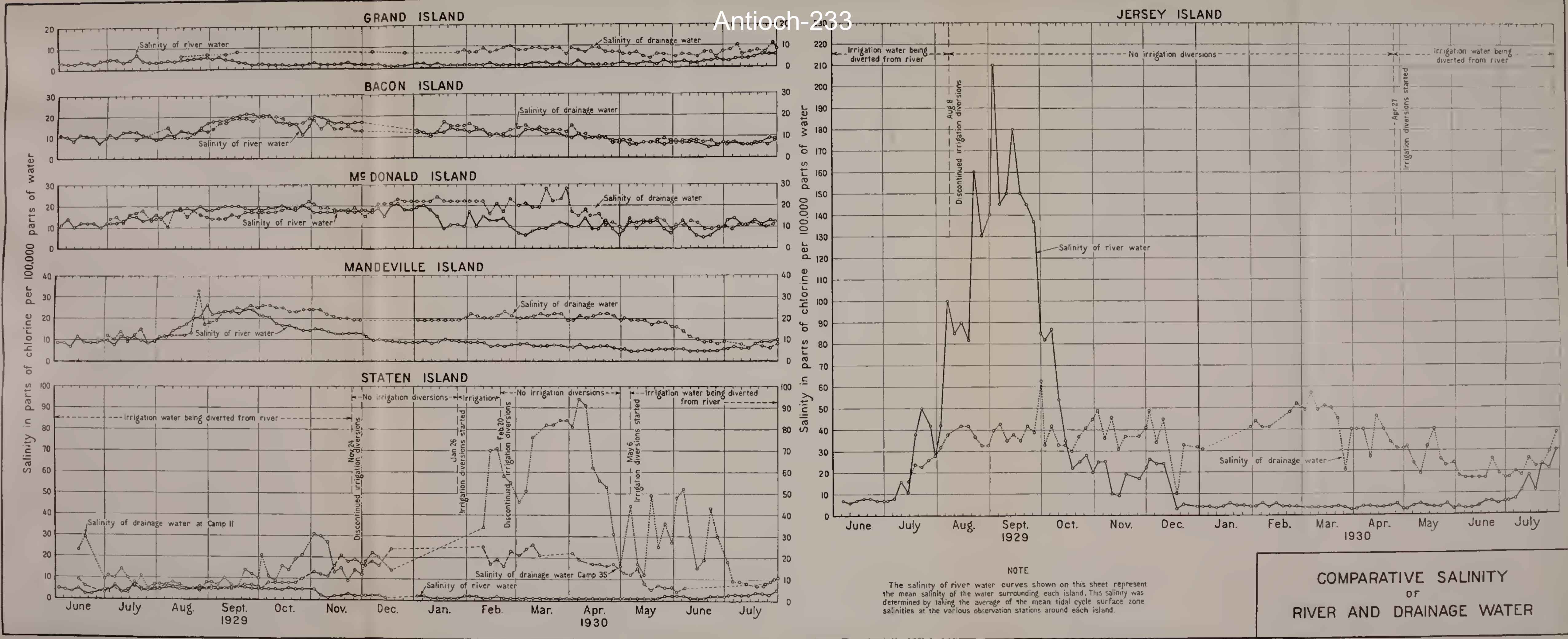

NOTE

The salinity of river water curves shown on this sheet represent the mean salinity of the water surrounding each island. This salinity was determined by taking the average of the mean tidal cycle surface zone salinities at the various observation stations around each island.

COMPARATIVE SALINITY OF RIVER AND DRAINAGE WATER

islands, the salinity of drainage water was about the same as that of the river water during the irrigation season, while it exceeded that of the river water during the winter months. The conditions on Jersey Island in 1929–30 were markedly different than on the other islands. On this island the salinity of river and drainage water was about the same when the record started in the middle of July, 1929. Thereafter, during the months of July, August and September, the salinity of the river was greatly in excess of the drainage water, the river water reaching a maximum of 365 parts in early September. In comparison, the drainage water reached a salinity of about 40 parts in August and continued at about this degree until May, 1930, although the salinity of the river water dropped below 10 parts in December, 1929, and remained below 10 until July, 1930. It is stated that there were no irrigation diversions from August, 1929, to the latter part of April, 1930. Samples and analyses of drainage water on Sherman Island during the 1929 season taken by Reclamation District 341, indicate a similar condition on this island. It appears from this record on Jersey Island and the data on Sherman Island that, in the lower part of the river where the channels become impregnated most every season with a relatively high degree of salinity, the water inside the island, at least that portion appearing in the drainage ditches, is unaffected. Definite conclusion as to this matter can not of course be made with but one year's record, but it appears that the shortness of the period of time in which water of a relatively high salinity surrounds the islands results in no appreciable effect on the water inside the islands, at least within the depth of the drainage ditches. It should be understood, of course, that, during this period of high salinity in the river channels, it is the usual practice not to divert water for irrigation. Hence, any effect of saline water in the adjacent channels would be indicated presumably by an increase of salinity in the ground water within the island. Any increase in salinity of ground water would show up presumably in the drainage water, providing no water were being diverted for irrigation. The apparent lack of effect of relatively high salinity in the river channels on the water inside the islands is of significant importance in a consideration of the possible damage to the delta island lands and crops by reason of saline invasion.

Based upon these records of comparative salinity of drainage water and river water, a study was made of the possible effect of irrigation supplies and drainage pumping on the residual salt content of the islands in the delta. This involved an estimate of the amount of salt entering and leaving the islands for the purpose of obtaining information as to whether more salt in the form of chlorine is being added to the lands by the irrigation water than is being taken out in the drainage water. In order to carry out such a study, it is necessary to have records of the amounts of water diverted into the island and the amounts of water pumped out by the drainage pumps. However, the study is complicated by the fact that there is also involved the extractions of water consumed by the crops, vegetation and evaporation from soil and inland waterways; and also the water coming into the island from rainfall and by what may be termed seepage. It is well known that the amount of seepage from the channels into the islands is substantial, especially in the lands of peat formation and that this source of supply materially contributes to the moisture requirements of crops and other moisture consuming agencies on the islands. However, no exact information is available as to the quantity or rate of seepage into the islands, as there is no method by which an exact measurement can be made of the same.

Exact data as to total input and output of water were not available and hence only an approximate analysis could be made. On only one of the islands, Staten Island, was a fairly accurate record available of the irrigation diversions. It was possible to make a fairly close estimate of the consumptive use of water by crops, vegetation and evaporation, based upon detailed crop surveys and estimates from experimental measurements of the rate of use by the several types of crops, vegetation and by evaporation. A study was then made setting up an equation between the total amount of water entering an island (irrigation diversions, seepage and rainfall) and the total amount of water leaving the same (drainage pumping and consumption by crops, vegetation and evaporation). Based upon estimates of the amount of water entering and leaving the island over a year's period and the known saline content of the waters entering and leaving, it was possible to make an estimate of the total amount of salt brought in and taken out during a year's period. It was necessary, in making this estimate, to assume that the average elevation of the water table at the beginning and end of the period was the same. This is an approximation in which some error might be involved, but which is believed to be fairly reasonable for the purposes of this estimate.

From the data on Staten Island and assuming an equality between the total amount of water entering the island and the total amount taken out during the year's period, it was demonstrated clearly that a considerable portion of the water supply entering this island would have had to be supplied by what may be termed seepage. The data indicated that slightly less than 50 per cent of the total water entering the island came through this source. A similar study for Jersey Island in 1929–30, using approximate estimates of irrigation diversions, indicated that seepage water comprised about the same proportion of the total water entering the island.

On the other islands, no data were available on irrigation diversions, but an estimate of the total amount of water entering the island was made on the assumption that it would be equal to the total amount taken out. Thus, with available data upon which to estimate the amount of water pumped by the drainage pumps and the amount of water consumed by crops, vegetation and evaporation, and an estimate of water added by precipitation, it was possible to estimate the amount of water entering the island by seepage and artificial diversions over a year's period.

The estimates resulting from this study of the amount of salt put in and taken out of the islands are believed to be too approximate to present actual figures. The actual net amounts of salt which the estimates showed as being left in or taken out for the periods considered were generally small. Of chief interest, however, the estimates indicated for the period studied that about as much salt is being taken out of the islands in the drainage water as is entering the islands in the water diverted or seeping in. In order to obtain conclusive data as to this matter it would be necessary to have detailed records of the ground water levels in the islands and more exact data on the amounts of water entering and leaving the islands than have been available for the limited period studied. The matter is one intimately connected with the problem of alkali accumulation in the delta soils, which is recognized as a problem which should receive attention looking toward a suitable solution.

Effect of Salinity Conditions on Developments and Interests.

The invasion of salinity into the upper bay and delta channels in certain years since 1917 has affected not only the delta but also the industrial and urban developments in the upper Suisun Bay area, particularly in the Antioch-Pittsburg district. The marshlands in upper Suisun Bay have also been affected to some extent.

Many of the industries in the Antioch-Pittsburg district are large users of fresh water for boiler and various industrial process purposes. A large part of their fresh-water supplies have been obtained from the river or bay channels offshore from the plants. With the greater degree and duration of saline invasion in recent years since 1917, the industries have been curtailed in their use of this source of fresh-water supply and it has been necessary for them to obtain a greater portion of their required fresh-water supplies from local underground sources or from public water supply systems, entailing additional capital and annual costs. The local underground supplies are limited in amount and are already being drawn upon in excess of the average amount of natural replenishment. This has caused an infiltration of saline water from the adjacent bay or river channels, resulting in the underground supplies becoming saline and hence not fully dependable as a source of fresh-water supply. Industries lower down in Suisun Bay and at points farther downstream have never been able to depend upon the immediate adjacent bay channels as a source of fresh-water supply because saline invasion has always resulted in the water remaining too salty for fresh-water purposes during a considerable portion of the year. Hence, in so far as fresh-water supply is concerned, the change in salinity conditions during the last ten to fifteen years has not affected these lower interests, except the California and Hawaiian Sugar Refining Corporation. Beginning in 1920, this company found it more economical to obtain its fresh-water supply in the summer and fall months from Marin County instead of by barges filled in the river above, because of the greater distance that had to be covered to reach fresh water. This latter arrangement was not wholly satisfactory and led to this company constructing a new private water supply system in 1930 to furnish fresh water for the sugar factory and the city of Crockett. Water is obtained from wells in lower Napa Valley and conveyed to Crockett by pipe line.

The greater degree and duration of saline invasion in the Suisun Bay channels has also affected the industries to some extent by reason of the increased rate of depreciation on cooling water equipment due to the greater corrosion caused by the salt water pumped from the bay for cooling and condensing purposes. Many of the industrial plants have had to replace their previous cooling equipment with salt-resisting equipment in order to decrease the expense of maintenance and depreciation. However, the additional cost of salt-resisting equipment does not greatly increase the expense of cooling water to the industries and the actual cost per 1000 gallons is small. Over 80 per cent of the total amount of water used by industries in the upper bay region is for cooling and condensing purposes. The use of saline water from the bay channels for cooling and condensing is satisfactory and little, if any, advantage would be gained if fresh water were available for this purpose.

From 1880 to 1920, Pittsburg (formerly Black Diamond) obtained all or most of its domestic and municipal water supply from New York Slough offshore. Although the records show that the water became too brackish to be suitable for domestic use during certain periods in the summer and fall months even before 1917 (See Table 34 for record of salinity, 1910 to 1916), the degree and duration of salinity greatly increased from 1917 on and necessitated the provision of a new source of supply. After providing temporary expedients, including the hauling of water in barges filled at points upstream where fresh water was available, the use of the river as a source of domestic and municipal water supply was discontinued in 1920 and since that time the supply has been obtained from local wells. From early days, Antioch has obtained all or most of its domestic and municipal supply from the San Joaquin River immediately offshore from the city. This supply also has always been affected to some extent by saline invasion with the water becoming brackish during certain periods in the late summer and early fall months. However, conditions were fairly satisfactory in this respect until 1917, when the increased degree and duration of saline invasion began to result in the water becoming too brackish for domestic use during considerable periods in the summer and fall. To meet this change in conditions, Antioch finally constructed a reservoir which is filled with fresh water from the river in the winter and spring and which is designed to supply the city during the period of the year when the water in the river is too brackish for municipal use.

The remaining cities and towns in the upper bay region have obtained fresh-water supplies from various local sources such as surface streams and wells and hence have not been affected by recent changes in salinity conditions. One public utility, serving the cities and towns of Contra Costa County from Pittsburg to Oleum as well as several industrial plants, has recently completed a new water supply development, pumping water from the lower river near Mallard Slough about two miles west of Pittsburg and piping the same to a storage reservoir at Clyde just south of Bay Point. Water is pumped when fresh and free from saline invasion and the storage capacity is designed to supply the demands during the remainder of the year when the water at the intake is too salty for fresh-water purposes.

The marshlands adjacent to Suisun Bay, especially the portion thereof in the upper half of the bay, have been affected to some extent by the more prolonged invasions of salinity of high degree since 1917. Although the area farmed is relatively small in extent, comprising only 5000 acres in 1929, water suitable in quality for irrigation has been available for much shorter periods during the last ten to fifteen years than in former years. This not only has curtailed irrigation diversions to crops, but also has limited the development of these marshlands because of the lack of availability for a sufficient period of time of fresh water for leaching the salts from the soils to make them fit for crop production. In former years these lands were utilized principally for cattle grazing and dairying. These activities have been adversely affected during recent years because of the difficulty in providing fresh water for the cattle during the more prolonged saline invasions.

Except for those specifically noted heretofore, the industrial, municipal and agricultural developments and interests in the upper San Francisco Bay region have not been affected thus far by saline invasion in regard to water supply, because the river and bay channels have not been used as a source of fresh-water supply. However, the studies presented in other reports * show that the ultimate water requirements for industrial, municipal and agricultural use in the upper bay region will necessitate the importation of supplies from some suitable source to supplement the local water resources which are capable of economic development. The nearest source of supply would be the lower Sacramento and San Joaquin rivers. The studies of water supply, yield and demand in the operation of the initial and ultimate developments of the State Water Plan show that most of the water supply required to be imported to the upper San Francisco Bay region could be furnished from this source. Therefore, the industrial, municipal and agricultural developments adjacent to Suisun and San Pablo bays are directly interested in the investigation of salinity, and particularly in the determination of a means of controlling saline invasion in such a way that water supplies now available or hereafter made available in the lower Sacramento and San Joaquin rivers would be maintained fresh at all times for diversion to supply the future needs of the upper bay region.

One of the results attributed to the increased degree and duration of saline invasion of the last ten to thirteen years is the destruction by the teredo of untreated timber piling in water-front structures along the shores of San Pablo and Suisun bays. Prior to 1919, most of the water-front structures in the entire upper bay region were supported on untreated timber piling, most of which had stood for many years without molestation by marine borers. The marine borer, known as the teredo navalis, was first reported in a structure at Mare Island in 1914, but its activities did not become serious until after 1917. By 1921, practically all untreated timber piling in the upper bay region had been destroyed by the teredo navalis and necessitated costly reconstruction with various forms of treated timber and concrete piling designed to resist the attacks of these borers. It should be noted, however, that the salinity of the water in San Pablo Bay and most of Suisun Bay was great enough prior to 1917 for the teredo to be active, and had it not been for the introduction of the teredo navalis into the upper bays, probably in a shipment of piling infested with this borer, the untreated timber piling would not have been attacked. Hence, it appears that the change in salinity conditions, in itself, was not the primary cause of the destruction of untreated timber piling, but rather only a contributing factor, providing conditions agreeable to the activities of teredo navalis after its introduction.

Within the delta, the greater extent, degree and duration of saline invasion in certain years since 1917 have resulted in the curtailment of irrigation on varying portions of the delta during the latter part of the

* Bulletin No. 25, Report to Legislature of 1931 on State Water Plan, Division of Water Resources, 1930.

Bulletin No. 28, Economic Aspects of a Salt Water Barrier below Confluence of Sacramento and San Joaquin Rivers, Division of Water Resources, 1931.

irrigation season. This has resulted possibly in some decrease in crop yields but no definite information has been found as to any losses in crops for any year up to 1930.† This no doubt is partly due to the judicious choice as to type of crops grown especially on the lower lands of the delta such as Sherman and Jersey islands. It is found that the crops grown on these lower lands are generally of a type which have the greatest tolerance to saline conditions and/or which do not require irrigation applications in the late irrigation season. Thus, one of the chief crops grown is asparagus, which is relatively tolerant to salt and which, being deep-rooted, draws its moisture from considerable depths and hence does not require irrigation applications in the late summer and fall months. Shallow-rooted crops requiring irrigation in the latter part of the irrigation season usually are not planted on these lands where saline invasion generally occurs in the adjacent channels to make the water unsuitable for irrigation use. Earlier, more prolonged and more extensive invasions of salinity than have occurred up to 1930 might result in material loss in crop production.†

There has been considerable speculation upon the effect of saline invasion on the quality of the lands within the delta. In so far as can be ascertained by the present investigation, the invasions of salinity which have occurred up to 1930 apparently have not affected the quality of land. This appears to be true even for those lands which lie nearest the lower end of the delta, including such areas as Sherman, Jersey, Bradford, Twitchell, and Brannon islands and the Webb Tract. The waters in the channels adjacent to these lands have been invaded by saline water to an extent sufficient to make the water unfit for irrigation use during varying periods in several of the past ten years. However, the period of saline invasion into the delta is usually about three to six months of the summer and fall in the lower delta channels and correspondingly lesser periods at points farther upstream.

Just what the effect of a longer period of saline invasion than has been experienced up to 1930 would be on these delta lands is impossible to state, nor can a statement be made with any degree of certainty as to what period of saline invasion could be experienced by these lands without affecting their quality. It appears probable that the saving feature in the conditions which have been experienced during the past ten years or even farther back is the fact that fresh water is present in the adjacent channels for a larger portion of the year and is therefore the predominating source of the ground water supplies which fill the voids in the island masses. A fresh water supply thus stored up in the ground is available for a considerable period of time and apparently its quality within the reach of plant roots is unaffected by invasions of saline water in the adjacent channels which extend over periods of considerable duration. However, if water of a high salinity were to remain present in the channels of the delta during a larger portion of the year, it appears probable that the ground waters in the islands would gradually become saline and thus affect the quality and utilization of the soil. Conditions would tend to approach those which are found in the marshlands of Suisun Bay, where saline water conditions have predominated over a longer period of time.

† Surveys and studies under way indicate that the uprecedented saline invasion in 1931 resulted in a very material loss in crops in the delta and also some loss in the delta uplands.

Although the evidence appears to show that the delta lands and crops have not been materially damaged by saline invasions which have occurred up to 1930, the salinity menace has tended to depreciate land values in the delta. Until this menace is removed there exists a more or less constant threat of more extensive and prolonged saline invasions than have heretofore occurred up to 1930, which might result in material damages to crops and lands in the delta.

There does exist a more or less serious problem of salt accumulations in the soils of the delta islands which it is deemed desirable to discuss in this connection, inasmuch as there has been a considerable tendency to confuse this problem with the invasions of saline water from the bay. Because of the method of irrigation in the delta with ground water levels held from six inches to three feet below the ground surface to supply the moisture requirements of the crops, there results a positive tendency for the gradual accumulation of salts in the surface layers of the soil. This is due to the fact that capillary action draws the moisture from the water table to the ground surface and upon evaporation leaves in the surface layers of the soil whatever salt content it had. Where the water is generally very pure and contains but a small amount of salts, the accumulation of salt by this action is extremely slow and it takes many years to accumulate enough salt to affect crop production. While the water supply in most of the delta is usually comparatively free from salt, the result of many years of irrigation under the methods used has been the gradual accumulation of considerable amounts of salt in the surface layers of some of the island soils. Direct rainfall, when of sufficient quantity, helps considerably in leaching out such accumulations. However, during periods of subnormal precipitation such as the last thirteen years, the leaching action of rainfall is greatly diminished. Thus far the problem has not reached serious proportions except in a few isolated instances. However, the evidence of actual accumulations is sufficiently clear to have brought it to the attention and serious consideration of many of the delta land owners. It is evident that measures should be taken before many years to eliminate these accumulations of salt which tend to gradually occur.

The evidence shows that the salt which has been accumulated in the surface layers of soils in the delta is chiefly the result of the methods used in irrigation involving the maintenance of high water tables for the growing of crops. However, it is important to point out that fresh water is especially essential with this method of irrigation, as the use of water of greater salinity would tend to increase salt accumulations in the soil.

Basic Factors Governing Salinity Conditions.

The basic factors governing the extent of saline invasion and retreat and the rates of advance and retreat of salinity are stream flow into the delta and tidal action. The effect of stream flow is modified by consumption of water in the delta by crops, vegetation and evaporation. In other words, the stream flow at the confluence of the Sacramento and San Joaquin rivers into Suisun Bay is the difference between the stream flow into the delta and the amount of water consumed within the delta. The studies of variation and control of salinity are chiefly directed to the determination of the relation of the variation of salinity to the basic factors affecting the same, namely; stream flow and tidal action. It has, therefore, been essential to obtain as accurate and complete data as possible as to these basic factors and the compilation of the data regarding the same has been an important part of the present investigation.

Stream Flow—The records of stream flow used in this investigation are from measurements made at established gaging stations maintained and operated by the United States Geological Survey in cooperation with the State together with special stream gaging stations maintained and operated by the State alone. The location of the stream gaging stations from which records of flow are used in this report are shown on Plates I and II. These gaging stations have been in operation for varying periods of time. During earlier years, most of the gaging stations established and operated were on the main streams at or near the rim of the valley. For the purpose of this investigation it was necessary to determine the inflow into the delta. Fortunately, during the past ten years since 1920, stations have been maintained and operated at or near the rim of the delta which has made it possible to closely estimate daily inflow into the delta, especially during the summer and fall months covering the period of invasion and retreat of salinity. These records of daily inflow into the delta, for the seasons 1919–1920 to 1928–1929 have been compiled and are presented in tabular and graphical form. Table 37 summarizes the daily inflow into the delta for both the Sacramento and San Joaquin River systems separately and combined from 1919 to 1929, inclusive. The basis of compilation of the figures on inflow are presented in detail with the table. The Sacramento River flow includes the flow of the main Sacramento River and all of its branches into the northern end of the delta, as measured at Sacramento. It also includes the flow of Cache and Putah creeks and Yolo By-Pass. The San Joaquin River flow includes the flow of the San Joaquin River as measured at the south rim of the delta near Mossdale Bridge, together with the flow of the Calaveras, Mokelumne, and Cosumnes rivers and Dry Creek.

These records of daily inflow into the delta are graphically presented on Plates V and VI. These are shown by the diagrams on the lower half of these plates directly below the graphical record of salinity so that the variation of inflow into the delta can be directly and conveniently compared with the variation of salinity. The heavy lines on the graph of stream flow are for the combined flow of the Sacramento and San Joaquin rivers into the delta. There is also shown in a lighter line the flow alone of the San Joaquin River and its branches. During the low flow period of the summer and fall months, the stream flow is shown each season on a larger scale so that the amounts of flow can be more readily taken off the graph. There is also shown on the larger-scale diagrams of flow the consumption of water in the delta, based upon estimates and data presented hereafter. This is shown for the entire delta and also separately for the Sacramento and San Joaquin deltas. The assumed dividing line between the Sacramento and San Joaquin deltas is shown on Plate III. The direct comparison between the stream flow into the delta and the consumption of water in the delta can be readily made on this graph which clearly illustrates the fact that, in several of the years during the ten-year period, the stream flow entering the delta has been insufficient to take care of the consumptive needs of the delta.

Prior to 1919, stream flow measurements are not available for estimating the daily inflow into the delta. However, the records available are sufficient to make a reasonably close estimate of the monthly inflow as far back as 1911–1912. The monthly stream flow has, therefore, been compiled for the period 1911 to 1919 for use in general studies as to relation of stream flow to salinity. The estimated monthly stream flow from 1911 to 1929 is shown in Table 38 and on Plate VIII, "Monthly Stream Flow into Delta of Sacramento and San Joaquin Rivers."

Table 39 summarizes the seasonal stream flow and the per cent of each season's stream flow to the average for the 58-year period, 1871 to 1929. The estimates of seasonal stream flow from 1871 to 1911 are not shown in Table 39, because only an approximate estimate could be made based upon the estimates in a previous report * and records of stream measurements at stations at the rim of the valley. However, the inflow for the seasons prior to 1911 has been estimated as a percentage of the 58-year mean (1871–1929) and shown with the percentage estimates from 1911 to 1929 on Plate IX, "Seasonal Stream Flow in Delta of Sacramento and San Joaquin Rivers." The percentage estimates of seasonal stream flow were made for the seasons prior to 1889, because it was desirable to correlate these earlier years' stream flow with historical information available on salinity conditions.

Variation of Stream Flow—Stream flow into the delta varies in magnitude in accordance with the wetness of the year. The mean seasonal stream flow into the delta for the period 1871 to 1929, inclusive, is estimated at 31,346,000 acre-feet. The 40-year mean from 1889 to 1929, inclusive, is practically the same amount. The mean for the last 20, 10- and 5-year periods is, however, considerably less than the long period means, the 20-year mean being estimated at 23,765,000 acre-feet and the 10- and 5-year means being about 19,000,000 acre-feet. During the last 58 years, the period up to and including 1916 contains a preponderance of wet or above normal years. As shown on the upper diagram of Plate IX, the accumulated percentage departure of seasonal stream flow from mean stream flow for the period 1871 to 1917 amounted to about 500 per cent excess above the 58-year mean. Beginning with the season 1916–1917, however, there has been a preponderance of dry years up to 1930, the effect of which is indicated by the almost continuous downward slope of the cumulative curve of percentage departure from the mean.

The total stream flow for individual seasons varies widely. Based on the 58-year mean (1871–1929), the percentage of mean seasonal stream flow varies from a minimum of 18 per cent for the season 1923–1924 to a maximum of 261 per cent for the season 1889–1890.** During the 58 years there have been 29 years in which the stream flow

* Bulletin No. 5, Flow in California Streams, Division of Engineering and Irrigation, 1923.

** The percentages of mean seasonal stream flow into the delta are affected by upstream diversions and, hence, differ for identical seasons from corresponding percentages of mean run-off naturally tributary to the delta. Upstream diversions effect a proportionately greater reduction of the tributary run-off in dry seasons than in wet seasons. Therefore, especially in dry seasons, the percentage indexes for stream flow into the delta are considerably less than those for the natural tributary run-off of the same seasons.

was equal to or greater than normal. However, in the 10-year period, 1919–1929, only two seasons have had normal stream flow and of the remainder, four have had but 50 per cent or less of normal stream flow. In the 13-year period, 1917–1929, there have been but two normal seasons of stream flow and of the balance, five seasons have had a total stream flow of 50 per cent or less than normal. It is particularly important to note that the period 1917–1929 has been one of unusual dryness and subnormal stream flow and that this condition has been a most important contributing factor to the abnormal extent of saline invasion which has occurred during this same time. Other factors which will be discussed hereafter have contributed to the salinity conditions, but the conditions of subnormal stream flow are believed to have been a major factor in bringing about the abnormal salinity conditions.

Even more marked variations occur in monthly stream flow into the delta. As shown in Table 38 and on Plate VIII, the monthly stream flow has varied from a minimum of 70,000 acre-feet in 1920 to a maximum of over 12,000,000 acre-feet in 1914, with an average of 1,845,000 acre-feet per month for the period 1911–1929. The average of the maximum monthly stream inflows for all seasons from 1911 to 1929 is 4,916,000 acre-feet. The smallest maximum monthly stream flow in any season during the period was in 1923–1924 and amounted to 1,254,000 acre-feet. For the thirteen-year period 1917 to 1929, the average monthly stream flow was 1,604,000 acre-feet. The minimum monthly stream flow from 1911 to 1929 during the summer period June to September, inclusive, in each season, ranged from 70,000 acre-feet in 1920 to 557,000 acre-feet in 1912.

The months of large stream flow generally occur in the period December to May corresponding with the winter and spring flood period. During the earlier months of December to March, inclusive, the larger stream flows are caused usually by rainfall in the valleys and foothill areas, occasionally augmented by melting snow in the lower mountains. It is in this period that most of the large floods have occurred. In the later months, April, May and June, the larger stream flows usually come directly from melting snows in the Sierra Nevada. Based on this period of record, 1911–1929, stream inflow during the six months' period, January to June, inclusive, on the average comprises 82 per cent of the total seasonal stream flow and during the seven months' period, December to June, inclusive, 88 per cent of the total seasonal stream flow. This leaves but twelve to eighteen per cent of the total seasonal stream flow occurring during the five or six summer and fall months up to the time that rains and winter freshets start normally each year. It is during this latter period that the maximum demands for irrigation and water consumption occur and this situation typifies the usual discrepancy which exists in California as between the occurrence of supply and demand for water. The period of low stream flow is also coincident with the annual invasion of salinity into the upper bay and delta channels.

The variations in rate of flow of the Sacramento and San Joaquin rivers into the delta are even more marked and of greater significance than the variations in monthly and seasonal inflow. During the period 1919 to 1929, inclusive, the combined flow of the Sacramento and San Joaquin rivers into the delta has varied from a minimum of about 700

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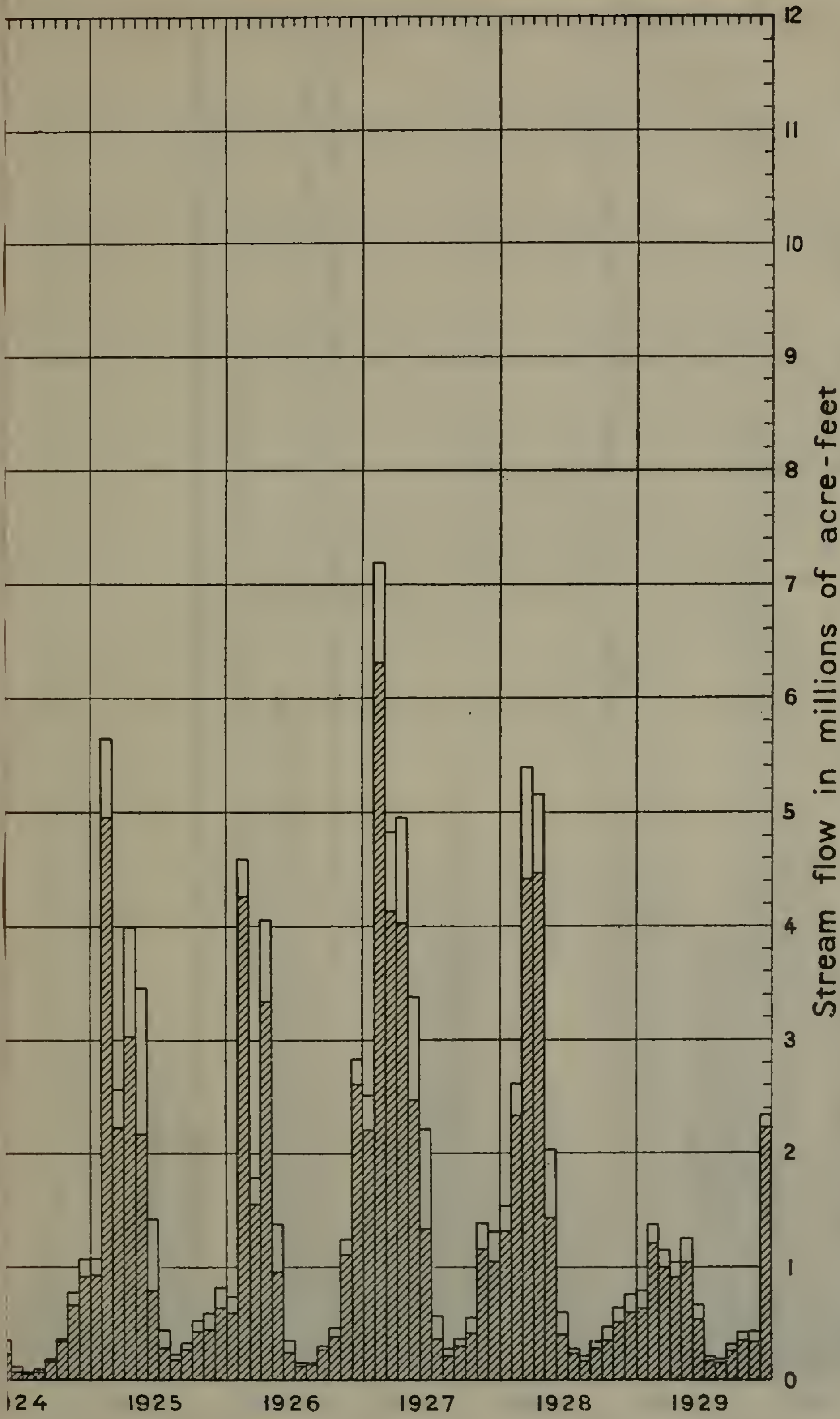

MONTHLY STREAM FLOW INTO DELTA
OF
SACRAMENTO AND SAN JOAQUIN RIVERS

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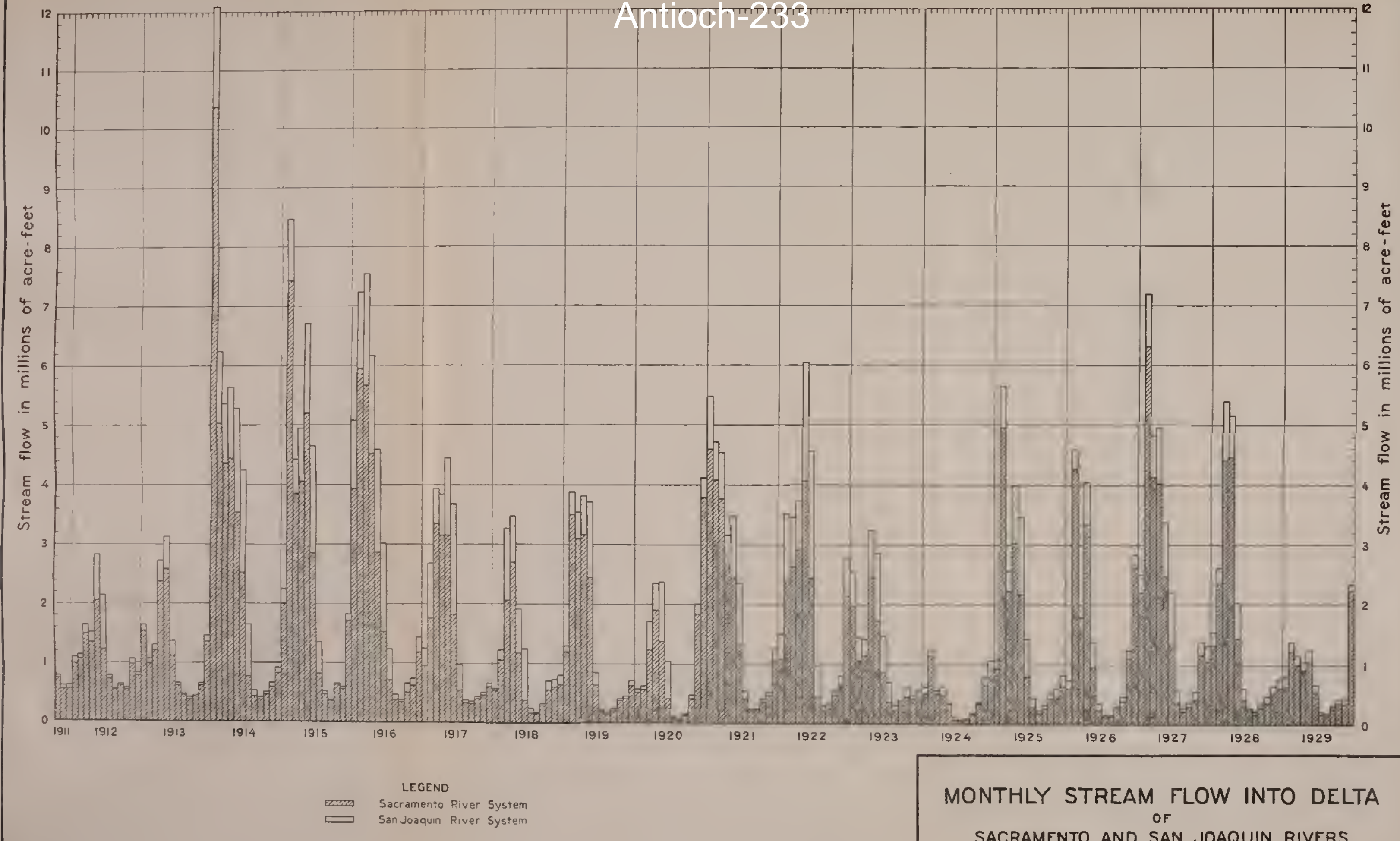

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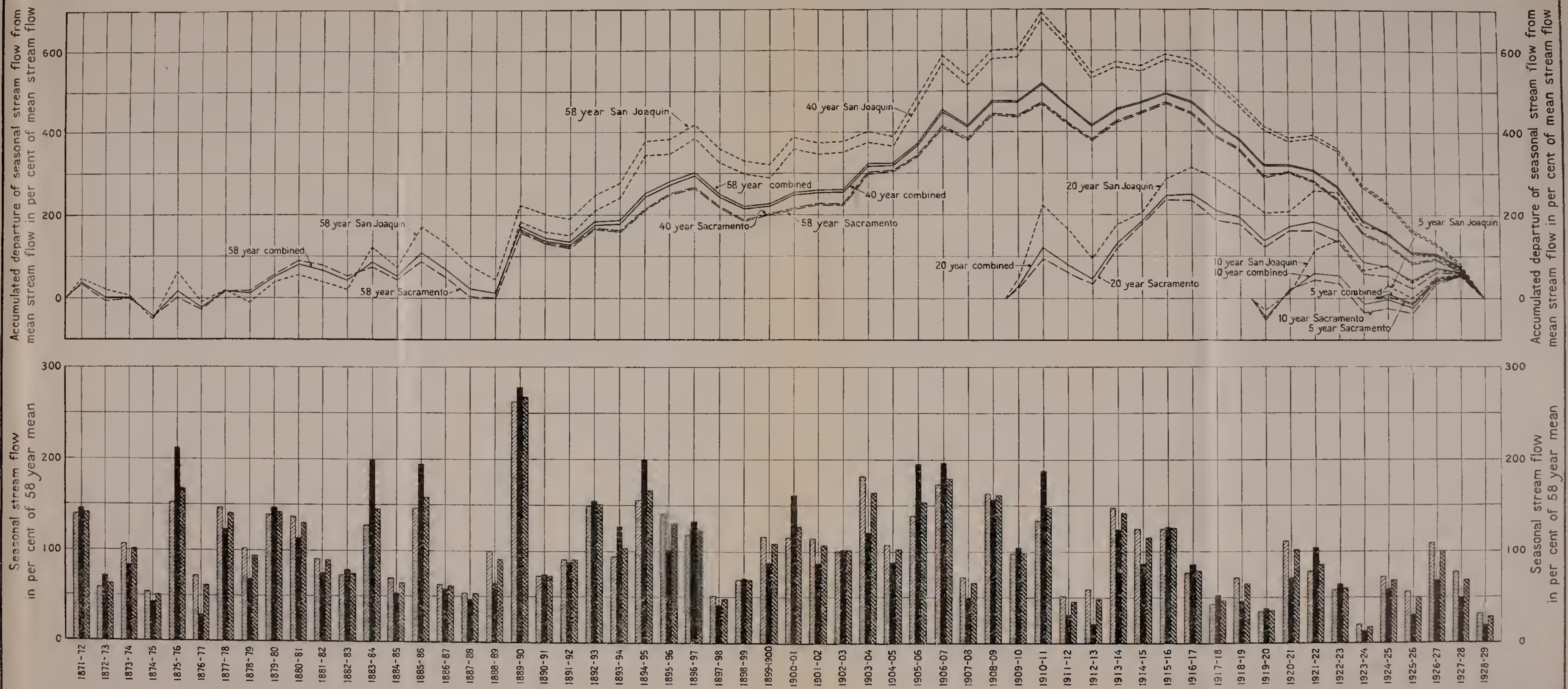

	Sacramento River	San Joaquin River	Combined
58 year mean stream flow	23,449,000 acre-feet	7,897,000 acre-feet	31,346,000 acre-feet
40 " " " "	23,442,000 " "	7,805,000 " "	31,247,000 " "
20 " " " "	18,228,000 " "	5,537,000 " "	23,765,000 " "
10 " " " "	14,995,000 " "	4,136,000 " "	19,131,000 " "
5 " " " "	16,058,000 " "	3,599,000 " "	19,657,000 " "

LEGEND

- Sacramento River
- San Joaquin River
- Combined Sacramento and San Joaquin Rivers

SEASONAL STREAM FLOW INTO DELTA
OF
SACRAMENTO AND SAN JOAQUIN RIVERS

second-feet in August, 1920, to a maximum of 353,000 second-feet in March, 1928. As far as is known, the minimum flow in 1920 is the smallest combined flow of the Sacramento and San Joaquin rivers into the delta that has ever occurred up to 1930.* At the time this minimum flow occurred, about half of the flow was supplied by the Sacramento River and about half by the San Joaquin River and its branches. From July 24 to August 23, 1920, or practically a month's period, the combined inflow ranged from 700 to 1600 second-feet with an average of about 1000 second-feet. In the summer of 1924, the minimum flow was nearly as small as in 1920, decreasing to about 1000 second-feet in the middle of July of that year. From July 1 to August 15, 1924, the average flow into the delta was about 1300 second-feet. In the summer of 1926, the minimum flow was 1600 second-feet with an average flow from July 20 to August 12 of about 1800 second-feet. As compared to these lower minimum flows which have occurred during the period 1920–1929, the minimum flow in 1928 was 3100 second-feet and in 1929 about 2600 second-feet, while in the more normal years of 1921, 1922, 1923, 1925 and 1927, the minimum flow was at all times greater than 3000 second-feet, and, with the exception of 1921 and 1925, was over 4000 second-feet. The minimum flow of the Sacramento River into the delta during the ten-year period was about 300 second-feet about August 1, 1920, as compared to about 700 second-feet in July, 1924, while the minimum flow of the San Joaquin River and its branches into the delta was about 200 second-feet in 1920, and 300 second-feet in 1924. In 1926 the minimum flow of the Sacramento River was 1300 second-feet while the minimum flow of the San Joaquin River was 200 second-feet.

The greater portion of the stream flow into the delta usually has come from the Sacramento River. The graphical record of flow on Plates V and VI clearly illustrates the proportionate amounts supplied from the two streams. This is of particular significance in the summer period. During the ten-year period from 1920 to 1929, except 1923 and 1927, the flow of the San Joaquin River and its branches has dropped below 1000 second-feet and in most years to 500 second-feet or less for a considerable period in the summer of every year, whereas in only two years, 1920 and 1924, did the flow of the Sacramento River into the delta reach such a low discharge.* Therefore, it is clear that the Sacramento-San Joaquin Delta is dependent to a large extent upon the flow of the Sacramento River into the delta for its water supply. It is equally clear that the usually greater flow of the Sacramento River is of relatively greater importance in the effect of stream flow on salinity conditions in the delta and upper bay channels. The maximum flow of 353,000 second-feet, which occurred during the ten-year period (1920–1929) is considerably less than the maximum flows which may be likely to occur in future years. It has been estimated that the maximum flood discharge of the combined Sacramento and San Joaquin

* Since the preparation of this report, the extremely dry season of 1930–31 has occurred, resulting in an unprecedented minimum flow into the delta during the summer of 1931. The combined flow of the Sacramento and San Joaquin River systems into the delta was less than 500 second-feet for a considerable period during the summer; and, for a period of about two weeks, there was practically no flow passing Sacramento in the Sacramento River. The only flow coming into the delta during this period comprised return water from lands irrigated on the San Joaquin River system and some water released from reservoirs on the Mokelumne River.

rivers into the delta under present conditions of reclamation and flood control development might reach a maximum of between 750,000 and 800,000 second-feet.

The amount and variation of stream flow into the delta during the summer and fall months are of chief significance and importance as affecting the extent, degree and duration of saline invasion into the upper bay and delta channels. The amount and variation of winter and spring flows, and especially the floods, chiefly affect the extent of retreat of salinity. However, the amount and variation of winter and spring flows also have a material effect upon the succeeding summer invasion of salinity. This feature will be discussed more fully in Chapter III.

Consumptive Use of Water in Delta—The consumptive use of water in the delta of the Sacramento and San Joaquin rivers is based chiefly upon six years of tank experiments made by the United States Department of Agriculture in cooperation with the State as previously described in Chapter I. The complete report of these measurements has not as yet been prepared. However, a summary of the results of the measurements has been made especially for this investigation, which furnishes what may be considered reasonably close figures on estimated water consumption by crops, vegetation and evaporation in the delta. In the data and discussions presented herein, the term "consumptive use" is used in its absolute sense. It represents amounts of water consumed irrespective of source and hence includes amounts consumed from rainfall. However, the greater part of both annual and seasonal consumption occurs in the dry months, and hence the source of supply is chiefly from the delta channels.

Table 1 shows the estimated consumptive use in feet depth (acre-feet per acre) for all important crops and, in addition, for natural vegetation, and evaporation from bare and idle land and open water. These rates of estimated consumptive use of water when applied to the acreages of crops, natural vegetation, idle land and open water surface give the water consumed in the delta in acre-feet. The estimated monthly, total seasonal and total annual consumption in acre-feet in 1929 are shown in Table 2. The total seasonal consumption comprises the estimated amounts of water used by crops and vegetation during the growing season and by evaporation for the entire year. The total annual consumption includes, in addition, the use of water on the cropped area during the nongrowing or dormant season. The consumptive areas are based upon the 1929 crop surveys of the Sacramento-San Joaquin Water Supervisor, supplemented by special surveys and compilations made for this report. Crop areas are available for all years from 1924 to 1929, inclusive. No reliable complete data are available for the years 1920 to 1923, inclusive. However, as shown in Table 3, which summarizes the area in irrigated crops and the estimated total seasonal consumption of water by crops from 1924 to 1929, inclusive, there has been no very great change in the irrigated crop area during these years and it is probable that the irrigated area was about the same as far back as 1920. The average depth of water used by irrigated crops in the entire delta, as estimated from the consumptive use figures adopted, is about 2.1 feet during the composite growing season of all crops.

TABLE 1

CONSUMPTIVE USE OF WATER IN SACRAMENTO-SAN JOAQUIN DELTA

Crop or water-using agency	Consumption in feet depth or in acre-feet per acre													
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total use for season	Total use for year
Alfalfa[1]	(.06)	(.08)	.10	.30	.40	.50	.65	.55	.50	.20	(.10)	(.07)	3.20	3.51
Asparagus[2]	.05	.05	.05	.05	.08	.14	.40	.68	.55	.42	.12	.10	2.69	2.69
Beans[2]	(.06)	(.08)	(.08)	(.16)	(.20)	.14	.24	.58	.37	(.09)	(.07)	(.05)	1.33	2.12
Beets[2]	(.06)	(.08)	(.08)	.13	.32	.51	*.61	*.53	*.20	(.13)	(.10)	(.07)	2.30	2.82
Celery[2]	(.04)	(.04)	(.04)	(.08)	(.10)	.10	.10	.20	.25	.30	.20	.05	1.20	1.50
Corn[2]	(.04)	(.04)	(.04)	(.08)	(.10)	.24	.85	*.84	*.40	.10	(.10)	(.07)	2.43	2.90
Fruit[1]	(.04)	(.04)	(.04)	.18	.32	.50	.57	.40	.23	.07	(.07)	(.05)	2.27	2.51
Grain and hay[2]	(.04)	(.04)	.07	.60	.83	.20	(.14)	(.23)	(.21)	(.14)	(.07)	(.05)	1.70	2.62
Onions[2]	(.04)	(.04)	.08	.13	.27	.49	.43	.20	(.16)	(.13)	(.10)	(.07)	1.60	2.14
Pasture[2]	.08	.10	.20	.25	.25	.25	.25	.25	.20	.15	.10	.08	2.16	2.16
Potatoes[2]	(.06)	(.08)	(.08)	(.16)	.15	.38	.52	.30	.15	(.09)	(.07)	(.05)	1.50	2.09
Seed[3]	(.06)	(.08)	(.08)	.10	.25	.50	.50	.50	.35	.10	(.10)	(.07)	2.30	2.69
Truck[2]	(.06)	(.08)	.10	.10	.25	.50	.45	.45	.30	.15	.10	(.07)	2.40	2.61
Tules[4]	.16	.09	.30	.74	1.10	1.28	1.53	1.32	1.18	.98	.59	.36	9.63	9.63
Bare land[2]	.04	.04	.04	.08	.10	.13	.14	.13	.11	.09	.07	.05	1.02	1.02
Average idle land with weeds below elevation 5.0 feet U. S. G. S. datum[3]	.06	.08	.08	.16	.20	.26	.28	.24	.16	.13	.10	.07	1.82	1.82
Open water surface[4]	.08	.13	.23	.34	.60	.76	.84	.78	.60	.33	.14	.08	4.91	4.91
Willows[5]	.05	.03	.09	.22	.33	.38	.46	.40	.35	.29	.18	.10	2.88	2.88

NOTE.—Figures shown in parentheses ( ) represent estimated consumptive use on cropped areas, before planting and after harvest, or during the dormant season.
*Includes additional use of water by weeds during these months.
[1] From experiments in adjacent areas.
[2] From recent cooperative experiments in Sacramento San Joaquin Delta by Division of Water Resources and U. S. Department of Agriculture.
[3] Estimated by U. S. Department of Agriculture by comparison with similar crops.
[4] From data of recent cooperative experiments and other agencies, modified by Chas. H. Lee.
[5] From data of recent cooperative experiments and other agencies, modified by Chas. H. Lee. Use based upon willows in large groves, with an additional ten per cent for isolated trees.

TABLE 2

TOTAL CONSUMPTIVE USE OF WATER IN SACRAMENTO-SAN JOAQUIN DELTA—1929 SEASON

Crop or classification	Area in acres	Monthly consumption in acre-feet												Total seasonal consumption		Total annual consumption	
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Depth in feet	Acre-feet	Depth in feet	Acre-feet
Alfalfa	24,500	(1,420)	(1,900)	2,450	7,350	9,800	12,250	15,930	13,470	12,250	4,900	(2,370)	(1,660)	3.2	78,400	3.5	85,750
Asparagus	62,500	3,140	3,140	3,140	3,140	5,020	8,780	25,090	42,660	34,500	26,350	7,530	6,260	2.7	168,750	2.7	168,750
Beans	32,500	(1,970)	(2,630)	(2,630)	(5,270)	(6,580)	4,450	7,620	18,430	11,750	(2,960)	(2,300)	(1,660)	1.3	42,250	2.1	68,250
Beets	18,300	(1,060)	(1,410)	(1,410)	2,380	5,860	9,330	*11,160	*9,700	*3,660	(2,290)	(1,760)	(1,220)	2.3	42,090	2.8	51,240
Celery	8,700	(350)	(350)	(350)	(700)	(860)	870	870	1,740	2,180	2,610	1,740	430	1.2	10,440	1.5	13,050
Corn	41,000	(1,740)	(1,740)	(1,740)	(3,490)	(4,380)	9,720	34,420	*34,010	*16,200	4,050	(4,360)	(3,050)	2.4	98,400	2.9	118,900
Fruit	15,000	(500)	(500)	(500)	2,740	4,860	7,600	8,660	6,080	3,500	1,060	(880)	(620)	2.3	34,500	2.5	37,500
Grain and hay	70,000	(2,740)	(2,740)	4,900	42,000	58,100	14,000	(9,590)	(15,750)	(14,380)	(9,590)	(4,790)	(3,420)	1.7	119,000	2.6	182,000
Onions	4,300	(160)	(160)	340	560	1,160	2,110	1,850	860	(640)	(520)	(400)	(270)	1.6	6,880	2.1	9,030
Pasture	9,500	770	970	1,940	2,420	2,420	2,420	2,420	2,420	1,940	1,450	970	760	2.2	20,900	2.2	20,900
Potatoes	18,100	(1,100)	(1,470)	(1,470)	(2,950)	2,720	6,880	9,410	5,430	2,710	(1,660)	(1,290)	(920)	1.5	27,150	2.1	38,010
Seed	9,700	(600)	(800)	(800)	970	2,420	4,850	4,850	4,850	3,400	970	(990)	(690)	2.3	22,310	2.7	26,190
Truck, vegetables	7,700	(440)	(590)	770	770	1,920	3,850	3,470	3,470	2,310	1,150	770	(510)	2.4	18,480	2.6	20,020
Total irrigated crops	321,800	15,990	18,400	22,440	74,740	106,100	87,110	135,340	158,870	109,420	59,560	30,150	21,470	2.1	689,550	2.6	839,590
Idle land below elevation 5.0 feet U.S.G.S. datum	31,800	1,890	2,520	2,520	5,020	6,290	8,180	8,810	7,550	5,030	4,090	3,140	2,200	1.8	57,240	1.8	57,240
Non-irrigated crops and idle land above elevation 5.0 feet U.S.G.S. datum	67,700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open water surface**	54,300	4,350	7,050	12,460	18,420	32,510	41,180	45,520	42,270	32,510	17,880	7,590	4,330	4.9	266,070	4.9	266,070
Tules	7,400	1,180	660	2,210	5,460	8,110	9,450	11,290	9,740	8,700	7,230	4,350	2,660	9.6	71,040	9.6	71,040
Willows	5,600	280	170	510	1,240	1,860	2,150	2,590	2,260	1,970	1,640	1,010	560	2.9	16,240	2.9	16,240
Total gross area***	488,600	23,690	28,800	40,140	104,880	154,870	148,070	203,550	220,690	157,630	90,400	46,240	31,220	2.2	1,100,140	2.6	1,250,180
		Average consumptive use in feet depth or in acre-feet per acre															
Total gross area	488,600	.05	.06	.10	.21	.32	.30	.42	.45	.32	.20	.10	.07			2.6	
Total irrigated crops	321,800	.05	06	07	.23	.33	.27	.42	.49	.34	.18	.09	.07	--------	--------	2.6	-------

Note.—Figures in parentheses ( ) represent consumptive use on cropped areas before planting and after harvest, or during the dormant season.

*Includes additional use of water by weeds during these months.

**This item of open water surface includes open channels within delta (37,600 acres), open channels between delta boundary and stream gaging stations (1,100 acres), interior water surface (6,490 acres), and temporarily flooded areas (9,200 acres).

***This total gross area includes 1,100 acres of water surface (see Note**) outside of delta boundary. Gross area of delta=487,500 acres.

TABLE 2—Continued

TOTAL CONSUMPTIVE USE OF WATER IN SAN JOAQUIN DELTA—1929 SEASON

Crop or classification	Area in acres	Monthly consumption in acre-feet												Total seasonal consumption		Total annual consumption	
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Depth in feet	Acre-feet	Depth in feet	Acre-feet
Alfalfa	15,900	(920)	(1,230)	1,590	4,770	6,360	7,950	10,340	8,740	7,950	3,180	(1,540)	(1,080)	3.2	50,880	3.5	55,650
Asparagus	33,400	1,670	1,680	1,680	1,680	2,680	4,690	13,410	22,800	18,440	14,080	4,020	3,350	2.7	90,180	2.7	90,180
Beans	14,300	(870)	(1,160)	(1,160)	(2,320)	(2,900)	1,960	3,350	8,110	5,170	(1,300)	(1,010)	(720)	1.3	18,590	2.1	30,030
Beets	11,000	(630)	(850)	(850)	1,430	3,520	5,610	*6,710	*5,830	*2,200	(1,370)	(1,060)	(740)	2.3	25,300	2.8	30,800
Celery	5,800	(230)	(230)	(240)	(460)	(580)	580	580	1,160	1,450	1,740	1,160	290	1.2	6,960	1.5	8,700
Corn	35,600	(1,510)	(1,510)	(1,520)	(3,030)	(3,790)	8,440	29,890	*29,530	*14,060	3,520	(3,790)	(2,650)	2.4	85,440	2.9	103,240
Fruit	2,400	(80)	(80)	(90)	440	780	1,220	1,390	970	560	160	(140)	(90)	2.3	5,520	2.5	6,000
Grain and hay	63,900	(2,500)	(2,500)	4,470	38,340	53,040	12,780	(8,750)	(14,380)	(13,130)	(8,750)	(4,370)	(3,130)	1.7	108,630	2.6	166,140
Onions	2,500	(90)	(90)	200	320	680	1,220	1,080	500	(370)	(300)	(230)	(170)	1.6	4,000	2.1	5,250
Pasture	9,000	730	920	1,830	2,290	2,290	2,290	2,290	2,290	1,830	1,380	920	740	2.2	19,800	2.2	19,800
Potatoes	17,100	(1,040)	(1,390)	(1,390)	(2,780)	2,560	6,500	8,890	5,130	2,570	(1,570)	(1,220)	(870)	1.5	25,650	2.1	35,910
Seed	6,100	(380)	(500)	(500)	610	1,520	3,050	3,050	3,050	2,130	610	(630)	(440)	2.3	14,030	2.7	16,470
Truck, vegetables	1,800	(100)	(140)	180	180	450	900	810	810	540	270	180	(120)	2.4	4,320	2.6	4,680
Total irrigated crops	218,800	10,750	12,280	15,700	58,650	81,150	57,190	90,540	103,300	70,400	38,230	20,270	14,390	2.1	459,300	2.6	572,850
Idle land below elevation 5.0 feet U.S.G.S. datum	25,000	1,480	1,980	1,980	3,960	4,950	6,430	6,920	5,930	3,960	3,210	2,470	1,730	1.8	45,000	1.8	45,000
Non-irrigated crops and idle land above elevation 5.0 feet U.S.G.S. datum	35,800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open water surface**	38,700	3,090	5,020	8,880	13,130	23,170	29,350	32,440	30,120	23,170	12,750	5,420	3,090	4.9	189,630	4.9	189,630
Tules	6,200	990	560	1,850	4,570	6,800	7,910	9,460	8,160	7,290	6,060	3,650	2,220	9.6	59,520	9.6	59,520
Willows	3,600	180	110	330	800	1,200	1,380	1,670	1,450	1,270	1,050	650	350	2.9	10,440	2.9	10,440
Total gross area***	328,100	16,490	19,950	28,740	81,110	117,270	102,260	141,030	148,960	106,090	61,300	32,460	21,780	2.3	763,890	2.7	877,440
		Average consumptive use in feet depth or in acre-feet per acre															
Total gross area	328,100	.05	.06	.09	.26	.37	.31	.43	.45	.32	.19	.10	.07	--------	--------	2.7	--------
Total irrigated crops	218,800	.05	.06	.07	.27	.37	.26	.41	.47	.32	.17	.09	.06	--------	--------	2.6	--------

NOTE.—Figures in parentheses ( ) represent consumptive use on cropped areas before planting and after harvest, or during the dormant season.
*Includes additional use of water by weeds during these months.
**This item of open water surface includes open channels within delta (24,600 acres), open channels between delta boundary and stream gaging stations (100 acres), interior water surface (4,800 acres), and temporarily flooded areas (9,200 acres).
***This total gross area includes 100 acres of water surface (see Note**) outside of delta boundary. Gross area of San Joaquin Delta=328,000 acres.

TABLE 2—Continued

TOTAL CONSUMPTIVE USE OF WATER IN SACRAMENTO DELTA—1929 SEASON

Crop or classification	Area in acres	Monthly consumption in acre-feet												Total seasonal consumption		Total annual consumption	
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Depth in feet	Acre-feet	Depth in feet	Acre-feet
Alfalfa	8,600	(500)	(670)	860	2,580	3,440	4,300	5,590	4,730	4,300	1,720	(830)	(580)	3.2	27,520	3.5	30,100
Asparagus	29,100	1,470	1,460	1,460	1,460	2,340	4,090	11,680	19,860	16,060	12,270	3,510	2,910	2.7	78,570	2.7	78,570
Beans	18,200	(1,100)	(1,470)	(1,470)	(2,950)	(3,680)	2,490	4,270	10,320	6,580	(1,660)	(1,290)	(940)	1.3	23,660	2.1	38,220
Beets	7,300	(430)	(560)	(560)	950	2,340	3,720	*4,450	*3,870	*1,460	(920)	(700)	(480)	2.3	16,790	2.8	20,440
Celery	2,900	(120)	(120)	(110)	(240)	(280)	290	290	580	730	870	580	140	1.2	3,480	1.5	4,350
Corn	5,400	(230)	(230)	(220)	(460)	(590)	1,280	4,530	*4,480	*2,140	530	(570)	(400)	2.4	12,960	2.9	15,660
Fruit	12,600	(420)	(420)	(410)	2,300	4,080	6,380	7,270	5,110	2,940	900	(740)	(530)	2.3	28,980	2.5	31,500
Grain and hay	6,100	(240)	(240)	430	3,660	5,060	1,220	(840)	(1,370)	(1,250)	(480)	(420)	(290)	1.7	10,370	2.6	15,860
Onions	1,800	(70)	(70)	140	240	480	890	770	360	(270)	(220)	(170)	(100)	1.6	2,880	2.1	3,780
Pasture	500	40	50	110	130	130	130	130	130	110	70	50	20	2.2	1,100	2.2	1,100
Potatoes	1,000	(60)	(80)	(80)	(170)	160	380	520	300	140	(90)	(70)	(50)	1.5	1,500	2.1	2100
Seed	3,600	(220)	(300)	(300)	360	900	1,800	1,800	1,800	1,270	360	(360)	(250)	2.3	8,280	2.7	9,720
Truck, vegetables	5,900	(340)	(450)	590	590	1,470	2,950	2,660	2,660	1,770	880	590	(390)	2.4	14,160	2.6	15,340
Total irrigated crops	103,000	5,240	6,120	6,740	16,090	24,950	29,920	44,800	55,570	39,020	21,330	9,880	7,080	2.2	230,250	2.6	266,740
Idle land below elevation 5.0 feet U.S.G.S. datum	6,800	410	540	540	1,060	1,340	1,750	1,890	1,620	1,070	880	670	470	1.8	12,240	1.8	12,240
Non-irrigated crops and idle land above elevation 5.0 feet U.S.G.S. datum	31,900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open water surface**	15,600	1,260	2,030	3,580	5,290	9,340	11,830	13,080	12,150	9,340	5,130	2,170	1,240	4.9	76,440	4.9	76,440
Tules	1,200	190	100	360	890	1,310	1,540	1,830	1,580	1,410	1,170	700	440	9.6	11,520	9.6	11 520
Willows	2,000	100	60	180	440	660	770	920	810	700	590	360	210	2.9	5,800	2.9	5,800
Total gross area***	160,500	7,200	8,850	11,410	23,770	37,600	45,810	62,520	71,730	51,540	29,100	13,780	9,440	2.1	336,250	2.3	372,740
		Average consumptive use in feet depth or in acre-feet per acre															
Total gross area	160,500	.04	.05	.07	.15	.23	.28	.39	.44	.32	.18	.09	.06	--------	--------	2.3	--------
Total irrigated crops	103,000	.05	.06	.07	.16	.24	.29	.43	.54	.38	.21	.10	.07	--------	--------	2.6	--------

NOTE.—Figures in parentheses ( ) represent consumptive use on cropped areas before planting and after harvest, or during the dormant season.

*Includes additional use of water by weeds during these months.

**This item of open water surface includes open channels within delta (13,000 acres), open channels between delta boundary and stream gaging stations (1,000 acres), and interior water surface (1,600 acres).

***This total gross area includes 1,000 acres of water surface (see Note**) outside of delta boundary. Gross area of Sacramento Delta=159,500 acres.

TABLE 3

AREA AND CONSUMPTIVE USE OF IRRIGATED CROPS IN SACRAMENTO-SAN JOAQUIN DELTA
1924 TO 1929

Year	Sacramento River Delta			San Joaquin River Delta			Combined deltas		
	Area of irrigated crops in acres	Seasonal consumption		Area of irrigated crops in acres	Seasonal consumption		Area of irrigated crops in acres	Seasonal consumption	
		Total in acre-feet	Depth in feet		Total in acre-feet	Depth in feet		Total in acre-feet	Depth in feet
1924	101,300	229,120	2.3	218,500	445,720	2.0	319,800	674,840	2.1
1925	101,000	227,550	2.3	214,600	433,350	2.0	315,600	660,900	2.1
1926	103,300	224,110	2.2	212,900	425,450	2.0	316,200	649,560	2.1
1927	104,600	227,520	2.2	211,000	421,570	2.0	315,600	649,090	2.1
1928	103,200	228,940	2.2	218,300	445,980	2.0	321,500	674,920	2.1
1929	103,000	230,250	2.2	218,800	459,300	2.1	321,800	689,550	2.1
Average 1924 to 1929	102,700	227,910	2.2	215,700	438,560	2.0	318,400	666,480	2.1

In compiling the area of irrigated crops, it is assumed that all crops planted on lands which lie below an elevation of five feet above mean sea level consume water from the delta channels even though no artificial diversion of water with siphons or pumps is made for irrigation. The assumption is based upon the fact that the average water level in the delta is about 1.5 feet above mean sea level and reaches higher levels each day, and the high water table in the islands resulting therefrom affords an opportunity for the plants to obtain their moisture without artificial diversions. However, most of the crops in the delta are irrigated by artificial diversions.

The total consumptive use of water has been estimated for the Sacramento and the San Joaquin deltas separately and for the entire delta. The line of division assumed between the Sacramento and San Joaquin deltas is based upon the source of water supply, the Sacramento Delta embracing all those lands which obtain their water supply from the Sacramento River channels and the San Joaquin Delta all those lands which obtain their supply from the San Joaquin River channels, including its branches, the Mokelumne and Calaveras rivers, as well. This division line is shown on Plate III. Plate X, "Consumptive Use of Water in Delta of Sacramento and San Joaquin Rivers," graphically shows for all months of the year the consumptive use of water in the Sacramento and San Joaquin deltas separately and combined and the proportionate use of the total consumption by each crop and water-using agency. Crop acreages for 1929 are used in the compilation of this graph. The results for other years during the last 10 would be quite similar in the total use but with certain variations as to the proportionate use by different crops and other agencies. The estimated monthly consumption shown in Table 2 for each individual water use was plotted cumulatively on the vertical scale.* The lines on the graphs are drawn as smooth curves through the plotted points. The areas, designated by index number between the curved lines, as compared to the total area under the upper curved line of each graph give a graphical representation of the proportionate use of the total consumption by the different crops and agencies. As shown by this graph and the tabulations, the present estimated consumptive use of water in the entire delta varies from a minimum of about 800 acre-feet per day or 400 second-feet during the winter months to a maximum of about 7400 acre-feet per day or 3700 second-feet at the peak of the irrigation season, which occurs about the middle of August.

The total annual consumption in 1929 by irrigated crops, comprising 321,800 acres, averages 2.6 feet in depth. The difference between this amount and the total seasonal use by the irrigated crops of 2.1 feet in depth is due to soil evaporation and use by weeds and similar vegetation on the cropped areas during the nongrowing or dormant season. As a coincidence, the total annual consumption for the gross area of 488,600 acres and the total seasonal consumption for the total consumptive area of 420,900 acres (see Plate X) also averages 2.6 feet in depth. It is of particular interest to note the large amount of

* In plotting and tabulating the consumption and consumptive areas on Plate X, certain items in Table 2 were combined. The area shown for index No. 11 includes 9500 acres of pasture, 1800 acres of brush and oaks, 3700 acres of weeds and 5600 acres of willows, totaling 20,600 acres. Under the summary in the tabulation, the area of pasture is included with other irrigated crops; brush and oaks with tules and willows as natural vegetation; and weeds with the idle land below elevation 5.0.

LEGEND

Crops or classification	Area in acres in delta			Seasonal consumptive use of water in feet depth
	Sacramento	San Joaquin	Combined	
Grain and hay	6,100	63,900	70,000	1.7
Asparagus	29,100	33,400	62,500	2.7
Alfalfa	8,600	15,900	24,500	3.2
Beans	18,200	14,300	32,500	1.3
Beets	7,300	11,000	18,300	2.3
Corn	5,400	35,600	41,000	2.4
Fruit	12,600	2,400	15,000	2.3
Celery, onions, and potatoes	5,700	25,400	31,100	1.4
Seed and truck	9,500	7,900	17,400	2.3
Tules	1,200	6,200	7,400	9.6
Brush, willows, pasture etc.	4,200	16,400	20,600	2.3
Idle land below elev. 5º U.S.G.S.	5,100	21,200	26,300	1.8
Evaporation from water surface *	15,600	38,700	54,300	4.9
SUMMARY				
Total area of irrigated crops	103,000	218,800	321,800	2.1
Natural vegetation **	3,300	11,500	14,800	6.1
Idle land below elev. 5º U.S.G.S.	6,700	23,300	30,000	1.8
Water surface	15,600	38,700	54,300	4.9
Total consumptive area	128,600	292,300	420,900	2.6
Average seasonal consumptive use of water in feet depth	2.6	2.6	2.6	

NOTE

Data obtained from 1929 crop survey.

* Water surface area includes 1,100 acres of channel water surface between delta boundary and stream gaging stations.

** Includes willows, tules, brush and oaks.

CONSUMPTIVE USE OF WATER

IN THE

DELTA OF THE SACRAMENTO AND SAN JOAQUIN RIVERS

In compiling the area of irrigated crops, it is assumed that all crops planted on lands which lie below an elevation of five feet above mean sea level consume water from the delta channels even though no artificial diversion of water with siphons or pumps is made for irrigation. The assumption is based upon the fact that the average water level in the delta is about 1.5 feet above mean sea level and reaches higher levels each day, and the high water table in the islands resulting therefrom affords an opportunity for the plants to obtain their moisture without artificial diversions. However, most of the crops in the delta are irrigated by artificial diversions.

The total consumptive use of water has been estimated for the Sacramento and the San Joaquin deltas separately and for the entire delta. The line of division assumed between the Sacramento and San Joaquin deltas is based upon the source of water supply, the Sacramento Delta embracing all those lands which obtain their water supply from the Sacramento River channels and the San Joaquin Delta all those lands which obtain their supply from the San Joaquin River channels, including its branches, the Mokelumne and Calaveras rivers, as well. This division line is shown on Plate III. Plate X, "Consumptive Use of Water in Delta of Sacramento and San Joaquin Rivers," graphically shows for all months of the year the consumptive use of water in the Sacramento and San Joaquin deltas separately and combined and the proportionate use of the total consumption by each crop and water-using agency. Crop acreages for 1929 are used in the compilation of this graph. The results for other years during the last 10 would be quite similar in the total use but with certain variations as to the proportionate use by different crops and other agencies. The estimated monthly consumption shown in Table 2 for each individual water use was plotted cumulatively on the vertical scale.* The lines on the graphs are drawn as smooth curves through the plotted points. The areas, designated by index number between the curved lines, as compared to the total area under the upper curved line of each graph give a graphical representation of the proportionate use of the total consumption by the different crops and agencies. As shown by this graph and the tabulations, the present estimated consumptive use of water in the entire delta varies from a minimum of about 800 acre-feet per day or 400 second-feet during the winter months to a maximum of about 7400 acre-feet per day or 3700 second-feet at the peak of the irrigation season, which occurs about the middle of August.

The total annual consumption in 1929 by irrigated crops, comprising 321,800 acres, averages 2.6 feet in depth. The difference between this amount and the total seasonal use by the irrigated crops of 2.1 feet in depth is due to soil evaporation and use by weeds and similar vegetation on the cropped areas during the nongrowing or dormant season. As a coincidence, the total annual consumption for the gross area of 488,600 acres and the total seasonal consumption for the total consumptive area of 420,900 acres (see Plate X) also averages 2.6 feet in depth. It is of particular interest to note the large amount of

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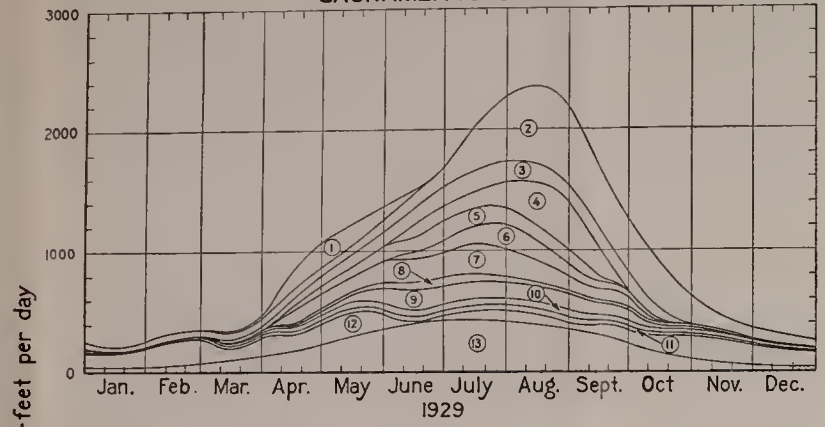
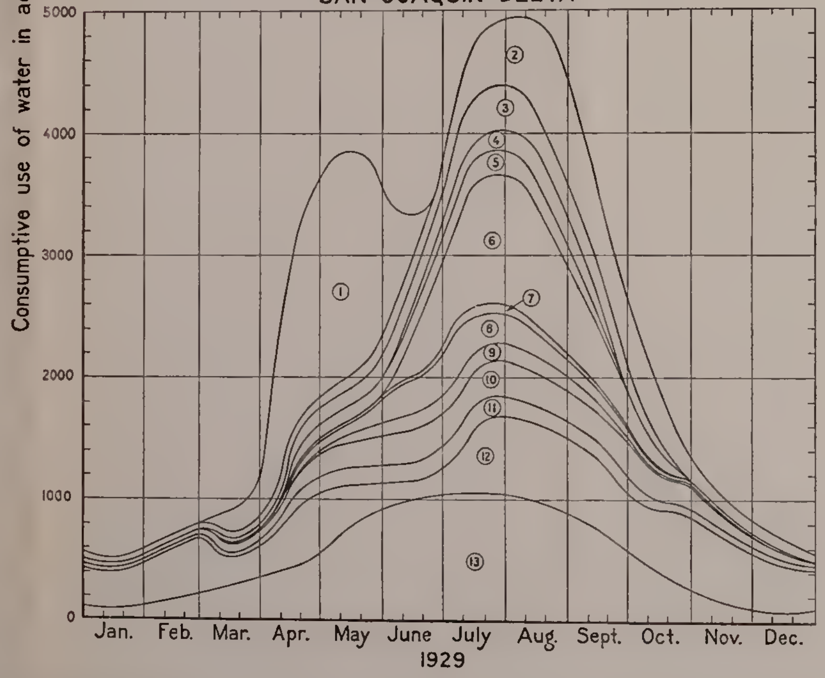
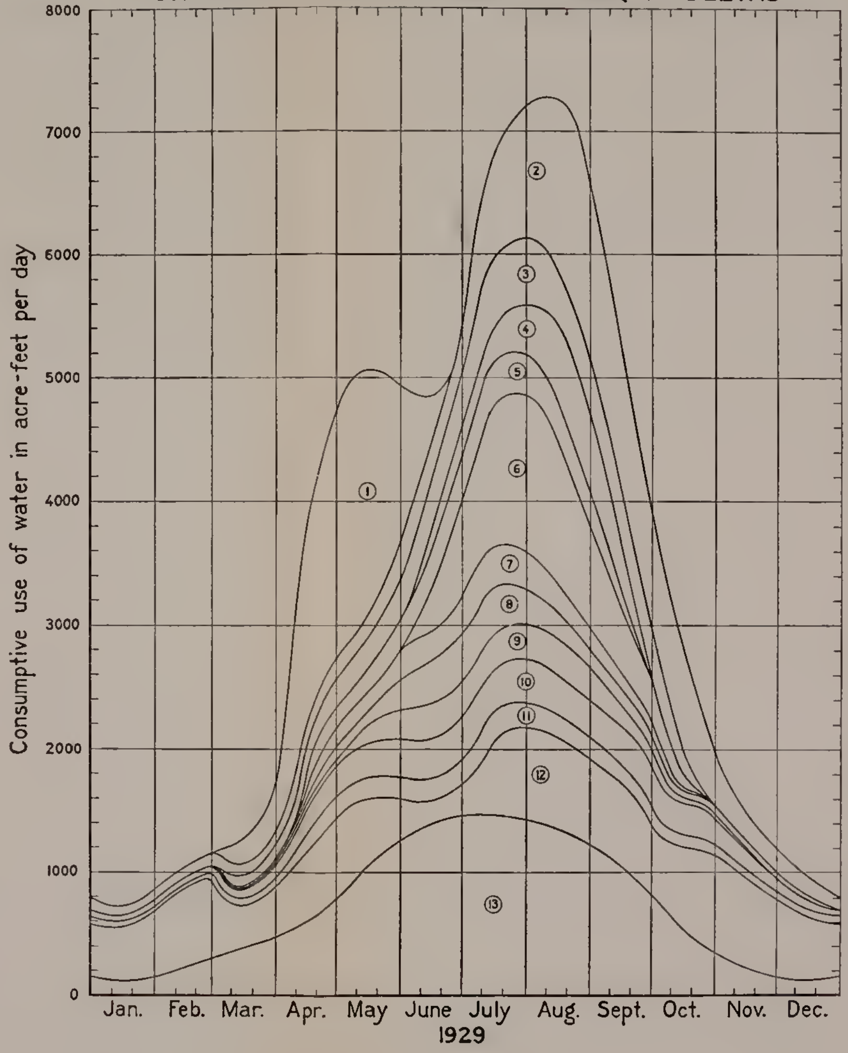
SACRAMENTO DELTA



SAN JOAQUIN DELTA



COMBINED SACRAMENTO AND SAN JOAQUIN DELTAS



LEGEND

Index number	Crops or classification	Area in acres in delta			Seasonal consumptive use of water in feet depth
		Sacramento	San Joaquin	Combined	
1	Grain and hay	6,100	63,900	70,000	1.7
2	Asparagus	29,100	33,400	62,500	2.7
3	Alfalfa	8,600	15,900	24,500	3.2
4	Beans	18,200	14,300	32,500	1.3
5	Beets	7,300	11,000	18,300	2.3
6	Corn	5,400	35,600	41,000	2.4
7	Fruit	12,600	2,400	15,000	2.3
8	Celery, onions, and potatoes	5,700	25,400	31,100	1.4
9	Seed and truck	9,500	7,900	17,400	2.3
10	Tules	1,200	6,200	7,400	9.6
11	Brush, willows, pasture etc.	4,200	16,400	20,600	2.3
12	Idle land below elev. 5º U.S.G.S.	5,100	21,200	26,300	1.8
13	Evaporation from water surface *	15,600	38,700	54,300	4.9
	SUMMARY				
	Total area of irrigated crops	103,000	218,800	321,800	2.1
	Natural vegetation **	3,300	11,500	14,800	6.1
	Idle land below elev. 5º U.S.G.S.	6,700	23,300	30,000	1.8
	Water surface	15,600	38,700	54,300	4.9
	Total consumptive area	128,600	292,300	420,900	2.6
	Average seasonal consumptive use of water in feet depth	2.6	2.6	2.6	

NOTE

Data obtained from 1929 crop survey.

* Water surface area includes 1,100 acres of channel water surface between delta boundary and stream gaging stations.

** Includes willows, tules, brush and oaks.

CONSUMPTIVE USE OF WATER
IN THE
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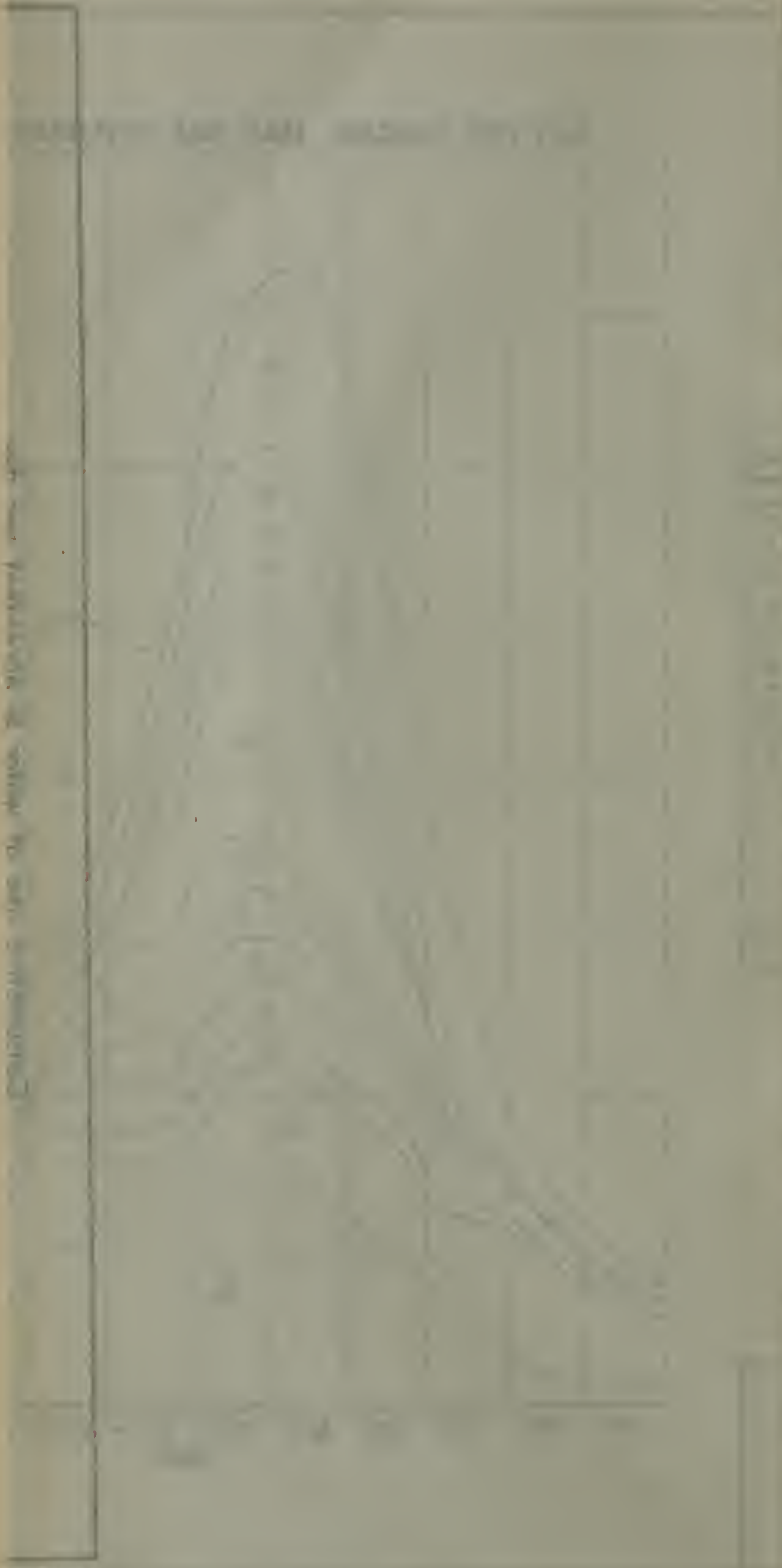


water used by native vegetation, especially by tules and cat-tails which are estimated to consume 9.6 feet in depth annually or nearly three times as much as alfalfa and nearly four times as much as the average for all crops grown in the delta. Evaporation from open water is also relatively large, with an estimated amount of nearly five feet in depth per annum, or about twice the amount used by the crops.

By comparing these amounts of consumptive use with the stream flow into the delta, it will be noted that there have been several months in several years since 1919 in which the flow into the delta was insufficient to take care of the consumptive demands therein. The comparison of flow with consumptive use is graphically shown on Plates V and VI. With a maximum monthly consumptive use in August of about 221,000 acre-feet and an average for July and August of 212,000 acre-feet, there have been shortages in these two months in 1920, 1924, and 1926, and a shortage in one month in 1928 and most of one month in 1929. In 1924, there was also a shortage in the supply meeting the demand in the month of June. In these years in which shortages have occurred in the supply meeting the consumptive demand in the delta, the greater invasions of salinity into the delta have occurred. The largest monthly shortage which occurred during the ten-year period 1920 to 1929 was in August, 1920, when it amounted to 151,000 acre-feet or about 2500 second-feet average daily flow. The shortage during the two months of July and August in 1924 amounted to an average of 121,000 acre-feet a month, or at the average daily rate of about 2000 second-feet. On the other hand, in years such as 1921 to 1923, inclusive, and again in 1925 and 1927, when there was no shortage in the water supply entering the delta meeting the demand, the maximum extent of saline invasion to a degree of 100 parts or more of chlorine per 100,000 parts of water was relatively small, affecting less than 5 per cent of the delta area. The significance of these relations will be more fully discussed in Chapter III.

Tides—The tidal records gathered in connection with this investigation represent the first attempt which has ever been made to obtain anything like complete tidal information in the bay and delta channels. Prior to this investigation there have been a few scattered observations made usually for short intervals only. Some of these were made by the United States Coast and Geodetic Survey and others by the United States Army Engineers, the State and private agencies. Never before has a comprehensive system of automatic tide gages giving continuous records of tidal stage been connected together by precise level lines so that the relative elevation of the water surface at the same time and at different points in the bay and in the delta channels might be ascertained. The records obtained, therefore, are of great value, giving definite information for the first time as to the action of the tides, which is a most important factor affecting salinity conditions.

A great deal of data could be compiled from automatic tide gage records. For the purpose of this investigation, however, there have been compiled only those elements which are chiefly important to this study. Table 4 summarizes the location and period of record for all of the automatic tide gages from which records have been obtained and used in this investigation. There are also shown the owner of the tide gage and the elevations of the zero of the tide gage staff referred to mean sea

TABLE 4

LOCATION AND PERIOD OF RECORD OF AUTOMATIC TIDE GAGES

Station	Location	Owner	Period of record	Elevation of zero on staff, in feet, U. S. G. S. datum
	South San Francisco Bay			
Hunters Point	On east end of north side of slip to north drydock	Division of Water Resources and U. S. Army Engineers	January 16 to July 7, 1930	—6.75
San Mateo Bridge	On San Francisco Bay Bridge at east end of lift span	Division of Water Resources and U. S. Army Engineers	January 17 to August 25, 1930	—7.67
Dumbarton Bridge	On Dumbarton Bridge at west end of lift span	Division of Water Resources and U. S. Army Engineers	January 18 to October 12, 1930	—6.14
	San Francisco, San Pablo and Suisun Bays			
Presidio[1]	Crissy Field Wharf, San Francisco	U. S. Coast and Geodetic Survey	July 15, 1897, to date	[4]—5.24
Point Bluff	North end of Government Dock, at California City	U. S. Army Engineers	April 30 to October 10, 1930	—2.37
Oakland Mole	Oakland Seventh Street Mole near toll gate at north side of pump house	U. S. Army Engineers	May 5 to October 15, 1930	—2 94
Point Orient	Standard Oil Company inner wharf	Division of Water Resources and U. S. Army Engineers	January 20, 1930, to October, 1931	[5]—3.62
Pinole Point	Giant Powder Company wharf	U. S. Army Engineers	April 29 to October 7, 1930	—3.08
Beacon No. 2	On Beacon No. 2 in San Pablo Bay at entrance to Petaluma Creek Channel	U. S. Army Engineers	July 27 to October 17, 1930	
Sonoma Creek	On Sears Point Toll Bridge at Sonoma Creek entrance	U. S. Army Engineers	April 17 to July 28, 1930	—2.94
Petaluma Creek	On Northwestern Pacific Railroad drawbridge on Petaluma Creek at Black Point	U. S. Army Engineers	April 16 to October 21, 1930	—3.06
Selby	On east end of American Smelting and Refining Company dock	U. S. Army Engineers	April 1 to October 21, 1930	—3.20
Crockett	Carquinez Bridge Company wharf	Division of Water Resources	October 10 to November 22, 1929	—3.32
Crockett	California Hawaiian Sugar Company wharf	Division of Water Resources	November 22, 1929, to January 14, 1930	—4.53
Mare Island[2]	South side of Mare Island-Vallejo Causeway at lift span	United States Navy	Approximately 30 years to date	—3.48
Benicia	United States Army Arsenal wharf at Benicia	Division of Water Resources	June 20, 1929, to October, 1931	—2.21
Bay Point	East end of Coos Bay Lumber Company dock	U. S. Army Engineers	March 10 to October 10, 1930	—2 97
Suisun Light	On Suisun Echo Board, at entrance to Suisun Slough	U. S. Army Engineers	March 11 to October 14, 1930	—2.96
Point Buckler	On tripod located 50 feet off north shore of Point Buckler	U. S. Army Engineers	April 24 to October 18, 1930	Not determined
Mallard Slough[3]	Staff gage at California Water Service Company's pump house on Mallard Slough	California Water Service Corporation	January 30 to June 10, 1930	[7]—0.25
Meins Landing	North end of dock at Meins Landing on Montezuma Slough	U. S. Army Engineers	February 25 to July 28, 1930	—2.67
	Sacramento River Delta			
Collinsville	End of Main Street Wharf at Collinsville	Division of Water Resources	June 27, 1929, to date	—2.89
Three Mile Slough, Sacramento River end	On Three Mile Slough Bridge	Division of Water Resources	April 2, 1929, to date	[8]—2.89

Rio Vista	On United States Army Engineers wharf, west bank of Sacramento River	U. S. Army Engineers	April 4, 1908, to date	—2.87
Walnut Grove	On Walnut Grove Bridge across Sacramento River	Division of Water Resources	February 19, 1929, to date	[9]—2.46
Sacramento	"Old Pioneer Mill Co." wharf, 300 feet north of Southern Pacific Railroad Bridge	Division of Water Resources	1920, intermittently, to date	+ .07
	San Joaquin River Delta			
Antioch	Antioch Water Works wharf	Division of Water Resources	June 21, 1929, to date	—2.94
Three Mile Slough, San Joaquin River end	On pile at junction of Three Mile Slough with San Joaquin River	Division of Water Resources	June 6, 1929, to date	—2.86
Venice Island	At Blakes Landing, Venice Island	U. S. Army Engineers	January 5, 1928, to date	[10]—3.20
Georgiana Slough	Golden Gate Asparagus Company wharf on Georgiana Slough at junction with Mokelumne River	Division of Water Resources	June 8, 1929, to date	[11]—3.17
East Contra Costa Irrigation District[4]	Inside of Pumping Plant No. 1 at west end of Indian Slough	East Contra Costa Irrigation District	1913 to date	+0.40
New Hope Bridge	At southwest corner of bridge across South Fork, Mokelumne River near New Hope Landing	Staten Island Land Company	August 20, 1920, to date	—2.58
Stockton	East end of McLeod Lake between Freemont and Oak Sts., Stockton	U. S. Army Engineers	December 1, 1927, to date	—3.18
Mossdale, S. P. R. R. Bridge	West of Lathrop on S. P. R. R. Bridge over San Joaquin River	Division of Water Resources	1920, intermittently, to date	+1.96

1 Records previous to 1927 were from other locations near the Golden Gate, San Francisco, California.
2 Prior to 1920 gage was installed on wharf south of causeway.
3 No automatic instrument. Staff gage read hourly by California Water Service Company.
4 Record from 1913 to 1915 from readings taken every two hours during the irrigation season.
5 This elevation is for the zero of the present tide gage staff installed in 1927. The datum of tide tabulations at the Presidio is the zero of the 1897 tide staff and is 3.28 feet below the zero of the present tide staff.
6 Since September 29, 1930, the elevation of zero on the tide gage staff is —3.04 feet U. S. G. S. datum.
7 Since November 30, 1930 the elevation of zero on the tide gage staff is +0.17 feet U. S. G. S. datum.
8 From July 26, 1931 elevation of zero gage was —3.20 feet, U. S. G. S. datum.
9 From April 19, 1930 to April 10, 1931 elevation of zero gage was —2.80 feet, U. S. G. S. datum.
10 Levels run by U. S. Army Engineers. Simultaneous tide elevations at nearby tide gages indicate that the elevation of zero on the staff should be about —3.45 U. S. G. S. datum.
11 Since June 25, 1931, elevation of zero of tide gage staff is —3.12 feet U. S. G. S. datum.

TABLE 5

TIDAL DATA FOR SAN FRANCISCO BAY AND SACRAMENTO-SAN JOAQUIN DELTA CHANNELS

(Compiled from automatic tide gage records)

Tide gage station	Tidal elevation in feet, U. S. G. S. datum					Tidal range, in feet			Period of record from which data are compiled
	Maximum high tide	Minimum low tide	Mean half tide	Mean high tide	Mean low tide	Maximum range	Minimum range	Mean range	
South San Francisco Bay									
Hunters Point	+5.2	−4.6	+0.50	+3.20	−2.20	9.2	1.2	5.40	Jan. 18, 1930 to Feb. 13, 1930
San Mateo Bridge	+5.1	−5.3	+0.60	+3.35	−2.10	10.0	1.6	5.50	Jan. 18, 1930 to Mar. 4, 1930
Dumbarton Bridge	+5.1	−5.4	+0.70	+3.70	−2.30	10.5	2.4	6.00	Jan. 18, 1930 to Feb. 11, 1930
San Francisco, San Pablo and Suisun Bays									
Presidio	+5.2	−5.3	+0.10	+2.10	−1.90	10.5	—	3.95	26 years, 1898 to 1923
Presidio	+4.5	−4.7	+0.20	+2.25	−1.80	8.8	0.9	4.05	Aug. 1, 1929 to Nov. 30, 1929
Presidio	+4.5	−5.2	+0.20	+2.20	−1.80	9.0	0.7	3.95	Oct. 1, 1929 to Mar. 4, 1930
Presidio	+4.1	−4.9	+0.15	+2.15	−1.80	8.7	0.5	3.95	Mar. 11, 1930 to Aug. 30, 1930
Point Bluff	+3.7	−4.9	+0.15	+2.10	−1.85	8.6	0.9	3.95	May 1, 1930 to July 1, 1930
Oakland Mole	+4.0	−4.7	+0.25	+2.40	−1.95	8.7	1.1	4.35	May 5, 1930 to July 1, 1930
Point Orient	+4.1	−4.4	+0.40	+2.35	−1.55	8.2	0.7	3.90	Jan. 20, 1930 to Mar. 4, 1930
Pinole Point	+4.4	−4.5	+0.40	+2.55	−1.75	7.7	1.2	4.30	May 1, 1930 to Sept. 1, 1930
Beacon No. 2	—	—	—	—	—	6.9	1.1	4.20	July 28, 1930 to Oct. 20, 1930
Sonoma Creek	+4.3	−3.5	+0.25	+2.65	−2.00	7.8	1.3	4.65	May 1, 1930 to June 30, 1930
Petaluma Creek	+4.1	−3.6	+0.25	+2.55	−2.00	7.7	1.2	4.55	May 1, 1930 to July 1, 1930
Selby	+4.4	−3.3	+0.50	+2.65	−1.75	8.1	—	4.40	Apr. 1, 1930 to Sept. 30, 1930
Crockett	+3.8	−4.1	+0.40	+2.50	−1.70	8.3	1.4	4.20	Oct. 10, 1929 to Feb. 13, 1930
Mare Island	+4.3	−3.7	+0.65	+2.90	−1.65	8.4	1.2	4.60	Aug. 1, 1929 to Nov. 30, 1929
Benicia	+4.2	−3.4	+0.50	+2.70	−1.50	7.6	1.0	4.20	Aug. 1, 1929 to Nov. 30, 1929
Bay Point	+4.7	−2.8	+1.10	+3.05	−0.85	7.1	0.8	3.90	Mar. 11, 1930 to Aug. 30, 1930
Suisun Light	+5.1	−2.8	+1.15	+3.20	−0.90	7.4	0.2	4.10	Mar. 11, 1930 to Aug. 26, 1930
Mallard Slough*	+3.9	−2.1	+1.10	+2.90	−0.65	5.8	0.8	3.55	Mar. 20, 1930 to May 18, 1930
Meins Landing	+5.1	−2.7	+1.25	+3.45	−0.95	7.6	1.0	4.40	Mar. 3, 1930 to July 30, 1930

Sacramento River Delta									
Collinsville	+4.0	−2.0	+1.10	+2.70	−0.50	5.6	0 9	3.20	Aug. 1, 1929 to Nov. 30, 1929
Three Mile Slough, Sacramento River end	+4.0	−2.0	+1.00	+2.70	−0.65	5.5	1.1	3.30	Aug. 1, 1929 to Nov. 30, 1929
Rio Vista	+4.0	−1.9	+1.10	+2.80	−0.55	5.6	1.0	3.35	Aug. 1, 1929 to Nov. 30, 1929
Walnut Grove	+4.4	−0.2	+2.05	+3.25	+0.85	3.9	0.8	2.40	Aug. 1, 1929 to Nov. 30, 1929
Sacramento	+5.0	+0.8	+2.65	+3.45	+1.85	3.1	0.5	1.65	Aug. 1, 1929 to Nov. 30, 1929
San Joaquin River Delta									
Antioch	+4.0	−1.9	+1.00	+2.60	−0.60	5.5	1.1	3.20	Aug. 1, 1929 to Nov. 30, 1929
Three Mile Slough, San Joaquin River end	+3.9	−1 7	+1.10	+2.55	−0.35	4.9	0.9	2.90	Aug. 1, 1929 to Nov. 30, 1929
Venice Island	+4.3	−1.2	+1.50	+3 00	+0.05	4.8	0.9	2.90	Aug. 1, 1929 to Nov. 30, 1929
Georgiana Slough	+4.0	−1.5	+1.20	+2.70	−0.25	4.8	1.0	2.95	Aug. 1, 1929 to Nov. 30, 1929
East Contra Costa Irrigation Dist.	+3.7	−1.5	+1.10	+2.50	−0.35	4.6	1.1	2.85	Aug. 1, 1929 to Nov. 30, 1929
New Hope Bridge	+3.9	−1.4	+1.25	+2.75	−0.30	4.8	1.1	3.05	Aug. 1, 1929 to Nov. 30, 1929
Stockton	+4.4	−1.2	+1.60	+3.15	+0.10	4.7	1.3	3.05	Aug. 1, 1929 to Nov. 11, 1929
Mossdale S. P. R. R. Bridge	+4.0	+0.3	+2.05	+3.05	+1.10	3.4	1.0	1.95	Aug. 1, 1929 to Nov. 30, 1929

* No automatic instrument. Staff gage read hourly by California Water Service Company.

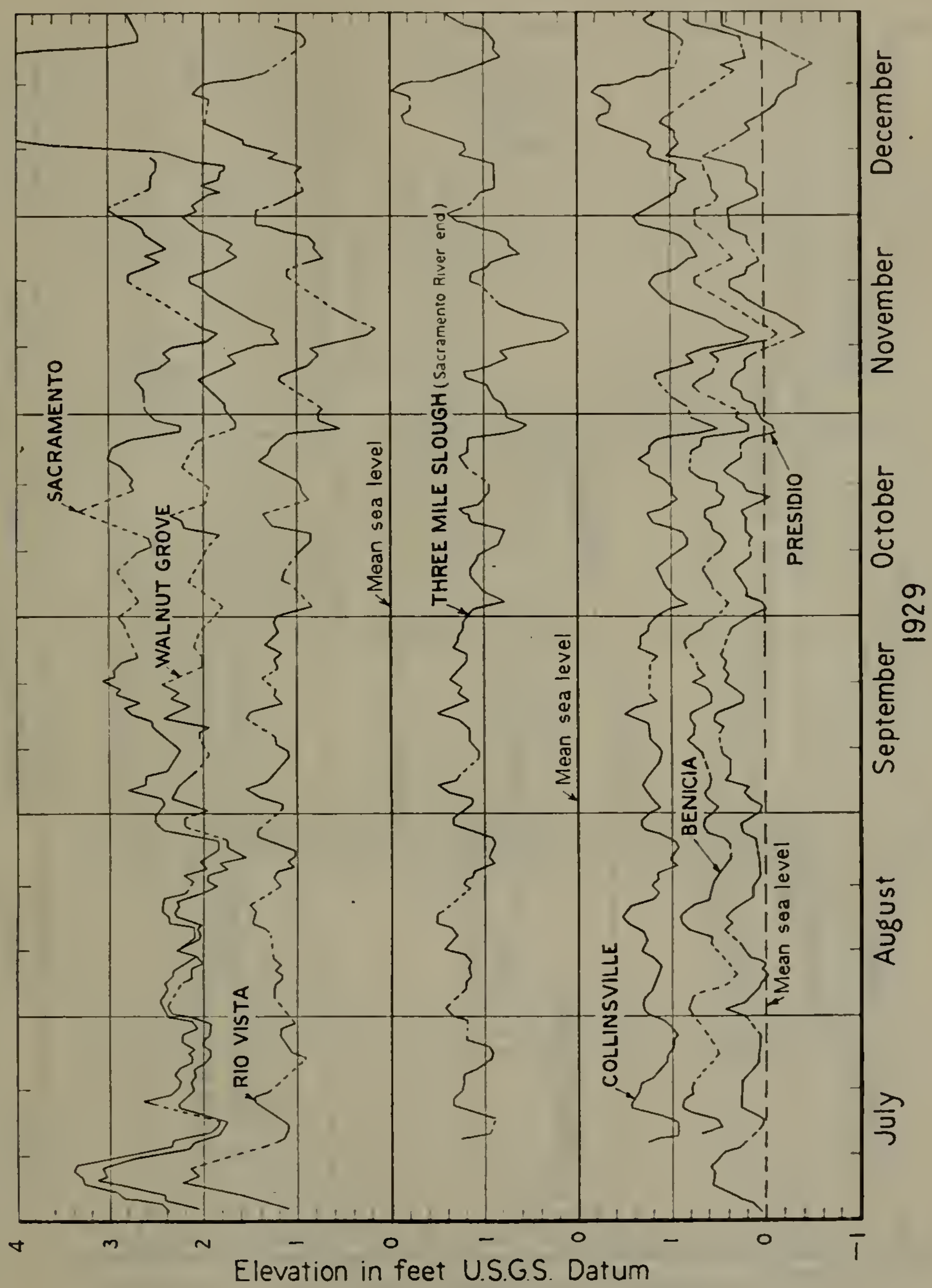
level (U.S.G.S. datum). These tide gages have been located at strategic points covering the entire San Francisco Bay tidal basin from the Golden Gate to the upper limits of the delta. The period of record is not of the same length at all stations. There were twelve automatic gages operating at the time the investigation started in the summer of 1929, comprising the basic gage at Presidio of the United States Coast and Geodetic Survey, one at Mare Island Navy Yard, four in the delta maintained by the United States Army Engineers, four in the delta maintained by the State, and two others in the delta maintained by private interests. Five new tide gages were installed by the State in the delta and upper bay in the summer of 1929. At the same time, new and more suitable tide gage recorders were installed at the four stations already operated by the State. These were followed in the succeeding winter by installation by the State of five additional gages at lower bay points and later, in the succeeding spring and summer of 1930, by eleven additional gages installed by the United States Army Engineers in their cooperative investigations. Thus, during a substantial part of 1930, 33 automatic tide gages were in operation. All of these gages have been referred to a common datum (U.S.G.S. datum) by precise level lines run by the United States Geological Survey in cooperation with the State. The connecting level ties to the individual gages were run by the State and the United States Army Engineers.

Table 5 summarizes the maximum, minimum and mean elevations of high and low tides, mean half tide, and the maximum, minimum and mean range of the tide for all of the tide gage stations in the bay and delta for which records are available. The elevations shown are all referred to mean sea level (U.S.G.S. datum). The period of record from which the data were compiled is also shown.

The height of mean tide (approximately the same as half tide) varies from day to day through the season. This is shown on Plate XI, "Mean Daily Tide Elevations in San Francisco Bay and Delta of Sacramento River," and Plate XII, "Mean Daily Tide Elevations in San Francisco Bay and Delta of San Joaquin River." On these plates the elevation of half tide is plotted for each day during the season of 1929 from July to December, at which time the first winter freshets occurred. There is a marked similarity in the general shape of the curves for both bay and river channels. The elevation of half tide rises and falls at each point in an almost exactly similar and parallel way. A rise in water level resulting from increases in stream flow in the fall is shown at upstream stations such as Sacramento, but the variations in mean water level from day to day continue to follow the variations at stations downstream and in the bay. These graphs also show the gradual increase in elevation of mean water level from the bay upstream.

Plate XIII, "Height of Mean Daily Tide Above Mean Daily Tide at Presidio in San Francisco Bay and Delta of Sacramento River," and Plate XIV, "Height of Mean Daily Tide Above Mean Daily Tide at Presidio in Delta of San Joaquin River," show the height of mean water level (half tide) at points in the bay and delta above the mean water level (half tide) at the Presidio. The tidal variations at the Presidio, which may be considered to represent the basic tidal fluctuation of the entire San Francisco Bay tidal basin, are simulated by all of the other tide gage stations above in the bay and delta

PLATE XI

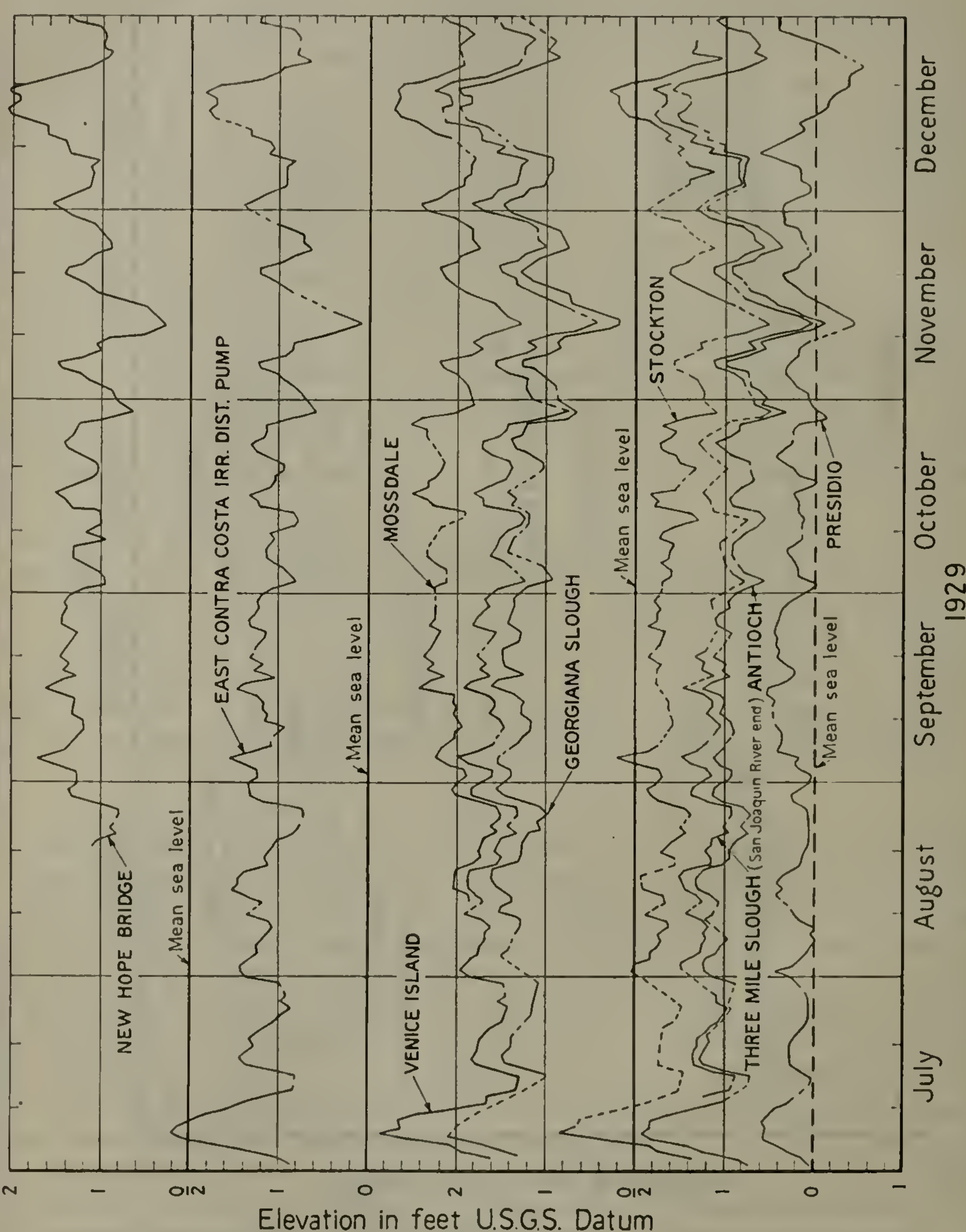


NOTE

Mean daily tide elevations are computed as the mean of the elevations of high-high, low-high high-low and the average of the two low-low tides occurring during each tidal cycle

MEAN DAILY TIDE ELEVATIONS
IN
SAN FRANCISCO BAY
AND
DELTA OF SACRAMENTO RIVER

PLATE XII

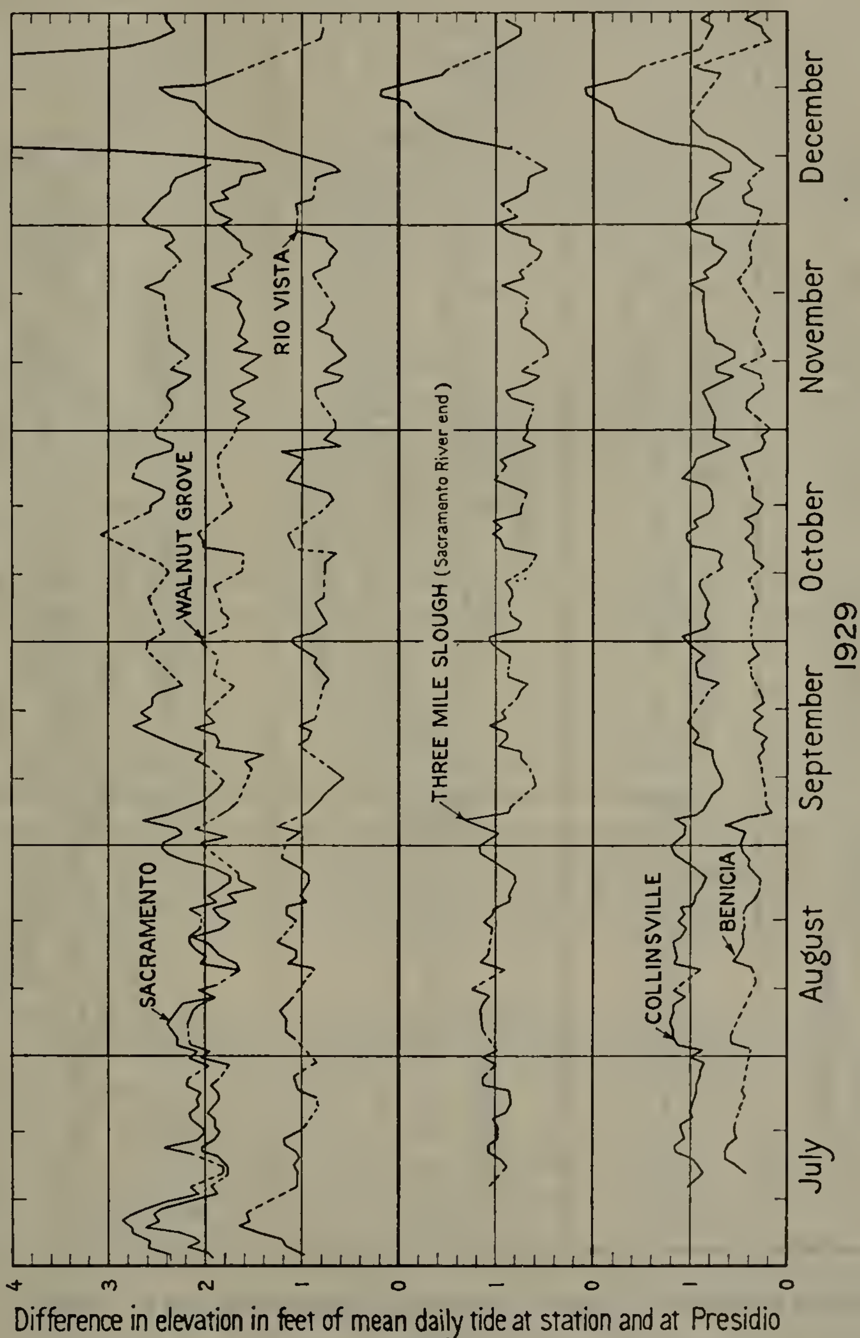


NOTE

Mean daily tide elevations are computed as the mean of the elevations of high-high, low-high high-low and the average of the two low-low tides occurring during each tidal cycle.

MEAN DAILY TIDE ELEVATIONS
IN
SAN FRANCISCO BAY
AND
DELTA OF SAN JOAQUIN RIVER

PLATE XIII



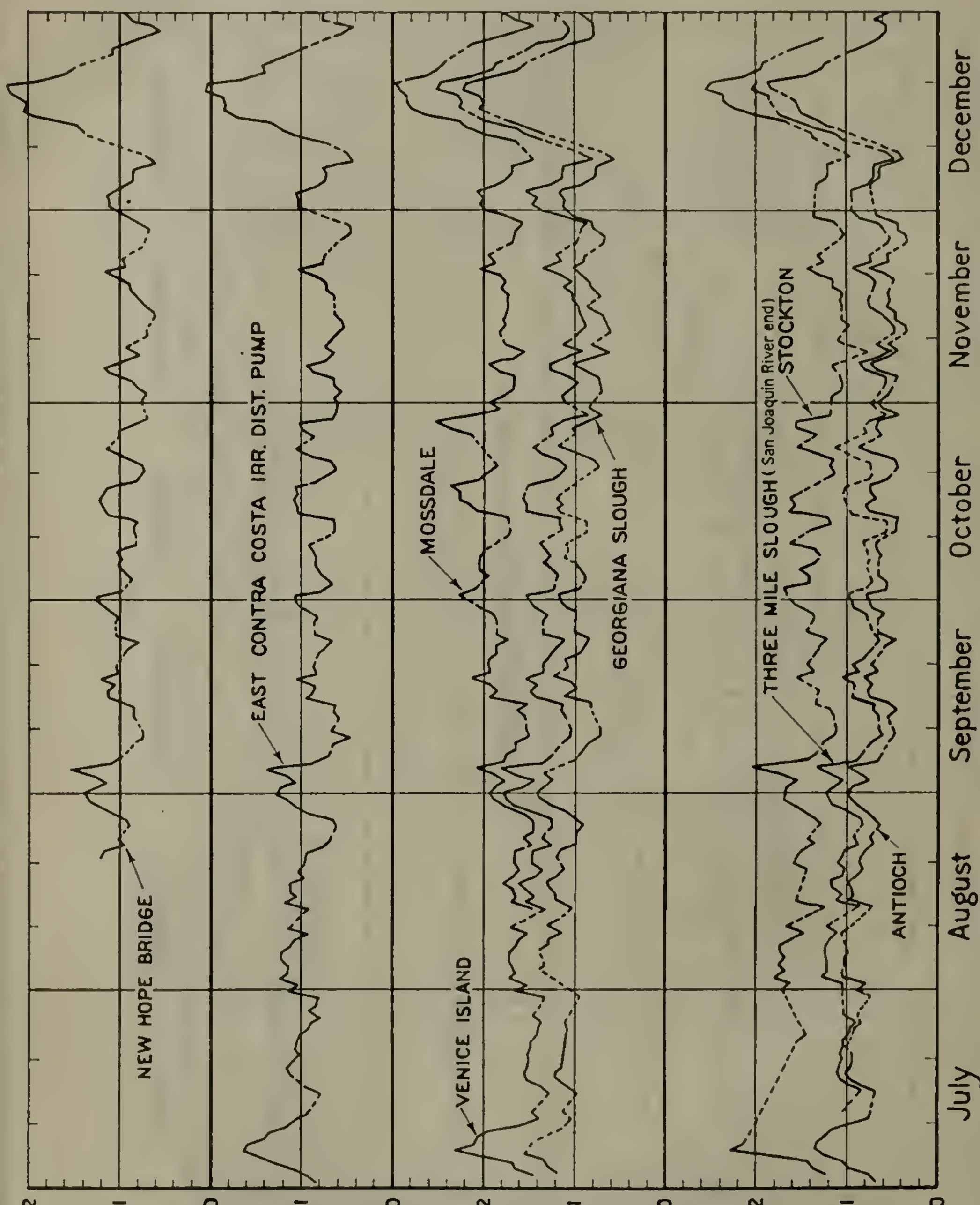
NOTE

Mean daily tide elevations are computed as the mean of the elevations of high-high, low-high high-low and the average of the two low-low tides occurring during each tidal cycle.

HEIGHT OF MEAN DAILY TIDE
ABOVE
MEAN DAILY TIDE AT PRESIDIO
IN
SAN FRANCISCO BAY AND DELTA OF SACRAMENTO RIVER

Antioch-233

PLATE XIV



Difference in elevation in feet of mean daily tide at station and at Presidio

NOTE

Mean daily tide elevations are computed as the mean of the elevations of high-high, low-high high-low and the average of the two low-low tides occurring during each tidal cycle.

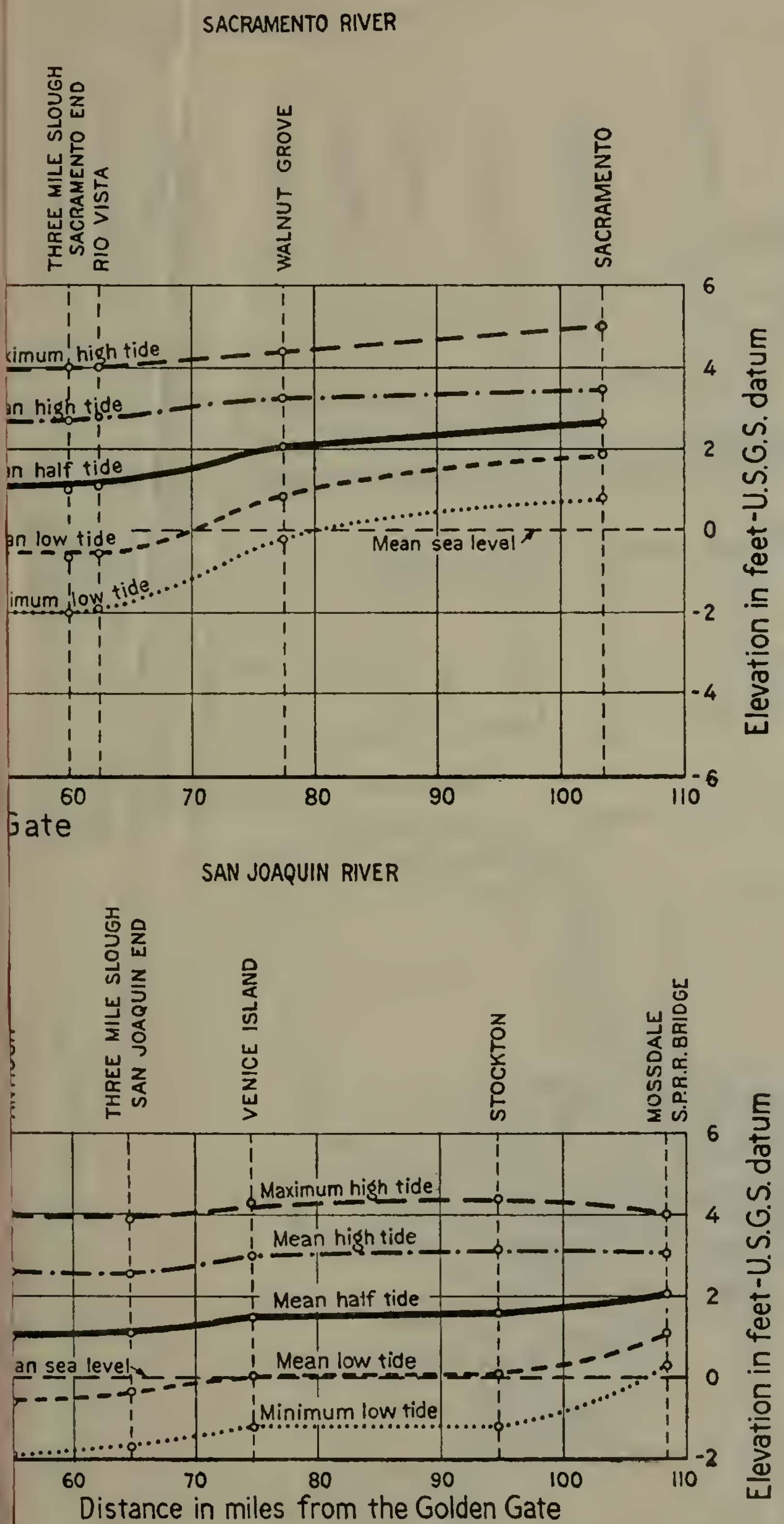
HEIGHT OF MEAN DAILY TIDE
ABOVE
MEAN DAILY TIDE AT PRESIDIO
IN
DELTA OF SAN JOAQUIN RIVER

channels. Plotting the height of mean tide level for the upper stations above the level of mean tide at the Presidio, therefore, has the effect of eliminating the primary tidal variation, which is approximately paralleled by the variations from day to day at all points in the tidal basin. Although there are variations in the difference in elevation from day to day, the graph shows that the general water level in the delta channels gradually lowered during the 1929 season from about July to November. This is shown by all of the downstream stations such as Walnut Grove, Three Mile Slough, Rio Vista, Georgiana Slough, Antioch and Collinsville. The upper stations, Mossdale, New Hope Bridge and Sacramento, show the effect of increased stream flow in the fall months.

The fact that the water level in the delta channels fell during the summer and autumn of 1929 appears to indicate that the basin formed by the delta channels may be considered to be similar to a storage reservoir. The water level in this storage reservoir averages one to two feet or more above mean sea level during the period of low stream flow, although it fluctuates up and down with the tide several times daily. The gradual lowering of mean daily water level in the late summer and early fall months of 1929 appears to be partly due to the fact that there was an excess of consumption of water in the delta over and above the stream inflow. This would not entirely explain the occurrence, however, because the mean water level continued to lower after the supply coming into the delta was sufficient to take care of the consumptive demands. Other factors, including, especially, the variation in the tidal flow at the Golden Gate and into and out of the delta tidal basin, and, possibly to some extent, the progressive change in relative salinity and specific gravity of the waters in the upper bay and delta, probably had an effect of equal or even greater importance upon this change in average water level in the delta. Studies of records for other years would be necessary before a definite conclusion could be made as to this situation.

The tabulations and graphs previously presented show a gradual increase in the elevation of the mean water levels for various tidal phases with greater distance from the Golden Gate. It may also be noted that the mean and maximum ranges of the tide gradually decrease for points farther upstream. These relations are more clearly shown by the graphs on Plate XV, "Tidal Reference Planes in San Francisco Bay and Delta of Sacramento and San Joaquin Rivers." On this graph, the data in Table 5 are plotted for each station with reference to its distance from the Golden Gate. The points for each phase of the tide have been joined by smooth lines. There results a graphic illustration of the more important tidal reference planes of particular value in this study. These reference planes are shown with separate diagrams, one extending from the Presidio through San Pablo and Suisun bays up the Sacramento River, a second up the San Joaquin River from the confluence of the two rivers, and a third extending from the Presidio through South San Francisco Bay to its southerly end. The graphs show the relative elevation of the water in all parts of the bay for the minimum and mean low tides, for mean half tide and for the mean and maximum high tides. The relative magnitude of the mean and maximum ranges of the tide at various points in the bay and delta can also be clearly pictured. The data for the sections of the tidal basin along the Sacramento and San Joaquin rivers are representative of the low flow conditions of these streams. Table 5 shows the period of record which was used for each station in compiling the mean, minimum and maximum tidal elevations shown. For the river stations, this period generally included August to November, 1929. With a large flow in the rivers, the water levels at all stages of the tide would tend to be at a considerably higher elevation than those shown.

The collection and compilation of the tidal data have been a most essential part of the present investigation. These data have been used in evolving the relation between tidal action and salinity, which is presented in Chapter IV.



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TIDAL REFERENCE PLANES

IN

SAN FRANCISCO BAY AND DELTA OF
SACRAMENTO AND SAN JOAQUIN RIVERS

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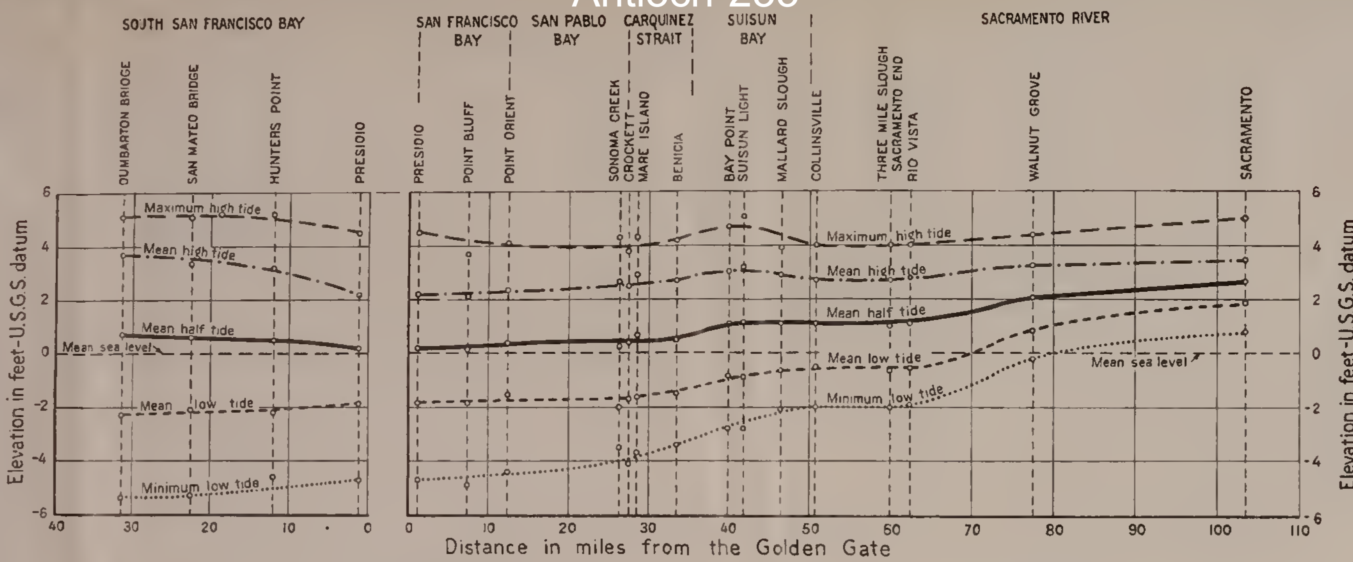
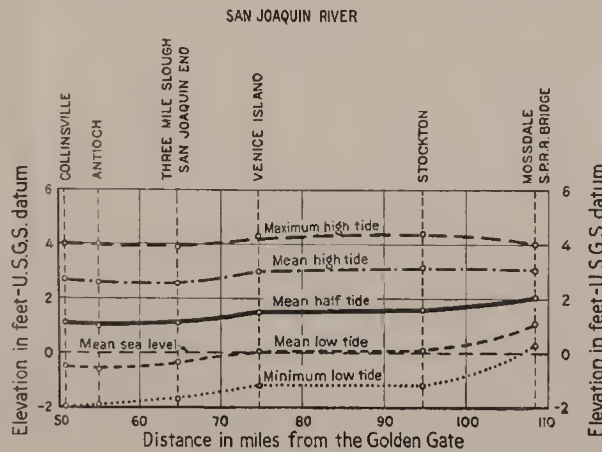




NOTE:
Compiled from automatic tide gage records obtained during 1929 and 1930. The tidal levels for the Sacramento and San Joaquin river channels are representative of low stream flow conditions in the summer and fall months.

TIDAL REFERENCE PLANES
IN
SAN FRANCISCO BAY AND DELTA OF SACRAMENTO AND SAN JOAQUIN RIVERS

CHAPTER III

RELATION OF STREAM FLOW INTO DELTA TO SALINITY

One of the two basic factors governing salinity conditions in the bay and delta channels is the stream flow of the Sacramento and San Joaquin rivers into the delta. The variation of salinity and extent of saline invasion and retreat are related generally to the total amount and the monthly distribution of seasonal stream flow, but are more particularly related directly to the actual rate of flow as it varies in amount from day to day during any season. Evidence of the direct effect of stream flow entering the delta upon salinity conditions in the upper bay and delta channels is shown by the records of salinity and stream flow delineated on Plates V and VI. An exhaustive analysis has been made of the records of stream flow and salinity to determine, if possible, their relation.

Relation of Total Seasonal Stream Flow into Delta to Salinity.

It appears from a study of the records of stream flow and salinity during the period 1920 to 1929 that there is a general relation existing between the total amount of seasonal run-off into the delta and the extent of saline invasion and retreat. It has been previously pointed out that the maximum extent of saline invasion into the delta during this ten-year period occurred during the summer of 1924 following the driest season, 1923–24, of the period 1920 to 1929. The invasions next in extent occurred in 1920 and 1926 following subnormal run-off seasons. It appears that the drier the season or the smaller the total seasonal stream flow entering the delta, the greater has been the extent of saline invasion. Furthermore, the records show that the extent of retreat of salinity is also related to the total seasonal stream flow. The wetter the season and the greater the total seasonal stream flow, the farther downstream has saline water been displaced by fresh water.

Maximum Salinity During Season—The maximum extent of saline invasion during the season is shown directly by the maximum observed salinity for the season at the various points in the delta and upper bay channels. These maximum values of observed salinity (in the surface zone after high tide) at the more important observation stations are given in Table 6 for the period 1920–1929. In a parallel column of this table is shown also the total seasonal stream flow into the delta, expressed as a percentage of the 58-year mean (1871 to 1929). The values of maximum salinity are shown for the actual observations (samples taken in the surface zone usually after high tide) and also for the estimated mean salinity (mean tidal cycle surface zone salinity), representing an average value of the salinity during a tidal cycle period of about 24 hours. These mean tidal cycle values of salinity have been computed from a relationship established as to variation of salinity with tidal stage, which is described in Chapter IV.

TABLE 6
RELATION OF SEASONAL STREAM FLOW INTO DELTA TO MAXIMUM SALINITY DURING SEASON
1920-1929

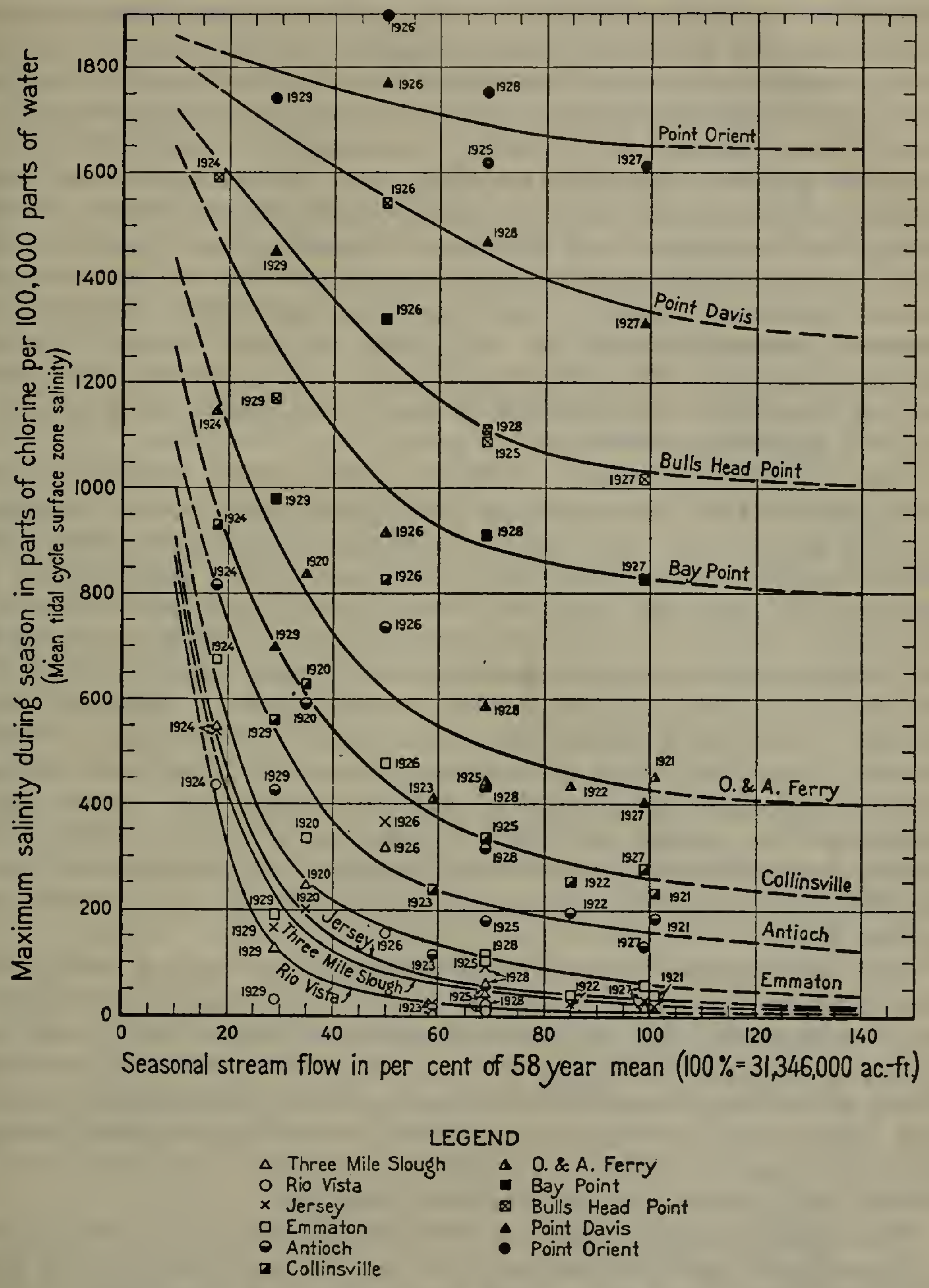
Maximum salinity during season in parts of chlorine per 100,000 parts of water

Season	Seasonal stream flow in per cent of 58 year mean	Point Orient		Point Davis		Bulls Head Point		Bay Point		O. and A. Ferry		Collinsville	
		Observed salinity[1]	Estimated mean salinity[2]	Observed salinity[1]	Estimated mean salinity[2]	Observed salinity[1]	Estimated mean salinity[2]	Observed salinity[1]	Estimated mean salinity[2]	Observed salinity[1]	Estimated mean salinity[2]	Observed salinity[1]	Estimated mean salinity[2]
1919-20	34	------	------	------	------	------	------	------	------	981	835	890	630
1920-21	101	------	------	------	------	------	------	------	------	650	455	384	235
1921-22	85	------	------	------	------	------	------	------	------	574	435	370	255
1922-23	59	------	------	------	------	------	------	------	------	518	415	358	235
1923-24	18	------	------	------	------	------	*1,590	------	------	1,345	1,145	1,150	930
1924-25	68	------	*1,620	------	------	------	*1,090	------	------	762	445	448	340
1925-26	50	2,020	±1,900	1,850	1,770	1,690	1,540	1,400	1,320	1,070	915	1,020	825
1926-27	99	1,880	1,610	1,510	1,315	1,330	1,020	950	830	510	405	370	275
1927-28	69	1,870	1,750	1,610	1,470	1,410	1,110	1,170	910	750	585	590	440
1928-29	29	1,830	1,740	1,660	1,450	1,370	1,170	1,240	980	830	700	680	560

Season	Seasonal stream flow in per cent of 58 year mean	Antioch		Jersey		Emmaton		Three Mile Slough		Rio Vista	
		Observed salinity[1]	Estimated mean salinity[2]	Observed salinity[1]	Estimated mean salinity[2]	Observed salinity[1]	Estimated mean salinity[2]	Observed salinity[1]	Estimated mean salinity[2]	Observed salinity[1]	Estimated mean salinity[2]
1919-20	34	766	590	346	210	474	335	475	250	235	125
1920-21	101	258	185	42	20	66	45	30	------	------	------
1921-22	85	260	195	33	20	44	25	------	------	4	------
1922-23	59	239	115	34	20	[3]44	20	17	10	5	------
1923-24	18	1,085	815	708	540	802	675	730	545	608	435
1924-25	68	356	180	81	45	136	100	81	40	21	10
1925-26	50	920	730	470	365	540	475	430	315	256	155
1926-27	99	179	130	53	30	65	60	25	25	12	------
1927-28	69	450	320	192	95	156	115	109	55	44	20
1928-29	29	580	425	365	165	310	190	205	125	67	30

*From graphical record, Bulletin 22, Vol. 2, Plate 9-8.
[1] From samples taken in surface zone usually after high tide.
[2] Mean tidal cycle surface zone salinity, estimated from observed maximum salinity.
[3] Estimated—no record.

PLATE XVI



RELATION OF

SEASONAL STREAM FLOW INTO DELTA

TO

MAXIMUM SALINITY DURING SEASON

The data in Table 6 have been plotted and graphically shown on Plate XVI, "Relation of Seasonal Stream Flow into Delta to Maximum Salinity During Season." The mean tidal cycle values of maximum salinity (in the surface zone) for the season at the several representative stations have been plotted against the total seasonal stream flow expressed in per cent of the 58-year mean for each season of record. Smooth curves have been drawn for each station averaging the plotted points. It will be noted that these curves depart considerably from the actual points in most of the years, thus indicating that no exact relation, uninfluenced by other conditions, exists between the maximum salinity for the season and the total seasonal stream flow into the delta. However, an approximate general relation of interest and value is indicated, that, in the upper bay and delta channels, the maximum seasonal salinity at any point and the extent of saline invasion is greater, the smaller the total amount of seasonal stream flow into the delta. This relation is more pronounced for points progressively further upstream.

Only two of the seasons, 1920–21 and 1926–27 of the ten-year period, 1920 to 1929, had a normal amount of stream flow as compared to the 58-year mean. In general the minimum values of maximum seasonal salinity during the entire ten-year period occurred at all stations in the years 1921 and 1927, when the total seasonal stream flow was normal. There are exceptions, however, to be noted, especially in 1922, 1923 and 1925 when the maximum salinities at points in the lower delta were about the same as in the normal years of 1921 and 1927. Therefore, in so far as stream flow is a factor in the extent of saline invasion, it is evident that other elements must be taken into account in addition to the total amount of seasonal stream flow. These other elements are the monthly and daily distribution of seasonal stream flow, which vary considerably from year to year and explain the wide variations between the average curves and the actual plotted points shown on Plate XVI.

That the relation between maximum salinity reached during any season and the total seasonal stream flow is approximate and variable simply means, first, that the distribution of the stream flow during the season is not similar from year to year, and, second, especially, that the portion of the total seasonal flow occurring during the summer months bears only a general relation each season to the total seasonal stream flow. The curves (Plate XVI) should therefore be considered as showing only general and approximate relations.

The general relation shown is of chief interest in that it furnishes an approximate basis for estimating what the maximum salinity conditions will be in the future and also what they may have been in past years before any records were available. It is generally possible prior to the summer period of saline invasion to obtain a fairly close estimate of the total seasonal stream flow. Accurate surveys are now being made by the State of the depth and water content of snow in the mountains so that, in April or May, rough predictions can be made of the remaining portion of the seasonal stream flow from which, with the previously measured flow, the total amounts for the season can be estimated. With this estimated total seasonal stream flow available and the approximate general relations shown on Plate XVI, predictions can be made of the maximum salinities which are likely to occur in the following summer. The relations shown are, of course, for conditions during the ten-year period 1920 to 1929, especially as to upstream irrigation and storage diversions which effect the summer stream flow into the delta. Hence, with changed conditions as to upstream diversions in the future, the relations shown would be somewhat altered.

This also would be true, of course, in any application of the general relations shown to estimates of stream flow for early years, when conditions were certainly very different than in recent years. The summer stream flow into the delta has been decreased in the last two decades or more by upstream diversions, and hence the relative amount of summer stream flow to total seasonal stream flow is now considerably different than in early years. However, it is of interest to apply the relations of Plate XVI to the estimates of seasonal stream flow shown on Plate IX. These estimates show a 62 per cent season for 1872–1873,. 52 per cent for 1874–1875 and 60 per cent for 1876–1877. Applying these values to the curves on Plate XVI, it is indicated that there was a material amount of salinity in the lower river channels in those years as far up as Three Mile Slough, with a maximum salinity at Antioch of 200 parts or more of chlorine per 100,000 parts of water. It is probable that the actual maximum salinity was considerably less than the amount indicated by the curve because of a greater summer stream flow in the period 1870 to 1880 than during the period 1920 to 1929. Regardless of the accuracy of the actual amount of salinity indicated, it is especially interesting inasmuch as it confirms the testimony given in the Antioch suit to the fact that saline water was present in the San Joaquin River at Antioch during several years of the period from 1870 to 1880, and even as far up as Three Mile Slough during the same period. The relations also clearly evidence the fact, confirmed by the observation of inhabitants familar with the conditions since the early period of settlement, that the waters in Suisun Bay have always been invaded by saline water during a portion of the year. Even with a total seasonal run-off of as much as 150 to 200 per cent of the 58-year mean, it may be concluded from the relations shown on Plate XVI that the waters of Suisun Bay would become impregnated with saline water at the time of maximum invasion to an extent sufficient to make the water unquestionably unsuitable for domestic or industrial fresh-water uses and unfit even for irrigation use in most of Suisun Bay. The seasons 1911–12 and 1912–13 had an estimated seasonal stream flow of less than 50 per cent of the 58-year mean, which would indicate a saline invasion into the lower delta as far up as Three Mile Slough. This is substantiated by the records of barge travel of the California Hawaiian Sugar Refining Corporation showing the distance traveled above Crockett of 32 to 37 miles maximum or six to eleven miles above Antioch and also by some actual tests of salinity taken in 1913 and shown in Table 34.

Minimum Salinity During Season—A similar approximate relation appears to exist between the total seasonal stream flow and the extent of retreat of salinity as evidenced by the minimum values of salinity during the season. Table 7 summarizes the data from the available

TABLE 7

RELATION OF SEASONAL STREAM FLOW INTO DELTA TO MINIMUM SALINITY DURING SEASON

1923-1929

Season	Seasonal stream flow in per cent of 58 year mean	Minimum salinity during season in parts of chlorine per 100,000 parts of water									
		Point Orient		Point Davis		Crockett		Bulls Head Point		Bay Point	
		Observed salinity [1]	Estimated mean salinity [2]	Observed salinity [1]	Estimated mean salinity [2]	Observed salinity*	Estimated mean salinity [2]	Observed salinity [1]	Estimated mean salinity [2]	Observed salinity [1]	Estimated mean salinity [2]
1922–23	59					133	115				
1923–24	18					390	430	**325	315		
1924–25	68					4	6				
1925–26	50	950	830	82	90	5	25	3	10	3	5
1926–27	99	350	350	24	25	2	5	6	5	4	3
1927–28	69	570	550	30	30	1	10	8	10	2	5
1928–29	29	1,350	1,270	540	590	200	320	240	265	50	35

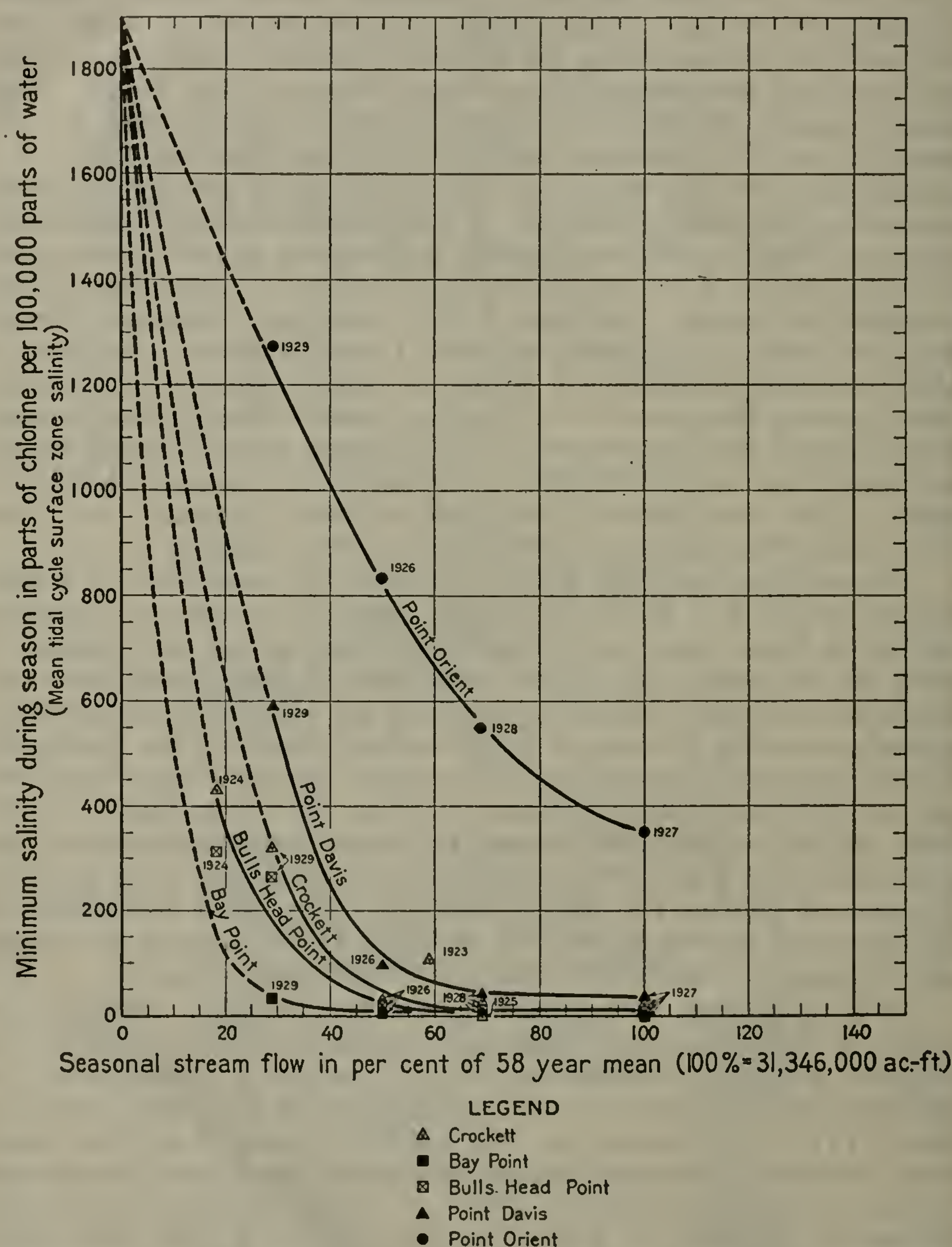
* From records of California-Hawaiian Sugar Refining Corporation. Samples taken at low tide.
** From graphical record, Bulletin 22, Vol. 2, Plate 9-8.
[1] From samples taken in surface zone usually after high tide.
[2] Mean tidal cycle surface zone salinity, estimated from observed minimum salinity.

records in regard to this relation, showing the seasonal stream flow in per cent of the 58-year mean, the minimum observed salinity for the season (samples taken in the surface zone usually after high tide.) and the estimated mean tidal cycle surface zone salinity corresponding to the observed salinity, for each station and year of record. Records of salinity in the bay channels were not started by the State until 1926 and the data available for the study of this relation cover only four years and five stations from Point Orient to Bay Point. Some private records of observations at Crockett were procured for the years 1923 to 1925, inclusive, and at Bulls Head Point for 1924. For the stations above Bay Point, the minimum salinity during the season was zero for the years of record. In other words, in every year during the period 1926 to 1929, the channels in the delta and all of the upper portion of Suisun Bay were filled with fresh water sometime during the winter and spring. On Plate XVII, ''Relation of Seasonal Stream Flow into Delta to Minimum Salinity During Season,'' the data in Table 7 are graphically shown, minimum mean tidal cycle surface zone salinity during the season for all years of record being plotted against seasonal stream flow in per cent of the 58-year mean. Smooth curves have been drawn on the diagram averaging the points plotted for each station. The curves through the points of record, especially for Point Orient and Point Davis, indicate a fairly close relation.

The relations on Plate XVII show that the occurrence of a total seasonal stream flow of 70 per cent or more of the 58-year mean has resulted in fresh water extending downstream as far as Crockett or nearly to the upper end of San Pablo Bay in those years for which records are available. Salinity records are not available for other years, especially covering periods of large floods. However, the freshening effect of winter and spring flood flows on the waters of San Pablo Bay even as far down as Point Orient is shown by the available records. Thus, in 1927, which was a season of about normal stream flow, the mean salinity at Point Orient dropped to a minimum value of about 350 parts of chlorine per 100,000 parts of water, while the salinity at the upper end of San Pablo Bay at Point Davis dropped to a mean value of about 25 parts of chlorine per 100,000 parts of water.

It is of interest to compare the records of barge travel of the California-Hawaiian Sugar Refining Corporation (Plate IV) with the estimated minimum seasonal salinity at Crockett as indicated by the application of estimated seasonal stream flow to the curve shown on Plate XVII. The relations on Plate XVII indicate that fresh water would occur at Crockett with a seasonal stream flow of 70 to 100 per cent or more of the 58-year mean. Plate IV shows that fresh water was obtained at Crockett for a short period of time in 1909, 1910, 1911, 1914, 1915, 1916, 1917, 1919, 1925, 1926, 1927 and 1928. In most all of these years the total seasonal stream flow ranged from 100 to 160 per cent of 58-year mean. In three of these years, it was 70 to 80 per cent and, in two of these years, less than 70 per cent of the mean. In 1926, which was a year with 50 per cent of mean stream flow, the fact that fresh water was available at Crockett is explained by large floods which occurred in February and April of that season. The relations shown on Plate XVII for Crockett are supported by the barge travel records.

PLATE XVII



RELATION OF
SEASONAL STREAM FLOW INTO DELTA
TO
MINIMUM SALINITY DURING SEASON

The closer relation indicated between the total seasonal stream flow and minimum salinity during the season than in the case of maximum salinity during the season is probably due to the fact that the greater part of the total seasonal run-off occurs during the winter and spring months. It is this portion of the seasonal run-off which directly governs the maximum retreat of salinity and hence it is reasonable to expect that a closer relation would be found. It is true, undoubtedly, that the maximum salinity during the season is also partly affected by the larger portion of the total seasonal run-off occurring during the winter and spring, because of the fact that, the greater the magnitude of winter and spring flow, the greater will be the extent of retreat of salinity and hence the longer will the period of time tend to be for the salinity to advance upstream to invade points in the upper bay and delta. In other words, a large winter and spring stream flow putting fresh water in Suisun and San Pablo bays will delay the advance of saline water upstream and hence tend to decrease the extent of saline invasion in the succeeding summer period. However, the records indicate that the rate of advance of salinity upstream is dependent also upon the rapidity with which the stream flow decreases after the late spring freshets of relatively large magnitude. If a relatively large stream flow is maintained into the late spring or early summer months, the records show that it has a marked retarding effect upon the advance of salinity.

Advance of Salinity—The time at which saline invasion starts at any point in the bay and delta varies to a considerable extent in different years. From a study of the records of salinity and stream flow during the period 1920 to 1929, as graphically shown on Plates V and VI, the effects of the amount and distribution of stream flow are evident.

In seasons of large stream flow, there has been a tendency for the invasion of salinity to be delayed at points in the upper bay and lower delta. Thus, in a year like 1927 which followed a normal season from the standpoint of total seasonal stream flow and during which salinity retreated to a greater extent than in any other year of record from 1926 to 1929, salinity did not start to advance at the mouth of the river until July 13th. In 1921, which followed a normal season of stream flow, salinity started to advance into the delta about the same date. Compared with this, in 1929, when the retreat of salinity was much smaller and the seasonal stream flow (1928–1929) was about 30 per cent of the 58-year mean, saline invasion started at the mouth of the river about June 1st. After advance of salinity had started, a storm followed by a fairly large freshet occurred after the middle of June and temporarily halted the advance which had previously started but invasion started again prior to the first of July. As another comparative example, in 1926, which followed a 50 per cent season as regards total seasonal run-off, salinity invasion started at Collinsville on June 1. No records are available in 1924, but it is probable that the advance started at the mouth of the river as early as May.*

Table 8 summarizes the data from all the available records showing the relation between the total seasonal stream flow and the date

* In the dry season of 1931, salinity started to advance into the delta in early April.

TABLE 8

RELATION OF SEASONAL STREAM FLOW INTO DELTA TO DATE OF BEGINNING OF ADVANCE OF SALINITY

1920–1929

Season	Seasonal stream flow in per cent of 58 year mean	Date on which salinity started to advance										
		Point Orient	Point Davis	Bulls Head Point	Bay Point	O. and A. Ferry	Collinsville	Antioch	Jersey	Emmaton	Three Mile Slough	Rio Vista
1919–20	34	----------	----------	----------	----------	June 17	July 3	July 7	July 23	July 12	July 14	----------
1920–21	101	----------	----------	----------	----------	July 7	July 14	July 26	Aug. 25	Aug. 7	Aug. 7	----------
1921–22	85	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
1922–23	59	----------	----------	----------	----------	July 13	July 23	July 30	----------	----------	----------	----------
1923–24	18	----------	----------	*Feb. 15	----------	----------	----------	----------	June 1	----------	----------	June 12
1924–25	68	----------	----------	*June 10	----------	June 29	July 1	July 15	July 30	July 20	July 28	----------
1925–26	50	April 15	April 16	April 22	May 10	May 27	June 1	June 13	June 27	June 19	June 30	July 15
1926–27	99	Feb. 27	Feb. 27	May 1	June 25	July 6	July 13	July 16	Aug. 4	Aug. 5	Aug. 6	----------
1927–28	69	Mar. 31	Mar. 26	April 12	May 12	June 6	June 14	June 21	June 25	----------	June 22	----------
1928–29	29	Mar. 14	Mar. 26	May 20	May 26	May 28	June 3	June 10	July 8	July 7	July 15	Aug. 6

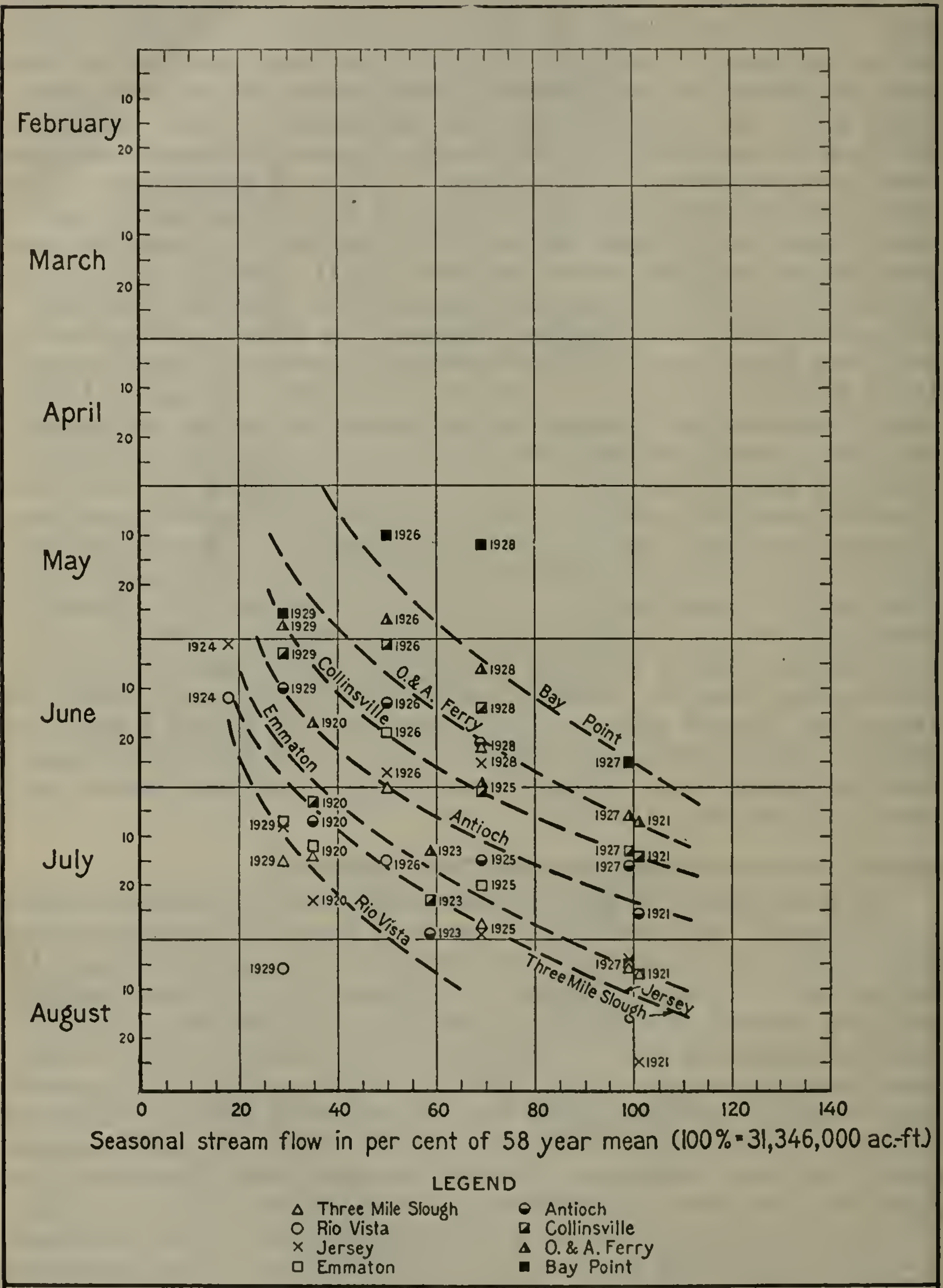
* From graphical record, Bulletin 22, Vol. 2, Plate 9—8.

of beginning of advance of salinity for eleven representative stations in the bay and delta. The total seasonal stream flow is shown in per cent of the 58-year mean. At the lower bay stations, the date shown for the beginning of advance of salinity has been taken as the time when the salinity at the particular station started to increase continuously above the minimum value for the season. At the stations in the upper bay and delta, the date shown is generally taken at the time when saline water of a definite degree of about 10 parts started to be present at the particular station with the salinity increasing continuously thereafter to higher values. The data for the upper bay and delta stations have been plotted on Plate XVIII, "Relation of Seasonal Stream Flow into Delta to Date of Beginning of Advance of Salinity." In general there is considerable discrepancy in these records, showing that there is no clear and direct relation between the total seasonal stream flow and the date at which salinity starts to advance. Dotted curved lines have been drawn on the diagram, indicating the approximate trend for each station. Although the relation is only approximate, it shows a general tendency of wet years, with normal or more than normal stream flow, to delay the time at which salinity starts to advance at points in the upper bay and lower delta channels. That no exact relation exists is to be expected because of the fact that the exact time at which saline invasion starts at any point obviously must be affected by the monthly and daily distribution of the total seasonal stream flow and, especially, the monthly and daily stream flow during the late spring and early summer months. In other words, the rapidity with which the stream flow falls off after the floods of winter and spring is bound to affect the rate of advance of salinity upstream from the points of maximum retreat and hence the date at which saline invasion starts at any point in the basin.

Relation of Summer Stream Flow into Delta to Salinity.

As shown by the records in Table 8 and Plate XVIII, the invasion of salinity into the lower end of the delta generally starts some time between May and July, with an average perhaps of about June 15. The period of advance of salinity upstream into the delta generally continues thereafter until about the first of September, when the maximum salinities for the season generally occur on the average, based upon the records during the period 1920 to 1929. This period from the middle of June to the first of September generally embraces the period of minimum stream flow into the delta. During the same period, the main movement of saline invasion occurs throughout the upper bay and delta. In general, the period from about the middle of June to the first of September covers the entire period of advance of salinity in the delta channels above the confluence of the Sacramento and San Joaquin rivers, except in cases of "pocketed" salinity where there is little or no inflow to effect its retreat. In analyzing the records of stream flow and salinity, it appeared reasonable to assume that the stream flow into the delta during the period of advance of salinity should bear some direct relation to the maximum salinity occurring during the season at the end of the period of advance. Several trial studies were made of this relation, using different periods of the total summer flow. Based on these trial studies it was found that the summer stream flow during the period from June 15 to August 31

PLATE XVIII



RELATION OF

SEASONAL STREAM FLOW INTO DELTA

TO

DATE OF BEGINNING OF ADVANCE OF SALINITY appeared to bear the most direct relation to the maximum salinity occurring during the season. Compiled data showing the relation between summer stream flow into the delta from June 15 to September 1 and the maximum salinity (mean tidal cycle surface zone salinity estimated from observed maximum salinity) for the season are summarized in Table 9 and graphically shown on Plate XIX, "Relation of Summer Stream Flow into Delta to Maximum Salinity." Smooth curves have been drawn on Plate XIX averaging the plotted points for each station. For the most part the curves fit the points for the years of record (1920 to 1929) quite closely, indicating a fairly close relation between the summer stream flow into the delta during this period and the maximum salinity for the season. It must be assumed, of course, that the conditions within the delta, especially as regards consumption of water and tidal action, were about the same during all of these years of record. It has been previously shown that the estimated consumption of water in the delta, as far back as 1923 at any rate, was about the same each year both as to total amount and distribution during the irrigation season. Tidal action and the magnitude of tidal flow into and out of the delta probably has not been the same during the entire period because there have been changes in the channel conditions in the lower Sacramento River, comprising widening and deepening of the river from Collinsville to Rio Vista, and flooding of previously reclaimed lands. However, such change in tidal action probably has not greatly affected the maximum seasonal salinity and the relation of summer stream flow thereto.

The relations on Plate XIX indicate that the invasions of salinity of relatively large extent into the delta channels have occurred in years when the summer stream flow from June 15 to September 1 was less than 1,000,000 to 1,200,000 acre-feet, or an average daily flow of from 6500 to about 8000 second-feet during the period. With greater inflows than these amounts during the period, the maximum salinities occurring tend to be somewhat lower but the decrease in amount appears to be relatively small and tends to gradually diminish for even larger flows during the period. For points in the bay channels from Point Orient as far up as Bay Point, the effect of the summer stream flow during this period, as might be expected, is considerably less than for points in the delta, but the effect of smaller amounts of summer stream flow in increasing the maximum salinity is clearly shown. With summer stream flows of less than 1,000,000 acre-feet, the maximum salinities occurring especially in the delta tend to increase considerably with decreasing flow. However, saline invasion at points farther upstream than Jersey and Emmaton has not occurred in any magnitude until the total summer flow decreased below 800,000 acre-feet, or an average daily flow of about 5000 second-feet. The maximum salinities reached in 1924 occurred with a summer flow of but 233,000 acre-feet, or an average daily flow of less than 1600 second-feet during the period. The maximum salinities reached in 1920 and 1926 occurred with a summer flow of 400,000 to 500,000 acre-feet, or an average daily flow during the period of about 3000 second-feet. It may be concluded from these relations that serious invasions of salinity into the delta would not occur under similar conditions to the present if an average flow, without large fluctuations, of about 5000 second-feet into the delta were maintained during the period June 15 to September 1.

TABLE 9

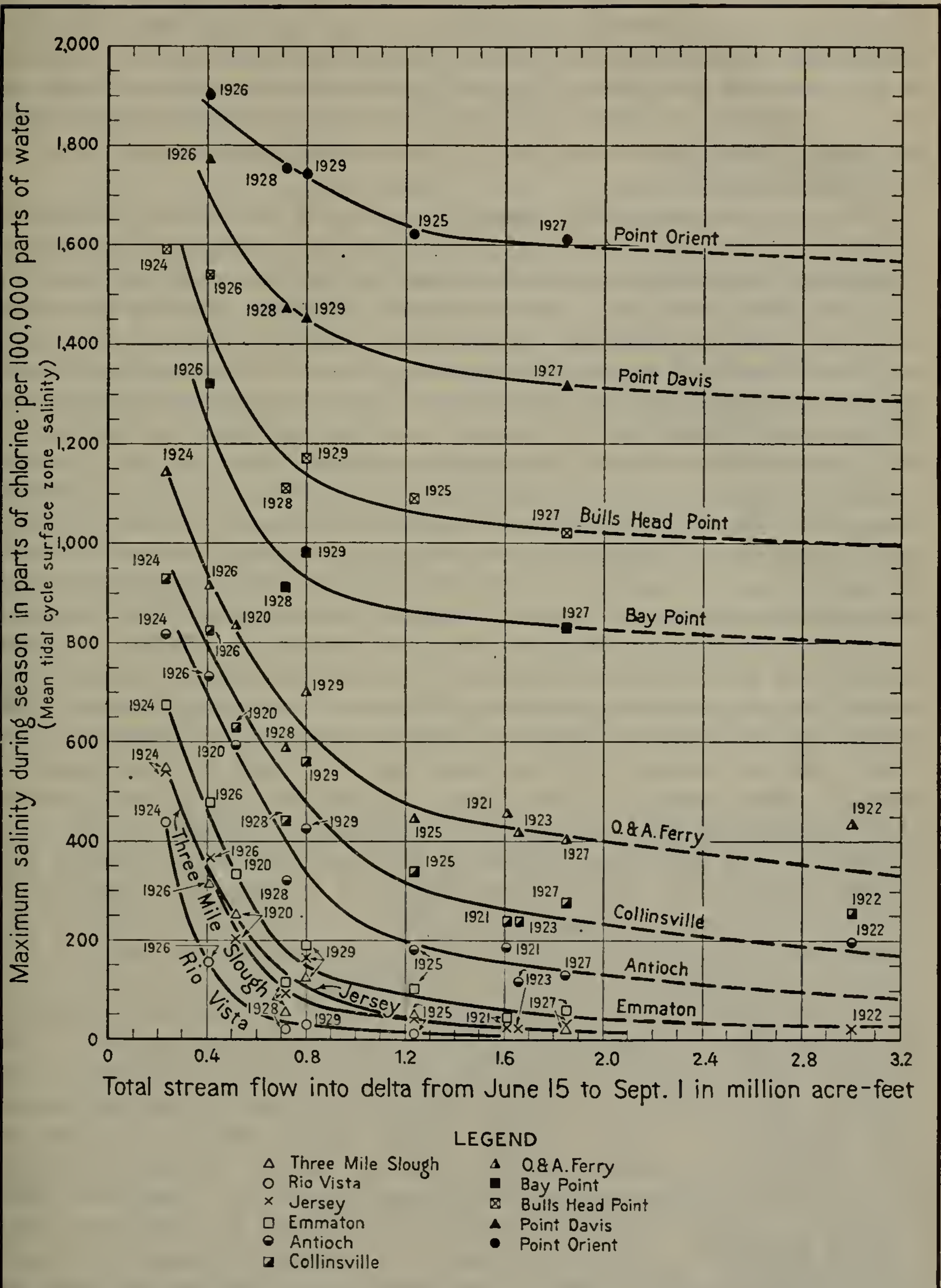
RELATION OF SUMMER STREAM FLOW INTO DELTA TO MAXIMUM SALINITY DURING SEASON

1920-1929

Year	Total stream flow June 15 to Sept. 1 in acre-feet[2]	[1]Maximum mean salinity during season in parts of chlorine per 100,000 parts of water										
		Point Orient	Point Davis	Bulls Head Point	Bay Point	O. and A. Ferry	Collinsville	Antioch	Jersey	Emmaton	Three Mile Slough	Rio Vista
1920	516,600	----------	----------	----------	----------	835	630	590	210	335	250	125
1921	1,609,900	----------	----------	----------	----------	455	235	185	20	45	----------	----------
1922	3,040,000	----------	----------	----------	----------	435	255	195	20	25	----------	----------
1923	1,658,900	----------	----------	----------	----------	415	235	115	20	20	10	----------
1924	232,700	----------	----------	*1,590	----------	1,145	930	815	540	675	545	435
1925	1,234,900	*1,620	----------	*1,090	----------	445	340	180	45	100	40	10
1926	409,100	±1,900	1,770	1,540	1,320	915	825	730	365	475	315	155
1927	1,867,600	1,610	1,315	1,020	830	405	275	130	30	60	25	----------
1928	714,500	1,750	1,470	1,110	910	585	440	320	95	115	55	20
1929	798,000	1,740	1,450	1,170	980	700	560	425	165	190	125	30

* From graphical record, Bulletin 22, Vol. 2, Plate 9-8.
[1] Mean tidal cycle surface zone salinity estimated from observed maximum salinity (samples taken in surface zone usually after high tide).
[2] Stream flow on June 15 not included.

PLATE XIX



RELATION OF

SUMMER STREAM FLOW INTO DELTA

TO

MAXIMUM SALINITY

Relation of Rate of Stream Flow into Delta to Salinity.

The study of the detailed records of daily stream flow into the delta and salinity at various points in the bay and delta channels during the period 1920 to 1929 indicates that the degree of salinity at any point in the basin is generally related to and varies with the rate of stream flow. This is well shown on Plates V and VI on which the salinity records are graphically shown directly above the graphical record of stream flow.

The general relation of salinity to rate of flow and the effect of changes in rate of flow upon salinity may be set forth most effectively by a consideration of the records of stream flow into the delta and salinity at a particular point in a typical season. For this purpose the variations and relations at O. and A. ferry in 1929, as shown by the curves on Plate VI, afford a good illustration. In the following discussion it will be understood that the figures for salinity are expressed in parts of chlorine per 100,000 parts of water. At the beginning of the year in 1929, the salinity was 50 parts with a stream inflow of about 18,000 second-feet. From January 1 to January 15, the stream flow gradually dropped to about 10,000 second-feet and salinity at O. and A. ferry rose to a little over 100 parts. The stream flow then increased to 14,000 second-feet, and the salinity immediately decreased, dropping to about 50 parts on the first of February with a flow of about 12,000 second-feet. The stream flow then increased to 50,000 second-feet on about February 5 and the salinity dropped off to less than ten parts. The stream flow decreased immediately thereafter, reaching about 16,000 second-feet on February 17 and 13,000 second-feet on March 1. The salinity did not immediately increase, but by March 1, it had risen to about 50 parts again. About March 10, the flow increased to about 30,000 second-feet and the salinity immediately dropped to less than ten parts. The flow then decreased to about 20,000 second-feet and averaged about this amount from March 20 to May 20. During this period, the salinity averaged about 25 to 40 parts. On May 20, the stream flow dropped off, reaching 10,000 second-feet on June 1 and continued at about this rate for about fifteen days. By June 10th, salinity increased to about 100 parts. A small freshet then occurred, the stream flow increasing to a little over 20,000 second-feet. This caused a drop in salinity, but the freshet was only of short duration and the stream flow immediately decreased, reaching about 6000 second-feet on July 1. The salinity again rose to 100 parts on July 1 and then increased rapidly with the further decrease of stream flow. The stream flow reached a minimum about July 20 of about 2500 second-feet. At this time the salinity at O. and A. ferry had risen to about 400 parts. The stream flow then increased gradually to about 3000 second-feet on August 1 and continued at about this rate on the average during the month of August. During this time, however, the salinity did not remain constant at O. and A. ferry but continued to increase from about 400 parts on July 20 to a maximum of about 800 parts on September 1. During September the flow gradually increased to a little over 6000 second-feet and in October to about 7000 second-feet, remaining about this average flow until December 10. During this period the salinity at O. and A. ferry gradually dropped to about 300 parts. A relatively large flood flow then occurred, reaching about 106,000 second-feet on December 18. This freshet resulted in saline water being removed entirely from the lower delta channels and the water became fresh at O. and A. ferry at the peak of the freshet. The stream flow rapidly fell off, however, and by the first of the year had decreased to about 15,000 second-feet, accompanied by an increase in salinity at O. and A. ferry to about 25 parts.

The relations shown between rate of flow into the delta and salinity at O. and A. ferry may be considered as typical of those which have occurred at all of the upper bay and delta observation stations during the period of record. Although there is no constant relation indicated between the degree of salinity and the rate of flow during all times of the year, the record clearly shows that the salinity at any particular time at a typical point usually is directly affected by a change in the rate of stream flow. An increase in stream flow at any particular time tends to decrease the salinity, while, on the contrary, a decrease in stream flow tends to increase the salinity. It is evident that the question as to whether an increase in stream flow effects a decrease in the salinity depends upon the degree of salinity present at the time as well as the amount of increase in flow. The effect of stream flow is also modified by the relative amount of consumption in the delta as will be more fully explained hereafter. When the salinity at O. and A. ferry was about 100 parts on June 10, an increase in stream flow from 10,000 to 22,000 second-feet resulted in a decrease in salinity to about 10 parts, whereas, with a salinity of about 400 parts on July 20, an increase in stream flow from 2500 second-feet to 3500 second-feet did not decrease the salinity but, instead, the salinity continued to increase and advance upstream.

A great multiplicity of studies have been carried out in an effort to discover any relations existing between rate of stream flow into the delta and resulting degree and variation of salinity at various points in the delta and bay. These have included analyses as to relation of rate of flow to date of beginning of advance of salinity, rate of increase and advance of salinity, rate of decrease and retreat of salinity and maximum seasonal salinity. The analyses as to date of beginning of advance of salinity and rate of increase or decrease of salinity were not conclusive. With respect to maximum seasonal salinity, trial studies were made of the relation of minimum rate of flow during the season to maximum salinity during the season, using minimum one-day, five-day and ten-day average daily rate of stream inflow. No definite relations were shown by any of these trial studies. The reason why a definite relation does not exist between minimum rate of stream inflow and maximum salinity during the season appears to be evident if the governing factors be carefully analyzed. Thus, considering any typical point in the lower delta, the salinity, after invasion starts, increases at a rate depending upon the rate of decrease in stream flow. When the rate of stream flow has reached a minimum for the season and starts to increase again, the increased flow usually is not sufficient at first to prevent a continued advance of salinity, especially at points in the lower delta and upper bay channels, and the salinity continues to increase generally and reaches a maximum for the season only at a time when the stream flow has increased to a sufficient extent above the minimum flow for the season to start a decrease of salinity for the degree which has been reached at any typical point by that time. It is evident, therefore, that the maximum salinity reached during the season at any point is dependent upon the amount and variation of stream flow during the entire period of advance of salinity, that is, the period between the time when salinity starts to advance and the time at which the maximum salinity for the season is reached. There is no reason to assume that the minimum stream flow during the season is the direct cause of the maximum salinity during the season or that they are directly related. The conditions of salinity and flow at the time of maximum salinity are entirely different than those at the time of minimum stream flow, and their occurrence is separated usually by a considerable interval of time.

As a result of these studies as to maximum seasonal salinity, it appeared that the rate of flow into the delta at the time of occurrence of maximum salinity for the season should be related most closely to the maximum salinity reached at various points in the delta and upper bay. Studies were, therefore, made of this relation, based upon all the available records during the period 1920 to 1929. Table 10 summarizes the records of maximun salinity during the season and the rate of stream flow into the delta at the time of occurrence of maximum salinity. The data are compiled from the records for eleven typical stations from Point Orient to Rio Vista. The maximum salinities in the tabulation have been estimated from the observed maximum salinities (from samples taken in the surface zone usually after high tide) as the mean values during the tidal cycle period corresponding to the observer's sample. The basis of these estimates of mean tidal cycle salinity is presented in Chapter IV. Mean tidal cycle salinity is used in place of the observed salinity taken from samples after high tide because the rate of flow is the mean daily rate and should be related to the mean salinity for the day, which is approximately the period of a tidal cycle. The relation is more exact because of the fact that there is considerable variation between the mean salinity for a tidal cycle and the maximum salinity after high tide depending upon the range of the tide occurring at the particular time the sample was taken. The detailed relations on the tidal variations of salinity are discussed in Chapter IV.

The data in Table 10 are presented in graphical form on Plate XX, "Relation of Rate of Stream Flow into Delta to Maximum Salinity." Smooth curves have been drawn averaging the plotted points for each station. For the most part the points conform fairly closely with the average curves, thus indicating a fairly close relation between the maximum salinity for the season and the rate of stream flow into the delta at the time of occurrence of maximum salinity. The reason that the plotted points do not more closely conform to the average curves drawn for each station may be explained by the fact that there is a considerable variation in the actual time of occurrence of maximum salinity from year to year at each station and hence some material difference in the amount of water being consumed in the delta at the time of occurrence of maximum salinity in different years. The average relations shown should be considered to be for average conditions as to consumption in the delta in early September, which is about the average time of occurrence of maximum salinity for the several years of record at the typical stations considered. For any other time in the year the

TABLE 10

RELATION OF RATE OF STREAM FLOW INTO DELTA AT TIME OF MAXIMUM SALINITY TO MAXIMUM SALINITY DURING SEASON

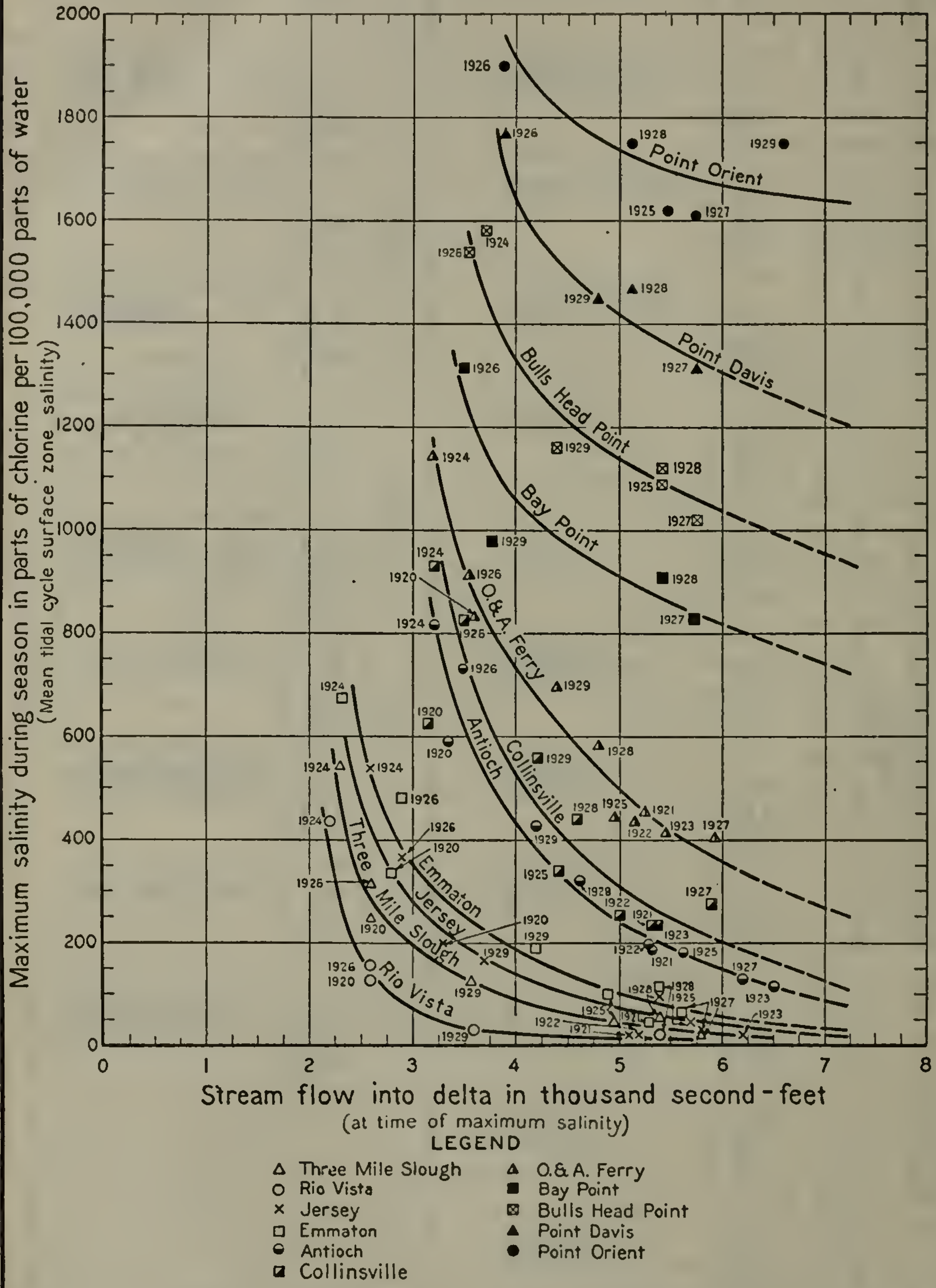
1920-1929

Year	Point Orient		Point Davis		Bulls Head Point		Bay Point		O. and A. Ferry		Collinsville	
	Stream flow in second-feet[2]	Maximum salinity[1]	Stream flow in second-feet[2]	Maximum salinity[1]	Stream flow in second-feet[2]	Maximum salinity[1]	Stream flow in second-feet[2]	Maximum salinity[1]	Stream flow in second-feet[2]	Maximum salinity[1]	Stream flow in second-feet[2]	Maximum salinity[1]
1920	----	----	----	----	----	----	----	----	3,600	835	3,100	630
1921	----	----	----	----	----	----	----	----	5,300	455	5,300	235
1922	----	----	----	----	----	----	----	----	5,200	435	5,000	255
1923	----	----	----	----	----	----	----	----	5,400	415	5,400	235
1924	----	----	----	----	3,700	*1,590	----	----	3,200	1,145	3,200	930
1925	5,400	*1,620	----	----	5,400	*1,090	----	----	4,900	445	4,400	340
1926	3,900	±1,900	3,900	1,770	3,500	1,540	3,500	1,320	3,500	915	3,500	825
1927	5,800	1,610	5,800	1,315	5,800	1,020	5,800	830	5,900	405	5,900	275
1928	5,100	1,750	5,100	1,470	5,400	1,110	5,400	910	4,800	585	4,600	440
1929	6,600	1,740	4,800	1,450	4,400	1,170	3,700	980	4,400	700	4,200	560

Year	Antioch		Jersey		Emmaton		Three Mile Slough		Rio Vista	
	Stream flow in second-feet[2]	Maximum salinity[1]	Stream flow in second-feet[2]	Maximum salinity[1]	Stream flow in second-feet[2]	Maximum salinity[1]	Stream flow in second-feet[2]	Maximum salinity[1]	Stream flow in second-feet[2]	Maximum salinity[1]
1920	3,400	590	3,300	210	2,800	335	2,600	250	2,600	125
1921	5,300	185	5,100	20	5,300	45	----	----	----	----
1922	5,200	195	5,200	20	----	25	----	----	----	----
1923	6,500	115	6,200	20	----	20	----	10	----	----
1924	3,200	815	2,600	540	2,300	675	2,300	545	2,200	435
1925	5,600	180	5,700	45	4,900	100	4,900	40	3,400	10
1926	3,500	730	2,900	365	2,900	475	2,600	315	2,600	155
1927	6,200	130	5,800	30	5,600	60	5,800	25	----	----
1928	4,600	320	5,400	95	5,400	115	5,400	55	5,400	20
1929	4,200	425	3,700	165	4,200	190	3,600	125	3,600	30

* Estimated from graphical record, Bulletin 22, Vol. 2, Plate 9-8.
[1] Mean tidal cycle surface zone salinity (in parts of chlorine per 100,000 parts of water), estimated from observed maximum salinity (samples taken in surface zone usually after high tide).
[2] Stream flow into delta on date of occurrence of maximum salinity during season.

PLATE XX



RELATION OF

RATE OF STREAM FLOW INTO DELTA

TO

MAXIMUM SALINITY

relation shown between the rate of flow into the delta and the maximum salinity would be modified by the difference in amount of consumption of water in the delta at the particular time and that on September 1. At a time when the consumption of water was greater than that on September 1, the rate of flow into the delta related to a particular degree of salinity at a particular point would be greater than that shown by the curves by an amount equal to the difference between the greater consumptive use and the use in early September. It is clear, therefore, that the relation between rate of flow into the delta and maximum salinity shown on Plate XX is not strictly applicable to any time of the season, but only for the particular time of year as of about September 1. The relation also takes no account of possible differences in magnitude of tidal flow at the time of occurrence of maximum salinity in different years, which might affect the relation to some extent.

With a flow of 6000 second-feet into the delta, the curves on Plate XX show that the mean tidal cycle salinity might reach maximum degrees of 360 at O. and A. ferry, 200 at Collinsville, 150 at Antioch, 60 at Emmaton, 40 at Jersey, 20 at Three Mile Slough, and 10 or less at Rio Vista, all in parts of chlorine per 100,000 parts of water. With a flow of 5000 second-feet, the maximum degrees of mean tidal cycle salinity in parts of chlorine per 100,000 parts of water would be: O. and A. ferry, 500; Collinsville, 310; Antioch, 250; Emmaton, 100; Jersey, 70; Three Mile Slough, 40; Rio Vista, 10. These values of maximum salinity relative to these inflows into the delta would be for conditions of consumptive use in the delta as of September 1. It is interesting to note that all of the curves for the stations near the mouth of the river have a trend toward the vertical at a flow of about 3000 second-feet. This is to be expected inasmuch as at the usual time, in early September, when the maximum salinities in the lower delta have occurred in the several years of record, the consumption of water in the delta is at the rate of about 3000 second-feet, resulting in practically zero flow at the mouth of the river and affording the potential opportunity, if the same conditions continued, for salinity to increase to that of sea water. The vertical trend of the curves indicates this tendency.

The relations shown are of particular interest from the standpoint of control of salinity. Inasmuch as the rates of flow were of simultaneous occurrence with the maximum salinities reached at the various typical stations, it is evident that these flows were sufficient under the conditions obtaining at the time to prevent the further advance or increase of salinity at the particular points and for the particular degrees of salinity reached. Hence, these rates of inflow represent control flows for various degrees of maximum salinity reached at these particular points at particular times of the season. A subsequent increase in flow resulted in a decrease of salinity and a retreat movement. The maximum salinities occurring during the years of record at Antioch and Collinsville near the lower end of the delta, have all been above 100 parts of chlorine per 100,000 parts of water. Therefore, the curves of relation between rate of stream flow into the delta and maximum salinity must be extended to obtain an approximation of what the control flows would be for preventing a further increase of salinity at a degree of 100 parts or less at these points. The protection of the entire delta from harmful saline invasion in such a way as to make available fresh-water supplies at all times with 100 parts or less of chlorine per 100,000 parts of water would require a determination of the amount of flow required to prevent the salinity from increasing further after reaching a degree of 100 parts or less near the lower end of the delta. By extending the curve for Antioch, the relation shows that a flow into the delta of about 7000 second-feet would prevent the salinity from increasing at Antioch above a mean degree of 100 parts for conditions as of about September 1. Although this is somewhat of an approximation, the relation indicated is of considerable value as a check on the more accurate determinations of control by stream flow evolved from a consideration of tidal action as well as stream flow as presented in Chapter IV. The curves of relation for Antioch and Collinsville and the stations upstream indicate that a flow of about 7000 second-feet into the delta would afford ample protection from harmful saline invasion into the delta for conditions as of about September 1.

Relation of Source and Distribution of Stream Flow into Delta to Salinity.

The source and distribution of flow into the delta has an important bearing on salinity conditions therein. The greater part of the stream flow entering the delta comes from the Sacramento River. The detailed records of stream flow presented in the tabular summaries and on the graphs show the relative magnitude of the flow from the two stream systems which in combination make up the total inflow into the delta. During the summer months of July and August, for example, the flow from the San Joaquin River system during the period 1920 to 1929 has averaged but 30 per cent of the total combined flow. Thus, the delta usually must depend to the greater extent for its water supply on the flow of the Sacramento River.

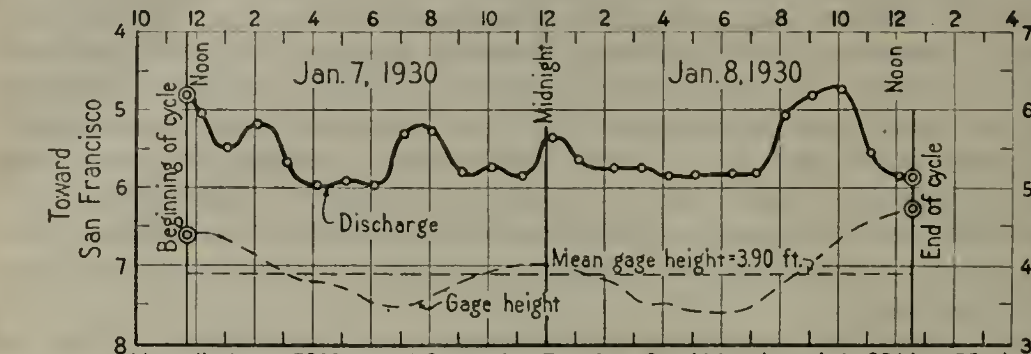
The portion of the total inflow of the Sacramento River entering the San Joaquin Delta comes through two interconnecting channels of limited capacity. Because of the relatively small inflow usually available from the San Joaquin River system, salinity conditions in the San Joaquin Delta depend to a large extent on the water supply contributed from the Sacramento River. The limitation in this chief source of supply for the San Joaquin Delta has resulted in considerably different salinity conditions in the San Joaquin than in the Sacramento Delta. This is shown especially for the years 1920, 1926, and 1924, when the extent of saline invasion was much greater in the San Joaquin than in the Sacramento Delta. For example, in 1924, the channels of 54 per cent of the San Joaquin Delta were invaded by salinity to 100 parts or more, while only 30 per cent of the Sacramento Delta was similarly affected. In years of subnormal streamflow, the portion of the Sacramento River flow supplied to the San Joaquin Delta together with the relatively small inflow usually available from the San Joaquin River system has not been sufficient to take care of the combined requirements of water consumption and resistance to saline invasion. Even in such years as 1929, the salinity in the channels of the San Joaquin Delta was in general considerably greater than in the Sacramento Delta at points equidistant from the mouth of the river. The records also show that salinity has tended to remain in the San Joaquin Delta channels, especially in the region of Middle and Old rivers and the upper Mokelumne

River, for a considerable period of time after the Sacramento Delta channels have been completely flushed out. In all years in which the invasion of salinity into the San Joaquin Delta did not reach a material extent, the inflow from the San Joaquin River system, during the period of low stream flow, was considerably larger than in the years of greater invasion. If this larger flow had not been available in these years, the salinity conditions in the San Joaquin Delta undoubtedly would have been entirely different with a greater extent of invasion in all of these years. Any future developments which would still further decrease the inflow from the San Joaquin River and its main tributaries would tend to increase the extent of saline invasion into the San Joaquin Delta.

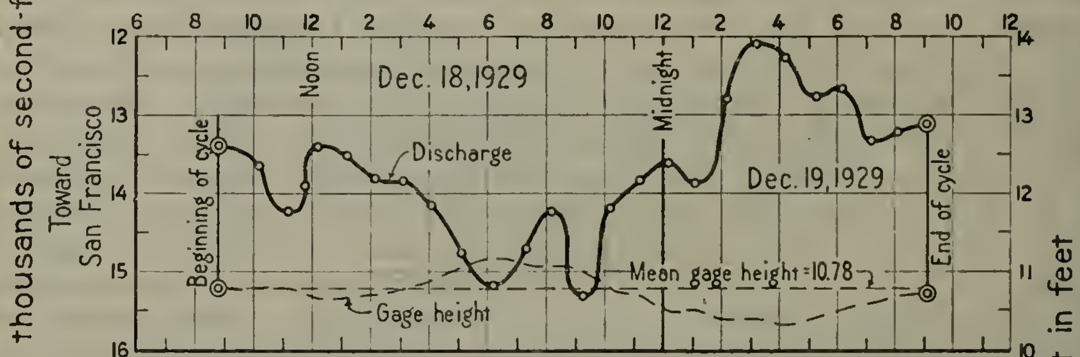
It is, therefore, important to determine the distribution of flow of the Sacramento River between the several channels into which this river branches below Sacramento and more particularly as regards the proportion of the total Sacramento River flow which is carried into the San Joaquin Delta by the two connecting sloughs, Georgiana and Three Mile. This has been determined by a series of measurements of the flow through the branch channels, comprising Sutter, Steamboat, Georgiana and Three Mile sloughs and of the Sacramento River below its junction with Georgiana Slough. The location of these branch channels is shown on Plate III. The first branch below Sacramento is Sutter Slough, which leaves the main stream on its right or westerly bank about opposite Courtland, or about 25 miles downstream from Sacramento. The next branch downstream is Steamboat Slough, which leaves the main channel on the right or westerly bank about two miles below Courtland. These two sloughs form a junction a few miles downstream and finally again join the main river about two miles above Rio Vista. Georgiana Slough branches off from the main river on its left or easterly bank immediately downstream from Walnut Grove, or about 32 miles below Sacramento. This is the first branch channel which connects with the San Joaquin Delta. It joins the Mokelumne River about three miles upstream from the confluence of the Mokelumne and San Joaquin rivers. Three Mile Slough forms the second and farthest downstream connecting channel between the Sacramento and San Joaquin rivers. It leaves the left or easterly bank of the Sacramento River about three miles downstream from Rio Vista, or about 50 miles below Sacramento. It is located about ten miles above the confluence of the Sacramento and San Joaquin rivers.

Distribution of Flow of Sacramento River in Delta Channels—Plates XXI to XXV, inclusive, show the results of typical measurements made of the flow through the several branch channels of the Sacramento River below Sacramento. For each channel, typical stream flow measurements have been selected for graphical presentation covering different rates of discharge of the Sacramento River past Sacramento. Plate XXI shows typical measurements for Sutter Slough; Plate XXII for Steamboat Slough; Plate XXIII for Georgiana Slough; Plate XXIV for the Sacramento River below Walnut Grove (below junction of upper mouth of Georgiana Slough) ; and Plate XXV for Three Mile Slough. The graphs show the character of the flow which varies in rate from time to time during a period of 24 hours with the rise and fall and the flood and ebb of the tides. Each separate measurement of flow made

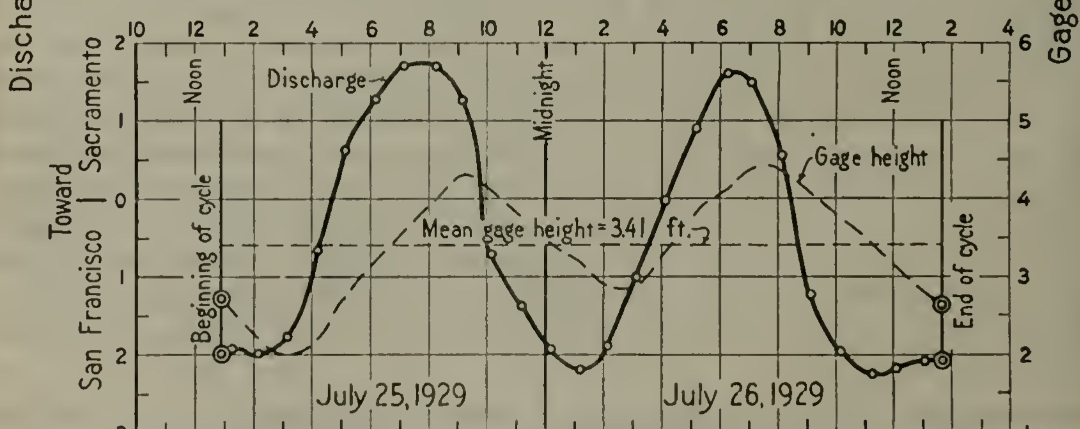
PLATE XXI



Mean discharge 5600 second-feet to San Francisco for tidal cycle period of 24 hrs., 55 min. from 11:40 A.M. Jan. 7, gage height 4.4 ft. to 12:35 P.M. Jan. 8, gage height 4.70 ft.
Flow of Sacramento River at Sacramento 23,600 second-feet.



Mean discharge 13,800 second-feet to San Francisco for tidal cycle period of 24 hrs., 21 min. from 8:45 A.M. Dec. 18, gage height 10.8 ft. to 9.06 A.M. Dec. 19, gage height 10.70 ft.
Flow of Sacramento River at Sacramento 64,400 second-feet.



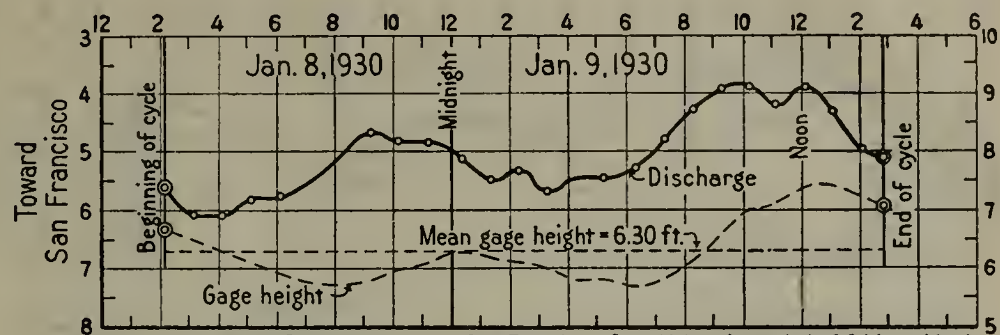
Mean discharge 540 second-feet to San Francisco for tidal cycle period of 24 hrs., 50 min. from 12:50 P.M. July 25, gage height 2.7 ft. to 1:40 P.M. July 26, gage height 2.6 ft.
Flow of Sacramento River at Sacramento 2,490 second-feet.

MEASURED FLOW THROUGH SUTTER SLOUGH

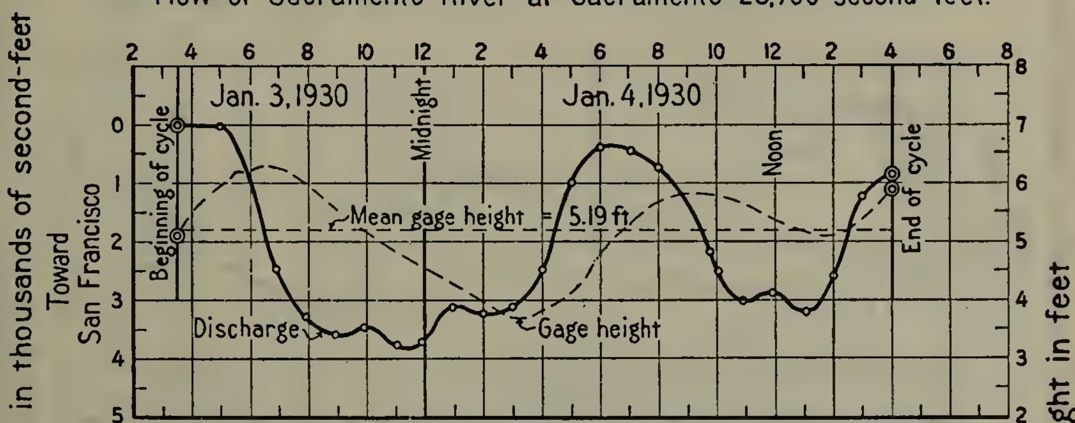
AS SHOWN BY

TYPICAL MEASUREMENTS THROUGHOUT COMPLETE TIDAL CYCLE PERIODS

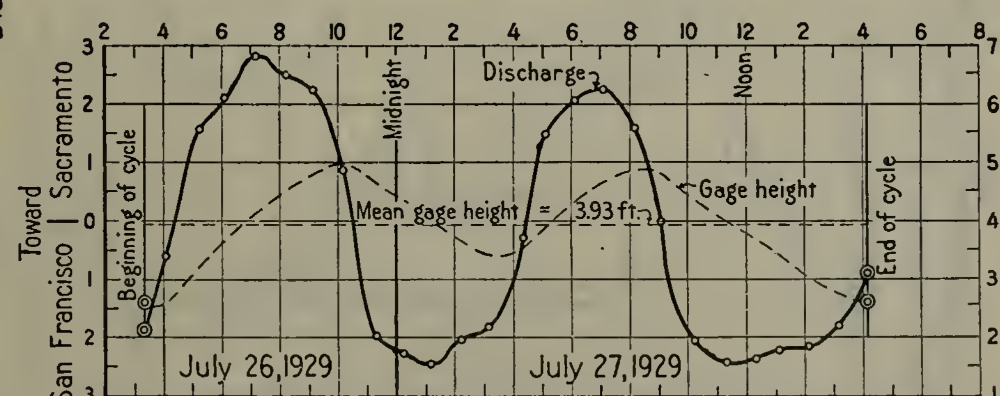
PLATE XXII



Mean discharge 5050 second-feet to San Francisco for tidal cycle period of 24 hrs., 40 min. from 2:10 P.M. Jan. 8, gage height 6.7 ft. to 2:50 P.M. Jan. 9, gage height 7.05 ft.
Flow of Sacramento River at Sacramento 25,700 second-feet.



Mean discharge 2160 second-feet to San Francisco for tidal cycle period of 24 hrs., 30 min. from 3:30 P.M. Jan. 3, gage height 5.1 ft. to 4:00 P.M. Jan. 4, gage height 5.9 ft.
Flow of Sacramento River at Sacramento 14,500 second-feet.



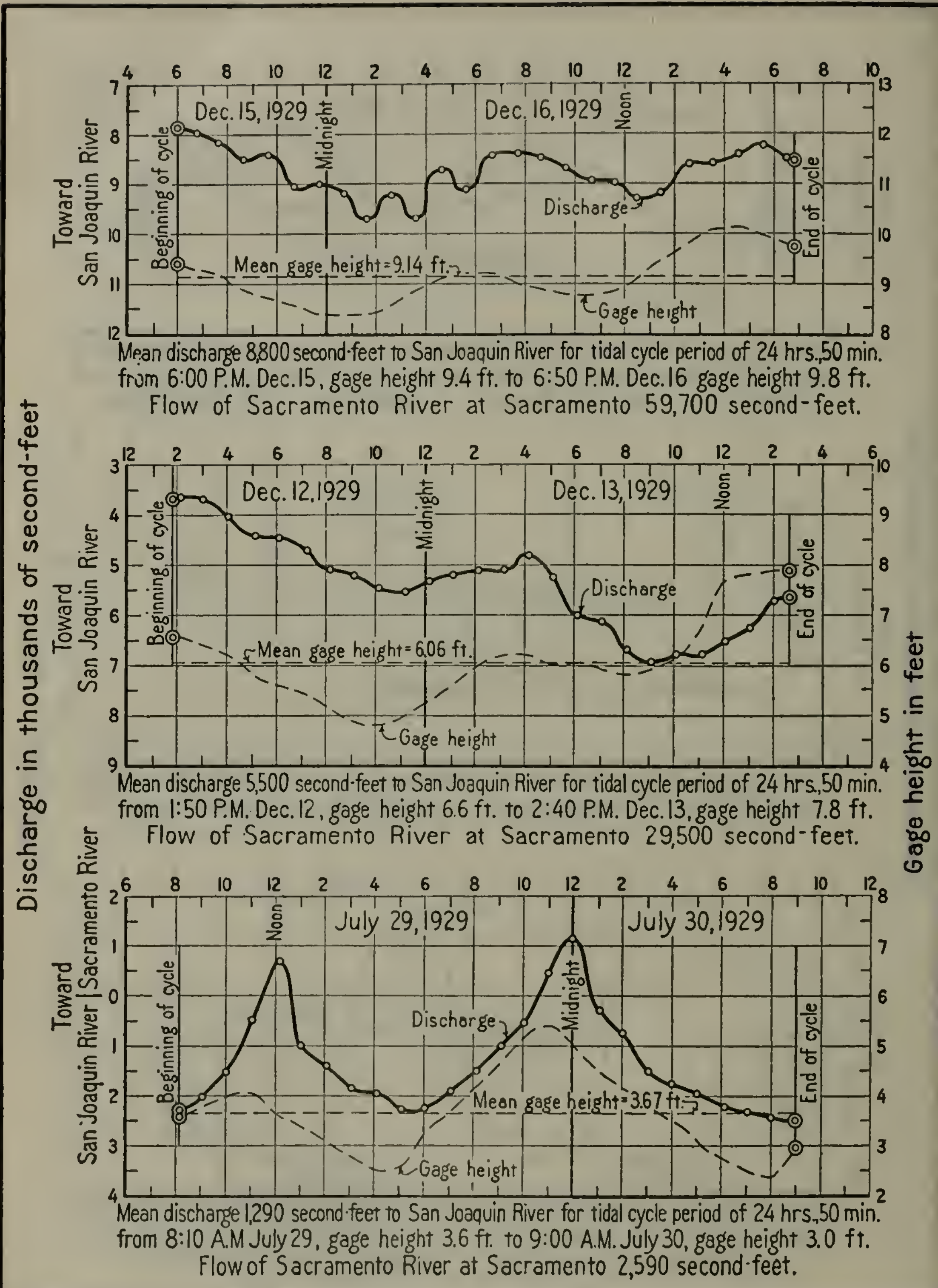
Mean discharge 240 second-feet to San Francisco for tidal cycle period of 24 hrs., 50 min. from 3:20 P.M. July 26, gage height 2.6 ft. to 4:10 P.M. July 27, gage height 2.6 ft.
Flow of Sacramento River at Sacramento 2,490 second-feet.

MEASURED FLOW THROUGH STEAMBOAT SLOUGH

AS SHOWN BY

TYPICAL MEASUREMENTS THROUGHOUT COMPLETE TIDAL CYCLE PERIODS

PLATE XXIII

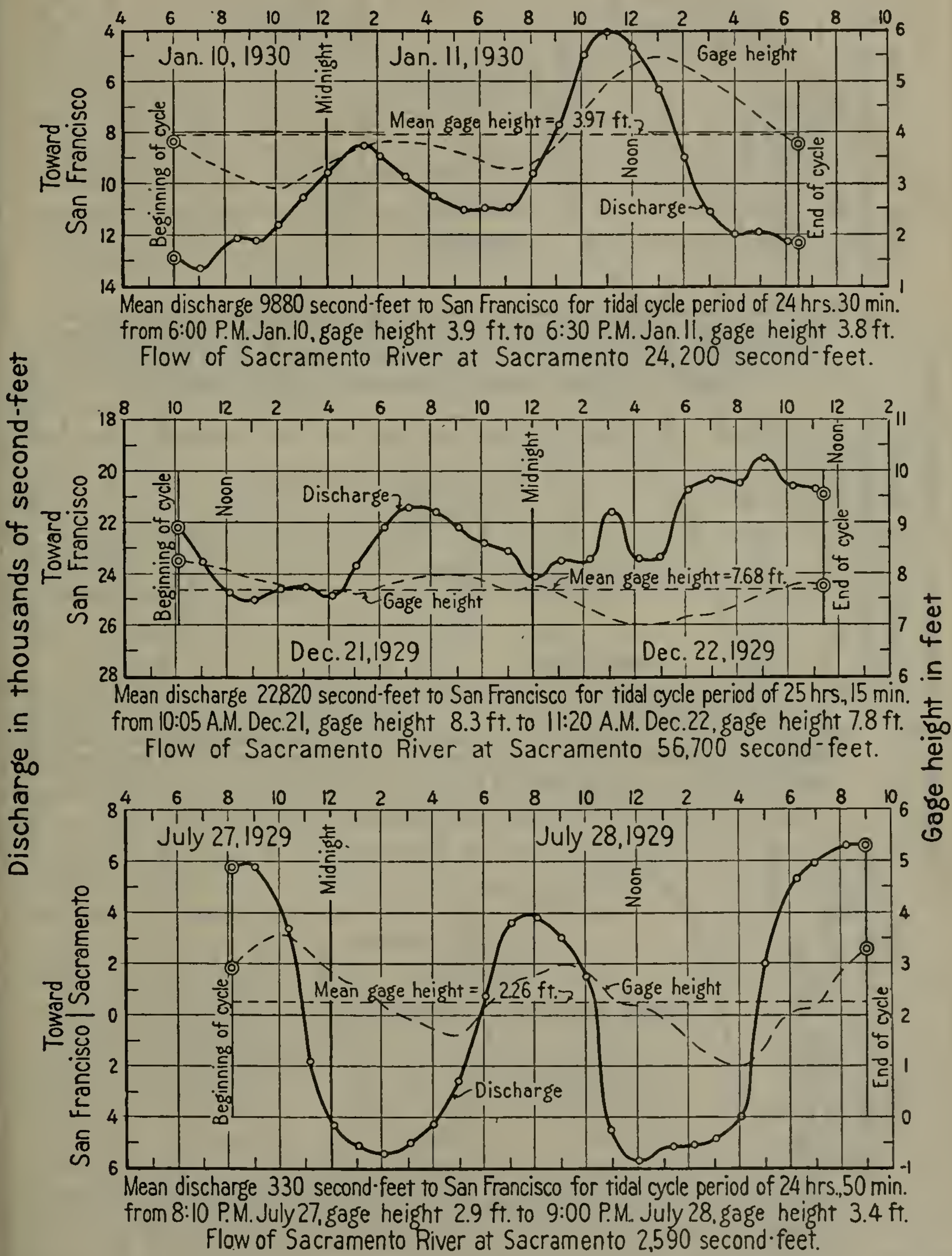


MEASURED FLOW THROUGH GEORGIANA SLOUGH

AS SHOWN BY

TYPICAL MEASUREMENTS THROUGHOUT COMPLETE TIDAL CYCLE PERIODS

PLATE XXIV



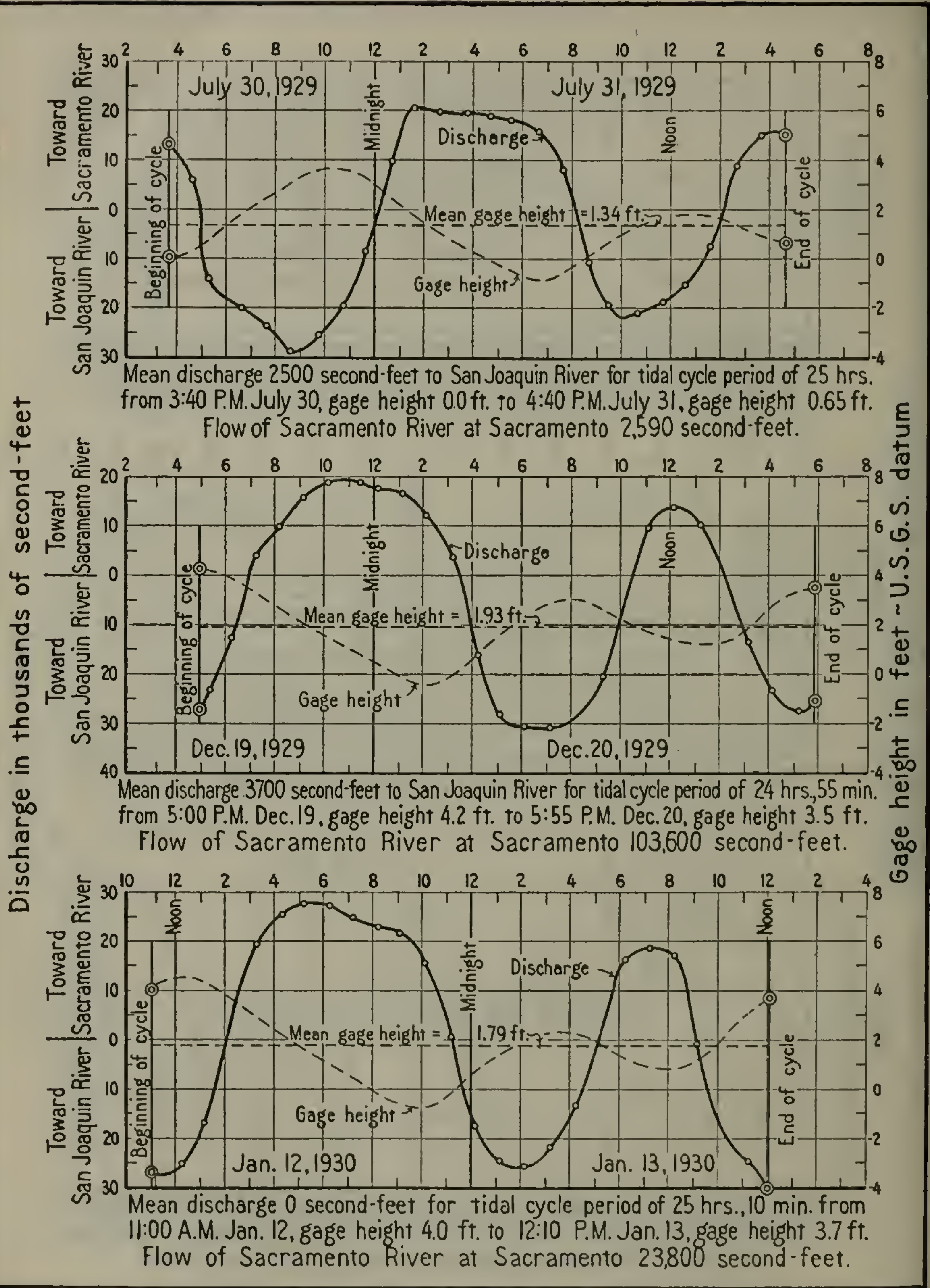
MEASURED FLOW OF SACRAMENTO RIVER

BELOW WALNUT GROVE

AS SHOWN BY

TYPICAL MEASUREMENTS THROUGHOUT COMPLETE TIDAL CYCLE PERIODS

PLATE XXV



MEASURED FLOW THROUGH THREE MILE SLOUGH

AS SHOWN BY

TYPICAL MEASUREMENTS THROUGHOUT COMPLETE TIDAL CYCLE PERIODS

at about hourly intervals during a tidal cycle period of about 24 to 25 hours is plotted on the graph. When the flow of the Sacramento River is small, there is usually a reversal of current and flow in each of these channels during flood tides. This is shown on the lower graphs of Plates XXI, XXII, XXIII, and XXIV. However, with larger flows, there is no reversal but usually a slackening of downstream velocity and flow during flood tide. For the flow conditions in the Sacramento River during the 1929 season, it was found that the net flow for a 24-hour period in all channels except Three Mile Slough was always downstream towards San Francisco or towards the San Joaquin River. The net flow for the approximate 24-hour period is computed as an average of the variable flow during the tidal cycle period.

In Three Mile Slough, there is always a reversal of flow during a tidal cycle period of 24 to 25 hours regardless of the flow in the Sacramento River at least up to maximum flows of 100,000 second-feet past Sacramento which is the largest flow at which a measurement was taken. The measurements on Three Mile Slough indicate that the preponderance of net flow through Three Mile Slough is from the Sacramento to the San Joaquin River. However, three of the measurements which were made indicated a zero net flow; that is, the net result of the tidal flow from the Sacramento to the San Joaquin and from the San Joaquin to the Sacramento River during the tidal cycle period of about 25 hours was no net transfer of water either way.

In making all of these stream flow measurements, but especially those on Three Mile Slough, an effort was made to schedule the measurements so that they would cover all variations of tidal conditions including range and type of tide. In addition, the schedule for measurements was fixed to cover different discharges of the Sacramento River. The compiled data covering all measurements are summarized in Table 11. There are shown for each station the date of measurement, the computed net flow from each measurement and the flow of the Sacramento, San Joaquin, Cosumnes and Mokelumne rivers, and the combined flow into the delta on the date of each measurement. The figures shown in Table 11 for the flow of the Sacramento River past Sacramento, except for Three Mile Slough, comprise only the flow in the main channel and hence differ from amounts on corresponding dates in Table 37, the latter of which include the flow, if occurring, in Yolo By-Pass. Those for Three Mile Slough include the flow in the main channel and in the Yolo By-Pass as well. The dates shown in Table 11 indicate the day on which the mean time of measurements fell. The corresponding flows for the Sacramento River past Sacramento and for the San Joaquin River and its tributaries are for dates preceding the actual dates of measurement in the branch channels, differing by the estimated period of time required for the water to flow, at the rate prevailing at the time of measurement, from Sacramento to the gaging stations on the branch channels.

The division of flow and its relation to the flow of the Sacramento River past Sacramento are shown for all branch channels except Three Mile Slough on Plate XXVI, "Distribution of Flow of Sacramento River Through Branch Channels Below Sacramento." For each slough, the computed discharges for each measurement are plotted

TABLE 11

SUMMARY OF TIDAL CYCLE STREAM FLOW MEASUREMENTS

Stream channel	Date of measurements	Measured net flow in stream channel from Sacramento River, in second-feet[1]	Stream flow into delta, in second-feet					
			Sacramento River at Sacramento	San Joaquin River at Vernalis	Cosumnes River at Michigan Bar	Mokelumne River at Woodbridge*	San Joaquin, Cosumnes, Mokelumne and Calaveras rivers and Dry Creek	Combined Sacramento and San Joaquin River systems
Sutter Slough	June 16, 1929	1,830	7,790	1,480	106	418	2,010	9,800
	June 30, 1929	1,300	5,840	1,080	88	142	1,320	7,160
	July 26, 1929	540	2,490	340	10	10	360	2,850
	Sept. 12, 1929	862	3,860	1,010	1	8	1,020	4,880
	Dec. 18, 1929	13,800	64,400	1,380	136	41	1,560	65,960
	Jan. 3, 1930	2,850	15,100	1,380	39	22	1,450	16,550
	Jan. 8, 1930	5,600	23,600	1,430	262	34	1,820	25,420
Steamboat Slough	June 16, 1929	1,310	7,790	1,480	106	418	2,010	9,800
	June 30, 1929	983	5,840	1,080	88	142	1,320	7,160
	July 27, 1929	240	2,490	340	10	10	360	2,850
	Sept. 13, 1929	527	3,860	1,010	1	8	1,020	4,880
	Dec. 18, 1929	13,000	64,400	1,380	136	41	1,560	65,960
	Jan. 4, 1930	2,160	14,500	1,380	39	21	1,450	15,950
	Jan. 9, 1930	5,050	25,700	1,630	178	49	1,950	27,650
Sacramento River below Walnut Grove	June 19, 1929	**6,850	17,400	1,960	320	2,770	5,130	22,530
	July 1, 1929	**1,600	5,340	1,070	79	123	1,270	6,610
	July 28, 1929	** 330	2,590	190	9	10	210	2,800
	Sept. 14, 1929	**1,320	4,060	1,040	1	8	1,050	5,110
	Dec. 21, 1929	**22,820	56,700	1,380	88	34	1,510	58,210
	Jan. 6, 1930	**7,580	17,200	1,430	430	25	1,900	19,100
	Jan. 11, 1930	**9,880	24,200	2,110	149	33	2,390	26,590
Georgiana Slough	May 30, 1929	2,170	9,130	2,260	136	427	2,840	11,970
	June 2, 1929	1,920	7,990	1,960	132	106	2,210	10,200
	June 8, 1929	1,900	7,200	1,250	100	122	1,480	8,680
	June 19, 1929	3,200	16,900	1,960	320	2,770	5,130	22,030
	June 23, 1929	2,400	10,500	2,570	229	886	3,720	14,220
	June 26, 1929	2,060	7,390	1,340	115	224	1,690	9,080
	July 1, 1929	1,870	5,320	1,070	79	123	1,270	6,590
	July 6, 1929	1,430	3,940	870	51	94	1,040	4,980
	July 10, 1929	1,280	3,200	500	37	27	570	3,770
	July 29, 1929	1,290	2,590	260	8	10	280	2,870
	Sept. 20, 1929	1,800	4,930	1,090	1	11	1,100	6,030
	Oct. 15, 1929	1,870	5,770	1,240	5	8	1,250	7,020
	Dec. 13, 1929	5,500	29,500	1,380	162	86	1,630	31,130
	Dec. 16, 1929	8,800	59,700	1,380	157	52	1,590	61,290
	Jan. 5, 1930	2,470	14,300	1,380	39	21	1,450	15,750
	Jan. 10, 1930	4.080	25,300	1,930	178	42	2,250	27,550

Three Mile Slough	June 1, 1929	387	8,970	1,970	134	350	2,460	11,430
	June 3, 1929	561	7,960	1,960	132	106	2,210	10,170
	June 10, 1929	600	7,200	1,250	100	122	1,480	8,680
	June 20, 1929	936	16,800	3,100	291	1,650	5,090	21,890
	June 24, 1929	279	10,200	2,070	192	751	3,030	13,230
	June 28, 1929	1,780	7,330	1,340	115	224	1,690	9,020
	July 2, 1929	205	5,330	1,070	79	123	1,270	6,600
	July 8, 1929	1,370	4,040	870	51	94	1,040	5,080
	July 12, 1929	895	3,450	670	45	35	760	4,210
	July 31, 1929	2,500	2,590	190	9	10	210	2,800
	Aug. 4, 1929	0	2,780	410	5	10	430	3,210
	Aug. 15, 1929	0	2,770	320	2	11	330	3,100
	Aug. 18, 1929	113	2,830	380	2	9	390	3,220
	Aug. 22, 1929	360	2,590	370	1	8	380	2,970
	Aug. 23, 1929	630	2,640	330	1	8	340	2,980
	Aug. 24, 1929	1,520	2,710	350	1	8	360	3,070
	Aug. 25, 1929	983	2,700	350	1	7	360	3,060
	Aug. 27, 1929	990	2,680	290	1	7	300	2,980
	Aug. 29, 1929	1,190	2,760	370	1	7	380	3,140
	Sept. 2, 1929	724	2,690	370	1	7	380	3,070
	Dec. 20, 1929	3,700	103,600	1,330	115	38	1,480	105,080
	Jan. 12, 1930	0	23,800	2,170	162	38	2,470	26,270

* After June 30, 1929, flow records at Thornton were used.
** Flow toward Rio Vista.
[1] Computed net flow for a tidal cycle period of 24 to 25 hours, based upon hourly gagings.

against the flow of the Sacramento River past Sacramento. Separate graphs are shown for Georgiana, Steamboat and Sutter sloughs and the Sacramento River below the head of Georgiana Slough. The data thus plotted show that a close relation exists between the flow in the Sacramento River past Sacramento and the flow through the various sloughs and the lower river.

In the case of all these measurements of flow and the relations established, it must be understood that they apply especially to conditions which existed covering the range of measurements during the 1929 season. In all of the measurements, the flow into the delta from the San Joaquin River system was very small. It is possible that the relation shown as to division of flow would be changed with larger inflow coming from the San Joaquin River system but with like conditions of flow on the Sacramento River. Moreover, any changes in channel conditions or reclamation affecting tidal fluctuation and flow also might modify the relations established from the 1929 measurements.

It is of interest to note that measurements in previous years of the flow through Georgiana Slough, including several made in the summer and fall of 1920 by engineers employed in the Antioch case and a single measurement in August, 1908, by the United States War Department,* check the curve on Plate XXVI reasonably closely. The measurements in 1920 were made for flows in the Sacramento River past Sacramento ranging from about 700 to 8000 second-feet and with small inflows from the San Joaquin River system of similar amount to 1929. The measurement made in 1908 was for a flow in the Sacramento River passing Courtland of about 7400 second-feet. These data from measurements in previous years indicate that the division of flow through Georgiana Slough was about the same as 1929, at least as far back as 1920 and possibly even in previous years.

The flow from the Sacramento River through Georgiana and Three Mile sloughs into the San Joaquin Delta is of chief importance when the flow from the San Joaquin River system is small and insufficient in amount to meet the demands in the San Joaquin Delta for consumptive demands, present or proposed diversions to outside areas, and the repulsion of saline invasion. Hence, inasmuch as conditions approximating those during the period of measurements in 1929 probably will prevail in the future during the summer and fall months, especially with future increase of storage and use of water on the San Joaquin River system, the distribution of flow and particularly the proportional flow through Georgiana Slough as shown by the 1929 measurements may be considered to be applicable to future conditions of consumptive demands in the delta and salinity control. The only changes which might affect the distribution of flow shown by the 1929 measurements and the accuracy of applying the relation shown to future years, would be channel dredging or reclamation works subsequent to 1929 that would result in modification of tidal fluctuation and flow.**

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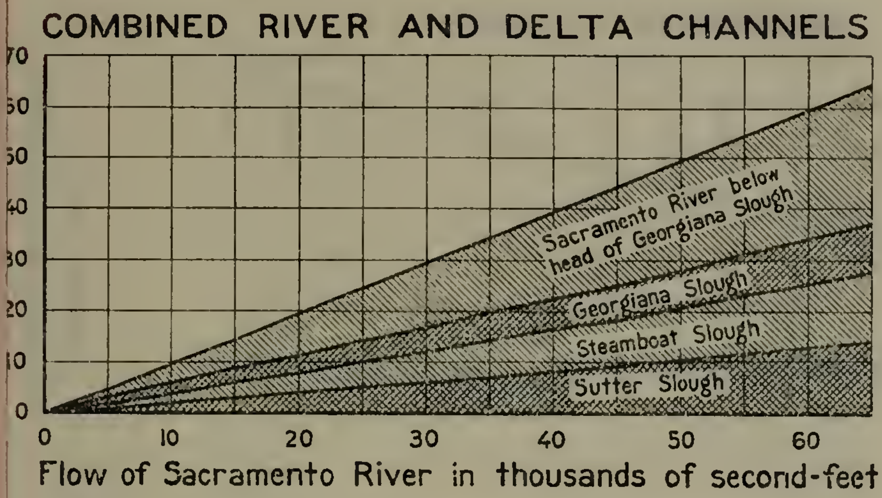
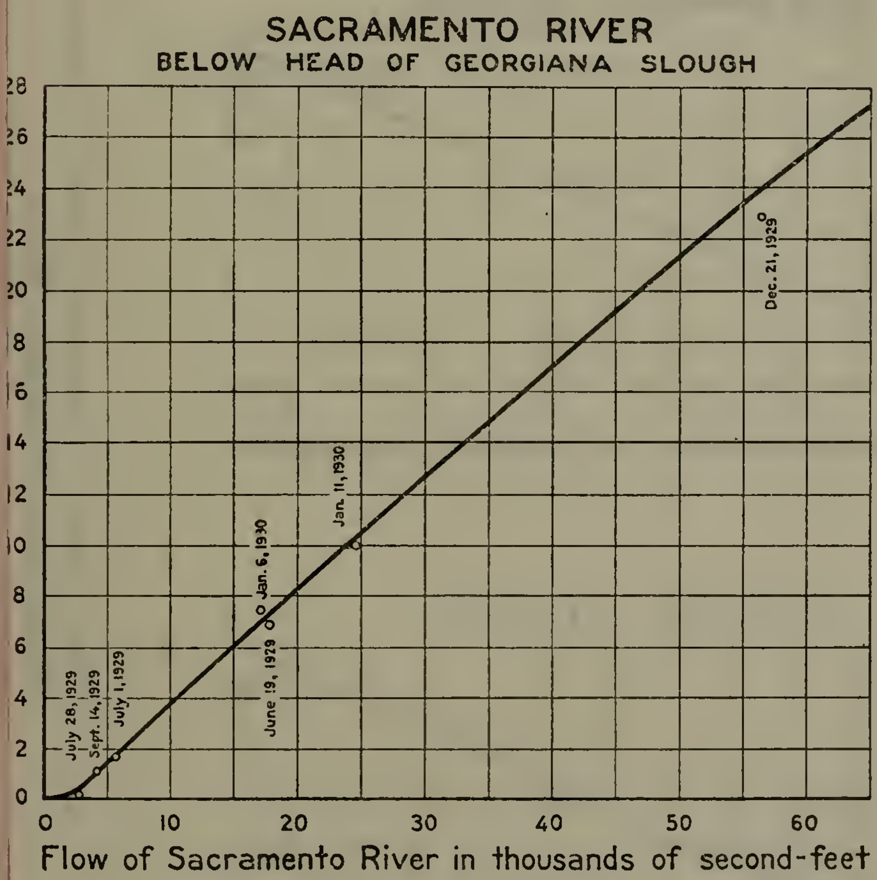
* House document 1123, Sixtieth Congress, Second Session, House of Representatives, 1909, page 18.

** Since the measurements were made in 1929, considerable dredging work was done by the United States War Department in the Sacramento River channel from Rio Vista up to the triple junction of Steamboat Slough, Cache Slough and the main river channel and also up into the main river channel toward Isleton. In order to determine, if possible, whether the changes thus made in the channel had modified the proportional flow through Georgiana Slough, a few measurements were made of





DISTRIBUTION OF FLOW
OF
SACRAMENTO RIVER
THROUGH BRANCH CHANNELS
BELOW SACRAMENTO

against the flow of the Sacramento River past Sacramento. Separate graphs are shown for Georgiana, Steamboat and Sutter sloughs and the Sacramento River below the head of Georgiana Slough. The data thus plotted show that a close relation exists between the flow in the Sacramento River past Sacramento and the flow through the various sloughs and the lower river.

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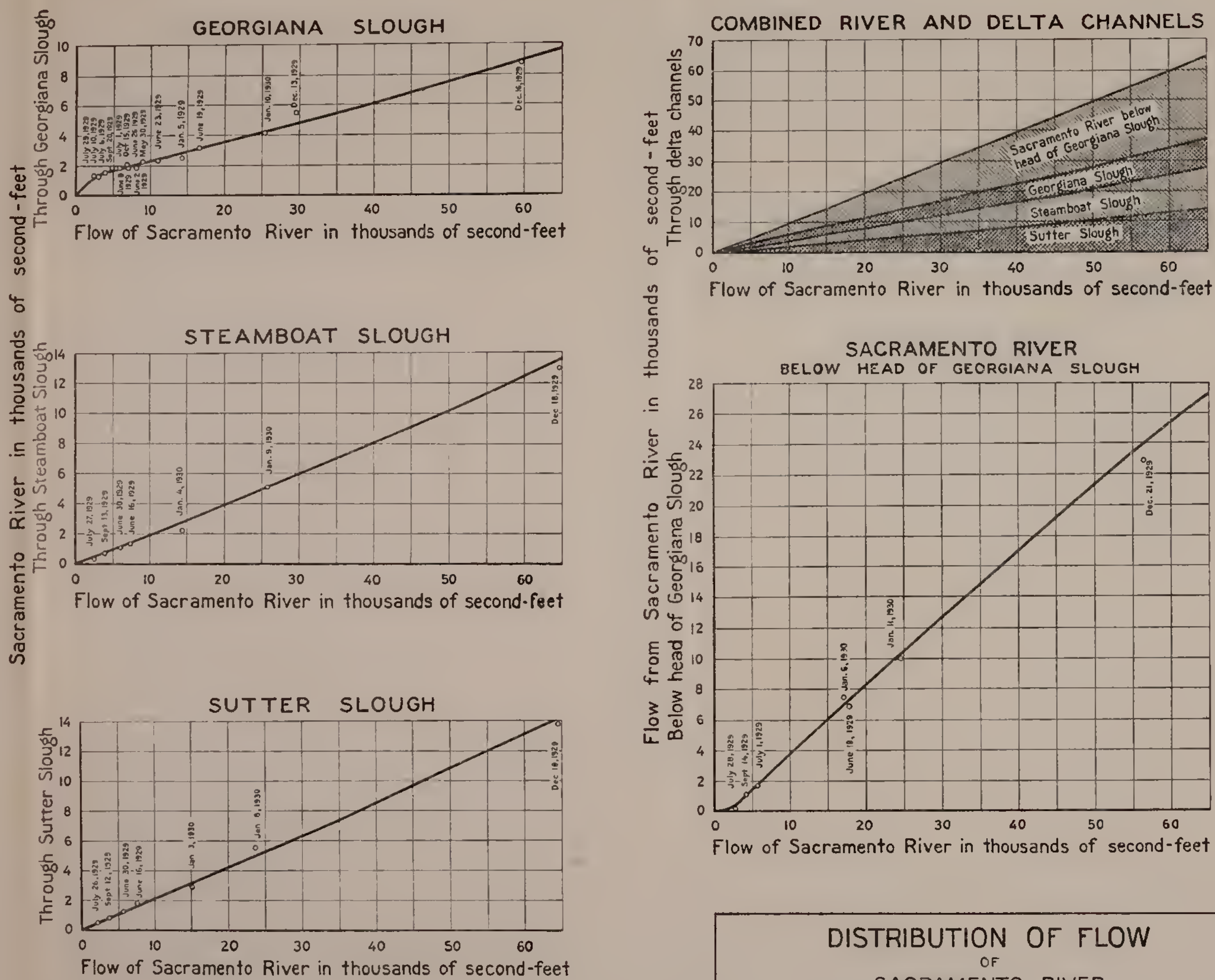
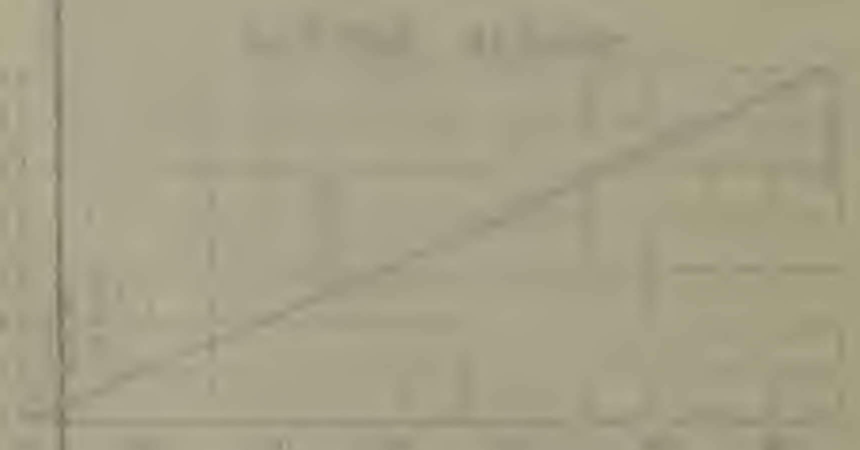
* House document 1123, Sixtieth Congress, Second Session, House of Representatives, 1909, page 18.

** Since the measurements were made in 1929, considerable dredging work was done by the United States War Department in the Sacramento River channel from Rio Vista up to the triple junction of Steamboat Slough, Cache Slough and the main river channel and also up into the main river channel toward Isleton. In order to determine, if possible, whether the changes thus made in the channel had modified the proportional flow through Georgiana Slough, a few measurements were made of



DISTRIBUTION OF FLOW
OF
SACRAMENTO RIVER
THROUGH BRANCH CHANNELS
BELOW SACRAMENTO



The flow through Georgiana Slough is of particular importance, because this slough is the chief connecting channel through which the San Joaquin Delta obtains water from the Sacramento River. Based upon the 1929 measurements, with a flow in the Sacramento River past Sacramento of 3000 second-feet, about 1300 second-feet or 43½ per cent of the total flow is discharged through Georgiana Slough into the San Joaquin Delta; with 5000 second-feet, about 1800 second-feet or 36 per cent of the total flow; with 10,000 second-feet, about 2400 second-feet or 24 per cent; with 20,000 second-feet, about 3500 second-feet or 17½ per cent; with 40,000 second-feet, about 6000 second-feet or 15 per cent; and with 60,000 second-feet, about 9000 second-feet or 15 per cent. It is thus seen that, for the lower flows in the Sacramento River with conditions as in 1929, Georgiana Slough takes a relatively larger share of the total. As the flow of the Sacramento River increases, however, the percentage of the total which flows through Georgiana Slough decreases rapidly.

The diagram in the upper right-hand corner of Plate XXVI shows the division of flow of the Sacramento River between the three sloughs, Georgiana, Steamboat and Sutter, and the Sacramento River below Georgiana Slough. For any flow of the Sacramento River passing Sacramento, the division of flow through the separate channels can be obtained from the diagram. Points on the upper line of the diagram show the total combined flow through the four channels for any flow in the Sacramento River. It will be noted that the points on this line for any flow give total flows through the branch channels slightly less than the flow coming past Sacramento. This is to be expected inasmuch as a part of the total flow is diverted to irrigation or otherwise consumed.

The results of the measurements of flow through Three Mile Slough show that no relation exists between the flow in the Sacramento River and the flow through this slough. Thus, in Table 11 which summarizes all of the measurements made and the corresponding flow of the Sacramento River past Sacramento, the measured flow through Three Mile Slough ranged from nothing to 2500 second-feet with a flow of 2500 to 2800 second-feet in the Sacramento River. With a flow of 7000 second-feet in the Sacramento River, the measured flow through Three Mile Slough ranged for two separate measurements from about 600 to 1800 second-feet. The largest measured net flow through Three Mile Slough occurred when the flow of the Sacramento River was 103.600 second-feet. However, this measured flow which amounted to about 3700 second-feet does not greatly exceed the measured flow on July 31 of 2500 second-feet when the flow of the Sacramento River was only 2590 second-feet. Therefore, it is concluded that the flow through Three Mile Slough is a tidal flow, the magnitude of which depends upon the character of the tide.

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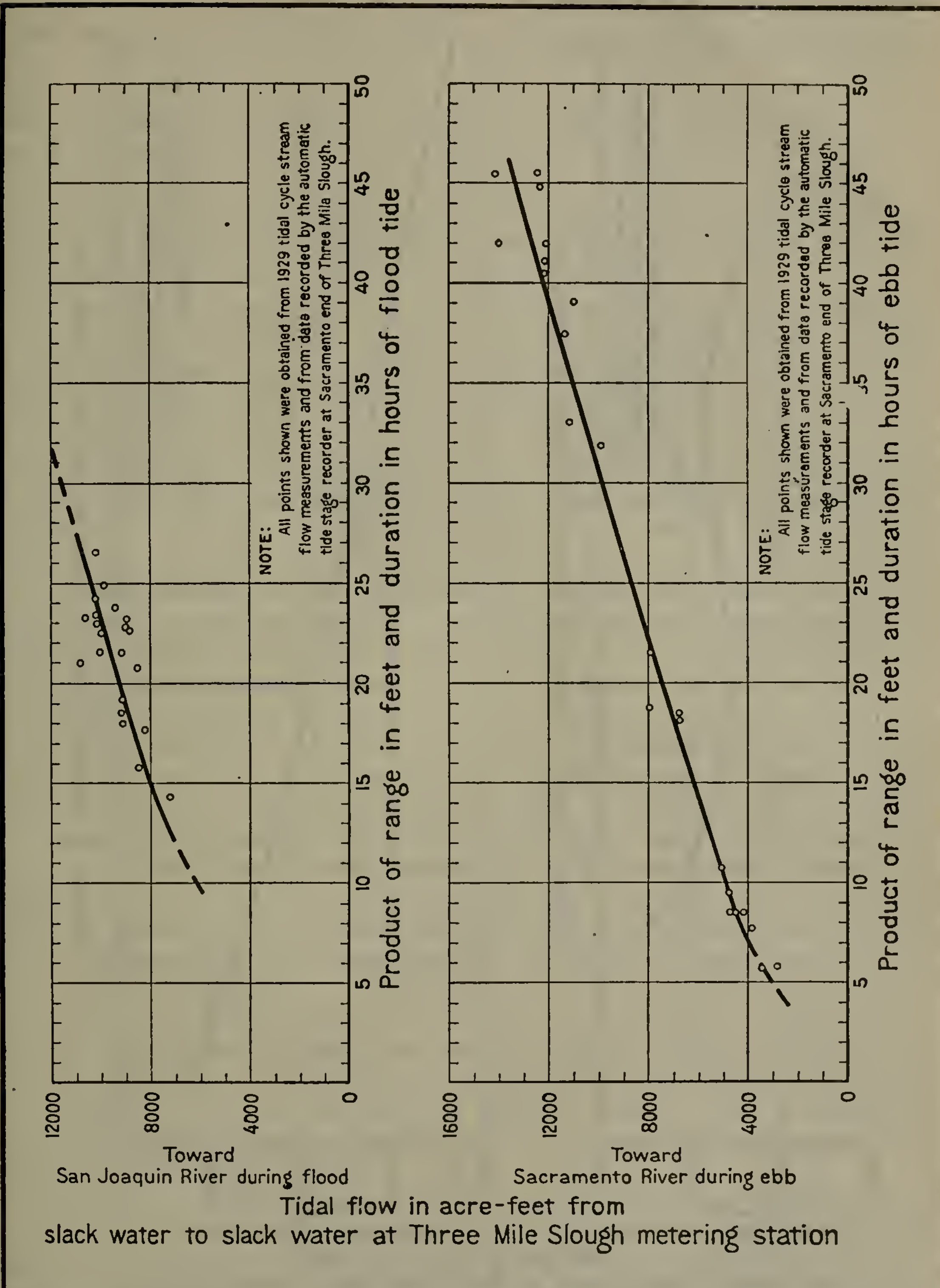
the flow through Georgiana Slough in 1931. These covered ranges in flow of the Sacramento River past Sacramento from 4500 to 1800 second-feet. The results of these measurements indicate that the proportional amount of flow through Georgiana Slough has been decreased below that shown by the 1929 measurements; or in other words that a greater proportion of the flow passing Walnut Grove is now continuing down the main river channel than in 1929. However, the number of measurements made is not sufficient upon which to base a conclusion as to what change, if any, has occurred in the division of. flow at this point.

This fact is supported by the graphs on Plate XXVII, "Relation of Flow Through Three Mile Slough to Range and Duration of Tides at Three Mile Slough," and Plate XXVIII, "Relation of Flow Through Three Mile Slough to Range and Duration of Tides at Presidio." The points on the graphs are plotted using the flow between any two successive tidal phases, such as from low-low to low-high tide, and a figure computed as the product of the tidal range in feet by the duration in hours between the two successive tidal phases. In a tidal cycle of 24 to 25 hours, there are usually four distinct tidal movements which follow in sequence, consisting of a flood tide from low-low to low-high tide, an ebb tide from low-high to high-low tide, a flood tide from high-low to high-high tide and finally an ebb tide from high-high to low-low tide. As shown on Plates XXV, XXVII and XXVIII, the flow through Three Mile Slough is from the Sacramento River to the San Joaquin River during flood tides and from the San Joaquin River to the Sacramento River during the ebb tides. Plate XXVII has been compiled using the tidal data at Three Mile Slough, while Plate XXVIII has been compiled with tidal data at the Presidio. The upper diagrams show the relation of the tidal factor to flow from the Sacramento to the San Joaquin River during flood tides, while the lower diagrams similarly show the relation of the tidal factor to the flow from the San Joaquin to the Sacramento River during ebb tides. There is some scattering of the points but the curves averaging the plotted points show that a fairly close relation exists.

On the basis of the relation established, the movement of the water through Three Mile Slough, during the period of low stream flow when conditions are similar to those during which the measurements were taken in 1929, can be closely estimated in the future if exact tidal records are available either at Three Mile Slough or at the Presidio. If a tide gage were not maintained in the future at Three Mile Slough, the Presidio record will always be available as a basis of estimate and the relations established on Plate XXVIII would be of particular value for this purpose. The computations of flow through Three Mile Slough, based upon the application of tide gage records to the curves on Plate XXVII indicate an average net flow from the Sacramento River to the San Joaquin River of about 950 second-feet with variations from no flow to 2350 second-feet, averaged over a period of about three months in the low water season.

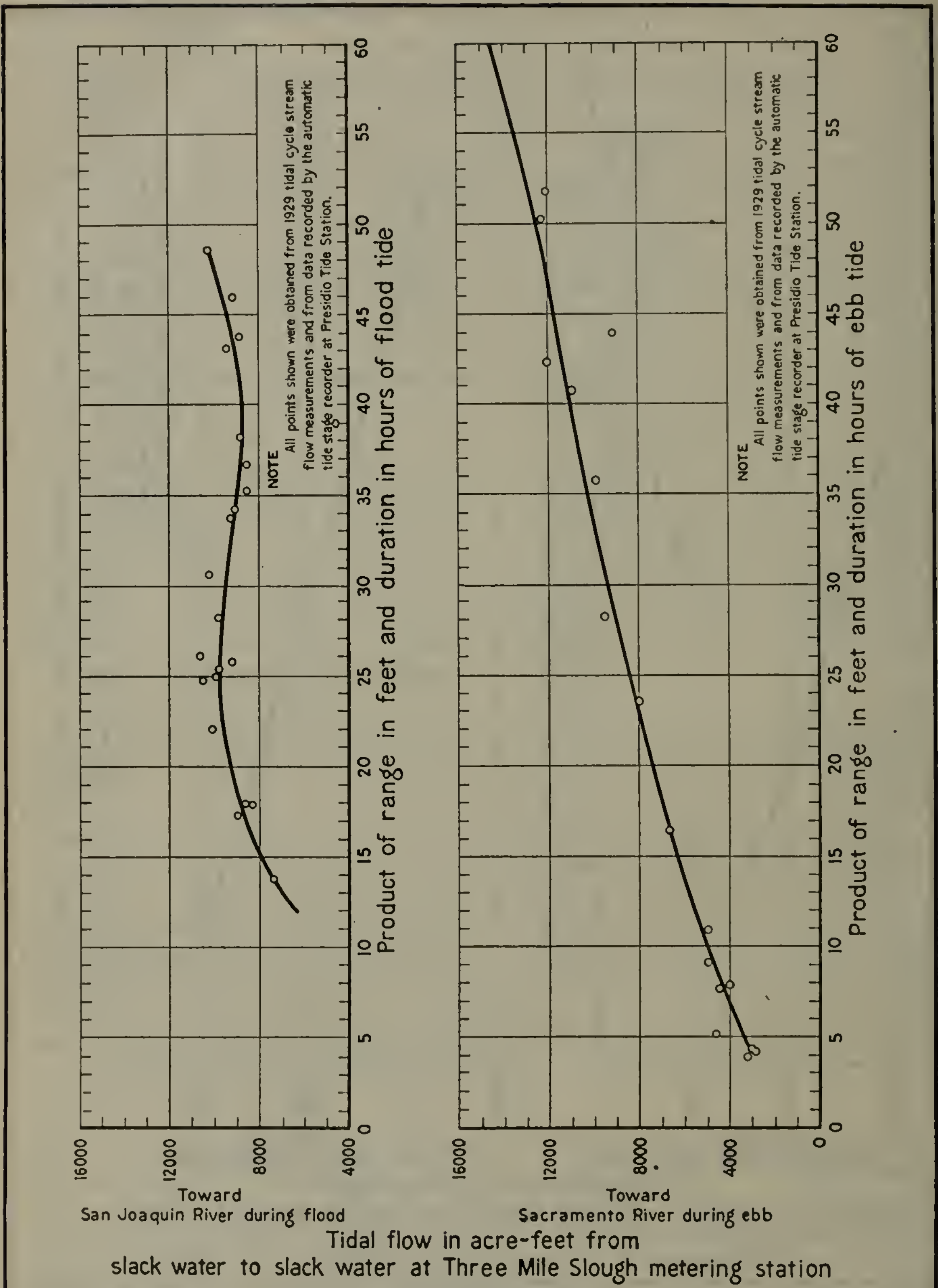
Effect of Distribution of Sacramento River Flow on Salinity—The San Joaquin Delta is dependent in most seasons upon the Sacramento River for the greater part of its water supply. Most of this supply must come through Georgiana Slough. A small additional contribution comes through Three Mile Slough but this is extremely variable and tends to become noneffective, in so far as fresh-water supply is concerned, when the salinity has advanced upstream as far as Three Mile Slough. However, assuming on the average that an average flow of 950 second-feet through Three Mile Slough is an effective additional supply from the Sacramento River to the San Joaquin Delta, there is about an equal division of the total flow of the Sacramento River as between the San Joaquin Delta and the Sacramento Delta, when the flow in the Sacramento River past Sacramento is about 5200 second-feet. For greater flows than 5200 second-feet, a constantly increasing propor-

PLATE XXVII



RELATION OF
TIDAL FLOW THROUGH THREE MILE SLOUGH
TO
RANGE AND DURATION OF TIDES
AT
THREE MILE SLOUGH

PLATE XXVIII



RELATION OF
TIDAL FLOW THROUGH THREE MILE SLOUGH
TO
RANGE AND DURATION OF TIDES
AT
PRESIDIO

tion of the total flow remains in the Sacramento Delta and a constantly decreasing portion goes to the San Joaquin Delta. Thus, with 8000 second-feet in the Sacramento River, only about 3000 second-feet or 37 per cent would be carried to the San Joaquin Delta while 5000 second-feet or 63 per cent would remain in the Sacramento Delta. For flows less than 5200 second-feet, a larger portion of the total goes to the San Joaquin Delta. Thus with 3000 second-feet passing Sacramento, about 2200 second-feet or 73 per cent would go to the San Joaquin and about 800 second-feet or 27 per cent remain in the Sacramento River. All of these figures are based upon measurements for 1929, and might be modified for different conditions in future years.

The total maximum rate of consumption in the delta is estimated at about 3700 second-feet. About two-thirds of this total, or 2500 second-feet, is estimated to be the maximum consumptive rate in the San Joaquin Delta. If it be assumed that all of the water required for the delta would have to come from the Sacramento River, a flow of about 3700 second-feet, or enough to satisfy the total water requirements would result in a flow into the San Joaquin Delta of about 2300 second-feet, while about 1400 second-feet would remain in the Sacramento River channels. This indicates that the present channel capacity between the Sacramento and San Joaquin deltas, as shown by the 1929 measurements, would be just about sufficient to satisfy the proportionate consumptive water requirements, there being only a slight deficiency in the San Joaquin Delta.

However, if the entire supply were coming from the Sacramento River and were just sufficient to meet the consumptive demands of the delta, there would be no excess stream flow available to keep saline water from advancing into the delta. Since the San Joaquin Delta tidal basin has a very much greater area and volume than the Sacramento Delta tidal basin, there would be a greater tendency for the saline water to advance into the San Joaquin than into the Sacramento Delta. Therefore, of the total additional inflow required to prevent saline invasion, the greater proportion of the total would be required in the San Joaquin Delta. If the entire flow required to repel saline invasion were to be furnished from the Sacramento River together with the total supply for consumptive use, the division of the total required flow would not be in proportion to the respective combined requirements of consumptive use and repulsion of saline invasion in the Sacramento and San Joaquin deltas. The portion of the total inflow going to the San Joaquin Delta would be deficient.

Therefore, under conditions where all or most of the water supply for the delta comes from the Sacramento River, it may be concluded that the present channel capacity connecting the two deltas is insufficient to provide the proportionate amount of water required for the San Joaquin Delta. Under present conditions this results usually in a greater extent of saline invasion into the San Joaquin Delta than into the Sacramento Delta, unless the inflow continuously available from the Sacramento River is considerably in excess of the total consumptive requirements of the delta. Moreover, if the entire future water requirements of the delta in the height of the growing season during the summer were to be furnished from the Sacramento River together with additional water supplies required for control of salinity, the effectiveness and flexibility of control would be limited by the lack of required channel capacity from the Sacramento River to the San Joaquin Delta, and it would be necessary to enlarge this connecting channel capacity in order to insure the most effective and efficient results from the water supplies provided.

Water requirements for consumptive demands and salinity control in the San Joaquin Delta could be provided either by increasing the flow into the delta from the San Joaquin River and its main branches, or by making available a supply from the Sacramento River by increasing the present capacity of the interconnecting channels. To provide the greatest effectiveness, this additional channel capacity between the Sacramento River and the San Joaquin Delta should be placed as far upstream as possible so that the flow would be affected least by tidal action and above any point of possible pollution by saline invasion. An increase in channel capacity in the vicinity of Three Mile Slough would have little effectiveness on account of the marked variability and small amount of net flow through this channel. The matter of additional channel capacity will be further discussed in Chapter V.

Effect of Irrigation, Storage and Reclamation Developments on Stream Flow into Delta.

The importance of stream flow as a primary factor governing salinity conditions in the delta and bay channels has heretofore been demonstrated. Therefore, it is of special interest to consider the factors which have modified, or will modify, stream flow. The chief factors modifying stream flow are upstream irrigation and storage developments. Irrigation affects stream flow by a direct consumption of a part of the available natural flow, whereas storage of water may affect not only the distribution of stream flow, but also may result in a final reduction of flow for such storage developments as are primarily for irrigation. As far as the delta and upper bay are concerned and the effect on salinity conditions therein, only developments which directly affect the distribution and amount of surface water in the natural streams which flow into the delta are involved. Consideration has also been given to the affect of reclamation of upstream flood basins, chiefly in the Sacramento Valley, which is a third modifying factor.

The compilation of data on irrigation and storage developments has been somewhat difficult. For the most part, authentic data on irrigated areas, irrigation diversions and storage operations are meagre and frequently unavailable. A search has been made for all sources of data. These have included the U. S. census, State publications, results of unpublished investigations, reports of the U. S. Geological Survey and the U. S. Department of Agriculture, county assessor's records, records of irrigation districts and public and private irrigation companies, power companies and other miscellaneous agencies. The records have been compiled and critically analyzed and it is believed that the data presented are reasonably accurate and the best that can be obtained from the sources available.

Growth of Irrigation—The practice of irrigation in California had its beginnings in the early days of the Spanish occupation. With the coming of the Spanish missionaries, ditches were constructed and water diverted from the streams near the missions for the irrigation of small areas of crops. With the coming of the American settlers into California in the fifties, the necessity of irrigation was immediately realized by the farmers and ditches were constructed and water diverted from the streams for this purpose. In many cases ditches constructed primarily for carrying out of hydraulic-mining enterprises supplied water for the irrigation of nearby farms.

On the streams of the San Joaquin Valley draining directly to the delta area, the first extensive ditch system built primarily for irrigation was constructed in 1852 diverting water from the Merced River for the irrigation of bottom lands. The first large irrigation canal to be completed in the San Joaquin Valley was the San Joaquin and Kings River Canal which started operation in 1871. This canal, the first of a number of canals to be constructed by the Miller and Lux interests, diverts water from the San Joaquin River. By 1890, almost all of the major irrigation systems taking their supply from tributaries of the San Joaquin River, including the Fresno, Merced, Tuolumne, Stanislaus and Mokelumne rivers, had been started. On the main San Joaquin River, considerable development occurred at a later period. Between Patterson and the delta, some irrigation was started as early as 1910 and additional lands were irrigated in 1911 and 1913. However, most of the development taking its supply from this section of the stream was carried out after 1915.

Irrigation in the Sacramento Valley was started just about as early as in the San Joaquin Valley. Development was much slower than in the San Joaquin Valley, due to the more abundant rainfall and to the unusual success of grain farming in the bonanza days of that industry. Most of the early irrigation was on farms in the mountain valleys and foothills served by water supplied from mining ditches. It was not until about 1910 that any great or rapid increase in irrigation development occurred in the Sacramento Valley. At about this time, because of the decline in grain prices and yields and the interest stimulated in irrigation, many of the larger ranches were subdivided and put under irrigation, giving rise to a rapid growth in irrigated agriculture. Later, in about 1916, a more rapid increase in area irrigated and in consumption of water by irrigation was brought about by the inception and growth of the rice industry. This was stimulated by the abnormal demand for foodstuffs during the World War. In 1920 the rice market broke and for the next three years a decline was experienced in irrigated agriculture, mostly due to a reduction of rice farming. Since 1923, however, the area irrigated has again increased and reached a total acreage in excess of that in 1920.

The area irrigated by direct diversion from the Sacramento and San Joaquin River systems is summarized for each year from 1879 to 1929 in Table 12, and graphically shown on Plate XXIX, "Growth in Area Irrigated by Direct Diversion from Sacramento and San Joaquin River Systems Exclusive of Delta of Sacramento and San Joaquin Rivers." Lands irrigated by wells are not included nor are there included any lands irrigated from the Kings River which at times is partially tributary to the San Joaquin River. In the Sacramento Valley, the irrigated area has gradually increased from about 80,000 acres in 1879 to about 220,000 acres in 1910, 286,000 acres in 1915, 502,000 acres in 1920 and 537,000 acres in 1929. In the San Joaquin Valley, the area irrigated gradually increased from about 70,000 in 1879 to 170,000 acres in 1900, and then at a greater rate to about 780,000 acres in 1929. In the 20-year period since 1910, the combined area irrigated in the two valleys from the Sacramento and San Joaquin River systems has more than doubled. The growth in the Sacramento Valley during the last 15 years has been even more noteworthy, with nearly a 100 per cent increase in area irrigated. Most of this growth

TABLE 12

AREA IRRIGATED BY DIRECT DIVERSION FROM SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

Exclusive of Sacramento-San Joaquin Delta

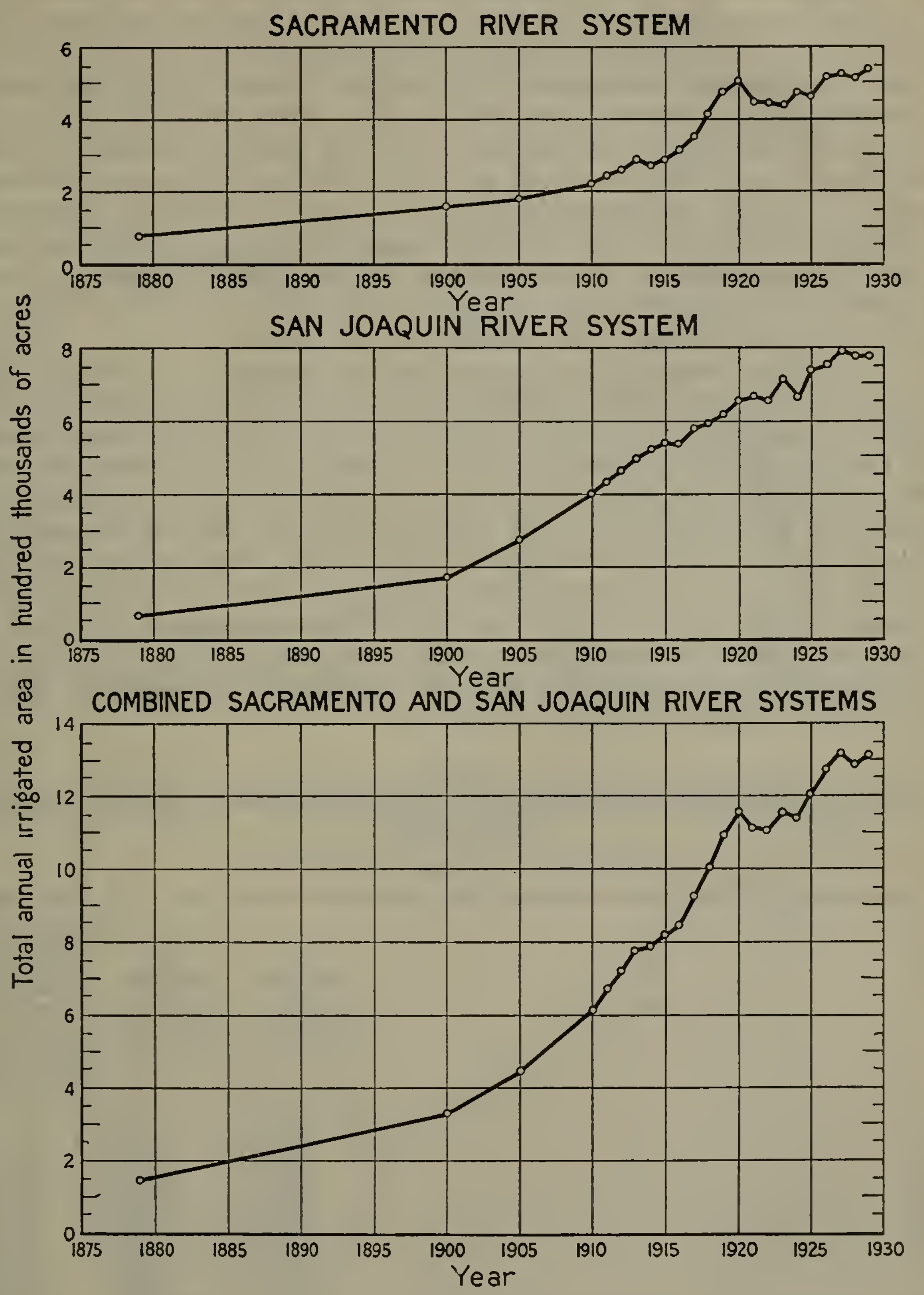
1879-1929

Year	Area irrigated from Sacramento River system in acres	Area irrigated from San Joaquin River system in acres	Total area irrigated from the combined Sacramento and San Joaquin River systems in acres
1879	80,000	70,000	150,000
1900	160,000	170,000	330,000
1905	180,000	270,000	450,000
1910	220,000	400,000	620,000
1911	243,000	430,000	673,000
1912	260,000	463,000	723,000
1913	286,000	494,000	780,000
1914	270,000	522,000	792,000
1915	286,000	540,000	826,000
1916	313,000	537,000	850,000
1917	351,000	579,000	930,000
1918	412,000	599,000	1,011,000
1919	474,000	618,000	1,092,000
1920	502,000	657,000	1,159,000
1921	448,000	669,000	1,117,000
1922	445,000	660,000	1,105,000
1923	438,000	719,000	1,157,000
1924	475,000	668,000	1,143,000
1925	463,000	743,000	1,206,000
1926	515,000	759,000	1,274,000
1927	525,000	794,000	1,319,000
1928	512,000	776,000	1,288,000
1929	537,000	780,000	1,317,000

NOTE.—This table was compiled from data obtained from the U. S. census, county horticultural reports, State Railroad Commission files, irrigation district and water company reports, Federal and State reports and estimates.

occurred in the five-year period, 1915 to 1920, there having been an average increase during this period of over 40,000 acres per year. In the San Joaquin Valley, from 1900 to 1929, there has been a fairly uniform growth averaging about 21,000 acres increase annually. The area irrigated in 1929 is a little less than one and one-half times that irrigated in 1915. For the total area irrigated from the combined river systems, the average growth from 1910 to 1929 has been at the rate of about 36,000 acres annually. During this period, the most rapid growth occurred from 1915 to 1920, chiefly as a reflection of the development in the Sacramento Valley, and was at the rate of about 67,000 acres annually. The foregoing data presented on irrigated areas are compiled from miscellaneous sources and it is not known whether they represent net or gross irrigated areas. However, this is not important in respect to the purpose of presenting these data, namely that of showing the general trend of growth in area irrigated

PLATE XXIX



GROWTH IN AREA IRRIGATED BY DIRECT DIVERSION
FROM
SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS
EXCLUSIVE OF DELTA OF
SACRAMENTO AND SAN JOAQUIN RIVERS

upstream from the delta by direct diversions from the Sacramento and San Joaquin River systems.

These data on area irrigated reflect the effect that irrigation has had upon natural stream flow into the delta. However, the magnitude of this effect is more clearly shown by the amounts of irrigation diversions. Records and estimates of irrigation diversions from the Sacramento and San Joaquin River systems have been compiled by seasons to show the growth in irrigation diversions and by months to show the amount and variation of the monthly distribution of seasonal diversions. Table 13 and Plate XXX, "Growth of Irrigation Diversions from Sacramento and San Joaquin River Systems," show the total annual gross irrigation diversions from 1879 to 1929. Irrigation diversions in the Sacramento-San Joaquin Delta and in the San Joaquin Valley from the Kings River south are not included.

The data presented on annual gross irrigation diversions are partly based upon actual records and partly upon estimates. The estimated amounts have been computed from the irrigated areas, using the best available information as to probable duty of water in acre-feet per acre. For the earlier years, prior to 1900, the figures are practically all estimated. Since 1924, about 70 per cent of the amounts shown for the Sacramento River system, is from actual records. For the San Joaquin River system, however, from 65 to 90 per cent or more of the amounts shown are from actual records as far back as 1912; and, with the exception of 1925 when about 30 per cent of the amount shown was estimated, 85 to 92 per cent of the amounts shown from 1919 to 1929 is from actual records.

TABLE 13

GROSS ANNUAL IRRIGATION DIVERSIONS FROM SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

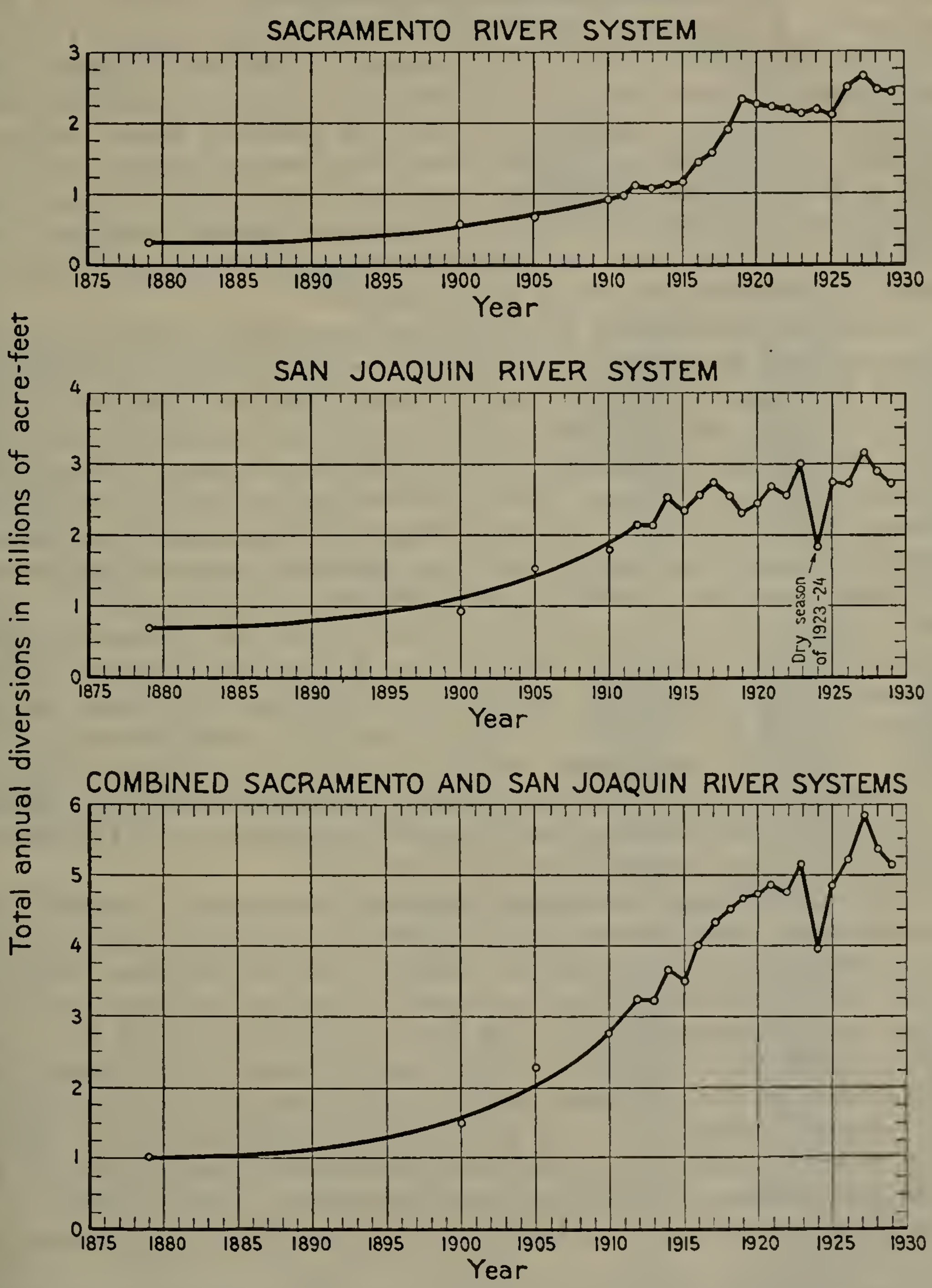
Exclusive of Sacramento-San Joaquin Delta

1879-1929

Year	Gross diversions from Sacramento River system in acre-feet	Gross diversions from San Joaquin River system in acre-feet	Total gross diversions from combined Sacramento and San Joaquin River systems in acre-feet
1879	333,000	674,000	1,007,000
1900	640,000	921,000	1,561,000
1905	730,000	1,529,000	2,259,000
1910	942,000	1,809,000	2,751,000
1912	1,106,000	2,135,000	3,241,000
1913	1,094,000	2,130,000	3,224,000
1914	1,106,000	2,541,000	3,647,000
1915	1,154,000	2,352,000	3,506,000
1916	1,443,000	2,560,000	4,003,000
1917	1,567,000	2,755,000	4,322,000
1918	1,914,000	2,590,000	4,504,000
1919	2,329,000	2,281,000	4,610,000
1920	2,273,000	2,433,000	4,706,000
1921	2,221,000	2,643,000	4,864,000
1922	2,196,000	2,550,000	4,746,000
1923	2,138,000	3,002,000	5,140,000
1924	2,171,000	1,770,000	3,941,000
1925	2,108,000	2,745,000	4,853,000
1926	2,492,000	2,706,000	5,198,000
1927	2,654,000	3,203,000	5,857,000
1928	2,476,000	2,855,000	5,331,000
1929	2,425,000	2,707,000	5,132,000

NOTE.—Compiled from data obtained from the U. S. census, county horticultural report, State Railroad Commission files, irrigation district and water company reports and estimates, Federal and State reports, and estimates.

PLATE XXX



GROWTH OF IRRIGATION DIVERSIONS
FROM
SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

The data indicate that the gross annual irrigation diversions have increased over five times in the 50-year period from 1879 to 1929. For the San Joaquin River system, annual irrigation diversions gradually increased from 674,000 acre-feet in 1879 to 921,000 acre-feet in 1900, and then at a more rapid rate to about 3,000,000 acre-feet in 1923, and 3,200,000 acre-feet in 1927. The decrease in annual irrigation diversions since 1927 and in 1924 has been due chiefly to deficient water supply during dry years. This effect of deficient water supply is particularly noteworthy in 1924 when there was an abrupt drop from 1923 to 1924 of about 1,230,000 acre-feet or about 40 per cent of the total diverted in 1923. As of 1929 the gross annual irrigation diversions from the San Joaquin River system appear to be at the rate of about 3.5 acre-feet per acre of area irrigated.

From the Sacramento River system, gross annual irrigation diversions gradually increased from 333,000 acre-feet in 1879 to 640,000 acre-feet in 1900, and then at a slightly greater rate to 1,154,000 acre-feet in 1915. From 1915 to 1920 a much more rapid increase occurred due to the rice industry, gross annual diversions increasing to about 2,300,000 acre-feet in 1919 and 1920. Following the failure of the rice industry in 1920, the use of water from the Sacramento River system slightly decreased up to 1925 and then gradually increased in the next two years, reaching a total of over 2,600,000 acre-feet in 1927. As of 1929, the gross annual irrigation diversions from the Sacramento River system appear to be at the rate of about 4.5 acre-feet per acre of area irrigated. This larger rate of use in the Sacramento Valley as compared with the San Joaquin Valley is due to the large acreage of rice which is a heavy water user, and the relatively large use of water in the mountain valleys. For the combined Sacramento and San Joaquin River systems, the gross annual irrigation diversions as of 1929 appear to be at the rate of about 3.9 acre-feet per acre.

The growth in gross annual irrigation diversions in general indicates the total magnitude of the progressively increasing diminution of natural stream flow by irrigation. However, all of the water diverted is not actually consumed by the crops and it is estimated from records of return water measurements which have been made during the period 1924 to 1929, that from 35 to 40 per cent or more of the gross irrigation diversions for the main valley lands is returned to the streams and becomes available for use at farther downstream points. Hence, as an approximation, the actual total reduction in natural stream flow of the Sacramento and San Joaquin River system into the delta, due to irrigation, may be considered to be about two-thirds of the gross annual diversions.

The amount of water diverted for irrigation from month to month during the irrigation season varies considerably. Therefore, in order to ascertain the effect of irrigation diversions on stream flow into the delta, the amounts diverted month by month are of special importance and have been compiled for the period 1912 to 1929 from available records and estimates. Records are available on some of the larger canals and irrigation systems over a considerable period of time. Measurements by the Sacramento-San Joaquin water supervisor are available for the years 1924 to 1929 for the Sacramento River system and for the diversions to the delta uplands from the lower San Joaquin

TABLE 14

GROSS MONTHLY IRRIGATION DIVERSIONS FROM SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

Exclusive of Sacramento-San Joaquin Delta

1912 to 1929

Year and month	Gross diversions from Sacramento River system in acre-feet	Gross diversions from San Joaquin River system in acre-feet	Total gross diversions from combined Sacramento and San Joaquin River systems in acre-feet
1912—			
January	0	43,000	43,000
February	0	77,000	77,000
March	4,000	188,000	192,000
April	124,000	286,000	410,000
May	225,000	446,000	671,000
June	221,000	382,000	603,000
July	191,000	288,000	479,000
August	161,000	171,000	332,000
September	154,000	118,000	272,000
October	25,000	68,000	93,000
November	1,000	36,000	37,000
December	0	32,000	32,000
Total annual	1,106,000	2,135,000	3,241,000
1913—			
January	0	43,000	43,000
February	0	77,000	77,000
March	3,000	187,000	190,000
April	116,000	286,000	402,000
May	216,000	445,000	661,000
June	217,000	381,000	598,000
July	194,000	288,000	482,000
August	166,000	170,000	336,000
September	153,000	117,000	270,000
October	28,000	68,000	96,000
November	1,000	36,000	37,000
December	0	32,000	32,000
Total annual	1,094,000	2,130,000	3,224,000
1914—			
January	0	51,000	51,000
February	0	91,000	91,000
March	2,000	224,000	226,000
April	112,000	341,000	453,000
May	214,000	531,000	745,000
June	218,000	455,000	673,000
July	200,000	343,000	543,000
August	173,000	203,000	376,000
September	155,000	140,000	295,000
October	31,000	81,000	112,000
November	1,000	43,000	44,000
December	0	38,000	38,000
Total annual	1,106,000	2,541,000	3,647,000
1915—			
January	0	47,000	47,000
February	0	85,000	85,000
March	3,000	207,000	210,000
April	119,000	315,000	434,000
May	226,000	492,000	718,000
June	228,000	421,000	649,000
July	207,000	318,000	525,000
August	178,000	188,000	366,000
September	161,000	129,000	290,000
October	31,000	75,000	106,000
November	1,000	40,000	41,000
December	0	35,000	35,000
Total annual	1,154,000	2,352,000	3,506,000

TABLE 14—Continued

GROSS MONTHLY IRRIGATION DIVERSIONS FROM SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

Exclusive of Sacramento-San Joaquin Delta

1912 to 1929

Year and month	Gross diversions from Sacramento River system in acre-feet	Gross diversions from San Joaquin River system in acre-feet	Total gross diversions from combined Sacramento and San Joaquin River systems in acre-feet
1916—			
January	0	51,000	51,000
February	0	92,000	92,000
March	5,000	225,000	230,000
April	135,000	343,000	478,000
May	270,000	535,000	805,000
June	285,000	458,000	743,000
July	270,000	346,000	616,000
August	235,000	205,000	440,000
September	198,000	141,000	339,000
October	43,000	82,000	125,000
November	2,000	44,000	46,000
December	0	38,000	38,000
Total annual	1,443,000	2,560,000	4,003,000
1917—			
January	0	55,000	55,000
February	0	99,000	99,000
March	7,000	242,000	249,000
April	142,000	369,000	511,000
May	290,000	576,000	866,000
June	310,000	493,000	803,000
July	296,000	372,000	668,000
August	260,000	221,000	481,000
September	213,000	152,000	365,000
October	47,000	88,000	135,000
November	2,000	47,000	49,000
December	0	41,000	41,000
Total annual	1,567,000	2,755,000	4,322,000
1918—			
January	0	52,000	52,000
February	0	93,000	93,000
March	6,000	228,000	234,000
April	154,000	347,000	501,000
May	347,000	541,000	888,000
June	383,000	464,000	847,000
July	377,000	350,000	727,000
August	333,000	207,000	540,000
September	254,000	142,000	396,000
October	58,000	83,000	141,000
November	2,000	44,000	46,000
December	0	39,000	39,000
Total annual	1,914,000	2,590,000	4,504,000
1919—			
January	0	47,000	47,000
February	0	84,000	84,000
March	7,000	204,000	211,000
April	179,000	312,000	491,000
May	418,000	486,000	904,000
June	467,000	417,000	884,000
July	465,000	314,000	779,000
August	413,000	186,000	599,000
September	305,000	128,000	433,000
October	73,000	52,000	125,000
November	2,000	25,000	27,000
December	0	26,000	26,000
Total annual	2,329,000	2,281,000	4,610,000

TABLE 14—Continued

GROSS MONTHLY IRRIGATION DIVERSIONS FROM SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

Exclusive of Sacramento-San Joaquin Delta

1912 to 1929

Year and month	Gross diversions from Sacramento River system in acre-feet	Gross diversions from San Joaquin River system in acre-feet	Total gross diversions from combined Sacramento and San Joaquin River systems in acre-feet
1920—			
January	0	39,000	39,000
February	0	58,000	58,000
March	3,000	225,000	228,000
April	167,000	411,000	578,000
May	406,000	559,000	965,000
June	457,000	519,000	976,000
July	458,000	269,000	727,000
August	409,000	120,000	529,000
September	299,000	93,000	392,000
October	72,000	67,000	139,000
November	2,000	41,000	43,000
December	0	32,000	32,000
Total annual	2,273,000	2,433,000	4,706,000
1921—			
January	0	35,000	35,000
February	0	70,000	70,000
March	7,000	203,000	210,000
April	169,000	399,000	568,000
May	397,000	559,000	956,000
June	445,000	610,000	1,055,000
July	444,000	397,000	841,000
August	395,000	139,000	534,000
September	291,000	99,000	390,000
October	71,000	63,000	134,000
November	2,000	38,000	40,000
December	0	31,000	31,000
Total annual	2,221,000	2,643,000	4,864,000
1922—			
January	0	50,000	50,000
February	0	51,000	51,000
March	7,000	116,000	123,000
April	169,000	231,000	400,000
May	391,000	567,000	958,000
June	438,000	617,000	1,055,000
July	438,000	514,000	952,000
August	390,000	184,000	574,000
September	290,000	108,000	398,000
October	71,000	70,000	141,000
November	2,000	26,000	28,000
December	0	16,000	16,000
Total annual	2,196,000	2,550,000	4,746,000
1923—			
January	0	20,000	20,000
February	0	71,000	71,000
March	6,000	242,000	248,000
April	165,000	361,000	526,000
May	384,000	637,000	1,021,000
June	428,000	600,000	1,028,000
July	425,000	450,000	875,000
August	378,000	260,000	638,000
September	282,000	163,000	445,000
October	68,000	109,000	177,000
November	2,000	54,000	56,000
December	0	35,000	35,000
Total annual	2,138,000	3,002,000	5,140,000

TABLE 14—Continued

GROSS MONTHLY IRRIGATION DIVERSIONS FROM SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

Exclusive of Sacramento-San Joaquin Delta

1912 to 1929

Year and month	Gross diversions from Sacramento River system in acre-feet	Gross diversions from San Joaquin River system in acre-feet	Total gross diversions from combined Sacramento and San Joaquin River systems in acre-feet
1924—			
January	0	39,000	39,000
February	0	88,000	88,000
March	3,000	170,000	173,000
April	223,000	296,000	519,000
May	414,000	439,000	853,000
June	423,000	210,000	633,000
July	410,000	168,000	578,000
August	357,000	132,000	489,000
September	277,000	81,000	358,000
October	62,000	62,000	124,000
November	2,000	50,000	52,000
December	0	35,000	35,000
Total annual	2,171,000	1,770,000	3,941,000
1925—			
January	0	79,000	79,000
February	0	86,000	86,000
March	6,000	180,000	186,000
April	126,000	300,000	426,000
May	315,000	556,000	871,000
June	426,000	578,000	1,004,000
July	447,000	417,000	864,000
August	403,000	226,000	629,000
September	318,000	156,000	474,000
October	65,000	90,000	155,000
November	2,000	44,000	46,000
December	0	33,000	33,000
Total annual	2,108,000	2,745,000	4,853,000
1926—			
January	0	54,000	54,000
February	0	106,000	106,000
March	7,000	242,000	249,000
April	164,000	409,000	573,000
May	447,000	590,000	1,037,000
June	525,000	404,000	929,000
July	517,000	312,000	829,000
August	453,000	244,000	697,000
September	299,000	156,000	455,000
October	78,000	92,000	170,000
November	2,000	62,000	64,000
December	0	35,000	35,000
Total annual	2,492,000	2,706,000	5,198,000
1927—			
January	0	59,000	59,000
February	0	42,000	42,000
March	8,000	133,000	141,000
April	168,000	323,000	491,000
May	474,000	633,000	1,107,000
June	521,000	630,000	1,151,000
July	540,000	517,000	1,057,000
August	488,000	351,000	839,000
September	355,000	270,000	625,000
October	97,000	152,000	249,000
November	3,000	50,000	53,000
December	0	43,000	43,000
Total annual	2,654,000	3,203,000	5,857,000

TABLE 14—Continued

GROSS MONTHLY IRRIGATION DIVERSIONS FROM SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

Exclusive of Sacramento-San Joaquin Delta

1912 to 1929

Year and month	Gross diversions from Sacramento River system in acre-feet	Gross diversions from San Joaquin River system in acre-feet	Total gross diversions from combined Sacramento and San Joaquin River systems in acre-feet
1928—			
January	0	34,000	34,000
February	0	79,000	79,000
March	7,000	179,000	186,000
April	184,000	318,000	502,000
May	464,000	609,000	1,073,000
June	502,000	489,000	991,000
July	491,000	369,000	860,000
August	448,000	312,000	760,000
September	299,000	238,000	537,000
October	79,000	125,000	204,000
November	2,000	65,000	67,000
December	0	38,000	38,000
Total annual	2,476,000	2,855,000	5,331,000
1929—			
January	0	16,000	16,000
February	0	46,000	46,000
March	4,000	162,000	166,000
April	295,000	363,000	658,000
May	493,000	570,000	1,063,000
June	431,000	410,000	841,000
July	445,000	382,000	827,000
August	399,000	364,000	763,000
September	274,000	211,000	485,000
October	82,000	95,000	177,000
November	2,000	46,000	48,000
December	0	42,000	42,000
Total annual	2,425,000	2,707,000	5,132,000

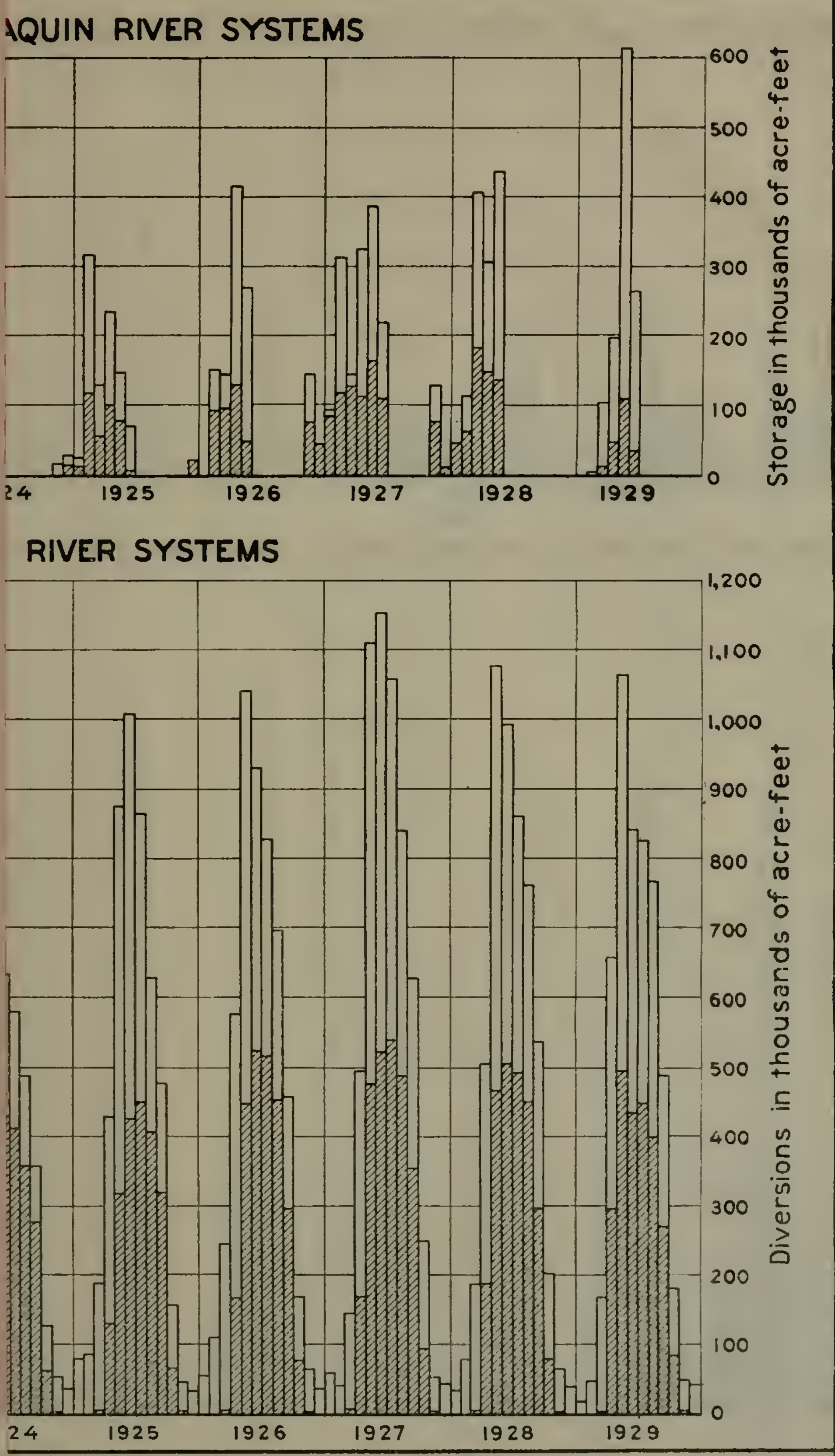
NOTE.—This table was compiled from data obtained from the U. S. census, county horticultural reports, State Railroad Commission files, irrigation district and water company reports and estimates, Federal and State reports, and estimates.

River and tributary channels of the delta. On the San Joaquin River system, there are records of the diversions from the Tuolumne and Stanislaus rivers, from the main San Joaquin River through some of the Miller and Lux canals, from the Fresno River (Madera Canal) and from the Merced and Mokelumne rivers. These afford a fairly complete record during the period 1920 to 1929, but estimates in a few instances were necessary to complete periods of missing records. No records were available for the Chowchilla, Calaveras and Cosumnes rivers. Where no records were available, the monthly diversions were estimated from the total annual diversions based upon the best data available as to the monthly distribution of total annual use. The estimates of the monthly diversions for periods of missing records were based upon actual measurements on irrigation systems supplying areas of similar character.

The gross monthly irrigation diversions are summarized for the years 1912 to 1929, inclusive, in Table 14, and are graphically shown on the lower diagram of Plate XXXI, "Monthly Diversions for Irrigation and Storage from Sacramento and San Joaquin River Systems, Exclusive of Deltas of Sacramento and San Joaquin Rivers." The data presented, although approximate, furnish a reasonable estimate of the gross monthly irrigation diversions, and afford a basis for judging the gross amount of the progressively increasing monthly diminution of stream flow into the delta by direct irrigation diversions.

Growth of Reservoir Storage Developments—The growth and development of storage works for irrigation, power and municipal water supply is another important factor modifying stream flow into the delta. Data have been gathered on reservoir storage capacity and on the amounts diverted to and released from storage. The data have been obtained from all available sources and include all of the important storage developments on the Sacramento and San Joaquin River systems.

Table 15 and Plate XXXII, "Growth of Reservoir Storage Capacity in Sacramento and San Joaquin River Systems," show the growth in reservoir storage capacity for the Sacramento River and the San Joaquin River systems separately and combined. The capacity of storage reservoirs for the combined river systems increased from about 2000 acre-feet in 1850, which is the earliest record available, to about 200,000 acre-feet in 1907, or an increase at the rate of only 3500 acre-feet per year. Most of the storage development has occurred since 1910, and about two-thirds of the total since 1920. In the period 1910 to 1929, new storage developments have been constructed on the Sacramento River system to the amount of 2,171,000 acre-feet, and on the San Joaquin River system to the amount of 1,576,000 acre-feet. Nearly 3,000,000 acre-feet of storage on the combined river systems was added from 1920 to 1929. The average rate of growth of storage capacity on the combined river systems from 1910 to 1929 has been about 200,000 acre-feet per year. This development has been partly for irrigation, partly for power and to a smaller extent for municipal water supply. Table 16 summarizes data for the more important reservoirs having a capacity of 50,000 acre-feet or more, showing gross storage capacity, date of construction, location and the purpose for which the water is used.



LY DIVERSIONS FOR IRRIGATION AND STORAGE
FROM
ACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS
E OF DELTAS OF SACRAMENTO AND SAN JOAQUIN RIVERS

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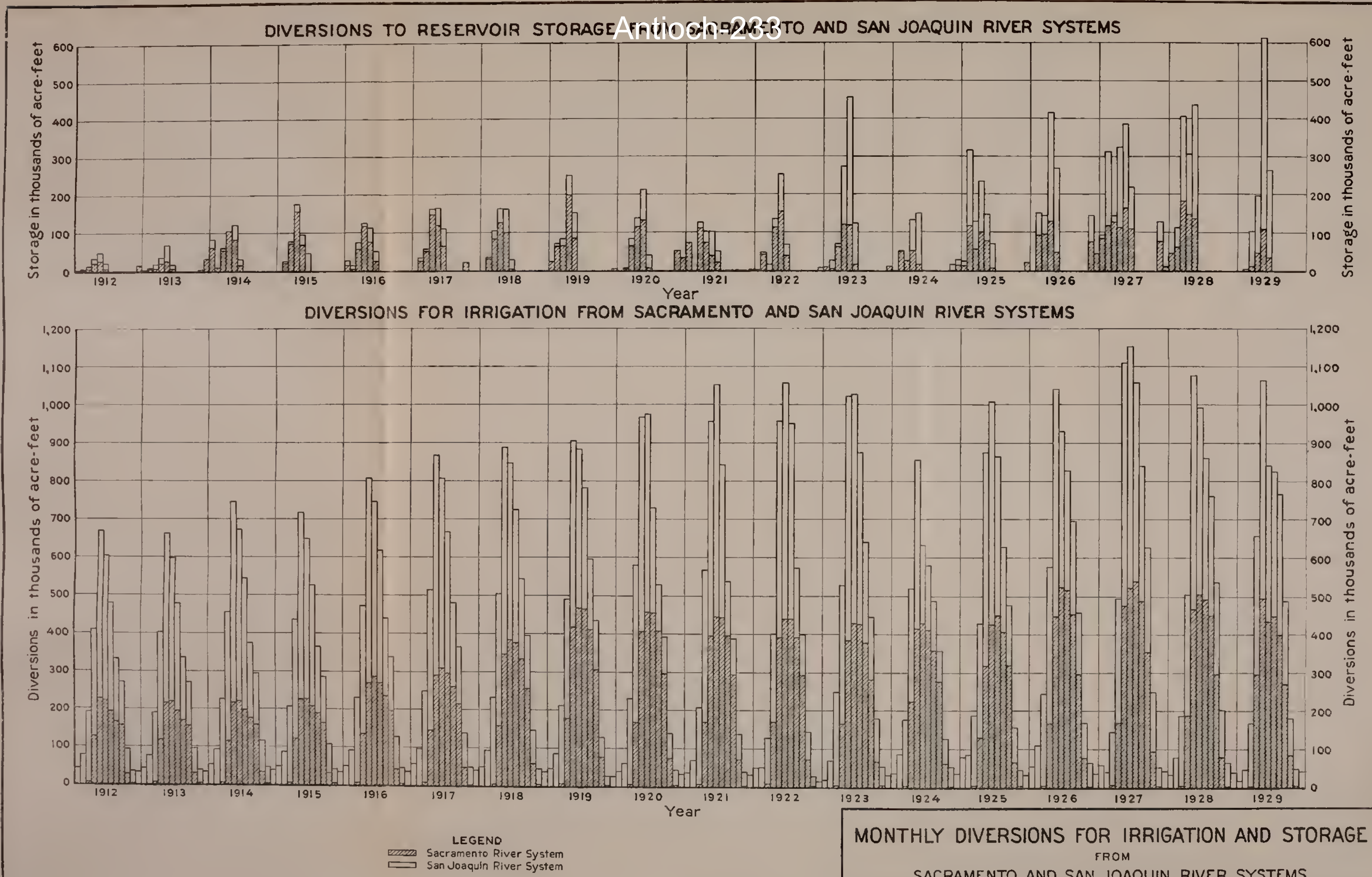

MONTHLY DIVERSIONS FOR IRRIGATION AND STORAGE
FROM
SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS
EXCLUSIVE OF DELTAS OF SACRAMENTO AND SAN JOAQUIN RIVERS

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TABLE 15

RESERVOIR STORAGE CAPACITY ON SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

1850-1929

Year	Sacramento River system		San Joaquin River system		Combined Sacramento and San Joaquin River systems	
	Storage capacity added in acre-feet	Accumulated storage capacity in acre-feet	Storage capacity added in acre-feet	Accumulated storage capacity in acre-feet	Storage capacity added in acre-feet	Accumulated storage capacity in acre-feet
1850	2,000	2,000	0	0	2,000	2,000
1852	0	2,000	3,000	3,000	3,000	5,000
1855	2,000	4,000	0	3,000	2,000	7,000
1856	15,000	19,000	4,000	7,000	19,000	26,000
1857	0	19,000	1,000	8,000	1,000	27,000
1859	16,000	35,000	0	8,000	16,000	43,000
1962	0	35,000	10,000	18,000	10,000	53,000
1864	10,000	45,000	0	18,000	10,000	63,000
1870	4,000	49,000	0	18,000	4,000	67,000
1871	1,000	50,000	0	18,000	1,000	68,000
1872	12,000	62,000	7,000	25,000	19,000	87,000
1873	3,000	65,000	0	25,000	3,000	90,000
1874	0	65,000	4,000	29,000	4,000	94,000
1875	1,000	66,000	0	29,000	1,000	95,000
1876	10,000	76,000	6,000	35,000	16,000	111,000
1877	3,000	79,000	0	35,000	3,000	114,000
1878	1,000	80,000	0	35,000	1,000	115,000
1880	0	80,000	1,000	36,000	1,000	116,000
1881	16,000	96,000	0	36,000	16,000	132,000
1883	[1]—15,000	81,000	0	36,000	[1]—15,000	117,000
1884	8,000	89,000	15,000	51,000	23,000	140,000
1885	5,000	94,000	1,000	52,000	6,000	146,000
1887	0	94,000	1,000	53,000	1,000	147,000
1888	0	94,000	3,000	56,000	3,000	150,000
1890	1,000	95,000	0	56,000	1,000	151,000
1891	0	95,000	5,000	61,000	5,000	156,000
1895	1,000	96,000	0	61,000	1,000	157,000
1898	1,000	97,000	1,000	62,000	2,000	159,000
1899	0	97,000	6,000	68,000	6,000	165,000
1900	8,000	105,000	7,000	75,000	15,000	180,000
1901	3,000	108,000	2,000	77,000	5,000	185,000
1902	11,000	119,000	2,000	79,000	13,000	198,000
1905	2,000	121,000	0	79,000	2,000	200,000
1907	2,000	123,000	2,000	81,000	4,000	204,000
1909	56,000	179,000	5,000	86,000	61,000	265,000
1910	2,000	181,000	86,000	172,000	88,000	353,000
1911	10,000	191,000	0	172,000	10,000	363,000
1912	1,000	192,000	0	172,000	1,000	364,000
1913	47,000	239,000	89,000	261,000	136,000	500,000
1914	535,000	774,000	0	261,000	535,000	1,035,000
1915	3,000	777,000	49,000	310,000	52,000	1,087,000
1916	26,000	803,000	17,000	327,000	43,000	1,130,000
1917	79,000	882,000	28,000	355,000	107,000	1,237,000
1918	24,000	906,000	36,000	391,000	60,000	1,297,000
1919	12,000	918,000	0	391,000	12,000	1,309,000
1920	1,000	919,000	4,000	395,000	5,000	1,314,000
1921	80,000	999,000	3,000	398,000	83,000	1,397,000
1922	3,000	1,022,000	26,000	424,000	29,000	1,426,000
1923	6,000	1,008,000	469,000	893,000	475,000	1,901,000
1924	79,000	1,087,000	0	893,000	79,000	1,980,000
1925	46,000	1,133,000	0	893,000	46,000	2,026,000
1926	1,041,000	2,174,000	466,000	1,359,000	1,507,000	3,533,000
1927	14,000	2,188,000	136,000	1,495,000	150,000	3,683,000
1928	165,000	2,353,000	240,000	1,735,000	405,000	4,088,000
1929	[2]—1,000	2,352,000	13,000	1,748,000	12,000	4,100,000

[1] English dam on the Middle Yuba River failed.
[2] Dams in Modoc County failed.

NOTES:
This table was compiled from data from the following sources:
Bulletin No. 100, "Report of Irrigation Investigations in California," United States Department of Agriculture, Office of Experiment Stations, 1901.
"Practical Treatise on Hydraulic Mining," August J. Bowie, 1885.
"Reservoirs for Irrigation and Water Supply," James D. Schuyler, 1900.
Water Supply Paper No. 493, 1923.
Bulletin No. 21, "Irrigation Districts in California," Division of Engineering and Irrigation, 1929.
Data on file in office of State Engineer.

TABLE 16

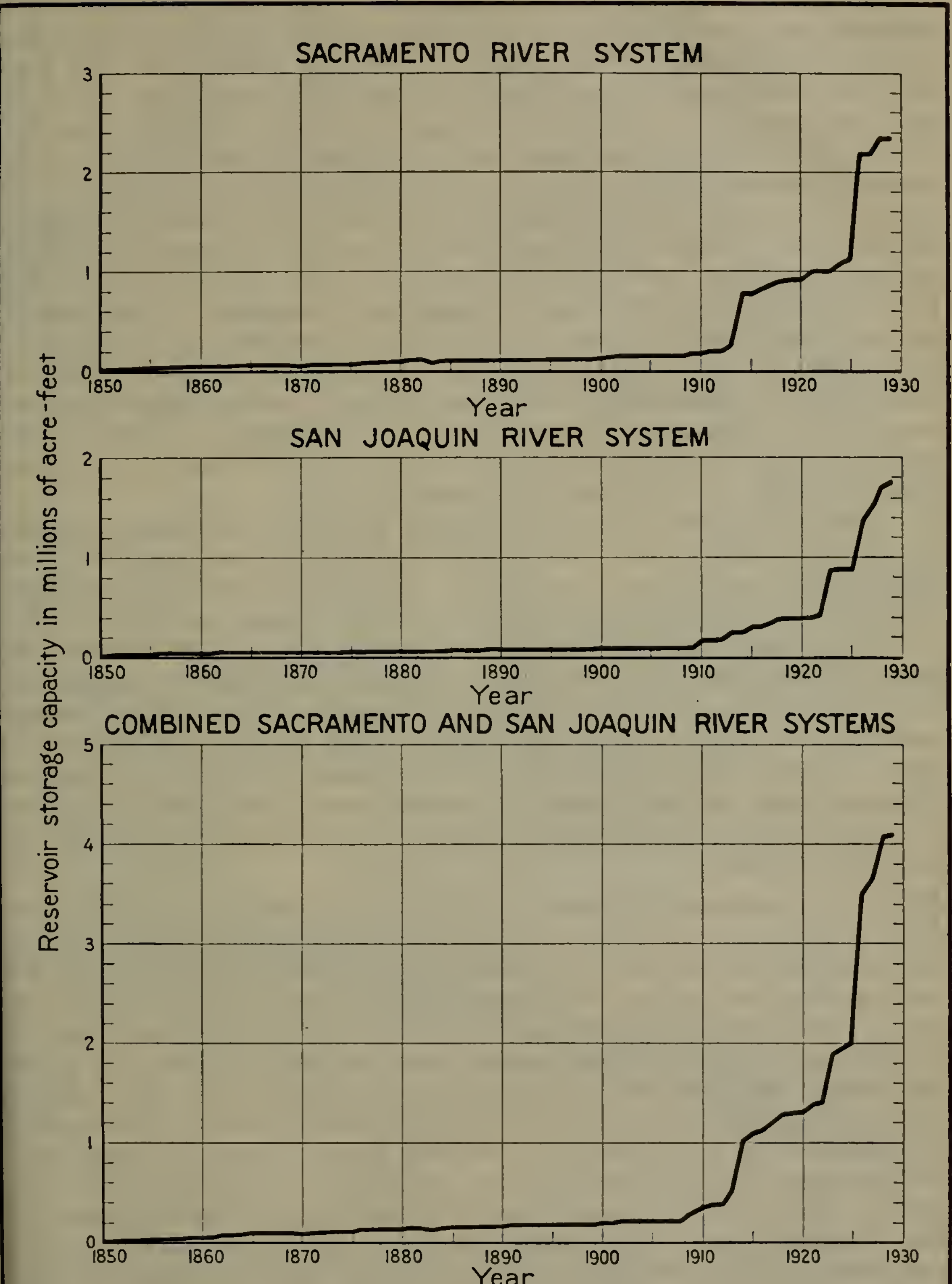
PRINCIPAL STORAGE RESERVOIRS ON SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

Including only reservoirs of 50,000 acre-feet or more capacity.

Stream	Reservoir	Date of construction	Total storage capacity in acre-feet	Use of water
Stony Creek	East Park	1910	51,000	Irrigation
	Stony Gorge	1928	50,200	Irrigation
Feather River	Lake Almanor	1914	224,000	Power and irrigation
	Lake Almanor	1917	300,000	Power and irrigation
	Lake Almanor	1927	1,308,000	Power and irrigation
	Butt Valley	1924	49,800	Power and irrigation
	Bucks Creek	1928	103,000	Power and irrigation
Pit River	Big Sage	1921	*77,000	Irrigation
Yuba River	Bowman	1876	20,700	Irrigation, power and mining
	Bowman	1927	67,000	Irrigation, power and mining
	Lake Spaulding	1913	43,500	Power and irrigation
	Lake Spaulding	1916	64,000	Power and irrigation
	Lake Spaulding	1919	74,500	Power and irrigation
Mokelumne River	Pardee	1929	222,000	Municipal
Stanislaus River	Melones	1926	113,000	Power and irrigation
Tuolumne River	Hetch Hetchy	1923	206,000	Power and municipal
	Don Pedro	1923	290,000	Power and irrigation
Merced River	Exchequer	1926	279,000	Power and irrigation
San Joaquin River	Huntington Lake	1913	45,000	Power
	Huntington Lake	1917	88,800	Power
	Florence Lake	1926	64,400	Power
	Shaver Lake	1927	135,300	Power

*Largest volume stored, 22,500 acre-feet in 1922.

PLATE XXXII



GROWTH OF RESERVOIR STORAGE CAPACITY

IN

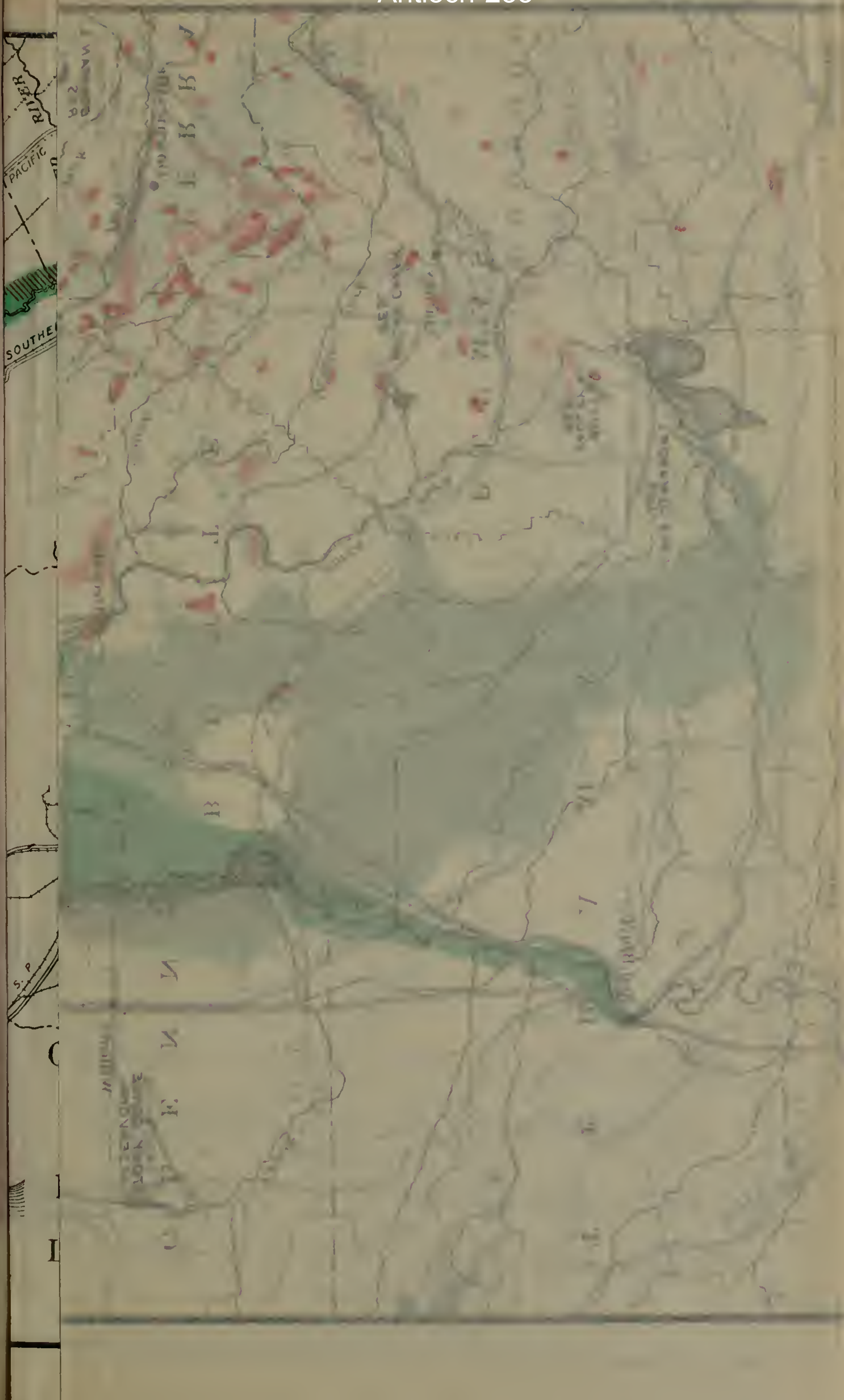
SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

The operation of these storage developments has modified the stream flow naturally tributary to the delta. The effect on stream flow is shown by a consideration of the available data on diversions to and releases from storage. Such data for both the Sacramento and San Joaquin River systems have been compiled as a composite of actual operating records of individual storage reservoirs, obtained from the owners of the various reservoirs, including power companies, irrigation districts, municipalities and private and public water systems of all kinds. In general, the computations of the diversions to storage and the releases from storage have been based on records of water levels and the area-capacity curves of the reservoirs. In certain cases actual figures of measured inflow and release were available. In the case of all large reservoirs, the amounts computed from reservoir levels have been corrected for evaporation. For diversions to storage, estimated evaporation has been added to the net volume of increased storage computed from difference in water levels. For reservoir releases, estimated evaporation has been deducted from the net amount of release computed from the difference in reservoir levels.

Table 17 shows the estimated gross monthly diversions to storage for the Sacramento and San Joaquin River systems separately and combined for each year covering the period 1912 to 1929, inclusive. These are also graphically shown on the upper diagram of Plate XXXI.

The gross monthly diversions to storage taken together with the gross monthly irrigation diversions in general indicate the magnitude of the reduction of natural stream flow into the delta for the various months and years covering the period 1912 to 1929. However, to obtain a more exact conception of the combined effect of irrigation diversions and storage operations, account must be taken of the amount of return water from irrigation, and the period, amount and use of reservoir releases.

Effect of Upstream Reclamation Development on Stream Flow into Delta—Reclamation development, especially in the Sacramento Valley, has modified the regimen of stream flow into the delta because of the cutting-off of the natural flood basins which flank the main river channels. Under natural conditions, water stored in these basins from the overflow of the rivers during winter floods gradually drained out in the late spring and early summer months and augmented the flow into the delta during these latter periods. The flood basins which, under natural conditions, held large quantities of flood water in years of large runoff comprise Butte, Sutter, Colusa, American, Sacramento and Yolo basins. There were also smaller areas of bottom lands flooded along the San Joaquin River. These basins and the area flooded under natural conditions by overflow along the Sacramento and San Joaquin River systems are shown in green on Plate XXXIII, "Changes in Flood Channels and Basins of Sacramento and San Joaquin Rivers Effected by Flood Control and Reclamation Development and Location of Auriferous Gravel Areas." The portion of the original flooded area now reclaimed is shown by red cross hatching superimposed on the green.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The operation of these storage developments has modified the stream flow naturally tributary to the delta. The effect on stream flow is shown by a consideration of the available data on diversions to and releases from storage. Such data for both the Sacramento and San Joaquin River systems have been compiled as a composite of actual operating records of individual storage reservoirs, obtained from the owners of the various reservoirs, including power companies, irrigation districts, municipalities and private and public water systems of all kinds. In general, the computations of the diversions to storage and the releases from storage have been based on records of water levels and the area-capacity curves of the reservoirs. In certain cases actual figures of measured inflow and release were available. In the case of all large reservoirs, the amounts computed from reservoir levels have been corrected for evaporation. For diversions to storage, estimated evaporation has been added to the net volume of increased storage computed from difference in water levels. For reservoir releases, estimated evaporation has been deducted from the net amount of release computed from the difference in reservoir levels.

Table 17 shows the estimated gross monthly diversions to storage for the Sacramento and San Joaquin River systems separately and combined for each year covering the period 1912 to 1929, inclusive. These are also graphically shown on the upper diagram of Plate XXXI.

The gross monthly diversions to storage taken together with the gross monthly irrigation diversions in general indicate the magnitude of the reduction of natural stream flow into the delta for the various months and years covering the period 1912 to 1929. However, to obtain a more exact conception of the combined effect of irrigation diversions and storage operations, account must be taken of the amount of return water from irrigation, and the period, amount and use of reservoir releases.

Effect of Upstream Reclamation Development on Stream Flow into Delta—Reclamation development, especially in the Sacramento Valley, has modified the regimen of stream flow into the delta because of the cutting-off of the natural flood basins which flank the main river channels. Under natural conditions, water stored in these basins from the overflow of the rivers during winter floods gradually drained out in the late spring and early summer months and augmented the flow into the delta during these latter periods. The flood basins which, under natural conditions, held large quantities of flood water in years of large run-off comprise Butte, Sutter, Colusa, American, Sacramento and Yolo basins. There were also smaller areas of bottom lands flooded along the San Joaquin River. These basins and the area flooded under natural conditions by overflow along the Sacramento and San Joaquin River systems are shown in green on Plate XXXIII, "Changes in Flood Channels and Basins of Sacramento and San Joaquin Rivers Effected by Flood Control and Reclamation Development and Location of Auriferous Gravel Areas." The portion of the original flooded area now reclaimed is shown by red cross hatching superimposed on the green.

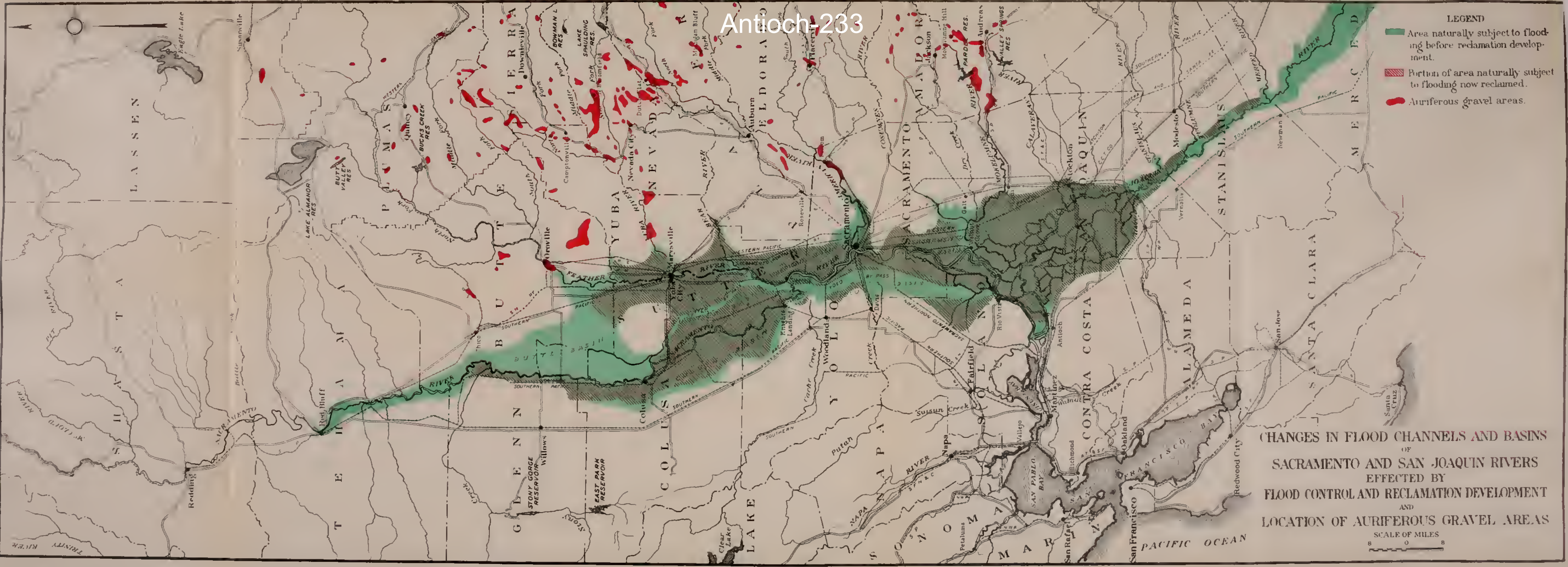
Antioch-233
LEGEND
Area naturally subject to flooding before reclamation development.
Portion of area naturally subject to flooding now reclaimed.
Auriferous gravel areas.
CHANGES IN FLOOD CHANNELS AND BASINS
OF
SACRAMENTO AND SAN JOAQUIN RIVERS
EFFECTED BY
FLOOD CONTROL AND RECLAMATION DEVELOPMENT
AND
LOCATION OF AURIFEROUS GRAVEL AREAS
SCALE OF MILES
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TABLE 17

MONTHLY GROSS DIVERSIONS TO STORAGE ON SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

1912–1929

Year and month	Gross storage diversions from Sacramento River system in acre-feet	Gross storage diversions from San Joaquin River system in acre-feet	Total gross storage diversions from combined Sacramento and San Joaquin River systems in acre-feet
1912—			
January	2,000	0	2,000
February	3,000	3,000	6,000
March	5,000	8,000	13,000
April	20,000	13,000	33,000
May	26,000	24,000	50,000
June	7,000	13,000	20,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	13,000	0	13,000
Total annual	76,000	61,000	137,000
1913—			
January	0	2,000	2,000
February	5,000	4,000	9,000
March	7,000	11,000	18,000
April	20,000	14,000	34,000
May	25,000	45,000	70,000
June	4,000	12,000	16,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	3,000	0	3,000
December	31,000	0	31,000
Total annual	95,000	88,000	183,000
1914—			
January	62,000	21,000	83,000
February	9,000	5,000	14,000
March	54,000	7,000	61,000
April	106,000	0	106,000
May	83,000	39,000	122,000
June	16,000	16,000	32,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total annual	330,000	88,000	418,000
1915—			
January	0	0	0
February	21,000	4,000	25,000
March	72,000	5,000	77,000
April	159,000	18,000	177,000
May	69,000	28,000	97,000
June	0	46,000	46,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total annual	321,000	101,000	422,000

TABLE 17—Continued

MONTHLY GROSS DIVERSIONS TO STORAGE ON SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

1912-1929

Year and month	Gross storage diversions from Sacramento River system in acre-feet	Gross storage diversions from San Joaquin River system in acre-feet	Total gross storage diversions from combined Sacramento and San Joaquin River systems in acre-feet
1916—			
January	16,000	12,000	28,000
February	3,000	11,000	14,000
March	59,000	14,000	73,000
April	116,000	7,000	123,000
May	75,000	37,000	112,000
June	26,000	25,000	51,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total annual	295,000	106,000	401,000
1917—			
January	0	0	0
February	28,000	7,000	35,000
March	51,000	6,000	57,000
April	145,000	16,000	161,000
May	120,000	44,000	164,000
June	65,000	45,000	110,000
July	0	0	0
August	0	0	0
September	0	0	0
October	14,000	0	14,000
November	0	0	0
December	0	0	0
Total annual	423,000	118,000	541,000
1918—			
January	0	0	0
February	31,000	3,000	34,000
March	83,000	20,000	103,000
April	128,000	36,000	164,000
May	101,000	61,000	162,000
June	3,000	26,000	29,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total annual	346,000	146,000	492,000
1919—			
January	23,000	0	23,000
February	65,000	6,000	71,000
March	66,000	18,000	84,000
April	199,000	51,000	250,000
May	86,000	69,000	155,000
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	4,000	0	4,000
Total annual	443,000	144,000	587,000

TABLE 17—Continued

MONTHLY GROSS DIVERSIONS TO STORAGE ON SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

1912-1929

Year and month	Gross storage diversions from Sacramento River system in acre-feet	Gross storage diversions from San Joaquin River system in acre-feet	Total gross storage diversions from combined Sacramento and San Joaquin River systems in acre-feet
1920—			
January	0	0	0
February	7,000	1,000	8,000
March	66,000	20,000	86,000
April	116,000	23,000	139,000
May	130,000	81,000	211,000
June	8,000	34,000	42,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	52,000	0	52,000
December	31,000	0	31,000
Total annual	410,000	159,000	569,000
1921—			
January	75,000	0	75,000
February	0	0	0
March	111,000	17,000	128,000
April	74,000	30,000	104,000
May	40,000	63,000	103,000
June	22,000	31,000	53,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	2,000	2,000
Total annual	322,000	143,000	465,000
1922—			
January	0	1,000	1,000
February	45,000	4,000	49,000
March	0	16,000	16,000
April	114,000	24,000	138,000
May	156,000	98,000	254,000
June	41,000	30,000	71,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	7,000	7,000
Total annual	356,000	180,000	536,000
1923—			
January	9,000	0	9,000
February	5,000	25,000	30,000
March	66,000	8,000	74,000
April	121,000	154,000	275,000
May	119,000	339,000	458,000
June	18,000	108,000	126,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	13,000	0	13,000
Total annual	351,000	634,000	985,000

TABLE 17—Continued

MONTHLY GROSS DIVERSIONS TO STORAGE ON SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

1912-1929

Year and month	Gross storage diversions from Sacramento River system in acre-feet	Gross storage diversions from San Joaquin River system in acre-feet	Total gross storage diversions from combined Sacramento and San Joaquin River systems in acre-feet
1924—			
January	0	0	0
February	50,000	1,000	51,000
March	24,000	0	24,000
April	53,000	78,000	131,000
May	14,000	135,000	149,000
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	18,000	18,000
December	15,000	14,000	29,000
Total annual	156,000	246,000	402,000
1925—			
January	13,000	13,000	26,000
February	116,000	201,000	317,000
March	60,000	72,000	132,000
April	100,000	137,000	237,000
May	76,000	73,000	149,000
June	9,000	61,000	70,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	22,000	0	22,000
Total annual	396,000	557,000	953,000
1926—			
January	0	0	0
February	98,000	54,000	152,000
March	94,000	48,000	142,000
April	129,000	284,000	413,000
May	46,000	225,000	271,000
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	78,000	69,000	147,000
December	48,000	47,000	95,000
Total annual	493,000	727,000	1,220,000
1927—			
January	87,000	9,000	96,000
February	116,000	198,000	314,000
March	129,000	15,000	144,000
April	113,000	213,000	326,000
May	165,000	223,000	388,000
June	108,000	111,000	219,000
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	78,000	48,000	126,000
December	11,000	0	11,000
Total annual	807,000	817,000	1,624,000

TABLE 17—Continued

MONTHLY GROSS DIVERSIONS TO STORAGE ON SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

1912-1929

Year and month	Gross storage diversions from Sacramento River system in acre-feet	Gross storage diversions from San Joaquin River system in acre-feet	Total gross storage diversions from combined Sacramento and San Joaquin River systems in acre-feet
1928—			
January	44,000	0	44,000
February	62,000	50,000	112,000
March	186,000	223,000	409,000
April	148,000	160,000	308,000
May	138,000	299,000	437,000
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total annual	578,000	732,000	1,310,000
1929—			
January	0	0	0
February	0	3,000	3,000
March	13,000	91,000	104,000
April	50,000	149,000	199,000
May	105,000	506,000	611,000
June	34,000	232,000	266,000
July	0	0	0
August	0	0	0
September	0	0	0
October	---	---	---
November	---	---	---
December	---	---	---
Total annual	202,000	981,000	1,183,000

NOTE.—This table was compiled from data obtained from State Railroad Commission files, irrigation districts, power companies, municipalities and public and private water systems.

Most of the area in the large flood basins of the Sacramento Valley has now been reclaimed and eliminated from any normal possibility of flooding. This development is part of the adopted flood control plan for the Sacramento Valley. In general, the plan provides the dual function of maximum reclamation development together with adequate flood control. Works have been constructed with the idea of keeping as large a part as possible of the flood discharge in the natural stream channels. The excess waters over and above the quantities which can be carried in the natural stream channels are by-passed by a series of weirs and by-pass channels located in the natural troughs or basins which flank and parallel the main Sacramento River. Above the mouth of the Feather River the excess water is by-passed at three points, comprising the Moulton and Colusa weirs above Colusa and the Tisdale Weir between Colusa and Knights Landing. These waters are carried easterly to the main Sutter By-pass which is constructed along the easterly rim of the Sutter Basin. At the junction of the Feather and Sacramento rivers, the excess waters of the combined Sacramento and Feather River systems are discharged over the Fremont Weir on the west side of the river into the Yolo By-pass which extends from this point in a southerly direction and about parallel with the main river, finally emptying into the main river channel immediately above Rio Vista. A short distance above Sacramento, excess flood waters are by-passed through the Sacramento Weir westerly into the Yolo By-pass. Between these by-passes and the main river channel, a large portion of the area in the original flood basins has been reclaimed. Large expenditures have been made for the construction of flood control levees and levees of private reclamation districts flanking the main river channels. The operation of the flood control plan naturally results in a more rapid passage of the floods from the mountains into the bay. The by-passes provided for carrying the floods are of a magnitude sufficient to act to some extent as detaining reservoirs but not sufficiently to hold the flood water back long enough to afford additional stream flow into the lower delta in any great quantity in the late spring and early summer months.

The reclamation development of lands in the flood basins above enumerated has been carried out progressively over a considerable period of years. However, the complete closing-off of the basins from floods has occurred in the last two decades. The reclamation of Sacramento Basin was completed in 1913, American Basin in 1915, Yolo Basin in 1920, Colusa Basin in 1916 and most of Sutter Basin in 1919. The greater part of Butte Basin is still subject to flooding.

During the trial of the "Antioch" suit, an estimate was presented by an engineer for the defendants, of the amount of water that would have been discharged from Colusa, Sutter and American basins in the months of June and July, during the period 1907 to 1920, on the assumption that the basins were in their natural state before reclamation development had taken place. This estimate is shown in Table 18. The estimate indicates that a considerable quantity of water would have been contributed to the delta in June and July from water previously stored in the flood basins during the flood season, varying from practically nothing to a maximum of as much as 1,000,000 acre-feet in 1915. Additional stream inflow during these months in the magnitude indicated would help to delay the advance of salinity into the delta to some extent. However, the amount of additional flow indicated as available is relatively small in July, with none in August, and, hence, it would not greatly augment the low stream flow in summer. Moreover, the larger amounts of these estimated contributions in June and July are for normal or more than normal run-off years, while in subnormal or dry years, the delayed outflow would usually be practically nothing. Therefore, the elimination of the flood basins and the modification of flow into the delta resulting therefrom has had some effect on salinity conditions during certain past years, but it is believed to be a minor factor as compared to upstream irrigation and storage diversions. It appears that it has had little or no effect in dry years and hence can not be considered as a material factor in the saline invasions of serious magnitude which have occurred.

TABLE 18

DELAYED OUTFLOW FROM SACRAMENTO VALLEY FLOOD BASINS IN THEIR NATURAL STATE BEFORE RECLAMATION

1907–1920

Data taken from Volume I, Reporter's Transcript of "Antioch Suit."

Year	Month	Estimated outflow, in acre-feet				
		Colusa Basin	Sutter Basin	American Basin	Combined Basins	Combined total for June and July
1907	June	142,500	129,450	48,000	319,950	
	July	143,060	113,850	103,200	360,110	680,060
1908	June	95,625	65,025	60,610	221,260	
	July	3,850	----------	840	4,690	225,950
1909	June	145,860	123,240	90,240	359,340	
	July	70,090	42,120	24,080	136,290	495,630
1910	June	19,375	6,160	15,750	41,285	
	July	----------	----------	----------	----------	41,285
1911	June	207,600	186,240	122,360	516,200	
	July	99,400	65,250	97,605	262,255	788,455
1912	June	172,400	127,305	79,920	379,625	
	July	----------	----------	----------	----------	379,625
1913	June	72,480	44,400	43,120	160,000	
	July	----------	----------	----------	----------	160,000
1914	June	187,880	151,280	172,000	511,360	
	July	20,800	69,750	11,020	101,570	612,930
1915	June	354,220	327,025	308,580	989,825	
	July	37,800	18,960	11,020	67,780	1,057,605
1916	June	45,030	23,625	33,500	102,155	
	July	----------	----------	----------	----------	102,155
1917	June	102,030	65,100	100,040	267,170	
	July	----------	----------	----------	----------	267,570
1918	June	----------	----------	----------	----------	
	July	----------	----------	----------	----------	----------
1919	June	----------	----------	----------	----------	
	July	----------	----------	----------	----------	----------
1920	June	----------	----------	----------	----------	
	July	----------	----------	----------	----------	----------

Estimated Reduction in Stream Flow into Delta—Estimates have been made of the reduction in stream flow into the delta, based upon the records and estimates of upstream irrigation and storage diversions, storage releases and estimates of return water. This study has been made for the purpose of indicating what the combined effect of upstream irrigation and storage developments has been on the stream flow into the delta, and on the related salinity conditions. No estimate has been made of the effect of upstream reclamation development on stream flow because of insufficient data available to estimate the modification in flow resulting therefrom and because it has had only a relatively minor effect on salinity conditions.

Table 19 shows the estimated monthly reductions in stream flow into the delta for the period 1912 to 1929. The estimated monthly amounts of reduced flow were computed as the sum of the gross monthly diversions to storage and irrigation, less the estimated monthly amounts of return water from total gross irrigation diversions, less the monthly amounts of reservoir releases. The resulting figures for most months during this period indicate a positive reduction in flow of varying amount. However, the estimates appear to show in some months in the late fall or early winter that the amounts of return water together with reservoir releases have exceeded the gross diversions to storage and irrigation, thus indicating that the flow into the delta during these months was actually greater than it would have been had there been no upstream irrigation and storage developments.

Estimates of return water were based upon measurements made by the Sacramento-San Joaquin water supervisor from 1924 to 1929 on both the Sacramento and San Joaquin rivers. In addition, the measurements and studies of return water from several large irrigation projects were used.

For the Sacramento Valley, the total annual amount of return water was estimated at 42½ per cent of the total annual gross irrigation diversions. Of this total amount of return water, it was estimated that 75 per cent returns during the seven months' period of the irrigation season from April to October, inclusive, with the remaining 25 per cent in the months of November to March, inclusive. The monthly distribution of return water in per cent of the total was assumed as follows:

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
5	5	5	5	10	15	15	15	10	5	5	5

For the San Joaquin Valley, the total annual return flow from the main valley lands was estimated at 35 per cent of the total annual gross irrigation diversions, with an estimated monthly distribution in per cent of the total as follows:

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
7	7	7	7	8	11	12	10	9	8	7	7

For the delta uplands, the total annual return flow was estimated at 15 per cent of the total gross annual diversions, with the same monthly distribution as for the San Joaquin Valley. For the Mokelumne River diversions, the total annual return was estimated as 14 per cent of the total annual gross diversions, and the amount of return each month was estimated as 14 per cent of the gross diversions during the previous month. This latter was based on special measurements and analyses on the Mokelumne River made by the U. S. Geological Survey.

Although the estimates of reduction in stream flow into the delta in Table 19 must be considered as an approximation, it is believed that they furnish a fairly close estimate of the resulting effect of upstream irrigation and storage developments. The estimates indicate that the average monthly reduction of inflow during the period 1911 to 1929 amounted to 241,000 acre-feet, with a maximum for any one month of 1,496,000 acre-feet in May, 1929. The estimated reduction during the

TABLE 19

REDUCTION IN STREAM FLOW INTO DELTA RESULTING FROM UPSTREAM IRRIGATION AND STORAGE DEVELOPMENTS

1911-1929

Season	Estimated decrease (—) or increase (+) in stream flow into delta in acre-feet												
	October	November	December	January	February	March	April	May	June	July	August	September	Total, season
1911-12	+25,000	+57,000	+54,000	+34,000	—7,000	—129,000	—367,000	—614,000	—471,000	—286,000	—151,000	—132,000	—1,987,000
1912-13	+13,000	+40,000	+31,000	+40,000	—11,000	—134,000	—360,000	—624,000	—462,000	—302,000	—154,000	—132,000	—2,055,000
1913-14	+7,000	+46,000	+16,000	—49,000	—19,000	—201,000	—473,000	—749,000	—537,000	—363,000	—142,000	—84,000	—2,548,000
1914-15	+47,000	+108,000	+100,000	+59,000	—29,000	—206,000	—529,000	—700,000	—529,000	—327,000	—144,000	—77,000	—2,227,000
1915-16	+51,000	+101,000	+70,000	+12,000	—12,000	—209,000	—507,000	—785,000	—603,000	—380,000	—220,000	—155,000	—2,637,000
1916-17	+42,000	+89,000	+79,000	+75,000	—34,000	—205,000	—572,000	—887,000	—708,000	—387,000	—166,000	—94,000	—2,768,000
1917-18	—13,000	+220,000	+91,000	+78,000	—22,000	—232,000	—560,000	—897,000	—654,000	—420,000	—234,000	—193,000	—2,835,000
1918-19	+34,000	+117,000	+144,000	+58,000	—48,000	—188,000	—634,000	—895,000	—621,000	—433,000	—252,000	—173,000	—2,891,000
1919-20	+81,000	+137,000	+81,000	+123,000	+41,000	—206,000	—610,000	—1,012,000	—779,000	—402,000	—192,000	—145,000	—2,883,000
1920-21	+28,000	+16,000	+56,000	+9,000	+47,000	—228,000	—561,000	—891,000	—864,000	—502,000	—184,000	—96,000	—3,170,000
1921-22	+78,000	+112,000	+79,000	+69,000	+10,000	—12,000	—430,000	—1,048,000	—887,000	—658,000	—244,000	—113,000	—3,044,000
1922-23	+54,000	+124,000	+130,000	+91,000	+19,000	—204,000	—682,000	—1,303,000	—901,000	—549,000	—182,000	—97,000	—3,500,000
1923-24	+97,000	+125,000	+93,000	+64,000	—50,000	—70,000	—560,000	—871,000	—318,000	—243,000	—167,000	—133,000	—2,033,000
1924-25	+3,000	+21,000	+26,000	—5,000	—291,000	—207,000	—551,000	—853,000	—834,000	—523,000	—234,000	—124,000	—3,562,000
1925-26	+74,000	+130,000	+114,000	+115,000	—137,000	—269,000	—864,000	—1,123,000	—600,000	—276,000	—183,000	—83,000	—3,102,000
1926-27	+70,000	—91,000	—12,000	—21,000	—221,000	—152,000	—682,000	—1,292,000	—1,077,000	—682,000	—242,000	—102,000	—4,504,000
1927-28	+83,000	—44,000	+166,000	+170,000	—68,000	—472,000	—687,000	—1,326,000	—750,000	—286,000	—152,000	—41,000	—3,407,000
1928-29	+174,000	+182,000	+141,000	+148,000	+69,000	—154,000	—739,000	—1,496,000	—859,000	—272,000	—60,000	+11,000	—2,855,000

NOTE: This table was compiled from Tables 14 and 17, records of water released from reservoirs, and estimates of return water from irrigation diversions.

irrigation season, April to October, inclusive, averages 412,000 acre-feet per month.

For the period June 15 to September 1, from 1912 to 1929, the indicated reduction averages 374,000 acre-feet per month, varying during the two and one-half month's period from a minimum average of 228,000 acre-feet per month in 1924 to a maximum average of 585,000 acre-feet per month in 1927. Since 1917, the corresponding average reduction in flow amounts to 402,000 acre-feet per month. The indicated amount of reduced flow in this summer period is of particular significance as this is the period when maximum consumptive demands in the delta occur and the flow naturally available is a minimum. Hence, reductions in flow during this period have the most marked effect upon saline invasion into the delta. On the other hand, it is of interest to note that the flow into the delta during the late fall and early winter months, starting occasionally as early as September, appears to have been increased due to the effect of return water from irrigation combined with water releases from power reservoirs in excess of the simultaneous irrigation diversions. Hence, the effect of upstream irrigation and storage developments, up to the present, does not appear to be all on the negative side.

It is evident from the above estimates that upstream irrigation and storage diversions have substantially reduced the stream flow naturally available to the delta and that the amount of reduction has increased in recent years. Of more importance is the fact that the amount of reduction in dry years such as 1924 is relatively large in comparison with the actual inflow. Since the degree, extent and duration of saline invasion in the delta is governed mostly by summer flow, it appears evident that the reduction in stream flow by upstream irrigation and storage diversions probably has very materially increased the degree and extent of saline invasion above that which would have been experienced if the inflow naturally available had been unimpaired. However, it is certain that saline invasions of considerable magnitude would have occurred even though natural stream flow had been available. Estimates of salinity under conditions of estimated natural stream flow into the delta have been made and are presented in Chapter V.

CHAPTER IV

RELATION OF TIDAL ACTION TO SALINITY

Tidal action is of equal importance to stream flow as a basic factor affecting salinity conditions in the upper bay and delta channels. If it were not for the action of the tides, resulting in the movement of saline water from the ocean and lower bay into the upper bay and delta, there would be no salinity problem. The study of the effect of tidal action on the variation of salinity and its relation to the control of salinity has therefore been an essential feature of this investigation. It has involved first, a consideration of the governing factors and characteristics of tidal action and, secondly, a detailed analysis of the effect of tidal action on salinity.

San Francisco Bay Tidal Basin.

The tidal basin of San Francisco Bay has a total area at mean water level of about 500 square miles, and total volumes of about 3,000,000 and 1,400,000 acre-feet between the respective limits of maximum and mean tidal range. Table 20 summarizes, for the chief geographical subdivisions of the entire tidal basin, the area in acres at mean water level, the estimated maximum and mean range of the tide and the estimated total effective volume in acre-feet in the tidal prism between the limits of maximum and mean range of tide.

As shown by Table 20, the channels of the Sacramento-San Joaquin Delta above Collinsville comprise only about 12 per cent of the total area and 8 per cent of the total tidal volume of the entire tidal basin, and about 57 per cent of the area and 50 per cent of the volume of that portion of the tidal basin above Carquinez Strait, including Suisun Bay and the delta combined.

TABLE 20

AREA AND VOLUME OF TIDAL PRISM IN SAN FRANCISCO BAY TIDAL BASIN

Geographical subdivision	Area at mean water level, in acres	Estimated tidal range, in feet		Estimated tidal volume in tidal prism, in acre-feet	
		Maximum	Mean	Maximum	Mean
South San Francisco Bay	120,700	11.3	5.4	1,364,000	651,800
North San Francisco Bay	52,900	10.2	3.9	540,000	206,300
San Pablo Bay	72,700	9.5	4.1	691,000	298,100
Carquinez Strait	4,500	8.8	4.1	40,000	18,500
Suisun Bay	29,400	8.2	3.8	241,000	111,700
Delta of Sacramento and San Joaquin rivers	38,700	6.3	3.0	244,000	116,100
Entire San Francisco Bay tidal prism	318,900	------------	------------	3,120,000	1,402,500

NOTE.—The areas of each geographical subdivision were obtained from the most recent maps available, including those of the United States Army Engineers, Coast and Geodetic Survey and Geological Survey.

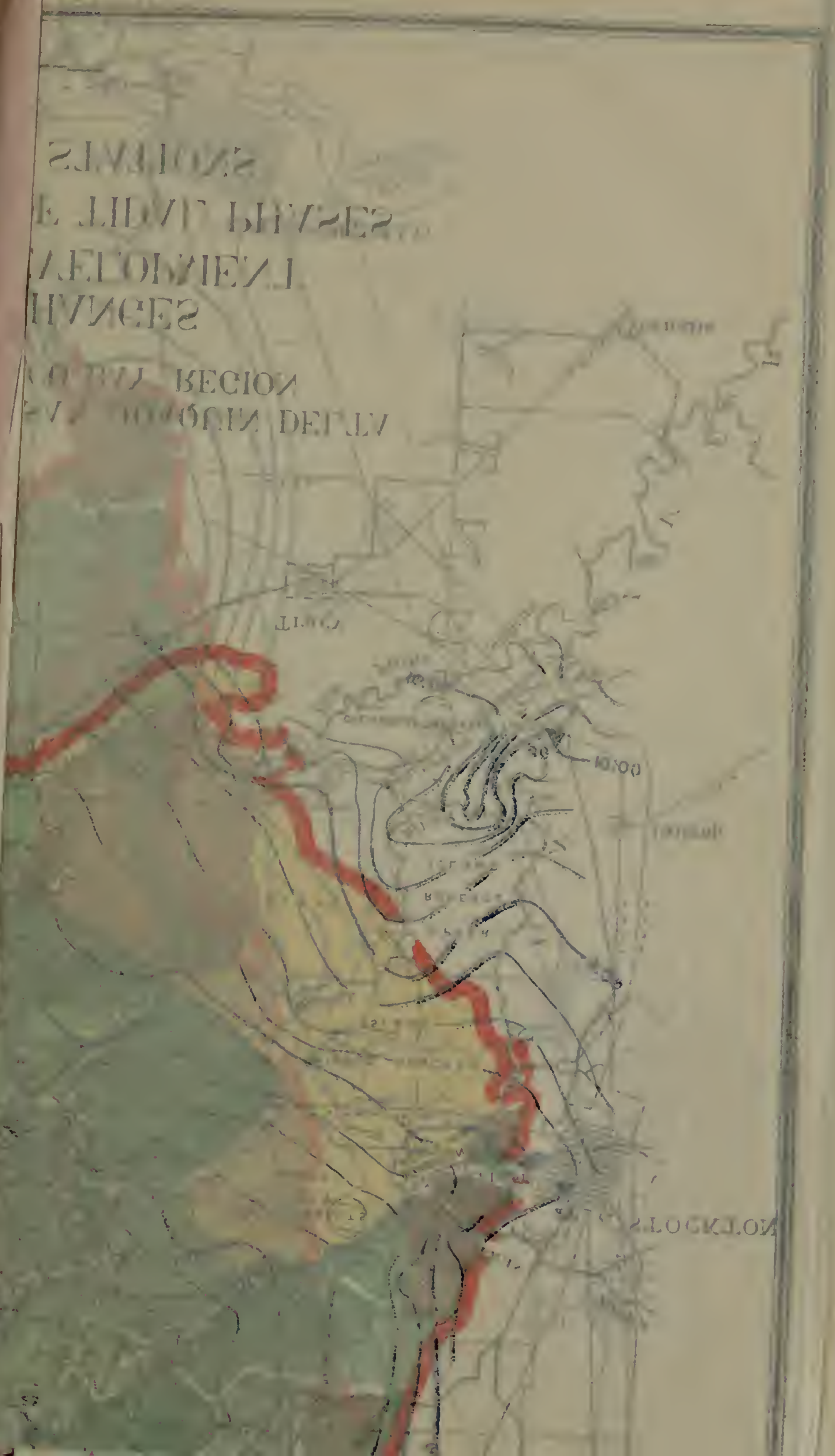
The tidal ranges for each area are compiled from the records of automatic tide gages obtained during 1929 and 1930. The maximum tidal range for this period was corrected to an estimated long time maximum range on the basis of the ratio between the observed maximum range at the Presidio during the period of record to the long time maximum range at the Presidio.

The water level in the tidal basin of San Francisco Bay is never a continuous plane surface at the same instant. The mean water level (see Plate XV) closely approximates a plane surface which in general extends on a rising slope from the Golden Gate to the upper limits of the basin. However, at any particular time, the actual level at various points in the basin is above and below this mean level. This is due to the fact that there is a lag in occurrence of tidal phases at points upstream from the Golden Gate, which increases with greater distance from the Golden Gate. This lag amounts to as much as 10 hours or more for points at the extreme upper limits of the tidal basin on the Sacramento and San Joaquin rivers. Since the tide in San Francisco Bay usually rises and falls twice in a lunar day of approximately 24 to 25 hours, with four tidal phases comprising two high and two low water levels occurring during this period at intervals approximately six hours apart, identical tidal phases or stages occur at different times and different tidal phases or stages occur at the same time at various points in the tidal basin.

At the present time, the effect of tidal action is felt at points as far upstream as a few miles below Verona (near mouth of Feather River) on the Sacramento River, between Mossdale Bridge and Vernalis on the San Joaquin River and between New Hope Bridge and Thornton on the Mokelumne River. These limits vary considerably throughout the season, depending upon the magnitude of stream inflow and tidal action. During the winter and spring when the streams are in flood, the limits of tidal action are forced a considerable distance downstream. Thus, on the Sacramento River, the records show that when the flow of the Sacramento River passing Sacramento reaches about 25,000 second-feet, there is no tidal action at Sacramento. As the flow of the Sacramento River increases, the limit of tidal action is forced still farther downstream to the vicinity of Freeport. Similarly on the San Joaquin River, the effect of tidal action is eliminated at the Mossdale Bridge when the flow of the San Joaquin River reaches about 13,000 second-feet or more. During large flood flows, it is stated by observers in the delta that the effect of tidal action is eliminated as far downstream as McDonald Island on the San Joaquin River and the Santa Fe Railroad crossing on Middle River.

During periods of large floods, the range of the tide within the limits of tidal action is materially reduced at all points as far down as the mouth of the two rivers at Collinsville. For the period of low stream flow, the minimum, maximum and average ranges of the tide at the various points in the delta and bay channels are summarized in Table 5, and are graphically shown on Plate XV.

Historical Limits—Under natural conditions, before any development of reclamation occurred within the delta, the tidal basin potentially embraced a large part of the delta area. Most of the lands within the delta were originally low-lying marsh lands, of varying elevation. If it be assumed that the mean water level at various points in the delta was about the same under the original natural conditions as at present, it is possible to estimate the original boundary line of the limits of tidal action. This boundary line showing the estimated limit of tidal action under natural conditions in the delta is shown in red on Plate XXXIV, "Tidal Basin of Sacramento-San Joaquin Delta



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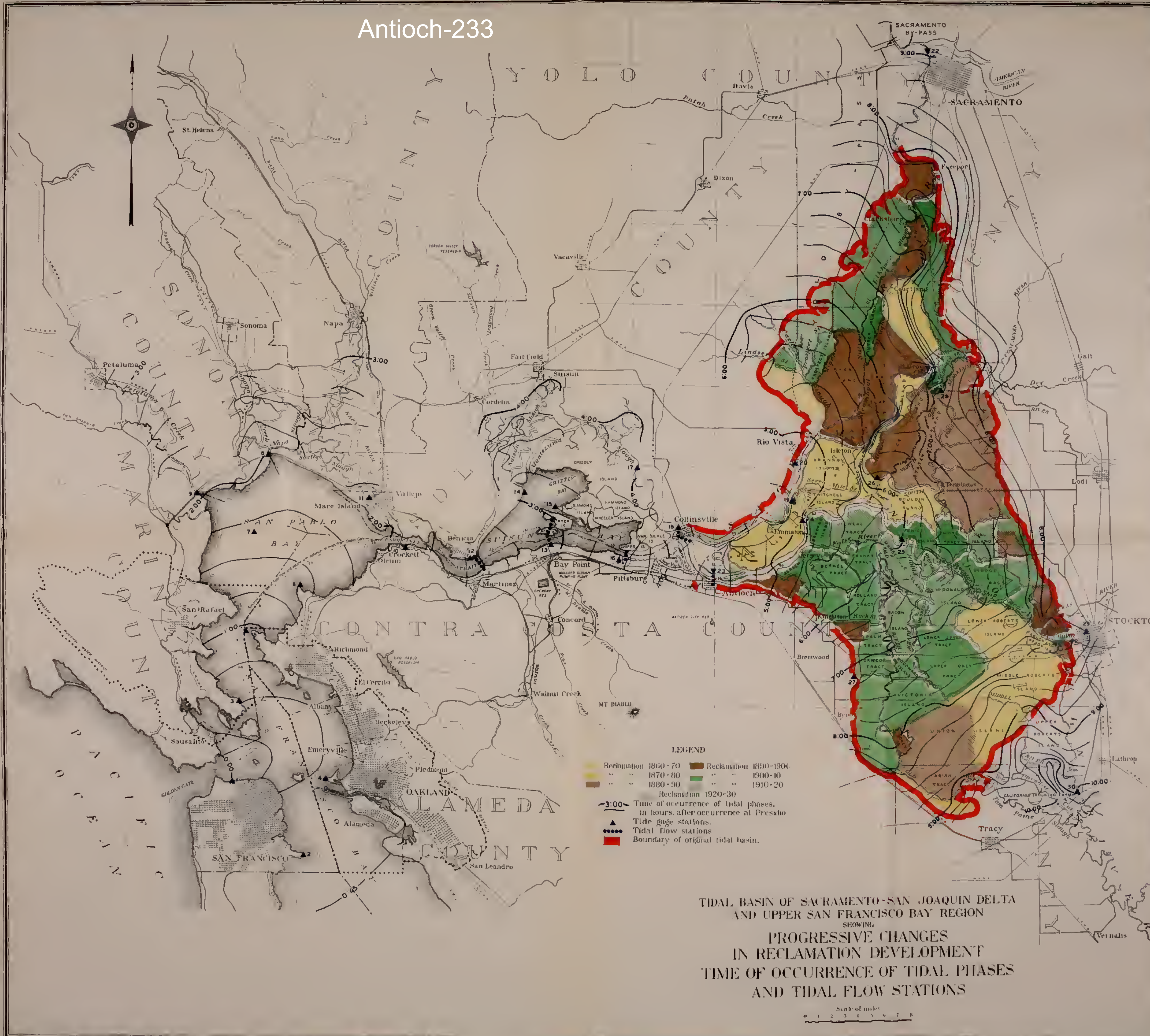
MEAN DEPARTURE IN TIME OF ACTUAL TIDAL PHASE FROM MEAN TIME OF ALL FOUR TIDAL PHASES

Station		Phase of tide			
	Name	High-High Hours-Minutes	Low-High Hours-Minutes	High-Low Hours-Minutes	Low-Low Hours-Minutes
1	Presidio	0 00	0:00	0:00	0:00
2	Hunters Point	—0 06	—0:08	+0:06	+0:08
Not Shown	San Mateo Bridge	0 12	—0 21	+0.13	+0:16
Not Shown	Dumbarton Bridge	0 09	—0:30	+0:22	+0:17
3	Point Bluff	—0.02	—0:01	+0:01	+0:02
4	Oakland Mole	—0:04	—0:04	+0:03	+0:05
5	Point Orient	—0 06	—0:06	+0:07	+0:04
[illegible]	Pinole Point	—0:05	—0:06	+0:03	+0:05
7	Beacon No. 2	0.08	—0:10	+0·02	+0:19
8	Sonoma Creek	—0:25	—0:27	—0:06	+0:54
9	Petaluma Creek	—0:25	—0:25	—0:08	+0:59
[illegible]	Crockett	0:11	—0:09	+0·03	+0:17
[illegible]	Mare Island	0 09	—0 08	—0 01	+0:17
12	Benicia	0 05	—0.08	—0:02	+0:17
[illegible]	Bay Point	—0 16	—0:16	+0:03	+0.27
14	Suisun Light	0 16	—0 19	+0:04	+0:29
15	Point Buckler	—0:29	—0:26	+0:12	+0:40
[illegible]	Mallard Slough	—0:20	—0:15	+0:01	+0:36
[illegible]	Meins Landing	—0 15	—0.24	—0:04	+0:43
[illegible]	Collinsville	0 17	—0.17	—0:02	+0:27
	Three Mile Slough Sacramento River End	—0 21	—0 20	—0:02	+0.42
[illegible]	Rio Vista	—0 22	—0:18	—0:04	+0:45
[illegible]	Walnut Grove	0 30	—0:32	+0:01	+0:59
[illegible]	Sacramento	0·55	—1:00	+0:20	+1:34
23	Antioch	—0 15	—0.13	—0:05	+0 34
24	Three Mile Slough San Joaquin River End	—0 20	—0 20	0·00	0 40
25	Venice Island	—0:17	—0·14	—0:07	+0:37
26	Georgiana Slough	0 22	0:19	—0:01	+0 43
27	East Contra Costa Irrigation District	—0·17	—0 21	—0:05	+0.43
28	New Hope Bridge	0 31	—0·24	—0.02	+0:57
29	Stockton	—0 28	—0 25	—0:05	+0:57
30	Mossdale, S.P.R.R. Bridge	—0.50	—0:53	+0:10	+1:33

+ indicates time of actual phase is later than mean time of all four phases
— indicates time of actual phase is earlier than mean time of all four phases



and Upper San Francisco Bay Region, Showing Progressive Changes in Reclamation Development, Time of Occurrence of Tidal Phases and Tidal Flow Stations.'' This line is drawn at the intersection of the present mean water level during the low water season at the various points in the delta with the corresponding ground elevation or contour. In addition to the area shown within this boundary, tidal action extended up the channels of Sacramento, San Joaquin and Mokelumne rivers about the same distance as at present. Under natural conditions, the potential gross area of the tidal basin in the delta within the red line on Plate XXXIV comprised about 300,000 acres. However, it appears that only a portion of the lands potentially within the tidal basin were actually submerged by tidal fluctuations during the period of low stream flow in the summer and fall months.

The limits of the tidal basin and the volume in the tidal prism have been modified in past years by three important agencies; namely, hydraulic mining and natural erosion, channel erosion and improvements, and reclamation.

Effect of Hydraulic Mining and Silting—The Sacramento and San Joaquin River systems when in flood bring down large quantities of debris from the natural erosion of the valleys, foothills and mountains. It has been estimated * that the volume of material brought down by the Sacramento and San Joaquin rivers from this natural erosion amounted to 700,000,000 cubic yards during the 65-year period, 1850 to 1914, or about 11,000,000 cubic yards per year on the average. Of this total it is estimated that 420,000,000 cubic yards or an average of about 6,500,000 cubic yards per year was brought down by the Sacramento River alone and the balance by the San Joaquin River. It may be assumed that considerably larger quantities of debris than the average have been brought down during years of very large floods, perhaps as much as two or three times the average estimated amount. Under natural conditions, this debris was deposited in the channels and in the flanking overflow basins of the river systems, and especially in the lower portions of the channels where the gradients flattened out and the velocities decreased to such an extent that the loads of material were dropped. Large amounts of debris were deposited also in Suisun and San Pablo bays. These deposits in the river channels and upper bays formed shoals and islands. The lighter materials deposited in the bays were transported by tidal currents toward the shores, gradually building up extensive areas of mud flats extending out for considerable distances from the shore line.

The debris from natural erosion transported by the Sacramento and San Joaquin rivers was greatly augmented by the advent of hydraulic mining in California. This system of gold mining was started in the early fifties soon after the discovery of gold. Hydraulic-mining operations thereafter increased with rapid strides, reaching maximum proportions in the early eighties. In 1880, it is estimated by Wm. Ham Hall, former state engineer, that there was a total of over 53,000,000 cubic yards of gravel washed in the hydraulic-mining operations during that year alone.

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* Prof. Paper No. 105, "Hydraulic-Mining Debris in the Sierra Nevada," G. K. Gilbert, U. S. Geological Survey, 1917.

The location of the auriferous gravels is shown on Plate XXXIII. The bulk of these gravels are situated within the drainage basins of the Feather, Yuba, Bear and American rivers. Smaller deposits are located on tributaries of the San Joaquin River from the Mokelumne River as far south as the Tuolumne River. The larger operations were carried on in the drainage basins of the Yuba, Bear and American rivers. The scale of operations was much smaller on the San Joaquin River tributaries. The larger hydraulic mines, such as the Malakoff of the North Bloomfield Mining Company, North Columbia, Omega, Sailor Flat, Blue Tent, Scott's Flat, Quaker Hill, Red Dog, You-Bet, Dutch Flat, Gold Run, Iowa Hill and Michigan Bluff all lie within the Yuba, Bear and American River basins and are famous in the annals of the hydraulic-mining industry.

The debris washed out by these hydraulic mines was discharged into the natural streams nearby and was gradually carried downstream into the lower portions of the river channels and into the bay. It was estimated by Gilbert * that the total amounts of debris discharged into the natural streams from hydraulic-mining operations amounted to 1,675,000,000 cubic yards in the period from 1850 to 1914. Of this total over 80 per cent, or about 1,400,000,000 cubic yards, is estimated to have been brought down by the Feather, Yuba, Bear and American rivers. It is thus seen that the estimated amount of debris brought down from these mining operations is nearly two and one-half times the estimated amount emanating from natural erosion of mountain, foothill and valley areas.

Of the total amount of debris brought down by the two river systems from both natural erosion and hydraulic-mining operations during the period 1850 to 1914, inclusive, estimated by Gilbert at 2,375,000,000 cubic yards, the same authority estimated the distribution of the deposition of this material as of the year 1914 in accordance with the following tabulation:

	Million cubic yards
Deposits within the Sierra Nevada	205
Piedmont deposits	520
Deposits in the channels of valley rivers	100
Deposits on inundated lands, including tidal marshes	294
Deposits in the bays	1,146
Deposits in the ocean	50
Total	2,375

It appears from Gilbert's estimates that nearly half of the total amount of debris brought down by the rivers during this period had been carried into the bays by 1914, while only about 37 per cent still remained in the river channels.

This tremendous increase in the load of debris carried by the streams in flood resulted in the creation of very serious conditions in the Sacramento Valley. The river channels were gradually filled with debris and choked up to such an extent that the larger floods overtopped the banks and low levees constructed by the early settlers and inundated large areas of farm lands, covering them in large part with debris which

* Prof. Paper No. 105, "Hydraulic-Mining Debris in the Sierra Nevada," G. K. Gilbert, U. S. Geological Survey, 1917.

destroyed growing crops and rendered the land useless at that time for farming. These conditions brought about a prompt response from the farmers of the Sacramento Valley, which took the form of several suits filed in the courts seeking to enjoin hydraulic-mining operations. This issue was finally settled by the decision in the famous suit of *Woodruff* vs. *The North Bloomfield Mining Company*, rendered on appeal to the Federal Circuit Court in 1884. By the decision of the court, the operators of hydraulic mines were enjoined from discharging debris into the streams. After this decision was made no operations of large magnitude were continued and in about 1895 hydraulic mining was practically terminated. In 1893 the California Debris Commission Act was passed by Congress creating a commission of army engineers to take charge of the whole debris problem created by hydraulic-mining operations and prohibiting and declaring unlawful hydraulic mining on the Sacramento and San Joaquin River systems, except under certain restrictions. This commission not only has charge of the regulation of hydraulic mining but also the preparation of plans and the construction of works for flood control and improvement and maintenance of navigation.

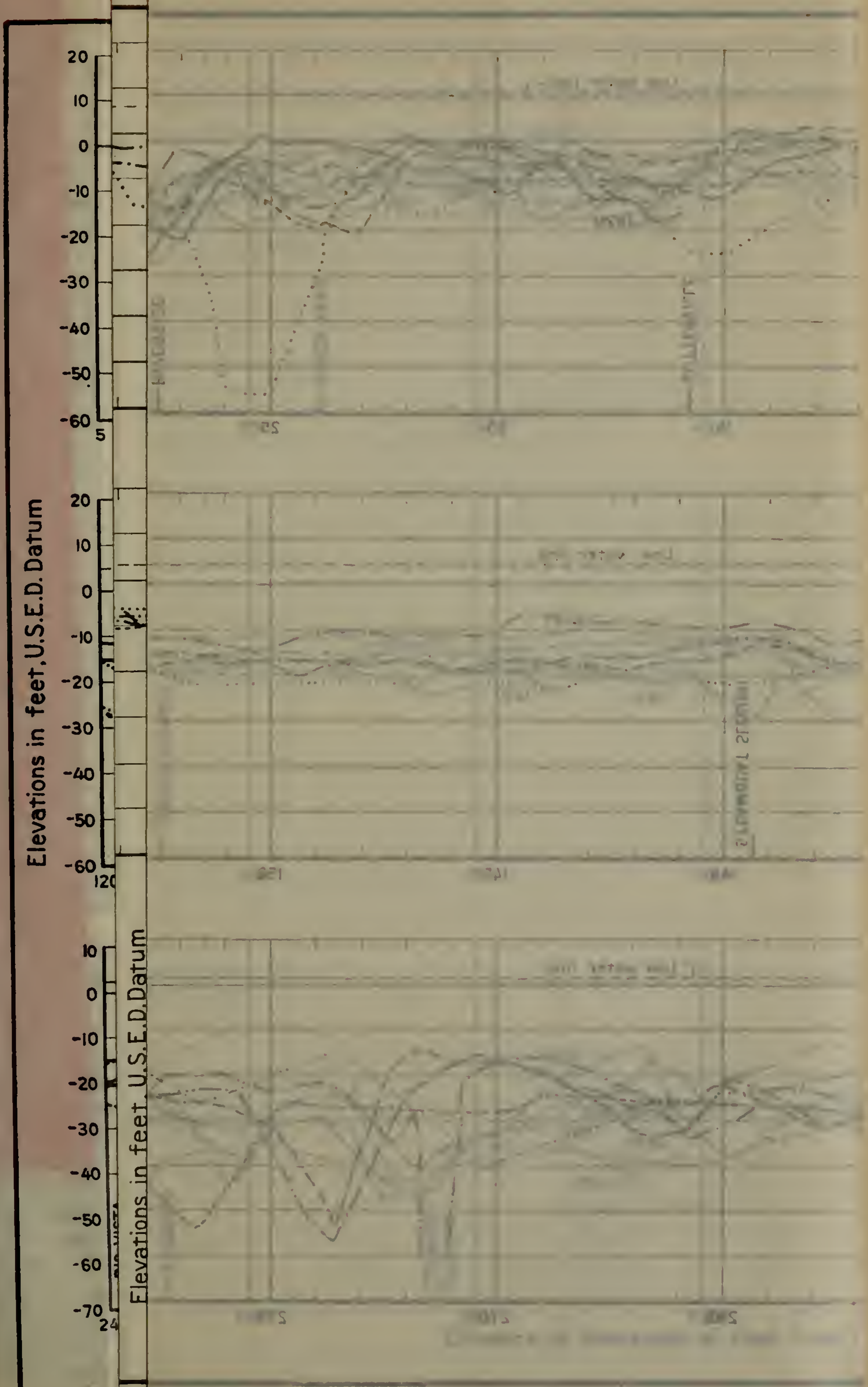
As far as salinity conditions and this investigation are concerned, it is of particular interest to determine what the effect of hydraulic mining and the consequent abnormal silting of the river channels and upper bays has been upon the tidal prism and the magnitude of tidal flow and tidal action. The abnormal load of debris carried down from the hydraulic-mining operations was deposited initially in the channels of the rivers below the rim of the valley. In the early stages of the movement of debris downstream, the channels of the branch rivers such as the Yuba, Bear and American, were first filled with debris in the mountain sections. This debris gradually moved downstream each year in constantly increasing magnitude.

The gradual filling of the channel of the main Sacramento River is best illustrated by the graph on Plate XXXV, "Changes in Channel Bed of Sacramento River, 1841 to 1929," which shows profiles of the channel bed of the Sacramento River from the city of Sacramento to Suisun Bay, based upon the records of surveys made in different years from 1841 to 1930. For purposes of comparison, it is particularly fortunate to have the early profile of 1841, which is based on a survey made in that year and enlarged in 1850 by Wilkes and Ringgold. This is the best information available as to the natural level of the stream bed prior to hydraulic mining. The next survey was made in 1878 and by that year the debris from hydraulic mining had already started to fill the river channels clear through to the bay. Later surveys in 1894, 1895, 1907, 1917, 1920, were made by the Federal and State governments and finally the last available survey in 1929 and 1930 by the Federal government. These data show the magnitude of the filling of the river channels after hydraulic mining started until about 1894 and 1895, when the accumulation of debris reached maximum proportions in the channel from Sacramento downstream. It appears that the debris filled up the channel to a depth of ten feet or more for a considerable distance below Sacramento, the depth of filling in general decreasing at points farther downstream.

Subsequent to 1895, the data indicate that the bed of the river channel has gradually lowered, due to the combined effect of scour by floods, and dredging for reclamation development and channel improvements. Although the deepening of the channel has not been uniform in all portions of this stretch of the river, the records evidence a positive tendency toward a lowering of the channel bed. Up to 1930, the data from the available surveys indicate that the main channel of the Sacramento River from Sacramento to the lower end of Grand Island has been deepened an average of about five feet below the levels of 1895.

These changes in the channel of the Sacramento River had a material effect upon the water level in the channel and the extent and magnitude of tidal action. Table 21 summarizes the record of minimum and maximum seasonal gage heights of the Sacramento River at Sacramento from 1849 to 1929, as obtained from the U. S. Weather Bureau records published in government reports. The gage heights are referred to a gage established in 1856, the zero of which is approximately mean sea level (U. S. G. S. Datum). As shown in this record, the low water level for the season in early years was as low as zero on the gage. Following the advent of hydraulic mining, the elevation of low water gradually increased from year to year until it reached a maximum in 1890 to 1895 of about seven to eight feet. At about this time, tidal fluctuation at Sacramento is reported to have ceased. Where under natural conditions the tidal range at Sacramento was about two feet, it was gradually decreased from 1860 to 1871 to about one foot and by 1883 is stated to have entirely disappeared. It is reported that the limit of tidal action at about this time was over ten miles below the city of Sacramento. Since 1896 the low water level at Sacramento has gradually lowered until at the present time it is within one-half foot to one foot of the low level during the days before hydraulic mining. This low level, of course, is materially affected by the quantity of the summer and fall stream flow which, because of large diversions from the river in recent years, is probably very materially less than in the fifties and sixties. However, the fact that the elevation of low water at Sacramento has decreased six or seven feet during the last 30 years is a fairly good index of the cleaning out of the channel by the combined action of stream erosion and dredging operations. This lowering of water level at Sacramento may also be assumed to be an index of a proportional amount of lowering, although of smaller amount, at points farther downstream. At the same time the effect of tidal action and the tidal limits have advanced upstream during this 30-year period until the range of fluctuation and the limits of tidal action evidently are at present about the same as in the early days before hydraulic mining.

Under the maximum conditions of channel filling by hydraulic-mining debris, there is no question but what there was some effect upon the magnitude and extent of tidal action. Other things being equal, the tidal flow into the tidal basin of the delta was probably diminished during this stage of debris-loaded channels. As will appear from the discussion hereafter, such a change in tidal flow would have had some effect upon the advance and retreat of salinity. However, conditions in the delta and river channels have been restored practically to their original natural state, at least as to any limiting effect on the tidal prism is concerned. Therefore, it appears evident that the salinity conditions in the upper bay and delta channels during recent years have not been affected by or connected in any way with the deposition of debris emanating from past operations of hydraulic mining.


Elevations in feet, U.S.E.D. Datum
20
10
0
-10
-20
-30
-40
-50
-60
25
20
10
0
-10
-20
-30
-40
-50
-60
10
0
-10
-20
-30
-40
-50
-60
-70
Elevations in feet, U.S.E.D. Datum

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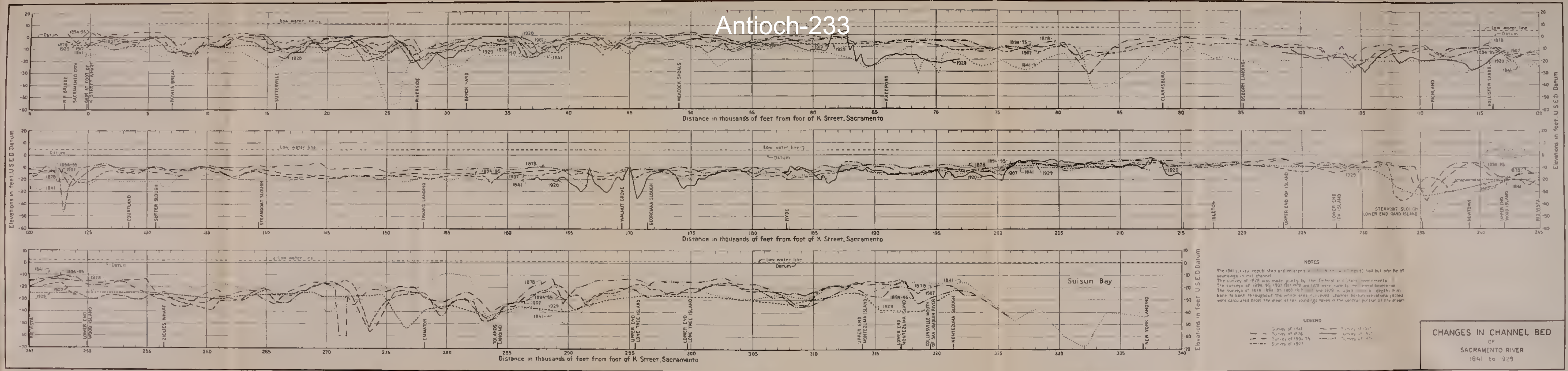

Distance in thousands of feet from foot of K Street, Sacramento
Elevations in feet, U.S.E.D. Datum
Low water line
Datum
R.R. BRIDGE
SACRAMENTO CITY
GAGE AT FOOT OF K STREET WHARF
PAYNES BREAK
SUTTERVILLE
RIVERSIDE
BRICK YARD
MEACOCK SHOALS
FREEPORT
CLARKSBURG
OSBORN LANDING
RICHLAND
HOLLISTER LANDING
COURTLAND
SUTTER SLOUGH
STEAMBOAT SLOUGH
TRASKS LANDING
WALNUT GROVE
GEORGIANA SLOUGH
RYDE
ISLETON
UPPER END IDA ISLAND
LOWER END IDA ISLAND
STEAMBOAT SLOUGH LOWER END GRAND ISLAND
NEWTOWN
UPPER END WOOD ISLAND
RIO VISTA
LOWER END WOOD ISLAND
ZIEGLERS WHARF
EMMATON
TOLANDS LANDING
UPPER END LONE TREE ISLAND
LOWER END LONE TREE ISLAND
UPPER END MONTEZUMA ISLAND
LOWER END MONTEZUMA ISLAND
COLLINSVILLE MOUTH OF SAN JOAQUIN RIVER
MONTEZUMA SLOUGH
NEW YORK LANDING
Suisun Bay
NOTES
LEGEND
Survey of 1841
Survey of 1878
Survey of 1894-95
Survey of 1907
CHANGES IN CHANNEL BED
OF
SACRAMENTO RIVER
1841 to 1929

Antioch-233

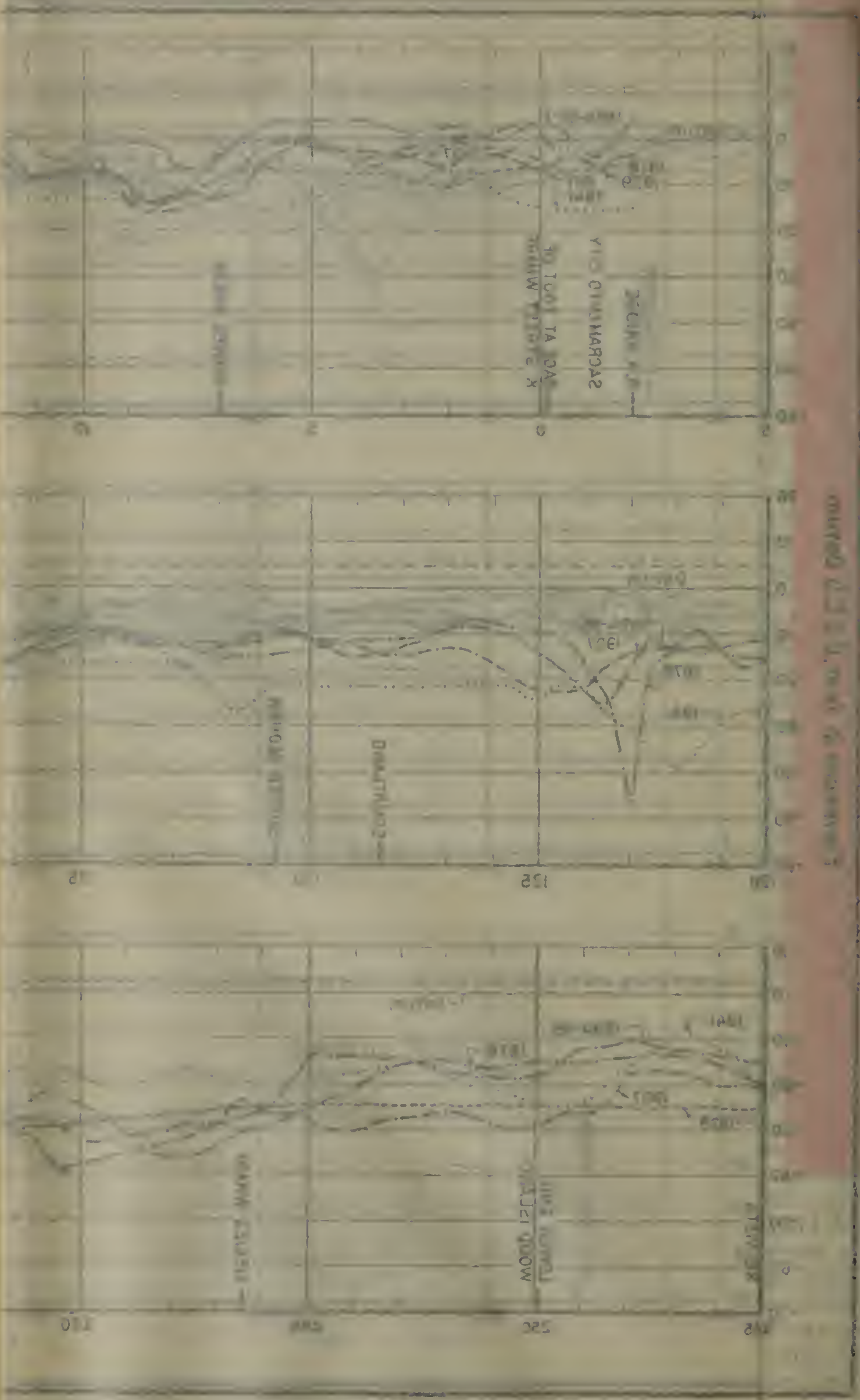


TABLE 21

ANNUAL MINIMUM AND MAXIMUM RIVER STAGES OF SACRAMENTO RIVER AT SACRAMENTO

1849-1929

Year	Gage heights, in feet		Year	Gage heights, in feet	
	Minimum stage	Maximum stage		Minimum stage	Maximum stage
1849	—0.6	18.8	1895	8.3	26.6
1850	—0.1	20.2	1896	8.5	26.7
1851	—0.1	9.8	1897	8.3	24.2
1852	2.1	21.7	1898	7.1	16.7
1853	0.3	19.4	1899	7.4	24.2
1854	1.9	20.2	1900	7.6	27.0
1855	1.3	20.3	1901	7.2	28.2
1856	0	12.4	1902	6.9	28.2
1857	1.6	18.2	1903	7.0	27.6
1858	0.2	18.9	1904	8.2	27.9
1859	1.0	19.0	1905	6.3	22.0
1860	1.9	15.2	1906	6.8	27.4
1861	1.3	21.8	1907	7.3	27.2
1862	----------	24.0	1908	5.3	20.4
1867	----------	24.1	1909	5.5	29.6
1869	2.9	----------	1910	5.1	22.8
1874	4.6	19.1	1911	5.5	26.9
1875	4.3	22.2	1912	4.1	16.7
1876	7.1	24.7	1913	2.6	17.9
1877	5.2	18.1	1914	4.2	27.8
1878	5.3	26.0	1915	4.0	26.8
1879	5.8	23.7	1916	2.9	25.9
1880	7.4	24.4	1917	2.7	26.4
1881	6.4	26.5	1918	0.9	20.6
1882	6.5	21.2	1919	0.7	28.6
1883	6.5	20.7	1920	—0.3	23.8
1884	7.5	24.6	1921	1.2	26.3
1885	7.3	23.9	1922	1.3	25.4
1886	7.5	25.6	1923	0.8	21.3
1887	7.2	20.5	1924	—0.2	18.4
1888	7.1	20.0	1925	0.8	28.0
1889	7.0	27.0	1926	0.1	24.8
1890	9.3	24.6	1927	0.8	27.4
1891	7.4	26.9	1928	0.7	29.5
1892	7.0	28.6	1929	0.8	23.2
1893	7.6	26.5			
1894	7.5	22.6			

NOTE.—Data for periods 1849 to 1879 and 1889 to 1890 from report of Commissioner of Public Works 1894-95; for periods 1879 to 1888 and 1891 to 1929 from reports on Daily River Stages on Important Rivers in United States, by U. S. Weather Bureau.

Growth and Effect of Reclamation in Delta—Reclamation development in the delta of the Sacramento and San Joaquin rivers was started in the fifties. The first work was done on a very small scale by individuals who put up small levees, usually by hand labor, to partially reclaim small acreages. Following the adoption of the "Arkansas Act" by the United States Congress in 1850, which provided for Federal grant of swamp and overflow lands to the various states, the State Legislature passed several acts beginning in 1855, consummating in the creation of a Board of Swampland Commissioners in 1861. This act provided for the sale of swamp lands by the State to individuals who would undertake to reclaim the lands purchased. From the time of the passage of this act, reclamation development increased rather rapidly. The works required were of considerable magnitude and hence it soon became the usual practice for groups of individuals to band together in a cooperative organization to carry out the required construction work. Swampland or Reclamation districts were formed in large numbers immediately after the passage of the Swampland Act in 1861. District No. 1 comprised the whole of the American Basin between the American and Bear rivers; District No. 2, the Sacramento Basin between the American and Mokelumne rivers; and District No. 3, Grand Island. Considerable work was started after the formation of these districts but the magnitude and cost of the work was very much greater than was first estimated by the promoters. Frequently the initial group of promoters failed to complete the reclamation works. For the most part, a considerable number of years, accompanied often by changes in ownership and management, were required before reclamation was completed. In some cases low levees were first completed affording partial protection, at least for conditions of low stream flow, from tidal fluctuations. During winter floods these partially reclaimed lands would be submerged and often considerable portions of the levees were destroyed.

A search of all available records and sources of information was made for the purpose of ascertaining the date at which the various reclamations were completed within the delta area. These have included all the records in the office of the State Reclamation Board, State and Federal reports, county records, early maps and newspapers, and information from reclamation district officials and early settlers in the delta. It has been found that, in many cases, there is considerable doubt as to the exact time when levee reclamation may be considered to have been completed. From the standpoint of its possible effect on the tidal basin, effort has been made to determine the date when each reclamation development completed its levees to a sufficient extent to permanently eliminate the area thus reclaimed from the tidal basin. For those areas which, after first being reclaimed, were later flooded again by breaks in the levees, the last date of complete reclamation after the breaks were repaired has been taken.

TABLE 22

GROWTH OF RECLAMATION IN SACRAMENTO-SAN JOAQUIN DELTA

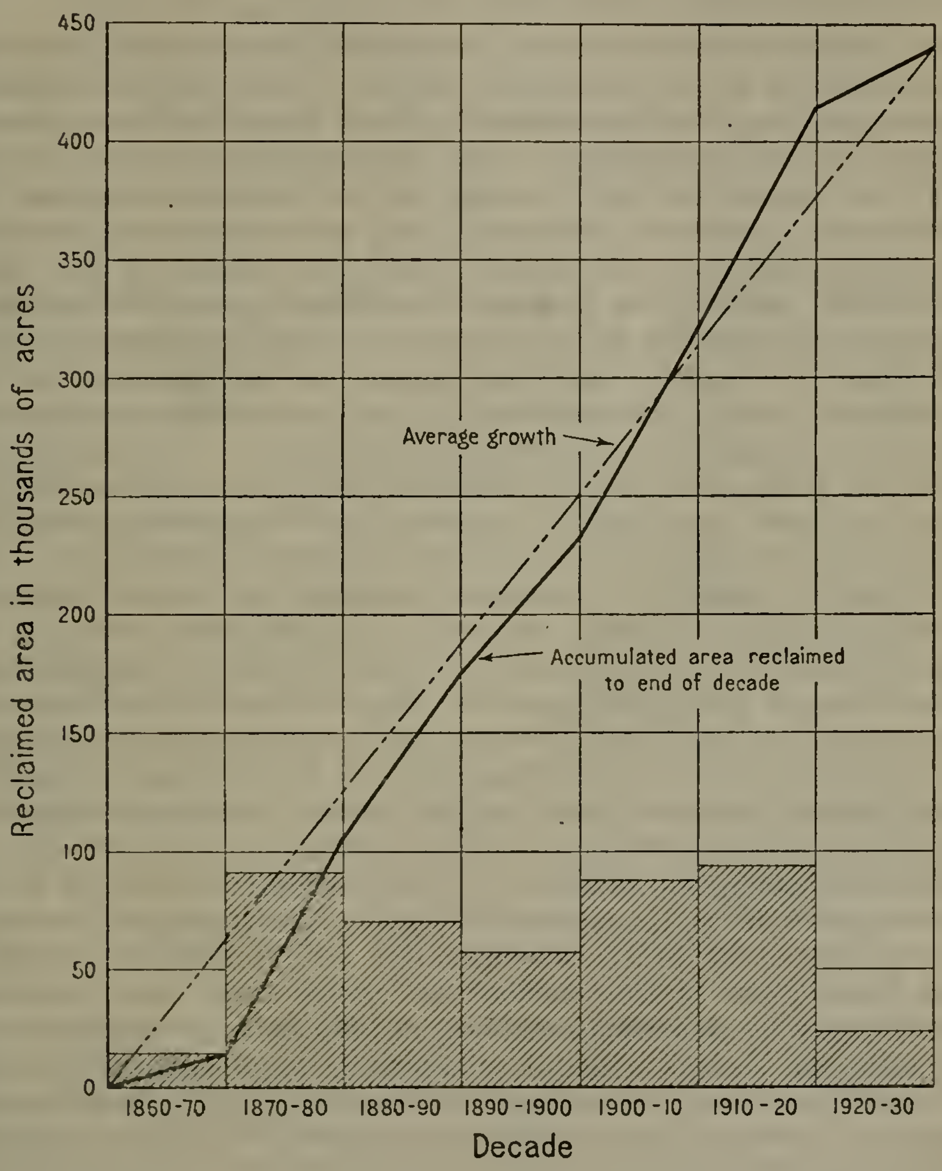
1860-1930

Decade	Area reclaimed, in acres	Accumulated area reclaimed, in acres
1860-1870	15,000	15,000
1870-1880	92,000	107,000
1880-1890	70,000	177,000
1890-1900	58,000	235,000
1900-1910	88,600	323,600
1910-1920	94,000	417,600
1920-1930	24,000	441,600

NOTE.—Prior to 1860 reclamation was of a temporary nature and its exact extent small but indefinite.

The compiled data on growth of reclamation are shown in Table 22 and graphically illustrated on Plate XXXVI, "Growth in Reclamation Development in the Sacramento-San Joaquin Delta." The progressive growth of reclamation is also shown on Plate XXXIV, on which is depicted in various colors the area reclaimed during successive decades from 1860 to 1930. The data show that there was but little acreage actually reclaimed prior to 1870. During the decade 1870–1880 a very substantial development took place, over 90,000 acres being reclaimed.

PLATE XXXVI



GROWTH IN RECLAMATION DEVELOPMENT

IN THE

SACRAMENTO-SAN JOAQUIN DELTA

From 1880 to 1900, the rate of development fell off somewhat, there being less than 130,000 acres reclaimed. However, from 1900 to 1920, an additional area of over 180,000 acres was reclaimed. The maximum area reclaimed in any decade from 1860 to 1930 was 94,000 acres during the period 1910–1920. It is important to note that the bulk of the reclamation development was completed prior to 1920. Only about 24,000 acres have been added during the last decade.

The reclamation of the delta has resulted in a change in the total area and volume of the delta tidal basin. Under natural conditions, the gross area potentially embraced within the tidal basin above the confluence of the Sacramento and San Joaquin rivers (see Plate XXXIV) at mean tide level during the low water season was about 300,000 acres. However, all of this gross area was not submerged by the tidal fluctuation. The lands along the banks of the natural channels were built up by deposits of sediment from the overflow of the streams during flood, so that the rims of the islands were considerably higher in elevation than the interior of the islands. In many cases the banks were high enough to keep out the tidal waters during the period of low stream flow in the summer and fall. Within the Sacramento Delta, pronounced ridges were built up by silt deposits along the banks of the river and branch channels and, thus, considerable areas of land lay above tidal levels in the period of low stream flow. There is no definite or complete information available as to the elevation of most of the lands in the delta before reclamation or as to what areas were submerged by tidal fluctuation. The available information as to elevation consists of the topographic maps of the United States Geological Survey compiled from surveys which were made after the delta lands were reclaimed. It is well known that the peat lands comprising most of the San Joaquin Delta and the lower Sacramento Delta have subsided materially since their reclamation and, hence, the elevations shown on these topographic maps for the peat lands can not be assumed to show the level of the lands under natural conditions prior to reclamation. It is stated by individuals familiar with conditions in the San Joaquin Delta prior to reclamation that considerable areas in the San Joaquin Delta were not submerged by tidal fluctuations in the low water season, although the government topographic maps indicate that these areas would have been submerged at mean high or high tidal stages. Therefore, it is impossible to make an estimate of the area submerged by tidal fluctuation under natural conditions before reclamation but it appears that a substantial portion of the gross area of 300,000 acres potentially within the delta tidal basin was submerged at least by the high tides.

In connection with the reclamation of lands in the delta, there has been a considerable alteration of the open channels. Some of the smaller natural channels have been closed, but many new artificial channels have been created by dredge cuts for levee construction. Most of the main natural channels have been widened by the excavation of levee material. New channels have also been created along the San Joaquin River by the Federal Government for improvement of navigation. All of this work has probably increased the area and volume of open channels within the tidal prism. However, the simultaneous leveeing-off of lands which were originally submerged by tidal flow probably has more than counterbalanced the increase in open channels.

At the present time the area of the tidal basin is about 39,000 acres. Assuming that the tidal levels and fluctuations in the delta under natural conditions were about the same as at present, the tidal volume within the limits of mean tidal range probably was somewhat greater under natural conditions than the present tidal volume of about 120,000 acre-feet. However, it can not be inferred that the tidal flow into the delta before reclamation was very materially greater than the present tidal flow. The original natural conditions within the delta were entirely different than at present. The lands subject to tidal submergence were covered largely with a thick growth of tules and similar aquatic vegetation. It is reasonable to assume that the movement or flow of water onto and away from the lands subject to submergence would have been substantially delayed by the retarding effect of this vegetation. Hence, the flow of tidal waters into and out of the original tidal basin, taken as a whole, undoubtedly would have taken place with a different rate and character of tidal movement than occurs at present. It appears that the actual tidal flow into the delta tidal basin, under original natural conditions, could not have been much greater in magnitude than the present tidal flow. The historical information previously presented in Chapter II as to salinity conditions, including data as far back as 1775, again in 1841 and also in the sixties and seventies, shows that the invasion of saline water into the delta, under natural conditions before reclamation, extended only a short distance above the confluence of the Sacramento and San Joaquin rivers even in dry years. If the original tidal flow had been materially greater than the present tidal flow, it would have resulted in a much greater magnitude of saline invasion than is known to have occurred.

The reclamation of the lands in the delta has eliminated a large area of aquatic vegetation such as cat-tails and tules which consume three to four times as much water as the crops which are now grown on these reclaimed lands. As a result, it appears probable that the consumption of water within the delta has been decreased by reclamation development, and that a greater proportion of the stream flow entering the delta now reaches the lower end of the delta to repel saline invasion than before reclamation.

Based upon the foregoing considerations, it appears reasonable to conclude that the reclamation of lands in the delta, by decreasing tidal flow and reducing consumption in the delta, has had the effect of decreasing to some extent the degree and extent to which saline invasion would have occurred during the last decade, if these lands had not been previously reclaimed. In other words, with the same stream flow into the delta as during the period 1920 to 1929, salinity conditions probably would have been worse in the delta if the lands had not been reclaimed.

The reclamation of the marsh lands adjacent to Suisun Bay also has had the effect of decreasing the magnitude of tidal flow into Suisun Bay to some extent and hence reducing the tendency of saline invasion into the Suisun Bay channels and tending to delay the advance of salinity through Suisun Bay to the delta.

Effect of Recent Changes in Delta Tidal Basin—There are certain changes during the last ten to fifteen years in connection with reclamation and flood control works within the delta which have had the effect of increasing tidal flow into the delta. These changes are of importance, in that they have been a contributing factor to the conditions giving rise to the degree and extent of saline invasion in recent years. The recent changes comprise the channel enlargement of the lower Sacramento River from Collinsville to the junction of Steamboat Slough above Rio Vista, the flooding of the lower end of Sherman Island which occurred during this river improvement work in 1925, and the flooding through failure of levees in 1927 of a private reclamation lying south of the San Joaquin River and Dutch Slough.

The widening and deepening of the lower Sacramento River has been progressively carried out from 1913 to date as a part of the Sacramento Flood Control Project. This part of the flood control project calls for a channel about 3000 feet wide and 26 feet in depth below mean lower low water. It is estimated that 141,000,000 cubic yards of material have been moved up to June, 1929, since the work was started. This work has included not only widening and deepening but also the straightening of the channel. The straightening work is especially noteworthy in the vicinity of Emmaton where a new channel cuts across a large bend of the old river channel. Dredging operations which have continued during recent years have included a considerable amount of what may be termed maintenance work, the magnitude of which is difficult to estimate, but nevertheless of considerable amount. This stretch of the river now acts essentially as a great settling basin where large quantities of the debris coming down the river are deposited because of the abrupt decrease in channel velocity where the river gradient flattens and tidal action becomes more effective. As a result of this work, the area of water surface in the tidal basin from Collinsville to Junction Point above Rio Vista has been increased about 3000 acres, with an attendant increase in the tidal prism volume between the limits of mean tidal range of 8000 to 9000 acre-feet. The total volume of channel below mean tide level in this stretch of the river has been increased from about 69,000 acre-feet to 138,000 acre-feet. As an approximation, the increase in volume of the tidal prism above Collinsville of about 9000 acre-feet would have the effect of increasing the total tidal flow per lunar day past Collinsville by about 36,000 acre-feet or an approximate increase of ten per cent. The increase in tidal flow from this work did not become effective to much extent until after 1920 and gradually approached the full amount estimated during the succeeding ten years.

The flooding of the lower part of Sherman Island and the reclamation south of Dutch Slough has increased the area of the tidal prism above the confluence of the rivers by about 4000 acres with an attendant increase in the volume of the tidal prism within the limits of mean range of tide of about 8000 to 12,000 acre-feet. This has had the effect of increasing the tidal flow past Collinsville by about the same amount as the channel improvement work of the lower Sacramento River.

It is evident that the increase in tidal flow resulting from these changes in the lower delta has increased tidal action and the tendency for saline invasion induced thereby. The analysis of the effect of these recent changes will be considered in a later portion of this chapter.

Tidal Action.

Tidal action in any tidal basin is evidenced by the periodic rise and fall of water level and the tidal currents induced by the movement of water into and out of the basin. On the Pacific coast, the tide generally rises and falls twice during a lunar day of 24 to 25 hours, resulting in the occurrence of two high and two low phases of water level. The primary tide which originates at some mid-point in the Pacific Ocean may be considered to be essentially a vertical movement. Extending out from its point of origin toward the shallower depths along the shores, this primary vertical movement gradually induces a horizontal component of motion which, upon reaching the shores, is exhibited by the well known phenomenon of tidal currents. As a result, when the tide rises in what is known as the flood period, it is accompanied by a considerable horizontal current projected landward. When the tide falls in what is known as the ebb period, it is accompanied by a current in the opposite direction away from shore. Thus, as the tide rises and falls, the water of the ocean flows into and out of the tidal basin of San Francisco Bay twice each day.

The level actually reached by the high and low tidal phases varies considerably from day to day and on the same day as well. The sequence of occurrence of tidal phases during a lunar day, or what may be termed a tidal cycle period of from 24 to 25 hours, is generally as follows: Starting with a low tide, the water level rises in a flood period to a high tide. This is followed by a period of ebb with the level falling to a second low tide. The level again rises in another flood period to a second high tide of the tidal cycle and finally falls in an ebb period to a low tide. The levels reached by the two high tides as well as the two low tides during a particular tidal cycle usually differ considerably. The lower of the two high tides has been designated as the low-high tide and the higher as the high-high tide. Similarly the two low tides have been designated as the low-low and high-low tides. It sometimes happens that the level of the two high tides or the two low tides is about the same on the same day. (See Plate LXX for typical tidal record at Antioch.)

The difference in level between the various tidal phases is termed the tidal range. There is considerable inequality in the range of the tide, both as between the four consecutive tidal phases on a particular day and as between any two identical tidal phases on different days. The variation in water level and range at different points in the tidal basin as compiled from the tide gage records, is shown in Table 5 and Plate XV.

The various kinds of tides having marked characteristics as to magnitude of range and relative height of high and low waters are given specific names, based upon the relative position of the moon and the sun which combine to set up the forces acting to produce tidal action. At the time of new moon and full moon these tidal forces of the moon and sun are acting in the same direction. High water then rises higher and low water falls lower than usual so that the range of the tide at such times is greater than the average. The tides occurring at new moon or full moon are called "spring tides" and the range of the tide is known as the "spring range." When the moon is in its first and third quarters, the tidal forces of the sun and moon are opposed and hence the tide does not rise as high nor fall as low as on the average. Tides occurring at such times are called "neap tides" and the corresponding range the "neap range."

The varying distance of the moon from the earth likewise affects the range of the tide. When the moon is nearest the earth or in "perigee," the tide producing force is increased, resulting in an increased rise and fall of the tide. The tides occurring at the time of the moon's closest position to the earth are known as "perigean tides" and the corresponding range the "perigean range." When the moon is farthest from the earth or in "apogee" the tide producing force is diminished, resulting in a decreased magnitude of rise and fall. The corresponding tides produced are known as "apogean tides" and the corresponding range the "apogean range."

There is still a third variation of the relative position of the moon and the earth; namely, the changing magnitude of the moon's declination from the plane of the earth's equator which varies from day to day, due to the fact that the moon's orbit makes an angle with the plane of the earth's equator of approximately 23½ degrees. When the moon is on or close to the equator the consecutive ranges of the tide in morning and afternoon do not differ much in magnitude. As the declination increases, however, the difference in consecutive ranges increases, reaching a maximum difference when the moon has reached its maximum declination. The tides occurring at the time the moon is on or close to the equator are known as "equatorial tides" and the tides occurring at the time of the moon's semimonthly maximum declination are known as "tropic tides."

The tides occurring on the coast of northern California and in San Francisco Bay include a mixture of all of the above types of tides. There is usually considerable diurnal inequality between the heights of the two high waters and the two low waters occurring each day. However, about every 14 days or semimonthly, the two high tides and the two low tides occurring during the day usually reach about an equal height.

The Tidal Prism—The tidal prism of any tidal basin is defined as the volume of water in the basin between the levels of high and low tides. The maximum effective volume potentially available in the tidal prism is the total volume within the maximum range of the tide from lower low water to higher high water. As shown in Table 20, the maximum potential tidal prism volume for the entire tidal basin of San Francisco Bay is 3,120,000 acre-feet. That of the delta tidal basin alone is 244,000 acre-feet. As between these maximum limits of range, the actual change in volume in the tidal basin between any two successive phases of the tide is only a fraction of this total potential volume even under conditions of maximum tidal range. This is due to the fact that tidal movement advances upstream from the lower end of a tidal basin, and hence identical tidal phases do not occur at the same time at all points in the basin, but instead, different tidal phases or stages of the tide occur simultaneously at different points in the tidal basin. Thus, the tide may be in flood and rising in the lower end of the basin, and at the same time falling or in ebb in the upper part of the basin, while in between may be occurring intermediate stages of the tide. The actual change in volume in the tidal basin, during the interval between two successive phases of the tide at the lower end of the basin, is equal to the volume between the two actual levels of water surface over the entire basin, at the time of occurrence of these successive tidal phases at the lower end of the basin. The water surfaces which define the limits of change in volume in the tidal basin are generally irregular in shape and the volume between the limits thereof is but a small portion of the maximum effective tidal prism potentially available within the maximum limits of tidal range. The actual change in volume in the tidal basin during flood or ebb tide between successive high and low tidal phases is the chief measure of the volume of tidal flow entering or leaving the tidal basin.

Advance of Tides—The rate of advance of the tide in ebb and flood, between the Golden Gate and farthest upstream points in the tidal basin, has been determined from a study of the automatic tide gage records. The time of occurrence of high and low tidal phases has been compiled for various periods of record at all automatic tide gage stations, and the compiled data are shown in Table 23. In all cases the time of occurrence has been expressed as the difference in time between the occurrence of identical tidal phases at the Presidio and at bay and delta stations. These differences in time have been compiled for all four phases of the tide for purposes of comparison. The table shows the maximum and minimum as well as the average time intervals. The period chosen in compiling these data, especially for stations in the delta and upper bay channels, is that of low stream flow. The data are, therefore, representative of tidal conditions during the period of advance and retreat of salinity in the upper bay and delta. As shown in the tabulation, there is a constantly increasing time interval between the occurrence of identical tidal phases at the Presidio and at points upstream. This is more clearly shown in graphical form on Plate XXXIV. On this map of the bay and delta regions, lines of equal time of occurrence of tidal phases have been drawn on the basis of the data in Table 23. These lines are based upon the mean time interval for all tidal phases. The time interval at points between tide gages has been interpolated from the actual tide gage records based upon the rate of advance of the tide for different channel conditions. A tabulation is also shown on Plate XXXIV, giving the mean departure in time of occurrence of each particular tidal phase from the mean of the four tidal phases.

As shown by Table 23 and Plate XXXIV, the time interval between occurrence of identical tidal phases at the Presidio and at upper bay and delta points reaches a maximum of 10 to 13 hours at the upper limits of the tidal basin. It should be noted again that these data apply to the normal low stream flow conditions in the summer and fall months. In the winter and spring with larger stream flow, these time intervals would be considerably changed in the delta region. There would also be greater departures from the mean for the actual tidal phases. During periods of large stream flow, the time interval for the tidal phases following ebb tide in general would be increased, whereas for the tidal phases following flood tide, the time interval would be decreased.

TABLE 23

TIME INTERVAL BETWEEN OCCURRENCE OF TIDAL PHASES AT PRESIDIO AND AT POINTS IN SAN FRANCISCO BAY AND SACRAMENTO-SAN JOAQUIN DELTA

Based upon automatic tide gage records in 1929 and 1930

Station	High-high tide						Low-high tide						High-low tide						Low-low tide						Mean time interval for all tidal phases		Period of record from which data are compiled
	Maximum time interval		Minimum time interval		Mean time interval		Maximum time interval		Minimum time interval		Mean time interval		Maximum time interval		Minimum time interval		Mean time interval		Maximum time interval		Minimum time interval		Mean time interval				
	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	Hours	Minutes	
South San Francisco Bay																											
Hunters Point	1	00	0	06	0	27	0	48	0	06	0	25	1	06	0	06	0	39	1	12	0	18	0	41	0	33	Jan. 16 to Feb. 13, 1930
San Mateo Bridge	1	18	0	18	0	53	1	12	0	06	0	44	1	36	1	00	1	18	2	18	0	54	1	21	1	05	Jan. 18 to Feb. 24, 1930
Dumbarton Bridge	1	36	0	48	1	05	1	18	0	12	0	44	1	54	1	12	1	36	2	00	1	12	1	31	1	14	Jan. 18 to Feb. 11, 1930
San Francisco, San Pablo and Suisun Bays																											
Point Bluff	1	00	0	06	0	28	1	18	0	06	0	30	0	54	0	12	0	32	1	36	-	--	0	33	0	31	May 1 to July 1, 1930
Oakland Mole	0	48	-	--	0	31	0	54	-	--	0	31	1	00	0	12	0	38	1	12	0	48	0	40	0	35	May 6 to July 1, 1930
Point Orient	1	12	0	06	0	48	1	12	0	18	0	48	1	36	0	36	1	01	1	30	0	30	0	58	0	54	Jan. 21 to Mar. 3, 1930
Pinole Point	1	48	0	48	1	20	1	48	0	36	1	19	2	00	0	30	1	28	2	00	0	30	1	31	1	25	May 1 to Sept. 30, 1930
Beacon No. 2	2	30	1	00	1	34	2	18	1	06	1	32	2	18	1	06	1	44	2	36	1	24	2	01	1	42	July 28 to Sept. 30, 1930
Sonoma Creek	2	30	0	42	1	35	2	42	0	36	1	33	3	06	0	54	1	54	4	06	1	24	2	54	2	00	May 1 to June 30, 1930
Petaluma Creek	2	30	1	00	1	37	2	18	0	36	1	37	3	00	1	18	1	54	4	00	1	48	3	01	2	02	May 1 to July 1, 1930
Crockett	2	24	1	18	1	54	2	36	1	18	1	56	2	42	1	06	2	08	3	00	1	36	2	22	2	05	Oct. 10, '29 to Jan. 7, '30
Mare Island	2	24	1	42	2	02	2	24	1	24	2	03	2	30	1	48	2	10	3	12	1	54	2	28	2	11	July 1 to Oct. 31, 1929
Benicia	2	54	1	42	2	26	2	42	1	36	2	26	3	00	1	42	2	32	3	24	2	06	2	51	2	34	July 7 to Oct. 31, 1929
Bay Point	3	12	2	06	2	41	3	18	2	00	2	42	3	36	2	36	3	00	3	54	2	42	3	24	2	57	April 1 to July 30, 1930
Suisun Light	3	30	2	06	2	49	3	24	2	06	2	46	3	54	2	00	3	09	4	24	2	18	3	34	3	05	April 1 to July 30, 1930
Point Buckler	3	12	2	06	2	37	3	24	1	54	2	40	4	00	2	12	3	18	4	36	2	42	3	46	3	06	Aug. 9 to Aug. 31, 1930
Mallard Slough*	3	36	2	18	3	11	3	42	2	48	3	13	4	12	2	48	3	32	4	36	3	42	4	07	3	31	April 1 to May 18, 1930
Meins Landing	4	24	2	36	3	40	4	36	2	18	3	31	4	48	2	24	3	51	5	24	3	36	4	38	3	55	April 1 to July 30, 1930

Sacramento River Delta																										
Collinsville	4	18	3	30	3	55	4	30	3	30	3	55	4	48	3	00	4	09	5	30	4	12	4	49	4	12	July 1 to Oct. 31, 1929
Three Mile Slough, Sacramento River End	5	12	3	54	4	23	5	30	3	48	4	24	5	18	4	06	4	41	6	36	4	36	5	26	4	44	July 1 to Oct. 31, 1929
Rio Vista	5	00	4	06	4	30	5	36	3	54	4	34	5	48	4	06	4	48	6	36	4	42	5	37	4	52	July 1 to Oct. 31, 1929
Walnut Grove	7	18	5	00	5	55	7	06	5	00	5	53	7	12	5	36	6	26	8	30	5	54	7	24	6	25	July 1 to Oct. 31, 1929
Sacramento	9	30	7	24	8	04	9	12	7	00	7	59	10	24	8	18	9	19	11	54	9	24	10	33	8	59	July 3 to Sept. 30, 1929
San Joaquin River Delta																										
Antioch	5	18	3	42	4	24	5	00	3	54	4	26	5	42	4	00	4	34	5	42	4	24	5	13	4	39	July 1 to Oct. 31, 1929
Three Mile Slough, San Joaquin River End	5	54	4	24	4	59	6	18	4	30	4	59	6	06	4	36	5	19	7	24	5	24	5	59	5	19	July 1 to Oct. 31, 1929
Venice Island	6	54	4	48	5	43	6	30	5	00	5	46	6	48	4	36	5	53	7	18	5	00	6	37	6	00	July 1 to Sept. 30, 1929
Georgiana Slough	6	48	5	12	5	48	7	06	5	12	5	52	7	00	5	12	6	10	7	42	6	00	6	54	6	11	July 1 to Oct. 31, 1929
East Contra Costa Irrigation District	7	42	5	54	6	50	7	36	5	30	6	46	8	18	5	36	7	02	9	00	7	42	7	50	7	07	July 1 to Sept. 30, 1929
New Hope Bridge	7	24	6	03	6	39	7	18	6	06	6	46	8	09	6	18	7	08	8	54	7	24	8	07	7	10	July 1 to Sept. 30, 1929
Stockton	8	30	6	54	7	44	9	36	6	42	7	47	9	42	7	18	8	07	10	36	8	06	9	09	8	12	July 1 to Sept. 30, 1929
Mossdale, S. P. R.R. Bridge	10	18	8	24	9	16	10	30	8	24	9	13	11	42	9	12	10	16	13	54	10	12	11	39	10	06	July 4 to Oct. 31, 1929

*No automatic instrument; staff gage read hourly by California Water Service Company.

The advance of the tide in the tidal basin of San Francisco Bay and particularly in the upper bay and delta channels represents a progressive wave movement. The crest of this wave advances progressively upstream, and the culmination of low and high waters takes place at constantly increasing time intervals after the occurrence of the same at the Golden Gate, as the distance from the Golden Gate is increased. In a tidal movement, it is necessary to distinguish clearly between the velocity of current induced and the progression or rate of advance of the tide. In the former case, reference is made to the actual speed of a moving particle of water while, in the latter case, reference is to the rate of advance of a particular tidal phase or the velocity of propagation of the progressive wave. In general, the rate of advance of a tidal phase or the progressive wave is many times greater than the actual velocity of the current induced by the tidal movement. It does not necessarily follow that there is a relation between the velocity of tidal current in any channel section and the rate of advance of the tide in this same section. The existence or non-existence of a velocity of tidal current can not be inferred alone from a known rate of advance of the tide. The velocity of tidal current or the actual speed with which the particles of water are moving past any fixed point depends upon the volume of water which passes the given point and the cross-section of the channel at that point. The velocity of the tidal current is, therefore, independent of the rate of advance of the tide.

The rate of advance of the tide in any given channel depends upon the type of the tidal movement. For the upper bay and delta channels the tidal movement takes the form of a progressive wave which moves approximately in accordance with the following theoretical formula:

$$r = \sqrt{gd}$$

in which

r = rate of advance of the tide in feet per second.
g = acceleration of gravity in feet per second squared.
d = the depth of the waterway in feet.

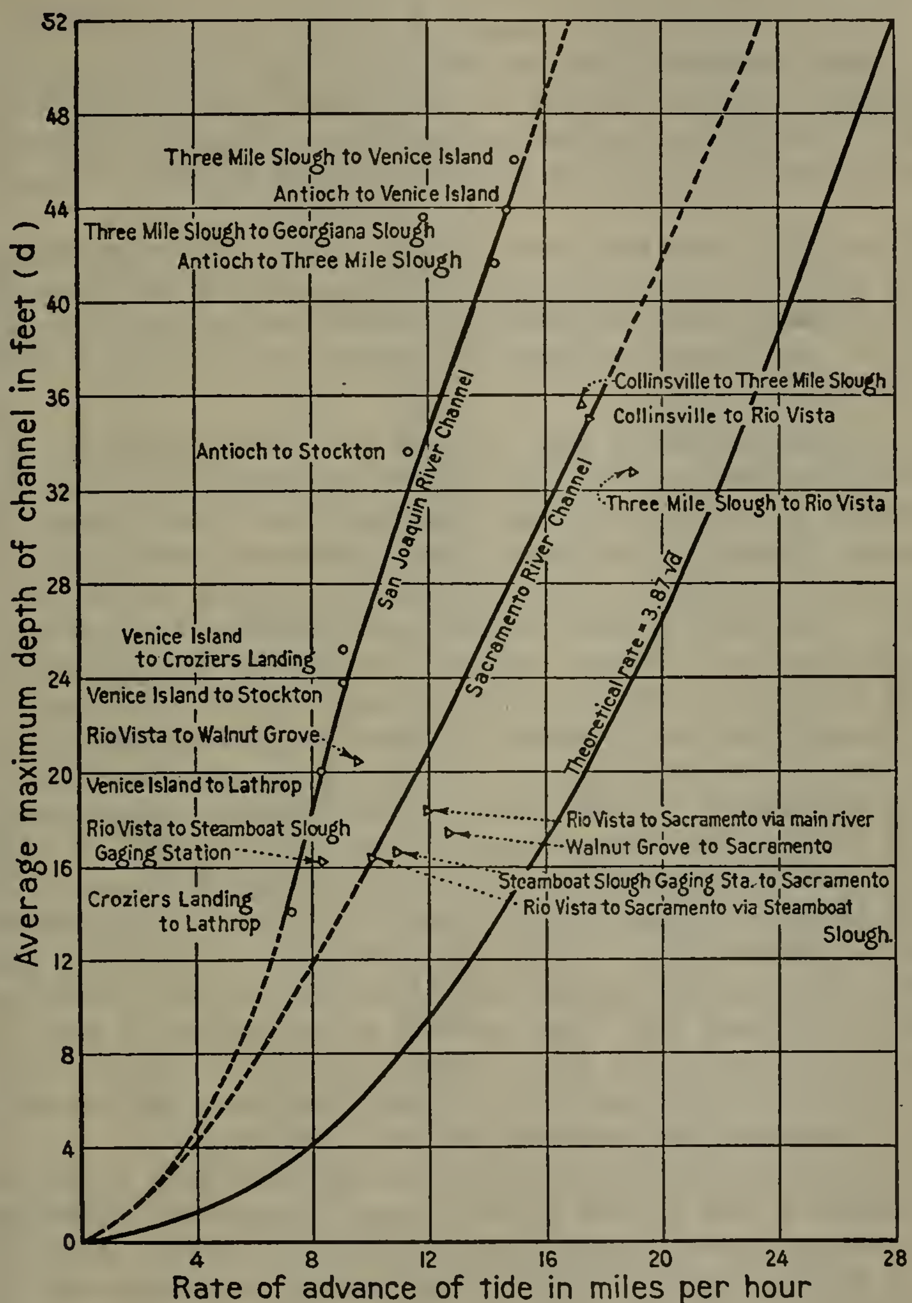
This formula becomes

$$r = 3.87 \sqrt{d}$$

with r expressed in miles per hour.

Based upon the data on time of occurrence of tidal phases as previously presented, computations were made to determine the rate of advance of the tides in the channels of the Sacramento and San Joaquin rivers. The results of this study are shown on Plate XXXVII, "Rate of Advance of Tides in Sacramento-San Joaquin Delta Channels." On this plate the curve plotted from the theoretical formula is shown on the lower part of the diagram and, in addition, a separate curve is shown for the Sacramento River and San Joaquin River channels. These curves are drawn through plotted points determined from a computation of the difference in time of occurrence of tidal phases and channel depths. Thus for the channel section from Collinsville to Three Mile Slough on the Sacramento River, the difference in time of the occurrence of tides as shown on Plate XXXIV is 0 hours

PLATE XXXVII



RATE OF ADVANCE OF TIDES

IN

SACRAMENTO-SAN JOAQUIN DELTA CHANNELS

and 32 minutes over a channel distance of 9.2 miles, from which the actual rate of advance of the tide is computed as 17.2 miles per hour. This channel section has an average depth of 35.5 feet. In a similar manner all of the points on the diagram were computed and plotted. The difference between the curves determined for points along the Sacramento River and San Joaquin River channels probably is due to the variable character and composition of the net work of branch channels which affect the tidal movement along these main channels of the basin. The rate of advance in relation to channel depth as shown by these curves indicates that the movement is similar to a progressive wave.

These curves have been used for the purpose of interpolating points of equal time of occurrence of tidal phases between tide gage stations. These data have been especially important and essential in the compilation of the maximum effective volume in the tidal prism of the delta and Suisun Bay.

Tidal Volumes in Delta and Suisun Bay—The maximum effective volume of the tidal prism in the delta of the Sacramento and San Joaquin rivers and in Suisun Bay comprises the total volume between the extreme limits of tidal range from lower low water to higher high water. For convenience, this volume is referred to as the "tidal volume." For the purposes of this investigation, the limits of tidal range considered are for the period of low stream flow during summer and fall months, covering the advance and retreat of salinity. These tidal volumes have been computed separately for the tidal basin in the delta proper above the confluence of the Sacramento and San Joaquin rivers at Collinsville (Chain Island) and for Suisun Bay from Army Point to Collinsville. The results of the computations are shown on Plate XXXVIII, "Accumulated Tidal Volume in Sacramento and San Joaquin Delta Channels," and Plate XXXIX, "Accumulated Tidal Volume in Suisun Bay." The tidal volume in the delta has been divided as between the Sacramento Delta and the San Joaquin Delta. It should be noted that tidal volume is distinct from total storage volume in the basin, the latter being the total volume in the basin from the bed of the channel to the water surface and the former including only the volume between the limits of tidal range.

The tidal volumes of the delta channels have been computed from the surveys of the United States Army Engineers. These surveys have been made over a considerable period of years. Some are far from up to date, particularly for portions of the channels in the San Joaquin Delta, such as Old River and Middle River and the connecting channels thereof, and the lower San Joaquin River below the mouth of the Mokelumne River, which were surveyed in 1908. For the upper San Joaquin River from the mouth of the Mokelumne River to Stockton, the rather recent surveys made in connection with the Stockton Ship Canal are available. There are similar variations in the dates of surveys on the Sacramento River. Certain portions, especially the lower end of the Sacramento River, have been surveyed during 1929 and 1930 and other portions during the previous ten years. In all cases, however, the latest survey data have been used in the compilation of tidal volumes.

Storage volume in thousands of acre-feet

.E OF TWO-MILE INCREMENTS
CRAMENTO RIVER CHANNELS

FROM END ... SLAND	VOLUME IN ACRE-FEET BETWEEN ELEV. -3.0 & +7.0 U.S.G.S. DATUM	VOLUME IN ACRE-FEET PER FOOT OF DEPTH BELOW ELEV. +1.0 U.S.G.S. DATUM	ABOVE ELEV. +1.0 U.S.G.S. DATUM
0	8,400	775	883
2	8,300	775	867
4	16,600	975	2,117
6	10,100	900	1,083
8	8,700	775	933
0	7,700	625	867
2	8,000	750	834
4	8,200	800	833
6	9,000	775	984
8	12,100	1,075	1,300
0	7,700	600	883
2	4,100	325	467
4	3,200	300	333
6	3,400	300	367
8	3,400	300	367
0	2,100	200	217
2	1,600	150	167
4	1,700	150	183
6	1,800	150	200
8	1,700	150	183
0	1,500	125	167
2	1,200	100	133
4	1,000	100	117
6	1,200	100	133
8	1,600	150	167
0	1,100	100	117
2	1,100	100	117
4	1,100	100	117
6	900	75	100
8	1,200	100	133
0	1,000	75	117
2	1,000	75	133
4	900	75	100
6	1,000	75	116
8	1,000	50	133
0	800	75	83
2	500	25	67
4			
6			
8			

TABLE OF TWO-MILE INCREMENTS
SAN JOAQUIN RIVER CHANNELS

MILES FROM LOWER END OF CHAIN ISLAND	VOLUME IN ACRE-FEET BETWEEN ELEV. -3.0 & +7.0 U.S.G.S. DATUM	VOLUME IN ACRE-FEET PER FOOT OF DEPTH BELOW ELEV. +1.0 U.S.G.S. DATUM	ABOVE ELEV. +1.0 U.S.G.S. DATUM
0	8,200	800	833
2	8,200	725	833
4	7,900	750	817
6	14,500	1,200	1,617
8	27,600	2,175	3,150
10	8,600	775	917
12	6,600	600	700
14	6,600	600	700
16	7,900	750	817
18	8,900	725	1,000
20	11,800	812	1,425
22	11,800	1,000	1,300
24	7,800	637	875
26	9,700	875	1,033
28	13,000	1,000	1,500
30	17,300	1,262	2,041
32	14,000	1,237	1,508
34	14,900	1,075	1,767
36	14,500	1,075	1,700
38	18,800	1,450	2,167
40	10,800	725	1,317
42	8,900	725	1,000
44	7,700	650	850
46	3,200	300	333
48	2,700	237	292
50	2,900	187	358
52	2,000	162	225
54	2,100	187	225
56	1,400	137	142
58	1,400	100	167
60	500	37	58
62	600	50	67
64	300	25	33
66	300		50
68	300		50
70	300		50
72	150		25
74	150		25
76			
78			

Storage volume in thousands of acre-feet

ACCUMULATED TIDAL VOLUME
IN
SACRAMENTO AND SAN JOAQUIN DELTA CHANNELS

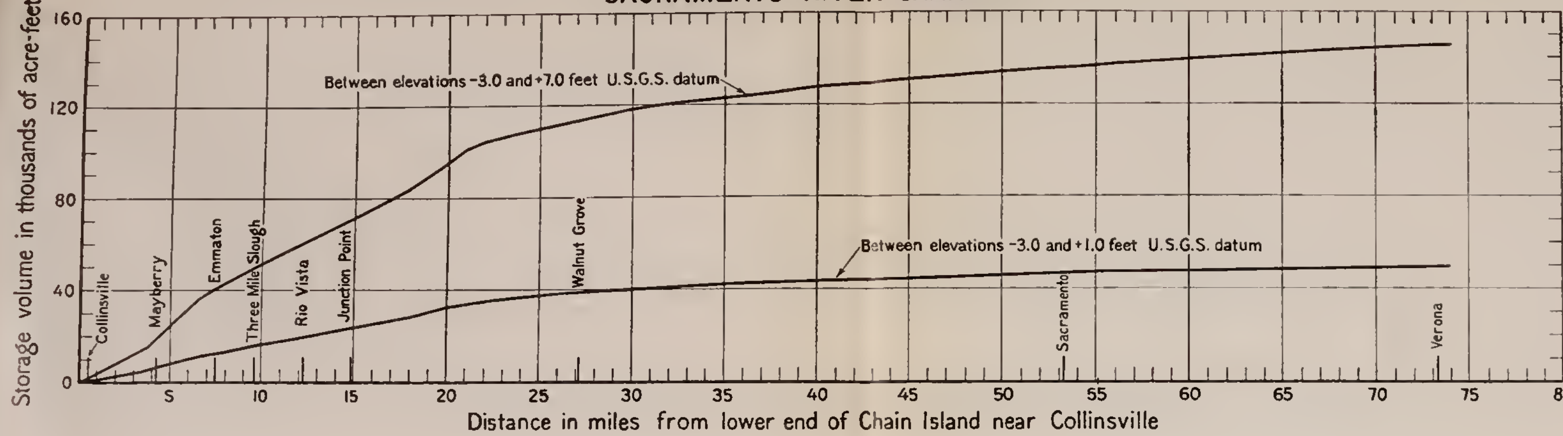
and 32 minutes over a channel distance of 9.2 miles, from which the actual rate of advance of the tide is computed as 17.2 miles per hour. This channel section has an average depth of 35.5 feet. In a similar manner all of the points on the diagram were computed and plotted. The difference between the curves determined for points along the Sacramento River and San Joaquin River channels probably is due to the variable character and composition of the net work of branch channels which affect the tidal movement along these main channels of the basin. The rate of advance in relation to channel depth as shown by these curves indicates that the movement is similar to a progressive wave.

These curves have been used for the purpose of interpolating points of equal time of occurrence of tidal phases between tide gage stations. These data have been especially important and essential in the compilation of the maximum effective volume in the tidal prism of the delta and Suisun Bay.

Tidal Volumes in Delta and Suisun Bay—The maximum effective volume of the tidal prism in the delta of the Sacramento and San Joaquin rivers and in Suisun Bay comprises the total volume between the extreme limits of tidal range from lower low water to higher high water. For convenience, this volume is referred to as the "tidal volume." For the purposes of this investigation, the limits of tidal range considered are for the period of low stream flow during summer and fall months, covering the advance and retreat of salinity. These tidal volumes have been computed separately for the tidal basin in the delta proper above the confluence of the Sacramento and San Joaquin rivers at Collinsville (Chain Island) and for Suisun Bay from Army Point to Collinsville. The results of the computations are shown on Plate XXXVIII, "Accumulated Tidal Volume in Sacramento and San Joaquin Delta Channels," and Plate XXXIX, "Accumulated Tidal Volume in Suisun Bay." The tidal volume in the delta has been divided as between the Sacramento Delta and the San Joaquin Delta. It should be noted that tidal volume is distinct from total storage volume in the basin, the latter being the total volume in the basin from the bed of the channel to the water surface and the former including only the volume between the limits of tidal range.

The tidal volumes of the delta channels have been computed from the surveys of the United States Army Engineers. These surveys have been made over a considerable period of years. Some are far from up to date, particularly for portions of the channels in the San Joaquin Delta, such as Old River and Middle River and the connecting channels thereof, and the lower San Joaquin River below the mouth of the Mokelumne River, which were surveyed in 1908. For the upper San Joaquin River from the mouth of the Mokelumne River to Stockton, the rather recent surveys made in connection with the Stockton Ship Canal are available. There are similar variations in the dates of surveys on the Sacramento River. Certain portions, especially the lower end of the Sacramento River, have been surveyed during 1929 and 1930 and other portions during the previous ten years. In all cases, however, the latest survey data have been used in the compilation of tidal volumes.

SACRAMENTO RIVER CHANNELS



SAN JOAQUIN RIVER CHANNELS

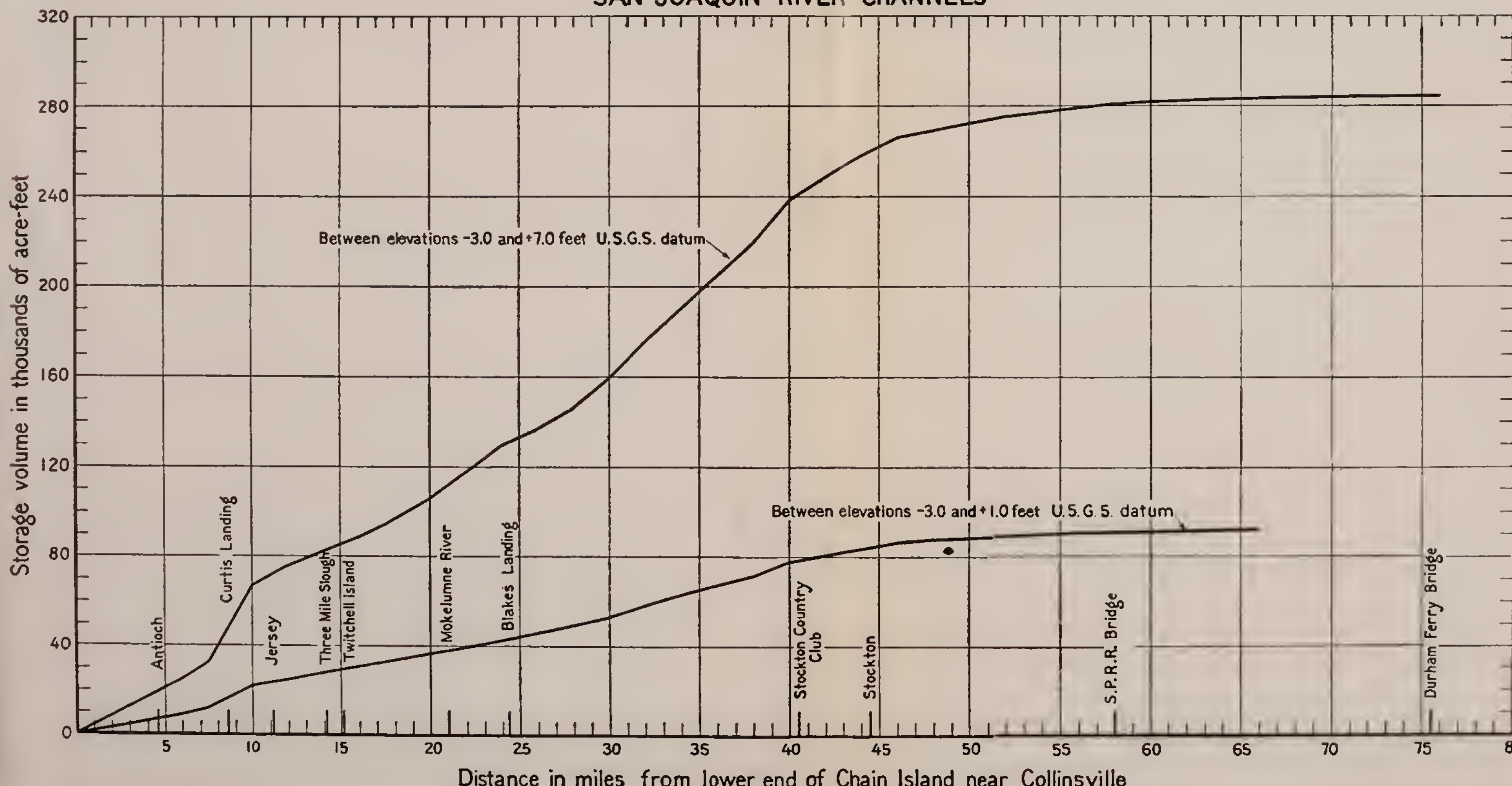


TABLE OF TWO-MILE INCREMENTS SACRAMENTO RIVER CHANNELS

MILES FROM LOWER END OF CHAIN ISLAND	VOLUME IN ACRE-FEET BETWEEN ELEV. -3.0 & +7.0 U.S.G.S. DATUM	VOLUME IN ACRE-FEET PER FOOT OF DEPTH	
		BELOW ELEV. +1.0 U.S.G.S. DATUM	ABOVE ELEV. +1.0 U.S.G.S. DATUM
0	8,400	775	883
2	8,300	775	867
4	16,600	975	2,117
6	10,100	900	1,083
8	8,700	775	933
10	7,700	625	867
12	8,000	750	834
14	8,200	800	833
16	9,000	775	984
18	12,100	1,075	1,300
20	7,700	600	883
22	4,100	325	467
24	3,200	300	333
26	3,400	300	367
28	3,400	300	367
30	2,100	200	217
32	1,600	150	167
34	1,700	150	183
36	1,800	150	200
38	1,700	150	183
40	1,500	125	167
42	1,200	100	133
44	1,000	100	117
46	1,200	100	133
48	1,600	150	167
50	1,100	100	117
52	1,100	100	117
54	1,100	100	117
56	900	75	100
58	1,200	100	133
60	1,000	75	117
62	1,000	75	133
64	900	75	100
66	1,000	75	116
68	1,000	50	133
70	800	75	83
72	500	25	67
74			
76			
78			

TABLE OF TWO-MILE INCREMENTS SAN JOAQUIN RIVER CHANNELS

MILES FROM LOWER END OF CHAIN ISLAND	VOLUME IN ACRE-FEET BETWEEN ELEV. -3.0 & +7.0 U.S.G.S. DATUM	VOLUME IN ACRE-FEET PER FOOT OF DEPTH	
		BELOW ELEV. +1.0 U.S.G.S. DATUM	ABOVE ELEV. +1.0 U.S.G.S. DATUM
0	8,200	800	833
2	8,200	725	833
4	7,900	750	817
6	14,500	1,200	1,617
8	27,600	2,175	3,150
10	8,600	775	917
12	6,600	600	700
14	6,600	600	700
16	7,900	750	817
18	8,900	725	1,000
20	11,800	812	1,425
22	11,800	1,000	1,300
24	7,800	637	875
26	9,700	875	1,033
28	13,000	1,000	1,500
30	17,300	1,262	2,041
32	14,000	1,237	1,508
34	14,900	1,075	1,767
36	14,500	1,075	1,700
38	18,800	1,450	2,167
40	10,800	725	1,317
42	8,900	725	1,000
44	7,700	650	850
46	3,200	300	333
48	2,700	237	292
50	2,900	187	358
52	2,000	162	225
54	2,100	187	225
56	1,400	137	142
58	1,400	100	167
60	500	37	58
62	600	50	67
64	300	25	33
66	300		50
68	300		50
70	300		50
72	150		25
74	150		25
76			
78			

ACCUMULATED TIDAL VOLUME
IN
SACRAMENTO AND SAN JOAQUIN DELTA CHANNELS

PLATE XXXIX

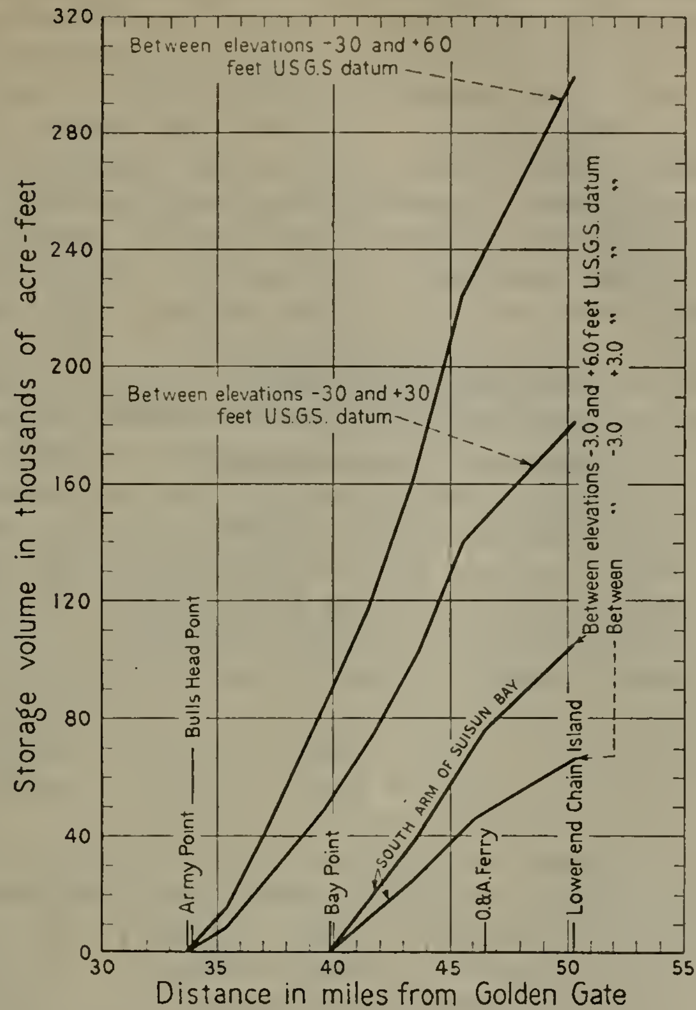


TABLE OF INCREMENTS

MILES FROM GOLDEN GATE	ABOVE ARMY POINT: VOLUME IN ACRE-FEET BETWEEN ELEV. -3.0 & +6.0 U.S.G.S. DATUM	ABOVE ARMY POINT: VOLUME IN ACRE-FEET PER FOOT OF DEPTH BETWEEN ELEVATIONS -3.0 & +3.0 U.S.G.S. DATUM	ABOVE ARMY POINT: VOLUME IN ACRE-FEET PER FOOT OF DEPTH BETWEEN ELEVATIONS +3.0 & +6.0 U.S.G.S. DATUM	ABOVE BAY POINT: VOLUME IN ACRE-FEET BETWEEN ELEV. -3.0 & +6.0 U.S.G.S. DATUM	ABOVE BAY POINT: VOLUME IN ACRE-FEET PER FOOT OF DEPTH BETWEEN ELEVATIONS -3.0 & +3.0 U.S.G.S. DATUM	ABOVE BAY POINT: VOLUME IN ACRE-FEET PER FOOT OF DEPTH BETWEEN ELEVATIONS +3.0 & +6.0 U.S.G.S. DATUM
33.8						
	1933	195	255			
34.0						
	22418	2221	3031			
36.0						
	31969	3122	4411			
38.0						
	33928	3530	4250	* 1092	* 116	* 132
40.0						
	38876	4195	4569	21890	2338	2621
42.0						
	49385	5274	5914	22937	2480	2685
44.0						
	54111	5524	6989	24337	2595	2922
46.0						
	31520	2830	4846	16534	1707	2098
48.0						
	30857	2830	4626	15342	1582	1951
50.0						
	4629	425	694	2302	237	293
50.3						

* Volume above mile 39.9

ACCUMULATED TIDAL VOLUME

IN

SUISUN BAY

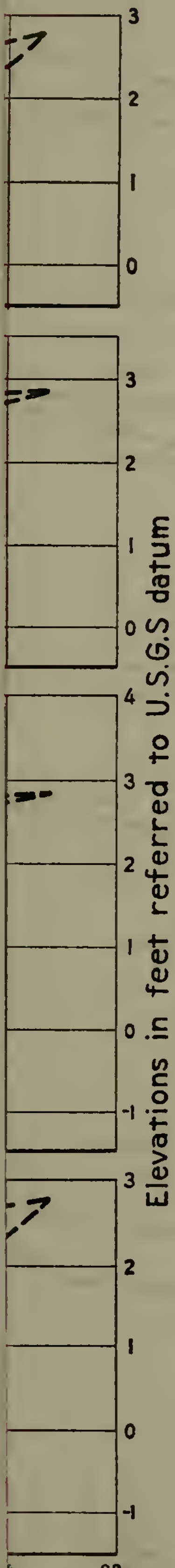
The computations of tidal volume in the delta are of a tedious and voluminous nature, involving some 550 miles of channels. Volumes within the tidal range were first computed for successive segments of each channel from the channel cross sections on the survey maps and these volumes were then accumulated with distance from the lower to the upper end of each channel. The total tidal volume for the Sacramento and San Joaquin Delta tidal basins was then accumulated separately for each basin, progressing upstream from the confluence of the rivers at Collinsville (Chain Island) to the upper limits of the tidal basin. In this progressive accumulation, the distance in miles from the mouth of the river up through each basin was measured along the main channels, as shown on Plate XXXIV. The volumes in the branch channels were accumulated with the volumes in the main channels on the basis of equal time of occurrence of tidal phases. Thus, the volume in any branch channel was accumulated with the volume in the main channel up to points having an equal time of occurrence of tide. By this method, the volume of the tidal basin was accumulated in the same manner as the basin is filled or emptied by tidal waters.

The accumulated tidal volumes for both the San Joaquin and Sacramento River channels have been computed for the tidal volume between elevations — 3 and + 1 and between elevations — 3 and + 7, U. S. G. S. Datum. The tabulations on Plate XXXVIII summarize, by two miles increments, the tidal volumes in acre-feet and, in addition, the variation of tidal volume per foot of depth for each zone between elevations — 3 and + 1 and elevations + 1 and + 7.

For the tidal volume in Suisun Bay, the hydrographic survey made in the spring of 1930 by the United States Army Engineers was used. The compiled data are shown on Plate XXXIX. The tidal volumes between elevations — 3 and + 3 and elevations — 3 and + 6, U. S. G. S. datum, were progressively accumulated from the lower end to the upper end of the basin. The distance in miles along which the accumulation was made was measured along a median line from Army Point to the mouth of the river, as shown on Plate XXXIV. The accumulation of the volumes for the bay proper and for the branch channels was made in the same manner as in the case of the delta channels in proportion to the advance of the tide.

Tidal Prism Volumes in Delta and Suisun Bay—The actual changes in volume in the tidal prism of the delta and Suisun Bay between successive tidal phases vary with the range of the tide and include only a portion of the total tidal volume. These volumes of actual tidal prisms are designated herein as "tidal prism volumes." The determination of actual tidal prism volumes is made possible by the continuous records of tidal stage obtained from the several automatic tide gage stations established in the basin, combined with the tabulations of tidal volume compiled in the manner previously described.

Typical tidal prisms for the delta and for Suisun Bay are shown on Plates XL to XLV, inclusive. These are representative of a large number of actual tidal prisms compiled and computed for these basins covering considerable variations of tidal range. As an example, Plate XL, "Tidal Prism Volumes in Sacramento River Channels," shows the tidal prisms or changes in tidal volume during a tidal cycle on August 27 and 28, 1929. The instantaneous position or profile of the water



TIDAL PRISM VOLUME

Computed from slack water to slack water

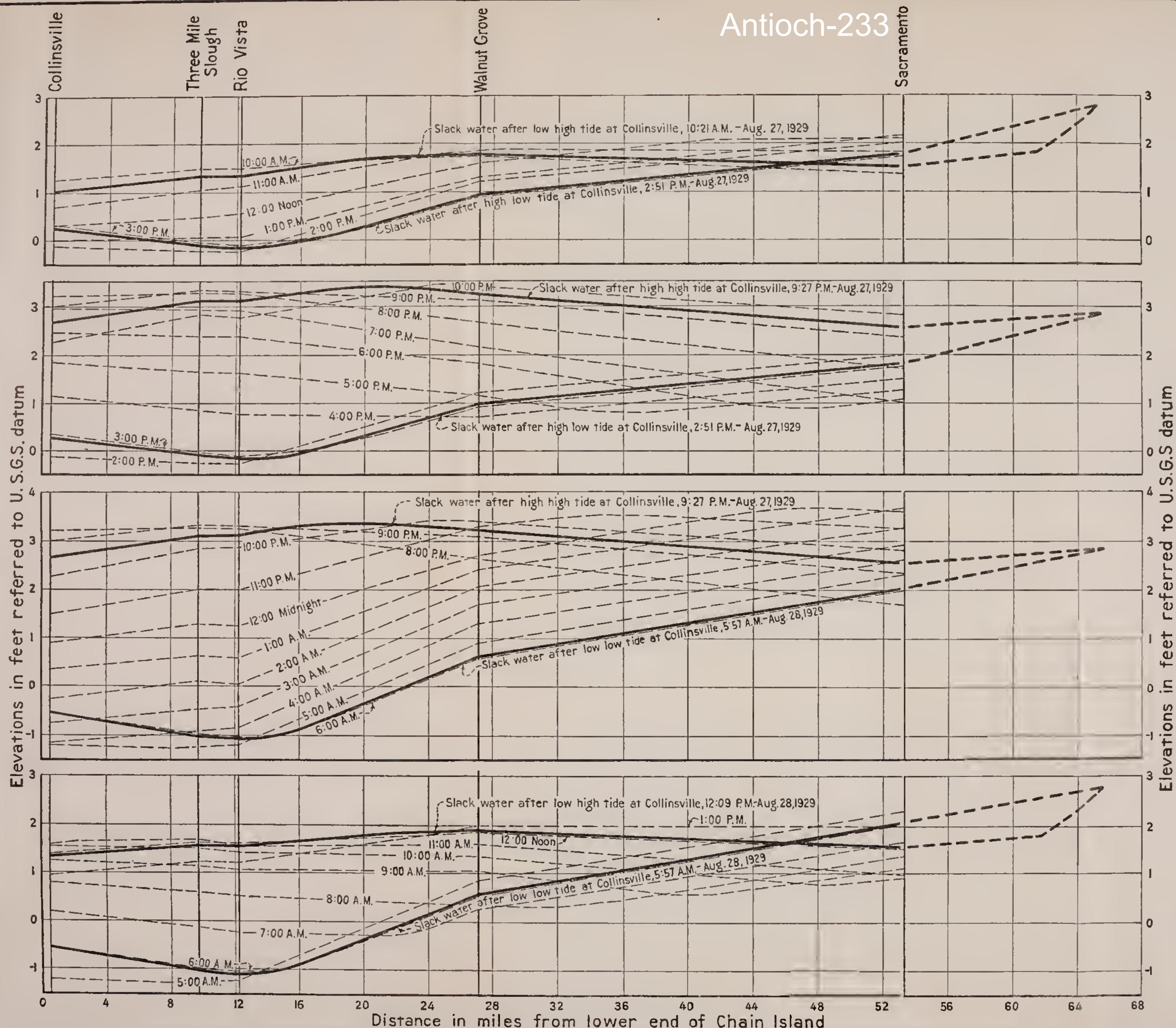
Change in volume in tidal basin

Tidal period	Acre-feet Increase	Acre-feet Decrease
Low high to high low		13,700
High low to high high	38,400	
High high to low low		45,700
Low low to low high	24,000	
Total	62,400	59,400

NOTE

Slack water lines as shown indicate the position of the water surface throughout the tidal basin at the time of occurrence of slack water at Collinsville. Time of slack water assumed at 1¼ hours after time of occurrence of tidal phases at Collinsville.

TIDAL PRISM VOLUMES
IN
SACRAMENTO RIVER CHANNELS



TIDAL PRISM VOLUME

Computed from slack water to slack water

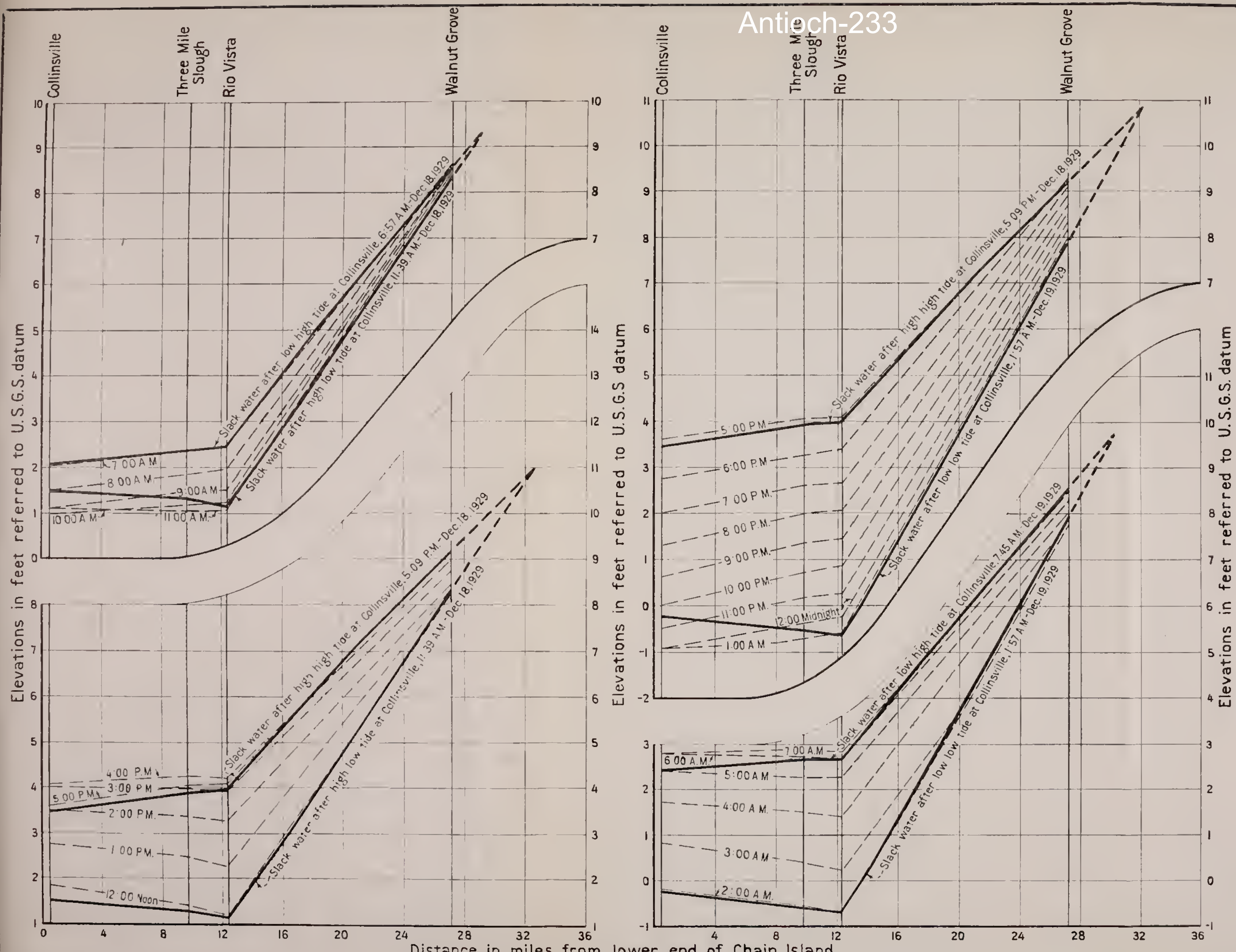
Change in volume in tidal basin

Tidal period	Acre-feet Increase	Acre-feet Decrease
Low high to high low		13,700
High low to high high	38,400	
High high to low low		45,700
Low low to low high	24,000	
Total	62,400	59,400

NOTE

Slack water lines as shown indicate the position of the water surface throughout the tidal basin at the time of occurrence of slack water at Collinsville. Time of slack water assumed at 1¼ hours after time of occurrence of tidal phases at Collinsville.

TIDAL PRISM VOLUMES IN SACRAMENTO RIVER CHANNELS



TIDAL PRISM VOLUME

Computed from slack water to slack water

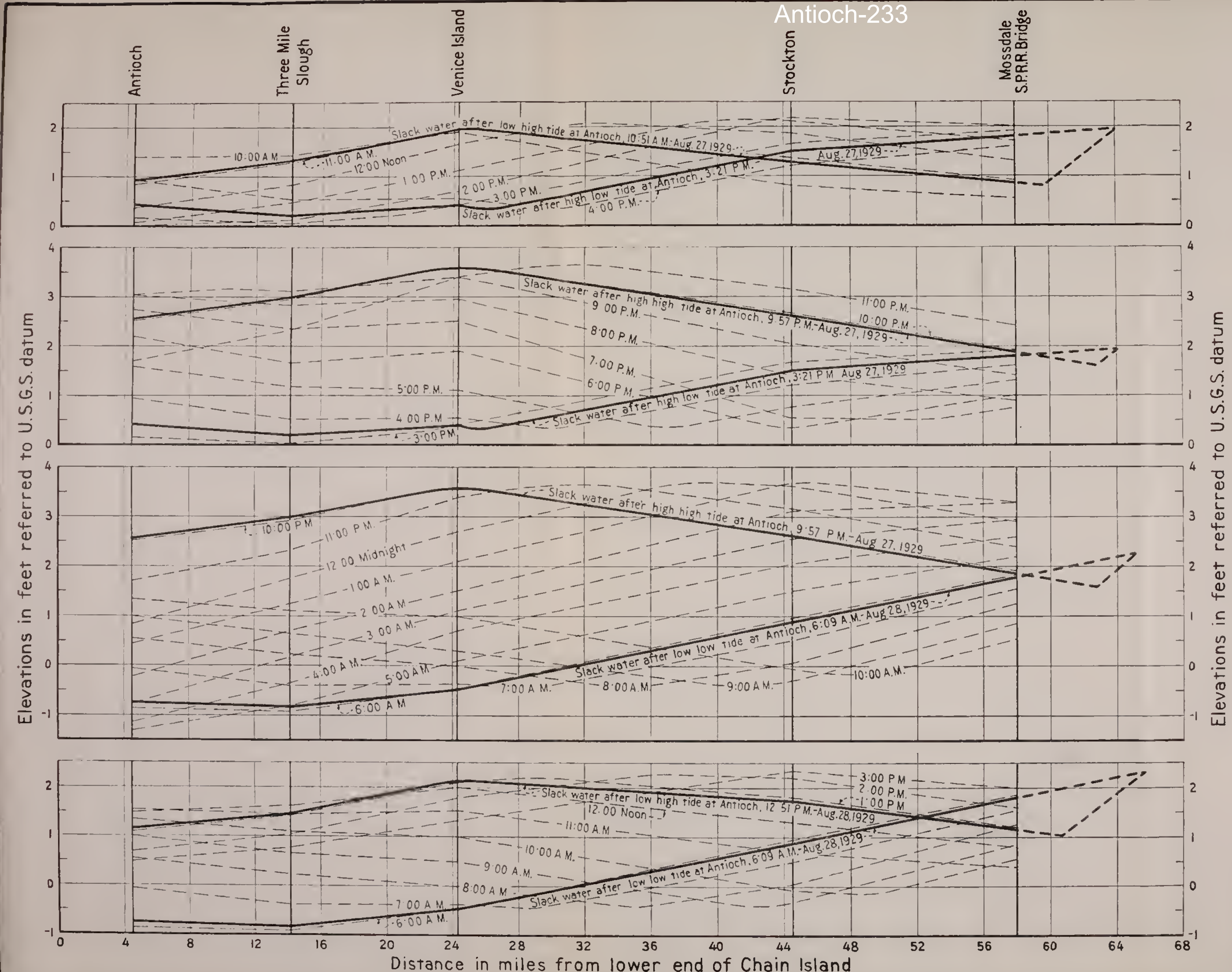
Change in volume in tidal basin

Tidal period	Acre-feet Increase	Acre-feet Decrease
Low high to high low		11,600
High low to high high	28,700	
High high to low low		44,600
Low low to low high	30,600	
Total	59,300	56,200

NOTE

Slack water lines as shown indicate the position of the water surface throughout the tidal basin at the time of occurrence of slack water at Collinsville. Time of slack water assumed at 1¼ hours after time of occurrence of tidal phases at Collinsville.

TIDAL PRISM VOLUMES
IN
SACRAMENTO RIVER CHANNELS



TIDAL PRISM VOLUME

Computed from slack water to slack water

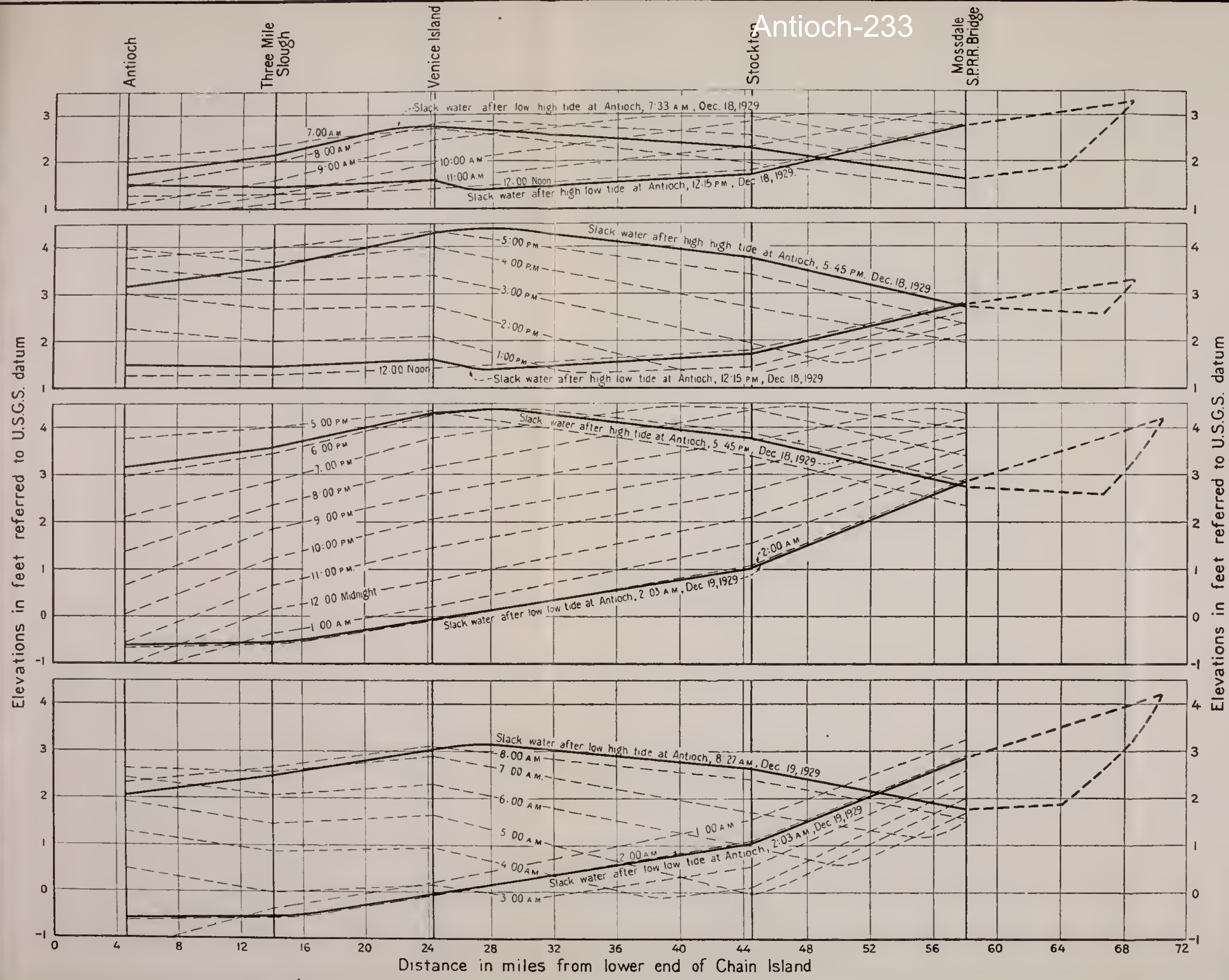
Change in volume in tidal basin

Tidal period	Acre-feet Increase	Acre-feet Decrease
Low high to high low		19,900
High low to high high	62,600	
High high to low low		81,300
Low low to low high	44,700	
Total	107,300	101,200

NOTE

Slack water lines as shown indicate the position of the water surface throughout the tidal basin at the time of occurrence of slack water at Antioch. Time of slack water assumed at 1¼ hours after time of occurrence of tidal phases at Antioch.

TIDAL PRISM VOLUMES IN SAN JOAQUIN RIVER CHANNELS



TIDAL PRISM VOLUME

Computed from slack water to slack water

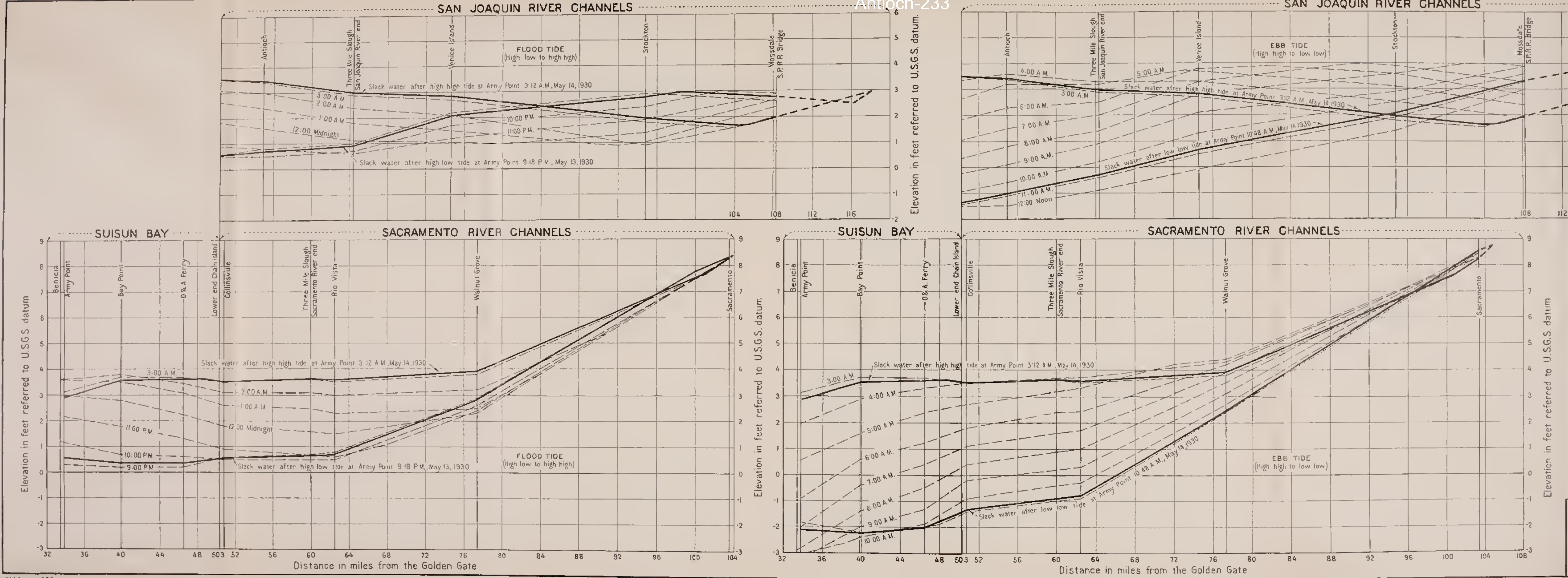
Change in volume in tidal basin

Tidal period	Acre-feet Increase	Acre-feet Decrease
Low high to high low		22,700
High low to high high	67,800	
High high to low low		101,500
Low low to low high	66,700	
Total	134,500	124,200

NOTE

Slack water lines as shown indicate the position of the water surface throughout the tidal basin at the time of occurrence of slack water at Antioch. Time of slack water assumed at 1¼ hours after time of occurrence of tidal phases at Antioch.

TIDAL PRISM VOLUMES IN SAN JOAQUIN RIVER CHANNELS



TIDAL PRISM VOLUME

Computed from slack water to slack water

Change in volume in tidal basin

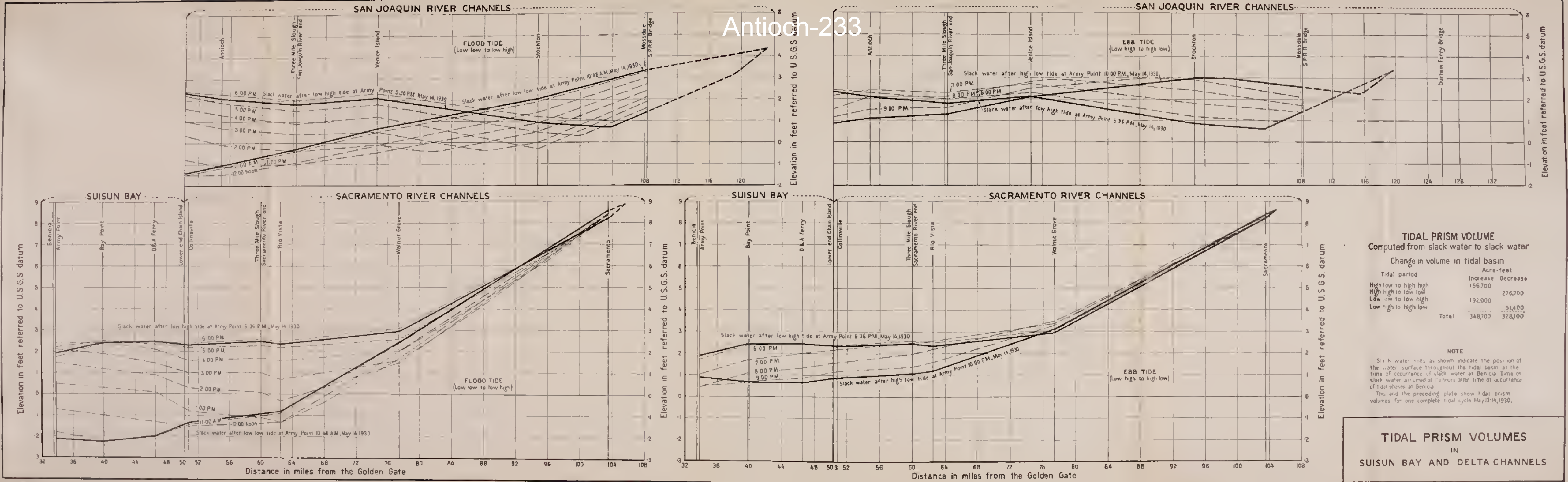
Tidal period	Acre-feet Increase	Acre-feet Decrease
High low to high high	156,700	
High high to low low		276,700
Low low to low high	192,000	
Low high to high low		51,400
Total	348,700	328,100

NOTE

Slack water lines as shown indicate the position of the water surface throughout the tidal basin at the time of occurrence of slack water at Benicia. Time of slack water assumed at 1½ hours after time of occurrence of tidal phases at Benicia.

This and the following plate show tidal prism volumes for one complete tidal cycle May 13-14, 1930.

TIDAL PRISM VOLUMES IN SUISUN BAY AND DELTA CHANNELS



TIDAL PRISM VOLUME

Computed from slack water to slack water

Change in volume in tidal basin

Tidal period	Acre-feet Increase	Acre-feet Decrease
High low to high high	156,700	
High high to low low		276,700
Low low to low high	192,000	
Low high to high low		51,400
Total	348,700	328,100

NOTE

Slack water lines as shown indicate the position of the water surface throughout the tidal basin at the time of occurrence of slack water at Benicia. Time of slack water assumed at 1½ hours after time of occurrence of tidal phases at Benicia.

This and the preceding plate show tidal prism volumes for one complete tidal cycle May 13-14, 1930.

TIDAL PRISM VOLUMES IN SUISUN BAY AND DELTA CHANNELS

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surface in the basin for each hour during the tidal cycle is plotted from the automatic tide gage records. The uppermost diagram on Plate XL covers the period of ebb from low-high to high-low tide; the second from the top covers the flood period from high-low to high-high tide; the third diagram covers the ebb period from high-high to low-low, and the bottom diagram covers the flood period from low-low to low-high tide. The heavy lines at the bottom and top of each of these diagrams show the profile or position of the water surface at time of slack water following the several tidal phases. Hence, the area between these two heavy lines graphically represents in cross-section the magnitude of the actual change in volume in the tidal basin during the particular periods of ebb and flood.

The computation of the actual change in volume between tidal phases is based on the actual water levels shown in these diagrams, combined with the tidal volumes shown on Plates XXXVIII and XXXIX. These computations of volume were made for each two-mile section. Using the vertical range between the upper and lower water level at time of slack water and the variation of volume per foot of depth as shown in the tabulations on Plates XXXVIII and XXXIX, the total volumes for each two-mile section are readily computed. The volume above and below elevation +1 U.S.G.S. Datum was computed separately in order to take care of the variation in volume per foot of depth as between upper and lower zones. It was not considered necessary to use any smaller subdivisions of vertical depth than those two. The total tidal prism volume was then obtained by summing up the volumes computed for each two-mile increment.

It will be noted on Plate XL in the case of both the period of ebb from low-high to high-low and of flood from low-low to low-high tides that the change in volume in the extreme upper part of the basin was opposite to that in the lower part. In other words the water levels in the upper part of the basin were rising, while those in the lower part of the basin were falling and vice versa. In computing the total change in volume for such cases, the volume changes of opposite sign were added algebraically.

The tidal prism volumes computed in the above manner, are shown tabulated on each plate. The total change in volume during flood and during ebb tides very nearly balance each other. This is characteristic of all tidal movements in the tidal basin, especially during periods of low stream flow. The difference between the total change in volume for the two flood tides and for the two ebb tides is represented by the difference in water level in the basin at the beginning and end of the tidal cycle. If the water level at the beginning and end of the tidal cycle happens to be the same, which is frequently the case, the volume changes during ebb and flood will equalize each other.

The effect of greatly increased stream flow upon the shape of the tidal prisms is shown on Plate XLI, covering the tidal cycle period of December 18 and 19, 1929, when the flow of the Sacramento River past Sacramento was about 100,000 second-feet. As would be expected, the profile of the water surface in the basin is materially changed from that of the low stream flow period, the water levels in the upper part of the basin being generally at much higher elevations. The shortening-up of the tidal basin with the limits of tidal action pushed downstream is evident also. All of the tidal prisms extend only a short distance above Walnut Grove whereas, during the low flow period, they extend about twelve miles above Sacramento.

Tidal prism volumes have been computed in the above manner for the delta and for Suisun Bay covering typical variations of tidal range in the basins and for several different tidal cycles during the low water season within the period of advance and retreat of salinity. The results of these computations are shown in Table 24. This table shows the computed increase and decrease and net change in volume in the tidal basin and the corresponding tidal range from slack water to slack water at the lower end of the basin ("Home Section") for numerous typical tidal prisms covering the delta alone and all or portions of Suisun Bay in combination with the delta.

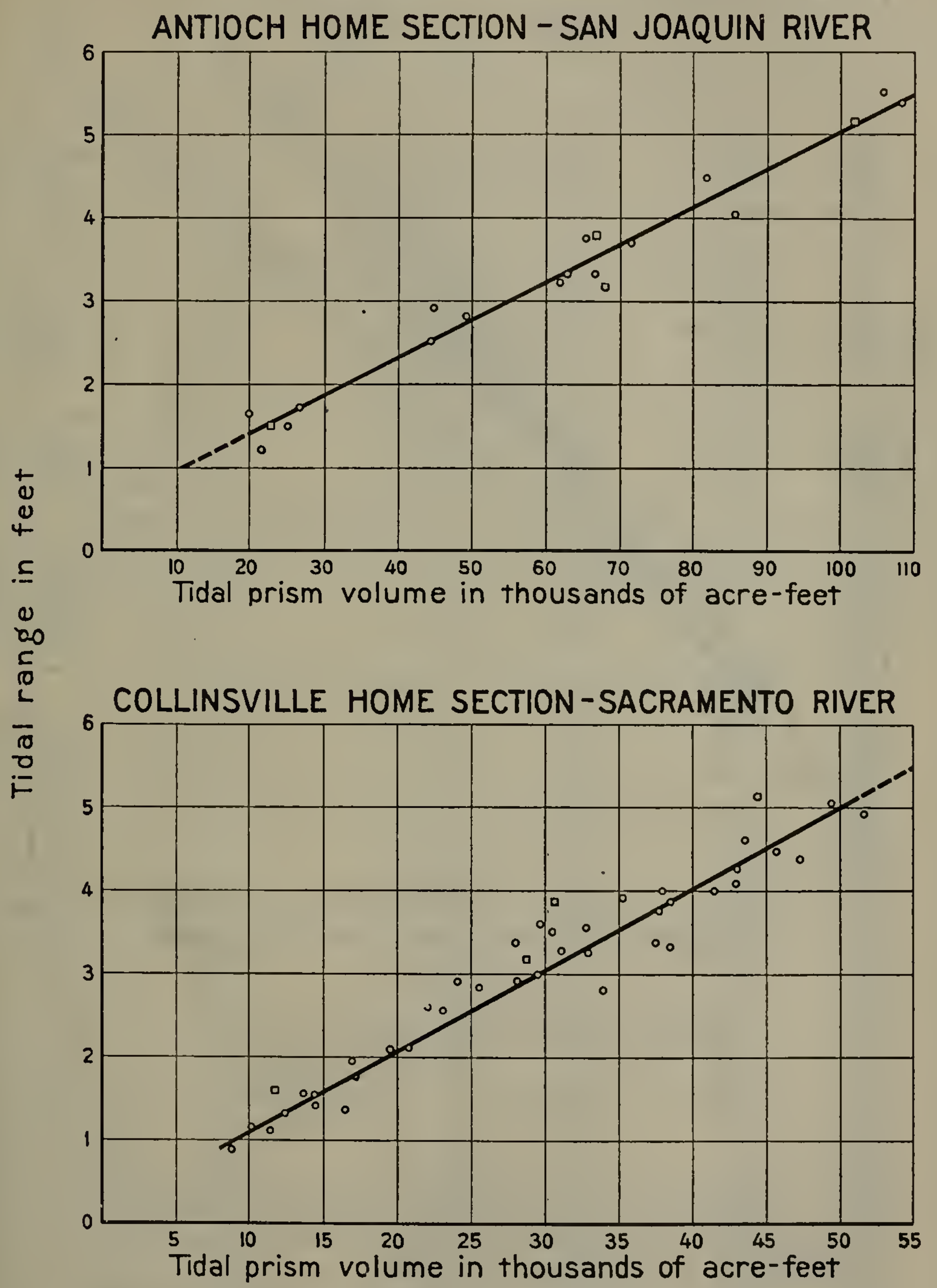
The change in volume in the tidal basin of the delta and Suisun Bay between successive tidal phases is related to the tidal range at the "Home Section" between these two phases. This is graphically shown on Plate XLVI, "Relation of Tidal Prism Volumes to Tidal Range (Antioch and Collinsville Home sections)" and Plate XLVII, "Relation of Tidal Prism Volumes to Tidal Range (Suisun Bay Home sections)." The points plotted on these diagrams are based upon the computed tidal prism volumes and the coincident tidal range at the section at the lower end at the tidal basin, designated the "home section." The relation appears to be approximately a straight line variation. The actual plotted points depart somewhat from the average lines, but the variation is not of great magnitude and it is believed that the relation indicated is as accurate as the data and computations warrant. The relation established is of great value inasmuch as it saves a tremendous amount of detailed computations which would be required to obtain the tidal prism volumes for each tidal cycle during the season. With the use of these established graphical relations, the tidal prism volumes or net changes in tidal volume in the tidal basin for any tidal movement can be obtained immediately from the diagrams with the known range of the tide available from the tide gage records at the home section.

Tidal Flow—Tidal flow is defined as the amount of water entering or leaving a tidal basin between any two successive tidal phases. The actual tidal prism volume or the change in volume in a tidal basin between any two successive tidal phases is a measure of the tidal flow passing into or out of a tidal basin. However, it is not an exact measure of tidal flow. The exact measure of tidal flow must be based not only upon the change in volume in the tidal basin but also upon the additions and extractions from the tidal basin during any particular period of tidal flow. These additions and extractions consist of stream inflow and water consumption, respectively. The actual change in volume in the tidal basin is the combined result of the tidal flow entering or leaving the tidal basin and the water entering and leaving the basin by stream flow and consumption respectively. Considering any period of ebb or flood between two successive phases of the tide, the magnitude of tidal flow into or out of a tidal basin is expressed by the following formulae:

$$t = v - s + e \text{ (for flood tides)}$$
$$t = v + s - e \text{ (for ebb tides)}$$

where, t = the tidal flow entering or leaving the tidal basin
v = the change in volume in the tidal basin
s = the stream flow into the tidal basin
e = the extractions of water from the tidal basin.

PLATE XLVI



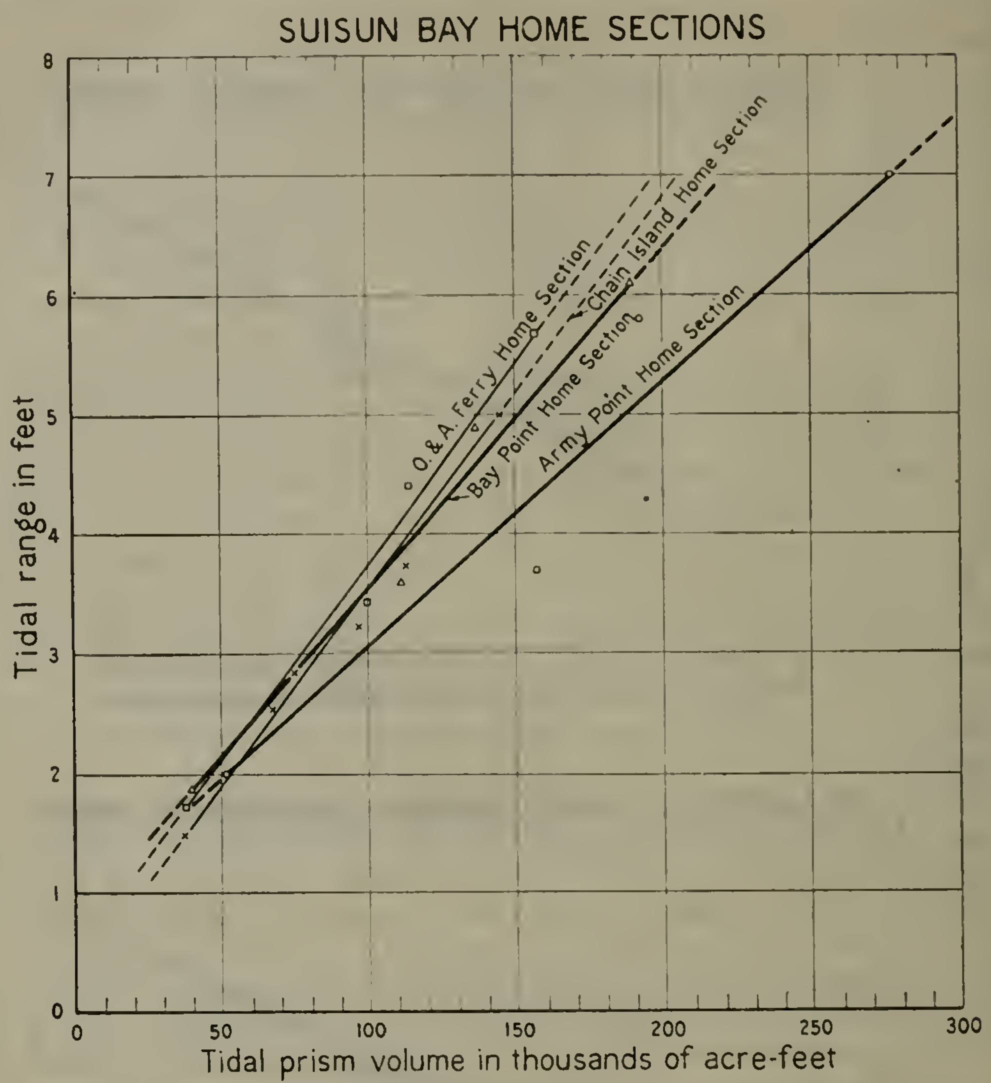
RELATION OF TIDAL PRISM VOLUMES
TO
TIDAL RANGE

LEGEND

○ Stream flow into delta less than 6,000 sec.-ft.

□ Stream flow into delta more than 100,000 sec.-ft. (from Sacramento River).

PLATE XLVII



LEGEND

o	Computed	tidal	prism	volume	above	Army Point
▵	"	"	"	"	"	Bay Point
▫	"	"	"	"	"	O.&A. Ferry
×	"	"	"	"	"	Chain Island

NOTE

The computed tidal prism volumes above a home section at Bay Point and O.&A. Ferry include only the south arm of Suisun Bay and the Sacramento and San Joaquin River channels.

The computed tidal prism volumes above a home section at Chain Island include the channels of the Sacramento and San Joaquin Rivers

RELATION OF TIDAL PRISM VOLUMES
TO
TIDAL RANGE

TABLE 24

TIDAL PRISM VOLUMES IN TIDAL BASIN OF SUISUN BAY AND OF SACRAMENTO-SAN JOAQUIN DELTA

Date	Tide	Tidal range in feet at home section [1]	Period of time between slack water at beginning and end of tide	Change in volume in tidal basin, in acre-feet		Net change in tidal prism volume in acre-feet
				Increase	Decrease	
Suisun Bay and Delta Tidal Basin Above Army Point Home Section						
May 13-14, 1930	Flood	3.70	9.18 p.m.— 3.12 a.m.	162,000	5,300	156,700
May 14, 1930	Ebb	7.00	3.12 a.m.—10.48 a.m.	2,200	278,900	276,700
May 14, 1930	Flood	5.80	10.48 a.m.— 5.36 p.m.	199,300	7,300	192,000
May 14, 1930	Ebb	2.00	5.36 p.m.—10.00 p.m.	21,100	72,500	51,400
Suisun Bay* and Delta Tidal Basin Above Bay Point Home Section						
May 13-14, 1930	Flood	3.6	10.24 p.m.— 3.54 a.m.	112,800	900	111,900
May 14, 1930	Ebb	6.2	3.54 a.m.—11.54 a.m.	1,000	189,800	188,800
May 14, 1930	Flood	4.9	11.54 a.m.— 6.30 p.m.	137,800	1,700	136,100
May 14, 1930	Ebb	1.8	6.30 p.m.—11.00 p.m.	7,000	46,300	39,300
Suisun Bay* and Delta Tidal Basin Above O. and A. Ferry Home Section						
May 13-14, 1930	Flood	3.45	10.30 p.m.— 4.30 a.m.	98,900	500	98,400
May 14, 1930	Ebb	5.66	4.30 a.m.—12.12 p.m.	600	156,700	156,100
May 14, 1930	Flood	4.43	12.12 p.m.— 7.00 p.m.	114,400	1,500	112,900
May 14, 1930	Ebb	1.76	7.00 p.m.—11.30 p.m.	3,300	40,900	37,600
Sacramento-San Joaquin Delta Tidal Basin Above Lower End of Chain Island Home Section						
August 24, 1929	Flood	3.75	1.09 p.m.— 7.45 p.m.	113,200	700	112,500
August 24-25, 1929	Ebb	3.25	7.45 p.m.— 2.03 a.m.	1,600	98,100	96,500
August 25, 1929	Flood	2.55	2.03 a.m.— 7.45 a.m.	68,900	1,900	67,000
August 25, 1929	Ebb	2.85	7.45 a.m.— 1.39 p.m.	1,100	75,600	74,500
May 14, 1930	Ebb	5.00	4.45 a.m.—11.42 a.m.	500	145,100	144,600
May 14, 1930	Ebb	1.50	7.15 p.m.—11.51 p.m.	2,000	39,000	37,000
Sacramento River Tidal Basin Above Collinsville Home Section						
July 7, 1929	Flood	3.9	12.15 p.m.— 6.27 p.m.	36,400	1,200	35,200
July 7, 1929	Ebb	1.75	6.27 p.m.—10.39 p.m.	800	17,900	17,100
July 7-8, 1929	Flood	3.35	10.39 p.m.— 4.33 a.m.	38,300	700	37,600
July 8, 1929	Ebb	5.40	4.33 a.m.—12.57 p.m.	600	58,500	57,900
July 20, 1929	Ebb	4.90	2.45 a.m.—11.15 a.m.	----------	51,600	51,600
July 20, 1929	Flood	3.50	11.15 a.m.— 6.03 p.m.	30,600	100	30,500
July 20, 1929	Ebb	1.10	6.03 p.m.— 9.57 p.m.	400	11,700	11,300
August 3, 1929	Ebb	1.55	4.39 p.m.— 8.42 p.m.	1,200	15,500	14,300
August 4, 1929	Ebb	5.60	2.54 a.m.—11.12 a.m.	400	56,300	55,900
August 13, 1929	Ebb	1.15	12.51 p.m.— 4.57 p.m.	700	11,000	10,300
August 13, 1929	Flood	2.80	4.57 p.m.—11.15 p.m.	33,900	----------	33,900
August 13-14, 1929	Ebb	4.35	11.15 p.m.— 7.33 a.m.	200	47,400	47,200
August 24, 1929	Flood	3.75	1.09 p.m.— 7.45 p.m.	38,000	200	37,800
August 24-25, 1929	Ebb	3.25	7.45 p.m.— 2.03 a.m.	600	33,600	33,000
August 25, 1929	Flood	2.55	2.03 a.m.— 7.45 a.m.	23,600	600	23,000
August 25, 1929	Ebb	2.85	7.45 a.m.— 1.39 p.m.	300	25,700	25,400
August 27, 1929	Ebb	1.55	10.21 a.m.— 2.51 p.m.	600	14,300	13,700
August 27, 1929	Flood	3.30	2.51 p.m.— 9.27 p.m.	38,500	100	38,400
August 27-28, 1929	Ebb	4.45	9.27 p.m.— 5.57 a.m.	300	46,000	45,700
August 28, 1929	Flood	2.90	5.57 a.m.—12.09 p.m.	24,900	900	24,000
September 1, 1929	Ebb	2.10	4.09 p.m.— 8.45 p.m.	1,200	20,500	19,300
September 2, 1929	Ebb	5.05	2.51 a.m.—10.39 a.m.	300	49,600	49,300
September 7, 1929	Ebb	3.00	7.15 a.m.— 1.15 p.m.	600	30,000	29,400
September 7, 8, 1929	Ebb	3.85	7.30 p.m.— 2.42 a.m.	600	39,000	38,400
September 9-10, 1929	Ebb	4.00	8.48 p.m.— 4.33 a.m.	400	41,900	41,500
September 10, 1929	Ebb	1.30	11.00 a.m.— 3.30 p.m.	800	13,200	12,400
September 12-13, 1929	Ebb	4.10	11.48 p.m.— 8.00 a.m.	200	43,200	43,000
September 13, 1929	Ebb	1.40	2.36 p.m.— 7.12 p.m.	900	15,300	14,400
September 18, 1929	Ebb	2.90	4.51 p.m.—10.39 p.m.	900	29,000	28,100
September 19, 1929	Ebb	4.00	4.09 a.m.—11.15 a.m.	800	38,600	37,800
September 22-23, 1929	Ebb	4.25	6.33 p.m.— 2.03 a.m.	800	43,900	43,100
September 23, 1929	Ebb	2.10	8.00 a.m.— 1.03 p.m.	500	21,200	20,700
October 10, 1929	Flood	3.25	4.45 a.m.—12.09 p.m.	31,900	900	31,000
October 10, 1929	Ebb	0.85	12.09 p.m.— 4.21 p.m.	600	9,300	8,700
October 10, 1929	Flood	1.35	4.21 p.m.— 9.15 p.m.	16,400	100	16,300
October 29, 1929	Ebb	3.60	2.45 p.m.— 9.15 p.m.	700	30,200	29,500
October 30, 1929	Ebb	3.55	3.00 a.m.— 8.15 a.m.	600	33,300	32,700
November 2-3, 1929	Ebb	4.60	4.33 p.m.— 0.21 a.m.	1,000	44,600	43,600
November 3, 1929	Ebb	1.95	6.33 a.m.—11.15 a.m.	600	17,300	16,700
November 11, 1929	Ebb	2.60	1.15 p.m.— 7.21 p.m.	600	22,500	21,900
November 12, 1929	Ebb	3.35	0.21 a.m.— 7.09 a.m.	100	28,000	27,900
December 18, 1929	Ebb	1.60	6.57 a.m.—11.39 a.m.	----------	11,600	11,600
December 18, 1929	Flood	3.15	11.39 a.m.— 5.09 p.m.	28,700	----------	28,700
December 18-19, 1929	Ebb	5.12	5.09 p.m.— 1.57 a.m.	----------	44,600	44,600
December 19, 1929	Flood	3.86	1.57 a.m.— 7.45 a.m.	30,600	----------	30,600

* South arm of Suisun Bay only.

TABLE 24—Continued

TIDAL PRISM VOLUMES IN TIDAL BASIN OF SUISUN BAY AND OF SACRAMENTO-SAN JOAQUIN DELTA

Date	Tide	Tidal range in feet at home section [1]	Period of time between slack water at beginning and end of tide	Change in volume in tidal basin, in acre-feet		Net change in tidal prism volume in acre-feet
				Increase	Decrease	
San Joaquin River Tidal Basin Above Antioch Home Section						
July 7, 1929	Flood	3.75	12.33 p.m.— 7.00 p.m.	66,400	1,200	65,200
July 7, 1929	Ebb	1.70	7.00 p.m.—11.00 p.m.	1,400	27,900	26,500
July 7-8, 1929	Flood	3.30	11.00 p.m.— 4.57 a.m.	66,900	300	66,600
July 8, 1929	Ebb	5.35	4.57 a.m.— 1.15 p.m.	300	108,200	107,900
August 3, 1929	Ebb	5.50	2.27 a.m.—10.51 a.m.	200	105,900	105,700
August 3, 1929	Ebb	1.50	5.03 p.m.— 9.21 p.m.	1,100	26,000	24,900
August 24, 1929	Flood	3.70	1.39 p.m.— 8.15 p.m.	71,600	300	71,300
August 24-25, 1929	Ebb	3.20	8.15 p.m.— 2.39 a.m.	600	62,100	61,500
August 25, 1929	Flood	2.50	2.39 a.m.— 8.21 a.m.	44,900	700	44,200
August 25, 1929	Ebb	2.80	8.21 a.m.— 2.03 p.m.	600	49,600	49,000
August 27, 1929	Ebb	1.65	10.51 a.m.— 3.21 p.m.	1,400	21,300	19,900
August 27, 1929	Flood	3.30	3.21 p.m.— 9.57 p.m.	62,700	100	62,600
August 27-28, 1929	Ebb	4.45	9.57 p.m.— 6.09 a.m.	100	81,400	81,300
August 28, 1929	Flood	2.90	6.09 a.m.—12.51 p.m.	45,200	500	44,700
September 10, 1929	Ebb	1.20	11.21 a.m.— 3.51 p.m.	900	22,500	21,600
September 10-11, 1929	Ebb	4.05	9.57 p.m.— 6.09 a.m.	200	86,100	85,900
December 18, 1929	Ebb	1.51	7.33 a.m.—12.15 p.m.	900	23,600	22,700
December 18, 1929	Flood	3.16	12.15 p.m.— 5.45 p.m.	67,900	100	67,800
December 18-19, 1929	Ebb	5.16	5.45 p.m.— 2.03 a.m.	300	101,800	101,500
December 19, 1929	Flood	3.80	2.03 a.m.— 8.27 a.m.	67,500	800	66,700

[1] The "home" section designates the section at the lower end of a particular tidal basin. Thus, Army Point is the "home" section for the tidal basin comprising Suisun Bay and the delta channels. See Plates XL to XLV for typical tidal prism volumes.

For tidal flows during flood tide, stream flow acts to decrease the magnitude of tidal flow, whereas water consumption acts to increase the same. On the other hand, for tidal flows during ebb tide, stream flow acts to increase the tidal flow, whereas water consumption acts to decrease the same. It may be seen that should conditions arise in a tidal basin wherein the amount of water consumed or extracted is equal to or greater than the amount of stream flow entering the basin, the tidal flow during flood tides would be increased, whereas the tidal flow during ebb tides would be decreased. The net effect of such conditions would be a greater amount of tidal flow entering the tidal basin than leaving the same, thus resulting in considerable quantities of water from downstream remaining and accumulating upstream in the tidal basin. Such conditions have actually occurred during the last ten years, or more, in the summer months. During winter and spring with relatively large stream flow entering a tidal basin and with water consumption at a minimum, the tidal flow entering a basin during flood tide would be decreased and possibly eliminated, whereas the tidal flow leaving a basin during ebb tide would be greatly increased. If the magnitude of stream flow were great enough in relation to the tidal prism volume, it is possible that such conditions would result in a continuous ebb tide. The amount of tidal flow, therefore, depends upon the relative magnitude of tidal prism volumes, stream flow and water consumption.

During periods of low stream flow, the magnitude of tidal flow past any section in a tidal basin is chiefly dependent upon the volume of the tidal prism in the tidal basin above the section and therefore increases the further downstream the section is located. This is shown by comparing the relative magnitude of the tidal prism volumes as computed for the delta tidal basin and for the combined Suisun Bay and delta tidal basin. Based upon a mean range of the tide at the various sections considered and tidal prism volumes for low stream flow conditions, the average change in tidal volume for the Sacramento River channels of the delta above Collinsville is 31,400 acre-feet; for the San Joaquin River channels of the delta above Antioch, 59,400 acre-feet; and for the combined delta channels above Chain Island, 88,000 acre-feet. Considering the tidal basin of both Suisun Bay and the delta above Army Point (near Bulls Head Point), the average change in tidal volume is 150,000 acre-feet or 1.7 times the average change in tidal volume in the delta. Other things being equal, the above figures indicate the relative magnitude of tidal flow past these home sections into and out of their respective basins, averaged for periods of flood and ebb tide.

Effect of Tidal Action on Salinity.

That tidal action plays an important part in the variation of salinity at points in the upper bay and delta is shown by the results of the comprehensive series of special salinity surveys made during the 1929 season. These special surveys, including tidal cycle salinity surveys, river cross section salinity surveys and combinations thereof with measurements of tidal velocity, have been described in Chapter I. The computations and analyses which have been made from the data obtained from these special surveys have involved a large amount of detailed work. The results of the analyses are of significant importance in the proper understanding of the basic elemental effects of tidal action on salinity conditions in the upper bay and delta region.

TABLE 25

SUMMARY OF TIDAL CYCLE SALINITY SURVEYS—1929

Station	Survey No.	Date	Salinity in parts of chlorine per 100,000 parts of water: Surface zone: Minimum	Surface zone: Mean (Ss)	Surface zone: Maximum (S)	Vertical section: Minimum	Vertical section: Mean (Sv)	Vertical section: Maximum	Mean vertical salinity in per cent of mean surface zone salinity (Sv) to (Ss)	Mean vertical salinity in per cent of maximum surface zone salinity (Sv) to (S)	Mean surface zone salinity in per cent of maximum surface zone salinity (Ss) to (S)
Point Orient	1	Nov. 3	1,550	1,688	1,780	1,550	1,703	1,810	101	96	95
	2	Nov. 6	1,540	1,674	1,780	1,540	1,704	1,810	102	96	94
	3	Nov. 10	1,530	1,623	1,700	1,530	1,664	1,770	103	98	95
Crockett	1	June 10	510	864	1,110	510	915	1,240	106	82	79
	2	July 8	1,000	1,281	1,490	920	1,253	1,490	98	84	86
	3	July 18	860	1,135	1,340						85
	4	Aug. 2	1,020	1,303	1,480	1,000	1,320	1,540	101	89	88
	5	Aug. 14	1,140	1,338	1,460	1,140	1,359	1,530	102	93	92
	6	Aug. 30	1,160	1,393	1,550	1,160	1,415	1,570	102	91	90
	7	Oct. 10	1,030	1,238	1,390	1,030	1,327	1,530	107	95	89
	8	Oct. 25	990	1,240	1,400	990	1,279	1,510	103	91	89
	9	Oct. 31	980	1,226	1,470	980	1,257	1,500	103	86	83
Bulls Head Point	1	May 23	70	298	610						49
	2	June 1	140	406	770	140	406	770	100	53	53
	3	June 14	300	523	870						60
	4	July 5	640	881	1,260	620	898	1,260	102	71	70
	5	July 16	480	863	1,040						83
	7	July 21	760	1,028	1,270	730	1,055	1,340	103	83	81
	8	Aug. 2	840	1,055	1,340	820	1,092	1,400	104	82	79
	9	Aug. 14	880	1,076	1,300	880	1,123	1,380	104	86	83
	10	Aug. 30	980	1,160	1,370	980	1,202	1,460	104	88	85
	11	Oct. 24	770	971	1,290	770	1,031	1,320	106	80	75
Avon	1	Nov. 4	590	905	1,140	590	939	1,220	104	82	79
	2	Nov. 20	600	905	1,170	600	954	1,270	105	82	77
Bay Point	1	Nov. 1	510	724	910	490	732	960	101	81	80
	2	Nov. 26	490	692	890	490	706	910	102	79	78
Nicholls	1	Nov. 19	300	570	830	300	609	920	107	73	69
Collinsville	1	May 25	2	3.1	5	2	3.2	5	104	64	62
	2	June 19	4	8.8	23	4	10.2	30	115	44	39
	3	June 23	4	9.9	26	3	10.7	34	108	41	38
	4	June 27	6	15.6	28	4	16.2	36	104	58	56
	5	July 2	10	28.4	102	8	31.5	120	112	31	28
	6	July 7	54	133	284	48	137	326	104	48	47
	7	July 11	150	231	310	140	236	330	102	76	74
	8	July 19	120	249	360	120	265	490	107	74	69
	9	July 30	220	323	480	220	334	660	104	70	67
	10	Aug. 3	220	370	540	220	391	600	106	73	68
	11	Aug. 13	300	425	600	300	453	640	107	76	71

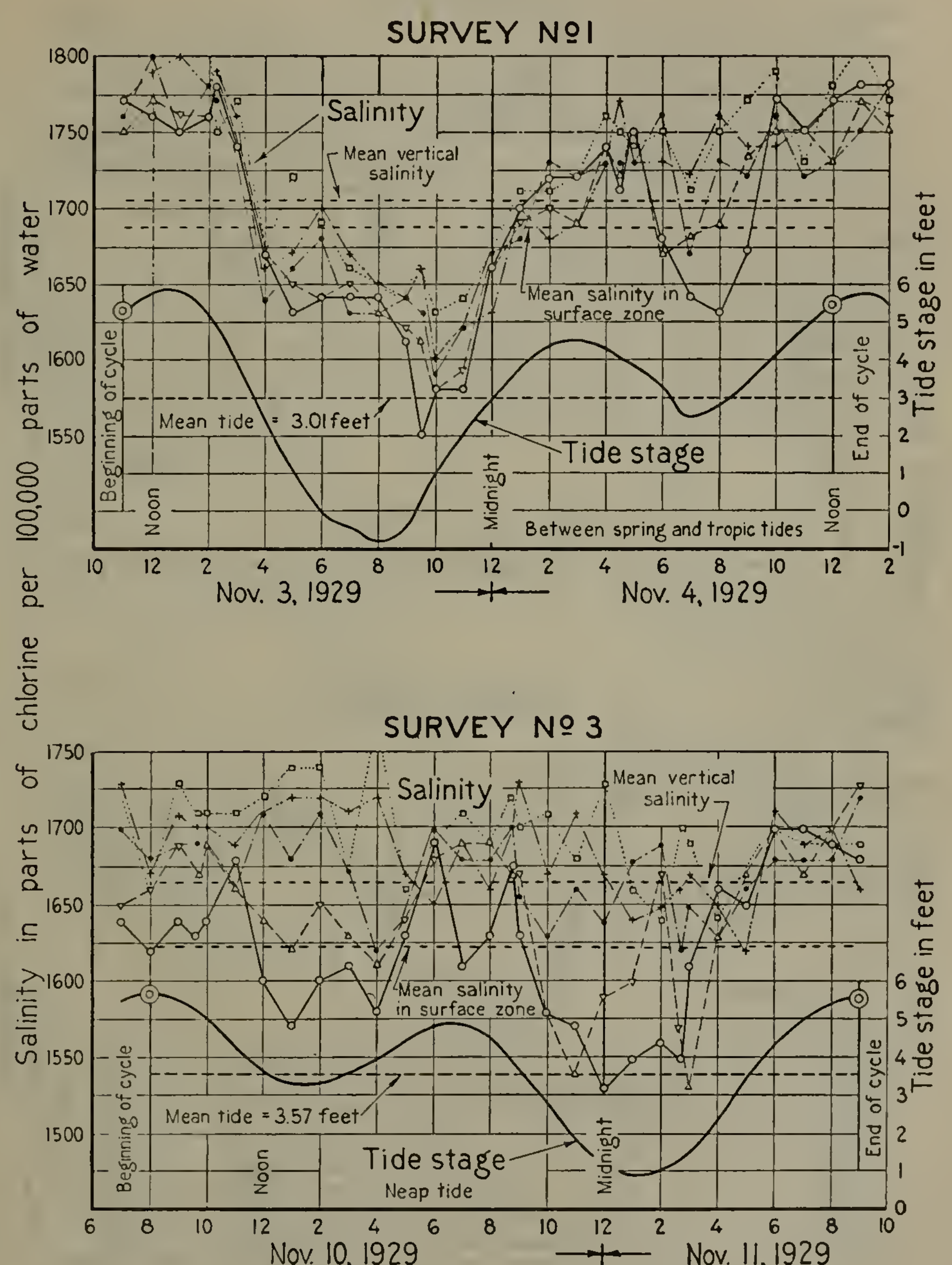
	12	(not	made)								
	13	Aug. 18	290	443	620	260	468	680	106	76	72
	14 Cycle #1	Aug. 21	340	467	630	340	478	650	102	80	78
	14 Cycle #2	Aug. 22	340	473	590	340	489	640	103	83	80
	15 Cycle #1	Aug. 24	330	469	620	330	484	620	103	78	76
	15 Cycle #2	Aug. 25	370	482	650	370	497	660	103	76	74
	16	Aug. 27	370	501	690	370	526	710	105	76	73
	17	Aug. 29	410	571	770	410	589	790	103	76	74
	18	Sept. 1	400	549	720	400	571	770	104	79	76
	19	Sept. 14	260	399	510	260	427	560	107	84	78
	20	Sept. 16	250	392	570	250	414	570	106	73	69
	21	Sept. 18	260	392	520	260	412	540	105	79	75
	22 Cycle #1	Sept. 22	200	340	470	200	369	540	109	79	72
	22 Cycle #2	Sept. 23	200	326	450	200	364	550	112	81	72
	23	Sept. 26	170	312	450	170	347	540	111	77	69
	24	Oct. 29	100	209	310	100	224	340	107	72	68
	25	Nov. 2	100	201	350	100	225	415	112	64	57
	26	Nov. 6	100	215	315	100	237	400	111	75	68
Antioch	1	May 27	4	4.4	6	3	4.4	6	98	73	74
	2	June 19	3	5.7	9	3	5.6	9	98	62	64
	3	June 23	4	7.8	15	4	7.8	15	100	52	52
	4	June 27	7	12.9	19	7	12.7	19	96	65	68
	5	July 2	8	19.6	46	6	19.8	52	101	43	43
	6	July 7	28	83.4	186	24	85.5	212	103	46	45
	7	July 11	31	91.5	170	31	93.4	210	102	55	54
	8	July 15	60	111	200						56
	9	July 30	130	253	400	130	256	450	101	64	63
	10	Aug. 3	150	312	470	150	318	500	102	68	66
	11	Aug. 13	200	341	490	200	360	530	105	73	70
	12	Aug. 18	170	337	460	170	350	500	104	76	73
	13	Aug. 21	250	376	530	240	392	540	104	74	71
	14	Aug. 24	250	372	510	250	387	530	104	76	73
	15	Aug. 27	240	393	560	240	411	580	105	73	70
	16	Aug. 29	260	441	610	260	455	650	103	75	72
	17	Sept. 1	220	416	570	220	435	610	105	76	73
Curtis Landing	1	Nov. 3	20	61	114	19	66	142	109	58	53
Antioch Bridge	1	Nov. 5	24	89	160	24	94	190	106	59	56
	2	Nov. 10	15	51	100	13	52	100	101	52	51
Central Landing	1	June 2	2	3.5	6	1	3.2	6	92	54	58
	2	July 10	3	3.4	5	3	3.3	5	98	67	68
	3	Aug. 4	5	7.7	11	5	8.5	12	110	77	70
Mossdale Highway Bridge	1	June 4	4	4.7	6	3	4.6	8	99	77	78
	2	July 10	8	9.0	10	8	9.0	10	99	90	90
	3	Aug. 5	9	10.7	14	9	10.8	14	101	77	76
Rio Vista	1	June 4	1	2.2	4	1	2.1	4	98	54	55
	2	July 5	3	4.6	7	2	4.8	7	106	69	65
	3	Aug. 2	4	5.4	13	4	5.6	16	103	43	42
	4	Aug. 30	11	21.8	71	11	23.6	82	108	33	31
Sacramento (I Street bridge)	1	June 4	1	2.6	4	1	2.5	4	97	62	65
	2	July 8	2	2.6	5	1	2.6	5	98	52	53
	3	Aug. 5	3	3.5	4	3	3.4	5	99	86	87

Tidal Variations of Salinity—The effect of tidal action on the variation of salinity at points in the bay and delta channels is best indicated by the results of the special tidal cycle salinity surveys. The data compiled from these surveys are summarized in Table 25. The variation of salinity during a tidal cycle resulting from tidal action is more clearly shown, however, in graphical form. Plates XLVIII to LIX, inclusive, "Tidal Variation of Salinity" graphically present the results of typical surveys of this type made at fourteen stations in the bay and delta channels during 1929. In general, the surveys shown in graphical form have been selected to illustrate the variations under different salinity and tidal conditions. Two surveys each are shown for Point Orient, Bulls Head Point, Bay Point, Collinsville, Antioch, Antioch Bridge, Rio Vista; three for Crockett; and one each for Avon, Nichols, Central Landing, Curtis Landing, Sacramento and Mossdale Bridge. Immediately below the salinity record on each diagram is shown the record of tidal stage. Separate lines are shown for the variation of salinity at each depth zone sampled. Thus, the graphs show the variation of salinity not only at various depths throughout the period of the tidal cycle, but also show the relative magnitude of salinity at the various depths from surface to bottom at any particular time.

While in some cases the survey data appear to indicate a considerable complication in the variation of the salinity at different depths, there is exhibited, nevertheless, for most of the surveys a substantially parallel variation at all depths from surface to bottom. In general, the data show that salinity increases and decreases practically in parallel with the rise and fall of the tide, thus demonstrating the direct effect of tidal action on salinity. There is usually a lag between the actual time that the high and low phases of the tide occur and the time of occurrence of maximum and minimum salinities corresponding thereto. The maximum and minimum salinities occur generally from one to two hours after the time of occurrence of high and low tides respectively, with an average lag of about one and one-half hours. As will be shown more clearly with the tidal velocity surveys, the actual time of occurrence of maximum and minimum salinities corresponds with the time of slack water following high and low tides respectively.

The data compiled in Table 25 are of great interest. For each tidal cycle survey are shown the minimum, maximum and mean salinity in the surface zone and in the vertical section and the relation of mean surface zone salinity (S_s) and mean salinity in the vertical section (S_v) to the maximum surface zone salinity (S). Both mean surface zone and mean vertical salinity are compiled as an average for a complete tidal cycle period. It appears from these data that the mean salinity in the surface zone (S_s) and the mean vertical salinity (S_v) for a tidal cycle period are usually about equal in magnitude. For all the surveys, the mean vertical salinity in per cent of mean surface zone salinity varies from about 92 to 115 per cent. The mean vertical salinity is usually only 3 to 5 per cent greater than the mean surface zone salinity. Hence, the relations of both mean vertical and mean surface zone to maximum surface zone salinity are about the same. The relative magnitude of mean surface zone and maximum

PLATE XLVIII

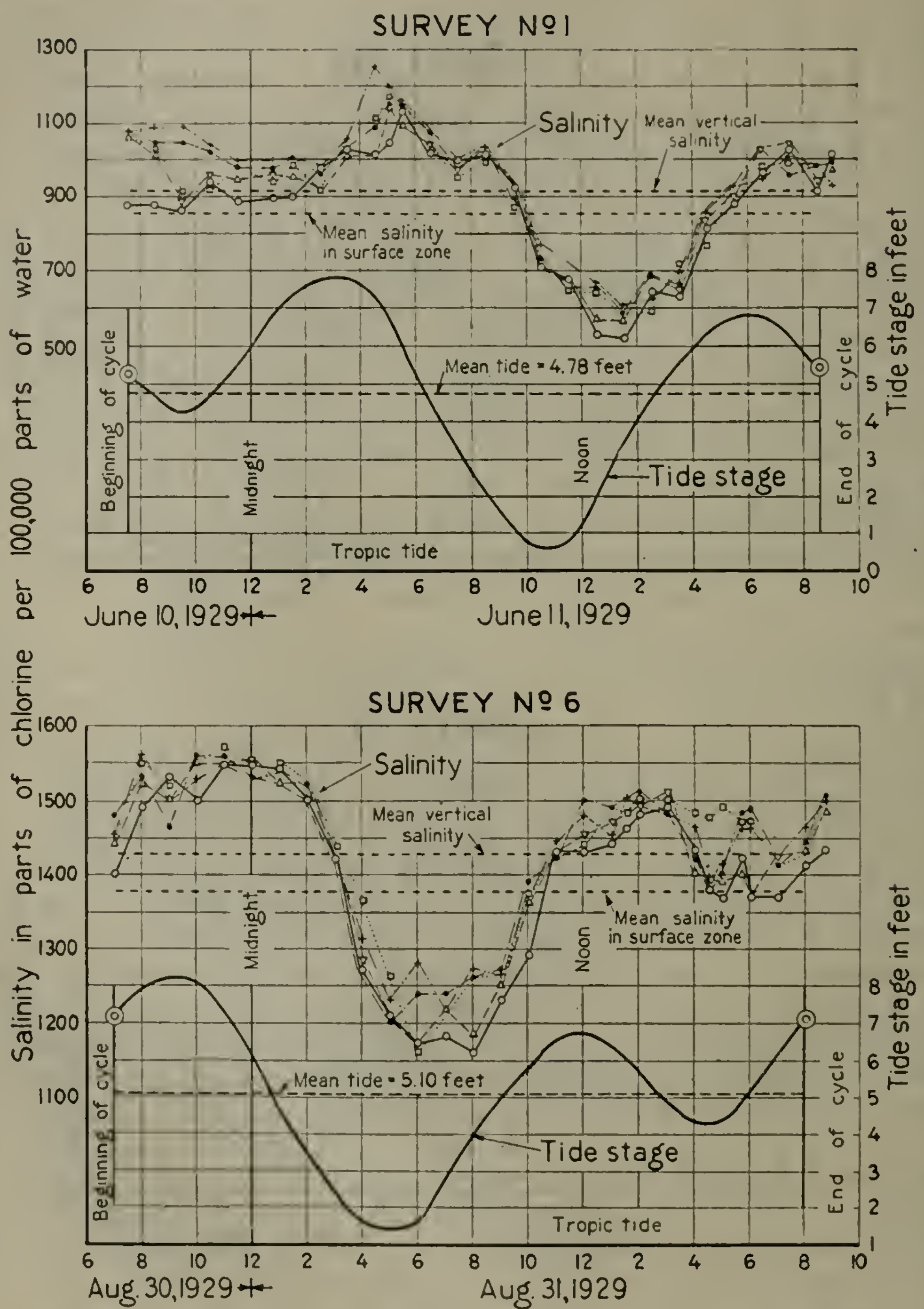


TIDAL VARIATION OF SALINITY
AT
POINT ORIENT

LEGEND

- SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
- " " " " 10 FEET
- " " " " 20 "
- " " " " 30 "
- " " 2 FEET FROM BOTTOM

PLATE XLIX

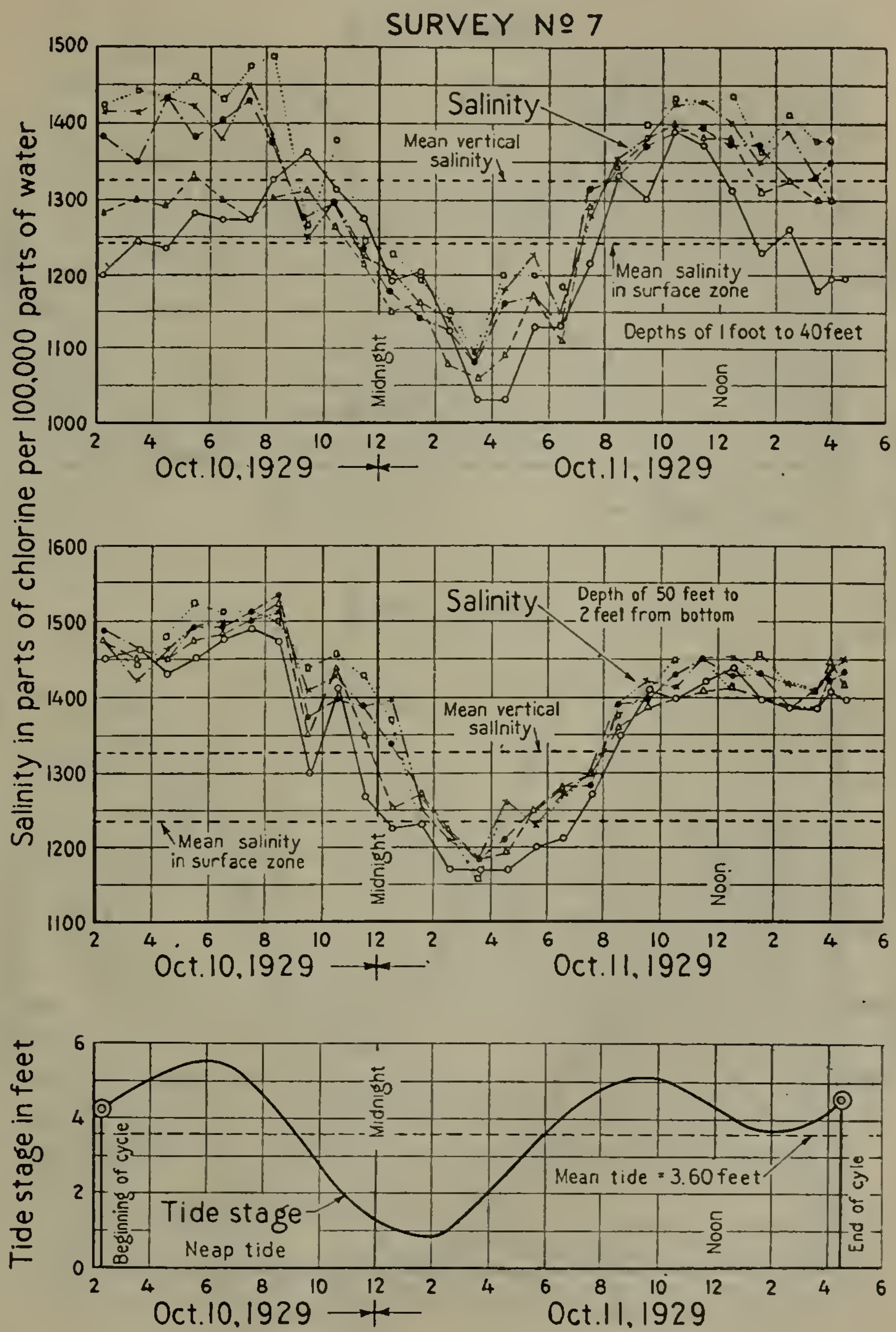


TIDAL VARIATION OF SALINITY
AT
CROCKETT

LEGEND

- o—— SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
- △— — " " " " 10 FEET
- •— — " " " " 20 "
- +—·— " " " " 30 "
- ▫ · " " 2 FEET FROM BOTTOM

PLATE L

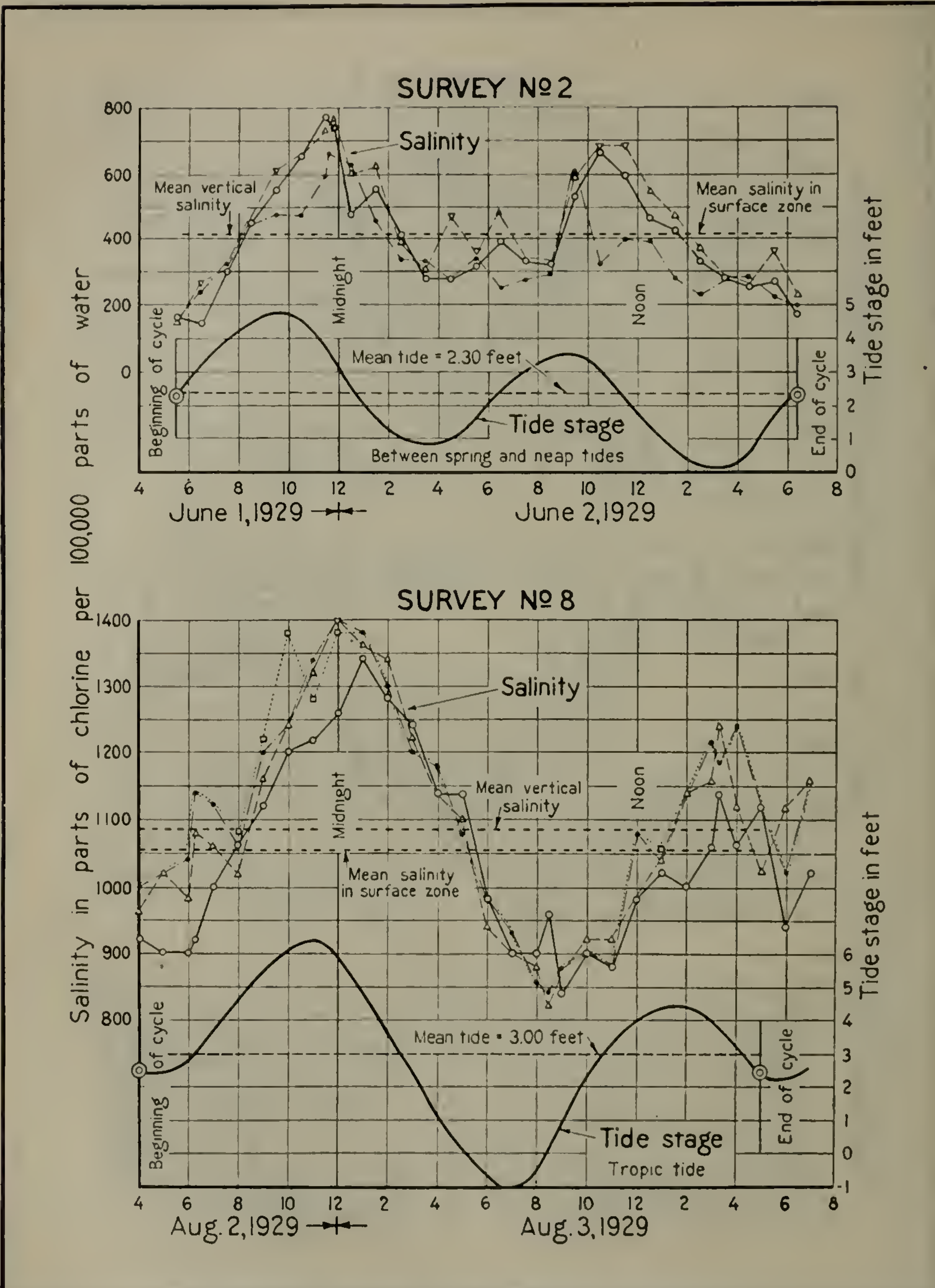


TIDAL VARIATION OF SALINITY
AT
CROCKETT

LEGEND

o—— SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)	o—— SALINITY AT DEPTH OF 50 FEET
Δ— — " " " 10 FEET	Δ— — " " " 60
•-·- " " " 20 "	•-·- " " " 70
+--- " " " 30 "	+-·- " " " 80
o······ " " " 40 "	o·-·- " " 2 FEET FROM BOTTOM

PLATE LI

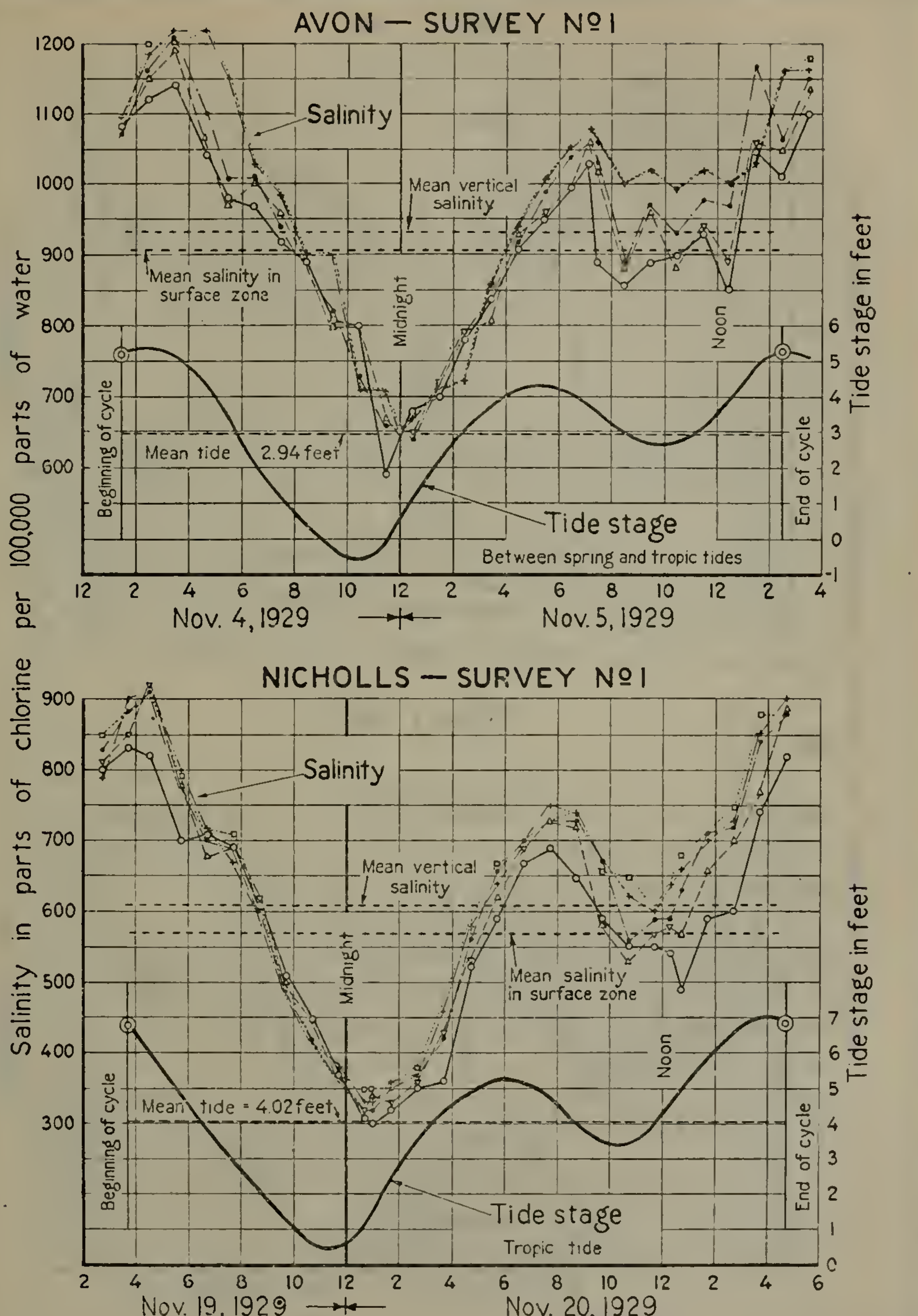


TIDAL VARIATION OF SALINITY
AT
BULLS HEAD POINT

LEGEND

- o——— SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
- Δ– – – " " " " 10 FEET
- •–·–· " " " " 20 "
- ◻······ " " 2 FEET FROM BOTTOM

PLATE LII

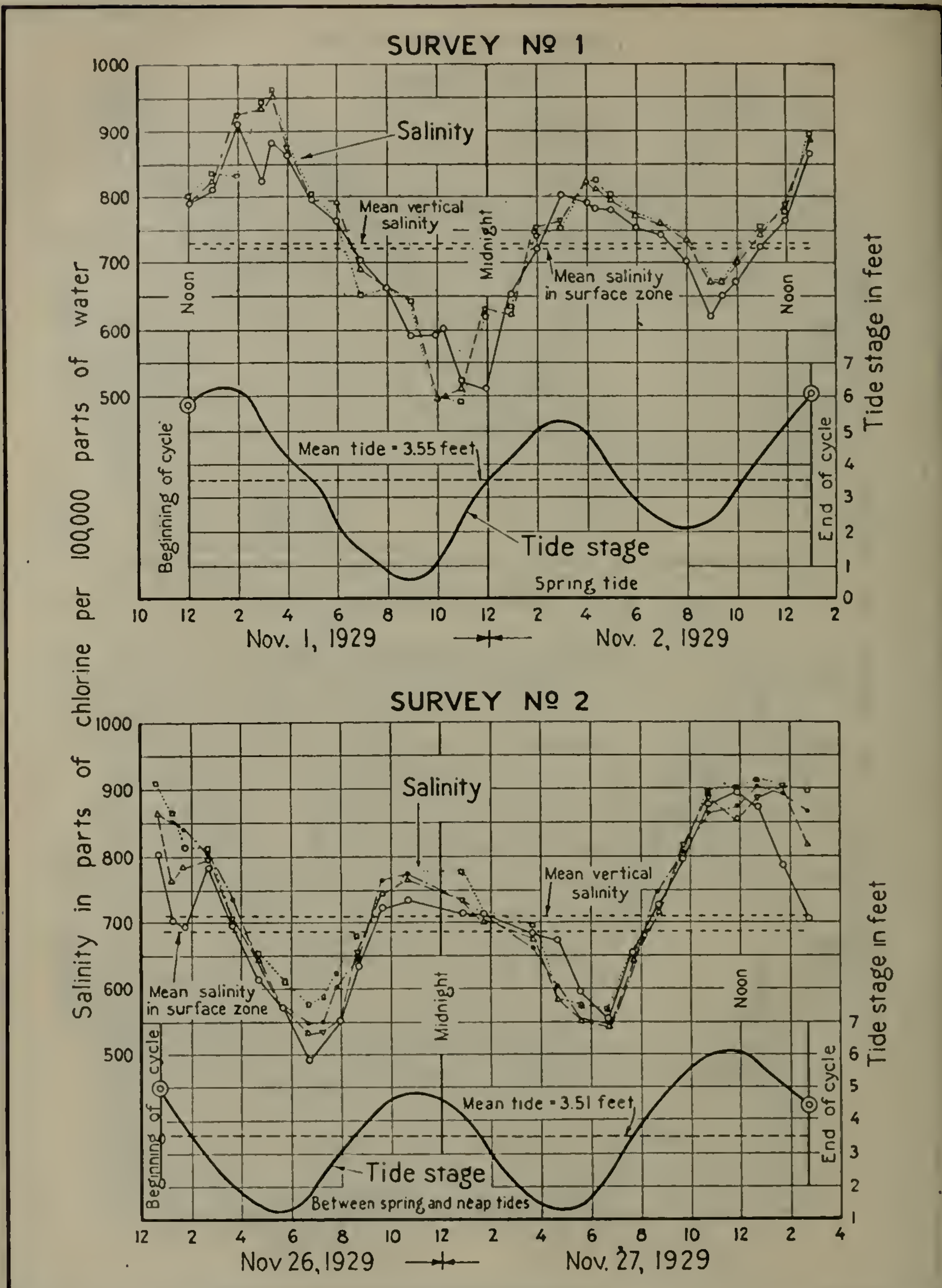


TIDAL VARIATION OF SALINITY
AT
AVON AND NICHOLLS

LEGEND

Salinity at depth of 1 foot (surface zone)
" " " " 10 feet
" " " " 20 "
" " " " 30 "
" " 2 feet from bottom

PLATE LIII

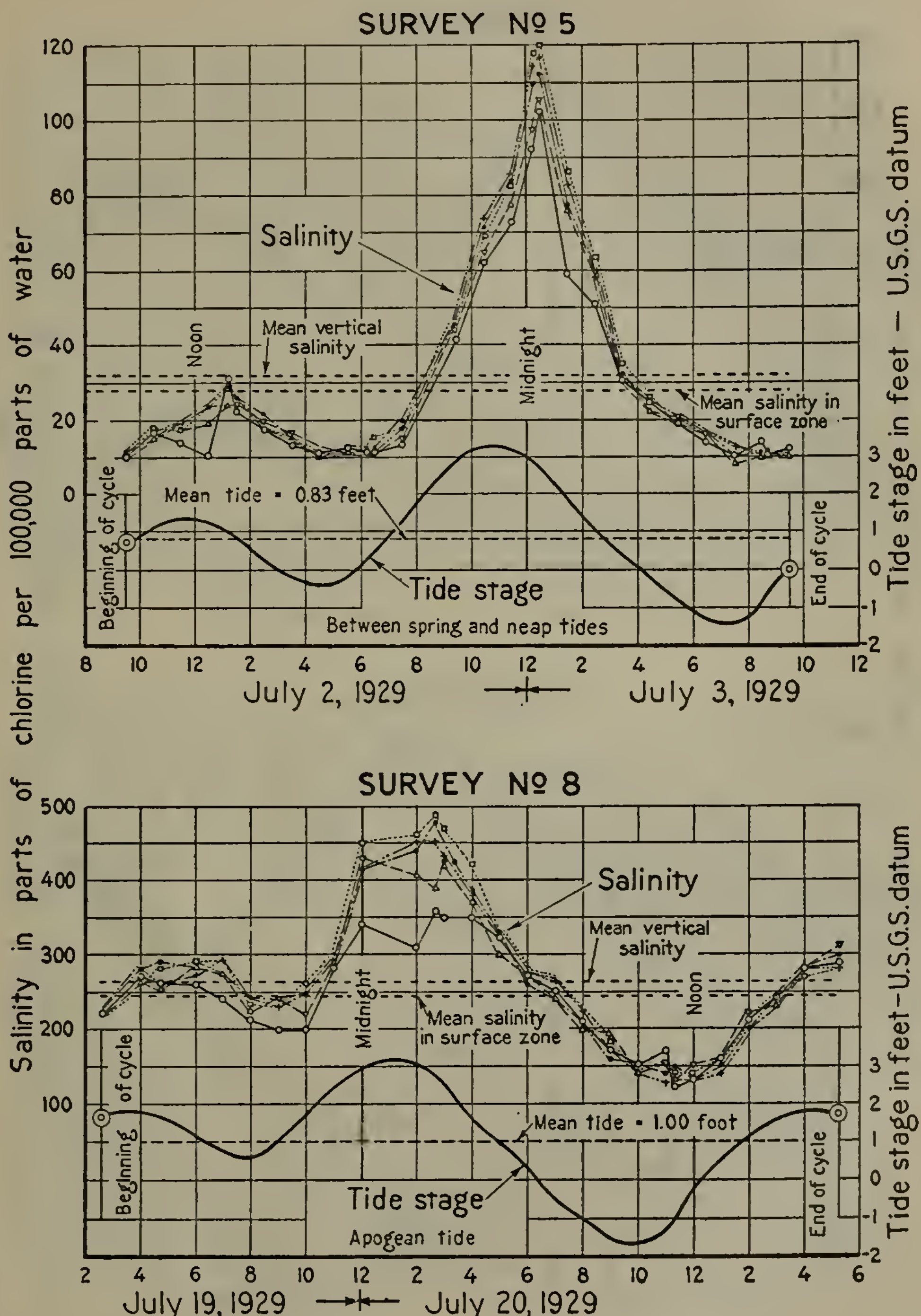


TIDAL VARIATION OF SALINITY
AT
BAY POINT

LEGEND

o—— SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
Δ– – – " " " " 10 FEET
•-·-·- " " " " 20 "
□ ····· " " 2 FEET FROM BOTTOM

PLATE LIV

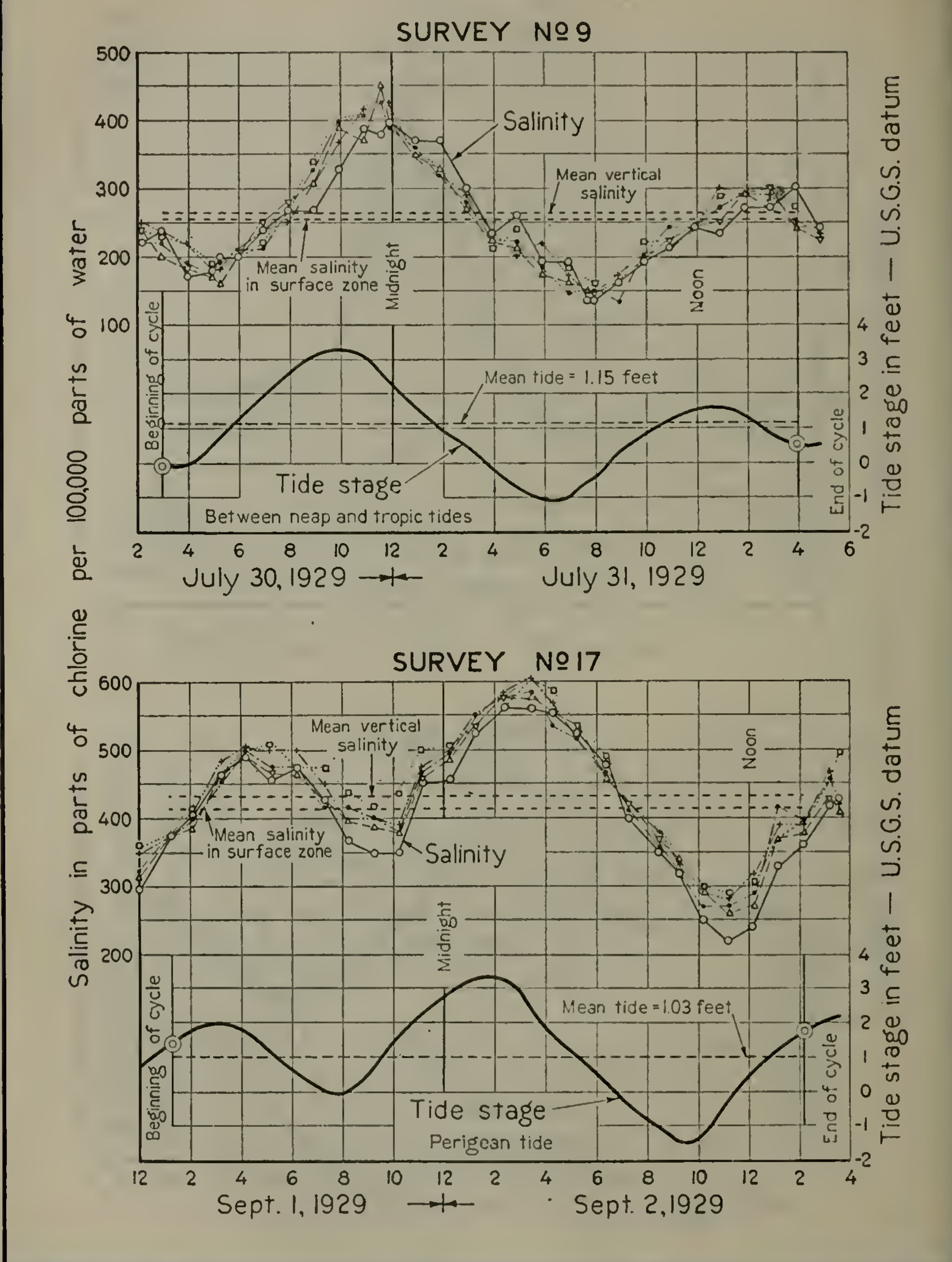


TIDAL VARIATION OF SALINITY AT COLLINSVILLE

LEGEND

- SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
- " " " " 10 FEET
- " " " " 20 "
- " " " " 30 "
- " " " 2 FEET FROM BOTTOM

PLATE LV

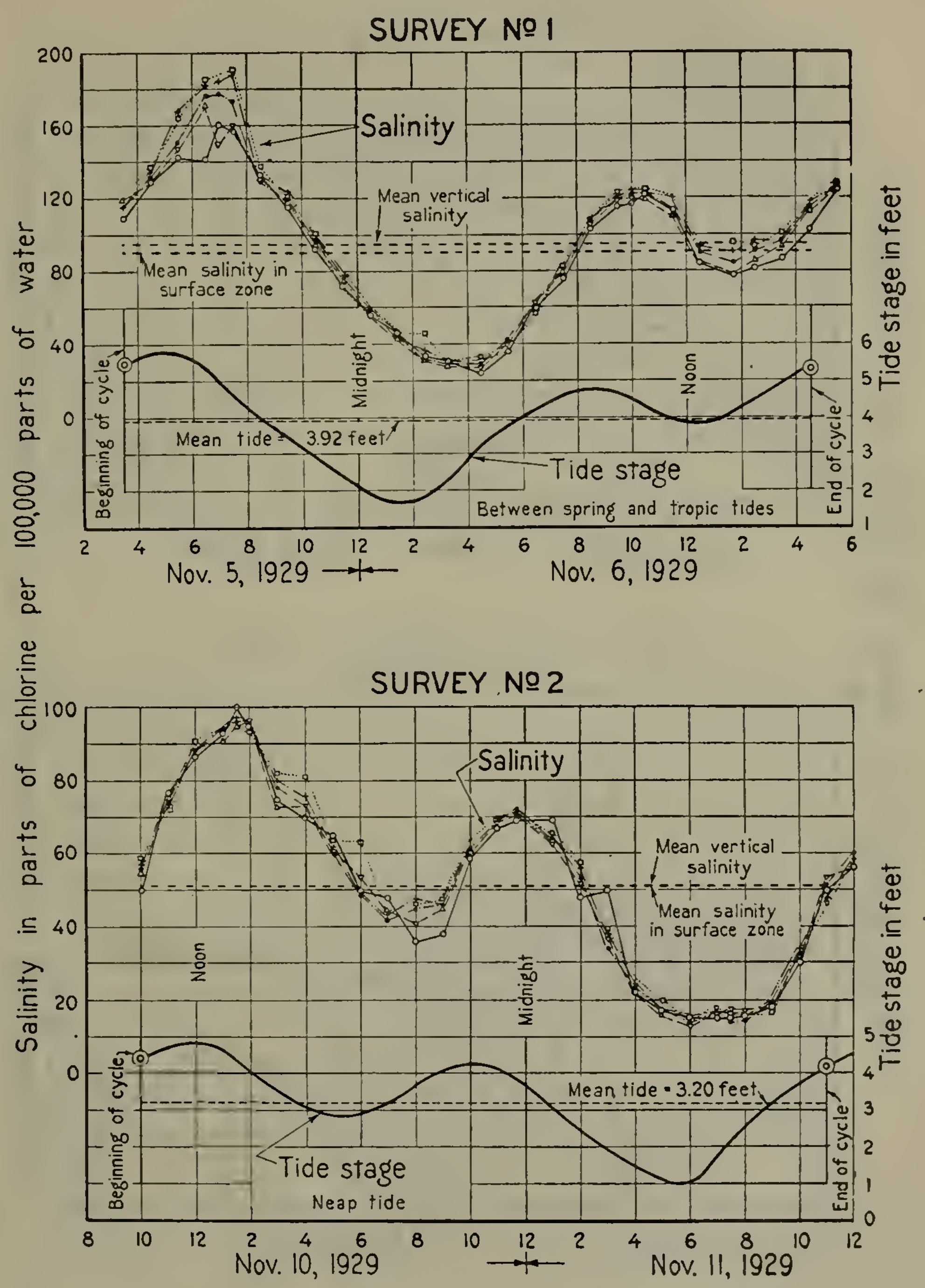


TIDAL VARIATION OF SALINITY
AT
ANTIOCH

LEGEND

- SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
- " " " " 10 FEET
- " " " " 20 "
- " " " " 30 "
- " " 2 FEET FROM BOTTOM

PLATE LVI

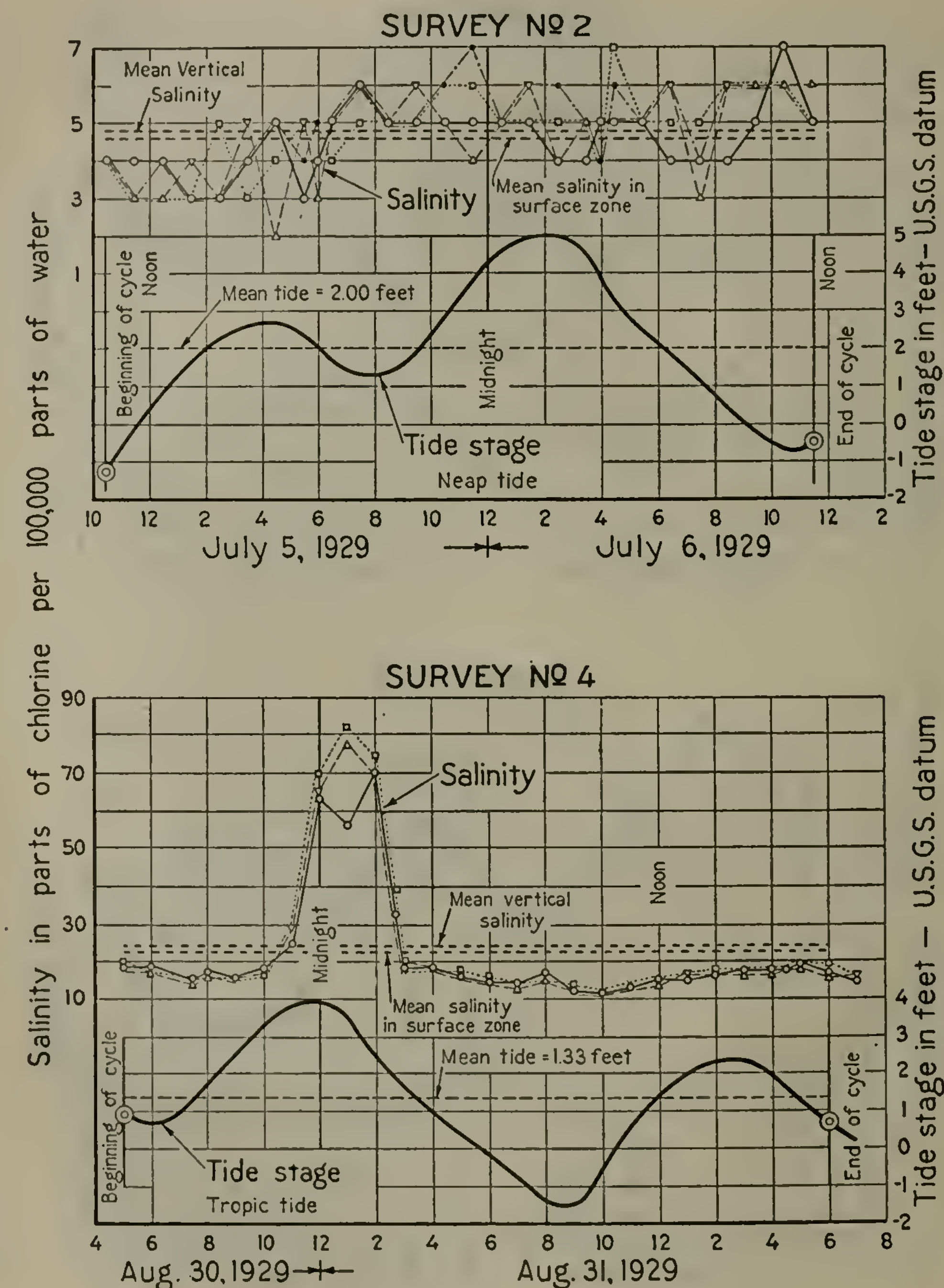


TIDAL VARIATION OF SALINITY
AT
ANTIOCH BRIDGE

LEGEND

o——	SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
Δ— — —	" " " 10 FEET
•—·—·	" " " 20 "
+—··—	" " " 30 "
□········	" " 2 FEET FROM BOTTOM

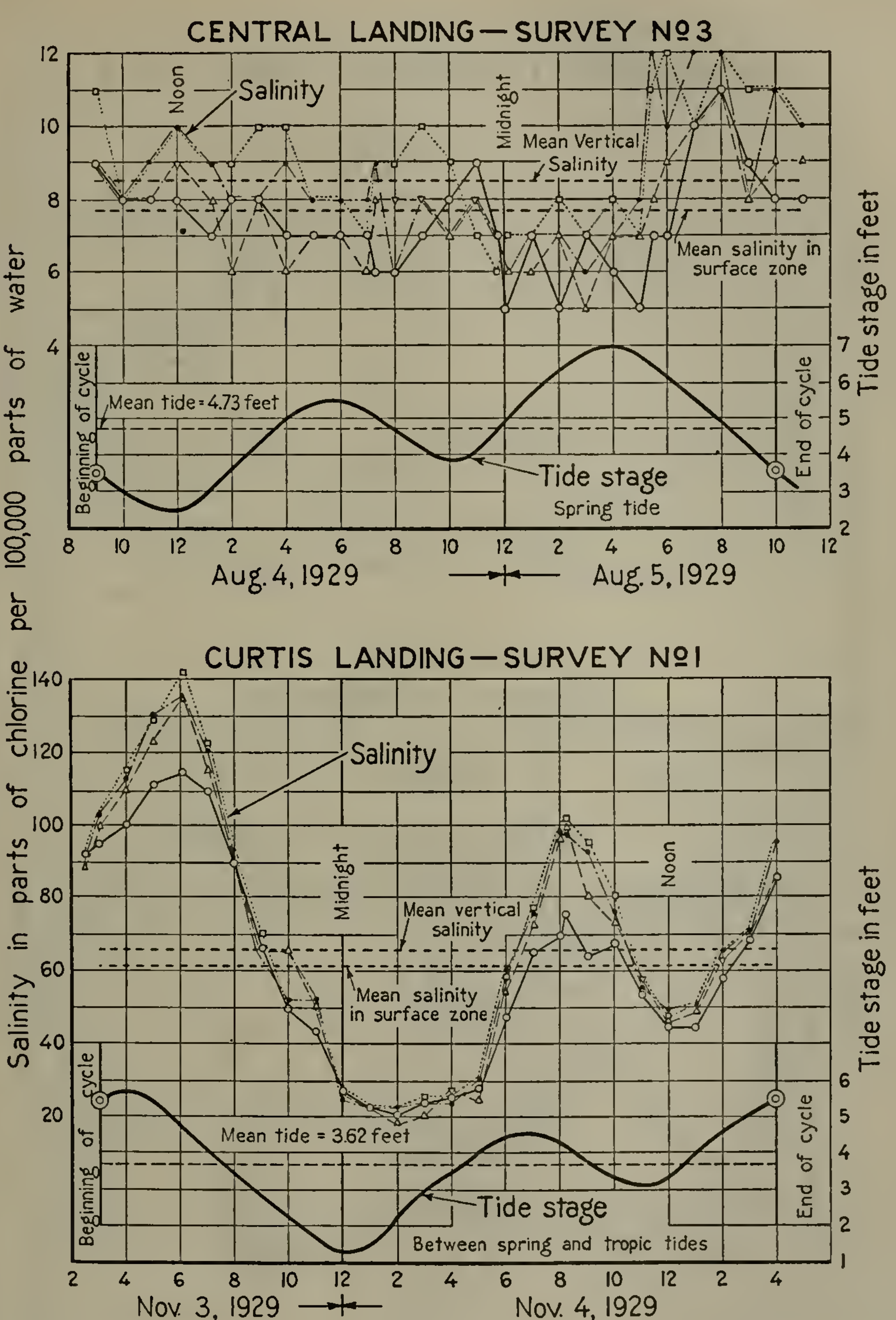
PLATE LVII



TIDAL VARIATION OF SALINITY
AT
RIO VISTA

LEGEND
SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
" " " " 10 FEET
" " " " 20 "
" " 2 FEET FROM BOTTOM

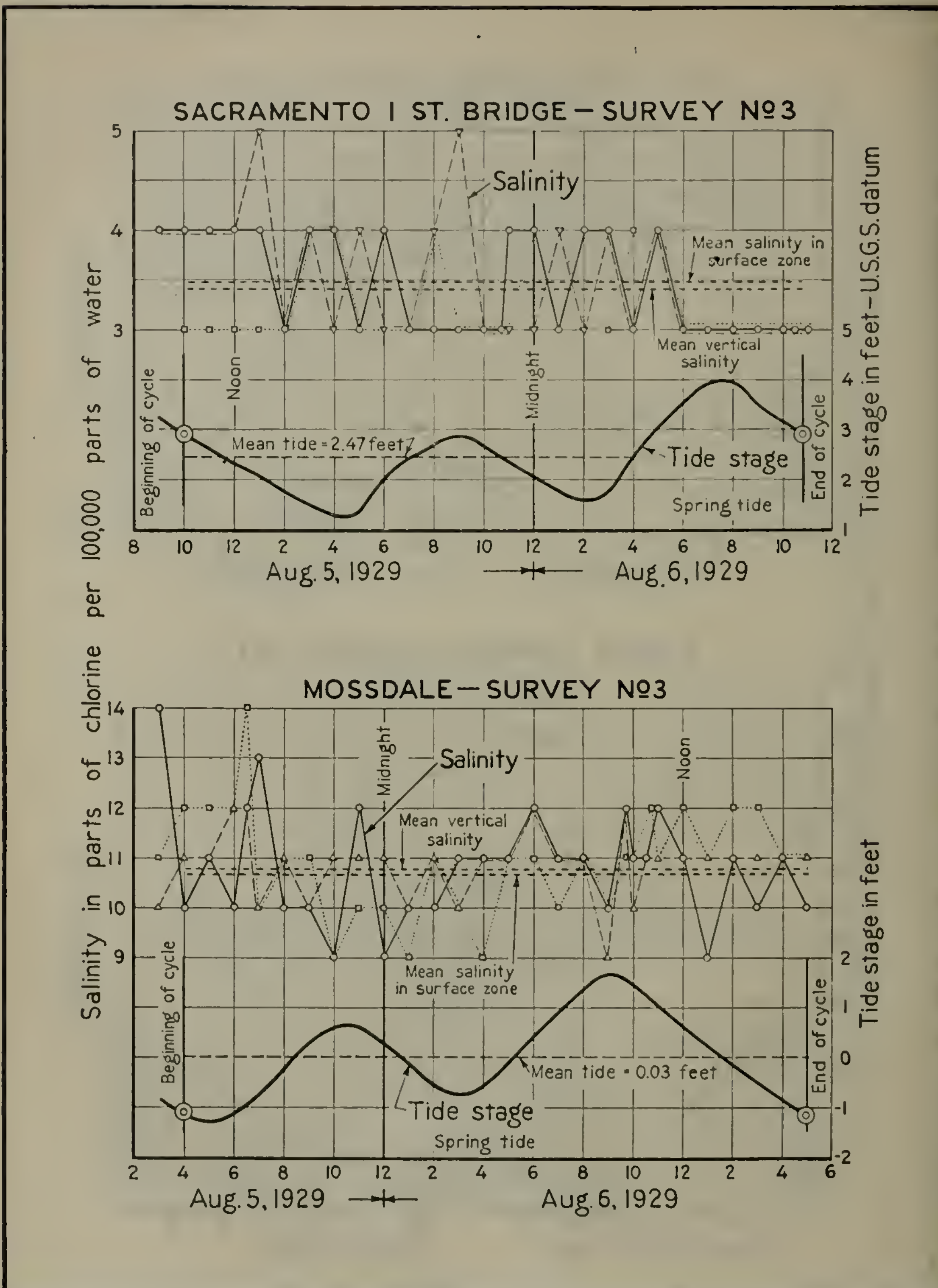
PLATE LVIII



TIDAL VARIATION OF SALINITY
AT
CENTRAL LANDING AND CURTIS LANDING

LEGEND
SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
" " " " 10 FEET
" " " " 20 "
" " " 2 FEET FROM BOTTOM

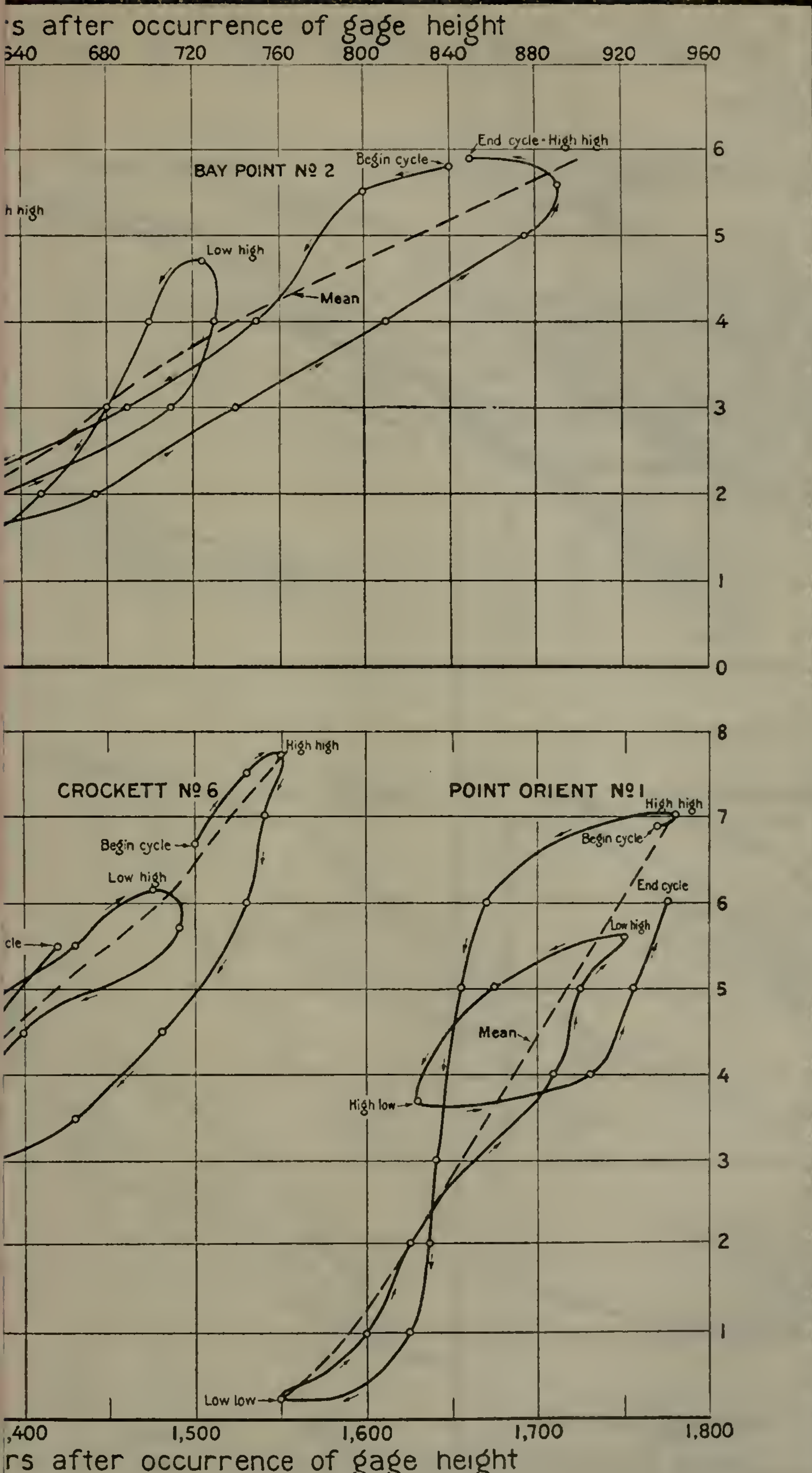
PLATE LIX



TIDAL VARIATION OF SALINITY
AT
SACRAMENTO I ST. BRIDGE AND MOSSDALE

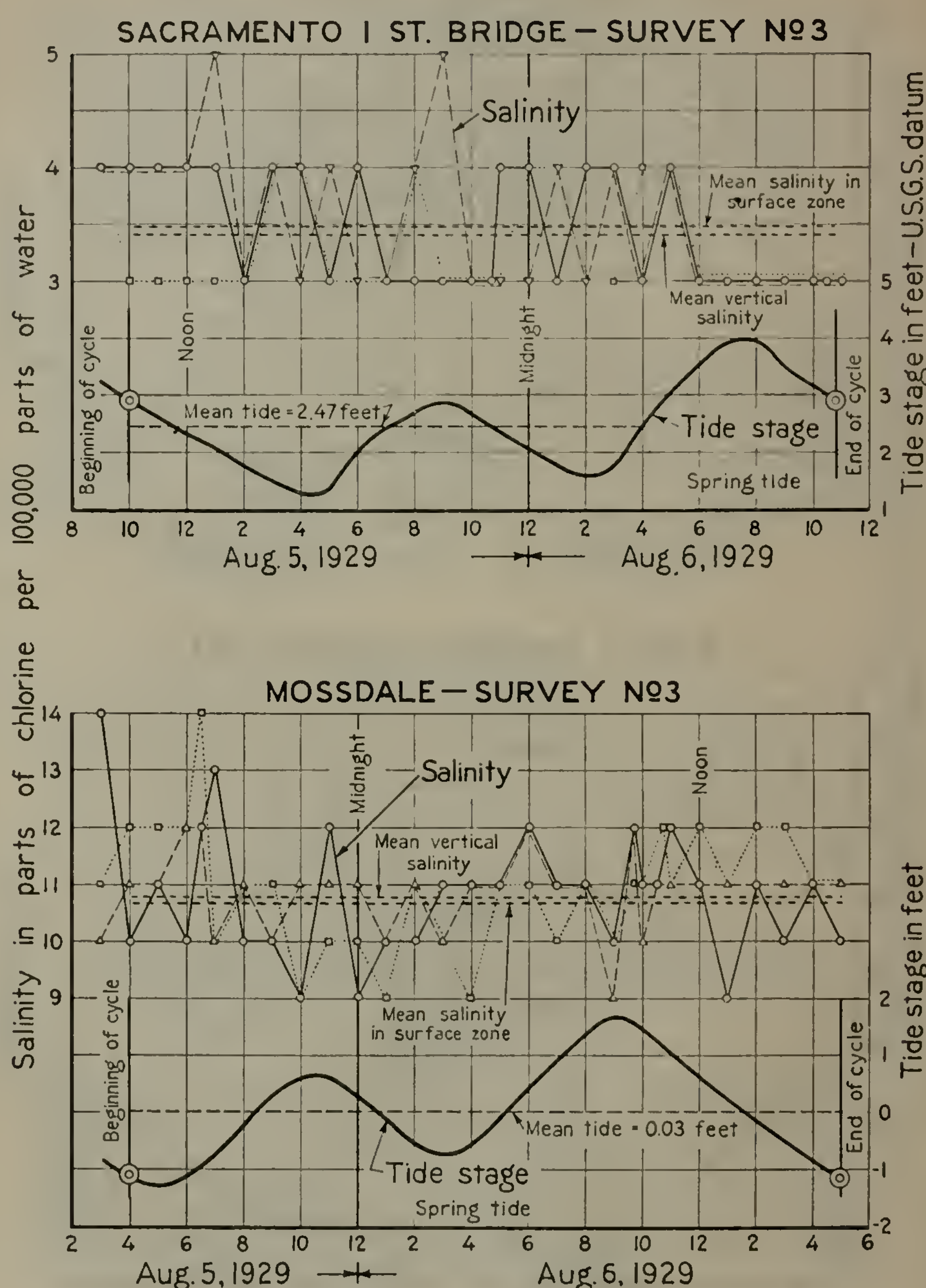
LEGEND

o——— SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
Δ– – – " " " 10 FEET
□······ " " 2 FEET FROM BOTTOM



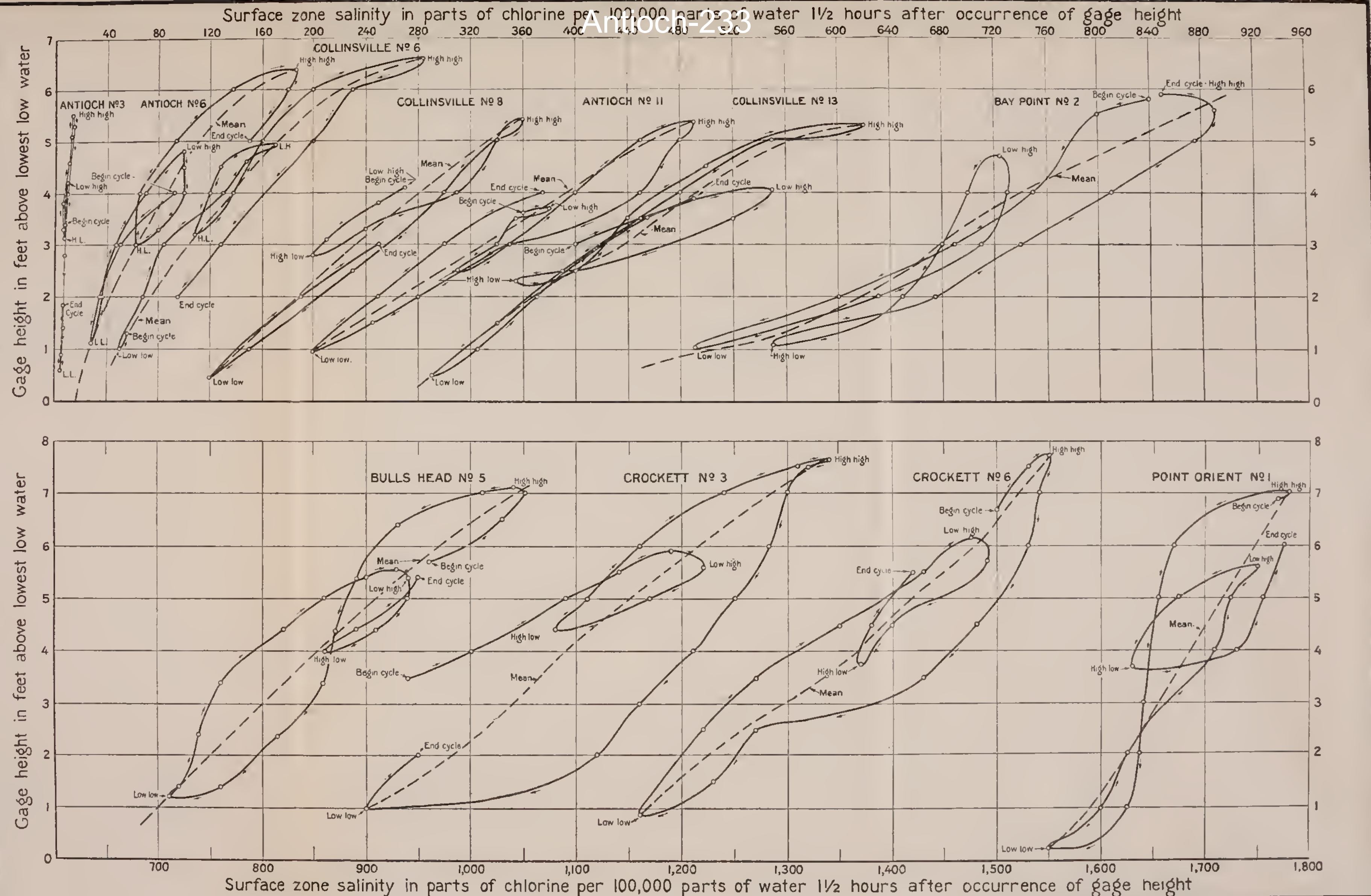
VARIATION OF SALINITY
WITH
TIDAL STAGE

PLATE LIX



TIDAL VARIATION OF SALINITY
AT
SACRAMENTO I ST. BRIDGE AND MOSSDALE

LEGEND
o—— SALINITY AT DEPTH OF 1 FOOT (SURFACE ZONE)
Δ- - - " " " 10 FEET
□······ " " 2 FEET FROM BOTTOM



NOTE Compiled from tidal cycle salinity surveys during 1929

VARIATION OF SALINITY
WITH
TIDAL STAGE

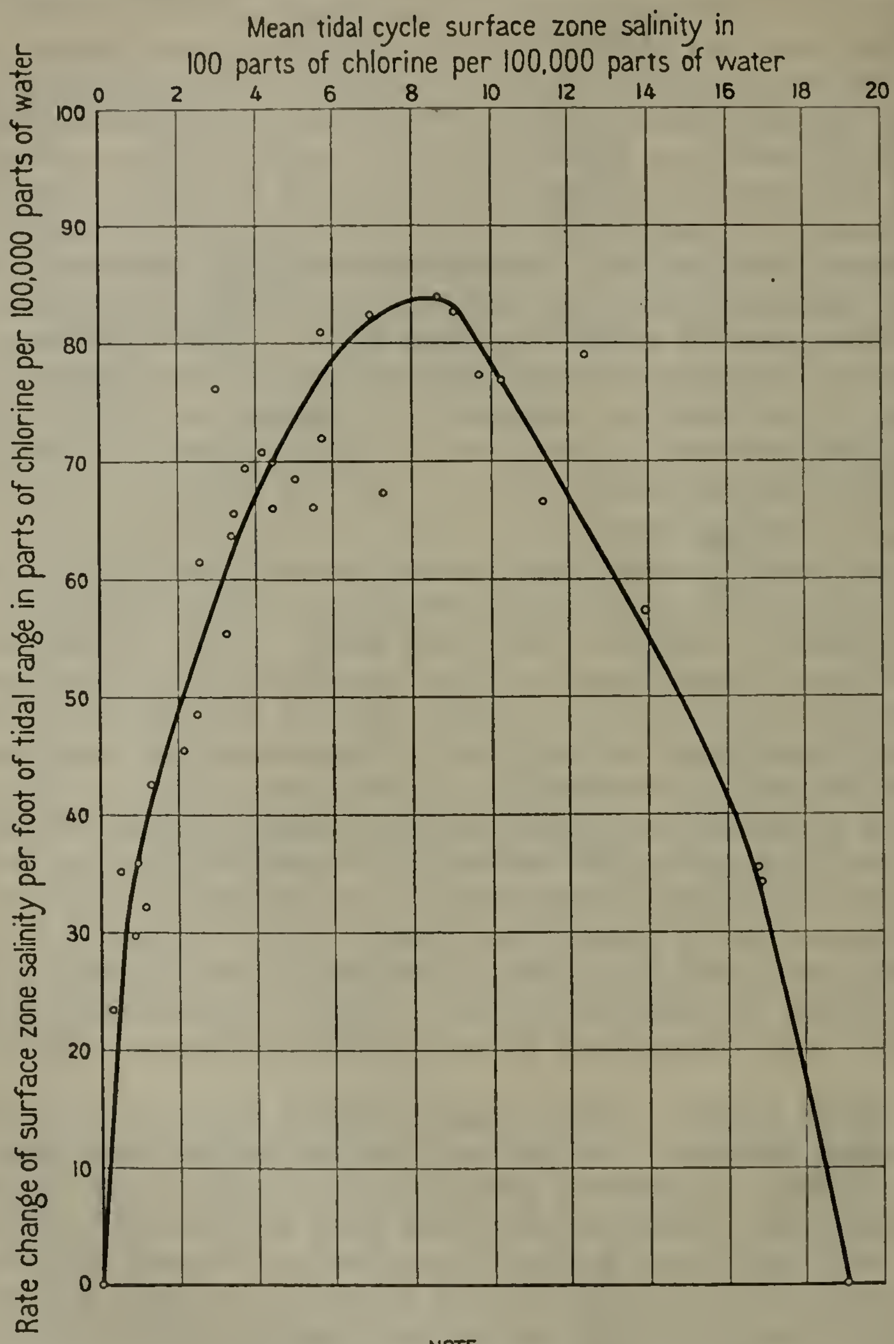
surface zone salinity exhibits marked variations both for different mean salinities and for equal mean salinities. Thus, for tidal cycle surveys No. 6 and 7 at Collinsville with a maximum salinity of 284 to 310 parts of chlorine per 100,000 parts of water, the mean salinity in per cent of maximum salinity shows a variation of from about 47 to 74 per cent. Again, for surveys No. 20 and 14 with a maximum salinity of about 580 parts per 100,000 parts of water, the mean salinity in per cent of maximum salinity was 69 and 80 per cent. Many other similar examples could be pointed out in the tabulation for any station. It is evident, therefore, that there is some modifying influence or factor, which is responsible for the variation in relative magnitude. The studies show that this modifying factor is the variable character of the tide and in particular the variable range and diurnal inequalities of the tide. It is therefore impossible to obtain any simple relation ...een the magnitude of mean and maximum salinity during a tidal ... without taking into account the variable character of the tide.

...riation of Salinity with Tidal Stage—It has been pointed out previously that salinity varies during a tidal cycle in parallel with the rise and fall of the tide. That this is true is more clearly shown on Plate LX, "Variation of Salinity with Tidal Stage." The graphs on Plate LX have been plotted from the data of the tidal cycle salinity surveys. Taking into account the lag averaging one and one-half hours between the time of occurrence of high and low tides and the maximum and minimum salinities corresponding thereto, the graphs on Plate LX have been prepared by plotting the gage height or tidal stage above lowest low water against the salinity in the surface zone one and one-half hours after the particular gage height. Smooth curves have been drawn connecting the points thus plotted. While in detail they take ... a rather fantastic form, there is exhibited, nevertheless, a fundamental relation showing that salinity directly increases and decreases respectively with the rise and fall of the tide during a particular tidal ...cle.

The mean relation of tidal stage to salinity is shown by the dashed lines on each diagram. For the most part the actual departures from the mean lines at different times during the tidal cycle are not of ... magnitude. The diagrams show that the rate of variation of ...y with tidal stage gradually increases as the salinity increases, ...ng a maximum variation with salinities of about 800 to 1100 ... of chlorine per 100,000 parts of water and then gradually decreas... higher salinities. The variation shown appears to be an entirely ...al one. It is evident that, for entirely fresh-water or entirely salt-... conditions, there should be no variation of salinity with the rise ...d ... of the tide. It appears reasonable that the maximum variation ...ould be found for water with about 50 per cent saline content. This ... more clearly shown on Plate LXI, "Rate of Variation of Salinity ...ith Tidal Range in Relation to Mean Salinity." The graph on this ...late has been plotted using as ordinates the mean rate change of surface zone salinity per foot of tidal range during a tidal cycle and the mean surface zone salinity for the tidal cycle as abscissae.

Based upon the relation established between variation of salinity and tidal stage during a tidal cycle for various mean degrees of salinity, there is presented on Plate LXII, "Relation of Salinity to Tidal

PLATE LXI



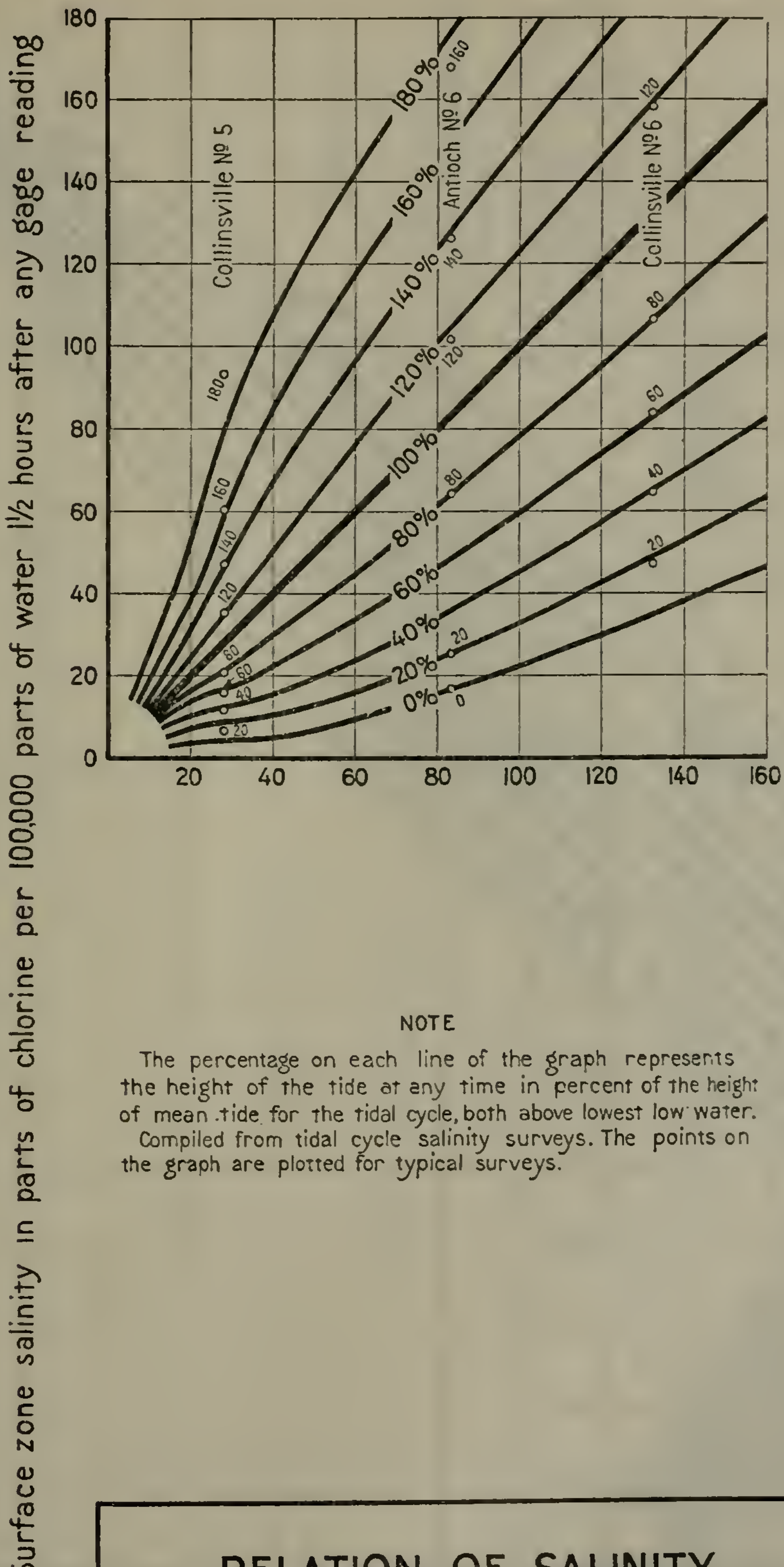
NOTE

The mean surface zone salinities for the tidal cycles were plotted as abscissas.
The rate change per foot of tidal range was computed by dividing the difference in surface zone salinity in parts of chlorine per 100,000 parts of water after high high and low low tides by the tidal range in feet between high high and low low tides, and these values were plotted as ordinates.

RATE OF VARIATION OF SALINITY WITH TIDAL RANGE

IN RELATION TO

MEAN SALINITY



NOTE

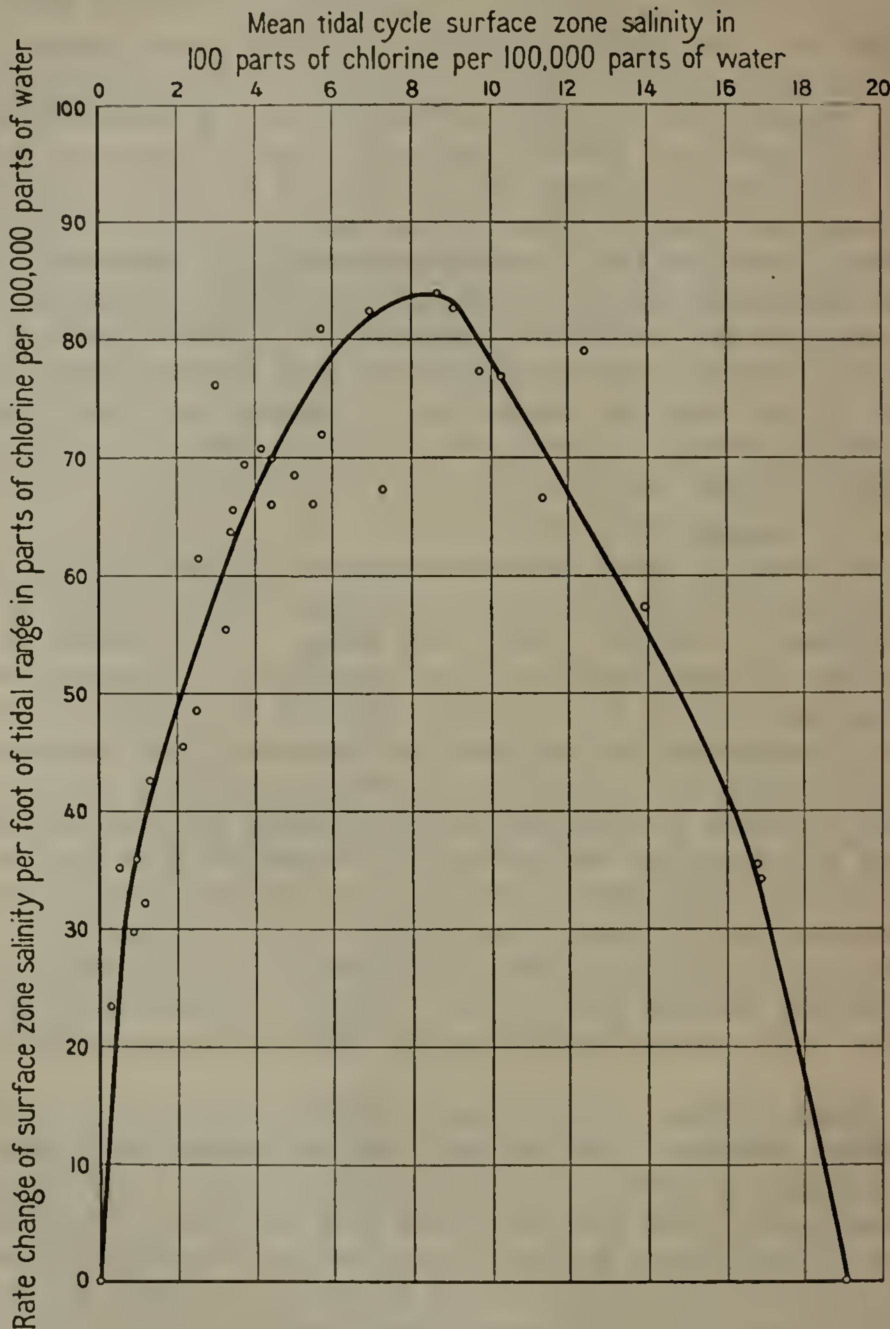
The percentage on each line of the graph represents the height of the tide at any time in percent of the height of mean tide for the tidal cycle, both above lowest low water.

Compiled from tidal cycle salinity surveys. The points on the graph are plotted for typical surveys.

RELATION OF SALINITY
TO
TIDAL STAGE

1900

PLATE LXI



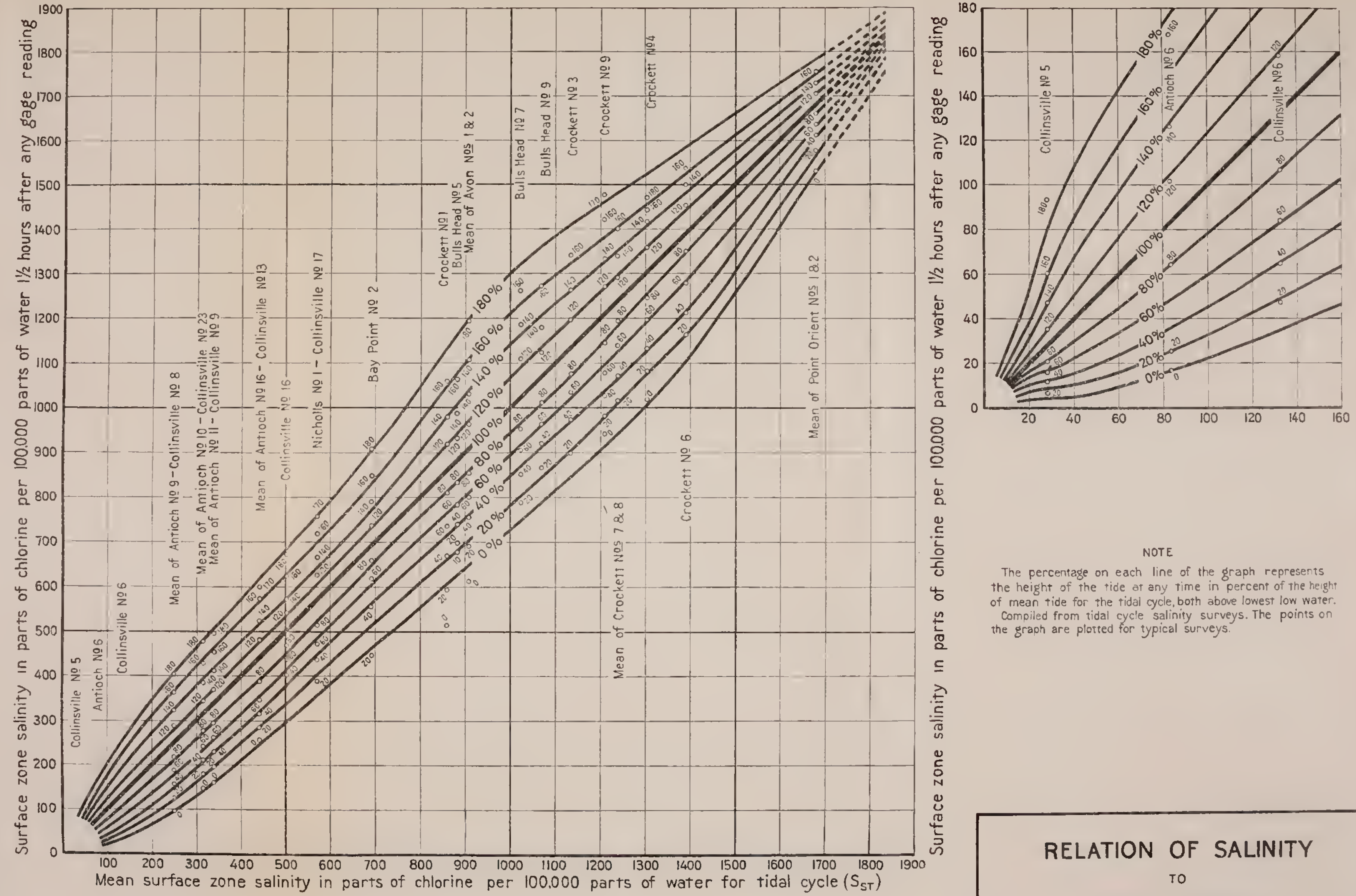
NOTE

The mean surface zone salinities for the tidal cycles were plotted as abscissas.
The rate change per foot of tidal range was computed by dividing the difference in surface zone salinity in parts of chlorine per 100,000 parts of water after high high and low low tides by the tidal range in feet between high high and low low tides, and these values were plotted as ordinates.

RATE OF VARIATION OF SALINITY WITH TIDAL RANGE

IN RELATION TO

MEAN SALINITY



NOTE

The percentage on each line of the graph represents the height of the tide at any time in percent of the height of mean tide for the tidal cycle, both above lowest low water.
Compiled from tidal cycle salinity surveys. The points on the graph are plotted for typical surveys.

RELATION OF SALINITY
TO
TIDAL STAGE

Stage," a comprehensive graph showing in detail the relation of salinity to tidal stage for all variations of tidal conditions and degrees of salinity covered by the surveys in 1929. The basis of compilation of this diagram is somewhat complex. From the mean curves of variation of salinity with tidal stage, typified by those shown on Plate LX, corresponding values of salinity and gage height were taken at convenient intervals of salinity and tidal stage. The actual gage height was then expressed as a percentage of the height of mean tide above lowest low water at the particular station. Thus, mean tide is expressed as 100 per cent. The mean salinity for the tidal cycle also was determined for each survey. Points were plotted on the graph, using mean surface zone salinities for each tidal cycle as abscissae, and the different values of salinity for various gage heights, as taken from the mean curves, as ordinates. Each of these plotted points was then marked with a percentage computed as the gage height (corresponding to the particular value of salinity) in per cent of the mean height of the tide, both above lowest low water. Through the points thus plotted, smooth curves were drawn representing the variations of salinity for different tidal stages expressed as a per cent from zero to 180 per cent and at intervals of 20 per cent.

The derivation of the diagram shown on Plate LXII of the relation of salinity to tidal stage represents one of the important contributions of the salinity investigation. It has been of invaluable use in carrying out the analyses of the relation of salinity to stream flow and tidal action. All of the records of salinity which furnish the basic data on variation of salinity during invasion and retreat for the last decade have been from samples usually taken after high tide. The salinity records of the regular observation stations therefore represent nearly maximum degrees of salinity at the various stations on the dates when samples were taken. The relations of salinity to stream flow and tidal action, however, have to do with the variation and advance and retreat of mean daily, or tidal cycle, salinity. Therefore, inasmuch as it is evident from the data heretofore presented that mean salinity does not bear a constant relation to maximum salinity during a tidal cycle for all degrees of salinity and for variable tidal conditions, it has been deemed necessary to use mean salinity for a tidal cycle instead of the maximum salinities of the observer's samples. In all of the relations analyzed in this study as between stream flow and salinity and as between tidal action and salinity, mean surface zone salinity for the tidal cycle, or, what has been termed for convenience mean surface zone salinity, has been used throughout.

The use of the diagram is explained as follows: Having a value of the surface zone salinity determined from an actual sample taken at any particular time, the diagram is entered with this value on the ordinate scale, and a horizontal line drawn to intersect the percentage line corresponding to the height of the tide, one and one-half hours before the time the sample was taken, in per cent of the mean height of tide, both measured above lowest low water. The mean surface zone salinity is then taken off the abscissa scale of the diagram by drawing a vertical line directly from this point of intersection to the abscissa scale. The salinity at any other stage of the tide is also readily obtained at points on the ordinate scale directly opposite horizontally from the points of intersection of the vertical line previously described with the various curves of percentage of tidal stage. For example, if the observed salinity is 500 parts taken about one and one-half hours after high-high tide, at which time the height of the tide was 180 per cent of the height of mean tide above lowest low water, the mean surface zone salinity corresponding therewith would be about 340 parts and the minimum surface zone salinity under these conditions at low tide, with a gage height corresponding to 20 per cent of the mean height of tide, would be about 200 parts.

It is thus possible with this diagram to estimate the variation of salinity throughout an entire tidal cycle, if the actual salinity at any one time during the tidal cycle be known, together with some knowledge of the actual height of tide at the time the sample is taken compared with the mean height of tide above lowest low water. It has been found approximately true that the use of the tide gage records at the Presidio during the low water season will give the value of the tide percentage to be used with approximately the same degree of accuracy as records at nearby tide gage stations. However, it is, of course, necessary to take care of the difference in time between the occurrence of the tidal phases at the Presidio and at the point of observation if percentages based upon the Presidio records are used.

It should be understood that the relations shown on Plate LXII are empirical and are strictly applicable only to that part of the lower delta and the bay region, down to Point Orient where the data were obtained on which the diagram is based. For this portion of the tidal basin of San Francisco Bay along the main channels through which major tidal movement occurs, it is believed that the relations shown are closely approximate. It is probable that the relations would not apply as closely at points in the upper delta channels because of the difference in magnitude and character of tidal movement and the complicating effect of interconnecting branch channels. The relation could not be expected to apply to points on the dead end of channels, where the conditions of pulsating flow are entirely different than along main channels.

Lateral and Depth Variations of Salinity—One of the important parts of the 1929 program of salinity investigations was the determination of the relative degree of salinity at different depths and in different parts of a channel. It has been somewhat commonly believed and statements have been made to the effect that the saline water from the bay creeps along the bottom or sides of the channels of the upper bay and delta.

The data indicate that the variation of salinity with depth is not of as great magnitude as has been popularly believed. In many instances, the salinity at all depths has been found to be practically the same. There does not appear to be any fixed time during a tidal cycle when a maximum variation with depth occurs, some of the surveys indicating a tendency for greater variation during flood tide and others at a different time of the tidal cycle. Hence, no fixed rule can be stated. Plate LXIII, "Variation of Salinity With Depth," shows data compiled from typical tidal cycle surveys in 1929. The variation with depth is shown at the time of minimum and maximum salinity and also for the mean salinity at each depth during a tidal cycle. The increase of salinity with depth appears to be greatest for

Depth in feet below water surface

LEGEND

Nº	Station	Tidal cycle salinity survey No.
(1)	Antioch	1
(2)	"	4
(3)	"	6
(4)	"	7
(5)	Collinsville	6
(6)	"	24
(7)	Antioch	9
(8)	"	10
(9)	"	11
(10)	"	15
(11)	Collinsville	13
(12)	"	11
(13)	"	16
(14)	"	17
(15)	Bay Point	2
(16)	Avon	1
(17)	Bulls Head Point	7
(18)	" " "	8
(19)	" " "	10
(20)	Crockett	7
(21)	"	5
(22)	Point Orient	3

NOTE
Compiled from tidal cycle salinity surveys during 1929.

VARIATION OF SALINITY WITH DEPTH

points of intersection of the vertical line previously described with the various curves of percentage of tidal stage. For example, if the observed salinity is 500 parts taken about one and one-half hours after high-high tide, at which time the height of the tide was 180 per cent of the height of mean tide above lowest low water, the mean surface zone salinity corresponding therewith would be about 340 parts and the minimum surface zone salinity under these conditions at low tide, with a gage height corresponding to 20 per cent of the mean height of tide, would be about 200 parts.

It is thus possible with this diagram to estimate the variation of salinity throughout an entire tidal cycle, if the actual salinity at any one time during the tidal cycle be known, together with some knowledge of the actual height of tide at the time the sample is taken compared with the mean height of tide above lowest low water. It has been found approximately true that the use of the tide gage records at the Presidio during the low water season will give the value of the tide percentage to be used with approximately the same degree of accuracy as records at nearby tide gage stations. However, it is, of course, necessary to take care of the difference in time between the occurrence of the tidal phases at the Presidio and at the point of observation if percentages based upon the Presidio records are used.

It should be understood that the relations shown on Plate LXII are empirical and are strictly applicable only to that part of the lower delta and the bay region, down to Point Orient where the data were obtained on which the diagram is based. For this portion of the tidal basin of San Francisco Bay along the main channels through which major tidal movement occurs, it is believed that the relations shown are closely approximate. It is probable that the relations would not apply as closely at points in the upper delta channels because of the difference in magnitude and character of tidal movement and the complicating effect of interconnecting branch channels. The relation could not be expected to apply to points on the dead end of channels, where the conditions of pulsating flow are entirely different than along main channels.

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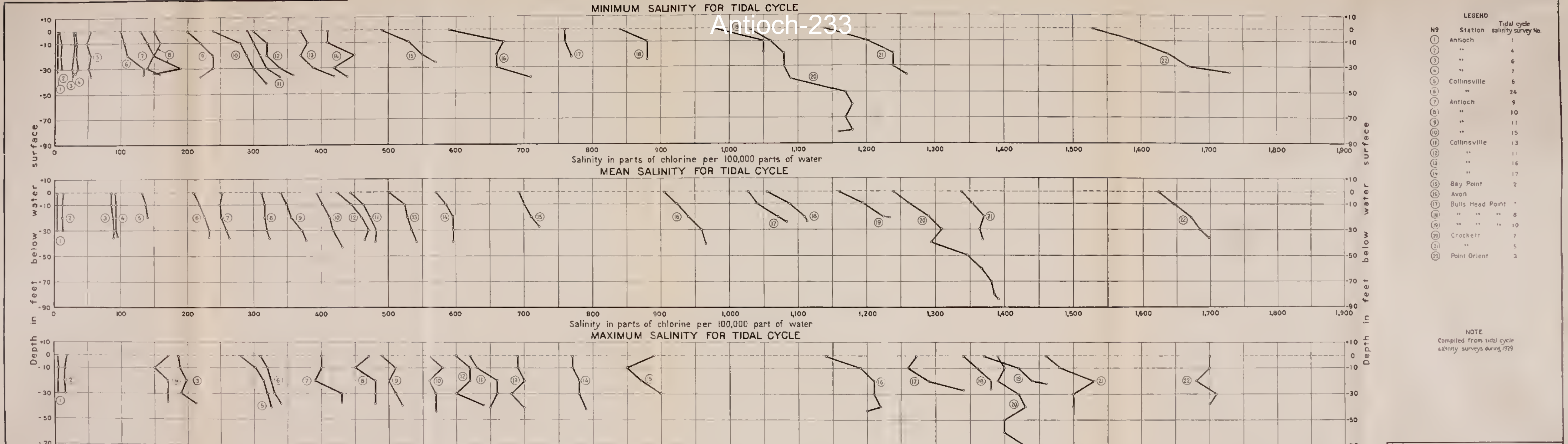
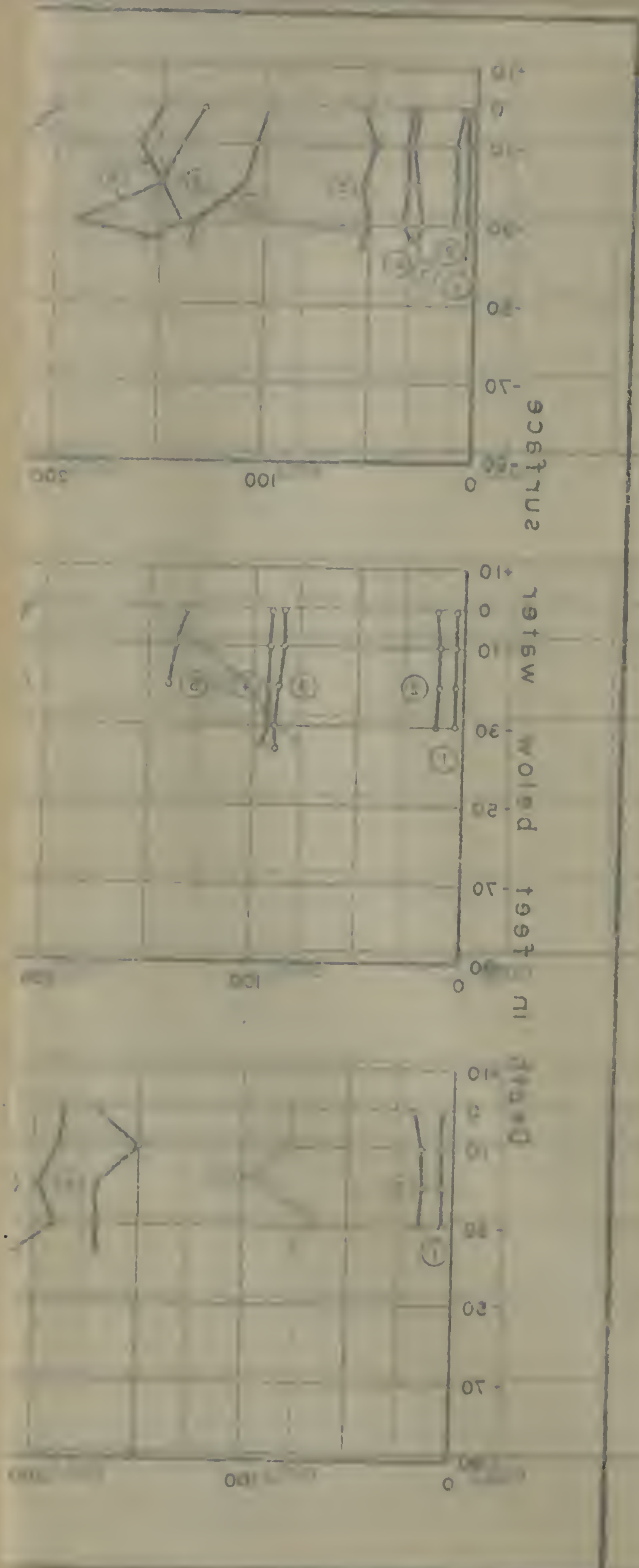


VARIATION OF SALINITY WITH DEPTH



salinities of about 1000 to 1300 parts of chlorine per 100,000 parts of water. For the low and high salinities as well, there appears to be less variation with depth. This is to be expected inasmuch as no variation should occur in the case of either entirely fresh or salt water. One of the most interesting surveys showing the variation with depth is that taken at Crockett (Index No. 20 on Plate LXIII) which was made on October 10 and 11, 1929. This survey covered a depth of channel of about 90 feet. The mean salinity varied from 1240 parts at the surface to about 1400 parts at the bottom of the channel or an increase of about 160 parts, or 13 per cent of the surface zone salinity, or about 0.15 per cent increase per foot of depth. Surveys at other points showed an increase of as much as 0.3 per cent per foot of depth for mean salinity. At the time of minimum salinity during this tidal cycle at Crockett, the magnitude of variation with depth appears to be about the same. However, at the time of maximum salinity, the increase appears considerably less, being not over 60 parts, or about 4 per cent of the salinity at the surface zone. Variations in the individual surveys from a gradual increase of salinity with depth are difficult to explain but are probably due in large part to the erratic character of the tidal currents which are known to exist in the various parts of the channels during the flood and ebb of the tide.

The extent of lateral variation of salinity throughout a typical channel section is indicated by the special river cross-section salinity surveys, described in Chapter I. These surveys were made chiefly at high-high tide but a few were made at low-low and low-high tide. The work was scheduled so that the samples would be taken as near as possible to the time of slack water following the particular high or low tidal phase for which the survey was made. However, each survey usually involved a time interval of three-quarters of an hour to an hour or more to take the large number of samples across the entire channel section. Hence, the actual samples taken over the entire section were not representative of a particular time. This was not important for the lower degrees of salinity in the surveys early in the season. However, for the surveys of higher salinity, the observed salinities were corrected by relations established from tidal cycle salinity surveys at Antioch and Collinsville and values of salinity were computed for the time of slack water following the particular tidal phase of the survey. These adjusted values of salinity have been used in the diagrams and tables presented hereafter.

Table 26 summarizes the results of these special river cross-section salinity surveys. The data are more clearly illustrated graphically on Plate LXIV, "Lateral Variation of Salinity," which presents the results of typical surveys of this type both for the San Joaquin River cross-section at Antioch and the Sacramento River cross-section immediately north of Antioch, designated as near Collinsville. The location of these sections is shown on Plate III. The upper diagrams show the results of three typical surveys taken in the San Joaquin River at Antioch, two for high-high tide conditions on June 10 and July 31, 1929, and one for low-low tide conditions on August 4, 1929. The lower diagrams show the results of surveys for two high-high tides and one low-low tide in the Sacramento River cross-section above Collinsville. The heavy line represents the bottom of the river bed

TABLE 26

SUMMARY OF RIVER CROSS SECTION SALINITY SURVEYS—1929

Collinsville River Cross Section

Survey No.	Date	Salinity in parts of chlorine per 100,000 parts of water						Mean sectional salinity in per cent of mean surface zone salinity (Sa) to (Ss)	Mean sectional salinity in per cent of maximum surface zone salinity (Sa) to (S)	Mean surface zone salinity in per cent of maximum surface zone salinity (Ss) to (S)	Tidal phase
		Surface zone			Cross section						
		Minimum	Mean (Ss)	Maximum (S)	Minimum	Mean (Sa)	Maximum				
1	May 31	3	3.4	5	3	3.5	5	103	70	68	Low low
2	May 31	2	3.7	5	2	3.8	5	103	76	75	High high
3	June 2	4	4.7	6	3	5.0	8	107	83	78	High high
4	June 4	4	6.4	9	4	6.1	10	95	63	71	High high
5	June 10	29	35.9	43	18	36.3	43	101	84	84	High high
6	June 20	8	8.0	13	8	9.9	13	99	76	77	High high
7	June 24	5	9.0	15	4	9.2	15	102	61	60	High high
8	June 27	4	7.8	10	4	8.4	13	108	84	78	Low high
9	July 2	36	42.3	52	36	51.2	66	121	98	81	High high
10	July 8	180	208	230	180	217	270	104	94	90	High high
11	July 12	121	165	261	121	168	261	102	64	63	Low high
12	July 30	380	393	420	360	405	460	103	96	94	High high
13	Aug. 4	400	463	500	380	460	560	99	92	93	High high
14	Aug. 4	157	191	214	157	202	244	106	94	89	Low low
15	Aug. 13	440	484	520	430	502	600	104	97	93	High high
16	Sept. 2	560	581	600	560	623	670	107	104	97	High high
Average of high-high tides								104	85	82	
Maximum of high-high tides								121	104	97	
Minimum of high-high tides								95	61	60	

TABLE 26—Continued

SUMMARY OF RIVER CROSS SECTION SALINITY SURVEYS—1929

Antioch River Cross Section

Survey No.	Date	Salinity in parts of chlorine per 100,000 parts of water: Surface zone: Minimum	Surface zone: Mean (Ss)	Surface zone: Maximum (S)	Cross section: Minimum	Cross section: Mean (Sa)	Cross section: Maximum	Mean sectional salinity in per cent of mean surface zone salinity (Sa) to (Ss)	Mean sectional salinity in per cent of maximum surface zone salinity (Sa) to (S)	Mean surface zone salinity in per cent of maximum surface zone salinity (Ss) to (S)	Tidal phase
1	May 31	4	4.8	6	4	4.8	6	101	80	79	Low low
2	June 1	5	5.5	6	5	5.3	6	97	89	91	High high
3	June 3	4	4.5	6	4	4.7	6	104	79	76	High high
4	June 4	6	7.3	9	6	7.6	9	104	84	81	High high
5	June 10	31	38.5	44	29	39.8	45	103	90	88	High high
6	June 20	9	10.8	12	9	11.4	14	105	95	90	High high
7	June 24	8	11.1	17	8	12.8	19	110	75	65	High high
8	June 27	7	9.1	13	7	9.5	13	104	73	70	High low
9	July 4	28	53.3	70	28	61.5	82	115	88	76	High high
10	July 8	127	166	185	127	173	190	104	94	90	High high
11	July 11	163	185	242	141	189	258	102	78	77	High high
12	July 12	130	138	150	120	150	180	108	100	92	Low high
13	July 31	337	377	420	337	387	467	103	92	90	High high
14	Aug. 4	403	436	469	318	442	508	101	94	93	High high
15	Aug. 4	116	124	145	115	135	172	108	93	86	Low low
16	Sept. 18	439	466	505	437	483	558	104	96	92	High high
17	Sept. 2	470	501	510	470	513	540	102	101	98	Low high
Average of high-high tides								104	88	84	
Maximum of high-high tides								115	96	93	
Minimum of high-high tides								97	75	65	
Average of high-high tides for Collinsville and Antioch river cross sections								104	87	83	
Maximum of high-high tides for Collinsville and Antioch river cross sections								121	104	97	
Minimum of high-high tides for Collinsville and Antioch river cross sections								95	61	60	

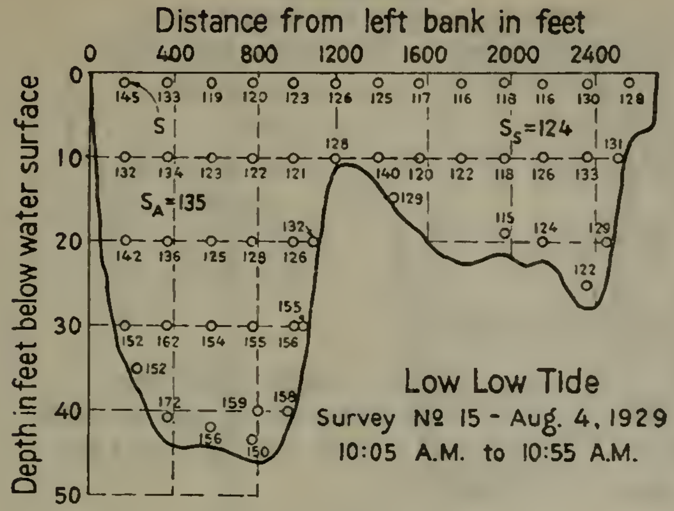
in profile on the line of the cross-section. The small circles represent the points where samples were taken and along side of each circle is shown the salinity in parts of chlorine per 100,000 parts of water, as determined from the analysis of the sample. There are also shown the maximum salinity in the surface zone (S), the computed mean surface zone salinity (S_s), and the mean salinity in the entire channel cross-section. (S_a). Below each diagram is finally shown the relation between the maximum and mean salinities above described. The mean salinity in the surface zone and the mean salinity in the section is expressed in per cent of the maximum salinity in the surface zone and the mean salinity in the section is expressed in per cent of the mean salinity in the surface zone. The summarized data in Table 26 present similar percentage relations for all of the surveys made.

In general, the data from these surveys indicate no large variations of salinity either laterally or vertically in these channels. As shown in Table 26, the mean sectional salinity (S_a) averages 104 per cent of the mean surface zone salinity (S_s) for all surveys at both river cross-sections, and varies from a minimum of 95 to a maximum of 121 per cent. This is a measure of the magnitude of variation found. No abnormally high salinities were found either along the bottom or sides of these channels.

The variation of salinity in the surface zone across a river section is indicated by the relation of the mean to the maximum surface zone salinity. This relation for all surveys at both cross-sections shows a variation from a minimum of 60 to a maximum of 97 per cent with an average of 83 per cent. It would appear from this that, in any large channel such as those in which the surveys were made, there may be individual variations of salinity of considerable magnitude and that the single point observations of salinity at the regular observation stations may occasionally not be accurately representative of the average salinity conditions for the entire channel. This would happen perhaps only occasionally, but possibly explains the fact that some of the observed salinities at regular observation stations, as also some of the observed samples on tidal cycle surveys do not appear to follow in line with similar or related data. However, it is believed that the observed salinities in the surface zone as taken at the single point observation stations afford a close enough approximation of the average salinity conditions in the entire channel for ascertaining the relative variation of salinity at various points during the period of advance and retreat. The results, hereafter presented, of the special tidal cycle salinity and velocity surveys afford further verification of this conclusion.

Variation of Salinity with Tidal Velocity—The relation of tidal velocity to salinity is of significant importance because tidal velocity represents the basic element and direct evidence of tidal flow which is one of the chief factors affecting the variation and advance and retreat of salinity. Measurements of tidal velocity, made during 1929, have been described in Chapter I. Tidal velocity was measured by current meter at three stations in each of the river cross-sections on the San Joaquin River at Antioch and on the Sacramento River above Collinsville. The position of these current meter stations and the results of typical tidal velocity measurements are shown on Plate LXV, "Variation of Tidal

ANTIOCH

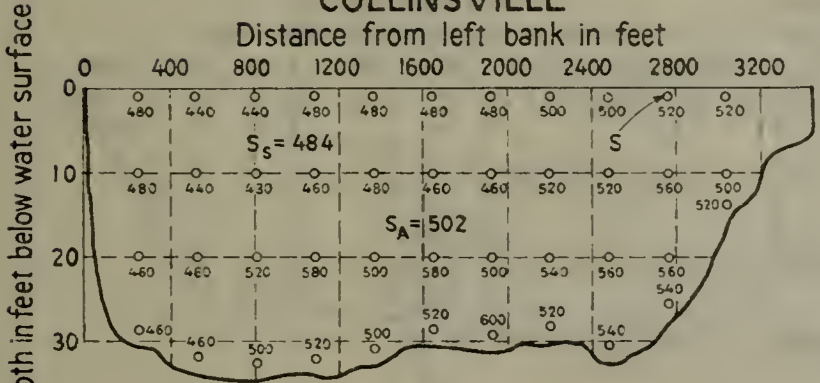


S_S in per cent of S = 86

S_A in per cent of S = 93

S_A in per cent of S_S = 108

COLLINSVILLE



High High Tide

Survey Nº 15 – Aug. 13, 1929

10:20 P.M. to 11:25 P.M.

S_S in per cent of S = 93

S_A in per cent of S = 97

S_A in per cent of S_S = 104

LATERAL VARIATION OF SALINITY

in profile on the line of the cross-section. The small circles represent the points where samples were taken and along side of each circle is shown the salinity in parts of chlorine per 100,000 parts of water, as determined from the analysis of the sample. There are also shown the maximum salinity in the surface zone (S), the computed mean surface zone salinity (S_s), and the mean salinity in the entire channel cross-section. (S_a). Below each diagram is finally shown the relation between the maximum and mean salinities above described. The mean salinity in the surface zone and the mean salinity in the section is expressed in per cent of the maximum salinity in the surface zone and the mean salinity in the section is expressed in per cent of the mean salinity in the surface zone. The summarized data in Table 26 present similar percentage relations for all of the surveys made.

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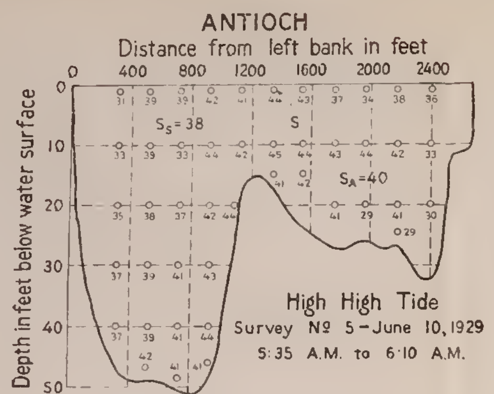
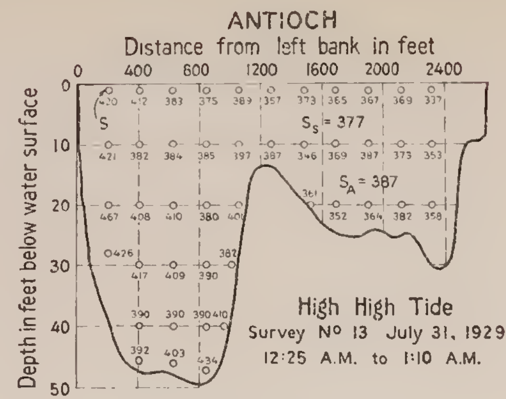
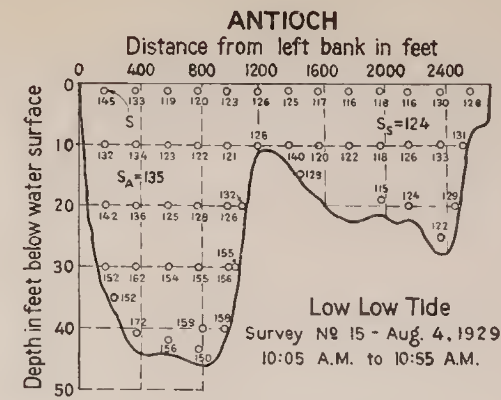
Antioch-233



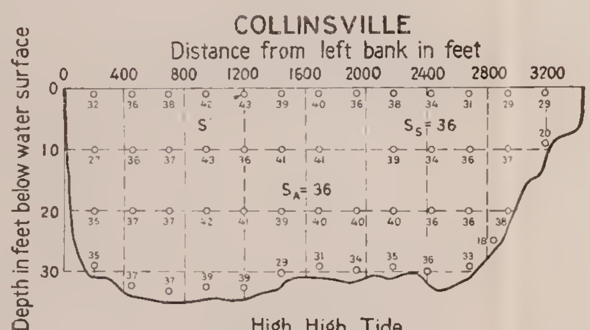
S_S in per cent of S = 88
S_A in per cent of S = 90
S_A in per cent of S_S = 103



S_S in per cent of S = 90
S_A in per cent of S = 92
S_A in per cent of S_S = 103

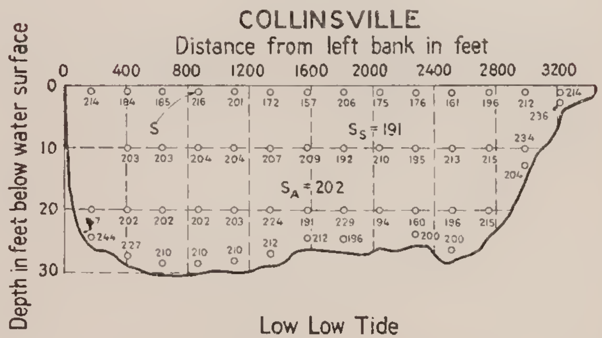


S_S in per cent of S = 86
S_A in per cent of S = 93
S_A in per cent of S_S = 108



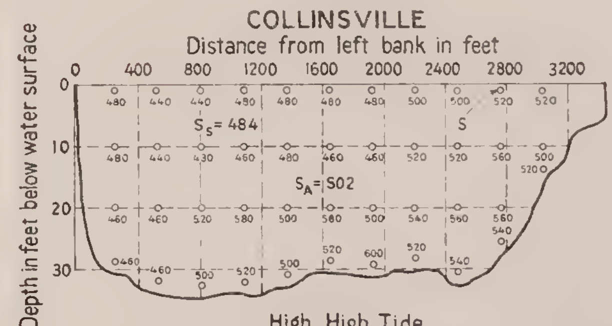
High High Tide
Survey Nº 5 – June 10, 1929
3:40 A.M. to 4:40 A.M.

S_S in per cent of S = 84
S_A in per cent of S = 84
S_A in per cent of S_S = 101



Low Low Tide
Survey Nº 14 Aug. 4, 1929
8:15 A.M. to 9:05 A.M.

S_S in per cent of S = 89
S_A in per cent of S = 94
S_A in per cent of S_S = 106



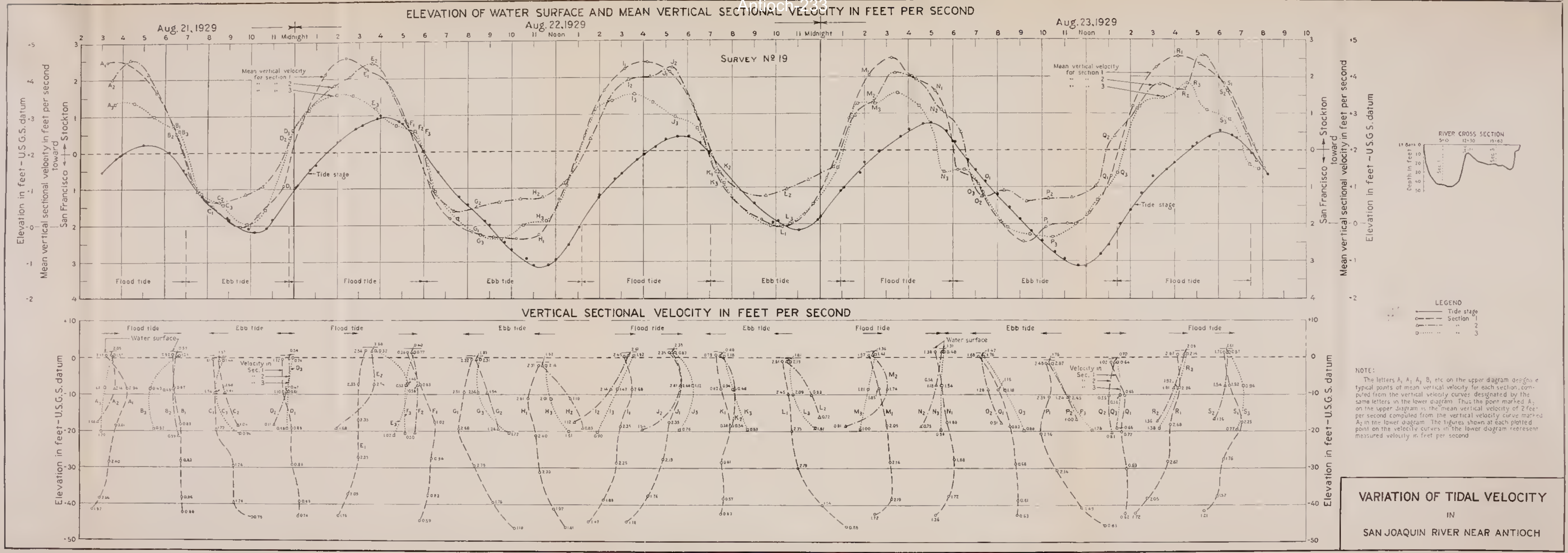
High High Tide
Survey Nº 15 – Aug. 13, 1929
10:20 P.M. to 11:25 P.M.

S_S in per cent of S = 93
S_A in per cent of S = 97
S_A in per cent of S_S = 104

LEGEND
S_A = Mean sectional salinity
S_S = Mean surface zone salinity
S = Maximum surface zone salinity

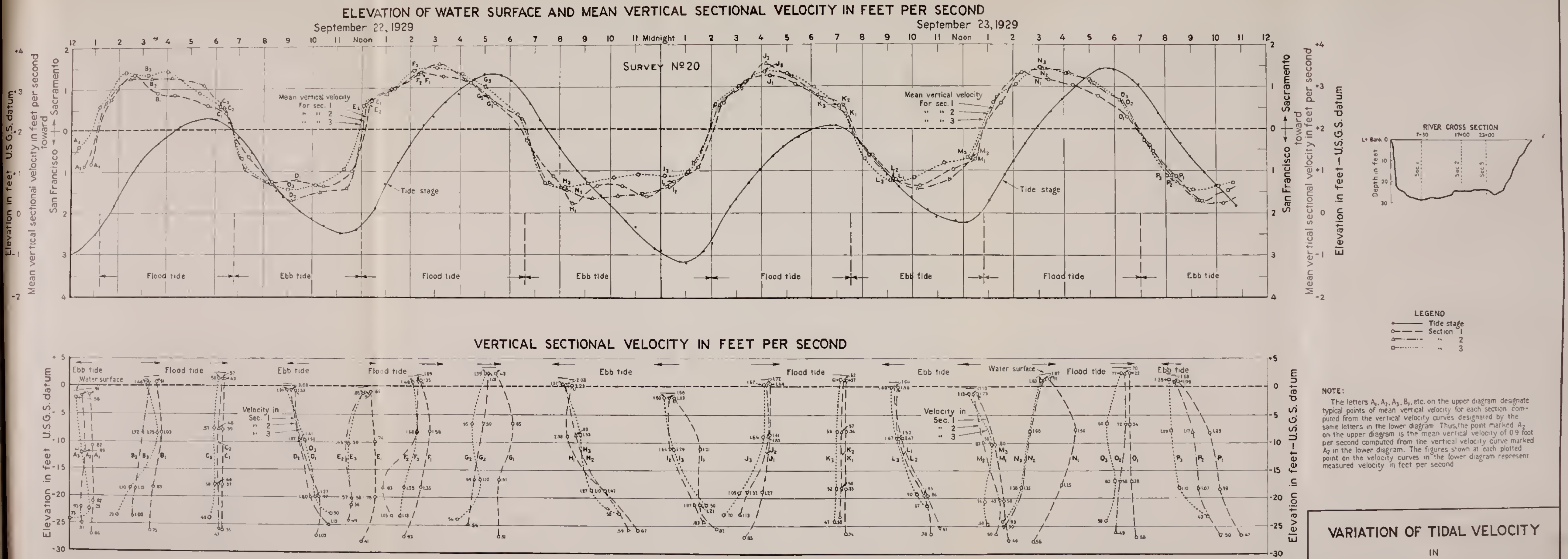
NOTE
Figures in diagram show salinity in parts of chlorine per 100,000 parts of water

LATERAL VARIATION OF SALINITY



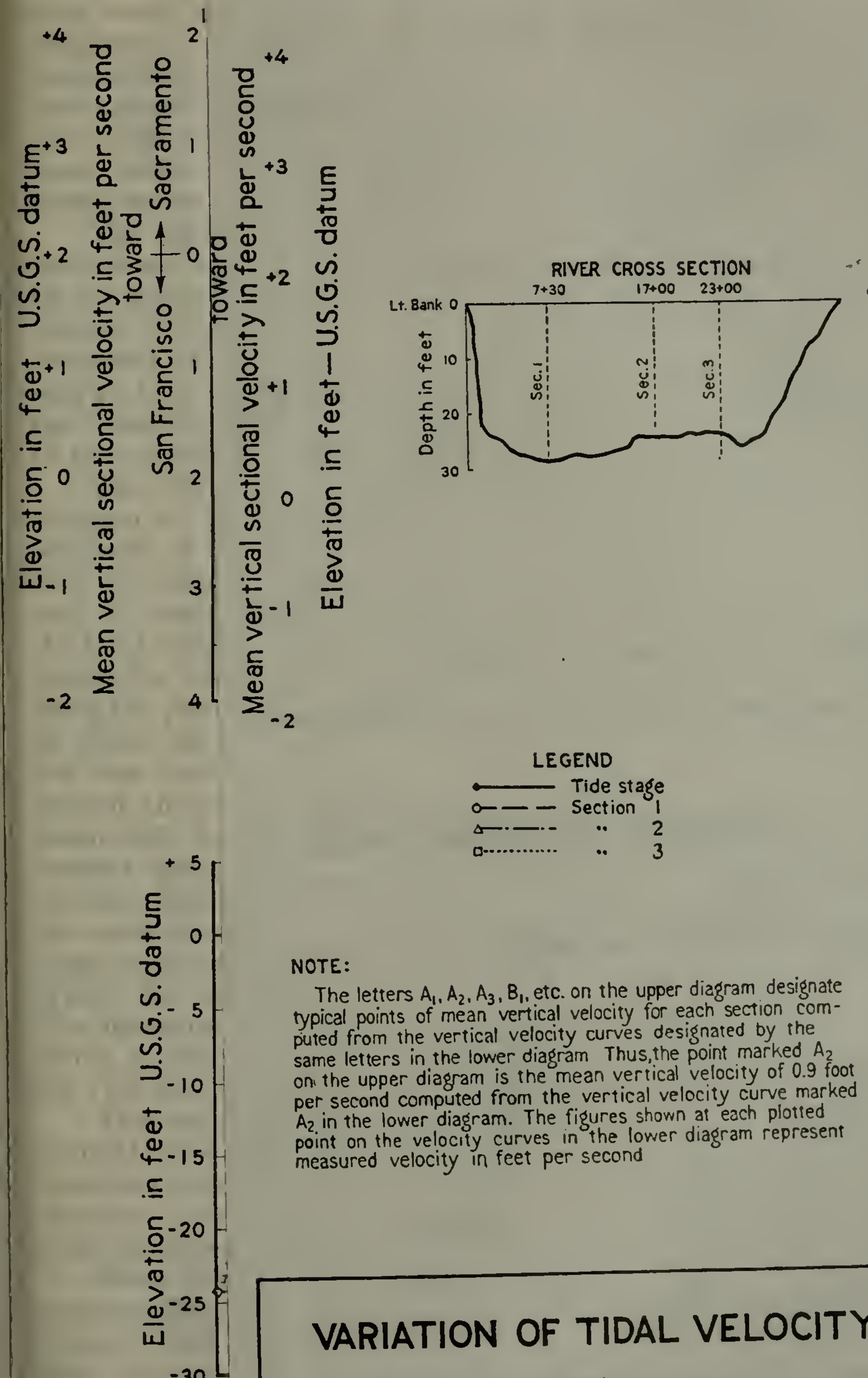
VARIATION OF TIDAL VELOCITY IN SAN JOAQUIN RIVER NEAR ANTIOCH

Antioch-233



NOTE:
The letters A_1, A_2, A_3, B_1, etc. on the upper diagram designate typical points of mean vertical velocity for each section computed from the vertical velocity curves designated by the same letters in the lower diagram. Thus, the point marked A_2 on the upper diagram is the mean vertical velocity of 0.9 foot per second computed from the vertical velocity curve marked A_2 in the lower diagram. The figures shown at each plotted point on the velocity curves in the lower diagram represent measured velocity in feet per second.

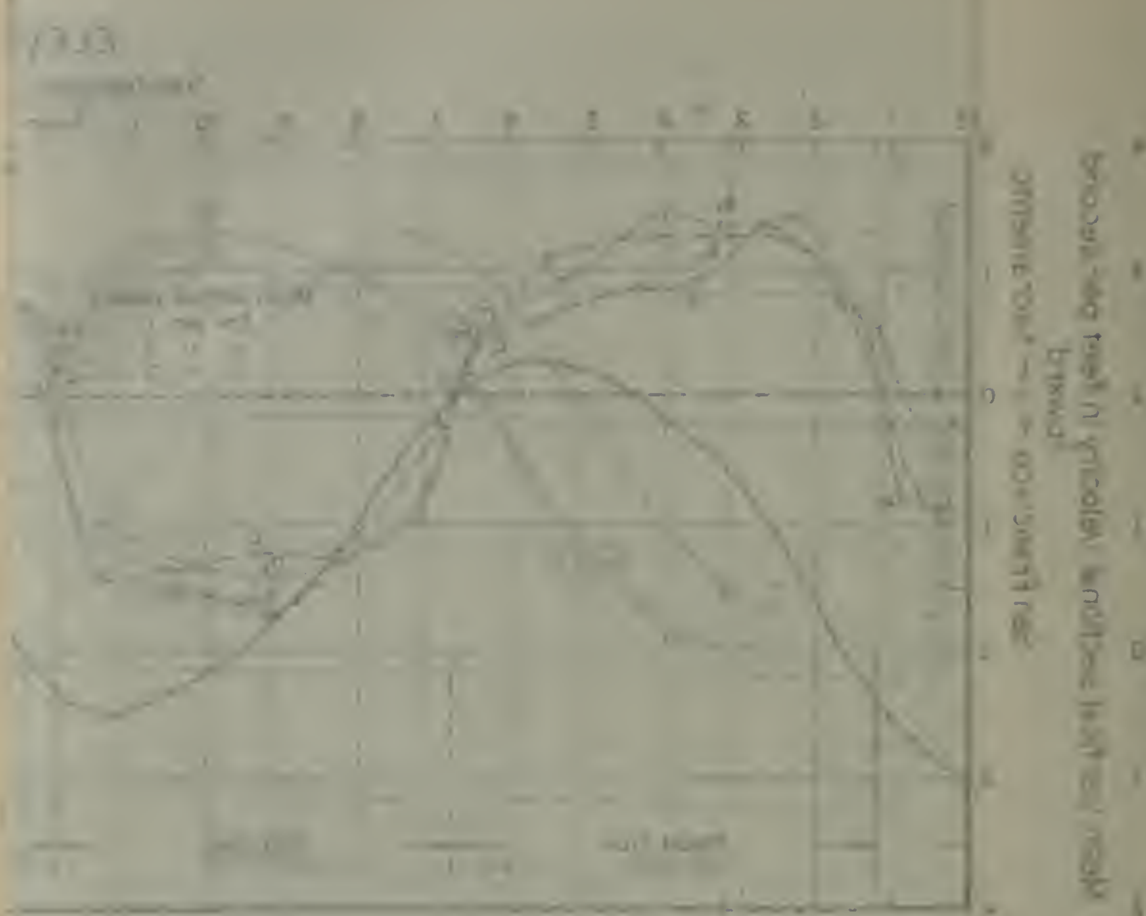
VARIATION OF TIDAL VELOCITY IN SACRAMENTO RIVER NEAR COLLINSVILLE

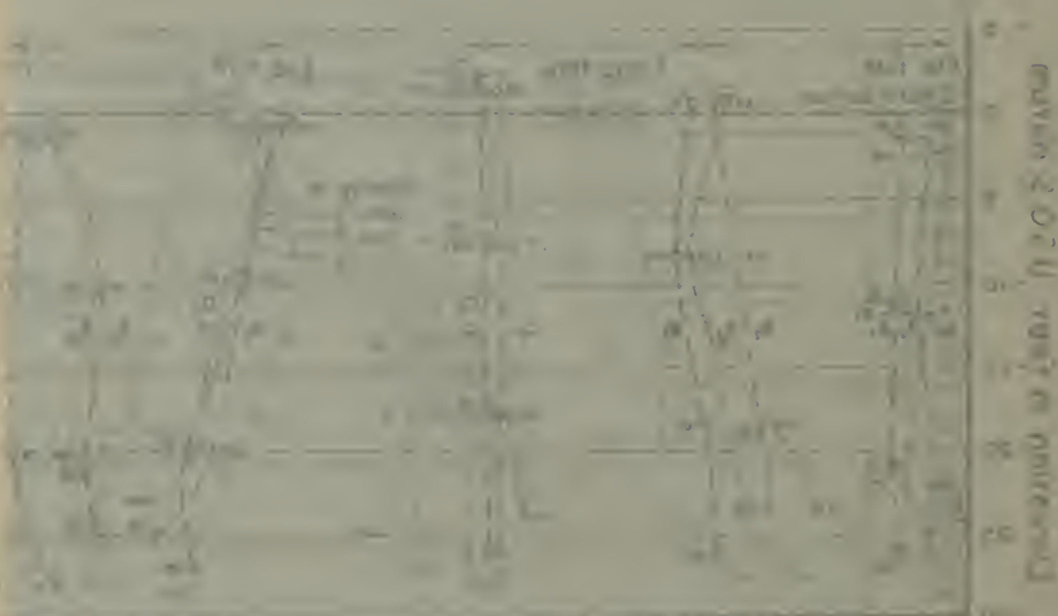


NOTE:
The letters A_1, A_2, A_3, B_1, etc. on the upper diagram designate typical points of mean vertical velocity for each section computed from the vertical velocity curves designated by the same letters in the lower diagram. Thus, the point marked A_2 on the upper diagram is the mean vertical velocity of 0.9 foot per second computed from the vertical velocity curve marked A_2 in the lower diagram. The figures shown at each plotted point on the velocity curves in the lower diagram represent measured velocity in feet per second

VARIATION OF TIDAL VELOCITY IN SACRAMENTO RIVER NEAR COLLINSVILLE

Antioch-233





Velocity in San Joaquin River near Antioch,'' and Plate LXVI, ''Variation of Tidal Velocity in Sacramento River near Collinsville.'' The small diagram on the right hand side of these plates shows, for each river cross-section, the position of the current meter stations designated as sections 1, 2 and 3. At these stations, current meter measurements of velocity were made at hourly intervals and at depth intervals of five to ten feet from surface to bottom throughout one or more tidal cycle periods. Coincident with the current meter observations, water samples were taken at the identical points of velocity measurement and analyzed for salinity.

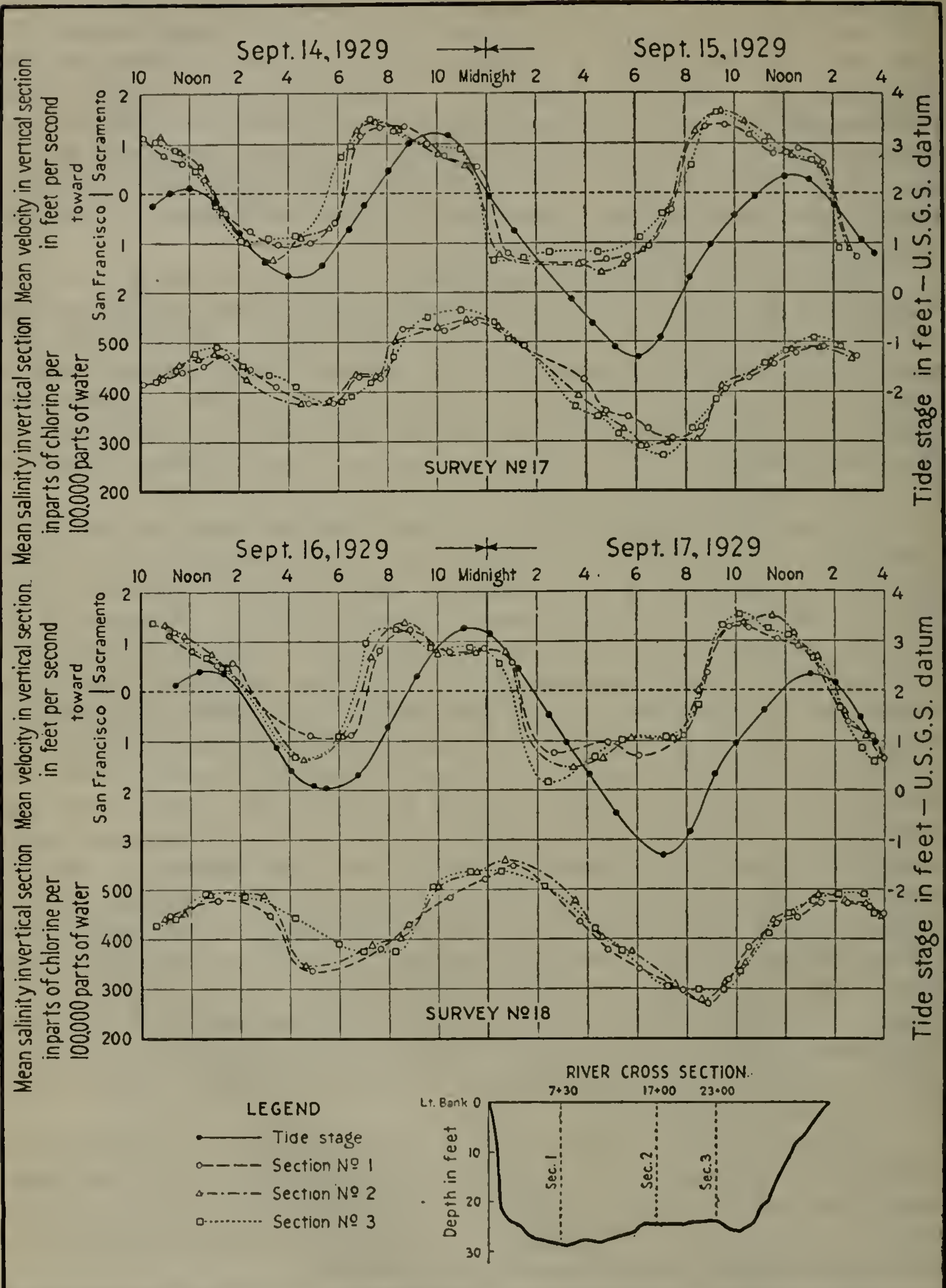
The variation of tidal velocity with the rise and fall of the tide throughout a tidal cycle is shown graphically for two typical surveys by the upper diagrams on Plates LXV and LXVI. These curves are plotted for each station, using the mean velocity in the vertical section computed from each measurement. The record of tidal stage at the nearby tide gage station is also plotted on these upper graphs. In the lower diagrams, the variation of velocity from surface to bottom in the vertical section is shown by typical velocity curves.

The relation of tidal velocity to tidal stage, as shown by the upper diagram of Plates LXV and LXVI, is of importance as it is characteristic of the tidal movement in the upper bay and delta channels. For the survey on the San Joaquin River section on August 21, 22 and 23, starting at about 3 p.m. on August 21 during a flood tide, the tidal current was upstream towards Stockton, reaching a maximum velocity a little before low-high tide and then gradually diminishing until the point of no velocity or slack water was reached about 7 p.m. or about one and one-half to two hours following low-high tide. As the tide continued to fall in ebb, a tidal current downstream was started, the velocity of which gradually increased, reaching a maximum magnitude immediately before high-low tide. The velocity of this ebb current gradually decreased from the maximum, reaching a zero velocity about midnight or from one and one-half to two hours after the occurrence of high-low tide. Similar variations as related to tidal stage continued to occur throughout the period of measurement, which typify the usual interrelations of tidal fluctuations and currents. The measurements show that the mean velocity at all three current meter stations in each cross-section varied in a parallel manner with the rise and fall of the tide.

The variation of velocity in the vertical section as shown by the vertical velocity curves in the lower diagrams is similar to the usual variation found in open channels. For the most part, the maximum velocities occur near the surface or at shallow depths, and there is a gradual decrease to a minimum near the bottom.

Plate LXVII, ''Variation of Salinity and Tidal Velocity in Sacramento River near Collinsville,'' and Plate LXVIII, ''Variation of Salinity and Tidal Velocity in San Joaquin River near Antioch,'' show for typical surveys the relation of mean velocity and mean salinity in the vertical section, and tidal stage throughout a tidal cycle. The curves on those plates demonstrate again that maximum and minimum salinities are usually reached at the time of slack water about one to two hours after the occurrence of the high and low tidal stages. It is also interesting to note that both mean salinity and mean tidal

PLATE LXVII

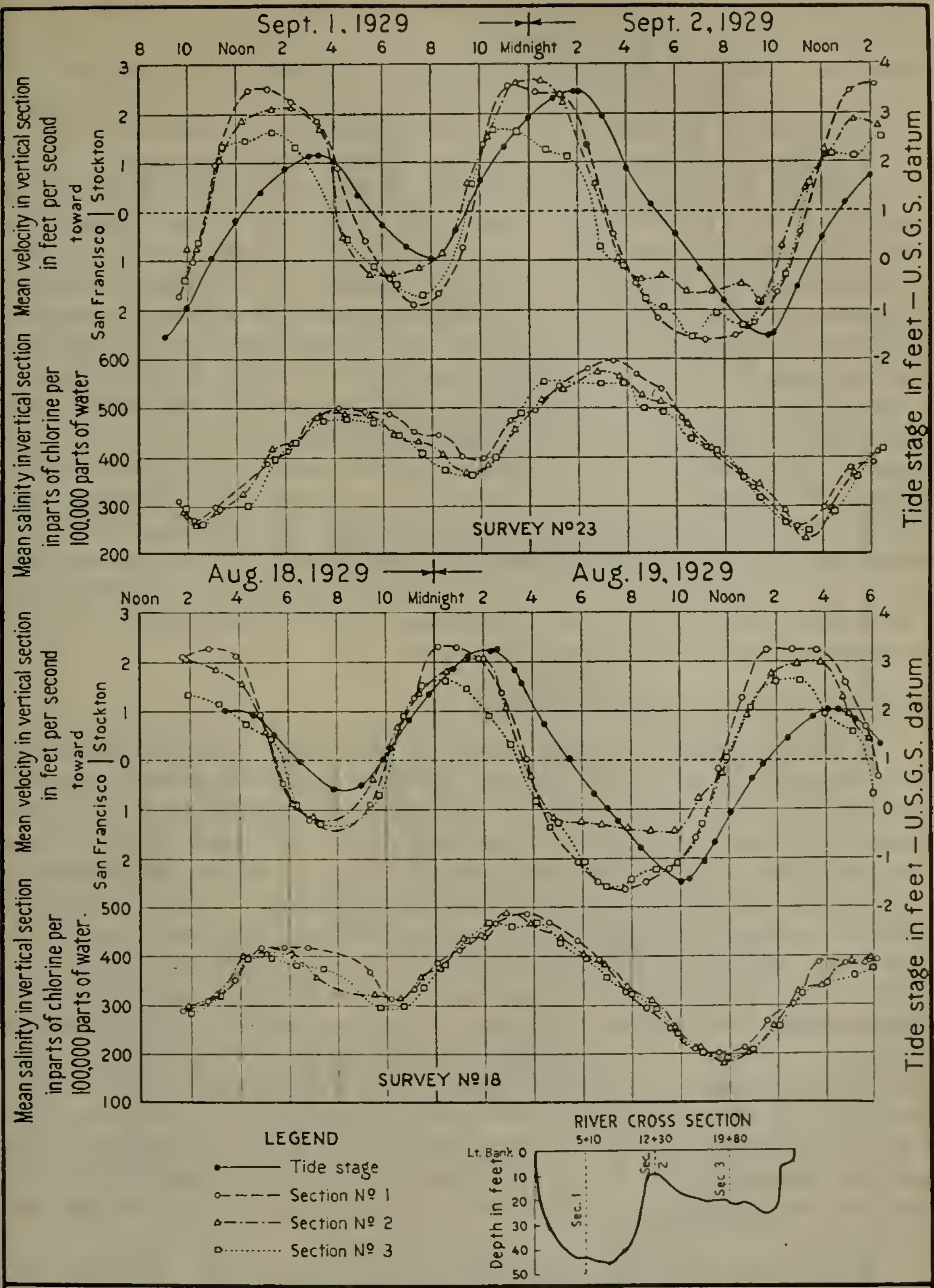


VARIATION OF SALINITY AND TIDAL VELOCITY

IN

SACRAMENTO RIVER NEAR COLLINSVILLE

PLATE LXVIII



VARIATION OF SALINITY AND TIDAL VELOCITY

IN

SAN JOAQUIN RIVER NEAR ANTIOCH

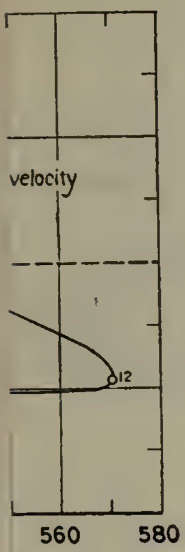
velocity at the three different stations in the two river cross sections vary quite uniformly, with only slight differences in the amounts at any particular time. It is evident that, for all practical purposes, the variation of salinity throughout a large river channel is a uniform one and, hence, observations at one point or at one section in a channel may be considered in general to be representative of an entire channel.

The relation between salinity and tidal velocity perhaps is shown more clearly by the graphs presented on Plate LXIX, "Variation of Salinity and Tidal Velocity with Depth." On these graphs the observed salinity has been plotted directly against simultaneous measurements of velocity at identical points. The upper and lower diagrams present data from typical measurements on the Sacramento and San Joaquin rivers respectively. The data have been plotted for observations at various depths at ten-foot intervals from surface to bottom at one station in each of the sections used on the Sacramento and San Joaquin rivers. The variations indicated are similar for each depth. The relation of mean salinity and mean velocity in the vertical section is shown for each station by the heavy solid line on each graph. As shown by these mean relations, the maximum and minimum salinities during a tidal cycle occur approximately at the time of slack water or when there is no current either upstream or downstream. The curves indicate the cyclic character of the variation of both tidal velocity and salinity during a tidal cycle.

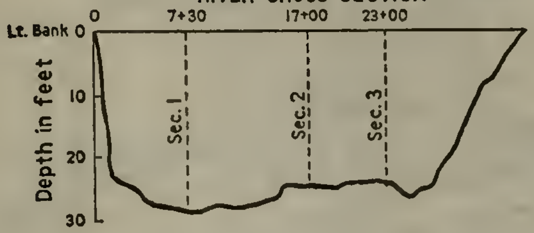
Variation of Salinity with Tidal Flow.

From the above demonstrations of the direct relation that exists between salinity and tidal velocity, and the inter-relations of these to the rise and fall of the tide, it is evident that tidal flow is a basic factor affecting the variation of salinity. It is a factor entirely independent from stream flow and has an effect of equal importance to stream flow on the advance and retreat of salinity. As the tides rise and fall in flood and ebb, tidal flows of varying magnitude occur, the pulsating action of which cause a mixing and diffusion of the more saline waters from points downstream with the fresher waters upstream. This action of the tides exerts at all times a positive and continuing tendency to push the more saline waters from downstream to points farther upstream in the tidal basin. Opposed to this action, stream flow into the basin is at all times exerting a tendency to push the saline waters to points farther downstream in the tidal basin. It is the relative magnitude of these two opposite and opposing forces which governs the advance or retreat of salinity at any point in the tidal basin.

The effect of tidal action and tidal flow on the variation and advance and retreat of salinity is well illustrated by the data presented on Plate LXX, "Variation of Salinity with Tidal Action and Stream Flow at Antioch, 1929." On this plate, the record of salinity at Antioch is graphically shown for the period July to December, 1929, while in parallel diagrams are shown detailed data covering all of the basic factors affecting the variation of salinity at this point. These basic factors include stream flow into the delta, consumption of water in the delta above Antioch and tidal flow at Antioch. The record of high and low stages of the tide at Antioch is also shown. The upper-



SACRAMENTO
RIVER CROSS SECTION

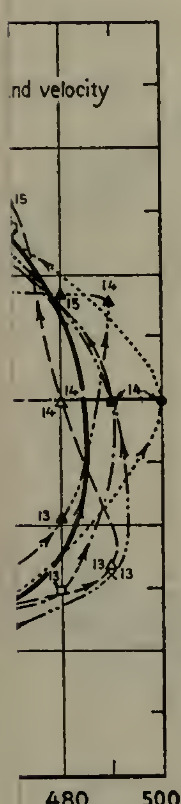


NOTE:
Number 1 indicates beginning of survey
" 21 " end " "

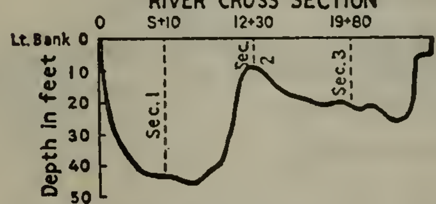
LEGEND

- Mean salinity and velocity
- Salinity and velocity at depth of 1 foot
- " " " " " " 10 feet
- " " " " " " 20 "
- " " " " 2 feet from bottom

Salinities and velocity as measured in section 1 of Sacramento River cross section.



SAN JOAQUIN
RIVER CROSS SECTION



NOTE:
Number 1 indicates beginning of survey
" 25 " end " "

LEGEND

- Mean salinity and velocity
- Salinity and velocity at depth of 1 foot
- " " " " " " 10 feet
- " " " " " " 20 "
- " " " " " " 30 "
- " " " " " " 40 "
- " " " " 2 feet from bottom

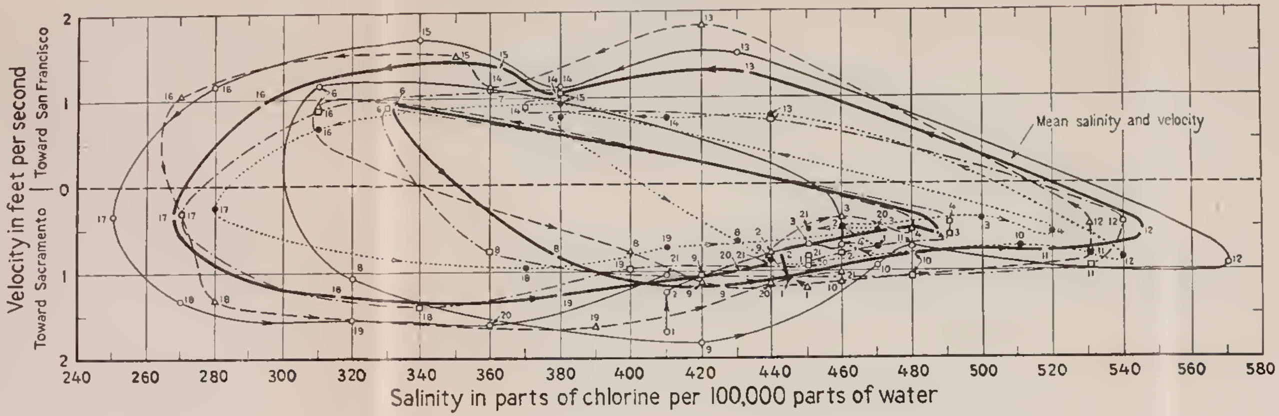
Salinities and velocity as measured in section 1 of San Joaquin River cross section.

VARIATION OF

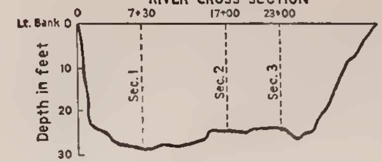
SALINITY AND TIDAL VELOCITY WITH DEPTH

SACRAMENTO RIVER NEAR COLLINSVILLE

SECTION Nº 1 SURVEY Nº 18 SEPT. 16-17, 1929



SACRAMENTO RIVER CROSS SECTION



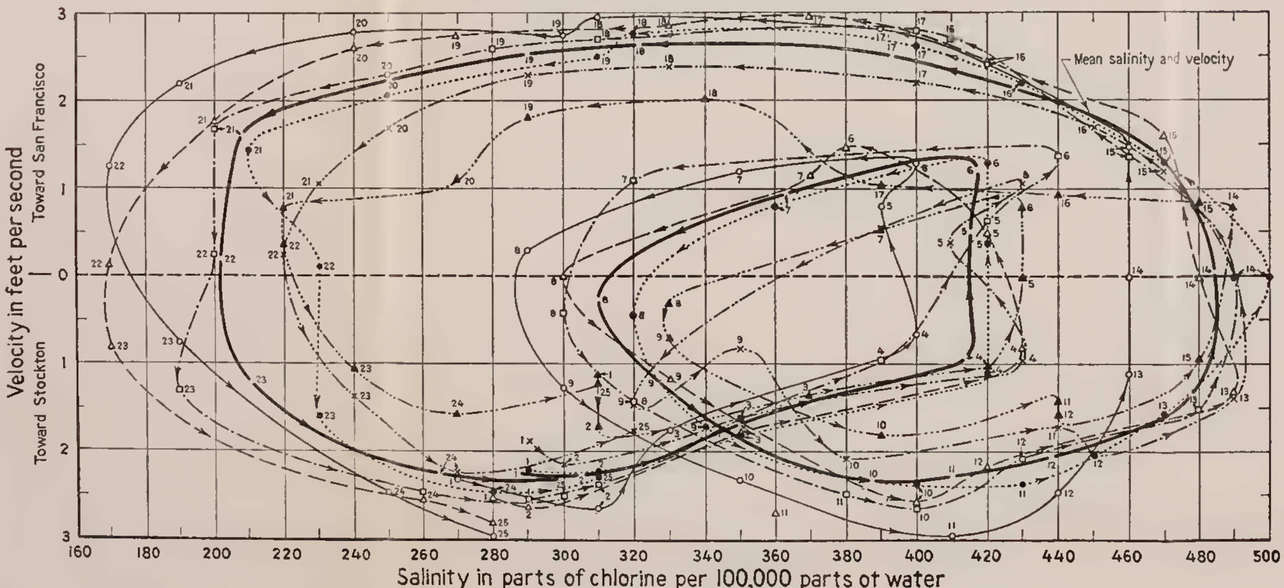
NOTE:
Number 1 indicates beginning of survey
" 21 " end " "

LEGEND
- Mean salinity and velocity
- Salinity and velocity at depth of 1 foot
- " " " " " " 10 feet
- " " " " " " 20 "
- " " " " 2 feet from bottom

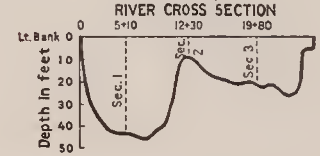
Salinities and velocity as measured in section 1 of Sacramento River cross section.

SAN JOAQUIN RIVER NEAR ANTIOCH

SECTION Nº 1 SURVEY Nº 18 AUG. 18-19, 1929



SAN JOAQUIN RIVER CROSS SECTION

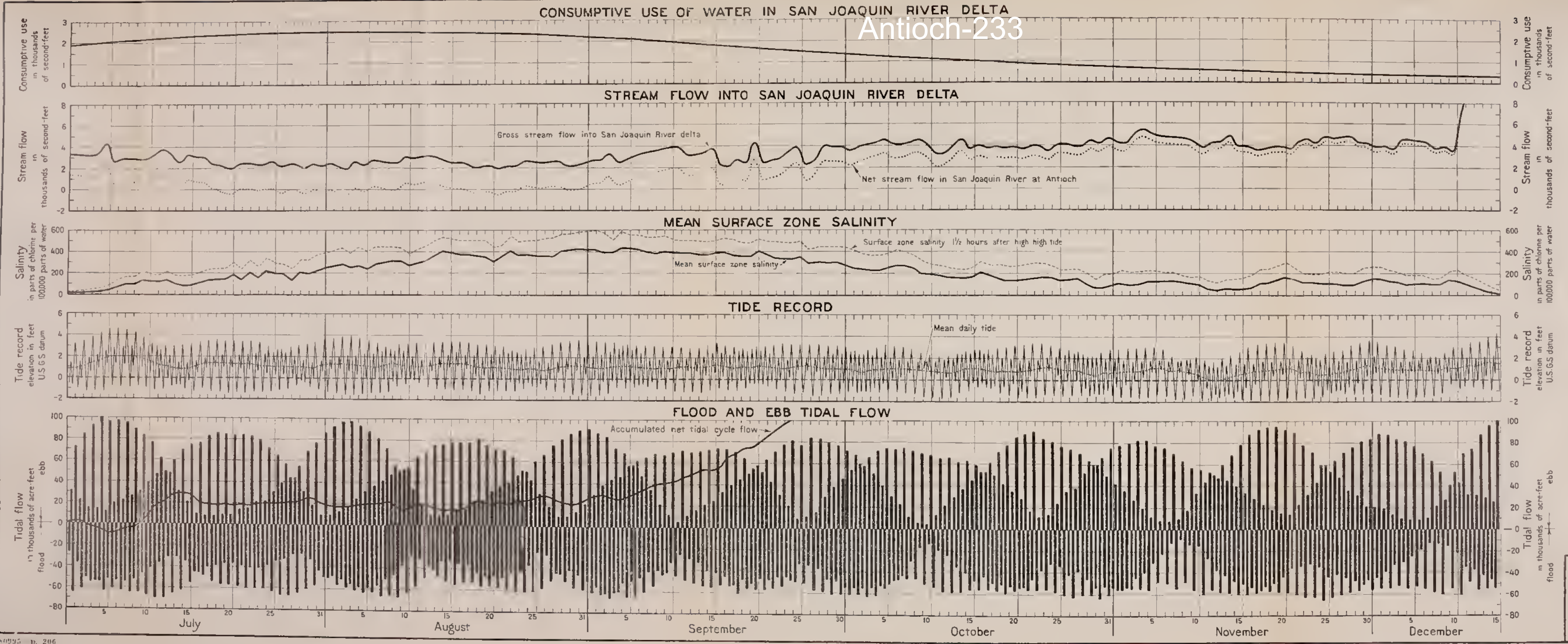


NOTE:
Number 1 indicates beginning of survey
" 25 " end " "

LEGEND
- Mean salinity and velocity
- Salinity and velocity at depth of 1 foot
- " " " " " " 10 feet
- " " " " " " 20 "
- " " " " " " 30 "
- " " " " " " 40 "
- " " " " 2 feet from bottom

Salinities and velocity as measured in section 1 of San Joaquin River cross section.

VARIATION OF SALINITY AND TIDAL VELOCITY WITH DEPTH



VARIATION OF SALINITY WITH TIDAL ACTION AND STREAM FLOW AT ANTIOCH 1929

most diagram shows the variation of estimated consumptive use of water in the San Joaquin Delta above Antioch. The next diagram below shows the stream flow into the San Joaquin Delta, including inflow of the San Joaquin River and its main tributaries and also the flow from the Sacramento River into the San Joaquin Delta. The light dotted line on this same diagram shows the estimated net stream flow in the San Joaquin River at Antioch, which represents the difference between the gross flow into the San Joaquin Delta and the consumption in the San Joaquin Delta above Antioch. The third diagram from the top shows the variation of salinity at Antioch, the light dashed line showing the actual observed salinities from samples taken in the surface zone usually after high-high tide and the heavy solid line the estimated mean tidal cycle surface zone salinities corresponding thereto. The lower diagram on the plate shows the computed tidal flow into and out of the San Joaquin Delta tidal basin past Antioch. The tidal flow was computed on the basis of the formulae previously presented. There is also shown on this diagram the accumulated net tidal cycle flow from the beginning of July to the latter part of September, which represents the successive accumulations of the net algebraic sums of the two flood and two ebb flows for each tidal cycle. It will be noted that the magnitude of flood and ebb tidal flows is directly related to the magnitude of tidal range as shown by the tide record in the diagram immediately above, and varies between maximum and minimum values reached at intervals of about fourteen to fifteen days.

The data show that the variation of salinity at Antioch during this period is due to the combined effect and relative magnitude of the net stream flow and the flood and ebb tidal flows passing Antioch. On July 1, the salinity at Antioch was about 25 parts with a net stream flow past Antioch of about 1500 second-feet. By July 20 the net stream flow had dropped to practically a zero quantity, remaining so until about the end of August. The net tidal cycle flow, which is approximately equal to net stream flow, was also practically zero during this period. From July 20 to the end of August, the mean salinity at Antioch increased to over 400 parts of chlorine per 100,000 parts of water. Inasmuch as there was practically no change in the net stream flow and the net tidal cycle flow during this period, it is evident that the increase of salinity must have been due to the pulsating flow of the tide. It will be noted that the rate of increase in salinity varied with the magnitude of tidal flow. Thus, from July 1 to July 10, the salinity rapidly increased from about 25 to over 100 parts in parallel with the rapidly increasing magnitude of tidal flow during this period. From July 10 to about July 15 or 16, the salinity remained about the same or, if anything, decreased, corresponding to a simultaneous decrease in magnitude of tidal flow. There then followed another period of greater rate of increase in salinity coincident with an increasing magnitude of tidal flow, with the salinity reaching 200 parts about July 25. Similarly the record of increase in salinity at Antioch may be seen to be in sympathy with the varying magnitude of ebb and flood tidal flows passing Antioch. After the maximum salinity was reached about September 1 to 5, the decrease and retreat of salinity was exceedingly slow during the next 15 days, even though the net stream flow past Antioch gradually increased to about 2000 second-feet during this period. After September 20, the record of salinity shows a definite trend downward with a gradually increasing stream flow. However, the effect of pulsating tidal flow in definitely retarding the decrease of salinity or even temporarily increasing the salinity at about 14 day intervals when the tidal flow was at a maximum. is evident during this retreat period. Although the net stream flow past Antioch had reached about 4000 second-feet about November 1 and continued at about this rate until December 10, salinity averaging about 100 parts continued to remain at Antioch until a large increase in stream flow starting about December 10 carried the saline water out of the delta entirely. If salinity in any degree is once present at any point in the tidal basin, these data indicate that a larger amount of stream flow is required to effect a decrease in salinity than would be required to prevent salinity of the same degree from increasing at the same point. This will be more fully referred to in a later portion of the report.

It is not a necessary part of the conditions giving rise to saline invasion and increasing salinity at any point in the tidal basin that the net stream flow should drop to zero as it did at Antioch in 1929. In a year like 1927, the records indicate that there was at all times a net flow downstream at the confluence of the Sacramento and San Joaquin rivers. Nevertheless, salinity increased at Collinsville and Antioch and advanced into the lower delta in that year. Thus, if the net stream flow is not sufficient to counteract the force exerted by the pulsating tidal flows tending to push saline water upstream, saline invasion will occur. However, if net stream flow is zero or is actually negative in quantity, it is evident that the effect of tidal action without any repelling force of stream flow would be increased. It is under conditions of negative net stream flow at the lower end of the delta that the more abnormal invasions of salinity such as in 1924 have occurred.

The study demonstrates that tidal flow has a direct effect upon the variation of salinity and that tidal action is a basic factor of equal importance to stream flow governing the rate and extent of advance and retreat of salinity. The positive and continuing effect of tidal action, tending always toward pushing saline water upstream, will always result in an increase and advance of salinity unless the stream flow is of sufficient magnitude to counteract the forces exerted by the pulsating tidal flows.

Tidal Diffusion.

The magnitude of advance or retreat of salinity during a particular time interval is measured by the volume of water in the channel or channels through which salinity of a particular degree has traveled. This total amount of advance or retreat is due to the combined effect of tidal action and net stream flow in the particular channel section. The effect of tidal action on the advance or retreat of salinity during a particular time interval is represented by the difference between the total volume of channel through which advance or retreat takes place and the total volume of net stream flow passing the section during the same period of time. It is the result of the pulsating tidal flows, accompanied always by the positive and continuing tendency to mix the generally more saline waters from downstream with the fresher waters upstream. This effect of tidal action has been designated as "Tidal Diffusion."

The magnitude of tidal diffusion in any channel section of the tidal basin varies with the magnitude of tidal flow passing the particular section. The effect of tidal diffusion in any time interval on the magnitude of advance or retreat of salinity in any channel section depends upon the volume of channel through which diffusion takes place, and upon the amount of net stream flow tending to oppose the same. Tidal diffusion is always directed upstream during both advance and retreat of salinity. However, the net stream flow may be either upstream or downstream at any particular section in the tidal basin, depending at a particular time on the relative magnitude of stream flow into the basin and of water extractions from the basin above the section. The theory evolved for the relation between the magnitude of advance or retreat of salinity and the basic factors of tidal diffusion and net stream flow governing the same, is expressed by the following formulae:

Let C = the total amount of advance or retreat of salinity in a particular channel section, expressed as the volume of channel through which salinity of a particular degree advances or retreats during a particular time interval.

D = tidal diffusion, or the effect of tidal action on the total amount of advance or retreat of salinity (expressed in terms of channel volume) during the same time interval.

S = the net stream flow passing the particular channel section during the same time interval.

Then,

$$C = D \pm S \qquad (1)$$

And

$$D = C \mp S \qquad (2)$$

The above relation evolved between advance or retreat of salinity, tidal diffusion and net stream flow is the most important result of this investigation. The fundamental relation expressed by the formula affords an adequate basis for a complete understanding of the phenomena of advance and retreat of salinity. It furnishes the basis for the determination of the amount of stream flow required for control of salinity.

From equation (1), it is evident that, if the net stream flow "S" is downstream and equal in magnitude to tidal diffusion "D," the advance or retreat of salinity "C" will be zero. If, however, the magnitude of tidal diffusion is greater than the net stream flow even though the latter be in a downstream direction, advance of salinity will result therefrom. If tidal diffusion is smaller in magnitude than net stream flow downstream, there will be retreat of salinity. Finally, if the net stream flow is negative or upstream, both stream flow and tidal diffusion are acting in the same direction and hence, for any given degree of salinity, the maximum advance of salinity will occur. It is under this latter combination of conditions which have occurred frequently during the period of low stream flow in the last ten years or more that the greatest degree and extent of saline invasion has occurred in the upper bay and delta channels.

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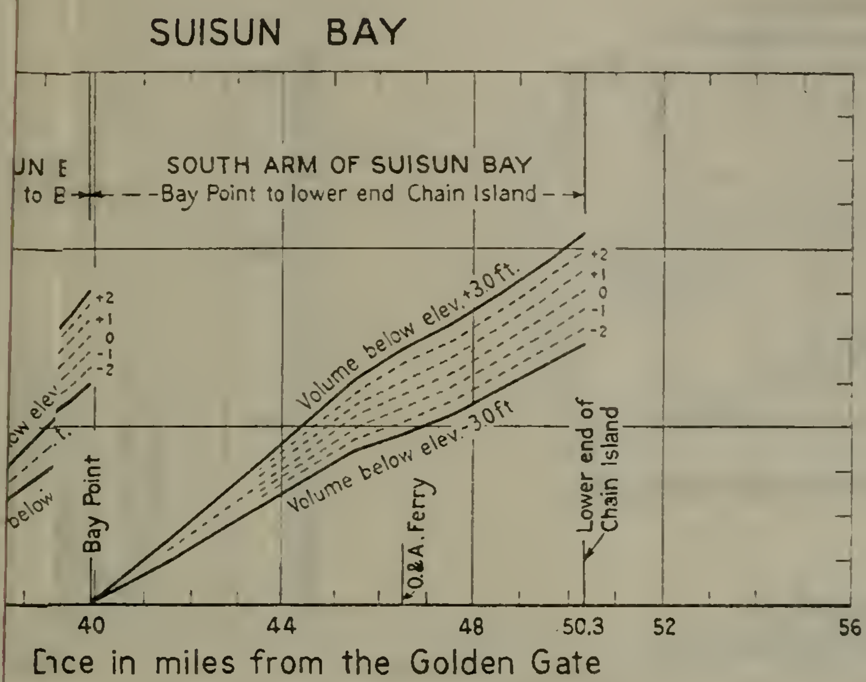
Magnitude of Tidal Diffusion—The magnitude of tidal diffusion has been determined from the relations shown in equation (2) by the use of the available data on stream flow, salinity and channel volumes. The net stream flow at any particular section was computed from the records of stream flow into the delta, reduced by the estimated amount of water consumed above the section. The channel volumes for the sections of channel for which diffusion was computed were compiled from the hydrographic surveys of the United States Army Engineers previously referred to in describing the computations of tidal volumes. These channel volumes are graphically shown on Plate LXXI, "Channel Volumes in Suisun Bay, Sacramento and San Joaquin Rivers." The volumes are accumulated with distance upstream from the lower end of the delta near Collinsville for the two river channels and from Army Point to the mouth of the river for Suisun Bay. Separate graphs are shown for volumes below various levels for each foot of elevation. The records of salinity for the period 1920 to 1929 provided the necessary data for determining the time required for various degrees of salinity to advance or retreat through a particular channel volume. Tidal diffusion has been computed for several sections in the tidal basin from Bulls Head Point as far upstream as Emmaton and Jersey. The channel sections selected comprise the following:

Bulls Head Point to Bay Point, Bay Point to O. and A. ferry, O. and A. ferry to Collinsville, Collinsville to Antioch, Collinsville to Mayberry Slough, Collinsville to Emmaton, Antioch to Curtis Landing, Antioch to Jersey, Mayberry Slough to Emmaton, Emmaton to Three Mile Slough. For the sections above Collinsville, the combined channels of the Sacramento and San Joaquin rivers were used in computing tidal diffusion quantities.

The detailed method used for the computations of tidal diffusion during advance of salinity is described briefly as follows:

For any assumed degree of salinity, the time interval required for salinity of this degree to advance from the lower to the upper end of each of the sections was obtained from the salinity records of the regular observation stations. These salinity records were first reduced to mean tidal cycle surface zone salinity. The values of mean salinity for each year of record were then plotted on an appropriate scale and smooth curves drawn to average the points. These graphs of mean salinity for the various key stations are shown on Plates LXXII and LXXIII, "Estimated Mean Surface Zone Salinity." Time intervals for various degrees of salinity to advance from the lower to the upper end of each section were taken from these curves. Having determined the period of time for the advance of a particular degree of salinity, the net stream flow passing the section during the same period of time was then computed in acre-feet as the difference between the total inflow into the basin and the consumption of water above the particular section. The total magnitude of advance was computed as the volume of channel in acre-feet between the two ends of each section. This volume was taken from the curves shown on Plate LXXI, using the mean water level during the period of advance considered. The total tidal diffusion in acre-feet during the particular period of time considered was then computed by equation (2) using the total volume of channel through which the advance occurred and the total net stream flow, due regard being given to the proper algebraic signs of the quan-



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All eons referred to U.S.G.S. datum.

CHANNEL VOLUMES
IN
SUISUN BAY, SACRAMENTO AND
SAN JOAQUIN RIVERS

Magnitude of Tidal Diffusion—The magnitude of tidal diffusion has been determined from the relations shown in equation (2) by the use of the available data on stream flow, salinity and channel volumes. The net stream flow at any particular section was computed from the records of stream flow into the delta, reduced by the estimated amount of water consumed above the section. The channel volumes for the sections of channel for which diffusion was computed were compiled from the hydrographic surveys of the United States Army Engineers previously referred to in describing the computations of tidal volumes. These channel volumes are graphically shown on Plate LXXI, "Channel Volumes in Suisun Bay, Sacramento and San Joaquin Rivers." The volumes are accumulated with distance upstream from the lower end of the delta near Collinsville for the two river channels and from Army Point to the mouth of the river for Suisun Bay. Separate graphs are shown for volumes below various levels for each foot of elevation. The records of salinity for the period 1920 to 1929 provided the necessary data for determining the time required for various degrees of salinity to advance or retreat through a particular channel volume. Tidal diffusion has been computed for several sections in the tidal basin from Bulls Head Point as far upstream as Emmaton and Jersey. The channel sections selected comprise the following:

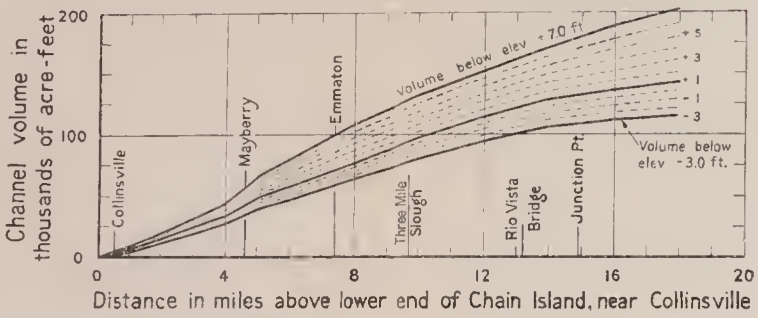
Bulls Head Point to Bay Point, Bay Point to O. and A. ferry, O. and A. ferry to Collinsville, Collinsville to Antioch, Collinsville to Mayberry Slough, Collinsville to Emmaton, Antioch to Curtis Landing, Antioch to Jersey, Mayberry Slough to Emmaton, Emmaton to Three Mile Slough. For the sections above Collinsville, the combined channels of the Sacramento and San Joaquin rivers were used in computing tidal diffusion quantities.

The detailed method used for the computations of tidal diffusion during advance of salinity is described briefly as follows:

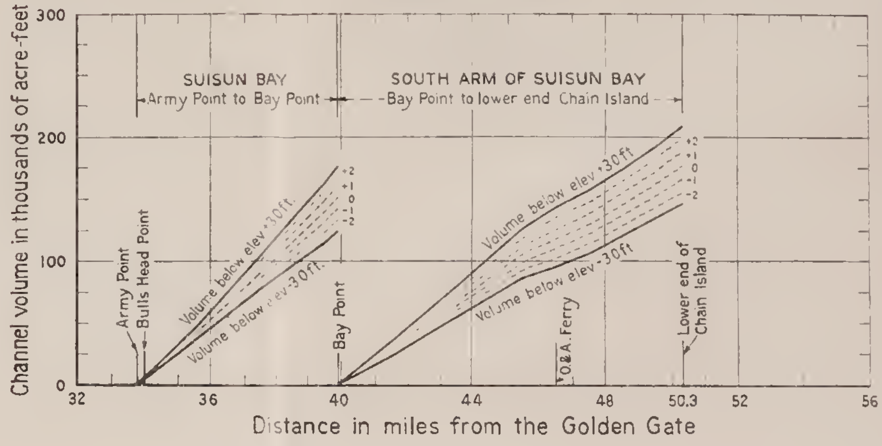
For any assumed degree of salinity, the time interval required for salinity of this degree to advance from the lower to the upper end of each of the sections was obtained from the salinity records of the regular observation stations. These salinity records were first reduced to mean tidal cycle surface zone salinity. The values of mean salinity for each year of record were then plotted on an appropriate scale and smooth curves drawn to average the points. These graphs of mean salinity for the various key stations are shown on Plates LXXII and LXXIII, "Estimated Mean Surface Zone Salinity." Time intervals for various degrees of salinity to advance from the lower to the upper end of each section were taken from these curves. Having determined the period of time for the advance of a particular degree of salinity, the net stream flow passing the section during the same period of time was then computed in acre-feet as the difference between the total inflow into the basin and the consumption of water above the particular section. The total magnitude of advance was computed as the volume of channel in acre-feet between the two ends of each section. This volume was taken from the curves shown on Plate LXXI, using the mean water level during the period of advance considered. The total tidal diffusion in acre-feet during the particular period of time considered was then computed by equation (2) using the total volume of channel through which the advance occurred and the total net stream flow, due regard being given to the proper algebraic signs of the quan-

SACRAMENTO RIVER CHANNELS

ABOVE LOWER END OF CHAIN ISLAND, NEAR COLLINSVILLE

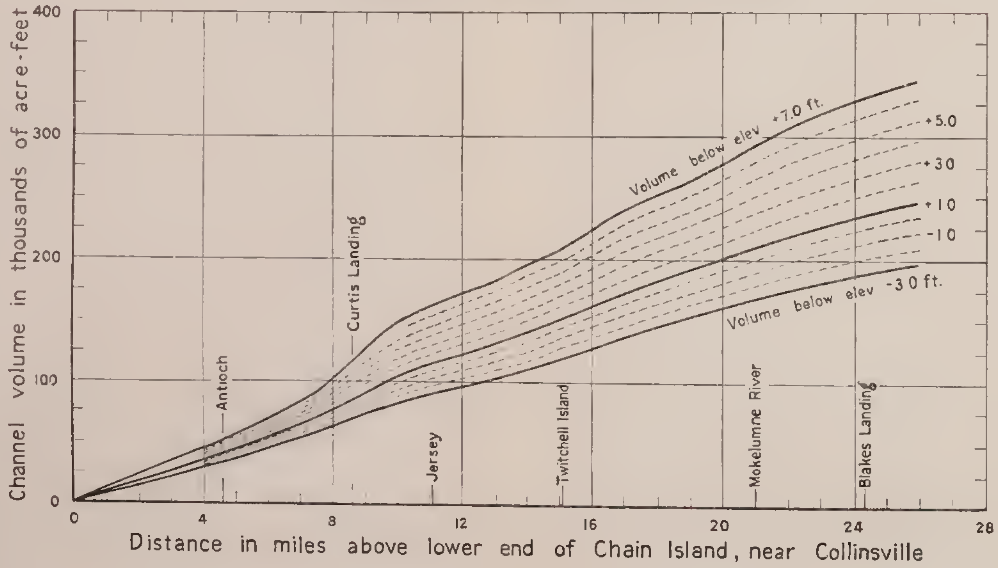


SUISUN BAY



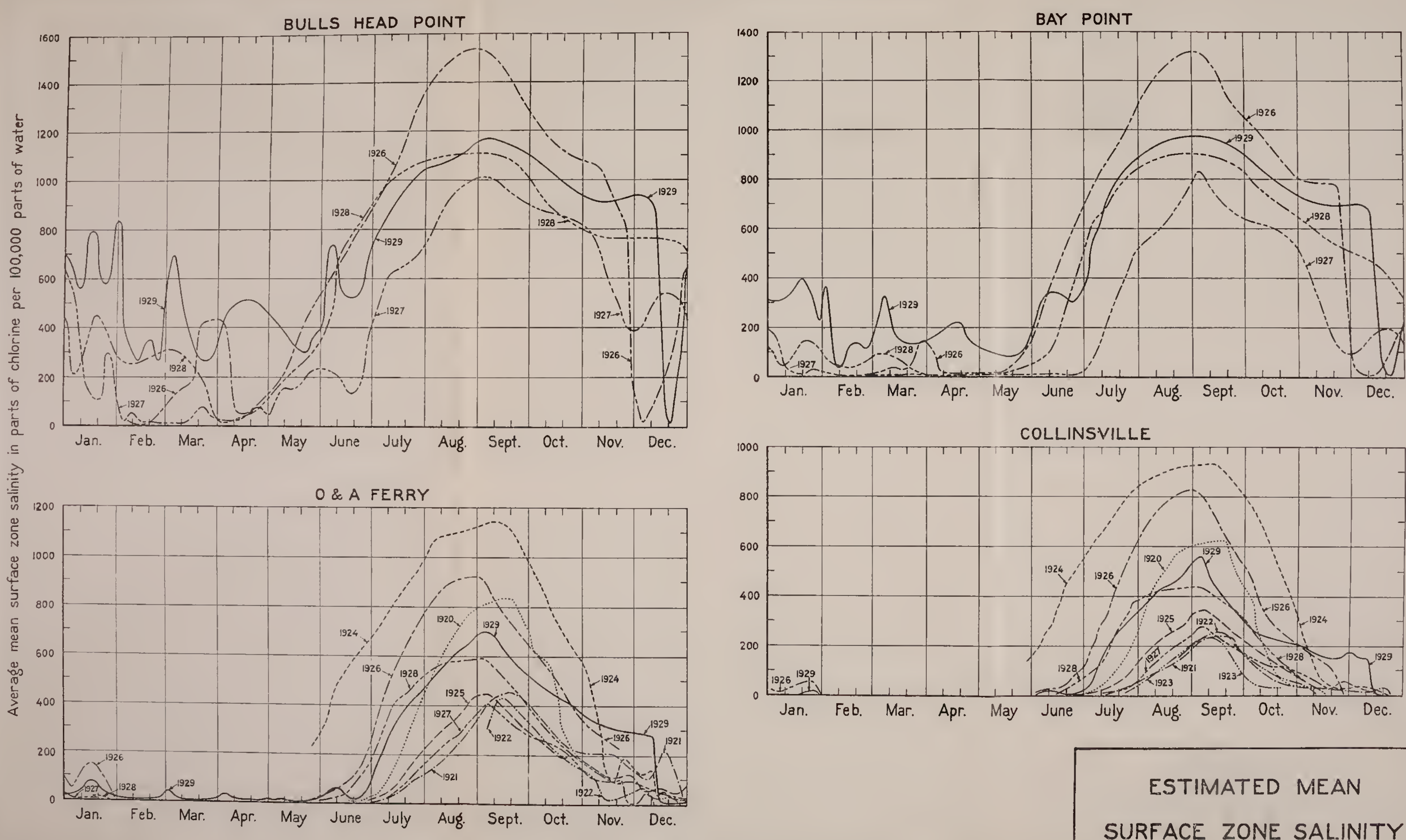
SAN JOAQUIN RIVER CHANNELS

ABOVE LOWER END OF CHAIN ISLAND NEAR COLLINSVILLE

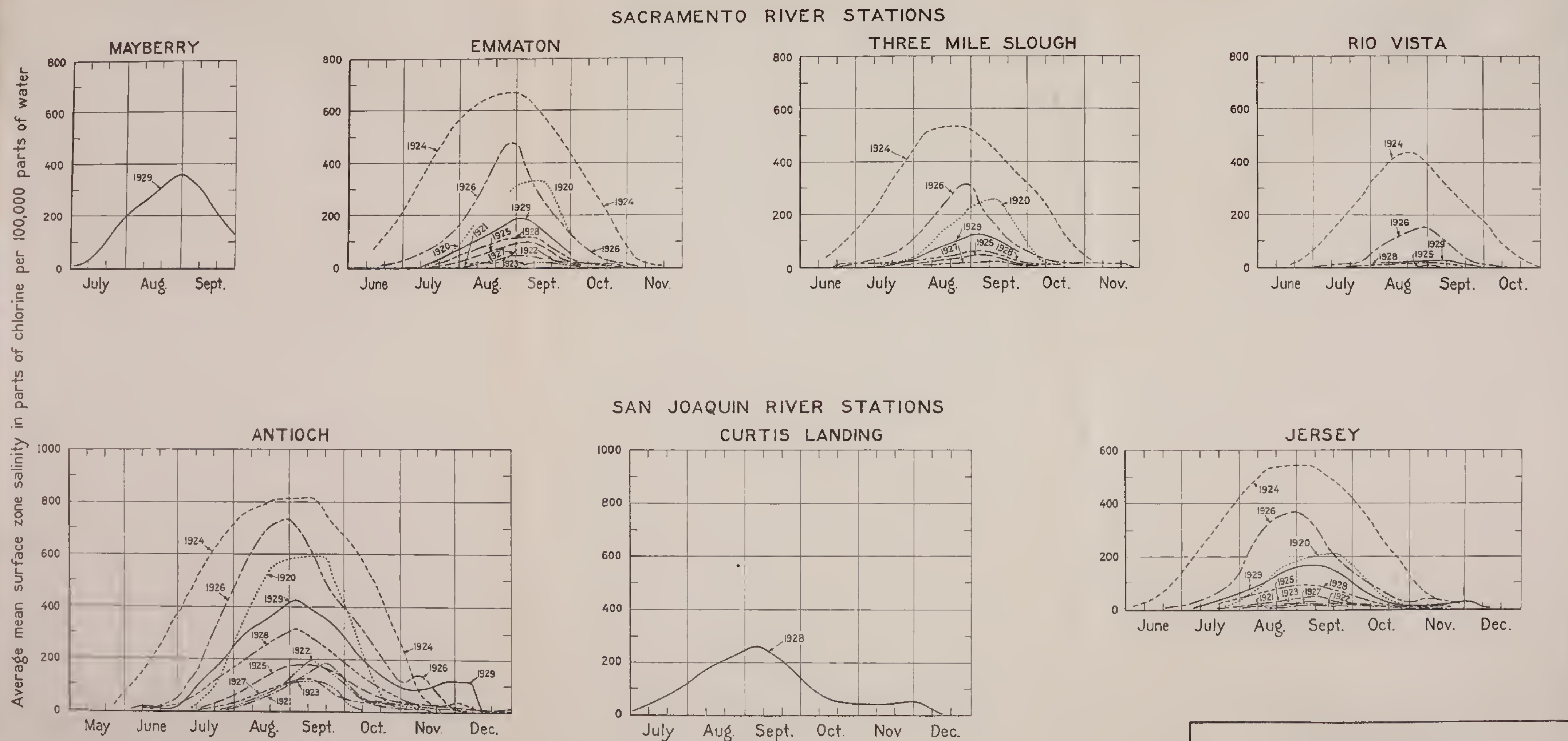


NOTE:-
All elevations referred to U.S.G.S. datum.

CHANNEL VOLUMES
IN
SUISUN BAY, SACRAMENTO AND SAN JOAQUIN RIVERS



ESTIMATED MEAN SURFACE ZONE SALINITY



ESTIMATED MEAN SURFACE ZONE SALINITY

Antioch-233

tities. The total tidal diffusion was then divided by the number of days in the particular time interval and a final figure obtained of tidal diffusion in acre-feet per day for the particular degree of salinity and in the particular section of channel considered.

The computations were carried out in this manner for all of the above channel sections for different degrees of mean surface zone salinity, including 15, 25, 50, 75, 150 and higher values as necessary, in parts of chlorine per 100,000 parts of water. The salinity records available for all years from 1920 to 1929 were used in the computations.

The results of these computations of tidal diffusion during the period of advance of salinity are graphically presented on Plate LXXIV, "Tidal Diffusion in the Combined Channels of the Sacramento and San Joaquin Rivers," and Plate LXXV, "Tidal Diffusion in Suisun Bay." The actual computed tidal diffusion quantities are shown by the points plotted on these graphs, a separate legend being used for each year of record. The points are plotted using the mean values of surface zone salinity, for which the diffusion was computed, as ordinates and the computed amounts of tidal diffusion in acre-feet per day as abscissae. Smooth curves have been drawn averaging the plotted points. The amounts of tidal diffusion shown by the graphs may be considered to be mean values corresponding to average tidal flow, because the time intervals involved in the computations of total diffusion in various channel sections generally covered a long enough period to include all of the variations in tidal flow occurring in periods of seven to fifteen days. The magnitude of tidal diffusion would be greater or less than the computed mean values when the tidal flow were respectively greater or less than average.

The amount of departure of the individual points during various years from the average curves drawn probably is due partly to inaccuracies in the basic data comprising records and estimates of salinity, stream flow, water consumption, and channel volumes. Changes in the tidal basin during the ten-year period of record covered by the study, affecting the magnitude of tidal flow, probably explain the discrepancies between the diffusion quantities computed for early years and those of more recent years. This will be referred to more fully in the latter part of this chapter. It is possible that the actual amount of consumption in the delta at the time of maximum saline invasion in the dry years such as 1920 and 1924 may have been less than the full demands estimated and used in the computations, because of curtailment of irrigation diversions. If this were true, the estimated negative net stream flows would be smaller and hence the diffusion quantities for the higher degrees of salinity during those years would be greater than estimated and the indicated negative values of diffusion possibly would be made positive. In plotting the curves, more weight has been given to the data for 1929 and more recent years than in the earlier years, because of the belief that the more recent data are more dependable and accurate, and because the relations for present conditions are of chief concern as related to remedial measures.

Similar computations of tidal diffusion were made for the period of retreat of salinity. For any particular degree of salinity, it was found that the computed amounts of diffusion for each channel section were somewhat greater during retreat than those computed for advance of salinity. The shape of the diffusion curves was practically the same as those shown on Plates LXXIV and LXXV. It appears that the proportional effect of tidal action on the variation of salinity is greater when the salinity is being pushed downstream by stream flow and retreating than when salinity is advancing upstream with stream flow resisting the same. The diffusion curves for the retreat period have not been presented because they are not related to the chief purpose of this study which is concerned with the factors governing advance of salinity and the means of preventing such advance. Therefore, the discussions and presentation of data which follow in regard to the relation of tidal diffusion to salinity and tidal flow, apply chiefly to tidal diffusion during advance of salinity.

Variation of Tidal Diffusion with Salinity—The basic variation of tidal diffusion with degree of salinity for various channel sections is shown by the graphs on Plates LXXIV and LXXV. It is evident from these graphs that the magnitude of tidal diffusion varies with the degree of salinity, increasing from a minimum approaching zero for relatively high salinities to a maximum for low salinities. The empirical relations evolved from the actual data appear to be logical, inasmuch as it is reasonable to presume that, during a continuous advance movement of progressively increasing salinity in any reach of channel, the pulsating flow of the tides would impregnate progressively lesser volumes of channel with an increased degree of salinity in a particular interval of time as the saline content of the water already present gradually increased to greater degrees.

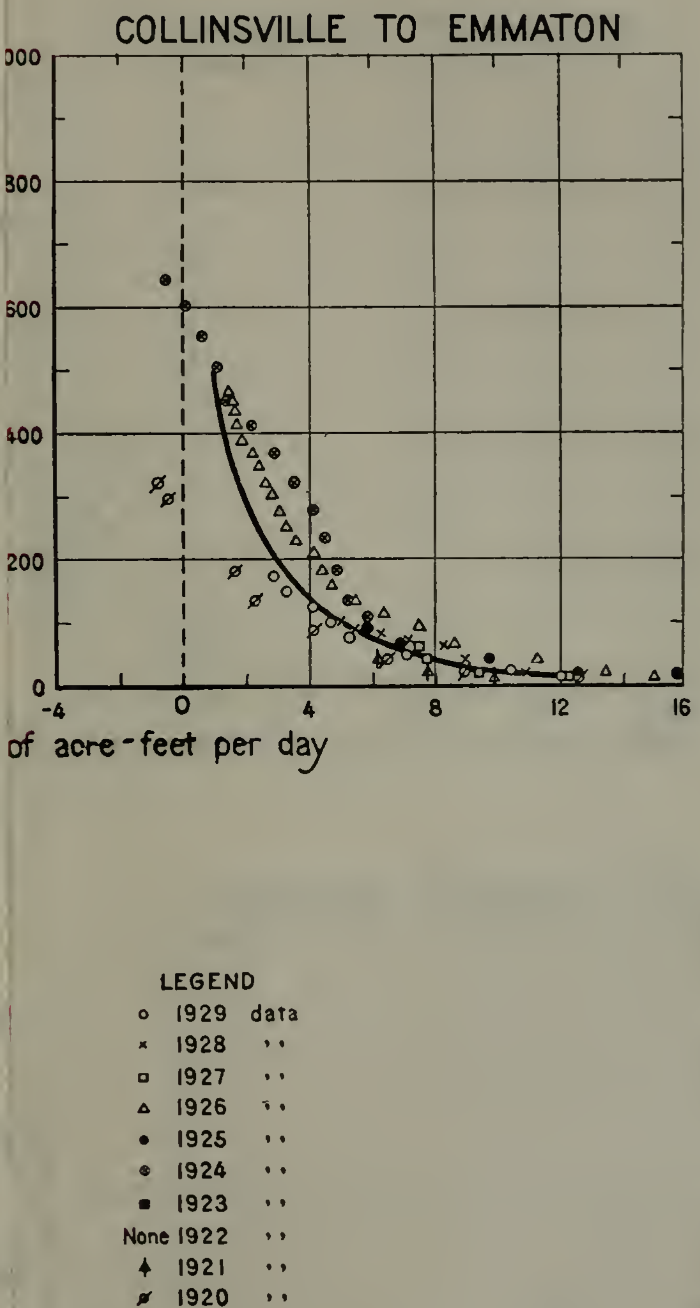
Geographical Variation of Tidal Diffusion—A study of these graphs indicates that the magnitude of tidal diffusion for any degree of salinity varies considerably for different geographical locations of the channel sections considered. It will be noted that the amount of tidal diffusion for any particular degree of salinity increases for channel sections farther downstream.

This variation is more clearly shown on Plate LXXVI, "Geographical Variation of Tidal Diffusion." This graph has been compiled from the curves shown on Plates LXXIV and LXXV. The variation of tidal diffusion for different degrees of salinity from 15 to 1000 parts of chlorine to 100,000 parts of water is shown in terms of distance in miles from the Golden Gate. The distances used for the points taken off the curves of tidal diffusion for the various channel sections correspond to the location of the center of mass of the channel volume in each section. Smooth curves have been drawn averaging the plotted points.

The relations depicted on this graph demonstrate that the magnitude of tidal diffusion for any degree of salinity increases for points farther downstream. For example, the diffusion at Bulls Head Point for a degree of salinity of 100 parts of chlorine per 100,000 parts of water is about 94,000 acre-feet per day as compared to about 8600 acre-feet per day at Collinsville or in the ratio of about eleven to one. For greater degrees of salinity, the difference is even more marked. Thus, for a salinity of 500 parts, the tidal diffusion at Bulls Head Point and Collinsville is in the ratio of about eighteen to one.

Relation of Tidal Diffusion to Tidal Flow—The greater magnitude of tidal diffusion at downstream points as compared to upstream points

Antioch-233

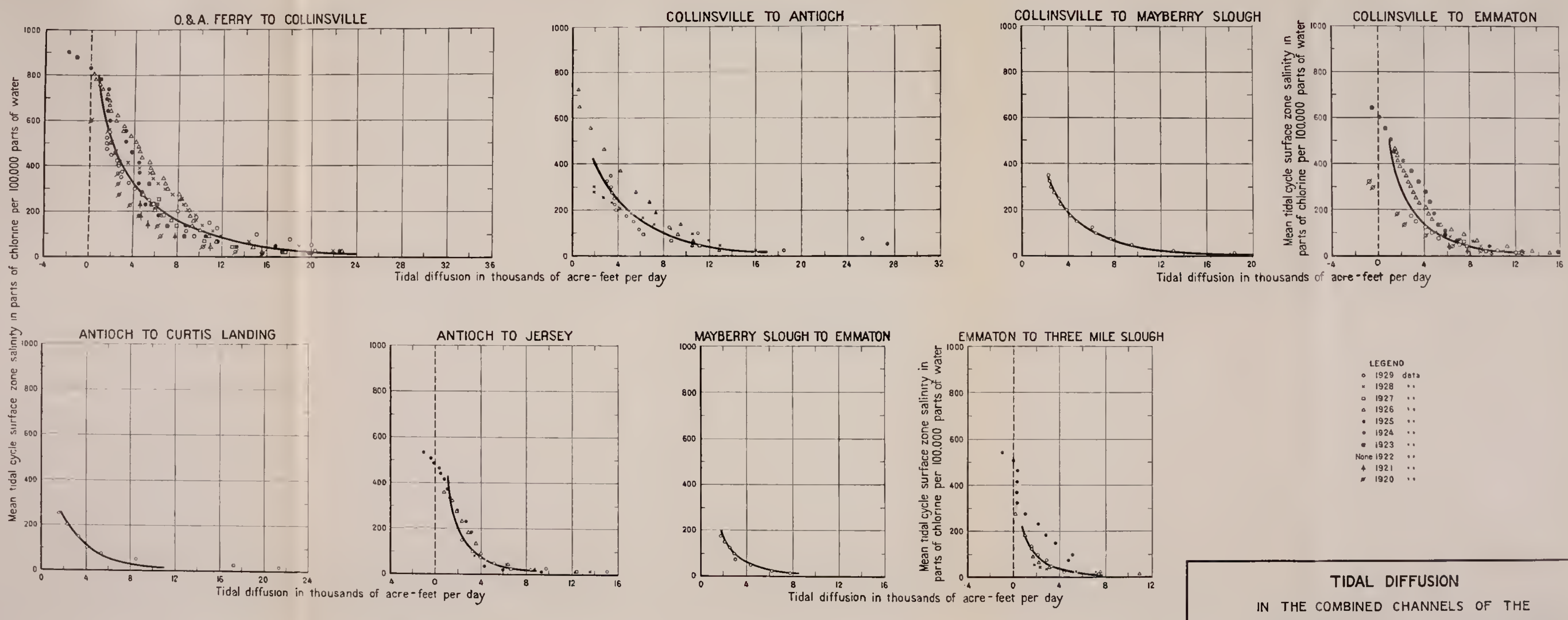


TIDAL DIFFUSION

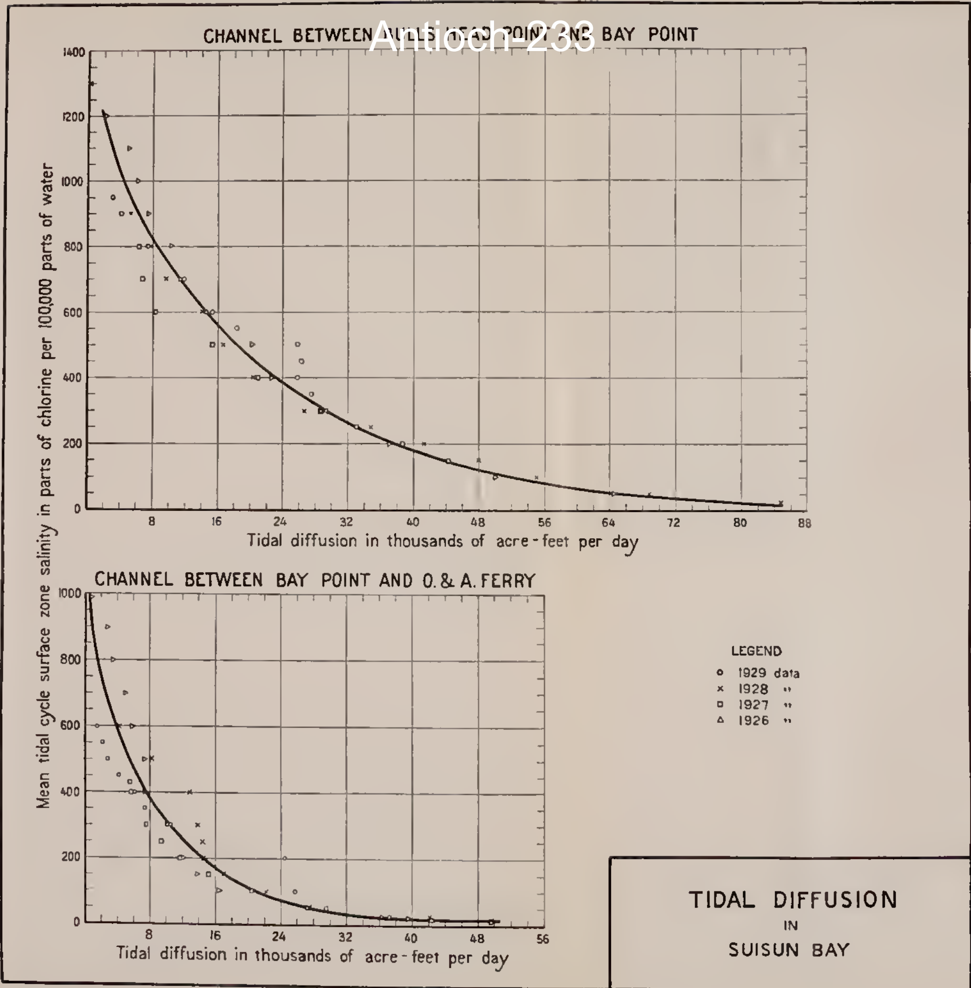
COMBINED CHANNELS OF THE

NTO & SAN JOAQUIN RIVERS

Antioch-233



TIDAL DIFFUSION
IN THE COMBINED CHANNELS OF THE
SACRAMENTO & SAN JOAQUIN RIVERS



TIDAL DIFFUSION IN SUISUN BAY

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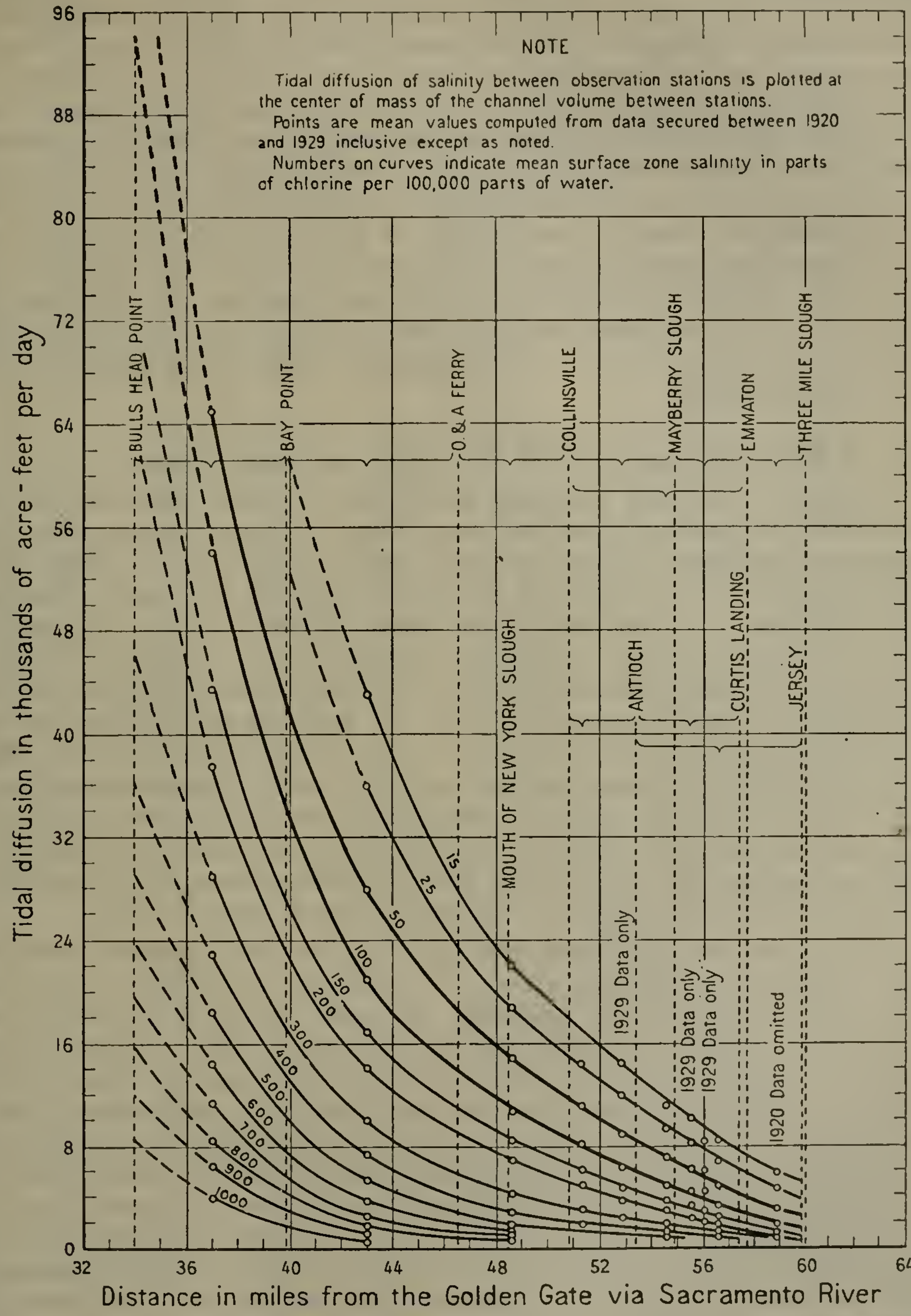
CHANNEL BETWEEN BULLS HEAD POINT
CHANNEL BETWEEN BAY POINT AND O.&A. FERRY

PLATE LXXVI



GEOGRAPHICAL VARIATION
OF
TIDAL DIFFUSION

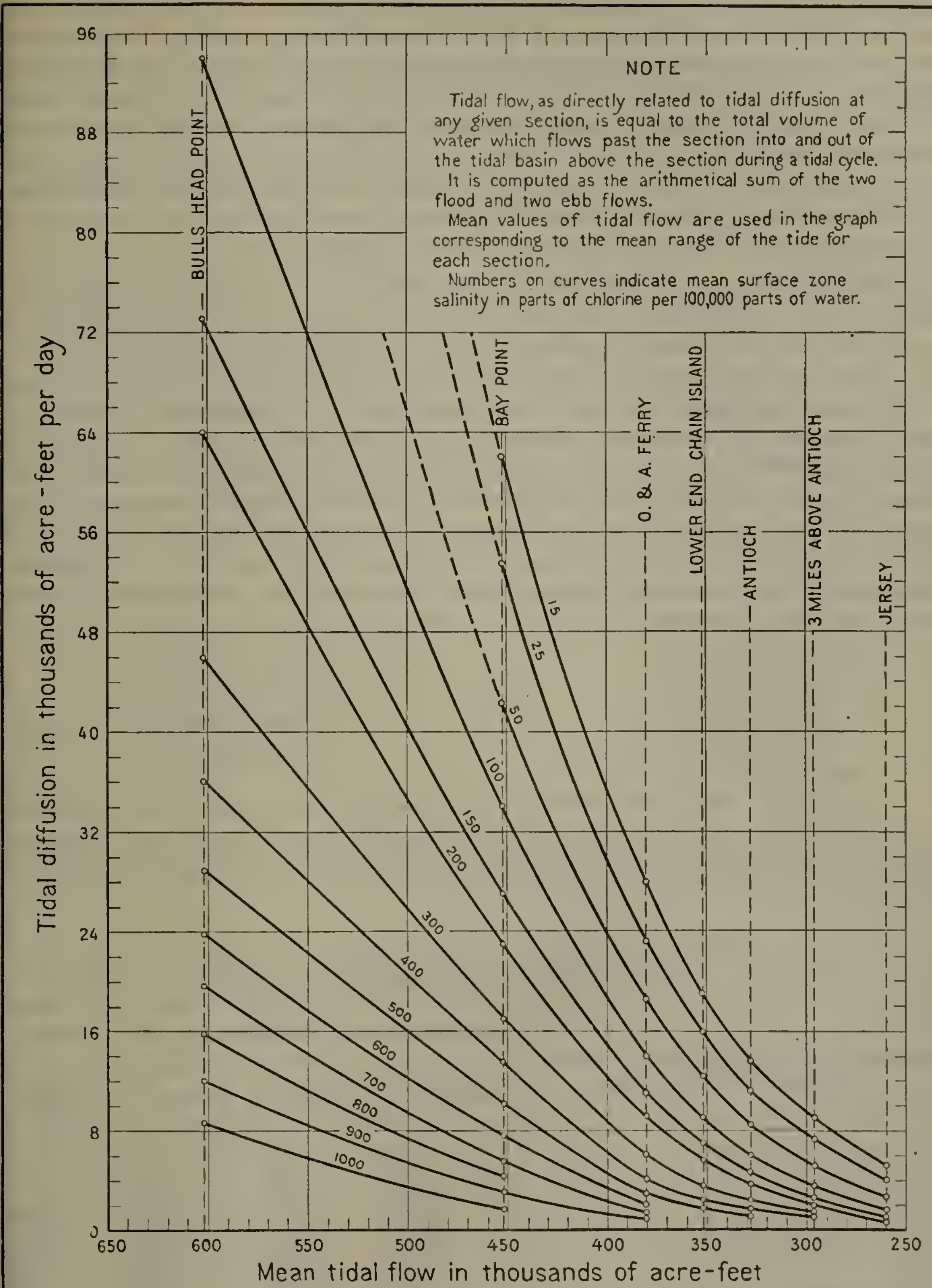
in the tidal basin is to be expected because of the greater magnitude of tidal flow at points farther downstream in the tidal basin. Tidal diffusion of salinity is the result of the pulsating tidal flows and hence tidal diffusion increases with the magnitude of tidal flow. This is demonstrated by the graph presented on Plate LXXVII, "Relation of Tidal Diffusion to Tidal Flow." This graph has been prepared by plotting for the various key stations or sections the tidal flow during a tidal cycle against tidal diffusion for various degrees of salinity as taken from the curves on Plate LXXVI. Tidal flow, as directly related to tidal diffusion at any given section, is equal to the total volume of water which flows past the section into and out of the tidal basin above the section during a tidal cycle. It is computed as the arithmetical sum of the two flood and two ebb flows. Mean values of total tidal flow are used on the graph, corresponding to the mean range of the tide for each section.

Effect of Recent Changes in Delta Tidal Basin on Saline Invasion.

From the foregoing relations established between tidal action and saline invasion in the upper bay and delta, it is possible to make an approximate estimate of the effect of recent changes in the delta tidal basin on tidal flow into the delta and tidal diffusion of salinity affecting saline invasion. As previously described in this chapter, the recent changes within the delta, which have modified the volume in the delta tidal prism, comprise the widening of the lower Sacramento River from Collinsville to a point above Rio Vista, the flooding of the lower end of Sherman Island, and the flooding of a previously reclaimed area lying south of Dutch Slough and the San Joaquin River. These changes have all had the effect of enlarging the volume in the tidal prism above the lower end of the delta. This has resulted in increasing the volume of tidal flow passing into and out of the tidal basin above all points from the lower end of the delta downstream through Suisun Bay.

The curves presented on Plate LXXVII show the relation between tidal diffusion for various degrees of salinity and tidal flow. The tidal flow used on these diagrams is based upon 1929 conditions in the tidal basin as computed from actual tidal prisms. The amounts of tidal diffusion were determined separately from actual records of salinity, stream flow into the delta, and estimates of consumption of water in the delta. It appears reasonable to assume that the relations established and shown on Plate LXXVII would hold for the different conditions in the tidal basin before these changes occurred, even though the rate of tidal movement in the lower Sacramento River channel probably has been increased to some extent by the deepening of this section of channel. It appears that the rate and character of tidal movement into the delta basin as a whole, past the lower end of the delta at Collinsville, may be considered to be approximately the same both before and after the changes took place. In other words, it is believed that the vertical limits of the tidal prisms in these sections of the tidal basin before the changes were made were probably about the same as those determined for present conditions. This is the chief element affecting the estimate of change in tidal flow, and it is believed that estimates of tidal flow for former years made on the basis of the present tidal prisms may be considered to be a fairly close approxi-

PLATE LXXVII



RELATION OF
TIDAL DIFFUSION
TO
TIDAL FLOW

mation. It has been demonstrated that the pulsating tidal flow is the direct cause of the tidal diffusion of salinity and it appears reasonable to conclude that an increase of tidal flow past any section would have the positive effect of increasing the magnitude of tidal diffusion at that section. It is believed that the following estimates of increased tidal diffusion, based upon the application of the change in tidal flow to the relations on Plate LXXVII, may be considered to be a fairly close approximation of the true effect of these changes in the tidal basin. However, the quantities estimated should not be considered as being exact, but as a fair indication of their magnitude.

Effect of Sacramento River Channel Enlargement—As previously stated, the enlargement of the Sacramento River channel from Collinsville to a point above Rio Vista has resulted in a progressive enlargement of the area in the tidal prism of about 3000 acres. With a mean tidal range of about three feet in this section of the tidal basin, this would result in increasing the volume in the tidal prism by between 8000 and 9000 acre-feet, and increasing the average total tidal flow passing points downstream by about 32,000 to 36,000 acre-feet. The actual change in tidal flow would not be this much, however, on account of the shape of the tidal prisms. (See Plates XL to XLV). It is estimated that the increase in total tidal flow resulting from this channel enlargement, at various downstream points, would be as follows:

Collinsville	28,000 acre-feet
O. and A. ferry	32,000 acre-feet
Bay Point	35,000 acre-feet
Bulls Head Point	30,000 acre-feet

Applying these increased amounts of tidal flow to the relations shown on Plate LXXVII, the following tabulation shows the estimated amounts of increased tidal diffusion resulting from this increased tidal flow:

INCREASE OF TIDAL DIFFUSION RESULTING FROM SACRAMENTO RIVER CHANNEL ENLARGEMENT

Mean tidal cycle surface zone salinity in parts of chlorine per 100,000 parts of water	Estimated increase of tidal diffusion in acre-feet per day			
	Collinsville	O. & A. Ferry	Bay Point	Bulls Head Point
15	5,600	9,800	----------	----------
25	4,900	7,900	17,300	----------
50	4,200	6,500	13,100	----------
100	3,300	5,200	10,600	13,000
150	2,600	4,300	8,400	10,200
200	2,200	3,800	7,600	9,400
300	1,200	2,600	5,500	6,300
400	900	1,700	5,100	4,800
500	----------	1,400	3,800	4,000
600	----------	----------	2,900	3.800
700	----------	----------	2,300	3,300
800	----------	----------	1,900	2,800
900	----------	----------	1,300	2,200

It is of particular interest to note that the amount of tidal diffusion for a mean surface zone salinity of 100 parts of chlorine per 100,000 parts of water is increased at Collinsville, at the lower end of the delta, by an estimated amount of 3300 acre-feet per day.

Saline invasion through Suisun Bay and into the delta has also been affected by this channel enlargement due to an increased rate of advance of salinity resulting from the increase in amount of tidal diffusion for all degrees of salinity at points down stream from the delta. It is evident from the formula previously presented on the relation between advance of salinity, stream flow and tidal diffusion, that the rate of advance of salinity for any degree would be increased with an increased amount of tidal diffusion. Thus, the time required for any degree of salinity to travel from the lower end of Suisun Bay to the lower end of the delta would be decreased. Hence, for any particular stream flow conditions, the channel enlargement of the lower Sacramento River has resulted in salinity arriving at the lower end of the delta earlier in the season than would have occurred before the enlargement was made.

On the other hand, the rate of advance of salinity along the enlarged channel section of the lower Sacramento River would be decreased. Even with the greater amounts of tidal diffusion resulting from increased tidal flow, studies indicate that the enlarged channel volume would have the effect of increasing the length of time required for any degree of salinity to travel from Collinsville to Rio Vista. Therefore, although this channel enlargement has resulted in saline water arriving at the lower end of the delta at an earlier date than would have occurred before the enlargement was made, it has also resulted in delaying the advance of salinity to points farther upstream in the delta. The studies indicate that the increased and decreased rates of advance below and above Collinsville respectively would tend to balance each other in regard to the total time of travel of salinity from lower Suisun Bay points to Rio Vista and points upstream therefrom on the Sacramento River.

Effect of Flooding of Previously Reclaimed Lands—The flooding of the lower end of Sherman Island and the previously reclaimed area south of Dutch Slough and the San Joaquin River has had a similar effect to the enlargement of the lower Sacramento River channel in increasing the volume of the tidal prism, and hence the volume of tidal flow and amount of tidal diffusion at points downstream. The area flooded on lower Sherman Island comprises about 1800 acres, while that near Dutch Slough amounts to 2200 acres or a combined total of about 4000 acres. Based on a similar analysis to that presented for the change on the lower Sacramento River, it is estimated that the tidal flow past Collinsville has been increased by about 30,000 acre-feet as a result of the flooding of these two previously reclaimed areas. The effect on tidal diffusion for any degree of salinity is, therefore, of about the same magnitude as that previously estimated for the channel change in the lower Sacramento River.

It appears from these estimates that, if the flooded reclamations on the lower end of Sherman Island and in the vicinity of Dutch Slough were reclaimed and removed from the tidal prism, the amount of tidal diffusion at the lower end of the delta (Collinsville) would be decreased by about 3200 acre-feet per day, for a mean surface zone salinity of 100 parts, and that the net stream flow required to repel tidal diffusion of salinity at this degree at Collinsville would be correspondingly decreased.

The flooding of the lower end of Sherman Island has probably not affected the tidal flow past the Antioch section; and hence, it may be assumed that the increase in tidal diffusion at Antioch resulting from recent changes in the tidal basin would include only the Dutch Slough reclamation and a portion of the Sacramento River channel enlargement. The effect of the Dutch Slough reclamation itself would be an estimated increase in tidal flow past Antioch of 16,000 acre-feet per day. This would increase tidal diffusion for 100 parts of mean surface zone salinity by 1600 acre-feet per day. The result of the lower Sacramento River channel enlargement at the Antioch section, is estimated to be an increased tidal diffusion of about 1600 acre-feet per day. Thus, if these changes had not occurred, the studies indicate that tidal diffusion at the Antioch section for 100 parts of salinity would be reduced by about 3200 acre-feet per day, and that the net stream flow for repelling tidal diffusion of salinity to this degree at this section would be correspondingly reduced. Moreover, if the previously reclaimed area near Dutch Slough were again reclaimed, the studies indicate that the net stream flow for preventing advance of salinity of 100 parts at the Antioch section might be decreased by about 1600 acre-feet per day.

Effect on Tidal Diffusion—In connection with the presentation of the tidal diffusion curves on Plates LXXIV and LXXV, it was pointed out that changes in the tidal basin during the period since 1920 might explain the discrepancies between the computed values of tidal diffusion in the earlier and later years of record. Inasmuch as the foregoing studies indicate that the changes in the tidal basin since 1920 have increased tidal diffusion at the lower end of the delta and points downstream it appears that this offers a reasonable explanation for the diffusion quantities, as computed for such years as 1920 and 1921, being generally smaller than those for the more recent years.

Effect of Stockton Ship Canal—The results of these studies indicate that any enlargement in tidal prism volume resulting from the construction of the Stockton Ship Canal would have a similar effect of increasing the amount of tidal diffusion at points lower down in the delta, and, hence, of increasing to some extent the stream flow required for control of salinity in the lower delta. Studies have been made of the proposed construction plans for this work. For the main work along the upper San Joaquin River, it appears that the widening of old channels and the construction of new channels will be largely offset by cutting off and filling in some of the existing channels and submerged areas. If the volume in the tidal prism is not materially increased by the work actually carried out in this section of the project, it would have no effect on salinity conditions. The widening of New York Slough, which is a part of this deep-water project, may have the effect of increasing tidal diffusion below the lower end of New York Slough and possibly increasing to some extent the degree of saline invasion in the vicinity of Pittsburg and Antioch. No studies have been made to estimate the possible effect of this particular channel enlargement.

CHAPTER V

CONTROL OF SALINITY

The primary purpose of the investigation of salinity is the determination of an effective means of controlling salinity and preventing the harmful effects of saline invasion in the upper bay and delta region. This is the objective toward which all the activities and studies of the investigation have been directed. The conditions brought about by saline invasion in the upper bay and delta region are of serious concern. The frequent repetition of saline invasions of considerable magnitude and the possibility of even more prolonged and more extensive invasions than have heretofore occurred may result in permanent injury to the rich agricultural lands in the delta. The saline menace has tended already to depreciate land values in the delta. The conditions have been the cause of expensive water right litigation and probably will lead to even more serious and expensive litigation between the delta interests and upstream water users, unless water supplies free from saline invasion are provided for the delta. The industries in the upper bay region have been curtailed in their use of cheap fresh-water supplies from the lower river and are experiencing considerable difficulty and expense in obtaining dependable and adequate fresh-water supplies for their needs. Remedial measures are desirable and necessary to protect the delta and provide adequate and dependable fresh-water supplies for the needs of the delta and upper bay region.

One method for controlling salinity would be the provision of a physical barrier to obstruct the entrance of saline water into the upper bay and delta channels. It is not within the province of this report to consider this method of control. The physical and economic aspects of a salt water barrier are presented in detail in other reports.*

The intensive investigations and studies presented in the foregoing chapters point to an obvious solution of this entire salinity problem; namely, the control and preventon of saline invasion into the delta by means of stream flow. The records and studies of the variation of salinity and stream flow demonstrate that the more extensive saline invasions into the delta channels have been due to deficiencies in stream flow entering the delta. It has been shown during the period 1920 to 1929 that the stream flow entering the delta in the summer months often has been insufficient to take care of even the comsumptive demands of crops and other uses in the delta. It has been under such conditions of deficient stream flow that the maximum invasions of salinity have occurred.

During the years 1921 to 1923, inclusive, and 1927, the stream flow into the delta during the summer months was just about sufficient to take care of the consumptive demands therein. In those years, the

* Bulletin No. 22, Report on Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers, California—2 Vols., Division of Water Resources, 1929.
Bulletin No. 28, Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers, Division of Water Resources, 1931.

degree and extent of saline invasion into the delta were relatively small. At the time of maximum extent of invasion, water with a salinity of 100 parts or more of chlorine per 100,000 parts of water extended only as far up the Sacramento and San Joaquin river channels as a mile below Emmaton and two miles below Jersey, respectively; while the salinity upstream from these points was considerably less, the water being practically fresh in most of the delta. The maximum extent of invasion in 1925 was but slightly greater. Thus, in these five years, over 95 per cent of the delta had a fresh-water supply suitable for agricultural purposes at all times; and for the greater portion of the season, practically all of the delta had a fresh-water supply entirely free from saline invasion. The records show that when the stream flow into the delta has been sufficient to take care of the consumptive demands of the delta, saline invasion has been of such small degree and extent as to be of little consequence to the delta.

It is evident, therefore, that the primary requirement for control and prevention of the invasion of salinity into the delta is the furnishing of a sufficient water supply flowing into the delta to fully satisfy the consumptive demands of crops together with the natural losses by evaporation and transpiration from vegetation. After this primary requirement is satisfied, additional water is necessary to repel tidal action and the tidal diffusion of salinity resulting therefrom. The amount of additional water required varies with the location at which control is sought or desired and the degree of salinity desired to be controlled at the particular location.

Stream Flow Required for Control of Salinity.

The stream flow required for the control of salinity at any point in the tidal basin is equal to the amount of tidal diffusion at the particular point with the degree of salinity for which control is sought or desired. The fundamental relation demonstrated in Chapter IV between stream flow, tidal diffusion and advance of salinity furnishes the basic law of control. This law is expressed by equation (1) as follows:

$$C = D - S$$

Where C = the magnitude of advance of salinity for any particular degree of salinity
S = the net stream flow
D = tidal diffusion for any particular degree of salinity.

It follows mathematically that if the advance "C" is zero, then "D" must be equal and opposite to "S." In other words, if the net stream flow downstream at a particular point is equal in magnitude to the tidal diffusion which is always directed upstream, there will be no advance of salinity. Hence, for control of salinity by stream flow at any particular point and for any particular degree of salinity, a net stream flow downstream at the particular point must be provided equal in magnitude to the amount of tidal diffusion with the particular degree of salinity for which control is sought or desired. The tidal diffusion curves previously presented in Chapter IV provide the basic figures for the determination of the amount of net stream flow required at any desired point or degree of control. (See Plates LXXIV, LXXV and LXXVI.)

Net Control Flows—The net stream flow required for control of salinity to various degrees from Bulls Head Point to Three Mile Slough and Jersey is graphically presented on Plate LXXVIII, "Net Stream Flow for Control of Salinity at Points in Suisun Bay and Lower Delta." The curves on this plate are identical with the curves on Plate LXXVI, on which the geographical variation of tidal diffusion is shown.

Desired Point and Degree of Control of Salinity—The point and degree of control of salinity by stream flow must be based primarily upon a consideration of the needs of the agricultural interests in the delta and the industrial, municipal and agricultural interests in the upper bay region. It would be desirable to adopt such measures of control as would most effectively and, at the same time, most economically provide for the present and ultimate needs of these water users. At the same time, consideration must be given to the general plan for the development and utilization of the State's water resources and the amount of additional water supplies created thereby in relation to the needs not only of the delta and upper bay region but also of the Sacramento and San Joaquin valleys. Finally consideration must be given also to the practical limit of control which is possible of attainment by means of stream flow.

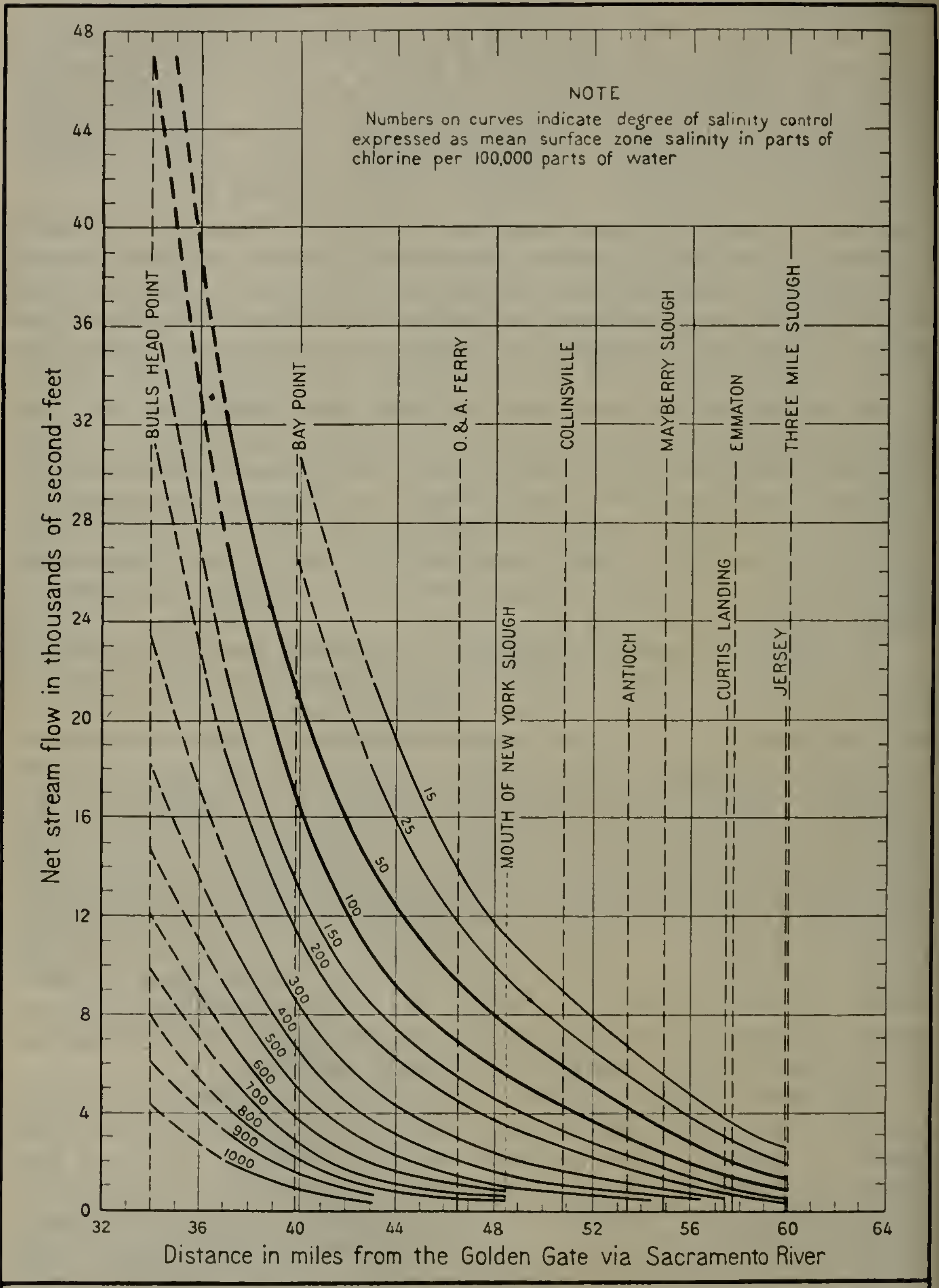
The degree of control required is dependent upon the quality of water necessary for agricultural, industrial and municipal demands. For agricultural use with average conditions and crops in the delta, it has been assumed that water having a salinity of over 100 parts or more of chlorine per 100,000 parts of water would not be suitable for irrigation. Hence, if the invasion of salinity were controlled at the lower end of the delta so that mean tidal cycle surface zone salinity would not exceed 100 parts of chlorine per 100,000 parts of water near Antioch and be considerably less in amount upstream, the water supply in practically the entire delta would be satisfactory in quality for irrigation at all times of the year and the lands and developments of the delta fully protected. There would be only limited areas of small extent in close proximity to Antioch for which a suitable quality of water might not be available in critically dry years for the irrigation of crops particularly susceptible to injury from salt.

The water required for use in boilers and processes by industries and for general domestic use in the upper bay region must be much fresher in quality. The maximum salinity allowable for these uses should not exceed 25 parts and preferably not over 10 parts of chlorine per 100,000 parts of water. In order to obtain water of as fresh a quality as 25 parts of chlorine per 100,000 parts of water (mean tidal cycle surface zone salinity), it will be seen by Plate LXXVIII that a net stream flow downstream would be required of

5600 second-feet at Antioch
7550 second-feet at Collinsville
11,600 second-feet at O. and A. ferry
26,800 second-feet at Bay Point

In addition to these net flows required at these points, the total stream flow provided into the delta would have to include the consumptive

PLATE LXXVIII



NET STREAM FLOW FOR CONTROL OF SALINITY AT POINTS IN SUISUN BAY AND LOWER DELTA demands above these several points, which for the delta itself varies from a minimum of about 400 second-feet in mid-winter to a maximum of about 3700 second-feet in mid-summer.

As compared to these requirements for industrial and domestic needs alone, control of mean tidal cycle surface zone salinity to 100 parts of chlorine per 100,000 parts of water could be obtained with the following net stream flows:

3000 second-feet at Antioch
4300 second-feet at Collinsville
6900 second-feet at O. and A. Ferry
17,000 second-feet at Bay Point

With this latter degree of control maintained near Antioch, the salinity would be considerably less upstream, and the channels of over 95 per cent of the delta would have fresh water suitable for both industrial and domestic use. Hence, fresh-water supplies of the purity required for industrial process and domestic use could be made available in the delta channels, and not far distant from the upper bay region. It is evident that the necessary supplies of fresh water for industrial and domestic use along Suisun Bay could be more economically obtained by conveying fresh water in special conduits from points within the delta, than by means of controlling salinity by stream flow to points farther downstream than the lower end of the delta. For example, to control salinity for obtaining the necessary quality of water for industrial and domestic use down to O. and A. ferry would require about 12,000 second-feet at least as compared with about 3000 second-feet necessary for maintaining fresh water in the delta channels or a difference of about 9000 second-feet. Even with control to this degree as far as O. and A. ferry, the demands of industries and other users located farther downstream could not be furnished except by the construction of a conduit to carry water from the controlled fresh-water area to downstream points.

The greater part of the water used by the industries along Suisun Bay is for purposes of cooling and condensing. Most of these industries are now equipped with such cooling and condensing apparatus, pipes and fittings, as will provide the most economical service with the present supply of water available for this use. As far as this greater part of the water supply demands of the industries is concerned, it appears that the present water supply is satisfactory for this purpose. The cost of cooling water, including operation, maintenance and depreciation expenses, is small. If salinity were controlled to 100 parts of chlorine per 100,000 parts of water near the lower end of the delta, the water downstream would be less saline than under present conditions, especially in the upper part of Suisun Bay and in the vicinity of Pittsburg where the density of industrial development is the greatest. Corrosion would be reduced and the expense of cooling and condensing water decreased.

The city of Antioch now obtains its supply from the San Joaquin River, pumping therefrom when the water is suitable in quality and storing the same in reservoirs for use during the period when the water in the river becomes too saline for domestic use. In order to provide water of the freshness required for domestic use at Antioch at all times, the net flow required would be 6000 second-feet or more, or at least double the amount required for the degree of control necessary for agricultural purposes in the delta. Therefore, it does not appear practical to consider a degree of control sufficient to provide fresh water at all times in front of Antioch of the quality required for domestic use. It is certain, however, that control to the degree required for agricultural purposes in the delta would improve the saline conditions at Antioch. In the event that the city's needs increase still farther than present facilities provide, it would be entirely feasible to obtain additional supplies by diverting water through a conduit from farther upstream, possibly in combination with service to the area south of Suisun Bay.

Proposed Net Control Flow—Based upon the foregoing considerations, it is concluded that the most desirable and practical plan to adopt for controlling salinity by means of stream flow would be a control at a point near Antioch sufficient to limit the increase of mean tidal cycle surface zone salinity to a degree not to exceed 100 parts of chlorine per 100,000 parts of water, and lesser degrees of salinity upstream. This would require a net flow of 3000 second-feet in the combined channels of Sacramento and San Joaquin rivers past Antioch. A quantity of 3300 second-feet has been adopted as the recommended amount of net control flow to be provided as a minimum flow in the combined river channels past Antioch into Suisun Bay. This would put the control point for a maximum degree of mean tidal cycle surface zone salinity of 100 parts of chlorine per 100,000 parts of water about 0.6 miles below Antioch.

It is of interest to determine what the resulting mean salinities would be at other points in the delta and bay channels with this degree of control maintained near Antioch. This is shown in Table 27. For purposes of comparison and interest, the flows required for control of salinity to a degree of 25, 50, 100 and 200 parts of chlorine per 100,000 parts of water (mean tidal cycle surface zone salinity) also are shown, together with the resulting salinities at other points. This table thus presents a clear picture of the relative degrees of salinity control obtained at representative control points in the upper bay and delta with different assumed net control flows at these respective stations. In computing the figures shown in Table 27, the difference in consumptive demands above the several stations has been taken into account in estimating the resulting mean salinities for the assumed control flows.

Of particular importance are the figures shown for the proposed control flow of 3300 second-feet which is recommended for adoption. With this net flow maintained as a minimum past the Antioch section into Suisun Bay, the maximum degrees of mean tidal cycle surface zone salinity, in parts of chlorine per 100,000 parts of water, at various points in Suisun Bay and the delta are estimated as follows:

Bulls Head Point	1200±
Bay Point	700
O. and A. ferry	275
Lower end of New York Slough	225
Collinsville	150
Antioch	90
Emmaton	15
Jersey	10

TABLE 27

NET STREAM FLOW FOR CONTROL OF SALINITY AND RESULTING MAXIMUM DEGREE OF MEAN SALINITY

Control station	Degree of salinity control, parts chlorine per 100,000 of water (Mean tidal cycle surface zone salinity)	Net control stream flow at control station in second-feet	Resulting maximum degree of mean tidal cycle surface zone salinity in parts chlorine per 100,000 parts water								
			Bulls Head Point	Bay Point	O. & A. Ferry	New York Slough, lower end	Collinsville	0.6 mile below Antioch	Antioch	Emmaton	Jersey
0.6 miles below Antioch	200	2,000		900	425	350	275	200	175	45	20
0.6 miles below Antioch	100	3,300	±1,200	700	275	225	150	100	90	15	10
0.6 miles below Antioch	50	4,600	1,100	650	200	150	100	50	40		
0.6 miles below Antioch	25	6,000	950	475	140	100	50	25	20		
Jersey	100	800				750	600	500	475	180	100
Jersey	50	1,300		1,100	600	500	400	350	325	110	50
Jersey	25	1,950		925	500	375	300	225	225	60	25
Emmaton	100	1,370		1,100	600	490	380	325	300	100	50
Emmaton	50	2,030		900	450	360	280	225	200	50	25
Emmaton	25	2,950		750	325	250	190	125	110	25	10
Antioch	200	1,850		910	450	375	275	225	200	50	25
Antioch	100	3,000		725	320	250	175	125	100	20	10
Antioch	50	4,200	1,100	600	225	160	100	60	50	10	
Antioch	25	5,600	1,000	500	150	100	75	35	25		
Collinsville	200	2,700		775	400	275	200	150	125	25	15
Collinsville	100	4,300	1,075	590	220	150	100	60	50	10	
Collinsville	50	5,900	960	475	140	100	50	25	20		
Collinsville	25	7,550	860	370	90	50	25	15	10		
Lower end of New York Slough	200	3,500	1,100	675	265	200	150	90	75	15	
Lower end of New York Slough	100	5,600	980	480	150	100	50	30	25		
Lower end of New York Slough	50	7,600	860	360	80	50	25	15	10		
Lower end of New York Slough	25	9,500	760	275	50	25	10				
O. & A. Ferry	200	4,600	1,050	560	200	140	85	50	40		
O. & A. Ferry	100	6,900	900	400	100	60	30	20	15		
O. & A. Ferry	50	9,250	775	275	50	25	15				
O. & A. Ferry	25	11,600	650	200	25	10					
Bay Point	200	11,500	650	200	25	10					
Bay Point	100	17,000	450	100							
Bay Point	50	21,100	350	50							
Bay Point	25	26,800	250	25							
Bulls Head Point	200	32,000	200	15							
Bulls Head Point	100	47.000	100								

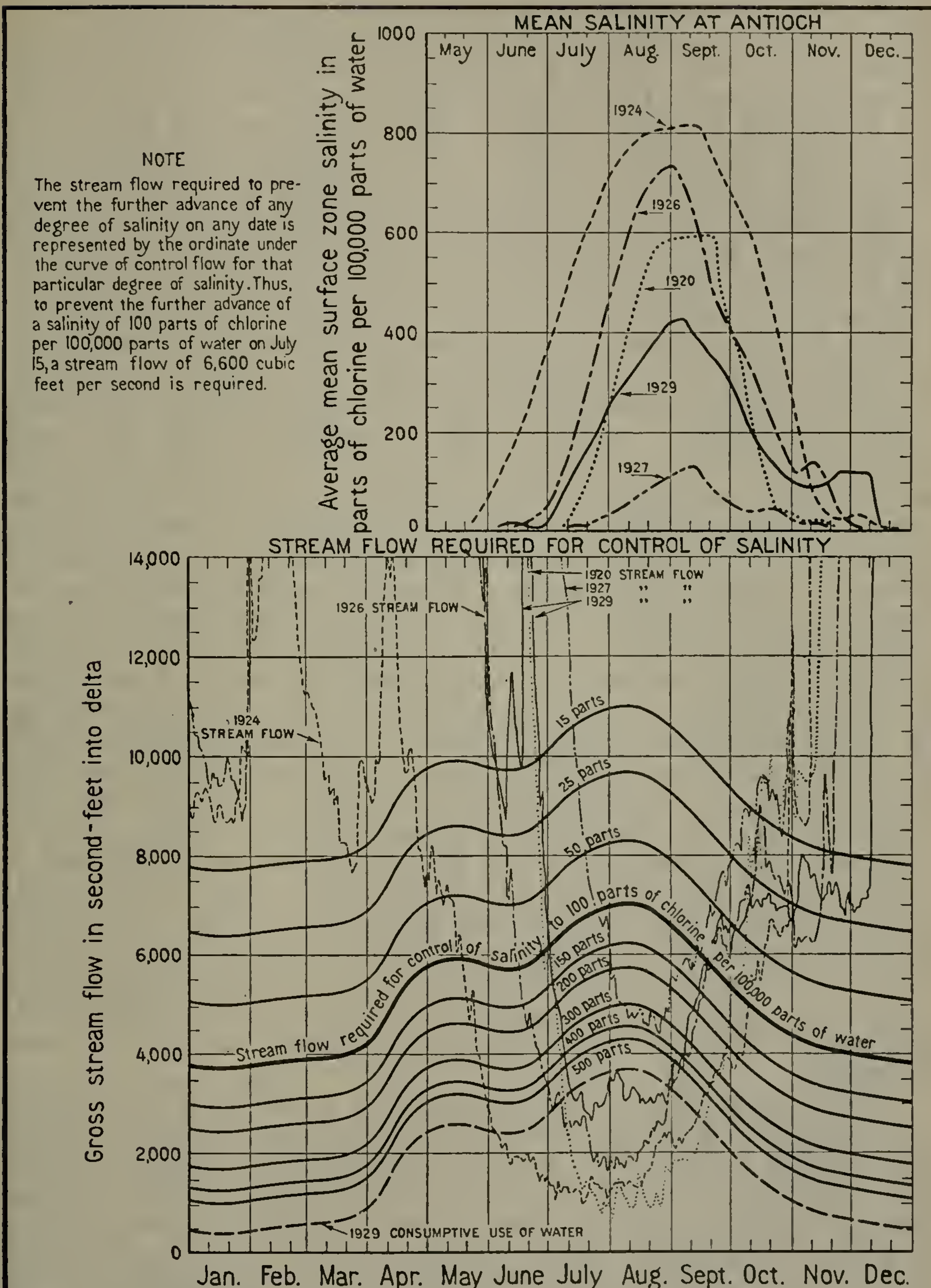
It will be noted that, under the proposed control, fresh water of suitable quality for industrial and domestic use would be maintained in the channels of the entire delta above Emmaton or Jersey.

Gross Stream Flow Into Delta for Control of Salinity—In order to carry out successfully the proposed method of control by stream flow and maintain the net flow required for control at the lower end of the delta, the consumptive demands of the delta also must be provided. The consumption of water by evaporation and transpiration from marginal vegetation is a continuous although variable demand, reaching a maximum rate in the summer months. Likewise, a considerable portion of the moisture used by crops on the delta lands is supplied by natural seepage into the islands. Hence, although irrigation by artificial diversions of water is essential to the successful production of most crops in the delta, the consumptive use by crops is only partially subject to control. Moreover, irrigation supplies would be artificially diverted as long as water of suitable quality were available. Hence, the primary essential for successful control of salinity by stream flow at the lower end of the delta would be the provision of adequate supplies to care for the full consumptive demands in the delta.

The total stream flow into the delta required for the combined needs of consumptive use in the delta and salinity control varies with the consumptive demands during the irrigation season. At any particular time during the season, the rate of inflow required is equal to the rate of consumption at the particular time plus the rate of net flow required for salinity control. The variation in rate of stream flow into the delta required to satisfy these combined demands, or what may be termed the "gross control flow," is best shown in the form of a graph. Plate LXXIX, "Gross Stream Flow Into Delta for Control of Salinity 0.6 Miles Below Antioch," shows the total gross inflow required throughout the season for various degrees of salinity control at the control section below Antioch. Each of the control curves plotted on this graph takes the same shape as the estimated curve of water consumption in the delta above the Antioch section. They have been obtained by adding to the curve of consumptive use the estimated net control flows required for various degrees of salinity control. The heavy curve shows the variation of gross control flow into the delta required for the proposed control of mean tidal cycle surface zone salinity to 100 parts of chlorine per 100,000 parts of water. As shown by this curve, the rate of gross inflow required for the combined needs of consumptive use and proposed salinity control varies from a minimum of about 4000 second-feet at the beginning of April to a maximum of about 7000 second-feet in August. After reaching the maximum rate in August, the total requirement gradually decreases to about 4000 second-feet in December.

As a means of checking the essential accuracy of this estimate of gross control flow, it is of value to compare the actual records of stream flow into the delta and the resulting salinities which occurred during recent years. For this purpose, graphs of actual stream flow into the delta and of mean tidal cycle surface zone salinity at Antioch (estimated from the actual records of salinity for samples taken in the surface zone usually after high tide), for the years 1920, 1924,

PLATE LXXIX



GROSS STREAM FLOW INTO DELTA
FOR
CONTROL OF SALINITY
0.6 MILES BELOW
ANTIOCH
WITH COMPARATIVE STREAM FLOW AND SALINITY RECORDS FOR YEARS 1920-'24-'26-'27 AND '29

1926, 1927 and 1929, are shown on Plate LXXIX. The hydrographs of stream flow are superimposed with appropriate legend on the control curves, making it possible to directly compare the actual stream flow that entered the delta with the gross stream flow into the delta required for salinity control. Directly above the hydrographs of gross control flow and actual measured inflow are shown the curves of variation of mean salinity at Antioch. Thus in 1924, a maximum mean tidal cycle surface zone salinity of slightly more than 800 parts of chlorine per 100,000 parts of water was reached about September 15. On the same date the stream flow was about 3200 second-feet and the required control flow at the same time for 800 parts of salinity, as shown by the curves, is of about the same amount. Thus, the condition was reached of an equality between stream inflow and total requirements of consumption and salinity control at that particular degree of salinity and advance of salinity ceased. Subsequently the flow increased and the salinity gradually retreated. Again in 1926, a maximum mean tidal cycle surface zone salinity of a little less than 750 parts of chlorine per 100,000 parts of water was reached about September 1. On the same date, the stream flow into the delta was about 3500 second-feet or about the same amount which the control curves show as required to prevent further advance of salinity at that degree. Before the maximum salinities were reached in both 1924 and 1926, the stream flow was considerably less than the gross control flow requirements, as shown by the control curves, and hence salinity continued to advance until the stream flow into the delta was sufficient in amount to take care of the control demands for the particular degree of salinity reached. In 1927, a maximum mean tidal cycle surface zone salinity of about 130 parts of chlorine per 100,000 parts of water was reached about September 12. On this same date, the stream flow into the delta was about 6200 second-feet, which is practically the amount shown by the control curves as required to prevent further advance of salinity at that degree. Prior to September 12, and extending back to about July 25, 1927, the stream flow into the delta was insufficient to prevent an increase of salinity to a degree of 130 parts of chlorine per 100,000 parts of water and hence the salinity continued to increase at Antioch until the stream flow was sufficient to take care of the gross control demands. The relations in other years are similar.

These comparisons of actual records of stream flow and salinity with the estimated gross control flows and the salinities resulting therefrom, provide a satisfactory check on the estimated amounts of stream flow required for control of salinity. The relation between stream flow and salinity at the time that maximum salinity is reached during the season, when there is neither advance or retreat occurring, provides the best means of checking the essential accuracy of the estimated net control flows derived from the determination of the magnitude of tidal diffusion of salinity resulting from tidal action. It is only at the time of maximum salinity when there is neither advance or retreat and a definite control point is reached that an absolute check can be made. It is evident that these comparisons with the actual records of stream flow and maximum salinity in recent years demonstrates the essential accuracy of the estimates of the gross stream flow required for salinity control, including the required net control flow as well as the consumptive demands in the delta.

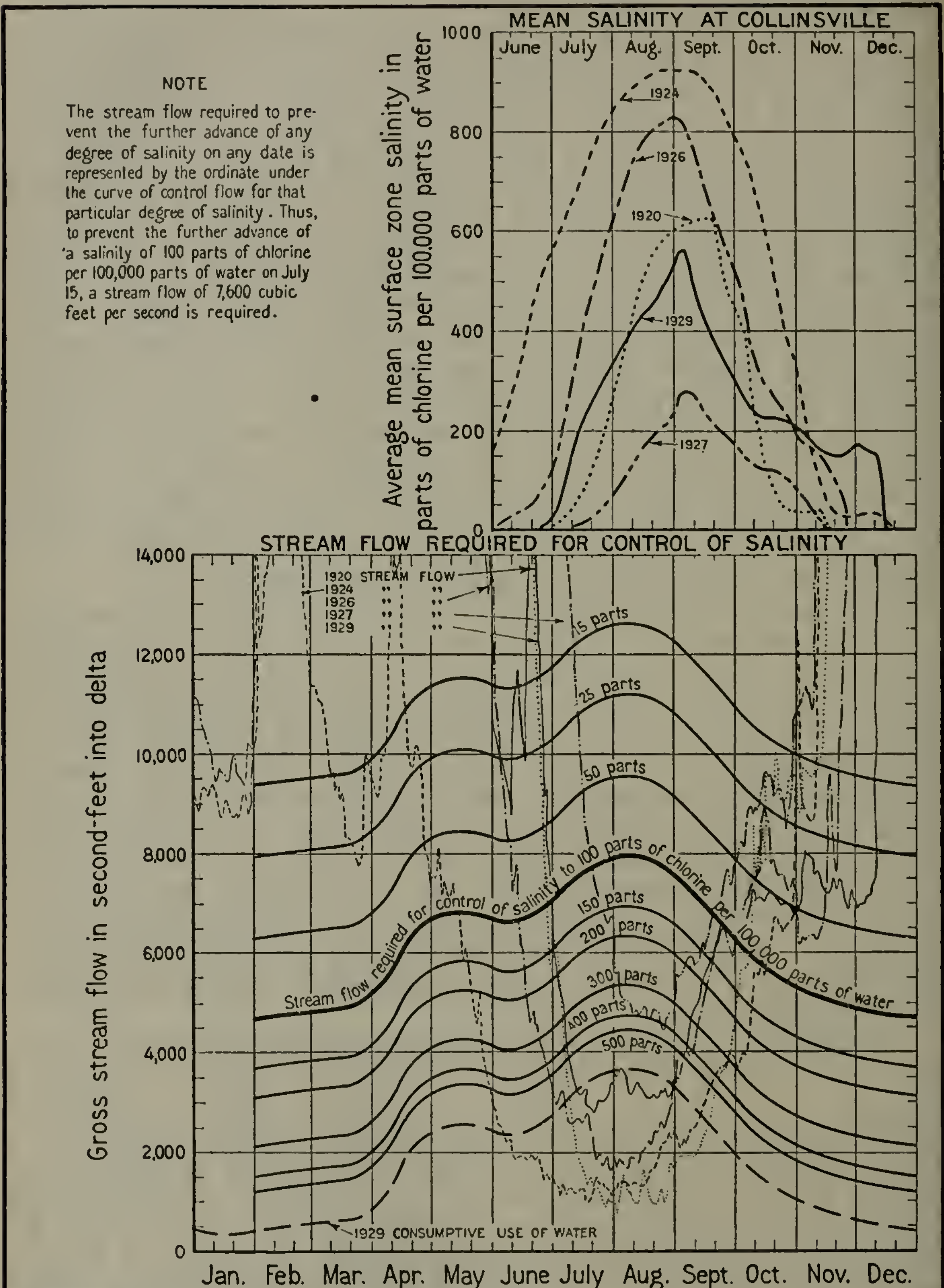
It is also interesting to compare the records of stream flow and salinity with the estimated control flows and salinities resulting therefrom during the period of advance and retreat of salinity in these several past years. It will be noted in each year that salinity did not start to advance at Antioch until the stream flow into the delta had decreased below the amount which the control curves indicate would be required to prevent the advance of salinity at the lower degrees. In general, the salinity started to increase immediately after the stream flow into the delta reached a rate less than the required amount shown for control at 15 parts of chlorine per 100,000 parts of water. Subsequently, the salinity continued to increase to higher degrees as the flow decreased to amounts less than those shown by the control curves as required to prevent further increase of salinity at these higher degrees. After the maximum salinities of the season were reached and retreat of salinity was in progress, the salinity continued to retreat below a particular degree of salinity when the actual stream flow became greater in magnitude than the control flow into the delta shown by the curves as required for that particular degree. These comparisons further demonstrate the essential accuracy of the control curves.

For any particular degree of salinity, there actually would be required a greater rate of flow to effect retreat than to prevent advance of salinity. This was demonstrated by tidal diffusion studies which were carried out in the investigation, covering the period of retreat of salinity in the same manner as those presented in Chapter IV for the period of advance of salinity. These studies were omitted from the report because of the fact that, from the standpoint of control or limitation of advance of salinity, it is necessary only to give consideration to the magnitude of tidal diffusion during advance of salinity. However, the fact that a greater rate of flow is required to effect retreat of salinity is of importance and points to the desirability of always maintaining a flow not less than the required amount for the desired point and degree of control, in order to obtain the most effective utilization of control flows.

As a matter of interest and comparison, control curves for Collinsville and O. and A. ferry, prepared similarly to those for the adopted point of control below Antioch, are shown on Plates LXXX and LXXXI, respectively. For the same degree of control; namely, for a mean tidal cycle surface zone salinity of 100 parts of chlorine per 100,000 parts of water, the maximum rates of gross control flow into the delta for Collinsville and O. and A. ferry amount to 8000 and 10,800 second-feet, respectively, as compared to 7000 second-feet at the proposed point of control. The relative magnitude of control flows at other times during the season and for different degrees of salinity are in about the same proportion.

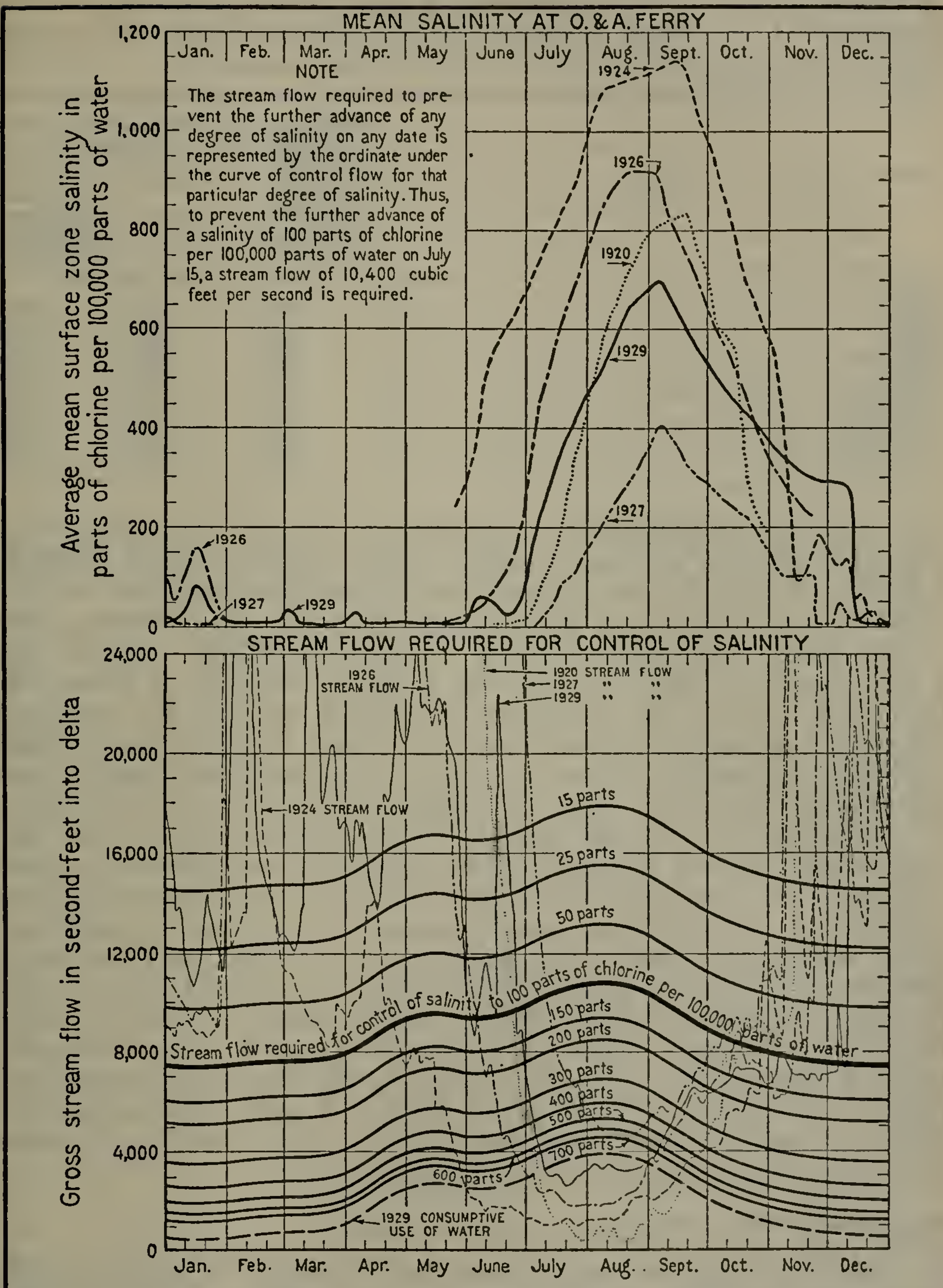
It is of value at this point to compare the determinations of gross stream flow for control as shown on Plates LXXIX, LXXX and LXXXI with the rates of stream flow into the delta related to maximum salinity as shown on Plate XX. It will be recalled that the average time of occurrence of maximum salinity during the season was about

PLATE LXXX



GROSS STREAM FLOW INTO DELTA
FOR
CONTROL OF SALINITY
AT
COLLINSVILLE
WITH COMPARATIVE STREAM FLOW AND SALINITY RECORDS FOR YEARS 1920-'24-'26-'27 AND '29

PLATE LXXXI



GROSS STREAM FLOW INTO DELTA
FOR
CONTROL OF SALINITY
AT
O. & A. FERRY
WITH COMPARATIVE STREAM FLOW AND SALINITY RECORDS FOR YEARS 1920-'24-'26-'27 AND '29

September 1. The comparative amounts of stream flow into the delta as shown by the curves on Plate XX and by the control curves for September 1 on Plates LXXIX, LXXX and LXXXI, for various degrees of salinity, are shown in the following tabulation:

Station	Maximum mean tidal cycle surface zone salinity in parts of chlorine per 100,000 parts of water	Rate of stream flow into delta in second-feet	
		From plate XX	Control flow from plates LXXIX, LXXX and LXXXI
Antioch	100	±6,700	6,600
Antioch	150	6,000	5,800
Antioch	200	5,400	5,300
Collinsville	100	±7,300	7,600
Collinsville	150	6,700	6,600
Collinsville	200	6,000	6,000
O. & A. Ferry	300	±6,600	6,500
O. & A. Ferry	350	6,100	6,000
O. & A. Ferry	400	5,600	5,500

The flows obtained from the curves on Plate XX, while not considered as accurate as those from the control curves on Plates LXXIX, LXXX and LXXXI, nevertheless furnish an additional check on the accuracy of the estimated gross control flows for one particular time of the year. The control curves on Plates LXXIX, LXXX and LXXXI are not only more accurate than the relations of Plate XX, but also have the great advantage of showing the gross flow required for control at any time of the year and for any degree of salinity and especially for smaller degrees of salinity than could be obtained from the available data from which the relations on Plate XX were evolved.

Although the analyses leading to the determination of the flow required for control of salinity have necessarily been rather involved because of the complexity of the basic factors governing the same, the estimates of control flow are amply supported by the more simple and direct relations of salinity and stream flow as determined from actual records for the 10-year period, 1920 to 1929. The rate of flow required for control of salinity and the positive effectiveness of control by stream flow do not rest upon theory, but are supported by the observed occurrence of natural control actually effected by the stream flow during this past 10-year period. The proposed control of salinity by stream flow offers not only a positive and dependable means of control, but also one that would be feasible of consummation.

Supplemental Water Supply for Control of Salinity.

In order to provide the proposed flow for control of salinity, additional water supplies would be required to supplement the stream flow available as under conditions of the last 10 years or more. The supplemental water supply required may be readily ascertained from a comparison of the available stream flow and required control flow. Estimates have been made, based upon the records of stream flow into the delta from 1920 to 1929 and the estimates of gross control flow for the proposed control at Antioch. The gross control flow provides for a net flow of not less than 3300 second-feet in the combined channels of the Sacramento and San Joaquin rivers past Antioch into Suisun Bay and the variable consumptive demands of the delta as estimated for 1929. This gross control flow is shown by the curve on Plate LXXIX, marked "Stream Flow Required for Control of Salinity to 100 Parts of Chlorine per 100,000 Parts of Water." The amounts of supplemental flow for several years of this period are indicated graphically on this plate, as the difference between the curve of gross control flow for 100 parts and the hydrograph of actual stream inflow for these years. The area between the two curves is a direct measure of the supplemental flow required, and the rate of supplemental flow required on any particular day is measured by the ordinate between the two curves.

The amounts of supplemental flow required by months and by seasons, with stream flow as during the past 10 seasons from 1919–1920 to 1928–29, are summarized in Tables 28 and 29. In Table 28, the monthly inflow into the delta and the estimated monthly consumption in the delta are shown in the first and second columns respectively and the third column shows the inflow in excess of consumption which, if positive, would be available for control of salinity at the mouth of the river. The negative quantities in this column indicate an excess of consumption over inflow. The last three columns in the table show the estimated monthly supplemental supply to provide the net flow for control of salinity and also to take care of the shortages in the inflow meeting the consumptive demands in the delta. Separate quantities are shown for control of mean tidal cycle surface zone salinity to 100, 50 and 25 parts of chlorine per 100,000 parts of water. The annual summaries presented in Table 29 show the shortages by excess of consumption in the delta over inflow both for the entire year and the maximum month in each year, and the amount of supplemental flow required for salinity control and shortages between supply and consumptive demands for both the entire year and the maximum month. Separate quantities are shown for control for mean tidal cycle surface zone salinities of 100 and 50 parts of chlorine per 100,000 parts of water.

For the proposed degree of control to 100 parts of chlorine per 100,000 parts of water, the maximum amount of supplemental supply would have been required in 1924, the driest year of record up to 1930, with a total of 1,128,000 acre-feet for the year and a maximum monthly amount of 330,000 acre-feet. Of this maximum annual supplemental supply in 1924, the shortage by reason of excess of consumptive demand over supply in the delta amounts to 277,000 acre-feet, with a maximum monthly shortage of 127,000 acre-feet. As to total annual supplemental supply required, the year 1920 is next in magnitude. However, the data indicate that the maximum monthly supplemental supply required in 1920 exceeds that of the maximum month in 1924 by 24,000 acre-feet. Likewise in 1920, the annual shortage in the supply meeting the consumptive demands in the delta totals 225,000 acre-feet, with a maximum monthly shortage of 151,000 acre-feet. The minimum total annual supplemental supply would have been required in 1923, amounting to 149,000 acre-feet, with about the same amount in 1927. The requirements in 1922 would not have been much greater. These years of 1922, 1923 and 1927 represent about average stream flow into the delta during the summer months under present conditions of upstream irrigation and storage developments.

TABLE 28

MONTHLY SUPPLEMENTAL WATER SUPPLY FOR CONTROL OF SALINITY 0.6 MILES BELOW ANTIOCH AND FOR SHORTAGES BETWEEN AVAILABLE SUPPLY AND CONSUMPTIVE USE IN DELTA

Year and month	Inflow into delta in acre-feet	Estimated consumption in delta in acre-feet	Inflow in excess of consumption in acre-feet	Required supplemental supply for salinity control* and for shortage between supply and consumption in delta in acre-feet		
				Control to a mean tidal cycle salinity of 100 parts of chlorine per 100,000 parts of water	Control to a mean tidal cycle salinity of 50 parts of chlorine per 100,000 parts of water	Control to a mean tidal cycle salinity of 25 parts of chlorine per 100,000 parts of water
1920—						
June	1,044,000	148,000	+896,000	8,000	10,000	27,000
July	130,000	204,000	−74,000	277,000	357,000	443,000
August	70,000	221,000	−151,000	354,000	434,000	520,000
September	168,000	158,000	+10,000	186,000	264,000	347,000
October	510,000	90,000	+420,000	—	11,000	31,000
1921—						
June	2,360,000	148,000	+2,212,000	—	—	—
July	539,000	204,000	+335,000	28,000	48,000	112,000
August	262,000	221,000	+41,000	162,000	242,000	328,000
September	275,000	158,000	+117,000	79,000	157,000	240,000
October	423,000	90,000	+333,000	—	3,000	40,000
November	520,000	46,000	+474,000	—	—	—
1922—						
July	974,000	204,000	+770,000	7,000	21,000	50,000
August	306,000	221,000	+85,000	118,000	198,000	284,000
September	314,000	158,000	+156,000	64,000	118,000	201,000
October	551,000	90,000	+461,000	—	—	8,000
1923—						
July	712,000	204,000	+508,000	7,000	24,000	60,000
August	312,000	221,000	+91,000	112,000	192,000	278,000
September	405,000	158,000	+247,000	30,000	78,000	140,000
October	624,000	90,000	+534,000	—	—	—
1924—						
April	622,000	105,000	+517,000	—	—	5,000
May	350,000	155,000	+195,000	60,000	100,000	174,000
June	113,000	148,000	−35,000	231,000	309,000	392,000
July	77,000	204,000	−127,000	330,000	410,000	496,000
August	106,000	221,000	−115,000	318,000	398,000	484,000
September	183,000	158,000	+25,000	171,000	249,000	332,000
October	375,000	90,000	+285,000	18,000	38,000	95,000
November	789,000	46,000	+743,000	—	—	—
1925—						
June	1,422,000	148,000	+1,274,000	—	—	—
July	441,000	204,000	+237,000	56,000	92,000	156,000
August	227,000	221,000	+6,000	197,000	277,000	363,000
September	334,000	158,000	+176,000	48,000	100,000	181,000
October	522,000	90,000	+432,000	—	—	3,000
1926—						
May	1,385,000	155,000	+1,230,000	—	—	—
June	367,000	148,000	+219,000	48,000	90,000	161,000
July	144,000	204,000	−60,000	263,000	343,000	429,000
August	141,000	221,000	−80,000	283,000	363,000	449,000
September	309,000	158,000	+151,000	65,000	123,000	206,000
October	462,000	90,000	+372,000	—	—	14,000
1927—						
July	591,000	204,000	+387,000	12,000	34,000	70,000
August	299,000	221,000	+78,000	125,000	205,000	291,000
September	388,000	158,000	+230,000	13,000	58,000	127,000
October	564,000	90,000	+474,000	—	—	—
1928—						
June	605,000	148,000	+457,000	1,000	16,000	48,000
July	293,000	204,000	+89,000	114,000	194,000	280,000
August	218,000	221,000	−3,000	206,000	286,000	372,000
September	360,000	158,000	+202,000	38,000	76,000	155,000
October	488,000	90,000	+398,000	—	—	8,000
1929—						
June	689,000	148,000	+541,000	—	3,000	6,000
July	212,000	204,000	+8,000	195,000	275,000	361,000
August	196,000	221,000	−25,000	228,000	308,000	394,000
September	324,000	158,000	+166,000	57,000	108,000	191,000
October	423,000	90,000	+333,000	—	—	40,000
November	434,000	46,000	+388,000	—	—	—

*The net flows for control of salinity at Antioch to 100, 50 and 25 parts are respectively 3,300, 4,600 and 6,000 second-feet.

TABLE 29

ANNUAL SUPPLEMENTAL WATER SUPPLY FOR CONTROL OF SALINITY 0.6 MILES BELOW ANTIOCH AND FOR SHORTAGES BETWEEN AVAILABLE SUPPLY AND CONSUMPTIVE USE IN DELTA

Year	Shortage between supply and consumption in delta in acre-feet		Required supplemental supply for salinity control* and for shortage between supply and consumption in delta in acre-feet			
			Control to a mean tidal cycle salinity of 100 parts of chlorine per 100,000 parts of water		Control to a mean tidal cycle salinity of 50 parts of chlorine per 100,000 parts of water	
	Total annual	Maximum monthly	Total annual	Maximum monthly	Total annual	Maximum monthly
1920	225,000	151,000	825,000	354,000	1,076,000	434,000
1921	0	0	269,000	162,000	450,000	242,000
1922	0	0	189,000	118,000	337,000	198,000
1923	0	0	149,000	112,000	294,000	192,000
1924	277,000	127,000	1,128,000	330,000	1,504,000	410,000
1925	0	0	301,000	197,000	469,000	277,000
1926	140,000	80,000	659,000	283,000	919,000	363,000
1927	0	0	150,000	125,000	297,000	205,000
1928	3,000	3,000	359,000	206,000	572,000	286,000
1929	25,000	25,000	480,000	228,000	694,000	308,000
Ten year average	67,000	39,000	451,000	212,000	661,000	292,000

*The net flows for control of salinity at Antioch to 100 and 50 parts of are respectively 3,300, and 4,600 second-feet.

The total annual amount of supplemental water supply which would have been required during the period 1920 to 1929 to provide only the net control flow of 3300 second-feet past Antioch varies from a minimum of about 150,000 acre-feet in 1923 and 1927 to a maximum of about 850,000 acre-feet in the exceedingly dry year of 1924, 600,000 acre-feet in 1920 and 519,000 acre-feet in the next driest year of 1926. The average for the 10-year period would have been 384,000 acre-feet.

With these supplemental supplies provided during each year of the period, 1920 to 1929, saline invasion would have been controlled and the increase of salinity at Antioch would have been limited to a maximum degree of mean tidal cycle surface zone salinity of 100 parts of chlorine per 100,000 parts of water. Moreover, the water in over 95 per cent of the delta channels, from Emmaton and Jersey upstream, would have been practically fresh. Assuming in each of these years that no additional water supply had been provided beyond that which actually flowed into the delta until such time as the actual flow was less than the required flow for the proposed control at Antioch, and that, thereafter, the required supplemental supplies for control had been provided, the salinity would have increased at Antioch and at other points in the same manner as during these previous years until a mean tidal cycle surface zone salinity of 100 parts of chlorine per 100,000 parts of water was reached at Antioch; but after having reached this degree, the mean salinity would have increased no farther, either at the control station or at points up and downstream.

Works Required for Proposed Control of Salinity by Stream Flow.

The proposed plan for control of salinity by stream flow would involve the construction of mountain storage reservoirs in order to provide required water supplies for release during the summer period of low stream flow to supplement the supply of water otherwise available and flowing into the delta. The studies of water supply, yield and demand in the operation of major storage units for both the initial and ultimate developments of the State Water Plan* show that ample supplies could be made available to fully meet the requirements for the proposed control of salinity by stream flow, in addition to the demands of the Great Central Valley, delta and upper San Francisco Bay region.

In addition to the storage works which would have to be provided to furnish the supplemental water supplies required, it would be necessary also to construct additional channel capacity between the Sacramento River and the San Joaquin Delta. As shown in Chapter III, the present channel capacity provided by the two interconnecting channels of Georgiana and Three Mile sloughs are hardly sufficient to take care of the consumptive demands in the San Joaquin Delta, if all or most of the water supply required were to come from the Sacramento River. The net stream flow past Antioch required for prevention of saline invasion into the delta, under the proposed plan of salinity control, must be distributed in both the Sacramento and San Joaquin River channels, in proportion to the magnitude of tidal diffusion in the two channels. Inasmuch as the tidal basin of the San Joaquin Delta is larger in volume than that in the Sacramento Delta, the amount of tidal flow and the magnitude of tidal diffusion in the lower San Joaquin River is greater than that in the lower Sacramento River in approximately the same proportion. The tidal diffusion as computed in the lower channels of the delta appertains to the combined channels of the Sacramento and San Joaquin rivers (see Plates LXXIV, LXXV and LXXVI), and has been determined empirically from the records of stream flow and salinity during the period 1920 to 1929. In all cases in this period, the diffusion quantities for the low degrees of salinity, as computed from the actual records, have been for conditions when there were considerable amounts of stream flow entering the San Joaquin Delta from the San Joaquin River and its tributaries. However, these would not be the conditions in future years if, as appears likely during periods of low flow and maximum demands in the delta, all or most of the water supply for the delta would have to be furnished from the Sacramento River, with little if any supply coming in from the San Joaquin River and its branches, especially with the further increase of storage and irrigation diversions which may be anticipated on the San Joaquin River system. The present connecting channels (see Chapter III) would not give the San Joaquin Delta the portion of the total inflow required. Therefore, it would be necessary to provide additional channel capacity from the Sacramento River to San Joaquin Delta, of such magnitude that complete flexibility in the distribution of the inflow would be available to allow the water to flow automatically to the portions of the basin where needed to satisfy the consumptive demands and the demands of salinity control. This required additional channel capacity, for flexible distribution of water supply furnished from the Sacramento River to control salinity and supply the consumptive demands of the delta, could be combined with the require-

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* Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930.
Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

ment of additional channel capacity for transfer of surplus water from the Sacramento River to the San Joaquin Delta, for exportation to the San Joaquin Valley by the San Joaquin River Pumping System of the proposed State Water Plan.

The preliminary plans * for additional channel capacity between the Sacramento River and the San Joaquin Delta provide for the construction of a new channel from a point on the Sacramento River below Hood, extending along the old natural channel of Snodgrass Slough to a triple connection with Georgiana Slough and the north and south forks of the Mokelumne River. These latter channels then would be enlarged to some extent to Central Landing. From this point the water would flow to the various portions of the San Joaquin Delta where needed. The proposed plan for opening up and enlarging the old natural channel of Snodgrass Slough would be essentially a restoration of original natural conditions before reclamation development closed off this natural connecting slough as well as several other smaller connecting channels.

Results of Proposed Control of Salinity.

It is of particular interest to consider the results which would be obtained from the proposed plan of controlling salinity at the lower end of the delta by stream flow. It has been demonstrated previously that the proposed control at a point below Antioch would provide fresh water of ten parts or less of chlorine per 100,000 parts of water in the channels above Emmaton and Jersey, or in over 95 per cent of the delta. Below the proposed control point, salinity would continue to vary in a similar manner as during the last ten years or more, except that the maximum salinity at points in Suisun Bay would be definitely limited and the modification of stream flow resulting from the proposed State Water Plan of storage regulation and release for various purposes, including control of salinity, would modify to some extent the saline conditions throughout the year. Hence, it is of importance to determine, if possible, the salinity conditions under the proposed plan of control and compare the same with those which actually occurred.

In both the initial and ultimate stages of development of the State Water Plan,*† provision has been made in the proposed operation of the storage units to furnish without deficiency water requirements of the Sacramento-San Joaquin Delta, including the full consumptive demands and the required supply for salinity control at the lower end of the delta to give positive protection to the water supplies and the lands and developments within the delta area. For the present study, the effect on salinity conditions of the operation of the initial development is considered to be of chief concern. In the proposed initial plan of development, Kennett Reservoir would be constructed with a storage capacity of 2,940,000 acre-feet, and operated to accomplish the following purposes: (See Plates I and II.)

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* Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930.

Bulletin No. 29, "San Joaquin River Basin," Division of Water Resources, 1931.

† Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

1. Floods on the Sacramento River would be controlled to 125,000 second-feet maximum flow at Red Bluff exceeded once in fourteen years on the average.
2. A navigable depth on the Sacramento River of five to six feet would be maintained from the city of Sacramento to Chico Landing with a substantial increase in depths from this latter point to Red Bluff.
3. Irrigation demands on the Sacramento River above Sacramento would be supplied, without deficiency, up to 6000 second-feet maximum draft in July.
4. An irrigation supply without deficiency would be furnished the Sacramento-San Joaquin Delta for its present requirements.
5. A fresh-water flow would be furnished of not less than 3300 second-feet past Antioch into Suisun Bay, controlling salinity to the lower end of the Sacramento-San Joaquin Delta.
6. A water supply without deficiency would be made available in the delta for the developed industrial and agricultural areas along the south shore of Suisun Bay in Contra Costa County.
7. An irrigation supply without deficiency, would be made available in the Sacramento-San Joaquin Delta sufficient in amount to fully supply the ''cropped lands'' now being served from the San Joaquin River above the mouth of the Merced River. This would be conveyed to these lands by the San Joaquin River Pumping System and would make possible the exportation of all the available supply in the San Joaquin River at Friant.
8. An annual average of 1,581,100,000 kilowatt hours of hydroelectric energy would be generated incidental to other uses.

Under this proposed method of operation, the resulting modified stream flow both into the delta and into Suisun Bay, which would have occurred during the period 1919 to 1929, has been estimated by months. These estimates of modified stream flow have been used for estimating the average monthly salinity which would have occurred during the same period at points from the lower end of Suisun Bay to the lower delta.

In order to carry out a study of estimated salinity conditions under the proposed control flow and operation of the initial development of Kennett Reservoir, it was necessary first to obtain a relation between average monthly salinity and average monthly stream flow, based upon the actual records of salinity and stream flow for the period 1920 to 1929. This special analysis was made for four typical stations in the area between the lower end of Suisun Bay and the lower end of the delta, including Bulls Head Point, Bay Point, O. and A. ferry and Antioch. Curves showing the relation between average monthly stream flow and average monthly salinity were plotted from the data for each year of available record at each of these stations, separate curves resulting for the period of advance and the period of retreat of salinity. For any one year, the two curves provided an empirical relation between average monthly stream flow and salinity covering the cycle of variation of salinity during both advance and retreat.

These curves are similar in character to the tidal diffusion curves heretofore presented, but are substantially different in that the relation between average monthly salinity and stream flow involves the element of time required for salinity to advance or retreat during any particular month, whereas the tidal diffusion curves express an instantaneous relation between tidal diffusion, or net control stream flow, and degree of salinity. The relation established therefore depends upon the variation of stream flow during the month and from month to month in any particular year. For this reason the curves of relation are considerably different in different years of record, depending upon the variation of stream flow.

Based upon these curves of empirical relation established from the actual records, estimates have been made of average monthly and maximum seasonal salinity, for the modified stream flow resulting from the initial plan of operation and development of the State Water Plan. The estimated salinities for each year from 1919 to 1929, inclusive, are shown in Table 30. The tabulation summarizes the maximum salinity for the season and the minimum and mean values of average monthly salinity for each year.

For comparative purposes the table also shows corresponding values of salinity from actual records, and estimated values of salinity actually occurring during years for which no records were available. No records of salinity were available at Antioch and O. and A. ferry prior to 1920, at Bay Point prior to 1926 and at Bulls Head Point prior to 1924. For these missing years of record, the estimated degrees of salinity which actually occurred were obtained from the curves of relation established from years of record, by applying the actual stream flow. These estimates of salinity which actually occurred were made for all four stations for the years 1912 to 1919, and also for the years 1920 to 1925 for Bay Point and 1920 to 1923 for Bulls Head Point. An entirely independent analysis was made also to check these estimates of salinity which actually occurred, based upon a relation established between mean monthly salinity and the water barge travel of the California and Hawaiian Sugar Refining Corporation (see Plate IV). Using the barge travel and the actual records of related salinity available during the last ten years, a relation was established between the distance in miles that the barge traveled above Crockett, averaged over a month, and the corresponding average monthly salinities at points downstream. This relation was then applied to the average monthly barge travel during the years of missing salinity records. The results of this independent method of analysis checked the previous method of analysis within reasonable limits. There were also a few scattered records of salinity at various points in the Suisun Bay area during the period of missing records, which provided some further check of the estimated values of actual salinity. In all cases the records of salinity checked the estimated values within reasonable limits. As a result of these independent checks on the primary basis of estimating mean salinity for both actual and modified stream flow, it is believed that the estimates presented in Table 30 may be considered to be a close approximation.

TABLE 30

COMPARISON OF SALINITY UNDER PROPOSED PLAN OF SALINITY CONTROL WITH ACTUAL SALINITY AND WITH SALINITY UNDER NATURAL STREAM FLOW

Mean tidal cycle surface zone salinity in parts of chlorine per 100,000 parts of water

Station and year	Estimated salinity with modified stream flow[1]			Actual salinity[2]			Estimated salinity with natural stream flow[3]		
	Maximum for season	Minimum average monthly	Mean of average monthly	Maximum for season	Minimum average monthly	Mean of average monthly	Maximum for season	Minimum average monthly	Mean of average monthly
Antioch									
1912	--------	--------	--------	*30	*0 to 10	*0 to 10	10	0 to 10	0 to 10
1913	--------	--------	--------	*50	*0 to 10	*10	30	0 to 10	0 to 10
1914	--------	--------	--------	*50	*0 to 10	*10	20	0 to 10	0 to 10
1915	--------	--------	--------	*60	*0 to 10	*10	20	0 to 10	0 to 10
1916	--------	--------	--------	*60	*0 to 10	*10	10	0 to 10	0 to 10
1917	--------	--------	--------	*60	*0 to 10	*15	40	0 to 10	10
1918	--------	--------	--------	*190	*0 to 10	*40	80	0 to 10	10
1919	100	0 to 10	20	*220	*0 to 10	*50	100	0 to 10	20
1920	100	0 to 10	20	592	0 to 10	109	140	0 to 10	20
1921	80	0 to 10	10	185	0 to 10	24	80	0 to 10	20
1922	80	0 to 10	10	194	0 to 10	22	90	0 to 10	15
1923	100	0 to 10	15	116	0 to 10	19	40	0 to 10	10
1924	100	0 to 10	40	815	0 to 10	246	400	0 to 10	65
1925	100	0 to 10	20	180	0 to 10	38	40	0 to 10	10
1926	100	0 to 10	30	731	0 to 10	152	160	0 to 10	25
1927	80	0 to 10	10	130	0 to 10	21	40	0 to 10	10
1928	100	0 to 10	25	319	0 to 10	62	120	0 to 10	30
1929	100	0 to 10	X	425	0 to 10	97	180	0 to 10	X
O. and A. Ferry									
1912	--------	--------	--------	*130	*0 to 10	*40	90	0 to 10	35
1913	--------	--------	--------	*200	*0 to 10	*60	150	0 to 10	40
1914	--------	--------	--------	*170	*0 to 10	*40	140	0 to 10	35
1915	--------	--------	--------	*170	*0 to 10	*40	100	0 to 10	30
1916	--------	--------	--------	*170	*0 to 10	*35	100	0 to 10	30
1917	--------	--------	--------	*190	*0 to 10	*50	150	0 to 10	50
1918	--------	--------	--------	*400	*0 to 10	*100	270	0 to 10	75
1919	280	0 to 10	85	*520	*0 to 10	*150	300	0 to 10	90
1920	280	0 to 10	85	834	0 to 10	182	420	0 to 10	110
1921	260	0 to 10	65	454	0 to 10	115	250	0 to 10	70
1922	260	0 to 10	60	435	0 to 10	87	250	0 to 10	40
1923	280	0 to 10	75	417	0 to 10	92	170	0 to 10	60
1924	280	40	140	1,146	20	423	650	20	190
1925	280	0 to 10	80	444	0 to 10	111	160	0 to 10	55
1926	280	0 to 10	95	915	0 to 10	272	400	0 to 10	85
1927	260	0 to 10	60	403	0 to 10	87	160	0 to 10	40
1928	280	0 to 10	100	587	0 to 10	138	350	0 to 10	100
1929	280	30	X	700	10	218	180	0 to 10	X
Bay Point									
1912	--------	--------	--------	*450	*80	*220	350	30	150
1913	--------	--------	--------	*600	*60	*240	480	0 to 10	170
1914	--------	--------	--------	*500	*0 to 10	*150	480	0 to 10	160
1915	--------	--------	--------	*500	*0 to 10	*150	400	0 to 10	130
1916	--------	--------	--------	*520	*0 to 10	*140	350	0 to 10	110
1917	--------	--------	--------	*550	*30	*210	500	0 to 10	200
1918	--------	--------	--------	*800	*40	*300	680	40	280
1919	700	30	300	*900	*0 to 10	*330	700	20	290
1920	700	50	280	*1,200	*30	*390	800	40	300
1921	680	10	230	*850	*10	*270	650	0 to 10	220
1922	680	10	200	*800	*0 to 10	*230	650	0 to 10	220
1923	700	50	260	*750	*60	*280	500	20	200
1924	700	210	440	*1,350	*170	*680	900	140	450
1925	700	30	280	*800	*0 to 10	*320	500	0 to 10	200
1926	700	40	320	1,320	20	486	800	10	270
1927	680	0 to 10	210	830	10	236	500	0 to 10	140
1928	700	0 to 10	300	910	10	388	700	0 to 10	280
1929	700	170	X	980	100	484	850	80	X

[1] The modified stream is that resulting from the operation of the initial development of the State Water Plan, with Kennett Reservoir (capacity 2,940,000 acre-feet) operated for various purposes, including the proposed control of salinity to the lower end of the delta near Antioch.

[2] Based upon actual records of salinity and estimates of salinity which actually occurred with stream flow during the period of record.

[3] Natural stream flow, based on estimates presented in Chapter III, which would have occurred if upstream irrigation and water supply developments were not in operation.

X Insufficient data for estimating salinity.

* Estimated.

TABLE 30—Continued

COMPARISON OF SALINITY UNDER PROPOSED PLAN OF SALINITY CONTROL WITH ACTUAL SALINITY AND WITH SALINITY UNDER NATURAL STREAM FLOW

Mean tidal cycle surface zone salinity in parts of chlorine per 100,000 parts of water

Station and year	Estimated salinity with modified stream flow[1]			Actual salinity[2]			Estimated salinity with natural stream flow[3]		
	Maximum for season	Minimum average monthly	Mean of average monthly	Maximum for season	Minimum average monthly	Mean of average monthly	Maximum for season	Minimum average monthly	Mean of average monthly
Bulls Head Point									
1912	---------	---------	---------	*800	*280	*520	840	180	480
1913	---------	---------	---------	*900	*200	*490	900	170	490
1914	---------	---------	---------	*850	*0 to 10	*330	900	0 to 10	350
1915	---------	---------	---------	*800	*20	*330	800	0 to 10	330
1916	---------	---------	---------	*800	*50	*310	800	30	300
1917	---------	---------	---------	*900	*130	*430	900	100	440
1918	---------	---------	---------	*1,100	*150	*570	1,000	140	530
1919	1,050	130	550	*1,200	*130	*580	1,000	100	500
1920	1,200	230	640	*1,650	*100	*710	1,020	140	540
1921	1,050	90	460	*1,200	*50	*520	950	70	410
1922	950	100	420	*1,050	*50	*400	900	60	360
1923	1,050	240	560	*1,000	*200	*530	900	150	450
1924	1,200	640	880	1,590	300	951	1,100	450	740
1925	1,100	100	540	1,090	100	529	950	70	460
1926	1,200	130	620	1,540	40	718	1,000	100	490
1927	1,100	40	450	1,020	30	436	900	40	350
1928	1,150	70	610	1,110	40	615	950	80	480
1929	1,150	510	X	1,170	380	717	1,030	250	X

[1] The modified stream flow is that resulting from the operation of the initial development of the State Water Plan, with Kennett Reservoir (capacity 2,940,000 acre-feet) operated for various purposes, including the proposed control of salinity to the lower end of the delta near Antioch.

[2] Based upon actual records of salinity and estimates of salinity which actually occurred with stream flow during the period of record.

[3] Natural stream flow, based on estimates presented in Chapter III, which would have occurred if upstream irrigation and water supply developments were not in operation.

X Insufficient data for estimating salinity.

* Estimated.

Based upon estimates of reduction in stream flow into the delta for the period 1912 to 1929, as presented in Chapter III, it is also possible to obtain an approximation of the salinity conditions which would have occurred if natural stream flow unimpaired by upstream irrigation and storage developments had been available in these years. The estimates of salinity under conditions of unimpaired natural stream flow are of considerable value inasmuch as there has been a conflict of opinion expressed in regard to the probable salinity conditions in Suisun Bay as they naturally occurred prior to the extensive developments of irrigation and storage works on the upper Sacramento and San Joaquin River systems. Therefore, although there has been ample evidence previously presented in this report to show that saline water annually invaded Suisun Bay to the lower end of the delta in early years before any upstream developments occurred, the possibility of estimating the salinity under natural stream flow conditions provides a basis for further confirmation. Based upon the estimated amounts of reduction in stream flow combined with the records and estimates of the actual inflow into the delta, estimates have been made of average monthly salinity which would have occurred under conditions of unimpaired stream flow into the delta by applying the estimated amounts of unimpaired stream flow to the relations established between monthly stream flow and average monthly salinity from records of recent years, as previously described. These estimates of salinity with natural stream flow are tabulated in Table 30, and afford an opportunity of directly comparing estimated salinity under natural stream flow conditions with the observed and estimated salinity which actually occurred, and also with predicted salinity which would have resulted from the proposed control of salinity by stream flow under the proposed plan of control and operation with the initial development of Kennett Reservoir.

The comparative values of predicted and actual salinity shown in Table 30 indicate that salinity conditions for Suisun Bay and the lower delta would have been substantially improved under the proposed plan of control as compared to those actually occurring during the ten-year period, 1919 to 1929. The maximum and average salinity would have been substantially reduced, especially in the upper part of Suisun Bay above Bay Point. Conditions at the lower end of Suisun Bay near Bulls Head Point would not have been materially changed, although the estimates indicate that some reduction of average annual salinity would have been effected under the modified regimen of stream flow, and the maximum salinity would have been reduced in certain years. On the other hand the minimum values of average monthly salinity near Bulls Head Point would have been increased to some extent in certain years due to the effect of storage regulation involved in the proposed operation of Kennett Reservoir. At points in the upper part of Suisun Bay above Bay Point, the minimum degrees of salinity would have been substantially the same as actually occurred during the period 1919 to 1929. This improvement in the quality of water of Suisun Bay, especially in the upper channels from the lower end of the delta to below Pittsburg, would be of value to the industrial developments along the south side of Suisun Bay. Corrosion of cooling water equipment would be decreased and the present attacks of the teredo on untreated timber piles of industrial water front structures would be prevented or materially reduced.

The comparative values of estimated salinity with the modified stream flow under the plan of proposed salinity control and under conditions of unimpaired natural stream flow are also significant. The estimates indicate that, with the modified flow resulting from the proposed operation of Kennett Reservoir under the initial development of the State Water Plan, salinity conditions in Suisun Bay would have been practically equivalent to those which would have prevailed if the stream flow naturally available had been allowed to flow unimpaired into the delta and Suisun Bay. In dry years, such as 1920, 1924 and 1926, and even in such years as 1928 and 1929, the maximum salinities at Antioch and O. and A. ferry would have been considerably less with the modified stream flow providing for proposed salinity control than with natural stream flow available, and hence salinity conditions would have been even better than under natural stream flow in some years.

Summarizing the foregoing studies, the proposed control of salinity by stream flow at the lower end of the delta coupled with the furnishing of required water supplies to meet the full consumptive demands of the delta would result in the following accomplishments:

1. The delta would be fully protected from any harmful saline invasion and the present salinity menace removed.
2. Ample and dependable irrigation supplies would be assured for the entire delta.
3. Land values in the delta would tend to be increased and the future possibility of expensive water right litigation between the delta and upstream water users would be eliminated.
4. The water in the channels of over 95 per cent of the delta would be fresh enough for industrial and domestic use. This would provide a suitable source of dependable fresh-water supplies for industrial, domestic, municipal and agricultural purposes in the upper bay region. Water supplies now or hereafter made available in the delta channels for these purposes could be feasibly conveyed by conduits.
5. The salinity of the waters in Suisun Bay would be reduced below that prevailing during the past ten years or more and would tend to approach the equivalent of conditions which would have occurred in the same years with natural stream flow unimpaired by upstream irrigation and storage diversions. The reduced salinity would benefit the industrial interests, especially in the upper Suisun Bay area, by decreasing corrosion and depreciation costs of cooling and condensing water equipment and by preventing or materially reducing the present destructive action of the teredo on untreated timber piling in water front structures.

Therefore, the proposed plan of controlling salinity by stream flow offers an effective remedy which, if adopted, and applied, would adequately take care of the salinity problem of the delta and upper bay region.

APPENDIX A

FIELD METHODS AND PROCEDURE IN SALINITY INVESTIGATION

FIELD METHODS AND PROCEDURE IN SALINITY INVESTIGATION

The program initiated in 1929 for the investigation of salinity in the Sacramento-San Joaquin Delta and upper San Francisco Bay was by far the most comprehensive and intensive in its scope of any undertaken in the previous years of salinity investigation by the State. Although much of the field work undertaken was conducted under methods and procedure similar to those used in previous years, the greatly increased magnitude and scope of the 1929 program of field investigation necessitated a perfection of organization, procedure and methods. Many original and novel methods were developed as the work proceeded. This appendix briefly describes the detailed procedure and methods employed in the field for the investigation of salinity in 1929.

Organization

The program carried out in 1929 required a much larger field organization than in any previous year. The organization of crews was effected and active work started immediately after the adoption of a program on May 20, 1929. During the course of the work from six to twenty-five men were employed directly in the field. These were grouped in various ways to meet the demands of the different special surveys and operations. Some of the special surveys required as many as twelve to fifteen men to a crew. Because of the large area to be covered, one of the most important necessities was efficient and adequate transportation. Crews were transported by automobile as far as possible, but much of the work required water transportation which was provided by special motor boats, and row boats or skiffs equipped with out-board motors. Much of the work on water had to be done at night under unfavorable weather conditions and with rough water, which at times made the work not only difficult but hazardous. Interference from passing commercial and pleasure craft and fishing boats and nets at times added to the difficulties.

Salinity Sampling at Regular Observation Stations

The sampling at the regular observation stations comprised a continuation of the program, but greatly enlarged, under which the variation of salinity had been observed at stations in the delta and upper bay for several years. The number of stations was increased greatly over previous years, 76 being maintained during most of the season. As the salinity gradually retreated from the delta in the latter part of the season, the number was reduced correspondingly. However, about eighteen stations were continuously maintained throughout the year, whereas, previously, such all-year stations were only seven in number.

Samples of water were taken by the local observers at all of these regular stations at four-day intervals about one and one-half hours after the predicted time for high tide and immediately below the water surface, designated as the surface zone. In order that the four-day intervals should be the same at all stations, definite arrangements were made for the sampling to be done after the high tides originating at the Golden Gate on the 2d, 6th, 10th, 14th, 18th, 22d, 26th and 30th of each month. Each observer was furnished with a schedule showing the exact time at which samples were to be taken. These schedules were prepared from the published tide tables of the U. S. Coast and Geodetic Survey for San Francisco Bay (at the Golden Gate) and data, previously collected but corrected later during the season, which furnished the average time allowance for travel of the high tide from the Golden Gate to each station. The times for sampling after both the high-high and low-high tides were given in the schedule but the observer was instructed to sample only after the high-high tide when possible. If not possible, or impracticable, the observer was instructed to sample after the low-high tide. At twenty-two stations, samples were taken after both high-high and low-high tide for a period of four months, and at Antioch, samples after both these tides were taken throughout the 1929 season. During periods of variable stream flow such as occurred in June and December, 1929, daily samples were taken at many of the stations.

The samples were taken by means of a weighted bottle and, to insure that there would be no carry-over of salt from a previous sampling, the observers were instructed to thoroughly rinse the bottle with the water in the channel just previous to sampling. Water from the sampling bottle was poured into a two-ounce mailing bottle. The observer filled in upon a sticker previously affixed to the mailing bottle at the laboratory the name of the station, the date, the actual time of sampling (something may have interfered with sampling at the scheduled time), and the tide, whether high-high or low-high. The two-ounce bottle was mailed in an individual cardboard and tin container, previously stamped and addressed, to the testing laboratory of the State Division of Highways at Sacramento, where the samples were analyzed. Upon completion of the analyses, the empty two-ounce bottles and mailing containers in cartons of fifteen were mailed by the laboratory to the observers.

The form used for reporting the results of the laboratory analyses is illustrated by the accompanying reduction shown in Figure 1. These forms were in quadruplet of standard letter size.

Form 128 SHEET 1 OF 3

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
Sacramento-San Joaquin Water Supervisor

Salinity Investigation in Delta of Sacramento and San Joaquin Rivers
Daily Laboratory Report of Analysis of Chlorine Content in Water

AT

OBSERVATION STATIONS

Sample taken one foot below water surface and approximately 1½ hours after high tide by local observers

__________________________________19____
(Month) (Day)

STATIONS	High High Tide			Low High Tide			Remarks
	Date	Time of Sample	Parts of Chlorine per 100,000 Parts Water	Date	Time of Sample	Parts of Chlorine per 100,000 Parts Water	
San Francisco—San Pablo & Suisun Bay:							
Point Orient							
Point Davis							
Bulls Head Point							
Bay Point							
O. and A. Ferry							
Innisfail Ferry							
North San Pablo Bay:							
Sonoma Creek Bridge							
Grand View							
Vallejo							
Cuttings Wharf							
Napa							
Petaluma							
Sacramento River Delta:							
Collinsville							
Mayberry							
Emmaton							
Three Mile Slough Bridge							
Rio Vista Bridge							
Junction Point							
Liberty Ferry							
Isleton Ferry							
Isleton Bridge							
Howard Ferry							
Sutter Slough							
R. D. 2068							
Little Holland Ferry							
Walnut Grove							

Figure 1

Tidal Cycle Salinity Surveys

This work involved the taking of samples at hourly intervals throughout a complete tidal cycle of about twenty-five hours and at vertical depth intervals of five or ten feet, depending on depth of water. It was always the endeavor to obtain at least four samples in the vertical including one in the surface zone (one-foot depth) and one two feet from the bottom.

As the results were to be used to determine the increase and decrease of the salinity with the rise and fall of the tide at the station selected, it was necessary to choose a point in the channel where there would be an unimpaired flow throughout the tidal cycle and where the depth would be representative of the average maximum depth. In some instances a wharf or a structure was found that provided a suitable sampling station. If no wharf or structure could be found, it was necessary to work from a boat.

At stations where it was anticipated that more than one series of samples would be taken, a permanent staff gage was set, and in some instances this gage was referred to a standard datum. At temporary stations a gage was set to an arbitrary datum and removed when the samples had been taken.

In order that the set of vertical samples should be truly representative of the variation of salinity in the vertical, it was necessary that there should be no delay between the taking of the samples. Various methods of sampling were considered and discarded because of requiring too much time, affording too great an opportunity for error under adverse field conditions, or other good reasons. In the first category were weighted bottles or containers and in the next, electrical indicating apparatus. It was considered highly desirable that a sample bottle of water be taken at the proper time and depth, thus insuring a semi-permanent field record and providing a sample which could be analyzed and checked at leisure under the best of conditions.

After trying out various methods, it was decided that some means of pumping a sample of water from the proper depth would overcome the objections outlined and would best answer the requirements. Extreme portability was desired and necessary if the work was to be properly completed at all of the locations selected for this special type of survey. It was considered that the apparatus constructed would be more or less standard for other types of special salinity surveys. Equipment was assembled as follows: A bucket-spray pump was converted by removing the screen and foot piece and welding in its place a one-half inch tee with the "run" horizontal. To one end of the tee was attached a street ell closed with a pipe plug and, at the other end, a hose adapter was inserted. This completed the pump which had a weight of about 7½ pounds. A high-grade one-half inch garden hose was chosen for a combined sounding line and conduit to convey the water from the desired depth. This was attached to the pump by a female coupling and the free end was closed with a one-half inch vertical check valve. This valve was only necessary when the work was from a wharf or other structure at some distance above the water and, in this case, eliminated the necessity for frequent priming of the pump. To permit rapid sampling even after dark, the hose was graduated by using hose clamps as markers with one clamp at the ten-foot mark, two clamps at the twenty-foot mark, and, similarly, additional clamps for greater depths. Heavy cord was wrapped at the intervening five-foot marks. This permitted the operator to determine the soundings in the dark by feeling the graduations. In most instances a standard fifteen-pound current meter weight was found sufficient to hold the hose sufficiently perpendicular for all practical purposes when sampling. This weight was fastened so that the bottom was just two feet from the end of the hose, thereby avoiding the possibility of the end of the hose touching bottom and pumping up mud. The capacity of fifty feet of one-half inch hose is about one-half gallon. Therefore, to insure a complete flushing of the apparatus, a gallon of water was pumped before taking each sample. When depths necessitated using two lengths of hose, double the amount was pumped. This apparatus was used very successfully in water with a depth of eighty-six feet and a velocity of about six feet per second. However, with such high velocities, it was necessary to use a graduated stay line, manipulated by an extra man, to maintain the hose in a vertical position.

The containers used for water samples were the standard two-ounce sample bottles. They were packed in a box made from standard box shook and holding about 180 bottles. This number was found sufficient for the average set of samples. The bottles were labeled in advance with a printed sticker for filling in the following data: Name of station, date, test no. and depth. To avoid the possibility of mixing the sample bottles, the men were not permitted to mark the labels in advance on a greater number of bottles than would be used immediately for a group of test samples.

A report form in quadruplet (standard letter size) was kept in the field and when the survey was finished it was put in the box with the samples to be taken to the laboratory. This form is shown reduced in size in Figure 2. The field men were required to fill in the blank spaces in the heading, test number (for each group of samples) and staff gage reading. The standard depth referring to a particular gage height was taken when conditions were favorable, usually at slack water, and furnished a check on the rest of the sampling.

When it was necessary to work from a boat, a buoy carrying a lantern was anchored in the channel at a point selected for sampling to mark the location after dark. In some instances, the travel on the river rendered this impossible so that it was necessary to rely to some extent on the judgment of the men to anchor their boat in about the same place for each group of samples. The buoy used was patterned after those used by fishermen to indicate the location of their nets. It was shaped like a small wooden sled and was about two by three feet in size with runners made from 2″ x 4″ stock. This sled worked satisfactorily except in very rough water when the spray would splash on the lantern and break the globe. The sled was fastened to a suitable anchor for which the weight and length of rope were determined according to the depth of water and velocity of the current. A length of rope fastened to the sled and kept afloat by a wooden block aided in tying to the buoy and, when maneuvering at night, eliminated the danger of bumping the buoy with the boat.

STATE OF CALIFORNIA—DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SACRAMENTO-SAN JOAQUIN WATER SUPERVISOR

Salinity Investigation in Delta of Sacramento and San Joaquin Rivers
Laboratory Report of Analysis of Chlorine Content in Water for Period

OF

TIDAL CYCLE

STATION________________________

Tidal Cycle Survey No.____Date________19____Depth______feet at______gage height
(At beginning)

Chlorine content for standard sample______parts per 100,000 (Sample taken one foot below water surface and at specified time after high tide, approximately 1½ hours, in accordance with instruction to local observer at this station. Standard sample for this tidal cycle is at one foot depth for Test____________)

Test No.	Time	Gage Height	Chlorine Content in Parts per 100,000 for Depth in Feet Below Surface of						Remarks

T. E. STANTON
Materials and Research Engineer

Surveyed by____________________________ *By*________________________________
Chemist

Figure 2

At most of the locations for the tidal cycle salinity surveys, it was found that two men working in shifts of about six hours each could handle the work very nicely. The procedure would be as follows: Both men would go to the appointed place to get everything in readiness, install the staff gage, locate the channel, measure the standard depth, put out the buoy if necessary, and generally make conditions convenient and comfortable for a thirty-hour stay. One man would then leave. The actual sampling operations were as follows: For convenience each set of samples was usually taken on the hour. Just prior to the hour, the man on shift would read the staff gage, calculate the depth, mark the sampling depth on each bottle in the space provided on the label and place the marked bottles in order in a small box provided for this purpose. Ordinarily this would not take more than a few minutes. He would then go to the sampling place, let the weighted hose to the bottom, thereby checking his depth calculation, and start pumping. While some of the men could pump so uniformly as to be able to estimate a gallon very closely, it was always demanded that a gallon container be used and filled to insure the pumping of a gallon, or twice the capacity of the hose, before taking each sample. While pumping, the man would pick up his marked bottle, note whether or not it was the correct one, and, after pumping at least a gallon, fill the sample bottle from the pump. The hose would then be lifted successively to the other depths of sampling at five to ten foot intervals from bottom to water surface and the operation repeated at each sampling point.

River Cross Section Salinity Surveys

In this type of survey the object was to determine the distribution of salinity throughout an entire channel cross section at a given phase of the tide. Nearly all of these surveys were made at or shortly after high-high tide. The work was complicated because of the fact that, in the period when most of this work was required, the high-high tide occurred at night and the water was usually very rough. These surveys were made at two channel cross sections in the delta, one on the San Joaquin River near Antioch and the other on the Sacramento River at a point north of Antioch. The San Joaquin River section was about 2700 feet wide and varied in depth from 15 to 50 feet. The Sacramento River channel was about 3500 feet wide and had a uniform depth of about 32 feet. In these channels it was desired to take a set of samples at about ten-foot depth intervals from surface to bottom, about every 200 feet across the section. Samples were to be taken from both cross-sections at the same tide and, since one crew only was available for this work, the time factor was of vital importance. A fast, seaworthy speedboat was necessary to permit the crew to travel from one cross-section to the other with a minimum loss of time.

Prior to the beginning of the season's work, sights for range lights were selected at each location to enable the operator of the boat to maintain a course on the section line in the dark. As it was not feasible to buoy the section at 200-foot interval sampling points and too much time would have been consumed in endeavoring to locate the boat by triangulation, dead reckoning was relied upon to locate the sampling points. This was accomplished as follows: The throttle of the speedboat was set at a moderate cruising speed, the quadrant marked, the bow headed into the current and the rudder turned just enough to cause the boat to maintain the course of the section. The elapsed time from shore to shore was measured with a stop watch and the proper allowance for current, wind, and engine speed thus determined. Knowing the number of stops to be made, it was then possible to closely determine the proper traveling time between sampling points.

Three men were used on these surveys. The sampling equipment was the same as that used on the tidal cycle salinity surveys. In the segregation of work, one man was assigned to man the sounding line (graduated hose) and make the soundings, another to man the pump and fill the bottles after flushing the hose between samples, and a third, usually in charge of the party, was responsible for the operation of the boat and the marking of the labels on the bottles as they were filled. Upon arrival at the cross-section, the first duties were to set the light on the north bank, make the speed test across channel and set the light on south bank. It was usually possible to make the preliminary run across the river in the darkness by the guidance of a star and some point silhouetted against the sky on the south bank. With the shore lights set, the men took their places in the boat and all equipment was put in readiness on the way to the first sampling point. Arriving here, the boat was headed into the current and held on line, without anchoring, by the motor. The sounding was made, the pump man began at once to take the bottom sample and as soon as he commenced filling the bottle, the hose man hauled up for the next depth sample. The alternate pumping, filling of the bottles and hauling were thus continued until the surface zone sample had been taken. The engine throttle was then advanced to give the same cruising speed as that used on the trial trip, and with the aid of a stop watch, the next sampling point was reached. These operations were continued until the opposite shore was reached. Ordinarily the correct number of stops were made, but at times the drift due to wind could not be calculated and more or less than the desired number of stops would be made. That the sampling points were spaced with surprising uniformity, however, was later shown when the soundings were plotted on actual cross-sections made from accurate soundings. Upon reaching the north shore, there remained only to gather the lights and proceed at full speed to the other section, where the same procedure was repeated. Using these methods, a maximum of 70 samples was taken in 70 minutes. This was elapsed time from the beginning of the first sounding until the last bottle was filled at the opposite shore. Recording gages near each of the sections were always inspected prior to each survey. Each bottle was marked with a label on which was filled in the name of the cross-section, the date, the station (sampling point) and the depth of sample. A special report form in quaduplet (letter size) was filled out in the field and sent with the bottles to the laboratory. This form, reduced, is shown in Figure 3.

River Cross-Section Tidal Cycle Salinity and Tidal Velocity Surveys

The purpose of this type of survey was to establish the relation between the variations of salinity and tidal velocity throughout a complete tidal cycle and for an entire river cross-section. The observations were made at each of three stations located at fixed points in the channel on each of the river sections previously used for the "River Cross-Section Salinity Surveys." It was considered that three stations on each section would be the maximum that one crew could handle and secure at each station a complete hourly set of velocity readings and water samples. In order to anchor buoys in the channel at the stations, it was necessary to obtain permission from the U. S. Lighthouse Service as both of the sections were on navigable waterways and the placing of new lights in the channel without proper notice would have been confusing to navigators. The buoys, made from fifteen-gallon oil drums painted the prescribed colors, red, white and green, were anchored in the channel with half-inch wire rope. A "sled" was fastened to each buoy with a short piece of rope and on the "sled" was placed a lantern. With the lanterns burning in rough weather and waves not infrequently breaking over the sled, some difficulty was experienced due to cracking of the lantern globes. This caused little delay, however, as the power boat used was equipped with an excellent spotlight with which an unlighted buoy could be readily located. Considerable difficulty in locating the buoys probably would have occurred, however, had the three lanterns been extinguished simultaneously.

STATE OF CALIFORNIA—DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SACRAMENTO-SAN JOAQUIN WATER SUPERVISOR

Salinity Investigation in Delta of Sacramento and San Joaquin Rivers
Laboratory Report of Analysis of Chlorine Content in Water

IN

RIVER CROSS SECTIONS

SECTION___________________

Survey No.___Date___19__ Gage Height: Beginning____ Ending______. Time of Survey: Beginning____ Ending______.

Station From Left Bank, In Feet	Depth at Station, In Feet	Chlorine Content in Parts Per 100,000 For Depth in Feet Below Surface of							Remarks

Surveyed at Time of Tidal Cycle Stream Flow Measurements:

Georgiana No.______________From______________to______________

Three Mile No.______________From______________to______________

T. E. STANTON
Materials and Research Engineer

Surveyed by________________________. *By*______________________________
Chemist

Figure 3

Comprising the equipment used were the standard sampling pump, the two-ounce bottles with the same label as that used for the cross-section surveys, and an electric current meter outfit. A staff gage set up at one end of the section was read at the beginning and end of each series of observations. In meeting the requirements in this work for a boat with plenty of room and one which could be maneuvered handily, a regular double-ended fishing launch was rented from a fisherman who was hired to operate the boat throughout the measurements.

The crew comprised one man for the sampling hose, one to operate the pump and fill the bottles, one to operate the current meter and keep the notes of this operation, and the boatman, who also rendered other assistance when needed. Ordinarily, the men worked in eight-hour shifts when the work was to extend over a period of several days. For one tidal cycle only, however, one crew would generally put in about one-half of the cycle to a shift. At each station in each section at hourly intervals throughout a tidal cycle or longer, measurements of velocity were taken at the same times and depths as those of the water samples. The time of the velocity reading as well as the depth was entered on the current meter sheet. The observations and samples at all three stations could usually be taken in about forty minutes elapsed time. The salinity samples were reported on the form shown in Figure 3.

Tidal Cycle Stream Flow Measurements

As a part of the 1929 investigation, measurements were made of the flow in the Sacramento River and its branch channels below Sacramento for the purpose of determining the division and distribution of the total flow passing Sacramento. All of these channels are affected by tidal action and required special methods and procedure for measurement of flow. The methods and procedure for this type of measurement had been previously developed and used in connection with the work of the Sacramento-San Joaquin water supervisor.

In a tidal channel there is no fixed relation between gage height and discharge as the relation is constantly changing with the change in slope resulting from the rise or fall of the tide. The flow is not only variable in rate but also may change in direction. It was necessary to resort, therefore, to some method of measurement which would determine the mean or net discharge for a complete tidal cycle period of 24 to 25 hours. This was accomplished by making current meter measurements of the flow in the channel at intervals of about one hour throughout a complete tidal cycle and deriving the mean or net discharge for a tidal cycle graphically from the results as plotted on cross-section paper. The hourly discharges in cubic feet per second were plotted as ordinates against time as abscissae. In cases of reversal in flow, the positive flows downstream and the negative flows upstream were plotted respectively above and below the line of zero flow. A smooth curve was then drawn through the plotted points and the total area, within the limits of the beginning and ending of the tidal cycle and enclosed between the curve and the line of zero flow, was measured by planimeter. In cases of reversal in flow, the areas above the line of zero flow, designated as positive for downstream flow, and those below, designated as negative for upstream flow, were planimetered separately and added algebraically. If this algebraic sum was positive, the net flow for the tidal cycle would be downstream, while, if negative, it would be upstream. The net or mean flow for the tidal cycle was then derived by dividing the total area by the length of the intercept between the ordinates at the beginning and ending of the cycle, and multiplying the resulting figure by a factor determined from the ordinate scale.

Because of the rapidly changing gage height and corresponding discharge, it was absolutely essential that each hourly set of current meter readings should be taken with maximum dispatch. Where the channel was of considerable width, therefore, time did not permit the number of velocity observations across the channel which usual standard methods of current meter measurements would prescribe. It was necessary that the number of velocity readings be reduced and this was accomplished by the following procedure: An initial set of readings was taken across the section in accordance with the usual standard methods; the resulting velocities at each measuring point were then plotted on a graph against distance from a fixed point on one side of the section and a smooth curve drawn through the plotted points; by inspection of this curve, it was then possible to select a smaller number of measuring points where it appeared that the velocities were representative averages for considerable sections of the channel width. The reduced number of measuring points were then used for the hourly current meter velocity readings throughout the tidal cycle. Current meter velocity measurements were taken only at six-tenths depth, as the gain in speed with this method was considered of greater value than the slightly greater accuracy which the use of the two-tenths and eight-tenths depth method would have given.

Further expedition was accomplished by eliminating the necessity for soundings before each hourly set of observations. Based upon accurate initial soundings, there was prepared a set of standard six-tenths depths for each measuring point referred to a specific gage reading. Just before each set of hourly measurements was started, the gage was read and the six-tenths depths for the ensuing measurements were computed and recorded in advance by applying the proper correction to the "standard" six-tenths depths.

Ordinarily the measurements were made from a boat which was fastened to and passed along a cable stretched across the channel on the section. Under these conditions, and using the methods that have been described, the hourly measurement for a channel 600 feet wide and 30 feet deep could be made by an experienced crew in less than fifteen minutes from the first to the last reading. Most of the channels were of smaller width and took less time per measurement.

For this type of measurement, the endeavor was to select a straight stretch of channel of more or less uniform depth. This was of particular importance where reversals of current occurred with the flood and ebb tides. If the channel were not fairly uniform under these conditions, the points selected to give average velocity for one direction of flow might not hold when the flow was in the opposite direction.

The actual measurements were ordinarily begun about two hours after either a high or a low tide. Hourly measurements were continued for a period of about 25 hours or more, or until the gage indicated the same tidal stage during the similar and next succeeding period of flood and ebb tide as that occurring at the beginning of the measurement. In cases of reversal in flow, the time of slack water was observed as nearly as possible by means of a rod float, and it was the usual practice to avoid making current meter measurements near the time of slack water.

In addition to the engineer in charge, the stream-gaging crew for each measuring station usually comprised two men each for three shifts in a twenty-four-hour period. One man would handle the boat and keep notes while the other operated the current meter. At the beginning of the measurement, the engineer in charge would aid in making the proper set-up, selecting the measuring points from the initial

17—80995

soundings and set of standard gagings, and deciding on all details of procedure.

Essential items of equipment were: row boat, cable, staff gage, electric current meter (cable suspension), rod float, current meter notes, cross-section paper on small drawing board, light block and tackle with a "come-along," lanterns, and temporary camp equipment. The cable was made up from Stone patent clothes line, about 3/16 inch in diameter. This has a twisted steel core and is galvanized. The cable was graduated by forcing strips of flagging through the strands; white strips every ten feet and red every fifty feet. It was necessary to arrange the cable suspension so that the cable could be easily and rapidly slacked to the bottom of the channel to permit the passing of boats and steamers. A rod float was used to observe the direction of current for each hourly measurement.

Tide Gage Operation

In order to obtain complete information on tides in the bay and delta channels, required for determining the effect of tidal action on the variation of salinity, a number of tide gage stations were established at the beginning of the work in 1929 to supplement those already in operation under Federal, State and private agencies. The following new stations were established: Benicia, Antioch, Collinsville, Sacramento and San Joaquin ends of Three-Mile Slough, Walnut Grove, San Joaquin end of Georgiana Slough, Mossdale Bridge and Sacramento. At a later time stations were established at Crockett, Point Orient, Hunters Point, San Mateo Bridge and Dumbarton Bridge. Automatic tide gage recorders were installed at all of these stations, including six "Stevens Type B" recorders equipped with special time and gage height ratios, two "Stierles" recorders, and one standard and several portable-type tide gages borrowed from the U. S. Coast and Geodetic Survey.

The maintenance of these new stations and the acquired maintenance of a number of those previously in operation by other agencies practically required the full time of one man who was designated to make the continuous rounds of the stations and keep all equipment in first-class working order. Staff readings were taken and the recorders checked at frequent intervals in accordance with the standard of the U. S. Coast and Geodetic Survey. In addition to the special man assigned to the maintenance and inspection of all gages, local observers were appointed to make daily readings of the staff and clock for a number of the gages.

All tide gages were tied to a common level datum by precise level lines. The basic precise level lines were run by the U. S. Geological Survey in cooperation with the State. From the precise level bench marks thus established, the tide gages were tied in by lines of levels run by the State. This was a most important part of the field work connected with the installation of these tide gages.

Summary of Operations

The following tabulation summarizes the number of the various types of special surveys made and the number of samples taken and analyzed for salinity during the investigation from May to December, 1929:

Type of station or survey	Number of stations	Number of surveys	Number of salinity samples
Regular salinity observations	76	--	4,695
Special tidal cycle salinity surveys	14	90	9,457
Special river cross-section salinity surveys	2	33	6,317
Miscellaneous salinity observations	--	--	150
Complete chemical analyses	*12	--	*18
Special stream gaging	5	59	----
Automatic tide gages	14	--	----
Totals	--	182	20,637

* Samples taken at four additional stations in January, 1930. (See Table 36.)

acramento-San Joaquin Water Supervisor

of Chlorine per 100,000 Parts of Water, 1920

Reproduced from 1931 Report Sacramento-San Joaquin Water Supervisor

Delta of Sacramento and San Joaquin Rivers, Showing Limits of Salinity Encroachment of 100 Parts of Chlorine per 100,000 Parts of Water, 1920 to 1931, Inclusive.

APPENDIX B

LABORATORY METHODS FOR DETERMINATION OF SALINITY

LABORATORY METHODS FOR DETERMINATION OF SALINITY

Although there are several methods used for determination of salinity in water, it is recognized generally that the most accurate is a chemical analysis. For a determination of all dissolved salts, this involves a complete quantitative and qualitative chemical analysis of the water. However the salinity of ocean water largely consists of common salt (Na Cl) and it is common practice to express the salinity of ocean water in terms of its chlorine content. Therefore, since the salinity of the waters of the upper bay and delta is mostly the result of invasion of saline water from the ocean, the salinity has been determined, from the beginning of investigations by the State, in terms of chlorine content.

There are three standard methods of chlorine determination.

1. Gravimetric Method.

   Determination of chlorine combined as chloride by precipitation as silver chloride.

2. Volumetric Method. (Volhard.)

   Determination of chlorine in acid solution, silver thiocyanate and ferric alum method.

3. Mohr Method.

   Volumetric determination of chlorine in a neutral solution, silver chromate method.

Under the first, or Gravimetric, the chloride ion is precipitated and weighed as silver chloride; under the second, or Volhard's method, the chloride is precipitated with an excess of silver nitrate, precipitated silver chloride filtered off, and the excess silver nitrate in the filtrate is then titrated with thiocyanate using ferric alum as an indicator; whereas under the third, or Mohr method, the neutral solution is titrated with silver nitrate using potassium chromate as an indicator.

While the precipitation and weighing method is very accurate, it requires considerable time and is subject to various possible errors through manipulation when an attempt is made to speed up the work. Volhard's method is more rapid than the first method, but is subject to the same limitations as to the number of determinations which can be made in a given time. Either the first or second method takes at least ten times as long as a determination by the Mohr method.

Adopted Method of Analysis

The method adopted and used for the chemical determination of chlorine content of salinity samples is that known as the "Mohr" method, involving the titration of a neutral solution of the sample of water with silver nitrate, using potassium chromate as an indicator.

This method can be used only with a neutral solution but, as the water which was being analyzed was seldom acid or alkaline, it was perfectly adapted to the problem. It is standard for analysis of water, is rapid, easily checked, and, while subject to certain errors, attains a high degree of accuracy by standardized procedure. Very few of the waters were alkaline to phenolphthalein but, where such was the case, the sample was neutralized with 1/50 normal acid. The accuracy obtainable with the method used was found to be close. Two experienced chemists could check one another within the limits of the burette, or 0.1 ml. The salinity range of the water analyzed was from one part to about 1900 parts of chlorine per 100,000 parts of water. Inasmuch as, under the method used, two chemists were able to check each other within a fractional part of one per cent or within 20 parts of chlorine per 100,000 parts of water when determining the highest concentration, it can be seen readily that the accuracy of the method adopted was amply sufficient for the purpose.

Laboratory Procedure

The solutions used in the titration of water samples for salinity comprised silver nitrate and potassium chromate. The standard solution of silver nitrate was prepared, in accordance with usual laboratory practice, of such strength that one milliliter (ml.) of the silver nitrate solution would completely react with and be equivalent to one milligram of chlorine in a standard sodium chloride solution containing one gram of chlorine per liter of sodium chloride solution. The standard silver nitrate solution contained about 4.794 grams (dry weight) per liter of silver nitrate solution, the exact amount depending upon the purity of the silver nitrate. The standard sodium chloride solution contained 1.6485 grams (dry weight) per liter of sodium chloride solution. The potassium chromate solution, used as a color indicator, was prepared by dissolving 50 grams of potassium chromate in sufficient distilled water to make one liter of solution. The potassium chromate must be free from chlorides.

In order to have a standard for comparison of color to denote the completion of the titration, a color standard was prepared by adding one milliliter of the potassium chromate solution, as above prepared, to 50 milliliters of distilled water and 0.3 milliliters of the standard silver nitrate solution. This color standard was of a reddish orange color due to the presence of silver chromate resulting from the combination of silver nitrate and potassium chromate. The volume of the color standard was the same as the volume of the diluted samples of water to be analyzed for salinity.

The procedure of titration was then as follows: The water sample to be analyzed for salinity was diluted with distilled water to make a total volume of the diluted sample equal to 50 milliliters. The amount of the water sample used was chosen so that about six milliliters of the standard silver nitrate solution would be required to complete the titration. To this diluted sample, one milliliter of the potassium chromate solution was added followed by the addition of the standard silver nitrate solution until the color of the sample matched with the color standard. The amount of standard silver nitrate solution in the color standard, namely 0.3 milliliters, was then subtracted from the total amount of silver nitrate solution added to the sample. The remaining number of milliliters of the standard silver nitrate solution used gave the number of milligrams of chlorine in the original quantity of the sample taken for dilution. It was then merely a matter of arithmetic to obtain the number of parts, or grams, of chlorine per 100,000 parts, or cubic centimeters, of the sample.

Two permanent set-ups were used, with the light conditions as near the same as it was possible to obtain. Two chemists were employed constantly for the most part in this work and, in order to eliminate the personal error, the personnel was not changed except that additional assistance was furnished from time to time when more samples were received in a shorter period than two men could handle expeditiously. Each man would prepare two sets of samples (about 30 to a set) and titrate one set. The positions would then be changed and the operators would titrate one another's second set. It was required that all samples check within 0.1 ml. The entire halogen content of the samples were reported in terms of chlorine; no separation between them being made.

When but a limited number of samples of water were being received at the laboratory daily and it was necessary for a chemist to switch from one job to another, such as clerical work, making out reports, and shipping sample bottles, chlorine determination of 60 samples was considered a good day's work for one man, not including a check determination.

During the early summer months of 1929, water samples for salinity investigation began to arrive in large numbers and it became evident that this would increase during the summer months so that a standard method of procedure would be needed to expedite the reporting of results with no delay. The procedure finally adopted to best meet the conditions was as follows:

Samples were handled in box lots as brought to the laboratory in order to complete sets of samples so box lots of clean bottles could be sent out again. All sample boxes contained a tabulated sheet giving time, date, location, and observer. Bottles were counted to check with the number shown and then compared against the list as to location, time and date, to check out any discrepancy so that a suitable record could be made. The time, date, and location of each sample was listed in a record book for further reference.

Thirty samples were run at one time by placing the bottles in a row, placing a beaker in front of each sample bottle, putting a suitable quantity of the sample in the beaker according to amount of salt present, diluting the sample with distilled water and titrating the same, and finally replacing the beaker in original position on the table so as not to leave any empty spaces in the beaker row in order to keep all samples in correct position. Each man took care of his own glassware. By this method one operator was able to report an average of 120 to 130 analyses per day. Where the operator was required to do all clerical work and care of glassware attached to reporting results, an average of 60 samples was analyzed.

Later on when it became apparent that duplicate results would be advisable, the method used was the same except that, instead of placing one beaker in front of the sample bottle, two beakers were placed in position and two samples of water taken. Duplicate results were obtained by having one operator complete one set and having another operator complete the other set. Results were then compared, and, if not checking within the variation allowed, another set of duplicate determinations were made. By this method of procedure one operator was able to complete an average of 90 samples or 180 determinations per day.

The methods of procedure above described apply particularly to the 1929 season, when over 20,000 samples of water were analyzed in a period of eight months. However, the methods of analysis used were the same in previous years from 1923 to 1929, during which period about 10,000 samples were analyzed; and also have been the same since 1929.

Complete Chemical Analysis of Water

For the more complete chemical analysis of water, the residue (total solids) was determined by weighing after evaporation of sample at 110°C. A qualitative and quantitive analysis was then made to determine carbonates, bicarbonates, silicates, iron and alumina, calcium, magnesium, sodium, chlorides, and sulphates. The total hardness was obtained from the magnesia lime content by the following formula:

$$\text{*Hardness (H)} = \text{Ca} \times 2.5 + \text{Mg} \times 4.1.$$

The alkalis, as Na, were calculated as follows:

$$\text{*Na} = .83\ CO_3 + .41\ HCO_3 + .71\ \text{Cl.} + .52\ SO_4 - .5\ \text{H (hardness)}$$

Other constants were obtained by standard practice for water analysis.

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* U. S. Geological Survey Water Supply Paper 495, 1923, page 95, 96.

APPENDIX C

RECORDS OF SALINITY OBSERVATIONS

TABLE 31

DESCRIPTION OF SALINITY OBSERVATION STATIONS, 1920 TO 1931

Station	Miles* from Golden Gate	Time interval between high tide at Golden Gate and time for taking samples at station		Location
		Hours	Minutes	
San Francisco, San Pablo and Suisun Bays				
Point Orient	12.3	2	20	Northerly end San Francisco Bay, east shore, one-half mile south of Point San Pablo, at wharf of Standard Oil Company.
Point Davis	25.2	3	15	Easterly end San Pablo Bay, south shore, Oleum wharf of Union Oil Co.
Carquinez Light Station	26.3	3	20	Carquinez Strait, near junction with Mare Island Strait.
Crockett	27.5	3	25	Carquinez Strait, south bank at wharf of California-Hawaiian Sugar Refining Corp.
Bulls Head Point [1]	34.0	3	50	Westerly end Suisun Bay, south shore, at wharf of Mountain Copper Co.
Bay Point	39.9	4	15	Suisun Bay, south shore, Bay Point wharf of Coos Bay Lumber Co.
Sprig Club	44.7	4	30	Montezuma Slough, about 2 miles from Suisun Bay end.
O. and A. Ferry	46.5	4	40	Upper end Suisun Bay between Mallard Station and Chipps Island on Sacramento-Northern R. R. Ferry crossing.
Innisfail Ferry	47.3	4	50	Montezuma Slough, about 1 mile east of junction with Cut-off Slough, near northerly end of Grizzly Island.
Pittsburg	50.0	5	25	South bank of New York Slough, at plant of Great Western Electro Chemical Co.
O. and A. Bridge	50.6	5	20	Montezuma Slough, at Sacramento-Northern Railroad crossing.
North of San Pablo Bay				
Grand View	27.0	3	10	Petaluma Creek, State Highway drawbridge near town of Grandview.
Sonoma Creek Bridge	26.4	3	10	Drawbridge, Sonoma Creek entrance.
Vallejo	29.1	3	35	Sears Point Toll Road bridge, on Napa River, about one mile from Mare Island Navy Yard Causeway.
Lakeville	33.8	3	40	Petaluma Creek, at town of Lakeville about 7½ miles from mouth of creek.
McGill	30.6	3	25	Sonoma Creek at McGill on Northwestern Pacific Railroad about 1 mile south of Wingo.
Cuttings Wharf	36.7	4	00	Right bank of Napa River, opposite north end of Bull Island, near Carneros Station on Southern Pacific Railroad.
Merazo	32.7	3	40	Hudemann Slough Bridge, due south of Merazo Station on Santa Rosa branch of Southern Pacific Railroad.
Napa	43.7	4	20	Third Street bridge on Napa River, at Napa.
Petaluma	45.7	4	30	Petaluma Creek, at Washington Street bridge in Petaluma.
Sacramento River Delta				
Collinsville	50.8	5	25	North bank Sacramento River at junction with San Joaquin River.
Mayberry	54.2	5	40	North bank of Sacramento River just below Mayberry Slough.
Mayberry prior to October, 1929 and in 1931	54.9	5	40	South bank of Sacramento River just above Mayberry Slough.
Emmaton	57.7	5	45	South bank Sacramento River on Horseshoe Bend.
Three Mile Slough Bridge	60.0	5	55	At junction of slough and Sacramento River.
Three Mile Slough Ferry	61.2	6	00	Near junction of Three- and Seven-Mile sloughs.
Rio Vista Bridge	63.5	6	05	Sacramento River near northerly limits of Rio Vista.
Junction Point	65.2	6	10	Right bank of Sacramento River just below the junction with Steamboat Slough.
Ryer Island Ferry	66.5	6	20	Lower end of Cache Slough, just above junction with Steamboat Slough.
Liberty Ferry	67.6	6	25	On Cache Slough at junction with Prospect Slough.
Grand Island (Steamboat Slough) [2]	68.2	6	30	Steamboat Slough at Grand Island Drainage Pumping Plant, 3 miles from Junction Point.
Jones Landing	68.2	6	30	Cache Slough, one-half mile above junction of Cache and Lindsey sloughs.

TABLE 31—Continued

DESCRIPTION OF SALINITY OBSERVATION STATIONS, 1920 TO 1931

Station	Miles* from Golden Gate	Time interval between high tide at Golden Gate and time for taking samples at station		Location
		Hours	Minutes	
Sacramento River Delta —Continued				
Isleton Bridge[3]	68.7	6	30	Sacramento River, one mile upstream from Isleton.
Cache Slough	68.7	6	35	On Cache Slough, 1½ miles above junction with Lindsey Slough.
Walker Landing	69.6	6	40	On Steamboat Slough, 4 miles above its junction with Sacramento River.
Howard Ferry	71.4	6	55	On Steamboat Slough, 1½ miles below junction with Sutter Slough.
Sutter Slough	72.8	7	00	At junction with Miner Slough.
Little Holland Ferry	73.2	7	05	Back borrow pit of Reclamation District 999, 2 miles above junction with Miner Slough.
Ryde	74.4	7	15	Sacramento River, right bank at town of Ryde.
Grand Island Bridge[4]	77.4	7	25	Sacramento River, one-half mile below upper end of Steamboat Slough.
Walnut Grove	77.4	7	25	Sacramento River at highway bridge crossing river.
Paintersville Bridge	77.6	7	25	Sacramento River, 1 mile below Courtland.
Hood Ferry	82.5	7	50	Sacramento River, one-half mile above Hood.
Freeport Ferry[5]	90.6	8	25	Sacramento River at Freeport.
Sacramento	103.5	9	30	Sacramento River at Southern Pacific Railroad Bridge.
Verona	123.5	No	tide	Sacramento River just below Verona.
San Joaquin River Delta				
Antioch	54.9	5	55	San Joaquin River, at City Water Works Pumping Plant.
Sherman Island Ferry	58.0	6	05	San Joaquin River, 3 miles above Antioch.
Curtis Landing	58.9	6	10	San Joaquin River, right bank, about three-fourths mile above Antioch Toll bridge.
Jersey	61.4	6	20	San Joaquin River, left bank, 1 mile below mouth of False River.
Blylock Landing[6]	63.5	6	25	San Joaquin River, 1 mile above False River on Bradford Island.
Twitchell Island Pump	65.4	6	30	San Joaquin River, 1½ miles above Three Mile Slough, on Twitchell Island.
Webb Point	71.0	6	55	San Joaquin River, at northeast corner of Webb Tract opposite mouth of Mokelumne River.
Webb Pump	72.0	7	00	False River, 2 miles below Old River Junction.
Central Landing, Bouldin Island	72.0	7	00	Mokelumne River, left bank, one-half mile above San Joaquin River Junction.
Central Landing, Main	72.0	7	00	Mokelumne River, in main channel opposite Central Landing.
Blakes Landing, Venice Island	74.6	7	15	San Joaquin River, right bank, about two miles above junction with Old River.
Quimby Pump	77.5	7	25	Sheep Slough at junction with Sand Mound Slough and Old River.
Ward Landing	79.6	7	35	San Joaquin River near junction with Little Connection Slough on the southwest side of Empire Tract.
Holland Pump	80.6	7	40	Rock Slough, north bank, 1½ miles west of Old River junction.
Medford Island Pump	81.0	7	40	South side Medford Island, on channel connecting Whiskey Slough and Middle River.
McDonald Pump	82.7	7	50	San Joaquin River, northeast corner of McDonald Island, about 1½ miles below Hog Island.
Mandeville Pump	83.0	7	50	Connection Slough, north bank, 1 mile west of Middle River, on south end of Mandeville Island.
Camp 3½, King Island[7]	84.7	8	00	West side King Island at junction of White Slough and Honkers Cut.
Zuckerman Pump	85.6	8	05	Empire Slough, on north side of Lower Jones Tract, about ¾ mile west of Whiskey Slough junction.
Rindge Pump	86.1	8	10	San Joaquin River, north bank, 1 mile below Fourteen Mile Slough junction.
Orwood Bridge	86.3	8	10	Old River, at Santa Fe Railroad crossing, Orwood.

TABLE 31—Continued

DESCRIPTION OF SALINITY OBSERVATION STATIONS, 1920 TO 1931

Station	Miles* from Golden Gate	Time interval between high tide at Golden Gate and time for taking samples at station		Location
		Hours	Minutes	
San Joaquin River Delta —Continued				
Palm Tract	86.3	8	10	Old River, west bank, near Palm Tract pump, just north of Santa Fe Railroad crossing.
Sing Kee Landing	86.6	8	15	White Slough, about 2 miles above junction with Honker Cut.
East Contra Costa Irrigation District[8]	86.7	8	20	Indian Slough, at East Contra Costa Irrigation District pumping plant.
Middle River, Post Office	87.7	8	20	Middle River, east bank, at Santa Fe Railroad crossing.
Middle River, Main	87.7	8	20	Middle River, center of main channel, at Santa Fe Railroad crossing.
Mansion House	88.4	8	30	Old River, east bank, at junction with North Victoria Canal.
Wakefield Landing	90.1	8	40	San Joaquin River, left bank, just downstream from lower mouth of Burns Cut-off.
Stockton Country Club	90.8	8	45	On Lindley Cut-off (San Joaquin River), north bank, about ¾ mile above Burns Cut-off junction.
Drexler Bridge	92.3	8	55	Middle River, at southwest corner of Drexler Tract, at Borden Highway bridge.
Clifton Court Ferry	94.2	9	10	Old River just below junction with Grant Line Canal.
Stockton	94.8	9	15	Near head of Stockton Channel at wharf of California Transportation Company.
Williams Bridge	101.6	9	55	Middle River, about 4 miles below Salmon Slough junction.
Whitehall	104.8	10	20	Old River, west of junction of Salmon Slough and Paradise Cut, due north of Tracy.
Mossdale Highway Bridge[9]	108.5	10	50	San Joaquin River at Lincoln Highway crossing, about 3 miles southwest of Lathrop.
Western Pacific Railroad Bridge	109.0	10	55	San Joaquin River, about one-half mile upstream from Mossdale Bridge.
Durham Ferry Bridge	125.8	No	tide	San Joaquin River, one-half mile below San Joaquin City.
Mokelumne River Delta				
Camp 2, Tyler Island	78.0	7	20	At junction of North and South Forks of Mokelumne River.
Camp 35, Staten Island	78.7	7	25	South Fork Mokelumne River, north bank, 1 mile above junction with North Fork.
Southwest Point, Staten Island	78.8	7	25	North Fork Mokelumne River, south bank, just above junction with South Fork.
Camp 33, Staten Island	80.2	7	30	South Fork Mokelumne River, north bank, 2 miles above North Fork junction.
Camp 7, Staten Island	81.8	7	40	North Fork Mokelumne River, south bank, approximately 3 miles above South Fork junction.
Tyler Island Ferry[10]	81.9	7	40	Georgiana Slough, about due east of Isleton.
Camp 11, Staten Island[11]	83.1	7	45	North Fork Mokelumne River, east bank, 4 miles above South Fork junction.
Camp 29, Staten Island[12]	83.4	7	50	South Fork Mokelumne River, north bank, opposite Terminous.
Eagle Tree	85.8	8	05	North Fork Mokelumne River, south bank 1¾ miles below Miller's Ferry Bridge.
Camp 25, Staten Island	86.4	8	05	South Fork Mokelumne River, west bank, 1 mile above Sycamore Slough Junction.
Camp 24, Staten Island	87.0	8	10	South Fork of Mokelumne River, one-half mile below junction with Hog Slough.

TABLE 31—Continued

DESCRIPTION OF SALINITY OBSERVATION STATIONS, 1920 TO 1931

Station	Miles* from Golden Gate	Time interval between high tide at Golden Gate and time for taking samples at station		Location
		Hours	Minutes	
Mokelumne River Delta—Continued				
New Hope Bridge	87.0	8	10	North end Staten Island near upper junction North and South Forks Mokelumne River
Camp 20, Staten Island	88.9	8	30	South Fork Mokelumne River, west bank, one-half mile below Beaver Slough Junction.
Drainage Water Stations				
Jersey Drain	61.4	----	----	Jersey Island drainage pump on San Joaquin River, about 1 mile below False River.
Grand Island Drain, Steamboat Slough	68.2	----	----	Grand Island drainage pump on Steamboat Slough, about 3 miles from Junction Point.
Camp 35, Staten Island Drain	78.7	----	----	Staten Island drainage pump on South Fork Mokelumne River, 1 mile from junction with North Fork Mokelumne River.
McDonald Drain	82.7	----	----	McDonald Island drainage pump on San Joaquin River, about 1½ miles below Hog Island.
Bacon Island Drain	82.9	----	----	Bacon Island drainage pump on Old River, near junction with Rock Slough.
Mandeville Drain	83.0	----	----	Mandeville Island drainage pump on Connection Slough, about 1 mile from Middle River.
Camp 11, Staten Island Drain	83.1	----	----	Staten Island drainage pump on North Fork Mokelumne River, 4 miles above junction with South Fork Mokelumne River.

* Mileage from Golden Gate to observation stations is measured along the main channel. For observation stations off the main channel, the mileage shown is the distance along the main channel to a point thereon where the time of occurcurence of tidal phases is the same as that at the observation station. (See Plate III for map showing location of observation stations.)

[1] This station is practically in the same location as Army Point. Salinity records in Tables 33 and 35 at this location for the years 1924, 1925 and January to March, 1926, are shown under the station designation "Army Point Site."

[2] Called Island Home in 1920.

[3] Observations during 1920 at Isleton Ferry.

[4] Bridge removed in 1925. Salinity records in 1924 only.

[5] Salinity observations at Freeport Bridge beginning in 1930.

[6] Observations at this station taken only from September 13 to 19, 1919. (See Table 34 for record of observations.)

[7] Observations in 1931 at King Island Pump.

[8] Called East Contra Costa Irrigation Company prior to organization of District in 1926.

[9] Also called Lincoln Highway Bridge and Mossdale Bridge.

[10] Not properly in Mokelumne River Delta, but on Georgiana Slough between Sacramento and Mokelumne rivers.

[11] Called North Fork Pump in 1920.

[12] Also called Terminous in 1920.

TABLE 32

PERIOD OF RECORD OF SALINITY OBSERVATION STATIONS, 1920 TO 1931

Station	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
San Francisco, San Pablo and Suisun Bays												
Point Orient							Feb. 16–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 3–Dec. 30
Point Davis							Feb. 6–Dec. 30	Jan. 2–Dec. 30	Jan. 6–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30
Carquinez Light Station										June 14–Oct. 30		
Crockett[1]		Jan. 10–Dec. 31	Jan. 5–Dec. 31	Jan. 2–Aug. 30	Feb. 18–Dec. 30	Jan. 2–Dec. 30	Jan. 20–Dec. 30	Jan. 4–Dec. 30	Jan. 3–Dec. 30	Jan. 3–Oct. 30		
Bulls Head Point[2]		Jan. 4–Dec. 5	Feb. 9–Dec. 31		Feb. 5–Dec. 30	Jan. 2–Dec. 30	Jan. 8–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30
Bay Point							Feb. 2–Dec. 30	Jan. 2–Dec. 22	Jan. 6–Dec. 26	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30
Sprig Club										June 10–Sept. 26		
O. and A. Ferry	June 2–Dec. 2	July 1–Dec. 30	Sept. 6–Dec. 14	June 24–Nov. 30	May 24–Dec. 30	May 12–Dec. 28	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 31
Innisfail Ferry										June 10–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30
O. and A. Bridge	June 16–Nov. 19	July 1–Dec. 31	Sept. 8–Dec. 14	June 24–Nov. 30						June 10–Dec. 22		
Pittsburg						Jan. 2–Dec. 24	Jan. 2–Dec. 24	Jan. 2–Dec. 24	Jan. 2–Dec. 24	Jan. 2–Dec. 30	Jan. 2–Dec. 26	Jan. 2–Dec. 31
North of San Pablo Bay												
Grand View											Feb. 26–Dec. 30	Jan. 2–Dec. 31
Sonoma Creek Bridge										June 14–Nov. 2	Feb. 26–Dec. 30	Jan. 2–Dec. 18
Vallejo											Feb. 26–Dec. 30	Jan. 2–Dec. 28
Lakeville											Feb. 26–Dec. 26	Jan. 2–June 6
McGill											Mar. 6–Dec. 18	
Cuttings Wharf											Feb. 26–Dec. 30	Jan. 2–Dec. 26
Merazo											Mar. 6–Nov. 22	
Napa											Feb. 26–Dec. 22	Jan. 2–April 14
Petaluma											Feb. 26–Dec. 30	Jan. 2–June 6
Sacramento River Delta												
Collinsville	June 2–Nov. 25	July 1–Dec. 23	Jan. 3–Nov. 30	June 24–Nov. 28	May 28–Dec. 30	May 10–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30
Mayberry										June 14–Dec. 23		April 30–Aug. 10
Emmaton	June 4–Oct. 6	Aug. 6–Sept. 13	Sept. 20–Nov. 16	June 24–Oct. 6	June 14–Dec. 30	July 10–Nov. 28	June 18–Dec. 14	Aug. 2–Sept. 10	June 18–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 22	Jan. 14–Dec. 30
Three Mile Slough Bridge							June 10–Dec. 22	Aug. 2–Nov. 26	June 18–Dec. 30	May 26–Dec. 30	Jan. 2–Dec. 26	May 6–Dec. 6
Three Mile Slough Ferry	June 2–Oct. 31	Aug. 7–Oct. 27		July 2–Oct. 30	June 14–Dec. 6	July 24–Dec. 26						
Rio Vista Bridge	July 23–Oct. 9		Sept. 22–Oct. 16	Aug. 22–Nov. 16	June 16–Nov. 21	July 28–Oct. 24	June 10–Nov. 22	Aug. 2–Nov. 18	July 18–Nov. 6	May 26–Dec. 30	Jan. 2–Nov. 10	May 6–Dec. 30
Junction Point										June 10–Oct. 22	July 18–Nov. 10	May 26–Dec. 2
Ryer Island Ferry	Aug. 16–Sept. 28											
Liberty Ferry					Aug. 4–Nov. 14		July 10–Nov. 10		Aug. 26–Oct. 26	May 20–Dec. 14	Jan. 14–Nov. 14	June 24–Dec. 6
Jones Landing	Aug. 27–Sept. 28											
Cache Slough						Aug. 22–Dec. 6						
Grand Island-Steamboat Slough[3]	Aug 14–Sept. 20									July 18–Oct. 22		
Walker Landing	Sept. 15–Oct. 6											
Ryde										June 14–Oct. 22		July 10–Oct. 2
Isleton Bridge[4]	Aug. 14–Sept. 28				July 2–Nov. 20	Aug. 4–Nov. 6	June 30–Oct. 18		Aug. 14–Nov. 6	May 26–Oct. 30	July 18–Nov. 6	May 25–Dec. 6
Howard Ferry					July 30–Oct. 26		July 22–Oct. 22			May 30–Oct. 30		July 14–Oct. 30
Sutter Slough					July 26–Oct. 30					June 2–Oct. 22		July 18–Oct. 10
Little Holland Ferry					Aug. 10–Oct. 2					June 2–Oct. 31		July 27–Oct. 26
Grand Island Bridge[5]					Aug. 6–Oct. 30							
Walnut Grove	Aug. 14–Oct. 31				July 18–Oct. 24		Aug. 19–Nov. 26			May 36–Dec. 26	Jan. 2–Nov. 14	July 15–Oct. 2
Paintersville Bridge							Aug. 18–Nov. 18			May 26–Oct. 30		July 15–Oct. 2
Hood Ferry					Aug. 10–Oct. 28					May 26–Oct. 30		July 18–Oct. 2
Freeport Ferry[6]					Aug. 16–Oct. 6					May 30–Oct. 22		July 16–Oct. 2
Sacramento	Sept. 21 (only)									June 2–Dec. 30	Jan. 2–Dec. 30	Jan. 3–Dec. 30
Verona										June 2–Oct. 30		
San Joaquin River Delta												
Antioch	June 3–Nov. 21	July 5–Nov. 28	Aug. 28–Nov. 28	June 28–Nov. 16	May 24–Dec. 30	May 2–Dec. 28	Jan. 2–Dec. 30	Jan. 6–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30
Sherman Island Ferry	June 2–Sept. 30	Aug. 6–Oct. 31										
Curtis Landing										May 30–Dec. 30	Jan. 2–Jan. 26	April 36–Dec. 26
Jersey	June 2–Dec. 14	Aug. 6–Oct. 31	Sept. 18–Nov. 10	June 28–Nov. 20	May 22–Dec. 30	July 10–Dec. 28	June 10–Dec. 22	Aug. 2–Nov. 22	June 18–Dec. 30	May 30–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 26
Twitchell Island Pump										June 6–Dec. 30	Jan. 2–Nov. 26	
Webb Point										June 14–Oct. 30		
Webb Pump	July 23–Dec. 12				July 16–Nov. 21	July 20–Dec. 30	June 10–Dec. 22	Aug. 6–Nov. 26	July 6–Dec. 10	May 30–Dec. 14	Jan. 2–Dec. 30	Jan. 2–Dec. 26
Quimby Pump	July 23–Nov. 24											
Central Landing, Bouldin Island	July 22–Nov. 11		Sept. 2–Nov. 15	June 28–Aug. 22	June 22–Dec. 22	Aug. 6–Nov. 14	July 10–Dec. 10		July 22–Oct. 30	June 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30
Central Landing Main										June 22–Sept. 26		
Blakes Landing, Venice Island[7]	July 23–Nov. 13									June 2–Nov. 14	July 22–Aug. 30	
Ward Landing										June 10–Dec. 18	Jan. 2–Dec. 30	July 27–Dec. 30
Holland Pump					July 26–Dec. 26	Aug. 6–Dec. 28	July 2–Dec. 14		July 18–Nov. 10	May 30–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30
Medford Island Pump					July 18–Nov. 20	Aug. 4–Nov. 6						
McDonald Pump	July 23–Nov. 19									June 10–Nov. 26	Sept. 26–Dec. 2	Aug. 2–Dec. 21
Mandeville Pump							July 10–Dec. 10		July 22–Oct. 22	May 30–Oct. 30	July 18–Dec. 30	Jan. 3–Dec. 30
King Island, Camp 3½[8]					Aug. 12–Dec. 26		Sept. 22–Nov. 26		Aug. 18–Oct. 30	June 2–Oct. 22		June 19–Dec. 30
Sing Kee Landing	Oct. 9–Oct. 14											
Zuckerman Pump	July 26–Dec. 3									June 16–Oct. 26		
Rindge Pump					Aug. 8–Dec. 30	Aug. 12–Dec. 28	July 26–Dec. 22		Aug. 14–Nov. 30	May 30–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30
Orwood Bridge	July 22–Nov. 24									June 14–Oct. 30	July 18–Dec. 30	July 15–Dec. 30
Palm Tract							Aug. 6–Dec. 22		July 18–Nov. 6	May 25–Oct. 30		
East Contra Costa Irrigation District[9]	Jan. 4–Dec. 1	Jan. 3–Feb. 2								June 10–Dec. 30	Jan. 10–Dec. 26	Jan. 6–Dec. 30
Middle River P.O.					Aug. 8–Dec. 31	Aug. 12–Nov. 30	June 30–Dec. 20		July 18–Oct. 30	May 26–Oct. 30	July 22–Dec. 30	Jan. 2–Dec. 30
Middle River Main										July 10–Sept. 10		
Mansion House					Aug. 6–Dec. 10	Aug. 12–Dec. 28	July 22–Dec. 28		Aug. 14–Nov. 2	May 30–Oct. 22	July 26–Dec. 26	Jan. 3–Dec. 30

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TABLE 32—Continued

PERIOD OF RECORD OF SALINITY OBSERVATION STATIONS, 1920 TO 1931

Station	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
San Joaquin River Delta—Continued												
Wakefield Landing	Aug. 7 (only)				Aug. 18–Dec. 22							
Stockton Country Club							Aug. 18–Nov. 30			June 2–Dec. 30	Jan. 2–Dec. 22	June 10–Dec. 26
Drexler Bridge										June 14–Dec. 30	Jan. 2–Dec. 30	
Clifton Court Ferry					Aug. 20–Nov. 14		Aug. 18–Oct. 10			June 2–Oct. 31		July 15–Dec. 30
Stockton										June 2–Dec. 18	Jan. 2–Dec. 22	Jan. 2–Dec. 26
Williams Bridge					Aug. 20–Oct. 20		Aug. 18–Nov. 18			May 27–Oct. 30		July 15–Nov. 30
Whitehall										June 26–Oct. 30		July 30–Nov. 10
Western Pacific Railroad Bridge	Sept. 24 (only)											
Mossdale Highway Bridge[10]					Sept. 8–Dec. 2					June 2–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 30
Durham Ferry Bridge										May 30–Oct. 30		April 30–Oct. 30
Mokelumne River Delta												
Camp 2, Tyler Island										June 14–Oct. 26		
Southwest Point, Staten Island	Aug. 26–Nov. 19						July 14–Dec. 2		July 18–Nov. 30	June 2–Oct. 26	July 18–Nov. 14	May 3–Dec. 18
Camp 33, Staten Island					July 22–Dec. 16		July 14–Dec. 2		July 18–Nov. 30	June 2–Oct. 26	July 18–Nov. 14	May 3–Dec. 6
Camp 7, Staten Island							July 30–Nov. 22					May 6–Dec. 7
Tyler Island Ferry[11]	Aug. 14–Oct. 30				July 30–Oct. 14		July 22–Oct. 22			June 2–Oct. 30	July 18–Nov. 6	May 27–Oct. 30
Camp 11, Staten Island[12]	Sept. 18–Oct. 9				July 22–Dec. 16		July 14–Dec. 2			June 2–Oct. 27		May 3–Dec. 17
Camp 29, Staten Island[13]	Sept. 18–Nov. 19						July 14–Dec. 2		Aug 14–Nov. 26	June 2–Oct. 26		May 3–Dec. 22
Eagle Tree							July 30–Nov. 22					May 6–Dec. 7
Camp 25, Staten Island					July 30–Dec. 16		July 14–Nov. 22			June 14–Oct. 26		May 3–Dec. 6
Camp 24, Staten Island	Sept. 18–Oct. 19											
New Hope Bridge	Aug. 26–Nov. 19						July 30–Nov. 22			June 2–Dec. 18	Jan. 2–Nov. 10	May 15–Dec. 26
Camp 20, Staten Island							July 30–Nov. 22			June 2–Oct. 26		May 3–Dec. 22
Camp 35, Staten Island	Aug. 26 (only)											
Drainage Water Stations												
Jersey Drain										July 10–Dec. 30	Jan. 2–Dec. 30	Jan. 2–Dec. 26
Grand Island Drain, Steamboat Slough										July 18–Dec. 26	Jan. 28–Dec. 31	Jan. 4–Dec. 28
Camp 35, Staten Island Drain										June 14–Dec. 18	Feb. 10–Dec. 30	Jan. 2–Dec. 18
McDonald Drain										July 6–Dec. 30	Jan. 3–Nov. 30	Jan. 31–Dec. 3
Bacon Island Drain										July 11–Dec. 30	Jan. 2–Dec. 31	Jan. 3–Dec. 30
Mandeville Drain										July 2–Nov. 30	Jan. 26–Dec. 30	Jan. 2–Dec. 30
Camp 11, Staten Island Drain										June 14–Dec. 18	Feb. 10–Dec. 14	Jan. 10–Dec. 18

[1] Observations in 1921 and 1922 by San Francisco Bay Marine Piling Committee. Observations from 1923 to June 14, 1929, by California and Hawaiian Sugar Refining Corporation.
[2] Observations in 1921 and 1922 by San Francisco Bay Marine Piling Committee. Observations in 1924, 1925 and January to March, 1926, by United States Bureau of Reclamation and Mountain Copper Company, are shown under the station designation "Army Point Site."
[3] Called Island Home in 1920.
[4] Observations during 1920 at Isleton Ferry.
[5] Bridge removed in 1925.
[6] Salinity observations at Freeport Bridge beginning in 1930.
[7] Observations in 1920 originally recorded under the station designation "Venice."
[8] Observations during 1931 at King Island pump.
[9] Called East Contra Costa Irrigation Company prior to organization of District in 1926.
[10] Also called Lincoln Highway Bridge and Mossdale Bridge.
[11] Not properly in Mokelumne River Delta, but on Georgiana Slough between Sacramento and Mokelumne rivers.
[12] Called North Fork pump in 1920.
[13] Also called Terminous in 1920.

18—80995

TABLE 33

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1920

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Carquinez Strait															
April	Vallejo Junction[1]					480			420			*240				570
	Benicia[1]					180			530			*120				300
	Martinez[1]					230					30					250
May	Vallejo Junction[1]				150				400			330			*390	
	Benicia[1]				300		400				*420					120
	Martinez[1]					120					150					160
	Carquinez Strait and Suisun Bay															
June	Vallejo Junction[1]	*750				*490				*850			*750			
	Benicia[1]	*450				*410				*500		48)				610
	Martinez[1]					240					420					610
	O. and A. Ferry	5	*4					11	*14			26		37	*71	
	O. and A. Bridge								5	8	11	6	26	34	37	38
	Sacramento River Delta															
	Collinsville	4	5	*4	4	4			*4		4	*5	*5		7	*10
	Emmaton		4	4	†2		*†3	*3		*5	6			3	6	*4
	Three Mile Slough Ferry	4	5	4	*5	*†4		3	7	*4		*5	4	4	*4	3
	San Joaquin River Delta															
	Antioch	*4	*4	*6	*5	*5		3	3	4	*5	6	5	*7	10	
	Sherman Island Ferry	6	6	4	*5	5	5	4	4	4	6	6	*3	5	4	4
	Jersey	5			7		5	†5	*3							
	East Contra Costa Irrigation Company[2]	*2	*2	*2		2				2	*2		2	2	*3	*3
	Carquinez Strait and Suisun Bay															
July	Vallejo Junction[1]	1,200				*1,100				1,400		*1,450				1,500
	Benicia[1]					950					*1,050					1,260
	Martinez[1]		590			920		920			1,030		1,200			1,210
	O. and A. Ferry	74	*79		127			302	*326		324	*418		†434	*507	
	O. and A. Bridge	46	47	49	73	95	93	94	142	157	218	204	314	351	336	†352

	Sacramento River Delta															
	Collinsville			*25	*†21	*34		79	*201		188	*209		†201	†282	
	Emmaton	6			*5		*6					60	†38	*98		140
	Three Mile Slough Ferry	*4	*4	*4		6		15		20		26	*41		40	*67
	Rio Vista Bridge											*12		*18	*19	
	San Joaquin River Delta															
	Antioch	15	10	9	13	*39		*67	*113	134	*115	204		264	339	350
	Sherman Island Ferry	6	*5	4		4	7	10	18		44	34	61	106	148	133
	Jersey						*4	*5	*8	*8		†7	18	20		27
	Webb Pump											*5	*5		6	11
	Central Landing											5	*5	*6	5	*5
	Blakes Landing, Venice Island											*6	*5	*6	*8	
	Quimby Pump											*5	*6		6	
	McDonald Pump											*11	*9	*12	*14	*8
	Zuckerman Pump												*11			6
	Orwood Pump											5	*4	*6	*4	*4
	East Contra Costa Irrigation Company[2]			*3		3	4	*3	*4	*4		4			5	
	Carquinez Strait and Suisun Bay															
August	Vallejo Junction[1]				*1,600						1,650				1,630	
	Benicia[1]		*1,430				1,370				1,660			1,580		
	Martinez[1]		1,270			1,420		1,450			1,510		1,460			1,640
	O. and A. Ferry	*726	638			712	*792		869							
	O. and A. Bridge	*466	*483	*546	*611	*542	*†590	*611	*680	*699	*741	*768	*771	*755	*774	*802
	Sacramento River Delta															
	Collinsville	*†354	462		682	*518	*509	†506	*765	*890	656	*†566	*†685	675	712	*789
	Emmaton		*195	217												406
	Three Mile Slough Ferry	93	82	82	*122	166	*†184	*213	*243	*254	*†195		*280	*270	*267	*336
	Rio Vista Bridge		25	45		73				206	*125		*208	†115	†130	
	Ryer Island Ferry								91	78	91					
	Island Home[3]							60			48	*†29				
	Jones Landing													*25		
	Isleton Ferry							60	30	36	†*9	*†13	*†11		18	
	Walker Landing															
	Walnut Grove							10	7	7	7	11	14	14	*16	22
	San Joaquin River Delta															
	Antioch	*363		419	*525		605	*†344	608	*650	†468	683	*736	*610	*†472	630
	Sherman Island Ferry	*205	*171	*256	*277	*350	*395		469	*†234	451	453	*†285	501		544
	Jersey	*96	*62	*102	*126	123	162	158	149	*218	*†218	*†163	243	*214		
	Webb Pump	16	*14			22	27	*70				*65				83
	Central Landing	7	7	*10	*20		16								*58	*57
	Blakes Landing, Venice Island										*43	*46	*39	*55	*54	*66
	Quimby Pump	*8		*9					38			41			64	*51
	McDonald Pump	10	10	13	13	15	14	16					*22	*21	*24	*29
	Zuckerman Pump	*8	*8	*9												
	Orwood Pump	5	4	3	5	5	6	7			*8	*8	*9	*10	*11	*10
	East Contra Costa Irrigation Company[2]	5	5	*5	*5	*5			6	*7		*8		9	10	12
	Wakefield Landing			*22												

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1920

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Mokelumne River Delta															
August (Continued)	Camp 35, Staten Island													22		
	Southwest Point, Staten Island													36		
	Tyler Island Ferry							5	7	7	*4	6	7		13	16
	New Hope Bridge													3		
	Carquinez Strait and Suisun Bay															
September	Vallejo Junction[1]			1,700		1,620				1,700			1,700			1,700
	Benicia[1]		*1,500		*1,620					1,660						1,580
	Martinez[1]		1,520			1,540		1,540			1,600	1,660	1,630			1,640
	O. and A. Ferry											981	912	*971	†792	950
	O. and A. Bridge	*848	*†746	*870	*863	*792	*848	*757	*976	*926	*744	*838	*723	*954	*907	*707
	Sacramento River Delta															
	Collinsville	*787		661	†598	*†613		*738	*850	731	698	*†581	†580	†475		
	Emmaton		472	*464	†397	*†390	474	459	†355	413	†373			*258		230
	Three Mile Slough Ferry		*301	291	334	320	326	475	*278	*258	*†234		186	192	184	*134
	Rio Vista Bridge				*235			*†88	194			*†27	93		*56	*74
	Ryer Island Ferry	†*57	117	†54			*136	139	72	*37			*19	29	34	
	Island Home[2]								33						*14	
	Jones Landing							32				*†24	*21		†19	
	Isleton Ferry									24	†16	11		10	10	
	Walker Landing							*13	14		14	13	14	11	10	*8
	Walnut Grove		*16	18	17	*17	15	19	14	13	12	*13	13	10	13	16
	Sacramento										*13					
	San Joaquin River Delta															
	Antioch	*762	†459	618	†478	696	666	*757	*766	†459				565	600	*576
	Sherman Island Ferry												547	523	472	532
	Jersey	*298		274	*285			346	298	245		278	269	240		320
	Webb Pump		*120	*168	*†39	*†101	*†109	*162	*160	*155	*150	*157	*149	*†114		
	Central Landing	63		*55	56	*70	*70	*80	*78	*61	*56	*56	*38			

	Blakes Landing, Venice Island	69	80	75	*83	*86		*84								
	Quimby Pump	64		74			*102	102	*101			96		96	*96	
	McDonald Pump	30	33	31	30	34	48	41	47	46	50	48	42	48	56	53
	Zuckerman Pump							*24		27	27	*32	*30		*32	*30
	Orwood Pump	13	12	14	*15	16	*15		18	21	*30	*30	*27	*27	*29	*30
	East Contra Costa Irrigation Company[2]	*13		13	*16		*18	*20	21	22	19	*24		*26		26
	Western Pacific Railroad Bridge												14			
	Mokelumne River Delta															
	Southwest Point, Staten Island					57							*27			
	Tyler Island Ferry					*17	17	15	14		12	*11	11	16	11	8
	North Fork Pump[4]									10			*13			
	Terminous, Camp 29, Staten Island									28			*26			
	Camp 24, Staten Island									21			*21			
	New Hope Bridge					4				6			*6			
	Carquinez Strait and Suisun Bay															
October	Vallejo Junction[1]				1,800			*1,700				*1,350				1,530
	Benicia[1]							*1,440							1,180	
	Martinez[1]	1,660	1,580			1,450					1,260					1,150
	O. and A. Ferry	803		†709	*760	*†506	768	*648		†400			357	*333		456
	O. and A. Bridge	*846	*669	*578	*528	*414	*643	*384	*304	*297	*336	*190	*266	*312	*341	*173
	Sacramento River Delta															
	Collinsville		490	578	*229	298	*†202	*†216		*203	*125	†18	*†50	112		†54
	Emmaton	†88		152												
	Three Mile Slough Ferry	101	93	74	*43	32	22	13	8	*6	*6			*6		*8
	Rio Vista Bridge				*14											
	Walker Landing	6	8	10												
	Walnut Grove	8	13	6	8	6	*8	6	5	5	6	6	5	6	5	*5
	San Joaquin River Delta															
	Antioch	*517	*526	†306	462	378	339	*266	*197	*157	†77	75	75	126		90
	Jersey		186	214	160	*149	154	106		*67	*61	56				37
	Webb Pump			139	*107	*104	*98	*78	*72	72	*†53	56	48	46	43	†35
	Quimby Pump		*88		93			*67				54	*46	†42		
	McDonald Pump	56														
	Zuckerman Pump	*34	*†38	*35	*35	*32	*42	*37	*37		37	34	27	27	22	26
	Orwood Pump	*29	*38	*32	*34	*35	*30	*32	*32	*32	*34		*27	*24	*24	*32
	Sing Kee Landing				*29	29	27	27								
	East Contra Costa Irrigation Company[2]		32	*33		*33	33	*34		34	34		*38	*38	*38	
	Mokelumne River Delta															
	Southwest Point, Staten Island				*27					*8						
	Tyler Island Ferry	6				*6	*5	5	*8	5	5	10		*6		5
	North Fork Pump[4]		8		*13											
	Terminous, Camp 29, Staten Island		26		*13					*9						
	Camp 24, Staten Island		20		*21					*19						
	New Hope Bridge		5		*8					*6						

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1920

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water														
		Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Carquinez Strait and Suisun Bay															
November	Vallejo Junction[1]		*1,350				1,400				*900			480		
	Benicia[1]		*1,170							*920		370				
	Martinez[1]					1,060		1,220			760		60			120
	O. and A. Ferry	197	222	*†120	334	*330		240	*106		35	*10		3	*5	
	O. and A. Bridge	*219	*338	*163	*370	*398	*291	*50	*74	*58						
	Sacramento River Delta															
	Collinsville	*†43	102			67	*66	*18	14		3	5	5			
	San Joaquin River Delta															
	Antioch	50		*31		43	61	30	22	*16	*14					
	Jersey	*32	32			*27	26	19					8	8	*6	5
	Webb Pump	*32	*34	*30	*29		26		22	*19	*15	*14		14	*†10	*7
	Central Landing			*37		*22										
	Blakes Landing, Venice Island		32	27	26	*24	*24									
	Quimby Pump	*38											13			
	McDonald Pump		*18	*19	*16	*13	*18	*14	*14	*†8						
	Zuckerman Pump	*22	*18	*14					*14	*13	*10	*10	*8	*10	*8	*8
	Orwood Pump	21	22	21	19	19	16	18	18	11	14	13	8			
	East Contra Costa Irrigation Company[2]	38	*38		38	37	*36	*35	*34		32	31	*30	*27	*26	*26
	Mokelumne River Delta															
	Southwest Point, Staten Island									*6						
	Terminous, Camp 29, Staten Island									*4						
	New Hope Bridge									*2						

December	**Carquinez Strait and Suisun Bay**															
	Vallejo Junction[1]	*210	--	--	--	420	--	--	--	--	--	--	--	--	--	*240
	Benicia[1]	210	--	--	--	240	--	--	--	370	--	240	--	--	--	90
	Martinez[1]	--	120	--	--	10	--	10	--	--	360	--	--	--	--	*5
	O. and A. Ferry	†3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	San Joaquin River Delta															
	Jersey	--	--	--	5	--	*4	6	--	--	--	--	--	--	--	--
	Webb Pump	--	--	*7	--	*6	†8	--	--	--	--	--	--	--	--	--
	Zuckerman Pump	*8	--	--	--	--	--	--	--	--	--	--	--	--	--	--

* Observation on next succeeding day.
† Observation after low tide.
[1] From records in final report, 1927, of San Francisco Bay Marine Piling Committee, "Marine Borers and Their Relation to Marine Construction on the Pacific Coast," Figure 19, page 42.
[2] From records of the East Contra Costa Irrigation Company. See Tables 34 and 35 for other miscellaneous records from 1919 to 1921.
[3] Same as Grand Island, Steamboat Slough.
[4] Same as Camp 11, Staten Island.

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1921

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month 1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31
	San Francisco, San Pablo and Suisun Bays																
January	Tiburon[1]					*1,395					*1,515				*1,140		
	Green Brae[1]					*340	*515								*150		
	Black Point[1]					*375	*390				*240				*150		
	Crockett[1]					*180					565	*30		*210			60
	Port Costa[1]		*240			*140				*575	*90					*5	
	Martinez[1]	85	195			*120				*305		*60				*5	
	Bulls Head Point[1]		*120			*48			*75		*5						
	Avon[1]	60														*5	
	San Francisco, San Pablo and Suisun Bays																
February	Tiburon[1]												*1,500				
	Green Brae[1]									*400			*410				
	Black Point[1]		*135			*290											
	Crockett[1]			145		60		*270				365			50		
	Port Costa[1]				*80					*240			*60				
	Martinez[1]			*5		60					30		30				
	Bulls Head Point[1]						5		120			5					
	Avon[1]						5			80				5			
	San Francisco, San Pablo and Suisun Bays																
March	Tiburon[1]						1,360										1,240
	Green Brae[1]						730			*395			*580				
	Black Point[1]						425			*400			*425				
	Crockett[1]	575		290	535		410	30			30	*230	30				120
	Port Costa[1]	*195				*30				*150			*30			*190	
	Martinez[1]			365		*48			175				30				
	Bulls Head Point[1]			5				20									10
	Avon[1]		50									10					25

	San Francisco, San Pablo and Suisun Bays																
April	Tiburon[1]				*1,635				1,515			*1,685			*1,455		
	Green Brae[1]	595			*850				770			865				835	
	Black Point[1]								660			*635				715	
	Crockett[1]				330		270		30			425		55		*270	
	Port Costa[1]		*50	*170		*90					*180		*90			*425	
	Martinez[1]	120		*240		*145					*255			110		*395	
	Bulls Head Point[1]					*40				115			70				
	Avon[1]												5				
	San Francisco, San Pablo and Suisun Bays																
May	Tiburon[1]						*1,640										
	Green Brae[1]						*945										
	Black Point[1]						*725										
	Crockett[1]	425			195	395	55			*240				55		*210	
	Port Costa[1]					*90					*145					*180	
	Martinez						180	365					120				
	Bulls Head Point[1]		75					58				90				60	
	Avon[1]			20				5								*30	
	San Francisco, San Pablo and Suisun Bays																
June	Tiburon[1]	*1,745											*1,605			*1,750	
	Green Brae[1]	940											*1,210			*1,210	
	Black Point[1]			710									*775			*770	
	Crockett[1]	545		240			345	120		335	210		475		365		
	Port Costa[1]									*180					*305	*575	
	Martinez[1]		320		180		315			110						620	
	Bulls Head Point[1]						180				180				240		
	Avon[1]		35			*10											
	San Francisco, San Pablo and Suisun Bays																
July	Tiburon[1]				*1,760			*1,830			*1,790						
	Green Brae[1]				*1,250			*1,560			*1,565					*1,640	
	Black Point[1]				*940			*950								1,170	
	Crockett[1]	845				850	775			1,020		790				970	
	Port Costa[1]				*620			*815		*775					*845	*1,020	
	Martinez[1]					725				845		755				880	
	Bulls Head Point[1]					*545					545			560			470
	Avon[1]	150			*300				270								
	O. and A. Ferry	5	6	11	16	39	71	65	100	99	115	116		129	123	181	205
	O. and A. Bridge	4	5	7	21	17	24	26	27	20	14	31	78	110	108	123	118
	Sacramento River Delta																
	Collinsville	4	*5	*6	*6		14	8	13			22	57	67	38	69	
	San Joaquin River Delta																
	Antioch			9	6	7	6	8	10	8	8	13	11	11	12	20	32

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1921

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month															
		1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31
	San Francisco. San Pablo and Suisun Bays																
August	Tiburon[1]		*1,865			*1,860				*1,890							
	Green Brae[1]						1,565			*1,680				*1,870			
	Black Point[1]			1,150										*1,395			
	Crockett[1]				1,305			1,455						1,575			
	Port Costa[1]	*970					*1,090	*1,030		*1,350			*1,120	*1,200			
	Martinez[1]				1,000						1,090			970		1,120	
	Bulls Head Point[1]				*970			*755			*1,060				*1,000		
	Avon[1]			715											110		
	O. and A. Ferry	*169	*188	*318	*245	*235	*230	*323	*310	*301	*398	*354	*350	*380	*361	*466	
	O. and A. Bridge	128	127	279	187	196	214	221	195	235	290	301	165	331	352	*241	376
	Sacramento River Delta																
	Collinsville	59		*142	*83	154	93	98	104	*197	†90	*232	206		*186	†165	†213
	Emmaton			*12			*26		30			*22				46	66
	Three Mile Slough Ferry				12		12	12	*14		*16	*14	*12	*11		14	
	San Joaquin River Delta																
	Antioch	*26	*21	*42	*†52	*51	*†62	*68	*†50	*52	*114	*†87	*150	*†70	*102	*†152	
	Sherman Island Ferry			*31	*40	*22	*26	*23						*43	*46		
	Jersey			*8							11	*14	*13			*18	
	San Francisco, San Pablo and Suisun Bays																
September	Tiburon[1]				1,910							*1,920				*1,880	
	Green Brae[1]				1,820				*1,820			*1,745				1,775	
	Black Point[1]				*1,455				*1,510			*1,505				1,540	
	Crockett[1]						1,395						1,395			*1,395	
	Port Costa[1]			*1,220		*1,350	*1,210									*1,345	
	Martinez[1]					*1,240					1,210						
	Bulls Head Point[1]		1,050											1,020	1,275		
	Avon[1]									110						120	
	O. and A. Ferry	579	422	437		*510	542	650	448	499	547	504	474	434	435	539	
	O. and A. Bridge	413	413	397	467	458	459	474	494	467	304	538	496	133	528	317	

Antioch-233

	Sacramento River Delta																
	Collinsville	262	302	384	371	288	341	259	†171	315	*227	333	285	248	†86	328	-------
	Emmaton	-------	-------	-------	-------	-------	-------	53	-------	-------	-------	-------	-------	-------	-------	-------	-------
	Three Mile Slough Ferry	-------	-------	-------	-------	28	30	23	24	23	-------	15	15	14	11	13	-------
	San Joaquin River Delta																
	Antioch	230	-------	145	204	198	206	128	245	251	221	235	237	117	51	214	-------
	Sherman Island Ferry	-------	-------	125	98	-------	55	124	144	141	-------	154	150	-------	98	133	-------
	Jersey	*37	-------	32	23	37	32	29	25	24	18	19	19	18	22	42	-------
	San Francisco, San Pablo and Suisun Bays																
October	Tiburon[1]	-------	-------	-------	1,750	-------	-------	-------	-------	-------	-------	-------	-------	-------	1,950	-------	-------
	Green Brae[1]	-------	-------	-------	-------	-------	-------	*1,730	-------	-------	*1,745	-------	-------	-------	-------	-------	-------
	Black Point[1]	-------	-------	-------	1,515	-------	-------	-------	-------	-------	*1,605	-------	-------	-------	1,605	-------	-------
	Crockett[1]	-------	-------	1,485	-------	-------	-------	1,395	-------	1,320	-------	-------	-------	-------	1,090	-------	-------
	Port Costa[1]	-------	-------	-------	-------	-------	-------	-------	*1,140	-------	-------	-------	-------	*1,335	-------	*1,030	-------
	Martinez[1]	1,300	-------	-------	-------	-------	-------	-------	970	1,090	-------	-------	-------	-------	940	-------	-------
	Bulls Head Point[1]	-------	-------	-------	970	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	755	-------
	Avon[1]	-------	-------	-------	180	-------	-------	-------	100	-------	-------	-------	-------	-------	-------	-------	-------
	O. and A. Ferry	469	552	506	429	†285	314	331	328	462	403	405	253	246	158	†318	320
	O. and A. Bridge	526	541	499	501	438	360	453	469	547	573	466	411	446	448	165	451
	Sacramento River Delta																
	Collinsville	-------	†162	*†221	181	*203	†88	†64	†75	†56	*138	†125	112	82	†45	†30	†53
	Three Mile Slough Ferry	15	-------	-------	-------	-------	-------	-------	6	5	5	5	6	5	5	-------	-------
	San Joaquin River Delta																
	Antioch	190	258	110	112	51	110	77	86	83	106	65	†19	-------	51	79	30
	Sherman Island Ferry	158	-------	83	63	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	4	4
	Jersey	34	27	18	14	14	14	13	-------	11	10	10	10	10	9	9	8
	San Francisco, San Pablo and Suisun Bays																
November	Tiburon[1]	-------	-------	-------	-------	*1,880	-------	-------	-------	-------	-------	-------	*1,930	-------	-------	-------	-------
	Green Brae[1]	-------	*1,620	-------	-------	-------	*1,700	-------	-------	-------	-------	-------	*1,545	-------	-------	-------	-------
	Black Point[1]	-------	-------	-------	-------	-------	*1,545	-------	-------	1,545	-------	-------	*1,515	-------	-------	-------	-------
	Crockett[1]	-------	-------	1,210	-------	*1,395	-------	-------	*1,515	-------	-------	-------	-------	1,150	-------	-------	-------
	Port Costa[1]	-------	-------	*1,120	-------	-------	-------	*1,275	-------	-------	-------	-------	*1,140	-------	-------	*1,140	-------
	Martinez[1]	-------	1,090	-------	970	-------	-------	-------	1,150	-------	-------	-------	-------	-------	970	-------	-------
	Bulls Head Point[1]	-------	-------	-------	940	-------	-------	*770	-------	-------	-------	*795	-------	-------	-------	-------	-------
	Avon[1]	-------	-------	-------	-------	*75	150	-------	-------	-------	-------	-------	-------	145	-------	-------	-------
	O. and A. Ferry	*314	*277	*256	*309	*357	*301	*394	*†181	*376	*264	*288	*226	-------	-------	*373	-------
	O. and A. Bridge	451	50	430	350	394	411	421	387	394	341	410	411	414	400	403	-------
	Sacramento River Delta																
	Collinsville	†30	†32	66	-------	*46	*†61	*24	†62	-------	-------	67	*45	-------	*†39	-------	-------
	San Joaquin River Delta																
	Antioch	*†41	*33	*50	*52	*30	*74	*39	*62	*53	*38	*40	*37	*37	*64	-------	-------

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1921

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water															
		Day of month															
		1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31
	San Francisco, San Pablo and Suisun Bays																
December	Tiburon[1]	--------	--------	--------	--------	*1,900	--------	--------	--------	--------	--------	*1,900	--------	--------	--------	*1,775	--------
	Green Brae[1]	*1,685	--------	--------	*1,540	--------	--------	--------	*1,545	--------	--------	--------	*1,180	--------	--------	*1,160	--------
	Black Point[1]	*1,545	--------	--------	*1,440	--------	--------	--------	*1,460	--------	--------	--------	*1,550	--------	--------	*1,120	--------
	Crockett[1]	--------	--------	1,240	1,260	1,255	*1,390	1,390	1,455	1,515	1,430	--------	1,365	--------	1,255	*730	--------
	Port Costa[1]	*1,060	--------	--------	--------	--------	--------	*1,170	--------	--------	--------	*1,120	--------	--------	--------	*410	--------
	Martinez[1]	--------	--------	*785	--------	--------	--------	--------	1,060	--------	--------	--------	--------	--------	815	--------	315
	Bulls Head Point[1]	--------	--------	775	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	Avon[1]	--------	--------	--------	85	--------	--------	--------	--------	--------	--------	--------	*85	--------	--------	--------	--------
	O. and A. Ferry	*195	*117	*90	*174	*59	*166	*307	*323	*341	*400	*115	*251	*237	*23	*7	--------
	O. and A. Bridge	416	131	389	304	285	336	470	552	462	80	371	325	38	88	13	10
	Sacramento River Delta																
	Collinsville	†26	*34	--------	--------	--------	*28	†24	†22	--------	--------	82	24	--------	--------	--------	--------

* Observation on next succeeding day.
† Observation after low tide.
[1] From data presented in Figures 93 and 99, pages 249 and 262 of final report, 1927, by San Francisco Bay Marine Piling Committee on "Marine borers and their relation to marine construction on the Pacific Coast."

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1922

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
January	Tiburon[1]			1,685			1,790							1,745		
	Green Brae[1]		*365				1,085				920			*1,260		
	Black Point[1]			1,060			*800									*790
	Crockett[1]		*505	700	*1,000	800	980		*1,020	*730		1,020	*915	1,090	1,150	990
	Port Costa[1]		*305			545					575			*775		
	Martinez[1]					440									660	
	Bulls Head Point[1]															
	Avon[1]							30							50	
	Sacramento River Delta															
	Collinsville	*6	*†4	5												
	San Francisco, San Pablo and Suisun Bays															
February	Tiburon[1]		1,650				1,810									
	Green Brae[1]						305						440			
	Black Point[1]	*790				1,120							535			
	Crockett[1]	850		910	1,235	1,210		180	*225	420	375	*365	255		220	
	Port Costa[1]				925			110		*180			25			
	Martinez[1]	470			770			60		*150				10		
	Bulls Head Point[1]				*575				110				35			
	Avon[1]														5	
	San Francisco, San Pablo and Suisun Bays															
March	Tiburon[1]	*1,100				1,635										*1,480
	Green Brae[1]	305				700										*465
	Black Point[1]	305											605			*575
	Crockett[1]	*205	270	220	515	575	*605	*605		195	410	315	365			240
	Port Costa[1]			180		365				150			255			*90
	Martinez[1]	10				30			*60			255				*120
	Bulls Head Point[1]			210			60			*60	*120					
	Avon[1]					20										5

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1922

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
April	Tiburon[1]							1,770			*1,165				1,635	
	Green Brae[1]														885	
	Black Point[1]			*670				*605							605	
	Crockett[1]	300		300	*330	*170		330		240	605		560	515	150	
	Port Costa[1]		*90	*210					60		305					60
	Martinez[1]		30	170		5							195			
	Bulls Head Point[1]					5										5
	Avon[1]							5				60				5
	San Francisco, San Pablo and Suisun Bays															
May	Tiburon[1]									*1,070						
	Green Brae[1]						500				910					
	Black Point[1]										515					495
	Crockett[1]		*285	140	*240	115	115		120	240	120	180		150		90
	Port Costa[1]										50					10
	Martinez[1]		*120								24		*5		120	5
	Bulls Head Point[1]					50							50			5
	Avon[1]															
	San Francisco, San Pablo and Suisun Bays															
June	Tiburon[1]	1,275			*1,320				1,180							1,530
	Green Brae[1]				*575											945
	Black Point[1]								410							
	Crockett[1]	48	*140	115	105	85	*85		210	*260		*200	425	395	310	350
	Port Costa[1]							10		*210						50
	Martinez[1]							5					90			
	Bulls Head Point[1]					5				75			35			
	Avon[1]												5			

	San Francisco San Pablo and Suisun Bays															
July	Tiburon[1]							1,530			1,745					
	Green Brae[1]							1,120								
	Black Point[1]							635			*755				700	
	Crockett[1]		*500		485		515	605	*730	700	665	880			*1,000	
	Port Costa[1]							305		*605						
	Martinez[1]	30											485			
	Bulls Head Point[1]													240		
	Avon[1]				60			10								
	San Francisco, San Pablo and Suisun Bays															
August	Tiburon[1]	*1,820											1,880			
	Green Brae[1]	*1,455								1,710			1,605			
	Black Point[1]									1,180						
	Crockett[1]				1,000							1,150				
	Port Costa[1]	*850						850								
	Martinez[1]				790										940	
	Bulls Head Point[1]				850											
	Avon[1]									75						
	Sacramento River Delta															
	Collinsville													232	244	204
	San Joaquin River Delta															
	Antioch													168	116	115
	San Francisco, San Pablo and Suisun Bays															
September	Tiburon[1]								1,930							
	Green Brae[1]	1,670			1,575				1,760						1,750	
	Black Point[1]	1,395										1,515				
	Crockett[1]			1,270				1,345								1,330
	Port Costa[1]	1,275		1,135				1,290				1,200		*1,260		
	Martinez[1]						1,030					1,180		*1,250		
	Bulls Head Point[1]	1,080										1,140				
	Avon[1]											115				
	O. and A. Ferry			402	450	444	574	472	424	450	564	484	460	468	408	420
	O. and A. Bridge				386	408	384	396	424	432	284	508	†200	532	524	†144
	Sacramento River Delta															
	Collinsville		296		320	312	308	288	308	332	370	†104	320	205	†36	248
	Emmaton										44	41	40	†22	24	22
	Rio Vista											4			*4	
	San Joaquin River Delta															
	Antioch	155	224	230	197	226	246	252	232	224	260	232	†196	252	196	168
	Jersey								33	24	28	31	18	†28	22	28
	Central Landing, Bouldin Island	6	6	6			5			6			6			*6

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1922

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water														
		Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
October	Tiburon[1]			1,940												
	Green Brae[1]													*1,485		
	Black Point[1]							1,505								
	Crockett[1]		1,240										1,150			
	Port Costa[1]											1,030				
	Martinez[1]						1,000					1,000				
	Bulls Head Point														780	
	Avon[1]											80				
	O. and A. Ferry	392	428	400	368	368	312	634	308	244	272	272	292	320	260	180
	O. and A. Bridge	480	608	568	536	236	280	508	304	500	120	520	504	468	440	496
	Sacramento River Delta															
	Collinsville	248	240	†60	140	120	152	76	*†22	†20	138	64	112	144	106	60
	Emmaton	22	16	10	*6	5		3		4	3		4			3
	Rio Vista		4			2			2							
	San Joaquin River Delta															
	Antioch		156	156	80	112	72	52	65	29	55	84	77	50	20	20
	Jersey	20	19	17		14	11	10	8	12	9	8	7	8	7	8
	Central Landing, Bouldin Island								*4				*4			
	San Francisco, San Pablo and Suisun Bays															
November	Tiburon[1]		1,840			1,920										
	Green Brae[1]					*1,700							1,365			
	Black Point[1]					1,300			*1,300					1,210		
	Crockett[1]			1,270		1,090			910							
	Port Costa[1]	1,090									620				1,000	
	Martinez[1]	*850		*1,090		635				820			*425			
	Bulls Head Point[1]					850					620					1,000
	Avon[1]								60							
	O. and A. Ferry	200	220			184	36	40	38	62	70	69	31	74	75	100
	O. and A. Bridge	420	480	476	428	212	160	252	388	220	364	316	56	312	292	284

	Sacramento River Delta															
	Collinsville					28	8	7	8	†3	†4		7			†5
	Emmaton	3							2							
	Rio Vista															
	San Joaquin River Delta															
	Antioch	20	30	16	26	14	8	6	6	6	7	7	7	7	7	
	Jersey	7				7										
	Central Landing, Bouldin Island	3		3				*4								
	San Francisco, San Pablo and Suisun Bays															
December	Tiburon[1]				1,820							1,575			1,605	
	Green Brae[1]				1,655			*665				655			*305	
	Black Point[1]				1,195				990						*305	
	Crockett[1]	970		*1,200		820			305		200				970	*485
	Port Costa[1]		800	970					210		210			*605		485
	Martinez[1]			1,090					75				140		545	*195
	Bulls Head Point[1]		790	910					210		210				605	*485
	Avon[1]					80			10						*50	
	O. and A. Ferry	169	134	171	77	71	8	5								
	O. and A. Bridge	300	272	272	204	200	75	18								

* Observation on next succeeding day.
† Observation after low tide.
[1] From data presented in figures 94 and 99, pages 251 and 262 of final report, 1927, of San Francisco Bay Marine Piling Committee, on "Marine borers and their relation to marine construction on the Pacific Coast."

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1923

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Carquinez Strait															
January	Crockett[1]	275	180	165	340	485	370	*420	840	545	†395	500	450	360	*420	295
	Carquinez Strait and Suisun Bay															
June	Crockett[1]	†220	320	330	370	*420	415	425	190	330	*455	515	*405	*455	500	435
	O. and A. Ferry												3	6	6	5
	O. and A. Bridge												3		9	
	Sacramento River Delta															
	Collinsville												1	2	3	
	Emmaton												†2			
	San Joaquin River Delta															
	Antioch														6	2
	Jersey														2	
	Central Landing, Bouldin Island														2	1
	Carquinez Strait and Suisun Bay															
July	Crockett[1]	435	*455	570	*620	715	620		605	700	800	*790	900	1,270	†915	1,110
	O. and A. Ferry	3	6	4	8	10	11			34	40	56	98	105	120	225
	O. and A. Bridge	16		8		6		22		28		36		69		93
	Sacramento River Delta															
	Collinsville	2	4	2			4	7	*7	4	4	5	†17	39	30	102
	Emmaton	†2		2	2			3	3			*3				8
	Three Mile Slough Ferry	3		2		2		4		2		2		4		7
	San Joaquin River Delta															
	Antioch	2	3	2	2	2	4	3	5	4	4	3	6	6	45	72
	Jersey	2		2		2		2		2		4		3		8
	Central Landing, Bouldin Island	2		2	1	2	3	2	2	2	6	3	3			
	Carquinez Strait and Suisun Bay															
August	Crockett[1]	1,320	830	1,170	1,270	*1,140	*970	*1,100	1,310	1,140	1,130	1,240	1,160	*1,200	*1,170	1,390
	O. and A. Ferry	182			197	241	232	375	260	317	332	334	287	334	454	384
	O. and A. Bridge	103		83		125		134		176		186		276		338

	Collinsville	64	59	69	73	100	133	190	153	154	112	73		*256	312	310
	Three Mile Slough Ferry	6			4			3		8		*3		13		17
	Rio Vista Bridge											4		*4		*4
	San Joaquin River Delta															
	Antioch	31	11	64	75	110	90	135	123	87	151	92	126	156	209	160
	Jersey		3		5		18		9		8		16		28	
	Central Landing, Bouldin Island	3	3	3	3	4		4	4	4	4	5				
	Suisun Bay															
September	O. and A. Ferry	380	344	343	373	518	454	457	468	367	374	425	369	355	322	194
	O. and A. Bridge	258		365		203		335		464		223		211		423
	Sacramento River Delta															
	Collinsville	254	214	153	256	265	358	286	275	236	266	243	76	227	131	117
	Emmaton		*19										19			
	Three Mile Slough Ferry	14		*13												
	Rio Vista Bridge		5			5		*5		5	*4		*4		1	
	San Joaquin River Delta															
	Antioch	119	153	153	99	126	239	87	193	112	187	175	185	139	112	49
	Jersey			19		31		33		27		34		18		
	Suisun Bay															
October	O. and A. Ferry	216	189	169	177	238	254	164	202	100	112	274	155	176	200	180
	O. and A. Bridge	205		422		129		441		433		412		247		162
	Sacramento River Delta															
	Collinsville	104	88	80	22	103	60	65	57	37	56	74	35	34	62	68
	Emmaton			8												
	Three Mile Slough Ferry	4		4		4		5		3		3		3		3
	Rio Vista Bridge	3		3		3	*3		*2			*2			*3	
	San Joaquin River Delta															
	Antioch	16	62	32	14	43	34	56	29	21	15	17	18	22	18	27
	Jersey		8		8		6		7		7		7		6	
	Suisun Bay															
November	O. and A. Ferry	95	110	176	227	259	251	163	154	184	244	228	256	223	178	154
	O. and A. Bridge	270		332		313		356		96		352		176		288
	Sacramento River Delta															
	Collinsville	43	9	90	†29	107	105	100	86	86	96	122	68	88	48	
	Rio Vista Bridge	*2	*2		*2		2		3							
	San Joaquin River Delta															
	Antioch	18	21	30	59	63	40	54	54							
	Jersey		6		6		5		5		4					

* Observation on next succeeding day.
† Observation after low tide.
[1] From records of salinity observations made by California and Hawaiian Sugar Refining Corporation.

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1924

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Carquinez Strait															
February	Crockett[1]									850	1,640	840	750	850	920	
March	Crockett[1]	820	995	770	830	830	700	1,100	1,270	1,080	915	1,100	1,685	1,330	825	*910
April	Crockett[1]	625	760	900	790	910	540	1,065	630	715	1,025	1,100	945	580	930	*1440
	Carquinez Strait and Suisun Bay															
May	Crockett[1]	1,600	1,030	950	900		1,060	880	1,160	1,440	1,320	1,180		1,150	*1,040	980
	Army Point Site[2]			*650				*715			*790					960
	O. and A. Ferry												308	282	294	334
	Sacramento River Delta															
	Collinsville														154	213
	San Joaquin River Delta															
	Antioch												77	72	50	95
	Jersey											8		8	7	14
	Carquinez Strait and Suisun Bay															
June	Crockett[1]	1,630	1,190	1,470	1,320	1,430	1,380	1,450	1,320	1,320	*1,510	1,420	1,460	1,500	1,510	1,610
	Army Point Site[2]			*960				1,200			*1,060			*1,220		
	O. and A. Ferry	380	448	422	586	472		682	654	680	610	742	656	668	664	780
	Sacramento River Delta															
	Collinsville		274	348	324	300	246	346	390	502	592	542	470	506	644	648
	Emmaton							98	120	144	260	192	192	218	255	278
	Three Mile Slough Ferry							55		125	222	138	132	146		
	Rio Vista Bridge								15	34	84	70	28	36	56	78
	San Joaquin River Delta															
	Antioch	139	222	260	216	220	210	280	324	342	460	376	378	376	346	468
	Jersey		20	47		29	34	47	134	144	104		100	114	119	209
	Central Landing, Bouldin Island											20	14	16	16	24
July	Carquinez Strait and Suisun Bay Crockett[1]															

	Carquinez Strait and Suisun Bay															
July	Crockett[1]	1,390			1,500	1,520	1,620	1,640	1,720	1,550		*1,550	1,980	1,510	1,380	1,530
	Army Point Site[2]		*1,310				1,325			*1,475						
	O. and A. Ferry	792	815	775	865	900	875	905	990	965	1,020	1,050	1,040	1,020	1,045	1,120
	Sacramento River Delta															
	Collinsville	674		782	776	738	776	796	800	916	960	864	876	910	710	940
	Emmaton	279		444	442	424	466	464	450	418	568	536	570	628	664	646
	Three Mile Slough Ferry										482	396	476	363	526	598
	Rio Vista Bridge	79	183	168	157	168	278	302	276	366	306	270	400	390	414	406
	Isleton Bridge	15	56	46	31	63	105	114	150	144	156			184	163	170
	Howard Ferry															96
	Sutter Slough													7	9	
	Walnut Grove									7	7	16	7	10	10	10
	Mokelumne River Delta															
	Camp 33, Staten Island											35		47	43	43
	Tyler Island Ferry															8
	Camp 11, Staten Island											12		17	20	23
	Camp 25, Staten Island															25
	San Joaquin River Delta															
	Antioch	520	624	568	594	592	524	614	576	820	810	874	696	772	712	772
	Jersey		213		302		274	296	356	398		402	392	384	414	
	Webb Pump								165	216	165	180	168	153	198	220
	Central Landing, Bouldin Island	25	32	29	39	52	52	56	66	86	87	94	104	110	128	108
	Holland Pump													67	83	96
	Medford Pump									26	52	47	56	69	70	78
	Carquinez Strait and Suisun Bay															
August	Crockett[1]	1,420	1,440	1,730	1,680		1,330			1,550	1,480		*1,720	1,710	1,830	
	Army Point Site[2]	1,475				1,550			1,535							*1,540
	O. and A. Ferry	1,155	1,255	1,285	1,285	1,290	1,225	1,250	1,230	1,240	1,175	1,240	1,190	1,270	1,345	1,325
	Sacramento River Delta															
	Collinsville	1,005	1,065	1,040	1,125	985	940	970	1,150	1,100	1,060	1,030	935	890	935	
	Emmaton	676	656	802	768	636	726	702	726	736	758	722	720	698	760	776
	Three Mile Slough Ferry	636	600	432	590	578	638	690	730	648	592	668	546	570	668	692
	Rio Vista Bridge	370	488	448	524	572	608	462	514	522	438	450	454	506	514	434
	Liberty Ferry		139	151	164	179	178	183	192	173	170	188	156	138	155	160
	Isleton Bridge	208	174	180	300		288	310	294	68	118	156	*38	*48	*112	*18
	Howard Ferry	88	100	83	71	81	84	81	157	76	42	37	21	11	13	14
	Sutter Slough		28		46		36		45	12		16	10			
	Little Holland Ferry					48	37	31	27	23	24	21		13		
	Grand Island Bridge			25	34	47	30	21	13	14	9	15	11	10	10	9
	Walnut Grove	*14	*21	*32	*42	*29	*29	*20		14	11	*16	*10	*9	*11	*10
	Hood Ferry					46	30	21	12	15	10	13	12	19	9	8
	Freeport Ferry								15	11	9	10		10	9	8

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1924

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Mokelumne River Delta															
August (Continued)	Camp 33, Staten Island	58	71	75	76	--	85	95	95	84	79	88	--	87	92	113
	Tyler Island Ferry	30	23	43	44	33	23	21	12	10	--	--	--	12	12	10
	Camp 11, Staten Island	33	49	47	50	--	44	62	57	53	44	48	--	53	65	61
	Camp 25, Staten Island	35	44	52	60	--	55	57	65	48	54	37	--	33	71	55
	San Joaquin River Delta															
	Antioch	938	928	868	1,024	864	904	946	984	958	1,080	990	822	870	992	1,042
	Jersey	--	578	566	532	--	--	648	666	612	558	--	490	614	634	708
	Webb Pump	258	199	--	--	--	--	--	--	--	243	264	299	324	356	324
	Central Landing, Bouldin Island	*166	*160	--	222	180	182	230	200	176	--	--	--	--	--	--
	Holland Pump	99	148	123	137	98	138	187	186	172	155	155	164	175	200	224
	Medford Pump	92	107	111	100	108	120	140	148	138	136	--	164	164	192	200
	King Island, Camp 3½	--	--	--	--	--	65	66	67	68	80	84	--	98	95	99
	Rindge Pump	--	--	--	89	89	80	78	85	--	66	88	75	76	84	98
	Middle River P.O.	--	--	--	82	--	82	81	84	74	75	86	89	98	106	110
	Mansion House	--	--	55	73	64	64	74	72	59	59	68	69	70	85	--
	Wakefield Landing	--	--	--	--	--	--	--	--	54	65	--	73	74	79	90
	Clifton Court Ferry	--	--	--	--	--	--	--	--	24	24	36	*38	*37	*41	*27
	Williams Bridge	--	--	--	--	--	--	--	--	--	17	16	10	--	18	--
	Carquinez Strait and Suisun Bay															
September	Crockett[1]	--	1,460	1,500	1,720	1,320	*1,640	*1,430	*1,650	1,730	1,630	*1,480	1,600	1,650	1,570	1,610
	Army Point Site[2]	--	--	--	1,585	--	--	1,555	--	--	--	--	--	--	--	--
	O. and A. Ferry	1,300	1,295	1,220	1,150	1,235	1,330	1,335	1,345	1,340	1,250	1,190	1,275	1,150	1,160	1,270
	Sacramento River Delta															
	Collinsville	1,150	966	988	835	1,085	960	975	1,060	1,055	1,075	840	860	--	1,085	915
	Emmaton	760	610	778	586	676	688	734	738	696	610	566	608	--	546	--
	Three Mile Slough Ferry	--	--	384	594	566	650	676	524	416	528	488	378	--	--	--
	Rio Vista Bridge	280	496	450	428	402	560	396	450	294	210	408	312	258	288	316

	Liberty Ferry	*101	*112	*112	*108		110	144	114	98	88	68	72	60	42	48
	Isleton Bridge	17	18		*40	*30	*23	6	9	7	*7	*7	*8	*7	5	
	Howard Ferry	11	7	9	6	10	8	8	7	8	7	7	7	7	7	
	Sutter Slough	8		8	7		9		5		8	8		8		6
	Little Holland Ferry	12	10		14	16	22	16	7	14	12	9	7	10	9	5
	Grand Island Bridge	8	9	7	7	6	9	5	10	8	8	6	7	7	6	6
	Walnut Grove	9	7	8	8	8	10	10	7						6	5
	Hood Ferry	13	8	8	6	8	11	8	6	9	6	7	7	6	5	
	Freeport Ferry		8	5	6		7	6	8	6	6	9	8	9	5	
	Mokelumne River Delta															
	Camp 33, Staten Island	78	93	92	94	105	113		96	88	86	70	76	76		52
	Tyler Island Ferry	7	7	11	9	9	8	7					7	6	8	
	Camp 11, Staten Island	72	47	47	60	71	76		82	84	68	72	86	96		74
	Camp 25, Staten Island	106	70	70	89	61	89		92	100	106	100	110	78		90
	San Joaquin River Delta															
	Antioch	896	870	955	900	1,065	1,085	985	1,055	1,045	785	970		775	865	925
	Jersey	628	564	506	620	604	698		566	562	512		526	562		
	Webb Pump		374	414	326											
	Central Landing, Bouldin Island					164	280	238	184	142	166	198	288	204	196	142
	Holland Pump	202	175	159												
	Medford Pump	94	160	167	200	212	232	228	222	218			234	236		
	King Island, Camp 3½	98	102	113	130	136	136		148	146	154	152	160	156	162	160
	Rindge Pump	91	80	92	103	93	104	114	126	116	110	106	106	114	120	140
	Middle River P. O.	128	112		124	142	151	156	154	164	154	146			*176	186
	Mansion House	85	88	96	104		116		146	132	126	130		144	150	146
	Wakefield Landing	92	80	80	67	95	93	100	108		88	88	104	92	94	
	Clifton Court Ferry	48	40	42	48	60	64	63	69	62	66		69	72	73	76
	Williams Bridge	37	42												13	11
	Mossdale Bridge				14	12	10	9	8	11	10	11	11	10	10	11
	Carquinez Strait and Suisun Bay															
October	Crockett[1]		1,580	1,450	1,670	*1,510	1,340	1,550	1,550		*1,580	1,460		1,530	1,550	1,350
	Army Point Site[2]			*1,550				*1,520	*1,360				*1,335			*1,270
	O. and A. Ferry	1,270	1,175	1,080	1,100	1,030	1,000	835	870	900	870	780	760	800	870	815
	Sacramento River Delta															
	Collinsville	905	640	645	900	915	880	435	730	590	615	580	415	442	676	380
	Emmaton	542	482	494	472	352	434	355	328	252	286	212	192	210	194	170
	Three Mile Slough Ferry		378	386	348	378	284			248	190	184	156	156	150	118
	Rio Vista Bridge	206	332	144	246	124	126	54	54	86	35	84	77	*59	*10	6
	Liberty Ferry	41	40	38	29	30	24	16	18	16			15	15	13	13
	Isleton Bridge	7		*5		4		2		6		5		5		6
	Howard Ferry	5		5		6		3		3		5		4		
	Sutter Slough	*5		5				2		4		5		5		3
	Little Holland Ferry	6														
	Grand Island Bridge	5		6		7		3		3		4		3		5
	Walnut Grove	4		6	5		6		2		3		4			
	Hood Ferry		6		6		5		4		4		5		5	
	Freeport Ferry	5		5												

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1924

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Mokelumne River Delta															
October (Continued)	Camp 33, Staten Island	52	49	54	52	42	--------	20	16	19	18	16	16	--------	12	15
	Tyler Island Ferry	6	6	5	5	7	3	2	--------	--------	--------	--------	--------	--------	--------	--------
	Camp 11, Staten Island	78	82	76	68	82	--------	56	58	72	74	59	56	--------	57	44
	Camp 25, Staten Island	82	84	66	76	80	--------	57	54	56	59	62	48	--------	58	57
	San Joaquin River Delta															
	Antioch	800	790	805	725	735	780	645	604	568	590	425	510	516	534	374
	Jersey	478	--------	--------	468	434	--------	370	346	294	320	306	290	--------	248	--------
	Webb Pump	--------	225	268	267	223	245	236	*200	*194	180	148	176	164	154	144
	Central Landing, Bouldin Island	138	142	152	90	--------	62	60	--------	--------	44	50	66	84	84	34
	Holland Pump	--------	308	260	260	248	274	248	254	--------	250	226	230	242	220	218
	Medford Pump	220	--------	180	--------	173	--------	192	*188	--------	--------	--------	*164	*162	*158	*148
	King Island, Camp 3½	164	164	158	156	136	--------	--------	148	154	--------	134	132	134	116	120
	Rindge Pump	122	122	114	110	--------	112	89	86	94	62	52	76	94	90	78
	Middle River P.O.	174	182	178	180	178	178	152	176	--------	168	168	178	--------	164	158
	Mansion House	--------	138	138	--------	144	148	128	--------	120	90	--------	124	--------	128	88
	Wakefield Landing	88	96	--------	82	--------	80	50	60	--------	44	--------	50	*65	*59	52
	Clifton Court Ferry	80	80	78	75	79	63	51	--------	--------	--------	--------	--------	35	37	34
	Williams Bridge	--------	--------	--------	--------	7	7	8	10	11	11	--------	--------	--------	--------	--------
	Mossdale Bridge	11	10	10	11	10	11	10	10	10	12	12	13	12	12	13
	Carquinez Strait and Suisun Bay															
November	Crockett[1]	1,420	1,300	1,410	1,210	1,260	1,320	1,450	900	1,080	1,150	1,070	875	1,050	*1,130	895
	Army Point Site[2]	--------	--------	*1,125	--------	--------	--------	800	--------	--------	--------	755	--------	--------	*845	--------
	O. and A. Ferry	595	635	465	480	456	294	166	144	98	132	272	338	212	238	216
	Sacramento River Delta															
	Collinsville	422	395	240	200	206	32	66	72	64	70	146	52	22	80	82
	Emmaton	90	88	64	48	26	18	10	16	15	14	--------	12	10	--------	13
	Three Mile Slough Ferry	66	52	33	38	28	14	16	11	12	12	14	12	--------	11	14
	Rio Vista Bridge	7	*5	*9	--------	6	5	5	*4	--------	*6	--------	--------	--------	--------	--------
	Liberty Ferry	8	8	8	9	9	8	6	--------	--------	--------	--------	--------	--------	--------	--------
	Isleton Bridge	--------	2	--------	3	--------	4	--------	5	--------	7	--------	--------	--------	--------	--------

	Mokelumne River Delta															
	Camp 33, Staten Island	13		15	10	7	13	21	17	13	12	9		6	7	8
	Camp 11, Staten Island	49		45	34	34	47	42	20	9	11	13		11	13	14
	Camp 25, Staten Island	59		31	50	55	39	9	31	20	29	27		24	23	25
	San Joaquin River Delta															
	Antioch	342	204	250	238	176	130	70	66	53	55	60	62	72	60	57
	Jersey		146		104	98	94	76								
	Webb Pump	136	132	128	112	108	70	88	*84	*75	*62					
	Central Landing, Bouldin Island	36	24		31	26	16	16	18	*20	28		20	23	17	
	Holland Pump	198	172	186	186	180	168	164	150	144	144	130		136	114	104
	Medford Pump		138		124			114	104		*94					
	King Island, Camp 3½		98	90	102	82	80	76	70	67	56	62		58		58
	Rindge Pump	84	56	62	52	48	52	32	25	19	13	22	18	20	28	22
	Middle River P.O.		148	146	140	136	128	114		82	73		60		48	46
	Mansion House	110	74	84		108	90	42	34	23	25	22		25		
	Wakefield Landing	*44	50	*48		*33		26		*17	*16		*18		*18	*16
	Clifton Court Ferry	36	29	23	24	22	14	13								
	Mossdale Bridge	9	12	13	10	9	7	6	5	7	7	7	6	6	7	7
	Carquinez Strait and Suisun Bay															
December	Crockett[1]	*890	1,030		*1,020	880	980		780	1,060	700			820	960	880
	Army Point Site[2]						560				665			475		
	O. and A. Ferry	164	136	172	184	302	52	91	118	39	52	107	37	51	25	50
	Sacramento River Delta															
	Collinsville	108	98	36	46	158	15	17	43	23	15	15		40	17	11
	Emmaton	16					7	6	5	5						
	Three Mile Slough Ferry	12	12	8												
	Mokelumne River Delta															
	Camp 33, Staten Island	6	7		6	3	7	2	7							
	Camp 11, Staten Island	12	10		9	4	4	3	6							
	Camp 25, Staten Island	21	18		22	16	6	14	16							
	San Joaquin River Delta															
	Antioch	58	51	50	50	40	26	28	31	27	22	19	17	14	16	17
	Jersey									29	25					18
	Webb Pump	*57		46		36			32	30	29					
	Central Landing, Bouldin Island	18		8	9	8		11	10	14	5	10				
	Holland Pump	102	87	82	79	68	64	58	54	46	42	44	34	54		
	Medford Pump															
	King Island, Camp 3½	54	50	47	44		41		41	31	30	30	24	29		
	Rindge Pump	18		15	21	14	13	14			13	13	10	13	13	11
	Middle River P.O.	36		36	31	27	22	21	18		12	12	12	12		*11
	Mansion House	15	12		14	6										
	Wakefield Landing	16		12	*12	*13	15	13	18			12				
	Clifton Court Ferry	7		8	4	6	9	8	8	5	5	5				
	Williams Bridge															
	Mossdale Bridge	7														

* Observation on next succeeding day.
[1] From records of salinity observations made by California and Hawaiian Sugar Refining Corporation.
[2] Average of samples at surface and bottom at high and low tide. Mountain Copper Company records, Bulletin 22, Vol. II, Plate 9-8. See Table 35 for records prior to May 1.

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1925

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Carquinez Strait and Suisun Bay															
January	Crockett[1]	820	705	720	790	790	685	650	760		975	640	1,010	1,150	850	880
	Pittsburg[3]	28			28				18				19			
February	Crockett[1]	730	830	*150	135	73	18	*51		98	97	188	55			
	Pittsburg[3]	20			13				8				7			
March	Crockett[1]	103	194	*300	358	350	273	*265	376	500	126	97	48	110	*110	224
	Pittsburg[3]	5			4				6				4			
April	Crockett[1]	273	84	218	350			167	15	15	79	73	158	*170	155	
	Pittsburg[3]	4			6				9				4			
	Carquinez Strait and Suisun Bay															
May	Crockett[1]	160	360	330	320	245	170	225	*320	*420	410		335	330	165	205
	Army Point Site[2]				62			*115				102				
	O. and A. Ferry						2		2		2		3		5	4
	Pittsburg[3]	4			4				8				7			
	Sacramento River Delta															
	Collinsville					2		2		2		4		3		3
	San Joaquin River Delta															
	Antioch	2	2		2		2		2		2		2		2	*5
	Carquinez Strait and Suisun Bay															
June	Crockett[1]	405	490		230	450	390	535	515	640		595	575	730	620	635
	Army Point Site[2]			62				*175			*285					465
	O. and A. Ferry		4		2		6		7		7		8		10	
	Pittsburg[3]	6			8				8				9			
	Sacramento River Delta															
	Collinsville			4	4		6		7		7		8		8	
	San Joaquin River Delta															
	Antioch		3		4		4		4		4		5		6	

	Carquinez Strait and Suisun Bay															
July	Crockett[1]	635	*710	*1,000	760	*850	740	*655	780			*1,160	840	1,080		1,150
	Army Point Site[2]					*405					800					*815
	O. and A. Ferry	30		53		64		70		198		184		200		238
	Pittsburgh[3]	7			18				27				52			
	Sacramento River Delta															
	Collinsville	15		27		39		28		90		118		74		106
	Emmaton					9		7		8		12		27	*16	
	Three Mile Slough Ferry												10	13	11	12
	Rio Vista Bridge														8	7
	San Joaquin River Delta															
	Antioch	6		10		14		11		39		60		47		65
	Jersey					5		7		8		10		9		10
	Webb Pump										5	5	6	8	7	
	Carquinez Strait and Suisun Bay															
August	Crockett[1]	1150	1,170	820	*1,340	1,120	*1,320		1,280	1,370	1,310		1,350	1,330	1,360	*1,380
	Army Point Site[2]						*900				910				*1,135	
	O. and A. Ferry		318		446		362		384		424		426		496	
	Pittsburg[3]	95			160				255				292			
	Sacramento River Delta															
	Collinsville	191		360		274		260		318		328		344	380	
	Emmaton	53		75		89		65		85		88		93		132
	Three Mile Slough Ferry	16	20	30	46	28	30	35	43	46	44	46				
	Rio Vista Bridge	10	9	15	10	10	10	6	8	7	8	7	8	8	8	
	Isleton Bridge		8	8	8		8	8	6	6	6	6	6	*8	*8	
	Cache Slough											7	6	6	5	5
	San Joaquin River Delta															
	Antioch	206		153		142		174		212		224		254		218
	Jersey	*15		*47		*16			38		42		30		30	
	Webb Pump	7	9	8	8	8	8	10	10	7	7	6	9	15	17	16
	Central Landing, Bouldin Island			8		8			7		7		6	8		
	Holland Pump			9		9		8		10		7		10		13
	Medford Pump		11					*8		9	11			11	10	
	Rindge Pump						23		21		20		23			
	Middle River P. O.						5		8		8		6		*10	
	Mansion House						5		6		5		5		7	
	Carquinez Strait and Suisun Bay															
September	Crockett[1]	*1,390	1,430	1,450		*1,360	*1,310	*990	1,050	1,380			630	1,240		1,520
	Army Point Site[2]		*925				*1,075				962			*840		
	O. and A. Ferry	558		564		484		478		482		652		762		348
	Pittsburg[3]	365			405				370				340			
	Sacramento River Delta															
	Collinsville	438		448				388		400		340		302		322
	Emmaton		136		108		130			102		68			57	21
	Three Mile Slough Ferry	67		81		53		48		44		34		20		17
	Rio Vista Bridge	21		7		*9		7		7		5		3		3
	Isleton Bridge	8		5			7	*12		7		6		*3		
	Cache Slough	6	6	6	7	6	7		11			7		6		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1925

Samples taken in surface zone usually about two hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Joaquin River Delta															
September (Continued)	Antioch		356		246		246		268		258		166		188	132
	Jersey	71		81		58		67		55		34		26		36
	Webb Pump	21	24	13	23	23	24	17	20		22					11
	Central Landing, Bouldin Island	10		8		9		9		10		6			6	
	Holland Pump	17		12		15		18		17		18		14		16
	Medford Pump	9	11	*12		16		*17		*19	*17		*11			
	Rindge Pump	35		24		27		26		26		19		18		20
	Middle River P. O.	9				13										
	Mansion House	7		8		11		9		11		9		8		9
	Carquinez Strait and Suisun Bay															
October	Crockett[1]	*1,410	1630	*1,160	1,140	1,130	*1,260	1,230	1,310	1,210	*1,330	1,290	1,170	*1,180	1,200	1,220
	Army Point Site[2]	*935					900				915			1,100		
	O. and A. Ferry		412		386		284		266		322		296		312	
	Pittsburg[3]	300			270				210				139			
	Sacramento River Delta															
	Collinsville	328		230		252		200		204		174		122		204
	Emmaton	36	26	33	34	44	13	11	15			13	17	18	14	11
	Three Mile Slough Ferry		21		13		10		8		9		12		9	
	Rio Vista Bridge				4		3		3		*5		5			
	Isleton Bridge	3	3		4		3		2		5		*5		4	
	Cache Slough		7		5		5		5			4			8	7
	San Joaquin River Delta															
	Antioch		218		136		106		124		86	104			92	
	Jersey		40		21		21		14		15				15	
	Webb Pump		13	14		16	14	12	12	11	14	14	12		15	13
	Central Landing, Bouldin Island	6		6		6		5			5		7		8	
	Holland Pump		14		16		14		16		16		17		16	
	Medford Pump		*12			14	*14						17	19		16
	Rindge Pump		17		13		17		16		15		17		16	
	Mansion House		8		8		7		8		10		9		10	

November	**Carquinez Strait and Suisun Bay**															
	Crockett[1]		1,300	1,090	1,130	1,140			1,120		1,210		1,180	*1,180	1,140	1,210
	Army Point Site[2]	900					1,180			*975						1,000
	O. and A. Ferry	304		202		200		180		212		164		230		210
	Pittsburg[3]	125			85				62				64			
	Sacramento River Delta															
	Collinsville	136		74		103		43		42		62		115		92
	Emmaton		14	12	7	7	7	7	8	8	11	6	6	13	9	
	Three Mile Slough Ferry		7		8		8		7		8		7		7	
	Isleton Bridge	5		5												
	Cache Slough	7		6		5		6		7		4			5	
	San Joaquin River Delta															
	Antioch	67		56		49		29		48		20		60		65
	Jersey	17		13		*10		10		10		10		9		11
	Webb Pump	11	12	11		10	12	12	12	12	10	13	9		10	
	Central Landing, Bouldin Island	8				7		6								
	Holland Pump	15	13	13				14		13		12		11		11
	Medford Pump			14												
	Rindge Pump	14		12		14		14		13		13		15		14
	Middle River P. O.								*10	7	9	11		9	8	8
	Mansion House	7				10		8		7		9		7		9
December	**Carquinez Strait and Suisun Bay**															
	Crockett[1]	1,030		1,030	950	1,080	1,110	*1,110	1,200		880	850			*810	1,070
	Army Point Site[2]									965						*750
	O. and A. Ferry		77		87		124		150		84		84		143	
	Pittsburg[3]	69			38				15				33			
	Sacramento River Delta															
	Collinsville	66		22		26		40		39		28		74		35
	Three Mile Slough Ferry	8		5		7		9		6		6		6		
	Cache Slough	6		5												
	San Joaquin River Delta															
	Antioch	32		17		17		17		21			14		20	
	Jersey		9		9		10		8		10				10	
	Webb Pump			10		10	*8	*10		11	9	11			8	9
	Holland Pump		12		12		10		10		11		10		9	
	Rindge Pump		16		13		11		13		12		12		13	
	Mansion House		8		9		7		8		6				8	

* Observation on next succeeding day.
[1] From records of salinity observations made by California and Hawaiian Sugar Refining Corporation.
[2] Average of samples at surface and bottom at high and low tide. Mountain Copper Company records, Bulletin 22, Volume II, Plate 9-8, See table 35 for records prior to May 1.
[3] Mean weekly salinities from drip samples by Great Western Electro Chemical Company.

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1926

Samples taken in surface zone usually about one and one-half hours after high tide

Salinity in parts of chlorine per 100,000 parts of water

Month	Station	Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Carquinez Strait and Suisun Bay															
January	Crockett[1]										1,030		1,030	1,050	1,100	1,260
	Army Point Site[2]				875			810			*635					*800
	O. and A. Ferry	148		66		214		291		221		128		159		4
	Pittsburg[3]	35			40				70				45			
	Sacramento River Delta															
	Collinsville	37				72		68		106		79		112		4
	San Joaquin River Delta															
	Antioch	20		15		22		36		27		31		29		4
	San Francisco, San Pablo and Suisun Bays															
February	Point Orient					1,140		970		980		1,180		1,260		
	Point Davis			370		195		151		350				690		
	Crockett[1]	715	*345	680	265	240	210	*30	36	*182	145	242	158		375	
	Army Point Site[2]				70			50		*57					132	
	Bulls Head Point	3		28		24		10		8		17		124		
	Bay Point	3		11		7		30		19		12		9		
	O. and A. Ferry		5		6		10		8		7		8		8	
	Pittsburg[3]	50			58				10				10			
	Sacramento River Delta															
	Collinsville	4		8		5		16		6		7		8		
	San Joaquin River Delta															
	Antioch	4		8		7		8		8		10		9		
	San Francisco, San Pablo and Suisun Bays															
March	Point Orient	1,060		1,150		1,340		1,300		1,510		1,370		1,270		1,260
	Point Davis	580		550		650		700		580		500				790
	Crockett[1]	295	380	430	480	*400	600	*680	490	235	300	315	340	515	*305	710
	Army Point Site[2]	*217														
	Bulls Head Point	79		158		*180		286		198		430		490		500

	Bay Point	16		23		69				28		40		212		
	O. and A. Ferry		6		16		8		8		16		7		9	
	Pittsburg[3]	2			10				0				8			
	Sacramento River Delta															
	Collinsville	8		6		6		7		7		6		7		7
	San Joaquin River Delta															
	Antioch	8		10		8		11		8		7		8		7
	San Francisco, San Pablo and Suisun Bays															
April	Point Orient	*1,380		*1,410		*1,160		*960		*1,170		950		1,110		1,440
	Point Davis		820	*570		*190		*82		*160		*480				
	Crockett[1]	650	425	650	480		255	79	105	42	91	*435		480	590	125
	Bulls Head Point	530		*410		120		130		60		44		*193		148
	Bay Point	*93		28		7		11	*7			9		10		13
	O. and A. Ferry	6		9		6		6		6		8		8		6
	Pittsburg[3]	3			10				5				8			
	Sacramento River Delta															
	Collinsville	5		5		5		6		6		7		8		6
	San Joaquin River Delta															
	Antioch	6		6		6		7		8		9		8		8
	San Francisco, San Pablo and Suisun Bays															
May	Point Orient	1,210		1,510		1,180		1,270		1,330		1,460		1,540		1,680
	Point Davis	500		500				740		610		840		760		
	Crockett[1]	*335	440	*325		420	525	430	440	*520	635		470	740	710	*790
	Bulls Head Point	182		*226		234		386		440		530		450		460
	Bay Point	11		*10		15		41		37		*106		111	*156	
	O. and A. Ferry		8		9		7		8		9		8		18	
	Pittsburg[3]	2			0				0				3			
	Sacramento River Delta															
	Collinsville	6		7		6		8		8		9		8		14
	San Joaquin River Delta															
	Antioch	7		10		6		6		7		7		9		9
	San Francisco, San Pablo and Suisun Bays															
June	Point Orient	1,520		1,670		1,470		1,660		1,650		1,560		1,520		1,620
	Point Davis	990		1,000		1,230		1,120		1,110		1,400				1,240
	Crockett[1]	*720	*820	*1,000	1,000	1,100	940	950	970	970		980	1,140	1,230	*1,200	1,210
	Bulls Head Point	460		680		750		890		970		880		700		1,050
	Bay Point	289	*191			520		*620		360		680			640	800
	O. and A. Ferry	60		56		100		103		117		164		246		
	Pittsburg[3]	9			30				50				65			

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1926

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Sacramento River Delta															
June (Continued)	Collinsville	14		32		55		68		43		90		130		188
	Emmaton									10		11		7		21
	Three Mile Slough Bridge					11		9		12		12		8		12
	Rio Vista Bridge					11		11		8		11				6
	Isleton Bridge															6
	San Joaquin River Delta															
	Antioch	11		16		14		14		20		37		33		93
	Jersey					10		10		15		11		10		24
	Webb Pump					2		*4		*5		*4		*5		5
	Middle River P. O.															6
	San Francisco, San Pablo and Suisun Bays															
July	Point Orient	1,710		1,680		1,760		*1,680		1,760		1,950		1,840		1,850
	Point Davis			1,460										1,640		1,750
	Crockett[1]				1,370	1,375	1,370	1,320	1,375	*1,360	1,000	1,200	1,430	1,400	1,450	1,480
	Bulls Head Point	920		1,240		1,200		1,010		1,180		1,490		1,440		1,450
	Bay Point	700		910		1,000		950		*980		860		1,090		1,180
	O. and A. Ferry		373		500		580			620		730		810		920
	Pittsburg[3]	190			240				350				460			
	Sacramento River Delta															
	Collinsville	154		470		530		480		460		560		780		700
	Emmaton	30		61		84		92						183		
	Three Mile Slough Bridge		24	26	59			46		54		68		143		131
	Rio Vista Bridge		14	13		23		17		20		22		53		77
	Liberty Ferry					10				11		14		19		15
	Isleton Bridge	6		14		*18		14		14		15		26		34
	Howard Ferry											14		17		16
	Mokelumne River Delta															
	Southwest Point, Staten Island							14		12		14		18		21
	Camp 33, Staten Island							17		9		9		19		18
	Camp 7, Staten Island															13

	Tyler Island Ferry											15		16		16
	Camp 11, Staten Island							14		11		11		17		17
	Camp 29, Staten Island							17		13		15		18		17
	Eagle Tree															11
	Camp 25, Staten Island							15		11		13		18		15
	New Hope Bridge															13
	Camp 20, Staten Island															14
	San Joaquin River Delta															
	Antioch			250		365		360		320		540		570		570
	Jersey				32		97	64				85		147		198
	Webb Pump	*12		16	*14	19		15				21	*31	29		36
	Central Landing, Bouldin Island					22		13		16		22				28
	Holland Pump	33		13		15		19		15		17		31		37
	Mandeville Pump					14		13		13		23				17
	Rindge Pump													25		31
	Middle River P.O.	6		15		17		13		12		19		14		19
	Mansion House											16		16		13
	San Francisco, San Pablo and Suisun Bays															
August	Point Orient	1,900		1,840		1,870		1,840				1,950		1,890		2,000
	Point Davis	1,690		1,760		1,750		1,650		1,750				1,850		1,720
	Crockett[1]	1,570	1,380	1,550	1,600	*1,480			1,530	1,590	1,520	*1,540	*1,570	*1,750	*1,670	1,520
	Bulls Head Point	1,520		1,500		1,610		1,410		1,600		1,400		1,470		1,690
	Bay Point	*1,120		1,270		*1,190		1,280		1,290		*1,400		1,380		1,370
	O. and A. Ferry	940		990		1,030		1,010		1,020		1,060		1,070		1,060
	Pittsburg[3]	510			560				730				720			
	Sacramento River Delta															
	Collinsville	750		980		940		810		820		880		940		890
	Emmaton	240		268				320		420		540		410		
	Three Mile Slough Bridge	161		249		270		340		360		291		430		290
	Rio Vista Bridge	72		144		158		140		204		185		196		256
	Liberty Ferry	*22		*27		*27		*24		29		31		32		26
	Isleton Bridge	*46		*55		20		55		*68		15		18		*24
	Howard Ferry	18		27		14		14		15		15		15		17
	Walnut Grove									*15		13		15		12
	Paintersville Bridge									13		14		13		13
	Mokelumne River Delta															
	Southwest Point, Staten Island	21		31		32		30		32		21		65		35
	Camp 33, Staten Island	16		21		21		20		24		25		25		28
	Camp 7, Staten Island					16						13				15
	Tyler Island Ferry	19		19		14		13		14		11		12		10
	Camp 11, Staten Island	12		16		15		14		14		17		17		20
	Camp 29, Staten Island	19		20		15		17		20		23		21		23
	Eagle Tree					15						13				15
	Camp 25, Staten Island	19		20		14		13		18		20		20		19
	New Hope Bridge					12						13				11
	Camp 20, Staten Island					14						15				17

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1926

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Joaquin River Delta															
August (Continued)	Antioch			730		730		690		610		870		920		850
	Jersey	176		326		400		370		360		430		470		400
	Webb Pump	63		108		135		147		130			116	112	*114	
	Central Landing, Bouldin Island	28		43		46		53			86		50	80		70
	Holland Pump	38		61		65			77	69		101		124		112
	Mandeville Pump	*23		*34		*31		*41		49		52		60		71
	Rindge Pump	31		44		33		33		35		34		45		40
	Palm Tract			25		26		30		40		47		50		64
	Middle River P.O.	*19		24		20		20		23		28		33		42
	Mansion House		15		16		13			28		29		43		47
	Stockton Country Club									45		40		45		48
	Clifton Court Ferry									13		22		22		24
	Williams Bridge									17		14		16		17
	San Francisco, San Pablo and Suisun Bays															
September	Point Orient	960		1,880		1,830		2,000		1,840		1,900				2,020
	Point Davis	1,680		1,850		1,720		1,730		1,670		1,610		1,810		1,730
	Crockett[1]	1,640		*1,550		1,545	*1,500	1,510		1,530	1,510	1,520	*1,450		1,540	1,540
	Bulls Head Point	1,580		1,580		1,410		1,640		1,420		1,460		1,410		1,510
	Bay Point	1,370		*1,390		*1,300		1,310		1,220		1,190		*1,220		1,010
	O. and A. Ferry	1,000		1,070		1,020		900		1,020		880		840		760
	Pittsburg[3]	780			775				750				660			
	Sacramento River Delta															
	Collinsville	980		1,020		820		810		750		760		690		570
	Emmaton		410		310						256	192		154		172
	Three Mile Slough Bridge		350		254		230	182		168		156		120		92
	Rio Vista Bridge	194		174		132		130		122		50		27		20
	Liberty Ferry	24		26		18		13		11		11		12		9
	Isleton Bridge	15		16		16		12		9		9		7		9
	Howard Ferry	15		15		14		13		12		12		9		6
	Walnut Grove	12		11		14		11		10		9		7		8
	Paintersville Bridge	*17		*9		*12		11		9		9		7		7

	Mokelumne River Delta															
	Southwest Point, Staten Island	28		41		24		18				24		22		18
	Camp 33, Staten Island	22		32		19		16				12		10		11
	Camp 7, Staten Island					21						17				12
	Tyler Island Ferry	12		14		11		9		8		9		9		7
	Camp 11, Staten Island	17		23		19		17				18		16		14
	Camp 29, Staten Island	25		25		22		23				17		13		14
	Eagle Tree					15						18				14
	Camp 25, Staten Island	20		23		22		24				19		16		17
	New Hope Bridge					17						13				15
	Camp 20, Staten Island					21						20				21
	San Joaquin River Delta															
	Antioch	870		860		710		790		590		570		590		490
	Jersey			460		410		310				310		228		200
	Webb Pump	110							124	126	118	100	96		96	98
	Central Landing, Bouldin Island	98				*52		*35				36		*42		42
	Holland Pump	148		144		132		142		130		126		124		118
	Mandeville Pump			82		75		82		82		76		82		84
	King Island, Camp 3½											40	40	44	48	39
	Rindge Pump	49		37		48		50		45		45		41		42
	Palm Tract	74		80		85		82		86		85		86		84
	Middle River P. O.	46		53		55		56		63		65		64		65
	Mansion House	54		65		30		62		61		65		69		67
	Stockton Country Club			48		45		28				35	*28		*33	
	Clifton Court Ferry	23		32		28		29		27		25		23		28
	Williams Bridge	*18		15		15		14		9		14		8		12
	San Francisco, San Pablo and Suisun Bays															
October	Point Orient	1,880		1,990		1,930		1,880		1,890		1,870		1,810		1,840
	Point Davis	1,650		1,550		1,550		1,540	1,710			1,580				
	Crockett[1]	1,510	1,460			*1,370	1,375	*1,370	1,370	1,450	1,550	1,340	*1,350	1,310	1,280	1,340
	Bulls Head Point	1,390		1,290		1,340		1,260		1,270		1,240		1,290		1,140
	Bay Point		1,080	1,100	*1,330			1,070		1,090		1,070		870		*840
	O. and A. Ferry	770		780		620		570		700		670		420		430
	Pittsburg[3]	570			500				400				325			
	Sacramento River Delta															
	Collinsville	550		640		340		480		440		440		310		278
	Emmaton	144		156		78		60		56		52		30		26
	Three Mile Slough Bridge	78		82		62		48		28		27		23		20
	Rio Vista Bridge	27		12		12		7		9		11		9		7
	Liberty Ferry	8		9		8		6		5		7		5		4
	Isleton Bridge	8		5		10		5		6						
	Howard Ferry	7		10		4		8		7		8				
	Walnut Grove	7		7		*6		4		7		4		4		5
	Paintersville Bridge	7		6		7		6		7		6		6		3

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1926

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Mokelumne River Delta															
October (Continued)	Southwest Point, Staten Island	11		12		11		11		15		19		8		11
	Camp 33, Staten Island	12		8		8		9		6		8		6		6
	Camp 7, Staten Island					12						9				12
	Tyler Island Ferry	7		6		9		5		5		5				
	Camp 11, Staten Island	19		15		14		12		11		10		11		14
	Camp 29, Staten Island	15		14		12		10		8		7		9		9
	Eagle Tree					15						13				11
	Camp 25, Staten Island	23		16		16		13		18		12		12		9
	New Hope Bridge					15						13				13
	Camp 20, Staten Island					22						13				13
	San Joaquin River Delta															
	Antioch	630		480		460		380	*320					250		180
	Jersey	176		184		152		110		82		84				27
	Webb Pump	94		92		70		60		55		54		49		39
	Central Landing, Bouldin Island	28		32		*19		20				18		16		18
	Holland Pump	108		102		98		94		84		74		82		66
	Mandeville Pump	82		69		67		73		65		57		57		53
	King Island, Camp 3½	39	38	37	37			34		37		25		32		31
	Rindge Pump	36		38		30		34		32		26		26		25
	Palm Tract	81		82		76		74		67		57		*49		42
	Middle River P. O.		66		69		62	62		61		57		58		42
	Mansion House		69		69		52		49			45		45		44
	Stockton Country Club	32		32		28		30		26		23		20		
	Clifton Court Ferry	27		22		24										
	Williams Bridge	*12		12		15		11		12		*11		9		
	San Francisco, San Pablo and Suisun Bays															
November	Point Orient	1,730		1,840		1,840		1,820		1,760		1,750		1,780		1,220
	Point Davis	1,470		1,360		1,480		1,450		1,540		1,500		1,040	*570	
	Crockett[1]	1,370	1,260		580	1,350	1,250	1,430	*1,300	1,290	1,370		1,180	*1,100	*850	400
	Bulls Head Point	1,190		1,200		1,300		990		1,070		970		920		210

	Bay Point	900		930		830	*900			980		910				90
	O. and A. Ferry	480		412		436		306		392		330		20		6
	Pittsburg[3]	280			135				100				130			
	Sacramento River Delta															
	Collinsville	196		228		272		202		274		144		29		5
	Emmaton			21		36		18		14		10		5		6
	Three Mile Slough Bridge	18		24		22		21		17		16		6		5
	Rio Vista Bridge	5		9		5		5		7		5				
	Liberty Ferry			3		8										
	Walnut Grove	3						6		4		5		5		
	Paintersville Bridge	5		6		5		5		3						
	Mokelumne River Delta															
	Southwest Point, Staten Island	8		7		7		*7		5		4				
	Camp 33, Staten Island	6		7		8		*6		5		11				
	Camp 7, Staten Island					6						9				
	Camp 11, Staten Island	11		10		10		*12		10		12				
	Camp 29, Staten Island	8		10		11		*10		8		8				
	Eagle Tree					13						9				
	Camp 25, Staten Island	11		12		11		*13		11		11				
	New Hope Bridge					11						5				
	Camp 20, Staten Island					16						12				
	San Joaquin River Delta															
	Antioch	154		210		252		196		162		174		40		24
	Jersey			44		39		42		61		35				18
	Webb Pump				37		33		33		31				28	
	Central Landing, Bouldin Island			18		13		14		16		8		8		
	Holland Pump	58		60		58		56		45		45		48		28
	Mandeville Pump			46		55			*42	37		34		30		28
	King Island, Camp 3½		34		31		29		27		23			16		
	Rindge Pump	25		24		23		21		22		22		8		16
	Palm Tract	37		38		34		25		26		26				20
	Middle River P. O.	38		33		34			24	35		28		21		23
	Mansion House	20		23		21		23								
	Stockton Country Club					19				21		21		12		12
	Williams Bridge	[2]9	10	*5		8		10		8						
	San Francisco, San Pablo and Suisun Bays															
December	Point Orient	1,310		1,180		1,250		1,540		1,500		1,260		1,350		1,250
	Point Davis	760		380		490		580		740		730		900		1,190
	Crockett[1]	395		510	730	390	*485	*285	690	1,080	940		550			880
	Bulls Head Point	138		24		104		235		452		240		320		710
	Bay Point	32		22		8		10		111				175		384
	O. and A. Ferry	7		6		5		9		9		10		35		46
	Pittsburg[3]	70			10				4				5			

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1926

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Sacramento River Delta															
December (Continued)	Collinsville	10		12		5		6		9		9		9		10
	Emmaton			5				7								
	Three Mile Slough Bridge	5		6		6		5		4		7				
	Mokelumne River Delta															
	Southwest Point, Staten Island	7														
	Camp 33, Staten Island	4														
	Camp 11, Staten Island	6														
	Camp 29, Staten Island	5														
	San Joaquin River Delta															
	Antioch	20		8		4		9		11		11		15		12
	Jersey	18		11		11		11		13		20				
	Webb Pump	*20		18		12		12		12		13				
	Central Landing, Bouldin Island			5		7										
	Holland Pump	34		28		28		27								
	Mandeville Pump	26		27		25										
	Rindge Pump	20		14		13		13		14		22				
	Palm Tract	19		16		*13		9		9		10				
	Middle River P. O.	18		16		12		11		10		9		8		
	Mansion House														8	

* Observation on next succeeding day.
[1] From records of salinity observations made by California and Hawaiian Sugar Refining Corporation.
[2] Average of samples at surface and bottom at high and low tide. Mountain Copper Co. records. Bulletin 22, Volume II, Plate 9-8.
[3] Mean weekly salinities from drip samples, by Great Western Electro Chemical Co.

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1927

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
January	Point Orient	1,700	....	1,500	....	1,630	....	....	....	1,190	....	890	....	1,390	....	1,280
	Point Davis	1,270	....	860	....	830	....	790	....	620	....	420	....	650	....	640
	Crockett[1]	....	960	1,480	460	540	515	....	*620	510	*305	275	240	*455	....	*520
	Bulls Head Point	680	....	570	....	380	....	230	....	*104	....	120	....	460	....	290
	Bay Point	36	198	166	*40	3	....	28	....	....	....	16	....	56	....	*38
	O. and A. Ferry	67	....	11	....	9	....	6	....	7	....	8	....	7	....	11
	Pittsburg[2]	6	....	....	10	....	....	....	8	....	....	....	10	....	....	....
	Sacramento River Delta															
	Collinsville	32	....	8	....	7	....	6	....	7	....	7	....	8	....	7
	San Joaquin River Delta															
	Antioch	....	....	9	....	13	....	8	....	5	....	9	....	....	....	7
	Webb Pump	....	9	....	11	....	*9	....	....	....	....	....	....	....	....	....
	San Francisco, San Pablo and Suisun Bays															
February	Point Orient	1,210	....	1,000	....	....	....	1,170	....	610	....	790	....	350	....	....
	Point Davis	140	....	290	....	254	....	374	....	100	....	....	....	24	....	....
	Crockett[1]	510	175	127	109	....	....	330	170	24	175	4	5	....	....	....
	Bulls Head Point	118	....	12	....	120	....	20	....	16	....	18	....	14	....	....
	Bay Point	18	*18	....	....	16	....	14	....	20	....	*16	....	12	....	....
	O. and A. Ferry	7	....	9	....	5	....	*8	....	9	....	6	....	6	....	....
	Pittsburg[2]	5	....	....	2	....	....	....	8	....	....	....	4	....	....	....
	Sacramento River Delta															
	Collinsville	7	....	6	....	11	....	5	....	5	....	4	....	5	....	....
	San Joaquin River Delta															
	Antioch	9	....	10	....	11	....	7	....	8	....	10	....	7	....	....

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1927

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
March	Point Orient	1,020		1,250		1,100		1,260		930		1,230		1,240		
	Point Davis	184		66		120		260		164		258				464
	Crockett[1]	175	60	54	91	12		113	230	190	92	280	175		225	485
	Bulls Head Point	12		22		12		30		16		185		101		22
	Bay Point			*18		12		16		14		5		9		15
	O. and A. Ferry	5		7		9		6		5		6		5		6
	Pittsburg[2]	6			6				6				4			
	Sacramento River Delta															
	Collinsville	6		8		7		6		5		8		5		6
	San Joaquin River Delta															
	Antioch	5		9		7		7		6		7		6		7
	San Francisco, San Pablo and Suisun Bays															
April	Point Orient	1,080		1,010		700				890		1,270				
	Point Davis			76		272		340		290		500		510		
	Crockett[1]	192	109	*55	42	*42	212	194	158	155	275	250	235	*395	*230	250
	Bulls Head Point	42		8		6		53		8		74		158		12
	Bay Point	9		8		*4		4		5		8		*9		5
	O. and A. Ferry	7		5		5		5		6		5		6		6
	Pittsburg[2]	6			5				3				0			
	Sacramento River Delta															
	Collinsville	6		5		7		6		5		7		9		4
	San Joaquin River Delta															
	Antioch	6		7		6		12		6		10		9		10

	San Francisco, San Pablo and Suisun Bays															
May	Point Orient	610		1,120		960		1,160				1,390		1,340		1,470
	Point Davis	360		180		440		490		320		480		*740		410
	Crockett[1]	215	91	206		187	365	300	330		172	*73	365	495	430	330
	Bulls Head Point	34		78		236		194		100		102		350		150
	Bay Point	*8		7		19		7		6				12		
	O. and A. Ferry	5		10		10		8		5		6		6		6
	Pittsburg[2]	2			4				5				5			
	Sacramento River Delta															
	Collinsville	6		25		11				5		6		7		9
	San Joaquin River Delta															
	Antioch	11		4		6		9		5		6		8		6
	San Francisco, San Pablo and Suisun Bays															
June	Point Orient	1,130				1,370				1,130		1,240		1,510		1,310
	Point Davis	600		490		590		430		640		390				
	Crockett[1]	*350		350	415	515	270	350	390	235	131	*490	570	550	530	620
	Bulls Head Point	360		130		510		340		76		220		268		650
	Bay Point	11		13		11		8	*8			*7	*11			46
	O. and A. Ferry	6		9		8		6		5		6		9		9
	Pittsburg[2]	2			4				8				3			
	Sacramento River Delta															
	Collinsville			6		7		4		4		7		8		8
	San Joaquin River Delta															
	Antioch	16		7				5		7		6		10		7
	San Francisco, San Pablo and Suisun Bays															
July	Point Orient	1,370		1,390		1,550		1,740		1,660		1,530		1,560		1,370
	Point Davis							1,200		1,100		910				
	Crockett[1]		*560	655	990	890	830	910		1,100	980	1,100	1,150	1,250	1,100	
	Bulls Head Point	600		360		560		810		650		740		*900		770
	Bay Point			89		*272		*384		*344		378		504		552
	O. and A. Ferry	8		7		26		83		89		128		178		229
	Pittsburg[2]	2			4				8				30			
	Sacramento River Delta															
	Collinsville	6		7		4		35		46		35		77		119
	San Joaquin River Delta															
	Antioch	7		*4		4		15		22		20		23		90

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1927

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
August	Point Orient	1,530		1,490				1,620		1,510		1,560		1,460		1,550
	Point Davis	1,240				1,160		1,280		1,120				1,510		1,350
	Crockett[1]	1,280	1,090	1,280	1,180	1,440	1,270			910	1,320	1,370	1,330	1,335	1,300	1,880
	Bulls Head Point	770		720		980		1,080		1,050		980		970		1,140
	Bay Point	480		542		640				550		670		730		720
	O. and A. Ferry	221		229		283		364		322		348		380		510
	Pittsburg[2]	50			120				170				235			
	Sacramento River Delta															
	Collinsville	117		103		180		260		228		258		276		304
	Emmaton	14				17		38		16				35		65
	Three Mile Slough Bridge	9		14		13		17		14		17		22		23
	Rio Vista Bridge	5		10		11		9		8		9		6		7
	San Joaquin River Delta															
	Antioch	48		52		74		145		108		154		104		106
	Jersey	12		12		16		23		18		17		24		48
	Webb Pump			9		8		12		9		8		7		12
	San Francisco, San Pablo and Suisun Bays															
September	Point Orient	1,650		1,820		1,880		1,550		1,490		1,540		1,570		1,510
	Point Davis			1,480		1,420		1,340		1,260		1,120		1,260		1,330
	Crockett[1]	1,360		2,060	1,300	1,400	1,300	1,370	*1,420	1,470	1,390	1,520		1,280	1,180	1,390
	Bulls Head Point	1,330		1,120		1,070		1,100		1,050		890		920		1,000
	Bay Point	950		840		870		730				750		690		620
	O. and A. Ferry	500		410		510		500		390		400		400		370
	Pittsburg[2]	260			280				250				290			

	Sacramento River Delta															
	Collinsville	340		310		370		330		260		280		280		250
	Emmaton					25										
	Three Mile Slough Bridge	24		21		25		24		25		16		12		10
	Rio Vista Bridge	9		10		10		7		7		10		12		8
	San Joaquin River Delta															
	Antioch	128		156		86		164		179		99		83		106
	Jersey	39		26		41		53		25		21		29		18
	Webb Pump	13		14		16		16		12		11		12		14
	San Francisco, San Pablo and Suisun Bays															
October	Point Orient	1,570						1,690		1,600		1,580		1,590		
	Point Davis	1,240		1,180		1,320		1,220		1,200		1,270				
	Crockett[1]	*1,240	1,260	1,220		1,340	1,380	1,370	1,300	1,190	1,240		1,270	1,330	1,270	1,090
	Bulls Head Point	1,040		990		1,000		1,010		1,020		850		1,060		870
	Bay Point			780		670		720		600		630		740		550
	O. and A. Ferry	400		270		390			380		310		270	280		230
	Pittsburg[2]	240			155				160				115			
	Sacramento River Delta															
	Collinsville	190		190		200		210		170		190		190		120
	Three Mile Slough Bridge	11		10		10		12		9		9		8		6
	Rio Vista Bridge	8		8		6		7		9		4		7		4
	San Joaquin River Delta															
	Antioch	122		56		78		84		82		80		76		22
	Jersey	18		20		20		16		15		11		11		10
	Webb Pump	12		10		11		12		10		10		10		8
	San Francisco, San Pablo and Suisun Bays															
November	Point Orient	1,490		1,540		1,360		1,370		1,230		1,450				1,250
	Point Davis	1,080		1,140		1,260		670		800		760				650
	Crockett[1]	1,330	1,070	1,180	1,370	1,230	1,150	*1,300	730	700	1,040	640	*750	755	700	*595
	Bulls Head Point	800		1,010		990		600		610		630		570		330
	Bay Point	520				600		260				106		138		106
	O. and A. Ferry	140		210		60		30		16		12		8		12
	Pittsburg[2]	90			60				50				20			
	Sacramento River Delta															
	Collinsville	68		118		118		20		10		6		4		5
	Three Mile Slough Bridge	5		6		4		5		6		5		3		
	Rio Vista Bridge	3		3		25		2		4						
	San Joaquin River Delta															
	Antioch	16		20		24		14		8		7		5		7
	Jersey	13		7		11		12		7		7				
	Webb Pump	8		8		6		11		6		7		8		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1927

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water														
		Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
December	Point Orient	--------	1,400	1,450	--------	1,450	--------	--------	--------	1,330	--------	1,190	--------	--------	--------	1,160
	Point Davis	620	--------	980	--------	930	--------	840	--------	--------	--------	--------	--------	1,000	--------	650
	Crockett[1]	670	*990	890	970	950	790	750	680	*850	800	840	--------	*810	710	660
	Bulls Head Point	500	--------	660	--------	550	--------	480	--------	630	--------	610	--------	610	--------	420
	Bay Point	108	--------	264	--------	318	--------	178	--------	--------	--------	340	--------	--------	--------	--------
	O. and A. Ferry	10	--------	114	--------	60	--------	14	--------	24	--------	74	--------	26	--------	6
	Pittsburg[2]	4	--------	--------	7	--------	--------	--------	12	--------	--------	--------	8	--------	--------	--------
	Sacramento River Delta															
	Collinsville	4	--------	21	--------	7	--------	12	--------	6	--------	13	--------	14	--------	6
	San Joaquin River Delta															
	Antioch	5	--------	7	--------	4	--------	6	--------	6	--------	11	--------	8	--------	8

* Observation on next succeeding day.
[1] From records of salinity observation made by California and Hawaiian Sugar Refining Corporation.
[2] Mean weekly salinities from drip samples, by Great Western Electro Chemical Company.

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1928

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water														
		Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
January	Point Orient	1,070	--------	1,170	--------	1,290	--------	1,310	--------	1,370	--------	1,240	--------	1,240	--------	1,460
	Point Davis	--------	--------	630	--------	--------	--------	650	--------	970	--------	990	--------	690	--------	--------
	Crockett[1]	*670	640	670	*560	545	480	475	680	820	825	950	840	680	560	530
	Bulls Head Point	550	--------	206	--------	350	--------	502	--------	580	--------	520	--------	476	--------	234
	Bay Point	--------	--------	114	--------	86	--------	138	--------	212	--------	--------	--------	--------	--------	252
	O. and A. Ferry	7	--------	5	--------	6	--------	6	--------	17	--------	24	--------	7	--------	7
	Pittsburg[2]	10	--------	--------	8	--------	--------	--------	7	--------	--------	--------	10	--------	--------	--------
	Sacramento River Delta															
	Collinsville	5	--------	6	--------	5	--------	8	--------	5	--------	6	--------	--------	--------	9
	San Joaquin River Delta															
	Antioch	7	--------	6	--------	7	--------	6	--------	5	--------	7	--------	5	--------	5
	San Francisco, San Pablo and Suisun Bays															
February	Point Orient	1,410	--------	1,180	--------	1,060	--------	1,160	--------	1,190	--------	1,330	--------	1,360	--------	--------
	Point Davis	--------	--------	350	--------	340	--------	--------	--------	760	--------	610	--------	690	--------	--------
	Crockett[1]	770	520	345	240	115	*310	260	710	630	770	670	205	*530	535	--------
	Bulls Head Point	316	--------	174	--------	120	--------	202	--------	434	--------	348	--------	206	--------	--------
	Bay Point	182	--------	16	--------	8	--------	16	--------	66	--------	106	--------	--------	--------	--------
	O. and A. Ferry	3	--------	1	--------	2	--------	5	--------	4	--------	9	--------	4	--------	--------
	Pittsburg[2]	9	--------	--------	9	--------	--------	--------	10	--------	--------	--------	10	--------	--------	--------
	Sacramento River Delta															
	Collinsville	8	--------	1	--------	2	--------	5	--------	3	--------	5	--------	5	--------	--------
	San Joaquin River Delta															
	Antioch	5	--------	5	--------	5	--------	6	--------	6	--------	4	--------	4	--------	--------

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1928

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
March	Point Orient	1,360		1,320		1,050		1,120		1,250				1,100		570
	Point Davis	710										740		30		50
	Crockett[1]	605	730	660	610	530	545	425	605	440	550	665	660	585	24	18
	Bulls Head Point	360		368		378		192		470		388		220		14
	Bay Point	204		138		32		30				106		80		10
	O. and A. Ferry	10		6		5		4		2		3		3		4
	Pittsburg[2]	10			10				10				10			
	Sacramento River Delta															
	Collinsville	5				2		4		3				1		3
	San Joaquin River Delta															
	Antioch	3		5		5		3		3		4		7		7
	San Francisco, San Pablo and Suisun Bays															
April	Point Orient	940		760		870		990		870		900		1,200		*1,160
	Point Davis	110		140				230		250		360		370		560
	Crockett[1]	18	2	45	*73	53	76	140	*230	130	220	*260	205	155	155	405
	Bulls Head Point	14		8		*10		104		39		100		50		264
	Bay Point	12		12		8		3		5		2		6		8
	O. and A. Ferry	4		3		5		3		3		7		5		4
	Pittsburg[2]	9			8				9				9			
	Sacramento River Delta															
	Collinsville	3		4		4		4		3		2		4		2
	San Joaquin River Delta															
	Antioch	4		4		2		2		4		3		3		3

	San Francisco, San Pablo and Suisun Bays															
May	Point Orient	*1,240	----	1,030	----	1,220	----	1,080	----	1,570	----	1,530	----	1,190	----	----
	Point Davis	430	----	710	----	----	----	630	----	----	----	----	----	----	----	550
	Crockett[1]	405	485	*520	480	270	300	525	580	620	*665	515	465	550	535	575
	Bulls Head Point	224	----	158	----	166	----	312	----	394	----	570	----	200	----	390
	Bay Point	----	----	----	----	6	----	68	----	35	----	----	----	25	----	----
	O. and A. Ferry	3	----	2	----	3	----	6	----	6	----	5	----	6	----	5
	Pittsburg[2]	12	----	----	21	----	----	----	8	----	----	----	8	----	----	----
	Sacramento River Delta															
	Collinsville	3	----	2	----	6	----	4	----	6	----	5	----	5	----	4
	San Joaquin River Delta															
	Antioch	2	----	2	----	4	----	3	----	7	----	4	----	4	----	4
	San Francisco, San Pablo and Suisun Bays															
June	Point Orient	----	----	1,320	----	1,550	----	1,720	----	1,650	----	1,610	----	1,640	----	*1,790
	Point Davis	690	----	930	----	920	----	900	----	1,190	1,130	----	*1,200	*1,330	----	----
	Crockett[1]	690	695	675	785	830	825	880	1,030	1,000	1,030	1,010	970	1,080	1,080	1,180
	Bulls Head Point	400	----	440	----	740	----	870	----	1,050	----	910	----	820	----	1,100
	Bay Point	95	----	102	----	----	----	238	----	----	----	254	----	394	----	544
	O. and A. Ferry	7	----	22	----	22	----	63	----	88	----	178	----	136	----	160
	Pittsburg[2]	8	----	----	9	----	----	----	10	----	----	----	70	----	----	----
	Sacramento River Delta															
	Collinsville	7	----	7	----	14	----	12	----	84	----	83	----	72	----	106
	Emmaton	----	----	----	----	----	----	----	----	12	----	13	----	14	----	15
	Three Mile Slough Bridge	----	----	----	----	----	----	----	----	11	----	12	----	14	----	13
	San Joaquin River Delta															
	Antioch	4	----	10	----	11	----	11	----	13	----	44	----	26	----	46
	Jersey	----	----	----	----	----	----	----	----	12	----	12	----	13	----	16
	Webb Pump	----	----	----	----	----	----	----	----	----	----	11	----	13	----	12
	San Francisco, San Pablo and Suisun Bays															
July	Point Orient	*1,590	----	*1,720	----	1,720	----	1,830	----	1,780	----	1,640	----	1,780	----	*1,870
	Point Davis	----	----	1,420	----	1,310	----	1,360	----	1,310	----	1,420	----	1,460	----	1,600
	Crockett[1]	1,180	----	1,230	1,120	1,230	1,300	1,280	1,300	1,230	1,340	*1,280	1,390	1,400	1,380	1,370
	Bulls Head Point	1,180	----	1,180	----	900	----	1,180	----	1,320	----	1,200	----	1,090	----	1,190
	Bay Point	----	----	690	----	700	----	790	----	850	----	860	----	850	----	950
	O. and A. Ferry	208	----	358	----	276	----	510	----	460	----	600	----	460	----	600
	Pittsburg[2]	60	----	----	80	----	----	----	222	----	----	----	300	----	----	----
	Sacramento River Delta															
	Collinsville	142	----	192	----	148	----	238	----	390	----	430	----	380	----	490
	Emmaton	15	----	44	----	22	----	27	----	35	----	33	----	50	----	69
	Three Mile Slough Bridge	18	----	16	----	17	----	23	----	25	----	----	----	26	----	*36
	Rio Vista Bridge	----	----	----	----	----	----	----	----	17	----	13	----	12	----	16

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1928

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Mokelumne River Delta															
July (Continued)	Southwest Point, Staten Island									13		13		10		18
	Camp 33, Staten Island									15		13		12		25
	San Joaquin River Delta															
	Antioch	42		106		78		126		270		204		194		204
	Jersey	13		21		24		18		77		37		29		39
	Webb Pump			15		13		19		22		21		14		16
	Central Landing, Bouldin Island											13		13		16
	Holland Pump									19		17		15		19
	Mandeville Pump											18		14		17
	Palm Tract									16		15		12		13
	Middle River P. O.									16		15		17		14
	San Francisco, San Pablo and Suisun Bays															
August	Point Orient	1,820		1,730		1,850		*1,660		1,600		1,610		1,680		1,700
	Point Davis	1,610		1,540				1,460		1,380		1,320		1,460		1,510
	Crockett[1]	1,390	1,420	1,415	1,390	1,420	1,370	1,500	1,460	1,510	1,380	1,450	1,470	1,510	1,410	1,430
	Bulls Head Point	1,230		1,310		1,410		1,280		950		1,170		1,120		1,240
	Bay Point	1,020		1,080		1,170		980		970		930				1,010
	O. and A. Ferry	600		650		630		640		690		750		690		680
	Pittsburg[2]	270			310				360				480			
	Sacramento River Delta															
	Collinsville	500		560		420		520		560		470		500		560
	Emmaton	83				72				142		156		154		98
	Three Mile Slough Bridge	47		55		69		57		75		71		53		83
	Rio Vista Bridge	19		18		31		11		17		26		24		44
	Liberty Ferry													5		5
	Isleton Bridge							7		13		6		*7		*8

	Mokelumne River Delta															
	Southwest Point, Staten Island	17		17		23		10		4		6		11		10
	Camp 33, Staten Island	18		13		14		9		4		4		8		8
	Camp 29, Staten Island							8		4		7		9		16
	San Joaquin River Delta															
	Antioch	272		208		398		390		440		280		330		390
	Jersey	84										93		112		126
	Webb Pump	33		19		19		22		29		10		35		46
	Central Landing, Bouldin Island	19		15		9		10		15		6		13		12
	Holland Pump	23		20		15		24		10		16		23		29
	Mandeville Pump	25		16		17		10		14		11		19		14
	King Island, Camp 3½									9		10		*11		11
	Rindge Pump							25		18		17		24		24
	Palm Tract	20		19		15		7		10		9		12		12
	Middle River P. O.	21		16		20		16			9	6			10	11
	Mansion House							10		15		15		15		12
	San Francisco, San Pablo and Suisun Bays															
September	Point Orient	1,690		1,660		1,680		1,650		1,670		1,640		1,640		1,650
	Point Davis			1,370		1,510		1,380		1,540						
	Crockett[1]		1,490	1,520	1,600	1,490	1,510	1,530	*1,450	*1,490	1,430	1,370	1,460	1,460	1,840	*1,440
	Bulls Head Point	1,130		1,160		1,370		1,260		1,240		1,220		1,290		1,150
	Bay Point	970		950		850		970		960		1,050				950
	O. and A. Ferry	680		680		630		620		610		540		580		540
	Pittsburg[2]	465			522				450				380			
	Sacramento River Delta															
	Collinsville	590		500				490		530		470		410		430
	Emmaton	96		82				144		108		59		55		29
	Three Mile Slough Bridge	109		56		96		72		35		16		45		21
	Rio Vista Bridge	28		23		24		16		7		6		9		7
	Liberty Ferry	6		5		4		5				5		7		6
	Isleton Bridge	7		6		*6		7		7		3		*5		2
	Mokelumne River Delta															
	Southwest Point, Staten Island	9		6		12		15		10		17		5		10
	Camp 33, Staten Island	8		7		6		7		10		10		9		7
	Camp 29, Staten Island	6		6		8		6		8		9		7		5
	San Joaquin River Delta															
	Antioch	450		420		390		390		450		350		230		266
	Jersey	140		192		106		136		112		98		76		60
	Webb Pump	41		32		33		29		32		28		27		
	Central Landing, Bouldin Island	12		14				11		10		10				
	Holland Pump			26		28		32		28		30		21		
	Mandeville Pump	14		17		17		16		20		18		22		12
	King Island, Camp 3½			17				15		*13				15		13
	Rindge Pump	23		21		23		21		26		12		19		28
	Palm Tract	11		12		15		15		14		21		14		13
	Middle River P. O.	9		11		12		14		13		15		14		17
	Mansion House	16		14		11		14		13		12				

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1928

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
October	Point Orient	1,760		1,650		1,750		1,680		1,590		1,460		1,650		1,650
	Point Davis	1,480		1,390		1,410		1,390		1,360		1,290		1,310		
	Crockett[1]	1,280	*1,280	1,390	1,400	1,360	1,440	*1,600	1,430	1,270	1,275	1,380	1,300	1,280	*1,330	1,290
	Bulls Head Point	1,390		960		1,110		1,000		880				950		770
	Bay Point	1,030		830		810		790		750		690		830		850
	O. and A. Ferry	390		460		390		400		280		360		370		280
	Pittsburg[2]	330			300				260				200			
	Sacramento River Delta															
	Collinsville	390		310				270		192		146		182		116
	Emmaton	36		28		25		22				10		9		26
	Three Mile Slough Bridge	33		24		17		13		11		10		6		7
	Rio Vista Bridge	9				5		3		2		2		2		2
	Liberty Ferry	5*		2				3		5		1		3		
	Isleton Bridge	6		5		2		3		3		1		13		*2
	Mokelumne River Delta															
	Southwest Point, Staten Island	7		7		4		5		2		2		3		4
	Camp 33, Staten Island	5		4		3		3		4		1		3		3
	Camp 29, Staten Island	7		5		5		5		4		5		6		4
	San Joaquin River Delta															
	Antioch	304		202		184		180		140		126		120		90
	Jersey	67		41		40		28		29		22		17		9
	Webb Pump	24		21		18		20		22		14		11		11
	Central Landing, Bouldin Island	6		3		7		5		7		4		4		1
	Holland Pump	27		25		34		22		21		16		18		17
	Mandeville Pump	17		19		18		17		17		14				
	King Island, Camp 3½						19			*14		11		12		11
	Rindge Pump	18		16		14		13		10		9		8		7
	Palm Tract	15		11		10		10		12		6		5		8
	Middle River P. O.	16		13		13		*11		11		10		8		8
	Mansion House	12		10		8		11		8				6		5

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	San Francisco, San Pablo and Suisun Bays															
November	Point Orient	1,600		1,580				1,700		1,690		1,640		1,680		1,670
	Point Davis	1,260		1,170		1,330		1,250		1,060	*1,270			*1,130		1,220
	Crockett[1]	1,280	*1,210	1,390	1,150	1,260	1,310	1,210	1,000	880	885	1,040	1,090	1,230	1,199	1,240
	Bulls Head Point	890		800		900		960		620		1,000		860		920
	Bay Point	790				650		700				480		730		660
	O. and A. Ferry	260		200		300				80		120		242		208
	Pittsburg[2]	150			130				80				15			
	Sacramento River Delta															
	Collinsville	138		136		142		70		32		30		144		72
	Emmaton	14		7		8		5		4		6		6		5
	Three Mile Slough Bridge	7		8		5		7		3		3		2		3
	Rio Vista Bridge	3		1												
	Isleton Bridge	1		2												
	Mokelumne River Delta															
	Southwest Point, Staten Island	9		9		8				3		5		2		2
	Camp 33, Staten Island	5		3		2				6		3		2		2
	Camp 29, Staten Island	9		8		6				12		10		7		
	San Joaquin River Delta															
	Antioch	126		52		36		98		22		22		34		28
	Jersey	14		14		19		19		10		9		9		10
	Webb Pump	10		16		9		12		8		10		9		6
	Holland Pump	9		10		13										
	Rindge Pump	8		10		11		13		11		9		6		12
	Palm Tract	5		5												
	San Francisco, San Pablo and Suisun Bays															
December	Point Orient	1,680		*1,510		1,650		1,590		1,570		1,590				1,560
	Point Davis			1,300		1,330		1,130		1,120		1,180		1,220		1,050
	Crockett[1]	970	1,070	1,120	1,090	1,220	1,140	940	*760	880	860	1,080		1,020	1,200	820
	Bulls Head Point	770		950		820		750		720		850		*1,110		910
	Bay Point			550						350		500		640		
	O. and A. Ferry	106		140		158		96		38		146		72		54
	Pittsburg[2]	20			30				16				10			
	Sacramento River Delta															
	Collinsville	82		57		44		38		12		14		126		13
	Emmaton			3		4		11		2		8		5		4
	Three Mile Slough Bridge	12		4		3		1		2		4		3		2
	San Joaquin River Delta															
	Antioch	28		32		44		30		11		10		22		10
	Jersey	9		7		8		13		7				7		9
	Webb Pump	12		6		6										

* Observation on next succeeding day.

[1] From records of salinity observations made by California and Hawaiian Sugar Refining Corporation.

[2] Mean weekly salinities from drip samples, by Great Western Electro Chemical Co.

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TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1929

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water														
		Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
January	Point Orient	1,530		1,510		1,590		1,480		1,560		1,620		1,660		1,410
	Poiot Davis	880		940		1,040		1,210		1,050		1,160		1,040		1,010
	Crockett[1]	*870	860	890	895	980	910	*920	910	1,040		940	995	1,030	*600	550
	Bulls Head Point	730		680		580		880		960		660		620		870
	Bay Point	290		410		430		420		590		500		460		300
	O. and A. Ferry[1]	20		42		54		92		152		75		71		51
	Pittsburg[2]	15				8				7				22		
	Sacramento River Delta															
	Collinsville	17		17		15		19		16		36		38		15
	Emmaton	4		6		8		4		4		5		6		6
	San Joaquin River Delta															
	Antioch	8		11		12		15		9		17		14		14
	Jersey	5		7		5				6		8		6		8
	San Francisco, San Pablo and Suisun Bays															
February	Point Orient	1,410		1,500		1,350		1,380		1,390		1,530	*1,420			
	Point Davis	950		820		720		580		760		850		760		
	Crockett[1]	840	835	530	520	370	*545	560	580	590	725	930	640	580	675	
	Bulls Head Point	980		390		400		300		370		420		340		
	Bay Point	460		140		60		152		206				160		
	O. and A. Ferry	16		9		6		7		9		12		10		
	Pittsburg[2]	21				13				13				4		
	Sacramento River Delta															
	Collinsville	17		8		6		8		5		9		8		
	Emmaton	6		5		4		3		3		5		4		
	San Joaquin River Delta															
	Antioch	12		8		6				9		8		10		
	Jersey	10		8				10		12		7		7		

	San Francisco, San Pablo and Suisun Bays															
March	Point Orient	1,420		1,530		1,540		1,350		1,390		1,450		1,440		1,460
	Point Davis	750		1,050		1,140		660				*740		540		610
	Crockett[1]	730	860	890	940	960	760	720	605	560	575	650	465	610	675	710
	Bulls Head Point	670		750		620		490		350		390		420		250
	Bay Point	200		430				110		190		250		160		150
	O. and A. Ferry	74		16		7		8		7		8		6		5
	Pittsburg[2]	4				7				9				9		
	Sacramento River Delta															
	Collinsville	9		8		5		6		8		6		5		3
	Emmaton	4		3		5		5		4		8		5		4
	San Joaquin River Delta															
	Antioch	7		8		13		6		7		8		11		5
	San Francisco, San Pablo and Suisun Bays															
April	Point Orient	1,360		1,530		*1,590				1,470		*1,520		1,410		1,600
	Point Davis	810		930		830				820				810		650
	Crockett[1]	760	960	810	760	850	895	*680	695	770	875	880	835	740	745	500
	Bulls Head Point	530		500		510		740		600		460		590		300
	Bay Point	170		260		290		290		310		180		170		
	O. and A. Ferry	31		44		22		23		11		9		6		12
	Pittsburg[2]	8				8				8				8		
	Sacramento River Delta															
	Collinsville	4		9		9		10		4		6		6		2
	Emmaton	2		7		6		5		3		4				
	San Joaquin River Delta															
	Antioch	4		6		5		12		9		7		10		3
	San Francisco, San Pablo and Suisun Bays															
May	Point Orient	1,210		*1,550		*1,520		1,540		1,440		1,550		*1,470		1,560
	Point Davis	590		820		740		800		710		930		660		810
	Carquinez Light Station															
	Sonoma Creek Bridge															
	Crockett[1]	570	890	830	905	910	*795	810	850	780	835	840	695	*640	725	660
	Bulls Head Point	240		530		610		650		520		340		430		710
	Bay Point			140		108		158		104		110		50		250
	Sprig Club															
	O. and A. Ferry	10		17		10		7		6		8		10		12
	Innisfail Ferry															
	O. and A. Bridge															
	Pittsburg[2]	10				9				10				10		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1929

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Sacramento River Delta															
May (Continued)	Collinsville	3		4		4		11		5		7		7		5
	Mayberry															
	Emmaton	4		3		4		3				6		3		8
	Three Mile Slough Bridge													4		3
	Rio Vista Bridge													5		3
	Junction Point															
	Liberty Ferry													8		5
	Isleton Bridge													5		4
	Howard Ferry															4
	Sutter Slough															
	Little Holland Ferry															
	Ryde															
	Walnut Grove															3
	Paintersville Bridge													4		4
	Hood Ferry													4		2
	Freeport Ferry															4
	Sacramento															
	Verona															
	San Joaquin River Delta															
	Antioch	5		5		10		6		2		2		2		4
	Curtis Landing															4
	Jersey															7
	Twitchell Island Pump															
	Webb Point															
	Webb Pump															5
	Central Landing, Bouldin Island															
	Central Landing, Main															
	Blakes Landing, Venice Island															
	Ward Landing															
	Holland Pump															11
	McDonald Pump															
	Mandeville Pump															19
	King Island, Camp 3½															

	Zuckerman Pump															
	Rindge Pump															9
	Orwood Bridge															
	Palm Tract													10		12
	East Contra Costa Irrigation District															
	Middle River, P. O.													18		14
	Mansion House															7
	Stockton Country Club															
	Drexler Bridge															
	Clifton Court Ferry															
	Stockton															
	Williams Bridge													*7		8
	Whitehall															
	Mossdale Highway Bridge															
	Durham Ferry Bridge															6
	Mokelumne River Delta															
	Camp 2, Tyler Island															
	Southwest Point, Staten Island															
	Camp 33, Staten Island															
	Tyler Island Ferry															
	Camp 11, Staten Island															
	Camp 29, Staten Island															
	Camp 25, Staten Island															
	New Hope Bridge															
	Camp 20, Staten Island															
	Drainage Water in Delta Islands															
	Camp 35, Staten Island Drain															
	Camp 11, Staten Island Drain															
	San Francisco, San Pablo and Suisun Bays															
June	Point Orient			1,610		1,530		1,500		1,450		1,400		1,540		1,510
	Point Davis	970		1,030		1,140		930		940		1,010		1,040		970
	Carquinez Light Station							810		1,040		*1,040		1,050		1,050
	Sonoma Creek Bridge							1,140		1,140		970		940		1,040
	Crockett[1]	900	1020	1,030	1,140	1,090	880	1,060		980		790		1,010		970
	Bulls Head Point	*520		1,020		930		770		560	680	660		650		570
	Bay Point	138		440		400		550		400		*350	390	250	370	
	Sprig Club					200		180		120		120				
	O. and A. Ferry	38		72		57		65				18	9		102	54
	Innisfail Ferry					200		180		150		140		73		96
	O. and A. Bridge					60		75		72		81		95		99
	Pittsburg[2]	10				10				45				13		
	Sacramento River Delta															
	Collinsville	4		26		61		28		10	8	4		8	22	9
	Mayberry							6		4		10		7		6
	Emmaton	5		4		2		6		4		*4	13	4		11
	Three Mile Slough Bridge	3		4		2		6		8		4		4		9
	Rio Vista Bridge	3		2		6		9		8	4	3	3	5	4	

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1929

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Sacramento River Delta —Continued															
June (Continued)	Junction Point					3		5		3		2		5		4
	Liberty Ferry	2		15		7		9		9		3		5		5
	Isleton Bridge	2		3		3		4		*5		*4		6		*9
	Howard Ferry	3		3		2				4		2		4		4
	Sutter Slough	4		4		3		4		4		6		3		6
	Little Holland Ferry	4		2		7		3				2		4		4
	Ryde							4		3				4		4
	Walnut Grove					3		3		3	6	3		4	5	6
	Paintersville Bridge	4		5		3		4		3	5			6		5
	Hood Ferry	5		5		3		2		3		3		4		3
	Freeport Ferry			2		3		4				5		4		4
	Sacramento	1		2		3		4		2		*3		5		2
	Verona	3		1				2		3		2		3		3
	San Joaquin River Delta															
	Antioch	6		22	21	33	18	16	25	*15	8	12	*14	11	16	14
	Curtis Landing							7				10		7		7
	Jersey			9		12		7		9	7	9	9	11	7	--
	Twitchell Island Pump			4		7		6		6		5		10		6
	Webb Point							*5		*5		*7		7		5
	Webb Pump	6		4		4		16		8		6		9		*14
	Central Landing, Bouldin Island	6		5		2		6		*6	6	*6	7	*6	5	5
	Central Landing, Main											3				5
	Blakes Landing, Venice Island	7		6		6		10		10		3		7		5
	Ward Landing					7		11	10			10		9		11
	Holland Pump	12		15		11		15		11		15		10		*10
	McDonald Pump					9		12		12		11		10		12
	Mandeville Pump	12		11		10		13		11		9		9		12
	King Island, Camp 3½	10		11		8		8		7		3		7		10
	Zuckerman Pump					10		11		12		13		10		12
	Rindge Pump	11		14		11		12		*15	20	15	14	*17	12	13
	Orwood Bridge							8		8		9		4		10
	Palm Tract	12		11		10		19		12		7		12		9

	East Contra Costa Irrigation District	--	--	--	--	7	--	*8	--	9	--	10	--	8	--	9
	Middle River P.O.	12	--	7	--	5	--	9	--	13	--	11	--	6	--	8
	Mansion House	5	--	7	--	8	--	7	--	7	--	7	--	10	--	7
	Stockton Country Club	13	--	13	--	10	--	*76	--	16	--	8	--	12	--	16
	Drexler Bridge	--	--	--	--	--	--	7	--	7	--	15	--	8	--	12
	Clifton Court Ferry	5	--	4	--	5	--	6	--	7	9	*9	8	6	8	7
	Stockton	106	--	86	--	76	--	76	--	76	--	67	--	71	--	94
	Williams Bridge	6	--	5	--	4	--	7	--	8	--	14	--	9	--	9
	Whitehall	--	--	--	--	--	--	--	--	--	--	--	--	5	--	7
	Mossdale Highway Bridge	7	--	7	--	6	--	5	--	5	--	6	--	12	--	11
	Durham Ferry Bridge	5	--	7	--	6	--	7	--	8	--	6	--	4	--	11
	Mokelumne River Delta															
	Camp 2, Tyler Island	--	--	--	--	--	--	2	--	2	--	2	--	--	--	--
	Southwest Point, Staten Island	4	--	4	--	4	--	4	--	3	--	--	--	--	--	5
	Camp 33, Staten Island	9	--	3	--	4	--	4	--	2	--	3	--	--	--	6
	Tyler Island Ferry	3	--	2	--	3	--	7	--	2	--	2	--	3	--	5
	Camp 11, Staten Island	3	--	7	--	2	--	4	--	2	--	3	--	--	--	5
	Camp 29, Staten Island	3	--	3	--	3	--	5	--	4	--	3	--	--	--	4
	Camp 25, Staten Island	--	--	--	--	--	--	7	--	2	--	2	--	--	--	3
	New Hope Bridge	2	--	3	--	2	--	2	--	1	--	1	--	--	--	4
	Camp 20, Staten Island	7	--	4	--	4	--	9	--	2	--	1	--	--	--	2
	Drainage Water in Delta Islands															
	Camp 35, Staten Island Drain	--	--	--	--	--	--	9	--	6	--	--	--	--	--	--
	Camp 11, Staten Island Drain	--	--	--	--	--	--	23	--	29	--	--	--	--	--	9
	San Francisco, San Pablo and Suisun Bays															
July	Point Orient	1,600	--	*1,680	--	1,640	--	1,660	--	1,780	--	*1,200	--	1,620	--	1,640
	Point Davis	980	--	--	*1,300	1,380	--	*1,270	--	1,360	--	*900	--	1,320	--	1,340
	Carquinez Light Station	1,180	--	1,010	--	1,240	--	1,120	--	*1,060	--	*1,120	--	1,160	--	1,290
	Sonoma Creek Bridge	--	--	1,140	--	1,080	--	1,190	--	640	--	--	--	--	--	--
	Crockett	1,190	--	*1,340	--	1,290	--	1,290	--	*1,480	--	*900	--	1,280	--	1,380
	Bulls Head Point	990	--	1,030	--	1,050	--	970	--	960	--	*840	--	1,180	--	1,260
	Bay Point	--	--	*880	--	830	--	770	--	790	--	*1,020	--	920	--	1,110
	Sprig Club	--	--	390	--	560	--	--	--	600	--	*460	--	560	--	720
	O. and A. Ferry	74	--	442	--	370	--	350	--	--	--	450	--	500	--	580
	Innisfail Ferry	150	--	225	--	380	--	370	--	360	--	*540	--	460	--	580
	O. and A. Bridge	*112	--	172	--	200	--	250	--	*300	--	260	--	320	--	400
	Pittsburg[2]	22	--	--	--	150	--	--	--	170	--	--	--	280	--	--
	Sacramento River Delta															
	Collinsville	18	--	152	--	300	--	200	--	--	--	220	--	360	--	280
	Mayberry	8	--	40	--	94	--	56	--	103	--	320	--	380	--	230
	Emmaton	4	--	--	--	37	--	14	--	36	--	28	--	77	--	100
	Three Mile Slough Bridge	6	--	9	--	19	--	9	--	20	--	36	--	37	--	100
	Rio Vista Bridge	4	--	6	--	2	--	11	--	*6	--	*3	--	4	--	7
	Junction Point	4	--	3	--	--	--	7	--	6	--	4	--	6	--	--
	Liberty Ferry	8	--	2	--	5	--	6	--	6	--	14	--	2	--	--
	Grand Island, Steamboat Slough	--	--	--	--	--	--	--	--	6	--	4	--	--	--	3

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1929

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Sacramento River Delta—Continued															
July (Continued)	Isleton Bridge	7		3		7		2		*3		3		4		*3
	Howard Ferry	3		3		3		7		6		4		3		
	Sutter Slough	6		9		6						6		5		4
	Little Holland Ferry	6		*7		7		9		11		4		4		6
	Ryde									9		4				4
	Walnut Grove	6		7		3		3		9		2		4		3
	Paintersville Bridge	5		*7		3		4		*9		7		4		5
	Hood Ferry	7		*2		10		10		*7		*7		4		3
	Freeport Ferry	5				8		7		*6		*4		4		3
	Sacramento	*8		4		3		3		*3		*2		*3		*3
	Verona	4		5		3		2		6		6		2		2
	San Joaquin River Delta															
	Antioch	*36	61	*164	166	190	*180	100	180	240	300	320	340	280	320	370
	Curtis Landing	10		35				33		85		112		150		100
	Jersey	7		10		26		12		*89		40		85		36
	Twitchell Island Pump	12		10		9		8		*18		*25		19		15
	Webb Point	7		*5		7		*9		*8		*7		9		*13
	Webb Pump	*14		*6		13		8		10						12
	Central Landing, Bouldin Island	7		5		6		*6		9		4		5		*6
	Central Landing, Main	6						6				*3		5		6
	Blakes Landing, Venice Island					9		11		11		4				
	Ward Landing			6		9		13		10		*8		7		
	Holland Pump	14		15		9		12		14		*15		9		*12
	McDonald Pump	12		15		11		16		15		*13		10		13
	Mandeville Pump	11		*10		20				*13		12		10		9
	King Island, Camp 3½	7		13		9		11		10				9		10

	Zuckerman Pump	11		*11		12		13		11		*10		12		*16
	Rindge Pump		16			18		19		*21		16		21		23
	Orwood Bridge	10		*11		11		*13		14		9		*10		*7
	Palm Tract	11		9		9		*9		13		9		9		7
	East Contra Costa Irrigation District	10		*8		11		*13		12		10		8		*10
	Middle River, P.O.	*12		11		11		12		11		*10		14		9
	Middle River, Main					11		12				*9		5		9
	Mansion House	11		7		10		10		12		*8		14		
	Stockton Country Club	20		*18		19		27				*21		26		31
	Drexler Bridge	12		8		12	14			*15		*13		11		8
	Clifton Court Ferry	6		*9		9		9		*12		*14		8		8
	Stockton	92		84		150		170		220		180		180		*100
	Williams Bridge	8		9		8		*12		*12		11		*9		*10
	Whitehall	*9		*11		12		*15		*15		*12		11		
	Mossdale Highway Bridge		9		*10		*12		10		16		8	*11		11
	Durham Ferry Bridge	12		12		11		13		13		17		11		14
	Mokelumne River Delta															
	Southwest Point, Staten Island	5		7		4		8		6		*4		4		4
	Camp 33, Staten Island	3		6		4		3		8		*4		3		4
	Tyler Island Ferry	5		4		6		6		6		*9		6		4
	Camp 11, Staten Island	4		7		2		5		3		*4		2		3
	Camp 29, Staten Island	4		11		3		4		8		*5		5		5
	Camp 25, Staten Island	3		5		3		4		6		*5		6		7
	New Hope Bridge	3		6		2		1		6		*3		2		2
	Camp 20, Staten Island	4		4		4		5		8		*5		5		7
	Drainage Water in Delta Islands															
	Jersey Drain					14		16		*24		23		26		28
	Grand Island Drain, Steamboat Slough															
	Camp 35, Staten Island Drain	4		5		3		3		8		*5		4		5
	McDonald Drain			15		12		16		17		18		13		14
	Bacon Island Drain					*5		7		9		*10		7		*7
	Mandeville Drain	12		*10		14		9		*12		15		8		9
	Camp 11, Staten Island Drain	11		10		14		10		6		*11		5		7
	San Francisco, San Pablo and Suisun Bays															
August	Point Orient	1,700		1,720		1,720		1,740		*1,720		1,760		1,720		1,740
	Point Davis	1,460		1,460		1,520		1,520		1,400		1,600		1,480		1,660
	Carquinez Light Station	*1,520		1,360		1,440		1,520		*1,380		1,400		1,370		1,360
	Sonoma Creek Bridge					1,380		1,560		*1,440		1,560		1,480		1,490
	Crockett	*1,420		1,380		1,460		1,360		*1,540		1,520		1,470		1,460
	Bulls Head Point	*1,300		1,180		1,320		1,220		*1,100		1,340		1,240		1,360
	Bay Point	*1,100		940		1,040		1,160		1,040		1,140		1,080		*1,240
	Sprig Club	740		740				810								*920
	O. and A. Ferry	640		540		660		800		720		670		820		*830
	Innisfail Ferry	*610		720		740		*720		*700		760		770		*780
	O. and A. Bridge	490		480		550		640		*660		610		600		*720
	Pittsburg[2]	300				405				450				490		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1929

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Sacramento River Delta															
August (Continued)	Collinsville	390		470		600				*580				440		540
	Mayberry	500		360		320		310		400		380		340		
	Emmaton	96		138		198		142		172		204		232		202
	Three Mile Slough Bridge	84		114		130		126		124		142		88		*168
	Rio Vista Bridge	*10		*17		15		*23		*29		35		40		*57
	Junction Point			6		7		*9		10		*11		12		14
	Liberty Ferry	6		4		5		7		6		7		4		
	Grand Island, Steamboat Slough			5												5
	Isleton Bridge	6		3		5		*7		*5		6		8		*13
	Howard Ferry			4		3		5		4		3		4		4
	Sutter Slough	3		3		11		5		3		4				
	Little Holland Ferry	4		4		4		4		4		4		5		4
	Ryde			4				4								4
	Walnut Grove			4		4		*4		3		4	4	4		4
	Paintersville Bridge	*4		3		4		*4		7		4		4		4
	Hood Ferry							4		5		3		4		4
	Freeport Ferry	*3		*6		4		*4		*3		4				*3
	Sacramento	3		*3		*3		*3		*3		3		5		3
	Verona	2		2		2		2		2		4		2		2
	San Joaquin River Delta															
	Antioch	430	440	440	440	380	450	*530	500	*500	440	540	500	520	560	*580
	Curtis Landing	380		290		200		280		360		280		250		
	Jersey	58		174				104		*222		224		240		175
	Twitchell Island Pump	29		48		40		*43		* 76		77		58		64
	Webb Point	*11		14		16		20		23		26		29		*38
	Webb Pump	29		16		43		*45		*46		56		61		*80
	Central Landing, Bouldin Island	*8		8		8		*8		*14		12		12		*20
	Central Landing, Main	6						9		14		12		11		14
	Blakes Landing, Venice Island															
	Ward Landing	*9		9		8		11		*12		17		14		16
	Holland Pump	*14		17		21		*27		*26		31		33		*39
	McDonald Pump	*15		12		16		15		22		16		19		*16
	Mandeville Pump	11		11		12		11		*13		13		14		17
	King Island, Camp 3½			8												

	Zuckerman Pump	12		12		17		14		17		12				
	Rindge Pump	*21		26		20		*25		*22		30		28		*24
	Orwood Bridge	9		12		9		*12		*10		11		12		*14
	Palm Tract	13		9		10		12		14		12		12		14
	East Contra Costa Irrigation Dist.	*10		12		10		10		*11		9		11		11
	Middle River, P. O.	*10		11		9		12		10		14		11		12
	Middle River, Main	*9				9		12		10		13		11		12
	Mansion House	*15		9		12		14		9		9		10		12
	Stockton Country Club	32				29		36		32				32		30
	Drexler Bridge	*9		10		11		10		11		12		10		11
	Clifton Court Ferry	*11		11		11		11		23		10		11		*10
	Stockton	*120		130		*160		*90		200		130		*130		*115
	Williams Bridge	*10		9		*12		*12		9		11		9		9
	Whitehall	*13		12		10		*13		*13		10		10		*9
	Mossdale Highway Bridge	13		10		8		11		10		12		12		10
	Durham Ferry Bridge	9		12		12		9		10		13		9		9
	Mokelumne River Delta															
	Southwest Point, Staten Island	5		7		6		5		*7		7		5		5
	Camp 33, Staten Island	4		4				4		*4		4				4
	Tyler Island Ferry	3		5		4		3		3		4		5		4
	Camp 11, Staten Island	*3		4		*4		*4		*4		4		4		*6
	Camp 29, Staten Island	5		5		5		5		*3		5		5		5
	Camp 25, Staten Island	6		5		6		6		*5		5		6		6
	New Hope Bridge	2		5		4		3		4		5		4		4
	Camp 20, Staten Island	7		8		7		5		*6		5		6		6
	Drainage Water in Delta Islands															
	Jersey Drain	32		38				42		42		36		33		33
	Grand Island Drain, Steamboat Slough							6								7
	Camp 35, Staten Island Drain	5		7		6		6		5		4		6		5
	McDonald Drain	15		10		18		19		15		18		16		*15
	Bacon Island Drain	*9		16		10		*11		10		13		14		13
	Mandeville Drain	10		12		12				12		13		33		17
	Camp 11, Staten Island Drain	7		7		8		7		5		5		4		8
	San Francisco, San Pablo and Suisun Bays															
September	Point Orient	*1,770		1,760		1,740		1,730		*1,810		1,770		1,830		1,750
	Point Davis	*1,520		1,580		1,470		1,500		*1,550		1,590		1,540		*1,540
	Carquinez Light Station	*1,390		1,440		1,360		1,500		*1,380		1,400		1,400		1,490
	Sonoma Creek Bridge	*1,490		1,510		1,460		1,500		*1,550		1,590		1,600		1,580
	Crockett	*1,520		1,510		1,430		1,460		*1,490		1,530		1,510		*1,400
	Bulls Head Point	*1,340		1,370		1,210		*1,200		*1,280		1,350		1,320		*1,220
	Bay Point			1,100		1,070		*1,080		*1,160		1,130		1,070		*1,050
	Sprig Club							*880		860				820		
	O. and A. Ferry	740		740		750		*800		740		690		700		560
	Innisfail Ferry	840		850		850		*830		*870		860		844		820
	O. and A. Bridge	*710		750		760		*770		770		820		850		*830
	Pittsburg[2]	530		570				580		530				500		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1929

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Sacramento River Delta															
September (Continued)	Collinsville	*680		590		510		580		590		530		440		420
	Mayberry									350		270		300		220
	Emmaton	255		310		180		130		*280		165		140		
	Three Mile Slough Bridge	160		205		80		66		*160		130		120		100
	Rio Vista Bridge	*67		40		49		*47		*21		12		15		*5
	Junction Point	11		17		*11		10		*7		5		3		3
	Liberty Ferry	*5		7		4		4		*4		4		3		2
	Steamboat Slough					3						3				
	Isleton Bridge	*5		6		5		*4		*3		3		3		2
	Howard Ferry	5		4		4		3		*3				2		2
	Sutter Slough															
	Little Holland Ferry	*4		4		3		3		*3		3		3		3
	Ryde					3						3				
	Walnut Grove	*4		4		3		*3		*3		2		2		3
	Paintersville Bridge	*3		4		3		4		*3		3		*2		
	Hood Ferry	*3		4	*4			*3		*2		2		2		2
	Freeport Ferry	*3														
	Sacramento	*3		3		3		3		*3		*2		2		*2
	Verona	2		2		1		2		1		1		1		1
	San Joaquin River Delta															
	Antioch	570	580	550		510		500		480		490		420		440
	Curtis Landing	320		400		450				385		330		260		165
	Jersey	*365		220		185		*285		185		250		175		140
	Twitchell Island Pump	*115		98		55		69		*82		73		36		46
	Webb Point	*37		29		40		35		*34		33				
	Webb Pump	*39		54		67		44		43		60		51		
	Central Landing, Bouldin Island	*19		16		10		*20		*13		9		*10		
	Central Landing, Main	19		16		10		26		*14		9		10		
	Ward Landing	*19		18		19		*21		*22		22		*23		22
	Holland Pump	*39		38		37		*39		*40		42		*42		*36
	McDonald Pump	*17		18		19		23		21		21		21		*25
	Mandeville Pump	*19		19		20		21		*22		22		25		23
	King Island, Camp 3½							13		*14		15		16		

	Zuckerman Pump	13								19		18		18		19
	Rindge Pump			24		*27		*23		*20		18		*17		16
	Orwood Bridge	*13		15		15		*17		*18		19		*14		*17
	Palm Tract	13		14		14		17		*18		*17		18		19
	East Contra Costa Irrigation Dist.	*11		13		12		*13		*16		15		*15		15
	Middle River, P. O.	13		13						*17		17		17		17
	Middle River, Main			13		15										
	Mansion House	15		*12		*12				*16		15		15		14
	Stockton Country Club	*29		29		23			*17	17				15		
	Drexler Bridge	*12		12		11		*13		*13		15		12		11
	Clifton Court Ferry	*12		10		9		*9		*8		7		7		7
	Stockton	120		125		*130		100		*100		115		*105		
	Williams Bridge	13		10		6		*6		*5		4		4		4
	Whitehall	10		10		9		7		*5		5		4		4
	Mossdale Highway Bridge	9		6		5		5		*5		5		4		
	Durham Ferry Bridge	10		6		5		5		5		5		4		4
	Mokelumne River Delta															
	Camp 2, Tyler Island									*8						
	Southwest Point, Staten Island	*9		7		4		4		*5		5		2		3
	Camp 33, Staten Island	*5		5		5		4		*5		4		3		3
	Tyler Island Ferry	*4		4		3				*3		3		2		4
	Camp 11, Staten Island	*5		6		*5		*6		*6		7		*6		6
	Camp 29, Staten Island	*6		6		6		6		*5		5		5		5
	Camp 25, Staten Island	*6		5		6		7		*7		6		6		6
	New Hope Bridge	*5		4		4		5		*5		6		6		5
	Camp 20, Staten Island	*6		6		6		7		*7		7		7		8
	Drainage Water in Delta Islands															
	Jersey Drain	40		43		35		38		35		42		39		63
	Grand Island Drain, Steamboat Slough					7						8				
	Camp 35, Staten Island Drain	*5		5		5		5		6		7		7		6
	McDonald Drain	*14		14		14		*16		15		17		17		18
	Bacon Island Drain	14		17		*17		*19		*19		19		*18		*20
	Mandeville Drain	*18		19		23		23		25		24		26		25
	Camp 11, Staten Island Drain	*8		7		10		7		6		14		12		10
	San Francisco, San Pablo and Suisun Bays															
October	Point Orient	1,750		1,760		1,740		1,770		1,740				1,720		
	Point Davis	1,510		1,550		1,380		1,430		1,440		1,410		1,500		1,400
	Carquinez Light Station	1,330		1,330		1,270		1,225		1,360		1,350		1,230		1,270
	Sonoma Creek Bridge	1,600		1,520		1,540		1,480		*1,580		*1,580		*1,450		1,570
	Crockett	1,250		1,500		1,300		1,410		1,410		1,400		1,400		1,390
	Bulls Head Point	1,230		1,310		1,110		1,060		1,170		1,290		1,090		*1,250
	Bay Point	970		1,050				960		890		890		860		830
	Sprig Club															
	O. and A. Ferry	660		650		470		500		540		540		450		420
	Innisfail Ferry	780		810				680		690		660		860		
	O. and A. Ferry	730		820		510		560		770		720		620		750
	Pittsburg[2]	450				385				270				280		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1929

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Sacramento River Delta															
October (Continued)	Collinsville	410		380		340		320		390		245		255		210
	Mayberry	220		160												*175
	Emmaton	110		80		65		60		50		69		31		21
	Three Mile Slough Bridge	41		55		31		20		20		24		16		15
	Rio Vista Bridge	3		3		3		2		2		2		3		2
	Junction Point	3		3		2				2		2				
	Liberty Ferry	3		2		2		3		3		2		2		3
	Steamboat Slough											2				
	Isleton Bridge	2		2		2		2		3		2		*2		2
	Howard Ferry	*2		2		2		2		1		2		2		2
	Sutter Slough											2				
	Little Holland Ferry	3		3		2		3		3		2		2		*2
	Ryde											2				
	Walnut Grove	2		2		2		2		2		2		*2		3
	Paintersville Bridge	2		2		2		3		2		2		*2		3
	Hood Ferry	*2		2		2		2		2		2		2		1
	Freeport Ferry											2				
	Sacramento	2		*5		*2		2		2		*2		*1		2
	Verona	2		1		2		1		1		2		1		1
	San Joaquin River Delta															
	Antioch	380		410	*310	280	250	270	310	280	265	290	270	235	200	191
	Curtis Landing	145		160		115		100		139		111		119		
	Jersey	170		155		95		69		59		34		48		60
	Twitchell Island Pump	34				22		21		22		19		*16		14
	Webb Point	26		25		21		18		18		17		17		14
	Webb Pump	40		37				24		24		21				18
	Central Landing, Bouldin Island	9		10		7		7		9		7		7		6
	Central Landing, Main															
	Ward Landing	21		21		21				20		18				*19
	Holland Pump	36		37		28		29		28		27		*24		23
	McDonald Pump	19		22		*44		58		45		21		*21		17

	Mandeville Pump	25						20		20						19
	King Island, Camp 3½	*16						16		16		15				
	Zuckerman Pump	19		20		*19		22		20	*17		10	20		
	Rindge Pump			16		*16		16		17		16		*18		19
	Orwood Bridge	16		16		14		12		13		13		*13		12
	Palm Tract	16		17		17		16		14		13				12
	East Contra Costa Irrigation Dist.	15		12		12		11		10		10		*10		11
	Middle River, P. O.	17		18		17		17		16		14		13		15
	Middle River, Main															
	Mansion House	12		11		12		10		11		11				
	Stockton Country Club			14		13		16				*17				
	Drexler Bridge	12		11		*9		9		9		11		9		9
	Clifton Court Ferry	5		5		6		6		7		5		*6		*7
	Stockton	91		86		*90		88		106		86		*107		92
	Williams Bridge	7		5		5		*6		6		6			*7	7
	Whitehall	5		5		6		7		6		5		7		7
	Mossdale Highway Bridge	*5		5		7		6		6		6		7		7
	Durham Ferry Bridge	5		5		6		7		5		7		6		7
	Mokelumne River Delta															
	Camp 2, Tyler Island							4						3		
	Southwest Point, Staten Island	*3		3		2		3		3		3		3		
	Camp 33, Staten Island	*3		3		3		3		3		2		3		
	Tyler Island Ferry	2				3		3		2		2		3		2
	Camp 11, Staten Island	6		6		*6		5		6		4		*5		
	Camp 29, Staten Island	*5		4		4		4		4		5		5		
	Camp 25, Staten Island	*6		6		6		6		8		7		7		
	New Hope Bridge	5		5		6		6		6		6		6		
	Camp 20, Staten Island	*6		7		7		7		8		7		8		
	Drainage Water in Delta Islands															
	Jersey Drain	33		42		33		33		30		37				
	Grand Island Drain, Steamboat Slough															
	Camp 35, Staten Island Drain	5		8		8		8		8		8		10		
	McDonald Drain	18		17										*20		22
	Bacon Island Drain			20		20		19		16		16				19
	Mandeville Drain	26						25		23						24
	Camp 11, Staten Island Drain	*21		11		*9		16		14		19		*21		
	San Francisco, San Pablo and Suisun Bays															
November	Point Orient	1,770		1,740		1,620		1,690		1,730		1,730		1,760		1,730
	Point Davis	1,330		1,430		1,350		1,380		1,510				1,350		1,390
	Sonoma Creek Bridge	1,510														
	Bulls Head Point	1,140		1,070		1,050		1,070		1,250		1,140		1,140		1,140
	Bay Point	860		860				770		950		*800		840		
	O. and A. Ferry	450		480		440		520				450		390		360
	Innisfail Ferry	*670		640		610		590		590		590		580		570
	O. and A. Bridge															
	Pittsburg[2]	275				180				190				190		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1929

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Sacramento River Delta															
November (Continued)	Collinsville	240		280		270				255		285		285		430
	Mayberry															*195
	Emmaton	54		15				10		40		17		23		25
	Three Mile Slough Bridge	15		16		10		7		9				15		15
	Rio Vista Bridge	2		2		2		2		2		3		2		3
	Liberty Ferry	2		3		2		2		3		2		2		
	Walnut Grove	3		2		2		2		2		3		2		2
	Sacramento	2		*2		2		1		2		*2		2		1
	San Joaquin River Delta															
	Antioch	204	225	200	185	170	*140	145	180	240	295	200	195	210	*245	255
	Curtis Landing					92		52		105		93		96		150
	Jersey	80		46		20		30		63				44		55
	Twitchell Island Pump	16		14		11		11		12		12		12		13
	Webb Pump	13		*15		13		13		12		14		13		12
	Central Landing, Bouldin Island	7				3		4		5		5		5		5
	Blakes Landing, Venice Island	14		14		11		12								
	Ward Landing	17		17		17		*15		15		15		*16		
	Holland Pump	22		20		18		17		18		16		15		15
	McDonald Pump	17		17		17		17		18		16		16		
	Rindge Pump	17		18		18		18		18		19		18		18
	East Contra Costa Irrigation Dist.	10		9		12		9		9		9		11		11
	Stockton Country Club	16		20										18		
	Drexler Bridge	11		9		11		8		8		8		10		12
	Stockton	105		103		98		105		71				81		90
	Mossdale Highway Bridge	*7		7		7		*8		8		7		8		7
	Mokelumne River Delta															
	New Hope Bridge	6		2		1		2		2		3		2		2
	Drainage Water in Delta Islands															
	Jersey Drain	49		36		46		31		37				37		41
	Grand Is. Drain, Steamboat Slough															
	Camp 35, Staten Island Drain	13		12		11		16		21		18		19		17
	McDonald Drain	21		19		19		18		18		17		19		
	Bacon Island Drain	18		14		17		14		14		15		13		13
	Mandeville Drain			24		22		21		20		20		19		19
	Camp 11, Staten Island Drain	31		30		27		13		15		9		14		12

	San Francisco, San Pablo and Suisun Bays															
December	Point Orient			1,700		1,660		1,540		1,420		1,430		1,220		1,330
	Point Davis	1,360		1,280		1,290		1,220				500		600		830
	Sonoma Creek Bridge															
	Bulls Head Point	1,120		1,050		1,240	*1,070	860	570	250	28	*172		380	480	560
	Bay Point	890		700		920	810	520	270	32	8	8		*60	78	221
	O. and A. Ferry	400				380		140	28	11	5	4		4	7	21
	Innisfail Ferry	610		570		560		400		140		93		64		36
	O. and A. Bridge						*215	110	20	16	6	14				
	Pittsburg[2]	240				190				190				100		10
	Sacramento River Delta															
	Collinsville	320		195		250	165	48	16	2	1	2		*4	4	4
	Mayberry			110		100	*3	2	*1		2	*1				
	Emmaton	33				32		5	1			2				2
	Three Mile Slough Bridge	16		9		8	*2	2	1	1	2	1		3		4
	Rio Vista Bridge	2		2		2		1				1		1		1
	Liberty Ferry			2		2		3								
	Walnut Grove	2				2		1		1		1		1		
	Sacramento	2		*2		1		1		1		1		1		1
	San Joaquin River Delta															
	Antioch	230	180	180	160	230	155	75	16	9	5	5	5	4	4	5
	Curtis Landing	118		79		26	*65		21	6	*4	5		6		4
	Jersey	65		46		57	61	22	9	7	*5	6				5
	Twitchell Island Pump	12		10		9	*8	7	4	3	3	4	3	3		5
	Webb Pump	11		11		11		10								
	Central Landing, Bouldin Island	4		4		2		2				2		2		4
	Blakes Landing, Venice Island															
	Ward Landing									13						
	Holland Pump	15		14		13		13		12		12		11		11
	McDonald Pump															
	Rindge Pump	18		17		19		15		20		21		18		18
	East Contra Costa Irrigation District	15		12		11		10		10				11		11
	Stockton Country Club			17		17		15		23		17		17		17
	Drexler Bridge	11		10		9		10		9		9		8		9
	Stockton	122		99				59		86						
	Mossdale Highway Bridge	*7		8		8		8		10		9		8		9
	Mokelumne River Delta															
	New Hope Bridge	2		2		2				1						
	Drainage Water in Delta Islands															
	Jersey Drain	49		34		45				10		33				32
	Grand Island Drain, Steamboat Slough			8												
	Camp 35, Staten Island Drain	16		18		16				24						
	McDonald Drain	*15							21		21		23	*22		22
	Bacon Island Drain	13		13		12		13		12		12		12		12
	Mandeville Drain															
	Camp 11, Staten Island Drain	18		22		20				14						

*Observation on next succeeding day.
[1] Records prior to June 14, 1929, from salininty observations made by California and Hawaiian Sugar Refining Corporation.
[2] Mean weekly salinities from drip samples, by Great Western Electro Chemical Company.

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1930

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
January	Point Orient	1,310		1,400		1,220		1,500		1,250		1,190		1,210		1,310
	Point Davis	800		910		850		810		710		390		750		610
	Bulls Head Point	400	730	590	620	740	770	670		370		330		345		380
	Bay Point	175	375	270	160	268	400	270		75		20		31		37
	O. and A. Ferry	15	41	11	10	18	19	33		5		5		5		5
	Innisfail Ferry	62		77		72		40		73		112		45		
	Pittsburg[1]	5				5				8				10		
	North of San Pablo Bay															
	Grand View															
	Sonoma Creek Bridge															
	Vallejo															
	Lakeville															
	Cuttings Wharf															
	Napa															
	Petaluma															
	Sacramento River Delta															
	Collinsville	4	*6	8	5	4	*3	4		5		3		3		4
	Emmaton	2		2		2		2		3		2		*3		3
	Three Mile Slough Bridge	3		2		2		2		3		2		2		2
	Rio Vista Bridge	2		2		1		2				1		2		3
	Junction Point															
	Liberty Ferry							2		2		2		3		3
	Isleton Bridge															
	Walnut Grove	2		2		1		2		1				1		1
	Sacramento	2		1		1		2		1		1		1		1
	San Joaquin River Delta															
	Antioch	5		6		4		7				5		6		5
	Curtis Landing	6		6				5		5		6		5		
	Jersey	6		6		5		6		8		7		7		6
	Twitchell Island	4		5		5		4		6		5		6		6
	Webb Pump	6		8				7		12				8		8

	Central Landing, Bouldin Island	3		4		2		3		2				3		2
	Ward Landing	13		13		12		13		14		11		12		12
	Holland Pump	13		12		11		12		12		14		13		13
	Rindge Pump	19		20		18		15		9		11		11		10
	East Contra Costa Irrigation District					11		11				16		*15		15
	Stockton Country Club	18		22		15				13		5		*11		8
	Drexler Bridge	9		11		10		9		8		9		9		7
	Stockton	95		*101		101		49		49		104		55		
	Mossdale Highway Bridge	8		7		7		5		6		6		5		4
	Mokelumne River Delta															
	New Hope Bridge	2		2		1		1		1		1		*1		2
	Drainage Water in Delta Islands															
	Jersey Drain	31														41
	Grand Island Drain, Steamboat Slough													7		8
	Camp 35, Staten Island Drain															
	McDonald Drain	*22		22	*22		*24		*22							
	Bacon Island Drain	12		12		10		12		17			15			15
	Mandeville Drain													19		20
	Camp 11, Staten Island Drain															
	San Francisco, San Pablo and Suisun Bays															
February	Point Orient	1,340		1,200		1,370		1,310		1,370				1,200		
	Point Davis			780		860		720		730		640		640		
	Bulls Head Point	310		625		280		445		310		780		265		
	Bay Point	45				200		81		34		243		10		
	O. and A. Ferry	6		6		5		9		4		3		2		
	Innisfail Ferry	104		52		33		31		31		19		65		
	Pittsburg[1]	10				5				5				5		
	North of San Pablo Bay															
	Grand View													705		
	Sonoma Creek Bridge													480		
	Vallejo													320		
	Lakeville													225		
	Cuttings Wharf													13		
	Napa													1		
	Petaluma													6		
	Sacramento River Delta															
	Collinsville	5		4		3		2		3		3		3		
	Emmaton	3		3		3		3		3		3		*1		
	Three Mile Slough Bridge	3		2		2		3		2		2		1		
	Rio Vista Bridge			2		1		2		1		1		2		
	Junction Point															
	Liberty Ferry	2		2		2		2		1		2				
	Isleton Bridge															
	Walnut Grove	1		1		1		2		1		1		1		
	Sacramento	1		1		1		1		1		1		*1		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1930

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Joaquin River Delta															
February (Continued)	Antioch	7	--------	5	--------	7	--------	5	--------	5	--------	5	--------	5	--------	--------
	Curtis Landing	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	Jersey	6	--------	8	--------	6	--------	8	--------	6	--------	6	--------	6	--------	--------
	Twitchell Island	5	--------	7	--------	5	--------	5	--------	4	--------	5	--------	4	--------	--------
	Webb Pump	9	--------	7	--------	7	--------	6	--------	6	--------	6	--------	5	--------	--------
	Central Landing, Bouldin Island	2	--------	2	--------	3	--------	1	--------	1	--------	2	--------	--------	--------	--------
	Ward Landing	11	--------	12	--------	10	--------	10	--------	10	--------	9	--------	11	--------	--------
	Holland Pump	12	--------	13	--------	13	--------	10	--------	11	--------	10	--------	10	--------	--------
	Rindge Pump	17	--------	10	--------	15	--------	13	--------	13	--------	14	--------	--------	--------	--------
	East Contra Costa Irrigation District	17	--------	15	--------	15	--------	15	--------	12	--------	14	--------	*14	--------	--------
	Stockton Country Club	9	--------	--------	--------	13	--------	12	--------	15	--------	--------	--------	*5	--------	--------
	Drexler Bridge	8	--------	6	--------	7	--------	6	--------	7	--------	8	--------	9	--------	--------
	Stockton	102	--------	--------	--------	76	--------	81	--------	100	--------	--------	--------	91	--------	--------
	Mossdale Highway Bridge	4	--------	6	--------	9	--------	8	--------	8	--------	8	--------	7	--------	--------
	Mokelumne River Delta															
	New Hope Bridge	2	--------	2	--------	1	--------	1	--------	2	--------	1	--------	*1	--------	--------
	Drainage Water in Delta Islands															
	Jersey Drain	44	--------	41	--------	41	--------	--------	--------	--------	--------	48	--------	52	--------	--------
	Grand Island Drain, Steamboat Slough	7	--------	7	--------	9	--------	7	--------	8	--------	--------	--------	10	--------	--------
	Camp 35, Staten Island Drain	--------	--------	--------	--------	25	--------	17	--------	19	--------	16	--------	23	--------	--------
	McDonald Drain	--------	--------	--------	--------	22	16	--------	21	--------	*17	--------	23	--------	20	--------
	Bacon Island Drain	16	--------	14	--------	13	--------	11	--------	11	--------	11	--------	13	--------	--------
	Mandevil'e Drain	22	--------	21	--------	20	--------	20	--------	21	--------	23	--------	21	--------	--------
	Campbell, Staten Island Drain	--------	--------	--------	--------	34	--------	70	--------	71	--------	58	--------	55	--------	--------
	San Francisco, San Pablo and Suisun Bays															
March	Point Orient	1,080	--------	860	--------	1,160	--------	1,210	--------	1,140	--------	980	--------	1,360	--------	*1,260
	Point Davis	370	--------	400	--------	460	--------	505	--------	--------	--------	310	--------	670	--------	*860
	Bulls Head Point	140	--------	115	--------	105	--------	195	--------	7	--------	65	--------	330	--------	*285

Bay Point	6	--	6	--	6	--	8	--	6	--	--	--	92	--	35
O. and A. Ferry	2	--	6	--	4	--	5	--	3	--	4	--	3	--	*3
Innisfail Ferry	99	--	86	--	66	--	31	--	37	--	46	--	42	--	34
Pittsburg[1]	5	--	--	--	5	--	--	--	5	--	--	--	5	--	--
North of San Pablo Bay															
Grand View	630	--	380	--	395	--	425	--	360	--	350	--	515	--	*580
Sonoma Creek Bridge	240	--	150	*220	--	*135	--	--	130	--	215	--	185	--	270
Vallejo	260	--	152	--	220	--	120	70	32	105	191	--	--	--	--
Lakeville	260	--	29	--	85	--	172	--	135	--	--	--	190	--	--
McGill	--	--	4	--	27	--	71	--	73	--	70	--	93	--	154
Cuttings Wharf	33	--	7	--	16	--	62	--	34	--	14	--	55	--	260
Merazo	--	--	77	--	52	--	81	--	100	--	66	--	104	--	--
Napa	--	--	2	--	2	--	4	--	--	--	3	--	4	--	--
Petaluma	10	--	4	--	13	--	14	--	11	--	22	--	35	--	50
Sacramento River Delta															
Collinsville	3	--	3	--	2	--	2	--	2	--	3	--	2	--	1
Emmaton	3	--	3	--	3	--	4	--	1	--	*2	--	2	--	1
Three Mile Slough Bridge	1	--	2	--	2	--	1	--	2	--	2	--	--	--	*1
Rio Vista Bridge	1	--	1	--	2	--	2	--	2	--	2	--	1	--	1
Liberty Ferry	--	--	2	--	3	--	--	--	3	--	4	--	2	--	1
Walnut Grove	1	--	1	--	2	--	--	--	2	--	1	--	2	--	*1
Sacramento	1	--	1	--	1	--	*1	--	2	--	1	--	*1	--	*1
San Joaquin River Delta															
Antioch	4	--	7	--	4	--	5	--	4	--	5	--	5	--	4
Jersey	5	--	5	--	5	--	5	--	5	--	6	--	5	--	*4
Twitchell Island	4	--	9	--	4	--	5	--	4	--	5	--	3	--	*2
Webb Pump	7	--	8	--	7	--	5	--	6	--	7	--	6	--	*5
Central Landing, Bouldin Island	4	--	2	--	1	--	2	--	3	--	2	--	2	--	2
Ward Landing	10	--	9	--	7	--	7	--	8	--	--	--	9	--	9
Holland Pump	10	--	13	--	13	--	13	--	11	--	12	--	11	--	*10
Rindge Pump	7	--	6	--	8	--	9	--	9	--	11	--	12	--	11
East Contra Costa Irrigation Dist.	16	--	--	--	19	--	*18	--	15	--	16	--	11	--	*10
Stockton Country Club	--	--	--	--	8	--	*7	--	--	--	12	--	--	--	*8
Drexler Bridge	10	--	10	--	8	--	9	--	7	--	6	--	7	--	*9
Stockton	86	--	63	--	74	--	*104	--	--	--	81	--	75	--	*84
Mossdale Highway Bridge	8	--	6	--	4	--	--	--	7	--	8	--	8	--	*6
Mokelumne River Delta															
New Hope Bridge	1	--	1	--	1	--	*1	--	1	--	1	--	1	--	*1
Drainage Water in Delta Islands															
Jersey Drain	49	--	57	--	49	--	51	--	50	--	45	--	21	--	*40
Grand Island Drain, Steamboat Slough	8	--	*8	--	9	--	9	--	8	--	9	--	9	--	6
Camp 35, Staten Island Drain	21	--	24	--	26	--	21	--	--	--	--	--	--	--	--
McDonald Drain	--	21	--	--	19	--	19	*28	--	22	--	23	--	--	*28
Bacon Island Drain	*14	--	15	--	13	--	14	--	--	--	13	--	13	--	12
Mandeville Drain	20	--	20	--	21	--	22	--	21	--	22	--	22	--	19
Camp 11, Staten Island Drain	46	--	51	--	76	--	--	--	82	--	82	--	84	--	84

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1930

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
April	Point Orient	1,220	-------	1,220	-------	*1,320	-------	*1,240	-------	1,230	-------	970	-------	*1,220	-------	1,390
	Point Davis	640	-------	565	-------	*630	-------	*650	-------	520	-------	720	-------	*680	-------	*720
	Bulls Head Point	410	-------	380	-------	*260	-------	*235	-------	240	-------	*475	-------	*420	-------	*500
	Bay Point	11	-------	43	-------	14	-------	-------	-------	10	-------	41	-------	25	-------	-------
	O. and A. Ferry	3	-------	3	-------	*5	-------	*4	-------	3	-------	*6	-------	*3	-------	*3
	Innisfail Ferry	38	-------	34	-------	40	-------	27	-------	33	-------	44	-------	44	-------	37
	Pittsburg[1]	5	-------	-------	-------	5	-------	-------	-------	10	-------	-------	-------	10	-------	-------
	North of San Pablo Bay															
	Grand View	400	-------	615	-------	765	-------	660	-------	800	-------	790	-------	725	-------	810
	Sonoma Creek Bridge	-------	-------	435	*570	-------	-------	700	-------	590	-------	570	-------	640	-------	480
	Vallejo	470	-------	345	-------	*360	-------	-------	-------	290	-------	*480	-------	*370	-------	-------
	Lakeville	250	-------	-------	-------	300	-------	350	-------	380	-------	415	-------	420	-------	470
	McGill	177	-------	293	-------	350	-------	335	-------	-------	-------	-------	-------	280	-------	400
	Cuttings Wharf	201	-------	172	-------	280	-------	310	-------	220	-------	170	-------	240	-------	270
	Merazo	-------	-------	-------	-------	340	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
	Napa	3	-------	-------	-------	6	-------	5	-------	6	-------	6	-------	-------	-------	8
	Petaluma	63	-------	74	-------	130	-------	111	-------	160	-------	180	-------	185	-------	225
	Sacramento River Delta															
	Collinsville	3	-------	3	-------	1	-------	4	-------	3	-------	3	-------	*2	-------	*3
	Emmaton	2	-------	2	-------	*2	-------	-------	-------	-------	-------	2	-------	2	-------	2
	Three Mile Slough Bridge	2	-------	2	-------	1	-------	1	-------	1	-------	*2	-------	*1	-------	2
	Rio Vista Bridge	2	-------	2	-------	*2	-------	*1	-------	1	-------	*2	-------	*2	-------	*1
	Liberty Ferry	2	-------	3	-------	2	-------	2	-------	2	-------	2	-------	1	-------	2
	Walnut Grove	1	-------	3	-------	*1	-------	*1	-------	1	-------	-------	-------	*1	-------	-------
	Sacramento	1	-------	-------	-------	*1	-------	*1	-------	1	-------	*1	-------	*1	-------	*1
	San Joaquin River Delta															
	Antioch	3	-------	4	-------	5	-------	5	-------	5	-------	4	-------	3	-------	4
	Jersey	4	-------	6	-------	4	-------	*5	-------	5	-------	6	-------	5	-------	*4
	Twitchell Island	2	-------	4	-------	3	-------	*3	-------	5	-------	*4	-------	*4	-------	3
	Webb Pump	6	-------	7	-------	*5	-------	*6	-------	6	-------	*7	-------	*5	-------	5

	Central Landing, Bouldin Island	2		4		2		3		4		4		2		1
	Ward Landing	8		8		8		8				8		9		6
	Holland Pump	9		11		*9		*9		10		*9		*8		*8
	Rindge Pump			10		14		*9		9		*13		*9		6
	East Contra Costa Irrigation Dist.	9		11		9		*10		10		9		8		
	Stockton Country Club	10		15		13		*7		9						11
	Drexler Bridge	8		8		*7		*8		7		*7		*5		4
	Stockton	92		108				*100		104		*89		*102		11
	Mossdale Highway Bridge	5		7		*3		*4		6		5		3		
	Mokelumne River Delta															
	New Hope Bridge	1		1												
	Drainage Water in Delta Islands															
	Jersey Drain	40		40		27		*46		40		34		31		*31
	Grand Island Drain, Steamboat Slough	*9		*8		*7		*9		*9		*7		*7		*7
	Camp 35, Staten Island Drain		22		19				17		17		16		17	
	McDonald Drain		17		15		18		15		16		11		12	
	Bacon Island Drain	15		11		*11		*9		9		9		*7		*7
	Mandeville Drain	19		21		20		21		22		22		21		19
	Camp 11, Staten Island Drain	*81		*94		*91		*62		*56		*53		*31		*16
	San Francisco, San Pablo and Suisun Bays															
May	Point Orient			1,290		*1,360		*1,350		1,440		1,330		*1,270		*1,540
	Point Davis	550		750		*820		*700		530		590		*910		*960
	Bulls Head Point	525		360		*480		*400		430		*545		*730		*750
	Bay Point			28		55		*49		81				177		*125
	O. and A. Ferry	3		*3		*3		*5		6		*4		*15		*13
	Innisfail Ferry	34		32		30		32		29		24				42
	Pittsburg[1]	8				5				5				10		
	North of San Pablo Bay															
	Grand View	730		840		*900		930		990		880		960		930
	Sonoma Creek Bridge	690		530		700		720		700		880				820
	Vallejo	415		400		*410										
	Lakeville	*550				570		560		620		630				*760
	McGill	420		380										470		
	Cuttings Wharf	315		740		360		350		380		310		330		520
	Napa	7		*7		7		9				*11				
	Petaluma	265		300		300		360		420		430		450		510
	Sacramento River Delta															
	Collinsville	3		3		3		2		2		4		3		5
	Emmaton	2		3		2		3		3		3		2		*2
	Three Mile Slough Bridge	2		3		*2		*2		2		2		2		*2
	Rio Vista Bridge			*1		*2				2		*2		*4		*2
	Liberty Ferry	2		1		2		1		2		2		2		*2
	Walnut Grove	2		*1		*1		*2		2		*1		*3		*2
	Sacramento	1		1		1		*1		1		2		*1		1

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1930

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Joaquin River Delta															
May (Continued)	Antioch	3	*4			4		*4		4		5		4		*7
	Jersey	4		4		6		4		5		5		5		*4
	Twitchell Island	3		3		3		*3		3		4				*4
	Webb Pump	5		4		*5		*5		4		*5		*4		*4
	Central Landing, Bouldin Island	3		2		2		3		3		2		2		*3
	Ward Landing			6				5		5		7		9		9
	Holland Pump	8		6		*6		*7		7		*7		*6		*7
	Rindge Pump	8		12		*12		*13		12		13		*9		*7
	East Contra Costa Irrigation Dist.	4		5		6		*5		6		8		7		
	Stockton Country Club	8		15		*13						11		*9		*7
	Drexler Bridge	6		*5		*5		*6		5		*6		*6		*6
	Stockton	120		*91				*80		68		*74				
	Mossdale Highway Bridge	3		5		5		5		7		4		4		*4
	Mokelumne River Delta															
	New Hope Bridge			1		1		*1		1		1		*2		2
	Drainage Water in Delta Islands															
	Jersey Drain	32		24		19		32		40		26		23		*24
	Grand Island Drain, Steamboat Slough	6			*6		*7		*4		*6		*6		*6	
	Camp 35, Staten Island Drain	13		12		15	8		5		7		6		6	
	McDonald Drain	8		14		9		12		13		14		13		9
	Bacon Island Drain	*8		8		*6		7		7		*8		9		8
	Mandeville Drain	20		19		19		19		17		18		18		16
	Camp 11, Staten Island Drain		*44		*17		*12		*49			25	*36		*27	
	San Francisco, San Pablo and Suisun Bays															
June	Point Orient	1,380		1,440		*1,520		1,470		1,390		1,480		*1,550		1,510
	Point Davis	690		940				1,080				1,180		*1,150		1,120
	Bulls Head Point	510		*800		*690		680		820		*900		*960		860
	Bay Point	200		155		250		350		260		335				460

O. and A. Ferry	9	--------	*13	--------	*82	--------	65	--------	89	--------	*137	--------	*185	--------	215
Innisfail Ferry	42	--------	*40	--------	47	--------	77	--------	64	--------	70	--------	119	--------	172
Pittsburg[1]	10	--------	--------	--------	12	--------	--------	--------	20	--------	--------	--------	28	--------	--------
North of San Pablo Bay															
Grand View	960	--------	1,000	--------	1,000	--------	890	--------	1,010	--------	1,020	--------	1,100	--------	1.140
Sonoma Creek Bridge	980	--------	920	--------	900	--------	*860	--------	*940	--------	970	--------	--------	--------	--------
Vallejo	530	--------	--------	--------	--------	--------	*640	--------	700	--------	820	--------	--------	--------	880
Lakeville	790	--------	810	--------	810	--------	--------	--------	940	--------	*960	--------	--------	--------	1,060
McGill	--------	--------	--------	--------	--------	--------	540	--------	--------	--------	*700	--------	--------	--------	740
Cuttings Wharf	530	--------	540	--------	550	--------	500	--------	550	--------	640	--------	590	--------	620
Napa	23	--------	*49	--------	*56	--------	--------	--------	83	--------	*117	--------	*195	--------	180
Petaluma	560	--------	570	--------	620	--------	670	--------	700	--------	730	--------	760	--------	860
Sacramento River Delta															
Collinsville	4	--------	4	--------	9	--------	36	--------	9	--------	12	--------	41	--------	94
Emmaton	3	--------	3	--------	*4	--------	4	--------	4	--------	--------	--------	5	--------	5
Three Mile Slough Bridge	2	--------	*3	--------	4	--------	3	--------	5	--------	*4	--------	*4	--------	5
Rio Vista Bridge	2	--------	*4	--------	*3	--------	2	--------	4	--------	*3	--------	*6	--------	3
Liberty Ferry	2	--------	3	--------	--------	--------	2	--------	2	--------	--------	--------	--------	--------	3
Walnut Grove	2	--------	--------	--------	*2	--------	1	--------	*3	--------	*3	--------	--------	--------	3
Sacramento	1	--------	*1	--------	*1	--------	--------	--------	1	--------	*2	--------	*1	--------	2
San Joaquin River Delta															
Antioch	5	--------	5	--------	6	--------	13	--------	9	--------	7	--------	15	--------	43
Jersey	5	--------	--------	--------	4	--------	4	--------	6	--------	6	--------	5	--------	10
Twitchell Island	4	--------	*5	--------	*4	--------	4	--------	6	--------	5	--------	*6	--------	5
Webb Pump	5	--------	*6	--------	*5	--------	4	--------	5	--------	*6	--------	*5	--------	6
Central Landing, Bouldin Island	3	--------	4	--------	2	--------	2	--------	3	--------	3	--------	4	--------	4
Ward Landing	7	--------	7	--------	7	--------	6	--------	8	--------	7	--------	7	--------	8
Holland Pump	8	--------	*7	--------	*7	--------	7	--------	--------	--------	5	--------	*6	--------	7
Rindge Pump	10	--------	*13	--------	*9	--------	6	--------	5	--------	6	--------	*9	--------	10
East Contra Costa Irrigation Dist.	--------	--------	7	--------	6	--------	6	--------	6	--------	6	--------	*4	--------	--------
Stockton Country Club	11	--------	15	--------	*7	--------	6	--------	--------	--------	9	--------	--------	--------	12
Drexler Bridge	6	--------	*6	--------	*6	--------	6	--------	4	--------	*7	--------	5	--------	4
Stockton	111	--------	*79	--------	*82	--------	93	--------	*117	--------	*108	--------	*97	--------	--------
Mossdale Highway Bridge	6	--------	3	--------	--------	--------	2	--------	3	--------	3	--------	*4	--------	7
Mokelumne River Delta															
New Hope Bridge	1	--------	1	--------	1	--------	1	--------	1	--------	1	--------	*1	--------	1
Drainage Water in Delta Islands															
Jersey Drain	18	--------	--------	--------	17	--------	17	--------	17	--------	26	--------	19	--------	17
Grand Island Drain, Steamboat Slough	5	--------	6	--------	6	--------	5	--------	7	--------	7	--------	5	--------	7
Camp 35, Staten Island Drain	4	--------	6	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
McDonald Drain	*11	--------	*11	--------	*13	--------	*12	--------	*9	--------	*9	--------	*10	--------	*10
Bacon Island Drain	*7	--------	*8	--------	*8	--------	8	--------	7	--------	*8	--------	*6	--------	7
Mandeville Drain	16	--------	14	--------	11	--------	10	--------	9	--------	9	--------	8	--------	9
Camp 11, Staten Island Drain	*48	--------	*52	--------	*30	--------	15	--------	*19	--------	*43	*30	--------	--------	*18

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1930

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
July	Point Orient	1,620				*1,550		1,640		1,640		1,600		*1,650		1,740
	Point Davis	1,220		1,330		*1,270		1,160		1,190		1,390		*1,410		1,450
	Bulls Head Point	940		*1,000		*870		880		940		*1,190		*1,260		1,100
	Bay Point	640		560		560		620		*640		790				780
	O. and A. Ferry	220		*325		*340		320		540		*620		*590		540
	Innisfail Ferry			190		300		300		390				465		560
	Pittsburg[1]	50				95				135				230		
	North of San Pablo Bay															
	Grand View	1,170		1,120		1,200		1,220		1,200		1,170		1,240		1,320
	Sonoma Creek Bridge	1,050		1,045		1,090		1,130		1,200		1,210		1,180		*1,340
	Vallejo	840		950			930			1,060		1,090		*1,150		1,130
	Lakeville	1,050		1,060		1,100				1,160		1,180		1,240		1,300
	McGill	1,010		1,030		1,030		1,020		1,200						
	Cuttings Wharf	700		740		800		790		860		940		1,020		1,120
	Merazo					920										
	Napa	240				*225		285		320		*375				370
	Petaluma	860		890		890		950		990		1,030		1,100		1,000
	Sacramento River Delta															
	Collinsville	74		101		99		136		180		230		300		330
	Emmaton					12		20				36		80		74
	Three Mile Slough Bridge	6		8		*11		9		10		35		42		36
	Rio Vista Bridge	3		*4		*4		4		5		*6		*5		7
	Junction Point									6		6		5		6
	Liberty Ferry	3		4				5		5		5		6		6
	Isleton Bridge									5		*5		*4		5
	Walnut Grove	*4		*4		*4		4				*6		*6		6
	Sacramento	3		*4		*4		4		4		*4		*4		4
	San Joaquin River Delta															
	Antioch	34		48		77		126		85		168		240		305
	Jersey	8		8		15		25		13		29		33		62
	Twitchell Island	6		6		*8		7		8		*24		*24		12

	Webb Pump	*6		*7		*5		6		*8		*15		*15		13
	Central Landing, Bouldin Island	5		6		4		5		8		5		6		9
	Blakes Landing, Venice Island											6				
	Ward Landing	7		8		8		7		8		8				8
	Holland Pump	6		7		*6		6		7		7		*9		9
	Mandeville Pump									8		7		*6		9
	Rindge Pump	13		14		*11		11		13		11		*13		12
	Orwood Bridge									*7		*6		6		7
	East Contra Costa Irrigation Dist.	6		5		*4		5				7		*7		7
	Middle River, P. O.											8		7		8
	Mansion House													6		
	Stockton Country Club					*13				13				*14		
	Drexler Bridge	5		5		*5		4		6		*7		*6		6
	Stockton	*87		*62		84		*79		85		82		*94		*99
	Mossdale Highway Bridge	5		7		*6		7		8		*8		*6		*10
	Mokelumne River Delta															
	Southwest Point, Staten Island									7		7		5		9
	Camp 33, Staten Island									5		6		5		7
	Tyler Island Ferry									6		6		*5		9
	New Hope Bridge	1		1		*2		2		1		1		*1		1
	Drainage Water in Delta Islands															
	Jersey Drain	17		20		18		26		22		23		29		38
	Grand Island Drain, Steamboat Slough		8		10		6	7			8		7		11	
	Camp 35, Staten Island Drain												8		*10	
	McDonald Drain		*9		*11		*11		*12		*11		*10		*11	
	Bacon Island Drain	*7		*7		6		6		*7		7		6		8
	Mandeville Drain			8		8		6		8		7		*6		8
	Camp 11, Staten Island, Drain			9	*9		*8			*7		*7		*9		*11
	San Francisco, San Pablo and Suisun Bays															
August	Point Orient	1,660		1,680		*1,640		*1,630		1,680		*1,710		1,710		1,750
	Point Davis			*1,340		*1,420		1,390		1,510		1,540		*1,560		1,580
	Bulls Head Point	1,260		*1,290		*1,160		1,160		1,280		*1,360		1,140		1,340
	Bay Point	870		820		840		*950		850		950		1,000		980
	O. and A. Ferry	630		*625		*610		800		750		*660		680		780
	Innisfail Ferry	530		560		580		*650		700		*720		660		810
	Pittsburg[1]	300				400				540				470		
	North of San Pablo Bay															
	Grand View	1,200		1,320		1,400		1,420		1,480		1,500		1,430		1,540
	Sonoma Creek Bridge	1,320		*1,320			1,370		1,420	1,480		1,470		*1,500		
	Vallejo	1,150		*1,230		1,170				1,250		*1,240		1,270		1,320
	Lakeville	1,240		1,320		1,320		1,330				1,340				1,520
	McGill	1,260														
	Cuttings Wharf	1,040		1,010		940		1,060		1,050		1,050		1,210		1,160
	Merazo															
	Napa	485		*510		*525						*620				690
	Petaluma	1,180		1,120		1,120		1,150		1,200		1,240		1,270		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1930

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Sacramento River Delta															
August (Continued)	Collinsville	*340		400		360		450		400		460		500		500
	Emmaton			120		151		225		175		168		214		
	Three Mile Slough Bridge	*44		*62		52		78		148		*139		92		150
	Rio Vista Bridge	*10		*10		*7		9		32		*52		36		
	Junction Point			5		26		6		8		10		10		10
	Liberty Ferry			4		*6		6		5		6		5		6
	Isleton Bridge	*6		*6		*6		6		*7		*10		4		8
	Walnut Grove			*5		*5		5		*5		*6		5		4
	Sacramento	5		*5		*3				*4		*4		4		2
	San Joaquin River Delta															
	Antioch	230		315		*420		435		315		380		460		315
	Jersey	45		75		94		120		97		135		220		120
	Twitchell Island	18		*24		*46		23		23		56		50		42
	Webb Pump	*18		*26		*30		34		*41		*58		47		61
	Central Landing, Bouldin Island	6				7		11		10		12		9		11
	Blakes Landing, Venice Island			12		*12						19		18		20
	Ward Landing	8		9		7		9		10		11		12		13
	Holland Pump	12		*14		13		12		12		*22		23		16
	Mandeville Pump	8		8				7		9		*10		13		11
	Rindge Pump	16		*12		*10		14		14		*15		13		*15
	Orwood Bridge	*7		*7		*6		8		*8		*8		7		*10
	East Contra Costa Irrigation Dist.	9		9		*7				8		5		6		9
	Middle River P. O.	11		7		*6		9		8		7		8		*10
	Mansion House			*7		*7		8		8		8		7		9
	Stockton Country Club	17		*18		*16		17		17		15				15
	Drexler Bridge	5		*7		*6		7		7		*6		7		7
	Stockton	*100		*81		*83				*88		*85		95		*94
	Mossdale Highway Bridge	10		*9		*5		6		5		*6				
	Mokelumne River Delta															
	Southwest Point, Staten Island	6		5		*5		6		9		6		7		5
	Camp 33, Staten Island	5		5		*4		5		5		4		4		5
	Tyler Island Ferry	7		6		*4		6		4				4		6
	New Hope Bridge	*1		1		*1		1		1		*1		1		

	Drainage Water in Delta Islands															
	Jersey Drain	31		40		36		33		49		78		52		66
	Grand Island Dr., Steamboat Slough	6	*6				*8			7			*5		*6	
	Camp 35, Staten Island Drain		7			6				*6	*7	8				
	McDonald Drain	*10		*10												
	Bacon Island Drain	*7		*8		7		9		9		*9		8		11
	Mandeville Drain	7		8		*7		8		10		*10		13		15
	Camp 11, Staten Island Drain	8		19		9		7		20	10		7		10	
	San Francisco, San Pablo and Suisun Bays															
September	Point Orient	1,750		*1,750		1,780		1,690		1,770		1,730		1,680		1,750
	Point Davis	1,510		*1,460		1,560		1,500		1,550		1,620		1,480		
	Bulls Head Point	1,360		*1,380		1,320		1,170		1,300		1,290		1,240		1,140
	Bay Point			1,060		1,030		940		940		990		980		770
	O. and A. Ferry	*800		*690		650		640		*750				540		560
	Innisfail Ferry	790		780		790		800		770		810		660		700
	Pittsburg[1]	485				480				410				330		
	North of San Pablo Bay															
	Grand View	1,570		1,550		1,610		1,580		1,590				1,600		1,560
	Sonoma Creek Bridge	*1,540		1,580		1,630		1,600		1,560		*1,540		*1,670		
	Vallejo			1,320		1,340		1,330		1,300		1,230		1,260		
	Lakeville	1,530		1,500		1,510				1,610		*1,690		1,670		1,680
	McGill									1,490						
	Cuttings Wharf	1,190		1,240		1,270		1,240		1,320		1,290		1,240		1,320
	Merazo									1,410						
	Napa	620								800		840				900
	Petaluma	1,360		1,360		1,350		1,380		1,450				1,480		1,470
	Sacramento River Delta															
	Collinsville	570		530		550		450				365		320		245
	Emmaton	146				•250		200				*80				17
	Three Mile Slough Bridge	105		*115		150		70		*51		31		24		18
	Rio Vista Bridge	*20		*12		19		10		*9		4		6		5
	Junction Point	10		8		7		5		6		3		4		4
	Liberty Ferry	6		5		5		*4		5		3				
	Isleton Bridge	*7		*5		5		4		*3		3		3		*2
	Walnut Grove			*3		6		4		*5						*3
	Sacramento	*4		*3		3		3				2		3		2
	San Joaquin River Delta															
	Antioch	400		400		435		470		280		310		315		240
	Jersey	160		150		160				130		100		105		57
	Twitchell Island			*72		37		43		30		*28		27		14
	Webb Pump	*60		*47		44		41		*34		27		26		18
	Central Landing, Bouldin Island	14		15		11		10		8		10		6		7
	Ward Landing	15		13		13		16		16		14		16		13
	Holland Pump	22		22		18		19		20		20		23		
	McDonald Pump													15		14
	Mandeville Pump	14		*14		15		17		16		*15		17		17
	Rindge Pump	14		*13		14		16		14		14		11		11

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1930

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water: Day of month 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Joaquin River Delta—Continued															
September (Continued)	Orwood Bridge	*11		*11		11				*12		11		11		
	East Contra Costa Irrigation Dist.	9		8		*10		11		*10		9		9		9
	Middle River P. O.	*10				10		13		11		10		12		12
	Mansion House	9		8		9		11		8		*8		8		8
	Stockton Country Club	15				10		14				*9		13		10
	Drexler Bridge	8		*7		9		10		8		6		8		7
	Stockton	*70				99		*80		*82				71		*75
	Mossdale Highway Bridge	*5		*4		7		7		5		*6		7		5
	Mokelumne River Delta															
	Southwest Point, Staten Island	6		5		6		7		7		*4		4		3
	Camp 33, Staten Island	6		5		5		7		5		*4		4		4
	Tyler Island Ferry	5		4		5		7		4		*3		4		3
	New Hope Bridge	1		*1		1		1				1		1		1
	Drainage Water in Delta Islands															
	Jersey Drain			40		37				35		31		33		33
	Grand Island Drain, Steamboat Slough	6		6		7		9		9		6		7		6
	Camp 35, Staten Island Drain											*7		8		8
	McDonald Drain												16		17	
	Bacon Island Drain	*12		11		14		15		12				13		12
	Mandeville Drain	16		*16		19		21		19		*17		18		18
	Camp 11, Staten Island Drain	14	*19		*24		*39		*27					31	*31	
	San Francisco, San Pablo and Suisun Bays															
October	Point Orient	1,700		1,730		1,690		1,660		1,520		1,660		1,580		1,520
	Point Davis	1,310		*1,430		1,500				1,380		1,320		1,250		1,260
	Bulls Head Point	*1,090		1,100		1,180		1,120		980		960		1,050		980
	Bay Point	790		770		860		550		740		700		650		
	O. and A. Ferry	*400		350		560		340		305		330		240		310
	Innisfail Ferry	690		630		600		520		520				480		480
	Pittsburg[1]	280				210				170				130		

North of San Pablo Bay															
Grand View	1,600		1,560		1,490		1,490		1,520		1,500		1,520		1,450
Sonoma Creek Bridge	1,520		*1,500		*1,510		1,390		*1,380			1,360	1,380		*1,260
Vallejo	1,160		1,140		1,200		1,120		1,080		1,060		1,060		1,000
Lakeville			1,660		1,520		1,640				1,670		1,690		1,680
McGill	1,420		1,390		1,450		1,320				1,300				1.200
Cuttings Wharf	1,280		1,290		1,200		*1,180		1,180		1,160		1,140		1,170
Merazo			1,270		1,320								1,210		
Napa			875						900		860				850
Petaluma	1,500		1,480		1,520		1,330		1,400		1,480		1,530		1,580
Sacramento River Delta															
Collinsville	250		230		265		140		160		250		155		120
Emmaton	14		*20		10		5		*11		11		8		*4
Three Mile Slough Bridge	*11		10		11		7		7		6		6		*3
Rio Vista Bridge	*2		3		3		2		2		2		3		1
Junction Point	2		1		3		2		1		1		2		3
Liberty Ferry	2		5		3		2		1				2		2
Isleton Bridge	*2		2		2		2		1		1		2		1
Walnut Grove	*3		2		2				*3		2				2
Sacramento	2						1		1		3		2		1
San Joaquin River Delta															
Antioch	225		200		225		180		140		110		150		85
Jersey	48		43		50		44		20				27		10
Twitchell Island	14		15		12		11		7		8		8		8
Webb Pump	*14		14		14		11		8		12		9		8
Central Landing, Bouldin Island	6		6		5		5		2		6		3		3
Ward Landing	13		13		12		12		11		12		12		9
Holland Pump	8		16		17		15		15		15		13		10
McDonald Pump	13		13		13						*12		12		11
Mandeville Pump	14		13		11		12		12		12		12		10
Rindge Pump	10		12		14		13		11		10		14		13
Orwood Bridge	*10		8		8		9		7		8		8		7
East Contra Costa Irrigation District			7		8		9		7		11		12		11
Middle River P. O.	11		10		9		9		13		9		9		7
Mansion House	8		*7		8				8				9		
Stockton Country Club							14						10		
Drexler Bridge	*6		6		6		6		4		7		9		6
Stockton			62		67		*81		72		84		68		88
Mossdale Highway Bridge	6		*6		7		8		5		6		8		6
Mokelumne River Delta															
Southwest Point, Staten Island	3		*3		2		1		1		2		2		2
Camp 33, Staten Island	3		*2		3		2		2		2		2		2
Tyler Island Ferry	2		1		3		2		2		2		4		1
New Hope Bridge	1		*1		1		1		1		1		1		1

TABLE 33—Continued

S LINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1930

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water														
		Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Drainage Water in Delta Islands															
October (Continued)	Jersey Drain	28	....	27	....	26	....	30	....	29	....	....	....	42	....	37
	Grand Island Drain, Steamboat Slough	....	6	....	5	....	5	....	9	....	5	....	7	....	7	....
	Camp 35, Staten Island Drain	9	....	8	....	7	....	6	....	6	....	5	....	6	....	8
	McDonald Drain	17	....	14	....	18	....	17	....	17	....	....	16	12	17	....
	Bacon Island Drain	*12	....	11	....	14	....	13	....	*8	....	12	....	12	....	10
	Mandeville Drain	17	....	18	....	16	....	19	....	18	....	18	....	17	....	18
	Camp 11, Staten Island Drain	*23	....	*15	....	27	....	24	....	16	....	....	....	8	....	11
	San Francisco, San Pablo and Suisun Bays															
November	Point Orient	1,660	....	1,640	....	1,710	....	1,630	....	1,730	....	1,660	....	1,570	....	1,460
	Point Davis	1,320	....	1,280	....	1,240	....	1,300	....	*1,220	....	1,210	....	1,220	....	1,220
	Bulls Head Point	1,080	....	1,070	....	920	....	860	....	940	....	970	....	860	....	1,080
	Bay Point	....	....	....	....	750	....	690	....	*540	....	550	....	530	....	640
	O. and A. Ferry	340	....	260	....	360	....	250	....	225	....	230	....	205	....	300
	Innisfail Ferry	470	....	480	....	475	....	490	....	*460	....	415	....	405	....	420
	Pittsburg[1]	105	....	....	....	125	....	....	....	100	....	....	....	75	....	....
	North of San Pablo Bay															
	Grandview	1,500	....	1,470	*1,280	1,480	....	1,420	....	1,360	....	1,420	....	1,440	....	1,370
	Sonoma Creek Bridge	1,300	....	1,300	*1,280	....	....	1,260	....	*1,120	....	1,170	....	*1,160	....	....
	Vallejo	1,080	....	1,130	....	....	....	....	....	....	....	....	....	880	....	1,020
	Lakeville	1,660	....	....	....	1,700	....	1,700	....	1,620	....	....	....	1,670	....	....
	McGill	....	....	....	....	1,180	....	....	....	1,100	....	1,060	....	....	....	....
	Cuttings Wharf	1,090	....	1,100	....	1,160	....	1,090	....	1,020	....	1,050	....	1,020	....	960
	Merazo	1,140	....	1,150	....	....	....	....	....	....	....	1,030	....	....	....	....
	Napa	....	....	....	....	830	....	760	....	....	....	760	....	740	....	....
	Petaluma	1,500	....	1,540	....	1,550	....	1,540	....	1,500	....	1,500	....	1,470	....	1,440
	Sacramento River Delta															
	Collinsville	100	....	....	....	180	....	160	....	220	....	80	....	60	....	86
	Emmaton	....	....	....	....	3	....	....	....	4	....	2	....	2	....	3
	Three Mile Slough Bridge	3	....	11	....	6	....	3	....	*2	....	4	....	3	....	1
	Rio Vista Bridge	2	....	1	....	3	....	....	....	....	....	....	....	....	....	....

[1] Junction Point

	Junction Point	1		2		2										
	Liberty Ferry	1		2		2		2								
	Isleton Bridge	1		2												
	Walnut Grove	1				2		1								
	Sacramento	1		1		1		1		1		3		1		1
	San Joaquin River Delta															
	Antioch	140		133		120		89		78		52		30		36
	Jersey			20		10		13		14				9		7
	Twitchell Island	7		8		7		7		8	7	6		5		
	Webb Pump	7		8		9		7		8		7		6		5
	Central Landing, Bouldin Island	4		5		4		4		5		4		4		
	Ward Landing	12		11		11		10		9		10		11		10
	Holland Pump	10		11		11		8		9		12		9		9
	McDonald Pump	10		11		12		13		*13		13		11		11
	Mandeville Pump	11				10		13		10		10		9		9
	Rindge Pump	13		11		13		11		12		11		11		10
	Orwood Bridge	7		8		8		7		8		9		8		7
	East Contra Costa Irrigation District			13		12		13				13		17		
	Middle River P. O.	7		10		10		*11		10		11		9		9
	Mansion House	8		7		8		8		*8		9				
	Stockton Country Club											10		10		
	Drexler Bridge	8		8		9		7		6		8		6		11
	Stockton	90		77		68				82		82				
	Mossdale Highway Bridge	7		8		8		8		7		7		7		6
	Mokelumne River Delta															
	Southwest Point, Staten Island	2		2		2		1								
	Camp 33, Staten Island	1		2		2		2								
	Tyler Island Ferry	1		2												
	New Hope Bridge	1		1		1										
	Drainage Water in Delta Islands															
	Jersey Drain			29		26		45		43				26		41
	Grand Island Drain, Steamboat Slough	8	*7		*6		*5		*5		*6		*6		*6	
	Camp 35, Staten Island Drain	8		8		7		5								
	McDonald Drain	16	*18			15		22		16		18		18		16
	Bacon Island Drain	9		12		11		10		11		11		9		9
	Mandeville Drain	15				16		17		16		17		16		15
	Camp 11, Staten Island Drain	10		6			8			7		13		15		
	San Francisco, San Pablo and Suisun Bays															
December	Point Orient	1,540		1,710		1,600		1,600		1,670		1,690		1,600		1,560
	Point Davis	1,280		1,230		1,240		1,260		1,120		1,240		1,140		1,270
	Bulls Head Point	1,020		1,060		990		980		1,040		920		900		980
	Bay Point	750				560		600		*690		560		640		720
	O. and A. Ferry			280		160		320		230		250		190		440
	Innisfail Ferry	380		410		390		420		400		350				350
	Pittsburg[1]	90				80				70		55		50		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1930

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	North of San Pablo Bay															
December (Continued)	Grandview	1,410		1,400		1,340		1,280		1,360		1,410		1,300		1,280
	Sonoma Creek Bridge	*1,140		1,180		1,110		1,040		1,070		1,090		1,090		1,100
	Vallejo	1,060		1,030		1,000				970		920		980		1,100
	Lakeville	1,530				1,570		1,620		1,500				1,600		
	McGill	1,070								1,020						
	Cuttings Wharf	980		1,040		1,020		1,000		1,030		1,000		1,000		970
	Merazo															
	Napa	720		740		740		700				670				
	Petaluma	1,500		1,450		1,510		1,500		1,540		1,560		1,510		1,480
	Sacramento River Delta															
	Collinsville	78		148		105		104		102		90		69		125
	Emmaton	2		3				2		3		3				
	Three Mile Slough Bridge	2		1		2		1		3		2		3		
	Rio Vista Bridge															
	Junction Point															
	Liberty Ferry															
	Isleton Bridge															
	Walnut Grove															
	Sacramento	*1		1		1		1		*1		1				1
	San Joaquin River Delta															
	Antioch	36		92		54		50		69		52		37		45
	Jersey	7		16		11		7		14		11				7
	Twitchell Island															
	Webb Pump	5		7		8		7		7		7		7		6
	Central Landing, Bouldin Island	5		3		4		2		3		3		6		5
	Ward Landing	9		9		11		10		12		12		11		9
	Holland Pump	9		12		11		8		9		10		11		9
	McDonald Pump	11														
	Mandeville Pump	9		10		10		8		11		10				8
	Rindge Pump	10		12		11		8		10		10		9		9
	Orwood Bridge	7		8		9				8		8		7		7
	East Contra Costa Irrigation District	13		14				12		14		14		11		

Middle River P. O.	8	--------	10	--------	8	--------	9	--------	10	--------	8	--------	8	--------	8
Mansion House	*9	--------	8	--------	8	--------	8	--------	7	--------	9	--------	6	--------	--------
Stockton Country Club	11	--------	--------	--------	9	--------	--------	--------	--------	--------	10	--------	--------	--------	--------
Drexler Bridge	8	--------	8	--------	9	--------	7	--------	6	--------	7	--------	7	--------	9
Stockton	66	--------	60	--------	68	--------	--------	--------	--------	--------	57	--------	--------	--------	--------
Mossdale Highway Bridge	3	--------	7	--------	6	--------	4	--------	6	--------	7	--------	7	--------	9
Mokelumne River Delta															
Southwest Point, Staten Island	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Camp 33, Staten Island	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Tyler Island Ferry	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
New Hope Bridge	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Drainage Water in Delta Islands															
Jersey Drain	31	--------	32	--------	26	--------	27	--------	28	--------	29	--------	--------	--------	33
Grand Island Drain, Steamboat Slough	*5	--------	*6	--------	*5	--------	*7	--------	*6	--------	--------	--------	*5	--------	*5
Camp 35, Staten Island Drain	--------	--------	--------	--------	--------	--------	--------	*8	--------	--------	8	--------	11	--------	5
McDonald Drain	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Bacon Island Drain	10	--------	11	--------	10	--------	10	--------	16	--------	10	--------	11	--------	*9
Mandeville Drain	16	--------	17	--------	17	--------	15	--------	17	--------	16	--------	--------	--------	14
Camp 11, Staten Island Drain	9	--------	10	--------	7	--------	8	--------	--------	--------	--------	--------	--------	--------	--------

* Observation on next succeeding day.

[1] Mean weekly salinities from drip samples, by Great Western Electro Chemical Company.

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1931

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
January	Point Orient	*1,540		1,640		1,520		1,540		1,420		1,400		1,380		1,410
	Point Davis	1,250		1,150		1,080		940		1,100		1,020		810		1,020
	Bulls Head Point	1,150		910		790		900		680		660		700		850
	Bay Point	920		650		320		540				*435		325		
	O. and A. Ferry	162		185		95		118		116		97		87		61
	Innisfail Ferry	440		*390		345		270		180		*300		275		155
	Pittsburg[1]	50		120			40			20				20		
	North of San Pablo Bay															
	Grandview	1,230		1,250		1,200		1,170		1,160		1,080		1,050		960
	Sonoma Creek Bridge	1,040		920		*760		*850		770		*640		500		830
	Vallejo	980		930		820						800		750		800
	Lakeville	1,380		1,330		1,190		1,160				1,130		870		960
	Cuttings Wharf	900		720		580		680		730		720		260		390
	Napa	150				17		74				2				
	Petaluma	1,080		910		520		590		690		640		80		230
	Sacramento River Delta															
	Collinsville	215		126		30		33		34		29		8		9
	Emmaton							1		2		3		2		2
	Sacramento	*1		1		2		*2		5		2		1		2
	San Joaquin River Delta															
	Antioch	135		68		21		*13		20		14		9		6
	Jersey	19		6		6		7		8		6		7		6
	Webb Pump	6		6		5		6		6		7		6		5
	Central Landing	3		3		4		2		4		2		2		
	Holland Pump	7		9		10		11		10		10		11		8
	Mandeville Pump	7		7		8		8		9		9		10		10
	Rindge Pump	9		11		13		13		12		14		11		12
	East Contra Costa Irrigation District			10		12		12		13		13		15		
	Middle River P. O.	7		5		9		9		8		10		12		11
	Mansion House	*5				8		*8				9		10		
	Stockton	34		76		66		75				101		63		55
	Mossdale Highway Bridge	7		7		9		8		7		7		6		6

	Jersey Drain	24		26		30		31		48		33		32		34
	Grand Island Drain, Steamboat Slough		4		6		5		4		8		5		6	
	Camp 35, Staten Island Drain	7		15		19		19		13		18		23		30
	McDonald Drain															*15
	Bacon Island Drain	*11				11		9		10		9		17		*10
	Mandeville Drain	14		13		14		15		14		15		15		14
	Camp 11, Staten Island Drain					21		27		46		54		38		38
	San Francisco, San Pablo and Suisun Bays															
February	Point Orient	1,550		1,470		1,540				1,330		1,320		1,360		
	Point Davis	1,080		1,020		940		*990		*760		810		780		
	Bulls Head Point	700		680		780		840		600		280		500		
	Bay Point	465												300		
	O. and A. Ferry	92		66		58		81		31		9		10		
	Innisfail Ferry	170		190		175		190		220		190		140		
	Pittsburg [1]		12			12						20			10	
	North of San Pablo Bay															
	Grandview	950		930		940		910		930		900		980		
	Sonoma Creek Bridge	650		770		660		*760		680		680		820		
	Vallejo	790		690		730				700		620		680		
	Lakeville			960		900		1,020		900				910		
	Cuttings Wharf	615		460		490		510		635		380		400		
	Napa							93		63				50		
	Petaluma	460		520		580				600		520		500		
	Sacramento River Delta															
	Collinsville			20		22		25		7		3		7		
	Emmaton	2		2										3		
	Sacramento	*2		2		1		*1		1		1		1		
	San Joaquin River Delta															
	Antioch	12		12		11		19		9		6		6		
	Jersey	6		4		5		7		7		3		5		
	Webb Pump	6		5		6		7		6		6		8		
	Central Landing	4		4		2		2				2		4		
	Holland Pump	10		10		10		10		10		12		12		
	Mandeville Pump	10		10		10		10		11		10		10		
	Rindge Pump	10		11		12		12		14		9		12		
	East Contra Costa Irrigation Dist.	12		12		13				13				21		
	Middle River P. O.	11		15		9				9		8		9		
	Mansion House			9						9						
	Stockton	56				61				75		64		66		
	Mossdale Highway Bridge	6		7		*7		*7		8		7		7		
	Drainage Water in Delta Islands															
	Jersey Drain	34		47		34		35		38		53		37		
	Grand Island Drain, Steamboat Slough	7	*7		*5		*6		*6		*5		6			
	Camp 35, Staten Island Drain	41		28		29		28		23		23		30		
	McDonald Drain	*16		17	*17		16		17	*15		*14		17		
	Bacon Island Drain	10		12		10		10		10		12		9		
	Mandeville Drain	14		15		11		13		12		13		14		
	Camp 11, Staten Island Drain	31		57		53		45		38		47		33		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1931

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Francisco, San Pablo and Suisun Bays															
March	Point Orient	1,490		1,460		1,420		1,340		1,440		1,230		1,240		1,210
	Point Davis	960		960		860		920		910				580		*920
	Bulls Head Point	710		640		660		450		490		370		200		
	Bay Point			260		235		265		240				75		163
	O. and A. Ferry	12		72		35		48		24		5		3		*4
	Innisfail Ferry	75		85		103		112				106		106		79
	Pittsburg [1]		5		12					10				10		
	North of San Pablo Bay															
	Grandview	950		980		980		990		1,020		1,060		1,050		1,020
	Sonoma Creek Bridge	760														
	Vallejo	660														570
	Lakeville									910	940			880		
	Cuttings Wharf	600		480		590		540		460		410		260		300
	Napa	67		90				3						8		
	Petaluma	570		660		700		520		500		520		600		630
	Sacramento River Delta															
	Collinsville	6		4		11		8		3		1		2		3
	Mayberry															
	Emmaton	1		1		1		2		1		1				
	Sacramento							1		*1		1		1		1
	San Joaquin River Delta															
	Antioch	4		6		11		9		7		3		5		5
	Curtis Landing															
	Jersey	7		4		5		5		6		4		4		5
	Webb Pump	7		6		7		6		5		4		6		4
	Central Landing	4		4		4			3	1		1	1	3		4
	Holland Pump	10		9		11		10		10		9		11		10
	Mandeville Pump	*10		11		11		10		10		10		8		10
	Rindge Pump	12		12		12		14		15		17		17		13
	East Contra Costa Irrigation Dist.	14		16		12		9		9		9		9		11
	Middle River P. O.	12		9		11		11		14		10		12		13

[1] Mansion House

	Mansion House					9		8				7				11
	Stockton			64		64		71		83		86				67
	Mossdale Highway Bridge	*9		10		12		15		*15		13				*13
	Durham Ferry Bridge															
	Drainage Water in Delta Islands															
	Jersey Drain	34		48		41		44		34		42		34		40
	Grand Island Drain, Steamboat Slough	7	*4		*5		*6		*5		*5		*4		*7	
	Camp 35, Staten Island Drain	20		17		20		21		18		18		20		19
	McDonald Drain	16	*15		15		17	*17		15	*17		11	*17		18
	Bacon Island Drain	11		11		10		10		9		9		10		9
	Mandeville Drain	15		13		14		14		15		14		14		15
	Camp 11, Staten Island Drain	34		37		15		25		14		24		17		28
	San Francisco, San Pablo and Suisun Bays															
April	Point Orient	1,520		1,580		1,420		1,450		1,510		1,600		1,550		1,580
	Point Davis	*1,020		970		920		*940		1,040		1,340		1,250		1,270
	Bulls Head Point	*550		580		500		*630		*730		1,000		830		*970
	Bay Point	159		218		315		370		455		550				600
	O. and A. Ferry	*39		74		45		*162		*275		250		*210		270
	Inni-fail Ferry	59		70		74				98		200		240		270
	Pittsburg [1]	8				8			8				35			
	North of San Pablo Bay															
	Grandview			1,050		1,110		*1,100		*1,120		1,180		1,190		1,160
	Sonoma Creek Bridge															
	Vallejo	*590		640		680		*760		*840		850		850		*970
	Lakeville	870				990		950		990		1,020				
	Cuttings Wharf	510		390		440		410		570		440		580		750
	Napa	16				15		20								
	Petaluma	630		660		720		760		760		820		750		830
	Sacramento River Delta															
	Collinsville	4		37		20		16		40		92		107		81
	Mayberry															34
	Emmaton			3		13		1		12		4				
	Sacramento	*1		1		1		*1		*1		1		1		1
	San Joaquin River Delta															
	Antioch	4		9		9		10		17		70		78		60
	Curtis Landing															38
	Jersey	*3		3		5		4		4		18		17		*20
	Webb Pump	3		2		4		5		3		14		4		5
	Central Landing	4		3		3		3		1		2		2		
	Holland Pump	*9		7		9		*7		*7		7		10		*9
	Mandeville Pump	*9		9				*12		*7		6		7		*6
	Rindge Pump	22		19		20		*21		*16		15		16		17
	East Contra Costa Irrigation Dist.					12		13		*10		13		11		
	Middle River P. O.	12		12		13		*12		*11		12		11		11
	Mansion House	*11		11		11		11		*10						*14
	Stockton	80		80				*102		*98				92		
	Mossdale Highway Bridge	*13		12		*13		*12		*10		11		*10		10
	Durham Ferry Bridge															

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1931

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Drainage Water in Delta Islands															
April (Continued)	Jersey Drain	*45		41		32		43		19		28		21		42
	Grand Island Drain, Steamboat Slough	7		6		6		5		4		4		5		5
	Camp 35, Staten Island Drain	18		16		12										
	McDonald Drain	18	*15		16	*17		16	*15		13	*14				
	Bacon Island Drain	9		8		11		*11		10		12		10		
	Mandeville Drain	*14		15				*13		*13		15		5		*14
	Camp 11, Staten Island Drain	21		36		36		33		32		47		43		34
	San Francisco, San Pablo and Suisun Bays															
May	Point Orient	1,540		1,610		1,600		1,520		1,640		1,640		1,670		*1,690
	Point Davis	*1,320		1,320		1,280		1,250		1,280		1,400		1,410		*1,490
	Bulls Head Point	*1,030		1,050		900		*870		*870		1,200		1,110		*1,210
	Bay Point	530		600		640		630		540		760		700		810
	O. and A. Ferry	350		360		*355		*405		*420		430		*560		* 600
	Innisfail Ferry	290		350		345		350		390		440		450		505
	Pittsburg[1]	80		130						160		160		210		
	North of San Pablo Bay															
	Grandview	1,260		1,200				1,270		1,365		1,450		1,460		*1,420
	Sonoma Creek Bridge											1,240		1,340		*1,380
	Vallejo	*930		950		940						1,020		1,020		
	Lakeville	1,070		1,090		1,100						1,180		1,200		1,230
	Cuttings Wharf	770		530		780		750		920		920		890		900
	Petaluma	830		890		860		960		970		1,040		970		1,070
	Sacramento River Delta															
	Collinsville			229		166		150		*290		280		255		285
	Mayberry	41		134		*95				*78		200		132		165
	Emmaton	3		5		5		6								
	Three Mile Slough Bridge			7		3		6		*5		14		*26		30
	Rio Vista Bridge			4		*1		*4		*3		3		*3		5
	Junction Point													5		5
	Liberty Ferry															

	Isleton Bridge												*4	*3		*5
	Walnut Grove															
	Sacramento					1		*1		*2		2		1		*2
	San Joaquin River Delta															
	Antioch	62		144		88		90		70		260		150		204
	Curtis Landing	34		78		*64				*100		124		92		137
	Jersey	9		38		6		12		15		95		44		43
	Webb Pump	4		8		*6		*6		7		10		11		15
	Central Landing, Bouldin Island	4		3		3		3		4		5		5		6
	Holland Pump	*7		*7		7		*8		*10		10		9		*8
	Mandeville Pump	*8		8				7		*7		6		7		*8
	Rindge Pump	*16		19		14		*18		*17		22		22		*21
	East Contra Costa Irrigation District			10		11		10		*10		9				11
	Middle River P. O.	11		11		9		*10		*8		7		8		11
	Mansion House			11		7		*9				11				*11
	Stockton Country Club															
	Stockton			106		*94		*96		*85		85		*85		
	Mossdale Highway Bridge	*9		8		7		10		*10		10		10		*12
	Durham Ferry Bridge	6		8		6			11			9		10		11
	Mokelumne River Delta															
	Southwest Point	*5		11		2		4				4				
	Camp 33, Staten Island	*2				4				*3		2				
	Camp 7, Staten Island			4				4						7		
	Tyler Island Ferry													*4		4
	Camp 11, Staten Island	*4		4				7						7		
	Camp 29, Staten Island	*2				1				*4		4				
	Eagle Tree			8				6						7		
	Camp 25, Staten Island	*5				4				*5		4				
	New Hope Bridge							*3		*9		*2		9		6
	Camp 20, Staten Island	*5				6				*8		5				
	Drainage Water in Delta Islands															
	Jersey Drain	3		43		40		19		14		28		16		26
	Grand Island Drain, Steamboat Slough		6		13		5		8		6		5		8	
	Camp 35, Staten Island Drain	*5		16			4	7		*7		4		6		
	McDonald Drain			12		15		11		13		9				
	Bacon Island Drain	9		7		10		*10		10		9		10		9
	Mandeville Drain	*15		15		14		14		*12		11		9		*9
	Camp 11, Staten Island Drain	19		25			*33	8		*9		14		9		
	San Francisco, San Pablo and Suisun Bays															
June	Point Orient	1,740		1,680		1,640		1,740		*1,710		1,720		1,740		*1,740
	Point Davis	*1,440				1,380		1,500		1,500		1,460		1,510		1,540
	Bulls Head Point	*1,210		1,080		1,080		*1,280		*1,300		1,200		*1,360		*1,360
	Bay Point	830		800		780		920		980		920		*1,160		1,000
	O. and A. Ferry	*700		760		*660		*680		*740		660		*749		680
	Innisfail Ferry	560		600		560		640		*740		700		710		780
	Pittsburg[1]	280				350				420				460		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1931

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	North of San Pablo Bay															
June (Continued)	Grandview	1,440				1,440				1,540				1,580		
	Sonoma Creek Bridge					1,440		*1,420						1,560		
	Vallejo					1,100				1,220						1,380
	Lakeville	1,340		1,340												
	Cuttings Wharf	990				960				980				980		
	Petaluma	1,140		1,080												
	Sacramento River Delta															
	Collinsville	285		380		340		580		470		460		460		600
	Mayberry			230												
	Emmaton	*87		88		*170		184		220		192		170		*275
	Three Mile Slough Bridge	31		45		*70		76		100		90		100		155
	Pio Vista Bridge	*6		5		*10		*34		*46		29			*75	*85
	Junction Point	5		3		5		7		6		8		9		14
	Liberty Ferry												5			6
	Isleton Bridge	*4		4		4		*10		*7		5		*12		*21
	Walnut Grove															
	Sacramento	*1		4		4		*7		*2		1		5		*6
	San Joaquin River Delta															
	Antioch	280		280		270		340		420		450		410		475
	Curtis Landing			155						*234		280		310		
	Jersey	*118		60		42		90		*248		160		155		260
	Webb Pump	20		15		26		36		*49		40		76		95
	Central Landing, Bouldin Island			7		7		8		12		13		13		24
	Holland Pump	*7		8		*8		*10			10	*14		12		*17
	Mandeville Pump	*9		9		9		*9		*11		12		15		*19
	King Island Pump									*12		*11				*14
	Rindge Pump	*20		19		17		*23		*17		20		19		19
	East Contra Costa Irrigation Dist.	*12		10		10		*13		*12		12				12
	Middle River P. O.	*11		9		9		10		*10		10		11		13
	Mansion House	*8				8				10				*11		*12
	Stockton Country Club					28		*26				30				
	Stockton	76				*62				*80		*80		*76		*76
	Mossdale Highway Bridge	*11		11		13		*9		*9		8		11		
	Durham Ferry Bridge	9		8		10		*11		9		9		10		8

	Mokelumne River Delta															
	Southwest Point	*6		3		5		8		14		10		7		20
	Camp 33, Staten Island	*5				4				5		7		6		10
	Camp 7, Staten Island			4				6		*5		*5		*6		*7
	Tyler Island Ferry	4		3		4		3		*5		*3		*6		8
	Camp 11, Staten Island								7	*6		*5		*8		*9
	Camp 29, Staten Island	*4				4				5		6		8		8
	Eagle Tree			8				8		*8		*8		*9		*8
	Camp 25, Staten Island	*6				5				6		6		9		9
	New Hope Bridge	*6		5		7		*6		*7		6		8		*7
	Camp 20, Staten Island	*8				7				6		7		8		10
	Drainage Water in Delta Islands															
	Jersey Drain	*27		17		30		29		*57		56		63		77
	Grand Island Drain, Steamboat Slough	7		6		7		13		*4		8		8		9
	Camp 35, Staten Island Drain	*7		9		8		9		6		*8		*10		*9
	McDonald Drain											12		13		14
	Bacon Island Drain	11		8		10		11		11		11		13		14
	Mandeville Drain	*9		10		9		*8		*11		12		17		*17
	Camp 11, Staten Island Drain	*8		7		4		7		7		*7		*9		*10
	San Francisco, San Pablo and Suisun Bays															
July	Point Orient			1,770		1,780		*1,780		1,770		1,820		1,830		*1,840
	Point Davis	*1,480		1,640		1,660		1,620		1,680		1,680		1,700		*1,740
	Bulls Head Point	*1,340		1,370		1,390		*1,500		1,380		1,480		*1,610		*1,570
	Bay Point															
	O. and A. Ferry	780		870		980		*1,080		1,020		1,070		*1,230		*1,230
	Innisfail Ferry			840		780		910		1,030		1,080		1,140		*1,230
	Pittsburg[1]	500				590				800				960		
	North of San Pablo Bay															
	Grandview	1,570				1,660				1,670				1,760		
	Sonoma Creek Bridge	1,590				1,660										
	Vallejo	1,320				1,420				*1,560						
	Cuttings Wharf	1,050				1,200								1,340		
	Sacramento River Delta															
	Collinsville	620		600		660		810		880		890		1,090		1,110
	Mayberry							660				770				
	Emmaton	280		365		470		490		560		630				
	Three Mile Slough Bridge	*210		250		290		430		430		500		560		655
	Rio Vista Bridge	*98		132		*196		*315		370		450		*520		*580
	Junction Point									260		280		370		399
	Liberty Ferry			24	*22			58				116				
	Isleton Bridge		*36	68		*83		*146		230		250		*360		*380
	Howard Ferry							98		170		190		245		*342
	Sutter Slough									58		83		135		*220
	Little Holland Ferry													*110		142
	Ryde					6		29		48		71		109		190
	Walnut Grove							*21		27		*76		81		*130
	Painters-ville Bridge							*25		20		*48		*92		*112
	Hood Ferry									6		8		18		15
	Freeport Ferry							*7		7		*8		*8		*7
	Sacramento			*6		6		*7		5		5		*7		*6

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1931

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Joaquin River Delta															
July (Continued)	Antioch	520		540		510		710		830		920		900		
	Curtis Landing	*440		440		425				640		660		*830		850
	Jersey	*365		325		270		430		600		500		*790		*780
	Webb Pump	102		146		168		245		310		*380		460		480
	Central Landing, Bouldin Island	28		35		40		60		104		122		180	265	260
	Ward Landing														140	167
	Holland Pump	*19		*22		24		*38		46		51		*80		*105
	McDonald Pump															
	Mandeville Pump	19		*19		29		*43		55		65		111		*140
	King Island Pump	*16		*17				24				*47				*74
	Rindge Pump	*18		22		22		*23		25		28		35		*49
	Orwood Bridge							*25		31				*61		*74
	East Contra Costa Irrigation District	*12		12		14		15		19		*21		31		*39
	Middle River P. O.	*13		15		*18		22		27		34		*57		*79
	Mansion House	*10		15		15		*24		26				25		*66
	Stockton Country Club	*22		24				*25	*26			29		9		*44
	Clifton Court Ferry							*16		18		19		*27		*34
	Stockton	*76		*82				*80				*88				
	Williams Bridge							*15		15		*16		*20		*30
	Whitehall															16
	Mossdale Highway Bridge	*8		12		11		*10		9		9				*11
	Durham Ferry Bridge	8		7		10		8				8		8		8
	Mokelumne River Delta															
	Southwest Point, Staten Island	18		26		22		73		114		*145	172	230	250	240
	Camp 33, Staten Island	9		9		13		33		47		*72	80	105	123	115
	Camp 7, Staten Island	*7		*8		*10			35	*40		*56	71	91	96	90
	Tyler Island Ferry			5		5		6				*24		31	58	92
	Camp 11, Staten Island	*8		*8		*10			23	25		*31	39	49	47	42
	Camp 29, Staten Island	8		9		11		19		31		*45	52	55	*66	65
	Eagle Tree	*9		*8		*7			11	11		*15	18	22	19	16
	Camp 25, Staten Island	7		8		11		14		21		*29	33	38	41	43
	New Hope Bridge	*7				8		*11		11		9	13	13	9	*6
	Camp 20, Staten Island	9		9		14		12		14		*19	22	26	27	*26

	Drainage Water in Delta Islands															
	Jersey Drain	*79		141		162		130		126		92		*177		*180
	Grand Island Drain, Steamboat Slough		8		*11		11		32		52				116	
	Camp 35, Staten Island Drain	*8		*11		*14		*23		28			*41		55	
	McDonald Drain	13		15		20		23		24		30		46		55
	Bacon Island Drain	15		18		21		29				47		75		83
	Mandeville Drain	*18		19		27		*36		44		63		83		*115
	Camp 11, Staten Island Drain	*8		*8		*12		*19		*24			*37		42	
	San Francisco, San Pablo and Suisun Bays															
August	Point Orient	1,820		1,810		1,860		*1,860		1,840		1,870		*1,840		1,820
	Point Davis	1,760		1,770		1,770		*1,810		1,690		1,780		1,810		1,740
	Bulls Head Point	1,660		1,610		*1,610		*1,570		1,600		1,640		*1,690		1,560
	Bay Point											1,440		1,540		1,450
	O. and A. Ferry	1,240		1,250		*1,320		*1,320		1,300		1,390		*1,380		1,360
	Innisfail Ferry	1,180		1,140		1,260				1,340		1,400		1,380		
	Pittsburg [1]	1,040				1,100				1,210		1,210		1,230		
	North of San Pablo Bay															
	Grandview	1,820				1,820				1,800				1,870		
	Sonoma Creek Bridge									1,800						
	Vallejo	1,620				1,660										
	Cuttings Wharf	1,680				1,700				1,570				1,750		
	Sacramento River Delta															
	Collinsville	1,140				1,190		1,120		1,180		1,230		1,240		1,190
	Mayberry					1,010										
	Emmaton	870		860		870		920		930		780		840		930
	Three Mile Slough Bridge	680		760		*760		*790		790		*670		840		780
	Rio Vista Bridge	540		650		*700		*660		710		680		*740		680
	Junction Point	440		470		520		570		550		590		615		600
	Liberty Ferry					345		385					490	520		*540
	Isleton Bridge	420		440		*510		*545				*595		*635		460
	Howard Ferry			380				*480		500		485				460
	Sutter Slough		*260			235		*320				225		*155		120
	Little Holland Ferry	198		230		235		220		300		225		*250		120
	Ryde	*280		*220		*230		*220		*160				150		80
	Walnut Grove	160		*180		*200		*220		120		*126		*120		38
	Paintersville Bridge	122		*144		*139		*110		63		*59		*28		11
	Hood Ferry	13		12		8		8		10		11		10		10
	Freeport Ferry	7		9		*10		*9		10		11		8		9
	Sacramento	8		8		*8			8	9		9		*10		7
	San Joaquin River Delta															
	Antioch	1,000				1,050		1,090		1,160		1,030		1,100		1,080
	Curtis Landing			770		920		*1,020		990		920		*1,060		
	Jersey	720				700										
	Webb Pump	460		505		520		600		540		600		670		560
	Central Landing, Bouldin Island	280	240	270	350	390	380	300		340	345	425	430	415		350
	Ward Landing	165				225		238		275		250		310		290
	Holland Pump	*116		74		*180		*180		200		240		*250		230

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1931

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Joaquin River Delta—Continued															
August (Continued)	McDonald Pump	155	145	140		170	235	240				201		280		260
	Mandeville Pump	158		190		220		*265		230		280		*320		300
	King Island Pump			*89		*102				150		*175				200
	Rindge Pump	70		72		86		*120		112		160		*146		170
	Orwood Bridge	82		*100		*123		*144		154		182		*215		200
	East Contra Costa Irrigation District	45		54		71		*105		102		116		*129	*134	134
	Middle River P. O.	92		86		130		*180				200		230		220
	Mansion House	77		76		*118		*130				140		*170		170
	Stockton Country Club	45		53		69						84		97		102
	Clifton Court Ferry	39		39		56	*67	*68		37		81		*94		80
	Stockton	89		*97								*106				104
	Williams Bridge	31		*43		*52		*58		68		84		*94		100
	Whitehall	18	16			*19		*21		24		29		*28		28
	Mossdale Highway Bridge	9		10		*10		*9		9		10		*9		*6
	Durham Ferry Bridge	7		8		8		8		9		9		7		6
	Mokelumne River Delta															
	Southwest Point, Staten Island	250	260	260	275	315	345	390	310	340		*405	380	390	320	330
	Camp 33, Staten Island	140	150	160	150	195	205	240	220	210		*215	220	245	210	200
	Camp 7, Staten Island	72	78	92	100	35	131	185	130	165		*180	200	185	190	140
	Tyler Island Ferry	100	130	155	160	175	235	*200	*190	200	*135	155	135	135		62
	Camp 11, Staten Island	30	29	31	34	16	63	68	46	58		*71	73	82	85	58
	Camp 29, Staten Island	72	82	88	90	93	96	115	104	122		*121	120	119	124	124
	Eagle Tree	10	9	7	8	3	6	6	3	2		*4	4	4	4	3
	Camp 25, Staten Island	44	52	56	62	56	65	68	72	73		*82	81	85	85	72
	New Hope Bridge	3	2	3	1	2	3	2	2	1		1	1	*1	1	2
	Camp 20, Staten Island	23	22	22	26	17	21	23	22	26		*21	22	26	12	18
	Drainage Water in Delta Islands															
	Jersey Drain	325		165		125										
	Grand Island Drain, Steamboat Slough	154	*160		*155		*180		*260		*240		*150		*130	
	Camp 35, Staten Island Drain	43					*66							85		80
	McDonald Drain	64		87		78										

	Bacon Island Drain	92		48		75		126		180		180		158		170
	Mandeville Drain	130		171		180		*210		240		215		*220		180
	Camp 11, Staten Island Drain	30					*54							58		10
September	**San Francisco, San Pablo and Suisun Bays**															
	Point Orient	1,800		1,820		*1,780		1,800		1,760		1,800				*1,790
	Point Davis											1,750				1,730
	Bulls Head Point	1,620		1,660		*1,580		1,620		1,640		1,600		1,500		1,550
	Bay Point	1,520		1,500		1,460		1,520		*1,440		1,440		1,420		1,440
	O. and A. Ferry	1,320		1,360		*1,360		1,320		1,320		*1,260		1,150		*1,190
	Innisfail Ferry	1,360		1,360		1,340		1,380		1,380		1,390		1,390		*1,390
	Pittsburg[1]	1,215				1,270				1,220				1,130		
	North of San Pablo Bay															
	Grandview	1,820				1,740				1,820				1,835		
	Sonoma Creek Bridge															
	Vallejo					1,680				1,700				1,640		
	Cuttings Wharf	1,600				1,780				1,800				1,740		
	Sacramento River Delta															
	Collinsville	1,220		1,200		1,180		1,260		1,120		960		1,070		920
	Mayberry															
	Emmaton	1,000		955				970				660		680	660	540
	Three Mile Slough Bridge	860		820		840		740		680		*600		585		410
	Rio Vista Bridge	740		700		*640		680		400		*545		520		
	Junction Point	620		600		430		600		310		440		435		
	Liberty Ferry	*560		*460		*400		540		280		350		315		200
	Isleton	560		480		*440		460		230				42		*198
	Howard Ferry	480		210		37		50		18		4				
	Sutter Slough	48				*12		7		5				*4		4
	Little Holland Ferry	90		*88				27		11		8		4		5
	Ryde	42		19		12		8		5		3		4		3
	Walnut Grove	28				*10		8						3		
	Paintersville Bridge	10		*10		*7		8		*4		*3		4		
	Hood Ferry	9		9		7				4		4		3		3
	Freeport Bridge					*7		6		*4		*3		3		
	Sacramento	8				5		5		4		*2		*3		3
	San Joaquin River Delta															
	Antioch	1,160		1,240		1,100		1,200		1,170		980		940		870
	Curtis Landing	1,060				910		1,040		1,060		930		860		760
	Jersey	800				800		910						690		
	Webb Pump	680		*640		*620		660		600		545		490		470
	Central Landing, Bouldin Island	310		320		250		212		180		295		178		110
	Ward Landing	320		330		330		350		320		320		310		325
	Holland Pump			250			270			*280		*290		*325		*282
	McDonald Pump	*270		*280		*246		*305		*270		*290		*290		*263
	Mandeville Pump	325		330		350		350		340		345		340		315
	King Island Pump											*261		230		235
	Rindge Pump	160		170		*180		174		198		188		196		187
	Orwood Bridge	230		230		*230		246		*250		*255		260		*253
	East Contra Costa Irrigation District	140		156		*150		160		174		180		*174		

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1931

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month: 2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
September (Continued)	**San Joaquin River Delta—Continued**															
	Middle River P. O.	210		240		250		240		262		255		*270		265
	Mansion House	190		190		210		210		200		220		220		235
	Stockton Country Club	*98		120				122		110		118				89
	Clifton Court Ferry	94		110		*100		128		130		130		130		
	Stockton			*132				132						114		
	Williams Bridge	118		*80		*80		96		60		*50		42		
	Whitehall	31		*23		*23		24		16		*16				12
	Mossdale Highway Bridge	8		7		*8		9		8		*7		*9		8
	Durham Ferry Bridge	7		6		7		7		6		6		6		6
	Mokelumne River Delta															
	Southwest Point, Staten Island	380	350	285	310	340	270	256		134		142		*105		70
	Camp 33, Staten Island	200	200	160	210	230	180	156		116		98		*80		60
	Camp 7, Staten Island	160	170	190	220	230	170	172		*130		*116		104		*99
	Tyler Island Ferry	36						8						3		3
	Camp 11, Staten Island	82	90	96	138	118	116	134		*76		*100		107		*91
	Camp 29, Staten Island	152	152	146	184	182	184	166		148		132		*116		94
	Eagle Tree	4	10	41	37	26	19	48		*15		*20		29		*33
	Camp 25, Staten Island	96	92	94	134	146	140	164		136		130		*133		123
	New Hope Bridge	1	1	1	5	6	6	23				20		*21		21
	Camp 20, Staten Island	31	44	49	68	79	83	117		91		98		*124		114
	Drainage Water in Delta Islands															
	Jersey Drain	70				70		72						74		
	Grand Island Drain, Steamboat Slough	124		130	36	140		130		86		98		58		61
	Camp 35, Staten Island Drain	30		9		17		16		13		13			91	109
	McDonald Drain															
	Bacon Island Drain	110	110			160		180		150		118		124		125
	Mandeville Drain	190		190		200		210		190		210		200		194
	Camp 11, Staten Island Drain	8		6		6		8		9		18		23		75

October	**San Francisco, San Pablo and Suisun Bays**															
	Point Orient	1,800		1,800		1,800		*1,795		1,780		1,770		1,765		1,760
	Point Davis			1,760		1,790		1,690		1,705		1,700		*1,665		1,550
	Bulls Head Point	1,615		1,600		1,550		1,510		1,485		1,475		1,390		1,455
	Bay Point	1,380		1,300		1,365		1,410		1,320		1,315		1,275		1,190
	O. and A. Ferry	1,100		1,095		1,120		*1,140		995		1,060		965		855
	Innisfail Ferry	1,380		1,335		1,300		1,290		1,230		1,210		1,240		1,010
	Pittsburg[1]	1,045				965				900			760			
	North of San Pablo Bay															
	Grandview	1,800				1,835				1,765				1,750		
	Sonoma Creek Bridge															
	Vallejo	1,620														
	Cuttings Wharf	1,790				1,800				1,745				1,760		
	Sacramento River Delta															
	Collinsville	950		880		880		830		710		725		800		560
	Mayberry															
	Emmaton	450						533		385		517		310		272
	Three Mile Slough Bridge	545		417		457		375		425		435		225		227
	Rio Vista Bridge	440		*350		365		*292				291		200		142
	Junction Point	360		200		265		*145		85		188		125		133
	Liberty Ferry		190		212	151		*156		111		120		75		68
	Isleton	238		*116		114		177		5		118		3		4
	Howard Ferry	9						2		2				2		2
	Sutter Slough	4		3		2										
	Little Holland Ferry	6		4				3		3				2		
	Ryde	3														
	Walnut Grove	3														
	Paintersville Bridge	3														
	Hood Ferry	4														
	Freeport Bridge	3														
	Sacramento	3		*2		*1		2		2		*1		*1		1
	San Joaquin River Delta															
	Antioch	945		820		875		785		760		725		690		610
	Curtis Landing			695		705		*635		660		660		*475		465
	Jersey			600						430		532		435		390
	Webb Pump	390		*430		405		400		332		327		292		260
	Central Landing, Bouldin Island	188				151		99		172		98		93		62
	Ward Landing	278		225		270		216		246		185		212		132
	Holland Pump			292		290		*283		*279		270		263		256
	McDonald Pump		*266		*269		*219		*197		*215		*201		*187	
	Mandeville Pump	320		311		304		230		283		276		287		255
	King Island Pump	220		216		224		230		*223		200		199		191
	Rindge Pump	172		187		183		*155		141		130		133		106
	Orwood Bridge	277		268		272			254	*259		244		235		232
	East Contra Costa Irrigation District	180		187		199		*189				200		197		
	Middle River P. O.	260		268		*268		229		257		253		*215		232
	Mansion House	236		240		237		*220				234		*195		
	Stockton Country Club	87			91	*89		80				49				
	Clifton Court Ferry	109		112		125		*66		103		69		61		21

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1931

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	San Joaquin River Delta—Continued															
October (Continued)	Stockton	130		*76		74				*84		89		73		51
	Williams Bridge	21		19		24		*11			11*	8		8		11
	Whitehall	11		12		8		*8		*8		8		8		9
	Mossdale Highway Bridge	8		8		8		*8		7		8		*8		9
	Durham Ferry Bridge	7	7		5		6		6			7		8		9
	Mokelumne River Delta															
	Southwest Point, Staten Island	76		111		90		*76		76		62		24		20
	Camp 33, Staten Island	61		70		66		*43		38		37		22		16
	Camp 7, Staten Island	*87		*91		*78		71		63		*59		*54		42
	Tyler Island Ferry	3		3		2		3		2		1		2		2
	Camp 11, Staten Island	*94		*86		*82		77		72		*69		*64		60
	Camp 29, Staten Island	87		74		75		*65		56		55		44		37
	Eagle Tree	*36		*39		*50		53		57		*56		*55		57
	Camp 25, Staten Island	116		100		92		*89		83		78		68		67
	New Hope Bridge	22		30		50		37						*64		45
	Camp 20, Staten Island	116		114		110		*104		102		96		91		89
	Drainage Water in Delta Islands															
	Jersey Drain			78						63		60		60		83
	Grand Island Drain, Steamboat Slough		*62		*63		*52		*19		*25				*13	
	Camp 35, Staten Island Drain	*119		*112		*99		93		80		91		*59		59
	McDonald Drain															
	Bacon Island Drain	133		191		190		204		255		247		206		182
	Mandeville Drain	195				196		187		188		186		191		187
	Camp 11, Staten Island Drain	*100		*102		*95		79		48		34		*58		45
	San Francisco, San Pablo and Suisun Bays															
November	Point Orient	1,755				1,785		1,761		1,735		1,780		1,720		1,770
	Point Davis			1,490		1,590		1,510		1,515		1,455		1,470		1,370
	Bulls Head Point	1,345		1,300		1,360		1,385		1,040		1,010		1,230		1,080
	Bay Point			1,095		*1,155		1,070		930		850		970		840
	O. and A. Ferry	825		740		780		815		595		655		640		610

Innisfail Ferry			1,030		945		935		985		1,015		870		720
Pittsburg[1]			670			580			590				410		
North of San Pablo Bay															
Grandview	1,775				1,740				1,650				1,690		
Sonoma Creek Bridge															
Vallejo															
Cuttings Wharf	1,640				1,585				1,500				1,470		
Sacramento River Delta															
Collinsville	520		510		590		525		455		380		255		282
Mayberry															
Emmaton			253		289		253		163		85		153		100
Three Mile Slough Bridge	270		*202		231		246		113		84		44		75
Rio Vista Bridge	153		128		132		128		28		32		19		11
Junction Point	68				76		30		13		7		4		4
Liberty Ferry	66		57		39		29		21		10		10		10
Isleton	3		18		37		4		2		1		4		1
Howard Ferry															
Sutter Slough															
Little Holland Ferry															
Ryde															
Walnut Grove															
Paintersville Bridge															
Hood Ferry															
Freeport Bridge															
Sacramento	2		1		*2		1		1		*2		2		2
San Joaquin River Delta															
Antioch	560		485		560		535		430		333		375		
Curtis Landing	430		465		390		430		365		*215		305		215
Jersey	360										*245				
Webb Pump	221		216		235		185		169		132		128		109
Central Landing, Bouldin Island	76		71		45		73		15		72		74		18
Ward Landing	201		146		163		139		154		148		136		132
Holland Pump	253		241		229		217								
McDonald Pump	190		171		175		149		152				*170		
Mandeville Pump	237		234		225		203		201		201				168
King Island Pump	172		151		*167		140		130		*143		123		114
Rindge Pump	76		106		107		84		82		88		74		57
Orwood Bridge	223		210		209		199		181			171	163		150
East Contra Costa Irrigation District	172		159		154		133				126		99		100
Middle River P. O.	221		*205		212		198		181		*172		168		153
Mansion House	170		185		184		188				114				120
Stockton Country Club											*25		26		
Clifton Court Ferry	12						15		28		18		13		11
Stockton			71		55		58		58				45		
Williams Bridge	20		11		14		11		11		9		11		7
Whitehall	9		9		10										
Mossdale Highway Bridge	11		10		10		9		8				8		10
Durham Ferry Bridge															

TABLE 33—Continued

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1931

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water														
		Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	
	Mokelumne River Delta															
November (Continued)	Southwest Point Staten Island	41		42		24		28		19		6		13		5
	Camp 33, Staten Island	14		14		9		10		11		9		6		6
	Camp 7, Staten Island	*38		*31		*30	*32			*27		*24		*23		*31
	Tyler Island Ferry															
	Camp 11, Staten Island	*59		*52		*49	*52			*45		*38		*41		*46
	Camp 29, Staten Island	28		21		19		20		17		17		12		21
	Eagle Tree	*60		*57		*57	*59			*56		*53		*53		*51
	Camp 25, Staten Island	52		55		44		42		37		40		33		40
	New Hope Bridge	48		48		48		48		47		52				32
	Camp 20, Staten Island	85		78		75		72		62		62		53		57
	Drainage Water in Delta Islands															
	Jersey Drain	68										*94				
	Grand Island Drain, Steamboat Slough	21		21		22		17				21		16		17
	Camp 35, Staten Island Drain	*54		*61		*53	*54			*51		50		*62		46
	McDonald Drain															
	Bacon Island Drain	175		168		160		96		111		96		68		63
	Mandeville Drain	184		180		180		176		176		172				165
	Camp 11, Staten Island Drain	*74		*62		*64	*59			*73		60		*51		48
	San Francisco, San Pablo and Suisun Bays															
December	Point Orient	*1,750		1,660		1,820		1,680		1,660		1,650		1,680		1,350
	Point Davis	1,390		1,400		1,500		1,320		1,310		1,415				385
	Bulls Head Point	1,020		1,220		1,235		975		965		1,235		1,020		95
	Bay Point	880		960				730		690		950				45
	O. and A. Ferry	500		480		460						635		20		*20
	Innisfail Ferry	820		*700		750		775		690		665		480		290
	Pittsburg[1]	385				320			340				290			155
	North of San Pablo Bay															
	Grandview	1,740				1,660				1,640				1,300		*400
	Sonoma Creek Bridge									1,385						
	Vallejo	*1,270				1,210									432	
	Cuttings Wharf	1,320				1,400				1,275				440		

Sacramento River Delta															
Collinsville	290	----	320	----	370	----	245	----	222	----	293	----	96	----	21
Mayberry	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Emmaton	110	----	----	----	164	----	68	----	49	----	88	----	10	----	4
Three Mile Slough Bridge	64	----	60	----	----	----	----	----	----	----	----	----	----	----	----
Rio Vista Bridge	22	----	18	----	19	----	5	----	3	----	3	----	1	----	2
Junction Point	5	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Liberty Ferry	----	----	8	----	----	----	----	----	----	----	----	----	----	----	----
Isleton	1	----	1	----	----	----	----	----	----	----	----	----	----	----	----
Howard Ferry	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Sutter Slough	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Little Holland Ferry	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Ryde	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Walnut Grove	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Paintersville Bridge	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Hood Ferry	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Freeport Bridge	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Sacramento	1	----	1	----	1	----	2	----	3	----	*1	----	1	----	1
San Joaquin River Delta															
Antioch	268	----	300	----	390	----	250	----	220	----	273	----	113	----	34
Curtis Landing	----	----	237	----	239	----	173	----	164	----	161	----	104	----	----
Jersey	150	----	----	----	----	----	98	----	----	----	134	----	82	----	----
Webb Pump	*102	----	94	----	92	----	91	----	76	----	66	----	57	----	----
Central Landing, Bouldin Island	20	----	34	----	34	----	31	----	56	----	26	----	11	----	13
Ward Landing	122	----	116	----	80	----	72	----	71	----	79	----	52	----	32
Holland Pump	177	----	150	----	137	----	123	----	99	----	96	----	86	----	58
McDonald Pump	84	*146	----	*140	----	*117	----	*104	----	*97	----	----	----	----	----
Mandeville Pump	165	----	150	----	144	----	134	----	129	----	116	----	97	----	61
King Island Pump	----	----	108	----	130	----	----	----	93	----	84	----	73	----	63
Rindge Pump	64	----	56	----	56	----	48	----	28	----	33	----	7	----	3
Orwood Bridge	130	----	128	----	119	----	*82	----	72	----	72	----	63	----	29
East Contra Costa Irrigation District	86	----	82	----	70	----	62	----	54	----	51	----	43	----	31
Middle River P. O.	145	----	*124	----	110	----	100	----	88	----	91	----	72	----	51
Mansion House	94	----	*98	----	99	----	98	----	128	----	53	----	13	----	16
Stockton Country Club	----	----	22	----	22	----	19	----	----	----	18	----	12	----	----
Clifton Court Ferry	9	----	10	----	12	----	9	----	10	----	9	----	8	----	9
Stockton	----	----	----	----	----	----	----	----	*47	----	38	----	40	----	----
Williams Bridge	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Whitehall	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Mossdale Highway Bridge	11	----	6	----	8	----	----	----	7	----	8	----	8	----	2
Durham Ferry Bridge	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

TABLE 33—Concluded

SALINITY OBSERVATIONS, SACRAMENTO-SAN JOAQUIN DELTA AND UPPER SAN FRANCISCO BAY, 1931

Samples taken in surface zone usually about one and one-half hours after high tide

Month	Station	Salinity in parts of chlorine per 100,000 parts of water — Day of month														
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	Mokelumne River Delta															
December (Continued)	Southwest Point Staten Island	21	--------	28	*63	--------	*11	--------	--------	16	--------	--------	--------	--------	--------	--------
	Camp 33, Staten Island	6	--------	4	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	Camp 7, Staten Island	*16	--------	*10	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	Tyler Island Ferry	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	Camp 11, Staten Island	*30	--------	*26	--------	21	--------	42	*8	--------	--------	--------	--------	--------	--------	--------
	Camp 29, Staten Island	11	--------	7	*6	--------	*12	--------	--------	11	--------	7	--------	--------	--------	--------
	Eagle Tree	*48	--------	*44	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	Camp 25, Staten Island	38	--------	24	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	New Hope Bridge	30	--------	--------	--------	44	--------	30	--------	32	--------	--------	--------	2	--------	--------
	Camp 20, Staten Island	51	--------	43	*39	--------	*44	--------	--------	44	--------	40	--------	--------	--------	--------
	Drainage Water in Delta Islands															
	Jersey Drain	77	--------	--------	--------	--------	--------	96	--------	--------	--------	90	--------	88	--------	--------
	Grand Island Drain, Steamboat Slough	--------	24	--------	18	--------	--------	--------	14	--------	--------	10	12	--------	15	--------
	Camp 35, Staten Island Drain	*43	--------	38	--------	46	--------	24	--------	48	--------	32	--------	--------	--------	--------
	McDonald Drain	*55	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	Bacon Island Drain	--------	--------	42	--------	33	--------	53	--------	60	--------	45	--------	50	--------	49
	Mandeville Drain	162	--------	160	--------	162	--------	155	--------	149	--------	143	--------	128	--------	114
	Camp 11, Staten Island Drain	--------	--------	56	--------	50	--------	29	--------	63	--------	--------	--------	--------	--------	--------

* Observation on next succeeding day.
[1] Mean weekly salinities from drip samples, by Great Western Electro Chemical Company.

TABLE 34

MISCELLANEOUS SALINITY OBSERVATIONS, PRIOR TO 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Southern Pacific Railroad Bridge, near Lathrop	Sept. 21-30, 1906	6	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Oct. 1-10, 1906	8	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Oct. 11-20, 1906	9	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Oct. 21-31, 1906	9	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Nov. 1-10, 1906	8	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Nov. 11-20, 1906	7	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Aug. 7-16, 1908	10	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Aug. 17-26, 1908	10	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Aug. 27 to Sept. 5, 1908	11	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Sept. 6-15, 1908	12	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Sept. 16-25, 1908	12	Not given	U. S. Geological Survey[1]
Southern Pacific Railroad Bridge, near Lathrop	Sept. 26 to Oct. 5, 1908	9	Not given	U. S. Geological Survey[1]
Pittsburg	July 25, 1910	40	High	Black Diamond Water Co.[2]
Pittsburg	July 27, 1910	25	⅔ high	Black Diamond Water Co.[2]
Pittsburg	Aug. 1, 1910	21	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 1, 1910	50	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 2, 1910	21	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 2, 1910	39	½ tide	Black Diamond Water Co.[2]
Pittsburg	Aug. 3, 1910	19	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 5, 1910	31	¾ high	Black Diamond Water Co.[2]
Pittsburg	Aug. 10, 1910	22	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 12, 1910	36	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 18, 1910	37	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 29, 1910	35	Low	Black Diamond Water Co.[2]
Pittsburg	Sept. 8, 1910	58	Low	Black Diamond Water Co.[2]
Pittsburg	Oct. 22, 1910	46	Low	Black Diamond Water Co.[2]
Pittsburg	Dec. 3, 1910	12	Low	Black Diamond Water Co.[2]
Pittsburg	Dec. 6, 1910	14	High	Black Diamond Water Co.[2]
Pittsburg	Dec. 9, 1910	5	High	Black Diamond Water Co.[2]
Pittsburg	Dec. 11, 1910	6	High	Black Diamond Water Co.[2]
Pittsburg	Dec. 27, 1910	6	½ tide	Black Diamond Water Co.[2]
Pittsburg	Jan. 18, 1911	3	High	Black Diamond Water Co.[2]
Pittsburg	Aug. 28, 1911	14	High	Black Diamond Water Co.[2]
Pittsburg	Sept. 5, 1911	7	Low	Black Diamond Water Co.[2]
Pittsburg	Sept. 8, 1911	26	High	Black Diamond Water Co.[2]
Pittsburg	Sept. 11, 1911	30	Low	Black Diamond Water Co.[2]
Pittsburg	Sept. 13, 1911	15	Low	Black Diamond Water Co.[2]
Pittsburg	Sept. 15, 1911	22	Low	Black Diamond Water Co.[2]
Pittsburg	Sept. 20, 1911	54	Low	Black Diamond Water Co.[2]
Pittsburg	Sept. 21, 1911	41	Low	Black Diamond Water Co.[2]
Pittsburg	Oct. 5, 1911	19	Low	Black Diamond Water Co.[2]
Pittsburg	Jan. 8, 1912	50	High	Black Diamond Water Co.[2]
Pittsburg	Feb. 2, 1912	4	High	Black Diamond Water Co.[2]
Pittsburg	April 25, 1912	2	High	Black Diamond Water Co.[2]
Pittsburg	May 30, 1912	3	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 31, 1912	18	Low	Black Diamond Water Co.[2]
Pittsburg	Sept. 12, 1912	18	Low	Black Diamond Water Co.[2]
Pittsburg	Sept. 17, 1912	38	½ high	Black Diamond Water Co.[2]
Pittsburg	Oct. 23, 1912	42	Low	Black Diamond Water Co.[2]
Pittsburg	Nov. 11, 1912	7	Low	Black Diamond Water Co.[2]
Pittsburg	July 16, 1913	14	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 6, 1913	48	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 13, 1913	31	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 19, 1913	52	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 26, 1913	67	Low	Black Diamond Water Co.[2]
Pittsburg	Aug. 27, 1913	55	Low	Black Diamond Water Co.[2]
Pittsburg	Oct. 25, 1913	84	Low	Black Diamond Water Co.[2]
Pittsburg	Oct. 27, 1913	106	Low	Black Diamond Water Co.[2]
Pittsburg	Nov. 6, 1913	95	Low	Black Diamond Water Co.[2]
Pittsburg	Nov. 11, 1913	102	¾ high	Black Diamond Water Co.[2]
Pittsburg	Nov. 17, 1913	134	High	Black Diamond Water Co.[2]
Pittsburg	Nov. 21, 1913	32	Low	Black Diamond Water Co.[2]

TABLE 34—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, PRIOR TO 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Pittsburg	Nov. 23, 1913	31	High	Black Diamond Water Co.[2]
Pittsburg	Nov. 25, 1913	102	High	Black Diamond Water Co.[2]
Pittsburg	Aug. 13, 1914	10	½ high	Black Diamond Water Co.[2]
Pittsburg	Aug. 31, 1914	34	½ high	Black Diamond Water Co.[2]
Pittsburg	Nov. 23, 1914	30	Low	Black Diamond Water Co.[2]
Pittsburg	Dec. 12, 1914	1	¾ low	Black Diamond Water Co.[2]
Pittsburg	Aug. 1, 1915	9	Not given	Black Diamond Water Co.[2]
Pittsburg	Nov. — 1915	49	High	Black Diamond Water Co.[2]
Pittsburg	Dec. 20, 1915	0	High	Black Diamond Water Co.[2]
Pittsburg	Sept. 23, 1916	44	Low	Black Diamond Water Co.[2]
Pittsburg	Sept. 26, 1916	48	Low	Black Diamond Water Co.[2]
Pittsburg	Oct. 7, 1916	27	Low	Black Diamond Water Co.[2]
Pittsburg	Oct. 9, 1916	32	Low	Black Diamond Water Co.[2]
Pittsburg	Oct. 12, 1916	24	Low	Black Diamond Water Co.[2]
Pittsburg	Oct. 13, 1916	23	Low	Black Diamond Water Co.[2]
Pittsburg	Oct. 16, 1916	13	Low	Black Diamond Water Co.[2]
Pittsburg	Oct. 7, 1916	59	High	State Water Commission[3]
Pittsburg	Oct. 8, 1916	70	High	State Water Commission[3]
Pittsburg	Oct. 9, 1916	70	High	State Water Commission[3]
Pittsburg	Oct. 10, 1916	23	Low	State Water Commission[3]
Pittsburg	Oct. 12, 1916	76	High	State Water Commission[3]
Pittsburg	Oct. 13, 1916	85	High	State Water Commission[3]
Pittsburg	Oct. 14, 1916	76	High	State Water Commission[3]
Pittsburg	Oct. 15, 1916	35	High	State Water Commission[3]
Pittsburg	Feb. 25, 1919	10	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	July 9, 1919	66	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	July 14, 1919	236	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Aug. 16, 1919	561	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Aug. 28, 1919	493	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Sept. 16, 1919	451	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Sept. 27, 1919	425	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Oct. 3, 1919	221	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Oct. 14, 1919	183	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Oct. 29, 1919	65	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Oct. 31, 1919	65	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Nov. 9, 1919	58	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Nov. 24, 1919	47	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Dec. 16, 1919	13	Not given	Great Western Electro Chemical Co.[4]
Pittsburg	Dec. 31, 1919	14	Not given	Great Western Electro Chemical Co.[4]
Sherman Island, opposite Toland's Landing	Sept. 26, 1913	3	High high	Haviland, Dozier & Tibbetts[5]
Antioch	Sept. 26, 1913	63	Low high	Haviland, Dozier & Tibbetts[5]
Dutch Slough	Sept. 27, 1913	4	Low high	Haviland, Dozier & Tibbetts[5]
False River	Sept. 26, 1913	3	Low high	Haviland, Dozier & Tibbetts[5]
Antioch	Sept. 20, 1913	112	Not given	Haviland, Dozier & Tibbetts[5]
Dutch Slough	Sept. 20, 1913	6	Not given	Haviland, Dozier & Tibbetts[5]
False River	Sept. 20, 1913	2	Not given	Haviland, Dozier & Tibbetts[5]
Toland's Landing	Sept. 20, 1913	1	Not given	Haviland, Dozier & Tibbetts[5]
Toland's Landing	Nov. 1, 1913	1	Not given	Haviland, Dozier & Tibbetts[5]
Suisun Wharf, Suisun	Jan. 4, 1916	71	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Jan. 6, 1916	70	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Jan. 11, 1916	37	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Jan. 13, 1916	36	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Jan. 15, 1916	22	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Jan. 31, 1916	39	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Feb. 2, 1916	34	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Feb. 7, 1916	32	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Feb. 9, 1916	34	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Feb. 15, 1916	39	Not given	Pacific Portland Cement Co.[6]

TABLE 34—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, PRIOR TO 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Suisun Wharf, Suisun	Feb. 21, 1916	52	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Mar. 1, 1916	48	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Mar. 6, 1916	48	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Mar. 8, 1916	49	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Mar. 11, 1916	48	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Mar. 21, 1916	64	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Mar. 23, 1916	72	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Mar. 28, 1916	64	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	Mar. 31, 1916	62	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	April 3, 1916	71	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	April 5, 1916	72	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	April 7, 1916	69	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	April 22, 1916	74	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	April 24, 1916	65	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	May 1, 1916	64	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	May 3, 1916	64	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	May 5, 1916	67	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	May 8, 1916	68	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	May 12, 1916	76	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	June 2, 1916	52	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	June 5, 1916	61	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	June 7, 1916	52	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	June 12, 1916	47	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	June 16, 1916	99	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	June 30, 1916	111	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	July 3, 1916	111	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	July 5, 1916	112	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	July 11, 1916	127	Not given	Pacific Portland Cement Co.[6]
Suisun Wharf, Suisun	July 31, 1916	106	Not given	Pacific Portland Cement Co.[6]
Montezuma Slough, lower end	Oct. 8, 1916	350	High	State Water Commission[3]
Montezuma Slough, lower end	Oct. 9, 1916	330	High	State Water Commission[3]
Montezuma Slough, lower end	Oct. 10, 1916	390	High	State Water Commission[3]
Montezuma Slough, lower end	Oct 11, 1916	390	High	State Water Commission[3]
Montezuma Slough, lower end	Oct. 12, 1916	330	High	State Water Commission[3]
Montezuma Slough, lower end	Oct. 13, 1916	310	High	State Water Commission[3]
Montezuma Slough, lower end	Oct. 14, 1916	420	High	State Water Commission[3]
Montezuma Slough, lower end	Oct. 15, 1916	310	High	State Water Commission[3]
Montezuma Slough, upper end	Oct. 7, 1916	16	Low	State Water Commission[3]
Montezuma Slough, upper end	Oct. 8, 1916	12	High	State Water Commission[3]
Montezuma Slough, upper end	Oct. 9, 1916	13	High	State Water Commission[3]
Montezuma Slough, upper end	Oct. 10, 1916	11	High	State Water Commission[3]
Montezuma Slough, upper end	Oct. 11, 1916	9	High	State Water Commission[3]
Montezuma Slough, upper end	Oct. 12, 1916	9	High	State Water Commission[3]
Montezuma Slough, upper end	Oct. 13, 1916	22	High	State Water Commission[3]
Montezuma Slough, upper end	Oct. 14, 1916	12	Low	State Water Commission[3]
Montezuma Slough, upper end	Oct. 15, 1916	10	High	State Water Commission[3]
Bay Point	Oct. 9, 1916	340	High	State Water Commission[3]
Bay Point	Oct. 10, 1916	350	High	State Water Commission[3]
Bay Point	Oct. 11, 1916	400	High	State Water Commission[3]
Bay Point	Oct. 12, 1916	330	High	State Water Commission[3]
Bay Point	Oct. 13, 1916	270	Low	State Water Commission[3]
Bay Point	Oct. 14, 1916	330	High	State Water Commission[3]
Collinsville	Sept. 13, 1919	143	High	State Water Commission[3]
Collinsville	Sept. 14, 1919	161	High	State Water Commission[3]

TABLE 34—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, PRIOR TO 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Collinsville	Sept. 15, 1919	184	High	State Water Commission[3]
Collinsville	Sept. 16, 1919	246	High	State Water Commission[3]
Collinsville	Sept. 17, 1919	240	High	State Water Commission[3]
Collinsville	Sept. 18, 1919	176	High	State Water Commission[3]
Collinsville	Sept. 19, 1919	122	High	State Water Commission[3]
Emmaton	Sept. 14, 1919	51	High	State Water Commission[3]
Emmaton	Sept. 15, 1919	53	High	State Water Commission[3]
Emmaton	Sept. 16, 1919	55	High	State Water Commission[3]
Emmaton	Sept. 17, 1919	53	High	State Water Commission[3]
Emmaton	Sept. 18, 1919	41	High	State Water Commission[3]
Emmaton	Sept. 19, 1919	47	High	State Water Commission[3]
Emmaton	Sept. 24, 1919	47	Not given	Stephen E. Kieffer[4]
Emmaton	Sept. 28, 1919	33	Not given	Stephen E. Kieffer[4]
Emmaton	Oct. 2, 1919	14	Not given	Stephen E. Kieffer[4]
Emmaton	Oct. 7, 1919	7	Not given	Stephen E. Kieffer[4]
Rio Vista	Sept. 13, 1919	12	High	State Water Commission[3]
Rio Vista	Sept. 15, 1919	12	High	State Water Commission[3]
Rio Vista	Sept. 16, 1919	12	High	State Water Commission[3]
Rio Vista	Sept. 17, 1919	12	High	State Water Commission[3]
Rio Vista	Sept. 18, 1919	12	High	State Water Commission[3]
Rio Vista	Sept. 19, 1919	12	High	State Water Commission[3]
Antioch	May 31, 1916	1	Not given	City of Antioch[4]
Antioch	July 5, 1916	1	Not given	City of Antioch[4]
Antioch	July 11, 1916	1	Not given	City of Antioch[4]
Antioch	July 31, 1916	1	Not given	City of Antioch[4]
Antioch	Aug. 5, 1916	2	Not given	City of Antioch[4]
Antioch	Aug. 9, 1916	1	Not given	City of Antioch[4]
Antioch	Sept. 19, 1916	6	Not given	City of Antioch[4]
Antioch	Oct. 20, 1916	4	Not given	City of Antioch[4]
Antioch	Nov. 28, 1916	3	Not given	City of Antioch[4]
Antioch	Feb. 2, 1917	3	Not given	City of Antioch[4]
Antioch	Sept. 4, 1917	9	Not given	City of Antioch[4]
Antioch	Oct. 9, 1917	20	Not given	City of Antioch[4]
Antioch	Jan. 23, 1918	7	Not given	City of Antioch[4]
Antioch	Feb. 20, 1918	3	Not given	City of Antioch[4]
Antioch	Mar. 19, 1918	4	Not given	City of Antioch[4]
Antioch	May 16, 1918	1	Not given	City of Antioch[4]
Antioch	June 19, 1918	2	Not given	City of Antioch[4]
Antioch	Aug. 6, 1918	80	Not given	City of Antioch[4]
Antioch	Aug. 20, 1918	158	Not given	City of Antioch[4]
Antioch	Sept. 25, 1918	82	Not given	City of Antioch[4]
Antioch	Oct. 25, 1918	7	Not given	City of Antioch[4]
Antioch	Nov. 6, 1918	8	Not given	City of Antioch[4]
Antioch	Dec. 9, 1918	4	Not given	City of Antioch[4]
Antioch	Oct. 3, 1917	20	Not given	State Board of Health[4]
Antioch	July 25, 1918	86	Not given	State Board of Health[4]
Antioch	Aug. 13, 1918	180	Not given	State Board of Health[4]
Antioch	Sept. 23, 1918	95	Not given	State Board of Health[4]
Antioch	July 15, 1919	93	Not given	State Board of Health[4]
Antioch	July 28, 1919	72	Not given	State Board of Health[4]
Antioch	Aug. 12, 1919	72	Not given	State Board of Health[5]
Antioch	Sept. 14, 1919	105	High	State Water Commission[3]
Antioch	Sept. 15, 1919	96	High	State Water Commission[3]
Antioch	Sept. 16, 1919	96	High	State Water Commission[3]
Antioch	Sept. 17, 1919	95	High	State Water Commission[3]
Antioch	Sept. 18, 1919	87	High	State Water Commission[3]
Antioch	Sept. 19, 1919	95	High	State Water Commission[3]
Jersey	Sept. 13, 1919	63	High	State Water Commission[3]
Jersey	Sept. 14, 1919	58	High	State Water Commission[3]
Jersey	Sept. 15, 1919	52	High	State Water Commission[3]
Jersey	Sept. 16, 1919	55	High	State Water Commission[3]
Jersey	Sept. 17, 1919	55	High	State Water Commission[3]
Jersey	Sept. 18, 1919	47	High	State Water Commission[3]
Curtis Landing	Sept. 24, 1919	188	Not given	Stephen E. Kieffer[4]
Curtis Landing	Sept. 28, 1919	152	Not given	Stephen E. Kieffer[4]
Curtis Landing	Oct. 3, 1919	43	Not given	Stephen E. Kieffer[4]
Curtis Landing	Oct. 7, 1919	30	Not given	Stephen E. Kieffer[4]
Blylock Landing	Sept. 13, 1919	36	Low	State Water Commission[3]
Blylock Landing	Sept. 14, 1919	35	High	State Water Commission[3]
Blylock Landing	Sept. 15, 1919	37	High	State Water Commission[3]

TABLE 34—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, PRIOR TO 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Blylock Landing	Sept. 16, 1919	39	High	State Water Commission[3]
Blylock Landing	Sept. 17, 1919	36	High	State Water Commission[3]
Blylock Landing	Sept. 18, 1919	35	High	State Water Commission[3]
Blylock Landing	Sept. 19, 1919	34	High	State Water Commission[3]
Central Landing	Sept. 13, 1919	18	High	State Water Commission[3]
Central Landing	Sept. 14, 1919	24	High	State Water Commission[3]
Central Landing	Sept. 15, 1919	19	Low	State Water Commission[3]
East Contra Costa Irrigation Company Pump	Nov. 5, 1919	23	High	East Contra Costa Irrigation Company[7]
East Contra Costa Irrigation Company Pump	Nov. 6, 1919	23	Low	East Contra Costa Irrigation Company[7]
East Contra Costa Irrigation Company Pump	Nov. 24, 1919	24	Not given	East Contra Costa Irrigation Company[7]
East Contra Costa Irrigation Company Pump	Nov. 25, 1919	24	Not given	East Contra Costa Irrigation Company[7]
East Contra Costa Irrigation Company Pump	Dec. 1, 1919	24	Not given	East Contra Costa Irrigation Company[7]
East Contra Costa Irrigation Company Pump	Dec. 4, 1919	23	Not given	East Contra Costa Irrigation Company[7]
East Contra Costa Irrigation Company Pump	Dec. 6, 1919	24	Not given	East Contra Costa Irrigation Company[7]
East Contra Costa Irrigation Company Pump	Dec. 11, 1919	24	Not given	East Contra Costa Irrigation Company[7]
East Contra Costa Irrigation Company Pump	Dec. 15, 1919	24	Not given	East Contra Costa Irrigation Company[7]
East Contra Costa Irrigation Company Pump	Dec. 19, 1919	24	Not given	East Contra Costa Irrigation Company[7]
East Contra Costa Irrigation Company Pump	Dec. 26, 1919	23	Not given	East Contra Costa Irrigation Company[7]
Antioch	Oct. 28, 1919	41	High	California Hawaiian Sugar Co[8] (Capt. S. A. Johnson)
East Point of West Island	Oct. 28, 1919	15	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Dutch Slough, west entrance	Oct. 28, 1919	12	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
False River, west entrance	Oct. 28, 1919	12	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Three Mile Slough, San Joaquin end	Oct. 28, 1919	4	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
San Joaquin River, opposite Three Mile Slough	Oct. 28, 1919	8	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Oultens' Landing	Oct. 28, 1919	12	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Seven Mile Slough	Oct. 28, 1919	12	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
San Joaquin River, opposite Seven Mile Slough	Oct. 28, 1919	12	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Mouth of Mokelumne River	Oct. 28, 1919	10	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
San Joaquin River, opposite Mokelumne River	Oct. 28, 1919	12	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
San Joaquin River, opposite Old River	Oct. 28, 1919	12	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Old River mouth	Oct. 28, 1919	12	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)

TABLE 34—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, PRIOR TO 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Washington Slough, or False River, east entrance	Oct. 28, 1919	14	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Sand Mound Slough, Casa Rio Landing	Oct. 28, 1919	17	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
East entrance of Rock Slough	Oct. 28, 1919	18	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Orwood	Oct. 28, 1919	12	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
East entrance Indian Slough	Oct. 28, 1919	14	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
West end of Indian Slough	Oct. 28, 1919	14	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
One-half mile from west end of Indian Slough	Oct. 28, 1919	15	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Werner's Bridge	Oct. 28, 1919	15	First of flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Werner's Landing	Oct. 28, 1919	17	Mid-flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Werner's Landing	Oct. 28, 1919	18	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
West end Indian Slough	Oct. 29, 1919	14	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
One-half mile from west end of Indian Slough	Oct. 29, 1919	15	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
West end of Indian Slough	Oct. 29, 1919	14	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Indian Slough	Oct. 29, 1919	14	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction Rock and Indian sloughs	Oct. 29, 1919	20	First of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Sand Mound and Dutch sloughs	Oct. 29, 1919	21	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction Rock and Dutch sloughs	Oct. 29, 1919	20	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction Taylor and Dutch sloughs	Oct. 29, 1919	21	Ebbing	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
West entrance Dutch Slough	Oct. 29, 1919	15	Last of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Antioch	Nov. 5, 1919	14	Last of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
East Point of West Island	Nov. 5, 1919	8	Last of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
West entrance Dutch Slough	Nov. 5, 1919	16	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
West entrance of False River	Nov. 5, 1919	11	First of flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
San Joaquin end of Three Mile Slough	Nov. 5, 1919	8	First of flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
San Joaquin River opposite Three Mile Slough	Nov. 5, 1919	10	First of flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Oulton's Landing	Nov. 5, 1919	10	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Seven Mile Slough	Nov. 5, 1919	8	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
San Joaquin River opposite Seven Mile Slough	Nov. 5, 1919	10	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Mouth of Mokelumne River	Nov. 5, 1919	3	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
San Joaquin River opposite Mokelumne River	Nov. 5, 1919	11	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Old River	Nov. 5, 1919	13	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)

TABLE 34—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, PRIOR TO 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Mouth of Old River	Nov. 5, 1919	12	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
East entrance of False River	Nov. 5, 1919	12	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Sand Mound Slough at Casa Rio Landing	Nov. 5, 1919	17	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
East entrance of Rock Slough	Nov. 5, 1919	17	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Orwood	Nov. 5, 1919	14	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
East entrance Indian Slough	Nov. 5, 1919	13	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Werner's Landing	Nov. 5, 1919	17	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Dam at Intake of East Contra Costa Irrigation Co. Canal	Nov. 5, 1919	14	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
One-half mile from west end of Indian Slough	Nov. 5, 1919	14	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
East Contra Costa Irrigation Co. Pump	Nov. 6, 1919	14	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Dam at Intake of East Contra Costa Irrigation Co. Canal	Nov. 6, 1919	14	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
West end of Indian Slough	Nov. 6, 1919	15	Not given	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
East end of Indian Slough	Nov. 6, 1919	13	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Canal between Old and Middle rivers	Nov. 6, 1919	14	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Old River and Italian Slough	Nov. 6, 1919	10	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Old River at Herdlyn	Nov. 6, 1919	9	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Bethany Ferry on Old River	Nov. 6, 1919	9	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Naglee School on Old River	Nov. 6, 1919	9	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Whitehall, on Tom Payne Slough	Nov. 6, 1919	8	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
East entrance of Grant Line Canal	Nov. 6, 1919	8	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Middle River and Woodward Canal	Nov. 7, 1919	15	Low	California Hawaiian Sugar Co.[8] (Capt. S. A .Johnson)
Junction of Middle River and Victoria Canal	Nov. 7, 1919	11	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Middle River Bridge	Nov. 7, 1919	8	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Middle River 1½ miles south from Bridge	Nov. 7, 1919	8	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Rock and Indian sloughs	Nov. 7, 1919	17	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Rock and Dutch sloughs	Nov. 7, 1919	17	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Sand Mound and Dutch sloughs	Nov. 7, 1919	16	First of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Taylor and Dutch sloughs	Nov. 7, 1919	15	First of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Rio Vista	Nov. 11, 1919	2	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)

TABLE 34—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, PRIOR TO 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Newtown	Nov. 11, 1919	2	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Sacramento River and Cache Slough	Nov. 11, 1919	1	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Miner Slough	Nov. 11, 1919	2	First of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Prospect Slough	Nov. 11, 1919	2	First of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Lindsey Slough	Nov. 11, 1919	2	First of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Solano Irrigated Farms Canal	Nov. 11, 1919	6	Middle of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
End of Solano Irrigated Farms Canal	Nov. 11, 1919	8	Low	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Halfway up Lindsey Slough	Nov. 11, 1919	5	First of flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
One-half mile up Lindsey Slough	Nov. 11, 1919	3	First of flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Two miles up Hass Slough	Nov. 11, 1919	4	First of flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Hass Slough and Alamo Creek	Nov. 11, 1919	5	First of flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Main Prairie	Nov. 11, 1919	6	Middle of flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Steamboat and Cache sloughs	Nov. 12, 1919	2	First of flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Three Mile Slough and Seven Mile Slough	Nov. 13, 1919	2	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Sacramento River, end of Three Mile Slough	Nov. 13, 1919	2	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Emmaton Landing	Nov. 13, 1919	3	First of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Perley's Landing	Nov. 13, 1919	7	First of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Williams Landing	Nov. 13, 1919	28	Ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Rio Vista	Dec. 3, 1919	2	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction Point	Dec. 3, 1919	2	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Cache and Lindsey sloughs	Dec. 3, 1919	2	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
One mile up Lindsey Slough	Dec. 3, 1919	2	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Two miles up Lindsey Slough	Dec. 3, 1919	3	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Three miles up Lindsey Slough	Dec. 3, 1919	5	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Four miles up Lindsey Slough	Dec. 3, 1919	5	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Entrance of Solano Irrigated Farms Canal	Dec. 3, 1919	6	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Intake of Solano Irrigated Farms Canal	Dec. 3, 1919	6	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Hass Slough and Alamo Creek	Dec. 3, 1919	5	First of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Entrance to Steamboat Slough	Dec. 4, 1919	2	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)

TABLE 34—Concluded

MISCELLANEOUS SALINITY OBSERVATIONS, PRIOR TO 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Entrance to Miner Slough	Dec. 4, 1919	2	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Entrance to Prospect Slough	Dec. 4, 1919	2	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Entrance to Egbert Cut	Dec. 4, 1919	2	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Entrance to Duck Slough	Dec. 4, 1919	1	Flood	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Head of Netherlands Canal	Dec. 4, 1919	1	High	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Halfway up Netherlands Canal	Dec. 4, 1919	1	First of ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)
Junction of Netherlands Canal and Dutch Slough	Dec. 4, 1919	1	Ebb	California Hawaiian Sugar Co.[8] (Capt. S. A. Johnson)

[1] From Water Supply Paper Number 237, pages 46 and 47.

[2] From records on file in office of State Division of Water Resources, furnished by Black Diamond Water Company of Pittsburg in 1916.

[3] From data on file in office of State Division of Water Resources. Values of salinity approximate, having been determined by the electrolytic method.

[4] From records in Volumes II and III of transcript of "Antioch" suit.

[5] From report on Richmond Municipal Water District, by Haviland, Dozier and Tibbetts, 1913.

[6] From data furnished by Thomas H. Means, Consulting Engineer.

[7] From records on file in office of Division of Water Resources of salinity observations at pumping plant of East Contra Costa Irrigation Company (now East Contra Costa Irrigation District) near west end of Indian Slough in San Joaquin River Delta. See Tables 33 and 35 for records in 1920 and subsequent thereto.

[8] From records on file in office of Division of Water Resources, furnished by California and Hawaiian Sugar Refining Corporation.

TABLE 35

MISCELLANEOUS SALINITY OBSERVATIONS, AFTER 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Dumbarton Bridge	July 19, 1923	1,730	High-Low	San Francisco Bay Marine Piling Committee[1]
Dumbarton Bridge	July 20, 1923	1,700	Low-Low	San Francisco Bay Marine Piling Committee[1]
Dumbarton Bridge	July 26, 1923	1,710	High-Low	San Francisco Bay Marine Piling Committee[1]
Dumbarton Bridge	July 27, 1923	1,760	Low-Low	San Francisco Bay Marine Piling Committee[1]
Oakland Mole	July 10, 1923	1,590	High-Low	San Francisco Bay Marine Piling Committee[1]
Oakland Mole	July 11, 1923	1,590	Low-Low	San Francisco Bay Marine Piling Committee[1]
Oakland Mole	July 16, 1923	1,620	High-Low	San Francisco Bay Marine Piling Committee[1]
Oakland Mole	July 17, 1923	1,620	Low-Low	San Francisco Bay Marine Piling Committee[1]
Oakland Mole	July 23, 1923	1,730	High-Low	San Francisco Bay Marine Piling Committee[1]
Oakland Mole	July 24, 1923	1,670	Low-Low	San Francisco Bay Marine Piling Committee[1]
San Francisco (Ferry Bldg.)	July 11, 1923	1,740	High-High	San Francisco Bay Marine Piling Committee[1]
San Francisco (Ferry Bldg.)	July 12, 1923	1,640	Low-Low	San Francisco Bay Marine Piling Committee[1]
San Francisco (Ferry Bldg.)	July 17, 1923	1,780	High-Low	San Francisco Bay Marine Piling Committee[1]
San Francisco (Ferry Bldg.)	July 18, 1923	1,790	Low-High	San Francisco Bay Marine Piling Committee[1]
San Francisco (Ferry Bldg.)	July 24, 1923	1,810	High-High	San Francisco Bay Marine Piling Committee[1]
San Francisco (Ferry Bldg.)	July 25, 1923	1,720	Low-Low	San Francisco Bay Marine Piling Committee[1]
Fort Scott (Golden Gate)	July 12, 1923	1,850	High-High	San Francisco Bay Marine Piling Committee[1]
Fort Scott (Golden Gate)	July 13, 1923	1,780	Low-Low	San Francisco Bay Marine Piling Committee[1]
Fort Scott (Golden Gate)	July 18, 1923	1,880	High-High	San Francisco Bay Marine Piling Committee[1]
Fort Scott (Golden Gate)	July 19, 1923	1,910	Low-High	San Francisco Bay Marine Piling Committee[1]
Fort Scott (Golden Gate)	July 25, 1923	1,930	High-High	San Francisco Bay Marine Piling Committee[1]
Fort Scott (Golden Gate)	July 26, 1923	1,850	Low-Low	San Francisco Bay Marine Piling Committee[1]
Point San Pablo Site	Feb. 3, 1925	425	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	Mar. 12, 1925	905	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	April 16, 1925	805	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	May 16, 1925	950	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	June 15, 1925	1,135	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	July 7, 1925	1,315	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	Sept. 2, 1925	1,615	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	Oct. 16, 1925	1,580	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	Nov. 17, 1925	1,530	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	Dec. 17, 1925	1,510	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	Jan. 15, 1926	1,510	-	U. S. Bureau of Reclamation[2]
Point San Pablo Site	Feb. 12, 1926	860	-	U. S. Bureau of Reclamation[2]
15,500 feet south of Mare Island Strait Bascule Bridge	Jan. 14, 1923	630	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	Feb. 16, 1923	430	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	Mar. 16, 1923	450	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	April 18, 1923	330	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	May 16, 1923	270	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	July 16, 1923	790	High	U. S. Navy Yard[3]

TABLE 35—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, AFTER 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
15,500 feet south of Mare Island Strait Bascule Bridge	Sept. 28, 1923	1,260	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	Oct. 28, 1923	1,180	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	Nov. 18, 1923	1,350	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	Dec. 16, 1923	1,190	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	Jan. 30, 1924	1,060	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	May 18, 1924	1,070	High	U. S. Navy Yard[3]
15,500 feet south of Mare Island Strait Bascule Bridge	June 28, 1924	1,430	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	Jan. 14, 1923	550	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	Feb. 16, 1923	380	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	Mar. 16, 1923	460	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	April 18, 1923	280	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	May 16, 1923	250	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	July 16, 1923	630	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	Sept. 28, 1923	1,190	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	Oct. 28, 1923	1,060	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	Nov. 18, 1923	1,250	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	Dec. 16, 1923	1,110	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	Jan. 30, 1924	970	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	May 18, 1924	1,040	High	U. S. Navy Yard[3]
Mare Island Strait Bascule Bridge	June 28, 1924	1,250	High	U. S. Navy Yard[3]
Army Point Site	Feb. 5, 1924	525		Mountain Copper Co.[4]
Army Point Site	Feb. 13, 1924	325		Mountain Copper Co.[4]
Army Point Site	Feb. 22, 1924	325		Mountain Copper Co.[4]
Army Point Site	Mar. 1, 1924	375		Mountain Copper Co.[4]
Army Point Site	Mar. 11, 1924	425		Mountain Copper Co.[4]
Army Point Site	Mar. 28, 1924	650		Mountain Copper Co.[4]
Army Point Site	April 8, 1924	660		Mountain Copper Co.[4]
Army Point Site	April 15, 1924	385		Mountain Copper Co.[4]
Army Point Site	April 22, 1924	640		Mountain Copper Co.[4]
Army Point Site	April 30, 1924	565		Mountain Copper Co.[4]
Army Point Site	Jan. 1, 1925	325		Mountain Copper Co.[4]
Army Point Site	Jan. 11, 1925	385		Mountain Copper Co.[4]
Army Point Site	Jan. 18, 1925	375		Mountain Copper Co.[4]
Army Point Site	Jan. 26, 1925	510		Mountain Copper Co.[4]
Army Point Site	Feb. 1, 1925	335		Mountain Copper Co.[4]
Army Point Site	Feb. 10, 1925	15		Mountain Copper Co.[4]
Army Point Site	Feb. 21, 1925	45		Mountain Copper Co.[4]
Army Point Site	Feb. 25, 1925	10		Mountain Copper Co.[4]
Army Point Site	Mar. 3, 1925	225		Mountain Copper Co.[4]
Army Point Site	Mar. 12, 1925	125		Mountain Copper Co.[4]
Army Point Site	Mar. 18, 1925	165		Mountain Copper Co.[4]
Army Point Site	Mar. 26, 1925	120		Mountain Copper Co.[4]
Army Point Site	April 2, 1925	238		Mountain Copper Co.[4]
Army Point Site	April 9, 1925	82		Mountain Copper Co.[4]
Army Point Site	April 16, 1925	55		Mountain Copper Co.[4]
Army Point Site	April 24, 1925	30		Mountain Copper Co.[4]
Army Point Site	April 30, 1925	115		Mountain Copper Co.[4]

TABLE 35—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, AFTER 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
East Contra Costa Irrigation Company pump	Jan. 4, 1920	21		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Jan. 12, 1920	22		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Jan. 22, 1920	20		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Jan. 29, 1920	20		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Jan. 31, 1920	19		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Feb. 9, 1920	17		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Feb. 12, 1920	18		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Feb. 14, 1920	16		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Feb. 17, 1920	14		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Feb. 19, 1920	13		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Feb. 21, 1920	14		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Feb. 23, 1920	14		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Feb. 25, 1920	14		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Feb. 28, 1920	15		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 4, 1920	15		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 6, 1920	15		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 8, 1920	15		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 11, 1920	14		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 13, 1920	13		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 15, 1920	13		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 17, 1920	13		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 24, 1920	9		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 25, 1920	9		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 27, 1920	7		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Mar. 29, 1920	5		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	April 1, 1920	4		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	April 5, 1920	3		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	April 7, 1920	3		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	April 10, 1920	2		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	April 15, 1920	3		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	April 19, 1920	4		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	April 22, 1920	4		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	April 24, 1920	5		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	April 26, 1920	5		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	April 29, 1920	4		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	May 3, 1920	3		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	May 5, 1920	3		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	May 8, 1920	4		East Contra Costa Irrig. Co.[5]

TABLE 35—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, AFTER 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
East Contra Costa Irrigation Company pump	May 10, 1920	4		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	May 13, 1929	3		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	May 17, 1920	2		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	May 19, 1920	2		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	May 21, 1920	2		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	May 26, 1929	1		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	May 27, 1920	2		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	May 29, 1920	1		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Jan. 3, 1921	10		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Jan. 6, 1921	10		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Jan. 11, 1921	11		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Jan. 20, 1921	8		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Jan. 27, 1921	7		East Contra Costa Irrig. Co.[5]
East Contra Costa Irrigation Company pump	Feb. 2, 1921	7		East Contra Costa Irrig. Co.[5]
Nicholls	May 17, 1920	7		General Chemical Company[6]
Nicholls	May 25, 1920	2		General Chemical Company[6]
Nicholls	May 31, 1920	2	½ flood	General Chemical Company[6]
Nicholls	June 9, 1920	1	Low	General Chemical Company[6]
Nicholls	June 14, 1920	6	High	General Chemical Company[6]
Nicholls	June 21, 1920	142	⅔ ebb	General Chemical Company[6]
Nicholls	June 28, 1920	52	High	General Chemical Company[6]
Nicholls	July 6, 1920	262	½ ebb	General Chemical Company[6]
Nicholls	July 13, 1920	518	High	General Chemical Company[6]
Nicholls	July 16, 1920	317	High	General Chemical Company[6]
Nicholls	July 20, 1920	406	¼ flood	General Chemical Company[6]
Nicholls	July 26, 1920	645	High	General Chemical Company[6]
Nicholls	Aug. 2, 1920	665	High	General Chemical Company[6]
Nicholls	Aug. 9, 1920	919	½ ebb	General Chemical Company[6]
Nicholls	Aug. 16, 1920	1,020	High	General Chemical Company[6]
Nicholls	Aug. 23, 1930	1,030	High	General Chemical Company[6]
Nicholls	Aug. 30, 1920	1,168	High	General Chemical Company[6]
Nicholls	Sept. 10, 1920	1,203	High	General Chemical Company[6]
Nicholls	Sept. 13, 1920	1,203	High	General Chemical Company[6]
Nicholls	Sept. 20, 1920	1,211	½ ebb	General Chemical Company[6]
Nicholls	Sept. 27, 1920	1,177	Flood	General Chemical Company[6]
Nicholls	Oct. 5, 1920	1,092	High	General Chemical Company[6]
Nicholls	Oct. 11, 1920	1,159	High	General Chemical Company[6]
Nicholls	Oct. 18, 1920	925	¼ ebb	General Chemical Company[6]
Nicholls	Oct. 25, 1920	620	High	General Chemical Company[6]
Nicholls	Nov. 1, 1920	396	½ flood	General Chemical Company[6]
Nicholls	Nov. 8, 1920	520	¾ ebb	General Chemical Company[6]
Nicholls	Nov. 15, 1920	293	High	General Chemical Company[6]
Nicholls	Nov. 22, 1920	11	¾ ebb	General Chemical Company[6]
Nicholls	Nov. 29, 1920	5	High	General Chemical Company[6]
Nicholls	Dec. 6, 1920	4	High	General Chemical Company[6]
Nicholls	Dec. 13, 1920	3	High	General Chemical Company[6]
Nicholls	Dec. 21, 1920	2	High	General Chemical Company[6]
Nicholls	Dec. 28, 1920	4	½ ebb	General Chemical Company[6]
Nicholls	Jan. 3, 1921	4	Low	General Chemical Company[6]
Nicholls	Jan. 10, 1921	2	High	General Chemical Company[6]
Nicholls	Jan. 17, 1921	22	Low	General Chemical Company[6]
Nicholls	Jan. 24, 1921	2	High	General Chemical Company[6]
Nicholls	Feb. 1, 1921	3	Low	General Chemical Comnpay[6]
Nicholls	Feb. 7, 1921	2	⅓ ebb	General Chemical Company[6]
Nicholls	Feb. 15, 1921	2	Low	General Chemical Company[6]
Nicholls	Feb. 23, 1921	3	¾ flood	General Chemical Company[6]
Nicholls	Mar. 2, 1921	2	High	General Chemical Company[6]
Nicholls	Mar. 8, 1921	2	⅓ ebb	General Chemical Company[6]
Nicholls	Mar. 14, 1921	2	½ flood	General Chemical Company[6]
Nicholls	Mar. 23, 1921	2	¼ ebb	General Chemical Company[6]

TABLE 35—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, AFTER 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Nicholls	Mar. 30, 1921	2	1/3 flood	General Chemical Company[6]
Nicholls	April 5, 1921	1	2/3 flood	General Chemical Company[6]
Nicholls	April 11, 1921	2	Low	General Chemical Company[6]
Nicholls	April 18, 1921	2	1/2 flood	General Chemical Company[6]
Nicholls	April 25, 1921	1	3/4 flood	General Chemical Company[6]
Nicholls	May 2, 1921	1	1/2 flood	General Chemical Company[6]
Nicholls	May 9, 1921	2	Low	General Chemical Company[6]
Nicholls	May 16, 1921	1	3/4 flood	General Chemical Company[6]
Nicholls	May 23, 1921	2	Low	General Chemical Company[6]
Nicholls	May 31, 1921	1	Low	General Chemical Company[6]
Nicholls	June 6, 1921	2	Low	General Chemical Company[6]
Nicholls	June 13, 1921	1	3/4 ebb	General Chemical Company[6]
Nicholls	June 20, 1921	2	High	General Chemical Company[6]
Nicholls	June 27, 1921	1	3/4 flood	General Chemical Company[6]
Nicholls	July 5, 1921	60	7/8 flood	General Chemical Company[6]
Nicholls	July 7, 1921	34	1/3 flood	General Chemical Company[6]
Nicholls	July 9, 1921	169	3/4 ebb	General Chemical Company[6]
Nicholls	July 12, 1921	149	3/4 ebb	General Chemical Company[6]
Nicholls	Aug. 3, 1921	382	High	General Chemical Company[6]
Nicholls	Aug. 8, 1921	369	1/3 flood	General Chemical Company[6]
Nicholls	Aug. 15, 1921	268	3/4 ebb	General Chemical Company[6]
Nicholls	Aug. 21, 1921	616	Low	General Chemical Company[6]
Nicholls	Aug. 29, 1921	701	High	General Chemical Company[6]
Nicholls	Sept. 5, 1921	616	High	General Chemical Company[6]
Nicholls	Sept. 11, 1921	817	1/4 ebb	General Chemical Company[6]
Nicholls	Sept. 20, 1921	819	1/4 ebb	General Chemical Company[6]
Nicholls	Sept. 26, 1921	718	High	General Chemical Company[6]
Nicholls	Sept. 27, 1921	761	High	General Chemical Company[6]
Nicholls	Oct. 2, 1921	867	High	General Chemical Company[6]
Nicholls	Oct. 11, 1921	659	Low	General Chemical Company[6]
Nicholls	Oct. 17, 1921	615	High	General Chemical Company[6]
Nicholls	Oct. 24, 1921	613	1/2 ebb	General Chemical Company[6]
Nicholls	Oct. 31, 1921	634	1/3 ebb	General Chemical Company[6]
Nicholls	Nov. 8, 1921	509	2/3 flood	General Chemical Company[6]
Nicholls	Nov. 15, 1921	474	1/5 flood	General Chemical Company[6]
Nicholls	Nov. 21, 1921	504	Low	General Chemical Company[6]
Nicholls	Nov. 29, 1921	404	3/4 flood	General Chemical Company[6]
Nicholls	Dec. 5, 1921	308	Low	General Chemical Company[6]
Nicholls	Dec. 12, 1921	593	High	General Chemical Company[6]
Nicholls	Dec. 19, 1921	425	Low	General Chemical Company[6]
Nicholls	Dec. 27, 1921	150	High	General Chemical Company[6]
Nicholls	Jan. 7, 1922	42	Low	General Chemical Company[6]
Nicholls	Jan. 16, 1922	30	Low	General Chemical Company[6]
Nicholls	Jan. 23, 1922	130	High	General Chemical Company[6]
Nicholls	Jan. 30, 1922	70	1/2 flood	General Chemical Company[6]
Nicholls	Feb. 7, 1922	248	1/3 ebb	General Chemical Company[6]
Nicholls	Feb. 13, 1922	5	1/2 flood	General Chemical Company[6]
Nicholls	Feb. 20, 1922	4	Low	General Chemical Company[6]
Nicholls	Feb. 27, 1922	2	High	General Chemical Company[6]
Nicholls	Mar. 6, 1922	2	Low	General Chemical Company[6]
Nicholls	Mar. 13, 1922	4	High	General Chemical Company[6]
Nicholls	Mar. 20, 1922	2	1/2 ebb	General Chemical Company[6]
Nicholls	Mar. 29, 1922	3	Low	General Chemical Company[6]
Nicholls	April 3, 1922	2	Low	General Chemical Company[6]
Nicholls	April 10, 1922	2	High	General Chemical Company[6]
Nicholls	April 17, 1922	2	Low	General Chemical Company[6]
Nicholls	April 24, 1922	2	3/4 flood	General Chemical Company[6]
Nicholls	May 1, 1922	2	Low	General Chemical Company[6]
Nicholls	May 8, 1922	1	High	General Chemical Company[6]
Nicholls	May 15, 1922	1	Low	General Chemical Company[6]
Nicholls	May 22, 1922	1	3/4 flood	General Chemical Company[6]
Nicholls	May 29, 1922	1	1/2 flood	General Chemical Company[6]
Nicholls	June 5, 1922	1	1/4 ebb	General Chemical Company[6]
Nicholls	June 12, 1922	1	1/4 flood	General Chemical Company[6]
Nicholls	June 19, 1922	1	1/4 flood	General Chemical Company[6]
Nicholls	June 26, 1922	2	1/4 flood	General Chemical Company[6]
Nicholls	July 6, 1922	0	1/8 flood	General Chemical Company[6]
Nicholls	July 10, 1922	4	Low	General Chemical Company[6]
Nicholls	Aug. 7, 1922	167	7/8 flood	General Chemical Company[6]
Nicholls	Aug. 14, 1922	266	Low	General Chemical Company[6]
Nicholls	Aug. 21, 1922	451	High	General Chemical Company[6]
Nicholls	Aug. 28, 1922	407	1/3 flood	General Chemical Company[6]
Nicholls	Sept. 4, 1922	596	High	General Chemical Company[6]
Nicholls	Sept. 11, 1922	575	Low	General Chemical Company[6]
Nicholls	Sept. 18, 1922	696	7/8 ebb	General Chemical Company[6]

TABLE 35—Continued

MISCELLANEOUS SALINITY OBSERVATIONS, AFTER 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Nicholls	Sept. 25, 1922	534	⅛ ebb	General Chemical Company[6]
Nicholls	Oct. 2, 1922	735	High	General Chemical Company[6]
Nicholls	Oct. 9, 1922	413	High	General Chemical Company[6]
Nicholls	Oct. 16, 1922	540	High	General Chemical Company[6]
Nicholls	Oct. 23, 1922	339	High	General Chemical Company[6]
Nicholls	Oct. 30, 1922	484	High	General Chemical Company[6]
Nicholls	Nov. 6, 1922	295	High	General Chemical Company[6]
Nicholls	Nov. 11, 1922	121	High	General Chemical Company[6]
Nicholls	Nov. 27, 1922	204	Low	General Chemical Company[6]
Nicholls	Dec. 4, 1922	267	High	General Chemical Company[6]
Nicholls	Dec. 18, 1922	4	High	General Chemical Company[6]
Nicholls	Dec. 26, 1922	56	High	General Chemical Company[6]
Nicholls	Jan. 1, 1923	4	High	General Chemical Company[6]
Nicholls	Jan. 8, 1923	4	½ ebb	General Chemical Company[6]
Nicholls	Jan. 15, 1923	21	High	General Chemical Company[6]
Nicholls	Jan. 22, 1923	5	Low	General Chemical Company[6]
Nicholls	Jan. 29, 1923	4	High	General Chemical Company[6]
Nicholls	Feb. 5, 1923	5	Low	General Chemical Company[6]
Nicholls	Feb. 12, 1923	29	High	General Chemical Company[6]
Nicholls	Feb. 19, 1923	5	⅓ flood	General Chemical Company[6]
Nicholls	Feb. 26, 1923	11	¼ ebb	General Chemical Company[6]
Nicholls	Mar. 5, 1923	6	⅓ flood	General Chemical Company[6]
Nicholls	Mar. 12, 1923	7	½ ebb	General Chemical Company[6]
Nicholls	Mar. 19, 1923	7	¼ ebb	General Chemical Company[6]
Nicholls	Mar. 26, 1923	11	Low	General Chemical Company[6]
Nicholls	April 2, 1923	26	¼ flood	General Chemical Company[6]
Nicholls	April 9, 1923	2	½ ebb	General Chemical Company[6]
Nicholls	April 16, 1923	3	½ flood	General Chemical Company[6]
Nicholls	April 23, 1923	2	Low	General Chemical Company[6]
Nicholls	April 30, 1923	3	High	General Chemical Company[6]
Nicholls	May 7, 1923	2	¾ ebb	General Chemical Company[6]
Nicholls	May 14, 1923	2	¼ ebb	General Chemical Company[6]
Nicholls	May 21, 1923	2	Low	General Chemical Company[6]
Nicholls	May 28, 1923	2	½ flood	General Chemical Company[6]
Nicholls	June 4, 1923	4	Low	General Chemical Company[6]
Nicholls	June 11, 1923	5	High	General Chemical Company[6]
Nicholls	June 19, 1923	9	High	General Chemical Company[6]
Nicholls	June 27, 1923	31	½ flood	General Chemical Company[6]
Nicholls	July 2, 1923	26	Low	General Chemical Company[6]
Nicholls	July 16, 1923	41	Low	General Chemical Company[6]
Nicholls	July 30, 1923	350	⅞ flood	General Chemical Company[6]
Nicholls	Aug. 6, 1923	407	¼ ebb	General Chemical Company[6]
Nicholls	Aug. 13, 1923	334	½ flood	General Chemical Company[6]
Nicholls	Aug. 20, 1923	574	¾ ebb	General Chemical Company[6]
Nicholls	Aug. 27, 1923	540	¾ flood	General Chemical Company[6]
Nicholls	Sept. 4, 1923	610	¾ flood	General Chemical Company[6]
Nicholls	Sept. 10, 1923	667	High	General Chemical Company[6]
Nicholls	Sept. 17, 1923	574	Low	General Chemical Company[6]
Nicholls	Sept. 24, 1923	690	High	General Chemical Company[6]
Nicholls	Oct. 1, 1923	620	⅞ ebb	General Cyemical Company[6]
Nicholls	Oct. 8, 1923	427	High	General Chemical Company[6]
Nicholls	Oct. 15, 1923	317	½ flood	General Chemical Company[6]
Nicholls	Oct. 22, 1923	494	High	General Chemical Company[6]
Nicholls	Oct. 29, 1923	334	High	General Chemical Company[6]
Nicholls	Nov. 5, 1923	567	¼ ebb	General Chemical Company[6]
Nicholls	Nov. 12, 1923	327	½ flood	General Chemical Company[6]
Nicholls	Nov. 19, 1923	634	¼ ebb	General Chemical Company[6]
Nicholls	Nov. 26, 1923	394	High	General Chemical Company[6]
Nicholls	Dec. 3, 1923	627	½ ebb	General Chemical Company[6]
Nicholls	Dec. 10, 1923	314	High	General Chemical Company[6]
Nicholls	Dec. 17, 1923	527	½ ebb	General Chemical Company[6]
Nicholls	Dec. 24, 1923	554	High	General Chemical Company[6]
Nicholls	Dec. 31, 1923	457	Low	General Chemical Company[6]
Nicholls	Jan. 7, 1924	434	High	General Chemical Company[6]
Nicholls	Jan. 14, 1924	407	Low	General Chemical Company[6]
Nicholls	Jan. 21, 1924	640	½ ebb	General Chemical Company[6]
Nicholls	Jan. 28, 1924	407	Low	General Chemical Company[6]
Nicholls	Feb. 4, 1924	227	High	General Chemical Company[6]
Nicholls	Feb. 11, 1924	11	Low	General Chemical Company[6]
Nicholls	Feb. 18, 1924	128	High	General Chemical Company[6]
Nicholls	Feb. 25, 1924	25	Low	General Chemical Company[6]
Nicholls	Mar. 3, 1924	297	⅓ ebb	General Chemical Company[6]
Nicholls	Mar. 10, 1924	55	Low	General Chemical Company[6]
Nicholls	Mar. 17, 1924	377	⅕ ebb	General Chemical Company[6]
Nicholls	Mar. 24, 1924	175	Low	General Chemical Company[6]

TABLE 35—Concluded

MISCELLANEOUS SALINITY OBSERVATIONS, AFTER 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Nicholls	Mar. 31, 1924	377	High	General Chemical Company[6]
Nicholls	April 7, 1924	167	Low	General Chemical Company[6]
Nicholls	April 14, 1924	152	Low	General Chemical Company[6]
Nicholls	April 21, 1924	97	¼ flood	General Chemical Company[6]
Nicholls	April 28, 1924	290	⅛ flood	General Chemical Company[6]
Nicholls	May 5, 1924	88	Low	General Chemical Company[6]
Nicholls	May 12, 1924	197	Low	General Chemical Company[6]
Nicholls	May 19, 1924	286	¾ flood	General Chemical Company[6]
Nicholls	May 26, 1924	393	Low	General Chemical Company[6]
Nicholls	June 2, 1924	543	Low	General Chemical Company[6]
Nicholls	June 9, 1924	619	Low	General Chemical Company[6]
Nicholls	June 30, 1924	952	¾ flood	General Chemical Company[6]
Nicholls	July 7, 1924	1,166	Low	General Chemical Company[6]
Nicholls	July 14, 1924	1,126	High	General Chemical Company[6]
Nicholls	July 21, 1924	1,139	Low	General Chemical Company[6]
Nicholls	July 28, 1924	1,245	High	General Chemical Company[6]
Nicholls	Aug. 4, 1924	1,199	Low	General Chemical Company[6]
Nicholls	Aug. 11, 1924	1,365	⅛ ebb	General Chemical Company[6]
Nicholls	Aug. 18, 1924	1,245	Low	General Chemical Company[6]
Nicholls	Aug. 25, 1924	1,439	Low	General Chemical Company[6]
Nicholls	Sept. 1, 1924	1,345	¾ flood	General Chemical Company[6]
Nicholls	Sept. 8, 1924	1,492	½ ebb	General Chemical Company[6]
Nicholls	Sept. 15, 1924	1,425	Low	General Chemical Company[6]
Nicholls	Sept. 22, 1924	1,461	¾ ebb	General Chemical Company[6]
Nicholls	Sept. 29, 1924	1,346	High	General Chemical Company[6]
Nicholls	Oct. 6, 1924	1,346	¾ ebb	General Chemical Company[6]
Nicholls	Oct. 13, 1924	645	High	General Chemical Company[6]
Nicholls	Oct. 20, 1924	1,221	High	General Chemical Company[6]
Nicholls	Oct. 27, 1924	1,121	High	General Chemical Company[6]
Nicholls	Nov. 3, 1924	786	Low	General Chemical Company[6]
Nicholls	Nov. 10, 1924	680	High	General Chemical Company[6]
Nicholls	Nov. 17, 1924	288	Low	General Chemical Company[6]
Nicholls	Nov. 24, 1924	560	High	General Chemical Company[6]
Nicholls	Dec. 1, 1924	345	High	General Chemical Company[6]
Nicholls	Dec. 8, 1924	528	High	General Chemical Company[6]
Nicholls	Dec. 15, 1924	195	High	General Chemical Company[6]
Nicholls	Dec. 22, 1924	538	High	General Chemical Company[6]
Nicholls	Dec. 29, 1924	58	High	General Chemical Company[6]

[1] From data in final report, 1927, of San Francisco Bay Marine Piling Committee on "Marine borers and their relation to marine construction on the Pacific Coast." (Figures 101 to 105 inclusive opposite page 266)

[2] From data on Plate 9-8, Vol. II, Bulletin No. 22, "Report on Salt Water Barrier," Division of Water Resources, 1929. Values of salinity represent the average of samples taken at ten-foot intervals from surface to bottom at slack water following higher high and lower low waters on dates indicated.

[3] From data of salinity observations in Mare Island Strait furnished by U. S. Navy Yard.

[4] From data on Plate 9-8, Vol. II, Bulletin No. 22, "Report on Salt Water Barrier," Division of Water Resources, 1929. Values of salinity represent the average of samples taken at the surface and bottom at high and low tides on the dates indicated.

[5] From records on file in office of Division of Water Resources of salinity observations at pumping plant of East Contra Costa Irrigation Company (now East Contra Costa Irrigation District) near west end of Indian Slough in San Joaquin River Delta. See Table 33 for records subsequent to May, 1920. See Table 34 for records in 1919.

[6] From data furnished by C. W. Schedler, Jr., from observations by General Chemical Company.

TABLE 35—Concluded

MISCELLANEOUS SALINITY OBSERVATIONS, AFTER 1920

Location	Date	Salinity in parts of chlorine per 100,000 parts of water	Tidal phase	Observer
Nicholls	Mar. 31, 1924	377	High	General Chemical Company[6]
Nicholls	April 7, 1924	167	Low	General Chemical Company[6]
Nicholls	April 14, 1924	152	Low	General Chemical Company[6]
Nicholls	April 21, 1924	97	¼ flood	General Chemical Company[6]
Nicholls	April 28, 1924	290	⅛ flood	General Chemical Company[6]
Nicholls	May 5, 1924	88	Low	General Chemical Company[6]
Nicholls	May 12, 1924	197	Low	General Chemical Company[6]
Nicholls	May 19, 1924	286	¾ flood	General Chemical Company[6]
Nicholls	May 26, 1924	393	Low	General Chemical Company[6]
Nicholls	June 2, 1924	543	Low	General Chemical Company[6]
Nicholls	June 9, 1924	619	Low	General Chemical Company[6]
Nicholls	June 30, 1924	952	¾ flood	General Chemical Company[6]
Nicholls	July 7, 1924	1,166	Low	General Chemical Company[6]
Nicholls	July 14, 1924	1,126	High	General Chemical Company[6]
Nicholls	July 21, 1924	1,139	Low	General Chemical Company[6]
Nicholls	July 28, 1924	1,245	High	General Chemical Company[6]
Nicholls	Aug. 4, 1924	1,199	Low	General Chemical Company[6]
Nicholls	Aug. 11, 1924	1,365	⅓ ebb	General Chemical Company[6]
Nicholls	Aug. 18, 1924	1,245	Low	General Chemical Company[6]
Nicholls	Aug. 25, 1924	1,439	Low	General Chemical Company[6]
Nicholls	Sept. 1, 1924	1,345	¾ flood	General Chemical Company[6]
Nicholls	Sept. 8, 1924	1,492	½ ebb	General Chemical Company[6]
Nicholls	Sept. 15, 1924	1,425	Low	General Chemical Company[6]
Nicholls	Sept. 22, 1924	1,461	¾ ebb	General Chemical Company[6]
Nicholls	Sept. 29, 1924	1,346	High	General Chemical Company[6]
Nicholls	Oct. 6, 1924	1,346	¾ ebb	General Chemical Company[6]
Nicholls	Oct. 13, 1924	645	High	General Chemical Company[6]
Nicholls	Oct. 20, 1924	1,221	High	General Chemical Company[6]
Nicholls	Oct. 27, 1924	1,121	High	General Chemical Company[6]
Nicholls	Nov. 3, 1924	786	Low	General Chemical Company[6]
Nicholls	Nov. 10, 1924	680	High	General Chemical Company[6]
Nicholls	Nov. 17, 1924	288	Low	General Chemical Company[6]
Nicholls	Nov. 24, 1924	560	High	General Chemical Company[6]
Nicholls	Dec. 1, 1924	345	High	General Chemical Company[6]
Nicholls	Dec. 8, 1924	528	High	General Chemical Company[6]
Nicholls	Dec. 15, 1924	195	High	General Chemical Company[6]
Nicholls	Dec. 22, 1924	538	High	General Chemical Company[6]
Nicholls	Dec. 29, 1924	58	High	General Chemical Company[6]

[1] From data in final report, 1927, of San Francisco Bay Marine Piling Committee on "Marine borers and their relation to marine construction on the Pacific Coast." (Figures 101 to 105 inclusive opposite page 266)

[2] From data on Plate 9-8, Vol. II, Bulletin No. 22, "Report on Salt Water Barrier," Division of Water Resources, 1929. Values of salinity represent the average of samples taken at ten-foot intervals from surface to bottom at slack water following higher high and lower low waters on dates indicated.

[3] From data of salinity observations in Mare Island Strait furnished by U. S. Navy Yard.

[4] From data on Plate 9-8, Vol. II, Bulletin No. 22, "Report on Salt Water Barrier," Division of Water Resources, 1929. Values of salinity represent the average of samples taken at the surface and bottom at high and low tides on the dates indicated.

From records on file in office of Division of Water Resources of salinity observations at pumping plant of East Contra Costa Irrigation Company (now East Contra Costa Irrigation District) near west end of Indian Slough in San Joaquin River Delta. See Table 33 for records subsequent to May, 1929. See Table 34 for records in 1919.

[6] From data furnished by C. W. Schedler, Jr., from observations by General Chemical Company.

TABLE 36

SUMMARY OF COMPLETE CHEMICAL ANALYSES OF WATER AT POINTS IN SAN FRANCISCO BAY AND SACRAMENTO AND SAN JOAQUIN RIVER CHANNELS

Station	Date of sample	Time of sample	Residue on evaporation at 110° C., in parts per million	Total hardness, parts per million	Carbonates		Bicarbonates		Silicates		Iron and alumina		Calcium		Magnesium		Chlorides		Sulphates		Sodium	
					Parts per million	Per cent of total chemical constituents	Parts per million	Per cent of total chemical constituents	Parts per million	Per cent of total chemical constituents	Parts per million	Per cent of total chemical constituents	Parts per million	Per cent of total chemical constituents	Parts per million	Per cent of total chemical constituents	Parts per million	Per cent of total chemical constituents	Parts per million	Per cent of total chemical constituents	Parts per million	Per cent of total chemical constituents
Pacific Ocean near Cliff House	Aug 7, 1929		33,394	6,034	Nil		159	0.5	12	0.0	60	0.2	426	1.3	1,212	3.6	18,200	53.7	2,510	7.4	11,275	[illegible]
Point Orient	June 26, 1929	3:18 a.m.	28,304	5,721	14	0.1	105	0.4					906	3.2	843	3.0	15,300	54.8	1,780	6.4	8,983	32.1
Point Orient	Sept. 14, 1929	10:45 p.m.	32,826	4,947	Nil		139	0.4	28	0.1	21	0.1	124	0.4	1,131	3.4	17,800	53.9	2,325	7.1	11,430	34.6
Bay Point	June 26, 1929	5:18 a.m.	6,177	1,024	1	0.0	61	1.0					121	1.8	176	2.7	3,600	55.3	268	4.1	2,288	35.1
Bay point	Sept. 15, 1929	12:55 p.m.	22,370	456	Nil		116	0.5	5	0.0	21	0.1	84	0.4	60	0.3	12,000	52.0	1,592	6.9	6,168	39.8
Emmaton	June 26, 1929	6:03 a.m.	156	91	1	0.6	88	51.2					33	19.2	2	1.2	20	11.6	15	8.7	13	7.5
Emmaton	Aug 30, 1929	1:40 p.m.	4,437	821	Nil		165	3.6	5	0.1	15	0.3	84	1.8	119	3.2	2,400	51.7	320	6.9	1,502	32.4
Walnut Grove	June 26, 1929	7:48 a.m.	159	87	Trace	0.0	98	58.3					25	14.9	6	3.6	16	9.5	15	8.9	8	4.8
Sacramento, one-quarter mile below sewer outlet	Aug. 1, 1929	8.05 p.m.	171	150	Nil		132	53.0	18	7.2	5	2.0	24	9.7	21	8.4	30	12.1	12	4.8	7	2.8
Verona	June 26, 1929	No tide	145	75	12	8.1	66	44.3					27	18.1	2	1.3	18	12.1	8	5.4	16	10.7
Jersey	June 26, 1929	7:18 a.m.	206	103	19	9.5	51	25.5					39	19.5	4	2.0	44	22.0	18	9.0	25	12.5
Jersey	Sept. 24, 1929	9:10 p.m.	4,640	911	Nil		116	2.5	18	0.4	24	0.5	91	2.0	167	3.6	2,400	51.8	343	7.4	1,474	31.8
Blakes Landing, Venice Island	June 26, 1929	8:18 a.m.	216	97	12	6.5	49	26.3					35	18.8	25	1.6	46	24.7	18	9.7	23	12.4
Blakes Landing, Venice Island	Sept. 15, 1929	5:20 p.m.	617	286	Nil		116	16.5	24	3.4	21	3.0	36	5.1	48	6.8	260	37.0	65	9.3	133	18.9
New Hope Bridge	Aug. 1, 1929	11:55 a.m.	114	77	Nil		59	42.8	2	1.5	6	4.3	25	18.1	4	2.9	26	18.8	8	5.8	8	5.8
Stockton at California Transportation Co. wharf	Aug. 1, 1929	1:47 p.m.	1,986	689	Nil		139	6.9	32	1.6	9	0.5	232	11.5	29	1.4	1,080	53.5	18	0.9	470	23.7
Stockton at California Transportation Co. wharf	Sept. 3, 1929	3:15 p.m.	1,871	752	Nil		161	8.0	58	2.9	4	0.2	235	11.6	40	2.0	1,060	52.5	12	0.6	449	22.2
Vernalis	Jan. 5, 1930	5:00 p.m.	263	149	Nil		93	26.7	27	7.7	4	1.2	85	24.4	21	6.0	57	16.3	20	5.7	42	12.0
Durham Ferry	June 26, 1929	No tide	261	118	17	7.1	68	28.4					26	10.9	12	5.0	60	8.4	20	25.1	36	15.1
Stanislaus River at Elliot Ranch	Jan. 5, 1930	2:40 p.m.	146	90	Nil		122	58.1	20	9.5	5	2.4	31	14.8	3	1.4	10	4.8	4	1.9	15	7.1
Tuolumne River at Tuolumne City	Jan. 5, 1930	3:35 p.m.	126	70	Nil		73	44.3	20	12.1	4	2.4	21	12.7	4	2.4	27	16.4	2	1.2	14	8.5
Merced River at Hills Ferry Bridge	Jan. 6, 1930	4:15 p.m.	176	84	Nil		122	53.3	20	8.7	5	2.2	30	13.1	9	3.9	19	8.3	2	0.9	22	9.6

APPENDIX D

STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA

TABLE 37

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1919-1920

Flow in second-feet

Day	October, 1919			November, 1919			December, 1919			January, 1920		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	6,000	700	6,700	7,000	700	7,700	7,000	800	7,800	10,000	1,700	11,700
2	6,800	700	7,500	7,000	800	7,800	7,000	1,100	8,100	9,000	1,400	10,400
3	7,500	800	8,300	7,000	700	7,700	8,000	2,500	10,500	9,000	1,400	10,400
4	7,300	700	8,000	7,000	700	7,700	9,000	1,900	10,900	8,500	1,400	9,900
5	7,100	700	7,800	7,000	700	7,700	8,000	1,600	9,600	8,500	1,300	9,800
6	6,800	600	7,400	7,000	800	7,800	8,000	1,500	9,500	9,000	1,300	10,300
7	6,400	700	7,100	7,500	800	8,300	7,500	1,300	8,800	8,500	1,200	9,700
8	6,700	700	7,400	7,500	800	8,300	7,800	1,200	9,000	9,000	1,200	10,200
9	6,700	700	7,400	7,000	700	7,700	8,000	1,200	9,200	8,500	1,100	9,600
10	6,500	700	7,200	7,500	700	8,200	8,000	1,600	9,600	8,500	1,100	9,600
11	6,400	600	7,000	7,200	800	8,000	10,000	1,900	11,900	8,000	1,100	9,100
12	6,400	600	7,000	7,200	800	8,000	26,000	3,100	29,100	8,000	1,100	9,100
13	6,300	600	6,900	7,200	800	8,000	20,000	2,700	22,700	8,000	1,100	9,100
14	6,100	600	6,700	7,300	800	8,100	12,000	2,400	14,400	8,000	1,100	9,100
15	6,100	600	6,700	7,200	700	7,900	10,000	2,100	12,100	8,000	1,100	9,100
16	6,000	600	6,600	7,000	800	7,800	9,000	1,800	10,800	8,000	1,100	9,100
17	6,100	600	6,700	7,000	800	7,800	9,000	1,700	10,700	8,000	1,100	9,100
18	6,200	600	6,800	7,000	800	7,800	9,000	1,700	10,700	8,000	1,100	9,100
19	6,100	600	6,700	7,000	800	7,800	9,000	1,700	10,700	8,000	1,200	9,200
20	6,100	600	6,700	7,000	800	7,800	9,000	1,700	10,700	8,000	1,100	9,100
21	6,200	600	6,800	7,000	800	7,800	10,000	1,700	11,700	8,500	1,100	9,600
22	6,200	600	6,800	6,800	800	7,600	11,000	1,700	12,700	8,000	1,300	9,300
23	6,300	600	6,900	6,500	800	7,300	12,000	1,700	13,700	8,000	1,600	9,600
24	6,400	600	7,000	7,000	700	7,700	12,000	1,700	13,700	9,000	1,400	10,400
25	6,400	600	7,000	6,800	800	7,600	12,000	1,700	13,700	9,000	1,500	10,500
26	6,600	700	7,300	6,500	800	7,300	11,000	1,600	12,600	9,000	1,300	10,300
27	6,400	700	7,100	6,000	800	6,800	10,000	1,700	11,700	8,500	1,300	9,800
28	6,200	700	6,900	6,000	900	6,900	10,000	1,700	11,700	8,500	1,200	9,700
29	6,200	700	6,900	6,000	900	6,900	9,500	1,500	11,000	8,500	1,300	9,800
30	6,200	700	6,900	6,000	800	6,800	9,500	1,700	11,200	8,500	1,200	9,700
31	6,200	700	6,900				10,000	1,700	11,700	8,500	1,200	9,700
Totals in acre-feet	393,800	40,000	433,800	410,300	46,300	456,600	630,200	106,700	736,900	519,800	76,400	596,200

Total for season 1919-1920, in acre-feet..........Sacramento River.......... 7,729,500
Total for season 1919-1920, in acre-feet..........San Joaquin River.......... 3,014,000
Total for season 1919-1920, in acre-feet..........Combined rivers.......... 10,743,500

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1919-1920

Flow in second-feet

Day	February, 1920			March, 1920			April, 1920			May, 1920		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	8,000	1,300	9,300	15,000	6,800	21,800	21,300	5,300	26,600	30,800	10,900	41,700
2	8,000	1,200	9,200	17,000	18,200	35,200	21,000	4,800	25,800	29,600	9,200	38,800
3	8,000	1,300	9,300	24,000	11,300	35,300	20,200	4,100	24,300	28,500	8,300	36,800
4	8,000	1,300	9,300	22,000	6,300	28,300	18,500	3,200	21,700	27,000	9,300	36,300
5	8,000	1,200	9,200	18,000	4,700	22,700	18,200	4,200	22,400	25,200	9,200	34,400
6	8,000	1,200	9,200	17,000	4,200	21,200	19,100	5,400	24,500	24,200	10,000	34,200
7	8,000	1,100	9,100	16,000	2,500	18,500	20,700	5,800	26,500	24,200	12,300	36,500
8	8,000	1,000	9,000	15,000	2,200	17,200	22,100	6,600	28,700	25,000	13,100	38,100
9	9,000	1,000	10,000	15,000	2,100	17,100	23,900	7,200	31,100	25,500	13,600	39,100
10	12,000	1,100	13,100	16,000	6,000	22,000	29,500	7,600	37,100	26,100	10,900	37,000
11	16,000	1,100	17,100	18,000	4,000	22,000	31,000	7,100	38,100	23,900	9,600	33,500
12	20,000	1,100	21,100	18,000	2,900	20,900	32,900	6,300	39,200	20,100	10,300	30,400
13	14,000	1,100	15,100	17,000	2,700	19,700	31,700	6,400	38,100	20,300	10,700	31,000
14	11,000	1,100	12,100	17,000	2,600	19,600	30,000	6,100	36,100	20,800	11,800	32,600
15	9,000	1,100	10,100	18,000	2,600	20,600	31,400	12,400	43,800	21,500	13,900	35,400
16	9,000	1,000	10,000	18,000	6,900	24,900	52,100	23,700	75,800	22,800	15,300	38,100
17	9,000	1,100	10,100	18,000	9,000	27,000	57,300	17,400	74,700	24,100	19,900	44,000
18	9,000	1,000	10,000	18,000	6,500	24,500	57,300	11,200	68,500	25,500	22,200	47,700
19	9,000	900	9,900	18,000	4,300	22,300	54,200	8,600	62,800	25,800	25,600	51,400
20	9,000	1,100	10,100	18,000	4,400	22,400	49,000	8,000	57,000	25,700	28,000	53,700
21	9,000	1,200	10,200	19,000	16,200	35,200	43,900	7,500	51,400	26,000	28,900	54,900
22	9,000	1,200	10,200	22,000	24,500	46,500	38,900	6,100	45,000	25,800	27,200	53,000
23	9,000	1,200	10,200	26,000	19,800	45,800	35,100	5,500	40,600	24,600	22,300	46,900
24	9,000	1,300	10,300	31,000	12,400	43,400	31,900	5,400	37,300	19,200	18,000	37,200
25	9,000	1,400	10,400	33,000	9,800	42,800	30,000	4,300	34,300	16,300	16,300	32,600
26	10,000	1,400	11,400	32,000	10,400	42,400	27,600	4,600	32,200	16,500	17,000	33,500
27	11,000	1,500	12,500	28,000	9,000	37,000	26,400	5,400	31,800	14,700	18,700	33,400
28	12,000	1,400	13,400	24,000	7,500	31,500	27,300	7,700	35,000	14,800	20,400	35,200
29	16,000	1,700	17,700	20,000	6,800	26,800	28,400	10.300	38,700	14,900	22,200	37,100
30				19,000	6,100	25,100	30,500	13,200	43,700	14,800	22,000	36,800
31				18,000	5,800	23,800				13,800	20,200	34,000
Totals in acre-feet	582,100	68,500	650,600	1,237,500	472 200	1,709,700	1,903,600	458,200	2,361,800	1,382,000	1,004,500	2,386,500

Total for season 1919-1920, in acre-feet—Sacramento River—7,729,500
Total for season 1919-1920, in acre-feet—San Joaquin River—3,014,000
Total for season 1919-1920, in acre-feet—Combined rivers—10,743,500

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1919-1920

Flow in second-feet

Day	June, 1920			July, 1920			August, 1920			September, 1920		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	13,100	19,000	32,100	3,400	2,900	6,300	300	400	700	1,600	400	2,000
2	11,900	18,000	29,900	3,100	2,500	5,600	600	400	1,000	1,400	400	1,800
3	11,300	17,500	28,800	2,800	2,100	4,900	700	500	1,200	1,400	400	1,800
4	11,200	17,400	28,600	2,600	1,800	4,400	1,000	500	1,500	1,400	400	1,800
5	11,200	17,300	28,500	2,400	1,600	4,000	700	500	1,200	1,400	400	1,800
6	11,000	17,000	28,000	2,000	1,400	3,400	700	500	1,200	1,400	400	1,800
7	9,600	16,800	26,400	1,900	1,200	3,100	700	500	1,200	1,300	400	1,700
8	9,200	16,800	26,000	1,800	1,100	2,900	500	400	900	1,300	400	1,700
9	8,700	16,300	25,000	1,500	1,100	2,600	500	400	900	1,400	400	1,800
10	8,200	14,400	22,600	1,300	1,000	2,300	500	400	900	1,400	400	1,800
11	7,000	13,600	20,600	1,200	900	2,100	700	500	1,200	1,500	400	1,900
12	6,500	12,200	18,700	1,000	800	1 800	1,100	500	1,600	1,800	400	2,200
13	7,200	12,000	19,200	800	800	1,600	500	500	1,000	1,800	400	2,200
14	5,600	11,300	16,900	800	800	1,600	700	400	1,100	2,000	400	2,400
15	5,400	10,600	16,000	700	700	1,400	500	400	900	2,200	400	2,600
16	6,800	12,100	18,900	600	700	1,300	500	400	900	2,200	400	2,600
17	6,900	9,400	16,300	600	700	1,300	400	400	800	2,400	400	2,800
18	6,400	8,600	15,000	700	700	1,400	500	400	900	2,800	300	3,100
19	6,100	8,400	14,500	800	600	1,400	600	400	1,000	2,800	400	3,200
20	5,600	8,300	13,900	600	600	1,200	600	400	1,000	2,900	400	3,300
21	5,000	7,700	12,700	600	600	1,200	800	400	1,200	3,000	400	3,400
22	4,600	6,600	11,200	600	600	1,200	600	300	900	3,200	400	3,600
23	4,300	5,800	10,100	600	600	1,200	600	300	900	3,300	400	3,700
24	4,500	4,800	9,300	500	500	1,000	700	400	1,100	3,300	300	3,600
25	4,000	3,800	7,800	400	500	900	900	400	1,300	3,500	400	3,900
26	3,400	3,400	6,800	400	400	800	900	300	1,200	3,500	400	3,900
27	3,000	3,100	6,100	600	400	1,000	800	300	1,100	3,800	400	4,200
28	2,800	2,900	5,700	400	500	900	1,300	400	1,700	4,100	300	4,400
29	2,700	2,700	5,400	500	500	1,000	1,200	300	1,500	4,400	400	4,800
30	3,500	2,700	6,200	400	500	900	1,200	400	1,600	4,700	400	5,100
31	----------	----------	----------	300	500	800	1,400	200	1,600	----------	----------	----------
Totals in acre-feet	409,300	634,600	1,043,900	71,100	58,600	129,700	44,900	24,800	69,700	144,900	23,200	168,100

Total for season 1919–1920, in acre-feet .... Sacramento River 7,729,500
Total for season 1919–1920, in acre-feet .... San Joaquin Rivers 3,014,000
Total for season 1919–1920, in acre-feet .... Combined rivers 10,743,500

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1920-1921

Flow in second-feet

Day	October, 1920			November, 1920			December, 1920			January, 1921		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	4,900	500	5,400	7,000	1,800	8,800	57,500	3,400	60,900	58,700	7,500	66,200
2	5,000	600	5,600	7,000	1,700	8,700	58,600	4,000	62,600	57,600	6,800	64,400
3	5,200	500	5,700	8,000	1,700	9,700	57,800	4,000	61,800	56,000	6,600	62,600
4	5,200	500	5,700	8,000	1,600	9,600	56,400	3,700	60,100	53,900	6,400	60,300
5	5,000	600	5,600	8,000	1,500	9,500	54,800	3,600	58,400	52,900	6,200	59,100
6	5,300	600	5,900	8,000	1,400	9,400	52,100	3,400	55,500	54,800	7,200	62,000
7	6,200	800	7,000	8,000	1,400	9,400	49,200	3,900	53,100	54,200	6,200	60,400
8	7,500	1,000	8,500	8,000	1,500	9,500	47,700	4,500	52,200	59,400	5,900	65,300
9	6,500	1,000	7,500	8,000	1,600	9,600	47,400	4,200	51,600	59,600	5,700	65,300
10	6,900	1,200	8,100	8,000	1,600	9,600	52,800	6,000	58,800	59,600	5,500	65,100
11	7,000	1,200	8,200	8,000	1,800	9,800	60,700	7,400	68,100	57,100	5,200	62,300
12	6,500	1,100	7,600	8,000	2,000	10,000	67,900	7,300	75,200	53,100	5,200	58,300
13	7,100	1,300	8,400	9,000	3,300	12,300	65,400	6,100	71,500	49,800	5,200	55,000
14	7,800	1,400	9,200	12,000	3,300	15,300	63,600	4,900	68,500	46,100	5,100	51,200
15	8,100	1,400	9,500	15,000	3,000	18,000	61,900	4,400	66,300	42,700	5,000	47,700
16	7,900	1,500	9,400	17,000	3,000	20,000	59,500	4,100	63,600	38,800	4,900	43,700
17	8,100	1,400	9,500	20,000	3,200	23,200	55,400	4,000	59,400	60,600	6,300	66,900
18	7,800	1,300	9,100	25,000	3,100	28,100	50,700	3,900	54,600	69,500	77,300	146,800
19	8,200	1,800	10,000	35,000	3,200	38,200	54,300	5,200	59,500	96,100	37,500	133,600
20	8,200	1,700	9,900	70,000	6,900	76,900	62,600	5,800	68,400	117,600	34,600	152,200
21	7,900	1,600	9,500	68,000	4,700	72,700	67,400	4,900	72,300	122,500	25,600	148,100
22	7,500	1,500	9,000	67,000	4,100	71,100	70,700	5,200	75,900	117,800	20,300	138,100
23	7,500	1,500	9,000	69,000	3,800	72,800	72,500	8,500	81,000	109,700	18,900	128,600
24	7,300	1,700	9,000	66,000	3,500	69,500	74,000	7,800	81,800	99,900	18,000	117,900
25	7,200	1,800	9,000	63,000	3,200	66,200	77,900	8,700	86,600	91,100	11,500	102,600
26	7,300	1,900	9,200	60,000	3,100	63,100	79,800	7,700	87,500	86,000	10,600	96,600
27	7,500	2,000	9,500	54,000	3,300	57,300	76,400	7,000	83,400	84,600	12,600	97,200
28	7,600	2,000	9,600	61,000	4,000	65,000	72,900	7,000	79,900	87,000	15,900	102,900
29	7,500	2,000	9,500	62,000	3,600	65,600	65,500	6,700	72,200	92,000	14,400	106,400
30	7,300	1,900	9,200	62,000	3,400	65,400	59,500	6,600	66,100	99,900	42,800	142,700
31	7,300	1,800	9,100	----------	----------	----------	60,900	8,300	69,200	128,000	18,500	146,500
Totals in acre-feet	428,300	81,400	509,700	1,839,400	168,900	2,008,300	3,789,300	341,000	4,130,300	4,586,900	909,600	5,496,500

Total for season 1920–1921, in acre-feet	Sacramento River	25,719,700
Total for season 1920–1921, in acre-feet	San Joaquin River	5,770,600
Total for season 1920–1921, in acre-feet	Combined rivers	31,490,300

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1920-1921

Flow in second-feet

Day	February, 1921			March, 1921			April, 1921			May, 1921		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	132,800	15,000	147,800	58,400	11,200	69,600	54,800	11,500	66,300	43,800	19,300	63,100
2	128,400	13,900	142,300	57,700	12,000	69,700	54,800	13,100	67,900	43,800	14,500	58,300
3	125,700	13,500	139,200	57,300	13,600	70,900	55,400	12,800	68,200	43,500	13,800	57,300
4	117,600	12,900	130,500	57,600	17,000	74,600	56,300	10,700	67,000	42,000	14,300	56,300
5	101,200	15,000	116,200	58,600	16,300	74,900	54,700	8,900	63,600	40,500	13,100	53,600
6	95,900	12,100	108,000	59,700	15,500	75,200	52,200	7,700	59,900	37,600	12,400	50,000
7	89,500	11,500	101,000	60,700	14,200	74,900	49,900	7,100	57,000	35,800	11,600	47,400
8	64,400	11,100	75,500	61,400	13,300	74,700	47,400	6,900	54,300	34,900	11,700	46,600
9	61,400	10,600	72,000	61,300	13,100	74,400	45,200	7,900	53,100	35,200	13,000	48,200
10	58,400	10,300	68,700	60,900	12,700	73,600	44,400	8,100	52,500	35,500	14,100	49,600
11	57,300	10,500	67,800	59,500	12,600	72,100	43,300	7,900	51,200	37,000	16,800	53,800
12	54,900	10,500	65,400	58,100	12,100	70,200	43,000	7,200	50,200	38,200	20,600	58,800
13	54,400	10,700	65,100	58,900	17,000	75,900	43,300	7,500	50,800	39,900	23,200	63,100
14	54,700	13,100	67,800	64,700	17,300	82,000	44,400	7,000	51,400	42,600	24,800	67,400
15	57,400	11,900	69,300	65,400	15,500	80,900	44,100	5,700	49,800	44,300	26,500	70,800
16	58,700	11,700	70,400	65,300	13,900	79,200	42,400	5,000	47,400	44,800	26,800	71,600
17	60,800	11,400	72,200	64,800	13,700	78,500	40,300	4,600	44,900	45,400	17,200	62,600
18	62,100	11,300	73,400	64,000	14,400	78,400	38,600	4,600	43,200	43,500	13,900	57,400
19	62,500	10,900	73,400	65,600	14,100	79,700	37,300	4,800	42,100	40,800	12,500	53,300
20	61,400	10,100	71,500	64,600	13,100	77,700	36,500	5,200	41,700	37,600	12,600	50,200
21	61,400	11,100	72,500	63,100	11,400	74,500	36,200	7,700	43,900	35,200	13,000	48,200
22	64,700	11,400	76,100	63,300	11,900	75,200	37,000	10,500	47,500	34,900	13,200	48,100
23	64,100	10,900	75,000	65,300	11,700	77,000	39,700	12,600	52,300	35,200	13,700	48,900
24	62,500	10,100	72,600	64,800	10,600	75,400	41,800	11,400	53,200	35,700	14,700	50,400
25	61,500	9,400	70,900	64,200	10,700	74,900	41,100	9,800	50,900	36,700	17,300	54,000
26	61,300	9,800	71,100	64,100	10,100	74,200	40,000	9,000	49,000	37,900	22,100	60,000
27	60,800	9,900	70,700	62,500	9,400	71,900	38,800	11,200	50,000	40,000	26,400	66,400
28	59,600	10,500	70,100	60,500	9,200	69,700	38,800	14,200	53,000	47,800	23,500	71,300
29				58,500	9,200	67,700	40,200	16,700	56,900	43,800	19,200	63,000
30				57,300	9,400	66,700	42,300	18,500	60,800	40,800	16,500	57,300
31				55,700	10,100	65,800				36,400	15,200	51,600
Totals in acre-feet	4,069,700	635,800	4,705,500	3,769,500	784,700	4,554,200	2,621,900	546,100	3,168,000	2,437,600	1,044,400	3,482,000

Total for season 1920–1921, in acre-feet	Sacramento River	25,719,700
Total for season 1920–1921, in acre-feet	San Joaquin River	5,770,600
Total for season 1920–1921, in acre-feet	Combined rivers	31,490,300

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1920-1921

Flow in second-feet

Day	June, 1921			July, 1921			August, 1921			September, 1921		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	28,300	12,200	40,500	10,600	6,400	17,000	4,400	700	5,100	3,600	600	4,200
2	27,300	12,600	39,900	10,200	6,100	16,300	4,500	700	5,200	3,600	600	4,200
3	28,400	14,900	43,300	10,000	6,000	16,000	4,400	700	5,100	3,500	500	4,000
4	29,300	16,000	45,300	9,100	5,700	14,800	4,300	700	5,000	3,400	500	3,900
5	31,100	19,900	51,000	8,800	4,500	13,300	4,200	700	4,900	3,500	500	4,000
6	32,700	24,500	57,200	8,400	3,500	11,900	4,200	800	5,000	3,700	500	4,200
7	32,500	28,300	60,800	8,400	3,300	11,700	3,900	800	4,700	3,600	500	4,100
8	31,800	28,700	60,500	7,900	3,100	11,000	4,100	700	4,800	3,700	500	4,200
9	31,300	27,200	58,500	7,800	2,700	10,500	4,200	700	4,900	3,700	500	4,200
10	30,600	27,900	58,500	7,300	2,500	9,800	4,000	700	4,700	3,500	500	4,000
11	29,800	29,200	59,000	6,800	2,100	8,900	3,800	700	4,500	3,400	500	3,900
12	29,000	29,200	58,200	6,500	1,800	8,300	3,600	700	4,300	3,400	500	3,900
13	26,900	28,300	55,200	6,500	1,900	8,400	3,600	600	4,200	3,600	500	4,100
14	25,000	25,800	50,800	6,300	1,800	8,100	3,600	600	4,200	3,800	500	4,300
15	21,800	23,600	45,400	6,300	1,600	7,900	3,500	600	4,100	3,900	500	4,400
16	19,200	16,200	35,400	5,900	1,400	7,300	3,600	600	4,200	3,900	500	4,400
17	19,100	11,900	31,000	5,800	1,400	7,200	3,400	600	4,000	3,900	500	4,400
18	16,500	10,200	26,700	5,800	1,100	6,900	3,400	600	4,000	3,900	500	4,400
19	15,000	10,100	25,100	5,500	1,200	6,700	3,400	600	4,000	4,200	500	4,700
20	15,100	11,000	26,100	5,400	1,300	6,700	3,400	600	4,000	4,600	500	5,100
21	15,200	14,400	29,600	5,400	1,200	6,600	3,400	600	4,000	4,800	500	5,300
22	16,500	18,200	34,700	5,300	1,200	6,500	3,200	500	3,700	4,800	500	5,300
23	16,300	17,900	34,200	5,200	1,200	6,400	3,000	600	3,600	4,800	500	5,300
24	15,100	15,400	30,500	5,100	900	6,000	3,000	600	3,600	4,800	500	5,300
25	14,400	13,700	28,100	4,900	800	5,700	3,100	500	3,600	5,000	500	5,500
26	13,400	10,300	23,700	4,700	800	5,500	3,200	500	3,700	4,900	400	5,300
27	13,400	9,900	23,300	4,900	800	5,700	3,300	500	3,800	4,900	500	5,400
28	12,000	8,900	20,900	4,700	800	5,500	3,400	500	3,900	5,000	500	5,500
29	11,500	8,400	19,900	4,600	700	5,300	3,300	500	3,800	5,000	500	5,500
30	11,300	7,200	18,500	4,500	800	5,300	3,300	500	3,800	5,300	500	5,800
31				4,400	800	5,200	3,400	500	3,900			
Totals in acre-feet	1,306,400	1,053,400	2,359,800	401,900	137,400	539,300	223,900	38,000	261,900	244,900	29,900	274,800

Total for season 1920-1921, in acre-feet	Sacramento River	25,719,700
Total for season 1920-1921, in acre-feet	San Joaquin River	5,770,600
Total for season 1920-1921, in acre-feet	Combined rivers	31,490,300

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1921-1922

Flow in second-feet

Day	October, 1921			November, 1921			December, 1921			January, 1922		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	5,500	600	6,100	7,000	1,000	8,000	10,000	1,000	11,000	35,000	11,400	46,400
2	5,400	600	6,000	7,000	800	7,800	11,000	1,000	12,000	40,000	22,100	62,100
3	5,300	500	5,800	7,000	800	7,800	14,000	1,100	15,100	41,000	15,100	56,100
4	5,400	700	6,100	7,000	800	7,800	12,000	1,100	13,100	33,000	12,000	50,000
5	5,900	700	6,600	6,800	800	7,600	11,000	1,000	12,000	32,000	10,800	42,800
6	5,900	700	6,600	6,600	800	7,400	9,700	1,000	10,700	27,000	10,700	37,700
7	5,900	700	6,600	6,600	800	7,400	9,700	1,000	10,700	25,000	10,800	35,800
8	6,000	700	6,700	6,900	900	7,800	9,600	900	10,500	24,000	9,600	33,600
9	5,900	700	6,600	6,900	900	7,800	8,700	800	9,500	23,000	8,900	31,900
10	5,600	700	6,300	6,900	1,000	7,900	9,000	800	9,800	23,000	8,100	31,100
11	5,500	700	6,200	6,700	1,000	7,700	8,500	800	9,300	20,000	7,000	27,000
12	5,800	700	6,500	6,800	900	7,700	8,600	800	9,400	16,000	6,300	22,300
13	6,000	700	6,700	6,700	900	7,600	8,600	900	9,500	14,000	5,900	19,900
14	6,100	700	6,800	6,800	900	7,700	8,600	900	9,500	12,000	5,400	17,400
15	6,300	700	7,000	6,900	900	7,800	8,300	900	9,200	11,000	5,200	16,200
16	6,200	700	6,900	7,100	900	8,000	8,100	900	9,000	11,000	4,400	15,400
17	6,300	700	7,000	7,100	900	8,000	7,900	900	8,800	11,000	4,300	15,300
18	7,000	700	7,700	7,100	900	8,000	8,300	1,000	9,300	11,000	4,400	15,400
19	7,300	800	8,100	7,000	900	7,900	8,500	1,200	9,700	11,000	4,200	15,200
20	7,200	800	8,000	6,500	900	7,400	11,000	1,600	12,600	10,000	3,700	13,700
21	7,100	800	7,900	6,300	900	7,700	13,000	3,200	16,200	10,000	3,700	13,700
22	6,600	800	7,400	7,000	900	7,900	18,000	5,100	23,100	9,500	3,900	13,400
23	6,200	800	7,000	8,000	1,000	9,000	20,000	4,000	24,000	9,800	3,600	13,400
24	6,000	900	6,900	9,000	1,100	10,100	23,000	8,900	31,900	9,700	3,700	13,400
25	6,000	700	6,700	11,000	1,000	12,000	24,000	10,600	34,600	10,000	3,600	13,600
26	6,200	800	7,000	12,000	900	12,900	33,000	12,600	45,600	10,000	3,500	13,500
27	6,300	800	7,100	11,000	1,000	12,000	39,000	15,600	54,600	10,000	3,500	13,500
28	6,700	800	7,500	11,000	1,000	12,000	45,000	13,400	58,400	10,000	3,500	13,500
29	6,700	900	7,600	11,000	1,000	12,000	44,000	10,400	54,400	9,900	3,500	13,400
30	6,400	800	7,200	11,000	1,000	12,000	39,000	9,400	48,400	9,900	4,600	14,500
31	6,400	900	7,300	----------	----------	----------	36,000	9,700	45,700	11,000	5,800	16,800
Totals in acre-feet	378,400	45,100	423,500	465,700	54,400	520,100	1,039,700	242,500	1,282,200	1,078,700	422,100	1,500,800

Total for season 1921–1922, in acre-feet .... Sacramento River 18,279,400
Total for season 1921–1922, in acre-feet .... San Joaquin River 8,350,000
Total for season 1921–1922, in acre-feet .... Combined rivers 26,629,400

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1921-1922

Flow in second-feet

Day	February, 1922			March, 1922			April, 1922			May, 1922		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	10,000	6,800	16,800	76,800	16,100	92,900	54,000	22,300	76,300	63,000	22,500	85,500
2	11,000	6,600	17,600	73,400	13,900	87,300	57,100	14,700	71,800	62,700	23,900	86,600
3	11,000	6,100	17,100	68,200	12,400	80,600	57,600	17,100	74,700	62,400	24,800	87,200
4	10,000	5,400	15,400	61,400	11,600	73,000	58,600	17,700	76,300	62,300	26,900	89,200
5	10,000	5,200	15,200	56,000	11,300	67,300	59,600	16,800	76,400	64,000	30,500	94,500
6	10,000	4,900	14,900	51,100	9,700	60,800	59,100	15,100	74,200	66,800	34,800	101,600
7	10,000	4,800	14,800	46,500	8,700	55,200	57,800	13,800	71,600	70,300	37,200	107,500
8	12,000	7,400	19,400	41,100	7,900	49,000	55,900	13,400	69,300	71,600	34,000	105,600
9	33,000	39,700	72,700	37,000	7,300	44,300	54,800	12,700	67,500	71,800	26,800	98,600
10	58,000	44,500	102,500	33,300	7,000	40,300	52,600	11,500	64,100	70,000	20,900	90,900
11	66,000	43,700	109,700	31,600	8,900	40,500	50,400	10,700	61,100	66,200	17,300	83,500
12	59,000	26,700	85,700	31,500	8,700	40,200	47,800	10,200	58,000	66,200	17,000	83,200
13	49,000	21,500	70,500	30,600	8,900	39,500	46,000	10,200	56,200	58,400	20,700	79,100
14	41,000	18,500	59,500	29,800	9,200	39,000	44,100	9,500	53,600	56,700	27,300	84,000
15	34,000	17,000	51,000	30,000	9,200	39,200	42,600	8,800	51,400	55,600	34,600	90,200
16	31,000	15,400	46,400	34,400	22,600	57,000	40,100	7,800	47,900	58,700	38,900	97,600
17	30,000	14,600	44,600	42,200	21,500	63,700	37,400	7,200	44,600	62,300	40,300	102,600
18	36,000	22,300	58,300	42,400	18,700	61,100	34,800	5,800	40,600	66,000	43,500	109,500
19	56,000	25,900	81,900	40,200	16,500	56,700	32,600	6,600	39,200	70,000	41,700	111,700
20	77,000	54,000	131,000	37,200	16,200	53,400	31,400	7,500	38,900	72,400	40,700	113,100
21	75,000	33,500	108,500	35,100	15,300	50,400	32,200	9,600	41,800	77,700	33,300	111,000
22	63,000	26,400	94,400	34,000	14,500	48,500	35,000	11,300	46,300	73,100	30,200	103,300
23	67,000	22,000	89,000	33,700	14,400	48,100	38,800	13,600	52,400	72,400	33,400	105,800
24	64,000	21,000	85,000	34,200	14,900	49,100	43,800	16,300	60,100	72,400	39,200	111,600
25	62,000	20,900	82,900	35,600	14,400	50,000	48,500	18,000	66,500	72,800	41,600	114,400
26	62,000	21,300	83,300	37,300	15,000	52,300	53,000	19,500	72,500	72,100	31,900	104,000
27	71,000	21,900	92,900	39,100	15,000	54,100	57,000	20,700	77,700	67,100	30,800	97,900
28	70,000	18,700	88,700	40,000	17,200	57,200	59,500	21,700	81,200	63,800	34,900	98,700
29	------	------	------	42,400	17,000	59,400	61,800	22,800	84,600	62,600	38,700	101,300
30	------	------	------	45,600	17,200	62,800	63,000	22,200	85,200	60,700	41,500	102,200
31	------	------	------	49,600	22,600	72,200	------	------	------	62,400	45,700	108,100
Totals in acre-feet	2,362,100	1,141,900	3,504,000	2,616,200	839,100	3,455,300	2,904,500	821,900	3,726,400	4,067,900	1,990,900	6,058,800

Total for season 1921-1922, in acre-feet .... Sacramento River 18,279,400
Total for season 1921-1920, in acre-feet .... San Joaquin River 8,350,000
Total for season 1921-1922, in acre-feet .... Combined rivers 26,629,400

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1921-1922

Flow in second-feet

Day	June, 1922			July, 1922			August, 1922			September, 1922		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	64,900	45,200	110,100	15,100	22,600	37,700	4,400	2,100	6,500	3,500	900	4,400
2	63,800	46,000	109,800	13,800	21,200	35,000	4,500	2,000	6,500	3,400	900	4,300
3	63,900	48,200	112,100	12,600	20,100	32,700	4,300	1,900	6,200	3,400	900	4,300
4	65,800	48,300	114,100	11,700	19,200	30,900	4,300	1,800	6,100	3,500	900	4,400
5	63,900	48,500	112,400	11,400	18,800	30,200	4,200	1,800	6,000	3,400	900	4,300
6	62,800	45,900	108,700	11,100	18,400	29,500	4,000	1,800	5,800	3,300	900	4,200
7	60,200	42,600	102,800	10,500	16,900	27,400	4,100	1,700	5,800	3,500	900	4,400
8	56,600	41,500	98,100	9,800	15,500	25,300	3,800	1,600	5,400	3,700	900	4,600
9	52,800	38,900	91,700	9,100	13,600	22,700	4,000	1,600	5,600	3,800	900	4,700
10	50,000	34,900	84,900	8,200	11,200	19,400	3,900	1,500	5,400	4,000	900	4,900
11	48,300	32,200	80,500	7,800	9,600	17,400	3,800	1,500	5,300	4,500	900	5,300
12	42,200	33,600	75,800	7,700	8,300	16,000	3,600	1,400	5,000	4,700	800	5,500
13	40,100	34,600	74,700	7,400	6,700	14,100	3,500	1,400	4,900	4,500	800	5,200
14	38,700	32,200	70,900	7,200	6,000	13,200	3,400	1,400	4,800	4,500	700	5,200
15	36,600	34,900	71,500	7,000	4,900	11,900	3,300	1,400	4,700	4,500	700	5,200
16	36,300	37,500	73,800	6,700	4,500	11,200	3,300	1,300	4,600	4,600	700	5,300
17	36,900	38,100	75,000	6,000	4,000	10,000	3,300	1,300	4,600	4,500	700	5,200
18	35,400	36,500	71,900	5,700	3,700	9,400	3,400	1,300	4,700	4,400	700	5,100
19	34,200	36,300	70,500	5,800	3,200	9,000	3,400	1,200	4,600	4,300	700	5,000
20	33,100	36,000	69,100	5,700	4,100	9,800	3,200	1,200	4,400	4,700	700	5,400
21	31,100	34,100	65,200	5,500	3,600	9,100	3,200	1,100	4,300	5,000	700	5,700
22	29,100	32,100	61,200	5,400	3,100	8,500	3,100	1,200	4,300	5,000	700	5,700
23	27,700	30,200	57,900	5,100	2,700	7,800	3,100	1,100	4,200	5,100	700	5,800
24	24,500	28,600	53,100	4,900	2,600	7,500	3,300	1,100	4,400	5,400	700	6,100
25	21,800	27,500	49,300	4,600	2,200	6,800	3,400	1,100	4,500	5,300	700	6,000
26	21,700	29,700	51,400	4,800	2,200	7,000	3,300	1,100	4,400	5,400	700	6,100
27	21,100	31,000	52,100	4,700	2,000	6,700	3,400	1,100	4,500	5,700	700	6,400
28	20,600	29,400	50,000	4,700	2,000	6,700	3,300	1,100	4,400	5,900	700	6,600
29	18,300	26,600	44,900	4,700	1,800	6,500	3,200	1,000	4,200	5,800	700	6,500
30	17,000	25,000	42,000	4,600	1,700	6,300	3,300	1,000	4,300	5,900	700	6,600
31	------	------	------	4,500	1,500	6,000	3,400	900	4,300	------	------	------
Totals in acre-feet	2,414,400	2,150,500	4,564,900	462,900	510,600	973,500	221,200	85,100	306,300	267,700	45,900	313,600

Total for season 1921-1922, in acre-feet........Sacramento River........18,279,400
Total for season 1921-1922, in acre-feet........San Joaquin River........8,350,000
Total for season 1921-1922, in acre-feet........Combined rivers........26,629,400

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1922-1923

Flow in second-feet

Day	October, 1922			November, 1922			December, 1922			January, 1923		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	6,000	800	6,800	7,000	1,300	8,300	8,000	1,600	9,600	60,000	9,200	69,200
2	6,000	800	6,800	7,000	1,300	8,300	8,000	2,600	10,600	56,000	8,500	64,500
3	6,200	900	7,100	7,000	1,400	8,400	8,000	3,300	11,300	52,000	7,900	59,900
4	7,100	900	8,000	7,000	1,400	8,400	8,000	2,000	10,000	46,000	7,400	53,400
5	8,600	1,000	9,600	7,000	1,400	8,400	9,000	2,000	11,000	38,000	7,100	45,100
6	9,700	1,000	10,700	7,500	1,400	8,900	14,000	3,400	17,400	34,000	6,800	40,800
7	9,500	1,000	10,500	8,000	1,800	9,800	20,000	7,400	27,400	30,000	6,500	36,500
8	8,800	1,100	9,900	14,000	2,200	16,200	21,000	7,500	28,500	26,000	6,200	32,200
9	8,300	1,000	9,300	20,000	4,500	24,500	21,000	4,400	25,400	24,000	6,100	30,100
10	8,000	1,000	9,000	26,000	4,800	30,800	44,000	9,200	53,200	22,000	5,700	27,700
11	8,200	1,000	9,200	25,000	5,200	30,200	48,000	12,700	60,700	20,000	5,500	25,500
12	8,300	1,000	9,300	24,000	4,600	28,600	50,000	26,400	76,400	18,000	5,200	23,200
13	8,400	1,000	9,400	18,000	3,600	21,600	67,000	39,400	106,400	17,000	4,800	21,800
14	8,700	1,000	9,700	13,000	3,300	16,300	80,000	30,300	110,300	16,000	4,800	20,800
15	8,400	1,000	9,400	11,000	2,900	13,900	70,000	20,300	90,300	16,000	4,700	20,700
16	8,100	1,000	9,100	10,000	2,900	12,900	63,000	15,100	78,100	16,000	4,700	20,700
17	7,800	1,000	8,800	10,000	2,800	12,800	56,000	13,800	69,800	20,000	7,400	27,400
18	8,000	1,000	9,000	10,000	2,600	12,600	48,000	12,600	60,600	28,000	8,000	36,000
19	8,000	1,000	9,000	10,000	2,500	12,500	40,000	10,800	50,800	32,000	7,300	39,300
20	8,300	1,000	9,300	9,000	1,800	10,800	41,000	9,700	50,700	32,000	6,400	38,400
21	8,100	1,000	9,100	9,000	1,700	10,700	30,000	8,600	38,600	30,000	6,000	36,000
22	7,900	1,000	8,900	9,000	1,700	10,700	26,000	7,700	33,700	28,000	7,100	35,100
23	7,500	1,000	8,500	8,500	3,500	12,000	27,000	7,200	34,200	32,000	19,400	51,400
24	7,500	1,100	8,600	8,500	2,500	11,000	21,000	6,400	27,400	46,000	28,400	74,400
25	7,600	1,100	8,700	8,000	1,700	9,700	18,000	6,200	24,200	46,000	22,400	68,400
26	7,800	1,100	8,900	8,000	1,700	9,700	16,000	5,700	21,700	44,000	16,400	60,400
27	7,800	1,100	8,900	8,000	1,600	9,600	20,000	5,100	25,100	40,000	14,500	54,500
28	8,100	1,200	9,300	8,000	1,700	9,700	33,000	20,100	53,100	36,000	13,500	49,500
29	8,200	1,200	9,400	8,000	1,600	9,600	53,000	10,800	63,800	32,000	13,900	45,900
30	7,900	1,200	9,100	8,000	1,600	9,600	56,000	8,500	64,500	30,000	13,800	43,800
31	7,700	1,200	8,900				55,000	8,700	63,700	26,000	11,800	37,800
Totals in acre-feet	488,100	62,800	550,900	660,300	144,500	804,800	2,136,400	652,400	2,788,800	1,966,100	588,900	2,555,000

Total for season 1922–1923, in acre-feet	Sacramento River	13,405,500
Total for season 1922–1923, in acre-feet	San Joaquin River	5,188,000
Total for season 1922–1923, in acre-feet	Combined rivers	18,593,500

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1922-1923

Flow in second-feet

Day	February, 1923			March, 1923			April, 1923			May, 1923		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	24,000	9,600	33,600	22,000	5,300	27,300	23,900	3,800	27,700	28,700	8,900	37,600
2	22,000	8,200	30,200	22,000	6,000	28,000	24,600	4,200	28,800	28,500	9,800	38,300
3	20,000	8,200	28,200	22,000	6,000	28,000	26,400	4,800	31,200	28,600	10,600	39,200
4	18,000	9,500	27,500	21,000	5,600	26,600	28,000	4,300	32,300	28,600	11,100	39,700
5	17,000	9,800	26,800	20,000	5,700	25,700	29,600	5,900	35,500	28,200	13,300	41,500
6	17,000	9,300	26,300	19,000	5,900	24,900	43,400	22,300	65,700	29,100	15,300	44,400
7	17,000	8,200	25,200	18,000	5,100	23,100	48,200	20,100	68,300	30,200	21,300	51,500
8	17,000	7,000	24,000	18,000	4,900	22,900	58,400	14,500	72,900	31,900	23,600	55,500
9	17,000	7,200	24,200	18,000	4,900	22,900	57,600	12,800	70,400	33,500	23,800	57,300
10	17,000	6,900	23,900	18,000	4,900	22,900	59,100	17,100	76,200	33,800	25,000	58,800
11	17,000	6,700	23,700	17,000	4,700	21,700	60,200	18,900	79,100	34,700	23,100	57,800
12	17,000	8,900	25,900	17,000	4,400	21,400	58,700	17,400	76,100	33,800	22,000	55,800
13	19,000	8,900	27,900	17,000	4,300	21,300	57,000	16,200	73,200	31,600	17,900	49,500
14	20,000	8,300	28,300	17,000	4,200	21,200	55,100	15,700	70,800	29,300	19,100	48,400
15	19,000	7,800	26,800	17,000	4,200	21,200	52,300	15,400	67,700	29,300	19,800	49,100
16	18,000	6,800	24,800	17,000	3,900	20,900	50,100	17,800	67,900	30,100	24,300	54,400
17	17,000	6,600	23,600	17,000	3,900	20,900	48,500	19,800	68,300	32,200	24,000	56,200
18	17,000	6,300	23,300	17,000	3,400	20,400	47,300	18,800	66,100	32,200	22,400	54,600
19	18,000	6,200	24,200	17,000	3,000	20,000	45,000	17,700	62,700	30,100	20,800	50,900
20	18,000	6,200	24,200	17,000	3,700	20,700	42,300	16,500	58,800	28,400	19,000	47,400
21	18,000	6,000	24,000	17,000	3,500	20,500	40,500	16,300	56,800	25,800	17,700	43,500
22	19,000	6,100	25,100	17,000	3,700	20,700	38,200	15,000	53,200	23,900	17,300	41,200
23	21,000	6,500	27,500	17,000	3,500	20,500	35,400	13,800	49,200	23,700	18,200	41,900
24	22,000	7,200	29,200	17,000	3,200	20,200	33,100	12,600	45,700	24,400	21,700	46,100
25	22,000	7,600	29,600	17,000	3,400	20,400	30,500	10,900	41,400	25,200	23,200	48,400
26	22,000	8,600	30,600	17,000	3,700	20,700	30,200	10,600	40,800	25,500	20,600	46,100
27	22,000	8,400	30,400	18,000	4,100	22,100	29,600	9,800	39,400	24,100	18,500	42,600
28	22,000	6,400	28,400	20,000	4,200	24,200	28,800	8,800	37,600	21,100	17,000	38,100
29				22,000	4,200	26,200	29,200	9,100	38,300	18,800	15,800	34,600
30				22,000	4,200	26,200	29,200	8,900	38,100	20,800	15,500	36,300
31				23,000	4,500	27,500				20,000	14,200	34,200
Totals in acre-feet	1,057,300	422,500	1,479,800	1,138,500	269,700	1,408,200	2,456,000	791,600	3,247,600	1,714,900	1,138,100	2,853,000

Total for season 1922-1923, in acre-feet........Sacramento River........ 13,405,500
Total for season 1922-1923, in acre-feet........San Joaquin River........ 5,188,000
Total for season 1922-1923, in acre-feet........Combined rivers........ 18,593,500

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1922-1923

Flow in second-feet

Day	June, 1923			July, 1923			August, 1923			September, 1923		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	17,700	12,800	30,500	11,000	10,800	21,800	4,000	1,900	5,900	3,700	1,300	5,000
2	16,600	11,900	28,500	10,400	10,900	21,300	4,100	1,800	5,900	3,700	1,200	4,900
3	15,000	11,600	26,600	9,700	10,500	20,200	3,900	1,800	5,700	3,700	1,200	4,900
4	16,100	11,500	27,600	9,000	10,500	19,500	3,800	1,800	5,600	3,500	1,300	4,800
5	15,700	11,100	26,800	8,600	10,300	18,900	3,700	1,800	5,500	3,700	1,200	4,900
6	15,600	10,600	26,200	8,000	9,800	17,800	3,600	1,700	5,300	4,100	1,200	5,300
7	16,400	10,600	27,000	8,100	8,000	16,100	3,300	1,700	5,000	4,300	1,200	5,500
8	16,500	10,100	26,600	7,700	7,800	15,500	3,600	1,600	5,200	4,300	1,100	5,400
9	17,400	10,100	27,500	7,100	7,900	15,000	3,800	1,600	5,400	4,200	1,200	5,400
10	18,500	12,400	30,900	6,900	7,700	14,600	3,800	1,600	5,400	4,100	1,100	5,200
11	19,100	13,900	33,000	7,100	6,700	13,800	3,600	1,600	5,200	3,900	1,100	5,000
12	18,200	16,800	35,000	6,800	5,700	12,500	3,300	1,600	4,900	4,200	1,200	5,400
13	15,600	16,400	32,000	6,500	5,000	11,500	3,400	1,700	5,100	4,700	1,100	5,800
14	14,100	11,000	25,100	6,300	4,400	10,700	3,200	1,800	5,000	5,000	1,200	6,200
15	12,800	9,400	22,200	6,100	3,900	10,000	3,500	1,700	5,200	5,300	1,200	6,500
16	12,900	9,800	22,700	5,900	3,700	9,600	4,100	1,700	5,800	5,400	1,200	6,600
17	12,500	9,900	22,400	5,600	3,500	9,100	3,900	1,600	5,500	5,100	1,100	6,200
18	11,800	9,400	21,200	5,500	3,200	8,700	3,700	1,500	5,200	4,700	1,200	5,900
19	11,600	8,700	20,300	5,500	3,100	8,600	3,600	1,500	5,100	4,800	1,200	6,000
20	11,800	8,100	19,900	5,400	2,900	8,300	3,300	1,500	4,800	4,900	1,200	6,100
21	11,900	7,500	19,400	5,500	2,800	8,300	3,000	1,500	4,500	5,300	1,200	6,500
22	11,900	7,500	19,400	5,300	2,700	8,000	3,200	1,400	4,600	5,700	1,200	6,900
23	11,900	6,500	18,400	5,000	2,700	7,700	3,600	1,400	5,000	6,000	1,300	7,300
24	15,100	7,000	22,100	4,600	2,600	7,200	3,600	1,400	5,000	6,400	1,500	7,900
25	15,400	7,900	23,300	4,600	2,400	7,000	3,500	1,300	4,800	6,600	2,000	8,600
26	14,200	8,900	23,100	4,600	2,300	6,900	3,300	1,300	4,600	7,800	2,400	10,200
27	13,100	8,700	21,800	4,500	2,200	6,700	3,200	1,300	4,500	9,600	2,600	12,200
28	12,200	9,700	21,900	4,400	2,100	6,500	3,000	1,300	4,300	9,000	2,700	11,700
29	12,100	10,000	22,100	4,100	2,000	6,100	3,300	1,200	4,500	8,600	2,800	11,400
30	11,700	10,400	22,100	3,800	1,900	5,700	3,400	1,200	4,600	8,100	2,800	10,900
31				3,800	2,000	5,800	3,500	1,200	4,700			
Totals in acre-feet	862,100	614,200	1,476,300	390,800	320,800	711,600	217,400	95,000	312,400	317,600	87,500	405,100

Total for season 1922–1923, in acre-feet	Sacramento River	13,405,500
Total for season 1922–1923, in acre-feet	San Joaquin River	5,188,000
Total for season 1922–1923, in acre-feet	Combined rivers	18,593,500

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1923-1924

Flow in second-feet

Day	October, 1923			November, 1923			December, 1923			January, 1924		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	7,400	2,900	10,300	7,300	1,600	8,900	6,500	1,600	8,100	7,100	1,900	9,000
2	7,000	3,000	10,000	7,300	1,600	8,900	6,700	1,600	8,300	7,200	1,900	9,100
3	7,200	3,000	10,200	7,200	1,500	8,700	6,700	1,600	8,300	6,800	1,900	8,700
4	7,200	3,000	10,200	7,100	1,500	8,600	6,400	1,600	8,000	7,000	2,000	9,000
5	7,500	3,000	10,500	6,900	1,500	8,400	6,400	1,600	8,000	7,400	1,900	9,300
6	8,000	3,100	11,100	6,800	1,600	8,400	6,400	1,600	8,000	7,400	1,900	9,300
7	8,200	3,100	11,300	7,000	1,600	8,600	6,500	1,700	8,200	7,300	1,900	9,200
8	8,800	3,200	12,000	7,000	1,600	8,600	7,800	1,700	9,500	7,100	2,000	9,100
9	8,300	3,200	11,500	6,900	1,600	8,500	7,900	1,800	9,700	7,400	1,900	9,300
10	8,000	3,200	11,200	7,000	1,600	8,600	7,100	1,800	8,900	7,600	1,800	9,400
11	7,900	3,300	11,200	7,000	1,600	8,600	6,600	1,800	8,400	7,400	1,800	9,200
12	7,800	3,400	11,200	6,600	1,500	8,100	6,800	1,900	8,700	7,500	1,700	9,200
13	7,800	4,000	11,800	6,600	1,600	8,200	7,000	1,900	8,900	7,300	1,700	9,000
14	7,200	4,700	11,900	7,000	1,600	8,600	7,500	1,900	9,400	7,300	1,700	9,000
15	6,900	4,700	11,600	7,100	1,600	8,700	7,800	2,000	9,800	7,000	1,600	8,600
16	6,900	4,400	11,300	7,200	1,600	8,800	7,800	1,900	9,700	7,300	1,700	9,000
17	7,200	3,200	10,400	7,200	1,600	8,800	7,400	1,900	9,300	7,300	1,700	9,000
18	7,200	2,700	9,900	7,000	1,600	8,600	7,400	1,900	9,300	7,300	1,700	9,000
19	7,100	2,600	9,700	6,900	1,600	8,500	7,700	1,900	9,600	7,200	1,700	8,900
20	7,000	2,600	9,600	6,800	1,600	8,400	7,600	1,900	9,500	7,100	1,600	8,700
21	7,000	2,600	9,600	6,700	1,500	8,200	7,600	1,900	9,500	7,000	1,600	8,600
22	6,900	2,100	9,000	6,700	1,500	8,200	7,500	1,900	9,400	7,000	1,600	8,600
23	7,000	1,900	8,900	6,700	1,500	8,200	7,600	1,800	9,400	7,000	1,700	8,700
24	7,100	1,800	8,900	6,700	1,600	8,300	7,300	1,800	9,100	6,900	1,700	8,600
25	7,500	1,700	9,200	6,500	1,500	8,000	7,000	1,900	8,900	7,300	1,800	9,100
26	7,700	1,700	9,400	6,500	1,500	8,000	7,200	1,900	9,100	7,500	1,800	9,300
27	7,400	1,700	9,100	6,300	1,500	7,800	7,000	2,000	9,000	8,500	1,800	10,300
28	7,200	1,600	8,800	6,500	1,500	8,000	7,100	2,000	9,100	12,400	2,100	14,500
29	6,900	1,600	8,500	6,400	1,500	7,900	7,000	2,000	9,000	16,000	2,100	18,100
30	7,000	1,500	8,500	6,600	1,600	8,200	7,000	1,900	8,900	16,300	2,000	18,300
31	7,200	1,400	8,600				7,100	1,900	9,000	14,300	2,100	16,400
Totals in acre-feet	454,400	170,100	624,500	406,900	92,700	499,600	438,400	112,100	550,500	505,300	111,500	616,800

Total for season 1923-1924, in acre-feet ... Sacramento River ... 4,532,700
Total for season 1923-1924, in acre-feet ... San Joaquin River ... 1,043,400
Total for season 1923-1924, in acre-feet ... Combined rivers ... 5,576,100

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1923-1924

Flow in second-feet

Day	February, 1924			March, 1924			April, 1924			May, 1924		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	12,000	2,100	14,100	9,800	1,500	11,300	7,800	1,500	9,300	5,000	2,400	7,400
2	10,300	2,000	12,300	9,800	1,500	11,300	7,500	1,500	9,000	5,100	2,500	7,600
3	10,700	2,000	12,700	9,700	1,400	11,100	7,600	1,500	9,100	5,300	2,800	8,100
4	10,900	1,900	12,800	9,500	1,500	11,000	8,200	1,700	9,900	4,800	3,000	7,800
5	11,900	1,800	13,700	9,500	1,500	11,000	8,000	1,800	9,800	4,400	2,700	7,100
6	11,700	2,000	13,700	9,400	1,400	10,800	8,200	1,700	9,900	4,400	3,000	7,400
7	15,200	2,400	17,600	9,300	1,300	10,600	8,900	1,700	10,600	4,400	2,800	7,200
8	41,700	3,800	45,500	9,000	1,300	10,300	10,200	2,100	12,300	4,300	2,700	7,000
9	39,600	3,400	43,000	8,600	1,200	9,800	10,400	2,200	12,600	4,300	2,800	7,100
10	47,800	2,600	50,400	8,300	1,200	9,500	11,200	2,300	13,500	4,400	3,000	7,400
11	48,400	2,300	50,700	8,400	1,200	9,600	11,200	2,800	14,000	4,000	3,000	7,000
12	43,600	2,100	45,700	8,100	1,100	9,200	10,800	3,000	13,800	4,000	2,900	6,900
13	36,400	2,100	38,500	8,200	1,100	9,300	10,300	3,200	13,500	4,300	2,800	7,100
14	29,700	2,000	31,700	8,000	1,000	9,000	10,500	3,600	14,100	3,700	2,600	6,300
15	24,800	1,900	26,700	8,100	1,100	9,200	9,700	3,500	13,200	3,400	2,400	5,800
16	19,800	1,800	21,600	8,000	1,000	9,000	8,700	3,200	11,900	3,800	2,400	6,200
17	17,600	1,800	19,400	7,200	1,000	8,200	8,100	2,600	10,700	3,800	2,200	6,000
18	15,400	1,700	17,100	7,200	1,000	8,200	7,700	2,600	10,300	3,600	2,000	5,600
19	14,500	1,800	16,300	7,200	1,000	8,200	7,100	2,600	9,700	3,500	1,900	5,400
20	13,400	1,800	15,200	7,200	1,000	8,200	7,300	2,400	9,700	3,200	1,800	5,000
21	13,200	1,800	15,000	7,100	1,000	8,100	7,700	2,500	10,200	3,100	1,800	4,900
22	12,500	1,800	14,300	6,900	1,000	7,900	7,600	2,500	10,100	3,000	1,500	4,500
23	12,000	1,800	13,800	6,600	1,100	7,700	7,300	2,500	9,800	3,800	1,400	5,200
24	11,100	1,800	12,900	6,700	1,100	7,800	7,400	2,300	9,700	2,600	1,400	4,000
25	10,800	1,700	12,500	7,300	1,300	8,600	6,900	2,200	9,100	2,600	1,200	3,800
26	10,300	1,700	12,000	8,000	1,500	9,500	6,000	2,000	8,000	2,600	1,100	3,700
27	10,200	1,600	11,800	8,400	1,500	9,900	6,100	1,900	8,000	2,500	1,000	3,500
28	9,700	1,600	11,300	8,300	1,500	9,800	5,800	1,900	7,700	2,400	900	3,300
29	9,700	1,600	11,300	8,100	1,400	9,500	5,500	1,800	7,300	2,300	800	3,100
30	------	------	------	8,000	1,500	9,500	5,300	2,200	7,500	2,100	800	2,900
31	------	------	------	7,900	1,500	9,400	------	------	------	2,000	700	2,700
Totals in acre-feet	1,138,300	116,200	1,254,500	502,500	76,600	579,100	485,100	137,200	622,300	223,100	127,300	350,400

Total for season 1923-1924, in acre-feet .... Sacramento River 4,532,700
Total for season 1923-1924, in acre-feet .... San Joaquin River 1,043,400
Total for season 1923-1924, in acre-feet .... Combined rivers 5,576,100

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1923-1924

Flow in second-feet

Day	June, 1924			July, 1924			August, 1924			September, 1924		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	1,800	800	2,600	900	400	1,300	900	400	1,300	1,900	300	2,200
2	1,700	800	2,500	900	400	1,300	1,000	400	1,400	1,800	300	2,100
3	1,700	800	2,500	800	300	1,100	1,000	400	1,400	1,800	400	2,200
4	1,700	700	2,400	1,000	400	1,400	1,000	400	1,400	1,900	400	2,300
5	1,500	700	2,200	900	300	1,200	1,000	400	1,400	1,900	300	2,200
6	1,500	600	2,100	800	400	1,200	1,100	300	1,400	1,900	400	2,300
7	1,500	700	2,200	900	400	1,300	1,000	300	1,300	2,000	400	2,400
8	1,500	700	2,200	900	400	1,300	1,000	300	1,300	2,000	400	2,400
9	1,300	600	1,900	900	400	1,300	1,000	400	1,400	2,100	400	2,500
10	1,200	600	1,800	900	300	1,200	1,000	400	1,400	2,200	400	2,600
11	1,200	500	1,700	900	300	1,200	1,000	300	1,300	2,300	400	2,700
12	1,300	600	1,900	900	300	1,200	1,000	300	1,300	2,500	300	2,800
13	1,300	600	1,900	900	400	1,300	1,000	300	1,300	2,600	300	2,900
14	1,300	600	1,900	1,000	300	1,300	1,000	300	1,300	2,800	300	3,100
15	1,300	600	1,900	900	400	1,300	1,100	300	1,400	2,800	400	3,200
16	1,300	600	1,900	700	300	1,000	1,200	300	1,500	2,800	400	3,200
17	1,300	500	1,800	700	300	1,000	1,300	400	1,700	2,800	400	3,200
18	1,400	600	2,000	800	300	1,100	1,300	400	1,700	3,000	400	3,400
19	1,400	500	1,900	900	300	1,200	1,300	400	1,700	3,000	400	3,400
20	1,400	500	1,900	900	400	1,300	1,400	400	1,800	3,100	400	3,500
21	1,300	500	1,800	1,200	400	1,600	1,500	400	1,900	3,200	400	3,600
22	1,400	500	1,900	1,100	300	1,400	1,700	300	2,000	3,300	400	3,700
23	1,200	500	1,700	1,000	400	1,400	1,800	400	2,200	3,300	400	3,700
24	1,100	500	1,600	1,000	400	1,400	1,900	300	2,200	3,300	400	3,700
25	1,000	400	1,400	900	400	1,300	1,900	300	2,200	3,400	300	3,700
26	1,100	400	1,500	900	400	1,300	2,000	300	2,300	3,500	400	3,900
27	1,100	400	1,500	900	400	1,300	2,000	400	2,400	3,600	400	4,000
28	1,000	400	1,400	900	400	1,300	1,900	400	2,300	3,500	400	3,900
29	1,000	500	1,500	800	300	1,100	2,100	300	2,400	3,500	400	3,900
30	1,000	400	1,400	800	300	1,100	2,100	300	2,400	3,300	400	3,700
31	--------	--------	--------	900	400	1,300	2,000	300	2,300	--------	--------	--------
Totals in acre-feet	78,800	33,900	112,700	55,200	22,000	77,200	84,100	21,400	105,500	160,600	22,400	183,000

Total for season 1923-1924, in acre-feet..........Sacramento River.......... 4,532,700
Total for season 1923-1924, in acre-feet..........San Joaquin River.......... 1,043,400
Total for season 1923-1924, in acre-feet..........Combined rivers.......... 5,576,100

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1924-1925

Flow in second-feet

Day	October, 1924			November, 1924			December, 1924			January, 1925		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	3,400	300	3,700	8,800	1,100	9,900	7,800	1,800	9,600	28,000	8,900	36,900
2	3,500	400	3,900	8,100	1,000	9,100	7,800	1,800	9,600	23,700	7,700	31,400
3	3,600	400	4,000	8,000	900	8,900	8,200	1,800	10,000	20,200	6,900	27,100
4	3,500	400	3,900	7,800	1,000	8,800	9,300	1,800	11,100	18,700	5,000	23,700
5	3,600	500	4,100	7,700	1,000	8,700	10,500	1,800	12,300	17,200	3,900	21,100
6	3,900	500	4,400	7,800	900	8,700	11,200	1,700	12,900	15,500	3,000	18,500
7	4,500	500	5,000	7,700	900	8,600	11,600	1,700	13,300	14,600	2,400	17,000
8	5,000	500	5,500	7,600	1,300	8,900	13,100	2,300	15,400	13,800	2,300	16,100
9	5,000	600	5,600	11,900	1,700	13,600	16,800	2,900	19,700	13,200	2,200	15,400
10	4,900	600	5,500	22,900	2,300	25,200	17,200	2,900	20,100	12,800	2,300	15,100
11	4,900	600	5,500	22,900	5,700	28,600	16,000	3,000	19,000	12,400	2,100	14,500
12	5,100	700	5,800	20,500	4,100	24,600	14,600	2,800	17,400	11,800	1,900	13,700
13	5,000	600	5,600	16,800	3,100	19,900	13,400	2,500	15,900	11,500	1,800	13,300
14	4,900	600	5,500	14,300	2,600	16,900	12,500	2,400	14,900	11,900	1,800	13,700
15	5,200	600	5,800	12,500	2,500	15,000	12,100	2,300	14,400	12,200	1,900	14,100
16	5,300	600	5,900	11,200	2,400	13,600	11,600	2,300	13,900	12,100	1,700	13,800
17	5,500	700	6,200	10,400	2,300	12,700	11,700	2,300	14,000	12,100	1,600	13,700
18	5,700	700	6,400	9,800	1,800	11,600	11,900	2,300	14,200	11,800	1,700	13,500
19	6,000	700	6,700	9,400	1,700	11,100	11,400	2,400	13,800	11,500	1,600	13,100
20	6,000	700	6,700	9,100	1,800	10,900	10,500	2,400	12,900	11,300	1,500	12,800
21	5,800	700	6,500	9,000	1,800	10,800	11,300	2,600	13,900	11,000	1,500	12,500
22	5,800	700	6,500	11,000	1,800	12,800	34,400	4,000	38,400	11,000	1,400	12,400
23	5,700	600	6,300	13,700	1,800	15,500	30,400	3,500	33,900	10,900	1,400	12,300
24	5,700	600	6,300	13,000	1,800	14,800	22,600	4,100	26,700	10,700	1,400	12,100
25	5,800	600	6,400	11,500	1,800	13,300	18,200	3,900	22,100	12,100	1,500	13,600
26	5,900	600	6,500	10,700	1,800	12,500	15,500	3,600	19,100	17,600	2,100	19,700
27	5,900	600	6,500	9,900	1,800	11,700	13,800	3,100	16,900	17,000	2,200	19,200
28	6,000	600	6,600	9,300	1,900	11,200	13,400	3,200	16,600	19,100	2,100	21,200
29	7,600	700	8,300	8,600	1,800	10,400	14,100	3,200	17,300	20,800	2,300	23,100
30	11,700	900	12,600	8,400	1,800	10,200	17,200	5,600	22,800	20,600	2,100	22,700
31	10,200	1,000	11,200	------	------	------	27,000	8,100	35,100	20,400	1,900	22,300
Totals in acre-feet	337,800	37,200	375,000	673,800	115,200	789,000	905,100	178,400	1,083,500	925,600	162,600	1,088,200

Total for season 1924-1925, in acre-feet	Sacramento River	16,764,400
Total for season 1924-1925, in acre-feet	San Joaquin River	4,684,600
Total for season 1924-1925, in acre-feet	Combined rivers	21,449,000

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1924-1925

Flow in second-feet

Day	February, 1925			March, 1925			April, 1925			May, 1925		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	19,500	2,400	21,900	72,600	5,800	78,400	33,600	13,500	47,100	44,800	16,200	61,000
2	20,900	2,300	23,200	67,000	5,700	72,700	37,300	12,700	50,000	43,500	20,700	64,200
3	22,400	2,300	24,700	62,100	5,700	67,800	39,700	11,900	51,600	43,400	25,600	69,000
4	28,900	3,800	32,700	57,300	5,600	62,900	40,100	18,900	59,000	43,700	27,400	71,100
5	58,100	13,900	72,000	52,800	5,900	58,700	42,000	22,600	64,600	43,600	30,600	74,200
6	82,700	47,400	130,100	48,500	5,900	54,400	44,300	18,700	63,000	43,900	29,000	72,900
7	101,200	34,800	136,000	44,400	5,600	50,000	46,200	14,000	60,200	43,600	27,700	71,300
8	140,100	18,700	158,800	40,700	5,700	46,400	48,600	11,300	59,900	41,700	22,800	64,500
9	136,900	13,700	150,600	37,900	7,600	45,500	50,400	11,100	61,500	38,800	20,300	59,100
10	127,400	10,700	138,100	35,400	7,800	43,200	50,600	11,500	62,100	35,600	16,900	52,500
11	116,800	8,800	125,600	33,300	7,300	40,600	50,700	20,500	71,200	31,900	14,600	46,500
12	122,600	13,400	136,000	31,300	7,100	38,400	55,100	22,500	77,600	29,600	13,000	42,600
13	120,300	24,300	144,600	29,800	6,900	36,700	53,900	19,700	73,600	29,000	14,600	43,600
14	119,800	17,900	137,700	28,200	6,500	34,700	53,100	18,900	72,000	32,200	14,700	46,900
15	138,600	12,900	151,500	27,000	6,600	33,600	53,000	19,100	72,100	33,200	14,200	47,400
16	142,800	9,700	152,500	26,200	5,700	31,900	54,900	22,900	77,800	35,400	16,900	52,300
17	130,000	8,100	138,100	25,600	4,900	30,500	59,100	24,900	84,000	38,000	18,500	56,500
18	111,100	7,100	118,200	25,600	4,200	29,800	59,100	19,700	78,800	36,000	17,700	53,700
19	92,600	6,900	99,500	25,200	4,000	29,200	56,600	16,700	73,300	34,400	18,900	53,300
20	79,200	7,400	86,600	24,900	4,400	29,300	57,500	16,900	74,400	35,900	19,800	55,700
21	72,300	9,800	82,100	25,200	4,400	29,600	58,400	14,900	73,300	35,900	19,400	55,300
22	69,700	8,600	78,300	26,100	5,100	31,200	57,600	13,900	71,500	35,100	18,900	54,000
23	71,100	13,600	84,700	28,300	5,500	33,800	58,000	14,400	72,400	35,200	20,600	55,800
24	74,000	11,300	85,300	29,700	5,600	35,300	57,200	13,200	70,400	34,800	21,800	56,600
25	74,500	8,600	83,100	30,000	5,300	35,300	54,900	12,800	67,700	32,800	25,500	58,300
26	76,500	7,400	83,900	29,600	5,400	35,000	53,300	13,800	67,100	31,400	26,300	57,700
27	78,600	6,700	85,300	29,400	5,600	35,000	52,400	14,900	67,300	30,600	26,900	57,500
28	77,500	6,100	83,600	29,600	5,600	35,200	50,700	15,900	66,600	29,400	26,100	55,500
29				30,000	7,100	37,100	48,400	16,600	65,000	27,800	25,200	53,000
30				30,000	7,800	37,800	46,100	16,300	62,400	26,800	22,100	48,900
31				34,900	11,900	46,800				25,100	19,200	44,300
Totals in acre-feet	4,962,100	670,400	5,632,500	2,214,800	372,600	2,587,400	3,015,100	979,500	3,994,600	2,184,100	1,291,200	3,475,300

Total for season 1924–1925, in acre-feet — Sacramento River — 16,764,400
Total for season 1924–1925, in acre-feet — San Joaquin River — 4,684,600
Total for season 1924–1925, in acre-feet — Combined rivers — 21,449,000

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1924-1925

Flow in second-feet

Day	June, 1925			July, 1925			August, 1925			September, 1925		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	19,600	16,500	36,100	7,000	5,500	12,500	3,400	800	4,200	2,900	500	3,400
2	18,800	14,900	33,700	6,900	5,900	12,800	3,400	900	4,300	3,100	500	3,600
3	18,100	13,300	31,400	6,700	6,500	13,200	3,200	800	4,000	3,100	700	3,800
4	18,900	12,600	31,500	6,500	5,400	11,900	2,900	800	3,700	3,200	700	3,900
5	20,300	11,500	31,800	6,300	5,000	11,300	2,800	700	3,500	3,200	500	3,700
6	20,800	11,100	31,900	6,400	4,800	11,200	2,800	600	3,400	3,400	500	3,900
7	18,800	10,100	28,900	5,900	4,400	10,300	2,800	600	3,400	3,500	700	4,200
8	17,900	10,300	28,200	5,700	3,700	9,400	2,800	600	3,400	3,600	800	4,400
9	16,900	9,900	26,800	5,400	3,300	8,700	2,800	700	3,500	4,000	900	4,900
10	15,900	10,100	26,000	5,300	3,000	8,300	2,800	700	3,500	4,400	1,000	5,400
11	15,100	10,000	25,100	5,000	2,700	7,700	2,800	700	3,500	4,600	1,100	5,700
12	14,600	10,800	25,400	4,800	2,500	7,300	2,900	700	3,600	4,800	1,200	6,000
13	14,100	10,900	25,000	4,300	2,300	6,600	3,300	600	3,900	4,800	1,200	6,000
14	13,700	11,700	25,400	3,900	1,900	5,800	3,600	700	4,300	4,700	1,200	5,900
15	12,900	12,000	24,900	4,100	1,700	5,800	3,500	700	4,200	4,500	1,100	5,600
16	11,900	11,600	23,500	4,200	1,700	5,900	3,400	800	4,200	4,400	1,100	5,500
17	11,500	11,000	22,500	4,200	1,500	5,700	3,200	700	3,900	4,600	1,100	5,700
18	11,300	10,300	21,600	4,100	1,400	5,500	2,900	700	3,600	5,000	1,000	6,000
19	11,400	10,100	21,500	4,100	1,300	5,400	2,900	700	3,600	5,600	1,000	6,600
20	11,400	10,400	21,800	3,800	1,300	5,100	2,800	600	3,400	5,700	1,100	6,800
21	11,200	10,400	21,600	3,700	1,200	4,900	3,000	600	3,600	5,600	1,200	6,800
22	10,400	10,600	21,000	4,000	1,100	5,100	2,900	600	3,500	5,700	1,100	6,800
23	9,400	9,600	19,000	3,900	1,000	4,900	2,900	700	3,600	5,800	1,200	7,000
24	9,100	9,300	18,400	3,800	1,000	4,800	3,100	700	3,800	5,600	1,100	6,700
25	8,900	9,000	17,900	3,800	1,000	4,800	2,800	600	3,400	5,700	1,000	6,700
26	8,500	9,000	17,500	3,900	1,100	5,000	2,900	600	3,500	5,500	1,100	6,600
27	8,100	8,400	16,500	3,700	1,100	4,800	3,100	600	3,700	5,500	1,200	6,700
28	7,400	7,400	14,800	3,600	1,000	4,600	3,100	600	3,700	5,300	1,200	6,500
29	7,900	7,000	14,900	3,700	1,000	4,700	3,000	600	3,600	5,500	1,200	6,700
30	7,200	6,200	13,400	3,600	800	4,400	3,000	600	3,600	6,000	1,200	7,200
31				3,500	800	4,300	2,900	600	3,500			
Totals in acre-feet	796,000	625,700	1,421,700	288,700	152,200	440,900	185,500	41,400	226,900	275,800	58,200	334,000

Total for season 1924-1925, in acre-feet	Sacramento River	16,764,400
Total for season 1924-1925, in acre-feet	San Joaquin River	4,684,600
Total for season 924-1925, in acre-feet	Combined rivers	21,449,000

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1925-1926

Flow in second-feet

Day	October, 1925			November, 1925			December, 1925			January, 1926		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	6,100	1,300	7,400	6,000	2,100	8,100	8,100	2,500	10,600	8,300	2,700	11,000
2	6,400	1,400	7,800	5,800	2,100	7,900	12,300	2,900	15,200	8,100	2,800	10,900
3	6,300	1,400	7,700	5,700	2,200	7,900	18,200	3,200	21,400	7,600	2,800	10,400
4	6,300	1,400	7,700	6,200	2,200	8,400	18,500	3,200	21,700	7,600	2,800	10,400
5	6,400	1,400	7,800	6,400	2,300	8,700	15,900	3,100	19,000	7,500	2,700	10,200
6	6,200	1,400	7,690	6,500	2,300	8,800	13,400	3,000	16,400	7,700	2,500	10,200
7	6,800	1,400	8,200	6,500	2,300	8,800	11,700	2,900	14,600	7,700	2,400	10,100
8	7,700	1,400	9,100	6,500	2,300	8,800	10,400	2,900	13,300	7,600	2,400	10,000
9	7,900	1,500	9,400	6,400	2,300	8,700	10,000	2,900	12,900	7,500	2,400	9,900
10	7,700	1,400	9,100	6,300	2,300	8,600	9,600	2,900	12,500	7,400	2,300	9,700
11	7,300	1,500	8,800	7,100	2,400	9,500	9,400	3,900	13,300	7,300	2,200	9,500
12	7,200	1,600	8,800	7,700	2,500	10,200	9,300	3,900	13,200	7,100	2,200	9,300
13	7,400	1,600	9,000	9,000	2,500	11,500	9,300	3,900	13,200	7,500	2,200	9,700
14	7,800	1,700	9,500	10,200	2,600	12,800	8,900	3,800	12,700	7,400	2,200	9,600
15	7,700	1,700	9,400	9,000	2,700	11,700	8,500	3,600	12,100	7,400	2,200	9,600
16	7,400	1,800	9,200	8,400	2,700	11,100	8,800	3,600	12,400	7,300	2,100	9,400
17	7,200	1 800	9,000	8,200	2,600	10,800	8,800	3,600	12,400	7,300	2,100	9,400
18	7,100	1,800	8,900	9,000	2,600	11,600	9,000	3,600	12,600	7,300	2,100	9,400
19	6,700	1,800	8,500	9,300	2,600	11,900	9,400	3,500	12,900	7,500	2,100	9,600
20	6,400	1,800	8,200	8,900	2,500	11,400	10,200	3,500	13,700	7,800	2,100	9,900
21	6,700	1,900	8,600	8,800	2,500	11,300	10,100	3,400	13,500	7,700	2,000	9,700
22	6,800	2,000	8,800	8,500	2,500	11,000	9,700	3,100	12,800	7,500	2,000	9,500
23	6,600	2,100	8,700	8,300	2,500	10,800	9,900	2,800	12,700	7,600	1,900	9,500
24	6,600	2,100	8,700	7,800	2,400	10,200	9,300	2,800	12,100	7,300	1,900	9,200
25	6,500	2,000	8,500	8,000	2,500	10,500	9,100	2,900	12,000	7,200	1,900	9,100
26	6,300	1,900	8,200	7,900	2,500	10,400	8,800	2,900	11,700	6,800	1,800	8,600
27	6,000	2,000	8,000	7,700	2,500	10,200	8,200	2,800	11,000	7,000	1,800	8,800
28	6,100	2,100	8,200	7,400	2,400	9,800	8,300	2,900	11,200	7,100	1,900	9,000
29	6,300	2,100	8,400	7,600	2,500	10,100	8,200	3,000	11,200	16,600	2,200	18,800
30	6,200	2,100	8,300	7,500	2,500	10,000	8,500	2,500	11,000	30,400	3,000	33,400
31	6,000	2,100	8,100	------	------	------	8,400	2,600	11,000	45,700	3,400	49,100
Totals in acre-feet	416,000	105,900	521,900	452,600	144,300	596,900	630,000	194,200	824,200	597,600	140,800	738,400

Total for season 1925-1926, in acre-feet	Sacramento River	12,969,700
Total for season 1925-1926, in acre-feet	San Joaquin River	2,503,000
Total for season 1925-1926, in acre-feet	Combined rivers	15,472,700

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1925-1926

Flow in second-feet

Day	February, 1926			March, 1926			April, 1926			May, 1926		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	45,000	4,300	49,300	38,800	3,800	42,600	18,500	2,800	21,300	23,200	10,300	33,500
2	48,600	4,600	53,200	35,200	4,100	39,300	18,100	2,700	20,800	22,000	8,900	30,900
3	60,600	6,000	66,600	32,500	3,900	36,400	17,600	2,500	20,100	20,700	9,000	29,700
4	80,200	6,400	86,600	30,700	3,900	34,600	17,700	3,300	21,000	19,800	9,700	29,500
5	81,700	6,400	88,100	29,700	3,900	33,600	41,300	7,100	48,400	22,400	10,600	33,000
6	94,100	5,600	99,700	29,000	4,100	33,100	54,000	12,100	66,100	25,400	10,100	35,500
7	115,500	4,200	119,700	27,300	4,200	31,500	61,400	15,100	76,500	24,900	7,500	32,400
8	121,900	3,700	125,600	27,000	4,300	31,300	90,500	20,500	111,000	23,700	5,800	29,500
9	114,800	3,100	117,900	26,800	4,400	31,200	87,000	20,400	107,400	22,500	5,500	28,000
10	102,500	3,000	105,500	26,600	4,500	31,100	96,600	16,100	112,700	20,900	5,200	26,100
11	90,700	2,900	93,600	26,900	4,500	31,400	109,400	14,000	123,400	19,200	4,700	23,900
12	84,000	7,200	91,200	25,800	4,300	30,100	111,100	13,100	124,200	17,600	4,400	22,000
13	88,200	9,500	97,700	25,100	4,000	29,100	105,300	13,000	118,300	16,500	4,900	21,400
14	94,200	13,500	107,700	25,200	4,100	29,300	95,800	13,400	109,200	15,600	5,900	21,500
15	90,600	10,700	101,300	25,200	4,200	29,400	87,100	14,000	101,100	15,100	7,000	22,100
16	83,700	10,400	94,100	25,600	4,500	30,100	78,500	15,000	93,500	14,500	7,700	22,200
17	76,600	9,000	85,600	25,800	4,400	30,200	71,600	15,600	87,200	13,600	8,200	21,800
18	71,600	6,700	78,300	25,000	4,200	29,200	64,500	14,400	78,900	13,000	8,400	21,400
19	68,500	5,900	74,400	24,100	4,000	28,100	57,900	12,400	70,300	12,800	9,200	22,000
20	70,000	8,100	78,100	23,200	3,900	27,100	52,400	11,400	63,800	13,000	9,700	22,700
21	71,100	6,600	77,700	22,800	3,700	26,500	47,500	11,700	59,200	12,600	9,600	22,200
22	69,500	5,500	75,000	22,000	3,600	25,600	43,000	12,300	55,300	11,800	8,200	20,000
23	66,900	5,000	71,900	21,400	3,700	25,100	37,300	13,200	50,500	11,400	6,800	18,200
24	62,700	4,600	67,300	22,200	3,800	26,000	34,800	12,700	47,500	10,800	6,200	17,000
25	57,700	4,100	61,800	21,500	3,900	25,400	33,700	13,200	46,900	10,000	5,200	15,200
26	52,800	3,900	56,700	21,300	3,900	25,200	30,300	13,900	44,200	9,500	4,300	13,800
27	47,400	3,800	51,200	20,900	3,600	24,500	32,700	13,300	46,000	9,100	4,000	13,100
28	42,800	3,800	46,600	20,400	3,400	23,800	29,700	12,200	41,900	8,600	5,000	13,600
29				19,000	3,500	22,500	28,600	11,500	40,100	8,300	4,500	12,800
30				18,400	3,600	22,000	28,200	11,300	39,500	8,100	4,400	12,500
31				18,000	3,600	21,600				7,700	4,200	11,900
Totals in acre-feet	4,264,700	333,600	4,598,300	1,551,100	244,500	1,795,600	3,330,600	721,100	4,051,700	958,900	425,900	1,384,800

Total for season 1925-1926, in acre-feet .... Sacramento River 12,969,700
Total for season 1925-1926, in acre-feet .... San Joaquin River 2,503,000
Total for season 1925-1926, in acre-feet .... Combined rivers 15,472,700

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1925-1926

Flow in second-feet

Day	June, 1926			July, 1926			August, 1926			September, 1926		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	7,300	3,600	10,900	2,200	700	2,900	1,500	300	1,800	3,000	400	3,400
2	7,000	3,500	10,500	2,300	700	3,000	1,400	300	1,700	3,100	400	3,500
3	6,600	3,400	10,000	2,400	700	3,100	1,600	300	1,900	3,200	300	3,500
4	6,300	3,100	9,400	2,400	900	3,300	1,500	300	1,800	3,400	400	3,800
5	6,000	3,100	9,100	2,200	900	3,100	1,600	200	1,800	3,500	400	3,900
6	5,800	2,800	8,600	2,200	600	2,800	1,500	200	1,700	3,600	400	4,000
7	5,600	2,600	8,200	2,000	500	2,500	1,500	200	1,700	3,600	400	4,000
8	5,700	2,500	8,200	2,100	500	2,600	1,500	300	1,800	3,500	400	3,900
9	5,100	2,400	7,500	2,000	500	2,500	1,600	300	1,900	3,700	400	4,100
10	5,000	2,200	7,200	2,000	500	2,500	1,600	300	1,900	4,000	500	4,500
11	4,900	2,900	7,800	2,000	600	2,600	1,500	300	1,800	4,200	500	4,700
12	4,600	2,200	6,800	2,000	600	2,600	1,500	200	1,700	4,200	700	4,900
13	4,400	2,000	6,400	2,100	500	2,600	1,700	300	2,000	4,300	800	5,100
14	4,200	1,800	6,000	2,100	400	2,500	1,700	300	2,000	4,300	800	5,100
15	3,900	2,100	6,000	2,300	400	2,700	1,800	300	2,100	4,700	700	5,400
16	3,700	1,500	5,200	2,300	400	2,700	1,900	400	2,300	4,900	700	5,600
17	3,600	1,400	5,000	2,000	400	2,400	1,800	400	2,200	5,200	700	5,900
18	3,400	1,400	4,800	2,000	400	2,400	1,900	400	2,300	5,300	800	6,100
19	3,300	1,300	4,600	1,800	400	2,200	2,000	400	2,400	5,400	800	6,200
20	3,500	1,300	4,800	1,600	400	2,000	2,200	300	2,500	5,600	700	6,300
21	3,300	1,200	4,500	1,500	300	1,800	2,100	300	2,400	5,500	700	6,200
22	3,200	1,300	4,500	1,700	300	2,000	2,300	300	2,600	5,700	600	6,300
23	3,100	1,100	4,200	1,400	300	1,700	2,400	300	2,700	6,000	500	6,500
24	3,000	1,100	4,100	1,400	300	1,700	2,300	300	2,600	6,000	400	6,400
25	2,800	1,000	3,800	1,500	300	1,800	2,300	300	2,600	5,900	400	6,300
26	2,800	900	3,700	1,500	400	1,900	2,300	300	2,600	5,800	400	6,200
27	2,600	900	3,500	1,500	300	1,800	2,600	400	3,000	5,800	400	6,200
28	2,500	1,000	3,500	1,500	300	1,600	2,600	300	2,900	5,400	400	5,800
29	2,600	800	3,400	1,300	300	1,700	2,900	400	3,300	5,700	400	6,100
30	2,300	800	3,100	1,400	400	1,900	3,100	400	3,500	5,900	400	6,300
31				1,500	400	1,900	3,100	400	3,500			
Totals in acre-feet	253,600	113,300	366,900	115,200	28,900	144,100	121,400	19,200	140,600	278,000	31,300	309,300

Total for season 1925–1926, in acre-feet .... Sacramento River 12,969,700
Total for season 1925–1926, in acre-feet .... San Joaquin River 2,503,000
Total for season 1925–1926, in acre-feet .... Combined rivers 15,472,700

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1926-1927

Flow in second-feet

Day	October, 1926			November, 1926			December, 1926			January, 1927		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	5,900	600	6,500	4,800	1,400	6,200	80,000	5,100	85,100	13,500	3,400	16,900
2	6,000	700	6,700	4,700	1,500	6,200	82,200	4,800	87,000	14,800	3,400	18,200
3	6,200	800	7,000	4,800	1,600	6,400	85,800	5,200	91,000	20,100	3,500	23,600
4	6,400	700	7,100	4,800	1.500	6,300	89,200	5,300	94,500	28,200	4,400	32,600
5	6,300	800	7,100	4,900	1,400	6,300	91,200	4,900	96,100	31,200	4,700	35,900
6	6,400	900	7,300	4,900	1,500	6,400	93,500	4,700	98,200	32,400	6,800	39,200
7	6,400	1,000	7,400	4,900	1,500	6,400	92,400	4,900	97,300	37,900	6,700	44,600
8	6,300	1,000	7,300	4,900	1,500	6,400	84,300	4,500	88,800	40,500	5,700	46,200
9	6,100	1,100	7,200	4,800	1,500	6,300	73,500	4,100	77,600	40,400	5,200	45,600
10	6,200	1,200	7,400	4,800	1,500	6,300	64,300	3,900	68,200	38,400	5,400	43,800
11	6,500	1,100	7,600	4,900	1,500	6,400	56,500	3,700	60,200	41,000	6,100	47,100
12	7,500	1,100	8,600	5,200	1,500	6,700	48,200	3,600	51,800	37,200	5,600	42,800
13	8,000	1,100	9,100	5,800	1,600	7,400	40,500	3,400	43,900	36,000	5,300	41,300
14	7,600	1,100	8,700	7,400	1,600	9,000	34,000	3,400	37,400	35,700	4,900	40,600
15	7,000	1,200	8,200	8,100	1,600	9,700	28,700	3,200	31,900	34,800	4,300	39,100
16	6,600	1,200	7,800	7,200	1,600	8,800	21,800	3,100	24,900	34,100	4,500	38,600
17	6,500	1,200	7,700	6,400	1,500	7,900	20,000	3,100	23,100	37,000	4,700	41,700
18	6,600	1,200	7,800	6,100	1,500	7,600	19,100	3,100	22,200	37,300	4,500	41,800
19	6,500	1,200	7,700	6,200	1,500	7,700	18,800	3,100	21,900	38,200	4,300	42,500
20	6,500	1,100	7,600	8,900	1,600	10,500	18,100	3,100	21,200	39,000	4,800	43,800
21	6,400	1,200	7,600	8,400	1,700	10,100	17,300	3,000	20,300	42,800	5,300	48,100
22	6,300	1,200	7,500	10,300	1,800	12,100	17,400	3,100	20,500	43,800	5,800	49,600
23	6,300	1,300	7,600	17,800	1,700	19,500	17,200	3,200	20,400	43,200	5,600	48,800
24	6,300	1,300	7,600	34,100	2,500	36,600	16,900	3,500	20,400	41,600	5,200	46,800
25	6,100	1,300	7,400	46,000	5,100	51,100	16,200	3,500	19,700	38,700	4,800	43,500
26	5,900	1,300	7,200	50,700	5,700	56,400	15,700	3,500	19,200	35,300	4,300	39,600
27	6,000	1,300	7,300	59,900	9,600	69,500	14,900	3,500	18,400	34,300	4,500	38,800
28	6,100	1,300	7,400	67,900	7,900	75,800	14,500	3,500	18,000	37,200	4,100	41,300
29	6,100	1,300	7,400	70,700	6,100	76,800	14,100	3,500	17,600	40,000	4,700	44,700
30	5,900	1,300	7,200	76,600	5,900	82,500	14,000	3,400	17,400	43,700	4,400	48,100
31	5,800	1,400	7,200				13,800	3,400	17,200	44,400	4,100	48,500
Totals in acre-feet	393,400	68,300	461,700	1,102,700	155,200	1,257,900	2,601,900	232,300	2,834,200	2,203,100	299,000	2,502,100

Total for season 1926–1927, in acre-feet	Sacramento River	25,459,600
Total for season 1926–1927, in acre-feet	San Joaquin River	5,438,300
Total for season 1926–1927, in acre-feet	Combined rivers	30,897,900

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1926-1927

Flow in second-feet

Day	February, 1927			March, 1927			April, 1927			May, 1927		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	45,400	3,900	49,300	120,400	16,800	137,200	61,300	16,000	77,300	58,600	16,300	74,900
2	46,000	4,000	50,000	108,000	17,800	125,800	64,600	19,800	84,400	55,400	17,000	72,400
3	56,200	10,900	67,100	97,200	17,000	114,200	83,200	33,200	116,400	53,300	16,100	69,400
4	69,900	20,800	90,700	87,800	16,900	104,700	91,400	32,600	124,000	51,300	15,000	66,300
5	73,600	13,900	87,500	81,600	15,800	97,400	94,800	25,000	119,800	49,600	14,600	64,200
6	77,200	11,600	88,800	76,400	14,900	91,300	104,600	20,500	125,100	49,000	14,800	63,800
7	83,600	10,800	94,400	74,600	14,300	88,900	107,600	18,300	125,900	46,400	16,500	62,900
8	89,800	10,000	99,800	72,400	14,000	86,400	104,000	16,800	120,800	43,000	16,500	59,500
9	87,800	9,300	97,100	68,600	14,100	82,700	94,200	14,000	108,200	40,700	14,800	55,500
10	83,200	7,600	90,800	67,000	11,100	78,100	87,400	11,600	99,000	38,300	13,400	51,700
11	76,000	5,700	81,700	64,400	8,000	72,400	78,400	10,500	88,900	37,200	12,400	49,600
12	71,000	5,300	76,300	61,400	7,700	69,100	73,800	9,700	83,500	37,400	12,600	50,000
13	65,200	5,000	70,200	60,800	7,700	68,500	69,400	10,700	80,100	39,100	13,100	52,200
14	60,800	5,700	66,500	64,200	12,000	76,200	65,800	12,600	78,400	42,100	14,200	56,300
15	62,400	13,800	76,200	69,000	10,600	79,600	62,600	11,000	73,600	46,100	16,200	62,300
16	72,700	17,300	90,000	69,400	9,500	78,900	59,200	10,900	70,100	52,000	17,000	69,000
17	88,400	16,100	104,500	69,600	8,700	78,300	55,100	8,500	63,600	51,300	17,600	68,900
18	112,600	26,100	138,700	70,400	8,100	78,500	51,000	8,600	59,600	49,600	18,300	67,900
19	159,000	24,400	183,400	68,800	7,900	76,700	48,300	8,800	57,100	46,200	18,000	64,200
20	170,600	23,000	193,600	65,600	7,300	72,900	47,900	9,400	57,300	41,900	17,300	59,200
21	188,000	29,500	217,500	63,400	8,000	71,400	46,200	10,000	56,200	37,200	16,000	53,200
22	236,000	31,100	267,100	59,800	10,100	69,900	45,100	11,200	56,300	32,500	14,200	46,700
23	232,200	26,800	259,000	56,800	11,300	68,100	45,900	12,900	58,800	28,900	12,400	41,300
24	218,600	24,200	242,800	54,000	11,200	65,200	47,400	15,200	62,600	27,700	11,200	38,900
25	200,800	23,300	224,100	51,400	11,500	62,900	49,600	15,200	64,800	28,900	11,300	40,200
26	176,200	21,700	197,900	49,900	10,500	60,400	52,500	19,700	72,200	30,400	13,100	43,500
27	150,200	21,600	171,800	48,400	10,700	59,100	55,900	24,300	80,200	30,900	14,700	45,600
28	131,800	17,800	149,600	47,400	11,900	59,300	58,000	17,800	75,800	30,100	15,600	45,700
29				45,900	10,700	56,600	58,700	17,400	76,100	27,700	15,000	42,700
30				44,700	8,600	53,300	59,800	24,400	84,200	25,500	13,500	39,000
31				43,800	7,600	51,400				23,900	12,400	36,300
Totals in acre-feet	6,306,700	873,600	7,180,300	4,124,500	697,600	4,822,100	4,006,900	943,700	4,950,600	2,479,300	913,000	3,392,300

Total for season 1926–1927, in acre-feet — Sacramento River — 25,459,600
Total for season 1926–1927, in acre-feet — San Joaquin River — 5,438,300
Total for season 1926–1927, in acre-feet — Combined rivers — 30,897,900

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1926-1927

Flow in second-feet

Day	June, 1927			July, 1927			August, 1927			September, 1927		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	22,800	12,000	34,800	9,700	9,500	19,200	4,000	1,600	5,600	4,200	1,400	5,600
2	22,500	12,000	34,500	9,400	7,800	17,200	4,000	1,600	5,600	4,200	1,400	5,600
3	23,000	11,800	34,800	9,100	7,600	16,700	3,800	1,400	5,200	4,200	1,300	5,500
4	24,100	12,200	36,300	8,800	7,200	16,000	3,800	1,300	5,100	4,400	1,300	5,700
5	25,200	12,500	37,700	8,500	6,800	15,300	3,800	1,300	5,100	4,500	1,300	5,800
6	27,000	13,600	40,600	7,900	5,700	13,600	3,700	1,300	5,000	4,500	1,100	5,900
7	29,100	14,800	43,900	7,400	5,900	13,300	3,700	1,300	5,000	4,600	1,300	5,900
8	30,400	16,400	46,800	7,200	4,900	12,100	3,700	1,300	5,000	4,600	1,300	5,900
9	29,600	16,600	46,200	6,800	4,100	10,900	3,600	1,200	4,800	4,400	1,300	5,700
10	29,900	16,400	46,300	6,700	3,800	10,500	3,600	1,100	4,700	4,500	1,300	5,800
11	30,300	16,700	47,000	6,600	3,400	10,000	3,600	1,200	4,800	4,400	1,400	5,800
12	30,000	16,800	46,800	6,500	3,200	9,700	3,600	1,100	4,700	4,700	1,500	6,200
13	30,100	17,100	47,200	6,400	2,900	9,300	3,600	1,100	4,700	4,500	1,500	6,000
14	30,000	17,700	47,700	5,900	2,700	8,600	3,600	1,200	4,800	4,700	1,400	6,100
15	28,600	18,300	46,900	5,700	2,500	8,200	3,700	1,200	4,900	4,900	1,400	6,300
16	27,700	18,200	45,900	5,800	2,300	8,100	3,500	1,200	4,700	5,000	1,400	6,400
17	26,000	18,300	44,300	5,700	2,200	7,900	3,600	1,100	4,700	5,100	1,400	6,500
18	23,200	18,200	41,400	5,400	2,200	7,600	3,500	1,100	4,600	5,200	1,600	6,800
19	21,600	17,900	39,500	5,200	2,000	7,200	3,700	1,100	4,800	5,400	1,600	7,000
20	19,500	17,000	36,500	5,200	1,900	7,100	3,600	1,100	4,700	5,300	1,400	6,700
21	18,000	15,900	33,900	5,100	1,900	7,000	3,700	1,100	4,800	5,600	1,400	7,000
22	17,000	14,900	31,900	5,000	1,900	6,900	3,600	1,100	4,700	5,700	1,400	7,100
23	16,100	13,800	29,900	5,000	1,800	6,800	3,400	1,100	4,500	5,900	1,500	7,400
24	15,500	13,100	28,600	4,900	1,800	6,700	3,400	1,000	4,400	6,000	1,500	7,500
25	15,600	13,100	28,700	4,900	1,700	6,600	3,500	1,100	4,600	6,200	1,500	7,700
26	14,900	13,100	28,000	4,800	1,700	6,500	3,600	1,100	4,700	6,100	1,600	7,700
27	13,300	13,200	26,500	4,600	2,100	6,700	3,600	1,100	4,700	5,800	1,600	7,400
28	12,000	12,500	24,500	4,300	1,500	5,800	3,700	1,200	4,900	6,000	1,500	7,500
29	11,000	11,500	22,500	4,400	1,500	5,900	3,700	1,100	4,800	6,300	1,500	7,800
30	10,200	10,900	21,100	4,000	1,500	5,500	3,700	1,200	4,900	6,200	1,600	7,800
31	----------	----------	----------	4,100	1,500	5,600	4,000	1,300	5,300	----------	----------	----------
Totals in acre-feet	1,334,900	884,000	2,218,900	378,200	212,800	591,000	224,900	73,700	298,600	303,100	85,100	388,200

Total for season 1926-1927, in acre-feet	Sacramento River	25,459,600
Total for season 1926-1927, in acre-feet	San Joaquin River	5,438,300
Total for season 1926-1927, in acre-feet	Combined rivers	30,897,900

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1927-1928

Flow in second-feet

Day	October, 1927			November, 1927			December, 1927			January, 1928		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	6,400	1,500	7,900	8,500	3,000	11,500	16,600	3,500	20,100	28,100	5,000	33,100
2	6,600	1,600	8,200	8,800	2,900	11,700	16,200	3,500	19,700	25,800	5,100	30,900
3	6,400	1,800	8,200	8,300	2,800	11,100	15,800	3,500	19,300	26,700	5,900	32,600
4	6,300	1,800	8,100	8,200	3,100	11,300	15,000	3,500	18,500	29,700	4,700	34,400
5	6,600	2,000	8,600	7,800	3,400	11,200	14,400	3,500	17,900	31,400	4,900	36,300
6	6,600	2,300	8,900	7,600	3,600	11,200	13,700	3,400	17,100	30,700	4,700	35,400
7	6,600	2,300	8,900	7,200	3,600	10,800	13,400	3,300	16,700	29,100	4,600	33,700
8	6,600	2,100	8,700	7,800	3,600	11,400	13,200	3,400	16,600	27,000	4,500	31,500
9	6,800	2,100	8,900	11,000	3,700	14,700	13,000	3,300	16,300	24,500	3,500	28,000
10	6,700	2,200	8,900	27,800	3,900	31,700	12,600	3,400	16,000	21,500	3,600	25,100
11	6,600	2,200	8,800	27,900	5,000	32,900	13,100	3,400	16,500	20,500	3,600	24,100
12	6,900	2,300	9,200	31,600	3,900	35,500	14,200	3,400	17,600	19,900	3,600	23,500
13	7,100	2,400	9,500	33,700	3,600	37,300	14,500	3,500	18,000	19,200	3,500	22,700
14	7,100	2,500	9,600	28,400	4,200	32,600	15,200	4,300	19,500	18,900	3,600	22,500
15	7,100	2,500	9,600	29,000	3,800	32,800	17,100	4,300	21,400	18,400	3,500	21,900
16	6,900	2,500	9,400	26,800	3,700	30,500	16,600	4,200	20,800	17,900	4,100	22,000
17	6,700	2,500	9,200	22,900	3,800	26,700	15,800	4,100	19,900	17,600	4,000	21,600
18	6,500	2,400	8,900	21,200	5,200	26,400	14,800	4,000	18,800	17,100	3,500	20,600
19	6,800	2,500	9,300	19,900	5,600	25,500	13,400	4,500	17,900	16,700	3,700	20,400
20	6,800	2,600	9,400	19,200	5,400	24,600	12,800	3,900	16,700	16,000	3,500	19,500
21	6,700	2,600	9,300	20,800	6,300	27,100	12,400	3,300	15,700	15,500	3,500	19,000
22	6,900	2,400	9,300	22,500	6,100	28,600	12,100	4,000	16,100	15,100	3,200	18,300
23	6,900	2,400	9,300	27,400	5,800	33,200	11,800	3,700	15,500	15,500	3,800	19,300
24	6,700	2,300	9,000	27,100	4,200	31,300	11,800	3,800	15,600	16,200	4,100	20,300
25	6,400	1,900	8,300	25,800	3,200	29,000	16,400	4,200	20,600	16,400	3,600	20,000
26	6,700	2,100	8,800	20,900	3,300	24,200	21,900	3,400	25,300	16,800	3,300	20,100
27	7,100	2,600	9,700	19,500	3,300	22,800	26,400	4,000	30,400	17,100	3,300	20,400
28	7,800	3,000	10,800	20,000	3,400	23,400	27,100	4,900	32,300	17,000	3,100	20,100
29	7,900	2,900	10,800	19,800	3,200	23,000	31,400	11,900	43,300	19,400	2,900	22,300
30	7,900	2,700	10,600	18,200	3,100	21,300	34,300	7,800	42,100	25,100	3,800	28,900
31	8,100	2,700	10,800	----------	----------	----------	30,500	6,700	37,200	27,600	3,300	30,900
Totals in acre-feet	422,100	142,000	564,100	1,159,500	237,000	1,396,500	1,045,000	260,600	1,305,600	1,303,600	239,600	1,543,200

Total for season 1927–1928, in acre-feet..........Sacramento River.......... 17,672,800
Total for season 1927–1928, in acre-feet..........San Joaquin River.......... 3,815,800
Total for season 1927–1928, in acre-feet..........Combined rivers.......... 21,488,600

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1927-1928

Flow in second-feet

Day	February, 1928			March, 1928			April, 1928			May, 1928		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	31,300	2,900	34,200	17,600	2,500	20,100	190,700	19,500	210,200	33,700	8,500	42,200
2	35,500	2,900	38,400	17,700	2,500	20,200	168,900	21,300	190,200	34,000	9,500	43,500
3	37,500	5,100	42,600	18,400	2,400	20,800	154,800	23,700	178,500	33,000	9,100	42,100
4	48,400	14,100	62,500	19,400	2,900	22,300	140,900	16,000	156,900	31,600	8,300	39,900
5	59,700	9,100	68,800	21,100	2,900	24,000	124,400	14,800	139,200	29,900	7,600	37,500
6	66,500	6,300	72,800	21,900	3,200	25,100	114,400	14,300	128,700	29,300	8,400	37,700
7	71,900	5,600	77,500	22,700	4,100	26,800	103,100	13,700	116,800	29,100	9,700	38,800
8	78,600	4,700	83,300	23,500	4,900	28,400	94,600	13,300	107,900	29,000	10,300	39,300
9	81,600	4,400	86,000	26,700	3,700	30,400	88,200	13,100	101,300	28,600	10,700	39,300
10	78,500	4,000	82,500	30,800	3,600	34,400	83,400	12,800	96,200	27,900	10,300	38,200
11	71,100	3,600	74,700	34,300	3,600	37,900	78,100	12,800	90,900	27,600	10,500	38,100
12	63,700	3,400	67,100	35,400	3,700	39,100	74,700	12,500	87,200	26,900	10,800	37,700
13	56,100	3,900	60,000	34,700	3,900	38,600	72,100	11,700	83,800	26,100	10,700	36,800
14	48,900	4,700	53,600	33,400	4,000	37,400	68,100	11,500	79,600	25,100	10,900	36,000
15	42,900	4,700	47,600	32,400	4,100	36,500	64,400	11,500	75,900	24,200	11,000	35,200
16	37,400	4,500	41,900	30,600	4,200	34,800	60,200	11,500	71,700	23,000	10,300	33,300
17	32,600	4,300	36,900	28,900	4,400	33,300	56,100	11,400	67,500	22,100	9,500	31,600
18	28,500	4,300	32,800	26,500	4,200	30,700	52,000	10,900	62,900	21,300	8,800	30,100
19	22,200	4,200	26,400	25,500	4,100	29,600	49,100	10,600	59,700	20,300	8,400	28,700
20	21,000	4,100	25,100	24,700	4,000	28,700	46,800	10,200	57,000	19,500	8,400	27,900
21	20,200	4,300	24,500	26,600	3,800	30,400	43,500	7,400	50,900	19,000	10,400	29,400
22	19,600	4,200	23,800	26,200	3,900	30,100	41,300	7,100	48,400	18,400	10,900	29,300
23	19,000	4,200	23,200	29,800	5,500	35,300	38,100	7,800	45,900	18,300	10,900	29,200
24	18,600	4,400	23,000	55,100	17,200	72,300	38,500	7,400	45,900	17,600	10,500	28,100
25	18,200	4,200	22,400	91,800	72,800	164,600	36,900	7,300	44,200	17,000	11,400	28,400
26	18,500	3,000	21,500	154,700	81,300	236,000	35,000	6,800	41,800	17,000	11,800	28,800
27	18,600	2,600	21,200	280,500	68,400	348,900	34,400	7,000	41,400	15,600	12,100	27,700
28	18,100	2,700	20,800	294,300	58,400	352,700	34,600	7,600	42,200	14,700	12,200	26,900
29	17,700	2,700	20,400	271,100	43,400	314,500	34,600	8,400	43,000	13,500	11,300	24,800
30	----------	----------	----------	249,000	37,100	286,100	34,600	8,000	42,600	12,600	10,000	22,600
31	----------	----------	----------	220,800	33,500	254,300	----------	----------	----------	12,100	9,300	21,400
Totals in acre-feet	2,341,200	263,500	2,604,700	4,407,700	986,400	5,394,100	4,467,900	696,800	5,164,700	1,421,600	618,800	2,040,400

Total for season 1927-1928, in acre-feet .... Sacramento River 17,672,800
Total for season 1927-1928, in acre-feet .... San Joaquin River 3,815,800
Total for season 1927-1928, in acre-feet .... Combined rivers 21,488,600

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1927-1928

Flow in second-feet

Day	June, 1928			July, 1928			August, 1928			September, 1928		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	11,200	9,300	20,500	4,800	1,300	6,100	3,200	700	3,900	3,200	1,000	4,200
2	10,900	7,700	18,600	4,700	1,300	6,000	3,200	700	3,900	3,400	1,000	4,400
3	10,300	6,400	16,700	4,600	1,300	5,900	3,200	700	3,900	3,600	900	4,500
4	9,800	6,900	16,700	4,600	1,400	6,000	3,200	700	3,900	3,700	900	4,600
5	9,200	7,300	16,500	4,500	1,400	5,900	3,000	900	3,900	3,800	1,000	4,800
6	8,800	7,200	16,000	4,400	1,200	5,600	2,900	800	3,700	4,000	1,100	5,100
7	8,400	5,900	14,300	4,200	1,100	5,300	2,800	800	3,600	4,100	1,100	5,200
8	8,000	4,600	12,600	4,200	1,100	5,300	2,800	700	3,500	4,100	1,100	5,200
9	7,600	4,100	11,700	4,100	1,000	5,100	2,900	700	3,600	4,300	1,200	5,500
10	7,400	3,900	11,300	3,900	1,000	4,900	2,800	600	3,400	4,200	1,200	5,400
11	6,800	3,500	10,300	3,800	900	4,700	2,800	500	3,300	4,400	1,200	5,600
12	6,700	3,300	10,000	3,800	800	4,600	2,700	700	3,400	4,500	1,200	5,700
13	6,700	2,800	9,500	3,800	900	4,700	2,600	600	3,200	4,800	1,300	6,100
14	6,600	2,500	9,100	3,700	900	4,600	2,600	600	3,200	5,100	1,300	6,400
15	6,700	2,300	9,000	3,700	900	4,600	2,500	600	3,100	5,300	1,300	6,600
16	6,400	2,100	8,500	3,700	800	4,500	2,600	600	3,200	5,700	1,300	7,000
17	6,300	2,000	8,300	3,400	800	4,200	2,600	600	3,200	5,600	1,400	7,000
18	5,800	1,900	7,700	3,300	800	4,100	2,700	600	3,300	5,600	1,300	6,900
19	5,800	1,800	7,600	3,300	700	4,000	2,800	700	3,500	5,600	1,200	6,800
20	5,500	1,700	7,200	3,400	700	4,100	2,800	600	3,400	5,600	1,200	6,800
21	5,300	1,700	7,000	3,600	700	4,300	2,800	700	3,500	5,500	1,200	6,700
22	5,100	1,600	6,700	3,500	700	4,200	2,800	600	3,400	5,500	1,200	6,700
23	5,100	1,600	6,700	3,700	700	4,400	3,000	600	3,600	5,400	1,300	6,700
24	5,200	1,600	6,800	3,600	700	4,300	3,000	600	3,600	5,500	1,300	6,800
25	5,000	1,600	6,600	3,500	700	4,200	2,900	600	3,500	5,500	1,200	6,700
26	5,000	1,400	6,400	3,700	700	4,400	2,800	700	3,500	5,500	1,300	6,800
27	4,500	1,400	5,900	3,700	700	4,400	2,900	700	3,600	5,500	1,300	6,800
28	4,500	1,300	5,800	3,800	800	4,600	2,900	700	3,600	5,500	1,300	6,800
29	4,300	1,400	5,700	3,700	900	4,600	3,000	700	3,700	5,600	1,300	6,900
30	4,500	1,300	5,800	3,500	800	4,300	3,100	700	3,800	5,600	1,300	6,900
31	------	------	------	3,300	800	4,100	3,200	900	4,100	------	------	------
Totals in acre-feet	402,700	202,200	604,900	236,600	56,400	293,000	176,400	41,400	217,800	288,500	71,100	359,600

Total for season 1927–1928, in acre-feet .... Sacramento River 17,672,800
Total for season 1927–1928, in acre-feet .... San Joaquin River 3,815,800
Total for season 1927–1928, in acre-feet .... Combined rivers 21,488,600

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1928-1929

Flow in second-feet

Day	October, 1928			November, 1928			December, 1928			January, 1929		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	5,500	1,300	6,800	6,200	2,500	8,700	6,700	2,400	9,100	15,600	2,400	18,000
2	5,500	1,400	6,900	6,300	2,400	8,700	6,900	2,400	9,300	14,900	2,600	17,500
3	5,700	1,500	7,200	6,300	2,600	8,900	6,700	2,400	9,100	13,400	2,500	15,900
4	5,700	1,500	7,200	6,500	2,400	8,900	6,700	2,500	9,200	13,000	2,700	15,700
5	5,700	1,600	7,300	6,900	1,900	8,800	6,900	2,600	9,500	12,200	2,600	14,800
6	5,900	1,600	7,500	7,200	1,800	9,000	6,900	2,700	9,600	11,800	2,500	14,300
7	6,000	1,700	7,700	7,300	1,700	9,000	7,000	2,700	9,700	11,100	2,500	13,600
8	6,000	1,800	7,800	7,500	1,700	9,200	7,100	2,800	9,900	11,500	2,500	14,000
9	5,900	1,800	7,700	7,700	1,700	9,400	7,000	2,800	9,800	10,000	2,500	12,500
10	5,700	1,800	7,500	7,500	1,800	9,300	6,900	2,800	9,700	9,700	2,500	12,200
11	5,900	1,700	7,600	7,000	1,700	8,700	8,500	2,800	11,300	9,400	2,400	11,800
12	5,700	1,700	7,400	6,800	1,700	8,500	10,300	3,000	13,300	9,200	2,400	11,600
13	5,700	1,800	7,500	7,300	1,900	9,200	14,100	3,000	17,100	8,900	2,300	11,200
14	5,800	1,900	7,700	8,900	2,700	11,600	14,200	3,000	17,200	8,600	2,300	10,900
15	5,900	1,900	7,800	12,400	3,000	15,400	13,800	3,000	16,800	8,400	2,200	10,600
16	5,600	2,000	7,600	15,200	3,100	18,300	12,300	3,000	15,300	8,700	2,400	11,100
17	5,700	2,000	7,700	15,400	3,100	18,500	11,100	3,000	14,100	8,900	2,700	11,600
18	6,000	2,200	8,200	13,300	3,100	16,400	9,900	2,900	12,800	8,900	2,700	11,600
19	6,100	2,300	8,400	10,800	3,100	13,900	9,500	2,800	12,300	9,100	3,000	12,100
20	6,200	2,300	8,500	9,600	3,000	12,600	9,000	2,900	11,900	9,900	3,600	13,500
21	6,100	2,400	8,500	8,800	3,000	11,800	8,700	2,800	11,500	10,500	3,800	14,300
22	6,100	2,300	8,400	8,300	3,000	11,300	8,400	2,600	11,000	11,200	3,600	14,800
23	6,000	2,300	8,300	8,100	3,200	11,300	8,300	2,400	10,700	10,300	3,300	13,600
24	6,100	2,400	8,500	8,000	3,200	11,200	8,100	2,300	10,400	10,000	3,100	13,100
25	6,100	2,300	8,400	7,800	3,200	11,000	8,600	2,400	11,000	9,600	2,900	12,500
26	6,200	2,300	8,500	8,000	3,100	11,100	10,900	2,600	13,500	9,400	2,800	12,200
27	6,300	2,300	8,600	8,000	3,000	11,000	12,000	2,400	14,400	9,400	2,700	12,100
28	6,400	2,400	8,800	7,900	2,700	10,600	12,000	2,400	14,400	9,100	2,600	11,800
29	6,400	2,400	8,800	7,800	2,500	10,300	13,500	2,500	16,000	9,000	2,500	11,500
30	6,200	2,500	8,700	7,600	2,400	10,000	15,500	2,400	17,900	9,400	2,400	11,900
31	6,400	2,700	9,100	----------	----------	----------	16,100	2,500	18,600	10,800	2,400	13,200
Totals in acre-feet	365,300	123,000	488,300	507,700	150,900	658,600	601,100	163,900	765,000	637,400	165,100	802,500

Total for season 1928–1929, in acre-feet	Sacramento River	7,421,300
Total for season 1928–1929, in acre-feet	San Joaquin River	1,551,200
Total for season 1928–1929, in acre-feet	Combined rivers	8,972,500

TABLE 37—Continued

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1928-1929

Flow in second-feet

Day	February, 1929			March, 1929			April, 1929			May, 1929		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	11,600	2,300	13,900	11,000	1,900	12,900	14,600	1,800	16,400	19,700	2,300	22,000
2	13,300	2,900	16,200	10,600	1,800	12,400	14,000	1,700	15,700	20.100	2,400	22,500
3	25,100	4,100	29.200	10,600	1,800	12,400	13,800	1,900	15,700	20,700	3,000	23,700
4	32,200	7,600	39,800	10,200	1,900	12,100	13,700	2,100	15,800	21,800	3,000	24,800
5	43,800	6,500	50,300	10,500	1,900	12,400	14,800	2,700	17,500	21,500	3,000	24,500
6	44,900	5,200	50,100	11,100	2,000	13,100	15,200	2,400	17,600	21,000	3,100	24,100
7	45,500	4,600	50,100	11,500	2,000	13,500	14,700	2,300	17,000	20,100	2,800	22,900
8	45,600	4,000	49,600	11,800	2,100	13,900	14.200	2,500	16,700	19,700	2,300	22,000
9	42.500	3,600	46,100	12,100	2,000	14,100	14,500	3,000	17,500	19,500	2,600	22,100
10	37.200	3,300	40,500	15,800	4,100	19,900	14,200	2,800	17,000	18,900	3,000	21,900
11	31,500	3,200	34,700	24,300	3,800	28,100	13,200	2,600	15,800	18,400	3,200	21,600
12	27,800	3,000	30,800	26,400	3,400	29,800	12,500	2,600	15,100	18,100	3,500	21,600
13	20,000	3,000	23,000	27,800	2,900	30,700	12,300	2,100	14,400	18,000	3,600	21,600
14	16,900	3,000	19,900	26,000	2,600	28,600	11,900	2,300	14,200	18,300	3,700	22,000
15	15,200	2,900	18,100	23,600	2,400	26,000	11,300	2,400	13,700	18,000	3,700	21,700
16	14.200	2,800	17,000	19,300	2,300	21,600	11,400	2,400	13,800	18,300	3,700	22,000
17	13,500	2,700	16,200	18,000	2,300	20,300	12,500	2,500	15,000	18,700	3,700	22,400
18	13,000	2,600	15,600	17,200	2,200	19,400	13,900	2,500	16,400	18,800	3,800	22,600
19	12,500	2,500	15,000	16,600	2,200	18,800	14,700	2,800	17,500	18,000	4,200	22,200
20	12,300	2,500	14,800	16,300	2,100	18,400	15,400	3,200	18,600	17,100	4,700	21,800
21	11,900	2,500	14,400	15,900	2,100	18,000	15,900	2,200	18,100	16,900	5,000	21,900
22	11,700	2,500	14,200	16,200	2,100	18,300	17,100	2,200	19,300	16,800	4,000	20,800
23	11,500	2,500	14,000	18,300	2,200	20,500	17,800	2,300	20,100	16,300	4,000	20,300
24	11,200	2,400	13,600	18,100	2,500	20,600	18,800	2,100	20,900	15,900	4,200	20,100
25	10,900	2,300	13,200	16,900	2,300	19,200	20,000	2,200	22,200	14,800	4,900	19,700
26	10,800	2,300	13,100	15,700	2,200	17,900	20,100	2,200	22,300	13,200	5,100	18,300
27	10,600	2,100	12,700	15,000	2,300	17,300	19,300	2,500	21,800	11,700	5,000	16,700
28	10,900	2,000	12,900	14,700	2,300	17,000	19,000	2,600	21,600	10,100	4,100	14,200
29				15,000	2,200	17,200	18,600	2,500	21,100	9,400	2,800	12,200
30				15,300	2,100	17,400	18,100	2,400	20,500	8,700	2,500	11,100
31				15,200	2,100	17,300				8,300	2,200	10,500
Totals in acre-feet	1,204,000	180,000	1,384,000	1,003,900	142,700	1,146,600	905,800	142,200	1,048,000	1,043,100	216,000	1,259,100

Total for season 1928–29, in acre-feet .... Sacramento River 7,421,300
Total for season 1928–29, in acre-feet .... San Joaquin River 1,551,200
Total for season 1928–29, in acre-feet .... Combined rivers 8,972,500

TABLE 37—Concluded

DAILY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, SEASON 1928-1929

Flow in second-feet

Day	June, 1929			July, 1929			August, 1929			September, 1929		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1	8,000	2,200	10,200	4,500	1,200	5,700	2,900	500	3,400	3,200	600	3,800
2	7,800	2,200	10,000	4,200	1,100	5,300	2,900	500	3,400	3,200	600	3,800
3	7,700	2,200	9,900	3,900	1,000	4,900	3,000	600	3,600	3,100	600	3,700
4	7,400	2,100	9,500	3,900	1,100	5,000	2,900	600	3,500	3,100	500	3,600
5	7,400	1,900	9,300	3,800	900	4,700	2,900	500	3,400	3,100	600	3,700
6	7,300	1,700	9,000	3,500	800	4,300	2,700	500	3,200	3,400	800	4,200
7	7,200	1,500	8,700	3,300	700	4,000	2,800	300	3,100	3,600	800	4,400
8	7,200	2,800	10,000	3,200	600	3,800	2,800	300	3,100	3,800	1,000	4,800
9	8,200	2,400	10,600	2,900	500	3,400	2,800	300	3,100	4,000	800	4,800
10	8,800	2,300	11,100	2,800	500	3,300	2,800	300	3,100	3,900	1,000	4,900
11	9,000	2,800	11,800	2,800	400	3,200	2,900	500	3,400	4,000	1,000	5,000
12	8,600	2,500	11,100	2,700	400	3,100	2,900	400	3,300	4,200	1,000	5,200
13	8,300	2,100	10,400	2,700	400	3,100	2,800	400	3,200	4,500	1,000	5,500
14	7,800	2,000	9,800	2,600	500	3,100	2,700	300	3,000	4,600	1,100	5,700
15	7,800	2,000	9,800	2,600	600	3,200	2,700	400	3,100	4,700	1,100	5,800
16	13,500	3,500	17,000	2,400	400	2,800	2,600	400	3,000	4,700	1,100	5,800
17	17,000	4,600	21,600	2,500	300	2,800	2,700	300	3,000	4,600	1,100	5,700
18	17,500	5,200	22,700	2,400	300	2,700	2,700	400	3,100	4,900	1,100	6,000
19	16,100	5,100	21,200	2,400	300	2,700	2,700	400	3,100	5,000	1,200	6,200
20	13,500	4,600	18,100	2,400	300	2,700	2,600	400	3,000	5,100	1,100	6,200
21	11,300	3,700	15,000	2,300	300	2,600	2,700	300	3,000	5,200	1,200	6,400
22	9,900	3,000	12,900	2,500	400	2,900	2,700	300	3,000	5,300	1,300	6,600
23	9,100	2,800	11,900	2,600	400	3,000	2,800	400	3,200	5,400	1,300	6,700
24	8,000	2,200	10,200	2,600	300	2,900	2,800	300	3,100	5,200	1,200	6,400
25	7,300	1,700	9,000	2,700	200	2,900	2,800	400	3,200	5,200	1,300	6,500
26	7,700	1,500	9,200	2,700	300	3,000	2,700	400	3,100	5,200	1,200	6,400
27	6,300	1,500	7,800	2,700	300	3,000	2,600	400	3,000	5,100	1,200	6,300
28	5,900	1,300	7,200	2,800	400	3,200	2,700	300	3,000	5,200	1,200	6,400
29	5,400	1,300	6,700	2,900	400	3,300	2,900	400	3,300	5,200	1,300	6,500
30	4,900	1,300	6,200	2,700	400	3,100	3,100	300	3,400	5,200	1,300	6,500
31	------	------	------	2,800	600	3,400	3,100	400	3,500	------	------	------
Totals in acre-feet	538,400	150,500	688,900	179,800	32,300	212,100	171,700	24,000	195,700	263,100	60,600	323,700

Total for season 1928–29, in acre-feet	Sacramento River	7,421,300
Total for season 1928–29, in acre-feet	San Joaquin River	1,551,200
Total for season 1928–29, in acre-feet	Combined rivers	8,972,500

BASIS OF COMPILATION OF TABLE 37

(See Plates I and II for location of gaging stations)

Sacramento River.

The daily stream flow of the Sacramento River into the delta was compiled from the following stream flow records and estimates.

1. Sacramento River at Sacramento (used only when the flow at Sacramento is unaffected by tidal action or is 24,000 second-feet or more). (State and U. S. Weather Bureau Records.)
2. Sacramento River at Verona (U. S. G. S. Records).
3. Sacramento River at Knights Landing (U. S. G. S. and U. S. Weather Bureau Records).
4. Feather River at Nicolaus (U S. G. S. and U. S. Weather Bureau Records).
5. American River at Fairoaks (U. S. G. S. Records).
6. American River at H Street Bridge (State Records).
7. Yolo By-pass at Lisbon (State Records) (used only when the flow at this station is unaffected by tidal action).
8. Cache Creek at Yolo (U. S. G. S. Records).
9. Putah Creek at Winters (U. S. G. S. Records).
10. Estimate based upon U. S. Weather Bureau and State Records of single daily gage height at Sacramento and Lisbon, combined with a comparative study of the total daily flow at upstream stations near the rim of the valley.
11. Estimated net diversions below gaging stations and above Sacramento (based upon records in reports by Sacramento-San Joaquin Water Supervisor, 1924 to 1929).
12. Records of net diversions from measurements of Sacramento-San Joaquin Water Supervisor (1924 to 1929).

In general, the total combined flow of the Sacramento River into the delta was compiled from the records of the farthest downstream stations available. Thus, (1) and (7) were always used when the records were available and the flow at these stations is unaffected by tidal action. When records at these stations were not available, or could not be used on account of tidal effects, the best records available at stations immediately upstream were used.

Thus, when (1) was not available, the flow of the main Sacramento River was compiled from the sum of the following records:

1919–20 to 1923–24, inclusive—(3), (4) and (6) or (5) less (11).
1924–25 to 1928–29, inclusive—(2), (6) or (5) less (12).

Similarly, when the flow at (7) was low or affected by tidal action, the flow in the Yolo By-pass into the delta was compiled as the sum of (8) and (9) for the entire period 1919 to 1929.

During the periods of large winter flow from 1919 to 1923, inclusive, the records at (1) and (7) were incomplete and inaccurate and no winter records were available at (3) and (4). The winter flow during this period of missing records at (1) and (7) was estimated from relations established on the basis of comparative hydrographs of flow at upstream stations near the rim of the valley and at the lower stations for the period 1923 to 1929 when records at both rim and lower stations were available.

San Joaquin River.

The daily stream flow of the San Joaquin River into the delta was compiled from the following stream flow records and estimates:

1. San Joaquin River at Vernalis (U. S. G. S. Records). (This record was available only during the periods of small discharge and was always used when available.)
2. San Joaquin River at Newman (U. S. G. S.). (This record was used only when the Vernalis station record was not available.)
3. Calaveras River at Jenny Lind (U. S. G. S. Records).
4. Mokelumne River at Thornton (U. S. G. S. Records). (This record was only available during 1929 and was used in preference to Woodbridge or Clements when available.)
5. Mokelumne River at Woodbridge (U. S. G. S. Records). (This record was available for low water periods of 1924 and 1925 and for entire period from 1926 to 1929, inclusive. This record was used in preference to the record at Clements (6).)
6. Mokelumne River at Clements (U. S. G. S. Records). (Used only when both Thornton (4) and Woodbridge (5) records were not available.)
7. Tuolumne River at La Grange (U. S. G. S. Records). (Used only when the Newman record (2) was used.)
8. Stanislaus River at Knights Ferry (U. S. G. S. Records). (Used only when the Newman record (2) was used.)
9. Cosumnes River at Michigan Bar (U. S. G. S. Records).
10. Dry Creek at Galt (U. S. G. S. Records and estimates).
11. Diversions below points of measurement and above delta.
    a. When Vernalis record (1) was used the following records and estimates of diversions were used.
        1. By delta uplands below Vernalis (Records from 1924 to 1929 were from measurements by Sacramento-San Joaquin Water Supervisor and previous to 1924 were estimated based on those records).
        2. From Mokelumne River (U. S. G. S. and Woodbridge Irrigation District Records). (When Thornton (4) and Woodbridge (5) records were used, no correction was made for this diversion.)
    b. When Newman record (2) was used, the following records and estimates of diversions were used.
        1. By Modesto and Turlock Irrigation Districts from Tuolumne River (U. S. G. S. Records).

2. By Oakdale and South San Joaquin Irrigation Districts from Stanislaus River (U. S. G. S. Records).
3. By delta uplands and from main San Joaquin River below Newman. (Sacramento-San Joaquin Water Supervisor Records, 1924 to 1929, and estimates from 1919 to 1923.)
4. From Mokelumne River (U. S. G. S. and Woodbridge Irrigation District Records). (When Thornton (4) and Woodbridge (5) records were used, no correction was made for this diversion.)

12. Estimated return flow below points of measurement and above delta.

a. When Vernalis record was used, the following return flow was estimated:

1. From 75 per cent of diversions to South San Joaquin Irrigation District.
2. From delta uplands diversions.
3. From Woodbridge Irrigation District diversions. (When Thornton record was used no return flow was estimated.)

b. When Newman record was used, the following return flow was estimated.

1. From Modesto, Oakdale, South San Joaquin Irrigation District diversions.
2. From 85 per cent of Turlock Irrigation District diversions.
3. From Woodbridge Irrigation District diversions. (When Thornton (4) record was used, no return flow was estimated.)
4. From delta uplands and lower San Joaquin River (below Newman) diversions.

The total return flow from the Oakdale, South San Joaquin, Modesto and Turlock Irrigation District diversions was estimated as being 35 per cent of the total annual diversions, and for the delta uplands and lower San Joaquin River as being 15 per cent of the total annual diversions. This total return flow was segregated monthly as follows:

Monthly Return Flow in Per Cent of Annual Return Flow

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
7	7	7	7	8	11	12	10	9	8	7	7

For the Mokelumne River the total return flow was estimated as being 14 per cent of the total annual diversions and segregated monthly by computing the return flow of any month as equal to 14 per cent of the previous month's diversions.

In general, the total combined daily flow of the San Joaquin River into the delta was compiled from the records of the farthest downstream stations available. Thus the total sum of (1), (3), (4) or (5), (9), (10) and (12a), less (11a) was always used when the records were available. When the record at (1) was not available, then the total sum of the following items was used: (2), (7), (8), (3), (4) or (5) or (6), (9), (10) and (12b), less (11b).

TABLE 38

MONTHLY STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA, 1911-12 TO 1928-29

Source	Inflow in acre-feet												
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Total seasonal
Season of 1911-12—													
Sacramento River	726,000	541,000	552,000	982,000	1,059,000	1,493,000	1,340,000	2,046,000	1,217,000	708,000	529,000	602,000	11,795,000
San Joaquin River	53,000	69,000	64,000	120,000	74,000	148,000	166,000	768,000	913,000	79,000	28,000	33,000	2,515,000
Combined rivers	779,000	610,000	616,000	1,102,000	1,133,000	1,641,000	1,506,000	2,814,000	2,130,000	787,000	557,000	635,000	14,310,000
Season of 1912-13—													
Sacramento River	549,000	988,000	786,000	1,536,000	994,000	1,206,000	2,375,000	2,592,000	1,109,000	604,000	460,000	382,000	13,581,000
San Joaquin River	36,700	97,100	51,300	107,300	80,300	98,400	336,400	515,300	251,900	55,900	33,500	37,300	1,701,400
Combined rivers	585,700	1,085,100	837,300	1,643,300	1,074,300	1,304,400	2,711,400	3,107,300	1,360,900	659,900	493,500	419,300	15,282,400
Season of 1913-14—													
Sacramento River	413,000	612,000	1,364,000	10,365,000	5,019,000	4,352,000	4,443,000	3,513,000	2,512,000	775,000	427,000	381,000	34,176,000
San Joaquin River	31,200	55,600	114,300	1,739,300	1,205,300	1,019,600	1,181,600	1,770,000	1,739,600	886,800	121,600	43,900	9,908,800
Combined rivers	444,200	667,600	1,478,300	12,104,300	6,224,300	5,371,600	5,624,600	5,283,000	4,251,600	1,661,800	548,600	424,900	44,084,800
Season of 1914-15—													
Sacramento River	466,000	598,000	814,000	1,998,000	7,415,000	3,845,000	4,041,000	5,198,000	2,849,000	811,000	476,000	363,000	28,874,000
San Joaquin River	57,900	82,600	109,300	239,300	1,037,300	570,700	908,100	1,502,900	1,818,200	544,600	59,900	39,500	6,970,300
Combined rivers	523,900	680,600	923,300	2,237,300	8,452,300	4,415,700	4,949,100	6,700,900	4,667,200	1,355,600	535,900	402,500	35,844,300
Season of 1915-16—													
Sacramento River	623,000	568,000	1,703,000	3,924,000	5,954,000	5,649,000	4,511,000	2,854,000	1,526,000	705,000	391,000	355,000	28,763,000
San Joaquin River	42,500	48,900	127,600	1,164,600	1,266,600	1,905,900	1,663,800	1,754,800	1,490,300	563,100	108,700	55,300	10,192,100
Combined rivers	665,500	616,900	1,830,600	5,088,600	7,220,600	7,554,900	6,174,800	4,608,800	3,016,300	1,268,100	499,700	410,300	38,955,100
Season of 1916-17—													
Sacramento River	503,000	618,000	1,188,000	954,000	1,746,000	3,344,000	3,137,000	3,143,000	1,808,000	543,000	355,000	351,000	17,690,000
San Joaquin River	180,300	143,000	272,600	318,600	953,600	605,600	705,600	1,307,000	1,889,800	439,900	56,100	43,900	6,916,000
Combined rivers	683,300	761,000	1,460,600	1,272,600	2,699,600	3,949,600	3,842,600	4,450,000	3,697,800	982,900	411,100	394,900	24,606,000
Season of 1917-18—													
Sacramento River	408,000	475,000	614,000	541,000	1,055,000	2,054,000	2,698,000	1,173,000	381,000	169,000	153,000	299,000	10,020,000
San Joaquin River	35,200	50,700	58,300	51,300	184,300	1,226,200	789,700	737,200	884,400	79,800	33,400	39,900	4,170,400
Combined rivers	443,200	525,700	672,300	592,300	1,239,300	3,280,200	3,487,700	1,910,200	1,265,400	248,800	186,400	338,900	14,190,400
Season of 1918-19—													
Sacramento River	550,000	606,000	647,000	1,198,000	3,499,000	3,095,000	3,147,000	2,440,000	662,000	194,000	155,000	229,000	16,422,000
San Joaquin River	164,300	123,600	173,200	117,200	386,200	450,200	667,200	1,282,000	224,500	26,700	16,100	17,500	3,648,700
Combined rivers	714,300	729,600	820,200	1,315,200	3,885,200	3,545,200	3,814,200	3,722,000	886,500	220,700	171,100	246,500	20,070,700
Season of 1919-20—													
Sacramento River	393,800	410,300	630,200	519,800	582,100	1,237,500	1,903,600	1,382,000	409,300	71,100	44,900	144,900	7,729,500
San Joaquin River	40,000	46,300	106,700	76,400	68,500	472,200	458,200	1,004,500	634,600	58,600	24,800	23,200	3,014,000
Combined rivers	433,800	456,600	736,900	596,200	650,600	1,709,700	2,361,800	2,386,500	1,043,900	129,700	69,700	168,100	10,743,500

Season of 1920-21—													
Sacramento River	428,300	1,839,400	3,789,300	4,586,900	4,069,700	3,769,500	2,621,900	2,437,600	1,306,400	401,900	223,900	244,900	25,719,700
San Joaquin River	81,400	168,900	341,000	909,600	635,800	784,700	546,100	1,044,400	1,053,400	137,400	38,000	29,900	5,770,600
Combined rivers	509,700	2,008,300	4,130,300	5,496,500	4,705,500	4,554,200	3,168,000	3,482,000	2,359,800	539,300	261,900	274,800	31,490,300
Season of 1921-22—													
Sacramento River	378,400	465,700	1,039,700	1,078,700	2,362,100	2,616,200	2,904,500	4,067,900	2,414,400	462,900	221,200	267,700	18,279,400
San Joaquin River	45,100	54,400	242,500	422,100	1,141,900	839,100	821,900	1,990,900	2,150,500	510,600	85,100	45,900	8,350,000
Combined rivers	423,500	520,100	1,282,200	1,500,800	3,504,000	3,455,300	3,726,400	6,058,800	4,564,900	973,500	306,300	313,600	26,629,400
Season of 1922-23—													
Sacramento River	488,100	660,300	2,136,400	1,966,100	1,057,300	1,138,500	2,456,000	1,714,900	862,100	390,800	217,400	317,600	13,405,500
San Joaquin River	62,800	144,500	652,400	588,900	422,500	269,700	791,600	1,138,100	614,200	320,800	95,000	87,500	5,188,000
Combined rivers	550,900	804,800	2,788,800	2,555,000	1,479,800	1,408,200	3,247,600	2,853,000	1,476,300	711,600	312,400	405,100	18,593,500
Season of 1923-24—													
Sacramento River	454,400	406,900	438,400	505,300	1,138,300	502,500	485,100	233,100	78,800	55,200	84,100	160,600	4,532,700
San Joaquin River	170,100	92,700	112,100	111,500	116,200	76,600	137,200	127,300	33,900	22,000	21,400	22,400	1,043,400
Combined rivers	624,500	499,600	550,500	616,800	1,254,500	579,100	622,300	350,400	112,700	77,200	105,500	183,000	5,576,100
Season of 1924-25—													
Sacramento River	337,800	673,800	905,100	925,600	4,962,100	2,214,800	3,015,100	2,184,100	796,000	288,700	185,500	275,800	16,764,400
San Joaquin River	37,200	115,200	178,400	162,600	670,400	372,600	979,500	1,291,200	625,700	152,200	41,400	58,200	4,684,600
Combined rivers	375,000	789,000	1,083,500	1,088,200	5,632,500	2,587,400	3,994,600	3,475,300	1,421,700	440,900	226,900	334,000	21,449,000
Season of 1925-26—													
Sacramento River	416,000	452,600	630,000	597,600	4,264,700	1,551,100	3,330,600	958,900	253,600	115,200	121,400	278,000	12,969,700
San Joaquin River	105,900	144,300	194,200	140,800	333,600	244,500	721,100	425,900	113,300	28,900	19,200	31,300	2,503,000
Combined rivers	521,900	596,900	824,200	738,400	4,598,300	1,795,600	4,051,700	1,384,800	366,900	144,100	140,600	309,300	15,472,700
Season of 1926-27—													
Sacramento River	393,400	1,102,700	2,601,900	2,203,100	6,306,700	4,124,500	4,006,900	2,479,300	1,334,900	378,200	224,900	303,100	25,459,600
San Joaquin Rivers	68,300	155,200	232,300	299,000	873,600	697,600	943,700	913,000	84,000	212,800	73,700	85,100	5,438,300
Combined rivers	461,700	1,257,900	2,834,200	2,502,100	7,180,300	4,822,100	4,950,600	3,392,300	2,218,900	591,000	298,600	388,200	30,897,900
Season of 1927-28—													
Sacramento River	422,100	1,159,500	1,045,000	1,303,600	2,341,200	4,407,700	4,467,900	1,421,600	402,700	236,600	176,400	288,500	17,672,800
San Joaquin River	142,000	237,000	260,600	239,600	263,500	986,400	696,800	618,800	202,200	56,400	41,400	71,100	3,815,800
Combined rivers	564,100	1,396,500	1,305,600	1,543,200	2,604,700	5,394,100	5,164,700	2,040,400	604,900	293,000	217,800	359,600	21,488,600
Season of 1928-29—													
Sacramento River	365,300	507,700	601,100	637,400	1,204,000	1,003,900	905,800	1,043,100	538,400	179,800	171,700	263,100	7,421,300
San Joaquin River	123,000	150,900	163,900	165,100	180,000	142,700	142,200	216,000	150,500	32,300	24,000	60,600	1,551,200
Combined rivers	488,300	658,600	765,000	802,500	1,384,000	1,146,600	1,048,000	1,259,100	688,900	212,100	195,700	323,700	8,972,500

BASIS OF COMPILATION OF TABLE 38

For period 1911–12 to 1918–19

(See Plates I and II for location of gaging stations)

Sacramento River

A. The monthly stream flow of the Sacramento River into the delta during the winter period from November to March, each season, was compiled from the following stream flow records and estimates.

1. Hydrographs of the combined daily flow of the following rim stations having a continuous record were compiled:

   a. Sacramento River at Red Bluff (U. S. G. S. Records).
   b. Feather River at Oroville (U. S. G. S. Records).
   c. Yuba River at Smartsville (U. S. G. S. Records).
   d. Bear River at Van Trent (U. S. G. S. Records).
   e. American River at Fairoaks (U. S. G. S. Records).
   f. Cache Creek at Yolo (U. S. G. S. Records).
   g. Putah Creek at Winters (U. S. G. S. Records).

2. Hydrographs of the total daily flow of the Sacramento River into the delta were then estimated from the hydrographs of combined flow of the rim stations compiled under item (1), based upon the relation established between the flow at the rim stations and the measured flow passing Sacramento and Lisbon (Yolo By-pass) from a study of comparative hydrographs compiled for the seasons 1923-24 to 1928-29, inclusive, when records at both rim and lower stations were available. As a check on this method, all available records of the single daily gage heights at the Sacramento and Lisbon stations applied to the rating curves at these stations, were used as a guide to estimate the daily flow during periods of large discharge.

The monthly stream flow of the Sacramento River into the delta was compiled from the summations of the estimated daily flows taken from the hydrographs compiled under Item (2). No correction was necessary for diversions or return water under this method.

B. The stream flow during the period from April to October, each season, was compiled from the following stream flow records and estimates.

1. Records of stream flow at the following stations:

   a. Feather River at Nicolaus—U. S. Weather Bureau gage heights applied to State rating curve.
   b. Sacramento River at Knights Landing—U. S. Weather Bureau gage heights applied to State rating curve.
   c. American River at Fairoaks—U. S. G. S. Records.
   d. Cache Creek at Yolo—U. S. G. S. Records.
   e. Putah Creek at Winters—U. S. G. S. Records.

2. Diversions and return water between these stations and Sacramento were small in amount during this period. No corrections were made for such amounts, except for the

season 1918–19, when a deduction was made for estimated net diversions.

San Joaquin River

The monthly stream flow of the San Joaquin River into the delta was compiled from the following stream flow records and estimates.

1. Stream flow records at the following stations:
   a. San Joaquin River at Newman—U. S. G. S. Records.
   b. Tuolumne River at La Grange—U. S. G. S. Records.
   c. Stanislaus River at Knights Ferry—U. S. G. S. Records.
   d. Calaveras River at Jenny Lind—U. S. G. S. Records.
   e. Mokelumne River at Clements—U. S. G. S. Records.
   f. Cosumnes River at Michigan Bar—U. S. G. S. Records.

2. Diversions below points of measurement:
   a. From Tuolumne River below La Grange—U. S. G. S. Records.
   b. From Stanislaus River below Knights Ferry—U. S. G. S. Records.
   c. From main San Joaquin River and to delta uplands below Newman (estimated).
   d. From Mokelumne River below Clements—Woodbridge Irrigation District records and estimates.

3. Estimated return flow from the following diversions:
   a. Oakdale and South San Joaquin Irrigation Districts on Stanislaus River; Modesto Irrigation District and a portion (85 per cent) of Turlock Irrigation District on the Tuolumne River.
      1. For the above annual diversions, the total return water was computed as being 35 per cent of the total annual diversions and distributed as follows:

Monthly Return Water in Per Cent of Annual Return Water

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
7	7	7	7	8	11	12	10	9	8	7	7

   b. Delta Uplands and Lower San Joaquin River below Newman.
      1. The total return water was computed as being 15 per cent of the total annual diversions and distributed as above in item (a-1).
   c. Mokelumne River Diversions.
      1. The total return water was computed as being 14 per cent of the total annual diversions and distributed as follows:

         Monthly return water was computed as being 14 per cent of the previous month's diversion.

The monthly stream flow of the San Joaquin River into the delta was compiled as the sum of items (1) and (3), less item (2).

TABLE 39

SEASONAL STREAM FLOW INTO SACRAMENTO-SAN JOAQUIN DELTA

Season	Seasonal stream flow in in acre-feet			Seasonal stream flow in per cent of 58-year Mean		
	Sacramento River	San Joaquin River	Combined rivers	Sacramento River	San Joaquin River	Combined rivers
1911-12	11,795,000	2,515,000	14,310,000	50	32	46
1912-13	13,581,000	1,701,000	15,282,000	58	22	49
1913-14	34,176,000	9,909,000	44,085,000	146	125	141
1914-15	28,874,000	6,970,000	35,844,000	123	88	114
1915-16	28,763,000	10,192,000	38,955,000	123	129	124
1916-17	17,690,000	6,916,000	24,606,000	75	88	78
1917-18	10,020,000	4,170,000	14,190,000	43	53	45
1918-19	16,422,000	3,649,000	20,071,000	70	46	64
1919-20	7,730,000	3,014,000	10,744,000	33	38	34
1920-21	25,720,000	5,771,000	31,491,000	110	73	101
1921-22	18,279,000	8,350,000	26,629,000	78	106	85
1922-23	13,406,000	5,188,000	18,594,000	57	66	59
1923-24	4,533,000	1,043,000	5,576,000	19	13	18
1924-25	16,764,000	4,685,000	21,449,000	71	59	68
1925-26	12,970,000	2,503,000	15,473,000	55	32	49
1926-27	25,460,000	5,438,000	30,898,000	109	69	99
1927-28	17,673,000	3,816,000	21,489,000	75	48	69
1928-29	7,422,000	1,551,000	8,973,000	32	20	29
58-year mean 1871-72 to 1928-29	23,449,000	7,897,000	31,346,000	100	100	100
40-year mean 1889-90 to 1928-29	23,442,000	7,805,000	31,247,000	100	99	100
20-year mean 1909-10 to 1928-29	18,228,000	5,537,000	23,765,000	78	70	76
10-year mean 1919-20 to 1928-29	14,995,000	4,136,000	19,131,000	64	52	61
5-year mean 1924-25 to 1928-29	16,058,000	3,599,000	19,657,000	68	46	63

GLOSSARY

28—80995

GLOSSARY

DEFINITION OF TECHNICAL TERMS

Advance of salinity. The movement upstream of saline water, from the ocean or lower portion of a tidal basin, to the upper part of a tidal basin into which streams discharge fresh water continuously or intermittently in varying amount. The phenomenon is due to the lack of a sufficient stream inflow to counteract the force exerted by pulsating tidal flows, which mix and diffuse the more saline waters from downstream with the fresher waters upstream, and continuously tend to push saline water upstream.

Consumptive use. Designates the amount of water actually consumed through evaporation, transpiration by plant growth and other processes. As applied to use of water in the Sacramento-San Joaquin Delta, consumptive use is used in its absolute sense, representing total amount of water consumed irrespective of source of supply.

Cycle. An interval of time in which a regularly recurring succession of events or phenomenon is completed.

Cyclic. Moving or occurring in cycles or in more or less regularly recurring intervals of time.

Degree of salinity Designates the number of parts (by weight) of chlorine per 100,000 parts of water. (See "Salinity.")

Dry year or season. A year or season (12 months) having a smaller amount of precipitation or run-off than normal, as compared to the average or mean of amounts occurring in a series of previous years or seasons. "Dry season" is also used to designate that portion of the year when there is usually little if any precipitation. (See "Wet year or season.")

Fresh water. Water having little if any salt content. As used in this report, fresh water designates the quality of water usually found flowing in the streams tributary to the delta and bay and having a salinity of ten parts or less of chlorine per 100,000 parts of water.

Half tide. The mean or average of the water levels reached by the four tidal phases of one or more tidal cycles. Over a long period of time, half tide is approximately the same as mean tide. (See "Tidal phase.")

Mean tide. The mean or average level of fluctuating tidal waters over any particular period of time. It is usually computed as an average of hourly tidal stages.

Return water or flow. Water emanating from irrigated lands and appearing in channels downstream from irrigated areas, being that portion of the total water applied to the land for irrigation which is not consumed by plant transpiration and evaporation but passes to the stream channels below partly as surface waste and partly through underground strata.

Retreat of salinity. The movement downstream of saline water subsequent to a previous saline invasion, due to the stream flow into a tidal basin becoming sufficient to overcome the force exerted by tidal action and tidal diffusion of salinity resulting therefrom, thus displacing the saline water with fresh water and pushing the saline water downstream.

Saline. Salty or having some degree of salinity.

Saline invasion. The movement of saline water from the ocean upstream into tidal estuaries or channels through which fresh water streams flow, resulting in the fresh water becoming saline. An annually recurring phenomenon in the channels of upper San Francisco Bay and the delta of the Sacramento and San Joaquin rivers, when the flow of these streams is small during the summer and fall months. (See "Advance of salinity.")

Salinity. Degree of saltness or salt content. In general, it is inclusive of all kinds of salt. However, since common salt (NaCl) predominates in ocean water, salinity of water impregnated with ocean water is commonly expressed in terms of its chlorine (Cl) content. In this report, salinity or degree of salinity of water is expressed in parts (by weight) of chlorine per 100,000 parts by volume.

Salinity. {Advance of / Retreat of}. See "Advance of salinity" and "Retreat of salinity."

Salt water. Water having a high degree of salinity, such as ocean water. The water of the Pacific Ocean has a salinity of 1800 to 1900 parts of chlorine per 100,000 parts of water.

Seasonal (season). Of or pertaining to a particular period of time relating to a special activity or occurrence. "Seasonal" stream flow designates the total flow during the period October 1 of one year to October 1 of the succeeding year. "Seasonal" precipitation designates the total precipitation from July 1 of one year to July 1 of the succeeding year. The terms "a wet season" and "a dry season" designate seasons having respectively greater and smaller amounts of precipitation or run-off than normal, as compared to the average or mean of amounts occurring in a series of previous seasons. "Seasonal" consumptive use designates the amount of water consumed by crops or plants during the period of growth, and by evaporation or other agencies during the entire period of substantially continuous use. As related to salinity in the upper San Francisco Bay and Sacramento-San Joaquin Delta channels, "seasonal" or "season" is used with reference to the period of saline invasion or retreat. With reference to precipitation and run-off, the terms, "the wet season" and "the dry season" are used to designate respectively the period of the year during which most of the precipitation and run-off occurs and the period when little if any precipitation and only a small part of the run-off occurs.

Surface zone. Designation applied to the upper six inches to one foot of water in which samples of water for regular salinity observations are taken in any channel.

Teredo navalis. A species of shipworm living in salt water, having an extraordinary capacity for speedy and complete destruction of timber exposed to its ravages. This species of teredo will not live in water having a salinity continuously below about 300 parts of chlorine per 100,000 parts of water. However, it is able to survive limited periods of fresher water by protecting itself in its burrows from exposure to the same, but, under such conditions, its activities are curtailed. If the period of fresh water is not too prolonged, a subsequent recurrence of saline water of over 300 parts of chlorine per 100,000 parts of water revives the organism and its activities are resumed.

This species of teredo was not present in San Francisco Bay prior to 1913. It is believed that it was first introduced in the summer of that year, perhaps through the medium of a shipment of piling infected with the organism.

Tidal action. The action of the tide, or the alternate rising and falling of the water surface of the ocean and connecting bays, estuaries, rivers and other water courses; coupled with the currents and flow induced thereby in these tidal channels. The tide is due to forces exerted by the moon and the sun on the waters of the ocean. (See "Tidal phase" and "Tidal cycle.")

Tidal basin. A bay, estuary or other water course connected with the ocean, affected by tidal action. (See "Tidal action.")

Tidal channel. A water course connected to the ocean and affected by tidal action as exhibited by the characteristic tidal fluctuations of water level and tidal currents and flow induced thereby.

Tidal current. The movement of water through a tidal channel, induced by tidal action and resulting from tidal flow into and out of the tidal basin above any particular section of tidal channel.

Tidal cycle. As used in this report, a tidal cycle is the interval of time (abou 24 to 25 hours, or approximately a lunar day) for the tide to pass from on particular phase (*i.e.*, low-low tide) through its characteristic intervening fluctuations to the identical phase next succeeding. (See "Tidal phase.")

Tidal diffusion. As defined in this report, tidal diffusion designates the effect of the pulsating tidal flows in the channels of a tidal basin, which cause a mixing of the saline waters from the ocean or from downstream with the fresh waters upstream emanating from stream inflow, resulting in a positive and continuing tendency for saline water to advance upstream. It applies particularly to tidal channels into which or through which streams discharge fresh water continuously or intermittently in varying amount. If the stream inflow is not sufficient to counteract the force of tidal action and tidal diffusion of salinity resulting therefrom, saline water will advance upstream. If the magnitude of stream flow is sufficient, it may overcome this force of tidal action, pushing the saline water downstream and displacing it with fresh water.

Tidal flow. The flow of water past any particular section of tidal channel into and out of a tidal basin above the section, as a result of tidal action. Tidal flow, as distinct from stream flow, is typified by alternate periods of flow in opposite directions past a particular section in a tidal channel. The tidal flow taking place when the tide is falling or in "ebb," is directed toward the ocean and is designated an "ebb" flow. The tidal flow occurring during the period when the tide is rising or in "flood" is from the ocean upstream into the tidal basin and is designated a "flood" flow.

Tidal phase. A particular level of tidal waters recurring with varying elevation at fairly regular intervals. On the Pacific coast, there are usually two high and two low tidal phases or levels, occurring at intervals of about six hours apart during a tidal cycle, designated as low-low, high-low, low-high and high-high tides, in accordance with their relative elevations in a particular tidal cycle. The sequence of occurrence of tidal phases during a lunar day, or what may be termed a tidal cycle period of from 24 to 25 hours, is generally as follows: Starting with a low-low tide, the water level rises in a flood period to a low-high tide. This is followed by a period of ebb with the water level falling to a second but higher low tide (high-low tide). The water level again rises in another flood period to a second but higher high tide (high-high tide) of the tidal cycle and finally falls in an ebb period to a low-low tide which marks the end of one tidal cycle and the beginning of a new one. Occasionally, the sequence of occurrence of the lower and higher levels of low and high tides on a particular day is reversed, but the above sequence is the more usual on the Pacific coast of California and in the San Francisco Bay tidal basin. (See "Half tide" and "Mean tide.")

Tidal prism (tidal prism volume). As generally defined, a tidal prism is the volumetrical space in a tidal basin bounded by the limiting levels of tidal fluctuation or range. (See Plate XV.) In this report, the volume corresponding to this general definition of a tidal prism has been designated as the "tidal volume," in order to differentiate it from actual tidal prism volumes. (See "Tidal volume.") An actual tidal prism, defining the change in volume in a tidal basin during the interval between any two successive tidal phases, is bounded by the positions of the water surface over the entire basin, coincident with the two successive tidal phases at the lower end of the basin. Because of the progressive tidal movement from the lower to the upper end of a tidal basin, with identical tidal phases occurring at increasingly later times after their occurrence at the lower end as the distance from the lower end increases, the water surface levels at a particular time at points distant from the lower end are not of the same phase as that at the lower end, but may be of some different phase or at some intermediate tidal stage, varying at different points. Hence, the volume of actual tidal prisms may and frequently does comprise only a fractional part of the total tidal volume within the limiting levels of tidal fluctuation or range, even with a maximum tidal range between successive tidal phases at the lower end of the basin. (See Plates XL to XLV.)

Tidal range. The difference in water level reached by any two tidal phases.

Tidal stage. The height of tidal water with respect to a fixed point or plane of reference. Tidal level or gage height.

Tidal volume. In this report, it designates the total gross tidal prism volume in a tidal basin between the limits of tidal range over the entire basin. The maximum potentially effective tidal volume is the total volume in a tidal basin within the extreme limits of tidal range from higher-high water to lower-low water in all parts of a tidal basin. (See Plate XV.)

Tide gage. In its simplest form, a staff graduated in linear measure, on which the height of tidal waters is read to obtain a record of fluctuating tidal levels and high and low tidal stages. Automatic recording instruments (automatic tide gages) are instruments which automatically and continuously record the height of water level.

Tide {Half / Mean}. See "Half tide" and "Mean tide."

Titration. An analytical chemical process consisting in the addition of a liquid in measured volume to a known volume of another liquid, till a certain definite effect, usually a change in color in a color medium, is observed. Thus, salinity of water is determined by titration against silver nitrate with the use of potassium chromate as a color indicator.

Wet year or season. A year or season (12 months) having a greater amount of precipitation or run-off than normal, as compared to the average or mean of amounts occurring in a series of previous years or seasons. "Wet season" is also used to designate that portion of the year when precipitation occurs. (See "Dry year or season.")

PUBLICATIONS OF THE

DIVISION OF WATER RESOURCES

DEPARTMENT OF PUBLIC WORKS

STATE OF CALIFORNIA

When the Department of Public Works was created in July, 1921, the State Water Commission was succeeded by the Division of Water Rights, and the Department of Engineering was succeeded by the Division of Engineering and Irrigation in all duties except those pertaining to State Architect. Both the Division of Water Rights and the Division of Engineering and Irrigation functioned until August, 1929, when they were consolidated to form the Division of Water Resources.

STATE WATER COMMISSION

First Report, State Water Commission, March 24 to November 1, 1912.

Second Report, State Water Commission, November 1, 1912 to April 1, 1914.

*Biennial Report, State Water Commission, March 1, 1915, to December 1, 1916.

Biennial Report, State Water Commission, December 1, 1916, to September 1, 1918.

Biennial Report, State Water Commission, September 1, 1918, to September 1, 1920.

DIVISION OF WATER RIGHTS

*Bulletin No. 1—Hydrographic Investigation of San Joaquin River, 1920–1923.

*Bulletin No. 2—Kings River Investigation, Water Master's Reports, 1918–1923.

*Bulletin No. 3—Proceedings First Sacramento-San Joaquin River Problems Conference, 1924.

*Bulletin No. 4—Proceedings Second Sacramento-San Joaquin River Problems Conference, and Water Supervisor's Report, 1924.

*Bulletin No. 5—San Gabriel Investigation—Basic Data, 1923–1926.

Bulletin No. 6—San Gabriel Investigation—Basic Data, 1926–1928.

Bulletin No. 7—San Gabriel Investigation—Analysis and Conclusions, 1929.

*Biennial Report, Division of Water Rights, 1920–1922.

*Biennial Report, Division of Water Rights, 1922–1924.

Biennial Report, Division of Water Rights, 1924–1926.

Biennial Report, Division of Water Rights, 1926–1928.

DEPARTMENT OF ENGINEERING

*Bulletin No. 1—Cooperative Irrigation Investigations in California, 1912–1914.

*Bulletin No. 2—Irrigation Districts in California, 1887–1915.

Bulletin No. 3—Investigations of Economic Duty of Water for Alfalfa in Sacramento Valley, California, 1915.

*Bulletin No. 4—Preliminary Report on Conservation and Control of Flood Waters in Coachella Valley, California, 1917.

*Bulletin No. 5—Report on the Utilization of Mojave River for Irrigation in Victor Valley, California, 1918.

*Bulletin No. 6—California Irrigation District Laws, 1919 (now obsolete).

Bulletin No. 7—Use of water from Kings River, California, 1918.

*Bulletin No. 8—Flood Problems of the Calaveras River, 1919.

Bulletin No. 9—Water Resources of Kern River and Adjacent Streams and Their Utilization, 1920.

*Biennial Report, Department of Engineering, 1907–1908.

*Biennial Report, Department of Engineering, 1908–1910.

*Biennial Report, Department of Engineering, 1910–1912.

*Biennial Report, Department of Engineering, 1912–1914.

*Biennial Report, Department of Engineering, 1914–1916.

*Biennial Report, Department of Engineering, 1916–1918.

*Biennial Report, Department of Engineering, 1918–1920.

* Reports and Bulletins out of print. These may be borrowed by your local library from the California State Library at Sacramento, California.

DIVISION OF WATER RESOURCES

Including Reports of the Former Division of Engineering and Irrigation

*Bulletin No. 1—California Irrigation District Laws, 1921 (now obsolete).
*Bulletin No. 2—Formation of Irrigation Districts, Issuance of Bonds, etc., 1922.
Bulletin No. 3—Water Resources of Tulare County and Their Utilization, 1922.
Bulletin No. 4—Water Resources of California, 1923.
Bulletin No. 5—Flow in California Streams, 1923.
Bulletin No. 6—Irrigation Requirements of California Lands, 1923.
*Bulletin No. 7—California Irrigation District Laws, 1923 (now obsolete).
*Bulletin No. 8—Cost of Water to Irrigators in California, 1925.
Bulletin No. 9—Supplemental Report on Water Resources of California, 1925.
*Bulletin No. 10—California Irrigation District Laws, 1925 (now obsolete).
Bulletin No. 11—Ground Water Resources of Southern San Joaquin Valley, 1927.
Bulletin No. 12—Summary Report on the Water Resources of California and a Coordinated Plan for Their Development, 1927.
Bulletin No. 13—The Development of the Upper Sacramento River, containing U. S. R. S. Cooperative Report on Iron Canyon Project, 1927.
Bulletin No. 14—The Control of Floods by Reservoirs, 1928.
*Bulletin No. 18—California Irrigation District Laws, 1927 (now obsolete).
*Bulletin No. 18—California Irrigation District Laws, 1929 Revision (now obsolete).
Bulletin No. 18-B—California Irrigation District Laws, 1931, Revision.
Bulletin No. 19—Santa Ana Investigation, Flood Control and Conservation (with packet of maps), 1928.
Bulletin No. 20—Kennett Reservoir Development, an Analysis of Methods and Extent of Financing by Electric Power Revenue, 1929.
Bulletin No. 21—Irrigation Districts in California, 1929.
Bulletin No. 21-A—Report on Irrigation Districts in California for the Year 1929, 1930.
Bulletin No. 21-B—Report on Irrigation Districts in California for the year 1930, 1931.
Bulletin No. 22—Report on Salt Water Barrier (two volumes), 1929.
Bulletin No. 23—Report of Sacramento-San Joaquin Water Supervisor, 1924–1928.
Bulletin No. 24—A Proposed Major Development on American River, 1929.
Bulletin No. 25—Report to Legislature of 1931 on State Water Plan, 1930.
Bulletin No. 27—Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay, 1931.
Bulletin No. 28—Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers, 1931.
Bulletin No. 28-A—Industrial Survey of Upper San Francisco Bay Area, 1930.
Bulletin No. 31—Santa Ana River Basin, 1930.
Bulletin No. 32—South Coastal Basin, a Cooperative Symposium, 1930.
Bulletin No. 33—Rainfall Penetration and Consumptive Use of Water in Santa Ana River Valley and Coastal Plain, 1930.
Bulletin No. 34—Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley, 1930.
Bulletin No. 35—Permissible Economic Rate of Irrigation Development in California, 1930.
*Bulletin No. 36—Cost of Irrigation Water in California, 1930.
Bulletin No. 37—Financial and General Data Pertaining to Irrigation, Reclamation and Other Public Districts in California, 1930.
Bulletin No. 38—Report of Kings River Water Master for the Period 1918–1930.
Bulletin No. 39—South Coastal Basin Investigation, Records of Ground Water Levels at Wells, 1932.
Biennial Report, Division of Engineering and Irrigation, 1920–1922.
Biennial Report, Division of Engineering and Irrigation, 1922–1924.
Biennial Report, Division of Engineering and Irrigation, 1924–1926.
Biennial Report, Division of Engineering and Irrigation, 1926–1928.

* Reports and Bulletins out of print. These may be borrowed by your local library from the California State Library at Sacramento, California.

PAMPHLETS

Rules and Regulations Governing the Supervision of Dams in California, 1929.

Water Commission Act with Amendments Thereto, 1931.

Rules, Regulations and Information Pertaining to Appropriation of Water in California, 1930.

Rules and Regulations Governing the Determination of Rights to Use of Water in Accordance with the Water Commission Act, 1925.

Tables of Discharge for Parshall Measuring Flumes, 1928.

General Plans, Specifications and Bills of Material for Six and Nine Inch Parshall Measuring Flumes, 1930.

COOPERATIVE AND MISCELLANEOUS REPORTS

*Report of the Conservation Commission of California, 1912.

*Irrigation Resources of California and Their Utilization (Bul. 254, Office of Exp. U. S. D. A.) 1913.

*Report, State Water Problems Conference, November 25, 1916.

*Report on Pit River Basin, April, 1915.

*Report on Lower Pit River Project, July, 1915.

*Report on Iron Canyon Project, 1914.

*Report on Iron Canyon Project, California, May, 1920.

*Sacramento Flood Control Project (Revised Plans), 1925.

Report of Commission Appointed to Investigate Causes Leading to the Failure of St. Francis Dam, 1928.

Report of the Joint Committee of the Senate and Assembly Dealing With the Water Problems of the State, 1929.

Report of the California Joint Federal-State Water Resources Commission, 1930.

Conclusions and Recommendations of the Report of the California Irrigation and Reclamation Financing and Refinancing Commission, 1930.

Report of the Joint Committee of the Senate and Assembly Dealing with the Water Problems of the State, 1931.

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* Reports and Bulletins out of print. These may be borrowed by your local library from the California State Library at Sacramento, California.

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