

MEANS

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*Frank Adams*

# SALT WATER PROBLEM

SAN FRANCISCO BAY *and*  
DELTA *of* SACRAMENTO  
*and* SAN JOAQUIN RIVERS

APRIL, 1928

WATER RESOURCES  
CENTER ARCHIVES

UNIVERSITY OF CALIFORNIA  
BERKELEY

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216 PINE STREET / SAN FRANCISCO, CALIFORNIA

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—  
TELEPHONE BUTTER 78

June 10, 1908.

Association of Industrial Water Users of Contra Costa and Solano Counties.

Dear Sirs:

Statements in this report on pages 39, 51, 56, 63 and 69 concerning the proposed Southern Pacific Railroad's Suisun Bay Bridge, located near Army Point, were published before the plans of that company were made public. The information now available shows that the site selected for the railroad bridge lies from 800 to 1800 feet above the location for the Salt Water Barrier selected by Mr. Young. The plans for the bridge provide for piers founded on rock over both the waterway and marsh areas. The experiences of the railroad do not favor the location of the tracks upon rock fill dikes, as proposed by Mr. Young, but would require piers to rock throughout the length of the structure. According to estimates by the railroad company's engineer, the saving in cost by combining the railroad bridge with the barrier under these conditions would be small and the disadvantage of having the lift span located close to locks, where the movement of vessels is slow, serves to offset any saving in cost.

The railroad bridge as planned provides for a bridge giving a clearance of 70 feet (as compared with 50 feet in Young's plans), a height great enough to permit the free passage of river boats. The lift span will be used for ocean-going vessels. Piers are spaced 413 feet on centers and foundations in all cases will be carried to bedrock. The construction of the barrier as proposed by Young will not be interfered with if this site is selected.

The estimated cost of the bridge now proposed is about \$6,400,000, exclusive of approaches, track, etc.

There is no advantage to be gained by a combined structure unless the result is in decreased cost to both barrier and railroad. Since there is apparently no such advantage to be gained and the bridge will not interfere with the barrier if the Army Point site is selected, I suggest that this letter be attached to my report in correction of the statements made therein.

Very truly yours,

THOS. H. MEANS.

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APRIL, 1928

THOMAS H. MEANS, *Consulting Engineer*  
216 PINE STREET / SAN FRANCISCO, CALIFORNIA

MARTINEZ:  
MARTINEZ DAILY STANDARD

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## *Preface*

The following report by Engineer Thos. H. Means was financed by the Association of Industrial Water Users of Contra Costa and Solano Counties.

The only instructions given Mr. Means in preparing this report were to get the facts, and it is hoped that this document will be of benefit in establishing some of the facts relating to the proposed Salt Water Barrier as designed by Engineer Walker R. Young.

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ASSOCIATION OF INDUSTRIAL WATER USERS  
OF CONTRA COSTA AND SOLANO COUNTIES

C. W. SCHEDLER, *Chairman.*

## PENETRATION OF SALT WATER IN UPPER BAY AND LOWER RIVER REGION

Under natural conditions, Carquinez Straits marked, approximately, the boundary between salt and fresh water in the upper San Francisco Bay and delta region of the two tributary rivers—the Sacramento and San Joaquin. Ordinarily salt water was present below the straits and fresh water was present above. Native vegetation in the tide marshes was predominantly of salt water types around San Pablo Bay and of fresh water types around Suisun Bay.

In tidal waters, into which run fresh water streams of variable flow, there is an ebb and flow of salt water and the zone of mixing will move up and down stream as the fresh water flow increases and decreases. For short intervals in late summer of years of minimum flow, salt water penetrated the lower river and delta region, and in wet seasons the upper bay was fresh, part of the time, to the Golden Gate. This variation in quality of water was not, however, of sufficient duration to affect the characteristic vegetation growth of the regions on each side of the straits, nor to change the designation of Suisun Bay as ordinarily a fresh water body and San Francisco Bay as salt water.

The works of man have changed conditions in many ways. The most important changes have been brought about gradually,—so slowly as to be hardly noticeable. The dry season of 1918,—when large summer diversions for irrigation in the Sacramento Valley resulted in the sudden penetration of salt water farther upstream than ever known before, at such an early period in summer,—first brought the salt water problem to public notice. The slow effects of increasing diversions in previous years had escaped notice, but were brought prominently to the attention of the inhabitants of the upper bay and delta regions in this year. Since 1918, the dry years of 1920, 1924 and 1926 have more convincingly demonstrated the importance of the salt water problem.

An accurate picture of natural conditions is not possible, because no records have been collected on which such a picture can be based, but very close approximations can be made. The log of the distance traveled by the water barge of the California Hawaiian Sugar Company in going upstream to obtain fresh water has been kept since 1908. These figures give the means of determining approximately the conditions during that period. In 1908 irrigation had been extensively developed in both valleys and conditions then were not natural. For an estimate of earlier conditions we must go to the stream flow records of the tributary streams before important diversions are taken out.

It is the practice of the Sugar Company to send the barge upstream until water of approximately 50 to 70 parts per million chlorine is reached. The crew of the barge are equipped with apparatus by which water is analyzed until this degree of purity is reached. Since trips are made nearly every day during the summer months, the record is a very good indication of the point reached by salt water. A summary of the complete records shows the fluctuation of the line between fresh and salt water. Records of the Sugar Company are attached. (Table 1.)

The Sugar Company requires water of great purity. For irrigation, domestic or ordinary industrial uses, water of a lesser degree of purity may be used. A comparison of the point where the Sugar Company's barge is filled with the point where the remaining uses could be satisfied, indicates that from five to ten miles downstream from the place where the barge turns, water could be obtained satisfactory for domestic supply. Making an allowance of  $7\frac{1}{2}$  miles in the average records, we find

that an average flow of 5,000 second feet in both streams will maintain fresh water at Collinsville; 7,000 second feet will maintain fresh water at the San Francisco-Sacramento ferry.

If we sum up the flow of the important tributaries of the Sacramento and San Joaquin rivers at the points where these streams leave the mountains and assume that this flow under natural conditions would have reached the head of the Suisun Bay, we will find that at no time in the past ten years would the average monthly flow have been less than 5,100 second feet. It is probable, should all streams be running in a natural way, that salt water would have penetrated no farther in this extremely dry period than Antioch, and then only for a few days at a time.

It is not possible to make a more detailed study of this condition without making a number of assumptions as to speed of flow from the gaging stations to the head of the bay, and there is little accurate information on which the assumptions may be made. The definite statement that salt water under natural conditions did not penetrate higher upstream than the mouth of the river, except in the driest years and then only for a few days at a time, is warranted. (See Table 2 for monthly flow of tributary streams.)

At present salt water reaches Antioch every year, in two-thirds of the years running further upstream. It is to be expected that it will continue to do so in future, even in years of greatest runoff. In other words, the penetration of salt water has become a permanent phenomenon in the lower river region.

### CAUSE OF CHANGE IN SALT WATER CONDITIONS

The cause of this change in the salt water condition is due almost entirely to the works of man. If natural changes have had any effect, it is too small to be measured. The most important natural condition is the sequence of dry and wet periods. Since 1917 the State has experienced dry years with low runoff in nearly all streams. During this period two years have exceeded normal stream flow in some streams (1921 and 1927). In each of these years excessive salinity (over 100 parts chlorine per 100,000) was present at Antioch about two months.

#### *Irrigation*

Storage and diversion of water have been the principal causes of salinity increase in the upper bay country. The area irrigated varies from year to year; in 1926 the acreage of lands on the floor of the valley was approximately as follows:

#### *Estimate of Diversions and Area Irrigated 1926—Sacramento and San Joaquin Valleys, Not Including Mountain Areas*

	Acre Feet Diverted	Acres Irrigated
Sacramento and tributaries above Sacramento, including		
rice, 128,439 acres.....	1,644,973	235,995
Delta uplands.....	146,906	53,649
Delta area.....		264,479
San Joaquin Valley estimated.....	2,100,000	700,000
	<hr/> 3,891,879	<hr/> 1,254,123

In addition to this area on the valley floor, there is a large acreage in the mountains which uses water from the streams tributary to the rivers that drain through Suisun Bay. The acreage irrigated in the mountains is not so accurately known as the area on the valley floor, but it is large and, particularly in low flow season, very



effectively uses up the water in the streams. The use of water in the mountains is usually more economical than in the valley and the return seepage is less. The net effect is to consume all of the water diverted. The effect upon the flow is pronounced.

The latest accurate determination of area irrigated is that made by the United States Census.

## IRRIGATION IN CALIFORNIA

*Census of 1920*

	1902	1919	1920	1920
			Area in Enterprises	Area Capable of Irrigation
Sacramento River and Tributaries	206,312	640,950	1,204,769	864,605
Sacramento River direct.....	10,942	194,397	439,169	296,748
Pit River.....	72,072	89,984	129,984	107,478
Cow Creek.....	2,321	6,068	12,488	7,446
Cottonwood Creek.....	1,858	2,972	21,016	4,112
Battle Creek.....	2,642	2,966	6,590	5,108
Stony Creek.....	4,110	23,559	45,143	36,191
Feather River.....	67,111	142,841	186,756	167,463
Yuba River.....	Not Rep.	19,473	69,074	23,492
Cache Creek.....	3,756	24,541	56,498	31,212
American River.....	10,112	47,156	82,695	52,842
Other Tributaries.....	31,388	86,993	155,356	132,513
San Joaquin River and Tributaries	220,651	1,069,161	2,072,739	1,497,661
San Joaquin River direct.....	129,647	642,261	1,083,862	873,300
Fresno River.....	10,729	12,412	30,004	14,016
Merced River.....	19,636	65,151	222,715	71,709
Tuolumne River.....	Not Rep.	165,533	298,418	250,425
Stanislaus River.....	13,840	75,359	155,453	111,192
Calaveras River.....	Not Rep.	13,323	21,598	16,489
Mokelumne River.....	5,558	36,848	155,480	72,144
Cosumnes River.....	Not Rep.	3,259	9,011	6,405
Other Tributaries.....	41,241	55,015	96,198	81,981

The above includes springs and wells.

Where area in watershed is not reported (not rep.) it is included in other watersheds.

Records for other census periods have not been tabulated so as to be comparable.

This table shows that in the 18 years between 1902 and 1920 the area irrigated in the Sacramento Valley trebled, while in the San Joaquin Valley the increase was nearly five times as great. The area included in irrigation enterprises was only half watered in 1920, while the area capable of being irrigated was only about two-thirds watered. The total area irrigated in both watersheds was 1,710,000 acres in 1920.

No accurate records have been collected since 1920. It is known, however, that the growth of irrigation has continued, though at a slower rate than prior to 1920. Since 1920 the growth in area has been proportionally larger in the San Joaquin than in the Sacramento Valley. In the latter valley grain production (seldom irrigated) is still profitable and much land within irrigation projects goes into grain. Other crops, such as rice, vary in area with the price of rice.

United States Department of Agriculture tabulation of area in rice in California is shown below:

## ACRES IN RICE IN CALIFORNIA

1920	162,000
1921	135,000
1922	140,000
1923	106,000
1924	90,000
1925	103,000
1926	149,000

Storage reservoirs, both for irrigation and power, have been built on many streams in the past fifteen years. Many others are planned and their construction will be undertaken within a short time. The following list of reservoirs is as complete as it is possible to make it. Small reservoirs—less than 1,000 acre feet capacity—have been omitted.

STORAGE RESERVOIRS  
GOLDEN GATE DRAINAGE WATERSHED

SACRAMENTO BASIN		Height of Dam	Reservoir Capacity Acre-Feet
Cottonwood Creek	Misselbeck Reservoir	105	5,460
Pit River	Darris Reservoir		12,500
Pit River	Big Sage Reservoir		
Pit River	Mt. Shasta Power Co. No. 3	112	36,000
Stony Creek	East Park	139	51,000
	Stoney Gorge	120	50,000
Paradise Creek	Paradise Reservoir		
Battle Creek	2 Reservoirs		3,000
Feather River	Lake Almanor	125	1,317,000
	Bucks Creek	128	103,000
	Butte Valley	115	106,000
Yuba River	Bullards Bar	183	11,000
	Lake Francis	70	2,400
	Spalding		74,000
	25 Reservoirs, small		54,000
	Bowman being enlarged		
American	4 Reservoirs		12,800
Mokelumne	Pardee under construction	350	200,000
	Electra System, 7 Res.		24,800
Stanislaus	Salt Springs, under construction	300	130,000
	Relief	140	15,000
	Strawberry	135	18,000
	Utica, 3 Reservoirs		8,900
	Woodward		36,000
	Melones	191	112,500

Tuolumne.....	Hetch Hetchy.....		
	O'Shaughnessy Dam.....	344	206,000
	Dom Pedro.....	284	290,000
	Lake Eleanor.....		25,300
	Dallas Warner.....		28,000
	Davis.....		48,000
Merced.....	Exchequer.....	330	278,000
San Joaquin.....	Florence Lake.....		64,500
	Huntington.....	165	88,700
	Shaver Lake.....	183	138,500
	Crane Valley.....	150	38,000
Cache Creek.....	Clear Lake.....		400,000
Suisun Creek.....	Gordon Valley.....	104	10,000
Total Constructed Reservoirs.....			3,998,360

*Projected Reservoirs (Partial List)*

Sacramento.....	Kennett.....	420	2,838,000
	Iron Canyon.....		709,000
American.....	Folsom.....	220	300,000
Mokelumne.....	Dry Creek.....	140	1,200,000
Tuolumne.....	O'Shaughnessy, increased to.....	430	350,000
Total Projected Reservoirs.....			5,397,000

In round numbers, reservoirs of a capacity of 4,000,000 acre feet are in use on streams tributary to San Francisco Bay above Carquinez Strait. Reservoirs of much larger capacity are being considered for future construction.

*Mining Debris.* Mining debris and sediment in the rivers and by-pass channels have probably changed the tidal flow to a small extent, and may have affected salt water movements. The effect has been too small to measure, but it has been generally in the direction of reducing tidal prism and tidal flow where the deposits are laid down in bay waters, and of increasing tidal flow through the Golden Gate where deposited in the rivers. The net change has probably been very small. Gilbert, in his report upon Hydraulic Mining Debris (U. S. G. S. Prof. Paper 105, page 87) estimates the reduction in tidal currents in Golden Gate caused by deposition of debris as 2.49 per cent.

*Land Reclamation.* Reclamation of land by building levees has affected tidal flow and movement of salt water in two ways: first, by decreasing the tidal prism in the delta and, second, by changing the time of arrival of floods and of low water.

First, Reduction of Tidal Prism: The reduction in tidal prism by the construction of levees in the delta region and around the upper end of San Pablo Bay and around Suisun Bay has probably had the effect of slightly reducing the tidal flow through Golden Gate. As has been shown by Gilbert in the publication above referred to, the effect of leveeing in the lower river has had the tendency of increasing Golden Gate flow, while the same work in Suisun and San Pablo Bays has had the opposite effect. The net effect, however, is small and results in decreased flow. Gilbert (U. S. Geologic Survey Professional Paper 105, page 79) estimates the

average percentage of the flow through Golden Gate as follows, when all marshes are leveed:

MARSH LAND AREAS—AVERAGE VOLUME FLOWING THROUGH  
GOLDEN GATE EXPRESSED IN PERCENTAGE

	Per Cent
San Pablo Bay marshes and Napa River.....	*1.95
Suisun Bay.....	*1.18
Sacramento Delta.....	†1.04
San Joaquin Delta.....	†3.35
Net effect on Golden Gate flow.....	†1.26

\* Means decrease in tidal flow through Golden Gate.

† Means increase in tidal flow through Golden Gate.

Second, Change in Time of Arrival of Floods: The effect of leveeing upstream from tide lands has been to decrease the storage in basins and to increase the rate of travel of floods toward tide water. Under natural conditions the basin areas filled with water in flood time and slowly released this water in late summer, maintaining the flow well into the period of low water.

Most of these up-river basins have been leveed and floods run through the river channel and by-passes to the ocean with very little retardation by storage. There is no stored water from these basins to maintain low flow, consequently the low flow reaches the tidal channels earlier in the year than under natural conditions.

The effect of this reclamation work upon salt water conditions has been very pronounced. In the period just prior to 1918, some of the largest reclamation districts were leveed, Sutter Basin being a notable example. Prior to this closing off from flood flows these basins retained large volumes of water, sometimes until the middle of summer, the water slowly draining back into the channel. Nowadays instead of delivering water to the channel, water is taken from the channels for irrigation during summer months. Drainage returns a small part of the irrigation water directly to the river.

Return seepage from irrigation has had the effect of increasing the low water flow in the Sacramento. Stafford, in publications of the Division of Water Rights (Biennial Report November, 1924, page 133; Sacramento-San Joaquin Water Supervisor's Report 1926, page 85) estimates the water returned to the Sacramento River as follows:

WATER RETURNED TO SACRAMENTO RIVER  
(INCLUDING ALL ACCRETIONS)

	<i>Flow in Second Feet</i>		
	1924	1925	1926
June .....	879	.....	2280
July .....	734	1624	1573
August .....	785	1320	1240
September .....	634	1310	1077
October .....	.....	460	.....
Mean .....	763	1179	1543

*Dredging*, particularly in the Sacramento River, near its mouth, has had the effect of increasing the water prism, but the probable effect upon tides through Golden Gate is to decrease them. The dredging work is so far upstream as to be on the tidal movement opposite to that in the Golden Gate.

The deepening of the channel has, further, the effect of permitting the deep flowing salt water to pass upstream with more ease through the deep channel. A like effect will probably result from deepening of Suisun Bay and the San Joaquin River to Stockton, a navigation project authorized by Congress.

It is not possible to measure these effects, but it is well established that salt water being heavier moves along the bottom of deep channels with greater ease than over shallow ones. Any deepening of channels or straightening of approach through dredger cuts has the tendency to facilitate the movement of the deeper waters.

*Irrigation and Storage of Water in the San Joaquin Valley.* Irrigation in the San Joaquin Valley has had an effect upon tidal conditions and the movement of salt water in two ways: first, by diverting and storing water during flood period, and second, by increasing the flow in late summer and fall months through return seepage.

A much larger utilization of water resources has taken place in the San Joaquin than in the Sacramento Valley. Rainfall is lighter on the floor of the valley, so dry farming has been less profitable and there is greater necessity of irrigation. All streams tributary to the bay are now completely diverted during the low flow period and no water enters the tidal channels except return flow. This condition has been true for over ten years.

The following brief description of the streams and the irrigated area will show the extent to which the water supply has been put to use.

*Upper San Joaquin.* The upper San Joaquin enters the valley floor at Friant. The mean annual flow of the stream at the valley's edge averages 2,050,000 acre feet. Storage above this point, built by the San Joaquin Light and Power Corporation and the Southern California Edison Power Company under contract with riparian owners and appropriative users of water, amounts to 330,000 acre feet. Other storage reservoirs have been planned. Lands irrigated from the stream lie on both sides of the river and aggregate 400,000 acres. The diversion capacity of the ditches, sloughs and canals in use is very large.

Above the Merced River, canals, ditches and sloughs with control gates have a capacity in excess of 7,000 second feet. Sloughs and channels used for wild flooding increase this diversion capacity to in excess of 10,000 second feet. Below the Merced, a number of pumps take water from the river to West Side slope. Down to Paradise Dam, about the head of tide water, these diversions total in excess of 500 second feet.

All water entering the valley is diverted in late summer. The San Joaquin is dried above the Merced for three or four months a year. Return seepage commences to "make" about the mouth of the Merced. Below that point there is always water in the channel, except for short periods of time, just below some of the larger pumping plants.

*Fresno River.* This stream has a small watershed area of low mountains with a mean annual flow of 68,000 acre feet. The entire low flow is utilized around Madera and toward the San Joaquin. No return seepage makes from this area, as pumping plants have lowered the ground water plane and probably intercept nearly the entire ground water flow.

*Chowchilla River.* This stream has about the same area and topographic conditions in its watershed as has the Fresno. Its mean flow approximates 68,000

acre feet. All low flow is utilized. Pumping has been heavy on its lower course. No return seepage makes from this area.

*Merced River.* The Merced Irrigation District and riparian lands lying above the junction with the San Joaquin utilize all low flow. The Exchequer Reservoir of the Merced District, with a storage capacity of 278,000 acre feet, controls the stream except in wet years. The power plant at the dam delivers water into the river, when water is plentiful, in excess of the district's diverting capacity. Water always passes the district's headgate for use of lands lower down on the Merced. The mean flow of the stream is 1,330,000 acre feet. Return seepage maintains a continuous flow at the mouth of the Merced, the water coming from both the Turlock and Merced sides of the river. This return flow now amounts to 80 to 100 second feet in summer months and there are indications that it is increasing. Pumps along the Merced utilize a part of this return flow.

*Tuolumne River.* The Tuolumne drains a high mountain area and has a mean annual flow of 2,055,000 acre feet. Three irrigation districts—the Waterford, Modesto and Turlock, with a total area of 276,783 acres—divert water at the LaGrange Dam. Three storage reservoirs with capacity of 366,000 acre feet are operated by these districts. The City of San Francisco has rights on the upper watershed for water for domestic uses and has built reservoirs of capacity of 231,000 acre feet. A conduit of capacity of 620 second feet is under construction. San Francisco has control of other reservoir sites and proposes, ultimately, to divert 400 million gallons daily (620 second feet) from the watershed. To do this, storage of about 850,000 acre feet will be required.

Return seepage in the Tuolumne, at its mouth, resulting from irrigation now amounts to from 250 to 350 second feet constant flow. Additional seepage from these irrigated areas appears in the Merced, the Stanislaus and San Joaquin rivers.

*Stanislaus River.* The Stanislaus River—mean annual flow 1,376,000 acre feet—is under storage control for both power and irrigation. Power reservoirs with capacity built or being built of 172,000 acre feet, high on the stream, increase the low flow, but this water is re-stored in reservoirs or diverted by the South San Joaquin and Oakdale irrigation districts. These districts, with an area of 145,348 acres, have in Melones and Woodward reservoirs a storage capacity of 148,000 acre feet. All low flow is diverted. Return seepage in the Stanislaus River at its mouth (coming in part from the Modesto District) now varies from 100 to 160 second feet constant flow. An additional amount enters the San Joaquin River.

*Return Flow in the San Joaquin River.* Return seepage in the San Joaquin River from the mouth of the Merced to Durham Ferry (just above tide water) now amounts to a continuous flow of from 600 to 1,000 second feet. About 300 second feet of this water is diverted above tide water by pumps irrigating West Side lands. Additional pumps recently installed or in process of installation and pumps diverting from the tidal portion of the stream have a combined capacity of between 750 and 800 second feet. In the peak of the irrigating season these West Side pumps divert practically all of the visible flow in the San Joaquin River. The delta lands and islands are dependent upon ground water flow and such water as flows down the Calaveras, Mokelumne and connecting sloughs from the Sacramento River.

NET RESULT OF IRRIGATION AND STORAGE  
ON SALT WATER PROBLEM

Summarizing former statements upon the effect of irrigation and storage upon the flow of salt water in the lower river and upper bay region, the following may be said:

1. Under natural conditions the boundary between salt and fresh water was Carquinez Straits. In late summer, Suisun Bay became brackish but salt water penetrated as far as Antioch only rarely and then for but a few days' time.

2. The combined effects of irrigation and diversion in the Sacramento Valley have been to reduce the flow entering tidal waters to a small fraction of the flow under natural conditions. In 1924 the flow at Sacramento was about 720 second feet and was below 1,000 second feet for in excess of a month. In 1925 the flow at Sacramento reached a minimum of 2750 second feet and was below 3,000 for nearly a month. In 1926 the flow of the Sacramento reached a minimum of 1200 second feet and was below 2,000 for over a month.

3. The late summer flow of the San Joaquin—all return seepage—has been below 1,000 second feet in all years except 1927. The capacity of pumping plants irrigating West Side lands exceeds the inflow nearly every summer, so that, so far as visible flow in the San Joaquin is concerned, all of the late summer inflow into tidal channels is used on West Side area. The delta lands now must obtain their supply from the water stored in channels or which flows underground, or from the Calaveras, Mokelumne, and sloughs connecting with the Sacramento River.

4. The use of water by the delta lands on both San Joaquin and Sacramento rivers has not been accurately determined. The area irrigated amounts to 360,000 acres. If this area consumes  $1\frac{3}{4}$  acre feet of water per annum, of which 20 per cent is used in a month, the consumptive draft will be at the rate of 2100 second feet. This quantity exceeds the low flow in years of light rain.

PRESENT CONDITIONS OF SALT WATER IN  
UPPER BAY AND LOWER RIVER REGIONS

Salt water conditions have been under observation by the Division of Water Rights of the Department of Public Works since 1917. Results have been published in the annual reports of this Division. Earlier records of much value in the study of the problem are those of the California-Hawaiian Sugar Company, referred to earlier in this report, covering the period from 1908 to 1920. In 1920 the Sugar Company obtained a supply from the Marin Municipal Water District at San Quentin Point, approximately 15 miles from Crockett. Since then, when the distance traveled upstream to fresh water is less than 15 miles, the water is taken from the river; when the distance exceeds 15 miles, the Marin County water is used.

A number of other investigations of salt water conditions have been collected at various places and are of help in the determination of the changes which have taken place in recent years. Among these records are those collected by Mr. William Pierce north of Suisun Slough, on the north side of Suisun Bay; records for a short period by the Pacific Portland Cement Company at Suisun, showing salinity of Suisun Slough; records by the Great Western Electro Chemical Company at Pittsburg, extending from 1916 to date, giving total solids and chlorine in the river water; and information collected at various times in the investigation of water supplies by the City of San Francisco, the City of Richmond, and the East Bay Water Company. A large amount of information from these various sources has

been obtained and is helpful in interpreting the changes which have taken place and in formulating a fairly accurate conception of conditions in the past and what may be expected in the future.

Attached to this report is a chart of the region, the base being photographed from the Annual Report of the Division of Water Rights. On this chart red lines have been placed showing the penetration of salt water during the months of June and September, 1924. Similar charts for other years show that in every year, salt water has penetrated to a point beyond Antioch on the San Joaquin River and Collinsville on the Sacramento, and that in years of low flow, such as 1918, 1920, 1924 and 1926, the extreme limit of salt water penetration has been well into the delta region.

The year 1927 is one of approximately 100 per cent runoff in the streams tributary to San Francisco Bay. In this year salt water reached the middle of Suisun Bay in June, was approximately at Collinsville and Antioch in July, and during August and September had reached approximately to Emmaton on the Sacramento and the lower end of Jersey Island on the San Joaquin River.

Stream flow records show that approximately one-third of the years are in excess of 100 per cent runoff and two-thirds of the years below that figure. This gives, roughly, an approximation of the period of time in which salt water conditions will be worse than in 1927 and the period in which better results can be expected.

For practical purposes, a period of thirty days or more would be detrimental to either irrigation, domestic use or supply for industrial purposes. An examination of records in more detail indicates that, under the conditions now existing, in practically all dry years salt water will reach the lower end of the delta for at least a month's time, and that in two-thirds of the years water will be in the lower delta region in excess of a month's time or as much as three to four months.

The areas of delta land within the salt water flow are shown in the following table:

	Approximate Stream Flow in Per Cent, Normal	Area of Delta Penetrated by Salt Water
1924 -----	24	169,000
1926 -----	53	58,000
1925 -----	74	8,500
1927 -----	100	5,000

### PROSPECTIVE CHANGES IN THE FUTURE

Storage of water for power purposes and diversion for irrigation and domestic uses in the watersheds tributary to the bay are steadily increasing. The rate of increase of the irrigated area is not so rapid as during the decade 1910 to 1920, but there is a steady, continuous growth and plans are on foot for large increases in the use of water through new projects and through the extension of irrigation on old projects.

As illustrating the extent to which conditions are changing, reference may be made to the growth of the San Joaquin River basin since the year 1920, a period ordinarily regarded as one of stagnation in irrigation development in California. Since 1920, the Southern California Edison Power Company has constructed and placed in operation the Florence Lake and Shaver Lake Reservoirs on the San Joaquin River with a storage capacity of 203,000 acre feet. This stored water will be



diverted and used as fast as it is released for power purposes by the agricultural lands above the mouth of the Merced.

On the next stream, the Merced Irrigation District has built a storage reservoir of 278,000 acre foot capacity and has approximately trebled the area in irrigation in 1920. The district is rapidly growing and the entire irrigable acreage in the total of 189,000 acres will be all in cultivation within a few years.

On the Tuolumne River, since 1920, the Modesto and Turlock Irrigation Districts have built the Dom Pedro Reservoir of 290,000 acre foot capacity, and both districts have extensively increased their irrigated area. The growth is steady.

The Waterford District has acquired rights to use the water of the Yosemite Power Company, which formerly delivered approximately 60 cubic feet per second into the Tuolumne River below LaGrange Dam, further reducing the stream flow.

Since 1920 the City of San Francisco has built Lake Eleanor and the O'Shaughnessy Dam, storing 231,000 acre feet. The water released from these reservoirs has not yet been diverted from the watershed but it has been picked up, at least during the summer period, by the irrigation districts, and no water except return seepage has flowed into the Tuolumne River during the summer and early fall months.

On the Stanislaus River, the Melones Dam has been built by two irrigation districts in cooperation with the Pacific Gas and Electric Company, and the late summer use of water has been very much increased.

In addition the Power Companies have now under construction Salt Springs Reservoir on the headwaters of the Stanislaus, with the intention of ultimately raising this to storage capacity of 130,000 acre feet. This water when released will be caught by the Melones and Woodward reservoirs lower on the stream and utilized during the late summer.

The East Bay Utility District has now under construction the Lancha Plana Reservoir site on the Mokelumne River, a reservoir of 200,000 acre foot capacity, and has completed a pipe line from the Mokelumne to the East Bay district of a capacity of 60 million gallons daily (90 second feet). The water to be diverted by this Utility District will be taken out of the watershed and there will be no return flow from it.

In addition to the reservoirs and increased irrigated area on the east side of the San Joaquin, several pumping plants have been built lifting water up the West Side slope for the irrigation of high lands. Important among these are the Banta-Carbona Irrigation District, approximately at the head of tide water, which commenced irrigating in 1925 and now has a pumping capacity of 220 cubic feet per second.

The Burkhart Ranch further south has installed a pumping capacity of about 50 cubic feet per second since 1920, and a number of other districts and appropriators of water have increased either the size of their pumping equipment or the extent of their use, so that at the present time the capacity of the pumping plants irrigating West Side lands exceeds the flow in the San Joaquin River at the place where tide water is reached.

Further extension of this irrigated area is in progress and one new district is now engaged in preparation of plans which will result in the pumping of approximately 300 second feet from the river.

Extension of area supplied by pumping from wells has been going on at the same time. In Fresno, Madera, Merced, Stanislaus and San Joaquin counties, hundreds of pumping plants have been installed since 1920, all drawing from water

which, under natural conditions, would have its outlet to the sea through the San Joaquin River. It is impossible to accurately estimate the effect of this withdrawal of water upon the stream flow or the underflow to delta areas, but, if it has not already done so, it will at some time affect the flow by reducing the quantity of water which reaches the stream from underground sources and affecting to that extent the late summer discharge into tidal waters.

Irrigation development has not been so pronounced in the Sacramento watershed since 1920. There are a large number of irrigation and reclamation enterprises in the Sacramento Valley which have irrigation systems of a capacity larger than the irrigated area. There is, in addition, a large area of land still devoted to grain, rice, sugar beets and other general farm crops, which goes in and out of cultivation as economic conditions vary. The years when grain prices are high, large areas of grain go into cultivation, a portion of which is irrigated. With prospects of low prices for grain other crops are planted, some of which use more water than does grain. The most noticeable effect on the water supply, however, is the increase and decrease in the rice crop. The area irrigated in rice since the industry became stabilized varies from 130,000 to in excess of 200,000 acres a year, and in years of large crop the effect upon the water supply is very noticeable.

Although no large new enterprises have been built in the Sacramento Valley in recent years, the increase in irrigation in the older districts has been steady. The area devoted to orchards, to alfalfa, and to general farm crops requiring irrigation, steadily increases. The result has been continued drafts upon the supply from the river and to gradual reduction in the total flow downstream from the main cultivated section. The reduction in flow, to some extent, has been controlled by the operations of the Division of Water Rights through the Commissioner appointed to superintend the diversions from the Sacramento and San Joaquin rivers. The principal effect of the work of the Commissioner has been to reduce the waste of water, to encourage economy and to endeavor to keep the flow at Sacramento as high as possible, both for purposes of navigation and the use of delta lands.

Return seepage and waste from the lower ends of the rice irrigation canals have to some extent ameliorated the extreme low flow conditions experienced in 1920 and 1924, but the steady increase in irrigated area goes on each year. The total quantity of water which passes out of the valley in late summer is slowly but surely decreasing.

There is nothing to indicate any change of conditions in the immediate future. Irrigation has reached nearly stable conditions on the upland areas of the San Joaquin Valley, largely because the streams are nearly developed to their full capacities. On the Sacramento River, however, large areas of fertile land under irrigation systems built to supply them with water are certain to be placed in crop and increase the use of water. The result will be a steady depletion of the stream and an increase of the salt water menace.

Salt water conditions such as have occurred in the lower delta since 1918 have become permanent and will not be improved until some additional water supply is turned into the river during the low flow period, or unless a barrier is built to prevent the approach of salt water from the ocean. It is difficult to conceive a set of natural conditions that would change this situation. We have reason to expect years of heavy runoff to follow the long period of dry years since 1917, but a review of the past does not lead to the belief that summer water supply can be increased to such a point that any appreciable effect will be experienced by the delta region and industrial area.

## EFFECT OF SALT WATER ON DEVELOPMENT

The industrial and agricultural areas along the upper bay and lower river region came into being before there was any serious thought of the salt water problem, in other words prior to 1918, for that was the first year in which the encroachment of salt water was serious and over a long period of the year. Since 1918 there has been no large increase of cultivated land in the delta region and few new industries of importance have been established in the industrial area. There has been, however, a steady growth in the industries already established.

The effect of salt water upon the various users of water will be discussed in the following paragraphs.

*Agriculture.* Water to be supplied for agricultural purposes must be free from large quantities of soluble matter. The upper limit of concentration safe for use depends upon the soil, crop, rate at which it has been used, drainage facilities, and to some extent upon whether fresh water is available at other times in the year for leaching purposes. The determination of the safe limit is, therefore, a matter of considerable difficulty, as it will vary as these factors differ.

For the purposes of this report, however, it is fair to assume that water containing 100 parts of chlorine per 100,000, equivalent to 160 parts of sodium chloride or common salt per 100,000, is the upper limit of safety; since the water contains other salts the total salinity of water containing 100 parts of chlorine will vary from 175 to 200 parts per 100,000. Water of this degree of salinity is not safe for use, except where precautions are taken to provide good drainage and to continue leaching the water through the soil so that there is no accumulation of salty matter. Such water may be used with safety on light soils where drainage is good and the use excessive, and is not harmful where used occasionally during late summer. One-half of this quantity, or 50 parts per 100,000, is much safer for use and waters of this degree of salinity could be used with comparative safety.

The records quoted above show that in years of extreme low flow, waters of 100 parts of chlorine per 100,000 will penetrate into the delta region to points beyond Rio Vista on the Sacramento, and to Stockton and beyond the mouth of Middle River on the San Joaquin. During some part of the summer approximately one-half of the delta area will be surrounded by salt water.

This condition has several results: First, it renders questionable the irrigation of permanent crops, particularly such crops as are sensitive to salt; second, it has a tendency through the percolation beneath the levees of sub-irrigating the adjoining land with saline water; third, it reduces the value of lands through the fear of salinity; and fourth, it adds expense and uncertainty to the question of domestic supply, for on most of the delta the river is a source of domestic water.

The net effect of this condition is to render agriculture uncertain in the delta, to reduce the value of land, and to create a menace which will result in the destruction of the land by the accumulation of salts.

AREA OF AGRICULTURAL LAND AFFECTED BY  
SALT WATER BARRIER

The area of agricultural land affected by the salt water barrier is taken as:

1st—The area of marsh land lying practically at sea level.

2nd—The area of land up to elevation 150 above sea level; an elevation to which pumping has been carried with success.

These areas may be subdivided into geographic regions as follows:

- 1st—The area around San Pablo Bay, between Carquinez Strait and the site of the San Pablo barrier.
- 2nd—The area around Suisun Bay, that is, from the mouth of the river at Collinsville to Benicia.
- 3rd—The delta area or region upstream from the mouth of the river.
- 4th—Irrigated or irrigable lands above the delta.

*San Pablo Bay Area.* A large area of marsh land lies along the west and north shores of San Pablo Bay. At present a large part of this area is in process of reclamation. Much of it is growing grain crops or pasture, but little of it is irrigated. The surrounding waters are salty at nearly all times of the year. Fresh water fills the sloughs and bay during flood time, a period becoming shorter each year. Ground water of good quality has not been found and there is little likelihood of its ever being obtained, as deep wells have been drilled in many places.

Much of the land is yet salt and all of it is influenced to some extent by the salt in the bay, and the reclamation by using rainfall alone to wash out the salt is slow. The presence of fresh water surrounding the area would permit much more rapid reclamation and would make it possible to bring into profitable agriculture nearly this entire area.

Surrounding the marsh area is an area of high ground nearly as large, all of which is now unirrigated. This marginal area could be all watered and made available for many different crops by fresh water from San Pablo Bay and tributaries if this bay were kept full of fresh water. Novato, Petaluma and Sonoma Creeks and Napa River all penetrate the marsh lands and extend to high land; they would make fresh water available for the adjoining high ground and enable pumps to supply small units or large, depending upon the physical conditions.

It is to be expected that at some future time all agricultural lands in California will make use to some extent of irrigation water where such is available. Irrigation in the coastal belt has not advanced as rapidly as in the interior valleys, because owners of such land can grow profitable crops without artificial watering. Maximum results can be obtained only by irrigation and it is but natural to expect water to be in demand at some future time.

The San Pablo Bay areas which may at some time become interested in irrigation are all areas where climate and soil are acceptable to agricultural pursuits. The region is close to centers of population; transportation facilities are usually good or easily improved; it is one where increased population is certain. The availability of fresh water in the bay and tidal sloughs will serve to stimulate this growth.

Lands so situated, close to tidal waters and centers of population, are likewise attractive to industries. As the San Francisco Bay region grows, more and more of the territory adjoining the bay will change from agriculture to industrial or residential property. With a water supply attached to it, the change in use becomes easier, for the amount of water required for agriculture supplies the needs of residential or industrial occupation.

*Carquinez Strait.* Carquinez Strait— $7\frac{1}{2}$  miles long—extends from Suisun Bay to San Pablo Bay. High hills with only small areas of flat land bound the strait. The opportunities for extensive developments for use of water in this territory are limited by the topographic conditions. Industries already occupy much of the available territory and the small valleys, particularly in Contra Costa County, are now filled by towns, the population resulting from industrial, transportation and commercial enterprises along the waterfront.

If the strait is filled with fresh water and tidal fluctuations and currents are decreased, the more complete occupation of all available ground will be possible. At the present time growth is restricted by water supply. Martinez, Port Costa and adjoining territory obtain a part of their water from wells at Concord, 12 miles away. The supply from ground water is limited. Large additions to this supply are impractical. The Sugar Refinery at Crockett has barged water from the river or the Marin County shore at great cost for many years.

On the north side of the strait, the town of Benicia has a small water supply but cannot increase this supply very much without great expense.

*Suisun Bay Area.* Marsh lands adjoining Suisun Bay total 70,000 acres. Immediately adjacent to these marshes is an area of 93,000 acres of higher land suitable for agriculture but not now irrigated. Fresh water in Suisun Bay would make it possible to convert this area of dry land to irrigated areas of high value.

The marsh area of Suisun Bay is all practically at sea level. Much of it is salt marsh or at least contains enough salt to interfere with some kinds of agriculture. A large part has been leveed and utilized for pasture, but with unsatisfactory drainage, and salt has accumulated.

Fresh water in the surrounding tidal channels and freedom from daily tidal fluctuations will permit the leaching of this land and make the reclamation of it practical. The land is inherently fertile and will become very productive when leached of salt. The works to accomplish this are simple in character and the operation is simple and certain of success.

If fresh water is made available, there is little question but that these marsh lands can eventually be made as productive as the delta lands of the Sacramento and San Joaquin rivers further upstream.

The high ground above these marsh areas and which may be watered by practical lifts out of tidal channels includes the lower parts of Green Valley around Cordelia, the lower part of Suisun Valley, now highly developed to deciduous fruits, and the region from Suisun to Denverton.

South of the bay the lower parts of Walnut Creek and Ignacio and Seal Creek valleys may be reached with low pumping lifts. These valley lands are now in part planted to fruits and the agricultural possibilities of the region have been demonstrated. Irrigation water cannot be obtained for these areas from any other source known at this time. Wells are of small yield and uncertain life. Storage reservoirs on these streams may be possible but none is known except small ones, and these will serve only small local areas.

The most important difficulty is the extremely erratic nature of the runoff from this area. In wet years floods are heavy, but in years below normal precipitation the runoff may be very limited, often negligible. Storage to be dependable must hold water over two or three dry years, an impracticable condition for agriculture except in very limited areas. The greater part of the area will remain un-irrigated unless some cheaper, more dependable supply of water is made available. A salt water barrier will place fresh water at points where it can be readily obtained by practical developments.

*The Delta Region.* The delta region, affected by tide levels, extends as far up the San Joaquin River as Duncans Ferry (6 miles below the mouth of the Stanislaus River) and up the Sacramento a short distance above the City of Sacramento. The distance from the mouth of the San Joaquin to the head of tide water by river is 77 miles; to the head of tide water on the Sacramento is 56 miles. Between these extremes are many miles of tidal channels and sloughs affording

access by boat to nearly all parts of the region, and by relatively short dredger cuts, making it possible to deliver tidal water at the edge of high ground.

This region includes 367,000 acres of land, either marsh or swamp and overflow, and 91,000 acres of high ground immediately adjacent to the marsh on the west side of the valleys. These total 458,000 acres.

The entire area is irrigated or irrigable from waters at tide level. The most recent information indicates that of this area 360,000 acres are now irrigated in both deltas. In both deltas an area of 98,000 acres remain to be irrigated, parts of which are irrigated and farmed irregularly. The economic status of the farmer has much to do with the area under cultivation.

*The Up River Country.* The entire irrigated area tributary to Suisun Bay is to some extent interested in the salt water problem. At the present time a suit is before the Superior Court of San Joaquin Valley, between riparian users and appropriators in the delta region and 443 defendants on the streams above the delta. This suit involves nearly all of the large users of water, both for irrigation and power, on the stream. Much other litigation is in prospect. The outcome of this controversy cannot be foreseen but it is impossible to predict anything but serious complications and nearly endless difficulties no matter which turn the courts may take.

Should the outcome of the present suit be that tide water lands have no riparian rights upon waters of the streams, in excess of one-half of the present delta area will be periodically surrounded by salt water. The agricultural industry will be affected and the salt water menace to these lands will become permanent. The final result will be disastrous to a very large area of land which has been the most uniformly productive land in the state. The continued storage and use of water above tide level and the increase in pumping to high lands around the tidal area will cause salt water to enter the rivers in all years, and at times the greater part of the tidal waters will be contaminated with salt from the ocean.

Should the courts take the view that owners on tidal waters have riparian rights to the flow of the stream, a great deal of very valuable land now using water must release the water which has heretofore been used and a tremendous damage to higher areas will result. The release of waters may affect salt water conditions to some extent but it is impossible to conceive a condition in which enough water will be released to push back salt in years of light runoff.

As is shown later in this report in the chapter on "Storage and Release for Control of Salinity," the plan under which this proposal has been made does not look practical as a means of taking care of the irrigation problem of the delta. Furthermore, it leaves out of consideration the entire industrial area that lies just below the delta.

*Power Companies.* Two power companies supply the industrial region—the Great Western Power Company and the Pacific Gas and Electric Company. Both companies have an interest in the salt problem in two ways: The market for power is the first and most apparent interest the power companies have in this problem in that the maintenance of the present industries and their growth in the future affect the income of the distributing companies.

In a later chapter a statement of the approximate use of power for industrial and domestic purposes is included. The rate of growth of power sales indicates a steady increase in industrial activities. The more rapidly these factories grow and the more new factories there are installed, the better will be the power companies' incomes. A potential industrial territory offers opportunity for a very large increase

in use of power and the encouragement of these industries is a legitimate function of power companies.

The second way in which these companies are interested is the question of litigation mentioned above. The Great Western Power Company and the Pacific Gas and Electric Company and subsidiary companies, such as the Sierra and San Francisco Power Company and Mount Shasta Power Corporation, are parties to the suit previously mentioned. In addition to them the San Joaquin Light and Power Company and Southern California Edison Company, both developers of power on the San Joaquin River, are included, and the Modesto and Turlock, South San Joaquin and Merced irrigation districts are included on account of their storage and use of water on tributary streams. The interests of these concerns, therefore, are created by the direct attack upon their storage and use of water in the higher watersheds.

Should the outcome of this suit establish the riparian right of the delta land owners, the power companies will suffer very seriously in consequence, by the necessity of either releasing water now stored or condemning the right to continue the practice of controlling the flows.

*Fishing Industry.* Under present conditions, with the Sacramento and San Joaquin rivers open to the flow of tides, fish have free access from the ocean to the fresh water streams draining the Sierra Nevada Mountains. Several types of commercial fish are caught in these waters and other fish are important as food for the commercial varieties. There has developed a considerable fishing and fish-canning industry along the bay and lower river shore. The catch in river and upper bay approximates 5,000,000 to 6,000,000 pounds a year—largely salmon, shad and striped bass. (See table.)

The Fish and Game Commission has in charge the maintenance of fishing and the preservation and control of natural fish life, together with the propagation of existing species and the introduction of new forms suitable to these conditions.

Plans for the salt water barrier provide for fishways so that fish may travel upstream. Fish will have free travel at such times as gates are opened and will no doubt pass through the ship locks at all times.

### THE FUTURE OF THIS REGION

The future of the industrial region on Carquinez Straits and Suisun Bay depends upon the growth of population. California and other Pacific Coast states are growing more rapidly than any other section of the United States. There has been for many years a constant inflow of people from the East and an increase in population along the whole Pacific shore. The cities of Los Angeles, Oakland, San Francisco, Seattle and Portland have grown much more rapidly than is the average growth of American cities.

There is no such rapid development anywhere in the country except the industrial growth in the cities around the Great Lakes, where large manufacturing interests have centered. Aside from the City of Los Angeles, the rapid-growing cities of the country have been the industrial centers. In the case of Los Angeles, the industrial growth has been large but the great increase in population arises, to a large extent, from the attractive climate of this southern city.

Estimates of future population of the San Francisco Bay region have been made by several organizations in studies concerning public utility matters. The results of three such studies are shown in the table following. The first, Column I, is the estimate of the population of San Francisco and East Bay cities made in connec-

tion with studies of Trans-bay bridge; Column II is an estimate of the metropolitan district, taken as San Francisco, Alameda, Contra Costa and San Mateo counties, by the Telephone Company; and Column III the estimate of population of the East Bay Municipal Utility District by that organization. Each of these estimates indicates that the population will double in about 25 years.

## ESTIMATES OF GROWTH OF POPULATION

YEAR	I.	II.	III.
	San Francisco and Trans-bay Cities	San Francisco Metropolitan District	East Bay Municipal Utility District
1910 .....		686,873	229,404
1915 .....	760,000		
1920 .....	850,850	891,477	330,348
1925 .....	976,000		
1930 .....	1,100,000	1,329,200	501,000
1935 .....	1,250,000		
1940 .....	1,400,000	1,856,700	702,000
1945 .....	1,577,000	2,172,000	
1950 .....	1,750,000		948,000
1960 .....			1,230,000

- I. Estimate of population San Francisco and East Bay cities by Board of Engineers Trans-Bay Bridge, San Francisco, May, 1927.
- II. Pacific Telephone & Telegraph Company—estimate by Robert W. Bachelor, includes San Francisco, Alameda, Contra Costa and San Mateo counties, April, 1925. Published in "San Francisco Business" April 17, 1925.
- III. East Bay Municipal Utility District, Annual Report 1925, page 7.

Contra Costa County has grown at a more rapid rate than the Bay region as a whole. Census figures for the counties around the bay are shown in Table 4. Contra Costa's growth as compared with other bay counties is shown below:

Subdivision of State	Population 1920	Increase	Increase
		1910 to 1920 Per Cent	1900 to 1920 Per Cent
State .....	3,426,861	44	130
Alameda County.....	344,171	40	164
Contra Costa.....	53,889	70	198
Marin .....	27,342	9	74
Napa .....	20,678	4	26
Sacramento .....	91,029	34	98
San Francisco.....	506,676	22	48
San Joaquin .....	79,905	58	125
San Mateo .....	36,781	38	204
Solano .....	40,602	47	69

Recent figures to show increase in population are shown in Table 5, in which are given the school enrollments for years 1915, 1921 and 1927. These are summarized below:



SCHOOL ENROLLMENT  
BAY SHORE DISTRICTS—CONTRA COSTA COUNTY

	1915	1921	1927	Per Cent Increase	
				1915-21	1915-27
Elementary Schools .....	5020	7262	9118	45	82
High Schools.....	510	1037	1586	103	210
Totals.....	5530	8299	10,704	50	94
Increase.....		50%	30%		

*Population Growth and Its Cycles.* California, in common with other states, is going through a readjustment of population distribution and kind of occupation. A comparatively few years ago the greater part of our population was engaged in agriculture; today manufacturing and mechanical industries occupy more people than agriculture. In 1920 agricultural pursuits (including forestry) occupied 18 per cent of the wage earners of the state as compared with 28½ per cent engaged in manufacturing and mechanical industries. Today the percentage engaged in manufacturing is higher and increasing all the time.

Students of population growth recognize cycles of growth which, for certain reasons, start slowly, grow rapidly and decline slowly. California has gone through two cycles of growth—mining and agricultural—and is now entering upon a third cycle—industrial.

The gold rush commencing in 1848 caused the first rapid increase of population after California became a part of the United States. As mining gradually declined in importance, agriculture attracted many people and a great increase in population occurred. Agriculture ceased to make rapid growth in 1912 and since that period manufacturing and mechanical trades have been the principal source of increase in population.

There are several reasons for present conditions:

1. Agriculture has been depressed since the deflation period of 1921. Costs are still high and the sale price of products has not entirely recovered. Profits have been low.

2. Land values in California are high. There is no more chance for cheap land. The incentive which caused many to enter agricultural pursuits in the great period of agricultural growth does not now exist.

3. Farming is more and more becoming purely mechanical; the same area of land can be farmed now with fewer men. This releases men for other occupations and reduces the number of men trained in farming operations—the potential buyers of farms.

4. Freight rates increased during the war and added greatly to cost of placing agricultural products in eastern market centers. At the same time the increase in freight has made it practical and necessary for many manufacturers to establish branches on the Pacific Coast.

5. Since 1900, hydroelectric power and long distance transmission of energy to manufacturing centers have been made practical and cheap, and dependable power for manufacturing has resulted.

6. California, since 1900, has become a large producer of oil. The cheap oil has encouraged manufacturing in many ways.

7. The Panama Canal and better shipping facilities have made raw materials

for manufacturing more easily available, and have made it easier to ship products of manufacture to other markets.

8. The climate of the coast region of California has become recognized as being well adapted to manufacturing. The cool weather, uniformity of seasons, freedom from freezing or destructive storms, have attracted workmen and capitalists.

The result of all this is that at present the growth of California lies around industrial centers. We are now living in an industrial age. The future of the state depends largely upon the rate and quality of this manufacturing and industrial growth.

This does not mean that there is to be expected a decline in agricultural activity. On the contrary the growth of cities and centers of industrial enterprises will stimulate the growth in agriculture. Markets for more farm produce will result from increases in industrial population, there will be a better market for the raw products of manufacture which originate on the farm and the improvements in transportation that will result from manufacturing will benefit agriculture. We may expect the growth in agriculture to continue, but at a rate lower than during the years prior to 1912.

*Agricultural Extension Possible and to Be Expected.* In the chapter in which the region lying tributary to the upper end of the bay and lower river is described, the statement is made as to the area of land which could be irrigated from fresh water basin above the proposed salt water barrier. These areas are as follows:

AREAS IRRIGABLE FROM FRESH WATER BASIN  
ABOVE BARRIER

	Marsh	Upland	Total
San Pablo Barrier			
San Pablo Bay.....	51,000	48,000	99,000
Army Point Barrier			
Suisun Bay .....	70,000	93,000	163,000
Totals above San Pablo.....	121,000	141,000	262,000
Delta Region above mouth of river:			
San Joaquin .....	257,000	58,000	315,000
Sacramento .....	110,000	33,000	143,000
Grand Total.....	488,000	232,000	720,000
Of this area, that above			
Army Point is.....	437,000	184,000	621,000

Of this area, approximately 360,000 acres are irrigated in the delta region. The areas around Suisun Bay and on San Pablo Bay are surrounded by salt water for so much of the summer that pasture crops alone are grown to a considerable extent.

Following the history of growth of the country, it is reasonable to expect that all of the areas which can be irrigated from this fresh water basin will be irrigated and cultivated as rapidly as the population and increase in markets warrant. The region is close to markets, well supplied with transportation facilities, which will be both by rail and water, has a climate suitable to a great variety of crops, and it would be only natural that such areas would be put to use.

*Industrial Growth to be Expected.* There is no possible way of predicting what increase there will be in the industrial development except that it will be large and substantial in character. There are many basic industrial activities not represented in this part of the Pacific Coast—industries that will unquestionably settle in this region when a fresh water supply is assured—and there will be a continued and more rapid growth of the ones already on the ground.

Every large industrial region of the world has developed at points where fresh water is abundant and cheap, and where facilities for handling of raw products to factories and carrying the finished products to markets are well established, and the rates to markets are reasonable. San Francisco Bay, being in the geographical center of the Pacific Coast, is the natural point where large factories will locate. The fact that large cities are close at hand, that transportation facilities are established, that power is abundant and cheap where oil pipe lines bring oil from the fields further south, and that the climate is an unusually good one for a manufacturing business, are all important. If there is added to these essential conditions a large fresh water reservoir, there will be no more favorable location for manufacturing. It can be expected that the growth here will be as rapid as in any other part of the country and more rapid than has been true at any time in the past history of the state or Pacific Coast.

#### WATER REQUIREMENTS OF THE REGION

The present water requirements of the region are supplied from many sources. Richmond, on the upper end of San Pablo Bay, is within the East Bay Municipal Utility District, a public organization engaged in the construction of a water supply system from the Mokelumne River. It is to be expected that this district will purchase the distribution system of the East Bay Water Company now serving the territory, and that it will construct such additional facilities as may be required to supply industrial and domestic requirements of the territory. Water from this system will be costly. The charges of the East Bay Water Company average nearly 30 cents per 1,000 gallons. Little if any reduction in cost can be expected from the Utility District unless a part of the expense is raised as taxes.

The smaller towns, such as Martinez, Port Costa, Benicia, Bay Point, Antioch and Pittsburg, obtain water either from wells or by pumping from the river at fresh water times, or by small storage reservoirs filled during flood or fresh water season. In all of these towns water is high-priced (the average price of water from the Port Costa Water Company is about 27 cents per 1,000 gallons), usually of inferior quality at least some time of the year, and there is no great supply in sight to take care of rapid increase in growth of population. In fact the growth of the territory outside of the Utility District mentioned is to a large extent restricted by its water supply. The Utility District cannot serve the industrial plants on account of the high cost of water.

The construction of a salt water barrier will effectively remove this deterrent to growth, for it will place fresh water of good chemical quality alongside of all of these towns, and with the modern methods of filtration and purification the water will be suitable for domestic or any industrial use. The cost of pumping will be a small part of the cost of water from any other known source.

The industries now established between Oleum and Antioch, on both sides of the straits, use 10 million gallons daily and the use is increasing at the rate of a million gallons daily per year. Enlargements and extensions to these plants will probably increase this rate of growth.

Prediction as to the future is hazardous, as much depends upon whether or not a salt water barrier is built. This structure will greatly stimulate growth of present industries and will encourage the establishment of new ones. It is within the bounds of reason to expect 100 million gallons daily to be used by industries within the next 25 years.

*Domestic Supply for Cities and Towns.* Water for domestic purposes is higher priced in San Francisco and the East Bay cities than in any other large cities of America. This high price results from the difficulty of securing water in quantities sufficient to take care of the rapid growth of these communities. The same thing may be said of smaller cities along Carquinez Straits. Water for domestic use has been difficult to secure, the price is high, the quality is not good at all times. There is no known way by which small communities can satisfactorily grow unless the water supply is ample for the needs of their growing population.

As an example of this condition, the history of the Benicia Water Company may be cited. This company has made a careful investigation of the possibilities of securing water, has drilled wells for underground investigation, has considered storage possibilities in the hills back of the town, and has finally been required to use river water at such times as this water is available, and to supplement this supply with pumps. During much of the year the community is unable to supply water of a good quality without great difficulty.

On the south side of the straits the water supply for towns of Crockett, Martinez and surrounding territory is provided by the Port Costa Water Company, largely from wells in the neighborhood of Concord. Litigation has restricted the extent to which these wells can be utilized and this community will be faced with the very large expense of going to distant points for a water supply if the growth of the towns continues.

The town of Pittsburg is supplied from wells and, at seasons of the year when the water is fresh, from the San Joaquin River. The limit to the availability of underground waters is in sight and Pittsburg will be placed to great expense to secure a water supply if the growth continues to be as rapid as it has been in the past. Similar conditions prevail at Antioch, where protracted litigation called the attention of the state to the difficulties of this community carrying out its plan of pumping water from the river. Since 1920 Antioch has built a storage reservoir on the slopes to the south of the city, into which fresh water is pumped during the early summer, and stored and used in late summer. The result is that water is more costly and of poor quality for domestic purposes, largely on account of the taste of stored water in open reservoirs in bright sunlight.

The entire industrial areas along Suisun Bay and Carquinez Straits may be said to be restricted in growth on account of the fact that there is no easily obtainable supply of fresh water. The result has been a restricted rate of growth of population and an increase in cost of water to those who are already in the community.

The salt water barrier, to a large extent, will remove these difficulties. If the barrier is located at the San Pablo site, the entire area will be cared for. If it is placed at the Army Point site, the entire region upstream will be on a fresh water lake. The industrial area below the upper end of the straits can then be supplied from a relatively short pipe line heading above the barrier.

The reversal of flow, caused by tides at Sacramento, has endangered the cities' water supply by causing sewage to back upstream. The barrier will prevent this from occurring, as it will raise low water at Sacramento and prevent upstream flow.

## SURVEY OF REGION AFFECTED BY SALT WATER

The region affected by salt water includes the area from the lower end of Carquinez Straits upstream to Isleton on the Sacramento River, Wakefield Landing on the San Joaquin, and Mansion House on Old River. It includes Carquinez Straits, Suisun Bay, and approximately one-half of the delta on the San Joaquin and Sacramento rivers. San Pablo Bay is of course affected but salt water is more nearly a natural condition in that body of water. Indirect effects are experienced in all parts of the watershed draining through Carquinez Straits and the Bay region and cities which have commerce with these industrial and agricultural areas. The problem, in fact, is one which interests all of California, for the prosperity of this industrial region and the prospective growth of this country in some measure affect the entire area engaged in agriculture or trade in this part of the Pacific Coast.

The region directly affected by the recent invasion of salt water includes the cities and towns of Oleum, Crockett, Port Costa, Martinez, Bay Point, Pittsburg and Antioch on the south side of the straits and Suisun Bay, and Vallejo and Benicia on the north side. Salt water extends as far upstream as Rio Vista.

The estimated population of these towns and outlying territory is in excess of 30,000.

*Industries.* The important industries located along the Straits of Carquinez and Suisun Bay are as follows:

## INDUSTRIES

<i>Left Bank:</i>	CARQUINEZ STRAITS	<i>Town</i>
1—Union Oil Company.....	Refining, casing and shipping petroleum products.	Oleum
2—Selby Smelting & Lead Company.....	Branch of American Smelting & Refining Co. Smelting and refining non-ferrous metals.	Selby
3—California-Hawaiian Sugar Company.....	Sugar refineries, largest in world, 5,000,000 lbs. a day.	Crockett
4—Port Costa Brick Company.....	Makers of brick, etc.	Port Costa
5—Grain Warehouses.....	Storing, cleaning, shipping—principally barley.	Port Costa
6—Petroleum Products Company.....	Petroleum products.	Martinez
7—Mountain Copper Company.....	Copper smelting and refining, fertilizers.	Martinez
8—Shell Oil Company.....	Refining and shipping petroleum products.	Martinez
9—Southern Pacific Company.....	Operating railroad and ferries.	
<i>Right Bank:</i>		
10—Marc Island Navy Yard.....	Repairs and construction of naval ships.	Vallejo
11—Sperry Flour Company.....	Milling of wheat and other grains.	Vallejo
12—Benicia Barracks and Arsenal.....	U. S. Army stores.	Benicia
13—Kullman-Salz Tannery.....	Leather.	Benicia

## SUISUN BAY

<i>Left Bank:</i>	<i>Town</i>
1—Associated Oil Company..... Refining and packing for shipment petroleum products.	Avon
2—Coos Bay Lumber Company..... Manufacturing and wholesale lumber; large storage 75,000,000 F. B. M.	Bay Point
3—Pacific Coast Shipbuilding Company..... Ship building—steel and iron products.	Bay Point
4—General Chemical Company..... Large manufacturers of heavy chemicals.	Nichols
5—San Francisco & Sacramento Railroad Company.....	—

*Most Important From Pittsburg to Antioch:*

6—Booth Cannery Company..... Canners of fish, fruit and vegetables.	Pittsburg
7—Hickmott Cannery Company..... Fish, fruit and vegetables.	Pittsburg
8—Paraffine Company..... Paper board.	Pittsburg
9—Great Western Electro Chemical Company..... Diversified heavy chemicals.	Pittsburg
10—Redwood Manufacturing Company..... Redwood pipes and tanks and other products of redwood.	Pittsburg
11—Columbia Steel Company..... Steel products.	Pittsburg
12—Pioneer Rubber Company..... General rubber products.	Pittsburg
13—H. W. Johns-Manville Company..... Magnesium and asbestos building specialties.	Pittsburg
14—Santa Fe Railroad Company.....	—

Industries in Richmond and along the shores of San Pablo Bay are as follows:

<i>Left Bank—Below Carquinez Straits:</i>	<i>Town</i>
1—California Cap Company..... Caps for detonating high explosives.	Steger
2—Stauffer Chemical Company..... Bulk chemicals from crude ores.	Steger
3—Metropolitan Match Company..... Matches.	Steger
4—Pullman Manufacturing Company..... General shops, repairs and construction of cars.	Richmond
5—Santa Fe Railroad Company..... General shops, repairs and construction of cars.	Richmond
6—Standard Sanitary Mfg. Company..... Porcelain and enamel plumbing fixtures. Distribution of other porcelain and enamel ware.	Richmond
7—Certainteed Products Company..... Roofing and paints.	Richmond
8—Republic Steel Package Company..... Metal containers, principally drums for oil and gasoline.	Richmond

9—Standard Oil Company.....	Richmond Point
Refining and shipping of petroleum products.	
10—Philippine Refining Corporation.....	Richmond Point
Refining copra and other vegetable oils.	
11—California Wine Association.....	Winchaven, Richmond Point
Formerly largest winery in world; industrial alcohol.	
12—Giant Powder Company.....	Giant
Dynamite and other explosives.	
13—Hercules Powder Company.....	Hercules
Dynamite, T.N.T. and other explosives.	

The majority of these establishments along the Straits and Suisun Bay produce large outputs of material and are in the class ordinarily called "heavy" industries. They produce products essential to modern life both in peace and war times. Steel, iron, petroleum products of all kinds, chemicals, fertilizers, powder and fuse, leather, brick and tile, flour and feed, lumber and lumber products, ships and boats, sugar, fish and canned goods are produced in very large quantities.

A survey of the plants between Oleum and Antioch shows an annual production in 1927 of products valued at \$250,000,000. The increase in annual output is large and the growth has been regular. The first large factory to establish in this territory was the Sugar Company in 1907. The period up to 1920 was an active one in growth, but since salt water troubles became so prominent only one new plant of large size has located here.

Freight in and out of this district by rail and water, directly attributable to these plants, approximated 14,000,000 tons in 1927. Three railroad systems serve the territory. Vessels, both river and ocean-going, handle much freight. Oil pipe lines from the fields in the San Joaquin Valley deliver oil to the refineries, to large tank farms for storage, and to vessels.

Expenditure for electric power by these industries was \$800,000 in 1927. Electric power is furnished by the Pacific Gas and Electric Company and the Great Western Power Company. The use of power increases every year. Power rates are the same as in the Bay cities.

In 1927 these plants employed on an average of 8500 persons, the annual payroll amounting to \$15,000,000. Comparatively little seasonal employment is found—most of the factories run fairly constantly through the year. The population dependent upon the factories, using a ratio of 4 to 1, is 34,000.

The industrial territory on San Pablo Bay below Oleum, in Contra Costa County, is nearly as large as the district described above. If the entire waterfront area in Contra Costa County is considered, we find the annual products to be \$515,000,000; the number of employees to be 17,000; the annual payroll \$29,000,000.

The industries between Oleum and Antioch now use 10,000,000 gallons of water a day. The annual increase is 10 per cent or a million gallons a day. All of this water is pumped from tide water level when there is fresh water in the stream, but some of the factories use wells during the salt water period. Draft upon the ground water is causing a change in the quality of many wells by drawing in salt water. There is a definite limit to the amount of water which may be drawn from underground sources, and it is apparent that this limit has been reached.

Factories engaged in the production of large quantities of "heavy" products ordinarily locate where fresh water is abundant and can be had at the cost of pumping. New plants seldom locate under any other conditions and when there is a

choice between localities, the one where water is abundant and cheap is selected, providing the other factors which control locations are the same. There is only one place on the coast of California where such conditions existed in the past—the upper bay and lower river country. Industries now located there expected to obtain water by pumping direct from tide levels, and the change brought about by the invasion of salt water has added to expense of operation and has discouraged increase in plants which involve increased use of water.

There is great need of restoration of the favorable conditions of fresh water which formerly existed in this region. New industrial establishments will be attracted by abundant fresh water. If California does not provide such facilities, northern cities will offer greater inducements and many industries will locate Pacific Coast branches in these northern cities. There are in these other states large areas of land where pure, fresh water is abundant and may be had for the cost of pumping from permanent lakes or streams.

Rates for water in California cities are higher than in the north, as is shown in the following table:

#### COST OF 500,000 GALLONS OF WATER PER MONTH

San Francisco.....	\$157.56
Oakland .....	161.71
Los Angeles.....	72.16
Stockton .....	54.50
Portland .....	44.11
Seattle .....	32.94

The recent disaster to Los Angeles' St. Francis Dam will probably result in an increase in water rates in that city. Proposals have been made to increase the base rate from 5 cents per 100 cubic feet to 18 cents. If this proposal is carried into effect, the rate for 500,000 gallons in the above table will be nearly \$120.

Hardness of water is another factor in which northern cities have an advantage over the public supplies in California cities. Hardness is undesirable in water for either domestic or industrial uses—in some classes of industries hard water must be treated before use.

The comparison below will show the relative hardness of public water supplies of Pacific Coast cities:

#### HARDNESS IN CITY WATER SUPPLIES

*Hardness as Calcium Carbonate, Parts Per Million.*

(From Water Supply Paper 496)

	Maximum	Minimum	Average	
San Francisco.....	166	83		
Oakland .....			181	Reservoir and wells
Stockton .....			560	Wells.
Sacramento .....			60	River.
Los Angeles .....			163	Owens River.
			251	Los Angeles River.
Portland, Oregon.....	22	6	9	
Seattle, Washington.....	33	14	23	



The supply of Sacramento approximates the hardness of water that will be retained above a salt water barrier. The quality of water reservoired above the barrier will be better than any other city supply in California shown.

Hardness may be partly removed from water in modern purification plants. At Columbus, Ohio, water with average hardness of 272 parts per million was reduced to 97 parts at a cost of treatment of 2.45 cents per 1,000 gallons. (Proceedings of American Society of Civil Engineers, February, 1928.)

One of the needs of California today is a fresh water reservoir around which factories can be located with assurance of a permanent supply of pure water. Probably no single accomplishment in the construction program now under discussion will do more toward the general progress of the state. More factories mean greater population and more local markets for agricultural produce and amelioration of the general level of prosperity of the state.

A salt water barrier at San Pablo or Army Point will remove the obstacle now deterring the location of new industries in this region. It will remove the cause of added expense to the present plants and will encourage their more rapid growth.

Besides great quantities of water, large industries require cheap power, efficient transportation facilities, both by rail and water, and a good climate attractive to labor. The lower river and upper bay region lack only water. The salt water barrier will supply this single deficiency. If the barrier is not built, California, without doubt, will lose many important factories.

*Shipping Interests.* San Francisco Bay and the rivers drained through Carquinez Strait are used by boats engaged in river and bay traffic as well as ocean-going vessels. At the present time there is a large amount of river and bay traffic between Stockton, Sacramento and numerous delta landings and the cities around the bay. During parts of the year the river traffic extends beyond Sacramento and upstream from Stockton. Ocean-going vessels land at Carquinez Straits' points, Bay Point, Pittsburg and intermediate ports. Traffic by water is on the increase.

Tables 6, 7 and 8, in this report, give the tonnage and value of freight carried by water.

Projects for the improvement of navigation above Carquinez Strait have been approved by Congress and the work of acquiring rights-of-way in preparation for dredging is nearly completed. Two projects have been approved: First, the dredging of the channel through Suisun Bay to provide 26 feet of water for navigation purposes through this bay, and second, the Stockton deep channel which will provide 26 feet of water to Stockton.

Projects for deepening and regulating water depths for Sacramento River navigation are under consideration. A system of dams for controlling levels at low flow has been proposed, though not yet adopted by act of Congress. The present project provides 7 feet of water to Sacramento, 4 feet to Colusa, and with provision for 3 feet as far upstream as Chico Landing. Practical navigation upon the upper San Joaquin is now limited to the head of tide water, though if the project of the state for canalization of the San Joaquin under the "Coordinated Plan for Development of Water Resources" is carried out, navigation will be practical to points far above any places recently reached by boats.

Water transportation is available to all of the islands and reclaimed lands in the delta region, and nearly all of the agricultural produce grown in this country is shipped to market by boat.

Tides, currents and salt water phenomena in the upper bay and lower river region are important to shipping interests for several reasons: First and foremost

is the fact that the presence of salt water has retarded growth and, if continued, will decrease the agricultural productivity of this region. Second, and no less important to shipping interests, is the fact that the industrial region along Suisun Bay and Carquinez Strait is held back in its natural growth by the menace of salt water. The water-carried tonnage in and out of this industrial area is large and is on the increase. The completion of the deep water channel will give a stimulus to commerce by water.

The natural result of a salt water barrier would be to increase very rapidly the industrial territory and there would be, in consequence, much more freight to be moved, a larger population to be served, and a tremendous increase in shipping. The effect will be noticeable on both bay and river boats and upon ocean-going traffic.

The plans for a salt water barrier provide for locks so that vessels may have uninterrupted access to the fresh water basin above the barrier. As discussed later, the Young report considers thoroughly the shipping business and the plans provide for locks of at least two sizes—one for small vessels and the second for large vessels. Locks are designed to provide for future increase in traffic, both in size and amount of traffic and depth of drafts.

Tides and currents now cause a loss of time to the shipping interests and necessitate special provisions and greater care in the handling of vessels, particularly in the rapid currents in the Carquinez Strait region. A barrier will provide for a constant water level above the structure except during periods of flood, which will reduce the currents to one direction only, and that downstream, and will facilitate the movement of vessels by reducing the time now consumed by bucking adverse currents. The ability to dock without currents is an additional value to ships.

It is generally agreed by navigation interests that there is some benefit in sea-going vessels docking in fresh water, in the destruction of growths of salt water which cling to the bottoms of the vessels and reduce their speed. Ocean-going shipping entering the fresh water basin above the barrier will have the benefit of this condition.

Sediment carried by the river waters into Suisun and San Pablo Bays adds to the difficulties of navigation and causes annual expenses in its removal. Debris from hydraulic mining is one of the principal sources of such hindrances to navigation. The rivers which enter Suisun Bay bring to salt water each year a portion of the debris deposited in stream channels in years of unrestricted mining. From the best information available, it is probable that the peak of movement of debris has passed out of the rivers and is moving through Suisun and San Pablo bays en route to the ocean.

What effect the salt water barrier will have on the movement is important from the standpoint of navigation interests. Studies which furnish information on the problem have been made several times in the past twenty-five years. The brief statement below discusses these investigations.

In 1906 the writer, then in the employ of the United States Reclamation Service, made a study of the sediment carried by many important streams in the West. The results are in part published in Water Supply Papers Nos. 274 and 237. The investigation had in part the determination of the amount of sediment carried in streams that might be lodged in storage reservoirs. At the time this study was undertaken, experimental work was carried on to determine methods of field and laboratory work. Sampling apparatus was designed and tested to permit the collection of samples at any depth. The use of this apparatus indicated that the problem

resolved itself into two phases—suspended silt and sand rolled along the bottom. The suspended silt was found to be very fine and to remain in suspension a long time. It is moved as the water moves and in the tidal portions of the stream remains in suspension during the tidal movements.

Samples collected daily during 1906, a 125 per cent runoff year with heavy floods, gave an average silt content (weighted for flow) of 64.5 parts per million by weight or, for silt weighing 80 pounds per cubic foot, 0.081 cubic yards per acre foot. In 1908, a 67 per cent runoff year, the average silt content was 85 parts per million by weight or 0.106 cubic yards per acre foot. The total suspended silt in 1906 was 2,300,000 cubic yards; in 1908 it was 1,550,000 cubic yards.

The greater part of this material continues in suspension until the bay is reached, where slow currents permit a part of it to drop to the bottom. Flocculation from salt water to some extent encourages the deposition.

A salt water barrier will have the effect of improving conditions as affected by the deposition of the suspended silt. Fresh water above the barrier will remove the effect of salt water flocculation above the structure and there will be a greater tendency for the silt to be carried lower than under present conditions. As it is now, the flocculation commences in Suisun Bay or at the first point where fresh water and salt water mix. Eighty per cent of the sediment is carried in the flood months, at times when the barrier gates will be opened and the current above the barrier is highest. In these periods the tendency will be for sediment to be carried through the barrier with less deposition in Suisun Bay than under natural conditions.

Below the barrier, where fresh and salt water mix, there will be the same tendency for deposition and flocculation that now exists, the only important difference being the decreased tidal movements due to the barrier. There is no reason to expect any great change in conditions from those now found. Sediment moves to a large extent in flood periods, so that any accumulations which are deposited in low flow periods or in years of light runoff are swept away in flood years. Fine sediment which enters the streams probably will not greatly change in amount in future years, as the fine materials originating in former hydraulic mining operations are on the decrease. Storage reservoirs on the headwaters will tend to trap sediment and further reduce the load that will arrive at tide waters. On the whole, the barrier will probably benefit rather than harm the navigation interests so far as it affects suspended silt.

Sand and coarse debris rolled along the stream bottom make up an important but unknown part of the total stream load of sediment. Estimates by the writer, made in 1905, indicated that the equivalent of from 10 to 20 per cent of the suspended load was carried along the bottom. In a recent study of silt in the Colorado River (U. S. Dept. of Agriculture Technical Bulletin No. 67), the estimate is made that in that stream 80 per cent of the silt is in suspension and 20 per cent carried as bed load. Though the actual quantity may be in doubt, there is no question but that the stream bed at Sacramento and below has been lowering in recent years—an indication that the burden of debris from the old hydraulic mines is decreasing.

Sand and gravel along the stream bed do not move at ordinary flows but only when the stream is in flood. The barrier, therefore, will have little or no retarding effect upon the movement of sediment carried along the bed, for in times of flood the flow in all practical consideration will be unobstructed and the downstream velocity will be practically the same as without the barrier. The bed load will move as it now does, or at least will move as it would do if the barrier were not present.

*Structures in Water.* The teredo and other varieties of marine life which destroy wood have been noticeably active in San Francisco Bay and adjoining waters since about 1914. Prior to that time all wharves, docks and other structures in water in the upper bay country were built of untreated piles and the lives of the structures were very long. About 1914 the teredo became active and in the dry years which followed 1917 practically all wood structures in water below Antioch were destroyed. The Marine Piling Committee estimates that \$25,000,000 damage was done in this period. Of this sum several million dollars represent damages in the territory upstream from Richmond. Here the invasion of the teredo is encouraged on account of the encroachment of salt water. In earlier periods fresh water was present each year long enough to prevent wood-destroying animals establishing themselves.

Many of these structures have not yet been replaced. Those which have been replaced have been largely of creosote or other treated piling at an additional cost over untreated timber. No form of treatment gives permanent protection but reduces the activities of boring animals and lengthens the life of timber.

The cost of structures built of timber is, therefore, greatly increased over what it was prior to the invasion of salt water in the upper bay. Where concrete is used an additional increase in cost also occurs, for concrete to be placed in sea water has to be of much better quality than concrete suitable for fresh water conditions. The ordinary mix of concrete for sea water contains approximately two-thirds of a barrel of cement per cubic yard in excess of that considered good quality for fresh water conditions. On this account alone concrete work costs at least \$2.00 a yard more, due to the salt water invasion.

Under the present conditions, all future structures to be erected in this region must be built to resist teredo and other boring animals and salt water. The increased cost of wharves, docks, bulkheads, and all similar structures in water, will approximate 20 to 25 per cent more than if fresh water were present. The construction of a barrier to prevent the encroachment of salt water will greatly simplify such construction work and will reduce the cost under present conditions.

*Corrosion of Pumps, Piping and Equipment from Salt Water.* Steel and iron are corroded more rapidly in brackish or salt water than in fresh water. Experiments indicate that unpainted steel or iron lasts from two to ten times as long in fresh water as in brackish or salt water. This means that all gates, pipes, pumps and other parts of structures in water, or in industrial establishments where water is used, must be painted frequently or they will corrode more rapidly, require more frequent replacement, and cost more to operate than where fresh water is present. In the large industries, such as oil refineries, steel mills and plants where large amounts of cooling water are used, this becomes a very important factor.

Accurate estimates of the cost of salt water due to corrosion alone are difficult to make. Mr. C. W. Schedler, of the Great Western Electro Chemical Company of Pittsburg, California, estimates that there is a minimum of three million dollars' worth of equipment located in the plants between Crockett and Antioch being seriously depreciated by the presence of salt water. The normal life of this equipment is twenty years, or a depreciation of \$150,000 a year. Mr. Schedler estimates that the salt water conditions of 1924 caused a depreciation twice as fast as ordinarily. The loss between Crockett and Antioch in that year is a cash loss of \$150,000.

Conditions nearly as bad as 1924, so far as these industries are concerned, occurred in 1920 and again in 1926, and in each of the years between there is some

increase in corrosion from salt water. Conditions in the future offer little promise of improvement, and the probability is that unless a barrier is constructed the present industrial plants alone, without consideration of future extensions or new plants, will suffer an annual loss from salt water in excess of that experienced in the past.

Estimates by the writer in the territory from Oleum to Antioch, on both sides of the channel, indicate a loss from salt water corrosion in excess of that made by Mr. Schedler. The writer is of the opinion that the average annual loss approximates \$300,000 a year in the plants now operating.

*Railroads.* The natural and most feasible direction of travel north to south is across Carquinez Strait for both vehicular and rail traffic. At the present time all railroad transportation is handled by boats. Four lines of boats carry freight and passengers across this waterway. A year ago the first bridge was built—that across Carquinez Strait—for vehicular traffic only.

The Southern Pacific Company, the greatest railroad system in California, has studied a plan of bridging Carquinez Strait for many years. It is understood that a more active study of this problem is now going on than in any time in the past, and that prospects are good for the railroad to carry out such a development.

The San Francisco-Sacramento Railroad, which crosses the channel near the upper end of Suisun Bay, at one time acquired a permit to build a bridge at this point. The traffic carried by the company did not warrant such a heavy expenditure at that time, but recently the control of this road has been acquired by the Western Pacific Railroad Company, and it is likely that a large development of this transportation company will take place in the near future.

Any barrier built to hold back tide water can be easily arranged to act as a bridge for rail and vehicular traffic. In the Young report, a part of which is quoted later, estimates of the cost of providing such a barrier with a bridge are given.

Two applications have been recently filed with the County Board of Supervisors of Contra Costa County for a bridge permit across the bay region in the neighborhood of Richmond, the estimated costs being from \$9,000,000 to nearly \$20,000,000.

Should the barrier be built at San Pablo Point, it can serve there all present and probably future transportation needs. A barrier in Carquinez Straits, either at Army Point or Dillon Point, will be available for rail transportation and when the present bridge facilities are outgrown it may be used for vehicular traffic.

Mr. Herbert Benjamin, of the Southern Pacific Company, stated before the Joint Legislative Committee on April 16, 1928, that his company had made plans for a bridge between Bulls Head and Army Point, and that the cost, including approaches, was estimated to be less than \$10,000,000. The bridge was designed to give clearance of 70 feet. Application for permit had not been formally made to the War Department.

The site selected for this bridge is one of the sites investigated by Young, and any bridge built for the railroad would prevent its use as a site for a salt water barrier. It is highly advisable that full consideration be given of the barrier problem before any bridge permit is let for this location. The barrier can be made to serve as a bridge and the advantages of the double use are apparent. If the barrier is built to accommodate both rail and vehicular traffic and a proper allowance made for this service, the net cost to other interests can be lowered. This phase of the question is discussed later in this report.

*Ferries.* The ferry from Benicia to Port Costa, now operated to care for

vehicles, could be replaced by a barrier at Army Point or Dillon Point. The ferry now operating from Richmond to Point San Quentin could readily be replaced by a barrier at San Pablo Point. This slow method of crossing the water barrier can be replaced by a modern bridge, with little delay in traffic and with cost not greater than the present ferry charges. The automobile registration in California is on the increase and travel across the straits will be greatly stimulated by a bridge. There is no certain method of determining this quantity.

*Local Shipping.* The tonnage and value of local shipping on the Sacramento and San Joaquin rivers are given in attached tables. It will be seen that there has been a nearly constant increase in freight, except during the period of, and following, the World War. At present 2,100,000 tons of a value of \$140,000,000 are carried yearly.

The increase in shipping which will follow the construction of a barrier against salt water will benefit local shipping. As shown elsewhere, the advantages of the barrier will offset the disadvantages, and on the whole greatly benefit shipping.

*Ocean-borne Traffic.* Ocean-borne traffic is varied, though lumber and petroleum products make up the greater part of the business. The tables attached show the volume of business in Suisun Bay to be about  $2\frac{1}{2}$  million tons, valued at over \$40,000,000; for Carquinez Straits 4 to 5 million tons valued at \$100,000,000 to \$150,000,000; San Pablo Bay 4 million tons valued at over \$60,000,000.

Increases in ocean-borne traffic will follow the building of a barrier and completion of a deep water channel to Stockton. The stimulation to industrial production will greatly increase traffic for all classes of vessels. Ocean shipping will benefit by the ability to dock in fresh water without the menace now caused by tidal currents. Fresh water tends to cleanse ocean vessels of growths which retard movement.

The menace to shipping in passing through locks is so small that no additional insurance is charged to vessels which use locks. The safeguards to navigation, now provided around locks, greatly reduce the danger in using them. Periods of fog are the times of greatest difficulty. The removal of ferry traffic across the straits at Benicia will probably offset the dangers due to navigating through locks in foggy weather.

## SOLUTIONS OF THE SALT WATER PROBLEM

Several solutions of the salt water problems may be suggested:

1. Salt water barrier.
2. Storage and release.
3. Fresh water brought in by conduits or pipes.

The first is the only complete and the most satisfactory method of solving the problem. The Young report best describes the barrier and its effects upon the territory.

*The Young Report.* Mr. Walker R. Young, Construction Engineer, U. S. Bureau of Reclamation, has written a "Report on Salt Water Barrier—California, Below the Confluence of Sacramento and San Joaquin Rivers." This report is dated August 27, 1927, and was made by the U. S. Bureau of Reclamation in cooperation with the California State Department of Public Works, Division of Engineering and Irrigation, and Sacramento Development Association.

The report consists of a volume of 405 pages of discussion and descriptive

matter, a volume of 592 pages of exhibits and tabulations, a portfolio volume of drawings and diagrams, and three volumes giving records of borings at various sites. The work described in these volumes extended over a period in excess of three years, or from January, 1924, to the date of completion.

A large amount of field work was done as a basis for office studies. The investigations include all problems that affect the construction or operation of the structure.

In his report Mr. Young describes in detail the various investigations he has made concerning the salt water problem. He presents sixteen preliminary designs and estimates with three alternatives "in order that they may be readily available in the economic study which is considered necessary in the final determination of the feasibility of the barrier." He made "no attempt to study the economic aspect of the problem other than to enumerate the advantages and disadvantages, as such a study was not considered within the scope of this (his) report." The report, therefore, is an engineering study of the barrier so far as concerns its physical feasibility.

The report determines what kind of a barrier should be built to accomplish its purpose, and presents a large amount of data to show its bearing upon various activities which will be affected by it. Four sites were investigated and the merits and objections to each are set forth in detail, but no final recommendation as to a site is made.

The following quotation from this report gives in condensed form the essentials included therein:

#### "SUMMARY OF RESULTS

*General.* The studies made lead to the conclusion that it is physically feasible to construct a salt water barrier at any one of the sites investigated, but at great expense; and that it will be effective in controlling the salinity of the reservoir impounded above it. Not only will it protect the delta and industrial plants along the shores of the bays, but its construction will result in the conservation of a large part of the fresh water required to act as a natural barrier against invasion of water under present conditions.

"Without the barrier, salinity conditions will become more acute unless mountain storage is provided to be released during periods of low river discharge to act as a natural barrier against invasion of salt water. The amount estimated as necessary to act as a natural barrier was in excess of the flow in the Sacramento River above Red Bluff in 1924, and Red Bluff is located above the points of diversion of water used in irrigating the Sacramento Valley.

"The sites selected for development by drilling are considered geologically satisfactory for the type of structure proposed. Although preliminary designs and estimates are presented for four sites, there are only two general plans involved. A barrier, if constructed at the Army Point, Benicia, or Dillon Point site, would create a body of fresh water in Suisun Bay and in the delta channels, while a barrier at the Point San Pablo site would include San Pablo Bay as well.

*Type of Dam Proposed.* The type of structure to which principal consideration is given is one in which the ship locks and flood gates are located at one side upon rock foundations, the closure of the present waterway being effected by means of an earth and rock fill dam to be brought up to its designed

height after completion of the ship locks and flood gate structure. In another type studied the flood gates form the closure between concrete piers sunk to bed rock foundations in the present waterway by the open caisson method. Both types have been designed with and without provision for carrying a railroad and highway.

"The passage of floods is probably the most important problem since it involves the safety of the delta levee system. It would be desirable, if practicable, to provide gate area equivalent to, or slightly in excess of, the present waterway area in order that conditions of flow might remain unchanged, but the accomplishment of this plan would be very costly, if not altogether infeasible.

"In the design of the structure, advantage is taken of the difference in the elevation of water surface which it is possible to create above and below the barrier to discharge flood water. On account of the fluctuating head, resulting from tides on the downstream side, the discharge through the flood gates will vary from a maximum at low tide to a minimum at high tide. The reservoir above the barrier, therefore, will function as a basin in which the river discharge in excess of the flow through the flood gates at high tide is stored to be discharged at a rate in excess of the river discharge during low tide.

"The flood gates are of the Stoney roller type with sills depressed to 50 or 70 feet below sea level in order better to control the salinity of the water behind the barrier as explained in Chapter IX. In operation, the gates would be raised clear of the water surface as required to allow free passage of the floods. As the flood receded the gates would be lowered, one at a time, as necessary to maintain the water surface above the barrier at any predetermined elevation.

"The requirements for passing vessels through the barrier is an important consideration irrespective of where it might be located, but particularly, if located below Mare Island Navy Yard. In the designs proposed, ship locks have been provided in number to care for considerable growth in water-borne commerce, and in size to pass the largest ships likely to navigate the waters above the barrier.

"In some of the designs for the Army Point site, the ship locks would be constructed away from the flood gates, which, of course, would be advantageous for shipping during the passage of great floods from the rivers, but these are rare and considerable study would be required before it could be determined whether the advantage thus gained would offset the advantage of having the large salt water sump adjacent to the ship locks where the salt water entering the fresh water reservoir through the locks could be caught and returned to the salt water side. It is possible that the design with the ship locks and flood gates separated would be even more efficient in controlling salinity, but this is doubtful. The plan at the Army Point site in which the structures are separated interferes least with the plant of the Mountain Copper Company and results in economy otherwise.

"In the designs including a railroad and highway bridge across the locks these have been placed at an elevation to permit a large proportion of vessels using the locks to pass underneath without opening or lifting the bridges. In one design at the Dillon Point site, the clearance is made sufficient to pass



"It is probable that the rise in water surface at Collinsville, due to a barrier at the Point San Pablo site with equivalent gate area, would be less than if located at the Army Point site, but it would not be safe to reduce the gate area at Point San Pablo for the reason that extreme tides through the Golden Gate are more effective near the gate as evidenced by the fact that the tide of November 18, 1918, at Presidio, was 0.7 feet higher than that of January 25, 1914, at which time the maximum elevation of water surface at Suisun City was reached.

"At the Army Point and Dillon Point sites the ship locks are considered effective in passing extremely large floods but they are not considered available at the Point San Pablo site because of the greater necessity for keeping the locks open to navigation at that site, even during great floods.

"The effect of a barrier at the Army Point site would be to reduce the tidal volume passing the Golden Gate by less than 8% in comparison with about 35% if it were built at the Point San Pablo site. The occurrence of frequent high tides in the bays due to piling up of water in them as a result of storms on the ocean would be to eliminate through construction of a barrier at any one of the sites investigated. The effect on the elevations of tides below the structure would be to raise them slightly according to the U. S. Coast & Geodetic Survey.

"*Navigation and Bridge Traffic.* Any plan for the control of salinity involving the construction of a dam across the bay or river channels must be coordinated with the requirements of navigation.

"Ship locks are provided in number and size to meet the requirements of the present and immediate future. Provision for ultimate traffic at the time the barrier is constructed does not seem necessary since flood control on the upper rivers will improve to permit the replacement of flood gates by ship locks as the need for them develops. A summary of the operation as it would have occurred on July 6 and 7, 1925, is shown in Table 6-33.

"Although railroad and highway bridges are contemplated in most of the designs they are not regarded as indispensable and are omitted in some in anticipation of indifference on the part of railroad and highway interests toward the opportunities afforded by the barrier. In the studies made it is considered that traffic over them is subject at all times to the convenience to navigation. The bridges are designed to give a vertical channel of 50 feet above high water when in the lowered position and 135 feet when raised. The interruptions to bridge traffic, as they would have been on July 6 and 7, 1925, are summarized in Table 6-40.

"An examination of Plates 2-3 and 2-4, showing depths in San Pablo and Suisun Bays, will indicate the limitations placed upon commerce under present tidal conditions. If the elevation of the water surface above the barrier were maintained at about 2½ feet above mean sea level, a constant depth equivalent to that at mean high tide under present conditions, would be obtained. Uncertain and varying tidal currents would be eliminated above the barrier and they would be reduced in velocity below. The maintenance of a permanent water level would not only be convenient for navigators but would be a material benefit to owners of wharf property above the barrier.

"The farther downstream the barrier is located the more it will interfere with shipping. Locking requirements can be satisfied with least expense at the Army Point site and conditions are most unfavorable at the Point San Pablo site.

"The construction of a barrier at the Point San Pablo site probably would be looked upon with disfavor by the Navy Department for the reason that it would restrict free navigation through San Pablo Bay to the Mare Island Navy Yard by the necessity of passing war vessels through ship locks. This objection does not apply to the Dillon Point, Benicia or Army Point sites.

*"Storage in the Delta Channels and Bays.* For convenience the calculated storage in the tidal prism above each barrier site, between elevations  $-3.6$  and  $+6.4$  U. S. G. S. Datum (0 and 10, U. S. Engineer Datum) has been summarized in Table 7-2, Volume II.

*"Silt.* The problem has been attacked with the idea that any structure that would be detrimental to San Francisco Harbor would be looked upon with disfavor by those in jurisdiction. The investigation has not definitely determined the effect of a barrier upon silting. Conclusions must, therefore, take the form of conjecture until studies more comprehensive than it was possible to make in this investigation have been completed.

"The construction of a barrier at any one of the sites investigated may possibly have a beneficial effect upon the Golden Gate bar rather than detrimental. The movement of silt toward San Francisco Bay will be checked by the construction of a barrier at Army Point, Benicia, or Dillon Point. A beneficial effect upon the Pinole Shoal will result through the construction of a barrier at Army Point or Point San Pablo. The effect upon Pinole Shoal of a barrier at Dillon Point is at present indeterminate, as is also the effect on silting in San Francisco Bay of a barrier at Point San Pablo.

"Whether the scouring action of the tidal current tends to maintain or destroy fixed channels in the bay system remains to be determined. Should shoaling occur it will be comparatively small in amount and the channels can readily be maintained by dredging, perhaps with less effort and expense than without the barrier. Dredged material pumped into the marshes would build them up and improve their fertility.

*"Salinity.* In years of normal river discharge there is no salinity problem in the delta. It is menacing for a few days in the fall only but, considering the marshes surrounding the upper bays and the towns and industrial plants along their shores, the encroachment of salt water presents a serious problem almost every year.

"Conflict between irrigation interests in the upper valleys and in the delta region never will occur in years of large run-off for the reason that in the development of storage the construction of expensive reservoirs to hold the excessive run-off from the drainage area, occurring only once in a number of years, will not be practicable even though sufficient reservoir sites in which to store all of the run-off were available.

"The introduction of salt water into the fresh water lake through the ship locks can not be prevented but means are provided for drawing off this salt water and thereby controlling the salinity of the water up-stream from the barrier.

"Leakage of salt water past the flood gates, although comparatively small in amount, can be prevented by maintaining the water surface above the barrier at a higher elevation than below.

"Deep gates, opening from the bottom, are essential to the successful operation of the barrier for dependence is placed upon them as a means of drawing

off the heavier salt water which seeks the deep holes and channels, and for flushing out the reservoir above the barrier.

"Unless fresh water is available for occasional flushing, the reservoir above the barrier will gradually become salty. Flushing can be accomplished quite readily if water is available for that purpose. The studies of water supply, although based on meager data, indicate that in normal years there will be from eleven to twelve million acre feet available for that purpose. In years of deficient water supply there will be little, if any, fresh water available for flushing and the reservoir above the barrier may have to hold over one or more years without flushing.

"*Return Flow.* Return flow will increase with irrigation development in the upper valleys with the result that the salt menace in the delta will be alleviated; but, even though the return flow should increase to the 3500 second feet estimated to be sufficient to act as a natural barrier against encroachment of salt water, the demand for water will be such that it could not be used for that purpose unless it is replaced by water from mountain storage.

"*Control of Salinity by Storage in Mountain Reservoirs.* Salinity in the delta can be controlled through construction of storage reservoirs in the mountains from which water could be released during the season of low river discharge in the amount necessary to act as a natural barrier against invasions of salt water. Mountain storage would be a temporary expedient for the reason that, ultimately, there will be use for all of the available flow from the rivers, and the discharge into Suisun Bay and thence to the ocean, of water sufficient to act as a natural barrier against salt, would be an economic waste. However, storage created in mountain reservoirs constructed mainly for other purposes might be used for some time to control the salinity in the upper bays and delta channels during development of the requirement for full use of the reservoirs for the purpose for which they were primarily constructed, thus deferring the large investment in the salt water barrier.

"*Teredo.* The factor of salinity is one of fundamental importance in the distribution of teredo. The average lethal salinity for teredo navalis, the species to be feared most in the upper bays, has been determined experimentally as 5 parts per 1000; therefore, if the water above the barrier is maintained at a concentration below the limit for irrigation use teredo can not exist there.

"*Fish.* Fishing industries above the barrier, if constructed, should not suffer for the reason that, even though the fish ladder, which is an integral part of the structure, should fail to function, the fish would not be prevented from entering the fresh water reservoir because they would have free access to it through the ship locks which, under normal conditions, would be operated many times throughout each day and night.

"*Sewage.* No investigation was made of the effect of the barrier upon sewage, but from investigations made elsewhere it appears that fresh water will be better adapted for receiving sewage than either salt or brackish water since, gallon for gallon, fresh water disposed in a normal manner of more sewage than salt water. It will be best, in this respect, to keep the water above the barrier fresh because the intermittent admission of salt water interferes with bacterial, animal and vegetable growths that effectively aid in taking care of and digesting sewage.

"*Use of Water in Operation of the Barrier.* The seven main sources of

loss of fresh water accompanying the operation of the barrier are evaporation from the water surface of the reservoir created; water required for the operation of the ship locks; leakage around the flood gates; water used in operating the fish ladder; and water to supply the requirements of industries, municipalities and possibly irrigation. With the exception of losses past the flood gates and through the fish ladder, which are constant for the same type of structure, the losses increase as the barrier is moved downstream and this factor has an important bearing upon the selection of a site.

"Owing to the increasing difficulty of maintaining the reservoir created by the barrier free from salt water as the water surface is permitted to fall, and because of navigation requirements, it probably will not be advisable to allow the water surface to fall below mean sea level. Likewise, because of the nature of the delta levees and the cost of drainage in that region by pumping, the ultimate maximum allowable water surface for periods of several months' duration may be fixed at 4.0 feet above mean sea level, although later developments may show that this maximum storage level can be increased to 5.0 feet.

"It is not necessary to decide at this time at what elevation the water surface above the barrier should be maintained. To begin with, it should be held at, or a little below, ordinary high tide level. As time goes on the elevation may be raised as experience dictates.

"Water drawn from the fresh water lake for irrigation, domestic and industrial uses, as well as that required in the operation of the ship locks, should be replenished from river flow or mountain storage with the idea of maintaining a constant depth of water for the navigable waterways effected by construction of the barrier. In years of extreme low run-off the water surface could be drawn down to the elevation of mean sea level, or possibly, in an emergency, to the elevation of mean lower water.

"As the water surface behind the barrier is lowered, the cost of maintaining the Delta levee—not considering floods—should become less; the cost of pumping water out of the lake for any use becomes greater; the cost of pumping seepage water would become less; the difficulties of keeping the lake fresh would increase; and the depth of navigable channels affected would become less.

"Ship locks are provided in various sizes in order to economize on the use of fresh water and to prevent entrance into the fresh water lake of larger volumes of salt water than necessary by requiring vessels to use the smallest lock which will accommodate them. Intermediate lock gates are added for the same reason.

"Economy in the use of fresh water in the operation of the ship locks can be effected through the adoption of lock gates divided horizontally at a depth to allow a large portion of the vessels having a shallow draft to pass through the locks without opening the lower half of the gates and it is assumed that this type of construction will be adopted. It is estimated that the resulting annual saving of fresh water, based on an average daily traffic as it was on July 6-7, 1925, would be:

Army Point Site .....	173,000	Acre Feet
Dillon Point Site .....	146,000	" "
Point San Pablo Site .....	295,000	" " "

it being assumed that the water surface above the barrier would be maintained at an elevation  $2\frac{1}{2}$  feet above mean sea level.

"It will be necessary to flush the reservoir, preferably once each year, to rid it of accumulations of brackish water resulting, principally, through the inability to trap all of the salt water finding its way into the fresh water reservoir from one source or another. The amount of fresh water required cannot be predicted with any degree of accuracy but a study was made of the amount of fresh water available for the operation of the barrier, based upon the assumption that storage in the mountains was well developed. The study is based upon meager data but the results are believed to be indicative.

"From Table 10-13, it is evident that if the maximum height of water surface in the reservoir is restricted to  $2\frac{1}{2}$  feet above mean sea level, the water stored in the reservoir thus formed will not be sufficient to operate the barrier at any of the three sites studied during the irrigation season, even in years of heavy run-off, and it will be desirable, therefore, to seek the highest practicable elevation at which to maintain the storage level.

"The shortage due to lack of reservoir capacity increases as the barrier is moved downstream, although the capacity of the reservoir is greater. This is principally due to the greater evaporation, and to the larger requirements of navigation, industries and municipalities.

"As the storage elevation above the barrier is raised the amount of water available for flushing in years of low run-off is decreased. According to Table 10-13, no water would be available in the season 1923-24 for flushing out the reservoir created through construction of a barrier at the Point San Pablo site whether water were impounded to elevation  $+2.5$ ,  $+4.0$  or  $+5.0$ . It appears that, in any case, there would be no flushing water available in 1923-24 if water were stored to elevation  $+5.0$ , although in a normal year there would be a large amount available for flushing, regardless of where the barrier is constructed or of the elevation at which the water surface above the barrier is maintained.

"If the above analysis is correct, it may be concluded that since one of the principal objects of the salt water barrier is to conserve fresh water, it will be desirable to maintain the largest practicable storage capacity above the structure. Likewise, it is evident that the farther downstream the location for the barrier is chosen the greater will be the quantity of water required for operation, and the greater will be the shortage during seasons of low run-off. Since the shortage must be supplied from mountain storage in order to maintain sufficient depth for navigation, and to hold the water level at an elevation where the reservoir will not be deluged with salt water whenever the ship locks are opened, it is apparent that consideration of the necessity for conservation of water would require the selection of one of the upstream sites—Army Point, Dillon Point or Benicia, if the latter, upon investigation, is found to be suitable structurally."

*Discussion of Young's Report.* The summary just given of Young's report gives his main engineering conclusions. As will be seen, the engineering conclusions are as follows:

1. The construction of a salt water barrier is feasible at either San Pablo Point or at one of three sites near the upper end of Carquinez Strait.
2. The barrier can be utilized for both rail and automobile traffic.
3. The cost will depend upon the method of construction. A barrier can be built at Army Point with bridge of 50-foot clearance for \$49,800,000;

- at Benicia for \$46,200,000; at Dillon Point for \$44,700,000; at Point San Pablo for \$75,200,000.
4. The barrier will pass a flood of 750,000 second feet (larger than any flood measured into Suisun Bay) with an estimated raising of water surface of 0.7 of a foot at the barrier, at Army Point, and about 0.55 of a foot at Collinsville. Water levels in the delta under extreme conditions are estimated to be below elevations of high water computed by Flood Control Engineer of the state. With a barrier at Point San Pablo, the raise in water level would be slightly less than at Army Point.
  5. The barrier would effectively handle both water transportation through locks and bridge transportation.
  6. The barrier would store fresh water and prevent the encroachment of salinity now taking place every summer.
  7. The barrier will prevent teredo from working above its location.
  8. The barrier can be operated so as not to be a detriment to the fishing industry.
  9. The elevation at which water is maintained above the barrier in summer has not been determined. To begin with it should be held a little below ordinary high tide. This point is discussed in more detail in the following pages.
  10. Young makes no determination of the economic features of the barrier, nor does he recommend a site.

Two things in connection with Young's conclusions may be given further consideration: first, that return seepage will increase in quantity and ameliorate conditions in the delta, and, second, that water from the Sacramento river may be temporarily carried across the delta for use in the San Joaquin valley by releasing stored water and without the construction of the salt water barrier.

With reference to the first matter, it has been shown that return seepage in the San Joaquin Valley is being recaptured by the pumping plants on the west side of the valley and there is now no benefit from the return seepage to delta lands in late summer. There is no prospect for increase in return flow, in fact the increase in pumping from wells all over the valley and new pumps along the river will decrease that flow.

In the Sacramento valley similar conditions prevail. It is not certain that return seepage on this stream has reached a maximum, because a large area of land close to the river is not yet regularly irrigated. When this land becomes more intensively farmed, it is to be expected that it will utilize to a great extent this very return water and decrease the net amount which reaches the tidal waters. Return flow, therefore, cannot be depended upon, in either river, to improve salt water conditions in the delta.

As to the second matter, it may be said that so long as the tide ebbs and flows there will be the opportunity for salt water to penetrate the delta, just as far or farther than was the case in dry years since 1917. In 1920, 1924 and 1926, salt water went beyond Three Mile Slough, the principal connection between the Sacramento and the San Joaquin deltas. If water were drawn up the San Joaquin, there would be a greater tendency for salt water to penetrate the delta and be drawn southward. It should be remembered, too, that in dry years released water from storage reservoirs is going to be very difficult to deliver past the large areas of riparian

lands. The flow of the rivers will undoubtedly be so low that tides will carry salt water beyond Three Mile Slough. Certainly no dependence can be placed upon this method of carrying water across the delta. The barrier is essential to prevent tidal movements and the encroachments of salt water.

### ELEVATION OF WATER ABOVE BARRIER

Objection, from owners of delta land, has been raised to the proposal by Young that levels above the barrier might eventually be raised above mean high tide in order that more water might be stored for use by the towns, irrigated area and industries around the lake above the barrier.

Mr. G. A. Atherton, who is probably as thoroughly acquainted with the delta region as any other person, is authority for the statement that a level of 6.0 feet U. S. E. D. (or 2.4 U. S. G. S.) continuously maintained in summer months is as high as can be safely held against the delta levees under present conditions. According to him, to carry water higher would endanger the levees, would increase seepage and pumping, and therefore add greater maintenance cost to the delta land owner. It should be understood that Mr. Atherton has reference to the delta lands where peat predominates.

The answer to this argument is that the delta lands will be surrounded by salt water unless the barrier is built, but the barrier can, and should, be operated so as to do no damage to these peat areas.

There is some uncertainty as to the exact difference between the datum of the two surveys (U. S. G. S. and U. S. E. D.) and the level of tide as indicated by tide tables. U. S. G. S. elevations refer to mean sea level and are based upon a number of years of observation. U. S. E. D. levels are based theoretically upon mean lower low water but practically are taken as 3.6 feet lower than the U. S. G. S. levels. Tide gage levels are theoretically based upon mean lower low water but practically are referred to the elevation of a point on the Presidio tide gage staff in San Francisco. As near as can be determined, the U. S. E. D. and tide table datum planes are not the same, but the U. S. E. D. datum is about 0.63 feet lower. This figure is not exact, however, and for practical purposes it may be assumed that the two are the same. In the delta region the tidal range varies more in different parts of the delta than this variation between the two systems of measurement.

If water is held at 6.0 U. S. E. D., it will be at less than high tide in the central delta. Here the tide rises to over 7.0 feet two or three times a year, and in times of southwest storms it has risen to over 8.0. In 1907, during the flood, the elevation exceeded 10.3. With water held at 6.0 there will be no menace to levees and comparatively little increase in pumping out of seepage water. Furthermore, this elevation will permit the efficient operation of the barrier, for salt water is higher than 6.0 at the Golden Gate less than one per cent of the time, excluding storm and flood periods.

Any increase in height should be made only if it can be done without menace to the island levees. In storm periods water will be held lower than would naturally occur except in the most extreme floods. Reservoirs which have been constructed on nearly all tributaries of the Sacramento and San Joaquin rivers will undoubtedly have the effect of reducing the peaks of floods, and there is little likelihood of a repetition of the extremes experienced in 1907, at least such extremes will occur less frequently.

On the whole, the delta lands will be better off with the barrier than without

it. The one factor of slightly increased pumping with the summer level held at 6.0 will be more than overbalanced by the freedom from the present menace of salt water.

### SELECTION OF SITE FOR BARRIER

Mr. Young in his report sets forth the conditions surrounding the locations investigated as sites for the barrier. The following statement compares the two locations—the three sites investigated near the upper end of Carquinez Strait being treated as one:

*Water Supply:* Tables attached give the estimated quantities of water required for all uses above the barrier. The quantities here given are estimated uses when all area above the barrier is developed and are liberal figures, with an allowance for flushing to remove salt water let in by ship locks and leakage. The figures show that under these conditions the requirements for the full year are:

Point San Pablo .....	2,024,000	Acre Feet
Army Point .....	1,160,000	“ “
Difference .....	864,000	“ “

For the irrigation period May to September, inclusive, the requirements are:

Point San Pablo .....	1,236,000	Acre Feet
Army Point .....	638,000	“ “
Difference .....	598,000	“ “

The large difference comes principally from the quantity of water required to operate locks and the increased evaporation in the lower site. In other words, from six to eight hundred thousand acre feet are required to supply the additional unavoidable losses from evaporation and ship lockages in San Pablo Bay.

In the matter of cost, Young's estimates show for a barrier with 50 feet of clearance the following:

Point San Pablo .....	\$75,200,000
Army Point .....	49,800,000
Difference .....	\$25,400,000

The convenience to other interests is of great importance. The Mare Island Navy Yard is located above Point San Pablo but below Carquinez Strait, naval officers will object to the barrier. On account of the greater number of vessels which pass San Pablo than through the upper end of Carquinez Strait, there will be less objection to the upper site.

Barriers at both sites will serve as bridges. The San Pablo location will replace a ferry now in operation—the upper site in Carquinez Strait will serve both for rail and vehicular traffic and will replace two ferries.

The opportunity to combine the barrier with the Southern Pacific Railroad at Port Costa should not be overlooked. The Railroad Company is contemplating the construction of a bridge to replace the present ferry. If the Army Point-Suisun Point site is selected by the railroad, the barrier can not be built on this site.\* In some respects this is the most attractive site and until final determination is made of the location, no permit should be given for a bridge across this place.



## STORAGE AND RELEASE TO CONTROL SALT WATER

This method of solving the salt water problem has been suggested in several recent publications of the Department of Public Works. Examination in detail of the proposals shows that "salt water control" means the supplying of water of less than 100 parts chlorine per 100,000 to the delta lands. Emmaton on the Sacramento and Jersey Island on the San Joaquin are the limits of control and no suggestion has been made that it is practical to release water to supply Antioch or any of the lower industrial area. This, in fact, leaves out of consideration the area now most seriously damaged.

Studies by the Division of Water Rights based on records including the year 1925 show that to control salinity below 100 parts chlorine per 100,000, the combined flow of the Sacramento at Sacramento and San Joaquin at Vernalis (both points about the head of tide water in late summer) must exceed the following figures:

	Cubic Feet Per Second
For control at	
Emmaton and Jersey Island .....	3500
Antioch .....	5000
Collinsville .....	5500
O. & A. Ferry.....	6000

These quantities will depend to some extent upon the months preceding the period when control is desired and will, of course, vary with the diversions below the points of measurement. Furthermore, storage of water above tide level will affect the matter by limiting the distance salt water is forced downstream by spring floods.

To effectively supply these quantities of water will require very large storage capacity in dry years.

In 1924 storage in excess of a million acre feet would have been required to control salinity at the Oakland & Antioch Ferry and 370,000 at Emmaton and Jersey. In 1926 over 500,000 acre feet would have been required at the Oakland & Antioch Ferry and 200,000 acre feet at Emmaton and Jersey. Storage in large amount would be needed about half the years at Emmaton and Jersey and every year for control at the O. & A. Ferry.

The above is under the assumption that storage and diversions in these two valleys do not increase. As shown earlier, this condition has already been violated, for there has never been such increased activity in building storage reservoirs as in the period since 1924. Many reservoirs are planned for construction in the near future. Furthermore, diversions increase every year. Estimates of the quantities required for storage control must therefore be continuously revised upwards.

Release of stored water, to control salinity, will occur in dry parts of the year and to the greatest extent in dry years. To effectively control the right of storage and release, all riparian owners below the reservoir must agree to the arrangement. As the law now stands, the use of such a reservoir may be enjoined and it will be impossible to prevent, except through litigation, the riparian owners from diverting the released water. This difficulty can be removed by condemnation of rights along the stream. The problem looks too large for human accomplishment in any reasonable time and at any reasonable cost.

To one acquainted with water problems in California, it does not seem reasonable to expect that in the dry part of a dry year a flow of 5,000 or more feet per

second would be allowed to pass pumps and ditches, under which crops were suffering, in order that salt water could be pushed back into the ocean.

As to the cost of storage reservoirs to accomplish the release for salt control, there is little definite information which permits a comparison of costs. The following statements are of some interest:

Kennett reservoir is proposed by the State Department of Public Works as a unit in the "Coordinated Plan." (See Bulletin 13, Department of Public Works, 1928.) The recommended reservoir capacity is 2,940,000 acre feet; the estimated cost of dam and rights of way is \$55,000,000; of power plant \$25,000,000; a total of \$80,000,000. With allowances for prior rights, the mean annual irrigation yield of reservoir will be 2,838,000 acre feet. In minimum years the deficiency would be large; 19 per cent in 1920, 42 per cent in 1924. If this reservoir were depended upon for salinity control, the entire available supply would be needed to control salt water at the mouth of the river, leaving no water for the area depending on this reservoir for irrigation. In other words, the very year when the reservoir is most needed it would be of little practical use. Furthermore, Kennett is not practicable unless operated to generate electric power. If the water is held and released for salt water control, the power value is greatly decreased.

Iron Canyon Reservoir is proposed as a secondary unit in the "Coordinated Plan." (See Bulletin 13 of Department of Public Works.) The recommended capacity is 1,121,900 acre feet; the estimated cost of dam and power plant is estimated as \$26,000,000; the canal system to utilize this water is estimated at \$30,000,000. The reservoir may be utilized in controlling salinity. To quote from the above mentioned report, page 115:

"Sacrificing the power features at Iron Canyon dam would, with other construction unchanged with the exception of the arrangement of outlets through the dam, supply a reserve storage of 364,600 acre feet of water in Iron Canyon reservoir to overcome, or alleviate, the salt water menace in the delta region should such be desirable. Such use is not advocated, but it is demonstrated that there are possibilities along this line."

Should the irrigation feature likewise be disregarded, Iron Canyon would provide a net annual irrigation draft of 800,000 acre feet or just about enough water to control salt water as low as the mouth of the river—provided the water could be carried past head gates and pumps on its way to tidal waters. Under this condition the power feature would be sacrificed to a larger extent. It is difficult to picture a dry year when water and power are both scarce, in which it would be possible to release a large quantity of water, disregarding its best use for power, and have the riparian and appropriative users of water along the hundred and fifty miles of the Sacramento River permit this flow to pass by uninterrupted to tide water. The plan does not look practical.

Other reservoirs may be used for the same purpose, that of increasing the flow to control salt water. For example, a reservoir on Feather River has been suggested, another on the American at Folsom. Both of these reservoirs will have value for power development and that value will be greatly reduced if a large quantity of water is held for saline control. The most practical suggestion is in connection with a reservoir on Dry Creek, north of the Mokelumne, the water to be diverted from the Mokelumne River. The rights obtained by the East Bay Municipal Utility District for storage in Lancha Plana Reservoir practically eliminate this reservoir from consideration.

In connection with the proposal for storage and release of water, it should be

remembered that the State Department of Engineering has made the suggestion as a temporary expedient, with the expectation that permanent relief would be brought about by the construction of the salt water barrier. This state of affairs would leave the delta lands dependent on a temporary right to be replaced by a permanent right which would be arranged for at some later time. With the growing condition of California and the certainty that the temporary supply will be invaded by increased diversions, this is a very precarious water right, not one which will satisfy the delta land owners. Furthermore, the plan does not consider users below the delta, either towns or industries.

New industries will not be attracted by any temporary improvement in water conditions. Some permanent solution must be reached. It is important to California to have the decision made at once so that the great industrial expansion now going on can be located to a maximum extent in this state.

### WATER FROM OUTSIDE SOURCES

Water may be brought in from outside sources to supply the towns and industries along the Straits and Suisun Bay. It is not likely that the agricultural lands can be reclaimed by any outside source of water on account of the high cost. But for the uses of towns and factories it is possible to secure outside water.

Under present conditions water cannot be drawn at any point on tide water without either running the risk of getting salt water or of interfering with rights already vested. It may be possible to pump during the fresh water period into reservoirs and to pipe the water thus stored along the waterfront, supplying both domestic and industrial consumers. Reservoirs of good size are available in the Montezuma hills north of Suisun Bay and a few small reservoirs are found on the south side of the bay. No estimate has been made of the cost of this method. Surveys beyond the scope of this report would be required. It is known that the cost would be large, though cheaper than any other known source.

Other possible outside sources are:

Eel River—a supply which has been suggested for both San Francisco and East Bay cities. The distance to Carquinez Strait is 125 miles. Harroun estimates the cost at \$22,000,000 to carry 50,000,000 gallons daily to south sides of Carquinez Straits.

Conn Valley—a small tributary to Napa River with probable yield of 10,000,000 gallons daily. Cost not known but the supply would only furnish a part of present needs and would provide nothing for future growth.

Putah Creek—a tributary of Sacramento north of Dixon. Cost not known. About 50 miles north of Suisun Bay. Complicated with riparian claims. All storage at considerable distance in mountains.

Mokelumne or Cosumnes—draining Sierras north of Stockton. Cost unknown. Early rights conflicting. About 75 miles distant.

Pumped water from San Joaquin Valley—It has been suggested that the irrigation districts in the San Joaquin Valley could deliver pumped drainage water into the river to be pumped out above salt water limit and delivered to industries and towns along the bay through pipe lines.

East Bay Municipal Utility District—The main pipe line of this district parallels the bay shore from Antioch to Bay Point. To secure water from it the area must enter the district. The district has voted \$64,000,000 to complete a 60 m.g.d. supply. Water will be costly if the entire cost is collected from rates, and there

is little incentive for Contra Costa County and towns to enter this organization. The water is too costly for the heavy industries, such as now are located along the waterfront.

All of these sources are so distant and costly that the supplies are more of the nature of domestic supplies than of cheap industrial water supplies such as are required in any large and growing industrial region. None of them solves the salt water problem as affecting construction along the waterfront and none of them can possibly be made available for agricultural industries on the bay lands.

#### THE BARRIER AS A UNIT IN THE STATE COORDINATED PLAN OF WATER CONSERVATION

A plan for the development and use of all waters of the state upon a coordinated plan has been presented in part to the Legislature by the State Department of Public Works. This plan provides for the storage and utilization of all water required in the Sacramento Valley and the transmission of excess water to the San Joaquin Valley for use on lands for which insufficient water can be supplied from local sources. The salt water barrier is a necessary unit in this plan, for water can not be carried through the delta with tidal flow bringing salt water in and out of the channels twice a day.

#### GENERAL DEVELOPMENT OF BAY REGION

The entire bay region is interested in the salt water problem in that the prosperity of the region immediately concerned affects the prosperity of the cities. The industrial territory along Carquinez Strait is essential to the well being of the whole state. The industries are fundamental to modern civilization. Oil, gasoline, lubricants, steel, fertilizers, sugar, leather, timber, soda, chlorine, fire-proof roofing, paper board, brick, tile, flour, mill feed, and the remaining varieties of manufactured products are necessities of modern existence. To have them abundant and cheap is greatly to the advantage of modern society.

Many of these factories would be classed as nuisances if located in a large city, on account of the odors. Carquinez Strait and Suisun Bay have regular winds which prevent a serious nuisance in this locality. Other communities are not so fortunately situated.

The ratio of factory employees to population of towns is about 1 to 4. This means that the population of the towns immediately surrounding the industries will grow as the industries thrive. This population in towns makes a market for the products of the cities and the multitude of manufacturing establishments which have located in the cities. The heavy industries in turn furnish raw material for use in the factories in the cities.

As a result of this interlocking of interests, the large cities of the bay region have a direct interest in seeing a salt water barrier established. Behind it, around the fresh water lake thus created, there will grow up a thriving industrial community engaged in the production of essential materials which could not be produced within the cities themselves.

#### CALIFORNIA NOW IN THE INDUSTRIAL AGE

California is now in an age of industrial growth. Approximately one-third of the people of the state are engaged in manufacturing and mechanical industries as compared with less than 20 per cent engaged in agriculture, forestry and animal husbandry (the next largest class of workers). The present growth of the state is due largely to the activity in industrial matters.

Students of population growth recognize cycles of increase in population. There seems to be a definite limit to the number of people that can be reached in any set of circumstances. The growth of California very well illustrates three cycles of growth. In the early days of the state, mining was the attraction and the whole life of the community centered around the mines. As mining reached its climax in the seventies, agriculture came to the forefront and there was a continuous growth on this account. The agricultural era lasted until about 1915. In the meantime, through the discovery of oil and the unprecedented development of the electrical industry, cheap power was made available and manufacturing began to grow. At present there is very little actual increase in agricultural population but a large increase in industrial activities. So far as it is possible to see in the future, our growth will be industrial. Agriculturists have learned to grow more crops with less man power and there is comparatively little likelihood of any large increase in agricultural population. The problems of the state are nowadays to a large extent those of the people of the towns and cities and industrial areas.

### DISTRIBUTION OF BARRIER COST

Several interests should share in the cost of this barrier. As has been shown, conditions now existing have been brought about by developments on the higher parts of the watershed, an area covering 32,000 square miles. The Bay cities will be contributing to the salt water problem by diversions which they propose to make out of the watershed. The agricultural interests through both valleys are using fresh water in such a way as to contribute to the salt water troubles of the delta lands and the industrial territory. The power companies through use of water in the watershed also affect the problem, and in addition these companies are interested in the increase and prosperity of the industrial region. Other public utilities in this region have the same interest in its prosperity.

The problem is so large and its interests so widespread that it may be said to be state-wide in scope.

The federal government through its control of navigation, as well as its general interest in the prosperity of the country, is likewise interested in the problem. The California Debris Commission and the River and Harbor work under the Chief of Engineers of the Army already are engaged in river improvement and in control of reclamation work so far as it affects navigation. It would appear reasonable, therefore, to have participation in this construction work by the federal government.

Local interests which will receive direct and tangible benefits from this barrier, such as the towns, cities and lands which can use water directly from the fresh water lake above the barrier, should contribute to the cost of the structure. The delta lands so far as they divert water from tide water levels should also be included in the area contributing because of benefits.

Railroads and vehicular traffic utilizing the barrier as foundation of a bridge should pay the value of this service. It seems reasonable that railroad and vehicular traffic could reasonably contribute a large sum for the use of the bridge.

It appears from examination of Young's estimates that the sum of \$45,000,000 will complete a barrier with a bridge at a point near the upper end of Carquinez Strait. A detailed economic study should be made to determine the proportion of the cost that should be borne by each interest involved.

## SUMMARY

1. Carquinez Strait marked approximately the boundary between salt and fresh water under natural conditions.
2. Prior to diversions for irrigation, Suisun Bay was brackish in late summer and salt water may have penetrated as far as Antioch, but only for a few days at a time in years of lowest run-off.
3. If the water now diverted for irrigation and held in storage were released, natural conditions would again be brought about.
4. The dry year of 1918, in which the urge of war had encouraged heavy plantings of rice and other crops in the Sacramento Valley, resulted in penetration of salt water into the Delta for a longer time and to a greater distance up-stream than ever known before.
5. Examination of available information shows that the yearly increased diversion of water which had been going on since irrigation commenced in the valleys of California, had been gradually affecting the movements of salt water. This slow effect was hardly noticed until 1918.
6. Irrigation and storage are not solely responsible for the influx of salt water. The load of hydraulic mining debris deposited in the streams draining the Sierra Nevadas is a minor factor in the problem. As the sediment moves downstream the tidal prism is changed and the movement of water is affected.
7. Leveeing and reclamation of marsh lands, around the bays and in the delta region, have had a slight effect upon tidal movements. The net effect of leveeing marsh land has been to decrease the tendency of salt water to flow up-stream.
8. Leveeing of basin lands and diversion of floods through by-pass channels has had an important effect in sending floods rapidly to tide water and in reducing the late summer flow of water which under natural conditions was stored and slowly released from basins.
9. Dredging, particularly in lower portions of the rivers and in the navigation channels of San Pablo Bay, has increased the tendency for salt water to flow up-stream. Dredging in Suisun Bay and in the deep water channels to Stockton may have the same tendency. All increases in channel depth and in straightening of approach have a tendency to increase up-stream flow of salt water, though a quantitative estimate of this tendency cannot be made.
10. Irrigation now diverts the entire low flow of all streams entering the San Joaquin Valley. The only flows reaching tide water in late summer and early fall are return waters—seepage from irrigation.
11. Pumping plants on the west side of the San Joaquin Valley, lifting water to the west side slopes, now divert more water during late summer than enters tide-levels from the river. The San Joaquin delta under present conditions is dependent in late summer of dry years on flow from the Sacramento River. Additional pumping plants are being installed and there will be a greater tendency in the future than in the past for salt water to flow up-stream into the delta channels.
12. Irrigation in the Sacramento Valley in late summer diverts practically all the flow of streams entering the valley floor. The flow of the river at Sacramento, the head of tide water, is now largely return seepage or waste from canals. The low flow at Sacramento was 500 second feet in 1920; 2750 in 1921;

3200 in 1922; 3100 in 1923; 705 in 1924; 2760 in 1925; 1330 in 1926; and 3420 in 1927.

13. The area irrigated in the delta of both rivers is now 360,000 acres. The quantity of water used by this land has not been determined with any accuracy. Comparing crops and other conditions affecting use of water, it is probable that the annual consumption approximates  $1\frac{3}{4}$  acre feet per annum. Twenty per cent of the annual amount is used in the summer months of greatest evaporation. At this rate the consumption of water by the delta area is at the rate of 2100 second feet in the summer. This exceeds the flow into tide water by the river in all years of low flow.
14. Records of salt content of the water have been collected by the Division of Water Rights since 1917. The area of delta land surrounded by salt water (100 parts chlorine per 100,000) at high tide is shown in the following table:

Year	Approximate Stream Flow before Diversions in Per Cent of Normal.	Area in Delta Surrounded by Salt Water, Acres.
1924	24	169,000
1926	53	58,000
1925	74	8,500
1927	100	5,000

15. Contrary to popular opinion, the period since 1918 has not been one of stagnation in irrigation development. A number of large storage reservoirs have been built and placed in operation since then. Of approximately 4,000,000 acre feet of storage reservoirs on streams draining through Carquinez Strait, 55 per cent or 2,725,000 acre feet have been built since 1920. Diversions of water, particularly on the lower San Joaquin River, have increased. The area under irrigation has steadily increased in both valleys. In 1926 it is estimated that 1,250,000 acres were irrigated in the floor of the valley with 3,900,000 acre feet of water by diversions from streams draining toward Carquinez Strait. If mountain valleys and lands irrigated from wells are included, the total area irrigated is probably over 1,750,000 acres.
16. Further extensions of irrigated area are being planned in both valleys. Within the next five years the bay cities will have diverting capacity of about 185 second feet and will control 431,000 acre feet of storage reservoirs. These enterprises will tend to increase the salt water menace. There is reason to expect the same menace of salt water as occurred in 1920, 1924 and 1926 to be present every year.
17. Salt water will penetrate the lower delta region every summer under present conditions. The distance water will flow up-stream will depend less and less upon the flow of streams into the valleys as the increase in use of water continues. About one-half of the delta is likely to be menaced any year. The area may extend beyond this line.
18. There is now no legal control of diversions, other than by the slow and costly process of litigation, except upon a few small tributary streams where the Division of Water Rights has completed adjudications. Litigation between lower users of water in the delta and upper riparian users and appropriators has been in progress for several years. Other litigation may be started. The legal pro-

cesses are so slow, cumbersome and costly that little result is to be expected for many years, if ever.

The outcome of present litigation will be disastrous if the courts uphold the contentions of either of the parties to litigation. If the delta lands have riparian rights to the waters, a large area of land will have to release water, and storage reservoirs constructed by power companies will be decreased in efficiency and value. On the other hand, if the courts decide that riparian rights do not attach to lands on tide water, the delta will be further menaced by salt water and there will be grave danger of permanent injury to a large area of land.

19. The engineering study of a salt water barrier made by Walker Young, of the Bureau of Reclamation, in cooperation with the Department of Public Works of the State of California, concludes that the construction of such a barrier is feasible. Investigations were made at three sites—Point San Pablo, Dillon Point and Army Point. The estimated cost of the barrier with and without bridges is given in the table on Page 60.
20. This barrier will maintain a fresh water reservoir free from tidal fluctuations and currents other than those caused by the flow of river water toward the sea. The level of water up-stream of barrier will be maintained at the highest practical level. Young estimates this level at elevation 2.5, U. S. G. S., or 6.0 on tide gage. It is probable that this height of water will be controlled by conditions of levees in the peat areas. As these levees become more stable the level can be increased. Flood levels will not be increased above those of floods in the past, in fact flood conditions will be improved in all but the most severe and protracted floods.
21. The salt water barrier, if built, will affect agriculture and the industries and activities along the bay and lower river as shown in the following statement:

#### A. AGRICULTURE

(a) A salt water barrier at Point San Pablo will make fresh water available for the irrigation of 51,000 acres of marsh and 48,000 acres of high land around San Pablo Bay. There is no known source of water for this area of land at present. If such lands are increased \$50 an acre above cost of irrigation works, the total increase in value will be \$4,950,000.

(b) A salt water barrier in Carquinez Strait or at Army Point will make fresh water available for 163,000 acres (marsh 70,000 acres; high lands 93,000 acres) around Suisun Bay. There is no other known source of water for this area. At \$50.00 an acre, the increased value above cost of irrigation works will be \$8,150,000.

(c) Either location of barrier will solve the irrigation problem for the lands now irrigated from tide waters in the delta and adjoining it. The area now watered is about 360,000 acres. The total area of irrigable lands is estimated as 458,000 acres. The area menaced by salt water is 169,000 acres. The value of this land is \$35,000,000. Improvements at 20 per cent of land value add another \$7,000,000.

There will be some increment in value to all the delta area from the security which the salt water barrier will bring about.

(d) The salt water barrier will benefit the areas up-stream from tidal lands by removal of litigation which is now a source of expense and annoyance and which is an obstacle to future projects.



**SALT WATER BARRIER**  
*Comparison of Estimated Costs for Alternate Design at Four Sites.*  
**DISTINGUISHING FEATURES OF ASSUMPTIONS OF DESIGN**

No.	Estimated Cost	Highway and Railway Bridge			Locks		Flood Control Gates			Pier Width
		Minimum Clearance at Locks	Decks	Piers or Towers	No.	Location	No.	Size	Location	
1	\$46,300,000		No Bridge		3	In Suisun Point	14	70x80	Partially in Suisun Pt.	20 Ft.
2	49,800,000	50 Ft.	Single	Concrete	3	In Suisun Point	do	do	Partially in Suisun Pt.	15-20
3	54,100,000	50 Ft.	Single	Concrete	3	In Suisun Point	30	50x60	Partially in Suisun Pt.	15 Ft.
4	55,900,000	50 Ft.	Single	Concrete	3	Offshore from Suisun Pt.	15	70x80	Partially in Suisun Pt.	20 Ft.
5	58,500,000	50 Ft.	Single	Concrete	3	Offshore from Suisun Pt.	30	50x60	Partially in Suisun Pt.	15 Ft.
6	77,300,000	50 Ft.	Single	Concrete	3	Offshore from Martinez	15	70x80	Offshore from Martinez	20 Ft.
7	40,200,000		No Bridge		4	BENICIA-PORT COSTA	30	50x60	Offshore from Benicia	15 Ft.
8	46,200,000	50 Ft.	Single	Concrete	4	In Benicia	30	50x60	Offshore from Benicia	15 Ft.
9	38,900,000		No Bridge		4	DILLON POINT-ECKLEY	15	70x80	Offshore from Eckley	50 Ft.
10	44,700,000	50 Ft.	Double	Concrete	4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
11	44,900,000	50 Ft.	Double	Steel	4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
12	47,600,000	135 Ft.	Double	Steel	4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
13	50,400,000	50 Ft.	Double	Concrete	4	In Dillon Point	21	70x80	Across Carquinez Sts.	50 Ft.
14	50,600,000	50 Ft.	Double	Steel	4	In Dillon Point	21	70x80	Across Carquinez Sts.	50 Ft.
15	53,300,000	135 Ft.	Double	Steel	4	In Dillon Point	21	70x80	Across Carquinez Sts.	50 Ft.
16	97,100,000	50 Ft.	Single	Concrete	4	In Dillon Point	15	70x80	In Dillon Point	20 Ft.
17	66,000,000		No Bridge		5	POINT SAN PEDRO-POINT SAN PABLO	15	70x82	Offshore Pt. San Pablo	20 Ft.
18	75,200,000	50 Ft.	Single	Concrete	5	In Point San Pablo	15	70x82	Offshore Pt. San Pablo	20 Ft.
19	82,100,000	50 Ft.	Single	Concrete	5	In Point San Pablo	15	70x82	In Point San Pablo	20 Ft.

One estimate only is given for the Army Point-Martinez Location—Estimate No. 6.

This site was not drilled—Estimates based largely on assumed foundation conditions except for S. P. Co. test pile data.

NOTE—At all sites except Dillon Point-Eckley, conditions are such that flood gates, locks, piers, etc., would be constructed in the dry behind coffer dams. A limiting depth of 90 feet below mean sea level to rock surface is assumed for this method of construction. The depths at Dillon Point-Eckley exceed this, and estimates 9 to 15, inclusive, are based upon the placing of concrete under water by the tremie method using caisson gates for the final work on the Stoney Roller Gates. Estimate 16 uses construction methods comparable to those at the other sites as the flood gates are placed in Dillon Point.

(c) The salt water barrier is a step in the direction of carrying out the state's plan of supplying water to the Southern San Joaquin Valley—a step in the coordinated plan of water development. It is the first portion of the project which should be built.

## B. INDUSTRIES

Industries occupy a large area of land along the waterfront of San Francisco and San Pablo bays, Suisun Bay and Carquinez Strait. Between Oleum and Antioch there are seventeen large industrial plants and a number of smaller ones. On the north side of the straits there are two large industries besides the Mare Island Navy Yard and Benicia Arsenal.

These industries are of the "heavy" type, fundamental industries, which produce essential products necessary both in war and peace. Steel and iron, petroleum products, chemicals, fertilizers, powder and fuse works, leather, brick and tile, flour and feed, roofing lumber and wood products, fish, canned goods and sugar are produced in large quantities. The products of these works have an annual value of \$250,000,000. Freight in and out of the district approximates 14,000,000 tons a year. Expenditures for electric power average \$800,000 a year. The average number of employees is 8500, having an annual payroll of about \$15,000,000. The portion of the population of towns and suburban territory dependent on these industries includes 30,000 inhabitants.

The industries are large users of water. At present 10 million gallons a day are used, not including the Navy Yard or Arsenal, and the annual increase in use by the establishments is one million gallons a day.

Immediately adjoining the industrial area above described are other large establishments which could receive benefit from the fresh water reservoir created above the barrier. If the zone along the waterfront to Richmond were included, the annual value of products for the whole territory would be \$515,000,000; the number of employees 17,000; the annual payroll \$29,000,000. A part of this area is within the East Bay Municipal District.

Since the salt water menace became widely advertised through the Antioch litigation, only one new industry of large size has been established in this territory. The factories already established have continued to grow but the uncertainty about fresh water has discouraged new industries seeking location. Fresh water in large quantities at low prices is essential to the prosperity of such establishments. Water from any existing utility or municipal district is too high in price for these "heavy" industrial plants.

Ordinarily such works locate where water can be had for the cost of pumping, and such manufacturing establishments will not go to any place where practically free water is not available. There is no other location in California suitable for heavy industries where this condition can be created.

The establishment of new basic industries will be attracted to abundant cheap water. If California does not provide the proper location, Seattle or Portland or some other northern locality will offer greater inducements and many industries will establish Pacific Coast branches in these northern cities. There are in these other states large areas of land where pure fresh water is abundant and may be had for the cost of pumping from permanent running streams. Further than this, rates for water in the cities are cheaper than in California. Below are given the costs of 500,000 gallons of water in the principal Pacific Coast cities:

*Cost of 500,000 Gallons of Water Per Month*

San Francisco.....	\$157.56
Oakland .....	161.71
Los Angeles .....	72.16
Stockton .....	54.50
Portland .....	44.11
Seattle .....	32.94

One of the greatest needs of the state today is a fresh water reservoir around which factories could be located with assurance of a permanent supply of water. Probably no single accomplishment in the construction program now under discussion would do more toward progress. More factories mean greater population and more local markets for agricultural produce, and the general level of prosperity of the state will be raised.

Salt water is detrimental to the piping and more costly to handle in factories of this sort. The increased annual cost to the users of saline water is estimated to be \$300,000 a year through deterioration of equipment and piping in the industries now established. This sum capitalized at 6% means the equivalent of an investment of \$5,000,000.

Some of the industries, notably the sugar refinery at Crockett and the chemical works at Pittsburg and Nichol, require water free from saline matter. The presence of salt water in the river for long periods of each year has been the cause of much expense and annoyance in these establishments, and brings seriously to consideration the ability of these factories to continue to exist under the trying conditions.

The salt water barrier will remove the cause of additional expense to the plants now located here, will encourage their more rapid growth, and will offer a great incentive to new establishments to locate here. Large industries require, in addition to large quantities of pure water, cheap power, efficient transportation facilities, preferably both by rail and water, and a good climate attractive to labor. The lower river and upper bay regions lack only water. The salt water barrier will supply this single deficiency. If the barrier is not built, California, without doubt, will lose many important factories.

### C. DOMESTIC WATER SUPPLY

The domestic water supply of towns along the straits in Suisun Bay is high in price and limited in quantity. Vallejo, the only exception to this statement, recently has constructed Gordon Valley Reservoir on Suisun Creek, and has a permit to store 10,000 acre feet and to divert 5,000 acre feet annually. Other towns have no large amount of water for future growth. In fact lack of available water has been a deterrent to the location of industries and the resultant increase in population.

A salt water barrier will solve the water difficulties. If the barrier is located at San Pablo Point, the entire area can be supplied with fresh water; if the barrier is located at Army Point or in Carquinez Strait, all towns on Suisun Bay and in the lower river will be on fresh water; towns below the barrier, such as Crockett, can be readily supplied with short pipe lines heading above the barrier.

Either barrier will be of benefit to the city of Sacramento in preventing the up-flow of tide and reducing the menace of sewage water being carried toward the water intake.

#### D. TRAFFIC ACROSS STRAIT

Routes of travel between northern and southern parts of the state naturally pass through Carquinez Strait. The Southern Pacific Company maintains ferries for trains between Benicia and Port Costa and for passengers between Vallejo Junction and Vallejo. The Sacramento-San Francisco Railroad maintains a train ferry from Mallard to Chipps Island. A bridge for vehicular traffic now crosses the strait just below Crockett. A ferry for automobiles and passengers is maintained between Martinez and Benicia.

At Richmond an automobile ferry is in operation a short distance below the site of the proposed salt water barrier at Point San Pablo.

A barrier at San Pablo can be made to serve as a bridge. There are now two applications for bridge permits near this place. The estimated cost of these bridges is from \$10,000,000 to \$20,000,000. The difference between the cost of a barrier with and without bridge is estimated by Young to be \$9,000,000.

At Army Point a bridge 50 feet above water increases the cost \$3,500,000; at Benicia a bridge 50 feet above water level increases the cost \$6,000,000; at Dillon Point a bridge with a clearance of 50 feet increases the cost \$3,800,000; a bridge with clearance of 135 feet increases the cost \$8,700,000. Approximate figures indicate that a railroad bridge near the location of the present Southern Pacific ferry between Benicia and Port Costa will cost in excess of \$10,000,000. Upon this estimate railroad transportation could bear a part of the cost of barrier. Vehicular traffic is growing so rapidly that there will be need for a second bridge across the straits within a few years.

#### E. POWER COMPANIES

The power companies are interested in the salt water problem because it has decreased their market for power by discouraging new plants from locating here and by reducing the growth of those already established.

The litigation over water rights may seriously affect their plants supplied from storage in the mountains.

#### F. FISHING INDUSTRY

Fishing in the bay and rivers is important. Salmon, shad and striped bass are important commercial fish. Smelt and smaller fish are important in furnishing food for commercial varieties. Sturgeon are nearly extinct but it is the endeavor of the Fish and Game Commission to prevent complete extinction and to encourage increases in this species.

The salt water barrier will be an obstacle to migrating fish during low water season. Young's plans provide for fishways and it is his belief that fish will use the locks and that on the whole the barrier will not obstruct the migration. Objection to any forms of barrier will be raised by the fishing industry. Wherever the structure is built there will naturally be some obstruction to free migration of the fish. It is probable, however, that the structure can be so designed and operated as to do only a small amount of damage.

#### G. NAVIGATION

Any barrier is an obstacle to free movement of vessels, and it is to be expected that owners of vessels will object to the project. This objection arises from the delays caused by using locks and the danger of handling vessels in such restricted quarters, particularly in foggy periods.

As to delays, it may be said that ordinarily the time lost in transit through locks will be regained by the freedom from adverse currents above the locks. While this will depend upon the place to which the vessel is bound, it is believed that for the great bulk of traffic the delay is likely to be small.

The danger to vessels maneuvering in approach to locks is of course real, but with the safeguards now provided for vessels the risk is small and there are compensating advantages. The ability to dock without tidal currents, as would be true above the barrier, is both a saving in time and reduction of risk. The cleansing action of fresh water upon the bottoms of ocean-going vessels is valuable.

The fear that the barrier will cause silting in channels or will create changes in the Golden Gate bar does not seem to be well founded. Sediment moves almost entirely at flood times when the barrier will be open and the current constantly down-stream. The movement of sediment will probably be facilitated rather than retarded.

Owners of shipping facilities are of course interested in the growth and prosperity of the communities served. The industrial area which will grow up around the fresh water reservoir above the barrier will produce freight for vessels at a greatly increased rate. The depth of water through Suisun Bay and to Stockton will be increased to 26 feet under the plan already adopted by Congress. This depth of channel will be ample for from 73 to 88 per cent of the vessels normally entering the Golden Gate during a year.

In considering the location of the barrier, the extent of shipping is important. The farther downstream the greater the traffic through locks, the greater the quantity of water required for lock operation, and the greater will be the objection by the shipping interests. In this regard the upper location of the barrier will meet with the least objection.

The Navy Yard is above San Pablo site and naval officers will probably be impressed with the difficulties presented by the barrier in time of war. Here we have another and important reason for the selection of the upper site.

#### H. STRUCTURE BUILT IN WATER

Teredos and other wood-destroying animals have caused damage to structures in San Francisco Bay waters in excess of \$25,000,000 since 1914, according to estimates made by the San Francisco Bay Marine Piling Committee. In the upper bay region, teredos have gone as far as Antioch. All structures built in water which may become brackish must be constructed of treated piles or of concrete. Brackish water carried up by tides will continue to cause greater expense in all structures built in water and greater maintenance costs. It is difficult to measure this damage in dollars, but it is a very considerable sum annually.

A salt water barrier will reduce the maintenance cost of structures and will make it practical to build structures as economically as was done prior to the invasion of salt water.

#### I. THE BARRIER AS A UNIT IN THE STATE'S COORDINATED PLAN OF WATER CONSERVATION

A plan for the development and use of all waters of the state upon a coordinated plan has been presented in part to the legislature by the State Department of Public Works. This plan provides for the storage and utilization

of all water required in the Sacramento Valley and the transmission of excess water to the San Joaquin Valley for use on lands for which insufficient water can be supplied from local sources. The salt water barrier is a necessary unit in this plan, for fresh water cannot be carried through the delta with tidal flow bringing salt water in and out of the channels twice a day.

#### J. GENERAL DEVELOPMENT OF BAY REGION

The entire bay region is interested in the salt water problem in that the prosperity of the region immediately concerned affects the prosperity of the cities. The industrial territory along Carquinez Strait is essential to the well-being of the whole state. The industries are fundamental to modern civilization. Oil, gasoline, lubricants, steel, fertilizers, sugar, leather, timber, soda, chlorine, fire-proof roofing, paper board, brick, tile, flour, mill feed, and the remaining varieties of manufactured products are necessities of modern existence. To have them abundant and cheap is greatly to the advantage of modern society.

Many of these factories would be classed as nuisances if located in a large city on account of the odors. Carquinez Strait and Suisun Bay have regular winds which prevent a serious nuisance in this locality. Other communities are not so fortunately situated.

The ratio of factory employees to population of towns is about 1 to 4. This means that the population of the towns immediately surrounding the industries will grow as the industries thrive. This population in towns makes a market for the products of the cities and the multitude of manufacturing establishments which have located in the cities. The heavy industries in turn furnish raw material for use in the factories in the cities.

As a result of this interlocking of interests, the large cities of the bay region have a direct interest in seeing a salt water barrier established. Behind it, around the fresh water lake thus created, there will grow up a thriving industrial community engaged in the production of essential materials which could not be produced within the cities themselves.

#### CALIFORNIA NOW IN THE INDUSTRIAL AGE

22. California is now in an age of industrial growth. Approximately one-third of the people of the state are engaged in manufacturing and mechanical industries as compared with less than 20 per cent engaged in agriculture, forestry and animal husbandry (the next largest class of workers). The present growth of the state is due largely to the activity in industrial matters. Students of population growth recognize cycles of increase in population. There seems to be a definite limit to the number of people that can be reached in any set of circumstances. The growth of California very well illustrates three cycles of growth. In the early days of the state, mining was the attraction and the whole life of the community centered around the mines. As mining reached its climax in the 70's, agriculture came to the forefront and there was a continuous growth on this account. The agricultural era lasted until about 1912. In the meantime, through the discovery of oil and the unprecedented development of the electrical industry, cheap power was made available and manufacturing began to grow. At present there is very little actual increase in agricultural population but a large increase in industrial activities. So far as it is possible to see in the future, our growth will be industrial. Agriculturists have learned to grow more crops with less man power

and there is comparatively little likelihood of any large increase in agricultural population.

The problems of the state are nowadays to a large extent those of the people of the towns and cities and industrial centers.

#### SOLUTION OF THE SALT WATER PROBLEM

23. The salt water problem may be partially solved in several ways but completely only in one way. Conditions may be ameliorated by storage and release of water from reservoirs to push back the salt water or water supply from outside sources may be brought in to supply fresh water through conduits or pipes.

The only satisfactory solution of the problem is the salt water barrier.

These methods are briefly discussed below:

#### STORAGE AND RELEASE TO PUSH BACK SALT WATER

24. This method of solving the salt water problem has been suggested in several recent publications of the Department of Public Works. Examination in detail of the proposals shows that "salt water control" means the supplying of water of less than 100 parts chlorine per 100,000 to the delta lands.

Emmaton on the Sacramento River and Jersey Island on the San Joaquin are the limits of control and no suggestion has been made that it is practical to release water to supply Antioch or any of the lower industrial area. This, in fact, leaves out of consideration the area now most seriously damaged.

Studies by the Division of Water Rights based on records including the year 1925 show that to control salinity below 100 parts chlorine per 100,000, the combined flow of Sacramento River at Sacramento and the San Joaquin at Vernalis (both points about head of tide water in late summer) must exceed the following figures:

For Control at	Cubic Feet Per Second
Emmaton and Jersey Island.....	3500
Antioch .....	5000
Collinsville .....	5500
O. & A. Ferry .....	6000

These quantities will depend to some extent upon the months preceding the period when control is desired, and will, of course, vary with the diversions below the points of measurements. Furthermore, storage of water above tide level will affect the matter by limiting the distance salt water is forced downstream by spring floods.

To effectively supply these quantities of water will require very large storage capacity in dry years.

In 1924 storage in excess of a million acre feet would have been required to control salinity at the O. & A. Ferry and 200,000 acre feet at Emmaton and Jersey.

Storage in large amount would be needed about half the years at Emmaton and Jersey, and every year for control at the O. & A. Ferry.

The above is under the assumption that storage and diversions in these two valleys does not increase. As shown earlier, this condition has already been violated, for there has never been such increased activity in building storage reservoirs as in the period since 1924. Many reservoirs are planned for construction in the near future. Furthermore, diversions increase every year.

Estimates of the quantities required for storage control must therefore be continuously revised upwards.

Release of stored water, to control salinity, will occur in dry parts of the year and to greatest extent in dry years. To effectively control the right of storage and release, all riparian owners below the reservoir must agree to the arrangement. As the law now stands, the use of such a reservoir may be enjoined and it will be impossible to prevent—except through litigation—the riparian owners from diverting the released water. This difficulty can be removed by condemnation of rights along the stream. The problem looks too large for human accomplishment in any reasonable time and at any reasonable cost.

To one acquainted with water problems in California, it does not seem reasonable to expect that in the dry part of a dry year a flow of 5,000 or more feet per second would be allowed to pass pumps and ditches, under which crops were suffering, in order that salt water could be pushed back into the ocean. As to the cost of storage reservoirs to accomplish the release for salt control, there is little definite information which permits a comparison of costs. The following statements are of interest:

Kennett Reservoir is proposed by the State Department of Public Works as a unit in the "Coordinated Plan." (See Bulletin 13 of the Department of Public Works, 1928.) The recommended reservoir capacity is 2,940,000 acre feet; the estimated cost of dam and rights-of-way is \$55,000,000; of power plant \$25,000,000; a total of \$80,000,000. With allowances for prior rights, the mean annual irrigation yield of reservoir will be 2,838,000 acre feet. In minimum years the deficiency would be large; 19 per cent in 1920; 42 per cent in 1924. If this reservoir were depended upon for salinity control, the entire available supply would be needed to control salt water at the mouth of the river, leaving no water for the area depending on this reservoir for irrigation. In other words, the very year when the reservoir is most needed it would be of little practical use. Furthermore, Kennett is not practicable unless operated to generate electric power. If the water is held and released for salt water control, the power value is greatly decreased.

Iron Canyon Reservoir is proposed as a secondary unit in the "Coordinated Plan." (See Bul. 13, Dept. of Public Works.) The recommended capacity is 1,121,900 acre feet; the cost of dam and power plant is estimated as \$26,000,000; the canal system to utilize this water is estimated at \$30,000. The reservoir may be utilized in controlling salinity. To quote from the above mentioned report, page 115:

"Sacrificing the power feature at Iron Canyon dam would, with other construction unchanged with the exception of the arrangement of outlets through the dam, supply a reserve storage of 364,600 acre feet of water in Iron Canyon reservoir to overcome, or alleviate, the salt water menace in the delta region should such be desirable. Such use is not advocated, but it is demonstrated that there are possibilities along this line."

Should the irrigation feature likewise be disregarded, Iron Canyon would provide a net annual irrigation draft of 800,000 acre feet or just about enough water to control salt water as low as the mouth of the river—provided the water could be carried past head gates and pumps on its way to tidal waters. Under this condition the power feature would be sacrificed to a larger extent. It is difficult to picture a dry year when water and power are both scarce, in which it would be possible to release a large quantity of water, disregarding



its best use for power, and have the riparian and appropriative users of water along the hundred and fifty miles of the Sacramento River permit this flow to pass by uninterrupted to tide water. The plan does not look practical.

Other reservoirs may be used for the same purpose, that of increasing the flow to control salt water. For example, a reservoir on Feather River has been suggested, and another on the American at Folsom. Both of these reservoirs will have value for power development and that value will be greatly reduced if a large quantity of water is held for saline control. The most practical suggestion is in connection with a reservoir on Dry Creek, north of the Mokelumne, the water to be diverted from the Mokelumne River. The rights obtained by the East Bay Municipal Utility District for storage in Lanch Plana Reservoir practically eliminate this reservoir from consideration. In connection with the proposal for storage and release of water, it should be remembered that the State Department of Engineering has made the suggestion as a temporary expedient, with the expectation that permanent relief would be brought about by the construction of the salt water barrier. This state of affairs would leave the delta lands dependent on a temporary right to be replaced by a permanent right which would be arranged for at some later time. With the growing condition of California and the certainty that the temporary supply will be invaded by increased diversions, this is a very precarious water right, not one which will satisfy the delta land owners. Furthermore, the plan does not consider users below the delta, either towns or industries.

New industries will not be attracted by any temporary improvement in water conditions. Some permanent solution must be reached. It is important to California to have the decision made at once so that the great industrial expansion now going on can be located to a maximum extent in this state.

#### WATER FROM OUTSIDE SOURCES

25. Under present conditions the towns and industrial area cannot look to any place within tide water level for a source of water. Above tide levels the following are the principal supplies which may be considered:

Eel River,  
 Conn Valley,  
 Putah Creek,  
 Mokelumne or Cosumnes,  
 Pumped water from irrigation districts, San Joaquin Valley,  
 East Bay Municipal Utility District.

All of these sources may be considered, but as all are distant, with long pipe lines and other costly works, they will be able to supply water only at relatively high cost, prohibitory to the types of factories now located in Contra Costa and Solano Counties. Piping water across these straits will be a very costly and difficult affair. The barrier removes the necessity of any pipe line crossing.

#### LOCATION OF BARRIER

26. For the purpose of providing fresh water to cities, industries and agriculture on adjoining land, the lowest location of the barrier accomplishes the most. However, water supply, cost and convenience to other interests must be considered before the location can be selected. The following may be said on these points:

*Water Supply.* The attached tables give the requirements for fresh water above the barrier upon the assumption that development is complete. These figures, in part, are taken from the Young report—in part are the results of studies made for this investigation.

Requirements for the full year are:

Army Point.....	1,160,000 acre feet
Point San Pablo.....	2,024,000 " "
	864,000 " "
Difference.....	864,000 " "

For the irrigation period May to September, inclusive, the requirements are:

Army Point.....	638,000 acre feet
Point San Pablo.....	1,236,000 " "

Additional storage on the headwaters will be required to supply the barrier at San Pablo.

*Cost.* Young's estimate of cost of barrier with bridge of clearance of 50 feet is as follows:

Point San Pablo.....	\$75,200,000
Army Point.....	49,800,000
	\$25,400,000
Difference.....	\$25,400,000

*Convenience of Other Interests.* San Pablo site is below the Mare Island Navy Yard, a great obstacle. Navy men will be against the project. Shipping interests will be more inconvenienced with the lower site occupied. At present about two-thirds of the vessels that pass Point San Pablo continue upstream above Army Point. The San Pablo site will be a convenience to vehicular traffic. The Army Point site will be convenient for both vehicular and railroad traffic, though at present vehicular traffic is cared for by the Carquinez Bridge.

## FINAL CONCLUSION

27. If the salt water barrier is built at Army Point to carry vehicles and railroads, and the proper part of the cost paid by these interests, the salt water problem can be solved permanently and cheaper than by any other solution that has been suggested.

The cost of a bridge for rail and automobile traffic at Army Point cannot be determined without more work than is possible in an investigation such as this. It can be safely said, however, that the cost will exceed \$10,000,000. Automobile traffic over the Carquinez Bridge (which has been in use less than a year) is at the rate of approximately 1,100,000 automobiles a year and is growing rapidly. There will be economic justification for an auto bridge at Benicia before it can be built. Automobile traffic will justify an expenditure of over \$10,000,000. The two combined will be over \$20,000,000. If this figure is taken as the value to transportation, there will be left, approximately, an equal sum to be paid by other benefits.

Iron Canyon Reservoir, the only definite storage reservoir suggested for temporary control, will cost \$26,000,000. The salt water barrier would permanently solve the difficulties for a smaller sum.

[TABLE 1]

AVERAGE MILES TRAVELED BY WATER BARGE  
CALIFORNIA-HAWAIIAN SUGAR COMPANY

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1908	19.8	11.6	12.5	14.0	12.9	16.7	26.3	26.8	33.2	27.1	24.8	25.7
1909	6.9	0	4.5	7.7	5.0	4.7	10.5	19.4	23.2	24.2	21.0	11.7
1910	9.6	10.0	3.8	3.0	6.4	10.8	20.4	26.7	27.6	25.4	24.6	19.7
1911	11.6	2.3	16.2	1.0	2.1	0.7	5.7	16.4	23.2	24.5	24.7	25.5
1912	22.0	16.1	14.5	12.7	8.8	7.1	17.6	24.7	24.4	24.2	19.0	18.5
1913	16.4	13.6	13.2	9.9	6.9	10.3	21.0	25.7	26.6	27.8	26.1	20.4
1914	2.1	1.2	1.6	2.5	2.2	3.4	10.3	20.0	24.4	24.5	23.9	23.7
1915	16.4	2.3	3.1	4.3	2.6	3.7	12.6	20.8	24.4	24.2	23.0	17.5
1916	4.9	0.5	1.0	2.3	6.4	5.8	13.2	22.6	25.0	21.7	21.2	15.4
1917	16.0	13.1	6.5	6.3	3.5	4.8	15.5	24.9	26.2	26.0	25.1	24.4
1918	24.3	15.1	9.6	6.2	9.2	15.0	27.0	38.5	37.2	23.0	23.1	21.0
1919	20.4	9.4	7.7	5.7	4.3	14.1	35.3	37.7	37.7	26.8	25.7	25.5
1920	23.8	24.0	17.2	12.0	12.9	17.4	26.0					

[TABLE 3]

COMMERCIAL FISHING—SAN PABLO AND SUISUN BAYS AND  
SACRAMENTO AND SAN JOAQUIN RIVERS  
(Varieties)

Year	Salmon Native	Shad Planted	Striped Bass Planted	Total Pounds
1919.....	4,529,048	1,573,713	759,733	6,862,494
1920.....	3,860,312	1,409,322	668,290	5,937,924
1921.....	2,511,127	797,128	599,698	3,907,953
1922.....	1,765,066	1,109,445	682,717	3,557,228
1923.....	2,243,945	1,285,334	906,869	4,436,148
1924.....	2,640,110	1,538,735	658,244	4,837,089
1925.....	2,778,846	2,439,441	836,301	6,054,588
1926.....	1,261,776	902,202	749,573	2,913,551
1927.....	920,471	4,103,012	644,789	5,668,272
Total, 9 Years..	22,510,701	15,158,332	6,506,214	44,175,247
Mean.....	2,501,189	1,684,259	722,913	4,908,361

The run of fish will vary from year to year in accordance with weather, feed and unknown factors.

A low or high run for one year may not mean absolute evidence of either increase or decrease in the species.

For example, the extremely low run of salmon in 1927 does not necessarily mean still lower run in 1928, and similarly with shad in reverse tendency.

However, there seems to be a general decrease in salmon, probably an increase in shad, and a static condition in striped bass.

COMBINED FLOW OF SACRAMENTO AND SAN JOAQUIN TRIBUTARIES

[TABLE 2]

(Flow in Second Feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1916	66,670	92,200	99,830	88,621	73,060	55,619	23,990	11,112	9,300	12,261	11,522	19,986
1917	16,712	56,000	34,521	71,153	69,307	63,407	20,082	9,787	8,309	7,875	8,639	11,071
1918	9,180	21,849	50,360	51,091	39,145	32,183	9,563	6,885	8,621	13,041	11,956	12,118
1919	19,653	58,664	44,948	63,700	65,666	18,261	8,975	7,275	7,049	7,733	7,172	11,460
1920	9,075	9,550	26,759	41,822	49,582	27,404	9,931	6,722	6,059	8,557	39,737	48,539
1921	73,000	58,400	69,470	55,291	65,385	50,246	15,606	8,297	7,435	7,589	8,389	19,407
1922	17,560	50,030	41,389	61,190	109,494	82,327	20,879	9,022	7,329	8,334	11,828	35,715
1923	29,742	22,089	23,785	55,290	54,199	31,844	17,138	9,798	8,809	10,004	7,810	7,919
1924	8,617	19,248	10,222	15,623	14,438	7,007	5,981	5,601	5,171	7,056	13,214	15,029
1925	15,018	89,005	34,394	63,127	59,990	32,824	13,486	9,030	8,535	8,626	9,361	11,720
1926	13,056	57,377	26,323	60,494	30,503	13,603	9,732	8,522	7,364	7,730	32,243	31,338
1927	35,293	109,044	54,556	75,100	59,973	45,353	16,984	11,349	10,652			

No allowance for power storage or regulation.

Combination of and

- Sacramento at Red Bluff,
- Feather at Oroville,
- Yuba at Smartsville,
- Bear at Van Trent,
- American at Fair Oaks,

- Mokelumne at Clements,
- Stanislaus at Knights Ferry,
- Tuolumne at La Grange,
- Merced at Exchequer,
- San Joaquin at Friant.

POPULATION OF BAY COUNTIES— U. S. CENSUS

	1920	1910	1900	1890	1880	1870	1860	1850
State	3,426,861	2,377,459	1,485,053	1,213,398	864,694	560,247	379,994	92,597
Alameda	344,171	246,131	130,197	93,864	62,976	24,237	8,927	
Contra Costa	53,889	31,674	18,046	13,515	12,525	8,461	5,328	
Marin	27,342	25,114	15,702	13,072	11,324	6,903	3,334	323
Napa	20,678	19,800	16,451	16,411	13,235	7,163	5,521	405
Sacramento	91,029	67,806	45,915	40,339	34,390	26,830	24,142	9,087
San Francisco	506,676	416,912	342,782	298,997	233,959	149,473	56,802	
San Joaquin	79,905	50,731	35,452	28,629	24,349	21,050	9,435	
San Mateo	36,781	26,585	12,094	10,087	8,669	6,635	3,214	
Solano	40,602	27,559	24,143	20,946	18,475	16,871	7,169	

[TABLE 4]

## THE SALT WATER PROBLEM

[TABLE 5]

SCHOOL ENROLLMENT  
BAY SHORE DISTRICTS—CONTRA COSTA COUNTY

Elementary Schools:	1915	1921	1927
Oakley .....	85	118	158
Antioch .....	333	454	731
Pittsburg .....	668	1122	1485
Bay Point.....	85	-----	162
Martinez .....	403	792	1068
Port Costa .....	122	108	75
Carquinez (Crockett) .....	447	572	617
Selby .....	72	99	128
Rodeo .....	108	132	198
Pinole Hercules .....	227	258	217
San Pablo .....	182	227	282
Richmond .....	2288	3380	3997
<b>Total Elementary.....</b>	<b>5020</b>	<b>7262</b>	<b>9118</b>
High Schools:			
Antioch .....	} 105	142	149
Pittsburg .....			183
Alhambra, Martinez.....	77	121	294
John Swett, Crockett.....	86	119	206
Richmond .....	242	655	754
<b>Total High School.....</b>	<b>510</b>	<b>1037</b>	<b>1586</b>
<b>Total both.....</b>	<b>5530</b>	<b>8299</b>	<b>10,704</b>

[TABLE 6]

## WATER-BORNE TRAFFIC

## U. S. ENGINEERING DEPARTMENT DATA

(Total Movement, Tonnage and Values in Thousands of Tons and  
Thousands of Dollars)

Year	Suisan Bay		Carquinez Strait		San Pablo Bay		Grand Total	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
1917	Do Data		Incl. in San Pablo		11,946	\$212,592		
1918	No Data		Incl. in San Pablo		4,330	152,206		
1919	305	\$ 7,034	Incl. in San Pablo		4,634	184,476	4,939	191,510
1920	433	13,877	2,079	\$97,991	1,696	54,620	4,208	166,488
1921	562	19,670	1,720		2,019	96,177	4,301	
1922	1,329	32,006	No Data		2,652	118,234		
1923	2,659	43,764	No Data		2,466	109,022		
1924	2,341	51,066	No Data		4,200	156,999		
1925	4,204	88,670	7,673	183,000	4,754	234,409	16,631	506,079
1926	4,205	90,687	7,844	135,522	4,667	260,920	16,716	487,129

Totals are only shown where data are complete for all divisions.

In addition to above, in 1926, there was a total of 1,752,000 tons valued at \$124,077,616 to or from the Sacramento and San Joaquin Rivers, most of which passed through Carquinez Strait. However, all of this having origin and destination in the above Bay division, it appears there also.

Railroad ferry freight traffic across Carquinez Strait was, in 1925, 2,706,000 tons; in 1926, 2,650,000 tons.

[TABLE 7]

OCEAN-GOING WATER-BORNE TRAFFIC  
U. S. ENGINEERING DEPARTMENT DATA*(Tonnage in Thousands of Tons and Values in Thousands of Dollars.)*

Year	Suisun Bay		Carquinez Strait		San Pablo Bay		Grand Total	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
1925.....	2659	\$43,823	5188	\$147,485	4011	\$66,999	11,858	\$258,307
1926.....	2495	41,173	4264	107,228	3866	58,942	10,625	207,343

Data do not permit a separation of bay business from ocean-going business previous to 1925, and Carquinez Straits' data are entirely lacking for three years.

The magnitude of the Petroleum Products traffic and the proportion of the total it occupies are obvious when the following tables are compared with the above.

Year	Suisun Bay		Carquinez Strait		San Pablo Bay		Grand Total	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
1925.....	2464	\$34,391	4415	\$ 49,562	3837	\$45,714	10,716	\$129,667
1926.....	2168	33,663	3409	40,454	3708	43,837	9,285	117,954

## OUTGOING BAY AND OCEAN WATER-BORNE PETROLEUM PRODUCTS

1925.....	547	\$20,811	2949	\$ 38,217	1019	\$19,783	4,515	\$ 78,811
1926.....	615	29,989	2746	35,197	940	23,837	4,301	89,023

Does not include Standard Oil Co. Richmond plants.

[TABLE 8]

SACRAMENTO AND SAN JOAQUIN RIVER TRAFFIC  
U. S. ENGINEERING DEPARTMENT DATA*(Tonnage and Values)*

Year	Sacramento River		San Joaquin River	
	Tons	Value	Tons	Value
1910.....	496,147	\$ 29,522,151	631,681	\$ 32,878,108
1911.....	505,285	32,139,048	600,128	35,768,215
1912.....	477,292	27,755,325	632,591	38,854,539
1913.....	733,594	35,856,791	820,399	38,341,174
1914.....	721,090	38,211,760	772,156	35,479,741
1915.....	766,935	38,027,703	831,234	36,358,240
1916.....	875,780	46,908,093	824,222	42,179,160
1917.....	947,690	96,820,992	1,890,856	50,367,760
1918.....	1,053,510	113,991,123	2,114,382	65,204,825
1919.....	1,666,025	78,601,238	647,156	54,100,043
1920.....	1,377,700	53,946,146	692,306	42,203,211
1921.....	976,596	52,092,263	646,657	37,263,122
1922.....	1,291,135	60,606,728	678,751	34,291,675
1923.....	1,264,821	62,470,235	697,773	38,027,909
1924.....	1,796,105	58,662,997	727,499	38,185,313
1925.....	1,427,230	80,500,145	849,687	47,192,499
1926.....	1,222,993	85,315,284	934,809	56,455,662

Contains also movements between river points only.

[TABLE 9]

WATER REQUIREMENTS FOR OPERATION OF SALT WATER BARRIER  
WHEN FULLY DEVELOPED*(Quantities in Second Feet)*

	POINT SAN PABLO											
	1	2	3	4	5	6	7	8	9	10	11	12
Fish Ladder.....	35	35	35	35	35	35	35	35	35	35	35	35
Industries, etc.....	322	322	322	322	322	322	322	322	322	322	322	322
Gate Leakage.....	166	166	166	166	166	166	166	166	166	166	166	166
Oper. Locks.....	705	705	705	705	705	705	705	705	705	705	705	705
Evaporation.....	250	300	450	650	950	1200	1250	1170	1020	800	500	200
Irrigation.....	-----	-----	-----	-----	610	1680	2290	1910	1150	-----	-----	-----
Flushing.....	200	200	200	200	200	200	200	200	200	200	200	200
Totals, S. F.....	1678	1728	1878	2078	2988	4308	4968	4508	3598	2228	1928	1628

[TABLE 10]

WATER REQUIREMENTS FOR OPERATION OF SALT WATER BARRIER  
WHEN FULLY DEVELOPED*(Quantities in Second Feet)*

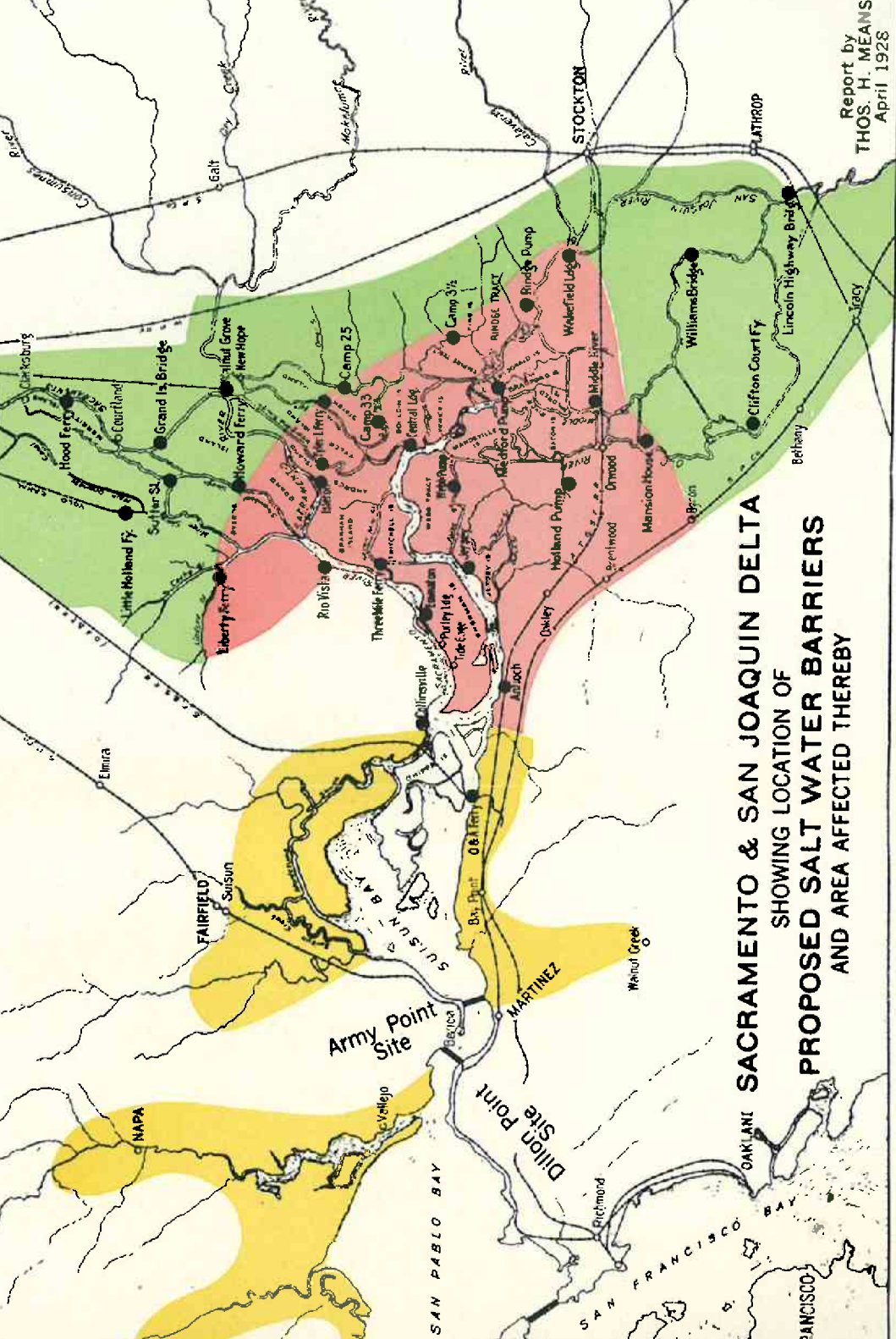
	ARMY POINT											
	1	2	3	4	5	6	7	8	9	10	11	12
Fish Ladder.....	35	35	35	35	35	35	35	35	35	35	35	35
Industries, etc. ....	155	155	155	155	155	155	155	155	155	155	155	155
Gate Leakage.....	166	166	166	166	166	166	166	166	166	166	166	166
Oper. Locks.....	246	246	246	246	246	246	246	246	246	246	246	246
Evaporation.....	110	146	200	288	422	530	555	522	455	355	222	89
Irrigation.....	-----	-----	-----	-----	380	1050	1430	1190	710	-----	-----	-----
Flushing.....	200	200	200	200	200	200	200	200	200	200	200	200
Totals, S. F.....	912	948	1002	1090	1604	2382	2787	2514	1967	1157	1024	89

[TABLE 11]

WATER REQUIREMENTS ABOVE SALT WATER BARRIER  
WHEN FULLY DEVELOPED*(Quantities in Acre Feet)*

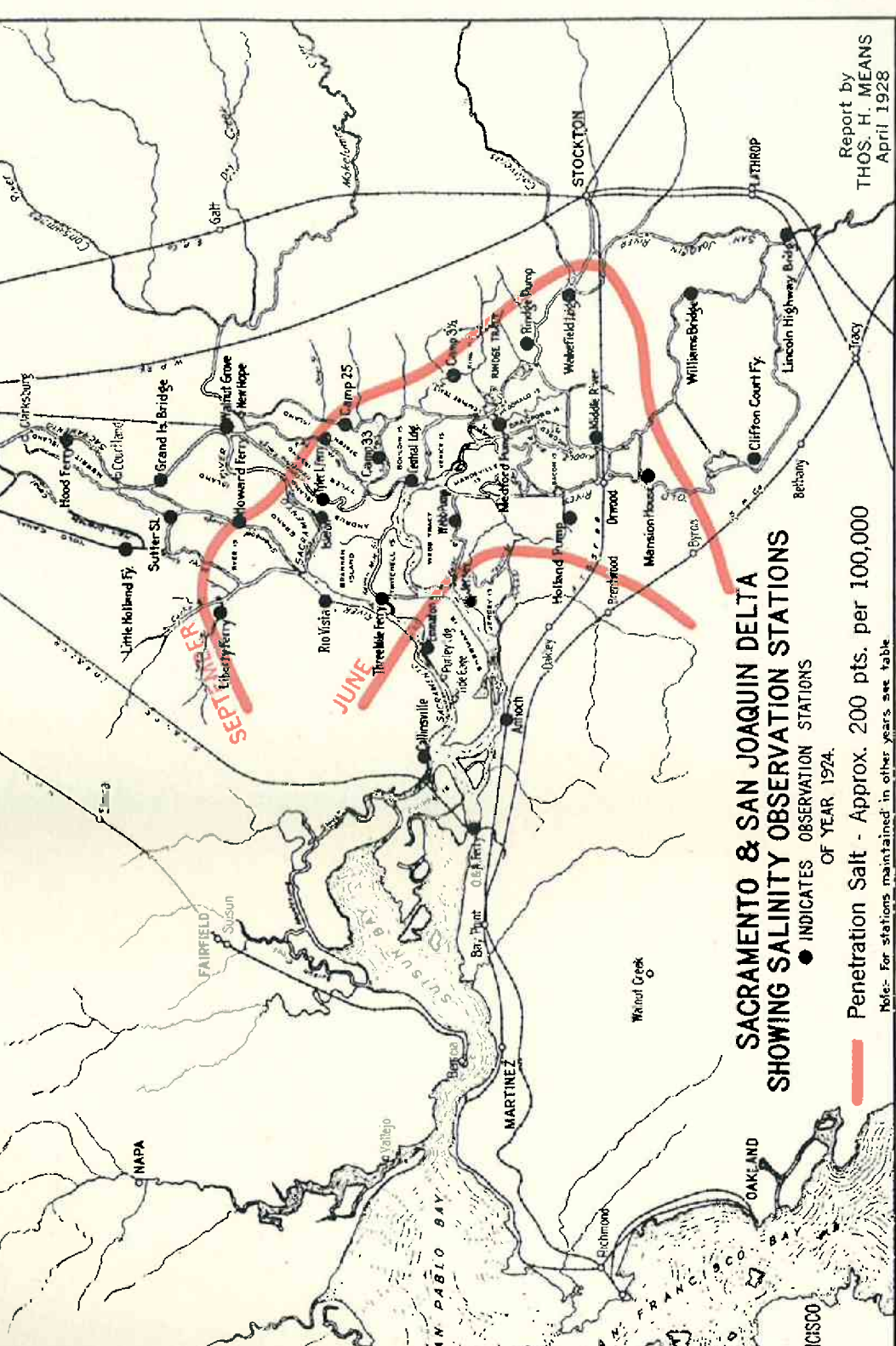
	Army Point	Point San Pablo
January .....	56,000	102,500
February .....	52,500	95,500
March .....	62,000	115,000
April .....	65,000	123,000
May .....	98,500	184,000
June .....	147,500	256,000
July .....	171,000	305,000
August .....	154,000	277,000
September .....	117,000	214,000
October .....	71,000	137,000
November .....	61,000	115,000
December .....	54,500	100,000
Totals.....	1,110,000	2,024,000





**SACRAMENTO & SAN JOAQUIN DELTA**  
 SHOWING LOCATION OF  
**PROPOSED SALT WATER BARRIERS**  
 AND AREA AFFECTED THEREBY

Report by  
 THOS. H. MEANS  
 April 1928



## SACRAMENTO & SAN JOAQUIN DELTA SHOWING SALINITY OBSERVATION STATIONS

● INDICATES OBSERVATION STATIONS  
OF YEAR 1924.

— Penetration Salt - Approx. 200 pts. per 100,000

Note: For stations maintained in other years see table

Report by  
THOS. H. MEANS  
April 1928