STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

PUBLICATIONS OF THE
DIVISION OF WATER RESOURCES
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Reports on State Water Plan Prepared Pursuant to Chapter 832, Statutes of 1929

BULLETIN No. 27

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

1931

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

Previous Investigations.

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

not greatly increase the expense of cooling water to the industries and the actual cost per 1000 gallons is small. Over 80 per cent of the total amount of water used by industries in the upper bay region is for cooling and condensing purposes. The use of saline water from the bay channels for cooling and condensing is satisfactory and little, if any, advantage would be gained if fresh water were available for this purpose.

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

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

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

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

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

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

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