

# THE IMPERIAL VALLEY

AND

# THE SALTON SINK

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WITH INTRODUCTORY MONOGRAPH

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# THE CHEMICAL COMPOSITION OF THE WATER OF SALTON SEA AND ITS ANNUAL VARIATION IN CONCENTRATION.

BY DR. W. H. ROSS

## PRELIMINARY ANALYSES.

A preliminary examination of samples taken at intervals from different points in the Sea showed the water was saltiest in the shallow regions overlying saline flats and least salty at the surface of the deep parts of the lake. June 10, 1906, when the maximum depth was 60 feet, a sample taken  $1\frac{1}{2}$  miles from the shore near Mecca contained 4016 parts of total solids per million; another from about 100 feet from shore, 6974 parts, while a third collected within a few feet of the shore near Travertine Point where the water was shallow and covered a saline deposit contained 11,528 parts.

A few months later, October 11, 1906, a marked increase in uniformity had taken place. A sample taken from shallow water near the shore contained 3632 parts of solids and another from a half mile out yielded 3596 parts.

During the first ten days in February, 1907, when the lake had reached its maximum volume, a number of samples from different points on the lake and at different depths showed very little differences in total solids and chlorine content, the minimum and maximum total solids being 3218 and 3418 on the surface, while the absolute maximum was 3520 found at a depth of 60 feet about  $1\frac{1}{2}$  miles off shore from Salton where the water was 84 feet deep. The corresponding figures for chlorine were 2380, 2500 and 2590 respectively. One sample, taken a few miles from the mouths of the New and Alamo rivers through which only a short time before flowed fresh water from the Colorado River, was exceptionally less salty, having only 2588 parts solids and 1850 parts chlorine, but this was of course to be expected. The fact that the greatest concentration was found near the bottom at a depth of 60 feet would indicate that leaching of salts from the lake bed was still taking place.

Thereafter samples were taken June 3, 1907, and each year following, from a point 4 miles southwesterly from Mecca Landing in approximately the same location.

## METHODS OF ANALYSIS.

The methods used were those best suited for determining the concentration of the various constituents and known by extensive use to give accurate results. All determinations were carried out in quadruple and when

it was thought necessary blank determinations were made of the reagents used.

#### YEARLY INCREASE OF TOTAL CONSTITUENTS.

In order to make comparisons from year to year correction must be made because samples were not collected at exactly the same date each year. To bring the results as of June 3rd of each year it was assumed that the daily evaporation during the last week in May and the first two weeks in June is  $1\frac{1}{2}$  times as great as the average daily evaporation for the whole year.

TABLE 1. PERCENTAGE YEARLY INCREASE OF THE TOTAL CONSTITUENTS

Date of Sampling	Total Constituents in parts per million			Chlorine calculated for June 3rd of each year	Percentage yearly increase of the constituents
	Determined in collected samples	Correction	Calculated for June 3rd of each year		
June 3, 1907.....	3549.3	00.0	3549.3	1697.5	
May 23, 1908.....	4262.7	+27.0	4289.7	2062.5	20.9
June 8, 1909.....	5006.1	-14.7	4991.4	2042.0	16.2
May 22, 1910.....	5821.7	+42.0	5863.7	2789.3	17.4
June 3, 1911.....	6972.8	00.0	6972.8	3394.2	18.9
June 10, 1912.....	8226.5	-36.5	8190.0	3938.4	17.6
June 18, 1913.....	9699.6	-57.5	9642.1	4712.9	17.7
June 12, 1914.....	11434.0	-37.0	11397.0	5576.0	18.1

The great increase during the first year period is doubtless because the water had not yet reached a state of equilibrium with respect to the solids in the bottom of the lake. The "total solids," which includes in addition to the "total constituents" as given in the table, the water of occlusion and hydration, were 10,025.6 parts per million on June 18, 1913, so that the water at that time was almost exactly 1 per cent brine.

From the completed yearly analyses it was found that the concentration of the principal constituents with respect to the water increased each year in almost the same proportion as the total constituents. Some variation took place, however, particularly calcium, potassium and carbonate ions—the total potassium, carbon dioxide, as also the bicarbonate radicle, show an actually less concentration in 1913 than in 1912. The ratio of potassium to sodium has decreased from 1 to 48.3 in 1907 to 1 to 94 in 1913. This decrease is probably due to a slow reaction of the potassium contained in the water with minerals on the bottom of the lake.

#### VARIATION IN CONCENTRATION OF THE LAKE AT DIFFERENT POINTS IN 1911.

Estimating from the rate at which the volume of water is decreasing and the amount of salt in the lake at the end of each year period, Mr. E. E. Free, of the Arizona Agricultural Experiment Station at Tucson, Ariz., has

shown that the increase in salt content of the lake is greater than can be ascribed to evaporation alone, and that the total amount of salt in solution is increasing instead of remaining constant or decreasing as might have been expected from deposition of salt on the shores as the water recedes. In order to determine if continued leachings of salts from the lake bottom is an important factor in this connection, analyses were made of a number of samples taken in 1911 from the surface and from the bottom of the lake at different points and on the same day as the regular sample was taken. It was shown by these examinations that the lake is now remarkably uniform in composition. In very shallow places near the shore the salinity of the water was slightly excessive, doubtless due to washing back recent depositions by occasional local rains, but samples taken from the bottom of the lake at a point, as near as could be determined, where the old salt beds were, had a salt content agreeing almost exactly with that of the other samples from the main body of the lake. From this it appears improbable that any appreciable leaching is now taking place and that the salt beds have disappeared. Consequently any increase in the total salt content which may be occurring must be due principally to incoming waters.

#### COMPOSITION OF THE SALTS LEACHED OUT FROM THE BOTTOM OF THE SALTON SEA.

Since the present water in the Salton Sea comes from the Colorado River, the excess of its constituents, expressed in parts per million over that brought in by the river water must represent the composition of the salts leached out from the lake bottom. By means of relative values showing the variation in the discharge and the analyses made by Prof. R. H. Forbes and W. W. Skinner throughout the year, January 10, 1900 to January 24, 1901,\* of composites of samples collected almost daily from the Colorado River at Yuma, the mean composition of the river water in a year may be readily calculated. In this way the composition of the salts leached out from the bottom of the Salton Sea was calculated from the excess of the constituents of the lake water over that of the water from which the lake was formed. The samples taken June 3, 1907, showed that about 90 per cent of the salt (sodium chloride) in the lake water had been taken up from the lake bottom, about 42 per cent of the calcium, 71 per cent of the magnesium, and 65 per cent of the sulphate radicle.

If it is assumed that all the salts deposited by the evaporation of the original lake were again taken up by the present lake then the constituents of the original lake were as shown in column C of Table II.

\*Bul. No. 44 Arizona Agricultural Experiment Station, 1902.

## COMPARISON BETWEEN THE COMPOSITION OF THE WATER OF THE SALTON SEA AND OTHER NATURAL WATERS.

Table II gives the composition of Salton Sea water and that of several other salt water bodies. In order that the table may make readily apparent the variation in the composition of the different waters, the constituents are expressed in percentages of the total constituents. At the bottom the concentration in total constituents of each water, designated as "Salinity," is given in parts per million and in percentages of the water.

TABLE II. COMPOSITION OF VARIOUS NOTED SALT WATER BODIES.

	A	B	C	D	E	F	G	H	
	Salton Sea Analysis 1907	Salton Sea Analysis 1913	Salton Sea (Original)	Colorado River at Yuma	Caspian Sea	Ocean Water	Great Salt Lake	Dead Sea	
Na.....	31.29	32.30	33.14	19.75	24.70	30.59	33.39	13.39	
K.....	0.65	.34	0.30	2.17	0.56	1.11	1.08	2.37	
Ca.....	2.80	1.97	1.37	10.35	2.29	1.20	0.42	4.79	
Mg.....	1.81	1.62	1.55	3.14	5.97	3.72	2.60	11.85	
Al <sub>2</sub> O <sub>3</sub> +Fe <sub>2</sub> O <sub>3</sub> .....	0.02	.01	.....	.....	0.03	.....	.....	Trace	
SiO <sub>2</sub> .....	0.26	.16	.....	3.04	.....	.....	.....	.....	
Cl.....	47.83	47.38	52.62	19.92	42.04	55.29	56.54	65.22	
Br.....	Trace	.....	Trace	.....	0.05	0.19	.....	2.08	
SO <sub>4</sub> .....	13.41	12.46	11.00	28.61	23.99	7.69	5.97	0.29	
CO <sub>2</sub> .....	.....	1.13	.....	.....	.....	.....	.....	.....	
CO <sub>3</sub> .....	1.85	.....	.....	13.02	0.37	0.21	.....	0.01	
HCO <sub>3</sub> .....	.....	1.57	.....	.....	.....	.....	.....	.....	
Other constituents.....	0.08	1.06	.....	.....	.....	.....	.....	.....	
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	
Salinity	Total const. per million	3,553.9	9,699.6	.....	695.9	12,940.0	35,190.0	195,580.0	222,834.0
	Percentage of water	0.355	0.97	.....	0.070	1.294	3.519	19.558	22.283

A. Salton Sea, according to Analysis of 1907.

B. " " " " " " " " 1913.

C. Original Salton Sea. Supposed composition as calculated from the excess of the constituents of the present lake in 1907 over that found for the Colorado River.

D. Colorado River at Yuma, Arizona. Mean of seven analyses, made at intervals of about two months, of composites of samples collected almost daily between January 10, 1900, and January 24, 1901. Analyses by R. H. Forbes and W. W. Skinner, Bull. Ariz. Agri. Expt. Sta. No. 44 (1902).

E. Caspian Sea. Mean of five analyses by C. Schmidt, Bull. Acad. St. Petersburg, 24, 177 (1878).

F. Ocean Water. Mean of 77 analyses by W. Dittmar, H. M. S. Challenger, Physics and Chemistry, Vol. 1, p. 203 (1884).

G. Great Salt Lake. Analyses by J. E. Talmage, Science, 14, 445 (1889).

H. Dead Sea. Analysis by F. A. Genth, Ann., 110, 240 (1859).

If the assumption is correct that the salts leached out from the bottom of the Salton Sea represents approximately the composition of the original

lake then this must have resembled in a striking way the composition of the water of Great Salt Lake.

The salts taken up by the Salton Sea likewise resemble in a general way the composition of the salts in the ocean. The higher sodium, the lower potassium and bromine, and the probable absence, or low proportion, of carbonates in the former are the principal points of difference. The concentration, however, of the former lake which deposited the salts taken up by the present lake was no doubt much different from that of the ocean for at its maximum volume the total salinity of the present lake was only about one-ninth that of sea water. Consequently if it be assumed that the salts taken up by Salton Sea originally came from the evaporation of the sea water without loss from being covered up with silt, then the volume of water which could have evaporated must have been much smaller than the present lake.

There is strong geological evidence on the other hand that a former lake existed in Salton Basin much larger than the present lake. It might be assumed that this original lake was once in contact with the ocean, and that the greater part, but not all, of the salts were buried beyond reach of the present water in the lake. If this were the case then it would be expected that the salts taken up by the water would have a similar composition to the salts found in bittern waters, or at least would be decidedly different from the ocean type of salts originally deposited.

Since no such difference is noted it seems safe to conclude that the salts which have been taken up by the Salton Sea are not of ocean origin but have a similar source with the salts in Great Salt Lake; and that if the Salton Basin were at some former time filled with sea water all salts contained therein and deposited when the water evaporated, must have been completely buried beyond the action of the present water of the lake.