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QUALITY OF WATER OF THE COLORADO RIVER IN 1926-1928

BY

C. S. HOWARD

Contributions to the hydrology of the United States, 1929
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ILLUSTRATIONS

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES, 1929

N. C. GROVER, Chief Hydraulic Engineer

QUALITY OF WATER OF THE COLORADO RIVER IN 1926–1928

By C. S. HOWARD

SAMPLES

This report gives the results obtained in the continuation of a study of the Colorado River begun in 1925.[1] Most of the analyses here given represent composites of daily samples collected by the observers at the gaging stations on the Colorado River at Grand Canyon, Topock, and Yuma, Ariz. The other samples analyzed were taken at Lees Ferry and on tributaries of the Colorado. These stations are operated under the direction of W. E. Dickinson, district engineer of the Geological Survey at Tucson, Ariz., who personally collected some of the samples at other points and arranged for the collection of others. The average discharges in Table 2 were calculated from data furnished by W. E. Dickinson. Complete discharge data for this period will be published in the regular series of water-supply papers.

At Grand Canyon the samples were taken by K. C. McCarter, A. H. Williams, H. S. Leak, and C. A. Wells. At Topock the samples were taken by J. E. Klohr, Frank Dodge, W. E. Code, and F. S. Gatewood. At Yuma the samples were collected by Daniel Martinez and J. E. Klohr. Other samples were collected by D. A. Dudley and D. H. Barber in connection with measurements of discharge at points in the river system. The points at which samples were taken are shown in Figure 1.

All the samples were collected in 4-ounce bottles and were sent to the laboratory in Washington for analysis. As a rule a single bottle was filled each day. It is believed that the samples truly represented the river water as to its content of dissolved mineral matter.

[1] Collins, W. D., and Howard, C. S., Quality of water of Colorado River in 1925–1926: U. S. Geol. Survey Water Supply Paper 596, pp. 33–43, 1927; Dissolved and suspended mineral matter in Colorado River: Ind. and Eng. Chemistry, vol. 20, p. 746, 1928.

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METHODS OF ANALYSIS

The analyses were made by the methods regularly used in the United States Geological Survey.[2]

The 4-ounce samples were allowed to stand in the laboratory till the suspended matter settled, leaving the liquid above apparently free from even traces of silt. A sample of 5 or 10 cubic centimeters was taken from each small bottle for a chloride determination before the daily samples were combined to make three composite samples for each month. The results of the chloride determinations for Grand

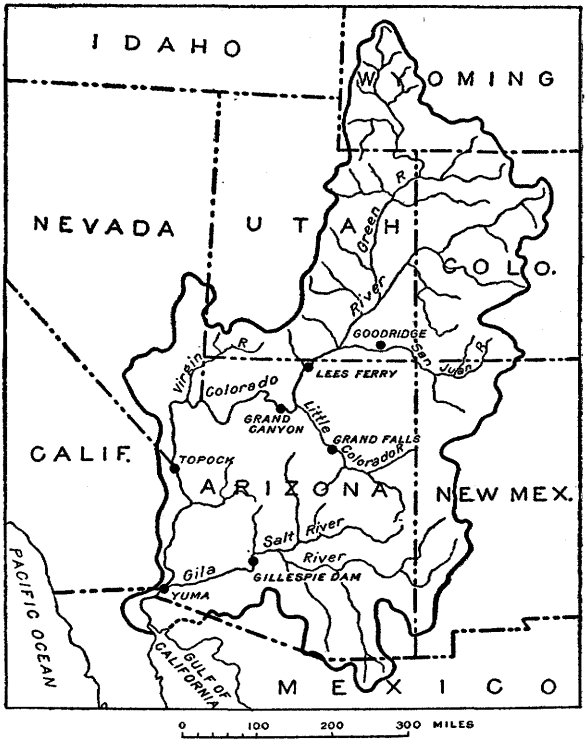

FIGURE 1.—Map of the Colorado River drainage basin showing sampling points

Canyon are given in Table 1. In the previous work[3] each of the composite samples represented a period of seven days. The composite samples were collected in flasks by drawing the clear liquid from the 4-ounce bottles through a siphon, without disturbing the sediment.

For most of the samples the weight of the suspended material in each bottle was determined. The suspended matter was washed into an evaporating dish with distilled water and dried on a steam bath.

[2] Collins, W. D., Notes on practical water analysis: U. S. Geol. Survey Water-Supply Paper 596, pp. 235–261, 1927.

[3] Collins, W. D., and Howard, C. S., op. cit. (Water-Supply Paper 596), pp. 33–43.

Correction was made for the weight of the soluble salts in the original water (usually 5 to 8 cubic centimeters) transferred to the evaporating dish with the suspended matter. The quantities of suspended matter reported for composite samples are averages of the determinations for the daily samples.

COMPOSITION OF THE WATER OF THE COLORADO RIVER AND TRIBUTARIES

The variations in the chloride content of the daily samples for Grand Canyon are shown in Table 1. As a rule the determinations made on the composite samples represent fairly well the composition for the entire period; the individual determinations indicate the fluctuations that take place during the period.

TABLE 1.—*Chloride in water of the Colorado River near Grand Canyon, Ariz., for year ending September 30, 1927*

[C. S. Howard, analyst. Results in parts per million]

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	120	160	165	265	165	115	105	40	18	28	68	68
2	130	170	165	270	160	100	120	40	20	35	78	------
3	150	155	155	------	180	110	115	42	18	22	78	95
4	165	170	150	290	180	120	110	25	20	25	82	108
5	155	175	170	300	170	130	110	32	22	28	75	132
6	150	170	170	280	175	115	105	28	25	28	80	105
7	160	180	160	235	165	95	95	20	22	28	78	88
8	160	165	155	225	170	135	85	20	28	25	70	102
9	190	165	155	225	165	115	65	15	28	28	55	82
10	165	175	145	200	190	130	70	20	28	35	65	75
11	110	175	120	185	160	130	60	15	18	30	72	52
12	135	180	125	205	165	100	70	25	25	38	78	58
13	140	165	130	255	165	110	60	18	22	45	72	45
14	140	175	145	195	175	115	60	20	25	32	82	40
15	130	170	145	190	170	100	55	25	20	42	70	50
16	145	160	135	190	175	120	65	20	25	45	82	45
17	135	175	135	180	150	110	55	25	25	42	75	38
18	130	160	140	180	155	130	65	28	22	38	75	35
19	135	165	140	165	------	125	65	25	20	42	72	45
20	140	165	155	160	110	115	55	20	22	45	75	48
21	135	175	150	155	110	115	60	18	22	48	70	45
22	135	165	160	160	120	125	65	18	15	48	78	45
23	155	170	175	155	130	115	65	20	18	55	90	45
24	140	170	170	175	120	120	65	15	20	60	85	48
25	155	170	170	145	------	115	70	20	25	55	115	52
26	145	170	180	155	115	145	70	15	25	55	100	50
27	145	165	180	145	115	160	65	15	22	60	105	50
28	145	165	190	145	140	155	50	20	25	62	100	50
29	155	175	195	155	------	140	50	15	18	78	95	58
30	145	165	225	160	------	100	45	20	32	78	78	58
31	145	------	255	160	------	90	------	18	------	70	75	------

The individual analyses made for this report and averages for the Colorado River at Grand Canyon are given in Table 2. The dates show the number of daily samples in each composite. The plan was to have a sample collected from the Colorado River each day for an entire year at Grand Canyon, Topock, and Yuma and for a shorter period at Lees Ferry and from San Juan River at Goodridge, Utah. Some of the samples were lost in transit, and a few that contained hydrogen sulphide when received were rejected.

The results for dissolved solids are sums of the constituents determined, with the bicarbonate divided by 2.03 to obtain the equivalent carbonate. The total hardness is the calcium carbonate equivalent to the calcium and magnesium together. The noncarbonate hardness is the total hardness minus the quantity of calcium carbonate equivalent to the bicarbonate. The mean discharge is that for the period represented by each composite analysis. The quantity of dissolved solids in tons per day is obtained by multiplying the dissolved solids in parts per million by the discharge in second-feet and the factor 0.002697. In other publications the quantity of dissolved material has been calculated from the results of determinations of the residue on evaporation, which is always greater than the anhydrous dissolved mineral matter.

Analysis 49 is the average of the 36 analyses for the Colorado River at Grand Canyon from October 1, 1926, to September 30, 1927, and analysis 176 is the average of 35 analyses for the same station from October 1, 1927, to September 30, 1928. Analysis 49 and diagram 49 in Figure 2 represent accurately the composition of water that would be contained in a vessel or reservoir that had received equal quantities of water from the river each day for the year 1926–27.

Analysis 50 is a weighted average of analyses 13–48, and analysis 177 is a weighted average of analyses 141–175. The quantities of the individual constituents in each analysis were multiplied by the mean discharge for the period represented by the analysis. The sum of the 36 products for each constituent was divided by the sum of the discharges to obtain the weighted averages given as analyses 50 and 177. Analysis 50 and diagram 50 in Figure 2 represent approximately the composition of water that would be found in a reservoir containing all the water that had reached Grand Canyon during the year 1926–27, after thorough mixing in the reservoir. Analysis 50 shows obviously better water than that represented by analysis 49 and diagram 49, because at times of high discharge the river carries the least amount of dissolved solids. Because the composite samples for analysis were made from equal daily samples, the analyses themselves do not represent accurately the water that would be found in a reservoir containing the whole flow of the river for the period covered by the individual analyses. The error due to this effect is not great, but its tendency is to make the weighted average show more dissolved matter than would be found in the water of a reservoir storing the whole flow of the river for a year. Analysis 51 is the weighted average for the river at Grand Canyon for the period 1925–26.

The analyses for Topock and Yuma show the water to have about the same content of dissolved mineral matter at those stations as at Grand Canyon. For the year 1926–27 the average load of dissolved

material was 36,600 tons a day at Grand Canyon, 37,400 tons at Topock, and 39,100 tons at Yuma. For the year 1927–28 the cor-

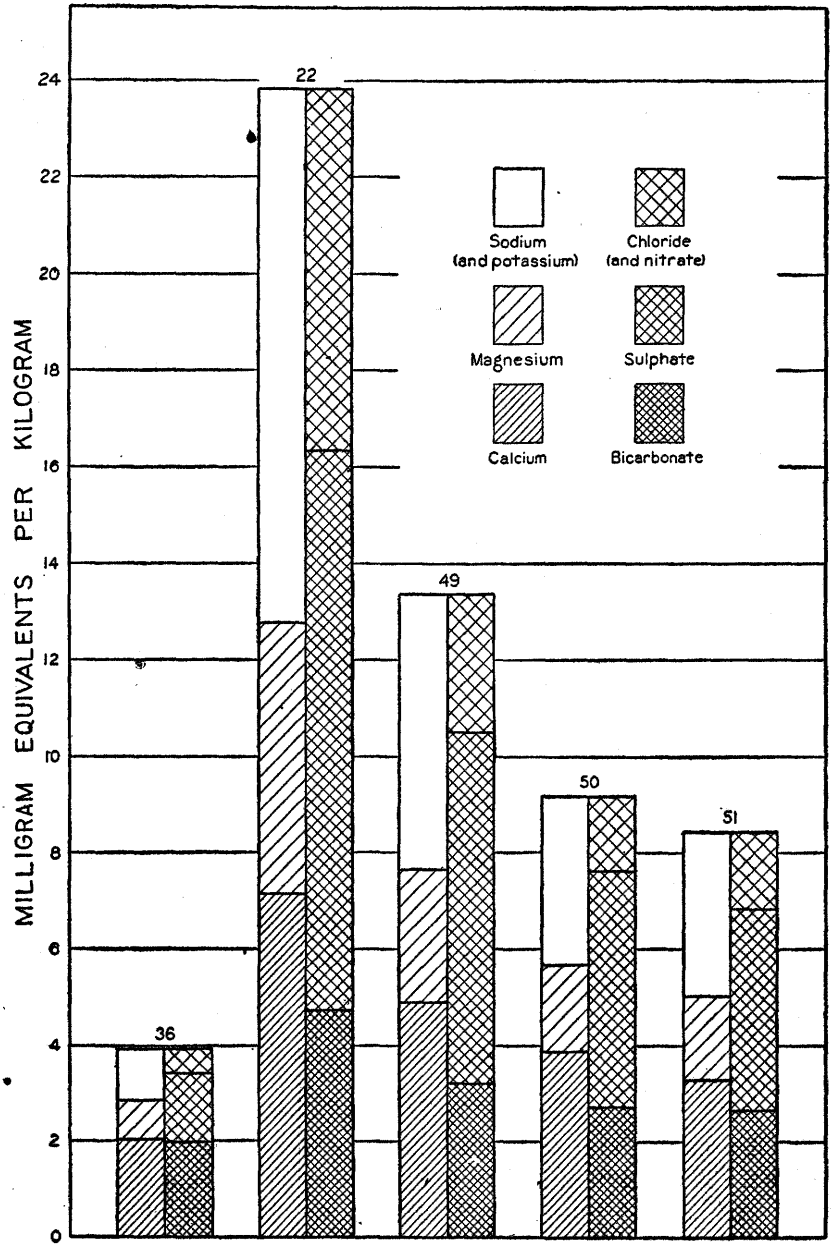

FIGURE 2.—Composition of Colorado River water. Numbers refer to analyses in Table 2, pp. 8-14.

responding figures are 29,400 tons at Grand Canyon and 26,200 tons at Yuma. Figure 3 shows the dissolved mineral matter at Grand Canyon and Topock for the two-year period 1925–1927, with the

discharge at Grand Canyon. The dissolved mineral matter shown in Figure 3 is the sum of the constituents with the bicarbonate calculated to carbonate.

Of the 213 analyses in Table 2, 122 represent samples collected from the Colorado River in 1926–27 during two months at Lees Ferry and the whole year at Grand Canyon, Topock, and Yuma, and 73 represent samples collected at Grand Canyon and Yuma in 1927–28. The other analyses represent occasional samples and can not serve for calculation of the quantities of material carried throughout the year. Consideration of the discharge and composition at the time of collection in comparison with the discharge and composition at other times throughout the year will give some basis for an opinion as to whether a given analysis may represent average or extreme concentration of dissolved mineral matter.

UTILIZATION OF THE WATER OF THE COLORADO RIVER

Clarified Colorado River water is nearly always satisfactory for drinking. It will serve for all ordinary domestic uses but does not attain the standard of quality generally demanded for a modern public water supply. The weighted average analysis for Grand Canyon for 1925–26 (No. 51, Table 2) shows a total hardness of 251 parts per million; the figure for 1926–27 (No. 50) is 285 parts; for 1927–28 (No. 177), 254 parts. Operators of municipal water plants in which softening is practiced have found that 100 parts per million is about the maximum hardness that will not cause complaints from users. The present trend in water treatment is toward a lower limit. The hardness of the water of public supplies of Boston, New York, and many other cities is less than one-tenth of the average hardness of the water of the Colorado River.

For use in steam boilers the river water can be treated to remove the scale-forming material, but it will even then not be of more than fair quality because of its comparatively high content of sodium salts.

The use of the river water for irrigation is wholly dependent on the drainage of the irrigated land. With good drainage and liberal use of the water no trouble should be experienced from the ordinary constituents of the water. Without adequate drainage the soil may be seriously damaged.

SUSPENDED MATTER

The figures given for suspended matter are accurate for the samples received. The samples, however, were taken at convenient sampling points and do not represent accurately the quantity of suspended matter being carried by the river. Other samples collected for a study of the silt problem indicate that the quantities of suspended matter reported in this paper are probably low, but the determinations are of value in indicating the quantities carried on days when regular silt samples were not taken.

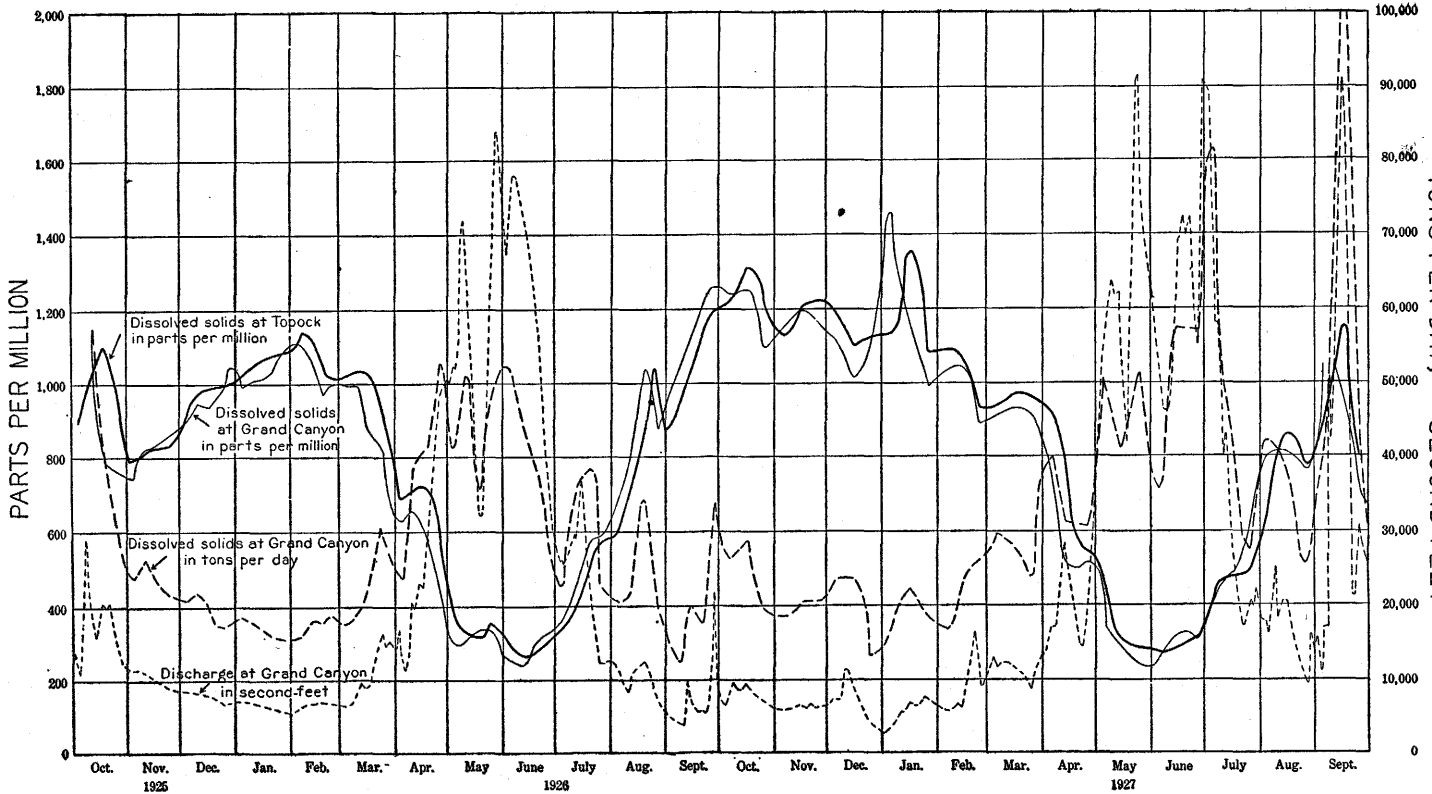

FIGURE 3.—Dissolved solids in the water of the Colorado River at Grand Canyon and Topock, Ariz., and discharge at Grand Canyon, 1926 and 1927

ANALYSES

TABLE 2.—*Analyses of water from Colorado River and certain tributaries*

[C. S. Howard, analyst, except as otherwise indicated. Analytical results in parts per million]

No.	Date of collection	Suspended matter	Residue on evaporation	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Dissolved solids	Hardness as $CaCO_3$ (calculated)		Mean discharge (second-feet)	Dissolved solids (tons per day)
															Total	Non-carbonate		
Colorado River at Lees Ferry, Ariz.																		
1	Oct. 12, 13, 1926	204	1,211	20	0.30	133	42	168	7.5	194	561	104	7.2	1,139	505	346	7,920	24,300
2	Dec. 7	718	1,075	25	.17	109	48	161	8.5	214	461	114	4.6	1,037	469	294	6,750	18,600
3	Feb. 24–27, 1927	765	968	30	.27	105	42	142	8.0	221	396	98	7.7	938	435	254	6,850	17,300
4	Mar. 26	2,330	964	13	.22	93	40	141	5.9	206	398	99	3.6	895	396	228	7,710	18,600
5	Apr. 18–24	2,610	529	14	.13	68	22	70	3.8	165	206	44	2.2	511	260	125	15,400	21,200
6	Apr. 25–29, May 1, 2	4,060	465	13	.13	60	20	58	3.5	157	172	38	1.9	444	232	103	29,800	35,700
7	May 3–9	6,320	311	23	.22	46	13	36	2.9	143	93	19	.58	304	168	51	58,900	48,300
8	May 10–16	3,800	290	25	.15	42	12	26	4.3	135	83	15	1.7	276	154	44	51,700	38,500
9	May 17–21, 26	3,020	272	28	.34	43	12	28	3.2	137	83	14	.68	280	157	44	75,500	57,000
10	May 28 to June 3	2,570	232	19	.24	39	10	25	1.9	123	62	14	.82	233	138	38	62,000	39,000
11	June 4–10	1,360	254	19	.31	40	12	31	2.9	117	83	16	.50	262	149	54	49,000	34,600
12	June 12–17	3,780	294	15	.30	45	13	31	2.2	122	104	16	.50	287	166	66	64,800	50,200
Colorado River at Grand Canyon, Ariz.																		
13	Oct. 1–10, 1926	14,700	1,312	17	0.26	143	42	199	8.0	214	576	140	7.0	1,238	530	354	7,840	26,200
14	Oct. 11–20	6,680	1,317	15	.19	150	50	192	8.7	211	597	135	3.1	1,255	580	407	8,450	27,100
15	Oct. 21–31	1,770	1,167	16	.16	120	47	174	7.7	206	483	139	5.6	1,094	493	324	6,660	19,600
16	Nov. 1–10	824	1,210	14	.18	122	50	192	7.7	228	493	158	2.6	1,152	510	323	5,980	18,600
17	Nov. 11–20	935	1,238	13	.17	124	52	201	7.7	237	517	164	4.3	1,200	523	329	6,280	20,300
18	Nov. 21–30	790	1,222	17	.15	128	52	179	11	235	488	165	8.8	1,160	521	328	6,480	20,300
19	Dec. 1–10	1,340	1,163	17	.15	114	48	190	9.2	223	467	150	12	1,117	482	299	7,810	23,500
20	Dec. 11–20	3,960	1,092	12	.14	114	43	157	9.2	210	438	128	13	1,018	461	289	8,540	23,400
21	Dec. 21–29	771	1,159	16	.14	112	46	203	12	238	467	170	9.8	1,153	469	274	4,180	13,000
22	Jan. 1, 2, 4–10, 1927	350	1,507	16	.15	143	68	245	12	289	557	248	22	1,454	636	400	3,940	15,400
23	Jan. 11–20	1,130	1,242	15	.24	125	53	199	7.2	264	460	185	9.0	1,183	530	313	6,660	21,200
24	Jan. 21–31	8,640	1,058	11	.20	106	45	168	5.8	227	391	148	9.2	996	450	264	6,920	18,600
25	Feb. 1–10	6,180	1,095	15	.22	106	46	174	8.3	226	401	163	7.2	1,034	459	273	6,030	16,800
26	Feb. 11–18	1,730	1,098	21	.28	108	43	185	7.5	224	405	161	5.8	1,047	446	263	8,430	23,300

27	Feb. 20–24, 26–28	11,000	914	18	.35	94	30	163	7.4	215	340	124	4.4	887	358	182	10,800	25,800
28	Mar. 1–10	6,440	936	16	.28	97	33	157	7.5	205	371	122	5.6	910	378	210	12,000	29,400
29	Mar. 11–20	5,060	986	5.4	.24	102	39	150	6.6	207	407	111	2.8	926	415	245	11,200	28,000
30	Mar. 21–31	3,670	964	4.4	.28	98	38	153	5.0	227	362	126	2.4	901	401	215	9,930	24,100
31	Apr. 1–10	7,920	767	4.4	.26	81	30	113	7.2	200	300	87	3.9	725	326	162	20,300	39,700
32	Apr. 11–20	5,680	522	6.0	.18	66	22	71	1.8	171	193	56	3.3	503	255	115	22,700	30,800
33	Apr. 21–30	4,550	525	8.0	.25	66	22	76	3.0	168	193	58	3.1	512	255	117	21,800	30,100
34	May 1–10	13,700	337	15	.16	49	15	42	3.7	159	104	29	1.2	337	184	54	55,100	50,100
35	May 11–20	3,710	284	16	.17	44	13	33	4.6	133	85	23	1.8	286	163	54	53,400	41,200
36	May 21–31	3,820	233	14	.21	41	10	23	5.1	121	66	18	1.5	238	144	44	78,900	50,600
37	June 1–10	1,270	261	23	.17	41	11	26	5.0	122	73	20	6.8	260	148	48	51,200	35,900
38	June 11–20	2,700	323	25	.18	51	12	37	3.8	128	110	21	1.4	324	177	72	65,600	57,300
39	June 21–30	5,450	302	17	.21	47	12	35	6.1	127	108	20	1.6	310	167	62	67,800	56,700
40	July 1–10	11,100	418	20	.24	65	14	48	5.9	142	169	24	1.1	417	220	103	72,100	81,100
41	July 11–20	7,070	501	23	.22	74	19	55	4.6	163	192	36	1.2	485	263	129	34,100	44,600
42	July 21–31	4,540	551	19	.19	71	22	71	3.2	163	205	53	1.7	526	268	134	19,300	27,400
43	Aug. 1–10	12,500	831	21	.26	116	29	101	4.8	189	371	67	1.4	805	409	254	19,200	41,700
44	Aug. 11–20	12,800	848	18	.17	117	29	103	4.2	179	378	66	1.5	805	411	265	17,300	37,600
45	Aug. 21–31	8,870	788	21	.11	95	28	109	6.4	179	325	86	2.9	762	352	206	12,300	25,300
46	Sept. 1, 3–10	20,800	1,121	22	.25	144	39	144	9.0	201	515	94	1.0	1,067	520	355	14,700	42,300
47	Sept 11–20	59,400	1,048	18	.61	152	32	109	5.8	188	518	46	.85	975	511	357	67,600	178,000
48	Sept. 21–30	14,600	742	16	.24	104	25	88	5.9	172	336	44	2.1	706	362	221	27,000	51,400
49	Average of analyses 13–48	7,600	863	16	.22	98	34	127	6.6	194	346	100	4.6	827	383	223	----------	----------
50	Weighted average of analyses 13–48 (see p. 4)	10,900	586	17	.24	77	22	77	5.5	162	235	53	2.4	569	285	152	23,800	36,600
51	Weighted average for 1925–1926 [a]	----------	546	19	.31	66	21	[b]75	[c]5.7	159	201	56	.16	523	251	121	19,900	28,100

Colorado River at Topock, Ariz.

52	Oct. 1–10, 1926	33,000	1,222	15	0.25	125	33	232	8.7	242	514	154	5.1	1,206	448	249	8,460	27,500
53	Oct. 11–20	13,000	1,365	14	.15	148	48	211	9.6	217	620	150	4.2	1,312	567	389	8,060	28,500
54	Oct. 21–31	524	1,279	15	.20	144	48	192	8.8	217	569	138	5.4	1,227	557	379	6,790	22,500
55	Nov. 1–10	2,400	1,175	12	.15	127	48	180	8.3	215	500	147	6.4	1,135	514	338	5,490	16,800
56	Nov. 11–20	2,120	1,248	20	.22	132	49	193	14	228	507	174	11	1,213	531	344	5,600	18,300
57	Nov. 21–31	1,840	1,270	21	.18	131	51	200	9.2	233	510	171	13	1,221	537	346	5,800	19,100
58	Nov. 1, 3–5, 7–10	2,220	1,241	21	.22	124	49	192	4.6	224	497	169	18	1,185	511	327	6,760	21,600
59	Dec. 11–20	2,720	1,145	24	.18	119	47	166	13	222	469	148	9.8	1,105	490	308	8,350	24,900
60	Dec. 21–28, 31	2,800	1,173	20	.17	122	44	177	15	203	490	146	9.8	1,124	485	319	5,440	16,500
61	Jan. 1–7, 9–10, 1927	1,370	1,186	10	.17	122	49	188	9.0	244	448	178	6.2	1,131	506	306	3,890	11,900
62	Jan. 11–20	1,300	1,434	16	.21	141	59	234	7.4	272	532	222	6.1	1,352	594	372	6,180	22,500
63	Jan. 21–31	1,450	1,210	10	.20	124	50	175	6.4	253	405	182	5.7	1,083	515	308	7,370	21,500
64	Feb. 1–10	1,030	1,107	17	.30	113	47	182	5.9	222	450	157	9.4	1,091	475	293	6,610	19,400
65	Feb. 11–19	2,260	1,120	17	.27	119	46	161	10.	229	422	168	6.0	1,062	486	298	8,840	25,300
66	Feb. 20–28	9,190	941	15	.28	104	34	160	9.6	212	361	134	2.7	925	399	226	12,950	32,300
67	Mar. 1–10	6,930	988	22	.24	108	34	156	8.5	223	369	126	4.5	938	409	227	11,700	29,600
68	Mar. 11–20	6,010	1,006	18	.20	111	37	153	6.1	221	398	122	7.0	961	429	248	11,600	30,100
69	Mar. 21–31	4,290	1,003	16	.16	107	38	157	6.6	222	393	120	5.5	953	423	241	9,510	24,400
70	Apr. 1–10	5,810	943	18	.24	101	37	154	6.4	221	365	121	5.1	917	404	223	16,200	40,100

[a] U. S. Geol. Survey Water-Supply Paper 596, p. 41, analysis 66, table 6.
[b] Average of 51. Sodium for 7 calculated for mixed chlorides on the assumption that the potassium was 5.7, the average of 44.
[c] Average of 44.

TABLE 2.—*Analyses of water from Colorado River and certain tributaries*—Continued

[C. S. Howard, analyst, except as otherwise indicated. Analytical results in parts per million]

Colorado River at Topock, Ariz.—Continued

No.	Date of collection	Suspended matter	Residue on evaporation	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Dissolved solids	Hardness as $CaCO_3$ (calculated)		Mean discharge (second-feet)	Dissolved solids (tons per day)
															Total	Non-carbonate		
71	Apr. 11–20	10,200	645	19	0.12	78	26	96	5.1	201	238	66	2.4	630	302	137	25,000	42,500
72	Apr. 21	12,100	534	18	.21	68	23	87		188	194	56	1.5	540	264	110	19,100	27,800
73	Apr. 21–30	9,210	572	19	.20	69	23	80	6.4	183	205	62	2.6	557	267	117	18,100	27,200
74	May 1–10	9,340	456	17	.18	63	19	59	4.6	172	154	44	1.9	447	235	94	48,500	58,400
75	May 11–20	9,670	300	17	.24	46	14	34	4.8	146	91	24	2.2	305	172	53	53,200	43,800
76	May 21–31	6,960	294	23	.22	47	12	26	5.9	149	81	21	.71	290	167	45	76,000	59,400
77	June 1–10	10,100	269	19	.19	45	11	31	6.1	135	81	18	1.0	279	158	47	53,800	40,500
78	June 11–20	7,320	294	19	.19	46	12	31	6.1	128	90	23	.69	291	164	59	58,600	50,600
79	June 21–30	7,770	328	17	.22	51	13	35	6.9	138	113	20	1.0	325	181	68	65,000	57,000
80	July 1–7, 9–10	13,800	448	19	.31	70	16	52	2.6	166	171	25	1.3	439	241	104	76,800	90,900
81	July 11–20	14,000	479	25	.24	74	19	49	4.3	160	189	31	1.3	472	263	132	39,700	50,500
82	July 21–31	8,210	487	20	.32	68	19	60	4.0	159	177	47	1.2	475	248	118	20,200	25,900
83	Aug. 1–10	14,900	735	19	.21	96	26	91	6.7	170	311	67	1.0	702	347	207	18,100	34,300
84	Aug. 11–20	19,800	913	18	.22	125	32	109	6.7	179	421	66	1.0	867	444	297	19,100	44,600
85	Aug. 21–31	11,100	825	20	.22	111	28	105	5.8	174	350	77	3.0	786	392	250	11,900	25,200
86	Sept. 1–10	18,100	948	23	.18	125	30	129	3.8	185	419	90	2.6	914	436	284	13,600	33,500
87	Sept. 11–20	48,500	1,228	21	.52	169	40	144	6.6	200	605	73	.75	1,158	586	422	62,000	194,000
88	Sept. 21–30	33,500	774	17	.23	108	24	93	4.2	167	359	47	.73	735	368	231	30,000	59,500
	Colorado River at Yuma, Ariz.																	
89	Oct. 1–10, 1926	33,800	1,289	21	0.33	131	39	224	9.8	227	486	210	2.4	1,235	487	301	9,810	32,700
90	Oct. 11–20	16,700	1,309	17	.17	135	38	213	8.5	216	506	187	2.3	1,213	493	316	8,690	28,400
91	Oct. 21, 22, 25–31	5,640	1,355	24	.20	148	48	196	8.2	205	579	170	5.2	1,280	567	399	5,570	19,200
92	Nov. 1–10	2,600	1,221	27	.21	133	47	187	11	207	518	157	3.7	1,186	525	356	4,260	13,600
93	Nov. 11–20	1,870	1,208	15	.17	129	50	187	9.9	215	500	164	5.5	1,166	528	351	3,950	12,400
94	Nov. 21–30	1,740	1,296	11	.17	133	49	208	6.1	224	519	178	5.1	1,220	533	350	4,630	15,200
95	Dec. 1–10	3,000	1,227	12	.21	128	47	191	5.3	214	483	178	3.9	1,154	513	337	7,540	23,500
96	Dec. 11, 13–20	4,270	1,175	12	.18	118	43	200	7.7	222	411	202	8.0	1,111	471	289	9,630	28,900
97	Dec. 21–31	3,180	1,147	13	.18	115	41	196	6.1	218	396	206	3.2	1,084	456	277	5,980	17,500
98	Jan. 1–10, 1927	1,880	1,224	14	.17	118	43	222	8.2	237	394	252	4.8	1,173	471	277	3,490	11,000
99	Jan. 11–20	1,390	1,356	18	.25	128	52	239	9.6	256	447	278	6.3	1,304	533	323	4,220	14,800

100	Jan. 21–31	1,600	1,350	18	.21	129	54	227	7.8	256	482	236	4.8	1,285	544	334	5,780	20,000
101	Feb. 1–10	1,530	1,134	9.4	.20	114	46	186	7.0	224	414	182	5.6	1,074	474	290	4,980	14,400
102	Feb. 11–19	6,600	891	22	.26	89	36	150	6.4	204	311	144	5.1	864	370	203	21,100	49,200
103	Feb. 20–28	8,480	781	15	.28	78	26	145	7.7	195	235	150	4.3	757	302	142	33,200	67,800
104	Mar. 1–8, 10	8,620	883	23	.16	92	30	152	6.7	214	284	153	3.6	850	353	178	14,000	32,100
105	Mar. 11–10	6,210	965	18	.17	102	34	164	7.7	217	339	158	2.8	933	394	217	12,700	32,000
106	Mar. 21–31	2,720	1,048	19	.24	112	37	171	8.3	211	384	160	2.4	998	432	259	8,830	23,800
107	Apr. 1–10	4,800	1,008	26	.18	105	38	163	8.2	217	367	150	2.3	957	418	240	12,800	33,000
108	Apr. 6	6,530	1,046	23	.15	106	39	171		205	404	149	3.2	996	425	257	11,800	31,700
109	Apr. 11–20	8,850	738	16	.21	85	29	120	6.7	196	287	89	2.1	732	331	171	22,200	43,800
110	Apr. 15	14,900	703	17	.16	76	27	119	6.7	195	269	81	2.0	694	301	141	24,400	45,700
111	Apr. 21–26, 28–30	4,860	576	19	.21	69	24	82	7.4	178	203	69	2.0	563	271	125	15,200	23,100
112	May 1–8, 10	6,160	537	17	.25	74	22	78	5.0	179	194	60	1.3	540	275	128	34,000	49,500
113	May 11–16, 18–20	5,000	347	14	.24	46	14	48	4.6	154	104	32	1.4	340	172	46	52,000	47,700
114	May 21–29, 31	3,540	329	15	.13	49	14	37	2.2	143	95	31	1.3	315	180	63	58,700	49,900
115	June 1–10	3,140	289	20	.26	47	12	30	5.6	146	75	25	.54	287	167	47	61,400	47,500
116	June 11–20	3,650	307	22	.23	45	13	38	5.9	133	89	30	.72	309	166	57	49,900	41,600
117	June 21–30	3,730	346	17	.32	51	16	40	3.8	135	117	28	.55	340	193	82	62,700	57,500
118	July 1–10	6,910	425	15	.20	60	16	52	4.5	143	162	33	.74	414	216	98	66,600	74,300
119	July 11–20	6,780	431	23	.11	59	18	55	4.8	152	161	35	1.1	432	221	96	45,500	53,000
120	July 22–31	4,720	513	21	.10	69	20	68	3.5	154	200	46	1.0	504	254	128	20,400	27,700
121	Aug. 1–10	6,400	645	28	.10	84	24	87	2.6	165	254	64	1.1	626	308	173	16,700	28,200
122	Aug. 11–19	12,400	864	26	.10	114	30	107	6.4	174	390	76	1.2	836	408	265	17,400	39,200
123	Aug. 21–31	9,660	815	23	.10	111	29	108	3.5	178	378	74	2.2	816	396	245	10,800	23,800
124	Sept. 1–10	11,000	910	18	.10	113	29	110	5.1	176	369	90	2.5	823	401	257	12,000	26,600
125	Sept. 11–20	26,600	1,132	22	.31	159	39	130	5.9	199	537	80	1.0	1,072	557	394	41,800	121,000
126	Sept. 22–30	25,200	892	23	.25	123	27	109	6.1	171	432	56	.79	861	418	278	36,800	85,400

San Juan River at Goodridge, Utah.

127	Feb. 19–26, 1927	11,800	944	14	0.25	108	30	126	7.2	184	483	23	2.1	884	393	242	-------	-------
128	Feb. 27 to Mar. 2, 4–7	16,700	760	18	.24	93	26	105	2.1	183	373	22	.75	730	339	189	-------	-------
129	Mar. 8–12, 14–16	7,190	724	12	.28	93	27	85	5.8	173	351	22	.82	682	343	201	-------	-------
130	June 15, 17–19	2,510	251	18	.23	43	9.3	27	3.8	112	95	6.0	.84	258	146	54	-------	-------

Little Colorado River at Grand Falls, Ariz.

131	Oct. 16, 1926	7,160	1,320	22	0.33	78	16	376	9.1	239	197	488	1.5	1,306	261	65	21	74
132	Jan. 19, 1927	582	1,013	8.4	.18	60	16	281	12	223	135	375	1.5	999	216	33	35	94
133	Feb. 1	149	1,464	21	.30	87	27	397	6.6	244	185	588	2.1	1,434	328	128	20	77
134	Mar. 22	11,300	354	6.8	.26	27	5.4	82	4.2	137	71	70	Trace.	334	90	0	655	590
135	Apr. 14	6,460	291	15	.28	-------	-------	[d] 68	6.6	101	58	72	-------	-------	88	0	495	-------
136	Apr. 15	5,790	291	18	.24	27	4.6	68	5.6	99	50	72	1.2	295	86	5	355	282

[d] Calculated.

TABLE 2.—*Analyses of water from Colorado River and certain tributaries*—Continued

[C. S. Howard, analyst, except as otherwise indicated. Analytical results in parts per million]

No.	Date of collection	Suspended matter	Residue on evaporation	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Dissolved solids	Hardness as $CaCO_3$ (calculated)		Mean discharge (second-feet)	Dissolved solids (tons per day)
															Total	Non-carbonate		
Gila River at Gillespie Dam, Ariz.																		
137	Dec. 10, 1926	1,690	1,283	28	0.15	102	36	290	11	259	185	463	0.68	1,243	403	190	1,240	4,150
138	Jan. 17, 1927	189	2,185	21	.18	152	62	532	12	304	315	862	14	2,120	634	385	360	2,060
139	June 25	95	3,055	37	.22	149	80	766	12	140	471	1,275	1.6	2,861	700	586	0	0
Bright Angel Creek near Grand Canyon, Ariz.																		
140	Apr. 27, 28, 1927	------	106	8.0	0.22	------	------	------	------	106	10	1.0	Trace.	------	------	------	------	------
Colorado River at Grand Canyon, Ariz.																		
141	Oct. 1–10, 1927	8,540	698	17	0.23	93	26	84	4.8	162	302	46	3.4	656	339	206	20,200	35,700
142	Oct. 11–20	2,470	671	16	.18	85	27	84	5.6	180	263	69	3.4	642	323	176	15,200	26,300
143	Oct. 21–31	1,450	760	12	.21	92	31	107	3.2	196	299	81	2.9	725	357	196	12,000	23,500
144	Nov. 1, 2, 4–10	7,480	1,013	16	.20	128	40	126	5.6	189	466	84	3.0	962	484	329	15,100	39,200
145	Nov. 11–20	3,250	844	16	.22	98	34	121	3.4	193	356	89	3.9	816	384	226	12,500	27,400
146	Nov. 21–30	1,930	831	11	.23	94	36	118	5.0	199	342	93	2.9	800	383	220	11,600	25,000
147	Dec. 1–3, 8	1,390	------	------	------	------	------	------	------	------	339	103	------	------	------	------	10,400	------
148	Dec. 11–20	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	7,790	------
149	Dec. 24–31	395	1,086	14	.22	113	46	169	10	240	407	151	9.8	1,038	471	274	5,790	16,200
150	Jan. 1–10, 1928	528	1,039	14	.24	111	47	156	8.5	234	410	140	6.8	1,009	470	278	7,660	20,800
151	Jan. 11–20	875	956	15	.24	104	44	147	6.2	231	380	123	6.2	939	440	251	8,700	22,000
152	Jan. 21–31	700	929	14	.23	96	41	[d] 142	7.8	218	358	120	6.8	893	408	230	7,960	19,200
153	Feb. 1–10	2,990	929	10	.20	99	40	144	6.6	210	357	126	4.8	891	412	239	9,520	22,900
154	Feb. 11–20	2,420	912	8.6	.23	99	37	145	7.2	218	353	117	4.3	879	399	221	8,810	20,900
155	Feb. 21–29	9,800	973	17	.09	101	41	153	5.6	226	375	125	3.2	932	421	235	7,720	19,400
156	Mar 1–10	2,780	936	16	.12	94	39	150	4.8	225	349	123	4.9	892	395	210	9,750	23,500
156a	Mar. 11–20	5,165	832	14	.12	90	34	131	5.8	207	335	92	4.1	808	364	195	13,200	28,800
157	Mar. 21–29	4,820	785	15	.13	86	32	122	4.3	201	307	86	3.2	755	346	181	14,900	30,300

158	Apr. 1–5, 7–10	6,360	581	13	.14	72	25	80	3.4	173	218	58	4.6	559	282	141	19,700	29,700
159	Apr. 11–20	2,640	589	19	.22	72	26	73	5.8	186	201	61	1.7	551	287	134	13,300	19,800
160	Apr. 22–30	3,180	616	18	.22	72	28	79	4.0	192	215	70	2.1	583	295	137	16,800	26,400
161	May 1–9	15,200	394	17	.28	58	19	40	5.1	173	125	33	.82	383	223	81	55,500	57,300
162	May 11, 13–20	11,100	309	15	.24	54	14	20	6.1	145	96	17	.78	295	192	68	79,300	63,100
163	May 21–31 *	7,560	309	18	.10	48	14	30	2.4	140	98	17	1.0	298	177	63	73,200	58,800
164	June 1–10 *	7,600	237	16	.06	40	11	23	2.1	131	66	10	.38	233	145	38	96,800	60,800
165	June 11–20 *	3,480	279	18	.10	46	12	31	3.0	131	85	20	2.1	282	164	57	52,800	40,200
166	June 21–29 *	2,820	342	15	.09	48	15	43	3.0	136	119	27	2.4	339	182	70	40,200	36,800
167	July 1–10 *	2,150	306	12	.06	44	14	35	2.9	126	99	26	1.8	297	167	64	35,200	28,200
168	July 11–20 *	1,310	377	13	.07	50	15	51	1.9	130	123	42	2.4	362	186	80	21,900	21,400
169	July 21–31 *	4,790	574	39	.13	69	21	76	4.5	160	205	56	3.3	553	259	127	19,300	28,800
170	Aug. 2–10 *	5,680	692	46	.04	79	23	96	5.9	176	254	73	4.6	668	292	147	13,800	24,900
171	Aug. 11–20 *	4,160	839	21	.04	96	34	117	5.8	174	351	90	6.3	807	379	237	10,100	22,000
172	Aug. 21–23, 25–31 *	8,950	1,020	14	.22	119	38	141	6.6	200	429	111	4.2	962	453	289	8,820	22,900
173	Sept. 1–10 *	7,900	1,223	12	.14	142	42	177	7.7	210	525	143	6.0	1,158	527	355	7,820	24,400
174	Sept. 11–20 *	1,910	1,124	15	.08	117	45	161	24	205	469	144	10	1,086	477	309	5,680	16,600
175	Sept. 21–30 *	555	1,237	14	.08	121	52	196	6.7	216	509	165	13	1,183	516	339	5,390	17,200
176	Average of analyses 141–175 †	4,490	742	16	.16	86	31	105	5.7	186	291	84	4.1	713	341	188	22,200	----
177	Weighted average of analyses 141–175 (see p. 4) †	6,310	509	17	.15	66	22	65	4.3	162	187	48	2.4	491	254	121	----	29,400

Colorado River at Yuma, Ariz.

178	Oct. 1-10, 1927	11,900	793	16	0.28	109	26	102	5.6	169	360	60	5.5	768	379	240	23,100	47,900
179	Oct. 11–20	17,000	710	14	.32	81	26	102	5.1	162	300	69	9.3	687	309	176	16,400	30,400
180	Oct. 21–30	13,510	706	13	.33	94	25	97	4.0	182	285	74	2.6	685	338	188	12,100	22,400
181	Nov. 9–10	4,370	----	----	----	----	----	----	----	----	375	99	----	----	----	----	14,000	----
182	Nov. 11–20	6,270	1,038	16	.23	137	39	128	5.0	182	477	91	2.9	986	502	353	11,800	31,400
183	Nov. 21–30	3,740	891	13	.26	109	34	128	5.3	193	377	113	2.6	877	412	254	10,900	25,800
184	Dec. 1–10	2,750	881	12	.14	103	34	130	5.4	202	359	103	1.6	848	397	231	9,880	22,600
185	Dec. 11–20	2,470	920	10	.26	107	38	131	8.6	215	359	112	4.6	876	423	247	7,660	20,300
186	Dec. 21–26, 31	1,820	957	14	.38	109	39	143	7.2	218	368	127	6.7	922	432	254	5,260	13,100
187	Jan. 1–10, 1928	1,650	1,070	9.0	.28	117	44	159	8.8	230	400	154	9.0	1,014	473	284	5,700	15,600
188	Jan. 11–16, 18–20	2,220	1,087	11	.27	120	45	164	7.0	234	419	151	6.5	1,039	484	292	6,300	17,700
189	Jan. 22–31	2,060	998	17	.33	110	42	146	8.2	225	383	134	5.8	957	447	263	7,180	18,500
190	Feb. 1–6, 8–10	2,640	954	14	.26	105	40	142	8.3	213	367	131	5.4	918	426	252	7,300	18,100
191	Feb. 11–20	3,900	982	14	.42	106	40	143	5.9	208	375	134	4.6	925	429	259	9,270	23,100
192	Feb. 21–27, 29	3,000	970	13	.37	105	38	154	8.0	217	362	144	4.8	936	418	240	6,550	16,500
193	Mar. 1–10	2,170	991	13	.13	108	38	156	4.8	221	370	137	4.4	940	426	245	6,960	17,600
194	Mar. 11–20	3,390	978	15	.13	101	39	159	4.0	221	370	138	4.0	939	412	236	10,200	25,800
195	Mar. 21–31	3,800	881	14	.15	95	33	139	4.6	208	343	105	3.8	840	373	202	9,600	21,700
196	Apr. 1–7, 9–10	7,140	801	8.2	.14	89	32	122	5.6	200	316	92	4.2	768	354	190	17,600	36,500
197	Apr. 11–20	4,350	603	13	.12	69	26	87	4.8	167	224	66	2.7	575	279	142	13,700	20,300
198	Apr. 21–30	2,970	623	19	.25	75	27	94	3.7	192	225	80	1.8	620	288	141	9,890	16,500
199	May 1–10	6,620	----	----	----	----	----	----	----	194	----	62	----	----	----	----	32,100	----

† Calculated. * Analyzed by S. K. Love, U. S. Geological Survey. † For averages for 1926–27 and 1927–28, see Nos. 49–51.

TABLE 2.—*Analyses of water from Colorado River and certain tributaries*—Continued

[C. S. Howard, analyst, except as otherwise indicated. Analytical results in parts per million]

Colorado River at Yuma, Ariz.—Continued

No.	Date of collection	Suspended matter	Residue on evaporation	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Dissolved solids	Hardness as $CaCO_3$ (calculated)		Mean discharge (second-feet)	Dissolved solids (tons per day)
															Total	Non-carbonate		
200	May 11–20	6,550	360	15	.54	55	16	39	2.6	159	112	28	.60	347	203	73	61,600	57,600
201	May 21–31	6,780	354	13	.25	53	16	39	2.2	148	116	27	.68	340	198	78	64,600	59,200
202	June 1–10 *	3,910	313	14	.27	45	14	37	4.3	147	92	23	.15	302	170	49	74,400	60,600
203	June 11–16, 18–20 *	4,640	289	15	.25	44	13	35	3.2	146	79	23	.44	285	163	44	77,700	59,700
204	June 21–30 *	4,280	333	14	.09	48	14	41	3.0	141	108	28	1.2	327	177	62	40,800	36,000
205	July 1–10 *	3,630	343	6.6	.12	48	15	43	2.7	134	113	31	2.0	327	182	72	36,300	32,000
206	July 11–20 *	2,960	342	16	.06	46	13	45	2.4	132	105	34	.92	327	168	60	23,800	21,000
207	July 21–31 *	3,330	462	23	.11	58	18	64	2.7	143	154	54	2.1	446	219	102	17,200	21,000
208	Aug. 1–10 *	4,310	606	9.2	.12	75	22	83	3.7	152	236	65	4.4	573	278	153	11,700	18,100
209	Aug. 11–20 *	4,270	665	14	.04	78	25	95	5.0	164	255	80	4.3	637	298	163	8,930	15,300
210	Aug. 21–31 *	2,700	871	19	.09	106	31	116	5.0	168	367	98	7.6	833	392	254	5,930	13,300
211	Sept. 1–10 *	3,510	944	28	.15	107	34	138	9.6	187	383	115	6.7	914	407	253	6,010	14,700
212	Sept. 11–17, 19–20 *	7,790	1,248	20	.09	152	44	167	7.4	193	557	131	7.5	1,181	560	402	3,900	12,400
213	Sept. 21–30 *	2,760	1,200	15	.04	129	42	186	7.0	195	563	157	10	1,145	495	335	2,630	8,120

* Analyzed by S. K. Love, U. S. Geological Survey.