Occurrence and Distribution of Strontium in Natural Water

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1496-D

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By MARVIN W. SKOUGSTAD *and* C. ALBERT HORR

CHEMISTRY OF STRONTIUM IN NATURAL WATER

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By Marvin W. Skougstad and C. Albert Horr

ABSTRACT

Strontium, an alkaline-earth element chemically similar to calcium and magnesium, occurs in trace quantities in all natural water. Analysis of samples from 75 major rivers of the conterminous United States shows that the strontium concentration ranges from 0.007 to 13.7 ppm (parts per million). The strontium concentration in the total dissolved solids carried by these waters ranges from a few hundredths of a percent to 0.37 percent. The greatest strontium concentration in surface water and in dissolved material occurs in the high-salinity streams of the Southwestern United States. In this area, characterized by relatively low annual rainfall, high evaporation rate, and low physical relief, the concentration of strontium in the streams is generally 2 to 3 times as great as in most other streams of the Nation.

The strontium content of ground water has a wider range than that of surface water. Of more than 175 ground-water samples analyzed, 60 percent contained less than 0.2 ppm, although some potable water samples contained as much as 50 ppm. One brine sample contained 2,960 ppm of strontium.

INTRODUCTION

Studies of the occurrence of strontium in water have, with few exceptions, been limited to investigations of areas where unusually high strontium concentrations have been noted, or to the analysis of brines or highly mineralized waters containing appreciable amounts of strontium.

Odum (1951, p. 20–21) reported the strontium and calcium content of certain Florida waters, including 14 springs, 4 rivers, and 6 lakes and ponds. The strontium content of the springs generally ranged from 0.107 to 0.784 ppm (part per million), although 1 spring was found to contain 6.308 ppm of strontium and 2 spring samples contained less than 0.10 ppm. Strontium in rivers and lakes ranged from a few hundredths of a part per million to about 0.8 ppm.

Lohr and Love (1954, p. 624) noted the unusually high strontium content of three municipally-owned wells at Waukesha, Wis. Later, Nichols and McNall (1957) analyzed more than 380 samples in a comprehensive survey of the occurrence of strontium in municipal water supplies in Wisconsin. They found that water in the eastern part of the State generally contained more than 1.0 ppm of strontium and that several wells in this area, including wells at Campbellsport, Greendale, Kaukauna, Menomonee Falls, Waukesha, and Wauwatosa, contained strontium in concentrations greater than 30 ppm. They tabulated the strontium content in the water supplies of 100 Wisconsin communities where the concentrations exceeded 1.0 ppm. Their analyses were made by a flame-photometric procedure using synthetic radiation buffers of a composition similar to the composition of the water analyzed. When the sample composition differed significantly from that of the synthetic buffer, an appropriate correction to the strontium value obtained was made.

Alexander, Nusbaum, and MacDonald (1954), in a study of the occurrence of strontium in the water supplies of 50 major cities of the United States, found only two sources which contained more than 1.0 ppm. The maximum concentration found in any untreated surface or ground water used as a source for municipal supply was 1.9 ppm in ground water at Wichita, Kans. The strontium content of the samples ranged from 0.0058 to 1.9 ppm. The analyses were made spectrographically and included determination of calcium and magnesium as well as strontium.

A more recent survey of the strontium content of the drinking water of seven cities (Chicago, Denver, Oak Ridge, Cincinnati, New York, Atlanta, and Charlottesville) was reported by Blanchard, Leddicotte, and Moeller (1958). They used a neutron-activation method to determine several minor elements, including strontium, and reported a range of strontium concentrations from 0.08 to 1.23 ppm.

Feulner and Hubble (1960) reported strontium concentrations in both surface and ground water in Champaign County, Ohio, where celestite-rich limestones and glacial deposits of Late Silurian age give rise to considerable amounts of strontium in ground water. Strontium concentrations ranging from a few tenths of a part per million to as much as 30 ppm were found in the wells tested. Surface water, particularly that fed by springs or ground-water seepage from celestite-rich limestone aquifers, contained up to 2.1 ppm of strontium. Two spring-discharge samples contained 8.7 and 9.0 ppm of strontium.

The "Committee on World-Wide Runoff of Dissolved Solids," appointed by the International Association of Hydrology of the International Union of Geodesy and Geophysics, has undertaken a program involving the analysis of samples from about 70 major rivers of the world. Four samples from each river, each sample taken at a different time of the year and representing a different flow stage of the river, have been analyzed for about 20 chemical substances by conventional chemical methods. In addition, spectrographic trace-elements techniques were used to determine up to 25 additional minor elements, including strontium. Preliminary data (Durum, Heidel, and Tison, 1960) for the several U.S. rivers included in this study indicate a range of strontium concentration from 0.0075 ppm (Apalachicola River, Fla.) to 0.802 ppm (Colorado River at Yuma, Ariz.).

Except for these data, little information is available on the general occurrence and distribution of strontium in fresh water. Recently, however, considerable interest has developed in the occurrence of strontium in water, soils, plants, and foods, particularly in relation to the fallout hazards associated with the radioactive isotopes of strontium. There are four naturally occurring isotopes of strontium, the predominant one being strontium-88. These isotopes are not radioactive and are nontoxic, at least no more toxic than calcium, an essential element which in its behavior is chemically similar to strontium. Strontium, while being one of the more abundant of the minor elements, is much less abundant than calcium and probably seldom occurs in nature in concentrations which might be harmful.

Two strontium isotopes resulting from nuclear fission, strontium-89 and strontium-90, are among the most hazardous substances present in atomic fall-out or atomic-waste materials. They create a serious hazard to human and animal life when present in water or foods. A knowledge of the concentration levels of strontium in natural water, therefore, is of considerable interest for the evaluation of potential hazards in connection with fallout or atomic-waste disposal. There is little evidence that indicates a physiological preference for calcium with respect to strontium or vice versa. Strontium and calcium are probably assimilated by the body of man and by plants in close to the same relative proportion in which they occur in the water or food material ingested or available to the organism. Because there is no physiological or chemical distinction between strontium-90 and the nonradioactive isotopes of strontium, the presence of natural strontium effectively dilutes the radioactive variety and reduces the amount of strontium-90 taken up by body tissue.

In order to have more extensive, accurate data on the concentration levels of strontium which occur in natural water, the U.S. Geological Survey has made a study of its occurrence and distribution in the natural waters of the United States. The study was made on behalf of the U.S. Atomic Energy Commission and was carried out under the direction of S. K. Love, Chief, Quality of Water Branch, U.S. Geological Survey.

SAMPLING PROGRAM

A program was established which provided for the sampling of 75 of the major rivers and streams of the conterminous United States. Several large rivers were sampled at more than one point so that a total of 85 different sampling points was included. Most of the sampling sites selected are regularly operating stations of the Quality of Water Branch of the Survey. An attempt was made to obtain three samples at each site over a period of several months or a year, in order to obtain samples representing high- , median- , and low-flow conditions at each site. At a few sites this was not possible because they were not sampled on a regular schedule, and multiple sampling was impractical. No attempt has been made to obtain exact flow data, and the designations "high," "medium," and "low" flow are to be considered as representing relative flow conditions only.

The discharge or flow rate varies widely for certain rivers and very little for others. Thus, for some rivers the difference between high and low flow may be very little, while for others it is large. Detailed data on flow rates for most of the rivers included in this report may be found in the U.S. Geological Survey Water-Supply Paper series "Surface Water Supply of the United States," published annually in 14 parts.

A chemical analysis was made of each sample collected. Most of these analyses were made in the laboratory of the district office operating the sampling station and collecting the sample for this study. The district office then transmitted a part of the sample, together with the analytical report, to the Denver Quality of Water laboratory of the Survey where all strontium analyses were made (table 4).

Although this study was primarily intended to provide a survey of strontium concentrations in surface water, a considerable number of ground waters, including some brines, mineral waters, and springs, and other miscellaneous water samples were analyzed for strontium when such samples were available. These additional samples were obtained as a result of sampling for other purposes, but the results of chemical analyses of these samples (including strontium) are included in this report (table 5). The analyses of several brines and highly mineralized waters are also included (table 6).

ANALYTICAL METHODS

Samples containing more than 1.0 ppm of strontium were analyzed by a direct flame-photometric method, utilizing a radiation buffer to minimize the effect of variation in sample composition with respect to other constituents. The determination of strontium by direct flame photometry is not sufficiently sensitive for water whose strontium concentration is less than 1.0 ppm, and two techniques were used for analysis of those waters. One, a flame-photometric method, involved a tenfold concentration of the cationic constituents in the sample by means of a strongly acidic cation-exchange resin before the determination of strontium. By this method, as little as 0.02 ppm of strontium could be detected with certainty. The ion exchange technique, in addition to accomplishing a tenfold concentration of the sample, had the added advantage that anionic interferences such as those from sulfate and phosphate were eliminated, and the final solutions used for the flame-photometric determination were of uniform anionic composition. The flame photometric procedures are described in detail by Horr (1962).

The second method used to determine strontium in samples containing less than 1.0 ppm of strontium was a spectrographic method. The spectrographic copper-spark technique used permitted detection of 0.005 ppm of strontium without prior concentration of the sample and had the added advantage that 20 to 30 ml of sample would suffice for the analysis. The spectrographic method was developed solely for the determination of trace amounts of strontium in dilute water and is not considered reliable for the analysis of water containing more than 500 to 600 ppm of dissolved solids. A detailed description of the spectrographic procedure is given by Skougstad (1961).

CHEMISTRY OF STRONTIUM

Strontium, atomic number 38, is the fourth member of the Group II elements, the alkaline-earth metals. The electron distribution in the strontium atom ($1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 5s^2$) determines its universal divalency in its compounds. This is characteristic of all elements in this group which have no partially filled subshells, and whose outermost electron shell is a completed s-shell. The nucleus may contain 46, 48, 49, or 50 neutrons. Thus, there are 4 stable isotopes of strontium having mass numbers of 84, 86, 87, and 88. The natural distribution of these 4 isotopes gives rise to an average atomic weight for strontium of 87.63 and an equivalent weight of 43.82.

Although no radioactive isotopes of strontium exist in nature, as many as 10 artificially produced isotopes have been identified. The most familiar of these are the isotopes of mass number 89, 90, and 91, which are a part of the material that results from atomic fission.

The other alkaline-earth elements are beryllium ($Z=4$, at. wt$=$ 9.013), magnesium ($Z=12$, at. wt$=$24.32), calcium ($Z=20$, at. wt$=$40.08), barium ($Z=56$, at. wt$=$137.36), and radium ($Z=88$, at. wt$=$226.05). Of the alkaline-earth elements, calcium and magnesium are by far the most abundant, both in the earth's crust and in the

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hydrosphere. Next in general abundance are strontium and barium, often of the same order of magnitude, and finally beryllium and radium, which occur in exceedingly small amounts relative to the others.

Physical properties of the several elements most closely resembling strontium (table 1) indicate that strontium should be intermediate between calcium and barium with respect to its chemical behavior, and in many instances should resemble potassium. This is indeed true, and strontium is commonly found in both calcium and barium minerals and, to some extent, even in potassium minerals, as a result of replacement of ions of these elements in the crystal lattice of their minerals. Strontium occurs in barite, where it replaces barium, and in aragonite, calcite, gypsum, and anyhdrite, where it replaces calcium. No doubt the widespread distribution of strontium in trace amounts in igneous rocks is due to its ability to substitute for potassium, particularly in potassium feldspars, or for calcium in other igneous rock minerals.

TABLE 1.—*Physical properties of strontium and related elements*

	Ca	Sr	Ba	K
M° radius..................angstroms..	1.97	2.15	2.22	2.02
M^{n+} radius..................do....	.99	1.13	1.35	1.33
M^{n+} radius, aqueous solution......do....	4	2.5	2.5	2.3
Ionic potential (ionic charge/ionic radius).	2.02	1.77	1.48	1.50
E° at 25°C, aqueous solution......volts..	2.87	2.89	2.90	2.92
Ionization potential:				
I..................do....	6.09	5.67	5.19	4.32
II..................do....	11.82	10.98	9.95	....

Strontium forms chemical compounds analagous to those of calcium and barium. The properties of such compounds are usually intermediate between those of the same compounds of calcium and barium. Thus, the carbonates, sulfates, chromates, and phosphates of all three metals are sparingly soluble in water, the solubility decreasing with increasing atomic number. In fact, the very low solubility of barium salts restricts the movement of barium through soils and by water transport. A few parts per million of sulfate in water, for example, precludes the possibility of the presence of much barium. Strontium sulfate, however, is much more soluble, hence appreciable amounts of strontium may exist in water containing significant concentrations of sulfate.

Strontium finds its way into natural water in much the same way as does calcium. Through normal weathering processes, water in contact with soil and rock materials dissolves appreciable amounts of minerals and other constituents largely through the action of hydrogen ions carried by the water. The carbonic acid-bicarbonate equilibrium in water provides a supply of hydrogen ions and permits retention of the reaction products in solution, as in the case of strontium and calcium, through the formation of soluble bicarbonates. Although carbonic acid, resulting from dissolved carbon dioxide, is a principal factor in causing attack on soil and rock particles, other factors are also effective. Organic solutes found in soil moisture, acid clays, strong mineral acids (particularly sulfuric and sulfurous acids formed by oxidation of sulfide minerals), and organic chelating compounds may also be effective under certain conditions.

Strontium in natural water may be removed or redeposited by several mechanisms and reactions. Strontium carbonate is less soluble than calcium carbonate and precipitates at a pH below that at which calcite precipitates. When calcium carbonate precipitates, and if strontium is present in the same solution, some strontium will almost certainly accompany the calcium by coprecipitation, even though the solubility product of strontium carbonate may not be exceeded. This is true also when other substances, such as ferric hydroxide, precipitate from water. Some strontium may be caught or adsorbed to the colloidal precipitate and dragged down with it

Other insoluble strontium compounds, such as sulfates or phosphates, may be formed. Strontium may also be adsorbed through ion exchange with clay minerals, or it may exchange with calcium minerals such as calcite or aragonite. In this respect, the relatively small radius of the hydrated strontium ion indicates a greater tendency for exchange than the larger calcium ions. This is generally true and it has been observed that strontium is more strongly held by exchange materials than is calcium.

The sources of strontium in natural water are mainly the trace amounts of strontium found in nearly all limestones and widely distributed in igneous and metamorphic rocks. When the strontium in in water is derived from these sources, the relative amounts of strontium and calcium do not usually differ greatly from their proportions in the rock material. Certain natural waters have much higher Sr/Ca ratios (Sr atoms per 1,000 Ca atoms) and indicate that the water has been in contact with strontium-mineral deposits, either celestite ($SrSO_4$) or strontianite ($SrCO_3$). Such deposits usually occur as beds or lenses in limestone deposits or in anhydrite or gypsum. Celestite frequently occurs disseminated in limestone and dolomite.

Probably relatively few waters are saturated with respect to either strontium carbonate or strontium sulfate. The amount of strontium present is largely controlled by its abundance in the rock material that has gone into solution.

The chemical similarity of strontium and calcium suggests that correlations may exist between these two elements with respect to their occurrence in the rocks and minerals. Turekian and Kulp (1956), reporting on the distribution of strontium in various rock materials, offer evidence that there is a direct relationship between the calcium content of granites and the amount of strontium present in these granites. They found that whereas all granitic rocks contain, on an average, an estimated 0.0285 percent strontium, granodiorites containing 1.0 to 5.0 percent calcium contain an estimated average of 0.0440 percent strontium. On the other hand, granites having 0.1 to 1.0 percent calcium contain an average of 0.0100 percent strontium. Previous estimates of the average strontium content of granitic rocks, 0.0090 percent (Noll, 1934) and 0.0120 percent (Hevesy and Wurstlein, 1934), were considerably lower. It is generally apparent, however, that in granitic rocks the amount of strontium increases as the amount of calcium increases.

These same investigators also estimated the average strontium content of basaltic rocks to be about three times as great as previously reported and found an average of 0.0465 percent strontium in all basalts, a figure that is considerably higher than the average for granites (0.0285 percent) and slightly higher than the average for high-calcium granites (0.0440 percent).

The average strontium content of all limestones was found by Turekian and Kulp (1956) to be 0.0610 percent; shales contained only about one-half of this amount. They concluded that sandstones probably contain, on an average, no more than 0.0020 percent strontium.

On the basis of these observations, some estimate of the probable occurrence of strontium in water might be projected. That is, in water draining areas where surficial geology consists primarily of basalt or sedimentary rocks, the proportion of strontium to calcium would be expected to be significantly less than in water draining areas of granitic igneous rocks. Such an extension of the geologic implications must be tempered with consideration of additional factors which can affect the behavior of strontium when it is dissolved in water. The movement of water through soil and rocks, involving contact with clay minerals and finely divided sediment material in the soil and in suspension in a stream, permits opportunity for several types of reactions which may alter the ratio of strontium to other major constituents in the water. Turekian and Kulp were unsuccessful in their attempts to correlate the occurrence of strontium with potassium.

STRONTIUM CONTENT OF WATER

SURFACE WATER

All surface-water samples collected as a part of this study contained a detectable amount of strontium (more than 0.005 ppm). The higher strontium concentrations were found in the streams of the Southwest, including eastern Arizona, New Mexico, western Oklahoma, and northern and western Texas, where the total dissolved-solids content of the surface waters is also the highest of any area of the conterminous United States. In many places in this area rocks of rather high solubility occur at or near the land surface. The low average-annual precipitation together with high rates of evaporation and loss of surface water to ground-water recharge tends to reduce stream-discharge rates downstream from the source and to increase the dissolved-solids concentration carried by the stream. The high-salinity streams of this area also carry proportionally more strontium, usually 1.5 ppm or more, and some as much as 5.4 and 9.5 ppm, as in the samples from the Double Mountain Fork and the Salt Fork of the Brazos River near Aspermont, Tex., respectively (table 4).

By contrast, streams of most of the Atlantic slope basins, Southeastern United States, the upper Great Lakes region, and the Pacific Northwest contain relatively low concentrations of strontium. This fact coincides with observations which may be made on the characteristics of rivers and streams of these areas. In general the salinity of water draining these areas is low, the average annual rainfall is relatively high, the evaporation rate is low, and the loss from streams due to ground-water recharge is low. Rarely do streams in these areas contain more than 0.5 ppm of strontium and frequently the strontium content is much less, especially during periods of high discharge.

Rivers of the rest of the Nation generally contain between 0.5 and 1.5 ppm of strontium. Several exceptions to these generalizations may be noted; the exceptions usually involve higher concentrations of strontium in a stream than would be expected from the generalizations just stated. One such exception is the high concentration of strontium in the Maumee River, Ohio. Samples taken at Waterville (table 4) contained 0.44 to 1.0 ppm of strontium. (An additional sample, containing 1.4 ppm of strontium, was analyzed but was not included in table 4 because of lack of other data.) This is considerably more than most of the rivers of the midcontinent area, more than was observed in samples collected from the Ohio, Kentucky, Wabash, and Cumberland Rivers, for example. Feulner and Hubble (1960) have pointed out the high strontium content of certain ground waters in an area of northwestern Ohio, and the celestite deposits and celestite-rich limestones and glacial deposits of that area. These celestite-bearing limestones of Late Silurian age extend north and northwest of Champaign County, Ohio, and no doubt contribute significant amounts of strontium to streams which are tributaries of the Maumee and which, therefore, serve to increase strontium content in the Maumee even as far downstream as Waterville, which is close to the mouth of the river.

Another obvious exception resulting from localized conditions involves an area along the east coast of Florida. Odum (1951, p. 20–21) reported strontium concentrations in water from several springs and spring-fed rivers which are higher than might be expected on the basis of the generalizations previously made. The results of the present study also indicate the presence of somewhat higher strontium concentrations in certain of the Florida rivers sampled, particularly rivers along the eastern coast. Thus, the St. Johns River showed concentrations of strontium ranging from 0.68 to 1.1 ppm. Other Florida rivers sampled contained 0.029 to 0.11 ppm of strontium, which is in accord with the expected concentration. The higher strontium concentration found in samples taken in the eastern part of the State may be attributed to underlying limestones containing a high concentration of strontium and to a significant flow of ground water to surface streams from these permeable limestone formations.

The average strontium concentration of samples obtained at each site are shown in figure 10.

Strontium-calcium ratios (Sr atoms per 1,000 Ca atoms) were calculated for all samples in which both ions were determined (table 7). The ratios ranged from 0.40 to 15.75. Calculation of an average Sr/Ca ratio has little significance because of the variability among the samples and the great irregularity in distribution of the sampling sites. However, it may be pointed out that the Sr/Ca ratios in three of the rivers sampled were exceptionally high: the St. Johns River near Cocoa, Fla.; the Canadian River at Logan, N. Mex., and the Paria River, at Lees Ferry, Ariz. Two samples from the Paria River had ratios of 10.5 and 4.19; the river is one of the sources of the Yuma Main Canal, one sample of which also had an unusually high Sr/Ca ratio (11.2) that probably reflected the upstream sources.

A median-flow sample from the Brazos River at Richmond, Tex., also showed an unusually high Sr/Ca ratio. Two other samples, one at high flow and one at low flow showed ratios of 2.60 and 3.68, respectively, whereas the median-flow sample had a ratio of 12.6. This sample also differed in other respects from the other two samples from this river. Sodium and chloride concentrations were approximately 6 times the amount found in the other 2 samples. Concentrations of

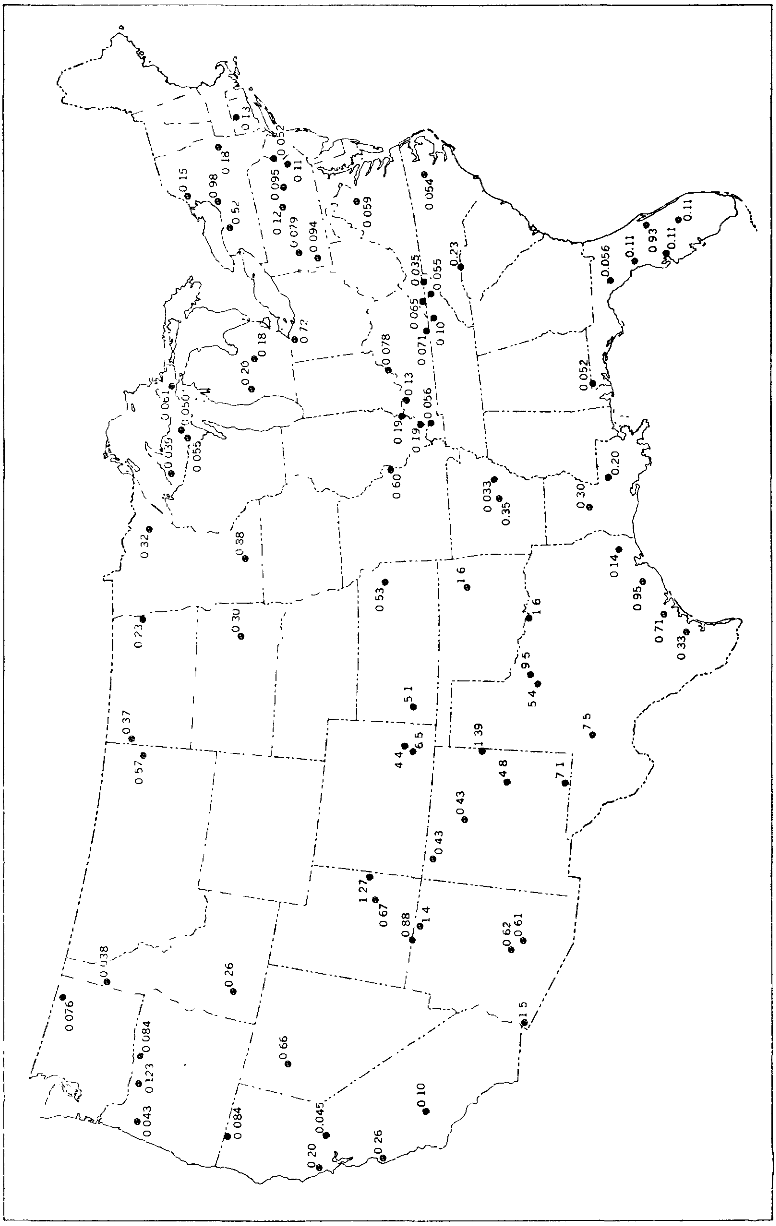

FIGURE 10.—Average strontium concentration (parts per million) in surface water.

the other major constituents did not increase to nearly the same extent: calcium and magnesium only about twice, potassium by about one-half, sulfate about three times, and bicarbonate only very little. This suggests drainage of salt water bearing significant strontium, since the strontium concentration increased about five times.

The median Sr/Ca ratio for all samples was 3.2. Those samples which had a ratio greater than twice the median are listed in table 2.

TABLE 2.—*Surface-water samples having a* Sr/Ca *ratio greater than twice the median for all samples*

River	Location	Flow stage	Sr in total dissolved solids (percent)
St. Johns	Cocoa, Fla	High	16. 3
Do	do	Median	15. 7
Canadian	Logan, N. Mex	High	15. 0
Do	do	Median	14. 7
Do	do	Low	14. 4
Do	do	do	14. 0
Brazos	Richmond, Tex	Median	12. 6
Arkansas	Tulsa, Okla	do	11. 4
Yuma, Main Canal	Yuma, Ariz	do	11. 2
St. Johns	Cocoa, Fla	Low	11. 1
Canadian	Logan, N. Mex	Median	11. 0
Paria	Lees Ferry, Ariz	Low	10. 5
Canadian	Logan, N. Mex	do	9. 7
Yuma, Main Canal	Yuma, Ariz		8. 51
Green	Green River, Utah	High	8. 47
Neches	Evadale, Tex	Low	8. 37
Humboldt	Rye Patch, Nev	do	8. 22
Arkansas	Tulsa, Okla	do	7. 75
Purgatoire	Las Animas, Colo		7. 71
Kissimmee	Okeechobee, Fla	High	7. 38
Rappahannock	Remington, W. Va		7. 13
Pecos	Puerto de Luna, N. Mex	Low	7. 77
Rio Grande	San Ildefonso, N. Mex	Median	7. 60
San Juan	Archuleta, N. Mex	Low	6. 70
Salt	Stewart Mt. Dam, Ariz	High	6. 64
American	Fair Oaks, Calif		6. 50

It will be observed that practically all of the rivers with unusually high Sr/Ca ratios are located in the southwest and along the east coast of Florida. A single exception is the Rappahannock River. One sample taken at approximately median flow showed a ratio twice the average ratio observed on three other samples taken over a period of several months. The chemical quality in the Rappahannock at Remington does not vary significantly throughout the year. However, it should be noted that in the one sample which showed a high Sr/Ca ratio, the sulfate concentration was also proportionally much greater than the median or nominal concentration of sulfate for this stream. While the concentrations of Ca, Mg, Na, K, HCO_3, and Cl, were about the same or slightly below the median concentration for these ions, the sulfate concentration in this particular sample was about double the median for this ion. This would indicate a possible pollution of the stream with $SrSO_4$ at or about the time of sampling, or a stream entering the Rappahannock above the sampling point and draining an area containing strontium-rich minerals.

Two rivers in Florida, both draining eastern coastal areas, showed unusually high Sr/Ca ratios. Ratios of 16.3, 15.7, and 11.1 were obtained on 3 samples from the St. Johns River near Cocoa, Fla. Two of these, however, are low-flow samples since the discharge measurements, 411 and 357 cfs (cubic feet per second), respectively, are much below the 1958 water-year median of 1,368 cfs, and not much greater than the minimum of 218 crs for that year. The 1958 water-year maximum discharge was 3,990 cfs and occurred on October 4–5. The Sr/Ca ratio for the high-flow sample, 16.3. at 2,323 cfs, is only slightly larger than the ratio for one of the low-flow samples, 15.7 at 411 cfs.

The Kissimmee River, sampled near Okeechobee, Fla., also showed a fairly high Sr/Ca ratio in the single sample obtained at this site. Although the discharge data are not available for this sample, the date of sampling, May 1–10, indicated that it was probably sampled at a time of about median flow. The chemical analysis of this sample shows a fairly high magnesium content and considerable sodium chloride, although the total concentration of dissolved solids is low and the water may be classified as a soft water.

Sr/Ca ratios in rivers of the rest of the Nation ranged from 0.40 to 6.4. There is no consistent correlation between discharge and the Sr/Ca ratio. In some streams the ratio increases with a decrease in discharge rate while for others the opposite is true. In general, the greatest variations in the Sr/Ca ratio in a single river sampled at different flow rates occurred when the ratio was much larger than the median. Thus, the Sr/Ca ratio in 6 samples from the Canadian River at Logan, N. Mex., ranged from 9.7 to 15.0. Similarly, the ratio in the Arkansas River, at Tulsa, Okla., ranged from 6.6 to 11.4.

In some rivers, the Sr/Ca ratio does not vary appreciably with discharge rate, as, for example, the Cumberland, Monongahela, St. Lawrence, Lehigh, Mohawk, Oswego, Susquehanna, and Roanoke Rivers.

The average Sr/Ca ratio for samples collected at each site is shown in figure 11.

Another indication of the general distribution of strontium in surface water may be obtained by calculating the strontium content in the total dissolved material carried by the river. This information was available (table 7) for the great majority of samples. Figure 12 shows the distribution of values. The strontium content ranged

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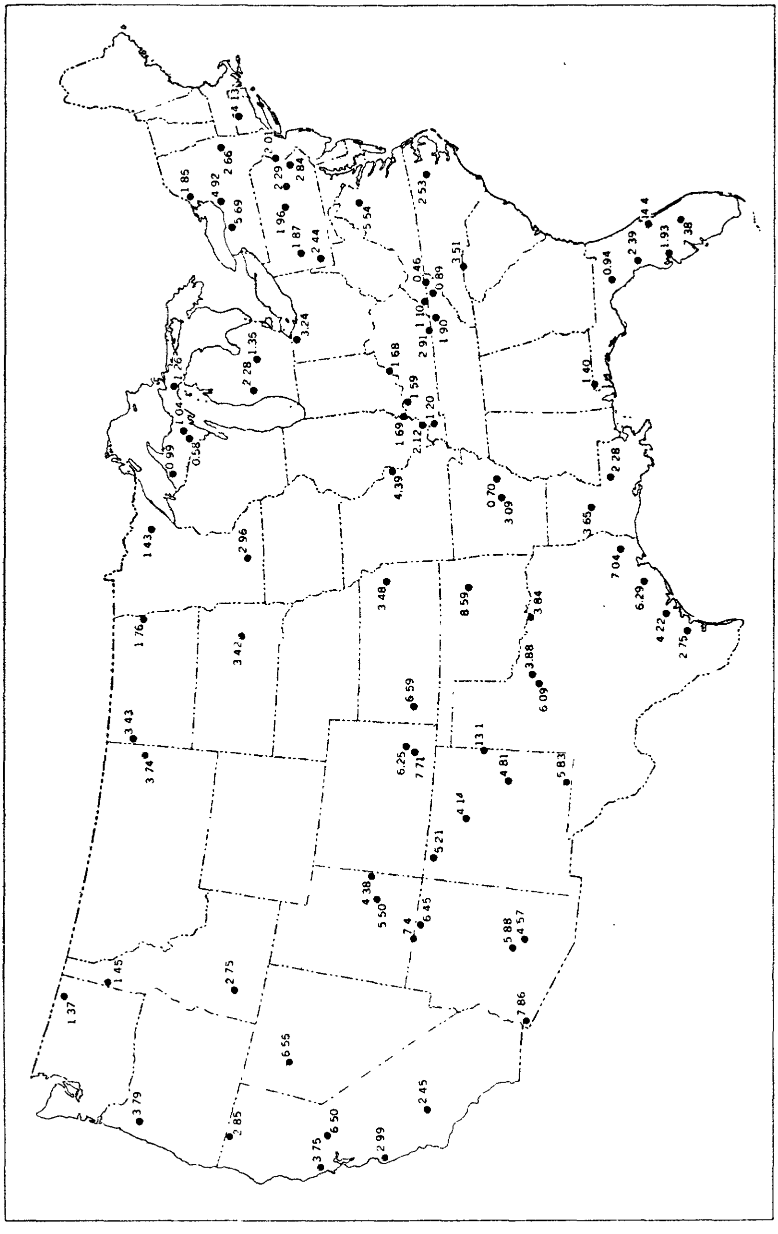

FIGURE 11.—Average Sr/Ca ratio in surface water.

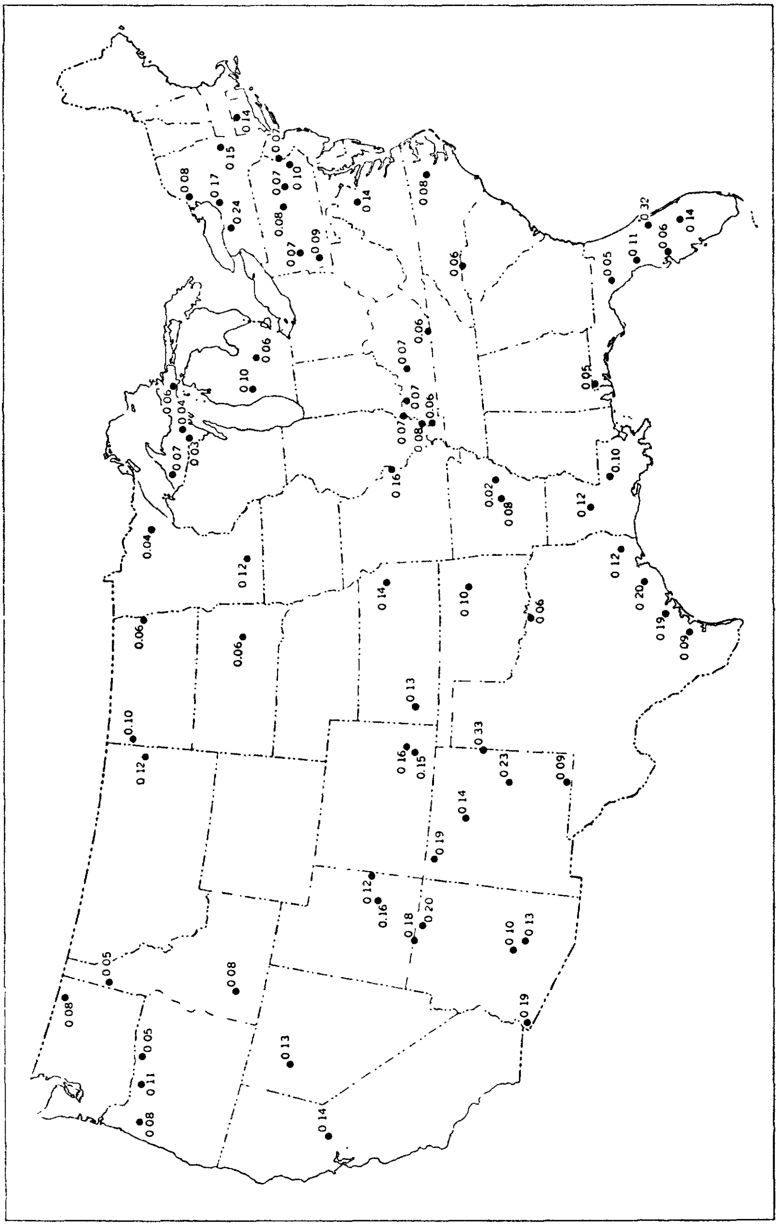

FIGURE 12.—Average strontium concentration (percent) in total dissolved solids in surface water.

from 0.01 to 0.38 percent, 0.09 percent being the median for all samples. Very low concentrations of strontium were found in the Embarrass (0.03, 0.04 percent), Escanaba (0.04 percent), and Ford (0.03 percent) Rivers, all in northern Minnesota or Michigan, and in the Escambia River (0.05 percent), in Florida. The White River, sampled at Clarendon, Ark., also had a very low concentration of strontium, 0.03, 0.02, and 0.02 percent being found in 3 samples analyzed. A high-flow sample from the James River at Huron, S. Dak., contained only 0.03 percent strontium, whereas near-median-flow and low-flow samples from this river contained 0.07 and 0.08 percent, respectively.

There is no general correlation between flow and the concentration of strontium. Thus, the concentration of strontium in the Pecos River at Puerto de Luna was observed to vary threefold, from 0.12 to 0.36, over a period of a year. Similarly the percentage of strontium in the Brazos River at Richmond, Tex., varied from 0.11 at high flow (42,980 cfs) to 0.35 at median flow (4,685 cfs) and to 0.13 at low flow (the unusual chemical characteristics of the median-flow sample have been noted on page 75).

Many other rivers showed only slight variation in percentage of strontium throughout the year, as, for example, the Yakima River at

TABLE 3.—*Surface-water samples having a strontium content greater than twice the median for all samples*

River	Location	Flow	Sr in total dissolved solids (Percent)
Canadian	Logan, N. Mex	High	0.38
Pecos	Puerto de Luna, N. Mex	Low	.36
Brazos	Richmond, Tex	Median	.35
St. Johns	Cocoa, Fla	High	.32
Canadian	Logan, N. Mex	Median	.31
Green	Green River, Utah	High	.31
Canadian	Logan, N. Mex	Low	.29
Yuma, Main Canal	Yuma, Ariz	Median	.27
Genesee	Rochester, N. Y.		.25
Paria	Lees Ferry, Ariz	Low	.25
Colorado	do	High	.23
San Juan	Archuleta, N. Mex	Low	.23
Do	do	do	.23
Genesee	Rochester, N.Y	do	.22
Yuma, Main Canal	Yuma, Ariz		.21
Colorado	Lees Ferry, Ariz	Low	.20
Gila	Kelvin, Ariz	High	.20
Pecos	Puerto de Luna, N. Mex	Low	.20
Rio Grande	San Ildefonso, N. Mex		.20
Gila	Kelvin, Ariz	Median	.19
Guadalupe	Victoria, Tex	High	.19
Mississippi	St. Louis, Mo		.19
Oswego	Oswego, N.Y	Median	.19

Northport, Wash., the White River at Clarendon, Ark., the Red River of the North at Grand Forks, N. Dak., and the Delaware and Lehigh Rivers, Pa. The strontium content trends to fluctuate to a greater extent in those rivers in which it is in excess of 0.1 percent of the total dissolved-solids content. If the strontium content in a river is close to, or below, the observed median for all rivers sampled, the variations in strontium content in samples taken throughout the year and at different flow stages are more likely to be small.

Surface-water samples found to have a strontium content which is more than twice the median for all samples analyzed are shown in table 3.

GROUND WATER

In addition to the surface-water sampling program, 175 samples of ground water were analyzed for strontium. Unlike the surface-water program, however, the ground-water samples were not obtained by a sampling program planned for this purpose, but were analyzed as they became available to the laboratory from various sources. Most of the ground-water samples were taken from public water supplies and were obtained in connection with other current projects. These samples were analyzed only by the direct flame-photometric procedure, whose limit of sensitivity is 0.2 ppm of strontium. No attempt was made to determine strontium in samples containing less than this amount. Many of the samples did contain less than 0.2 ppm of strontium (table 5).

A wide range in strontium concentration was observed in ground water. The unusually high concentration of strontium in ground water of east-central Wisconsin has previously been reported by Lohr and Love (1952) and by Nichols and McNall (1957). The Sr/Ca ratios calculated from the chemical analyses of water from 3 Waukesha, Wis., wells reported by Lohr and Love are 396, 285, and 208. These values are higher, by a factor of 100 to 300, than the maximum ratio calculated for any surface water sampled in the present study. The concentration of strontium in the dissolved solids of these samples is also exceptionally high: 11.8 percent, 9.8 percent, and 7.9 percent, respectively.

Two samples obtained from this area of Wisconsin for the present project contained 36.0 to 24. 4 ppm of strontium. These samples, one from a drilled well at Campbellsport in Fondulac County, the other from a drilled well at Kaukauna in Outagamie County, were not from the area of highest previously observed strontium concentrations. Nevertheless the Campbellsport sample had a Sr/Ca ratio of 162 and contained 5.9 percent strontium, and the Kaukauna sample a Sr/Ca ratio of 65.5 and a strontium content of 3.16 percent.

Feulner and Hubble (1960), in their study of the occurrence of strontium in surface and ground water of Champaign County, Ohio, found that, of 22 drilled-wells sampled, the water of 7 contained between 17 and 20 ppm of strontium and 1 contained 30 ppm. The Sr/Ca ratios in these 8 samples ranged from 89.7 to 132, and the strontium content in the dissolved solids ranged from 4.4 to 5.4. Other samples from this group of 22, with but one exception, had Sr/Ca ratios within the range generally found in surface water of the conterminous United States. However, in only two of the Champaign County wells was the strontium content within the range found in the Nation's surface waters.

The data of Feulner and Hubble are somewhat less complete for surface water of the same area, particularly for samples which were found to contain in excess of 1 ppm of strontium. For the most part, however, the surface-water samples showed Sr/Ca ratios of from 1.2 to 19.0, calculated on the basis of their reported results. The analyses of samples from two springs draining into Nettle Creek differed markedly from the others. The Sr/Ca ratios, 56 and 60, are several times as large as those found in most surface water.

The chemical data (including strontium concentrations) for ground-water samples are given in table 5. Most of the samples analyzed contain less than 0.2 ppm of strontium. Ground-water samples collected from Iowa and Kansas, however, contained more. Of 15 samples collected in Iowa, 4 contained less than 0.2 ppm of strontium. The strontium content of the other 11 samples ranged from 0.8 to 8.8 ppm. Of 15 samples collected from different wells in Kansas, 5 contained 0.2 ppm, or less, of strontium, 9 contained from 0.8 to 1.6 ppm, and 1 sample, from Eskridge, in Wabaunsee County, contained 9.2 ppm.

Several samples from ground-water sources in Eddy County, N. Mex., also contained considerable amounts of strontium, as much as 8.0 ppm in 1 sample. A single sample from Wayne County, N.Y., contained 13 ppm of strontium.

Sixty percent of the ground-water samples tested contained 0.2 ppm, or less, of strontium. Certain brine samples, however, contained unusually high concentrations; as much as 2,960 ppm in a sample from a brine source at Midland, Mich. Another sample from a brine well at Orlando, W. Va., contained 2,200 ppm of strontium.

Except for these brines, however, the strontium content generally ranged from 0.2 to 59 ppm, and only 9 samples of approximately 175 analyzed contained more than 10 ppm.

The chemical analyses of several brine samples are shown in table 6. The Sr/Ca ratio in these samples ranges from 4.4 to 28.6. These brines also show a high concentration of strontium in the dissolved solids, ranging from 0.07 to 0.84 percent. One brine sample, containing 0.07 to 0.84 percent. One brine sample, containing 0.07 percent strontium in the dried residue, was close to the median (0.09 percent) for all surface water tested. Another sample contained only slightly more strontium, whereas other brine samples contained from 2 to nearly 5 times the median strontium content in surface water. The maximum strontium content in any surface water tested was 0.38 in a sample from the Canadian River, at Logan, N. Mex. Four brine samples contained from 0.25 to 0.33 percent, and 2 samples contained 0.6 and 0.84 percent.

SUMMARY

A survey of the occurrence of strontium in the major rivers of the Nation shows that concentrations may range from 0.007 ppm to nearly 15 ppm. The percentage of strontium in the total dissolved-solids content carried by these streams ranges from 0.01 to 0.38. Relatively high concentrations of strontium occur in the streams of the southwest, where concentrations generally exceed 1.5 ppm and are locally as high as 13.7 ppm. Streams of this area are generally of relatively high salinity. They drain areas of low annual rainfall and of generally high evaporation losses.

Streams of the Pacific Northwest, most of the Atlantic Coastal Plain, and northern Minnesota and Michigan generally contain only small concentrations of strontium, usually less than 0.5 ppm, and frequently as little as 0.01 ppm or less.

Strontium concentrations in ground water vary greatly. Potable waters may contain up to 50 ppm. but certain brines from wells and other highly mineralized waters may contain several thousand parts per million. In addition to previously known areas of ground waters with a relatively high strontium content in eastern Wisconsin and west-central Ohio, several ground-water samples from Iowa, Kansas, and New Mexico were found to contain more than 3.0 ppm of strontium.

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TABLE 4.—*Chemical analyses of surface waters*

[Results in parts per million except as noted]

River and sampling point	U.S.G.S. gaging station identification No.	Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium-magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH
Alafia: At Lithia, Fla.	02B3015	Oct. 29, 1959	525	18	26	0.2	0.11	10	1.1	19	0	40	18	0.7	174	66	50	226	6.4
Allegheny: At Kittanning, Pa.	03A0365	Mar. 30–Apr. 22, 1958.	33,700	4.6	14	1.9	.063	5.7	1.1	19	0	25	8.8	1.5	77	43	28	126	6.8
		Aug. 4, 1958	10,400	14	21	4.9	.077	7.9	1.5	32	0	50	12	.9	127	73	47	200	7.0
		Oct. 5, 1958	9,300	----	----	----	.098	13		41	0	44	17	----	----	75	42	218	7.3
American: At Fair Oaks, Calif.	11 4465	Oct. 13, 1959	640	----	----	----	.050	----	----	----	----	----	----	----	----	22	0	57.2	7.2
		Sept. 18, 1958	----	----	2.8	1.9	.040	1.7	.6	18	0	----	----	----	28	15	0	39.8	6.5
Arkansas:																			
At Las Animas, Colo.	07 1240	Jan. 31, 1960	----	18	320	107	4.4	374	5.2	296	0	1,590	107	8.0	2,830	1,240	996	3,300	7.7
At Lamar, Colo.	07 1330	Jan. 31, 1960	----	21	352	170	5.1	584	6.8	282	0	2,320	138	6.1	3,980	1,580	1,350	4,430	7.9
At Springs Bridge, near Tulsa, Okla.	07 1644	Apr. 2–10, 1958	[1] 19,700	11	69	19	1.0	323		148	----	116	500	5.9	1,190	250	128	1,900	8.1
		Mar. 21–25, 1958	[1] 13,600	----	80	26	2.0	506		160	----	135	800	5.7	1,710	305	174	2,940	8.2
		Mar. 6–8, 1958	[1] 4,800	----	106	32	1.8	613		168	----	196	980	5.2	2,100	395	258	3,590	8.2
At Little Rock, Ark.	07 2635	July 12–20, 1958	79,000	4.3	39	7.9	.21	50	4.2	108	0	46	74	1.9	305	130	42	----	----
		Apr. 14–20, 1958	60,400	----	37	8.3	.18	54	2.7	94	0	42	85	3.6	313	126	50	----	----
		Sept. 10–12, 1958	12,800	----	67	15	.67	141	6.4	188	0	75	220	1.0	680	228	74	----	----
Brazos:																			
Double Mountain Fork: Near Aspermont, Tex.	08 0805	Oct. 4–11, 14–20, 1958.	8.3	11	405	50	5.4	629		116	0	1,130	930	0	----	1,220	1,120	4,700	7.9
Salt Fork, Near Aspermont, Tex.	08 0820	Oct. 4–11, 14–27, 1958.	3.3	11	1,120	297	9.5	13,600		156	0	2,800	21,700	----	----	4,020	3,890	53,900	7.8
At Richmond, Tex.	08 1140	May 1–10, 1958	42,980	13	42	5.3	.24	19	3.4	116	0	33	28	3.8	210	127	32	345	7.4
		July 15–31, 1958	4,685	14	80	13	2.2	111	4.9	156	0	107	183	1.5	632	253	125	1,040	7.2
		Oct. 10–14, 21–25, 1958.	2,590	14	51	8.4	.41	48	4.8	145	0	47	73	2.0	319	162	42	556	7.4
Broad: Near Boiling Springs, N.C.	02A1515	Apr. 21–30, 1958	4,320	9.8	2.0	1.7	.010	1.6	.6	12	0	1.7	1.5	.9	26	12	----	29.2	7.1
		July 11–20, 1958	1,650	15	3.4	.6	.040	2.4	1.1	16	0	1.8	2.4	1.3	39	11	----	34.9	6.6
		June 21–30, 1958	1,240	16	3.2	1.2	.020	1.9	.6	17	0	1.3	2.3	1.0	37	13	----	38.5	6.9
Canadian: At Logan, N. Mex.	07 2270	Aug. 15–17, 1959	2,180	20	29	7.9	.95	68	----	181	0	61	31	.5	----	105	0	493	7.7
		July 6, 1958	1,440	13	40	8.6	.85	27	3.3	184	0	24	17	.1	225	136	0	372	8.1
		July 6, 1958	(approx.) 500	13	33	8.3	.80	42	3.7	148	0	56	25	.1	260	116	0	468	8.4
		July 11–14, 1959	86	19	33	8.1	1.06	116	----	218	0	109	59	1.0	----	116	0	734	7.7
		July 19, 1958	45	10	59	16	1.8	124	6.5	175	0	182	117	.4	612	213	70	992	8.1
		Sept. 16–19, 1959	5	12	92	38	2.9	363	----	261	0	398	398	.8	----	384	170	2,310	7.9

See footnotes at end of table.

TABLE 4.—*Chemical analyses of surface waters*—Continued

[Results in parts per million except as noted]

River and sampling point	U.S.G.S. gaging station identification No.	Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids (residue at 180 °C	Hardness as $CaCO_3$: Calcium-magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (kmhos at 25 °C)	pH
Clinch: At Clinchport, Va.		Apr. 30, 1959			27	7.1	0.065	3.8	1.8	102	0	17	3.0	2.4		97	13	207	7.5
Clinch: At Speers Ferry, Va.	03B5270	April 30, 1959	1,640		28	7.1	.055	3.9	1.4	106	0	14	3.0	1.8		99	12	210	8.0
Coeur D'Alene: Near Cataldo, Idaho.	12 4135	July 14–Aug. 1,2,4, 1958.	533		12	5.5	.038	3.2		31	0	36	.8	.3	84	52	27	130	6.7
Colorado: Near Cisco, Utah	09 1805	June 1, 8, 11–19, 1958.	27,300	9.9	47	9.5	.42	27	1.8	113		94	21	2.7	276	157	64	441	7.8
		Oct. 1–17, 27–31, 1958.	2,560	11	161	70	1.4	213	7.3	224	0	690	190	11	1,560	688	504	2,090	8.1
		Sept. 1–13, 15–30, 1958.	2,540	14	180	72	2.0	215	6.6	222	0	768	168	12	1,620	746	564	2,120	7.4
At Lees Ferry, Ariz.	09 3800	May 22–31, 1959	22,130		59	14	.9	41		156	0				383	206	78	572	7.7
		July 21–24, 26–28, 1959.	6,150		90	24	1.1	87		181	0				654	322	174	978	7.8
		Aug. 31, Sept. 2–21, 1959.	3,980		148	42	2.2	146		219	0				1,120	544	364	1,540	7.8
Columbia: At Northport, Wash.	12 3995	Dec. 15–25, 1958	38,600	5.6	24	4.9	.072					15	2.0	.1					
		Jan. 29–Feb. 15, 1960.					.08	2.0		82	0				98	78	11	172	7.3
Columbia: At the Dalles, Oreg.	14 1057	June 1–22, 1958	495,600				.064	4.0		62	0				79	54	3	121	7.1
		Aug. 14–31, 1958	112,100				.095	6.6		82	0				102	75		172	7.1
		Oct. 16–30, 1958	103,000				.21	10		95	0				123	82		204	7.9
Copper Creek: Near Gate City, Va.	03B5260	Apr. 30, 1959	131		35	12	.035	1.9	1.2	158	0	4.3	3.0	2.8		137	7	264	7.9
Cumberland: At Williamsburg, Ky.	03B4040	Apr. 23–May 2, 1958.	16,130	7.2	6.3	3.2	.041	5.2	1.2	21	0	20	2.0	.9	74	28	12	97	6.4
		Jan. 26–Feb. 12, 1958.	6,090	9.3	7.8	3.7	.051	7.5	1.1	25	0	27	3.0	1.0	74	34	14	117	6.7
		Sept. 13–30, 1958	210	3.7	20	8.6	.12	36	2.7	101	0	65	7.5	.5	195	86	2	326	7.0
Delaware: At Morrisville, Pa. (Trenton, N. J.)	01B4635	Apr. 4–23, 1958	44,310	5.3	8.5	1.9	.042	2.3	.6	18	0	15	2.1	2.1	56	29	14	78	6.6
		July 13, 1958	5,540				.053	7.1		49	0	20	4.0	4.7		55	15	134	7.0
		Sept. 18, 1958	3,640	4.3	16	6.1	.061	4.8	2.9	48	0	28	5.5	4.7	95	29	14	167	6.9
Embarrass: At Embarrass, Minn.	04 0170	July 24, 1958	50	12	12	4.4	.041	2.8	.5	50	0	11	1.0	2.5	110	48	7	98.0	6.4
		May 23, 1958	47	5.3	8.0	2.4	.023	2.4	.1	27		11	0	1.6	85	30	8	57.4	6.8

Escambia: Near Century, Fla.	02B3755	Nov. 19, 1958	1,420	12	17	.4	.052	7.9	1.2	40	0	4.8	16	.7	97	44	11	--------	----
Escanaba: At Cornell, Mich.	04 0590	Jan. 14, 1960	--------------	8.6	22	8.8	.050	.9	1.0	98	0	11	.2	.8	115	91	11	181	7.5
Ford: Near Hyde, Mich	04 0595	Jan. 14, 1960	--------------	8.6	43	14	.055	.9	1.0	182	0	15	1.0	.6	192	165	16	337	7.9
Genesee: At Rochester, N.Y.	04 2320	Jan. 19, 1960	--------------	4.1	36	8.3	.50	13	1.6	81	0	50	25	4.6	202	124	58	337	6.9
		Sept. 17, 1958	1,140	2.7	48	9.2	.53	21	2.2	108	0	60	39	.8	244	158	70	421	7.0
Gila: At Kelvin, Ariz	09 4740	Aug. 6, 1958	2,860	28	63	13	.95	71	5.0	220	0	138	33	.2	482	210	30	715	7.6
		Aug. 9, 1958	698	24	60	12	.9	75	5.4	167	0	131	71	.2	476	199	62	736	7.8
		Sept. 1-14, 16-30, 1959.	269	35	54	8.6	.48	72	5.7	194	0	73	66	3.4	447	170	11	661	7.9
		Jan. 30, 1959	225	26	110	13	.11	144	7.3	190	0	214	195	.3	860	330	174	1,300	7 4
Green: At Green River, Utah	09 3150	June 1-30, 1958	19,730	11	43	12	.8	27	1.8	148	----	76	10	1.6	259	156	35	411	8.0
		Aug. 1-31, 1958	1,792	8.5	67	29	.6	89	3.2	204	0	246	36	1.7	612	286	119	915	7.6
		Oct. 1, 2, 5-31, 1958	1,470	7.3	70	37	.6	115	3.1	217	0	333	46	1.4	741	326	148	1,100	8.2
At Lock & Dam No. 1, Spottsville, Ky.	03A3215	Apr. 11-20, 1958	--------------	9.0	30	5.6	.080	5.0	1.0	91	0	26	6.0	2.8	136	98	24	224	7.2
		May 21-31, 1958	--------------	8.7	34	7.0	.14	6.8	1.1	94	0	42	7.5	3.0	165	114	37	265	6.9
		Oct. 1-10, 1958	--------------	11	46	9.1	.17	13	2.2	120	0	54	19	2.0	218	153	54	369	7.2
Guadalupe: At Victoria, Tex.	08 1765	May 11-21, 1958	3,225	18	77	15	.71	26	2.9	264	----	31	38	9.8	378	254	37	597	7.6
Humboldt: Near Rye Patch, Nev.	10 3350	Sept. 1-13, 15-30, 1958.	321	35	46	14	.83	105	13	318	0	65	68	1.2	509	173	0	790	7.7
		June 1-30, 1958	196	32	46	13	.56	89	11	280	----	65	54	.4	450	166	0	726	7.9
		Nov. 22, 1958	(Approx.).1	34	45	15	.58	112	11	328	0	69	70	.5	537	174	0	836	7.6
James: At Huron, S. Dak	06A4760	Mar. 29-Apr. 5, 1958.	56	12	33	20	.15	72	12	177	----	125	38	3.4	429	166	21	676	7.8
		July 11-24, 1958	.5	20	44	29	.34	83	13	214	0	174	46	2.5	518	230	55	810	7.2
		July 25-Aug. 3, 5, 1958.	.2	15	41	28	.42	95	15	237	0	173	54	3.1	538	219	25	863	7.6
Kansas: At Topeka, Kans	0688890	July 11-21, 1958	33,155	11	45	6.9	.28	11	6.3	148	0	26	14	4.9	212	141	20	242	7.2
		Aug. 24-Sept. 5, 1958.	5,577	16	67	12	.57	42	9.8	196		76	57	2.9	390	216	55	636	7.6
		May 12-18, 1958	4,966	13	91	19.74	.74	52	8.4	230	0	129	71	3.0	515	304	115	824	7.6
Kentucky: At Lock No. 4, Frankfort, Ky.	03A2875	May 10-12, 1958	53,300	----	11	3.8	.046	------	-----	35	0	19	2.0	.7	92	43	14	112	6.6
		Mar. 29-Apr. 10. 1958.	19,850	8.6	21	4.4	.080	3.4	.8	61	0	22	5.0	2.3	103	70	20	168	7.1
		Oct. 2-30, 1958	491	9.4	36	6.8	.11	5.4	1.8	122	0	18	10	1.6	154	118	18	265	7.5
Kern: Near Bakersfield, Calif.	11 1940	Sept. 3, 1958	[2] 1,370	11	11	1.8	.068	8.1	2.5	52	0	6.7	4.8	.8	------	35	----	108	7.5
		Jan. 6, 1960	[2] 170	21	22	4.6	.10	24	2.7	100	0	25	12	.4	------	74	0	252	8.0
		Oct. 6, 1959	[2] 145	----	-------	------	.12	23	-----	84	0	-------	14	----	------	59	0	227	7.9
Kissimmee: Near Okeechobee, Fla.	02B2730	May 1-10, 1959	2,316	3.2	6.8	2.4	.11	8.1	0	15	0	8.0	13	0	77	27	14	93.4	6.6
Klamath: Near Klamath, Calif.	11 5305	Feb. 3, 1959	--------------	----	-------	------	.055	4.1	-----	67	0	-------	2.5	----	------	56	1	131	7.7
		Oct. 7, 1959	3,980	----	-------	------	.098	12	-----	101	0	-------	5.4	----	------	78	0	197	7.9
		Sept. 9, 1958	3,690	15	16	9.7	.10	9.3	1.6	100	0	9.6	5.5	.8	------	80	0	196	7.5
Lehigh: At Glendon, Pa	------------	Apr. 1-23, 1958	[3] 6,960	4.9	10	3.4	.059	2.3	1.5	19	0	22	2.8	3.9	69	39	24	103	6.6
		July 13, 1958	[3] 849	----	-------	------	.077	2.5		71	0	34	7.8	8.8	------	106	48	245	6.7
		Sept. 15, 1958	[3] 547	6.9	29	13	.19	10	4.6	84	0	57	12	13	184	126	57	309	7.2
Maumee: At Waterville, Ohio.	04 1935	June 13, 1958	22,700	----	-------	------	1.0	-------	-----	----	----	-------	-------	----	------	----	----	--------	----
		Apr. 18-19, 1958	3,125	----	62	13	.44	5.3	3.2	160	0	46	10	34	------	208	77	433	7.7

See footnotes at end of table.

TABLE 4.—*Chemical analyses of surface waters*—Continued

[Results in parts per million except as noted]

River and sampling point	U.S.G.S. gaging station identification No.	Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids (residue at 180 °C	Hardness as $CaCO_3$: Calcium-magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (µmhos at 25 °C)	pH
Minnesota: At Mankato, Minn.	05 3250	Mar. 2, 1960		13	136	52	0.88	40	5.8	446	0	238	18	9.0	747	554	188	1,100	7.6
Mississippi: At St. Louis, Mo.	07 0100	Oct. 29, 1958	[4] 24,700	13	65	19	.6	56	6.0	216	0	153	16	2.6	444	242	65	695	7.3
		Oct. 29, 1958	[5] 24,700	8.8	53	18	.6	31	4.0	192	0	89	17	3.2	323	208	51	523	7.3
		Oct. 29, 1958	[6] 24,700	11	58	18	.6	45	5.1	198	0	119	20	3.3	387	220	58	599	7.4
At St. Francisville, La.	07 3734.20	June 11–20, 1958	407,000	11	40	8.8	.20	16	2.6	126	0	39	16	2.3	207	136	33	331	7.7
Missouri: Near Williston, N. Dak.	06A3300	May 28–June 5, 1958.	40,167	24	39	10	.27	22	2.7	136	0	69	2.4	.5	240	139	27	365	7.0
		May 12–22, 1958	17,370	12	49	18	.29	44	3.5	168	0	143	7.7	1.5	375	197	59	570	7.4
		Sept. 13–29, 1958	13,200	9.6	58	22	.56	59	3.7	198	0	191	9.7	.5	463	235	73	695	7.6
Mohawk: At Cohoes, N.Y.	01B3573	Apr. 3, 1959	42,000	4.1	32	4.1	.16	3.1	1.9	96	0	17	5.0	4.7	130	97	19	213	7.0
		May 27, 1958	3,760	3.2	30	5.5	.20	4.2	1.3	93	----	20	6.0	2.1	133	98	22	215	7.0
Monongahela: At Charleroi, Pa.	03A0750	Aug. 4, 1958	33,300	7.9	16	4.4	.087	4.5	1.5	2	0	68	2.0	.9	107	58	57	169	4.9
		Apr. 30–May 8, 1959.	9,190	6.3	19	6.1	.10	4.8	1.2	6	0	68	2.4	2.0	113	73	68	177	6.3
		Sept. 27, 1958	2,760	10	44	13	<.1	30	2.2	0	0	239	7.0	1.4	361	164	164	551	3.9
Muskegon: At Evart, Mich.	04 1215	Jan. 15, 1960		11	40	9.7	.20	8.8	1.0	150	0	15	15	.7	193	140	17	297	7.8
Neches: At Evadale, Tex.	08 0410	May 10–21, 1958	19,100	8.2	8.0	1.8	.10	19		20	----	16	24	.5	134	28	11	145	6.3
		July 21–31, 1958	1,800	15	9.8	3.4	.18	23		30	0	20	28	.8	116	38	14	196	6.5
Nueces: Near Mathis, Tex.	08 2210	Oct. 1–31, 1958	4,170	20	53	5.3	.32	26	8.3	189	0	22	27	1.5	280	154	0	430	8.1
		May 1–31, 1958	84	15	57	9.7	.34	69	7.1	184	----	68	85	4.0	415	182	31	691	7.4
Ohio: Lock & Dam No. 51 at Golconda, Ill.	03A3845	May 12–20, 1958	628,000	8.0	28	7.6	.16	6.4	1.5	74	0	41	7.0	3.5	153	101	40	231	7.0
		June 11–20, 1958	177,000	9.4	43	12	.20	11	1.7	118	0	61	14	3.9	220	157	60	378	7.2
		Nov. 1–10, 1958		4.0	56	18	.20	23	2.4	146	0	88	32	2.6	312	214	94	526	7.3
Ontonagon Near Rockland, Mich.	04 0400	Jan. 12, 1960		9.4	18	2.9	.039	1.8	1.2	66	0	6.2	1.0	.4	82	57	3	122	7.4
Oswego: at Lock No. 7, Oswego, N.Y.	04 2490	Jan. 19, 1960		2.0	69	12	.73	50	2.3	130	0	65	115	.6	450	222	115	725	7.8
		Sept. 17, 1958	4,720	2.3	88	14	1.0	68	2.5	120	0	68	182	.5	532	277	179	902	7.0
		Sept. 15, 1959		1.6	116	15	1.2	126	3.2	116	0	77	324	1.7	804	351	256	1,370	7.1
Paria: At Lees Ferry, Ariz.	09 3820	Oct. 24, 1958	7.5	12	87	32	.8	57	4.3	150	0	325	13	4.2	642	348	226	875	8.2
		June 11, 1959	3.0	--	36	22	.83	35	4.6	115	0	149	12	1.5	335	181	87	512	7.7
Pecos: Near Puerto de Luna, N. Mex.	08 3835	May 15, 1958	1,540	12	67	8.1	.36	8.2	1.0	100	----	114	11	2.7	300	200	118	420	7.9
		Dec. 2, 1958	116	14	496	59	4.7	96	5.5	162	0	1,360	118	.3	2,350	1,480	1,350	2,520	7.7
		Mar. 1–31, 1959	96	24	530	63	9.0	94	3.1	140	0	1,450	128	.4	2,520	1,580	1,460	2,620	7.7

At Red Bluff, N. Mex.	08 4075	Aug. 22, 1958	1,430	15	371	21	3.4	150	10	83	0	938	228	.2	1,890	1,010	944	2,310	7.4
		Dec. 4, 1958	166	13	478	144	4.8	1,030	25	183	0	1,570	1,630	5.7	5,210	1,780	1,630	7,210	7.6
		May 7–12, 1959	66	10	613	320	8.0	4,480	175	108	0	2,540	7,230	----	16,000	2,850	2,760	22,500	7.2
		July 1–6, 8–14, 1959	50	22	592	224	8.6	2,810	84	145	0	2,060	4,530	----	10,600	2,400	2,280	15,400	8.1
		Sept. 21–30, 1959	46	----	603	245	9.1	2,830	----	149	0	----	4,430	----	10,700	2,510	2,390	15,300	7.6
		Aug. 18–27, 1959	44	----	587	242	8.7	2,860	----	131	0	----	4,530	----	10,800	2,460	2,350	15,700	7.9
Near Girvin, Tex.	08 4465	May 1–29, 31, 1958	16	----	----	----	7.5	4,490	----	73	0	4,190	6,830	----	----	4,550	4,490	22,800	7.4
Pine: At Rudyard, Mich.	----	Jan. 14, 1960	----	8.0	22	4.9	.061	1.4	.6	82	0	8.7	.2	.7	98	75	8	151	7.4
Powell: At McDowells Shoal, Tenn.	----	Apr. 30, 1959	----	----	24	7.3	.10	6.1	1.2	89	0	22	3.5	2.4	----	90	17	205	7.6
Purgatoire: Near Las Animas, Colo.	07 1285	Jan. 31, 1960	----	12	384	243	6.5	520	7.0	292	0	2,620	86	3.3	4,410	1,960	1,720	4,560	7.7
Rappahannock: At Remington, Va.	01B6640	Apr. 6, 1960	----	9.3	4.6	1.6	.072	1.8	1.5	14	0	6.9	2.0	1.3	40	18	6	49	7.0
		Oct. 15, 1958	----	12	5.2	2.7	.045	3.2	1.8	29	0	1.4	3.7	3.0	50	24	1	61.6	6.8
Red: Near Gainesville, Tex.	08 3160	Apr. 21–27, 1958	3,866	11	160	51	1.0	493		154	----	355	840	3.3	2,120	610	484	3,400	8.1
		Apr. 11–18, 1958	740	11	208	63	2.2	757		178	----	496	1,250	----	3,000	780	634	4,720	8.1
At Alexandria, La.	07 3555	June 11–20, 1958	28,900	12	35	6.0	.28	32		102	0	28	48	.6	239	112	28	370	7.8
		Oct. 1–10, 1958	21,200	----	----	----	.32	----	----	----	----	----	----	----	----	----	----	----	----
Red River of the North: At Grand Forks, N. Dak.	05 0825	July 6–12, 1958	6,320	32	59	23	.19	12	5.4	218	0	82	5.7	.9	334	243	64	505	7.2
		Apr. 21–May 17, 1958.	1,730	5.9	69	37	.26	30	7.1	268	----	152	13	.9	479	326	106	718	7.5
		Sept. 17–30, 1958	460	1.8	55	35	.25	23	5.7	275	0	85	13	5.3	383	282	56	608	7.7
Rio Grande: At Otowi Bridge Near San Ildefonso, N. Mex.	08 3130	May 19, 1958	9,450	16	33	1.9	.22	13	2.1	88	0	36	3.0	.9	170	90	18	220	7.9
		Sept. 11, 1958	878	16	33	4.5	.12	10	2.0	100	0	40	3.5	.9	163	101	19	251	7.8
		Oct. 1–3, 7–31, 1959	----	30	52	8.6	.6	30	3.9	177	0	74	8.6	9	302	165	20	436	7.8
		Apr. 18–30, 1960	----	19	31	3.5	.25	9.7	----	98	0	28	3.4	.9	144	94	12	229	7.5
		Feb. 1–28, 1959	656	40	45	9.8	.75	27	----	159	0	66	8.5	.8	----	153	22	393	7.9
		Aug. 6–8, 17–18, 1959.	413	32	78	8.6	.78	43	----	255	0	980	6.6	1.2	----	230	21	595	7.5
		Sept. 24, 1958	365	23	44	8.1	.35	30	3.2	159		64	10	.3	259	144	13	407	7.7
		Sept. 1–15, 1959	189	29	46	5.8	.37	29	----	173	0	47	8.8	.9	----	139	8	389	7.6
Roanoke: At Jamesville, N.C.	02A0810.94	May 1–31, 1958	7 21,700	11	6.6	2.6	.040	1.4	----	31	0	2.3	3.8	1.8	60	27	----	743	6.6
		Sept. 1–30, 1958	7 5,580	8.8	10	3.2	.051	7.7	1.8	49	0	2.4	3.8	.7	66	39	----	102	7.0
		Sept. 1–30, 1959	7 5,420	9.4	13	2.6	.072	7.9	2.2	58	0	4.1	5.0	1.5	78	43	0	131	7.6
Russian: Near Guerneville, Calif.	11 4670	Feb. 5, 1959	1,050	----	----	----	.17	9.0	----	129	0	----	8.0	----	----	114	8	260	7.5
		Oct. 15, 1959	207	----	----	----	.20	10	----	165	0	----	7.0	----	----	132	0	285	8.1
		Sept. 12, 1958	177	13	28	16	.23	8.3	1.4	164	0	12	5.0	.5	----	137	3	288	8.0
Salinas: Near Spreckles, Calif.	11 1525	Sept. 9, 1958	308	22	32	13	.21	16	3.0	134	0	40	14	.6	----	110	22	320	8.1
		Feb. 9, 1959	51	----	----	----	.29	42	----	217	0	----	37	----	----	178	74	621	8.1
		Oct. 7, 1959	----	----	----	----	.27	135	----	212	0	----	190	----	----	232	58	1,050	7.0
Salt: Below Stewart Mt. Dam, Ariz.	09 5020	July 1–23, 25–31, 1959.	1,420	21	44	11	.64	151	4.9	158	0	40	220	.4	580	154	24	1,040	7.7
		June 1–2, 4, 1958	764	19	59	14	.72	225	6.2	171	0	59	355	.4	832	204	64	1,520	7.6
		Jan. 14–29, 1960	----	21	42	11	.5	118	2.5	136	0	35	180	2.0	491	150	38	873	7.6
San Juan: Near Archuleta, N. Mex.	09 3555	June 1–19, 1959	1,690	----	20	2.9	.18	8.5	----	67	0	----	----	----	99	62	7	159	7.1
		Oct. 1–12, 1957	1,120	14	30	4.5	.28	17	2.8	107	----	37	3.8	.4	172	94	6	264	7.5
		Oct. 1–26, 1958	396	13	40	6.3	.41	28	2.9	134	0	68	5.5	.4	236	126	16	364	7.8
		Nov. 18, 1958	250	14	47	8.1	.65	32	2.5	143	0	95	5.8	0	280	151	34	431	8.0
		July 18–31, 1959	236	29	43	7.7	.63	31	4.0	157	0	71	5.4	.6	278	139	10	400	7.9
Scantic: At Broad Brook, Conn.	01A1845	Dec. 10, 1959	297	12	11	2.8	.089	4.4	1.2	18	0	23	4.5	4.8	75	39	24	111	6.4
		June 25, 1958	78	8.9	18	3.4	.18	5.4	.8	33	----	29	6.2	7.1	104	59	32	154	6.6

See footnotes at end of table.

TABLE 4.—*Chemical analyses of surface waters*—Continued

[Results in parts per million except as noted]

River and sampling point	U.S.G.S. gaging station identification No.	Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids (residue at 180 °C)	Hardness as $CaCO_3$: Calcium-magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (kmhos at 25 °C)	pH
Shiawassee: At Owosso, Mich.	04 1445	Jan. 16, 1960	----	7.6	61	16	0.18	6.8	2.6	198	0	46	12	5.5	284	218	56	440	8.0
Snake: At King Hill, Idaho	13 1545	Dec. 16–31, 1958	9,140	----	----	----	.22	33	----	226	0	55	25	3.3	332	208	23	532	7.9
		June 1–30, 1958	9,102	----	46	20	.42	30	----	210	0	53	24	3.0	311	196	24	488	7.9
		Jan. 1–30, 1959	8,850	34	48	22	.14	32	4.8	220	0	----	----	----	336	209	28	514	8.0
St. John's: Near Cocoa, Fla.	02B2324	Sept. 23, 1959	2,323	8.9	19	4.0	.68	32	1.0	33	0	12	66	.3	211	64	37	298	7.2
		July 7, 1958	8,411	1.8	32	6.8	1.1	51		40	0	27	111	.4	----	108	75	485	7.0
		Sept. 2, 1958	8,357	2.2	41	11	1.0	76		54	0	42	160	0	----	148	103	728	7.0
St. Lawrence: At Thousand Island Pk., N.Y.	----	Oct. 5, 1959	----	1.3	38	8.3	.15	9.8	1.2	110	0	24	24	.5	180	129	39	306	6.9
		Oct. 7, 1958	----	1.1	36	8.3	.15	11	1.5	114	0	26	23	.1	170	124	31	297	7.3
Susquehanna: At Danville, Pa.	01B5405	Mar. 7–29, 1958	23,100	4.4	19	4.9	.086	4.9	1.3	32	0	40	5.4	2.7	111	68	42	173	7.6
		July 13, 1958	11,300	6.4	23	7.5	.088	5.6	1.6	51	0	49	5.0	3.3	138	89	47	218	7.3
		Sept. 7, 1958	2,380	3.4	42	17	.19	16	1.9	35	0	158	12	2.1	277	175	147	432	7.2
West Branch at Lewisburg, Pa.	01B5535	Mar. 11–30, 1958	14,500	----	----	----	.090	4.4		14	0	40	4.0	2.3	----	51	40	134	6.9
		July 13, 1958	4,980	9.0	18	5.8	.10	4.0	1.6	20	0	55	4.5	3.0	112	69	53	174	6.7
		Sept. 14, 1958	2,980	7.9	21	6.3	.094	4.5	1.5	14	0	71	5.8	2.4	129	79	67	203	6.9
Suwannee: At Branford, Fla.	02B3205	Apr. 23, 1959	19,200	6.0	24	2.9	.029	3.4	.0	78	0	6.8	4.5	.1	102	72	8	151	7.4
		July 15, 1958	13,400	6.5	21	2.1	.08	2.7	.5	61	0	12	4.0	.2	102	61	11	118	7.1
		Sept. 16, 1958	5,200	8.1	51	6.1	.059	2.9	.4	166	0	14	4.5	1.3	192	152	16	299	7.5
Tennessee: Kentucky Dam near Paducah, Ky.	03B6095	Apr. 21–30, 1958	97,350	4.6	22	2.1	.037	4.0	1.0	68	0	9.4	5.5	1.0	87	64	8	148	7.0
		June 1–10, 1958	55,470	8.1	19	3.0	.074	3.3	.4	64	0	8.8	4.0	1.4	86	60	8	139	7.2
		Nov. 21–29, 1958	39,600	6.5	24	4.4	.056	5.8	.8	76	0	12	14	.8	114	78	16	194	7.0
Wabash: Near New Haven, Ill.	03A3788	June 21–30, 1958	----	11	43	12	.20	4.5	1.9	146	0	33	8.0	8.3	199	157	37	327	7.2
		May 21–31, 1958	----	9.4	60	20	.23	12	1.6	221	0	56	14	4.9	307	232	50	486	7.7
		Nov. 21–30, 1958	----	12	54	18	.14	9.6	2.9	188	0	53	15	4.2	280	209	54	453	7.7
White: At Clarendon, Ark.	07 0778	May 11–23, 1958	----	----	13	4.7	.033	2.6	1.7	62	0	2.6	2.0	2.2	98	52	1	----	----
		Mar. 1–10, 1958	----	----	30	11	.028	4.1	1.9	140	0	6.4	6.0	0	138	120	6	----	----
		Sept. 11–20, 1958	----	----	35	14	.039	3.8	1.3	172	0	5.8	5.0	2.6	172	145	4	----	----
Willamette: At Salem, Oreg.	14 1910	Dec. 16–22, 24–31, 1958.	35,300	----	----	----	.043	3.0	----	24	0	----	----	----	49	18	0	53	6.7
		Jan. 1–29, 1960	----	16	5.0	1.3	.035	4.0	.6	26	0	2.6	2.2	.7	54	18	0	60	6.7
		July 1–3, 7–31, 1958	7,180	16	5.2	1.9	.050	4.4	1.5	32	0	1.9	3.0	.7	54	21	0	64	6.4
Withlacoochie: Near Holder, Fla.	B3130	Oct. 20, 1959	3,950	6.7	21	2.3	.11	3.7	.2	70	0	3.2	5.5	.6	97	62	4	130	6.9

Yakima: At Kiona, Wash.	12 5105	Dec. 23–31, 1958	4,900	----	-------	------	.059	10	-----	90	0	-------	--------	----	112	68	0	175	7.5
		Apr. 16–23, 1959	2,790	----	-------	------	.073	12	-----	112	0	-------	--------	----	137	85	0	214	7.9
		July 16–Aug. 13, 1958.	1,170	----	-------	------	.12	24	-----	183	0	-------	--------	----	219	136	0	349	7.3
Yellowstone: Near Sidney, Mont.	06A3295	May 26–31, 1958	35,970	13	38	8.5	.25	17	1.9	130	0	57	1.6	2.3	220	130	23	334	7.5
		Mar. 10, 18, 25, 1959.	19,200	9.9	50	17	.49	51	5.0	158	0	161	7.3	1.3	398	194	64	606	7.3
		Jan. 4, 9, 17, 25, 1959.	5,100	----	-------	------	.98	90	-----	266	----	-------	--------	----	712	358	140	1,010	7.7
Yuma Main Canal: Below Colorado River Siphon at Yuma, Ariz.	09 5255	Mar. 3–7, 10–14, 18–21, 24–28, 31, 1958.	4,840	22	94	26	.8	112	4.8	182	0	298	88	2.3	777	342	192	1,102	7.6
		Sept. 1–30, 1959	570	20	86	26	2.1	113	-----	157	0	-------	--------	----	768	320	192	1,110	8.0
		Oct. 1–30, 1959	--------------	20	86	28	1.6	114	4.8	156	0	289	107	1.2	754	328	200	1,120	7.7

[1] Discharge measured at Tulsa, Oklahoma (07 1645). [2] Discharge measured below Kern Canyon powerhouse, 11 miles northeast of Bakersfield (11 1930). [3] Discharge measured at Bethlehem, Pa. (01B4530). [4] Station No. 775 (25 percent of flow). [5] Station No. 1425 (75 percent of flow). [6] Composite of 10 verticals across the stream. [7] Discharge at Roanoke Rapids, N.C. [8] Discharge data near Christmas, Fla.

TABLE 5.—*Chemical analyses of ground water of low mineralization*

[Results in parts per million except as noted]

County	Well	Date of collection	Water-bearing formation	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Cholride (Cl)	Nitrate (NO_3)	Dissolved solids residue at (180°C)	Hardness: Calcium mag-nesium	Hardness: Noncar-bon-ate	Specific conductance umμos at 25°C	pH
Arizona																			
Greenlee	(D-4-30)30da	Jan. 11, 1956	Alluvium	70	898	34	18	3,040	173	115	0	66	6,360	----	11,200	2,470	2,380	18,200	7.0
Maricopa	(B-1-1)16dba	Jan. 31, 1958	Sand and gravel lenses in silt and clay beds.	34	8.0	.5	1.2	246	2.2	61	8	93	268	2.6	705	22	0	1,270	8.9
Arkansas																			
Bradley	13S-9Wbacb2	Mar. 6, 1958	Claiborne Group	20	3.2	0	<0.2	112	1.8	252	0	6.2	25	1.2	286	8	0	213	7.9
Calhoun	11S-14W12cbd	do	do	53	18	3.9	<.2	21	3.0	85	8	12	17	0	170	61	0	213	6.3
Crittenden	9N8E-29adb	Mar. 7, 1958	Wilcox Group	12	1.2	.1	<.2	38	1.0	96	0	7.6	0	1.1	101	3	0	153	7.6
	7N8E-24bca	do	do	11	1.6	0	<.2	45	1.2	112	0	10	1.0	.8	126	4	0	185	7.4
Ouachita	11S-15W35bcc	Mar. 6, 1958	Claiborne Group	31	14	2.9	<.2	29	3.4	116	0	9.3	8.0	0	156	47	0	219	6.9
	12S-16W25bdd	do	do	20	9.6	2.4	<.2	34	3.6	118	0	8.4	6.0	.3	141	34	0	209	6.9
Sehrcy	15N-16W25dcc	Mar. 4, 1958	St. Peter Sandstone and other rocks of Ordovician age.	9.0	91	4.9	<.2	5.8	1.0	252	0	36	11	3.2	294	247	40	487	7.3
California																			
Inyo	Bennett's Well.	Jan. 30, 1959	Valley fill	39	46	19	1.4	39	1.2	140	0	87	54	0.2	391	193	78	579	7.5
	25/5-14M	Jan. 27, 1959	do	34	2.0	1.0	.2	330	11	546	28	154	49	0	854	9	0	1,410	8.7
	26/5-5F	do	do	125	64	54	1.4	1,020	68	1,690	0	530	150	1.1	3,070	382	0	4,740	8.0
Kern	27/40-4L1	Mar. 5, 1958	Alluvium	39	8.0	2.9	<.2	114	2.0	149	7	27	83	1.9	354	32	0	590	8.5
	31/29-26E1	May 29, 1958	Alluvium of Pleistocene age.	25	46	3.9	<.2	130	2.4	90	0	93	143	49	558	131	57	892	8.1
Sacramento	9/5-23F2	do	Laguna Formation.	76	19	9.7	<.2	15	3.2	114	0	5.8	18	0	204	87	0	246	7.7
	9/5-23F2	do	do	76	24	14	<.2	16	3.6	114	0	4.1	42	1.5	260	117	24	323	7.7
San Bernardino.	1N/9E-31A3	Apr. 7, 1958	Alluvium	27	13	1.9	<.2	36	1.4	102	2	14	9.0	4.8	151	40	0	238	8.3

Santa Barbara	4/47-19H1	Apr. 8, 1958	Rincon Shale	23	649	3, 520	14	2, 520	46	1, 160	0	15, 900	1, 830	17	28, 900	16, 100	15, 100	23, 500	7. 2
	4/28-13D1	do	Alluvium and Santa Barbara Formation.	36	120	35	<. 2	129	2. 8	375	0	274	84	0	876	434	136	1, 300	7. 4
Tulare	23/27-34C1	May 27, 1958	Alluvium of Pleistocene age.	36	18	1. 9	<. 2	59	2. 4	142	0	37	18	6. 3	257	53	0	370	8. 0
Colorado																			
Arapahoe	C5-68-17caac	Jan. 13, 1958	Alluvium	17	78	19	<0. 2	50	2. 8	234	0	114	40	5. 8	463	272	80	722	7. 0
	C5-68-28aacb	do	Laramie Formation and Fox Hills Sandstone.	16	1. 6	0	<. 2	180	1. 0	352	18	1. 9	54	0	462	4	0	759	8. 7
	C5-65-33cccc	Feb. 5, 1958	Dawson Arkose	12	26	2. 9	<. 2	52	4. 2	195	0	17	11	. 1	254	77	0	366	8. 2
	C5-65-29babb	do	do	11	73	14	1. 0	66	19	276	0	149	19	. 8	535	240	14	742	7. 1
Baca	28-50-32c	Apr. 2, 1958	Cheyenne Sandstone Member of Purgatoire Formation.	12	152	66	. 8	191	19	326	0	695	50	5. 0	1, 410	650	384	1, 840	7. 1
Douglas	C7-67-3abd2	Feb. 4, 1958	Dawson Arkose	34	39	2. 9	<. 2	15	4. 2	156	0	14	2	1. 4	220	109	0	279	7. 6
	C8-67-11bab	do	Alluvium overlying Dawson Arkose.	36	58	7. 3	<. 2	19	3. 6	108	0	85	22	12	344	175	86	446	6. 9
Jackson	B9-79-21bccb	Oct. 4, 1959	Alluvium of the Michigan River.	-----	46	13	. 43	19	1. 2	232	0	19	2. 0	0. 4	215 [1]	168	0	390	7. 4
Las Animas	32-53-15a	Apr. 1, 1958	Cheyenne Sandstone Member of Purgatoire Formation.	9. 5	51	32	. 2	182	8. 4	388	0	317	18	. 6	788	258	0	1, 250	7. 2
Prowers	23-47-4dba	Apr. 2, 1958	Dakota Sandstone	0	90	19	. 2	195	3. 4	456	0	252	34	45	864 [1]	203	0	1, 330	7. 7
	23-44-12c	Apr. 3, 1958	do	14	34	17	<. 2	79	4. 8	238	0	120	11	. 3	367	155	0	641	7. 8
	2-42-15dab	Apr. 2, 1958	Cheyenne Sandstone Member of Purgatoire Formation.	13	69	19	<. 2	59	5. 8	234	0	172	13	0	450	250	58	723	7. 6
	22-47-8bbd	June 6, 1958	Dakota Sandstone and Cheyenne Sandstone Member of Purgatoire Formation.	9. 4	66	30	1. 6	568	15	530	0	1, 030	19	4. 4	2, 000	288	0	2, 800	7. 3
	22-47-8bad	do	do	15	77	26	1. 2	592	14	576	0	1, 060	19	0	2, 090	299	0	2, 970	7. 4
	23-44-12caa	June 6, 1958	do	16	30	17	. 3	87	5. 2	250	0	110	13	0	386	145	0	661	7. 8
Washington	B2-52-18cl	May 23, 1958	Ogallala Formation.	61	61	15	<. 2	26	11	206	0	50	24	27	413	214	44	558	7. 9
	B2-50-9d	do	do	56	35	11	<. 2	9. 6	7. 8	163	0	13	4. 0	8. 0	252	133	0	306	7. 9

See footnotes at end of table.

TABLE 5.—*Chemical analyses of ground water of low mineralization*—Continued

[Results in parts per million except as noted]

County	Well	Date of collection	Water-bearing formation	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Cholride (Cl)	Nitrate (NO_3)	Dissolved solids residue at (180°C)	Hardness: Calcium magnesium	Hardness: Noncarbonate	Specific conductance μmhos at 25°C	pH
Iowa																			
Adair	77-33-4B1	Mar. 11, 1958	Cedar Valley Limestone.	10	424	122	5.6	370	21	221	0	1,870	182	0	3,230	1,560	1,380	3,630	7.4
Allamakee	96-6-33L1	Mar. 12, 1958	Jordan Sandstone	8.3	67	26	<.2	3.3	2.2	312	0	29	2.0	0	290	274	18	514	7.8
Blackhawk	87-12-25L1	do	Dolomite and Limestone of Silurian age.	9.3	104	35	7.0	29	6.2	350	0	166	5.0	6.1	564	404	116	831	7.3
Cerro Gordo	94-22-24G1	Mar. 13, 1958	Cedar Valley Limestone.	8.8	94	23	<.2	37	11	480	0	12	10	1.4	426	329	0	755	7.4
Clinton	81-6-11	July 30, 1958	Prairie du Chien Group, Jordan Sandstone.	8.6	70	27	2.6	12	8.8	328	0	28	14	0	324	286	16	580	7.4
Ida	89-40-35d2	Mar. 13, 1958	Dakota Sandstone.	17	242	58	1.6	124	9.6	345	0	790	10	2.9	1,440	842	560	1,780	7.2
Jackson	84-2E-24A1	Mar. 12, 1958	Dresbach Group and Jordan Sandstone.	9.8	72	25	<.2	21	8.2	321	0	42	21	.8	364	282	20	619	7.5
Louisa	73-3-30	July 24, 1958	Galena Dolomite, Glenwood Shale Member of Platteville Formation, St. Peter Sandstone.	12	83	35	3.0	382	14	314	0	719	144	0	1,560	351	94	2,300	7.4
Lucas	71-20-6F1	Mar. 12, 1958	Root Valley [2] and Jordan Sandstone.	12	64	21	2.8	195	16	328	0	274	93	0	848	246	0	1,350	7.7
Madison	77-28-6N1	Mar. 11, 1958	Sandstone of Pennsylvanian age.	9.8	37	12	.8	616	4.1	233	0	1,170	31	5.1	2,020	142	0	2,850	7.7
Marshall	83-20-10	July 22, 1958	Prairie du Chien Group, Jordan Sandstone and St. Lawrence Formation.	9.5	102	39	3.0	164	20	364	0	374	66	0	948	415	116	1,440	7.3
Polk	80-25-31R1	Mar. 11, 1958	Wisconsin glacial fluvial deposit.	23	82	23	<.2	4.9	2.2	320	0	46	2.0	0	345	299	37	559	7.5
Story	83-22-6	July 22, 1958	Prairie du Chien Group, Jordan Sandstone.	9.5	120	42	3.0	160	17	344	0	458	46	0	1,040	472	190	1,470	7.5
	83-22-6	do	do	12	122	51	8.8	151	17	346	0	499	34	0	1,090	514	230	1,510	7.4

Warren	76-24-36	do	Prairie du Chien Group, Jordan Sandstone, St. Lawrence Formation.	11	60	24	2.4	156	15	314	0	282	34	0	712	248	0	1,140	7.4
Kansas																			
Cherokee	31-24-27d	Feb. 16, 1959	Roubidoux Dolomite.	13	66	26	0.4	44	5.2	317	0	60	34	0	401	272	12	712	7.5
	33-23-13b	Feb. 17, 1959	do	13	50	22	.8	98	5.2	338	0	69	52	0	474	216	0	834	7.2
	34-24-36d	do	do	12	37	16	.2	46	3.2	172	0	21	72	0	288	158	18	549	7.7
	34-25-24b	do	do	12	59	16	<.2	4.9	1.0	190	0	57	7.0	.2	276	213	67	422	7.6
Crawford	31-22-17a	do	do	12	75	31	1.6	372	13	349	0	89	540	0.0	1,300	314	28	2,410	7.3
	29-21-14d	Feb. 16, 1959	Cotter Dolomite	14	62	22	1.2	376	15	336	0	99	505	1.4	1,250	245	0	2,330	7.3
	29-23-24d	do	Roubidoux Dolomite.	11	61	46	1.2	445	15	230	0	74	735	0	1,540	341	152	2,830	7.5
	31-24-18d	do	do	11	62	27	.8	98	7.2	348	0	71	87	0	536	266	0	953	7.1
	28-22-20c	do	Cotter Dolomite	14	74	25	1.6	455	15	328	0	115	640	0	1,510	288	18	2,760	7.1
	32-25-31a	Feb. 17, 1959	do	10	58	24	1.0	17	4.8	268	0	56	5.0	0	302	243	24	529	7.5
	28-25-1c	Feb. 16, 1959	Swan Creed Sandstone.	12	54	23	1.0	250	8.4	476	0	46	250	0	858	229	0	1,550	7.5
	30-25-9c	do	Roubidoux Dolomite.	12	51	20	<.2	118	4.6	344	0	40	104	0	520	209	0	930	7.3
Douglas	15-17-1ac	Mar. 19, 1958	Tonganoxie Sandstone Member of the Stranger Formation.	19	38	12	<.2	167	2.2	340	0	39	127	0	539	144	0	1,010	7.6
Sedgwick	28-4-8db	Mar. 20, 1958	Ninnescah Shale	32	63	20	<.2	16	2.4	196	0	41	16	60	317	239	78	540	7.6
Wabaunsee	14-12-5acd	Mar. 19, 1958	Long Creek Limestone Member of the Foraker Limestone.	18	242	62	9.2	36	2.0	345	0	566	42	11	1,190	863	580	1,550	7.3
Louisiana																			
Calcasieu	Cu-683	Feb. 7, 1959	Sand and gravel of Pleistocene age.	40	40	8.8	<0.2	35	1.8	212	0	4.5	25	0	266	136	0	403	7.5
E. Feliciana	EF-2	Feb. 26, 1958	Sand of Miocene age.	37	4.8	0	<.2	65	1.4	160	2	12	4.0	1.5	213	12	0	288	8.3
Rapides	R-616	Feb. 7, 1958	Catahoula Formation.	56	.8	0	<.2	77	.8	171	0	6.6	17	.6	252	2	0	328	7.7
	R-607	do	do	47	3.2	0	<.2	192	1.8	416	0	2.1	61	0	528	8	0	803	7.8
Vernon	V-47	do	do	67	37	1.9	<.2	19	3.8	123	0	11	22	0	226	100	0	282	6.9

See footnotes at end of table.

TABLE 5.—*Chemical analyses of ground water of low mineralization*—Continued

[Results in parts per million except as noted]

County	Well	Date of collection	Water-bearing formation	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Cholride (Cl)	Nitrate (NO_3)	Dissolved solids residue at (180°C)	Hardness: Calcium magnesium	Hardness: Noncarbonate	Specific conductance umµos at 25°C	pH
Maine																			
Cumberland	C 354-028	Aug. 4, 1958	Sand and gravel	13	8.8	2.2	0.2	4.2	1.4	29	0	4.0	5.0	7.4	66	31	7	89.8	6.7
	C 350-026	do	do	16	6.8	2.2	.2	3.8	1.0	31	0	2.7	4.5	1.4	55	26	1	69.9	6.6
Michigan																			
Chippewa	46N2W8-1	Apr. 7, 1959	Jacobsville Sandstone.	12	93	18	1.8	114	12	82	0	27	335	0.3	754	306	239	1,270	7.9
Marquette	51N27W15-1	Apr. 10, 1959	do	14	43	4.9	<.2	5.4	1.4	149	0	12	4.0	.4	166	127	5	251	7.9
Minnesota																			
Lyon	111.41.8cdd	Feb. 13, 1958	Sandy gravel of Pleistocene age.	32	210	66	<0.2	98	9.2	463	0	611	4.0	0	1,310	796	416	1,650	7.4
Murray	105.40.25b	Nov. 25, 1958	Sioux Quartzite	19	272	98	1.2	165	8.8	406	0	1,050	6.0	0	1,920	1,080	749	2,250	7.2
Nobles	102.43.13add	June 10, 1958	Glacial outwash deposit.	32	118	40	.2	19	2.6	311	0	183	24	22	603	459	204	894	7.3
	101.39.24bbd	do	do	32	484	92	1.3	195	13	279	0	1,750	4.0	0	2,820	1,590	1,360	2,930	7.1
	102.40.27ccd4	do	do	30	118	37	.2	13	1.0	328	0	184	8.0	.7	552	446	178	825	7.2
	102.41.19ddb	do	do	36	328	112	.8	163	6.4	454	0	1,190	2.0	14	2,100	1,280	907	2,420	7.0
	102.40.25bbb2	do	do	32	272	88	.9	63	9.8	388	0	312	15	0	1,530	1,040	722	1,830	7.0
Pipestone	106.46.1bad	Nov. 26, 1958	Sioux Quartzite	18	75	32	.4	17	1.6	269	0	71	35	7.2	400	318	98	678	7.1
Rock	104.47.35abb	Nov. 25, 1958	do	17	51	18	<.2	11	1.2	200	0	35	5.0	22	250	201	37	564	7.2
Mississippi																			
Lee	O 15	June 18, 1958	Eutaw Formation	20	50	6.8	0.2	13	6.0	176	0	34	4.0	0	217	153	8	362	7.4
Rankin	K 42	June 12, 1958	Sparta Sand	20	3.2	0	.2	93	.8	206	14	14	2.0	.0	244	8	0	387	8.6

Montana																		
Custer	A8-47-32ac	June 11, 1958	Fort Union Formation.	13	1.6	0	0.4	342	0.8	724	41	43	24	1.8	813	4	0	1,340	8.7
Phillips	A-30-30-18d	May 14, 1958	Alluvium	20	69	36	.5	163	5.8	424	0	329	10	1.2	794	320	0	1,220	7.6
Richland	23-59-32a	May 15, 1958		22	67	55	.3	57	6.2	352	0	226	7.0	.3	602	393	104	932	7.5
Yellowstone	A-1-26-34aa	June 12, 1958	Alluvial sand and gravel.	21	165	87	.8	126	4.2	393	0	655	13	14	1,350	769	447	1,680	7.3
Nebraska																			
Burt	23-8-25b	July 8, 1958	Sand and gravel of Pleistocene age.	28	91	20	<0.02	25	3.2	399	0	25	9.0	.0	370	309	0	658	7.1
Cherry	34-27-31d	July 10, 1958	Ogallala Formation.	63	87	9.7	.02	12	8.2	172	0	32	42	69	448	257	116	604	7.5
Frontier	8-28-28c	July 11, 1958	Sand and gravel of Pleistocene age and Sandstone of Tertiary age.	70	51	9.7	.02	15	9.8	218	0	17	3.0	9.0	271	167	0	398	7.5
Garfield	21-16-23b	May 7, 1958	Sand and gravel of Pleistocene age.	52	69	12	<.2	13	13	230	0	29	9.0	38	388	222	33	509	7.4
Holt	30-14-32a	July 9, 1958	do	47	34	3.9	.2	14	8.2	136	0	17	4.0	7.7	199	101	0	282	7.1
Howard	14-10-3b	May 8, 1958	Sand and gravel	55	91	16	<.2	16	10	278	0	54	15	36	475	293	65	647	7.4
Pierce	28-4-33c	July 9, 1958	Sand and gravel of Pleistocene age.	57	64	8.8	<.02	11	6.0	246	0	17	1.0	9.5	271	196	0	420	7.3
Washington	18-11-11d	July 8, 1958	do	41	88	23	.8	20	6.6	403	0	20	14	0	390	314	0	675	7.0
Wayne	26-3-12d	July 9, 1958	do	32	126	28	<.02	33	5.4	425	0	128	8.0	14	556	430	81	889	6.9
New Mexico																			
Eddy	25.30.21.333	Feb. 5, 1959	Gatuña Formation	25	131	40	<0.2	236	5.0	149	0	347	370	5.0	1,260	492	370	2,020	7.6
	S23.30.19.123	Feb. 6, 1959	do	39	608	92	<.2	28	5.0	189	0	1,690	22	12	2,820	1,900	1,740	2,760	7.5
	25.29.16.444	Feb. 5, 1959	Culebra Dolomite Member of Rustler Formation.	36	284	83	<.2	114	5.0	138	0	546	440	0	1,780	1,050	936	2,390	7.5
	23.31.26.340	Feb. 4, 1959	Red beds of Triassic age.	21	552	156	<.2	198	3.8	116	0	2,080	128	1.5	3,430	2,020	1,950	3,540	7.4
	23.31.17.310	do	Gatuña Formation and Triassic rocks.	28	632	126	<.2	117	3.4	143	0	1,720	270	12	3,270	2,100	1,980	3,490	7.4
	22.30.32.111	Feb. 19, 1959		47	584	199	<0.2	110	5.8	142	0	2,080	152	12	3,570	2,280	2,160	3,570	7.6
	26.30.5.340	Feb. 18, 1959		21	99	35	<.2	238	5.6	168	0	285	340	0	1,170	391	254	1,900	7.8

See footnotes at end of table.

TABLE 5.—*Chemical analyses of ground water of low mineralization*—Continued

[Results in parts per million except as noted]

County	Well	Date of collection	Water-bearing formation	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Cholride (Cl)	Nitrate (NO_3)	Dissolved solids residue at (180°C)	Hardness: Calcium magnesium	Hardness: Noncarbonate	Specific conductance umμos at 25°C	pH
New Mexico—Continued																			
Eddy	25.31.21.000	Feb. 17, 1959		25	216	54	<0.2	142	4.6	130	0	794	92	5.1	1,530	761	654	1,900	7.5
	23.30.2.444	Mar. 26, 1959	Culebra Dolomite Member of Rustler Formation.	30	584	131	6.2	512	29	113	0	2,110	550	0	4,290	2,000	1,900	4,980	7.5
	24.30.8.113	Mar. 19, 1959		52	56	13	2.2	7.0	3.2	188	0	23	18	3.5	278	193	39	422	7.6
	24.31.4.430	do	Culebra Dolomite Member of Rustler Formation.	22	600	156	5.8	301	6.8	97	0	2,030	375	5.0	3,870	2,140	2,060	4,240	7.5
	24.30.18.231	Mar. 25, 1959		10	661	179	5.8	1,540	36	68	0	2,270	2,230	0	7,230	2,380	2,330	10,100	7.4
	25.29.32.211	Mar. 24, 1959		56	747	256	5.4	2,700	389	219	0	1,210	5,510	0	12,200	2,920	2,740	17,600	6.8
	24.30.36.333	Mar. 31, 1959		25	82	29	2.2	40	2.6	154	0	167	74	4.1	550	324	198	847	7.3
	23.31.29.113	Apr. 1, 1959		30	608	156	5.8	136	3.8	134	0	1,750	330	4.1	3,400	2,160	2,050	3,670	7.4
	24.31.33.124	Mar. 31, 1959	Gatuna Formation.	14	696	204	8.0	462	9.1	72	0	2,130	850	0	4,860	2,580	2,520	5,610	7.3
	24.31.17.111	do		57	162	15	1.4	21	7.4	440	0	32	59	55	657	466	105	1,080	7.0
	23.31.7.240	Apr. 3, 1959		51	156	56	1.37	152	2.0	252	0	539	89	49	1,320	619	412	1,740	7.5
	25.30.7.111	Apr. 14, 1959		5.2	34	22	.98	106	2.2	121	0	188	72	0	492	176	76	843	8.0
New York																			
Wayne	Wn-546	May 3, 1956	Salina Group	15	2,040	487	13	11,600	107	91	0	2,650	21,200	25	40,100	7,090	7,020	54,000	6.7
North Dakota																			
Benson	156-68-31aca	May 28, 1958	Dakota Sandstone	16	21	7.8	1.2	1,530	9.0	865	0	1,220	1,010	2.9	4,280	84	0	6,600	7.9
Emmons	131-76-26c	June 24, 1958	Fox Hills Sandstone.	36	133	43	<.02	34	7.4	423	0	224	1.0	5.8	680	509	162	1,010	7.1

Oklahoma

Caddo	5-9-3	Mar. 3, 1958	Rush Springs Sandstone.	20	114	3.4	<0.2	13	0.6	217	0	31	72	13	430	298	120	675	7.2
Carter	4-1-2	Feb. 4, 1958	Wichita Formation.	10	5.6	2.9	<.2	159	2.6	344	10	43	22	0	419	26	0	702	8.6
Cleveland	9-2-21	Mar. 5, 1958	Garber Sandstone and Wellington Formation.	12	2.0	0	<.2	161	.6	322	27	39	5.0	.6	411	5	0	662	8.9
Murray	1-3-35	Mar. 4, 1958	Simpson Group	13	75	32	<.2	7.0	2.2	384	0	17	5.0	0	333	318	0	596	7.5
Nowata	27-16-36	Dec. 19, 1958	Bartlesville Sand [4]	11	694	742	59	8,910	78	999	0	95	16,600	0	29,800	4,850	4,030	43,400	6.7
	27-17-31	do	Arbuckle Group	14	821	325	59	8,830	157	701	0	41	15,700	0	27,200	3,450	2,880	41,000	6.8
Oklahoma	11-2-8	Mar. 4, 1958	Garber Sandstone and Wellington Formation.	20	48	22	<.2	11	.8	268	0	7.4	6.0	1.1	235	210	0	424	7.8
Roger-Mills	12-24-11	Feb. 19, 1958		34	72	8.8	<.2	26	.6	284	0	25	5	7.2	334	216	0	509	7.6
Washita	11-19-36	do	Elk City Member of Quartermaster Formation.	28	56	20	<.2	38	1.6	343	0	10	10	3.7	343	222	0	562	7.5

Oregon

Deschutes	22/21-8N1	Apr. 18, 1958	Basalt and other volcanic rock.	84	13	5.8	<0.2	32	6.8	142	0	8.2	6.0	4.1	253	56	0	259	7.8
Jackson	35/3-21E1	Apr. 16, 1958	Volcanic rock of Tertiary age.	41	6.4	3.9	<.2	7.3	1.2	52	0	3.5	2.0	0	92	32	0	87.1	7.1
Jefferson	11/13-1D1	Apr. 18, 1958	Basalt	63	32	11	<.2	30	7.2	168	0	29	20	6.3	291	125	0	398	7.1
Klamath	41/10-2R1	Apr. 16, 1958	Basalt and Basaltic cinders.	54	11	4.9	<.2	44	3.8	97	0	26	28	5.4	264	48	0	319	7.4
	34/7-33K1	Apr. 17, 1958	Basalt	50	24	14	<.2	23	2.6	116	0	18	13	46	268	117	22	347	7.1
Marion	4/2N-19G1	Apr. 14, 1958	Valley fill	20	30	9.7	<.2	39	1.0	240	0	2.7	3.0	0	254	115	0	368	8.0
Morrow	1/25-23L1	June 16, 1958	Columbia River Basalt.	66	34	17	.2	28	6.2	186	0	4.3	48	0	290	155	2	447	7.7
	3/28-28N1	do	do	59	17	4.9	.2	18	4.2	111	0	10	2.0	1.5	166	63	0	205	7.8
Multnomah	1N/3-34D1	May 5, 1958	Troutdale Formation.	40	11	11	<.2	11	2.2	115	0	3.3	2.0	0	155	73	0	182	7.9
	1N/2-26R2	Apr. 22, 1958	Sand and gravel of Tertiary age.	64	16	7.8	<.2	7.2	1.2	101	0	4.1	2.0	0	151	72	0	167	7.2
Umatilla	4N/28-11n1	June 17, 1958	Basalt	74	4.8	0	.2	72	11	148	7	15	20	0	237	12	0	352	8.4
	4N/35-19L2	do	Columbia River Basalt.	76	21	5.8	.2	31	6.6	164	0	11	5.0	0	227	76	0	288	7.9
	5N/35-12K1	Aug. 1, 1958	do	52	14	4.4	.2	8.0	2.8	80	0	1.8	5.0	0	115	53	0	148	7.6
	5N/35-2H1	do	do	56	14	4.9	.2	6.5	3.2	81	0	2.3	4.0	0	114	55	0	145	7.6
Wasco	1N/13-4P1	July 30, 1958	do	74	17	6.8	.2	44	8.0	190	0	10	6.0	0	249	70	0	335	8.1
Washington	2/1W-10D1	Apr. 21, 1958	Basalt	72	21	8.8	<.2	8.5	2.8	124	0	3.1	5.0	0	183	89	0	209	7.1

See footnotes at end of table.

TABLE 5.—*Chemical analyses of ground water of low mineralization*—Continued

[Results in parts per million except as noted]

County	Well	Date of collection	Water-bearing formation	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids residue at (180°C)	Hardness: Calcium magnesium	Hardness: Noncarbonate	Specific conductance umhos at 25°C	pH
South Dakota																			
Bon Homme	93-60-24c	Feb. 20, 1959	Dakota Sandstone.	12	360	58	5.3	100	20	148	0	1,030	123	0.4	1,910	1,140	1,020	2,270	7.1
Washington																			
Grant	20/28-27E1	Mar. 28, 1958	Glacial outwash	42	42	15	<0.2	29	7.0	219	0	34	10	5.4	297	166	0	440	7.7
King	24/5-23E1	Apr. 11, 1958	Puget Group	48	32	6.3	<.2	18	9.6	171	0	16	3.0	0	196	106	0	307	8.0
Okanogan	33/26-16C1	Mar. 27, 1958	Alluvial sand and gravel.	19	54	23	<.2	34	4.4	227	0	109	3 0	.7	320	229	43	567	7.8
Stevens	35/39-10B1	do	Gravel	16	57	14	<.2	3.6	2.0	231	0	20	0	0	240	200	10	382	7.7
Thurston	18/1W-10R3	Apr. 17, 1958	Sand and clay	67	6.4	4.9	<.2	8.2	2.0	60	0	5.6	1.0	.8	106	36	0	110	6.9
	18/1W-21D3	Apr. 20, 1958	Sand and gravel	35	6.4	5.4	<.2	5.2	2.0	40	0	10	3.0	6.6	88	38	5	111	7.3
Whatcom	41/1-31Q1	Mar. 26, 1958	do	26	14	6.8	<.2	9.9	4.0	96	0	8.8	2.0	0	121	63	0	171	8.0
Whitman	15/45-32N2	Mar. 28, 1958	Columbia River Basalt.	67	22	15	<.2	25	4.4	207	0	4.9	2.0	.1	236	17	0	319	7.7
	15/44-15A2	do	Granite	50	42	13	<.2	17	2.4	171	0	22	13	22	243	158	18	404	6.8
Wisconsin																			
Fond du Lac	Fl 13/19/18-125	Feb. 18, 1958	Sandstone of Late Cambrian age.	10	118	33	36	21	5.2	315	0	184	24	0.8	610	430	172	859	7.4
Outagamie	Ou21/18/25-47	do	Galena Dolomite, Platteville Formation, Prairie du Chien Group, and Sandston of Cambrian age.	9.5	182	19	24	16	4.6	240	0	353	7.0	.7	773	532	336	997	7.4
	do	Oct. 27, 1955		6.9	157	21	20	14	4.6	241	0	330	8.0	.3	702	500	303	963	7.3

Wyoming

Albany	15-73-14d	Apr. 22, 1958	Casper Formation	10	54	13	<0.2	3.1	.6	244	0	10	1.0	3.3	195	188	5	364	7.8
Campbell	50-72-21a	Apr. 9, 1958	Fox Hills Sandstone.	13	8.0	2.9	<.2	126	3.6	359	0	3.1	8.0	0	312	32	0	565	7.9
Carbon	21-87-17a	Apr. 13, 1958	Rocks of Cambrian age.	14	118	26	<.2	108	6.0	208	0	242	144	0	774	402	231	1,210	7.6
Niobrara	32-63-7b	Apr. 8, 1958	Arikaree Formation.	57	54	7.3	<.2	11	5.2	219	0	9.9	3.0	3.9	234	165	0	370	7.5

[1] Calculated. [2] Of Stauffer and Thiel, 1941. [3] Values reported to two places analyzed by ion exchange method. [4] As used by Oklahoma.

TABLE 6.—*Chemical analyses of brines*

[Results in parts per million except as noted]

County	Well	Date of collection	Water-bearing formation	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (C_1)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCo_3$: Calcium magnesium	Hardness as $CaCo_3$: Non-carbonate	Specific conductance μmhos at 25°C	pH
California																			
San Bernardino	WCC Well 1-C.	Jan. 25, 1959	Lacustrine sediments.	529	77	23	11	125,000	17,800	-----	36,000	43,300	110,000	----	343,000	286	0	152,000	10.0
Michigan																			
Chippewa	47N1E21-2	Apr. 7, 1959	Sandstone of Cambrian age.	4.7	7,520	377	[1] 115	7,900	58	24	0	.0	26,000	39	46,200	20,300	20,300	63,500	7.0
Midland	Dow No. 3	June 6, 1954	Sylvania Sandstone	-----	65,700	9,420	2,960	27,600		445	0	112	187,000	----	-------	206,000	206,000	185,000	5.3
Mason	21N13N24	June 11, 1956	------------------	8.4	54,900	16,800	837	21,800	3,240	36	0	132	184,000	327	301,000	206,000	206,000	164,000	5.2
Gratiot	12N3W13	Mar. 28, 1952	Marshall Sandstone	24	37,700	9,696	892	49,190	834	0	0	64	171,500	----	273,800	-------	-------	143,000	----
Midland	14N2E27	Mar. 26, 1952	Sylvania Sandstone	102	73,340	9,477	2,730	22,070	9,208	0	0	13	200,100	----	325,600	-------	-------	-------	----
North Dakota																			
Burke	[2]	Apr., 1959	Mission Canyon Limestone.	16	5,990	975	315	86,000	4,260	143	0	17,600	150,000	0	271,000	19,000	18,800	214,000	6.7
West Virginia																			
Tyler	[2]	Dec. 9, 1955	Burgoon Sandstone Member of Pocono Formation.	7.5	7,960	1,330	[3] 76	31,100	179	28	0	0	66,700	104	112,000	24,400	24,500	130,000	5.4
Wirt	Wirt-127 [2]	Dec. 3, 1958	Salt sand and Pottsville Formation.	6.9	1,860	904	[4] 116	13,600	136	2,450	0	0	25,660	----	47,000	8,360	6,350	63,800	6.7
Roane	[2]	--------------	do	93	6,300	1,760	200	27,900	148	86	0	576	61,900	----	119,000	23,000	22,900	128,000	6.5
Braxton	[5]	Nov. 11, 1958	Burgoon Sandstone Member of Pocono Formation.	.0	77,600	15,300	2,200	15,700	943	31	0	19,500	188,000	----	349,000	256,000	256,000	162,000	4.7

[1] 1410 ppm Ba. [2] Oil well. [3] 206 ppm Ba. [4] 51 ppm Ba. [5] Gas well.

Table 7.—*Sr/Ca ratios and strontium content in total dissolved solids*

River and sampling point	U.S.G.S. gaging station identification No.	Date of collection	Mean discharge (cfs)	Ca (epm)	Sr (epm×10³)	Sr (epm×10³) / Ca(epm)	Average Sr (epm×10³) / Ca(epm)	Total dissolved solids (ppm)	Sr in total dissolved solids (percent)	Average Sr in total dissolved solids (percent)
Alafia: At Lithia, Fla.	02B3015	Oct. 29, 1959	525	1.30	2.51	1.93	1.93	174	0.06	0.06
Allegheny: At Kittanning, Pa.	03A0365	Mar. 30–Apr. 22, 1958	33,700	.70	1.44	2.06		77	.08	
		Aug. 4, 1958	10,400	1.05	1.76	1.68	1.87	127	.06	.07
		Oct. 5, 1958	9,300	----	2.23	----		----	----	
American: At Fair Oaks, Calif.	11 4465	Oct. 13, 1959	640	----	1.14	----		----	----	
		Sept. 18, 1958	----	.14	.91	6.50	6.50	28	.14	.14
Arkansas: At Las Animas, Colo.	07 1240	Jan. 31, 1960	----	16.0	100	6.25	6.25	2,830	.16	.16
At Lamar, Colo.	07 1330	do	----	17.6	116	6.59	6.59	3,980	.13	.13
At Springs Bridge, Near Tulsa, Okla.	07 1644	Apr. 2 10, 1958	[1] 19,700	3.44	22.8	6.63		1,190	.08	
		Mar. 21–25, 1958	[1] 13,600	3.99	45.6	11.4	8.59	1,710	.12	.10
		Mar. 6–8, 1958	[1] 4,800	5.29	41.0	7.75		2,100	.09	
At Little Rock, Ark.		July 12–20, 1958	79,000	1.95	4.79	2.46		305	.07	
	07 2635	Apr. 14–20, 1958	60,400	1.85	4.10	2.22	3.09	313	.06	.08
		Sept. 10–12, 1958	12,800	3.34	15.3	4.58		680	.10	
Brazos:										
Double Mountain Fork: Near Aspermont, Tex.	08 0805	Oct. 4–11, 14–20, 1958	8.3	20.2	123	6.09	6.09	----	----	----
Brazos, Salt Fork: Near Aspermont, Tex.	08 0820	Oct. 4–11, 14–27, 1958	3.3	55.9	217	3.88	3.88	----	----	----
Brazos: At Richmond, Tex.		May 1–10, 1958	42,980	2.10	5.47	2.60		210	.11	
	08 1140	July 15–31, 1958	4,685	3.99	50.2	12.6	6.29	632	.35	.20
		Oct. 10–14, 21–25, 1958	2,590	2.54	9.35	3.68		319	.13	
Broad: Near Boiling Springs, N.C.		Apr. 21–30, 1958	4,320	.10	.23	2.30		26	.04	
	02A1515	July 11–20, 1958	1,650	.17	.91	5.35	3.51	39	.10	.06
		June 21–30, 1958	1,240	.16	.46	2.88		37	.05	
Canadian: At Logan, N. Mex.		Aug. 15–17, 1959	2,180	1.45	21.7	15.0		----	----	
	07 2270	July 6, 1958	1,440	2.00	19.4	9.7		225	.38	
		do	—500	1.65	18.2	11.0		260	.31	
		July 11–14, 1959	86	1.65	24.2	14.7	13.1	----	----	.33
		July 19, 1958	45	2.94	41.0	14.0		612	.29	
		Sept. 16–19, 1959	5	4.59	66.1	14.4		----	----	
Clinch: At Clinchport, Va.	----	Apr. 30, 1959	----	1.35	1.48	1.10	1.10	----	----	----
Clinch: At Speers Ferry, Va.	03B5270	do	1,640	1.40	1.25	.89	.89	----	----	----
Coeur D'Alene: Near Cataldo, Idaho	12 4135	July 14–Aug. 1,2,4, 1958	533	.60	.87	1.45	1.45	84	.05	.05
Colorado: Near Cisco, Utah	09 1805	June 1, 8, 11–19, 1958	27,300	2.35	9.58	4.08		276	.15	
		Oct. 1–17, 27–31, 1958	2,560	8.03	31.9	3.97	4.38	1,560	.09	.12
		Sept. 1–13, 15–30, 1958	2,540	8.98	45.6	5.08		1,620	.12	
At Lees Ferry, Ariz.	09 3800	May 22–31, 1959	22,130	2.94	20.5	6.97		383	.23	
		July 21–24, 26–28, 1959	6,150	4.49	25.1	5.59	6.45	654	.17	.20
		Aug. 31, Sept. 2–21, 1959	3,980	7.39	50.2	6.79		1,120	.20	

See footnotes at end of table.

TABLE 7.—*Sr/Ca ratios and strontium content in total dissolved solids*—Continued

River and sampling point	U.S.G.S. gaging station identification No.	Date of collection	Mean discharge (cfs)	Ca (epm)	Sr (epm×10³)	Sr (epm×10³) / Ca(epm)	Average Sr (epm×10³) / Ca(epm)	Total dissolved solids (ppm)	Sr in total dissolved solids (percent)	Average Sr in total dissolved solids (percent)
Columbia: At Northport, Wash	12 3995	Dec. 15–25, 1958	38,600	1.20	1.64	1.37	1.37			.08
		Jan. 29–Feb. 15, 1960			1.82			98	.08	
At The Dalles, Oreg	14 1057	June 1–22, 1958	495,600		1.46			79	.08	
		Aug. 14–31, 1958	112,100		2.17			102	.09	.11
		Oct. 16–30, 1958	103,000		4.79			123	.17	
Copper Creek: Near Gate City, Va	03B5260	Apr. 30, 1959	131	1.75	.80	.46	.46			
Cumberland: At Williamsburg, Ky	03B4040	Apr. 23–May 2, 1958	16,130	.31	.93	3.00		74	.06	
		Jan. 26–Feb. 12, 1958	6,090	.39	1.16	2.97	2.91	74	.07	.06
		Sept. 13–30, 1958	210	1.00	2.74	2.74		195	.06	
Delaware: At Morrisville, Pa. (Trenton N. J.).	01B4635	Apr. 4–23, 1958	44,310	.42	.96	2.29		56	.08	
		July 13, 1958	5,540		1.21		2.01			.07
		Sept. 18, 1958	3,640	.80	1.39	1.74		95	.06	
Embarrass: At Embarrass, Minn	04 0170	July 24, 1958	50	.60	.93	1.55		710	.04	
		May 23, 1958	47	.40	.52	1.30	1.43	85	.03	.04
Escambia: Near Century, Fla	02B3755	Nov. 19, 1958	1,420	.85	1.19	1.40	1.40	97	.05	.05
At Cornell, Mich	04 0590	Jan. 14, 1960		1.10	1.14	1.04	1.04	115	.04	.04
Ford: Near Hyde, Mich	04 0595	do		2.15	1.25	.58	.58	192	.03	.03
Genesee: At Rochester, N.Y	04 2320	Jan. 19, 1960		1.80	11.4	6.33	5.69	202	.25	.24
		Sept. 17, 1958	1,140	2.40	12.1	5.04		244	.22	
Gila: At Kelvin, Ariz	09 4740	Aug. 6, 1958	2,860	3.14	21.7	6.91		482	.20	
		Aug. 9, 1958	698	2.99	20.52	6.86	4.57	476	.19	.13
		Sept. 1–14, 16–30, 1959	269	2.69	10.9	4.05		447	.11	
		Jan. 30, 1959	225	5.49	2.51	.46		860	.01	
Green: At Green River, Utah	09 3150	June 1–30, 1958	19,730	2.15	18.2	8.47		259	.31	
		Aug. 1–31, 1958	1,792	3.34	13.7	4.10	5.50	612	.10	.16
		Oct. 1, 2, 5–31, 1958	1,470	3.49	13.7	3.93		741	.08	
At Lock & Dam No. 1, Spottsville, Ky.	03A3215	Apr. 11–20, 1958		1.50	1.82	1.21		136	.06	
		May 21–31, 1958		1.70	3.19	1.88	1.59	165	.08	.07
		Oct. 1–10, 1958		2.30	3.88	1.69		218	.08	
Guadalupe: At Victoria, Tex	08 1765	May 11–21, 1958	3,225	3.84	16.2	4.22	4.22	378	.19	.19
Humboldt: Near Rye Patch, Nev	10 3350	Sept. 1–13, 15–30, 1958	321	2.30	18.9	8.22		509	.16	
		June 1–30, 1958	196	2.30	12.8	5.57	6.55	450	.12	.13
		Nov. 22, 1958	(approx) .1	2.25	13.2	5.87		537	.11	
James: At Huron, S. Dak	06A4760	Mar. 29–Apr. 5, 1958	56	1.65	3.42	2.07		429	.03	
		July 11–24, 1958	.5	2.20	7.75	3.52	3.42	518	.07	.06
		July 25–Aug. 3, 5, 1958	.2	2.05	9.58	4.67		538	.08	
Kansas: At Topeka, Kans	06B8890	July 11–21, 1958	33,155	2.25	6.38	2.84		212	.13	
		Aug. 24–Sept. 5, 1958	5,577	3.34	13.0	3.89	3.48	390	.15	.14
		May 12–18, 1958	4,966	4.54	16.9	3.72		515	.14	

Kentucky: At Lock No. 4, Frankfort, Ky.	03A2875	May 10-12, 1958	53,300	.55	1.05	1.91		92	.05	
		Mar. 29-Apr. 10, 1958	19,850	1.05	1.82	1.73	1.68	103	.08	.07
		Oct. 2-30, 1958	491	1.80	2.51	1.39		154	.07	
Kern: Near Bakersfield, Calif.	11 1940	Sept. 3, 1958	[2] 1,370	.55	1.55	2.82		---	---	
		Jan. 6, 1960	[2] 170	1.10	2.28	2.07	2.45	---	---	---
		Oct. 6, 1959	[2] 145	---	2.74	---		---	---	
Kissimmee: Near Okeechobee, Fla.	02B2730	May 1-10, 1959	2,316	.34	2.51	7.38	7.38	77	.14	.14
Klamath: Near Klamath, Calif.	11 5305	Feb. 3, 1959	---	---	1.25	---		---	---	
		Oct. 7, 1959	3,980	---	2.23	---	2.85	---	---	---
		Sept. 9, 1958	3,690	.80	2.28	2.85		---	---	
Lehigh: At Glendon, Pa.	---	Apr. 1-23, 1958	[3] 6,960	.50	1.35	2.70		69	.09	
		July 13, 1958	[3] 849	---	1.76	---	2.84			.10
		Sept. 15, 1958	[3] 547	1.45	4.33	2.99		184	.10	
Maumee: At Waterville, Ohio	04 1935	June 13, 1958	22,700	---	22.8	---	3.24	---	---	---
		Apr. 18-19, 1958	3,125	3.09	10.0	3.24		---	---	
Minnesota: At Mankato, Minn.	05 3250	Mar. 2, 1960	---	6.79	20.1	2.96	2.96	747	.12	.12
Mississippi: At St. Louis, Mo.	07 0100	Oct. 29, 1958	[4] 24,700	3.24	13.7	4.23		444	.14	
		do	[5] 24,700	2.64	13.7	5.19	4.39	323	.19	.16
		do	[6] 24,700	2.89	13.7	4.74		387	.16	
At St. Francisville, La.	07 3734.20	June 11-20, 1958	407,000	2.00	4.56	2.28	2.28	207	.10	.10
Missouri: Near Williston, N. Dak.	06A3300	May 28-June 5, 1958	40,167	1.95	6.16	3.16		240	.11	
		May 12-22, 1958	17,370	2.45	6.61	2.70	3.43	375	.08	.10
		Sept. 13-29, 1958	13,200	2.89	12.8	4.43		463	.12	
Mohawk: At Cohoes, N.Y.	01B3575	Apr. 3, 1959	42,000	1.60	3.65	2.28	2.66	130	.12	.14
		May 27, 1958	3,760	1.50	4.56	3.04		133	.15	
Monongahela: At Charleroi, Pa.	03A0750	Aug. 4, 1958	33,300	.80	1.98	2.48		107	.08	
		Apr. 30-May 8, 1959	9,190	.95	2.28	2.40	2.44	113	.09	.09
		Sept. 27, 1958	2,760	2.20	---	---		361	---	
Muskegon: At Evart, Mich.	04 1215	Jan. 15, 1960	---	2.00	4.56	2.28	2.28	193	.10	.10
Neches: At Evadale, Tex.	08 0410	May 10-21, 1958	19,100	.40	2.28	5.70	7.04	134	.07	.12
		July 21-31, 1958	1,800	.49	4.10	8.37		116	.16	
Nueces: Near Mathis, Tex.	08 2110	Oct. 1-31, 1958	4,170	2.64	7.30	2.77	2.75	280	.11	.09
		May 1-31, 1958	84	2.84	7.75	2.73		415	.08	
Ohio: Lock & Dam No. 51 at Golconda, Ill.	03A3845	May 12-20, 1958	628,000	1.40	3.65	2.61		153	.10	
		June 11-20, 1958	177,000	2.15	4.56	2.12	2.12	220	.09	.08
		Nov. 1-10, 1958	---	2.79	4.56	1 63		312	.06	
Ontonagon: Near Rockland, Mich.	04 0400	Jan. 12, 1960	---	.90	.89	.99	.99	82	.05	.07
Oswego: At Lock No. 7 Oswego, N.Y.	04 2490	Jan. 19, 1960	---	3.44	16.6	4.83		450	.16	
		Sept. 17, 1958	4,720	4.39	22.8	5.19	4.92	532	.19	.17
		Sept. 15, 1959	---	5.79	27.4	4.73		804	.15	
Paria: At Lees Ferry, Ariz.	09 3820	Oct. 24, 1958	7.5	4.34	18.2	4.19	7.4	642	.12	.18
		June 11, 1959	3.0	1.80	18.9	10.5		335	.25	
Pecos: Near Puerto de Luna, N. Mex.	08 3835	May 15, 1958	1,540	3.34	8.21	2.46		300	.12	
		Dec. 2, 1958	116	24.8	107	4.31	4.81	2,350	.20	.23
		Mar. 1-31, 1959	96	26.4	205	7.77		2,520	.36	
At Red Bluff, N. Mex.	08 4075	Aug. 22, 1958	1,430	18.5	77.5	4.19		1,890	.18	
		Dec. 4, 1958	166	23.9	109	4.56		5,210	.09	
		May 7-12, 1959	66	30.6	182	5.95	5.83	16,000	.05	.09
		July 1-6, 8-14, 1959	50	29.5	196	6.64		10,600	.08	
		Sept. 21-30, 1959	46	30.1	207	6.88		10,700	.09	
		Aug. 18-27, 1959	44	99.3	198	6.76		10,800	.08	

See footnotes at end of table.

TABLE 7.—*Sr/Ca ratios and strontium content in total dissolved solids*—Continued

River and sampling point	U.S.G.S. gaging station identification No.	Date of collection	Mean discharge (cfs)	Ca (epm)	Sr (epm×10³)	Sr (epm×10³) / Ca(epm)	Average Sr (epm×10³) / Ca(epm)	Total dissolved solids (ppm)	Sr in total dissolved solids (percent)	Average Sr in total dissolved solids (percent)
Pecos—Continued										
Near Girvin, Tex	08 4465	May 1–29, 31, 1958	16	--	171	--	--	--	--	--
Pine: At Rudyard, Mich	--	Jan. 14, 1960	--	1.10	1.39	1.26	1.26	98	.06	.06
Powell: At McDowells Shoal, Tenn	--	Apr. 30, 1959	--	1.20	2.28	1.90	1.90	--	--	--
Purgatoire: Near Las Animas, Colo	07 1285	Jan. 31, 1960	--	19.2	148	7.71	7.71	4,410	.15	.15
Rappahannock: At Remington, Va	01B6640	Apr. 6, 1960	--	.23	1.64	7.13	5.54	40	.18	.14
		Oct. 15, 1958	--	.26	1.03	3.96		50	.09	
Red: Near Gainesville, Tex	07 3160	Apr. 21–27, 1958	3,860	7.98	22.8	2.86	3.84	2,120	.05	.06
		Apr. 11–18, 1958	740	10.4	50.2	4.83		3,000	.07	
At Alexandria, La	07 3555	June 11–20, 1958	28,900	1.75	6.38	3.65	3.65	239	.12	.12
		Oct. 1–10, 1958	21,200	--	7.30	--		--	--	
Red River of the North: At Grand Forks, N. Dakota.	05 0825	July 6–12, 1958	6,320	2.94	4.34	1.48	1.76	334	.06	.06
		Apr. 21–May 17, 1958	1,730	3.44	5.93	1.72		479	.05	
		Sept. 17–30, 1958	460	2.74	5.70	2.08		383	.07	
Rio Grande: At Otowi Bridge near San Ildefonso, N. Mexico	08 3130	May 19, 1958	9,450	1.65	5.02	3.04	4.14	170	.13	.14
		Sept. 11, 1958	878	1.65	2.74	1.66		163	.07	
		Oct. 1–3, 7–31, 1959	--	2.59	13.7	5.29		302	.20	
		Apr. 18–30, 1960	--	1.55	5.70	3.68		144	.17	
		Feb. 1–28, 1959	656	2.25	17.1	7.60		--	--	
		Aug. 6–8, 17–18, 1959	413	3.89	17.8	4.58		--	--	
		Sept. 24, 1958	365	2.20	7.98	3.63		259	.14	
		Sept. 1–15, 1959	189	2.30	8.44	3.67		--	--	
Roanoke: At Jamesville, N.C	02A0810.94	May 1–31, 1958	[7] 21,700	.33	.91	2.76	2.53	60	.07	.08
		Sept. 1–30, 1958	[7] 5,580	.50	1.16	2.32		66	.08	
		Sept. 1–30, 1959	5,420	.65	1.64	2.52		78	.09	
Russian: Near Guerneville, Calif	11 4670	Feb. 5, 1959	[7] 1,050	--	3.88	--	3.75	--	--	--
		Oct. 15, 1959	207	--	4.56	--		--	--	
		Sept. 12, 1958	177	1.40	5.25	3.75		--	--	
Salinas: Near Spreckles, Calif	11 1525	Sept. 9, 1958	308	1.60	4.79	2.99	2.99	--	--	--
		Feb. 9, 1959	51	--	6.62	--		--	--	
		Oct. 7, 1959	--	--	6.16	--		--	--	
Salt: Below Stewart Mt. Dam, Ariz	09 5020	July 1–23, 25–31, 1959	1,420	2.20	14.6	6.64	5.88	580	.11	.10
		June 1–2, 4, 1958	764	2.94	16.4	5.58		832	.09	
		Jan. 14–29, 1960	--	2.10	11.4	5.43		491	.10	
San Juan: Near Archuleta, N. Mex	09 3555	June 1–19, 1959	1,690	1.00	4.10	4.10	5.21	99	.18	.19
		Oct. 1–12, 1957	1,120	1.50	6.38	4.25		172	.16	
		Oct. 1–26, 1958	396	2.00	9.35	4.68		236	.17	
		Nov. 18, 1958	250	2.35	14.8	6.30		280	.23	
		July 18–31 1959	236	2.15	14.4	6.70		278	.23	
Scantic: At Broad Brook, Conn	01A1845	Dec. 10, 1959	297	.55	2.03	3.69	4.13	75	.12	.14
		June 25, 1958	78	.90	4.10	4.56		104	.17	
Shiawassee: At Owosso, Mich	04 1445	Jan. 16, 1960	--	3.04	4.10	1.35	1.35	284	.06	.06

Snake: At King Hill, Idaho	13 1545	Dec. 16–31, 1958	9,140		5.02			332	.07	
		June 1–30, 1958	9,102	2.30	9.58	4.17	2.75	311	.14	.08
		Jan. 1–30, 1959	8,850	2.40	3.19	1.33		336	.04	
St. Johns: Near Cocoa, Fla	02B2324	Sept. 23, 1959	2,323	.95	15.5	16.3		211	.32	
		July 7, 1958	[8] 411	1.60	25.1	15.7	14.4			.32
		Sept. 2, 1958	[8] 357	2.05	22.8	11.1				
St. Lawrence: At Thousand Island Pk., N.Y.		Oct. 5, 1959		1.90	3.42	1.80	1.85	180	.08	.08
		Oct. 7, 1958		1.80	3.42	1.90		170	.09	
Susquehanna: At Danville, Pa	01B5405	Mar. 7–29, 1958	23,100	.95	1.96	2.06		111	.08	
		July 13, 1958	11,300	1.15	2.01	1.75	1.96	138	.06	.07
		Sept. 7, 1958	2,380	2.10	4.33	2.06		277	.07	
West Branch at Lewisburg, Pa	01B5535	Mar. 11–30, 1958	14,500		2.05					
		July 13, 1958	4,980	.90	2.28	2.53	2.29	112	.09	.08
		Sept. 14, 1958	2,980	1.05	2.15	2.05		129	.07	
Suwannee: At Branford, Fla	02B3205	Apr. 23, 1959	19,200	1.20	.66	.55		102	.03	
		July 15, 1958	13,400	1.05	1.82	1.73	.94	102	.08	.05
		Sept. 16, 1958	5,200	2.54	1.35	.53		192	.03	
Tennessee: Kentucky Dam near Paducah, Ky.	03B6095	Apr. 21–30, 1958	97,350	1.10	.84	.76		87	.04	
		June 1–10, 1958	55,470	.95	1.69	1.78	1.20	86	.09	.06
		Nov. 21–29, 1958	39,600	1.20	1.28	1.07		114	.05	
Wabash: Near New Haven, Ill	03A3788	June 21–30, 1958		2.15	4.56	2.12		199	.10	
		May 21–31, 1958		2.99	5.24	1.76	1.69	307	.07	.07
		Nov. 21–30, 1958		2.69	3.19	1.19		280	.05	
White: At Clarendon, Ark	07 0778	May 11–23, 1958		.65	.75	1.15		98	.03	
		Mar. 1–10, 1958		1.50	.64	.43	.70	138	.02	.02
		Sept. 11–20, 1958		1.75	.89	.51		172	.02	
Willamette: At Salem, Oreg	14 1910	Dec. 16–22, 24–31, 1958	35,300		.98			49	.09	
		Jan. 1–29, 1960		.25	.80	3.20	3.79	54	.06	.08
		July 1–3, 7–31, 1958	7,180	.26	1.14	4.38		54	.09	
Withlacoochie: Near Holder, Fla	02B3130	Oct. 20, 1959	3,950	1.05	2.51	2.39	2.39	97	.11	.11
Yakima: At Kiona, Wash	12 5105	Dec. 23–31, 1958	4,900		1.35			112	.05	
		Apr. 16–23, 1959	2,790		1.66			137	.05	.05
		July 16–Aug. 13, 1958	1,170		2.74			219	.05	
Yellowstone: Near Sidney, Mont	06A3295	May 26–31, 1958	35,970	1.90	5.70	3.00		220	.11	
		Mar. 10, 18, 25, 1959	19,200	2.50	11.2	4.48	3.74	398	.12	.12
		Jan. 4, 9, 17, 25, 1959	5,100		22.3			712	.14	
Yuma Main Canal: Below Colorado River Siphon at Yuma, Ariz.	09 5255	Mar. 3–7, 10–14, 18–21, 24–28, 31, 1958	4,840	4.69	18.2	3.88		777	.10	
		Sept. 1–30, 1959	570	4.29	47.9	11.2	7.86	768	.27	.19
		Oct. 1–30, 1959		4.29	36.5	8.51		754	.21	

[1] Discharge measured at Tulsa, Oklahoma (07 1645). [2] Discharge measured below Kern Canyon powerhouse. [3] Discharge measured at Bethlehem, Pa. (01B4530). [4] Station No. 775 (25 percent of flow). [5] Station No. 1425 (75 percent of flow). [6] Composite of 10 verticals across the stream. [7] Discharge at Roanoke Rapids, N.C. [8] Discharge data near Christmas, Fla.

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