Preliminary Survey of the Saline-Water Resources of the United States

By R. A. KRIEGER, J. L. HATCHETT, *and* J. L. POOLE

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A discussion of salinity and a compilation of measurements and chemical analyses of saline ground and surface waters, with an emphasis on their geographic and geologic distribution

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PRELIMINARY SURVEY OF THE SALINE-WATER RESOURCES OF THE UNITED STATES

By R. A. KRIEGER, J. L. HATCHETT, and J. L. POOLE

ABSTRACT

Basic hydrologic data available in the field offices of the U. S. Geological Survey and reports issued by the Survey furnish evidence that saline water (defined in this report as water containing more than 1,000 parts per million of dissolved solids) is available under diverse geologic and hydrologic conditions throughout the United States.

The number of areas in which undeveloped supplies of fresh water are available has diminished considerably with the rapid growth of industries and population in the past decade. Many areas previously considered to have relatively unlimited water resources have reached the point at which water-supply shortages exist or are threatened.

In the East, saline surface water occurs chiefly in tidal streams, estuaries, and bays. There the concentration of dissolved salts at any given place depends on the discharge of the river and on the tide. In the Connecticut River at Saybrook, Conn., chloride concentrations have been found as high as 14,330 ppm (parts per million) and in the Hudson River at West Point as high as 2,000 ppm. Sea-water intrusion occurs in the Delaware River upstream to Eddystone, Pa. Chesapeake Bay and parts of tributary streams contain a vast amount of saline water inland for a great distance.

In the Ohio River and St. Lawrence River basins, saline surface water occurs in few places, generally as the result of pollution by industrial and mine wastes. The Tuscarawas River in Ohio has a hardness which at times has exceeded 10,000 ppm, and the Grand River at Painesville, Ohio at times has contained more than 18,000 ppm of dissolved solids. In the Hudson Bay drainage basin in North Dakota, in East Stump Lake in the Devils Lake chain, dissolved solids of the sodium sulfate type have been as high as 106,000 ppm. The Sheyenne River has been saline at low flows.

In the semiarid section of the Missouri River basin, many of the rivers and streams are saline at low flows. The salinity commonly increases downstream owing to pickup of natural salt and to return flows from irrigated land. Typical examples of streams where such increases occur are the Powder and Bighorn Rivers in Wyoming. Several saline lakes occur in eastern Montana and in the Nebraska sandhills. Some lake waters are of the sodium, potassium bicarbonate type. Saline surface waters, principally of the sodium chloride type, occur in Kansas in a central north-south belt as a result of solution of salt from Cretaceous and Permian rocks and of the discharge of waste brines from oilfields. The principal saline streams are the Saline, Smoky Hill, and Solomon Rivers.

Salt-bearing rocks, drainage from salt marshes, brines from oilfields, and other pollution are sources of salinity in the Arkansas, Cimarron, Canadian, Verdigris, and Neosho Rivers of the Arkansas River basin. The salinity is variable, ranging

for example, from less than 1,000 to more than 15,000 ppm of dissolved solids in the North Canadian River at Oklahoma City. In western and northwestern Texas, the streams generally are saline during at least part of the year, but impoundment moderates the salinity to acceptable levels. Along the gulf coast of Texas and Louisiana, salt-water intrusion into the streams occurs, especially during low flow and where large quantities of fresh water are pumped from the river for ricefields and industrial plants. The Brazos, Colorado, and Pecos Rivers of Texas are sometimes saline. The salinity of the Pecos River increases from Roswell, N. Mex., south to the Red Bluff reservoir in Texas, owing to inflow from springs and irrigation return flow. The principal saline springs are in the Malaga Bend area above the Red Bluff reservoir, where brine, flowing about 0.5 cubic foot per second, enters the river carrying dissolved solids of concentrations as high as 270,000 ppm or about 8 times that of sea water. The nearly saturated solution, mainly of sodium chloride, adversely affects the quality of the river water to the extent that in the area downstream it can be used for irrigation only by excess irrigation of exceptionally well-drained soils. Dissolved material in the water from the Brazos River consists largely of calcium, sodium, sulfate, and chloride.

Waters of the upper Colorado River basin emerge from canyons dilute but pick up salt in the valleys, especially in late summer when return flows from irrigation are large. Samples of the San Juan River were of the calcium sulfate type, but samples from the Price, Gunnison, and Dolores Rivers and tributaries of the Green River were of the sodium chloride type, at times of moderate salinity. In the lower Colorado River basin, the Little Colorado River contains as much as 4,000 ppm of dissolved solids, and the Virgin River carries highly mineralized water from mineral springs below La Verkin, Utah. Low flows of the Gila River at Gillespie Dam in the lower basin carry more than 6,000 ppm of dissolved solids. In the Great Basin, Pyramid and Soda Lakes contained nearly 8,000 ppm of dissolved solids. Samples of the Salton Sea, in 1951, had 38,000 ppm of dissolved solids. The Alamo River in California and the Sevier River in Utah at times, have as much as 1,500 ppm and 3,000 ppm, respectively, of dissolved solids, principally from irrigation return flow.

Although data are meager, very little saline water has been found in the Columbia River basin and the rivers draining the western slopes of the Coast and Cascade Ranges.

The Atlantic and Gulf Coastal Plain region has the greatest reserve of fresh ground water in the entire country, but many areas of serious overdevelopment exist locally within the region. In general, slightly to moderately saline ground water is available in large quantities from the Cretaceous, Tertiary, and Quaternary formations in many parts of the region. A narrow belt along the coast from New England to Texas, almost the entire States of Louisiana and Florida, and large parts of Alabama, Mississippi, Arkansas, and Texas have, in addition to large supplies of fresh ground water, tremendous quantities of saline water at moderate depths.

In the East-Central region of Paleozoic and other old rocks the principal sources of fresh water are the glacial sand and gravel blanketing the northern part of the region as far south as the Ohio River, and the Paleozoic sandstone and limestone where they occur at shallow to moderate depths. The unglaciated part and, to some extent, the glaciated part of the region are areas of barely adequate ground-water supply, especially in some industrial localities where there has been overdevelopment of existing supplies. Except in the New England States, the Blue Ridge and Piedmont provinces, and parts of Minnesota and Wisconsin, which are underlain by crystalline rocks, moderate to large quantities of saline water are available from sedimentary rocks of Paleozoic age at moderate to great depths. In some localities saline water occurs in the overlying glacial drift. In the absence of more suitable supplies, many towns and villages in parts of the Mississippi Valley lowland presently are using slightly saline ground water.

The Great Plains region is one in which fresh ground-water supplies are generally deficient, except in some areas underlain by Tertiary and Quaternary sand and gravel. The most extensive aquifers are the Dakota sandstone, which yields water that generally is highly mineralized, and the Ogallala formation of the southern half of the region, which yields large quantities of hard water which locally is slightly saline. In this area the Ogallala is underlain by Permian, Cretaceous, and Tertiary formations which contain saline water at moderate depths. In the Roswell artesian basin of southeastern New Mexico, Permian limestone is the source of large quantities of water, most of which may be classed as slightly to moderately saline.

In the Western Mountain region, which occupies the western third of the United States, the principal sources of fresh ground water are the Tertiary and Quaternary lava flows of the Columbia Plateaus, the valley-fill deposits of the Basin and Range and Pacific Mountain provinces, and the glacial deposits of the Pacific Northwest. The southern half of the region is an area of perennial water shortage in which the problem is aggravated by recent increases in ground-water pumping for municipal and irrigation purposes. In many of these areas, the surface water is fully appropriated, and the fresh ground water is fully developed or overdeveloped; large volumes of slightly and moderately saline ground water have long been used in some localities. Wells tapping the Tertiary and Quaternary valley fill in these areas yield as much as 2,000 gallons per minute of water ranging from fresh to very saline. The valley fill of many of the closed basins of Utah, Nevada, California, and Arizona yields varying quantities of saline water. In a typical closed basin, however, highly mineralized water usually is limited to the central, or playa, area where the sediments are of low permeability. Ground-water supplies of the Colorado Plateau generally are deficient in quantity and low in chemical quality; however, moderate amounts of fresh to moderately saline water are produced from several aquifers of low permeability which underlie much of the region.

INTRODUCTION

PURPOSE AND SCOPE

The inventory of saline waters that follows is a contribution to the Interior Department's Saline Water Conversion Program; the objective is to develop economically feasible processes for converting saline water to fresh water. The inventory is an essential phase of the program of study to evaluate the Nation's saline-water resources. The report describes the availability of sources of saline water which will be important if the research being carried on under the sponsorship of the Department results in the development of economical methods of saline-water conversion.

The study is being directed toward the preparation of a generalized reconnaissance report on the occurrence and distribution of saline water in the United States, and the preparation of more detailed reconnaissance reports on the occurrence and distribution of saline waters in several representative States, beginning with Texas (Winslow and Kister, 1956).

This report provides preliminary information for different sections of the country regarding principal water-bearing formations in which saline waters are known to occur, approximate depth from the land surface to saline aquifers, yield of wells and representative chemical analyses, records or estimates of flow, and maximum and minimum concentrations of saline surface waters, and the approximate volume and chemical quality of saline lakes.

The increasing interest in saline-water resources stems from research activities which have led to development of processes for the demineralization of saline water wherein the energy cost is proportional to the mineral content of the water. Thus, greater interest is being shown in demineralization of "marginal" saline waters than of sea water and even more highly concentrated brines. Because the quantity of "marginal" ground and surface waters in the Nation is very large, they are a potential resource that eventually may be economically demineralized for agricultural, industrial, domestic, and other uses.

DEFINITION OF SALINE WATER

The term "saline water" is used in this report to designate water that is generally considered unsuitable for human consumption or for irrigation because of its high content of dissolved solids or because of the presence of certain constituents in quantities exceeding those set by the U. S. Public Health Service (1946) for drinking water.

The Public Health Service has established the following limits for certain chemical constituents commonly found in drinking water used on interstate carriers. The standards have been widely adopted for public supplies in general. They are as follows: iron and manganese together, 0.3 ppm; magnesium, 125 ppm; sulfate and chloride each, 250 ppm; and fluoride, 1.5 ppm. Dissolved solids should not exceed 500 ppm; however, if water of such quality is not available, a dissolved solids content of 1,000 ppm is permitted. Magistad and Christiansen (1944) have given tentative standards for irrigation waters, but they indicate that consideration should be given to the characteristics of the soil in evaluating the effect of a water of given chemical composition on a given soil. By these standards, water containing less than 700 ppm of dissolved solids and a percent sodium [1] less than 60 is considered suitable for irrigation of almost all plants under almost all conditions.

In a few locations in the southwestern United States, water containing more than 4,000 ppm of dissolved solids is used continuously for

[1] Percentage of sodium among the principal cations—sodium, potassium, calcium, and magnesium, all expressed as chemical equivalents.

irrigation, and in many areas in the southwestern States and the Great Plains region, supplies containing as much as 2,500 ppm of dissolved solids are used for drinking by those who have become accustomed to them (Ellis, 1954).

Water containing 1,000 ppm of dissolved solids is used for public supplies in many areas of the East-Central region where water of lower dissolved-solids content is not available.

Partly on the basis of the above standards of quality, and for consistency in this report, specific terms used in describing the degree of salinity of water have been selected arbitrarily.

Description	*Dissolved solids, in parts per million*
Slightly saline	1,000–3,000
Moderately saline	3,000–10,000
Very saline	10,000–35,000
Brine	35,000+

The "slightly saline" category includes many natural surface- and ground-water supplies that are currently in use or are potentially usable. The upper limit for very saline water was set as that for ocean water, which is commonly used as a gage in salinity of water. Concentrations exceeding that for ocean water are grouped arbitrarily as brines, no distinction being made as to the composition of the dissolved solids. By far the largest number of brines, however, represent concentrated ocean water containing mostly sodium chloride.

SOURCES OF DATA

The data used in the preparation of this report were obtained largely from the files of field offices of the Water Resources Division of the Geological Survey, but also partly from reports, published and unpublished, of water-resources studies carried on by the Survey, both independently and in cooperation with many State and Federal agencies. Other data were furnished by State agencies, directly or in the form of reports of investigations issued by them. Because many of the chemical analyses are unpublished, acknowledgment has been made to the organization from which each was obtained.

The Geological Survey has been collecting data about the quantity of surface water since 1888. Measurements of stage, discharge, and content of streams, lakes, and reservoirs in the United States are published in cooperation with States and other agencies in a regular series of annual water-supply papers. The regular series of annual water-supply papers—the Geological Survey's records of chemical analyses, suspended-sediment content, and temperature of surface water—was begun in 1941 in cooperation with State and Federal agencies. In 1941 there were about 40 stations at which daily samples of surface water were collected for chemical examination, in 1949 there were 143, and in 1954 there were 227. Currently each year's report is issued in four volumes; reports are available through the 1952 water year (year ended September 30, 1952).

The Subcommittee on Hydrologic Data of the Federal Inter-Agency River Basin Committee has prepared two inventories of published and unpublished chemical analyses of surface waters (1948, 1954).

Acknowledgment is made in the tables to sources of data other than the Geological Survey.

EXPRESSION OF RESULTS

The dissolved mineral constituents are reported in parts per million. A part per million is a unit weight of a constituent in a million unit weights of water. Equivalents per million are not given in this report, although the expression of analyses in equivalents per million is sometimes preferred. An equivalent per million is a unit chemical combining weight of a constituent in a million unit weights of water and is calculated by dividing the concentration in parts per million by the chemical combining weight of the constituent. For convenience in making this conversion by multiplication instead of division, the reciprocals of chemical combining weights of the most commonly reported constituents (ions) are given in the following tabulation.

Constituent	*Factor*	*Constituent*	*Factor*
Iron (Fe^{++})	0.03581	Bicarbonate (HCO_3^-)	0.01639
Iron (Fe^{+++})	.05372	Carbonate (CO_3^{--})	.03333
Calcium (Ca^{++})	.04990	Sulfate (SO_4^{--})	.02082
Magnesium (Mg^{++})	.08224	Chloride (Cl^-)	.02820
Sodium (Na^+)	.04350	Fluoride (F^-)	.05263
Potassium (K^+)	.02558	Nitrate (NO_3^-)	.01613

Results given in parts per million can be converted to grains per United States gallon by dividing by 17.12. A calculated quantity of sodium and potassium is given in some analyses and is the quantity of sodium needed in addition to the calcium and magnesium to balance the acid constituents.

The hardness, as calcium carbonate ($CaCO_3$), is calculated from the equivalents of calcium and magnesium except for a few samples for which the reported values also include equivalents of free mineral acid, aluminum, iron, and manganese when these are present in significant quantities. The hardness caused by calcium and magnesium (and other ions if significant) equivalent to the carbonate and bicarbonate is called carbonate or temporary hardness; the hardness in excess of this quantity is called noncarbonate or permanent hardness.

For those analyses where sodium and potassium are reported separately, the percent sodium has been computed by dividing the equivalents per million of sodium by the sum of the equivalents per million of calcium, magnesium, sodium, and potassium and multiplying the quotient by 100. For analyses where sodium and potassium were calculated and reported as a combined value, the value reported for percent sodium will include the equivalent quantity of potassium.

Specific-conductance values are expressed in reciprocal ohms times 10^6 (micromhos) at 25°C. Hydrogen-ion concentration, expressed as pH, is the negative logarithm of the number of moles of ionized hydrogen per liter of water.

An average of analyses (arithmetical or weighted) for the water year is given for most daily stream-sampling stations. An arithmetical average represents the composition of water that would be contained in a vessel or reservoir that had received equal quantities of water from the river each day for the water year. A weighted average represents approximately the composition of water that would be found in a reservoir containing all the water passing a given station during the year, after thorough mixing in the reservoir. The weighted average of the analyses is computed by multiplying the discharge for the sampling period by the quantities of the individual constituents for the corresponding period and dividing the sum of the products by the sum of the discharges. Water as represented by the weighted average is less concentrated than that represented by the average of the individual analyses for most streams because at times of high discharge the rivers generally have lower concentrations of dissolved solids than they do at times of low flow.

SURFACE WATER

By R. A. Krieger and J. L. Hatchett

DISCUSSION OF SALINITY

Surface water as considered here is that part of the precipitation appearing as runoff on the earth's surface. It includes both water that runs off directly at the surface into streams and lakes and water that seeps into these surface-water bodies after having traveled through the ground. The rest of the precipitation is intercepted by the leaves of vegetation and is evaporated, or is absorbed by the soil and later transpired by vegetation or evaporated directly from the soil. The total loss by evaporation and transpiration is called evapotranspiration or "water loss" and, together with the runoff, accounts for all the precipitation.

The interior of the United States, particularly the western part, where runoff is less than 10 inches per year (fig. 1) includes most of the areas where saline surface water has been observed.

The chemical composition of the dissolved solids of water has been the principal concern in this study of saline surface water, but the

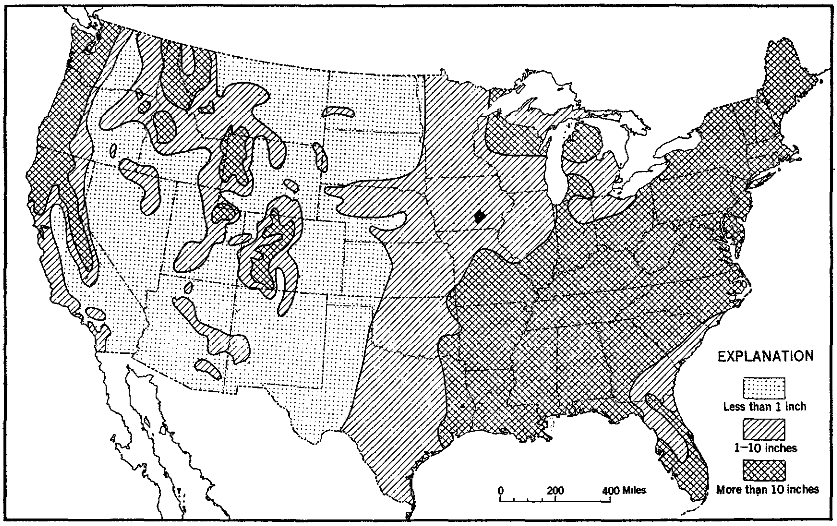

FIGURE 1.—Average annual runoff in the United States.

quantity of water available and the suspended-sediment content of the water also are important factors to consider in planning its use.

In closed-basin areas, evaporation of the surface waters causes an increase in the concentration of dissolved solids. Many lakes in the Great Basin contain water that has been concentrated by evaporation or that has redissolved accumulated salts left by receding water, so that the water is saline.

Saline waters occur in tidal streams along the coast where the mixing of sea water and surface water may extend several miles inland. Near the mouth of a stream the concentration of dissolved solids may approach that of sea water, and the sodium and chloride ions predominate.

Man creates saline water in places by the use of water for irrigation. Although some of the dissolved solids are removed by plants or precipitated during irrigation, most of them remain in solution. Because some water is taken up by plants and retained or transpired, and some is lost by direct evaporation, there is an increase in the concentration of dissolved solids in the irrigation return flow that contributes to the surface-water supply. Successive reuse of water for irrigation may increase the dissolved-solids content of the water from irrigated areas to several thousand parts per million.

Municipal and industrial wastes may increase the dissolved-solids content of surface water to the extent that it becomes saline. Oilfield wastes contribute to the salinity of surface water in some areas.

In most of the observed occurrences of saline surface water in streams, the mean daily flow was less than about 400 cfs (cubic feet per second) and the observed maximum concentration of dissolved solids was generally less than about 3,000 ppm (table 3). In general, the dissolved solids in the water at any specific location are highest when the flow is the lowest. For example, the flow and dissolved-solids content of the Pecos River at Puerto de Luna, N. Mex., were fairly constant for the first 6 months of the 1949 water year (October 1948 through March 1949), the water containing about 2,200 to 2,400 ppm of dissolved solids; during the remainder of the year, the water ranged from fresh to slightly saline in response to fluctuation in streamflow (table 1). On the other hand, the dissolved-solids content of the water in the Saline River near Russell, Kans. is not constant for any long period (table 2).

Specific-conductance duration curves for two stations on the Canadian River and one station on Elk Creek in Oklahoma are shown in figure 2. An approximate dissolved-solids figure can be obtained by multiplying the specific conductance by 0.7. The percentage of days and streamflow represented by any single specific conductance can be read directly from these curves. The curves represent cumulative data and not the chronologic occurrence of these conditions.

Figure 3 illustrates the range in dissolved solids and the variation in flow during a period of time for the Colorado River at Grand Canyon, Ariz. The maximum flow for the year at the Grand Canyon station occurs during the spring runoff, at which time the dissolved-

TABLE 1.—*Selected data for the Pecos River at Puerto de Luna and below Alamogordo Dam, N. Mex. (from U. S. Geol. Survey, 1953b)*

Date of collection	Mean discharge (cubic feet per second)	Dissolved solids (parts per million)	Percent sodium	Specific conductance (micromhos at 25°C)
Pecos River at Puerto de Luna, N. Mex.				
Oct. 1-8, 10, 1948	94.3	2,300	9	2,620
Nov. 1-10	109	2,260	10	2,590
Dec. 1-10	110	2,380	11	2,700
Jan. 1-10, 1949	95.4	2,400	11	2,730
Feb. 1-10	93.7	2,410	8	2,760
Mar. 1-10	112	2,450	9	2,780
Apr. 1-10	98.5	2,240	7	2,610
May 1-10	468	574	6	824
June 1-4, 6-9	342	943	6	1,250
June 28-30, July 1-9, 11	216	1,900	6	2,170
Aug. 1-3, 7-10	276	1,270	6	1,590
Sept. 1-2, 4-5, 7-9	1,282	1,500	3	1,850
Pecos River below Alamogordo Dam, N. Mex.				
Apr. 1-3, 5-6, 8-10, 1949	793	2,470	9	2,750
May 1-10	104	1,300	9	1,630
June 1-10	60.2	680	14	957
July 1-10	109	695	11	937
Aug. 1-10	426	654	9	895
Sept. 1-10	887	726	8	991

TABLE 2.—*Selected data for the Saline River near Russell, Kans., October 1947 to September 1948 (from U. S. Geol. Survey, 1953a)*

Date of collection	Mean discharge (cubic feet per second)	Dissolved solids (parts per million)	Percent sodium	Specific conductance (micromhos at 25°C)
Oct. 1-31, 1947	8.6	4,430	75	6,660
Nov. 1-30	12	3,620	69	5,640
Dec. 1-31	18	2,770	66	4,220
Jan. 1-Feb. 1, 1948	12	3,960	67	3,960
Feb. 2-29	16	1,890	61	2,900
Mar. 1-31	51	1,400	51	2,160
Apr 1-30	29	2,120	63	3,260
May 1-31	31	2,390	62	3,720
June 1-28	114	966	49	1,560
June 6	264	972	38	1,340
June 28, 12:45 p. m.	1,150	438	22	603
June 29-July 1	1,850	286	16	435
June 30	2,470	208	12	316
July 1	1,650	218	14	305
July 2-31	317	470	33	726
July 2	717	248	25	376
July 18	1,500	230	18	330
Aug. 1-31	145	696	43	972
Sept. 1-30	27	2,090	62	3,270

solids concentration in the water is lowest. These data should not be considered typical for all saline water. At other stations where saline water has been observed, the maximum flow and minimum concentration may appear during summer rains. Also, at other stations concentration of more than 1,000 ppm may exist during the entire year or for several years.

A change in concentration of dissolved solids that sometimes occurs during flood flows is an exception to the rule of high flow and low concentration. During the initial rise in a flood, the concentration of dissolved constituents may increase as the flow increases. This feature, which has been observed particularly in streams in semiarid or arid regions, is attributed to channel scour and to solution of salts deposited at low flow.

In areas where man has regulated the flow of streams by impoundment, there is less daily variation in the concentration of dissolved solids in water passing points downstream, even though the flow may vary considerably from day to day. The fluctuation of the dissolved-solids concentration of the Pecos River above and below Alamogordo Dam, N. Mex. (table 1), illustrates the effect of streamflow regulation.

EXPLANATION OF TABLES AND DEFINITION OF TERMS

The U. S. Geological Survey has divided the area of the United States into 14 parts which correspond generally to the major drainage areas, in order to facilitate publication of the annual series of surface-water reports. The area included in each part is shown in plate 1. The stations where saline water was observed are listed in downstream

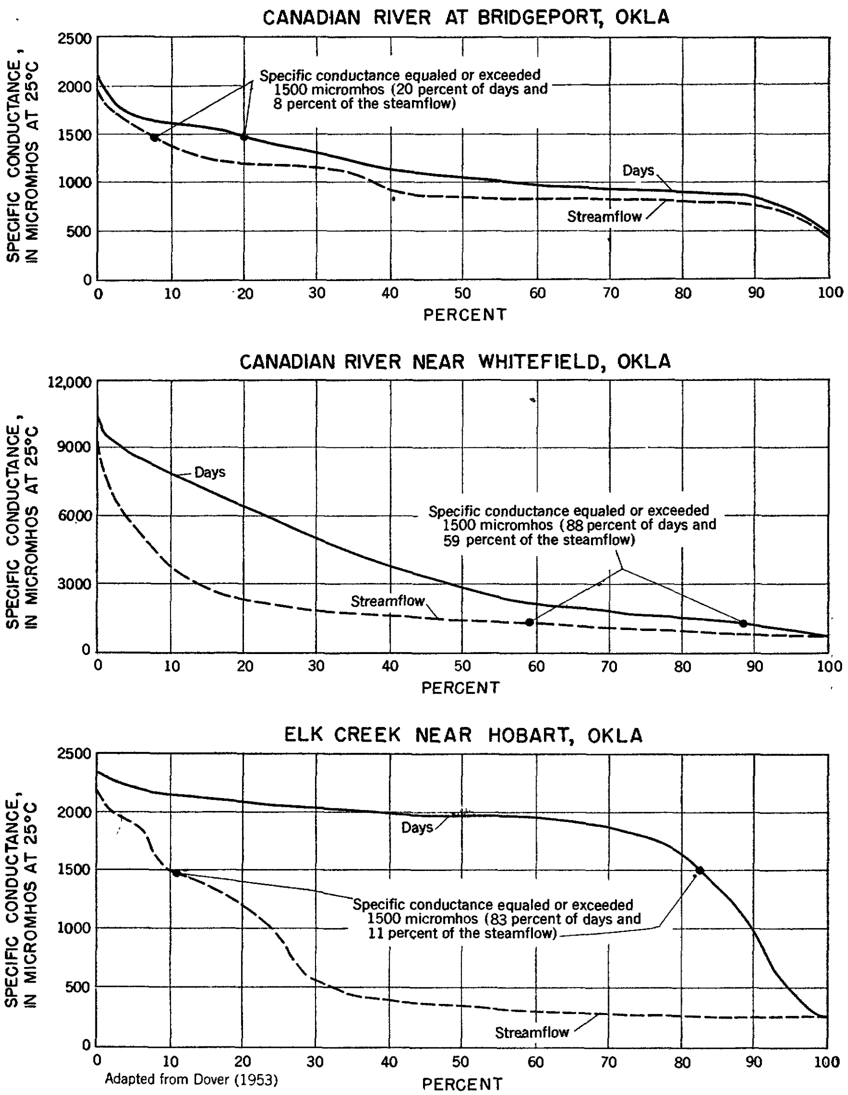

FIGURE 2.—Duration of dissolved-solids concentration for the Canadian River and Elk Creek, in Oklahoma.

order from headwater to mouth in accordance with the system adopted by the Geological Survey effective in October 1950. Previously all the stations on a stream were listed consecutively from headwater to mouth before listing any stations on tributaries to that stream. In the new order, stations on tributary streams are inserted between stations on the main streams in the order in which those tributaries enter the main stream. Stations on tributaries to tributaries are inserted in a like manner.

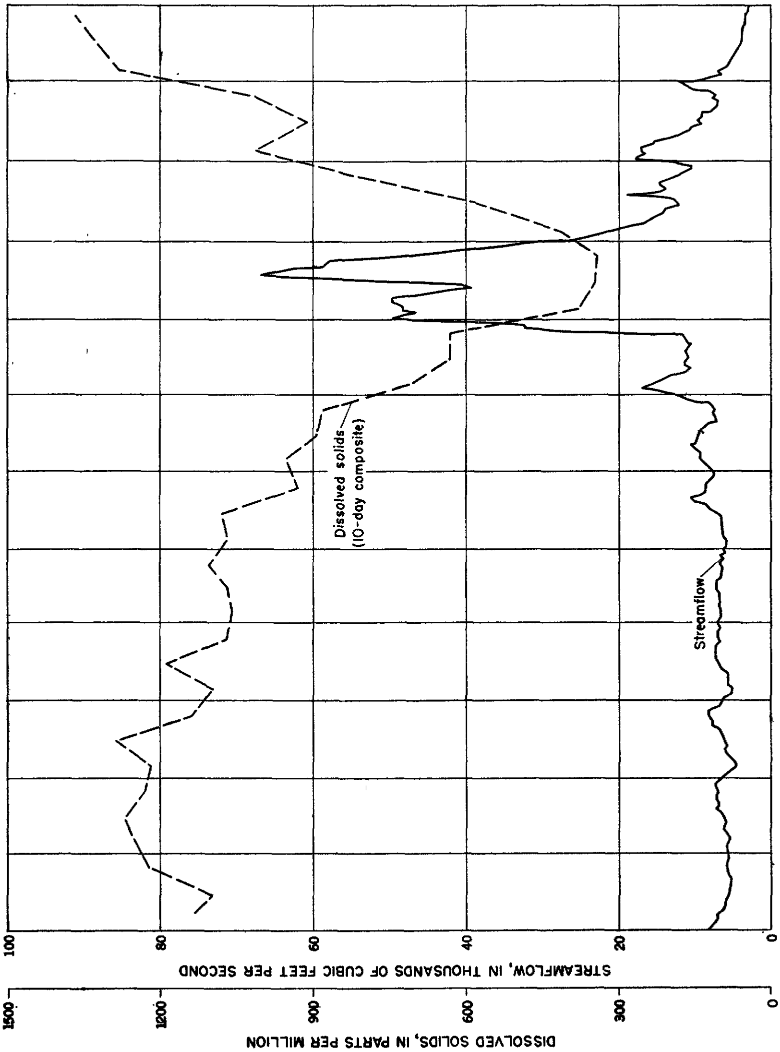

FIGURE 3.—Dissolved solids and discharge of Colorado River at Grand Canyon, Ariz.

Table 3 lists the sampling station and location according to drainage basin, and, where information is available, drainage area above station, period of record, number and frequency of samples collected, composite period, and source of basic data. The tabulated analyses may range from a few individual determinations to very complete analyses, and the period of record may range from a day to a year or more for which continuous records are available. In general, the analyses of the water represent the observed maximum and minimum dissolved-solids concentrations at a particular sampling site. At most stations the period of record is less than 10 years, and at many of these the period of record is less than 5 years. Ordinarily, the maximum concentration observed during a 10-year period will be closer to the expected extreme than that of a shorter period if the frequency of sampling is essentially the same for each of the two periods.

Many of the drainage areas given in the inventory are only approximate; however, all qualifying terms such as "about," "approximately," and "estimated" have been omitted.

When the information is available, the period of record is given to the nearest month and year. If samples were collected over a number of years, individual years were not listed separately unless there was a break in record, variation in available analytical data, or difference in source of information. Where only a few scattered observations were made, the dates are shown only for the first and last observations.

The number of analyses is intended to show the amount of analytical data available and hence the adequacy of the record. That column gives the actual number of analyses made of samples collected at each point.

The annual reports of the Geological Survey on surface water contain discharge records for many of the sampling locations.

The frequency of sampling is intended to show how often samples were collected—daily, weekly, monthly, or infrequently. The key to the symbols is given at the beginning of each table.

NORTH AND SOUTH ATLANTIC SLOPE BASINS AND EASTERN GULF OF MEXICO BASINS

Most of the saline surface waters in these basins (pl. 1, areas 1 and 2) occur in tidal streams and therefore are directly related to inland movement of ocean water or mixtures of fresh and ocean waters. There are few reported occurrences of saline surface waters above tidewaters. Much of the coastal plain is now the border zone between the fresh water of the continent and the brine of the ocean.

The volume of saline water in the coastal areas is almost unlimited; however, the chemical quality of estuarine water approaches that of ocean water where withdrawals from contributing streams or a decrease in runoff for the area cause inland movement of ocean water.

The eight principal river basins comprising the North Atlantic drainage are those of the Pennobscot, Kennebec, Androscoggin, Merrimac, and Connecticut Rivers in New England, and those of the Hudson, Delaware, and Susquehanna Rivers in the Middle Atlantic States.

In the North Atlantic drainage, relatively high annual precipitation of marked uniformity throughout the year averages 40 to 50 inches. Precipitation is higher on the mountain areas, reaching a maximum of about 80 inches annually on Mount Washington in New Hampshire. This abundant precipitation is reflected in a mean yearly runoff from the area ranging from about 35 inches (2.6 cfs per square mile) in the upper reaches of the White, Green, and Adirondack Mountains to less than 15 inches in northwestern Maine and central New York. Natural or artificial storage in some of the streams, particularly in Maine, has effected tremendous changes in the flow characteristics of the streams. Such regulation affects also the upstream extent and duration of salinity in tidal streams.

In general, not many data were available even for tidal streams; however, the general similarity of occurrence and chemical character of the water makes the available data applicable over a wide area. The Connecticut River is an example of a tidal stream affected by sea water. During 1937 the chloride content of the Connecticut River at Saybrook, Conn., ranged from 1 to 14,330 ppm, while at East Haddam, Conn., about 12 miles upstream the maximum chloride content was only 58 ppm. Such a wide range of chloride content between one station and nearby stations is to be expected in many streams in the Atlantic and Gulf of Mexico basins.

The Hudson and Delaware Rivers furnish further examples of salt-water penetration in the tidal reaches of large rivers. The Hudson River is affected by sea water as far upstream as Poughkeepsie, N. Y. Chloride concentration of 1,000 ppm were observed at West Point, more than 2,000 ppm chloride at Peekskill, and more than 8,000 ppm at Yonkers. Regulation of runoff from the basin upstream from the Sacandaga reservoir, New York, since 1930 is believed to have been a stabilizing influence on the position of the zone of mixing of the fresh and salt water. This zone is situated in the reach of channel near Poughkeepsie, about 75 miles upstream from Battery Park.

The Delaware River is the principal source of water for many industries and municipal supplies in the reach of the river from Trenton, N. J., to Marcus Hook, Pa., and both industries and municipalities use it for disposal of their wastes. Because of the importance of this area, the following brief summary of a recent Geological Survey investigation is included.

During the period August 1949 to December 1952 it was observed (Durfor and Keighton, 1954) that the mineral content of the water increases from Trenton to Marcus Hook. During protracted periods of low flow (which occurs only during the late summer months) salt water moves upstream along the river bottom and partly mixes with the river water, owing to currents from tidal action and other factors. The upstream movement causes chloride concentrations to increase sharply at Eddystone and at Marcus Hook; near its mouth the river water tends to approach the composition of sea water. During these periods higher concentrations of dissolved solids are observed at the bottom of the river than near the surface. During normal flow there is more calcium than magnesium and more sulfate than chloride in the water. This relation is reversed when the downstream flow is low and ocean water mixes with the river water. At such times it was observed that dissolved-solids concentrations became as high as 4,150 ppm (moderately saline) at Marcus Hook, but were only about 250 ppm at the Philadelphia-Camden bridge.

It is reported that at least one industry at Marcus Hook pumps river water through cooling towers during periods when concentrations are greater than 1,000 ppm; however, it was observed that the chloride content of the water at Marcus Hook was less than about 810 ppm in about 80 percent of the samples.

Chesapeake Bay and parts of tributary streams constitute a vast system of saline-water bodies extending inland for a great distance. The long shoreline of Chesapeake Bay makes possible many sites where saline water could be obtained; however, the chemical quality is variable and the degree of salinity may exceed the ability of presently economical methods to treat the water. Analyses 15 and 16 in table 3 show the range in specific conductance in Chesapeake Bay water at Chesapeake Bay bridge to be from 11,100 to 18,000 micromhos on October 29, 1952, reportedly at low and high tide, respectively. Some tidal streams on Maryland's Eastern Shore are saline for considerable distances upstream. For example, Murphy[2] observed a specific conductance of 1,750 micromhos at high tide in the Nanticoke River at Vienna, Md., about 18 miles upstream from the river's mouth. (See analysis 7, table 3.)

In the south Atlantic and eastern Gulf drainage system, the presence of the low-lying coastal plains and the rise from the plains to the Piedmont province and the Appalachian Plateaus have a profound effect on precipitation. The average annual precipitation is fairly uniform over the coastal plain, amounting to 50 to 60 inches near the coast, 40 to 45 inches over the Piedmont province, and 50 to 60

[2] Murphy, J. J., 1953, Salinity studies on estuaries of the Eastern Shore of Maryland: U. S. Geol. Survey open-file report, p. 1-39.

inches in the mountains. Approximately two-thirds of the land area of drainage is relatively level coastal plain, and the streams are sluggish and relatively uniform in flow.

Runoff from the Blue Ridge is high but flashy, amounting to as much as 45 inches (3.3 cfs per square mile) in some areas.

The Potomac, James, and Roanoke Rivers head in the Valley and Ridge province and cut eastward through the Blue Ridge. The Peedee, Santee, Savannah, and Apalachicola Rivers head in the Blue Ridge.

The Combahee River at Yemassee, S. C., is an example of the large change in salinity (see analyses 3 and 4 in table 3) that occurs in streams having a wide range in streamflow. For example, the dissolved-solids concentration on March 25, 1952, when the discharge was 1,220 cfs, was only 87 ppm, and on September 15, 1953, when the discharge was 47 cfs, the concentration was 5,780 ppm. Both samples were taken at high tide. Fluctuations of this magnitude would cause severe operating problems in converting saline water to fresh water.

Lake Tarpon near Tarpon Springs, Pinellas County, Fla., is connected hydrologically to the Gulf of Mexico, and consequently the salinity varies with the flow of water in and out of the lake. For many years the lake has drained rapidly at intervals, each period of draining being followed by an increase in the salinity of the lake water (maximum chloride content about 4,380 ppm), making it undependable as a fresh-water supply.

OHIO RIVER BASIN

Some saline surface water occurs in the Ohio River basin, but it is related principally to disposal of industrial and mine wastes. It is reported that there are no known natural saline lakes or streams in Ohio. The manmade saline waters occur chiefly in the eastern part of the basin, where drainage is westward in the principal streams receiving industrial wastes. Some flow of the Tuscarawas and Muskingum Rivers in Ohio and some in mining and industrial areas in the Tennessee and Allegheny River basins is saline. Normally if the discharge of wastes to the streams is not continuous, or if the water discharge is high, the concentrations of dissolved salts decrease to less than 1,000 ppm. The principal ions in these polluted streams are calcium, sodium, sulfate, and chloride. The hardness of some water of the Tuscarawas River exceeded 10,000 ppm at flows of about 60 cfs. Coal-mine wastes are generally high in calcium and sulfate. Data available for this type of saline water were so few that an adequate measure of the salinity is lacking.

In the western part of the Ohio River basin, the Illinois Geological Survey found periodic samples of water from the Saline River near

Junction, Ill., to be slightly saline at streamflows less than 25 cfs. Calcium and sulfate ions were predominant. The available data for the Ohio River basin are shown in analyses 17 to 49 (table 3).

ST. LAWRENCE RIVER BASIN

Only one stream in the St. Lawrence River basin was reported to be saline. The Grand River at Painesville, Ohio, at times contains a large amount of industrial waste brines and at low flow the water may be very saline, exceeding 18,000 ppm in dissolved solids, principally calcium and sodium chloride. Despite the existence of many salt seeps and springs in Michigan, no other saline surface waters have been reported in the basin.

HUDSON BAY AND UPPER MISSISSIPPI RIVER BASINS

The Hudson Bay drainage basin, which includes parts of North Dakota, South Dakota, and Minnesota, is the only known source of saline surface water throughout the area. Many waterways in this basin have no surface outlets at normal stages, and runoff collects in depressions, is concentrated by evaporation, and forms saline lakes. The most saline of the waters, ranging from slightly saline to brine, occur as lakes in closed basins, such as those in the Devils Lake chain. Recent investigations by the Geological Survey (Swenson and Colby, 1955) showed that the total surface area of Devils Lake had shrunk from about 90,000 acres in 1867 to about 6,500 acres in 1940, and the lake had become a shallow body of stagnant brine.

Scattered records from 1889 to 1923 and more comprehensive data from 1948 to 1952 show that the salt concentration ranges from about 6,000 to about 25,000 ppm in the water of Devils Lake. Although the total concentration of dissolved solids has varied, the proportion of individual constituents has not changed appreciably. Lake waters are more concentrated in the lower part of the basin, ranging from about 19,000 to 106,000 ppm in East Stump Lake during the periods of record.

The amount of runoff in the basin and the amount retained in upstream lakes differs greatly from year to year; therefore, the annual inflow to Devils Lake is extremely variable. During years of average precipitation, temperature, and evaporation, Devils Lake and lakes upstream should receive nearly a quarter of an inch of runoff annually from the drainage area of about 300 square miles.

Cranberry Lake is unusual among the North Dakota lakes because of its relatively high carbonate and bicarbonate content, whereas the other lakes generally are relatively low in carbonate and high in sulfate. Several lakes in the chain show anomalous ratios of magnesium to calcium.

Some streams of the Hudson Bay basin are saline during part of the year. The Sheyenne River at Sheyenne, N. Dak., at a low stage was slightly saline (dissolved solids 1,810 ppm) on February 3, 1950, but during a spring flood as on April 7, 1949, had a dissolved-solids content of only 11 ppm. The Sheyenne River drains the same general area in which the saline lakes are found. Other streams in the Hudson Bay basin, such as the Souris River and the Red River of the North, and those in the upper Mississippi River basin are not saline except possibly at low flow during extreme drought periods. Undoubtedly, other saline surface waters occur in North Dakota, but the amount of water available is small.

MISSOURI RIVER BASIN

The Missouri River basin, which comprises about one-sixth of the area of the continental United States and contributes about 14 percent of the flow of the Mississippi River, has much saline surface water owing to the chemical character of the sedimentary rocks and the runoff characteristics of the Great Plains province. The principal areas in which saline water is found are eastern Montana and Wyoming, western North Dakota and South Dakota, eastern Colorado, and parts of northern Kansas. Saline water occurs in some of the sandhills lakes in western Nebraksa and in places in eastern Nebraska where the stream channel dissects sedimentary rocks containing large amounts of soluble salts. No saline water has been reported in that part of the basin in Minnesota, Iowa, and Missouri.

In the headwater areas of the Missouri River and its tributaries, the average annual runoff is high, averaging 10 to 15 inches (0.7 to 1.1 cfs per square mile). East of the Rocky Mountains, the runoff in the Great Plains generally diminishes to an average of less than 1 inch per year (0.07 cfs per square mile), and then increases again to about 3 inches near the upper Mississippi River.

The concentration of dissolved solids in waters varies with the flow in the stream, the salinity is highest during periods of low flow. In many of the smaller tributaries a large part of the total annual flow may occur in a few weeks.

The principal sources of saline surface water in the basin are ground water from saliferous shales and sands, irrigation return flows, and industrial and municipal wastes, particularly from oilfield operation. Evaporation at low flow further increases the salinity of streams.

The chemical character of the saline water is different from that found in the bays and estuaries along the seacoasts. In the waters of the Missouri River basin calcium and sodium commonly are the principal cations, and bicarbonate and sulfate are the principal anions.

The data presented in table 3 were selected from the data available to give areal coverage of the main sources of the saline water in the Missouri River basin. Generally, where there were several stations on the same stream, only one was selected to represent the water in the stream.

In the upper part of the Missouri River basin, the streams draining the mountain valleys are not saline. However, the streams draining dry basins such as the Powder River basin and the Bighorn River basin become increasingly saline downstream from natural causes and from the return flow from irrigated areas. Most of the streams lose their saline character during periods of high discharge. The waters from these two basins are high in calcium, sodium, and sulfate and contain relatively large amounts of magnesium and bicarbonate. A number of dams impound the water, and therefore a controlled supply is available. Ocean Lake near Riverton, Wyo., fed by return flow from an irrigation project and by ground water, is of the sodium sulfate type but contains appreciable amounts of calcium and chloride. The concentration and composition of the water at the Ocean Lake outlet is comparatively uniform throughout the year, averaging slightly more than 2,000 ppm in dissolved solids. The mean discharge in 1950 at the Ocean Lake outlet was 19.2 cfs. Detailed analyses of Ocean Lake and stations in the Powder River and Bighorn River basins appear in table 3.

In northeastern Montana, the Milk River at Nashua, Mont., which has an average annual flow of 555 cfs, discharges water whose chemical character is similar to that in the aforementioned basins. However, saline lakes in northeastern Montana, such as Medicine Lake contain a mixed bicarbonate sulfate type of water. The percent sodium is higher than in most Montana streams. The Little Missouri River, which drains parts of eastern Montana and western North and South Dakota, contained a sodium bicarbonate sulfate water that ranged from fresh to slightly saline during the period October 1945 to September 1951. (See analyses 96–99, table 3.)

Many of the small and particularly the intermittent streams, generally in the eastern or plains area of Montana, probably carry slightly saline waters during low flow. These waters are used for stock watering, and rarely for irrigation, but not for domestic supplies. Their flows are considered to be too small to have a marked effect on the larger streams such as the Missouri and Yellowstone Rivers.

In North and South Dakota, the rivers flowing eastward into the Missouri River are saline much of the time. High runoff in the spring and after heavy rains causes a freshening of the river water. The water in some of the streams is used for irrigation, but frequently the percent sodium is so high that judicious application of the water is necessary.

East of the Missouri River in the Dakotas, the James River is slightly saline at low flows (at Jamestown, N. Dak., the average flow is 73.5 cfs). Increased irrigation in the James River basin, such as for the proposed Oahe-James River project, undoubtedly will increase the salinity below Huron, S. Dak. Saline lakes occur in the sandhills region of Nebraska, particularly in Cherry, Sheridan, and Garden Counties. Both sodium and potassium bicarbonate waters are found, and certain of the lakes such as Alkali Lake were a commercial source of potash in World War I. Generally, good-quality ground and surface waters are readily available in large quantities, and it is unlikely that these shallow lakes could be considered a potential source of water supply.

The upper Platte River basin includes some tributaries that are saline, and the main stem of the North Platte River, which is regulated at several points, has been observed to be slightly to moderately saline at times between Casper and Cassa, Wyo. The lower Platte River basin is freshened principally because of the low mineral content of water draining from the Nebraska sandhills. In the South Platte River basin, the Cache la Poudre River near Greeley, Colo., discharging on the average 91.7 cfs of water (31-year record), was slightly saline at less than average flow in 1950. The available data on the river at Kersey, and continuous records for Julesburg, Colo., show that the water in the lower reaches of the river is slightly saline during most of the year to its junction with the North Platte River. Irrigation return water is a principal factor in the salinity of the surface water.

Excessive dissolved solids in surface waters are one of the major problems in Kansas. The dissolved solids, principally sodium chloride and calcium sulfate from natural sources, are derived principally from salt springs, salt marshes, and direct contact with saliferous geologic formations. The major sources of saline waters occur in a north-south band about 150 miles wide across the central part of the State, where salt-bearing formations underlie the area from the southern border of the State northward almost to the valley of the South Fork of the Solomon River and eastward to about the confluence of the Saline and Smoky Hill Rivers. The major drainage across this area is generally from west to east. The concentration of the water in the upper reaches of the streams is generally low, but it increases sharply as the streams cross the older rock formations (Cretaceous and Permian) that yield mineralized ground water, and then decreases as the waters are diluted by tributary inflow of lower mineral content.

In places, highly mineralized base flow may constitute as much as 35 percent of the total flow.

The disposal of oilfield brine is now subject to control by the Kansas State Board of Health, but brine disposed of in the past is still a factor in yielding saline surface waters in some oilfield areas. Some of the brines are reported to contain nearly 250,000 ppm of dissolved solids.

Reports by the U. S. Public Health Service and the Geological Survey show that the principal saline streams are the Saline, Smoky Hill, and Solomon Rivers. Saline tributary streams, such as Salt Creek which drains a salt marsh below Concordia, Kans., have been observed in the Republican River basin.

The Smoky Hill River is saline from about Russell, Kans., to the Kanopolis Reservoir, where mixing with dilute runoff freshens the water to the extent that it is usable as a public water supply. The water becomes saline again downstream, principally from the inflow of the Saline River.

Summary of streamflow data for principal saline streams in Missouri River basin

Station	*Period of record*	*Average discharge (cubic feet per second)*	*Minimum daily discharge (cubic feet per second)*
Powder River near Locate, Mont	1938–50	763	0
Middle Fork Powder River near Kaycee, Wyo.	1938–39, 1940–50	157	0
South Fork Powder River near Kaycee, Wyo.	1938–40, 1950	--------	0
Powder River at Sussex, Wyo	1938–40, 1950	--------	1. 5
Little Missouri River at Marmarth, N. Dak.	1938–50	420	0
Heart River near Glen Ullin, N. Dak.	1943–50	[1] 196	0
Cannonball River at Breien, N. Dak	1934–50	277	0
Grand River near Wakpala, S. Dak	1930–50	313	0
Moreau River near Faith, S. Dak	1943–50	[1] 397	0
Moreau River at Promise, S. Dak	1930–50	281	0
Belle Fourche River near Elm Springs, S. Dak	1928–31, 1934–50	447	0
Cheyenne River near Hot Springs, S. Dak.	1914–20, 1943–50	391	2. 8
Cheyenne River near Eagle Butte, S. Dak.	1928–50	1, 008	0
White River near Kadoka, S. Dak	1942–50	[1] 219	0
Cache la Poudre River near Greeley, Colo.	1914–19, 1924–50	91. 7	0. 8
South Platte at Julesburg, Colo	1902–6, 1908–14, 1914–50	495	0
Smoky Hill River near Ellis, Kans	1941–50	[1] 291	0
Saline River near Russell, Kans	1945–50	[1] 214	5
Arikaree River at Haigler, Nebr	1932–50	31. 3	0

[1] Mean discharge for water year 1950–51.

LOWER MISSISSIPPI RIVER BASIN

Considerable basic data about water quality are available for the Arkansas River basin, and general statements can be made with regard to the saline surface water of this basin.

The Arkansas River enters an area of saliferous Permian rocks near Hutchinson, Kans., and drainage principally from salt marshes and industrial wastes from saltworks increases the salinity of the water. Inflow of the Salt Fork of the Arkansas River and the Cimarron River increases the salt load of the river above Tulsa. In the period 1947–50, the dissolved-solids content at Sand Springs, Okla., was rarely under 1,000 ppm and at times exceeded 5,000 ppm. Below Sand Springs, there is additional salty flow from the Canadian River. Even in eastern Oklahoma, water in the Arkansas River is less desirable for most uses than is water from other available sources.

Salt springs and seeps from underlying salt beds increase the salinity of the Cimarron River near Mocane, Okla., and some tributaries, such as Crooked Creek near Nye, Kans., are reported to be saline. The salinity of the Cimarron River is further increased in its lower reaches by natural salt beds and oilfield brines.

The Verdigris River near Inola, Okla., at flows of less than about 250 cfs is slightly saline at times.

In the Neosho River, the salinity of the water is principally associated with oilfield brines, mine wastes, and municipal sewage. It is believed that, because of improved oilfield brine disposal in recent years, the chloride content has been significantly reduced, and the water is not saline during most of the year.

Water is diverted from the North Canadian River at Oklahoma City to Lakes Overholser and Hefner for municipal water supply. Downstream from the point of diversion the stream is reportedly subject to pollution by oilfield brines and is too highly mineralized for general use. Concentrations of dissolved solids that exceed 15,000 ppm have been observed at Oklahoma City.

The Canadian River crosses Permian redbeds in western Oklahoma, and saline waters, in which the anions are principally sulfate and chloride, are observed at Bridgeport. Downstream near Whitefield, a chloride content of about 4,900 ppm has been observed at flows of more than 2,700 cfs.

The Canadian River crosses Texas in a canyon cut into the High Plains. Samples of water collected at Tascosa and near Amarillo show that during low flow the water is sometimes slightly saline. However, computations of weighted averages indicate that a reservoir proposed for construction at Sanford would impound water that would not be saline.

The Canadian River crosses the Panhandle oilfield near Borger, Tex., and many oil wells have been drilled in the riverbed. Some samples of the river water at Borger have been slightly to moderately saline, and it is probable that some saline flows occur all the way across the panhandle.

In the Red River basin, surface runoff from the High Plains is small, and much of the area is noncontributing. East of the caprock escarpment, the precipitation gradually increases to about 30 inches. The rock formations of the region contain highly soluble minerals, and at times runoff is saline, particularly in Deep Red Run and Little Beaver Creek.

The upper tributaries of the Red River cross Triassic and Permian formations which contain much readily soluble material. Consequently, the chemical composition of the stream waters often takes definite characteristics that are related to the rock outcrops. The Salt Fork of the Red River and Mulberry Creek contain relatively high proportions of calcium sulfate derived from gypsum. The Prairie Dog Town Fork of the Red River is so saline, particularly with common salt, that plans for a proposed reservoir on it were dropped from consideration. The water of the Pease River is notable for being high in both sulfate and chloride. Lake Kemp on the Big Wichita River originally was built for irrigation purposes, but the salinity of impounded water limited its usefulness for that purpose. The mixture of nonsaline floodwater and saline low-flow water that is released through Denison Dam on the Red River is seldom saline, although at Gainesville, Tex., above the reservoir, the river water is moderately saline for long periods.

Some water made saline by brines from the Talco oilfield is found in the Sulphur River during low flows. Water made saline by oil operations occurs in many other areas in the Red River basin, particularly in the vicinity of Wichita Falls, Tex.

Although saline waters have been found in streams in all parts of Texas, the areas in which saline water is present for extended periods are limited. Saline water is most common in western and northwestern Texas, where rainfall is low and evaporation high and where, in places, rock formations at the surface contain relatively large amounts of readily soluble minerals. Saline waters in streams of eastern or southern Texas generally originate in the west or northwest and move down the river channels, or are due to local oilfield contamination. Very saline water from the Gulf of Mexico mixes with river water in the tidal reaches of the rivers. The position of the salt-water interface is determined by the river discharge, which varies with runoff from the drainage area, with river controls, and with use for industrial and irrigation purposes.

Except for the Arkansas and the Ouachita Rivers, the saline streams in Arkansas drain small areas and at times during the summer months have no flow. However, Smackover Creek and Bayou Lapile contribute large amounts of dissolved solids to the Ouachita River and have caused the change in quality of the Ouachita River from Camden to the Arkansas-Louisiana State line. Bayou L'Outre, Three Creeks, and Cornie Bayou empty their salt loads into the Ouachita River in Louisiana, but their total effect on the quality of the river water is not known.

In Louisiana the principal saline surface-water problems are related to oil and gas production and sea-water intrusion. Although much of the salt water produced from the newer oilfields is injected underground, salt water in the older fields has customarily been discharged into pits or into stream channels. Consequently, tributaries of the Red and Ouachita Rivers often contain moderately to very saline water, particularly when the stream discharge is low.

In southwestern Louisiana thousands of acres of rice is irrigated by water pumped from numerous short streams. Salt water has been found many miles inland from the mouth of the Vermilion River because the heavy withdrawal has permitted water to move inland from the Gulf of Mexico. However, the salinity in the Vermilion River during periods of reversal of flow is modified because Vermilion Bay is considerably freshened by large volumes of water from the Atchafalaya River.

The salinity of the Mermentau River above the Intracoastal Waterway is controlled considerably by locks and control structures below Grand and White Lakes.

In the lower Mississippi River Delta, dependable fresh-water supplies are generally lacking, and cisterns are an important source of domestic supplies. Large volumes of brine are available in many channels and bayous.

WESTERN GULF OF MEXICO BASINS

The low flows of the Salt Fork of the Brazos River frequently are very saline. Weighted-average flows are moderately saline, although some low flows are fresh. The Double Mountain Fork of the Brazos River is fresh during flood periods, its low flows are moderately saline, and its weighted-average flows are slightly saline. The water of the Clear Fork generally is fresh, although slight to moderate salinity sometimes occurs. Mixtures of the three waters are stored about 20 miles northwest of Mineral Wells, Tex., in the Possum Kingdom reservoir on the Brazos River. Water released from the reservoir is slightly saline, and inflow to the Whitney reservoir about 80 miles downstream is sometimes slightly saline. Formerly saline water traveled to the mouth of the Brazos River, but under existing conditions it cannot occur below the Whitney reservoir except when caused by oil brines released through minor tributaries.

The Calcasieu River channel, Calcasieu Lake, Sabine Lake, and lower Sabine River sometimes have very saline waters—approaching that of the open gulf.

The Colorado River in Texas is sometimes slightly saline above Colorado City, owing to the presence of salt springs in the riverbed. Slightly saline water has been observed at Robert Lee also. Because construction of the dam forming Lake Colorado City, Cherry Creek frequently was slightly to moderately saline, but the impounded water is of good quality. Other tributaries of the upper Colorado contain saline water in low flows and fresh water during flood flows.

The Pecos River watershed extends from the Truchas Peaks of the Sangre de Cristo Range in northern New Mexico to the confluence of the Pecos River with the Rio Grande, near Comstock, Tex. The total drainage area of the Pecos River is 44,535 square miles, of which 11,313 square miles comprises noncontributing areas in closed basins. The Pecos River is perennial, except for a reach from about Anton Chico to the vicinity of Colonias, N. Mex., and the reach between Alamagordo Dam, N. Mex., and the mouth of Salt Creek.

The slightly saline water of the Pecos River below Alamagordo Dam is characterized by a high proportion of calcium and sulfate. From Roswell, N. Mex., south to the Red Bluff reservoir in Texas, inflow from springs and irrigation return flow cause an increase in salinity of the Pecos River and a change in the predominant ions in the water. The springs adding most of the salt are in the Malaga Bend area above the Red Bluff Reservoir. The brine inflow in this area averages only about 0.5 cfs, but the brine is a nearly saturated solution, mainly of sodium chloride. The concentration of dissolved solids is as much as 270,000 ppm, or about 8 times that of sea water; the average addition of salt amounts to about 430 tons per day. The brine inflow adversely affects the quality of the river water to the extent that it can be used for irrigation only by special land practices involving the use of large quantities of water to leach the soil.

Manufacturing, mining, and allied enterprises in the Pecos River basin use small amounts of surface water. The available water supply in the Pecos watershed is so limited that any increased large-scale use will necessitate the curtailment of some existing uses.

Water of the Pecos River at Orla, Tex., ranges from slightly to moderately saline. The river water at Grandfalls frequently is very saline, owing principally to inflow from salt springs. Tributary inflow of the Pecos River in Texas generally is small and moderately to very saline.

Mixtures of river water and gulf water in varying proportions are found on the entire gulf coast. Analyses of samples of nonsaline water and saline water at two points in the lower Trinity River are given in table 3.

The International Boundary and Water Commission (1951) reports annual average concentrations exceeding 1,000 ppm for the Rio Grande at Fort Quitman, at the upper Presidio Station, and for the Pecos River near Comstock, for the period 1935–51. The Fort Quitman station is 81.1 river miles below American Dam at El Paso, Tex., and streamflow which may range from more than 10,000 cfs to no flow is modified by reservoirs, diversions, and drainage returns. Other stations on the Rio Grande and many of its tributaries are saline during parts of the year, particularly during the winter months of low flow. At the upstream stations in Texas, the Rio Grande water is principally of the sodium chloride type, as is that of the Pecos River at Comstock, but sulfate also is important.

COLORADO RIVER BASIN

Most quality-of-water data for the Colorado River basin have been obtained since 1940, although records for some stations on the main stem date back to 1925. Data concerning the quantity of water available in the area have been accumulating for a much longer period of time.

The Colorado River drains an area of 244,000 square miles, of which 242,000 square miles is in the United States—about one-twelfth of the area of the continental United States. The basin from Wyoming to below the Mexican border is about 900 miles long and ranges in width from 300 miles in the upper part to 500 miles in the lower part. Tributaries, many of them saline, extend into seven of the large Western States, Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming.

Physical characteristics indicate division of the Colorado River basin in the United States into seven parts, three in the upper basin, or the drainage area above Lees Ferry, Ariz., and four in the lower basin, or the area below Lees Ferry.

UPPER COLORADO RIVER BASIN

The upper basin includes an area of 110,500 square miles. The upper tributaries of the Colorado River are fed largely by snowmelt, and, although dissolved solids increase with return flow from irrigation below an elevation of 7,000 feet, few tributaries having appreciable flow are saline.

The Green River division includes 45,000 square miles in Wyoming, Utah, and Colorado. Flows of the Green River and its tributaries are greatest in the spring when mountain snows are melting. About 60 percent of the annual runoff occurs during April, May, and June. Late summer flows are extremely low, and storage of the springtime flow is necessary to provide dependable supplies throughout the year. The streams emerge from canyons rather dilute and clear, but they pick up salt in the valleys, especially in late summer when return flows from irrigation are high. Runoff from exposed shale beds along LaBarge, Fontenelle, Big Sandy, and Bitter Creeks and the Strawberry River carries substantial salt concentrations. Heavier concentrations may result from expanded irrigation in the future, from proposed increased exportation of dilute water from headwaters, and from reservoir evaporation. The highest dissolved-solids concentration observed in the Colorado River basin, 8,220 ppm, was in a sample of water obtained from the Price River at Woodside, Utah (see analysis 280, table 3). The drainage area of the river at this station is 1,500 square miles. At the time the sample was obtained, the mean daily flow in the river was 22 cfs. Sodium and sulfate ions were predominant in the water at this time. Natural flows of the Price River are supplemented by irrigation releases from the Scofield Reservoir in Utah.

The Gunnison and Dolores Rivers are the principal tributaries of the Colorado River in the Grand division. The Grand division includes 26,500 square miles. At low flow (160 cfs) the observed moderately saline water of the Dolores River at Cisco, Utah, contained principally sodium and chloride (see analysis 292, table 3).

In the deeply entrenched plateau area is the San Juan division, 39,000 square miles, drained by the San Juan River, a main tributary to the Colorado River, and three smaller rivers, the Fremont, Escalante, and Paria. In 1946 about 214,000 acres of land was irrigated in the division, and proposed control and use of present surplus flow would further develop irrigation and provide for transmountain diversion. The proposed total ultimate annual depletion of about 1.267 million acre feet from the San Juan River may have a considerable effect on the salinity of the water remaining for use in the basin. Calcium and sulfate are predominant when the waters of the San Juan and Paria Rivers are slightly saline.

LOWER COLORADO RIVER BASIN

The lower Colorado River basin, embracing an area of 131,500 square miles in the United States, is slightly larger than the upper basin, on which it is dependent for most of its water supply. The lower basin's demands for water greatly exceed the available water resources. Water from the Colorado River system, in 1946, was irrigating about 1.35 million acres in the lower basin. Full development under existing or authorized projects in California would more than double present diversions by that State.

Flowing northwestward to join the Colorado River about midway in its course to the sea, the Little Colorado River, principal stream in the Little Colorado division, drains about 25,000 square miles in northeastern Arizona and west-central New Mexico. Rain is infrequent but sometimes falls with great intensity, at which times the streams become sediment-laden torrents. The channels contain water throughout the year at the higher elevations but flow only intermittently at the lower elevations. Storage is a prerequisite for development.

In most of the streams in the division, the water deteriorates in quality as it progresses downstream. Mineral springs, in places, contribute large quantities of dissolved salts to the waters of the stream. Several springs near the mouths of Chevelon and Clear Creeks near Winslow, Ariz., contribute to the flow of these streams with the result that the water is slightly saline at low flow. Sodium and chloride are predominant in this water. Dissolved-solids concentrations are as high as 3,000 to 4,000 ppm in the Little Colorado River near Winslow, Ariz.

The Virgin division, including 12,700 square miles, has as its principal streams the Virgin River, Kanab Creek, and the Muddy River. Streamflows are erratic, fluctuating from season to season and from year to year; thus storage regulation is necessary for utilization. The average annual flow of the Virgin River at Littlefield, Ariz., near its mouth for the period of record, 1930–51, is 250 cfs. Below La Verkin, Utah, mineral springs containing chiefly carbonate, sulfate, and chloride of calcium, magnesium, and sodium contribute highly mineralized water to the Virgin River. At Littlefield, near the mouth of the river, mineral springs contribute an average of about 60 cfs which constitutes most of the low flow of the stream. The slightly saline gypsiferous waters are used for irrigation but are not suitable for domestic use.

In the Boulder division, having a drainage area of 40,800 square miles, the range in concentration of dissolved solids in outflow from Lake Mead is moderated by storage, averaging annually slightly less than 700 ppm. Before the completion of Hoover Dam, low flows at times were slightly saline.

Surface water in the Gila division, which has a drainage area of 53,000 square miles, carries considerable quantities of dissolved solids, chiefly sodium, calcium, chloride, and sulfate. Low flows of the Gila River at Gillespie Dam in the lower part of the division carry more than 6,000 ppm of dissolved solids; however, flood flows are comparatively dilute.

The chemical character and concentration of the water in the Gila River change greatly from the headwaters of the river in New Mexico to Calva, Ariz., at the head of San Carlos Reservoir behind Coolidge Dam (Hem, 1950). In this general area one tributary, the San Francisco River, receives moderately saline water from Clifton Hot Springs (about 9,000 ppm of dissolved solids). At Bylas, Ariz., near the lower end of the Safford Valley, the water of the Gila River in 1944 contained an average of 957 ppm of dissolved solids, consisting mainly of sodium and chloride. A twofold increase in concentration of the river in the reach of the Safford Valley is caused largely by inflow of saline ground water and irrigation return flow.

GREAT BASIN

Many of the streams of the Great Basin drain into closed basins, forming landlocked lakes and playas. The water evaporates, leaving saline residues. Other streams drain into sinks, and there is little or no accumulation of surface water. The lakes in the interior at the lower altitudes usually are highly mineralized.

Runoff is low, averaging about 0.5 inch yearly in the Great Basin as a whole and 2.2 inches in the Great Salt Lake basin.

Pyramid Lake in the Truckee River basin, having an estimated volume to 20 to 30 million acre-feet, and Walker Lake, a smaller lake in the Walker River basin, were of about the same concentration (sampled during different years), but the proportion of chloride was somewhat higher in Pyramid Lake. (See analyses 340–341, table 3.) The specific conductances of the samples obtained from Pyramid Lake (1941) and Walker Lake (1937) were 6,780 and 7,570 micromhos, respectively. Soda Lake, which is in the Carson Sink, is highly mineralized; the principal constituents of the lake water are sodium chloride and sulfate.

Waters of the Muddy River are reportedly saline at times but are successfully used for irrigation.

The dissolved-solids content of the water of Great Salt Lake varies with the lake level; in 1930 the concentration was about 210,000 ppm, which is about 6 times that of sea water.

The dissolved-solids concentration of water from any of the lakes varies with the amount of fresh-water inflow. The dissolved-solids concentration of the Salton Sea was about 4,000 ppm, in 1908 and more than 38,000 ppm in 1951 (see analysis 335, table 3). The current estimate of the volume of water in the Salton Sea is 5 million acre-feet. Most of the water that drains to the Salton Sea is irrigation return flow.

In 1948 and 1949, the mineral content of the water of the Alamo

River near Calipatria, Calif., was consistently more than 1,500 ppm at flows of about 800 cfs.

The Sevier River near Lynndyl, Utah, was consistently saline during the period of sampling (1951–53). The observed maximum concentration, at a discharge of 20 cfs, was more than 3,000 ppm, principally sodium, sulfate, and chloride. Irrigation return flow is probably the principal contributor of saline water at this station.

PACIFIC SLOPE BASINS IN CALIFORNIA, WASHINGTON, AND OREGON, SNAKE RIVER BASIN, AND COLUMBIA RIVER BASIN

The Columbia River and its tributaries, and a few short rivers draining the slopes of the Coast Range and the western slope of the Cascades, have the greatest variation in average annual runoff to be found anywhere in the United States, ranging from about 175 inches from a part of the Olympic Mountains in Washington to a fraction of an inch from the part of the Columbia River basin near the mouth of the Snake River. In streams in eastern Oregon, and other streams originating in the mountains, uniformity of flow is caused chiefly by the presence of glaciers and large snowfields.

Quality-of-water data, other than on spot samples in these regions, are very meager; however, available information indicates that saline surface waters are unusual except where wastes and return flows and drainage discharges from irrigated land may be saline. These conditions have been observed in the valleys of the lower Payette and Boise Rivers. However, the waters of both streams in their lower reaches are being used for irrigation.

The waters of Crow, Stump, and Tygee Creeks, tributary to Salt Creek, Star Valley (Mansfield, 1927), may be affected by salt deposits or saline springs. The waters of Soda Creek, a tributary of the Bear River near Soda Springs, Idaho, are unusual and are unsatisfactory for irrigation. Alkali Creek, entering the Snake River near Glenns Ferry, is said to be salty.

There are no known saline streams in Washington. Several lakes in eastern Washington that reportedly are high in carbonate include Moses, Alkali, and Freshwater Lakes in Crab Creek Coulee. Omar and Soap Lakes in eastern Washington are both highly saline; the dissolved solids consist principally of sodium carbonate and sulfate. Lenore Lake, near Soap Lake, and Jameson and Medical Lakes are known to be saline; the latter at one time was a source of commercial salt. No data on volume are available except for Soap Lake, which at present has an estimated volume of 36,000 acre-feet.

GROUND WATER

By J. L. Poole

GROUND-WATER REGIONS

In order to summarize the occurrence of ground water in the United States, Meinzer (1948, p. 163) divided the country into four ground-water regions, the boundaries of which are shown in plate 2. These are the Atlantic and Gulf Coastal Plain, East-Central region of Paleozoic and other old rocks, Great Plains, and Western Mountain regions. These regions are further divided into ground-water provinces (Meinzer, 1923, p. 309). The divisions are somewhat arbitrary, but they serve a useful purpose in allowing a concise presentation of conditions in the entire country. These divisions of the United States also are well suited to a summary of the occurrence of saline ground water because they are based on a geographic and geologic grouping of the principal aquifers. Although there are many local exceptions, each region or province is characterized generally by similar ground-water conditions. These conditions are explained in more detail in the discussions of the ground-water regions and provinces.

TYPES OF SALINE-WATER OCCURRENCE

The occurrence of saline water in a geologic formation may be due to one or more of the following causes: Retention in the rock formation of the salty water in which the formation was deposited (connate water); solution of salt from the formation itself, or from adjacent formations; and entrance of salt water into the formation after it was deposited and subsequently exposed to the ocean or another source of salt water.

Connate water, some of which has undergone considerable chemical change since the formations in which it is contained were deposited, is present in many of the formations that are important sources of fresh water throughout the country, but to the greatest extent in the East-Central and the Coastal Plain regions. The extent to which connate water may have been diluted or flushed out of an aquifer depends on the amount of circulation of water, which in turn depends on the permeability of the rocks and the hydraulic gradient. The distribution of connate water may be determined also by structural features or lithologic characteristics of the formations which prevent the free circulation of ground water. In general, the salinity increases with depth in any given formation; however, many local variations can be expected because of structural and lithologic irregularities in the rocks.

Examples of saline water resulting from solution of salt from the aquifer or adjacent rocks are found in much of the region extending from north-central Texas to southeastern Nebraska and the Trans-Pecos region of western Texas and eastern New Mexico. These regions are underlain by formations of Permian age which contain beds of evaporites such as rock salt, anhydrite, and gypsum. Certain formations in many other parts of the country also contain such evaporites, but generally to a lesser extent. Ground water that enters these formations dissolves the salts from them and thus becomes highly mineralized.

In the arid and semiarid basins of the Southwestern States a large percentage of ground-water discharge is by evaporation from dry lakes, or playas, and transpiration by water-using plants called phreatophytes. Where evaporation and transpiration occur, the dissolved minerals in ground water become greatly concentrated as the residual salts accumulate. The water concentrated in this manner ordinarily is limited essentially to the vicinity of the area in which the natural discharge takes place.

In coastal areas saline water occurs in some geologic formations because of their contact with the sea. Where the pressure head of the salt water is greater than that of the fresh water, sea water moves into the water-bearing formations. Such encroachment of sea water has occurred in the past when sea level was higher than at the present time. In Recent time salt-water encroachment has occurred in coastal areas, contaminating fresh-water supplies, where the water table or artesian pressure has been lowered to such an extent that the fresh-water head in the water-bearing formation no longer exceeds the salt-water head. Lowering of the water table by construction of drainage canals has caused such encroachment in some areas, as in southern Florida; however, the most common cause along the coasts of the United States is withdrawal of water from wells.

Along beaches and on islands, fresh water usually floats on salt water because of the difference in density between the fresh water, which has a specific gravity of 1, and sea water, which has an average specific gravity of about 1.025. Theoretically the fresh water extends about 40 feet below sea level for every foot that the water table is above sea level. A similar ratio applies to the contact between fresh and salt water in an artesian aquifer exposed to a body of salt water.

TABULATION AND ILLUSTRATION OF DATA

Well data and chemical analyses of ground-water samples are contained in tables 4–7. As each analysis is an example of a single occurrence and does not necessarily represent average conditions, an attempt has been made to select a range of data that is representative for a given area in terms of both areal and geologic distribution of saline water. Thus, for any given State or ground-water province or region, the data presented indicate the principal aquifers, average depths of wells that draw water from them, yields that normally may be expected, and approximate areal extent of the aquifers as sources of ground water. The chemical analyses show the approximate average dissolved-solids content of saline water. They are not representative of the total ground-water supply in the aquifer.

Plate 2 shows the distribution, by States and ground-water provinces and regions, of the wells for which data are tabulated, and the geologic age of the aquifer or aquifers tapped by each well. In each State, wells are indicated by a symbol consisting of one or more letters and a number. The letters represent the geologic age of the aquifer, and the number is a serial number for consecutive wells in formations of that age in a single State and in a ground-water region. The detailed well data and the chemical analysis may be located under that number in tables 4–7. The tables are arranged according to ground-water regions, and, for each region, alphabetically by States or parts of States that lie in that region.

ATLANTIC AND GULF COASTAL PLAIN REGION

The eastern and southern margin of the United States is a lowland which passes under the sea almost without change of its gentle slope. The submerged part is known as the Continental Shelf and the emerged part, the Coastal Plain. The Coastal Plain begins with the islands off the southeastern coast of Massachusetts and extends southward and westward to include the southernmost part of Texas. Its landward boundary from New England to the vicinity of the Brazos River in Texas is the inner edge of Cretaceous formations, and from the Brazos River southward it is almost at the contact between Lower and Upper Cretaceous (Fenneman, 1938). From New Jersey to Alabama the landward boundary is known as the Fall Line, which separates the region from the Piedmont province of the East-Central region of Paleozoic and other old rocks. For the purpose of this report, however, and as defined by Meinzer, the Atlantic and Gulf Coastal Plain region includes the Edwards Plateau of south-central Texas, which is underlain by Lower Cretaceous formations (Meinzer, 1948, p. 162).

The region is underlain by seaward-dipping strata of sand, clay, marl, and limestone whose total thickness ranges from a featheredge at the inner boundary to thousands of feet near the southeastern coast. The rocks are largely unconsolidated except for the chalk formations of Alabama and Mississippi, the limestone beds of Florida and adjacent parts of Alabama, Georgia, and of South Carolina, and those of the Edwards Plateau in Texas. The general distribution of these formations at or near the surface is shown on many geologic maps.

Downdip, at some distance from the areas in which the artesian aquifers are at or near the surface, most of these aquifers contain salty water which is a large potential source of supply where the fresh ground-water supplies may not be adequate for future demands. It is estimated that more than half the region is underlain by one or more aquifers that contain salty water. Most, if not all, of the State of Florida is underlain by formations that contain saline water. The Floridan aquifer, which is the principal artesian aquifer in Florida and southeastern Georgia, is composed of the Ocala limestone of Eocene age and associated limestone, both older and younger (Parker, Ferguson, Love, and others, 1955). It is the source of water for thousands of wells and the largest limestone springs in the world. It contains water high in chloride in southern Florida and in a broad coastal belt extending from St. Johns County on the Atlantic Coast around the peninsula to Pinellas County on the west coast. This region is shown by Stringfield (1936, pl. 16).

A large area of the Coastal Plain from western Tennessee to the Gulf of Mexico, including southeastern Arkansas, all Louisiana, and large parts of Mississippi, Alabama, and Texas, is underlain by one or more formations that contain highly mineralized water.

CRETACEOUS FORMATIONS

Cretaceous formations crop out or occur at shallow depth along most of the inner margin of the Coastal Plain region from Massachusetts to the Rio Grande. Along the coast the depth to the top of these rocks range from a few hundred feet in the Long Island-Cape Cod area to several thousand feet in southern Florida.

The minimum depth of occurrence of saline water in Cretaceous formations varies widely in the Coastal Plain region. In many inland areas water containing more than 1,000 ppm of dissolved solids is found at depths of only a few hundred feet. The mineral content generally increases with depth in any given aquifer, and water having a salinity approaching that of sea water is found in many inland areas as well as in coastal areas. Slightly saline connate water is found at a depth of about 2,650 feet in Memphis, Tenn. (table 4), but water from the same aquifer obtained near its outcrop area at Paris, Tenn., at a depth of about 400 feet, is considerably fresher.

Along the Atlantic Coast, Cretaceous formations constitute one of the principal sources of ground-water supplies. In the New York-New Jersey area, aquifers of Late Cretaceous age are capable of yielding several hundred gallons per minute to individual wells. In New Jersey, because of heavy industrial pumping, the Magothy and Raritan formations yield salty water in the lower Delaware River area and in Middlesex County near Raritan Bay and the Raritan River.

The Peedee, Black Creek, and Tuscaloosa formations and their equivalents are the principal Cretaceous fresh-water aquifers of the area from North Carolina to Georgia. In Florida, water in the formations of Cretaceous age is salty. It is possible that the saline water is partly of connate origin. In southern Georgia, Cretaceous rocks below an approximate depth of 1,900 feet yield highly mineralized water. At Savannah, Ga., Cretaceous formations yield salty water, and at Parris Island, S. C., wells in the Cretaceous rocks yield fresh water at shallow depth and saline water at greater depth.

In the Gulf Coast States, Cretaceous rocks crop out at the inner margin of the Coastal Plain, but lie at great depths near the coast. The Tuscaloosa and Eutaw formations are the principal Cretaceous aquifers in Alabama and Mississippi. Downdip from the outcrop areas where the formations are quite deep and are overlain by Tertiary deposits, they yield water having a chloride content that is too high for domestic use. Wells in these formations may flow at rates ranging from a few gallons to several hundred gallons per minute and may yield substantially more when pumped. Saline water is present in large quantities in southeastern Arkansas at depths ranging from 150 to 2,600 feet. The saline water in Arkansas, some of which is brine, is sometimes found in association with oil and gas.

It is estimated that in southeastern Oklahoma about 70 million acre-feet of saline water is in storage in the Trinity sand of Cretaceous age. The water-bearing formations in this area have a total thickness that averages more than 750 feet in an area of about 1,800 square miles.

In general, yields of wells screened in Cretaceous aquifers are highly variable, ranging from only a few gallons per minute to about 2,000 gpm from properly constructed wells. The Tuscaloosa formation of Georgia and the Carolinas and the contemporaneous Raritan formation of New Jersey and Long Island are among the most highly productive aquifers of the region. The overlying Black Creek and Peedee formations of the southeastern Atlantic Coastal Plain yield water to wells at rates ranging from a few gallons per minute to about 1,200 gpm.

Important Cretaceous water-bearing formations in the Texas portion of the Coastal Plain region are the Travis Peak formation, Glen Rose limestone, and Paluxy sand of the Trinity group, the Edwards limestone, and the Woodbine sand. Except for the Woodbine sand they occur in a broad belt extending from Oklahoma southward to about the latitude of Austin, where the outcrop swings toward the west, and they underlie the Edwards Plateau in south-central Texas. The outcrop of the Woodbine sand extends from southern Oklahoma only as far south as McLennan County, Tex. Many cities in north-central and south-central Texas are supplied with water from these formations. Chemical analyses and well data shown in table 4 indicate that saline water is available from them at moderate depths. Yields of wells in the Trinity group are generally low, but some flowing wells yield more than 500 gpm in Hill, McLennan, and Falls Counties. A well owned by the city of Dallas was yielding 1,000 gpm in 1940.

The Edwards limestone is one of the most prolific aquifers in Texas, supplying large quantities of water to wells and springs from cavernous and faulted zones. In some places, localization of saline water probably is caused by faulting which prevents free circulation of the ground water. The municipal water supply of San Antonio, Tex., which contains less than 300 ppm of dissolved solids, is obtained from the Edwards limestone. South of a fault which crosses the southern part of the city, water from the same source contains 4,000 ppm or more of dissolved solids (Livingston, Sayre, and White, 1936).

TERTIARY FORMATIONS

The Tertiary formations of the Coastal Plain region consist largely of wedge-shaped beds of sand, clay, and semiconsolidated limestone which increase in thickness as they dip toward the sea. These sedimentary rocks, which include some of the most extensive aquifers in the United States, are found in most of the Coastal Plain region from southern Texas to east-central New Jersey.

Sea-water encroachment into Tertiary formations has occurred in many heavily pumped areas along the coast and is impending in many others. Many wells ranging in depth from 250 to 1,000 feet immediately adjacent to the coasts of New Jersey, Delaware, Maryland, and Virginia yield saline water. The yields of these wells range from a few gallons per minute to more than 1,200 gpm. The Cohansey sand in the Wildwood and Atlantic City areas, New Jersey, contains slightly saline water which may be, in part, of connate origin.

The underlying Kirkwood formation, though containing fresh water in the Atlantic City area, shows evidence of contamination downdip to the southeast along the coast of New Jersey, and the possibility exists that the encroachment may extend updip to the Atlantic City area if ground-water withdrawal from this formation is increased.[3]

Although the total thickness of Cretaceous and Tertiary rocks in southern Florida is more than 15,000 feet and the maximum thickness of the Tertiary in Florida is as much as several thousand feet, the geologic formations that yield fresh water in Florida represent only a small part (about 1,000 feet) of this thickness. Slightly to moderately saline water is pumped from wells of shallow to moderate depths in the

[3] Schaefer, E. J., 1941, Conditions affecting salt-water intrusion in the Atlantic City region; U. S. Geol. Survey open-file report.

principal artesian aquifer, which includes formations of Eocene, Oligocene, and Miocene age. These formations, which form a belt extending from St. Johns County on the Atlantic Coast to Pinellas County on the west coast, are shown by Stringfield (1936, pl. 16). Some of the saline ground water may be connate; however, some is residual sea water that entered the formations in Pleistocene time when the sea stood higher than its present level. In Recent time encroachment of sea water has occurred along the coast and contaminated some wells, including some formerly used for municipal supply by the cities of Miami, Tampa, and St. Petersburg.

The Citronelle and Pascagoula formations are important aquifers along the coast of the Gulf States. The Citronelle has been intruded by sea water where it is in direct contact with the water of the Pascagoula River estuary; however, the saline water in the sand of the Pascagoula formation at Biloxi probably is largely connate (Brown and others, 1944).

The Tertiary formations of Alabama probably have not been affected by sea-water encroachment as a result of ground-water withdrawal. Highly saline water occurs at depths of several thousand feet, however, and slightly saline water is found at moderate depths in some inland localities (table 4). In the Mobile area, Tertiary clay, sand, and gravel underlie the alluvium and extend downward to a depth of about 1,300 feet. A 717-foot well in the Tertiary in Mobile County flows 175 gpm of water that has a chloride content of 1,060 ppm (table 4).

Saline water is present in the Tertiary formations in many inland areas in southern Georgia, Louisiana, southern Arkansas, and northeastern Texas. It is found in Tertiary formations in Thomas County, Ga., at a depth of about 1,600 feet. In Louisiana highly mineralized water occurs in the Tertiary below a depth of a few tens of feet in local areas and below about 3,500 feet in the southeastern part of the State. In northern Louisiana the Sparta sand occurs at depths of 1,000 feet or less. In much of the northern part of the State, it is capable of yielding large supplies of slightly to moderately saline water. Fresh-water wells yielding as much as 2,000 gpm illustrate the potential yield of this aquifer.

The salinity of the ground water here, as in other parts of the Coastal Plain region, generally increases with depth, but local variations exist owing to structural features of the rocks, very highly mineralized water occuring at shallow depths in some areas. Ground water from Eocene rocks below a depth of 800 feet in the El Dorado area, Arkansas, is salty and probably is not of value either for the usual industrial uses or for domestic uses (Baker, Hewitt, and Billingsley, 1948).

The principal Tertiary aquifers of the Coastal Plain region in eastern Texas are formations of the Wilcox group, Carrizo sand, Sparta sand, Oakville-Lagarto sequence, and Goliad-Willis sequence. These formations crop out in belts roughly parallel to the coast. In the Houston-Galveston area increased withdrawal of ground water for industrial purposes has resulted in updip movement of saline water in these Tertiary formations. At great depths, and in areas where encroachment has occurred because of heavy withdrawal, they are potential sources of large quantities of saline water. Yields of 2,000 gpm or more are common from wells screened in the sands of these formations.

QUATERNARY FORMATIONS

Quaternary, chiefly Pleistocene, deposits crop out along the Atlantic and Gulf Coasts from Cape Cod to southernmost Texas, and in the Mississippi embayment they extend inland along the Mississippi River as far north as southern Illinois. In the Long Island-Cape Cod part of the Atlantic Coastal Plain the deposits are mainly of glacial moraines and outwash. In the remainder of the province they consist largely of marine and continental clastic deposits and marine limestone The total thickness ranges from a featheredge at the inland margin to several thousand feet in the Mississippi Delta region.

Saline water occurs in the Quaternary deposits where they are in direct contact with the sea, tidal streams, or other saline water bodies. Some of the deposits contain the remains of salty water that entered them during Pleistocene time when the sea stood higher than its present level.

In some localities, where withdrawal of water from the Quaternary deposits has exceeded the local fresh-water recharge, sea water has contaminated the fresh-water part of the aquifers. Locally along the Atlantic Coast, the Quaternary deposits are relatively thin and generally are not developed as sources of large water supplies. In these undeveloped nonartesian deposits the boundary between salt water and fresh water is nearly stable, usually at or near the shorelines of the saline water bodies.

On Long Island the glacial outwash, which includes the aquifers of highest yield, has been intruded by sea water in areas where heavy pumping has produced local cones of depression in the water table. The salt-water encroachment has been retarded, and to some extent even reversed, in critical areas by a decrease in pumping and by the use of recharge wells through which fresh water used for cooling is returned to the aquifer.

In the Baltimore industrial area Quaternary deposits are in contact with the brackish water of the Patapsco River estuary. They are largely contaminated with saline water, so that they no longer form an important source of fresh water supply, although they contain considerable highly permeable material (Bennett and Meyer, 1952).

Quaternary deposits are relatively thin along the coasts of New Jersey, Maryland, Delaware, and Virginia, and, except for local sand and gravel beds, do not yield water readily to wells. In some localities withdrawal of water from wells near the shore causes a rapid advance of sea water into the aquifer. An analysis of water collected from a discharging well may indicate excessively high salinity, whereas after the well recovers from pumping, a sample from it may be much lower in salinity.

Most of the Atlantic Coastal Plain province of North Carolina, South Carolina, and southeastern Georgia is covered by a thin blanket of Quaternary sediments. Ground water in these sedimentary deposits is usually saline in areas immediately adjacent to the coast and on barrier beaches and islands off the coast. The Quaternary deposits are generally thin and do not contain prolific aquifers except in southern Florida, where they form a large part of the high-yielding Biscayne aquifer (Parker, 1951). Ground-water discharge by pumping and by drainage operations in the Everglades and adjacent coastal strip has caused contamination of the Biscayne aquifer in a strip along the coast and for several miles inland along the canals in Dade County. However, dams in some of the canals have raised the ground-water level and stopped the encroachment along them.

Quaternary deposits are present in a narrow band along the coast of Alabama and Mississippi, but are much more extensive in southern Louisiana and northward along the Mississippi River lowland. Saline water occurs at depths of less than 100 feet in the Prairie formation of Pleistocene age in part of Franklin Parish, La., and in Recent alluvium in part of Chicot County, Ark. In these small areas it has been noted that a significant increase in salinity of the water accompanies increases in pumping for irrigation. Available records show that properly screened wells yield as much as 3,000 gpm from these deposits.

In the Mobile area, Alabama, wells which supply water for air conditioning and which range in depth from 25 to 90 feet are pumped at rates averaging 800 gpm. This pumping has resulted in local contamination of some shallow aquifers by the intrusion of saline water from Mobile Bay and the Mobile River.

In the coastal area of Texas the Quaternary aquifers supply moderate to large quantities of water to wells, but are especially important in the Houston-Galveston industrial area, where yields of more than 2,000 gpm are common from these beds and from later Tertiary (Pliocene) beds below. These aquifers crop out in a narrow belt parallel to the coast and dipping toward the sea. Near the coast they may be considered as a potential source of large quantities of saline water.

In summary, ground water in the surficial Quaternary formations of the Coastal Plain region is usually of good quality at places distant from surface saline waters. The water in these Quaternary aquifers, however, is highly mineralized in areas adjacent to saline surface-water bodies and also in many inland areas where geologic conditions have retarded flushing of connate water from the aquifers or where these aquifers have been contaminated by disposal of oilfield brines and industrial wastes.

EAST-CENTRAL REGION OF PALEOZOIC AND OTHER OLD ROCKS

The East-Central region of Paleozoic and other old rocks extends from the northeastern tip of Maine to north-central Texas and includes about one-third of the United States. The rocks of the region are chiefly of Paleozoic age, but for the purpose of this report the region is defined to include also the areas of Precambrian rocks in the New England States, northern Wisconsin, northern Minnesota, and the Piedmont province of the Atlantic Coastal States, including a few areas underlain by Triassic rocks. In the northern half of the region the bedrock is covered in large areas by glacial drift, deposited by successive ice sheets. The glacial deposits range in thickness from a featheredge in many places to slightly more than 1,000 feet in one area in Michigan and extend southward roughly to the Ohio and Missouri Rivers.

The Paleozoic rocks consist chiefly of sandstone, shale, and limestone or dolomite having a total thickness of many thousand feet. Except along the eastern margin in the Appalachian Mountains, and in a few other smaller areas, the strata are essentially horizontal, but they dip enough to produce significant differences in the depth to a particular formation from place to place.

Many important water-bearing formations are included in the Paleozoic rocks. At depths of more than a few hundred feet, however, they may yield water that is too highly mineralized to be used for most purposes. The quality of the deeper water depends more on its position with respect to the drainage level than on the formation in which it is found (Meinzer, 1923, p. 204).

PRECAMBRIAN FORMATIONS

The principal areas of Precambrian rocks are in the Lake Superior region of Minnesota and Wisconsin, the Piedmont province of the Atlantic Coastal States, and northeastern New York. Only in the Piedmont province do these rocks constitute an important source of ground water. Their importance as aquifers in that area is due largely to extensive fracturing and weathering, as well as to a lack of other good aquifers.

Saline water ordinarily is not found in the New England States except in coastal areas where sea water has moved inland through fracture systems in the crystalline rocks. Low-yielding wells are predominant; however, some tapping fractured and weathered zones yield several hundred gallons per minute.

In northern Minnesota and Wisconsin the Precambrian rocks commonly are overlain by glacial drift, which is the chief source of ground water, and are not drilled into except where the glacial drift is absent or too thin or clayey to satisfy water requirements. In Douglas County, Wis., saline water is produced from two wells in the Lake Superior sandstone at depths of 90 and 362 feet, and a 2,000-foot well in Precambrian slate near Florence, Florence County, also produced water of high mineral content. Yields of wells in these formations probably do not exceed a few gallons per minute.

CAMBRIAN FORMATIONS

Cambrian rocks crop out at the surface in parts of New England and in the Appalachian Valley from Pennsylvania to Alabama. To the west they are deeply buried under younger Paleozoic rocks, reappearing at the surface in extensive areas in Wisconsin and Missouri and adjacent States. Throughout the remainder of the East-Central region they are present at varying depths, as shown by logs of water-supply and oil-test wells. Cambrian rocks consist predominently of beds of sandstone, some of which are important water-bearing formations, but include also shale, limestone, and dolomite (Meinzer, 1923, p. 227).

In the region of Illinois, Iowa, Minnesota, and Wisconsin the Jordan, Franconia, Dresbach, and Mount Simon sandstone beds are the principal water-bearing formations of Cambrian age. In Wapello County, Iowa, a well 1,975 feet deep in Cambrian formations yields 2,500 gpm of water containing 1,240 ppm of dissolved solids. A water sample collected from a depth of about 2,900 feet in Ford County, Ill., contained 4,100 ppm of dissolved solids and 1,590 ppm of chloride (table 5). These data illustrate the normal pattern of increasing salinity with increasing depth from which water samples were taken for chemical analysis. Average depths at which saline water is first found in Cambrian formations range from less than 100 feet in parts of Wisconsin to more than 3,000 feet in Illinois; however, highly mineralized water in younger rocks generally is reached at depths greater than 200 to 300 feet.

In large parts of Missouri, Oklahoma, and Arkansas the Eminence and Potosi dolomites and the lower part of the Arbuckle group yield as much as 500 gpm to individual wells. Saline water may be reached at depths of 300 feet or more, depending largely on the local drainage level. Locally saline water may be found at shallower depths.

The Hickory sandstone member of the Riley formation of Cambrian age and the Ellenburger group of Ordovician age supply moderate to large quantities of water for municipal use in central Texas. Moderately saline water is found in the Hickory at 4,400 feet in Eden, Concho County. In the same general region the limestone of the Ellenburger group yields saline water which has a range in dissolved-solids content from 1,340 ppm at about 100 feet in depth in Burnet County to 143,000 ppm in an oil-test well 9,172 feet in depth in Reagan County (Winslow and Kister, 1956).

Cambrian formations of the Appalachian Valley from New York southward to Alabama generally do not yield large ground-water supplies. It is expected that the water-yielding capacity decreases and salinity of the water increases with depth in these formations.

ORDOVICIAN FORMATIONS

Throughout most of the East-Central Palezoic region Ordovician formations are buried beneath younger formations, coming to or near the surface in wide belts adjacent to the Cambrian outcrops and in other areas where the Cambrian rocks may be entirely concealed.

The Ordovician system in the Mississippi Valley includes the St. Peter sandstone, which furnishes municipal and industrial supplies from Illinois to Iowa and Missouri and from southeastern Minnesota to northern Arkansas. The St. Peter sandstone ranges in depth from outcrop to about 6,000 feet, becoming more deeply buried to the west. Yields of wells are also variable, ranging from 20–50 gpm in Missouri to as much as 500 gpm in Illinois. It is probable that a similar range in yield is characteristic of this formation where it contains saline water. To the east and west of a belt adjacent to the Mississippi Valley, water from the St. Peter becomes more highly mineralized as the formation reaches greater depths. Commercial brines are produced from the St. Peter sandstone in Ohio, where it has been reached by wells as much as 6,000 feet in depth. Water in the St. Peter in Indiana generally is saline, and not much of it is used at present.

The Shakopee and Oneota dolomites, lying beneath the St. Peter sandstone, are widespread in Iowa, Illinois, Minnesota, and Wisconsin. These formations, when reached at depths of more than a few hundred feet, are capable of yielding moderate quantities of saline water.

The Ordovician strata overlying the St. Peter sandstone include the Galena dolomite, which yields moderate to large quantities of water in Iowa, Minnesota, Wisconsin, Michigan, and Illinois. Although other limestone of Middle and Late Ordovician age supplies fresh water to shallow wells, deeper water in the formations is generally too salty for ordinary use. Wells in these limestone formations range in depths from very shallow to about 5,000 feet; the dissolved-solids content of the water reaches that of commercial brine in wells several thousand feet deep. Yields of as much as 700 gpm with only moderate drawdowns are common from some of these formations. One well tapping the Trenton limestone and reaching the St. Peter sandstone is reported to flow at a rate of 3,000 gpm from the combined section.

In Oklahoma, Kansas, and Missouri, saline water is found at moderate depths, and commonly is associated with oil and gas accumulations at great depths. In Oklahoma the upper part of the Arbuckle group and the Simpson group are the principal saline-water sources. They include highly permeable beds which supply as much as 500 gpm to wells. In Missouri the Roubidoux formation and the Gunter sandstone member of the Van Buren formation yield from a few gallons per minute to more than 300 gpm to wells that reach a depth of almost 5,000 feet.

Ordovician formations are at or near the surface also in the Central Basin of Tennessee and the Appalachian Valley from New York to Alabama. Those of the Appalachian Valley consist more commonly of shale and limestone of low permeability which usually are not prolific aquifers. The Knox dolomite, of Late Cambrian and Early Ordovician age, yields saline water in areas west of the Appalachian Valley where it occurs at depths of several hundred feet. In some localities in the Central Tennessee Basin, Ordovician limestones supply small quantities of highly mineralized water from shallow to moderate depths (Piper, 1932; Theis, 1936).

SILURIAN FORMATIONS

The Silurian rocks of the East-Central region consist chiefly of limestone and dolomite which are important sources of ground water in Iowa, Illinois, Wisconsin, Indiana, Ohio, and parts of adjacent States. Limestones of Niagara age yield saline water where they occur at moderate to great depths. A group of 20 wells averaging 300 feet in depth, in limestone of Niagara age in Adams County, Ind., yields moderately saline water; one well 650 feet deep yields 500 gpm of water containing more than 12,000 ppm of dissolved solids.

The Salina formation is an important source of saline water in Michigan and Ohio and vicinity. Brine is produced commercially and in conjunction with oil from wells as much as 6,000 feet deep in this formation. Highly mineralized ground water is found in the Salina formation at depths of less than 100 feet at some localities, where it contains considerably less mineral matter than where it is deeper.

In Ohio and Michigan the rocks formerly known as the Monroe group overlie the rocks of Niagara age and form the upper part of the Silurian system. Where the so-called Monroe lies at moderate depth below the surface it contains slightly saline water. The rocks of this group include the bedrock aquifers of highest yield in Ohio.

Silurian formations in other parts of the East-Central region generally yield highly mineralized water at depths of more than a few hundred feet, but usually they are not sufficiently permeable to supply significant quantities. The Hunton group, in Oklahoma, and Upper Silurian limestones of north-central Kentucky yield brine along with oil and gas, usually from depths of more than a thousand feet. In Pennsylvania the Clinton formation and the Cayuga group are the principal sources of saline water. Water from two wells in Mifflin and Northumberland Counties, 140 and 240 feet in depth, respectively, yield water containing about 2,100 ppm of dissolved solids (table 5). Moderately saline water is found in these formations in much of the Appalachian Valley province at relatively shallow depths, and brine at greater depths. It is expected that these formations will not yield more than a few gallons per minute to a well. The Red Mountain formation in Alabama and Georgia is approximately equivalent in age to the Clinton formation and Niagara group of the northern part of the East-Central region, and is similar to them in water-bearing characteristics.

DEVONIAN FORMATIONS

The Devonian system of rock formations is exposed in southern New York, northern Pennsylvania, and the Appalachian Valley from Pennsylvania to northern Alabama. Smaller areas of Devonian exposures occur also in Ohio and Indiana, the northern part of the southern peninsula of Michigan, and northeastern Iowa. The Devonian rocks are more than 14,000 feet thick in Pennsylvania, but they thin to the west and in much of the western part of the region Devonian rocks are absent. These formations are chiefly limestone and sandstone in the lower part and shale and sandstone in the upper part. In Pennsylvania the Devonian formations contain highly mineralized water at depths of only a few hundred feet (Lohman, 1938). They do not constitute an important source of ground water in the region but in some localities may yield moderate supplies.

The most important occurrences of saline water in the Devonian formations are the brines of the Dundee limestone in Michigan. Brine production from many oilfields exceeds 2,000 barrels per day and in some reaches as much as 34,000 barrels per day. Other

Devonian rocks in Michigan from which brine is produced along with petroleum are the Detroit River, Sylvania, and Traverse formations.

The Oriskany sandstone is an important gas and brine source in West Virginia, where it occurs at depths of as much as 9,000 feet. In Ohio also it is the principal Devonian saline-water source; it is reached at depths of 1,300 to 5,000 feet or more below the land surface. The Chemung and Helderberg formations, along with the Oriskany sandstone, contain highly mineralized water in southern New York and northern Pennsylvania. These formations usually do not yield more than a few gallons per minute to wells. Saline water in these rocks generally is found even at relatively shallow depths where the water-bearing rocks are covered by younger Paleozoic formations.

Devonian formations are absent or relatively thin and of low permeability in much of the western part of the East-Central region. The Cedar Valley limestone in Iowa yields only small quantities of water to wells of moderate depth. In Oklahoma the upper part of the Hunton group furnishes brine from depths of as much as 6,400 feet.

MISSISSIPPIAN FORMATIONS

Mississippian formations are at or near the land surface throughout much of the East-Central region from northeastern Oklahoma to northeastern Pennsylvania, They consist largely of sandstone and shale in Pennsylvania, where they reach a maximum thickness of 4,400 feet, but are mostly limestone in the Mississippi Valley region, where the aggregate thickness is about 1,500 feet (Meinzer, 1923, p. 239). From Michigan and Indiana eastward the Mississippian rocks generally yield saline water in small quantities, though locally the yield is larger and in places the water is fresh. In Iowa and Missouri and parts of adjacent States, some of the Mississippian formations yield highly saline water where they are deeply buried, especially from the upper part of the section where brines are found with oil and gas. In northern Oklahoma oil-test records show that highly mineralized water is almost always present in the upper part of the section. The remainder of the section usually contains very little water.

The Berea sandstone is the most important fresh-water aquifer of Mississippian age in Ohio and adjacent parts of neighboring States; however, below depths of approximately 150 feet beneath the local drainage level it yields highly mineralized water. Three wells ranging in depth from 146 to 275 feet in Cuyahoga County, Ohio, are typical of those in the Berea sandstone. These wells yield only small supplies of ground water containing 1,060 to 1,350 ppm of dissolved solids. Some wells are reported to yield as much as 350 gpm, but the average is considerably less, probably on the order of 25–50 gpm.

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The St. Louis and St. Genevieve limestone formations are the principal aquifers of Mississippian age in the Mississippi Valley region of Iowa, Illinois, and Missouri. They are used as sources of domestic water supply in parts of Kentucky and Tennessee also. In Illinois the depth to these formations ranges from a few hundred to about 5,000 feet. They constitute an important source of small supplies for many towns and villages in Illinois. In southwestern Indiana the St. Louis limestone is usually present at shallow depths, supplying water in small to moderate quantities. In many localities, the water from the St. Louis limestone is saline even at shallow depths and becomes more saline with increased depth of the formation. Water containing several thousand parts per million of dissolved solids is reported in wells less than 100 feet deep in parts of Indiana, Kentucky, and Tennessee.

Other Mississippian saline-water aquifers of significance are the Mauch Chunk and Pocono formations of West Virginia and Pennsylvania, Logan and Cuyahoga formations of Ohio, Marshall formation of southern Michigan, Warsaw limestone of the Mississippi Valley region and the southern Appalachian Valley, and Fort Payne chert of the Appalachian Valley in Tennessee and Alabama. All yield small, and locally larger, supplies of fresh water from shallow wells, but at moderate depths below the local drainage level they generally yield highly mineralized water. Brine is produced with oil and gas from the Mauch Chunk and Pocono formations of West Virginia and Pennsylvania, where they are present at depths ranging from outcrop to 2,500 feet.

PENNSYLVANIAN FORMATIONS

Pennsylvanian rocks underlie the Appalachian Plateaus province from western Pennsylvania to northern Alabama, a large area which includes parts of Indiana, Illinois, and Kentucky, and a broad belt extending from northern Iowa to north-central Texas. Satisfactory water supplies are not generally available in Pennsylvanian formations, because of either poor quality or insufficient quantity (Meinzer, 1923, p. 240–241).

In Oklahoma, Kansas, Missouri, and vicinity, Pennsylvanian rocks yield saline water at depths greater than 200 to 300 feet. Within short distances downdip from the outcrop areas, the salinity increases to several thousand parts per million of dissolved solids. In Oklahoma the dissolved solids in water in these formations range from about 40,000 ppm at a depth of about 700 feet to more than 200,000 ppm at a depth of approximately 4,000 feet. These waters are pumped only with oil and gas and at very low rates of discharge. Among the principal oil- and brine-bearing formations are the Elgin sandstone, which ranges in depth from 700 to 2,100 feet, Nelagoney formation

(Gould, 1925) from 2,300 to 4,300 feet, Coffeyville formation from 1,195 to 4,900 feet, Boggy shale from 650 to 4,000 feet, and Atoka formation from 2,100 to 3,800 feet.

The Ireland sandstone member of the Lawrence shale and the Tonganoxie sandstone member of the Stranger formation are the chief Pennsylvanian water-bearing formations in Kansas. Pennsylvanian rocks are, however, generally deficient as ground-water reservoirs. Beyond depths of a few hundred feet, water in these aquifers becomes increasingly saline, and yields of municipal and industrial wells screened in them are usually small.

In Missouri, water-bearing zones in the lower part of the Cherokee shale are the principal saline-water sources in Pennsylvanian rocks. The depth to the formation ranges from outcrop to 1,600 feet. Dissolved solids in water from this formation range from about 2,000 ppm in a well 265 feet deep to more than 27,000 ppm at a depth of about 700 feet in another locality. Yields of wells are very low, averaging 3 to 25 gpm.

Pennsylvanian rocks are relatively unimportant as aquifers in Texas; however, small supplies are available locally. The principal occurrences are in the Llano uplift of central Texas and along the eastern margin of the Osage Plains. Dissolved solids in saline water range from 1,030 ppm in McCulloch County to 83,600 ppm in Lampasas County (Winslow and Kister, 1956).

Pennsylvanian rocks in Illinois and vicinity yield brine with oil and gas in many oilfields and less highly mineralized water from shallow wells. Wells in Illinois in which brine occurs range in depth from less than 200 feet to more than 2,000 feet, with a content of dissolved solids as high as 55,000 ppm (Meents, Bell, Rees, and Tilburg, 1952).

In central Michigan the Saginaw formation, consisting of sandstone and shale, locally may yield as much as 200 gpm of water having a dissolved-solids content of about 1,400 ppm.

The Appalachian Plateaus province is underlain by Pennsylvanian formations ranging in thickness from 3,500 in Pennsylvania to more than 9,000 feet in Alabama. Saline water generally is found in these rocks, at depths below local drainage level, from the base of the Pottsville group upward to the lower members of the Monongahela formation. Yields of shallower fresh-water wells are as high as 100 gpm, and yields of saline water of this magnitude doubtless are available locally.

PERMIAN FORMATIONS

Permian formations underlie a broad belt in the western part of the East-Central region from southern Nebraska to central Texas, and a smaller area in southeastern Ohio and western West Virginia. In general, water supplies from these rocks are not completely satisfactory for domestic and municipal use; however, they are used extensively for irrigation in the western part of the region. The total thickness of Permian rocks ranges from about 3,000 in Kansas to 5,000 feet or more in Oklahoma and north-central Texas. The formations consist largely of sandstone, shale, limestone, and gypsum beds, many of which are highly permeable, constituting a huge reservoir of saline water.

The principal Permian aquifers in the Texas section of the East-Central region are the Wichita and Clear Fork groups, San Angelo sandstone, Blaine gypsum, and Quartermaster formation. These occur in a broad belt extending from Tom Green and Concho Counties northward into Oklahoma. Yields of wells in these formations range from small generally to 500 gpm from the Bullwagon dolomite member of the Vale formation (Clear Fork group) at Anson, Jones County, and to 1,400 gpm from the Blaine gypsum in Childress and Hardeman Counties. Wells of shallow depth yield moderately saline water, but at depths of several hundred feet the concentration of dissolved solids is more than 6,000 ppm (Winslow and Kister, 1956).

In the Permian formations of Oklahoma, saline water ranges in dissolved-solids content from about 1,000 ppm in wells less than 100 feet deep to more than 130,000 ppm in wells 1,300 feet or more in depth. The principal Permian water-bearing formations are the Rush Springs sandstone of the Whitehorse group, and the Blaine and Wellington formations. Wells in the Rush Springs sandstone range from very shallow to about 500 feet in depth, the dissolved solids in the water reaching 6,000 ppm or more in the deeper wells. Yields of wells in the Rush Springs sandstone range from a few gallons to several hundred gallons per minute. A 500-foot well in Ellis County, Okla., is reported to flow at a rate of 5,000 gpm. Wells in the Blaine gypsum range from shallow to only a few hundred feet in depth and yield as much as 1,350 gpm. The dissolved solids in water from this formation range from 2,500 ppm at depths of less than 100 feet to more than 6,000 ppm at depths of 150 feet or more. Wells in the Wellington formation range in depth from shallow to about 800 feet, yielding as much as 275 gpm of water containing 1,100 to 2,700 ppm of dissolved solids.

Southeastern Ohio, western Virginia, and adjacent parts of Pennsylvania and Maryland are underlain by sandstone and shale of the Permian Dunkard group, which reaches a maximum thickness of 1,180 feet in West Virginia. Four wells screened in aquifers of the Dunkard group in Monongalia County, W. Va., probably represent average ground-water conditions in the Permian rocks of this region. These wells range in depth from 59 to 169 feet and yield from 2 to 15 gpm of water whose dissolved-solids content ranges from 1,500 to 3,270 ppm.

GLACIAL DRIFT

In the northern part of the region the bedrock is covered by glacial deposits which are the principal sources of ground water in that part of the region. These deposits consist chiefly of till, or boulder clay, deposited by the successive Pleistocene ice sheets, alluvium (outwash) deposited by streams issuing from the ice, and stratified beds laid down in glacial lakes. Sand and gravel in the alluvium are highly permeable and locally are capable of yielding several thousand gallons per minute to wells.

Ground water in the glacial deposits is generally fresh but is saline locally where it is contaminated by leakage of saline water from underlying bedrock formations or by disposal of oilfield brines or industrial wastes, and in coastal areas where it is in direct contact with sea water. The mineral content of water from the deposits underlying the alluvial terraces along the Ohio River commonly exceeds 1,000 ppm but seldom exceeds 2,000 ppm. Along the coasts of the New England States glacial deposits overlying relatively impermeable bedrock formations furnish most of the ground-water supply. The water is saline in large urban and industrial areas where heavy pumping has caused intrusion of sea water. Such an area is the New Haven industrial area, Connecticut, where concentrated withdrawal of ground water had caused local overdevelopment and some sea-water intrusion as early as 1919 (Brown, 1925). Shallow wells in the New Haven area yield as much as 350 gpm; the yield per foot of drawdown ranges from 4 to 16 gpm.[4]

GREAT PLAINS REGION

The Great Plains region is an eastward-sloping plain which is about 500 miles wide at the northern boundary of the United States, tapering to about half that width at its southern end in western Texas and eastern New Mexico. Nearly all this region is underlain by great thicknesses of Cretaceous and Tertiary formations consisting largely of sand, sandstone, shale, and limestone. These are overlain in some areas, particularly in the sandhills region of central and western Nebraska, in the glaciated area of east-central Nebraska, and along streams throughout the region by unconsolidated deposits of Quaternary age. Paleozoic rocks underlie most of the region at considerable depths but are exposed in the Permian basin of New Mexico and Texas, the Black Hills of South Dakota, and the Bighorn Mountains area at the northwestern margin of the region. The northeastern and extreme northern parts of the Great Plains are covered by a mantle of glacial drift consisting of till, stream deposits, and stratified beds deposited in glacial lakes. Most of the glacial and associated deposits

[4] Ferris, J. G., 1941, Summary on salt-water intrusion in New Haven, Conn.; U. S. Geol. Survey mimeographed report.

are of lower permeability than deposits of similar origin farther east.

The Great Plains is a region in which water supply is prevailingly deficient in quantity and low in quality. The only aquifers that are both widespread and high in yield are the Ogallala formation and associated Tertiary and Quaternary deposits in the High Plains and adjacent area. The Dakota sandstone and associated sandstones form an aquifer that is widespread but not high in yield, though initial heads and yields were high decades ago, and which contains saline water in much of its extent. Other sandstone aquifers in the Great Plains generally do not have a high yield either, and much of the water they contain is saline.

PALEOZOIC FORMATIONS

Paleozoic rocks include important aquifers in the Pecos River valley and adjacent parts of New Mexico and Texas. They are, with a few notable exceptions, of relatively little consequence as sources of water elsewhere in the Great Plains. In the northern part of the region, which includes eastern Montana and Wyoming, North Dakota, and South Dakota, the water-bearing members of the Paleozoic formations generally are reached only at great depths.

Little is known of Cambrian and Ordovician formations in the northern part of the region except for data obtained in deep oil-test drilling. Wells reaching Ordovician rocks at depths of 5,500 to 9,100 feet in Montana frequently flow as much as 150 gpm of water containing as much as 11,000 ppm of dissolved solids.

The Madison limestone, of Mississippian age, is an important water source in South Dakota and Wyoming and is one of the most prolific aquifers of eastern Montana. Some water wells screened in this formation are reported to yield several cubic feet per second, or more than a thousand gallons per minute. Oil-test and other deep drilling has resulted in substantial flows of water containing dissolved solids ranging from about 1,000 to about 12,000 ppm. Such flowing wells generally are completed only at depths greater than about 2,000 feet, one having been completed at a depth of 7,200 feet.

Pennsylvanian rocks, including the Tensleep sandstone, Minnelusa sandstone, and Amsden formation, are present at depth in much of the northern part of the region. These rocks crop out around the Black Hills of South Dakota and in the Bighorn Basin adjoining the northwest edge of the Great Plains in Wyoming. At depths of several thousand feet water in the Tensleep sandstone is only moderately saline. This formation occurs at a depth of a few thousand feet in Montana and Wyoming, but in some areas it is overlain by at least 10,000 feet of younger rocks. Moderate to large supplies of water are obtained from the Tensleep sandstone, and free flows of several hundred gallons per minute are reported from some wells. The underlying Amsden formation generally is not considered a prolific aquifer, although locally substantial yields are reported. One well screened in the Amsden formation at a depth of 2,865 feet had a flow of 570 gpm of water containing 3,500 ppm of dissolved solids. The Minnelusa sandstone, which is the age equivalent of the Tensleep sandstone in the Bighorn Basin, yields moderate to large quantities of water in the Black Hills section to wells ranging from a few hundred to 1,800 feet in depth. Two wells are screened in the Minnelusa in Meade County, S. Dak., at depths of 690 and 1,800 feet, respectively. The 690-foot well flows at the rate of 3,000 gpm, and the 1,800-foot well is pumped at the rate of 540 gpm. The dissolved-solids content of water from these two wells is only slightly more than 1,000 ppm (table 6).

In southern New Mexico, particularly in the Roswell artesian basin and Carlsbad area, and western Texas cavernous limestone of Permian age yields large supplies of water. The Rustler and Castile formations and the Carlsbad limestone are the uppermost significant water-bearing formations of Permian age in southeastern New Mexico. These are a part of what was called the Pecos formation by Fiedler and Nye (1933) in a comprehensive study of the ground-water resources of the Roswell basin. Water levels are generally within a few hundred feet of the land surface, but the depths of wells in these formations vary because of the cavernous nature of the limestone. Beds of salt and gypsum are present, and consequently the ground water is, as a rule, too highly mineralized to be used for domestic purposes. It is used for irrigation and stock, although in some localities it may be unsuitable even for these purposes. Wells reaching these formations ordinarily yield only a few gallons per minute, but where the limestone is cavernous they are reported to yield as much as 3,000 gpm. The Carlsbad limestone is an especially prolific aquifer, yielding 600 to 3,000 gpm to wells whose depths range from 120 to 450 feet. The ground water in these formations ranges from fresh to moderately saline in parts of the area, but in general it is too saline for unrestricted use, averaging about 6,000 ppm in dissolved-solids content.

The San Andres formation is widespread in central and southeastern New Mexico. It includes the important Glorieta sandstone member and the limestones which are the principal aquifers of the Pecos River valley. In the Roswell artesian basin, Fiedler and Nye (1933) called equivalent rocks the Picacho limestone. The Glorieta sandstone member is at relatively shallow depth in Torrance County but becomes more deeply buried toward the south. It may yield from a few gallons per minute to more than 2,000 gpm to wells of moderate depth, but the water generally is too saline for use. Water from the Glorieta sandstone member contains as much as 9,000 ppm of dissolved solids even at relatively shallow depths. The limestone of the San Andres formation yields free flows of several hundred gallons per minute to wells of moderate depth in the Roswell artesian basin. Although the dissolved-solids content of the water may reach about 20,000 ppm locally, this aquifer is the principal source for irrigation and municipal supplies in areas where the water is fresh to only moderately saline. The average depth of wells obtaining water from San Andres in the Roswell basin is probably about 700 or 800 feet.

The Yeso formation, which underlies the San Andres formation, ordinarily is not important as a ground-water source. The depth of wells drilled to the Yeso ranges from less than 100 feet in northern Torrance County to more than 700 feet in the southeastern part. Yields are generally small but may be as much as 3,000 gpm from cavernous zones. In the Roswell basin the Nogal formation of Fiedler and Nye is now recognized as the Yeso. The water from this formation in and east of the artesian area of the Roswell basin is reported to be too highly mineralized for most purposes because of the presence of thick beds of gypsum and salt (Fiedler and Nye, 1933).

Water from the Permian formations of the Roswell basin ranges in dissolved solids from about 400 to more than 17,000 ppm. However, most of the water contains 1,000 to 3,000 ppm of dissolved solids. In those places where the soil is sufficiently permeable to allow use of large volumes of water and where natural drainage is sufficient to prevent the accumulation of harmful quantities of alkali, use of the water does not always result in deterioration of the soil.

In the Texas part of the Trans-Pecos region the Bone Spring limestone and the Rustler formation are the principal Permian ground-water sources. The Bone Spring limestone in the Dell City area, Hudspeth County, produces water for irrigation in quantities ranging from 350 to 3,500 gpm. The water from this formation is slightly to moderately saline, the water from two wells containing 1,120 and 6,040 ppm of dissolved solids from depths of 250 and 60 feet, respectively. The Rustler formation yields as much as 2,500 gpm to flowing wells in Pecos and Reeves Counties, although locally it may yield only small quantities. The dissolved-solids content of the water ranges from 1,180 to 38,700 ppm.

MESOZOIC FORMATIONS

The Dockum group of formations of Triassic age crops out in northeastern New Mexico and west-central Texas but is buried beneath younger formations in the High Plains of Texas. Most of the sandstone of these formations is fine grained and tightly cemented and consequently is of low permeability. Locally, however, moderate supplies of water for irrigation are obtained from wells ranging in depth from 115 to 315 feet. The concentration of dissolved solids in saline water from the Dockum group ranges from 1,140 ppm at a depth of 60 feet to 17,700 ppm at a depth of 119 feet. Generally there is little correlation between depth of the well and the mineral content of the water in this area.

Cretaceous formations are exposed in a wide belt along the eastern margin of the Great Plains and are buried beneath younger rocks to the west, reappearing at the surface throughout wide areas in Montana, Wyoming, and Colorado. The rocks consist of sandstone, commonly several hundred feet thick, alternating with beds of shale and limestone which provide favorable conditions for the occurrence of artesian water.

Throughout most of the Great Plains the basal Cretaceous formation is the Dakota sandstone, one of the most extensive aquifers in the United States and an important source of artesian water (Meinzer, 1923, p. 309). Many studies of ground-water conditions in the Dakota sandstone have been made by the U. S. Geological Survey and by State organizations in cooperation with the U. S. Geological Survey (listed in Waring and Meinzer, 1947). Geologic maps and maps showing the depths to the Dakota sandstone and areas of artesian flow in the central Great Plains region were given by Darton (1905).

The Dakota sandstone as it occurs in North Dakota, South Dakota, and Nebraska is perhaps typical of the formation throughout the Great Plains region. The depth to the formation ranges from outcrop in eastern South Dakota and Nebraska to 7,000 feet or more in western Nebraska. Ground water from the formation is used extensively for domestic, stock, and irrigation purposes despite its relatively high mineral content even in the outcrop area. The dissolved-solids content of saline water from the Dakota ranges from about 1,000 ppm in shallow wells to about 5,000 ppm at depths of 1,000 to 2,000 feet. At considerably greater depths in the western parts of these States, dissolved solids in water are as high as 40,000 ppm. Yields of wells tapping the Dakota sandstone range from only a few gallons to several hundred gallons per minute. In the early stages of ground-water development, flows of several hundred gallons and even several thousand gallons per minute and artesian heads of several hundred feet were reported. Most of the water, however, has been derived from storage, and the artesian head has reduced greatly in much of the region. Many of the wells now have ceased to flow, and many others flow only a small fraction of the original yield (McGuinness, 1951). Overlying the Dakota sandstone are several hundred feet of sandstone, shale, and clay which are sources of ground water in some areas but which are, generally, not important water-bearing formations. The lowermost of these is the Benton shale, which is equivalent to the Carlile shale, Greenhorn limestone, and Graneros shale of South Dakota, Nebraska, and Kansas. The formation includes water-bearing zones which yield moderate water supplies locally, but generally the yields are only a few gallons per minute. Wells in these rocks range in depth from very shallow to several hundred feet and supply water having a mineral content of as much as 4,000 ppm or more.

The Niobrara formation overlies the Benton and equivalents in most of the Great Plains region, but it is generally a poor aquifer. Only meager supplies of water containing as much as about 3,000 ppm of dissolved solids are available from relatively shallow wells.

Overlying the Niobrara formation in the northern half of the Great Plains is the Pierre or Colorado shale, which is equivalent to the Bearpaw shale, Judith River formation, Claggett shale, and Eagle sandstone of eastern Montana and Wyoming. With the exception of the Judith River formation and the Eagle sandstone in Montana and Wyoming, these rocks are unimportant as water-bearing formations, yielding only meager supplies of moderately saline water. The Judith River and Eagle formations, however, are important aquifers in Montana and Wyoming, yielding as much as 100 gpm locally to wells ranging in depth from shallow to about 1,100 feet. The water generally is only moderately saline, ranging in dissolved solids from slightly more than 1,000 ppm at shallow depths to about 4,000 ppm at greater depths.

The Fox Hills sandstone and the overlying Lance formation are the uppermost Cretaceous water-bearing formations, and are important sources of ground water in Montana, Wyoming, North Dakota, and South Dakota. Wells in both these formations yield water at low rates, 100 gpm being exceptional. Wells range in depth from less than 100 to more than 1,100 feet and yield water whose dissolved solids content approaches 5,000 ppm at relatively shallow depths.

TERTIARY FORMATIONS

The greater part of the Great Plains region is covered by Tertiary sediments which include several widespread and high-yielding aquifers. The lowermost of these is the Fort Union formation, which is especially important as a ground-water source in eastern Montana and Wyoming and western North Dakota. In eastern Montana it supplies water to more wells than any other bedrock formation; however, it yields only small supplies for domestic and stock use. Wells of shallow to moderate depth yield slightly saline water in which dissolved solids are usually less than 3,000 ppm. The Wasatch formation, overlying the Fort Union, includes sandstone which supplies water at rates as high as 100 gpm to wells a few hundred feet deep in northeastern Wyoming. At moderate depths the water has a concentration of more than 5,000 ppm of dissolved solids. The next highest formation is the White River formation (White River group, divided into the Brule clay above and Chadron formation below, in parts of Colorado, Wyoming, South Dakota, and Nebraska). The White River is only locally important as a ground-water source, yielding only meager supplies of water containing as much as 3,000 ppm of dissolved solids. In places, however, the Brule contains large fractures and is a prolific aquifer.

The principal Tertiary water-bearing formation of the Great Plains is the Ogallala formation, which covers much of the region from southern South Dakota to west-central Texas and east-central New Mexico. It is by far the most important aquifer in the High Plains region of northern Texas, western Oklahoma, and eastern New Mexico, where it is the major source of water supplies for all uses. Yields of several hundred gallons per minute are obtained from sand and gravel of the Ogallala at shallow to moderate depths, and yields of 1,500 gpm are not uncommon. Analyses of water samples from several localities indicate a mineral content of as much as approximately 2,000 ppm. The Ogallala is underlain in the High Plains by Permian, Triassic, and Cretaceous formations which contain highly mineralized water. Upward leakage of water from these older rocks may have resulted in some local contamination of water-bearing zones of the Ogallala formation. Some occurrences of saline water in the Ogallala formation may be the result of local drawdown of the fresh-water head of the aquifer and also concentration of residual salts by evaporation from playa lakes.

QUATERNARY ALLUVIUM AND GLACIAL DRIFT

Glacial drift covers a large area in the northern and northeastern parts of the Great Plains region and constitutes one of the major ground-water sources northeast of the Missouri River. Except for local gravel lenses the glacial deposits are generally of low permeability and will yield only small to moderate quantities of water to wells. Locally these deposits yield water containing as much as 7,000 ppm of dissolved solids at depths of a few hundred feet.

Unconsolidated sediments of Quaternary age are found along major streams and as a thin mantle overlying the older formations, notably in the sandhills and elsewhere in central Nebraska. In all the States of the Great Plains region they are important ground-water sources except where the water is highly mineralized. The mineral content of the ground water ranges from low concentrations in various places to about 6,000 ppm in parts of South Dakota. Relatively shallow irrigation wells in Quaternary alluvium in the Pecos River valley in the Roswell basin, New Mexico, yield large quantities of water having mineral concentrations of several thousand parts per million (Fiedler and Nye, 1933). Shallow wells in alluvium in eastern Colorado yield as much as 1,200 gpm of water having mineral content ranging from 1,100 to 2,800 ppm.

WESTERN MOUNTAIN REGION

The Western Mountain region, occupying the western third of the United States, is one of diverse climatic, topographic, and geologic conditions. It includes the Rocky Mountain and Pacific Mountain systems, separated by the broad expanse of the Columbia and Colorado Plateaus and the Basin and Range province.

The Rocky Mountain System, divided into three provinces by extensions of adjacent plateaus and basins, is a region of high and rugged mountains underlain largely by crystalline rocks of Proterozoic age but locally by sedimentary beds of Tertiary age.

The Colorado Plateaus province, extending from central Arizona and New Mexico to southern Montana, is for the most part an arid to semiarid plateau region in which water supplies are scarce and locally saline. It is underlain by sedimentary formations ranging in age from Paleozoic to Tertiary which are sufficiently deformed to cause large differences in ground-water conditions from place to place.

The Basin and Range province extends from southeastern Oregon across Nevada, southern California, Arizona, and New Mexico into the southwestern part of Texas. It is characterized by isolated mountain ranges and broad intervening valleys partly filled with alluvium of Tertiary and Quaternary age. Older consolidated sedimentary rocks and Tertiary volcanic rocks make up the mountain ranges and are deeply buried beneath the valley fill. The older rocks are not an important source of ground water except locally, but the unconsolidated alluvium furnishes water supplies of widely ranging quality and quantity.

The Columbia Plateaus province occupies eastern Washington and Oregon, southwestern Idaho, and small parts of northern Nevada and Utah. It is characterized by widespread Tertiary and Quaternary lava flows and interbedded Tertiary sedimentary rocks, most of which yield abundant supplies of ground water.

The broad belt of high mountains and intermontane valleys bordering the Pacific coast and extending eastward to the east face of the Sierra Nevada and the Cascades is called the Pacific Mountain System by Fenneman (1931). It is a region of considerable range in climate, topography, geology, and adequacy of water supply.

PALEOZOIC FORMATIONS

Paloeozoic rocks in the Western Mountain region occur in a large area in the Colorado Plateaus of northern Arizona and southeastern Utah and in many of the isolated mountain ranges of the Great Basin. Elsewhere in this region they are deeply buried beneath younger sedimentary and volcanic rocks.

Except for a few formations, such as the Coconino sandstone of the Colorado Plateau, Paleozoic rocks are relatively unimportant as ground-water sources, owing to their low permeability. They generally are tapped for water supplies only in areas where more prolific sources are absent. Locally, however, large springs originate in cavernous limestone, faulted zones, or outcrop belts where water is forced to the surface by confining beds of less permeable material. Springs flowing several cubic feet per second issue from Paleozoic limestone in southern Idaho, eastern Nevada, and several localities in Arizona. Saline water containing more than 5,000 ppm of dissolved solids is found in Paleozoic limestone in southern Idaho and adjacent parts of Utah (table 7).

The Mississippian Redwall limestone is the source of spring flow at Blue Spring totaling 193 cfs in the canyon of the Little Colorado River a few miles upstream from its confluence with the Colorado River in northcentral Arizona. Water from Blue Spring (table 7), which yields about half the total spring flow here (92 cfs), may be considered representative in terms of its chemical quality. It contains 2,340 ppm of dissolved solids; water from other springs in the same vicinity contains as much as 4,000 ppm. The percent sodium is as much as 76 in some of the spring waters. Ground-water conditions in the Mississippian Madison limestone and the Pennsylvanian Tensleep and Amsden formations have been discussed in connection with their occurrence in the Black Hills area of the Great Plains region. These formations are ground-water sources in the Bighorn and Wind River basins of Wyoming also.

The principal occurrence of Permian rocks in the Western Mountain region, and the only area where they are utilized extensively as ground-water sources, is in the Colorado Plateau of northern Arizona and southeastern Utah. The Coconino sandstone is the chief Permian water-bearing formation of this region, yielding several hundred gallons per minute to wells in some localities. An equivalent formation is an important aquifer in New Mexico, where it is known as the Glorieta sandstone member of the San Andres formation. Municipal wells in the Coconino sandstone supplying Joseph City and Holbrook, Ariz., yield several hundred gallons per minute with only a few feet of drawdown. Below the depth at which these municipal wells are screened, however, the water becomes increasingly highly mineralized. Specific examples of the relationship of depth to concentration of dissolved solids at one place are: 1,890 ppm at 500 feet, 12,000 ppm at 900 feet, and about 18,000 ppm at 1,800 feet. In the vicinity of Holbrook, Ariz., however, the dissolved solids in water from 24 wells averaged only 588 ppm (Harrell and Eckel, 1939).

Permian rocks of the Colorado Plateaus in northwestern New Mexico and western Colorado are deeply buried beneath sediments of Cretaceous and Tertiary age. At the depths at which they occur in this region the water undoubtedly is too highly mineralized for ordinary use.

MESOZOIC FORMATIONS

Triassic, Jurassic, and Cretaceous sedimentary rocks cover large areas in the southern part of the Colorado Plateaus and along the coast of northern California, and make up many of the mountain ranges of western Nevada. They do not contain significant water-bearing formations in either area; however, in the Colorado Plateaus they furnish meager water supplies in some places where other sources are lacking.

The Moenkopi formation of Triassic age and the Navajo sandstone of Jurassic age underlie much of the Colorado Plateaus in Arizona and Utah. The Moenkopi formation yields water containing about 3,500 ppm of dissolved solids to wells less than 300 feet deep, and, in the Holbrook area, Arizona, the average concentration of dissolved solids in water from 6 wells is 2,487 ppm (Harrell and Eckel, 1939). Yields from wells in the Moenkopi formation generally are rather low. The Navajo sandstone yields water containing as much as 2,800 ppm to wells ranging in depth from less than 200 to more than 800 feet. Wells in the Navajo sandstone in some localities, as at Tuba City, Ariz., flow as much as 50 gpm.

Cretaceous formations of the Western Mountain region that are significant saline-water sources are the Dakota sandstone and the Mesaverde formation. They occur in large areas of northwestern New Mexico, northeastern Arizona, western Colorado, eastern Utah, and southern Wyoming. In general, these formations may be expected to yield only small to moderate supplies of slightly saline ground water.

TERTIARY FORMATIONS

Water-bearing formations of Tertiary age are widespread in the Western Mountain region. Their principal occurrence, with respect to significant water supplies, is in the Columbia Plateaus of eastern

Washington and Oregon and adjacent States and as valley fill in the desert basins. In the Columbia Plateaus they consist of lava flows and interbedded sedimentary rocks in which artesian conditions exist locally. Water having a concentration of dissolved solids of as much as 3,500 ppm occurs at depths ranging from less than 200 to more than 1,300 feet. One oil-test well drilled near Lakeview in south-central Oregon produced a flow of 300 gpm from a depth of 1,200 feet. The water contained only 1,450 ppm of dissolved solids. Another oil-test well drilled near Portland, Oreg., yielded water containing more than 68,000 ppm from a depth of more than 9,000 feet.

Many of the closed basins of the Basin and Range province are underlain by unconsolidated to semiconsolidated sedimentary rocks of Tertiary age. They are commonly of low permeability, and, although moderate to large supplies can be derived from them in some basins, on the whole they are of less importance than the overlying Quaternary alluvium.

Along the coast of Washington and Oregon and the southern half of California, Tertiary sedimentary strata have a total thickness of several thousand feet. In the Long Beach-Santa Ana area of southern California, permeable zones in Tertiary formations contain brine of connate origin, effectively confined by essentially impermeable beds under natural conditions. The confining beds have been tapped by thousands of oil wells, however, and artificial conduits between fresh-water and connate-water zones have been created, thus forming a potential source of contamination (Piper, 1953). Tertiary formations of coastal Washington and Oregon are capable of yielding several hundred gallons per minute of moderately saline water.

Much of the Colorado Plateaus in Wyoming, Utah, Colorado, and northwestern New Mexico is underlain by Tertiary sedimentary rocks of the Wasatch and Wind River formations. Small to moderate quantities of water may be obtained locally at shallow depths; however, typical samples of water collected from depths of only a few hundred feet in western Wyoming contain about 5,000 ppm of dissolved solids.

QUATERNARY ALLUVIUM

Quaternary deposits are more widespread and by far more important with respect to water supply than any other group of formations in the Western Mountain region. Valley fill underlies perhaps half the entire Basin and Range Province, which extends from Nevada and western Utah across southern California, Arizona, and New Mexico into the Trans-Pecos region of western Texas. It also underlies the Great Central Valley of California (Sacramento and San Joaquin River valleys), most of the coastal basins in California, and many valleys in the Rocky Mountain region.

In a closed basin, typical of many of those found in the region, ground water moves by slow percolation through the alluvium from the base of the surrounding mountains to a central lowland or playa where it is returned to the atmosphere by evaporation and transpiration. In such discharge areas the dissolved solids become greatly concentrated, commonly reaching many thousand parts per million. The shallow sediments underlying playa areas of closed basins are, in general, very fine grained and do not yield water readily to wells; however, in western Utah, wells, some as deep as about 1,000 feet, but mostly only a few hundred feet deep, yield as much as 1,000 gpm of water in which dissolved solids reach 8,000 ppm or more. The San Luis Valley of south-central Colarado is a large basin, of which a part has interior drainage, underlain by Quaternary alluvium which is capable of yielding large quantities of water to properly constructed wells. As in other closed basins, ground water is not highly mineralized along the margins of the "sump" area of the San Luis Valley, but it becomes progressively more saline toward the discharge area. Yield of 3,000 gpm are common from wells of shallow to moderate depths, and yields of as much as 4,400 gpm are obtained from deeper artesian wells. A large area exists in this basin in which the ground water near the land surface contains more than 1,000 ppm of dissolved solids and has a percent sodium of more than 60.

In the Great Central Valley of California, which consists of the Sacramento and San Joaquin River valleys, saline water occurs in a wide belt extending from south of Bakersfield to the delta region near Stockton. In the Sacramento Valley it occurs at shallow depths in an area of about 75 square miles in the southern part of Sutter County. In both areas water containing 2,000 to 3,000 ppm of dissolved solids is obtained from wells yielding as much as 1,500 gpm; the water is used extensively for irrigation. The alluvium in other, smaller coastal basins also contains saline water under natural conditions, in addition to that which has intruded the formations through leakage from underlying Tertiary formations. Local overpumping also has resulted in the encroachment of sea water in some areas near the coast.

Large areas of Quaternary alluvium occur in the valleys of the Colorado River and its tributaries in southern Arizona, and the Rio Grande of New Mexico and western Texas. In Arizona abundant water supplies are obtained from the alluvium along the Gila River and its tributaries, the Salt, Santa Cruz, and San Pedro Rivers. In the upper Gila River basin near Safford, wells of shallow to moderate depth yield as much as 1,100 gpm of water containing as much as 8,000 ppm of dissolved solids. Much of the mineralization has occurred as a result of recharge of the shallow ground-water reservoir by surface water from irrigated fields, irrigation canals, and seepage from underlying Tertiary formations. In other parts of the Gila River valley wells yield as much as 3,800 gpm. Most of the water is saline; however, it is used extensively for irrigation in areas where soil drainage is good. Concentrations of dissolved solids are as high as 6,900 ppm in the lower Gila River basin. Saline ground water of the San Pedro and Santa Cruz basins also is used successfully for irrigation. Dissolved solids range from 1,000 to 9,000 ppm in the upper San Pedro basin and from 1,000 to 4,500 ppm in the Santa Cruz basin. Well yields range from moderate to more than 3,000 gpm.

Alluvium in the valley of the Rio Grande in Socorro, Sierra, and Dona Ana Counties, N. Mex., yields as much as 2,000 gpm of moderately saline water. At San Acacia, where the Rio Salado joins the Rio Grande, the ground water of the Rio Grande Valley is contaminated by saline water that moves into the area from the alluvium of the Rio Salado. Analyses of shallow ground-water samples from a series of about 250 hand-bored test wells in the Rio Grande Valley near El Paso, Tex., show concentrations of dissolved solids ranging from slightly less than 1,000 ppm to 28,000 ppm (Sayre and Livingston 1945). The average dissolved-solids content of the shallow water is probably about 2,000 to 3,000 ppm. Most of the wells in the El Paso area are of moderate depth, and they yield, on the average, several hundred gallons per minute; however, yields of more than 1,500 gpm are common. One well 304 feet in depth yielded 3,000 gpm from the alluvium. In the lower Rio Grande Valley in Texas, large quantities of saline water are pumped from irrigation wells tapping the alluvium. Yields as high as about 2,000 gpm have been reported.

SUMMARY OF SALINE GROUND WATER, BY PROVINCES

ATLANTIC AND GULF COASTAL PLAIN REGION

The Atlantic and Gulf Coastal Plain region is underlain by Cretaceous, Tertiary, and Quaternary formations which include some of the fresh-water aquifers with the highest yield in the United States, many of which contain large quantities of saline water some distance downdip from their outcrop areas and where they are in contact with saline surface-water bodies. Saline water is available at moderate depths and in moderate to large quantities in all parts of Louisiana and Florida, and in large parts of Alabama, Mississippi, Arkansas, and Texas. Some saline water in the Atlantic part of the Coastal Plain region is in areas where heavy ground-water pumping has caused encroachment of sea water into the water-bearing formations.

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EAST-CENTRAL REGION OF PALEOZOIC AND OTHER OLD ROCKS

Northeastern Drift province.—In the Northeastern Drift province the bedrock consists of crystalline rocks of low permeability, overlain by glacial deposits which furnish most of the larger ground-water supplies. Little or no saline water is present except in heavily pumped coastal areas where sea-water encroachment has occurred, as in the New Haven industrial area, Connecticut.

Piedmont province.—Little saline water is present in the Piedmont province. An occasional deep well taps a zone in which the water is saline owing to lack of fresh-water circulation.

Blue Ridge-Appalachian Valley province.—Only small quantities of saline water are obtained from the Paleozoic sandstone, limestone, and dolomite which underlie the province. The salinity of ground water increases with depth.

South-Central Paleozoic province.—Paleozoic sandstone, limestone, and dolomite furnish small to moderate quantities of saline water. The concentration of dissolved solids increases with the depth of burial of the aquifer. In much of the province saline water occurs with oil and gas. Slightly saline water is used for domestic supply in much of the province, and also for municipal use in places where surface water is inadequate or too expensive to treat.

North-Central Drift-Paleozoic province.—Water from Paleozoic formations at depths of more than a few hundred feet is generally slightly to moderately saline; however, some is used for municipal supply in parts of the area.

Wisconsin Paleozoic province.—Most of the ground-water supplies are obtained from Paleozoic sandstone and limestone. The water is generally fresh at shallow to moderate depths, but the salinity increases with depth of the aquifers.

Superior Drift-Crystalline province.—Glacial deposits in the western and northwestern parts of the province contain slightly saline water. The crystalline rocks underlying the glacial material yield only meager supplies.

GREAT PLAINS REGION

Dakota Drift-Cretaceous province.—The glacial drift in this province yields small amounts of ground water that ranges from fresh to saline. The principal aquifer is the Dakota sandstone, which underlies the entire province and yields large quantities of slightly to very saline water. Slightly saline water is used extensively for municipal, irrigation, and domestic supply.

Black Hills Cretaceous province.—This province is underlain largely by Cretaceous shale, which yields only meager supplies, and the Dakota sandstone, which yields saline water. In the Black Hills area, Paleozoic formations yield fairly large amounts of slightly saline water.

Great Plains Pliocene-Cretaceous province.—Saline ground water in this province is obtained locally from the Ogallala formation, which yields fresh water in most areas. The Dakota sandstone underlies the Ogallala throughout the province and almost everywhere yields saline water.

Great Plains Pliocene-Paleozoic province.—This province includes most of the High Plains of New Mexico, Texas, and Oklahoma. Large quantities of water ranging from fresh to moderately saline are obtained from the Ogallala formation. Locally the water has become more highly mineralized because of heavy pumping and consequent encroachment of saline water from the underlying Permian formations.

Trans-Pecos Paleozoic province.—Large quantities of moderately saline ground water are available from Permian and Triassic formations. Permian limestone supplies large amounts for irrigation in the Roswell artesian basin of southeastern New Mexico. Ground water containing as much as 4,000 ppm of dissolved solids is used extensively for irrigation in much of the province.

Northwestern Drift-Eocene-Cretaceous province.—The Eocene and Upper Cretaceous formations that underlie the province generally yield only meager supplies of water. These formations and Quaternary deposits, including glacial drift, yield saline water in some localities.

Montana Eocene-Cretaceous province.—Water-bearing formations yield only small supplies to wells in this province. Eocene and Upper Cretaceous formations yield saline water in small quantities at moderate depths.

Montana-Arizona Plateau province (Great Plains region).—This province is a northern extension of the Montana-Arizona Plateau province of the Western Mountain region. It is underlain largely by Cretaceous shale which yields only meager supplies of ground water, generally saline.

WESTERN MOUNTAIN REGION

Southern Rocky Mountain province.—Little or no saline water is present in this province. It is underlain by crystalline rocks which yield small quantities of fresh water to wells and springs.

Montana-Arizona Plateau province (Western Mountain region).—This is generally a region of deficient ground-water supply. Slightly saline water is present in all the formations at moderate depths. The Coconino sandstone is the principal water-bearing formation in the southern half of the province. It yields fresh water in some areas; elsewhere it contains saline water at moderate depth.

Northern Rocky Mountain province.—This province is underlain by crystalline rocks which yield only small supplies of fresh water. Alluvial sand and gravel in some places also supply moderate quantities. Little or no saline water is present.

Columbia Plateau lava province.—Relatively little saline water is present in this province except at great depths. Large yields of fresh water are reported for wells screened in Tertiary volcanic rocks.

Southwestern Bolson province.—The principal sources of ground water are the alluvial sand and gravel deposits in closed basins and along major streams. Saline water is available in large quantities from alluvium along streams and deeper alluvium in parts of many basins. Only small yields of saline water may be expected from the central areas of closed basins, however, because of the low permeability of the playa deposist. Saline water is used extensively for irrigation in the southern part of the province.

Pacific Mountain province.—The Pacific Mountain province includes the Sierra Nevada and Cascade Mountains and the Coast Ranges of California, Oregon, and Washington. Large quantities of potable ground water are obtained from glacial drift and alluvium in intermontane valleys. In some coastal areas where ground-water withdrawal by pumping is extensive, encroachment of sea water or connate saline water has occurred.

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TABLES OF MEASUREMENTS AND ANALYSES

TABLE 3.—*Physical measurements and chemical analyses of surface water*

[Frequency of sampling: D, daily; W, weekly; M, monthly; I, infrequently. Analyses in parts per million, except as indicated]

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
	Parts 1, 2. North Atlantic slope basins to eastern Gulf of Mexico basins							
1	Delaware River at Marcus Hook, Pa.[1]		3,430	8/49–12/52	11/2/49	41	M	Maximum.
2	Do.[2]		38,300		11/5/51			Minimum.
3	Wicomico River at Whitehaven, Md., low tide				8/12/52		I	
4	Do., high tide				8/12/52			
5	Nanticoke River at Vienna, Md., low tide		280		7/2/52		I	
6	Do., high tide		4,300		8/11/52			
7	Choptank River at Dover, Md., low tide				8/28/52		I	
8	Do., high tide				8/28/52			
9	Chester River at Chestertown, Md., low tide				10/27/52		I	
10	Do., high tide				10/27/52			
11	Chester River at Crumpton, Md., low tide				10/27/52		I	
12	Do., high tide				10/27/52			
13	Chesapeake Bay at Bay Bridge, low tide				10/29/52		I	
14	Do., high tide				10/29/52		I	
15	Combahee River near Yemassee, S. C., low tide		1,340	10/51–9/52	3/26/52	1	I	Minimum.
16	Do., high tide		47		9/15/53			Maximum.
	Part 3. Ohio River basin							
17	Tunungwant Creek at Limestone, Cattaraugus County, N. Y.				8/20/53	1	I	

See footnotes at end of table.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Parts 1, 2. North Atlantic slope basins to eastern Gulf of Mexico basins																	
1	2.0	0.07	73	140	1,030		26	370	1,920	0.4	1.0		3,940	757	75	5,970	6.3
2	5.7	.01	21	7.7	13		33	60	14	.1	6.6		173	84	24	257	7.5
3					950				1,600					800		6,000	7.0
4					2,200				3,500					1,200		10,800	7.3
5									498							1,750	
6									348							1,280	
7	4.2		46	78	680		35	179	1,220		1.0			430		4,190	7.0
8	4.0		61	155	1,260		41	330	2,240		1.2			790		7,370	6.9
9					1,764				2,960					990		9,140	7.1
10					2,160				3,820					1,320		11,800	7.1
11					212				360					150		1,380	6.9
12					353				625					248		2,330	6.9
13					1,900		53	484	3,450					1,280		11,100	7.5
14					3,900		65	1,100	6,820					2,250		18,100	7.5
15	4.6	.52	8.0	1.1	5.2		23	3.3	9.0	.0	.8		75	24	31	72.1	6.1
16	2.9	.10	75	197	1,690		54	377	3,000	.0	.2		5,780	997	79	9,270	6.7
Part 3. Ohio River basin																	
17	2.5	0.77	146	37	425	2.4	125	93	908	.0	1.0		2,130	518	64	3,110	7.5

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
Part 3. Ohio River basin—Continued								
18	Tuscarawas River at Newcomerstown, Ohio.	2,436	341	7/46–9/47	9/21–30/46	49	D	Maximum.
19	Do		1,630		7/14/46			Minimum.
20	Muskingum River at Zanesville, Ohio (above Licking River).			10/49–9/50	11/16/49	12	M	Maximum.
21	Do				2/16/50			Minimum.
22	Muskingum River at McConnelsville, Ohio.	7,411	1,763	10/50–9/51	11/1–10/50	36	D	Maximum.
23	Do		34,320		2/21–28/51			Minimum.
24	Tuscarawas River at Clinton, Ohio	165	64	10/2–27/50	10/16–17/50	7	D	Maximum.
25	Do		63		10/2/50			Minimum.
26	Chippewa Creek near Clinton, Ohio			10/2–27/50	10/24/50	9	D	Maximum.
27	Do				10/22/50			Minimum.
28	Short Creek near Dillonvale, Ohio		13.9		10/24/49	1	I	
29	Wheeling Creek at Bridgeport, Ohio				9/22/52	1	I	
30	Cross Creek at Mingo Junction, Ohio				9/23/52	1	I	
31	North Fork Holston River near Gate City, Va.	672	155	10/49–9/51	10/21–30/49	84	D	Maximum.
32	Do		10,310		2/1–4, 6/50			Minimum.
33	North Fork Holston River at Holston, Va.		51	10/51–9/52	9/11–21/52	50	D	Maximum.
34	Do		1,560		3/5/52			Minimum.
35	North Fork Holston River at Kingsport, Tenn.[3]	729	410	9/37–8/38	10/5/37		M	Maximum.
36	Do.[3]		2,370		3/9/38			Minimum.
37	Do.[4]		253	7/16–8/53	7/16/53	24	I	Maximum.
38	Do.[4]		193		8/3/53			Minimum.
39	Chattanooga Creek at Chattanooga, Tenn.[4]				4/23/52		I	Maximum.
40	Do.[4]				5/21/52			Minimum.

See footnotes at end of table.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 3. Ohio River basin—Continued																	
18	3.4	0.18	578	25	493	16	110	222	1,620	1.0	6.9	----	3,490	1,540	41	5,420	7.5
19	8.0	----	55	14	18		38	120	52	----	5.9	----	307	195	17	499	----
20	2.0	.10	232	22	156		154	134	525	.4	1.2	----	1,290	669	34	2,110	7.5
21	6.2	.11	26	6.1	10		44	55	11	.4	3.2	----	140	90	19	235	7.7
22	4.6	.12	212	18	158		152	150	470	.7	3.4	----	1,210	604	36	1,960	7.5
23	7.6	.03	34	8.3	11	2.4	59	58	24	.2	4.2	----	188	118	16	306	7.5
24	----	----	4,780	19	3,600	33	107	268	13,600	----	----	----	23,400	12,000	39	32,600	7.6
25	----	----	2,150	19	1,650	17	217	143	6,220	----	----	----	11,000	5,430	40	16,800	7.7
26	----	----	354	41	4,970	21	272	510	7,950	----	----	----	14,500	1,050	91	21,800	7.6
27	----	----	168	41	916	12	240	314	1,510	----	----	----	3,140	590	77	5,060	8.0
28	4.0	.28	302	90	193		39	1,330	88	.5	.8	----	2,230	1,120	27	2,580	6.7
29	7.7	.03	224	58	175	5.1	31	1,099	13	.5	1.7	----	1,705	800	32	2,030	7.1
30	6.0	.10	194	43	17	5.3	97	609	10	.3	.0	----	1,004	660	5	1,230	7.3
31	----	.03	950	26	512	24	57	48	2,420	----	2.2	----	4,010	2,480	31	7,550	7.4
32	6.0	.03	49	4.6	16		84	12	65	----	3.0	----	197	141	20	372	7.4
33	4.0	.02	1,070	389	1,530	11	42	123	5,200	----	10	----	8,360	4,270	44	14,300	6.9
34	7.2	----	44	7.3	28	.9	81	16	90	----	2.0	----	235	140	30	428	7.9
35	3	4.2	236	13.5	129	----	71	15.7	596	----	.18	----	1,250	691	30	----	7.6
36	6	.4	46	5.5	6.7	----	72	7.4	50	----	3.90	----	215	139	10	----	7.7
37	----	----	----	----	----	----	70	----	1,408	----	----	----	2,370	1,000	----	----	7.9
38	----	----	----	----	----	----	54	----	400	----	----	----	1,090	460	----	----	7.3
39	----	----	----	----	----	----	210	----	110	.1	----	----	2,430	----	----	----	7.6
40	----	----	----	----	----	----	168	----	90	----	----	----	560	----	----	----	9.2

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
Part 3. Ohio River basin—Continued								
41	Dobbs Creek at mouth at Chattanooga, Tenn.[4]				4/23/52	1	I	
42	Do.[4]				5/21/52			
43	Pigeon River above Crosby Creek, Tenn.[4]		98		9/15/53	1	I	
44	Do.[4]		64		9/15/53			
45	Pigeon River above Newport, Tenn.[4]				9/16/53	1	I	
46	Richland Creek above mouth at Nashville, Tenn.[4]				5/14/48	1	I	
47	Do.[4]				9/23/52			
48	Saline River near Junction, Ill.[5]	1,040	6.8	10/45–3/48	8/22/47	25	I	Maximum.
49	Do.		9,260		1/5/48			Minimum.
Part 4. St. Lawrence River basin								
50	Grand River at Painesville, Ohio	712	26	3/50–2/52	8/9/50	80	D	Maximum.
51	Do.		5,360		12/1–10/50			Minimum.
Part 5. Hudson Bay and upper Mississippi River basins								
52	Sheyenne River at Sheyenne, N. Dak.	1,830	0.01	3/49–11/50	2/3/50	16	M	Maximum.
53	Do.		1,340		4/7/49			Minimum.
54	Des Lacs River at Foxholm, N. Dak.	973	27	7/46–7/51	10/25/50	28	I	Maximum.
55	Do.		1,590		4/5/49			Minimum.
56	Goose River at Hillsboro, N. Dak.		34		5/19/49	1		

See footnotes at end of table.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 3. Ohio River basin—Continued																	
41							1,460		144	0.6			2,610				10.9
42							112						145				8.3
43							150		116				1,060	150			7.6
44							144		120				995	172			7.5
45							152		101				995	148			7.7
46							320						1,280				6.8
47													1,060				5.5
48	11.9	7.1	154.9	91.5	72.7		104	679.2	78		2.4		1,190	764	17		
49	10.6	7.7	12.6	6.1	3.5		8.0	43.2	7		1.6		105	57	12		
Part 4. St. Lawrence River basin																	
50			3,690	18	3,000 (Na + K)		76	79	11,100	0.0	1.4		18,900	9,280	41	26,800	6.7
51	6.7	0.06	74	5.3	60	2.6	54	38	186	.2	.4		430	206	38	763	6.7
Part 5. Hudson Bay and upper Mississippi River basins																	
52	28	0.04	123	104	412 (Na + K)		1,370	404	59	0.6	2.8		[6] 1,810	735	55	2,500	7.7
53	10	.04	14	5.5	11 (Na + K)		62	25	2.0	0	2.5	0	111	58	30	169	6.9
54	14	.02	59	40	259 (Na + K)		538	370	30	.4	5.1	.20	[6] 1,040	310	65	1,550	7.7
55	8.4	.15	15	3.0	12 (Na + K)		67	17	.8	.1	3.9	.01	115	50	35	157	7.2
56	19	.02	158	58	97 (Na + K)		360	456	50	.8	1.6	.42	[6] 1,020	633	25	1,380	7.5

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
Part 5. Hudson Bay and upper Mississippi River basins—Continued								
57	Cranberry Lake, Benson County, N. Dak.			6/49–10/52	10/3/52	4	I	Maximum.
58	Do.				8/2/50			Minimum.
59	East Devil's Lake, Benson County, N. Dak.			6/49–10/52	3/28/52	13	I	Maximum.
60	Do.				8/1/52			Minimum.
61	East Stump Lake, Nelson County, N. Dak.			5/49–10/52	3/29/52	32	I	Maximum.
62	Do.				6/14/50			Minimum.
63	Long Lake, Rollette County, N. Dak.				6/20/49	1		
Part 6. Missouri River basin								
64	Little Missouri River at Alzada, Mont.	780	0.2	5/49–7/51	1/4/51	13	I	Maximum.
65	Do.		8.2		3/8/50			Minimum.
66	Powder River near Locate, Mont.			8/48–7/53	11/27–12/7/52	105	M, D	Maximum.
67	Do.		7,000		3/29/52			Minimum.
68	Powder River at Moorhead, Mont.			2/51–7/53	7/22–24/53	82	D	Maximum.
69	Do.		1,600		5/1–8/52			Minimum.
70	Medicine Lake, Sheridan County, Mont.				5/27/47	1		
71	Milk River at Nashua, Mont.	23,300	75	12/49–5/53	12/8/50	16	I	Maximum.
72	Do.		920		5/29/51			Minimum.
73	Little Powder River near Broadus, Mont.		2.4		9/13/49	1	I	
74	Powder River near Broadus, Mont.				9/13/49	1	I	
75	Powder River at Terry, Mont.				9/13/49	1	I	
76	Ocean Lake, near Riverton, Wyo.			9/47–8/51	3/31/50	19	I	Maximum.[13]
77	Do.				9/3/48			Minimum.[14]

See footnotes at end of table.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 5. Hudson Bay and upper Mississippi River basins—Continued																	
57	----	----	----	----	----	----	[7] 35,700	----	----	----	----	----	35,700	49	----	36,600	9.6
58	27	0.02	2.0	15	4,340	74	[8] 4,710	5,060	347	----	0.4	----	[6] 12,200	67	98	14,400	9.7
59	----	----	3.6	----	14,100	----	[9] 2,860	35,100	5,700	----	----	----	62,000	----	65	50,500	8.7
60	14	.06	8.8	1,630	8,750	837	[10] 1,580	19,800	3,290	2.9	6.8	----	[6] 35,100	6,720	71	32,760	8.8
61	----	----	16	----	14,500	----	2,970	51,000	22,900	----	----	----	115,000	----	36	76,700	7.8
62	12	.04	3.0	2,980	10,200		749	24,400	5,910	1.4	.7	----	[6] 43,900	12,300	64	36,300	8.0
63	5.0	.02	73	82	144	30	305	536	55	.6	3.8	----	[6] 1,080	519	36	1,600	7.9
Part 6. Missouri River basin																	
64	8.1	0.06	159	55	225		351	778	0.8	0.8	1.3	0.30	[6] 1,410	622	44	1,760	7.3
65	20	.02	31	12	70		92	190	2.0	.4	2.0	.05	376	127	54	547	7.2
66	----	----	269	124	362	----	413	1,480	86	----	4.7	.23	2,750	1,180	39	3,140	7.8
67	----	----	29	8.6	43	----	[11] 106	112	4.0	----	5.0	.05	278	108	44	409	8.3
68	----	----	388	118	457	----	268	1,990	130	----	4.7	.32	3,460	1,450	40	3,850	6.8
69	----	----	61	17	37	----	141	168	13	----	3.6	.17	418	220	26	605	8.0
70	6.0	.02	24	54	457	28	[12] 752	600	50	.0	1.0	----	1,590	282	76	2,180	8.6
71	8.0	.05	120	43	235		448	545	37	.3	1.4	.39	1,210	478	52	1,710	8.1
72	----	----	----	----	69	----	202	183	9.0	----	----	----	----	----	41	695	7.5
73	6.2	.02	137	77	408		329	1,210	9.6	1.0	2.0	----	2,020	659	57	2,690	7.4
74	7.2	.02	124	80	147		244	712	10	.8	2.0	----	1,210	639	33	1,630	7.7
75	9.6	.02	154	71	261		240	968	25	1.2	1.4	----	1,610	677	46	2,140	7.5
76	22	.02	149	50	557		172	1,450	95	1.0	2.6	.05	[6] 2,410	578	68	3,130	7.5
77	6.7	.06	106	44	491		[4] 70	1,260	101	.7	0	.09	[6] 2,040	445	71	2,920	8.6

See footnotes at end of table.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
Part 6. Missouri River basin—Continued								
78	Fivemile Creek near Shoshoni, Wyo		30.9	9/49–6/53	2/7–10/51	46	D, M	Maximum.
79	Do		228		6/16–30/51			Minimum.
80	Muddy Creek near Shoshoni, Wyo		.9	9/49–3/53	9/4/49	16	I	Maximum.
81	Do		41		7/16/51			Minimum.
82	Bighorn River at Manderson, Wyo	11,900	236	3/47–12/48	8/17/48	10	I	Maximum.
83	Do		3,980		6/3/47			Minimum.
84	Dry Creek at Greybull, Wyo			12/50–9/51	2/6/51		M	Maximum.
85	Do		163		7/11/51			Minimum.
86	Shoshone River at Kane, Wyo			10/50–6/53	3/3/53	32	M	Maximum.
87	Do				6/8/51			Minimum.
88	Middle Fork Powder River near Kaycee, Wyo.	980		5/46–7/53	7/7–28/53	67	I, D	Maximum.
89	Do				5/29/53	67	I, D	Minimum.
90	South Fork Powder River near Kaycee, Wyo.	1,150		9/49–7/53	11/5/52	63	I, D	Maximum.
91	Do				7/19/53			Minimum.
92	Powder River at Sussex, Wyo		26	9/49–6/53	9/8/50	45	M	Maximum.
93	Do		310		6/7/50			Minimum.
94	Powder River at Arvada, Wyo	6,050		5/46–6/53	8/23/52	53	I	Maximum.
95	Do				5/3/46			Minimum.
96	Little Missouri River at Marmarth, N. Dak.	4,570	5.3	10/45–9/51	1/2/51	51	M	Maximum.
97	Do		2,730		4/4/50			Minimum.
98	Little Missouri River at Watford City, N. Dak.	8,490	13	5/46–9/49	9/8/49	23	I	Maximum.
99	Do		25,400		3/26/47			Minimum.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 6. Missouri River basin—Continued																	
78	--	--	--	--	736	--	251	2,160	99	--	--	--	--	--	62	4,300	7.7
79	--	--	--	--	170	--	172	550	20	--	--	--	--	--	50	1,360	7.5
80	26	0.02	448	267	493		482	2,690	61	1.8	1.4	1.54	[6] 4,230	2,220	33	4,670	7.1
81	--	--	--	--	26	--	142	118	4.0	--	--	--	310	--	23	475	8.2
82	19	0	130	37	184		312	540	38	.6	3.5	.15	1,110	476	46	1,460	8.0
83	15	.02	46	13	26		125	107	7.2	.3	1.1	--	[6] 274	168	25	433	8.0
84	19	.06	174	70	496		491	1,270	43	1.6	15	.2	[6] 2,330	722	60	3,050	7.8
85	16	.02	66	21	138		227	325	13	.7	5.1	.13	728	249	55	1,020	7.4
86	--	--	159	56	210		354	728	25	--	--	--	--	627	42	1,900	7.8
87	17	.03	40	12	51		122	144	5.5	.2	2.6	--	354	149	43	511	7.7
88	17	.00	173	63	206	6.2	293	740	116	.6	2.0	.19	[6] 1,470	690	39	1,990	7.5
89	--	--	57	14	34	2.4	--	--	--	--	--	--	352	200	27	540	7.6
90	16	.01	382	138	820	17	284	2,530	312	1.8	56	.46	[6] 4,410	1,520	54	5,260	7.3
91	19	--	220	44	164	7.9	282	770	32	--	1.0	.25	[6] 1,400	730	33	1,880	7.2
92	11	.04	321	109	467		238	1,540	327	1.1	.8	.3	[6] 2,890	1,250	45	3,660	7.7
93	14	.02	80	24	68		161	255	33	.4	2.1	.1	572	298	33	790	7.4
94	--	--	--	--	424	--	181	1,850	121	--	--	--	--	--	--	3,450	8.2
95	--	--	94	24	37	--	206	203	21	.3	4	--	509	333	19	704	7.7
96	10	.08	64	47	644		858	985	17	.5	.9	--	[6] 2,190	354	80	3,070	7.9
97	8.0	.16	15	3.5	19		68	34	0	.2	1.9	--	138	52	44	187	6.7
98	16	.02	86	40	350		456	725	6.5	.4	2.2	.39	[6] 1,450	379	67	2,030	8.1
99	7.8	.6	42	8.7	35	3.8	172	69	3.8	.1	3.0	.12	260	141	141	411	7.7

See footnotes at end of table.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
	Part 6. Missouri River basin—Continued							
100	Knife River at Hazen, N. Dak	2,352	181	5/46–9/51	5/31/49	43	I	Maximum.
101	Do		3,440		3/25/47			Minimum.
102	Heart River near Glen Ullin, N. Dak	1,760	9.0	10/45–10/46, 3/47–11/47, 3/48–9/50	12/1/45	79	M, D, I	Maximum.[15]
103	do		2,900		3/26/47			Minimum.
104	Cannonball River at Breien, N. Dak	4,066	3.5	10/45–10/50	12/16/49	21	I	Maximum.
105	do		5,700		3/28/49			Minimum.
106	Shadehill Reservoir near Shadehill, S. Dak.			9/50–6/53	11/20, 27, 12/15/50	210	I	Maximum.
107	do				4/17/52			Minimum.
108	Grand River near Wakpala, S. Dak	5,510		11/45–12/52	11/20–29/52	85	D, I	Maximum.
109	do		13,300		4/8/50			Minimum.
110	Moreau River near Faith, S. Dak	2,660	.5	11/45—9/49	1/1–20/49	121	D	Maximum.
111	do		1,700		3/9/49			Minimum.
112	Moreau River at Promise, S. Dak	5,223	1.4	11/45–11/51	1/15/51	25	I	Maximum.
113	Do		1,070		3/22/49			Minimum.
114	Belle Fourche River below Moorcroft, Wyo.	1,730	0.1	5/46–5/51	3/9/51	39	I	Maximum.
115	Do		872		9/9/46			Minimum.
116	Belle Fourche River near Elm Springs, S. Dak.	7,210	8	11/45–8/52	2/2/51	45	I	Maximum.
117	Do		12,200		4/1/52			Minimum.
118	Cheyenne River near Hot Springs, S. Dak.	8,710	34	11/45–12/46, 4/47–9/49, 10/49–9/51.	3/8/51	98	I, D, M	Maximum.
119	Do		3,230		9/5/51			Minimum.
120	Cheyenne River near Eagle Butte, S. Dak	24,500	2.4	11/45–2/53	1/9/50	81	I, D	Maximum.
121	Do		19,490		4/4–9/52			Minimum.
122	Bad River near Fort Pierre, S. Dak	3,107		4/46–5/53	2/4/53	36	I	Maximum.
123	Do		863		3/28/50			Minimum.

See footnotes at end of table.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 6. Missouri River basin—Continued																	
100	10	0.01	50	33	356		632	488	3.4	0.6	1.6		[6] 1,260	261	75	1,870	7.9
101	9.4	.80	12	5.6	30	8.3	73	34	20	.0	7.0	0.13	152	53	51	211	7.6
102			78	52	336		631	596	2.8		1.1		[6] 1,420	406	64	1,920	8.0
103	6	1.0	20	4.6	21		112	19	.5	.4	1.5		131	69	40	190	7.3
104	24	.02	92	54.4	494		908	715	24	.8	1.4		[6] 1,850	452	70	2,580	7.8
105	14	.02	28	1.5	31		122	38	.0	.0	3.8		180	76	47	276	7.7
106	6.0	.02	35	25	516	9.4	636	770	13	.7	2.1	.35	[6] 1,690	190	85	2,370	8.0
107	2.0	.10	9.0	3.3	36	4.1	78	52	1.0	.2	1.4	.05	166	36	66	240	7.6
108			199	74	590		908	1,310	24		1.2	.37	2,740	802	60	3,440	7.8
109	9.6	.04	22	3.3	30		110	38	1.6		1.1		162	69	48	262	7.4
110	25	.01	22	64	1,350	10	1,620	1,820	36	1.2	.8	1.2	[6] 4,140	318	90	5,460	7.9
111	7.8		9.2	9.2	8.3		65	20	1.0	.8	1.3		104	61	23	133	7.0
112	14	.10	376	78	527		505	1,840	53	.4	.5	.24	[6] 3,140	1,260	47	3,580	7.7
113	8.0	0	16	7.9	39		83	84	0	.2	2.2	0	214	73	54	321	7.5
114	10	.20	178	86	622		807	1,410	15	.7	.3		[6] 2,710	799	62	3,560	7.7
115			24	11	11		75	64	0	.2	1.6		183	105	19	273	8.3
116	15	.20	665	380	698		670	3,880	99	1.1	7.2	.94	[6] 6,080	3,220	32	6,230	7.5
117			52	16	54		82	225	7.0			.19		194	38	626	
118	13	.04	520	122	268		246	1,740	260	1.2	1.0		[6] 3,050	1,800	24	3,630	7.6
119	15	.01	71	18	64		222	188	7.5	.4	1.4		494	250	36	716	7.3
120	28	.01	330	116	322		342	1,580	51	.6	2.5	.4	[6] 2,600	1,300	35	2,880	7.7
121			83	14	57		157	245	6.0		3.7	.02	524	264	31	740	7.6
122			368	81	559		360	1,820	195					1,250	49	3,950	7.6
123	23	.02	73	9.3	49		164	173	6.0	.2	2.3	.30	510	220	32	614	7.5

See footnotes at end of table.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
	Part 6. Missouri River basin—Continued							
124	White River near Kadoka, S. Dak		4.6	11/45–8/48, 3/49–4/53	1/1–31/50	203	I, D	Maximum.
125	Do		6,605		3/29–30/52			Minimum.
126	James River at Jamestown, N. Dak		4.0	10/45–6/53	1/2/51	41	I	Maximum.
127	Do		72		3/12/49			Minimum.
128	James River at Huron, S. Dak		0.8	3/49–4/52	1/29/51			Maximum.
129	Do		2,580		4/3/50			Minimum.
130	North Platte River below Casper, Wyo	12,600		6/49–5/53	3/18/53	30	M	Maximum.
131	Do		5,570		8/27/52			Minimum.
132	North Platte River near Cassa, Wyo	15,700	120	6/49–6/52	12/7/50	16	I	Maximum.
133	Do		7,400		6/4/52			Minimum.
134	South Platte River at Evans, Colo			10/50–9/51	10/13/50	11	M	Maximum.
135	Do				6/4/51			Minimum.
136	Cache La Poudre River near Greeley, Colo.	1,840	56	1/50–9/53	12/6/50	21	I	Maximum.
137	Do				6/4/53			Minimum.
138	South Platte River at Julesburg, Colo	22,800	242	10/45–8/53	2/1/51	224	D	Maximum.
139	Do				8/19/53	224	D	Minimum.
140	Salt Creek at 27th St., Lincoln, Nebr			5/50–5/53	5/23/51	4	I	Maximum.
141	Do		16,700		5/9/50			Minimum.
142	Hoffland Lake, Sheridan Co., Nebr. (north end).				3/23/51	2	I	
143	Do (south end).				3/23/51			
144	Diamond Lake, Sheridan Co., Nebr				10/23/52	1	I	
145	Smoky Hill River near Ellis, Kans	5,630	14	3/47–8/50	9/17/48	22	I	Maximum.
146	Do		8,960		8/14/50			Minimum.
147	Smoky Hill River at Ellsworth, Kans	7,580		3/47–5/50	10/2/48	15	I	Maximum.
148	Do				6/9/49			Minimum.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 6. Missouri River basin—Continued																	
124	102	0.10	138	29	364	21	974	435	29	0.8	1.4	0.52	[6] 1,600	464	62	2,050	7.9
125			9.2	.7	62		151	28	2.0				238	26	84	304	7.9
126	24	.08	83	42	214		366	308	155	.2	6.7	.98	[6] 1,010	380	55	1,590	7.9
127	7.3	.05	15	5.0	13		53	30	4.5	.0	6.5	.08	125	58	33	173	6.5
128	26	.02	177	75	206	19	696	495	118	.6	1.0	.2	[6] 1,460	748	37	2,090	8.0
129	11	.20	21	5.3	20		77	37	9.0	.1	4.6	.2	182	75	37	239	7.4
130			136	57	196		207	690	79					574	43	1,840	7.2
131			49	14	36		142	124	10					182	30	497	8.0
132	20	.04	146	41	130	8.6	342	473	37	.4	4.2	.0	[6] 1,030	534	34	1,450	7.9
133	15	.04	49	11	31		141	103	7.5	.3	1.4	.07	312	168	29	460	7.7
134	16	.04	153	81	154	9.2	320	715	44	1.2	7.2	.3	[6] 1,340	715	32	1,740	7.8
135	11	.02	68	29	66	2.4	156	246	25	.7	9.0		570	290	33	831	7.8
136	15	.10	325	61	156		610	815	32	.3	6.0	.1	[6] 1,710	1,060	24	2,130	8.1
137			148	64	98		283	558	23					633	25	1,480	7.5
138					190								1,610	766		2,010	
139					44		176	154	18				446	228	29	617	7.3
140							282	255	1,600			.32		366	87	5,560	7.2
141	12		12	2.7	22		54	17	17	.5	1.5	.2	114	41	53	172	7.4
142					171	233						.21		504	32	1,930	
143					235	293						.47		536	36	2,490	
144	31				444	544	[16] 1,690	395					2,500	250	51	3,360	9.2
145	23	.02	130	28	288		206	258	442	.6	2.8	.12	[6] 1,280	440	59	2,110	7.9
146	17	.02	53	1.0	14		145	39	2.5	.3	3.9		208	136	19	315	7.6
147	27	.03	144	26	287		212	228	480	.5	.7	.18	[6] 1,300	466	57	2,180	8.0
148	17	.02	53	3.5	19		128	44	26	.2	1.1		222	147	22	359	7.9

See footnotes at end of table.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
	Part 6. Missouri River basin—Continued							
149	Saline River near Russell, Kans	1,502	8.6	10/45–6/51	10/1–31/47	132	D	Maximum.
150	Do		10,600		6/24/51			Minimum.
151	Arikaree River at Haigler, Nebr	1,460	.2	3/47–9/49	8/25/47	13	I	Maximum.
152	Do		373		6/28/49			Minimum.
153	White Rock Creek at Lovewell, Kans	358	4.6	12/49–5/53	12/19/49	19	I	Maximum.
154	Do		11,500		7/10/50			Minimum.
	Part 7. Lower Mississippi River basin							
155	Arkansas River below John Martin Dam, Colo	18,935	3.2	11/45–7/49, 1/51 9/52	1/8–20/48	200	I, D	Maximum.
156	Do		613		6/21–30/52			Minimum.
157	Arkansas River at Arkansas City, Kans	43,475		10/51–9/53	8/1–8/52	123	D	Maximum.
158	Do				10/1–10/51			Minimum.
159	Salt Fork Arkansas River near Jet, Okla	3,202	9.64	10/49–10/53	1/6/53	23	M	Maximum.
160	Do				5/13/52			Minimum.
161	Cimarron River near Mocane, Okla	8,653	55.3	10/46–9/48	1/1–3/48	93	D	Maximum.
162	Do		1,175		10/6–17/46			Minimum.
163	Cimarron River near Waynoka, Okla	13,307	34.2	10/51–9/53	5/15/53	36	M	Maximum.
164	Do		3,390		4/23/52			Minimum.
165	Skeleton Creek near Lovell, Okla	410	8.60	10/50–9/53	12/7–8/50	244	D	Maximum.
166	Do		688		9/13/51			Minimum.
167	Arkansas River at Sand Springs Bridge near Tulsa, Okla.	74,700	2,757	10/46–9/53	10/12–17/46	451	D	Maximum.
168	Do		49,430		7/18–20/50			Minimum.
169	Verdigris River near Inola, Okla	7,911	153	10/47–9/53	2/20–22/48	360	D	Maximum.
170	Do		46,200		6/22–7/2/48			Minimum.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 6. Missouri River basin—Continued																	
149	16	0.1	227	90	1,290	14	[11] 298	722	1,920	0.6	1.5	0.68	[6] 4,430	936	75	6,660	8.1
150	16	.02	37	3.8	15		106	28	15	.3	4.4	.04	198	108	24	284	7.8
151	49	.02	180	86	166		251	889	20	1.2	.2	.29	[6] 1,520	803	31	1,880	7.9
152	23	.02	48	9.2	21		200	30	4.5	.6	1.1	--	246	158	23	389	7.9
153	16	.02	223	36	84		528	362	32	.3	39	.14	[6] 1,050	705	21	1,450	7.5
154	12	.04	33	2.3	5.8		124	.6	.0	.3	1.8	.2	124	92	12	213	7.3
Part 7. Lower Mississippi River basin																	
155	19	--	435	175	535		270	2,420	158	--	5.5	--	3,880	1,800	39	4,570	7.7
156	14	0.06	103	36	88	4.4	137	424	22	0.6	4.4	0.18	763	405	32	1,080	8.0
157	--	--	76	33	457		151	216	685	--	6.4	--	1,580	325	75	1,580	7.4
158	--	--	52	12	112		152	100	135	--	3.6	--	501	180	57	862	7.5
159	--	--	306	96	--	--	149	--	4,630	--	--	--	--	1,160	--	15,700	7.8
160	--	--	224	71	--	--	168	--	725	--	--	--	--	850	--	3,520	8.0
161	--	--	137	58	536		360	251	840	--	7.0	--	2,010	300	67	3,460	--
162	--	--	48	16	89		180	67	113	--	2.0	--	435	186	51	756	--
163	--	--	392	152	--	--	201	--	20,700	--	--	--	--	1,600	--	51,800	8.1
164	--	--	477	83	--	--	177	--	1,620	--	--	--	--	1,530	--	6,680	7.7
165	--	--	173	58	525		606	221	765	--	6.6	--	2,100	670	63	3,530	--
166	--	--	30	8.6	--	--	67	21	19	--	9.6	--	122	110	--	246	7.6
167	--	--	210	51	1,770		137	323	2,930	--	4.0	--	5,360	734	84	9,200	--
168	--	--	36	54	36		112	18	55	--	1.8	--	232	112	41	391	--
169	--	--	133	41	436		190	45	880	--	5.0	--	1,630	673	65	3,040	--
170	--	--	17	4.4	11		48	9.7	22	--	3.0	--	91	60	28	173	--

See footnotes at end of table.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
	Part 7. Lower Mississippi River basin—Continued							
171	Canadian River near Sanchez, N. Mex.	5,925	153	9/39–6/49	6/10–11/43	340	D	Maximum.
172	Do		8,500		9/22, 28–29/41			Minimum.
173	Canadian River at Tascosa, Tex.	19,200	16.8	[17] 10/50–9/51	3/2–3, 14–15/51		D	Maximum.
174	Do		5,645		5/14–15/51			Minimum.
175	Do		196		11/50–9/51			Weighted average.
176	Canadian River near Borger, Tex.				10/2–3, 7–10/50		D	Maximum.
177	Do				9/21–30/51			Minimum.
178	Canadian River at Bridgeport, Okla.	25,071	360	10/48–9/53	6/20/50	302	D	Maximum.
179	Canadian River at Bridgeport, Okla.	25,071	2,980	10/48–9/53	5/23, 52	302	D	Minimum.
180	Deep Fork near Dewar, Okla.	2,307	38.7	10/48–9/51	12/1–3/48	173	D	Maximum.
181	Do		11,790		7/21–24/50			Minimum.
182	Canadian River near Whitefield, Okla.	47,576	2,760	10/46–9/53	7/18/52	698	D	Maximum.
183	Do		4,725		1/2, 5–7/48			
184	Arkansas River at Van Buren, Ark.	150,218	7,253	10/45–9/53	1/11–13/51	521	D	Maximum.
185	Do		188,700		7/18–27/51			Minimum.
186	Arkansas River at Little Rock, Ark.	157,936	7,147	10/45–9/53	8/21–22, 26/53	495	D	Maximum.
187	Do		188,300		12/11–20/46			Minimum.
188	Prairie Dog Town Fork Red River near Brice, Tex.	5,646	10.1	[18] 10/50–9/51	1/15/51	25	D	Maximum.
189	Do		6,032		5/17–20/51			Minimum.
190	Do		162					Weighted average.
191	Salt Fork Red River near Wellington, Tex.				8/6, 8, 18–20/53		D	Maximum.
192	Do				5/11–12, 14, 16–20/53			Minimum.
193	Lake Altus on North Fork Red River, Okla.				5/19, 51	18	I	Maximum.
194	Do				7/3/51			Minimum.
195	Elk Creek near Hobart, Okla.	549	7.18	10/49–9/51	5/11–16/51	118	D	Maximum.
196	Do		1,070		7/17–20/50			Minimum.

See footnotes at end of table.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 7. Lower Mississippi River basin—Continued																	
171			251	153	256		178	1,510	69		1.6		2,320	1,260	31	2,880	
172			31	6.6	8.5		103	34	2.2				133	104	15	241	
173	16		96	62	521		250	604	560	1.0	1.2		1,980	494	70	3,190	7.9
174	16		26	8.7	71		189	41	40		1.2		297	101	60	515	7.8
175	18		44	18	147		208	155	121	.8	2.2		622	184	63	1,020	
176	26		698	504	591		200	431	3,180	.4			5,530	3,810	25	9,580	7.8
177	15		32	12	84		150	95	60	.5	5.0		392	130	58	641	7.8
178			160	64	413		194	558	575		10		1,880	662	58	3,000	
179			34	13	15		112	66	4.0		5.4		192	138	19	226	7.9
180			158	56	817		198	50	1,550		2.5		2,730	624	74	4,120	
181			8.9	5.8	14		28	7.2	32		1.7		84	46	40	177	
182			461	127	2,500		99	47	4,940				9,730	1,670	76	13,600	8.1
183			6.4	2.8	10		16	13	14		4.0		89	27	45	77.4	
184			133	35	484		203	133	852		2.8		1,740	476	69	3,190	8.4
185			38	6.5	26		112	31	39		2.7		216	122	32	381	7.6
186			104	29	534		109	103	940		6.2		1,770	378	75	3,350	7.6
187			23	4.3	28		81	15	38		.2		187	75	45	294	
188	25		813	217	4,410		153	2,270	7,110				14,900	2,920	77	21,400	7.8
189	20		202	36	308		110	583	440		3.8		1,650	652	51	2,540	8.0
190	23		229	44	454		129	669	663				2,140	952	57	3,370	
191	28		542	101	185		110	1,690	225	.7	2.5		2,830	1,770	19	3,310	7.7
192	26		141	25	51		125	359	65	.5	1.5		730	455	20	1,080	7.7
193			169	48	131		183	455	208		0.0		1,270	619	32	1,710	8.5
194			120	36	96		133	351	128		1.1		848	448	32	1,250	8.2
195			207	109	141		481	668	127		1.9		1,710	964	24	2,120	7.9
196			31	7.7	9.0		108	28	6.0		3.2		173	109	15	258	

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
Part 7. Lower Mississippi River basin—Continued								
197	Pease River near Crowell, Tex.	2,940	49.0		12/24/42	22	D	Maximum.
198	Do.		1,060		4/17/43			Minimum.
199	Do.		146		10/1/42–6/30/43			Weighted average.
200	Lake Kemp near Mabelle, Tex.				6/16/52	1	I	
201	Red River near Gainesville, Tex.	29,460	054		1/11–20/45	58	D	Maximum.
202	Do.		18,090		4/1–3/45			Minimum.
203	Do.		4,193		10/44–9/45			Weighted average.
204	Washita River near Carnegie, Okla.	3,230		10/46–9/53	7/9/52	22	M	Maximum.
205	Do.				2/16/49			Minimum.
206	Washita River near Tabler, Okla.	4,706	242	10/46–9/52	5/11–16/51	289	D	Maximum.
207	Do.		8,450		7/20–21/50			Minimum.
208	Rush Creek near Purdy, Okla.	145	13.2	10/46–9/49	10/6–13/46	132	D	Maximum.
209	Do.		737		4/12–15/47	132	D	Minimum.
210	Black Bayou near Hosston, La.	225	3.8		11/18/43	3	I	Maximum.
211	Do.		1,530		2/27/44			Minimum.
212	Lake Bistineau near Minden, La.	1,458			6/17/43	21		Maximum.
213	Do.				7/18/43			Minimum.
214	Ouachita River at Calion, Ark.	6,540	[21] 3,000	10/49–9/53	10/22–23/49	323	D	Maximum.
215	Do.		12,800		1/6–10/52			Minimum.
216	Smackover Creek near Norphlet, Ark.	450	1.1	10/52–9/53	10/1, 3–8, 10/52	86	D	Maximum.
217	Do.				5/1–2/53			Minimum.
218	Catahoula Lake, La.	2,500			9/52	2	I	
219	Do.				6/24/53			
220	Vermillion River at Bancker Ferry near Abbeville, La.	652			9/9–19/52	62	D	Maximum.
221	Do.				3/22–23/49			Minimum.

See footnotes at end of table.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 7. Lower Mississippi River basin—Continued																	
197	------	------	864	170	4,050		145	2,300	6,480	------	2.5	------	13,930	2,860	75	20,400	------
198	12	0.12	326	33	134		76	847	208	0.6	1.5	0.6	1,600	949	23	2,420	------
199	13	.08	424	64	783	16	112	1,130	1,250	.4	3.2	------	3,740	1,320	57	5,540	------
200	7.4	.02	240	57	694		106	675	1,100	.4	.0	------	2,830	834	64	4,650	7.4
201	------	------	310	97	1,030		214	751	1,740	------	3.5	------	4,040	1,170	66	6,550	------
202	------	------	49	11	54		[19] 125	50	91	------	1.8	------	360	168	41	592	------
203	------	------	97	24	194		137	169	335	------	3.5	------	891	340	55	1,540	------
204	------	------	226	66	168	------	[20] 269	------	208	------	------	------	------	835	------	2,040	8.3
205	------	------	41	10	14		117	65	6.5	------	2.0	------	196	196	18	349	------
206	------	------	231	59	65		222	612	98	------	4.2	------	1,390	819	15	1,640	8.5
207	------	------	42	8.1	7.6		124	38	7.5	------	4.2	------	184	138	11	288	------
208	------	------	123	73	362		298	291	598	------	4.2	------	1,600	607	56	2,340	------
209	------	------	50	14	17		133	54	36	------	4.5	------	242	182	17	407	------
210	------	------	------	------	------	------	26	------	3,220	------	------	------	------	546	------	10,100	------
211	------	------	------	------	------	------	6	------	90	------	------	------	------	51	------	335	------
212	------	------	36	22	713		110	3	1,160	------	.5	------	1,990	180	90	3,800	------
213	------	------	18	8.1	105		30	4	198	------	.2	------	452	78	74	720	------
214	8.9	.06	57	20	372	10	0	7.6	742	.1	4.0	------	1,220	224	77	2,380	3.75
215	------	------	8.7	2.8	17	------	19	6.0	32	------	1.4	------	98	33	53	144	6.8
216	15	.04	2,930	750	16,200	185	78	.9	32,100	.1	.7	------	52,200	10,400	77	73,500	7.6
217	------	------	12	3.8	57	------	6	3.1	116	------	.9	------	285	44	73	407	6.3
218	34	.01	101	56	2,280	1.2	(22)	2.9	3,820	.1	2.0	1.9	6,300	482	91	11,300	4.3
219	4.4	.25	3.2	1.3	11	1.2	------	1.9	16	.2	.5	.04	47	13	62	93.6	6.6
220	12	------	80	202	1,640		68	405	2,920	------	------	------	5,290	1,030	78	9,350	7.5
221	3.0	------	1.1	1.5	7.9		11	2	10	------	1.2	------	42	9	66	53	6.7

See footnotes at end of table.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
	Part 8. Western Gulf of Mexico basins							
222	Trinity River at Barber Hill pumping plant near Cove, Tex.				8/22–23, 27–28, 30/48		1, D	Maximum.
223	Do.				6/1–10/48			Minimum.
224	Double Mountain Fork Brazos River near Aspermont, Tex.	7,979	1.62	10/49–9/50	2/1–13, 19–28/50	40	D	Maximum.
225	Do.		2,275		5/12–13/50			Minimum.
226	Do.		171					Weighted average.
227	Salt Fork Brazos River near Aspermont, Tex.	4,834	.41	10/49–9/50	4/1–15, 30/50	40	D	Maximum.
228	Do.		1,004		9/6–10, 27–29/50			Minimum.
229	Do.		166					Weighted average.
230	Clear Fork Brazos River near Nugent, Tex.	2,220	4.15	10/48–9/49	3/21–31/49	48	D	Maximum.
231	Do.		860		9/15–16/49			Minimum.
232	Do.		58.1					Weighted average.
233	Brazos River at Possum Kingdom Dam near Graford, Tex.		220	10/52–9/53			D	Weighted average.
234	Bull Creek near Ira, Tex.	388	.36	4/50–9/50	8/16–20/50	28	D	Maximum.
235	Do.		110		5/2/50	28	D	Minimum.
236	Do.		30.3					Weighted average.
237	Colorado River at Colorado City, Tex.	4,082	.0	10/49–9/50	3/10, 20–31, 4/1–12/50	51	D	Maximum.
238	Do.		1,091		9/6–9/50			Minimum.
239	Do.		86.6					Weighted average.
240	Colorado River at Robert Lee, Tex.	15,770	1.0	10/50–9/51	4/1–10/51	50	D	Maximum.
241	Do.		1,548		6/3, 4/51			Minimum.
242	Do.		75.8					Weighted average.
243	Jemez River at San Ysidro, N. Mex.	[23] 720	[23] 1	6/49–10/50	8/31/49	20	M	Maximum.
244	Do.				3/20/50			Minimum.

See footnotes at end of table.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 8. Western Gulf of Mexico basins																	
222	9.8	...	91	68	667		150	203	1,150	...	1.2	...	2,260	506	74	4,190	...
223	...	...	39	4.4	34		123	32	38	...	2.2	...	237	115	...	385	...
224	13	...	614	82	595		116	1,700	920	...	1.2	...	3,980	1,870	42	5,350	7.8
225	16	...	74	9.6	132		120	240	114	...	1.0	...	646	224	56	1,030	7.6
226	15	...	162	18	138		109	460	148	...	2.3	...	1,010	478	39	11,470	...
227	11	...	1,440	274	16,900		159	3,440	26,800	...	...	...	48,900	4,720	89	60,900	7.7
228	15	...	166	26	448		116	435	670	...	4.0	...	1,820	521	65	3,060	7.8
229	16	...	320	52	1,400		117	786	2,230	...	...	...	4,870	1,010	75	7,640	...
230	4.1	...	370	138	774		140	1,460	1,090	...	2.5	...	3,910	1,490	53	5,650	7.8
231	8.8	...	34	1.1	20		104	32	8.0	...	2.5	...	158	89	32	264	7.4
232	10	...	65	15	54		120	145	63	...	2.3	...	425	224	34	659	...
233	13	...	152	29	388		130	322	636	...	1.0	...	1,610	498	63	2,770	...
234	11	...	111	39	1,000		69	317	1,580	...	5.0	...	3,100	438	83	5,510	7.6
235	12	...	24	4.6	23		114	17	11	...	4.0	...	152	79	39	263	7.4
236	15	...	32	6.4	47		134	37	40	...	3.6	...	256	106	49	427	...
237	8.1	...	641	253	6,180		125	2,060	9,810	...	...	...	19,000	2,640	84	28,100	7.4
238	10	...	22	5.0	65		116	35	60	...	1.8	...	264	75	65	482	7.8
239	13	...	43	13	214		123	89	303	...	2.5	...	742	161	74	1,530	...
240	5.1	...	434	116	1,420	...	76	1,300	2,230	...	...	...	5,540	1,560	66	8,700	7.4
241	17	...	38	6.8	49		107	41	66	...	6.5	...	294	123	46	511	7.6
242	17	...	69	18	223		197	153	290	...	3.0	...	888	246	66	1,510	...
243	59	...	97	15	496		734	130	450	4.0	.8	...	1,610	304	78	2,650	...
244	34	...	40	7.1	72		196	22	71	1.0	.3	...	344	129	55	568	...

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
	Part 8. Western Gulf of Mexico basins—Continued							
245	Rio Salado near San Ysidro, N. Mex.	[23] 180	[23] 0.1	6/49–10/50	2/22/50	12	M	Maximum.
246	Do		[23] 20		6/14/49			Minimum.
247	Rio Grande at San Acacia, N. Mex.	26,770	31	7/46–9/52	7/18/46	250	D	Maximum.
248	Do		10,700		7/1–10/42			Minimum.
249	Rio Grande at San Marcial, N. Mex.	27,700	324	7/46–9/52	3/11–16, 19–22/46	[23] 225	D	Maximum.
250	Do	27,700	3,096		6/11–20/52	[23] 225	D	Minimum.
251	Rio Grande at El Paso, Tex.	29,267	86.2	1/51–12/51	12/1–31/51	12	D	Maximum.
252	Do		740		7/1, 3–31/51			Minimum.
253	Rio Grande at Fort Quitman, Tex.	31,990	15.1	1/51–12/51	4/4, 7, 11, 18/51	12	I	Maximum.
254	Do		2,900		8/30, 51			Minimum.
255	Pecos River at Puerto de Luna, N. Mex.	3,970	82	7/39–9/41, 11/46–9/52	3/11–20/52	[23] 290	D	Maximum.
256	Do		2,143		5/11–16, 18–20/41			Minimum.
257	Pecos River near Artesia, N. Mex.	15,300	.6	7/37–9/52	8/11–13, 17–21/45	[23] 650	D	Maximum.
258	Do		1,540		7/25, 27/50			Minimum.
259	Black River at Forehand Crossing near Malaga, N. Mex.	335		1/38–9/52	1/6/38	80	I	Maximum.
260	Do				6/2/48			Minimum.
261	Pecos River east of Malaga, N. Mex.	19,190	20	7/37–9/52	9/11–20/52	[23] 580	D	Maximum.
262	Do		20,650		9/21–22/41			Minimum.
263	Pecos River near Red Bluff, N. Mex.	19,540	15	10/37–9/52	8/21–31/52	[23] 750	D	Maximum.
264	Do		4,470		6/3/48			Minimum.
265	Pecos River near Orla, Tex.	21,300	19.6	10/50–9/51	9/1–30/51	15	D	Maximum.
266	Do		82.8		10/1–4/50			Minimum.
267	Do		152					Weighted average.
268	Toyah Creek below Toyah Lake near Pecos, Tex.	3,709	0.1		9/1–8/47		I	Maximum.
269	Do		15		7/31–8/1/48			Minimum.

See footnotes at end of table.

Part 8. Western Gulf of Mexico basins—Continued

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
245	...	...	...	...	...	...	420	...	3,310	...	...	...	...	...	...	20,800	...
246	34	...	44	7.6	49		177	47	36	1.0	0.2	0.20	306	141	43	429	7.9
247	...	0.04	255	61	451	9.2	285	1,400	130	111	1.0	...	2,470	887	52	3,170	...
248	21	.07	31	6.8	16	3.2	105	45	6.5	.4	1.0	.0	183	105	27	267	...
249	...	...	246	50	229		334	905	72	...	.4	...	1,670	820	38	2,180	...
250	...	...	44	6.8	19	...	...	...	...	...	...	...	233	138	23	350	...
251	...	...	...	...	...	...	...	...	...	...	...	.37	...	...	62	2,070	7.8
252	...	...	...	...	...	...	...	...	...	...	...	.17	...	...	53	1,160	7.7
253	...	...	...	...	...	...	...	...	...	...	...	.73	...	...	66	7,650	7.8
254	...	...	...	...	...	...	...	...	...	...	...	.12	...	...	44	802	7.9
255	19	...	604	79	103		178	1,620	158	...	1.5	...	2,670	1,830	11	3,000	7.3
256	20	.07	68	7.6	10	1.2	113	113	9.0	.1	2.0	.0	287	200	11	434	...
257	27	.12	815	340	2,560		86	3,080	4,050	1.0	2.4	.1	10,900	3,430	62	14,900	7.6
258	15	...	138	19	52		195	251	78	...	4.2	...	653	422	21	964	7.8
259	...	...	460	85	...	28	208	1,300	24	...	...	...	2,000	1,500	4	2,210	...
260	...	...	212	6.6	...	7.1	65	494	0	...	4.1	...	756	556	3	957	7.6
261	28	...	628	227	1,130		153	2,180	1,820	...	3.6	...	6,090	2,500	50	8,280	7.5
262	14	...	72	18	29		121	143	43	...	.7	.0	384	254	20	633	...
263	20	...	675	340	4,220		93	2,760	6,600	...	...	...	14,700	3,080	75	20,700	7.1
264	12	...	78	15	54		103	160	86	...	.2	...	456	256	32	744	8.0
265	23	...	590	219	1,500		96	2,120	2,380	...	...	...	6,880	2,370	58	10,100	7.2
266	11	...	241	34	270		70	635	430	...	4.5	...	1,660	742	44	2,560	7.3
267	21	...	505	164	813		109	1,750	1,260	...	1.4	...	4,580	1,930	48	6,420	...
268	...	...	876	157	2,380		60	4,250	2,510	...	...	...	10,200	2,830	65	13,500	...
269	11	...	408	37	218		38	1,190	265	...	2.0	...	2,150	1,170	29	2,780	...

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
	Part 8. Western Gulf of Mexico basins—Continued							
270	Pecos River below Grandfalls, Tex	27,820	28.0	10/49–9/50	12/1–31/49	12	D	Maximum.
271	Do		28.4		10/1–31/49			Minimum.
272	Do		25.1					Weighted average.
273	Pecos River near Comstock, Tex	35,293		1/51–12/51	2/2, 4, 6, 8, 10–26, 28/51	12		Maximum.
274	Do				5/1, 3, 5, 7–29, 31/51	12		Minimum.
275	Do							Weighted average.
276	Blacks Fork near Green River, Wyo	3,670	18	3/5–9/53	12/1–6, 8–10/52	93	D	Maximum.
277	Do		110		1/21–22, 26/53			Minimum.
278	Duchesne River near Randlett, Utah	3,920	133	12/50–10/51	9/11–20/51	41	D	Maximum.
279	Do		4,600		5/29/51			Minimum.
280	Price River at Woodside, Utah	1,500	22	12/46–9/49, 2/51–9/53	12/11/51	144	D	Maximum.
281	Do		1,484		5/21–31/52			Minimum.
282	San Rafael River near Green River, Utah	1,690	10.6	11/46–9/49, 10/50–9/53	10/10, 14, 21/48	172	D	Maximum.
283	Do		2,153		6/11–20/52			Minimum.
284	Eagle River below Gypsum, Colo	957	939	4/47–9/53	8/11–12/52	234	D	Maximum.
285	Do		3,730		6/11–20/53			Minimum.
286	Gunnison River near Grand Junction, Colo.	8,020	321	10/31–9/53	9/11–20/34	830	D	Maximum.
287	Do		17,270		5/11–20/44			Minimum.
288	Colorado River near Cisco, Utah	24,100	785	8/28–9/53	8/11–20/40	901	D	Maximum.
289	Do		46,530		6/11–20/52			Minimum.
290	Dolores River at Gateway, Colo	4,350	77.9	10/47–9/52	9/11–20/50	180	D	Maximum.
291	Do		8,970		5/4, 7–9/52			Minimum.
292	Dolores River near Cisco, Utah	4,600	160	3/51–9/53	2/15–18/53	101	D	Maximum.
293	Do		4,731		6/11–20/52			Minimum.
294	Dirty Devil River near Hite, Utah	4,300	0.1	10/47–9/53	6/24–27, 30/53	216	D	Maximum.
295	Do		189		3/21–24, 26–31/48			Minimum.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 8. Western Gulf of Mexico basins—Continued																	
270	19		745	372	2,790		191	2,930	4,430				11,400	3,390	64	15,600	7.6
271	30		627	306	1,990		146	2,530	3,120				8,670	2,820	61	12,200	7.9
272	22		715	354	2,420		154	2,850	3,840				10,300	3,290	62	14,400	
273												0.32			61	5,190	7.8
274												.14			58	2,000	7.7
275												.258			60	3,760	7.8
276	15	0.08	247	133	406	9.7	502	1,210	245	0.4	2.1		2,520	1,160	43	3,280	7.9
277	13	.34	14	3.3	83	1.7	190	53	16	.5	1.6		280	48	78	438	7.5
278	15		132	94	256		295	740	184		2.7		1,570	716	44	2,260	7.9
279													185			291	
280			432	469	1,520		646	5,310	175				8,220	3,010	52	8,540	
281	12	.03	78	39	65	3.3	262	245	14	.4	5.9		592	355	28	908	7.8
282	6.8		420	263	857		296	3,440	120		.3		5,250	2,130	47	5,800	
283	8.1	.13	76	34	55	2.8	237	235	12	.2	.9		541	330	26	809	7.8
284	20		308	49	49		300	786	8.5		.5		1,370	970	10	1,640	
285	5.5		24	3.2	4.1		66	25	4.3		.5		99	73	11	174	7.6
286	18	.03	335	130	348	7.0	227	1,790	58	.7	22	.2	2,820	1,370	35		
287			42	10	15		121	73	2		1.7		203	146	19	340	
288													2,670			3,130	
289	11		38	8.7	16	2.2	111	54	11		1.0		197	131	21	344	
290	2.9		218	144	1,370		179	1,020	2,050		11		4,900	1,140	72	7,700	7.5
291	7.8		32	5.5	6.4		102	21	7		1.5		131	102	12	225	8.1
292	11	.07	125	65	1,110	54	[21] 189	395	1,800	.3	9.2	.13	3,660	580	79	6,240	8.2
293	7.2		37	6.7	15		116	35	14		1.0		173	120	21	289	7.7
294	24	.22	716	262	1,170	100	520	2,440	1,810	.5	.8		6,780	2,860	46	8,740	7.2
295	29	.08	136	28	37	10	172	361	20	.3	2.2		708	454	15	956	7.7

See footnotes at end of table.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
	Part 8. Western Gulf of Mexico basins—Continued							
296	Colorado River at Hite, Utah	76,600	6,120	12/50–9/53	11/11–20/52	101	D	Maximum.
297	Do		89,220		6/11–20/52			Minimum.
298	McElmo Creek near Cortez, Colo	233			5/14/48	1	I	
299	San Juan River near Blanco, N. Mex	3,560	991	9/45–9/52	8/16/47	260	D	Maximum.
300	Do		4,628		7/1–8/49			Minimum.
301	Animas River at Farmington, N. Mex	1,360	276	6/40–9/52	8/19/44	450	D	Maximum.
302	Do	1,360	5,002		6/21–30/44	450	D	Minimum.
303	San Juan River near Bluff, Utah	23,000	674	10/29–9/53	7/21–31/34	870	D	Maximum.
304	Do		12,460		6/11–20/44			Minimum.
305	Colorado River at Lees Ferry, Ariz	107,900	14,500	1/26–9/52 [25]	10/11–20/28	434	I, D	Maximum.
306	Do		87,600		6/11–20/29			Minimum.
307	Little Colorado River near Hunt, Ariz	6,280	.8	12/42–2/43	12/9/42	2	I	Maximum.
308	Do		.3		2/10/43			Minimum.
309	Little Colorado River near Winslow, Ariz.		5	7/46–8/53	5/21/53	4	I	Maximum.
310	Do		1,000		7/22/46			Minimum.
311	Little Colorado River at Cameron, Ariz	26,500	394	4/51–9/52	8/2/51	32	I, D	Maximum.
312	Do		2,767		3/31–4/10/52			Minimum.
313	Colorado River near Grand Canyon, Ariz.	137,800	2,600	8/25–9/53	9/21–30/34	1,025	D	Maximum.
314	Do		76,580		6/11–16, 18–20/42			Minimum.
315	Virgin River at Littlefield, Ariz	5,090	144	7/49–9/53	8/11–20/50	153	D	Maximum.
316	Do		971		5/11–20/52			Minimum.
317	San Francisco River at Clifton, Ariz	2,760	22	8/40–1/50 [25]	6/21–28/43	81	I, D	Maximum.
318	Do		705		9/25–29/44			Minimum.
319	Gila River at Safford, Ariz	10,459	6.3	5/40–11/44	6/11–20/42	195	I, D	Maximum.
320	Do		6,010		3/15–20/41			Minimum.
321	Gila River at Kelvin, Ariz	18,011	3.5	12/50–9/52	10/21–30/51	70	D	Maximum.
322	Do		1,198		8/27–28/51			Minimum.

See footnotes at end of table.

Part 8. Western Gulf of Mexico basins—Continued

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
296	12		133	61	178	5.9	233	573	136		5.4		1,220	583	40	1,750	
297	11		44	11	20	2.4	141	63	11		1.7		234	155	22	399	
298	8.8		454	389	498		311	3,290	95		.3		4,890	2,730	28	5,210	
299			220	32	88		472	446	15				1,030	680	22	1,420	
300	12	0.03	15	2.6	7.1		57	13	1.5	0.3	.6	0.1	80	48	24	121	6.8
301			216	18	239		185	909	25				1,500	613	46	1,980	
302	5.8	.08	26	4.1	4.6	1.1	67	33	2.0	.2	.8	.0	111	82	11	184	
303	25	.16	271	48	247	6.2	285	1,070	43	.9	.1	.1	1,860	874	38		
304	12	.16	37	5.2	9.7	3.0	109	42	3.2	.2	1.0	.0	167	118	15	274	
305	22	.43	201	53	170	9.6	194	762	97		1.1	.1	1,410	720	34		
306	14	.33	35	12	14	4.3	127	57	9.0		.7	.1	209	137	18		
307			136	67	487		[19] 261	548	630		.5		2,000	615	63	3,260	
308	11	.04	126	37	411		[26] 258	393	522	.4	1.1	.2	1,630	466	66	2,590	8.3
309	9.6		110	71	1,290		276	341	1,980	.3	1.0		3,940	566	83	6,780	
310			44	11	235		271	161	195		.4		780	155	77	1,310	
311	20	.16	272	61	150	11	318	897	45	.3	1.2		1,610	930	26	2,060	7.1
312	15	.10	24	3.9	67	2.5	136	35	52	.3	1.1	.45	268	76	65	464	7.9
313	13	.20	184	74	339	11	254	826	308	.5	8.5	.2	1,890	764	49		
314	13	.04	34	11	22	4.8	102	72	17	.4	1.0		225	130	30	359	
315	28		438	106	257		312	1,310	332		1.4		2,630	1,530	27	3,390	7.5
316	13		108	29	76		214	238	91		1.8		662	388	30	983	7.8
317	44	.09	110	19	301		191	26	580	1.4	2.5	.1	1,180	352	65	2,160	
318	35	.46	34	8.7	21		143	13	21	.5	.2	.0	204	121	24	313	
319	36	.05	100	31	326		312	209	428	1.9	4.4		1,290	377	65	2,200	
320		.30	29	7.3	20		117	25	14	.8	2.0		156	102	30	260	
321	37	.01	306	73	154	4.6	302	810	220	.8	.6	.30	1,760	1,060	24	2,380	7.6
322	25		60	11	44		215	62	34	.6	.8		343	194	33	559	

Where sodium and potassium are not separated on the page, the single printed value spans both columns and is given here in the Sodium column.

See footnotes at end of table.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
Part 8. Western Gulf of Mexico basins—Continued								
323	Gila River above Salt River, Ariz.	20,615	66.3	10/44–9/45	3/12/45	47	W [27]	Maximum.
324	Do.		43.6		8/6/45			Minimum.
325	Salt River below Stewart Mountain Dam, Ariz.	6,220	1,291	12/50–9/52	8/21–28/51	70	D	Maximum.
326	Do.		1,460		9/11–20/52			Minimum.
327	Salt River near mouth, Ariz.		36	10/44–9/45	11/6/44	47	W	Maximum.
328	Do.		52.4		1/22/45			Minimum.
Part 9. Colorado River basin								
329	Gila River at Gillespie Dam, Ariz.	49,560	56.5	2/26–9/52	10/11–20/51	89	I, D	Maximum.
330	Do.		4,640		9/1/51			Minimum.
331	Muddy River at Logandale, Nev.	8,180	48			1		
Part 10. Great Basin								
332	Great Salt Lake, Utah [28]				3/30/30		I	
333	Sevier River near Lynndyl, Utah	6,270	20	3/51–9/53	3/11–16/53	92	D	Maximum.
334	Do.		135		3/29–31/52			Minimum.
335	Salton Sea, Calif. [29]				11/13/51	1	I	
336	Alamo River near Calipatria, Calif.		872	11/47–9/49	2/3/49	20	M	Maximum.
337	Do.		884		11/18/47	20	M	Minimum.
338	New River near Westmoreland, Calif.		602	10/48–9/49	3/18/48	11	M	Maximum.
339	Do.		596		6/23/49			Minimum.
340	Walker Lake near Hawthorne, Nev.		([30])		8/31/37		I	

See footnotes at end of table.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 8. Western Gulf of Mexico basins—Continued																	
323	------	------	366	134	832	0	234	443	1,850	------	4	------	3,746	1,460	55	6,550	------
324	------	------	214	65	543	0	248	299	1,040	------	4	------	2,289	802	60	4,110	------
325	21	0.01	60	26	382	8.8	175	80	610	0.5	2.8	0.35	1,280	256	76	2,340	7.5
326	21	.01	45	13	130	5.0	148	48	196	.5	2.6	.15	534	166	62	968	7.7
327	------	------	238	108	832	0	462	567	1,320	------	10	------	3,306	1,040	64	5,570	------
328	------	------	208	95	720	0	442	478	1,120	------	14	------	2,856	910	63	4,850	------
Part 9. Colorado River basin																	
329	37	0.01	448	200	1,570	11	390	1,310	2,650	2.2	34	3.3	6,450	1,940	64	10,000	7.6
330	20	------	41	7.9	39		167	39	27	------	6.0	------	262	135	39	420	------
331	------	------	129	59	164		295	500	113	------	------	------	1,110	564	39	1,650	------
Part 10. Great Basin																	
332	------	------	361	5,780	69,200	3,380	221	11,490	119,500	------	------	------	209,800	24,600	------	------	------
333	22	------	183	173	650	9.2	376	848	975	------	2.9	------	3,050	1,170	54	4,700	------
334	15	0.06	73	59	143	7.3	194	224	242	0.2	4.8	------	864	424	42	1,450	7.7
335	------	------	------	------	------	------	------	------	------	------	------	------	38,378	------	------	------	------
336	12	------	194	104	------	------	206	649	------	------	8.9	------	------	912	------	3,830	------
337	------	------	131	61	271		187	468	370	------	5.8	------	1,400	578	50	2,300	------
338	12	------	180	78	580		208	475	968	------	------	------	2,400	770	62	3,960	------
339	19	------	131	55	309		198	395	458	------	5.9	------	1,470	553	55	2,430	------
340	------	------	24	66	1,680	------	[31] 1,590	1,090	1,090	------	------	------	4,730	330	92	7,570	------

See footnotes at end of table.

TABLE 3.—*Physical measurements and chemical analyses of surface water*—Continued

Source no. on pl. 1	Source	Drainage area (square miles)	Water discharge (cubic feet per second)	Period of sampling	Date	Number of analyses	Frequency of sampling	Remarks
	Part 10. Great Basin—Continued							
341	Pyramid Lake at Sutcliffe, Nev				4/11/41	1	I	
342	Large Soda Lake, Nev				1934	1	I	
	Part 11. Pacific slope basins in California							
343	Los Angeles River at Los Angeles, Calif	510	14	1951–53	8/6/52			Maximum.
344	Do		3.5		4/13/51			Minimum.
345	Cuyama River near Ventucopa, Calif	90	8+		2/25/53	1		
346	San Joaquin River near Newman, Calif	9,990	240	1938–53	10/26/53			Maximum.
347	Do		4,600		6/24/40			Minimum.
348	Sulfur Creek at confluence with Bear Creek, Colusa Co., Calif.		7		4/15/52	1	I	
349	Ocean [34]			1873–76				

See footnotes at end of table.

Source no. on pl. 1	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25° C)	pH
Part 10. Great Basin—Continued																	
341			6.4	101	1,550		[32] 1,270	245	1,770				4,300	431	89	6,780	
342			22	239	9,120		[33] 4,200	6,180	7,790			55.20	25,500	1,040	95	36,541	
Part 11. Pacific slope basins in California																	
343													1,970				
344													378				
345													1,370				
346													1,300		65		
347													51				
348													2,170		71		
349			420	1,300	10,710	390	150	2,690	19,350				35,000				

1 Average of 5 samples in cross section.
2 Average of 3 samples in cross section.
3 Industrial water supplies of the Tennessee Valley region, TVA, June 1948.
4 Analysis by Tenn. Dept. Public Health.
5 Analysis by Ill. State Geol. Survey.
6 Sum of determined constituents.
7 Includes equivalent of 11,300 ppm of carbonate (CO_3).
8 Includes equivalent of 1,580 ppm of carbonate (CO_3).
9 Includes equivalent of 522 ppm of carbonate (CO_3).
10 Includes equivalent of 271 ppm of carbonate (CO_3).
11 Includes equivalent of 4 ppm of carbonate (CO_3).
12 Includes equivalent of 55 ppm of carbonate (CO_3).
13 Upper Ocean Lake drain.
14 Ocean Lake.
15 Collected and analyzed by U. S. Bureau of Reclamation.
16 Includes equivalent of 242 ppm of carbonate (CO_3).
17 Records available 6/49–9/53.
18 Records available 8/49–9/52.
19 Includes equivalent of 8 ppm of carbonate (CO_3).
20 Includes equivalent of 6 ppm of carbonate (CO_3).
21 Discharge estimated on basis of discharge at Camden, Ark.
22 Acidity as H_2SO_4, 2 ppm.
23 Estimated.
24 Includes equivalent of 13 ppm of carbonate (CO_3).
25 Not continuous.
26 Includes equivalent of 24 ppm of carbonate (CO_3).
27 Analyses by Salt River Valley Water Users Association.
28 Water level 4,201.0 feet, Lucin cutoff, west of Ogden, Box Elder County, Utah. Bromine, 9 ppm; iodine, 1 ppm.
29 Volume about 5 million acre-feet.
30 Estimated volume by Univ. Nevada, 7–9 million acre-feet.
31 Includes equivalent of 240 ppm of carbonate (CO_3).
32 Includes equivalent of 194 ppm of carbonate (CO_3).
33 Includes equivalent of 1,920 ppm of carbonate (CO_3).
34 Average of 77 analyses, *Challenger* Report (1884).

TABLE 4.—*Records of wells and springs and chemical analyses in the Coastal Plain Region*

[Use of water; D, domestic; S, stock; Ind, industrial; Irr, irrigation; PS, public supply; N, none. Analyses in parts per million, except as indicated]

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
						Alabama							
K1	City of Cottonwood.	Houston	4,280	6	Eutaw			80					U. S. Geol. Survey, Quality of Water Branch.
K2	6 mi. E. of Lowndesboro.	Lowndes	410	4	do	70		13			1/23/41		Do.
K3	City of Eutaw	Greene	306	15–8	do	83			150	PS	2/6/41	67.5	Do.
T1	City of Mobile	Mobile	717	10	Miocene			175	800		9/15/45	76	Do.
Q1	do	do	60	6	Alluvium				360		9/15/45		Do.
						Arkansas							
K1	Sec. 32, T. 14 S., R. 28W.	Miller	600	4	Nacatoch				5	D, S	7/26/51	74	U. S. Geol. Survey, Quality of Water Branch.
K2	Sec. 2, T. 8 S., R. 21W.	Clark	196	4–2	Ozan			1		D, S	9/14/50	69	Do.
K3	Sec. 19, T. 11 S., R. 29 W.	Sevier	300	2	Tokio			1		D, S	8/15/51		Do.
T1	10 miles E. of Stuttgart.	Arkansas	1,015		Cockfield					Irr			Do.
T2	Sec. 10, T. 3 N., R. 2 W.	Monroe	250		do				550	Irr	2/24/50	65	Do.
T3	City of Crossett	Ashley	265	6	do						1/14/49		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Alabama																	
K1							269	1	9,400	0.3	1			795			
K2	18	0.04	11	4.0	433	6.8	653	1.9	297	5.4	2.2		1,121	44			
K3	12	.05	9.9	2.1	391	7.7	338	1.2	428	2.4	2.9		1,027	33			
T1							444	3	1,060					39			
Q1							465	980	8,650	.8	22			3,490			
Arkansas																	
K1		0.12					245	2	1,480		1.0			70		4,900	8.6
K2		.32					140	260	1,880		8.4			321		6,270	7.9
K3		39					454	1	1,020		4.2			40		3,760	8.6
T1			2.9	9.5	611		352	1	772		.4			114		2,960	7.7
T2	15	.29	52	16	660	10	486	714	852	0.1	1.4		1,810	196	88	2,930	7.4
T3	15	.10	9	1.7	370	10	374	4.7	360	1.2	1.4		1,020	30	94	1,730	8.0

TABLE 4.—*Records of wells and springs and chemical analyses in the Coastal Plain Region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
Arkansas—Continued													
T4	Sec. 19, T. 19 S., R. 10 W.	Union	733		Sparta					PS		76	U. S. Geol. Survey, Quality of Water Branch.
T5	Sec. 25, T. 4 S., R. 2 E.	Phillips	1,508		Wilcox					PS	6/27/46	81	Do.
Q1	Sec. 21, T. 18 S., R. 3 W.	Chicot	77	18–10	Quaternary				2,100	Irr	2/15/52		Do.
Q2	Sec. 13, T. 18 S., R. 3 W.	do	110	18	do					Irr	2/15/52		Do.
Q3	Sec. 20, T. 9 S., R. 3 W.	Desha	100		do				1,125	Irr	7/30/52	65	Do.
Q4	Sec. 24, T. 6 S., R. 10 W.	Jefferson	40	8	do					D	3/28/49		Do.
Florida													
T1	Cocoa Beach	Brevard	245	4	Eocene	+29	3/10/47	300		Irr	3/10/47	77	U. S. Geol. Survey, Quality of Water Branch.
T2	U. S. Navy near Pensacola.	Escambia	180		Citronelle					N	1/18/40		Do.
T3	West of Bradenton.	Manatee	580	8–6	Suwanee						5/21/53		Do.
T4	City of Pinellas Park.	Pinellas	432	12	do					PS	3/10/49		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Arkansas—Continued																	
T4	8.5	0.08	7.6	2.3	509	3.8	292	0.4	638	0.2	0.2	------	1,330	28	97	2,460	7.9
T5	8	.06	3.8	1.3	616	16	610	1.1	618	1.0	.8	------	1,520	15	97	3,520	7.8
Q1	24	18	432	174	494	8.6	481	282	1,490	0	1.5	------	3,720	1,790	37	5,110	7.4
Q2	23	8.3	144	48	121	3.6	429	264	137	.1	2.2	------	1,000	557	32	1,430	7.1
Q3	------	10	------	------	------	------	500	172	173	------	.4	------	------	650	------	1,620	8.1
Q4	60	.43	196	83	393	8.8	2	1,260	280	.6	58	------	2,530	831	50	3,120	4.8
Florida																	
T1	------	------	------	------	------	------	160	200	1,220	0.2	------	------	------	728	------	4,340	7.1
T2	------	------	------	------	------	------	9	60	1,070	------	2.5	------	------	378	------	------	------
T3	21	0.59	326	135	407	5.6	160	803	925	1.9	.4	------	2,900	1,370	------	4,110	7.5
T4	29	.04	186	36	193	------	216	42	540	.1	1.0	------	1,130	612	------	2,140	7.5

TABLE 4.—*Records of wells and springs and chemical analyses in the Coastal Plain Region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
						Florida—Continued							
T5	City of St. Augustine.	St. Johns	300(?)	3	Ocala(?)	3	9/29/44			N	9/29/44		U. S. Geol. Survey, Quality of Water Branch.
T6	Sec. 16, T. 20 S., R. 31 E.	Seminole	125	2	do			25		D	1/30/53	74	Do.
T7	Miami Beach	Dade	950	8	Eocene	+25		100		N	8/19/39	68	Do.
T8	E. of Ft. Myers	Lee	810	5	do	+35		250		Irr	4/9/46	85	Do.
T9	Town of Everglades.	Collier	463	6	Miocene					PS	3/22/48	77	Do.
Q1	Miami, 27th Ave. and Andros.	Dade	83	6	Tamiami				1,000	Fire	10/31/40	78	Do.
Q2	Miami, 27th Ave. and U. S. 1.	do	64	6	Miocene				1,000		12/12/40	78	Do.
Q3	Miami, NW 36th St. and June Rd.	do	92	2							3/5/41		Do.
						Georgia							
T1	City of Thomasville.	Thomas	1,635		Tertiary					N	3/10/49		

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Florida—Continued																	
T5	21	0.02	130	76	----	----	163	324	610	1.0	0.4	----	1,660	637	----	1,660	7.8
T6	9.6	.05	108	71	632	14	142	188	1,170	.1	.7	----	2,410	562	----	4,060	----
T7	----	Tr	162	177	1,370		140	478	2,480	----	----	----	4,820	1,130	----	----	----
T8	----	.03	86	71	272		180	302	450	----	1.0	----	1,270	506	----	2,230	7.4
T9	----	.01	34	46	227		296	122	280	1.4	.3	----	856	274	----	1,490	7.4
Q1	----	----	460	1,070	8,810		230	2,160	15,800	----	----	----	----	5,540	----	44,000	----
Q2	----	----	146	20	260		272	65	512	----	----	----	1,140	447	----	2,080	----
Q3	----	.35	219	141	1,300		276	317	2,410	----	----	----	4,520	1,130	----	8,100	----
Georgia																	
T1	30	0.1	244	68	5,320		276	1,870	7,300	0	0	----	24,200	888	----	----	7.5

TABLE 4.—*Records of wells and springs and chemical analyses in the Coastal Plain Region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
Louisiana													
T1	City of Monroe	Ouachita	895	3	Sparta	78.9	7/30/46				7/30/46		U. S. Geol. Survey.
T2	City of Alexandria.	Rapides	1,202	12	Catahoula	120	June 1935		400	PS	10/22/38		Do.
Q1	City of Slidell	St. Tammany	1,080	8	Pleistocene	44		350		PS	5/20/42	82	Do.
Q2	City of La Place	St. Johns	130	4	do					Ind	8/2/40		Do.
Q3	Town of Cameron	Cameron	460	4	Quaternary					PS	10/2/49		Do.
Maryland													
K1	City of Baltimore	Baltimore		15	Patuxent				300		7/2/43		U. S. Geol. Survey.
K2	Do	do	125	6	Patapsco	8			65		9/14/43		Do.
K3	City of Crisfield	Somerset	994	8-6	Upper Cretaceous.				300	PS	10/19/51		Do.
T1	Town of Vienna	Dorchester	305	6	Miocene				90	PS	12/9/52		Do.
T2	Town of Hopewell.	Somerset	165	2	do	4	1950			D	12/8/52		Do.
T3	Do	do	362	1.5	Choptank(?)	1.4	1948			D, S	12/8/52		Do.
Q1	City of Baltimore	Baltimore	125	8	Pleistocene	17			65		6/9/44		Do.
Q2	Do	do		6	do	7			90		5/29/44		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Louisiana																	
T1	11	1.4	1.2	0.7	383	4.8	353	2.1	358	0.6	0.2		984	6			8.7
T2	49	.15	1.3	.5	89	1.5	212	11	11	.9	.05		270	5.3	97		8.7
Q1	28	.03	.9	.7	158	.4	393	7.0	18	.7	1.8		415	5	98		
Q2							1,070	1	95	0				705			
Q3	25	2.0	27	16	394	6.8	420	.3	470	.3	2.0	0.05	1,150	134		2,030	7.6
Maryland																	
K1		1.3					486	380	4,120		1.2			1,530		12,900	6.8
K2		1.3					0	190	880					330		3,100	4.0
K3	13	1.8	1.8	0.9	437	8.0	910	65	100	5.6	1.8		1,090	8		1,720	8.5
T1	55	3.0	9.0	6.2	438	14	820	163	170	1.0	.5		1,270	48		2,030	8.5
T2	15	.11	40	39	273	26	470	162	278	.2	2.1		1,080	260		1,810	7.9
T3	58	.17	31	31	1,260	45	1,200	62	1,360	.7	.7		3,440	205		5,780	7.6
Q1		1.6					260	125	1,770		15			765		6,040	8.3
Q2		83					545	560	4,950					1,710		15,200	7.0

TABLE 4.—*Records of wells and springs and chemical analyses in the Coastal Plain Region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
						Mississippi							
T1	Sec. 19, T. 7 S., R. 8 W. near Biloxi.	Jackson	1,290	4	Pascagoula	+90	1912	200		N	September 1919	88.5	U. S. Geol. Survey.
T2	Town of Sumner	Tallahatchie	1,680	4	Wilcox	+55	August 1939.	315		PS	1939	84	Do.
						New Jersey							
K1	Paulsboro	Gloucester	266	20	Magothy and Raritan.	29				Ind	7/9/51	58	U. S. Geol. Survey, Quality of Water Branch.
T1	City of Wildwood	Cape May	320	6	Cohan	13	11/15/51		200	Ind	9/4/52		Do.
						New York							
K1	Village of Cedarhurst.	Nassau	530	6	Magothy(?)	14.7	1/18/54		130	N	9/8/53		U. S. Geol. Survey, Quality of Water Branch.
Q1	3 Willoughby St.	Kings	137	30–10	Pleistocene				250	Ind	7/27/42		Do.
Q2	17th St. and Surf Ave.	do	140	12	do				350	Ind	8/4/43		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Mississippi																	
T1	42	Tr	12	0.6	619		312	4.3	756				1,640	32			
T2	12	0.09	4.5	1.4	704	9.8	661	1.7	725	1.8			1,810	17			
New Jersey																	
K1	12	1.0	12	7.2	195	3.2	0	465	14	0.03	16		738	59		1,240	3.5
T1	26	1.9	98	56	167		108	14	520		1.5			475		1,820	7.1
New York																	
K1		65	379	1,010	8,380	294	3.3	2,080	15,700	0	0		30,500	5,200		36,800	4.8
Q1		.10							3,400					1,700			
Q2		.30							14,800					5,750			

TABLE 4.—*Records of wells and springs and chemical analyses in the Coastal Plain Region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
						North Carolina							
K1	15 miles E. of Shallotte.	Brunswick	330	4	Peedee					N	2/21/49		U. S. Geol. Survey, Quality of Water Branch.
K2	5 miles E. of Kelly	Bladen			do					N	9/22/53		Do.
K3	Robersonville	Martin	400	10	do				500	PS	2/16/48		Do.
K4	2 miles E. of Rocky Point.	Pender	339	4	do	+8	2/4/53	10		D, S	2/4/53		Do.
T1	City of Belhaven	Beaufort	410	8	Eocene	Flows			600	PS	2/26/51		Do.
T2	Town of Swanquarter.	Hyde	100		do					PS	10/14/48		Do.
T3	Town of Jacksonville.	Onslow	138	6	do	8	1/4/50		75	D	1/4/50		Do.
						Oklahoma							
K1	Sec. 1, T. 8 S., R. 24 E.	McCurtain	416	8	Trinity				90		9/13/49	72	U. S. Geol. Survey, Quality of Water Branch.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
North Carolina																	
K1							[1] 633		1,070					69			
K2	9.3	0.71	26	25	823		254	44	1,200	0.4	1.2		2,390	168	91	4,280	7.1
K3	22	.39	2.0	3.7	386		444	156	235	.9	.2		1,050	20	98		7.8
K4	16	.12	7.5	7.6	777		926	53	650	2.7	1.2		2,020	50	97	3,410	8.0
T1	40	.09	41	39	538		514	80	655	1.3	.1		1,630	263	82	2,840	7.5
T2		.10	47	67	488		658	31	625		.2		1,700	393	73		7.6
T3	45	.10	9.9	5.3	380		504	17	310	1.3	.5		1,020	46	95	1,730	7.8
Oklahoma																	
K1			29	13	1,140		612	222	1,320	3.0	4.0		3,000	126	95	5,090	

See footnotes at end of table.

TABLE 4.—*Records of wells and springs and chemical analyses in the Coastal Plain Region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
South Carolina													
K1	City of Summerville.	Dorchester	925	8	Black Creek and Peedee.	22	11/28/50		60	N	11/28/50		U. S. Geol. Survey, Quality of Water Branch.
K2	City of Georgetown.	Georgetown	1,344	20	Black Creek	+113	July 1952	75	400	N	9/29/49	86	Do.
K3	12 miles N. of Myrtle Beach.	Horry	587	10	Black Creek and Peedee.	+12.4	5/8/48	70	400	PS	10/31/53		Do.
T1	Frogmore St. Helena Island.	Beaufort	90	2	Ocala	10–12	1944		60		4/17/44		Do.
T2	Parris Island	do	315	12	do				1,800	N	4/6/44		Do.
Tennessee													
K1	City of Memphis	Shelby	2,656	6	Cretaceous	+75				N	5/9/45	80	U. S. Geol. Survey, Quality of Water Branch.
Texas													
Є1	Eden	Concho	4,150	8⅝, 5½	Hickory	380	9/5/45		130	PS	3/16/52	127	U. S. Geol. Survey, Quality of Water Branch.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
South Carolina																	
K1	5.2	2.5	2.5	1.2	630		993	0.8	400	0.5	.8	------	1,540	11	99	2,560	8.1
K2	17	.66	6.4	3.0	874		1,260	1.8	625	3.8	2.5	------	2,190	28	99	3,670	7.7
K3	20	.10	4.6	2.5	368		706	1.4	162	5.2	.0	------	944	22	------	1,580	8.1
T1	------	------	------	------	------	------	224	36	645	------	------	------	------	342	------	------	------
T2	------	------	------	------	------	------	------	------	3,000	------	------	------	------	------	------	------	------
Tennessee																	
K1	12	0.1	2.0	0.7	415	1.9	1,020	0.9	12	4.4	0.1	------	1,010	7.9	------	------	8.7
Texas																	
Є1	25	0.05	5.9	2.2	417	19	438	23	400	2.6	0.5	1.3	1,110	24	95	2,040	8.0

TABLE 4.—*Records of wells and springs and chemical analyses in the Coastal Plain Region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
Texas—Continued													
K1	10.8 miles SW. of Uvalde.	Uvalde	2,000	6	Edwards	17.62	5/5/30			S	3/16/52		U. S. Geol. Survey, Quality of Water Branch.
K2	6.7 miles SW. of D'Hanis.	do	450	7	Anacacho	232	5/21/30			S	5/21/30		Do.
K3	City of Addison	Dallas	695		Woodbine						7/26/29		Do.
K4	City of Ladonia	Fannin	2,513		do						9/21/29		Do.
K5	City of Dawson	Navarro	1,473		do						11/20/29		Do.
K6	Von Ormy	Bexar	4,518	5	Trinity			250			9/25/50		Do.
K7	12 miles NE. from San Antonio.	do	1,355		Edwards						1/25/51		Do.
K8	Dallas	Dallas	819	11	Woodbine				250	Ind	7/11/49	85	Do.
T1	8 miles SW. of Freer.	Duval	105	7	Catahoula	59.3	2/2/31			S	6/9/31		Do.
T2	In San Jose	do	100	6	Goliad	63	5/15/31			D, S	6/13/31		Do.
T3	1.2 miles E. of Bruni.	Webb	365	4¾	Catahoula	+1				D	11/28/34		Do.
T4	2.5 miles NW. of Dilley.	Frio	305	10	Cook Mt	95			175	Irr	6/17/32		Do.
T5	Town of Christine.	Atascosa	1,314	6–4	Mt. Selman	+25		300		PS	6/19/32		Do.
T6	18 miles SE. of Lufkin.	Angelina	452	6	Yegua					Ind	1/20/37		Do.
T7	10.5 miles W. of Bryan.	Brazos	4,133	12–6	Wilcox	Flows	11/13/37	200		S			Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Texas—Continued																	
K1			652	197	399		344	2,240	490		2.0		4,150	2,440			
K2		1.8	84	77	431		749	13	592		.85		1,570	526			
K3			10	92	800		880	469	665				2,470				
K4							870		1,060								
K5			30	32	2,000		975		2,640				5,170				
K6	28	.07	186	56	619	35	320	956	580	2.4	.2	1.7	2,620	694	65	3,960	6.9
K7	14		652	259	532		313	2,040	1,040		2.5		4,690	2,690	30	6,060	8.0
K8	13	.14	13	6.6	1,170	13	591	1,400	472	2.6	.8		3,380	60			8.4
T1			100		779		263	336	1,080		112		2,580	488			
T2		.79	130		366		256	137	724		19		1,590	592			
T3		.24	12		769		[2] 623	313	542	2.7	.2		2,029	61			
T4	27	.31	102	36	221	9.6	341	254	248		.4		1,090	403			
T5			3		672		781	153	475		.7		1,650	9			
T6		4.6	197	61	636		390	740	730		6.0		2,560	743			
T7							516	1,200	360					123			

See footnotes at end of table.

TABLE 4.—*Records of wells and springs and chemical analyses in the Coastal Plain Region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
Texas—Continued													
T8	11 miles S. from Linn.	Hidalgo	1, 430	7	Catahoula and Oakville.	+23	6/10/47	275	750	Irr	3/24/48		U. S. Geol. Survey.
T9	3 miles NW. from Campbellton.	Atascosa	3, 600	±8	Carrizo	40. 5	5/25/44			S	5/25/44	109½	Do.
T10	Hemphill	Sabine	631	8, 6	Sparta	99. 75	5/8/42		40	PS	5/22/42	80	Do.
T11	1 mile S. from Sebastian.	Cameron	329	12¾	Goliad	18	July 1952			Irr	7/24/52		Do.
Q1	Galveston	Galveston	1, 317		"Alta Loma"				2, 000		4/10/51		Do.
Q2	Mission	Hidalgo	363		Alluvium				700	PS	7/21/53		Do.
Virginia													
K1	Roanes	Gloucester	716	6–4	Upper Cretaceous.			52		Washing	1906	70	U. S. Geol. Survey.
K2	West Norfolk	Norfolk	605	4	Cretaceous				285	Boiler	1938	68	Do.
K3	Lambert Point	do			do					Cooling	1891		Shepard Laboratory.
T1	Fort Eustis	Warwick	550	18–8	Eocene(?)	20	1941		1, 340		7/7/42		U. S. Geol. Survey.
T2	Gloucester	Gloucester	810	10–8–6	Paleocene(?)	51	1942			PS	2/12/41	72	Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Texas—Continued																	
T8	6.8		74	36	993		[3] 177	492	1,300		1.5	5.8	3,050	332	87	5,130	
T9	14	0.02	3.1	.8	820		1,450	129	322	3.4	1.8		2,010	11		3,440	8.3
T10	16	.9	2.0	1.0	514		[4] 1,040	3	191		.5		1,240	9			
T11	44		104	109	1,140		[5] 469	1,060	1,200	.6	15	5.8	3,910	708	78	6,090	8.5
Q1	35		87	53	2,130		330	0	3,400				5,870	435	91	10,500	7.5
Q2	21	.04	88	44	756	11	286	461	950	.9	3.0	3.7	2,480	400	80	4,160	7.5
Virginia																	
K1	20	1	23	14	1,190		544	155	1,630		Tr		3,420				
K2	11						627	32	260				1,140	21			
K3	10		5	1.7	415	21		43	351				1,090				
T1	17	.21	4.5	2.3	454	9.0	475	56	409	2.9	0.8		1,200	20			
T2	17	.09	4.6	1.9	528	16	773	60	345	2.8	.9		1,360	19			

[1] Includes equivalent of 22 ppm CO_3.
[2] Does not include equivalent of 75 ppm CO_3.
[3] Includes 23 ppm CO_3.
[4] Includes 28 ppm CO_3.
[5] Includes 22 ppm CO_3.

TABLE 5.—*Records of wells and springs and chemical analyses in the East-Central region of Paleozoic and other old rocks*

[Use of water: D, domestic; S, stock; Ind, industrial; Irr, irrigation; PS, public supply; N, none. Analyses in parts per million, except as indicated]

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
Alabama													
S1	City of Huntsville	Madison	525	6	Niagara	23.1	12/2/48	------	------	N	8/6/45	------	Picard Testing Laboratories.
Arkansas													
PAL1	Town of West Fork.	Washington	145	------	Paleozoic	------	------	------	------	------	7/12/52	------	U. S. Geol. Survey.
PAL2	9 miles E. of Fayetteville.	do	78	------	do	------	------	------	------	------	3/7/53	------	Do.
Connecticut													
Q1	City of New Haven (3 wells).	New Haven	40	16	Sand and gravel.	------	------	------	350, 150, 300	------	2/2/45	------	U. S. Geol. Survey.
Georgia													
S1	13 miles S. of Chattanooga.	Catoosa	500	------	Red Mountain.	------	------	------	------	------	6/10/46	------	Georgia State Chemist.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Alabama																	
S1	209	0.16	346	185	134	33	921	735	383	......	......	......	2,960	1,720	......	......	......
Arkansas																	
PAL1	......	1.2	......	......	......	......	1,670	1	192	......	0.4	......	......	48	......	3,430	8.4
PAL2	......	.42	......	......	......	......	1,440	1,300	49	......	.2	......	......	243	......	4,350	8.1
Connecticut																	
Q1	......	......	176	123	792		313	202	1,560	......	......	......	3,240	945	65	......	6.9
Georgia																	
S1	6.0	0.75	105	39	13		......	36	725	......	......	......	2,220	423	......	......	8.2

TABLE 5.—*Records of wells and springs and chemical analyses in the East-Central region of Paleozoic and other old rocks*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
Illinois													
€1	Sec. 19, T. 24 N., R. 7E.	Ford	[1] 2,759–2,985		Cambrian								Illinois Water Survey Division.
€2	Sec. 23, T. 36 N., R. 9 E.	Will	[1] 1,618–1,935		do								Do.
O1	Town of Aledo	Mercer	1,172	16–8	St. Peter	166	1932		500	PS	11/29/26		Do.
O2	Town of Bartonville.	Peoria	1,864	12–6	do				250	PS	1/4/34		Do.
O3	Town of Coal City.	Grundy	360	20–12	Galena	69			700	PS	7/21/38		Do.
P1	Sec. 4, T. 10 N., R. 14 W.	Clark	[1] 295–205		Pennsylvanian.								Do.
P2	Sec. 29, T. 6 N., R. 6 W.	Madison	[1] 527–545		do								Do.
Indiana													
€1	City of Hammond (5 wells).	Lake	1,800±		Cambrian(?)						1901±		Blatchley (1903).
O1	City of Aurora	Dearborn	366		Trenton	Flow					1901±		Do.
O2	Indianapolis	Marion	1,541	6	St. Peter	150					1899±	60	Do.
O3	City of Austin	Scott	1,720		do								Do.
S1	Michigan City	La Porte	648		Niagara	22			500		6/20/50	58	U. S. Geol. Survey, Blatchley (1903).
S2	Lafayette	Tippecanoe	230		do								Do.

See footnotes at end of table.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Illinois																	
Є1	10	[2] 0.0	607	0	911		[3] 266	355	1,590				4,100				
Є2	12	[2] .2	28	9	249		[3] 19	48	400				1,210				7.0
O1	8.6	.1	50	24	340	24	[4] 252	487	150		0.2		1,240	224			
O2	9.0	Tr	66	23	501		[4] 316	647	248		.9		1,660	261			
O3	18.0	28	116	57	364		[4] 364	565	259		1.1		1,610	511			
P1	11	36	72	89	4,390		2,940	0	5,450		9.9		11,600				7.2
P2	2.2	8.0	422	254	7,940		193	0	13,600		0		23,000				7.9
Indiana																	
Є1													1,900				
O1													9,650				
O2													16,000				
O3													16,300				
S1	7.0	1.3	998	300	1,650	185	391	1,640	3,770				8,600			12,600	6.9
S2													7,310				

See footnotes at end of table.

TABLE 5.—*Records of wells and springs and chemical analyses in the East-Central region of Paleozoic and other old rocks*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
Indiana—Continued													
M1	12 miles SW. of English.	Crawford	284		St. Louis	Flow					1878±		U. S. Geol. Survey, Blatchley (1903).
M2	Corydon	Harrison	• 28		do						1871±		Do.
P1	Jasonville	Greene	100±		Allegheny(?)								
Iowa													
€1	Ottumwa	Wapello	1,975	20–10	Cambrian	Flow	1945		2,500	Ind	2/16/44		Iowa Geol. Survey.
O1	Near Folsom, T. 73 N., R. 43 W.	Mills	2,512		Ordovician					N	11/12/50		Do.
O2	Near Bedford, T. 68 N., R. 34 W.	Taylor	2,878		do					N	5/9/42		Do.
S1	Melbourne, T. 82 N., R. 19 W.	Marshall	1,340	10–6	Silurian	202	1938		95	PS	3/5/52		Do.
D1	Near Washington, T. 75 N., R. 8 W.	Washington	675		Devonian	116	1940		61	N	3/29/40	63	Do.
M1	Bondurant, T. 80 N., R. 22 W.	Polk	650	8–6	Mississippian.	160	1951		36	PS	6/24/52		Do.
M2	Stockport, T. 70 N., R. 9 W.	Van Buren	448		do	97	1948			PS	10/15/48	56	Do.
P1	Near Murray, T. 72 N., R. 27 W.	Clarke	162		Pennsylvanian.	150	1940			D, S	9/26/40	53	Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Indiana—Continued																	
M1													4,500				
M2													7,710				
P1													3,560				
Iowa																	
Є1		Tr	66	66	271		293	489	154	0.8	Tr		1,240	434			7.9
01		1.9	106	47	445		173	700	420	2.4	0		1,940	458		2,660	7.6
02		1.6	237	78	1,360		127	1,010	1,940	3.0	4.4		4,340	913			7.6
S1		5.5	315	106	408		266	1,780	58	1.2	0		2,960	1,220		2,960	7.5
D1		.9	532	130	1,410		322	3,860	510	4.2	0		6,860	1,860			7.3
M1		.9	81	28	390	10	373	816	49	3	0		1,590	317		1,940	7.7
M2		.0	60	32	787		506	1,200	214	.5	0		2,580	282		3,490	8.2
P1		2.9	516	215	225		427	2,200	21	Tr	20		3,480	2,170			7.1

TABLE 5.—*Records of wells and springs and chemical analyses in the East-Central region of Paleozoic and other old rocks*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
					Iowa—Continued								
P2	Garden Grove, T. 70 N., R. 24 W.	Decatur	185		Pennsylvanian.					PS	5/22/48		Iowa Geol. Survey
Q1	Near Schaller, T. 89 N., R. 37 W.	Sac	158	4	Pleistocene				12	D, S	11/30/36	47	Do.
					Kansas								
O1	Sec. 13, T. 33 S, R. 21 E.	Labette			Roubidoux								Skelly Oil Company.
P1	NW. Lawrence, T. 12S, R. 19 E.	Douglas	190	7	Tonganoxie	82.2	6/25/50			D	3/16/50		Kans. State Board of Health.
P1	Sec. 9, T. 22 S, R. 8E.	Chase	61		Cottonwood						4/16/48	55	Do.
					Kentucky								
O1	Owingsville	Bath	98	6	Richmond					D	4/28/53	56	U. S. Geol. Survey.
O2	Town of Sanders	Carroll	75–80	6	Cynthiana					D	8/5/53	57	Do.
O3	Near Shelbyville	Shelby	41	8	Eden	8.2	1/13/53			D	1/31/53	55	Do.
S1	Near Middleton	Jefferson	81	6	Laurel and Osgood.					S	3/26/53		Do.
D1	Settle	Allen	400	6	"Corniferous limestone".				6		8/13/51	84	Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Iowa—Continued																	
P2	--	0.0	309	123	152		220	1,320	20	0.4	0	--	3,570	1,280	--	3,620	7.8
Q1	--	.8	460	198	138		451	1,850	15	.0	.20	--	3,580	1,960	--	--	7.0
Kansas																	
O1	--	--	--	--	--	--	--	420	8,970	--	--	--	17,800	--	--	--	--
P1	15	20	615	257	7,340		237	279	12,800	0.9	8.8	--	21,400	2,590	--	--	--
P1	15	.66	348	198	778		128	1,650	1,090	1.3	14	--	4,100	1,680	--	--	--
Kentucky																	
O1	--	1.8	--	--	--	--	435	13	2,220	0.9	0.0	--	--	430	--	8,050	--
O2	--	4.9	--	--	--	--	716	5.6	1,190	3.4	.2	--	--	313	--	4,550	--
O3	--	2.2	--	--	--	--	258	63	1,900	.8	18	--	--	406	--	6,030	--
S1	--	8.9	--	--	--	--	480	1,580	12	.4	.3	--	--	2,000	--	2,870	--
D1	7.7	.13	2,830	700	31,100	358	674	180	56,400	--	--	--	79,600	--	--	97,800	--

TABLE 5.—*Records of wells and springs and chemical analyses in the East-Central region of Paleozoic and other old rocks*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
					Kentucky—Continued								
D2	Near Sandy Hook	Elliott	1,285	6	"Corniferous limestone."					N	8/4/51		U. S. Geol. Survey.
M1	Near Scottsville	Allen	118	8	Warsaw	60	9/8/51		50–60		9/8/51	58	Do.
M2	Near Poole	Henderson			Waltersburg						7/18/51	89	Do.
P1	Town of Marion	Crittenden	425	8	Caseyville	60	12/10/52		15	PS	12/10/52	60	Do.
P2	Town of Prestonburg.	Floyd	91	6	Breathitt	7.55	9/14/51			N	9/27/51	59	Do.
P3	Fort Knox	Hardin	1,900	8	Carbondale					N	1/22/52	53	Do.
Q1	City of Louisville	Jefferson	110	12	Alluvium				200	Ind	8/7/50	60	Do.
Q2	City of Covington	Kenton	135	6	do				125	Ind	6/21/50	58	Do.
					Michigan								
O1	Grosse Isle	Wayne	2,375		Trenton			3,000			January 1905.	52	F. K. Ovity, Ann Arbor, Michigan, 1905.
D1	Near West Branch	Ogemaw	2,653	5	Dundee						3/27/51		Mich. Dept. of Health.
D2	Crystal	Montcalm	3,187	5	do						3/27/51		Do.
M1	Grand Rapids	Kent	300		Marshall				400	Ind	1/22/53		U. S. Geol. Survey.
M2	Birmingham	Oakland	207		Berea(?)	±38					11/16/38		Mich. Dept. of Health.
P1	City of Flint	Genessee	230	8	Saginaw(?)	10	6/27/36		200	Ind	3/27/53	55.3	Do.
P2	New Lothrop	Shiawassee	58±		do	5	1931		15	PS	June 1937		Do.
Q1	Grand Rapids	Kent	50	8	Michigan drift.	16			500	Ind	1/21/53	54	

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Kentucky—Continued																	
D2	6.5	41	1,520	672	9,520	106	225	9.6	19,600				32,300			44,000	7.0
M1	11	.38	348	68	23	6.9	266	919	18	0.9	0.6		1,620	1,150		1,690	7.2
M2	8.7	.8	287	189	21,600	155	458	764	33,700				44,700			59,000	
P1	15	14	170	67	60	5.7	292	872	12	.1	1.6		1,100	700		1,400	7.9
P2	20	6.5	248	119	16	6.1	42	1,100	2.5	.6	.8		1,650	1,100		1,650	6.5
P3	8.2	1.4	742	532	6,260	102	286	862	11,300				20,400			29,800	7.4
Q1		5.9					623	867	18		5.1			1,380		2,090	
Q2	14	6.6	150	56	167		584	191	204	.3	1.2		1,080	604		1,780	7.6
Michigan																	
O1	188		5,080	730	216	80	[4] 871	14,200					21,700				
D1		0.20	12,900	3,500	66,700	1,900	55	357	138,000	[5] 779	[6] 7.8	76	214,000			153,000	
D2		.09	29,600	5,160	54,200	1,860	70	171	158,000	[5] 1,000	[6] 10	[7] 257	258,000			147,000	
M1	14	3.4	400	39	199	7.9	242	974	272	0.5	0.5		2,130	1,160		2,670	7.3
M2	9.6	.3	31	18	670		392	3.3	900				1,820				
P1	8.0	.7	120	46	270		432	162	390	.4	0		1,290	490		1,800	
P2	8.0	.17	27	12	412		406	38	452				1,170	115			
Q1	14	.72	452	63	47	2.3	362	1,010	83	.1	.1		1,960	1,390		2,230	7.1

See footnotes at end of table.

TABLE 5.—*Records of wells and springs and chemical analyses in the East-Central region of Paleozoic and other old rocks*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
Minnesota													
Q1	Sec. 8, T. 127 N, R. 40 W.	Douglas	260		Glacial till								Minnesota Geol. Survey.
Q2	Sec. 13, T. 162 N, R. 48 W.	Kittson	12		Lake sediments.								Do.
Q3	Sec. 10, T. 145 N., R. 43 W.	Norman	108		Glacial drift								Do.
Missouri													
O1	Lagrange	Lewis	850	8	St. Peter	Flow		40				60	U. S. Geol. Survey.
O2	South of Clinton	Henry	800	8–6	Jefferson City and Gasconade.			400	1,887				Do.
P1	5 miles SW. of Utica	Livingston	421	6	Cherokee	Flow						59	Do.
Ohio													
S1	Near Castalia	Erie	168	10	Silurian	1.5	3/6/52		500		3/6/52	51	U. S. Geol. Survey.
M1	Brecksville	Cuyahoga	275	6½	Berea	185			5		1/14/52	52	Do.
M2	Near Garretsville	Portage	146		do				5	D	5/26/53	54	Do.
P1	T. 3 N., R. 10 W	Summit	100	6	Pottsville					S	2/18/49	45	Do.
Q1	Near Edgerton	Defiance	80	2	Gravel	40	4/8/53				4/8/53	52	Do.
Q2	Basil	Fairfield	60	6	do				2	D	6/26/50	55	Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Minnesota																	
Q1	19	Tr	107	94	134	23	603	456	1.8		Tr		1,200	653			
Q2	19	0.5	172	89	278	50	547	105	603		5.7		1,600	795			
Q3	18	.5	199	83	202	47	571	876	7.1		9.0		1,720	838			
Missouri																	
O1	40	1.3	293	89	1,930	Tr	3	1,060	2,980				6,390				
O2	12		117	51	419	16	375	110	719				1,820				
P1	13	10	312	136	2,730	45		1,290	4,250				8,780				
Ohio																	
S1	9.8	0.33	536	48	6.5	1.8	285	1,220	12	1.0	0.1		2,150	1,540		3,050	7.3
M1	8.9	.24	3.2	1.0	424	3.6	505	304	144	.8	.4		1,140	12		1,870	7.8
M2	10	3.5	42	14	468	8.4	508	.6	520	.2	.1		1,350	162		2,450	7.5
P1	5.5	.56	223	83	133 (Na + K)		484	705	38	.3	2.4		1,490	898		1,820	7.5
Q1	20	10	200	77	23	1.1	574	372	6.0	.6	.1		1,020	815		1,370	6.8
Q2	10	1.6	107	57	182 (Na + K)		222	610	52	.5	7.6		1,190	501		1,590	7.8

TABLE 5.—*Records of wells and springs and chemical analyses in the East-Central region of Paleozoic and other old rocks*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
Oklahoma													
O1	Sec. 12, T. 25 N., R. 20 E.	Craig	1,139	6	Roubidoux	55	3/10/50			PS	3/10/50		U. S. Geol. Survey.
P1	Seminole, T. 9 N., R. 6E.	Seminole	753	12	Vamoosa				150	PS	12/10/47		Do.
P2	Sec. 16, T. 21 N., R. 13 E.	Tulsa	83	6	Seminole	25.92	7/13/48			S	7/13/48	69	Do.
P1	Sec. 17, T. 3 N., R. 23 E.	Greer	125	16	Blaine	47.29			940	Irr	8/12/52		Do.
P2	Sec. 32, T. 1 N., R. 7 W.	Stephens	802	12½	Garber	315	12/11/44		148	PS	12/13/44	68	Do.
P3	Sec. 25, T. 17 N., R. 12 W.	Blaine			Blaine				500	Irr	7/12/45		Do.
Pennsylvania													
S1	City of Bedford	Bedford	180	8	Wills Creek	22			60	Ind	10/13/33	54	U. S. Geol. Survey.
S2	Hollidaysburg	Blair	496	8	Clinton	48			386	Ind	10/11/33	54	Do.
S3	Lewistown	Mifflin	140	8	Cayuga	±6			35	S	8/14/	55	Do.
S4	Milton	Northumberland.	240	8	do	10			90	Ind	9/4/31		Do.
D1	Bedford Springs	Bedford	Spring		Helderberg			±30			10/13/33	60	Do.
D2	5 miles E. of Albin	Erie	54	4	Chemung	±6				N	7/22/29	49	Do.
D3	0.7 miles S. of Tioga.	Tioga	410	10–8	do	±20			8	Ind	8/19/35	53	Do.

Source no. on pl. 2	Silica (SiO2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO3)	Boron (B)	Dissolved solids	Hardness as CaCO3	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Oklahoma																	
O1	12	0.10	38	23	372	27	124	28	620	2.2	4.5		1,190	189	78	2,210	7 9
P1			186	33	79		132	601	25	.5	1.0		1,080	600	22	1,360	
P2			31	59	641		564	271	685	.2	5.5		1,970	322	81	3,330	
P1			602	149	127		290	1,850	150		19		3,040	2,110	12	3,460	7.2
P2			11	2.9	397	13	369	270	235	.4	2.8		1,120	40	94	2,000	8.1
P3			554	48	69		92	1,510	51		13		2,290	1,580	9		
Pennsylvania																	
S1			226	77	7		235	659	12		0.80		1,000	881			
S2			310	69	453		163	141	1,250				2,300	1,060			
S3		0.87	480	121	5		202	1,460	5		.0		2,170	1,700			
S4		1.2	436	87	93		169	1,270	136		.5		2,100	1,450			
D1			558	146	<5		183	1,760	6.0		.2		2,560	1,990			
D2			18		596		404	3	716		1.4		1,490	49			
D3		.48	82	17	1,130		197	7	1,820		.0		3,160	275			

TABLE 5.—*Records of wells and springs and chemical analyses in the East-Central region of Paleozoic and other old rocks*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
Pennsylvania—Continued													
P1	1 mile E. of McDonald.	Allegheny	284	6	"Scottsburg"							50	U. S. Geol. Survey.
P2	Punxsutawney	Jefferson	170	4	Allegheny					Ind	10/10/29		Do.
Tennessee													
O1	Belleville	Lincoln	66	5	Hermitage	25.0	11/12/30			S	11/12/30		U. S. Geol. Survey.
O2	5 miles E. of Match.	Maury	75	6	Lebanon	67	10/14/30				11/8/30		Do.
O3	5½ miles E. of Norene.	Wilson	152	6	Lebanon(?)						10/24/27	56	Do.
S1	Beardstown	Perry	137	5	Brownsport	67.7	8/12/30			D	8/12/30		Do.
M1	1.5 miles N. of Belvidere.	Franklin	118	6	Warsaw(?)	72	11/24/30			S	11/24/30		Do.
M2	5 miles W. of Vanleer.	Dickson	65	6	Ft. Payne						10/7/27	59	Do.
M3	10 miles N. of Springfield.	Robertson	71	6	St. Louis or Warsaw.						10/9/27	58	Do.
Texas													
P1	14 miles NE. from San Angelo.	Tom Green	218	12	Clear Fork	98.3	2/24/50		642	Irr	8/1/50	70	
P2	7 miles E. from Childress.	Childress	270	16	Blaine	75	February 1953.		1,100	Irr	9/24/53	65	

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Pennsylvania—Continued																	
P1	9	1.1	55	15	895	12	442	57	1,250		Tr		2,500	199			
P2	16	11	188	37	935	18	167	72	1,760		0.6		3,190	622			
Tennessee																	
O1	18	2.7	1,440	104	935	20	361	3,490	1,460		2.3		7,720	4,020			
O2	14	1.8	848	52	35	4.1	414	1,880	60		.8		3,280	2,320			
O3	13	2.3	580	533	8,780	133	383	118	15,700		0		26,400	3,600			
S1	6.8	.66	83	39	903	15	194	1,540	402		20		3,120	367			
M1	16	2.1	305	31	16	3.4	302	615	27		.9		1,210	888			
M2	2.4	29	496	208	82	6.2	184	1,990	31		4.0		3,200	2,090			
M3	19	1.3	353	135	92		225	1,310	82		1.2		2,100	1,440			
Texas																	
P1	21		454	162	246		258	1,760	189		0	0.71	2,960	1,800	23	3,460	7.8
P2	16		620	232	730		220	2,400	1,040		.2	4.7	5,150	2,500	39	6,490	7.5

TABLE 5.—*Records of wells and springs and chemical analyses in the East-Central region of Paleozoic and other old rocks*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
Virginia													
O1	Sweet Chalybeate	Alleghany	Spring		Lowville			1,000			4/2/28	74	U. S. Geol. Survey.
West Virginia													
O1	White Sulphur Springs.	Greenbrier	Spring		Marcellus			25			6/3/35	62.5	W. Va. Geol. Survey.
M1	Webster Springs	Webster	do		Greenbrier			5			6/6/35	55	Do.
P1	Clarksburg	Harrison	230	6	Conemaugh				4	PS	10/25/41	54.5	U. S. Geol. Survey.
P2	Blacksville	Monongalia	169	6	Dunkard	30	1928		15	PS	2/24/49	54.3	Do.
Q1	Town of Power	Brook	80	10	Pleistocene	50			250	PS	3/9/53	57	Do.
Wisconsin													
Ꞓ1	Prairie du Chien, T. 7 N., R. 6 W.	Crawford	960	4.5	Cambrian	+18	1876			N		57	Wis. Geol. and Nat. History Survey.
O1	Kaukauna	Outagamie	798(?)		St. Peter and Upper Cambrian.						4/26/11		Do.
O2	Mequon	Ozaukee			do						5/7/07		Do.
S1	North Milwaukee	Milwaukee	160		Niagara						12/27/01		Do.
Q1	Hartford	Washington	14		Glacial drift						1/15/02		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Virginia																	
O1			400		95		777	466	30		33		1,350	757			
West Virginia																	
O1	17	1.1	439	125	22	1.2	205	1,420	17		0		2,220				
M1	14	.09	155	46	2,010	57	244	51	3,460		6.3		6,100				
P1	7.8	1.4	18	4.4	596	2.6	398	5.8	720	2.4	3.0		1,580	63			8.1
P2	5.8	.06	28	7.4	1,240	8.8	688	3.0	1,610	.3	.5		3,270	100		5,820	7.5
Q1	16	.12	278	43	33	4.1	256	680	24	.2	3.6		1,290	870		1,540	6.9
Wisconsin																	
Є1	65	1.2	80	55	678	34	140	333	967				2,350				
O1	28		272	21	146		266	604	12				1,350				
O2	19		452	56	69		153	1,770	28				2,550				
S1			183	77	164		44	999	10				1,480				
Q1			250	95	55		264	585	40		26		1,310				

[1] Depth from which sample was taken.
[2] Unfiltered.
[3] Does not include equivalent of 61 ppm CO_3.
[4] Alkalinity as $CaCO_3$.
[5] Bromide.
[6] Iodine.
[7] Borate.

TABLE 6.—*Records of wells and springs and chemical analyses in the Great Plains region*

[Use of water: D, domestic; S, stock; Ind, industrial; Irr, irrigation; PS, public supply; N, none. Analyses in parts per million, except as indicated]

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Colorado							
K1	Sec. 15, T. 4 N., R. 60 W.	Morgan	750	6	Pierre	95	8/31/48				8/31/48		U. S. Geol. Survey.
K2	Sec. 27, T. 7 N., R. 53 W.	Logan	230	6	do	16				D, S	8/18/48		Do.
K3	Sec. 25, T. 26 S., R. 68 W.	Huerfano			Dakota			2		S	5/22/52	59	Do.
Q1	Sec. 26, T. 4 N., R. 56 W.	Morgan	90		Alluvium	22	7/28/48		1,260	Irr	7/28/48	55	Do.
Q2	Sec. 4, T. 10 N., R. 48 W.	Logan	38	18	do	6	9/23/49		1,250	Irr	9/23/49	55	Do.
						Kansas							
K1	Sec. 12, T. 12 S., R. 7 W.	Lincoln	130		Dakota					S	9/15/47	60	U. S. Geol. Survey.
K2	Sec. 10, T. 16 S., R. 18 W.	Rush	168	5	do	69.32	10/29/49			D, S	10/29/49	59	Do.
T1	Sec. 25, T. 13 S., R. 39 W.	Wallace	20	18	Ogallala	6	9/20/51			S	9/20/51	57	Do.
Q1	Sec. 11, T. 12 S., R. 6 W.	Lincoln	37		Terrace deposit.					D	9/15/47	59	Do.
Q2	Sec. 34, T. 14 S., R. 21 W.	Trego	21	33	Alluvium	12.81	10/29/49			D, S	10/29/49	58	Do.
Q3	Sec. 2, T. 15 S., R. 35 W.	Logan	37	6	do	10	9/19/51		5 (est.)		9/19/51		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Colorado																	
K1	8.4		11	3.5	345	5.6	[1] 300	376	100	1.4	2.5	0.32	1,000	42	94	1,520	8.4
K2	15		6.0	5.2	432	9.6	[2] 810	2.4	235	2.8	0		1,110	36	95	1,880	8.2
K3					854		[3] 1,500	26	442			2.2	2,110	9	99	3,530	8.4
Q1	26		210	74	163	12	348	784	62	.7	2.1	.41	1,510	828	30	1,980	7.8
Q2	28	0.52	260	90	506	14	302	1,640	174	.8	.9		2,860	1,020	51	3,610	7.0
Kansas																	
K1	11		128	31	228	6.4	330	409	162	0.8	30	0.5	1,170	447	52	1,710	7.1
K2	18	3.2	21	12	792		344	268	886	5.0	.8		2,170	102	94	3,830	7.9
T1								1,270	48							2,720	
Q1	4.0		211	44	395	24	341	361	425	.9	420	.41	2,050	708	54	3,010	7.3
Q2	36	.26	342	48	20		194	496	97	.4	348		1,480	1,050	4	1,980	7.3
K3			573	100	192	18	453	1,760	23	1.2	37		3,190	1,840	18	3,260	7.2

See footnotes at end of table.

TABLE 6.—*Records of wells and springs and chemical analyses in the Great Plains region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
						Montana							
Q1	Sec. 24, T. 3 N., R. 22 E.	Stillwater	5, 552		Ordovician			150±					U. S. Geol. Survey.
M1	Sec. 34, T. 32 N., R. 34 E.	Phillips	3, 245		Madison			100±					Do.
M2	Sec. 13, T. 4 N., R. 61 E.	Fallon	7, 216		Lodgepole			20±					Do.
P1	Sec. 5, T. 3 N., R. 21 E.	Stillwater	2, 865	6¼	Amsden			570			1921	113	Do.
K1	Sec. 10, T. 2 N., R. 33 E.	Big Horn	202	4	Lance	25	1921			D	10/17/21		Do.
K2	Sec. 22, T. 27 N., R. 47 E.	McCone	1, 100	6	Judith River	Flows	1947	65		Pool	10/10/47	65	Do.
K3	Sec. 1, T. 6 N., R. 36 E.	Treasure	600	6	do	2	1921			D	8/24/21		Do.
T1	Sec. 2, T. 22 N., R. 59 E.	Richland	500		Fort Union						10/3/49		Do.
T2	Sec. 14, T. 10 N., R. 49 E.	Custer	625	6	do					D, S	10/15/48		Do.
Q1	Sec. 15, T. 27 N., R. 47 E.	Roosevelt	100	18	Alluvium				500	PS	10/15/47	51	Do.
Q2	Sec. 22, T. 29 N., R. 13 E	Chouteau	248	6	Pleistocene				50	D, S	5/14/46		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Montana																	
O1	------	------	526	109	460		305	2,160	192	------	------	------	3,590	------	------	------	7.0
M1	------	------	472	155	315		195	1,960	210	------	------	------	3,210	------	------	------	6.9
M2	------	------	529	165	1,420		195	1,940	2,060	------	------	------	6,210	------	------	------	8.5
P1	24	0.18	518	122	319		315	1,890	182	------	------	------	3,500	1,800	------	------	------
K1	12	.5	23	17	628		731	814	23	------	1.0	------	1,910	127	------	------	------
K2	13	.13	15	36	1,330	19	544	1.9	1,850	1.0	1.0	5.2	3,550	186	93	6,510	7.8
K3	10	.5	5	1.0	826		1,090	5.2	636	------	Tr	------	2,080	16	------	------	------
T1	16	.15	3	7.4	857	2.4	2,080	1.6	71	2.0	.2	.4	2,060	38	98	2,960	8.3
T2	11	4.0	46	36	347	2.8	596	480	6.1	.4	.8	.3	1,240	263	74	1,730	8.1
Q1	25	1.5	74	33	359	2.4	523	572	18	.8	4	.06	1,350	320	71	1,890	8.3
Q2	------	.1	31	15	665		934	570	140	1.8	3.1	1.5	1,940	139	91	------	8.3

TABLE 6.—*Records of wells and springs and chemical analyses in the Great Plains region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Nebraska							
K1	Sec. 26, T. 10 N., R. 6 W.	Lancaster	159	6	Dakota	48	4/24/51		500		4/24/51	60	U. S. Geol. Survey, Quality of Water Branch.
K2	Sec. 24, T. 34 N., R. 13 W.	Boyd	1,100	2	do	110	8/5/52			S	8/5/52	64	Do.
K3	Sec. 19, T. 35 N., R. 44 W.	Sheridan	310	4	Pierre	+80 (est.)	3/9/51	1		D	3/9/51	48	Do.
T1	Sec. 32, T. 13 N., R. 40 W.	Keith	195	18	Ogallala	65	9/15/49		800 (est.)	Irr	9/15/49	56	Do.
Q1	Sec. 16, T. 1 N., R. 11 W.	Webster	32.5	1½	Alluvium					N	12/7/50	43	Do.
Q2	Sec. 26, T. 1 N., R. 40 W.	Dundy	80	16	Pleistocene	15.5	5/1/47			Irr	5/1/47	54	Do.
Q3	Sec. 29, T. 10 N., R. 22 W.	Dawson	12	1	Gravel						6/20/51	53	Do.
						New Mexico							
P1	Sec. 20, T. 1 N., R. 12 E.	Torrence	400	8	Yeso	258.8	7/18/50			D, S	7/18/50		U. S. Geol. Survey.
P2	Sec. 19, T. 7 N., R. 10 E.	do	280		Glorieta	34.1	7/6/50		2,250	Irr	4/12/50		Do.
P3	Sec. 23, T. 21 S., R. 26 E.	Eddy	418	16	Carlsbad	36.9	5/23/49		1,400	Irr	5/23/49		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Nebraska																	
K1	22	0.16	298	122	8,660	11	419	1,340	12,800	2.2	35	0.69	23,500	1,250	94	36,100	7.0
K2	13	3.1	258	41	68	17	167	675	110	1.6	.4	.15	1,270	812	15	1,700	7.7
K3	10	.15	12	3.6	478	7.6	582	560	24	2.4	0	2.4	1,390	45	95	1,990	7.9
T1	36	.44	162	35	144	19	276	563	50	.4	.38	.3	1,150	548	35	1,490	7.2
Q1	34	6.8	289	36	93	16	312	675	49	.4	72	.13	1,430	868	19	1,740	7.7
Q2	40	6.5	236	85	205		311	1,030	35	1.6	1.0	----	1,790	938	32	2,290	8.0
Q3	40	----	193	47	150	25	411	560	62	.4	4.9	.12	1,280	676	32	1,720	7.5
New Mexico																	
P1	22	----	538	142	11		164	1,700	14	0.7	0.1	----	2,510	1,930	1	2,650	----
P2	----	----	1,140	1,610	----	----	242	----	6,300	----	----	----	----	9,460	----	19,600	----
P3	----	----	440	133	296		207	1,300	540	----	4.4	----	2,820	1,640	28	3,880	----

TABLE 6.—*Records of wells and springs and chemical analyses in the Great Plains region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
New Mexico—Continued													
P4	Sec. 23, T. 10 S., R. 24 E.	Chaves	300	8	San Andres	+16	1926		500	Irr	5/10/28	69	U. S. Geol. Survey.
TR1	Sec. 10, T. 24 S., R. 37 E.	Lee	747		Triassic	120			50	Ind	3/11/53		Do.
TR2	Sec. 24, T. 18 S., R. 29 E.	Eddy		6	Dockum	158.3	4/28/50		3	S	4/28/50		Do.
K1	Sec. 2, T. 8 S., R. 10 E.	Lincoln	895		Cretaceous	90				Ind	December 1901.		Do.
K2	Sec. 30, T. 25 N., R. 25 E.	Colfax			Greenhorn	10	4/4/46			S	1/23/46		Do.
North Dakota													
PAL1	Sec. 13, T. 157 N., R. 53 W.	Walsh	450	6	Paleozoic(?)	Flow	4/25/21	800		Fire	4/25/21		Simpson (1929).
PAL2	Sec. 35, T. 162 N., R. 53 W.	Pembina	1,560	6–4	Paleozoic	do	4/23/21			Fire	4/23/21		Do.
K1	Sec. 2, T. 146 N., R. 33 W.	Traill	437	4½	Dakota					N	9/17/48		N. Dak. Geol. Survey.
K2	Sec. 6, T. 159 N., R. 57 W.	Cavalier	20	60	Pierre	12	1938			D	1938		Do.
K3	Sec. 2, T. 133 N., R. 59 W.	LeMoure	1,100	2	Dakota	Flow	1938			D	1938		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
New Mexico—Continued																	
P4	18	0.13	231	71	867	7.2	206	639	1,380	6.0	------	------	3,330	869	------	------	------
R1	13	------	121	93	402		277	934	252	1.6	1.2	------	1,950	684	56	2,840	------
R2	25	------	397	58	43		167	911	110	1.4	98	------	1,730	1,230	71	2,150	------
K1	------	------	16	10	783		------	302	450	------	------	------	2,110	81	95	------	------
K2	------	------	194	45	130		269	679	13	.6	4.5	------	1,200	669	30	1,600	------
North Dakota																	
PAL1	24	0.40	44	22	1,640		881	605	1,720	------	9.0	------	4,560	200	95	------	------
PAL2	10	10	1,280	517	8,970	177	174	3,170	15,000	------	4.0	------	20,300	5,330	79	------	------
K1	------	2.1	202	80	876	------	222	1,380	870	------	104	------	3,620	830	70	------	------
K2	26	------	115	78	180		464	187	242	0.6	106	------	1,240	615	39	------	------
K3	15	.3	26	16	717		317	1,140	172	.8	2.2	------	2,300	130	92	------	------

TABLE 6.—*Records of wells and springs and chemical analyses in the Great Plains region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
					North Dakota—Continued								
K4	Sec. 31, T. 150 N., R. 72 W.	Wells	2,235	5	Dakota	+55	1921			D	6/12/21		Simpson (1929).
K5	Sec. 17, T. 39 N., R. 73 W.	Kidder	120	2½	Fox Hills	60							Do.
K6	Sec. 11, T. 131 N., R. 102 W.	Bowman	1,042	6	do	235	1938			D	1938		N. Dak. Geol. Survey.
T1	Sec. 17, T. 163 N., R. 98 W.	Divide	216	5	Fort Union	95.2	8/27/46			N	5/2/47	48	U. S. Geol. Survey.
T2	Sec. 25, T. 159 N., R. 87 W.	Ward	410	3	do					S	9/10/47		Do.
T3	Sec. 11, T. 146 N., R. 77 W.	Sheridan	430	6	do	175	1938			D	1938		N. Dak. Geol. Survey.
T4	Sec. 3, T. 139 N., R. 96 W.	Stark	202	6	do					D	6/25/21		Simpson (1929).
Q1	Sec. 7, T. 132 N., R. 76 W.	Emmons	56	8	Glacial drift					D, S	1938		N. Dak. Geol. Survey.
Q2	Sec. 23, T. 144 N., R. 89 W.	Mercer	28		Alluvium					D, S	1938		Do.
Q3	Sec. 30, T. 162 N., R. 72 W.	Rolette	190	Tr	Glacial drift	Flow	5/12/21			D	5/12/21		Simpson (1929).

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
North Dakota—Continued																	
K4	33	3.2	5.6	2.4	1,250		1,120	764	710				3,400	22	99		
K5	46	.72	150	62	101		561	366	6.0				1,040	629	26		
K6	4		3.3	4.1	359		621	252	22	1.6	3.1		1,020	25	97		
T1	7.6	.05	10	2.0	586	9.6	916	518	16	.4	7.5	0.51	1,610	33	97	2,550	9.2
T2	8.0	4.1	3.5	1.7	872	6.4	1,810	0.5	305	1.8	1.5	.66	2,090	16	99	3,440	7.2
T3	22	1.2	50	14	447		846	120	232	1.2	5.3		1,290	185	84		
T4	20	1.8	46	52	205		508	324	2.0		1.5		913	328	58		
Q1	24	.7	97	40	290		426	621	28	.2	1.0		1,320	409	60		
Q2	27	20	152	56	89		500	390	16	.2	7.5		1,140	649	24		
Q3	31		196	60	63		532	417	6.0		2.0		1,100	736	16		

TABLE 6.—*Records of wells and springs and chemical analyses in the Great Plains region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Oklahoma							
P1	Sec. 2, T. 21 N., R. 24 W.	Ellis	500	10	Rush Springs	0		5,000		Ind			U. S. Geol. Survey.
P2	Sec. 16, T. 24 N., R. 22 W.	Woodward	57	12	do	12.01	11/27/40		200	P, S, Irr	2/9/50	45	Do.
						South Dakota							
M1	Sec. 3, T. 10 N., R. 2 E.	Fall River	3,855	16	Madison			250		D	6/26/52	145	U. S. Geol. Survey.
P1	Sec. 11, T. 5 N., R. 5 E.	Meade	1,800	12	Minnelusa	140	9/23/52		540	D	9/23/52	50	Do.
P2	Sec. 18, T. 6 N., R. 5 E.	do	690	10	do			3,000		N	10/16/34	58	Do.
K1	Sec. 24, T, 9 N., R. 5 E.	Butte	50–60	12½	Pierre					N	7/12/34		Do.
K2	Sec. 24, T. 9 N., R. 5 E.	do	2,600	12½	Lakota	+23	3/27/35	30		N	11/26/34	81	Do.
K3	Sec. 13, T. 1 N., R. 20 E.	Haskon	2,293	6	do	+57.5	1935	14		PS		110	Do.
K4	Miller, T. 112 N., R. 68 W.	Hand	1,650		Dakota						June 1938		Do.
K5	Sec. 11, T. 108 N., R. 63 W.	Jerauld	790	3	do	+88	5/29/47	160		D, S, PS	9/8/47		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Oklahoma																	
P1	-----	-----	710	101	1,270		79	2,220	1,820	0.8	6.5	-----	6,170	2,190	56	8,170	-----
P2	44	0.18	262	49	98	7.2	460	510	95	.9	.5	-----	1,290	855	20	1,760	7.5
South Dakota																	
M1	27	0.25	114	31	213		197	315	270	1.2	2.3	-----	1,070	411	53	1,720	7.5
P1	11	1.7	210	56	45		258	605	4.0	.7	3.3	-----	1,060	753	12	1,340	7.2
P2	-----	-----	288	61		2.3	210	752	5.3	.6	.6	0.07	-----	970	-----	-----	-----
K1	-----	-----	-----	-----	5,060	-----	467	-----	2,820	-----	-----	-----	-----	-----	-----	-----	-----
K2	-----	-----	4.0	2.0	410	-----	589	361	8.9	4.2	Tr	.28	-----	18	-----	-----	-----
K3	38	-----	8.8	2.0	720	-----	1,300	8.1	259	-----	-----	-----	-----	30	-----	-----	-----
K4	16	1.0	192	58	-----	-----	134	1,210	99	2.4	-----	-----	2,120	721	-----	-----	-----
K5	11	2.1	172	52	383	17	125	1,220	90	2.4	6.2	-----	2,030	643	55	2,380	7.3

TABLE 6.—*Records of wells and springs and chemical analyses in the Great Plains region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
South Dakota—Continued													
Q1	Sec. 24, T. 21 N., R. 24 E.	Corson	26	36	Alluvium	21.79				D	5/13/47	48	U. S. Geol. Survey.
Q2	Sec. 21, T. 7 S., R. 8 E.	Fall River	88	48	Quaternary	63.79	4/19/46			D, S	9/17/46		Do.
Q3	Sec. 17, T. 114 N., R. 63 W.	Spink	85		Pleistocene	36.02	7/11/51		104	N	7/10/51	50	Do.
Texas													
P1	9 miles SW. from Fort Stockton.	Pecos	1,550	10	Rustler					Irr	4/11/46		U. S. Geol. Survey.
K1	14.5 miles SE. of Tahoka.	Lynn	27	16	Edwards	7.5	8/9/49		810	PS	5/17/50		Do.
T1	Plains	Yoakum	128	12	Ogallala	72	1940		150	PS	10/30/44		Do.
Q1	1.5 miles SW. of Balmorhea.	Reeves	20		Gravel	13.91	10/31/30			D, S	11/13/31		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
South Dakota—Continued																	
Q1	11	0.8	99	39	257	12	519	514	13	0.4	2	0.24	1,210	407	57	1,740	7.9
Q2		.10	228	96	616		378	1,810	40	.9	62	.3	3,260	964	58		7.9
Q3		9.0	241	95	63	15	504	685	9.5				1,470	994	12	1,760	7.5
Texas																	
P1			327	83	184		149	960	308		0.5		1,940	1,160	26		
K1	34		48	128	275		554	436	128		38	1.5	1,380	646	45	2,060	8.1
T1	42	0.08	114	111	179	34	241	779	102	5.5	8.0		1,490	741		2,160	7.7
Q1			306	86	574		330	881	835					1,120			

TABLE 6.—*Records of wells and springs and chemical analyses in the Great Plains region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
						Wyoming							
K1	Sec. 17, T. 21 N., R. 62 W.	Goshen	117	5	Lance	30	11/6/51			D, S	11/6/51	54	U. S. Geol. Survey, Quality of Water Branch.
K2	Sec. 10, T. 43 N., R. 81 W.	Johnson	400	4	Parkman	10	8/19/50			S	8/19/50	51	Do.
K3	Sec. 21, T. 50 N., R. 72 W.	Campbell	3,446	12	Fox Hills or Lance.				90	Ind	5/31/49	112	Do.
T1	Sec. 22, T. 24 N., R. 62 W.	Goshen	83	4	Chadron	23	8/15/50		2	S	8/15/50		Do.
T2	Sec. 27, T. 33 N., R. 73 W.	Converse	92	10	Wasatch	9	8/17/50		5–10	D, S	8/17/50	50	Do.
T3	Sec. 32, T. 51 N., R. 72 W.	Campbell	433	8–6	do	82	9/18/50	25		D	9/18/50	56	Do.
Q1	Sec. 12, T. 28 N., R. 68 W.	Platte	28	6	Alluvium	12	9/15/49		25	D	9/15/49	53	Do.
Q2	Sec. 11, T. 43 N., R. 79 W.	Johnson	12.5	6	do	5.44	9/22/50			S	9/22/50	54	Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Wyoming																	
K1	17	0.03	9.5	3.3	429	7.0	[4] 458	405	113	0.5	39	0.21	1,250	37	95	1,940	8.6
K2	7.1	12	55	8.9	692	2.2	220	1,430	36	.3	2.5	.0	2,340	174	90	3,120	7.8
K3	20	.01	5.0	1.0	473	5.2	[5] 1,220	2.0	31	8.0	4.3	.26	1,150	16	98	1,830	8.2
T1	50	--	16	4.9	324	11	353	298	99	.6	14	.2	996	60	91	1,460	7.8
T2	64	1.8	25	1.0	309	16	616	205	32	.7	18	.45	974	67	89	1,450	8.1
T3	--	45	--	--	--	--	424	--	5.5	.4	--	--	2,760	1,390	--	3,040	7.3
Q1	19	2.8	259	49	84	5.6	286	252	27	.2	622	.1	1,460	848	18	2,010	7.6
Q2	14	.14	395	197	355	13	385	1,820	207	.5	133	.2	3,320	1,790	30	3,780	7.4

[1] Includes equivalent of 12 ppm CO_3.
[2] Includes equivalent of 14 ppm CO_3.
[3] Includes equivalent of 35 ppm CO_3.
[4] Includes equivalent of 22 ppm CO_3.
[5] Includes equivalent of 18 ppm CO_3.

TABLE 7.—*Records of wells and springs and chemical analyses in the Western Mountain region*

[Use of water: D, domestic; S, stock; Ind, industrial; Irr, irrigation; PS, public supply; N, none. Analyses in parts per million, except as indicated]

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level: Below land surface (feet)	Reported water level: Date of measurement	Yield (gallons per minute): Flow	Yield (gallons per minute): Pump	Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
Arizona													
M1	T. 32 N., R. 7 E. (approx.)	Coconino	Spring		Redwall			92 cfs		N	6/14/50	69	U. S. Geol. Survey.
P1	Sec. 16, T. 18 N., R. 19 E.	Navajo	500	10	Coconino	84.9	11/24/53		480	D	11/24/53	63	Do.
T1	Sec. 25 or 27, T. 17 N., R. 22 E.	do	400		Moenkopi	120			20–25	S	12/4/33		Do.
K1	Navajo Reservation.	Apache	688	6-5/8	Dakota	162.0	6/29/35		3	D, S	5/5/50		Do.
QT1	Sec. 28, T. 4 S., R. 23 E.	Graham	90	16	Valley fill	69.55	12/3/52		200	Irr	8/28/52	70	Do.
QT2	Sec. 27, T. 16 S., R. 20 E.	Cochise	73	10	do	57.21	9/9/52			Irr	9/9/52	68	Do.
QT3	Sec. 13, T. 5 S., R. 8 E.	Pinal	204	20	do	73	March 1941		1,000	Irr	9/25/41	74	Do.
QT4	Sec. 31, T. 1 N., R. 4 W.	Maricopa	250	20	do	73.35	10/29/53		2,700	Irr	2/7/46	78	Do.
QT5	Sec. 8, T. 5 S., R. 4 W.	do	135	14	do	36.0	March 1948		1,030	Irr	4/23/53	78	Do.
QT6	Sec. 31, T. 8 S., R. 18 W.	Yuma	123	20	do	34.68	1/30/46		1,375	Irr	1/30/46	76	Do.
QT7	Sec. 19, T. 23 S., R. 27 E.	Cochise	80	6	do	35	May 1952			S	5/28/52	80	Do.
QT8	Sec. 13, T. 16 N., R. 13 W.	Mohave	140	12	do	9.03	4/11/52			D	4/11/52		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Arizona																	
M1	19	0.01	264	79	513	23	964	147	815	0.2	3.2	0.1	2,340	984	52	3,940	6.5
P1	12	------	64	32	569		241	186	805	.6	.9	------	1,790	291	81	3,180	------
R1	------	.73	176	47	2,160		330	294	3,360	.1	------	------	6,200	633	------	------	------
K1	8.7	------	5.5	2.3	525		372	777	27	3.9	1.3	------	1,530	23	98	2,260	------
QT1	36	------	936	161	498		306	870	2,050	.1	40	------	4,740	3,000	27	7,410	------
QT2	33	------	118	38	275		426	579	40	2.7	42	------	1,340	450	57	1,860	------
QT3	------	------	162	57	288		183	381	510	------	------	------	1,490	639	50	2,520	------
QT4	------	------	348	128	523		145	521	1,240	1.0	149	.9	2,980	1,400	45	4,960	------
QT5	37	------	307	82	1,100		327	575	1,820	2.5	82	3.2	4,180	1,100	69	6,860	------
QT6	------	------	388	212	926		264	426	2,260	1.3	3.8	.2	4,350	1,840	52	7,380	------
QT7	26	------	380	212	766		249	1,140	1,790	1.0	4.2	------	4,640	1,820	54	7,130	------
QT8	22	------	19	9.9	842		191	309	1,010	4.8	2.9	------	2,310	88	95	4,030	------

TABLE 7.—*Records of wells and springs and chemical analyses in the Western Mountain region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
California													
QT1	Sec. 23, T. 13 N., R. 3 E.[1]	Sutter	[2] 100	12	Valley fill	12			1,000	Irr	July 1949		U. S. Geol. Survey.
QT2	Sec. 26, T. 4 N., R. 3 E.[1]	Sacramento	211	12	do	40			500–1,000	PS	7/10/31		Do.
QT3	Sec. 1, T. 6 S., R. 9 E.[1]	Stanislaus	204	16	do	10			1,000–1,500	Drainage	9/15/50		Do.
QT4	Sec. 9, T. 13 S., R. 13 E.[1]	Fresno	1,484	18	do	250			1,500	Irr	9/11/51	88	Do.
QT5	Sec. 36, T. 19 S., R. 17 E.[1]	do	1,529	16	do	250			1,500	Irr	9/18/51	82	Do.
QT6	Sec. 9, T. 28 S., R. 22 E.[1]	Kern	1,300		do	45			500	Obsolete	4/12/52		Do.
QT7	Sec. 28, T. 4 N., R. 24 W.[3]	Santa Barbara	367	10	do	14	July 1947		270	N	5/19/51		Do.
QT8	Sec. 12, T. 10 N., R. 27 W.[3]	do	310	14	do	31.22	11/6/42		1,991	Irr	8/5/53	65	Do.
QT9	Sec. 35, T. 7 N., R. 34 W.[3]	do	144	16	do	18	1934		600	Irr	1935		Do.
QT10	T. 15 S., R. 45 E.[1]	Inyo			do								Do.
QT11	Sec. 19, T. 11 N., R. 4 W.[3]	San Bernardino.	210	12	do					D, S			Do.
QT12	Sec. 20, T. 5 N., R. 1 E.[3]	do	72	8	do					D			Do.
QT13	Sec. 35, T. 9 S., R. 9 E.[3]	Imperial			do								Do.
QT14	Sec. 21, T. 15 S., R. 15 E.[3]	do	643	2	do	14.5		12		D, S			Do.

See footnotes at end of table.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
California																	
QT1			237	204	154		336	16	1,030		Tr		[4] 2,000		19	3,390	
QT2			76	54	445		244	4.8	830			1.4	[4] 1,800		70	2,970	
QT3	41	1.6	103	24	251		259	22	472			.2	1,130		61		8.0
QT4	27		94	29	975	50	145	520	1,330			2.5	3,060		85	5,140	8.3
QT5	30		63	54	160	2.6	160	505	57		1.3	1.1	953		48	1,340	8.5
QT6			620	0.9	870	3.6	23	1,700	1,300			2.7	4,700		55	6,400	
QT7			153	56	128	4	425	232	216	0.3		.29	1,214	607			7.8
QT8	32		377	160	220	5.8	228	1,740	38		15	.39	2,700	1,600		3,030	
QT9			184	99	230		452	543	302				1,580	866			
QT10			16	38	598		765	458	290	1.1		4.2	2,250			3,640	8.1
QT11			158	25	625	13.4	166	241	1,060		14		2,310				7.4
QT12			158	31	653		85	237	1,170	1.0	4.8	.85	2,650		73		
QT13			492	169	3,010		1,680	40	5,010			22	10,410				
QT14			42	42	717		[5] 531	334	768	1.1		2.7	2,490			4,300	

See footnotes at end of table.

TABLE 7.—*Records of wells and springs and chemical analyses in the Western Mountain region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
						Idaho							
PAL1	Sec. 10, T. 16 S., R. 36 E.	Oneida	Spring		Limestone			8,100		Irr	10/17/47	89	U. S. Geol. Survey.
QT1	Sec. 28, T. 14 S., R. 36 E.	do	220	14		24.0	10/21/44		1,110	Irr	8/28/47	56	Do.
QT2	Sec. 25, T. 15 S., R. 21 E.	Cassia	2,435		Coarse gravel			490		N	March 1922	107	Do.
QT3	Sec. 11, T. 3 N., R. 2 E.	Ada	67	8					350	D	8/29/50	56	Idaho Dept. of Pub. Health.
						Nevada							
QT1	Sec. 4, T. 26 N., R. 20 E.	Washoe			Valley fill						7/30/46		Univ. Nev. Dept. of Food and Drugs.
QT2	Sec. 32, T. 29 N., 36 E.	Pershing	76	8	do	9.73	11/10/47			S	10/30/47		Univ. Nev. Agr. Expt. Sta.
QT3	Sec. 19, T. 20 N., R. 25 E.	Lyon	57	6	Pleistocene	8	6/15/53		5	N	9/3/47		Univ. Nev. Dept. of Food and Drugs.
QT4	Sec. 25, T. 13 N., R. 23 E.	Douglas	600	14	Valley fill	+23	3/31/48			Irr	6/13/50	82	U. S. Geol. Survey.
QT5	Sec. 10, T. 35 N., R. 32 E.	Humboldt	500		do	60			200	Railroad	9/3/36		Western Pacific R. R. Co.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Idaho																	
PAL1	34	----	234	122	1,570		588	66	2,780	----	30	----	5,130	1,090	----	8,760	----
QT1	32	----	101	31	261		506	20	360	----	5.1	----	1,060	380	----	1,860	----
QT2	64	0.07	4	1.2	106		159	22	17	----	Tr	----	344	15	90	----	----
QT3	43	.3	145	20	249		204	645	51	4.2	7.8	----	1,240	466	----	----	7.1
Nevada																	
QT1	----	----	54	13	780	----	524	378	749	----	----	----	----	----	90	3,570	----
QT2	----	----	----	----	----	----	390	----	858	----	----	----	----	----	----	3,680	----
QT3	90	Tr	242	75	984		383	2,400	170	----	----	----	4,180	----	----	----	----
QT4	86	----	5	----	71		162	22	7	1.0	0.2	0.16	----	14	92	307	----
QT5	----	----	7	4	262		357	120	133	----	----	----	----	----	94	1,260	----

TABLE 7.—*Records of wells and springs and chemical analyses in the Western Mountain region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
Nevada—Continued													
QT6	T. 33 N., R. 52 E., Carlin.	Elko			Valley fill						3/1/50		Southern Pacific R. R. Co.
QT7	30 miles N. of Austin.	Lander	16		do						1/25/43		Univ. Nev. Dept. of Food and Drugs.
QT8	Sec. 5, T. 34 N., R. 69 E.	Elko									1/29/43		U. S. Geol. Survey.
QT9	Sec. 34, T. 8 N., R. 34 E.	Mineral			do						5/28/46		Univ. Nev. Dept. of Food and Drugs.
QT10	Sec. 20, T. 1 S., R. 36 E.	Esmeralda	258	8	do			175		S, Irr	11/29/49	77	Do.
QT11	Sec. 8, T. 2 S., R. 68 E.	Lincoln			do	10.6	9/16/53		300		6/29/49		U. S. Geol. Survey.
QT12	Sec. 19, T. 13 S., R. 71 E.	Clark	98	5	do	22.4	4/20/49		15	D, Irr	4/20/49	68	Do.
QT13	Sec. 28, T. 21 S., R. 62 E.	do		8	do			1			9/20/12	72	
QT14	4 miles E. of Searchlight.	do			do						10/20/42		Univ. Nev. Dept. of Food and Drugs.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Nevada—Continued																	
QT6			82	26	179		338	119	217						55	1,350	
QT7			60	17	642		66	157	95						86	2,560	
QT8			109	41	742		348	33	1,230						79	3,500	
QT9			42	15	312		178	558	77						80	1,700	
QT10	112	0.17	49	9.6	268		614	120	74	4.3		1.0	940	162	78	1,340	7.0
QT11	85		22	24	795		1,130	507	282	12		1.0	2,280	154	92	3,390	
QT12	25	.03	94	50	232		228	395	245	.4	0.8	.3	1,150	440	53	1,830	
QT13			296	163	297		197	1,230	415						31	3,740	
QT14			337	108	18		183	1,000	61						3	2,440	

TABLE 7.—*Records of wells and springs and chemical analyses in the Western Mountain region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
New Mexico													
QT1	Sec. 11, T. 18 S., R. 9 E	Otero	50		Valley fill	36	September 1911.			D	September 1911.		U. S. Geol. Survey.
QT2	Sec. 34, T. 1 N., R. 1 W.	Socorro			Santa Fe	118.5	1/15/50			S	1/18/50		Do.
QT3	Sec. 11, T. 19 S., R. 4 W.	Dona Ana	74	10	Valley fill	11.92	11/23/46				4/17/47		Do.
QT4	Sec. 8, T. 23 S., R. 2 E.	do	300	13	do	185.09	4/15/47				5/6/47		Do.
QT5	Sec. 25, T. 28 S., R. 8 W.	Luna	529	14	do	18			370	Irr	8/8/52		Do.
QT6	Sec. 7, T. 25 S., R. 19 W.	Hidalgo	95	18	Sand and gravel.	31.7				Irr	4/28/49	210	Do.
Oregon													
QT1	Sec. 17, T. 1 S., R. 1 W.	Washington	1,374	8-6	Tertiary volcanic rocks.					N			U. S. Geol. Survey.
QT2	Sec. 10, T. 12 S., R. 5 W.	Benton	122	3	Tertiary shale.					N	10/12/28	54	Do.
QT3	Sec. 20, T. 33 S., R. 26 E.	Lake	600	6	Old valley fill.	40	8/13/48			S	8/13/48		Do.
QT4	Sec. 24, T. 35 S., R. 3 W.	Jackson	260	9	Umpqua	Flow	1/25/52		30	Irr	1/25/52		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
New Mexico																	
QT1	------	------	204	179	286		------	1,180	321	------	------	------	2,720	1,240	33	------	------
QT2	54	------	236	64	598		197	1,050	635	0.7	0.7	------	2,740	852	60	3,950	------
QT3	------	------	267	53	259		295	615	400	.3	1.5	------	1,740	884	39	2,640	------
QT4	------	------	124	32	94		232	227	153	.3	2.6	------	747	441	32	1,210	------
QT5	66	91	5.2	3.6	479		423	233	128	9.0	1.6	------	1,060	28	97	1,620	------
QT6	141	------	19	1.2	329		181	460	78	11	.9	------	1,130	52	93	1,540	------
Oregon																	
QT1	45	------	222	48	------	------	63	------	960	0.1	------	------	1,930	750	------	3,140	------
QT2	19	0.86	4,630	22	2,020	18	20	3.5	11,400	------	------	------	18,100	11,700	28	------	------
QT3	67	.07	42	46	402	24	748	226	246	.5	1.2	3.5	1,420	294	73	2,190	------
QT4	30	------	7.8	3.0	344	2.4	122	------	468	10	------	18	978	32	96	1,710	8.3

TABLE 7.—*Records of wells and springs and chemical analyses in the Western Mountain region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
Oregon—Continued													
QT5	Sec. 15, T. 9 S., R. 40 E.	Baker	740	14	Basalt	18	3/24/49		2,200	Irr	June 1947		U. S. Geol. Survey.
QT6	Sec. 33, T. 38 S., R. 20 E.	Lake	400		Tertiary volcanic rocks.	16	7/2/48	120		D	6/30/48	182	Do.
QT7	Sec. 7, T. 24 S., R. 32½ E.	Harney	41	6	Valley fill					S	5/13/32		Do.
Texas													
P1	1 mile E. from Dell City.	Hudspeth	187	18	Bone Spring	47.7	2/3/49		2,200	Irr	8/5/48		U. S. Geol. Survey.
QT1	City of El Paso	El Paso	52	20	Valley fill	8	April 1933		1,000	Drainage	9/28/37		Do.
QT2	Do	do	299	24	do	59.50	8/28/35		1,000	Ind	3/13/36	75	Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Oregon—Continued																	
QT5	------	------	12	7.6	175	9.8	476	12	14	------	------	1.9	------	61	84	600	8.1
QT6	95	0.07	12	2.6	209	5.8	72	259	119	4.7	0.1	6.7	743	40	90	1,100	8.1
QT7	------	------	106	129	871		1,150	1,170	375	------	------	------	3,230	794	71	------	------
Texas																	
P1	19	------	251	97	89		248	798	130	------	2.2	------	1,510	1,030	16	2,050	------
QT1	28	0.45	146	25	211	14	328	348	217	------	2.9	------	1,170	468	------	------	------
QT2	------	------	339	143	1,230		284	579	2,310	------	5.8	------	4,740	1,430	------	------	------

TABLE 7.—*Records of wells and springs and chemical analyses in the Western Mountain region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
						Utah							
QT1	Sec. 17, T. 28 S., R. 10 W.	Beaver	92	14	Valley fill	9.19	12/9/53		455		6/19/50		U. S. Geol. Survey.
QT2	T. 13 S., R. 1 E., Nephi.	Juab			do						8/29/51		Do.
QT3	Sec. 26, T. 1 N., R. 11 W.	Tooele	175	6	do	140	2/4/53			N	3/3/53		Do.
QT4	Sec. 27, T. 2 N., R. 1 W.	Davis	500	3	do	+31.9	3/13/36	120		D, Irr	5/9/47	67	Do.
QT5	Sec. 3, T. 35 S., R. 15 W.	Iron	350	16	do	15.06	12/6/53		1,150	Irr	8/22/49	55	Do.
QT6	Sec. 29, T. 21 S., R. 5W.	Millard	380	6	do	33.2	2/28/41	290		Irr	4/8/43	63	Do.
QT7	T. 28 S, R. 11 E., Hanksville.	Wayne			do					D	3/16/47		Do.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Utah																	
QT1	52		333	96	203		226	647	572		2.3		2,020	1,230	26	3,060	
QT2			86	32	711		293	165	1,050				2,190	346	82	2,970	
QT3			539	377			114	147	6,100				10,300	2,900		16,000	
QT4	8.2		66	20	331		125	3.3	610		0		1,100	246	74	2,100	
QT5	68		183	92	206		208	628	318	0.3	11		1,610	835	35	2,330	
QT6			181	51	171		302	362	287	.1	3.0	0.5	1,200	661	36	1,780	
QT7			124	62	1,020		179	257	1,680	.8			3,230	564	80	5,630	

TABLE 7.—*Records of wells and springs and chemical analyses in the Western Mountain region*—Continued

Source no. on pl. 2	Well or spring location	County	Depth of well (feet)	Diameter of well (inches)	Water-bearing unit	Reported water level		Yield (gallons per minute)		Use of water	Date of collection of sample	Temperature (°F.)	Source of analysis
						Below land surface (feet)	Date of measurement	Flow	Pump				
Washington													
QT1	Sec. 19, T. 24 N., R. 4 E.	King	631	(?)-4	Blakeley	11.18	9/16/53			N	5/3/49		
QT2	Sec. 22, T. 28 N., R. 2 E.	Kitsap	109	6	Pleistocene	76	August 1948.		50	Fire	6/3/49		
QT3	T. 13 N, R. 34 E., Kahlotus.	Franklin			Basalt(?)					Railroad			
QT4	Sec. 8, T. 18 N., R. 25 E.	Grant	134	6	Ringold	100				N	9/8/16		
Wyoming													
M1	Sec. 16, T. 43 N., R. 82 W.	Johnson	1,925		Madison			500		N	8/19/50		U. S. Geol. Survey.
K1	Sec. 15, T. 16 N., R. 74W.	Albany	1,035		Dakota	107.78					6/24/48		Do.
K2	Sec. 1, T. 49 N., R. 90 W.	Big Horn	200		Cloverly						9/11/47		Do.
QT1	Sec. 10, T. 2 N., R. 4 E.[6]	Fremont	350	6	Wind River					D, S	10/20/48	52	Do.

See footnotes at end of table.

Source no. on pl. 2	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Washington																	
QT1	55	10	84	119	445		----	119	990	----	----	----	2,360	732	----	----	7.2
QT2	42	Tr	56	48	283	----	317	1.0	489	----	0	----	1,230	335	----	----	6.8
QT3	----	----	----	----	329		1,010	114	74	----	----	----	[7] 1,200	335	----	----	----
QT4	72	.10	259	155		6.3	540	797	14	----	6.0	----	1,750	1,280	----	----	----
Wyoming																	
M1	14	0.16	430	129	1,830	29	116	1,500	2,830	1.6	2.7	0.3	6,820	1,600	71	9,970	6.7
K1	14	----	17	15	1,600	7.6	1,530	1,090	805	2.8	0	.90	4,320	104	97	6,260	7.6
K2	5.0	----	17	8.5	827	12	270	1,550	35	1.0	4.9	.41	2,590	78	95	3,540	7.6
QT1	15	.6	5.1	96	1,180	10	324	3,460	174	.9	4.8	.82	5,620	1,620	60	6,590	7.6

[1] Mount Diablo base and meridian.
[2] Average depth of wells in vicinity.
[3] San Bernardino base and meridian.
[4] Estimated from specific conductance.
[5] Includes equivalent of 33 ppm CO_3.
[6] Wind River base and meridian.
[7] Approximate.

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