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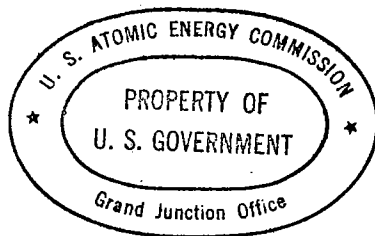
GEOHYDROLOGIC DATA IN THE NAVAJO AND HOPI INDIAN RESERVATIONS, ARIZONA, NEW MEXICO, AND UTAH

PART II

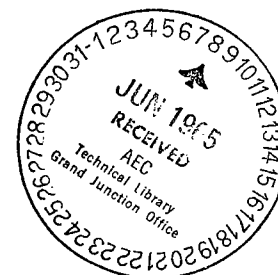
SELECTED CHEMICAL ANALYSES OF THE GROUND WATER

By L. R. Kister and J. L. Hatchett

United States Department of the Interior, Geological Survey
Prepared in cooperation with the Bureau of Indian Affairs
and the Navajo Tribe



Tucson, Arizona
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PART II
SELECTED CHEMICAL ANALYSES OF THE GROUND WATER

By L. R. Klster and J. L. Hatchett

Introduction

The geohydrologic data in this report consist of information about the chemical quality of the ground water in the Navajo and Hopi Indian Reservations in northeastern Arizona, northwestern New Mexico, and southeastern Utah (fig. 1). Chemical analyses were made of water from more than half of the 2,338 drilled wells, dug wells, and springs inventoried in the area before 1957. The data were compiled to provide information about the chemical quality of the ground water from 1,272 selected wells and springs, which will supplement the information contained in the forthcoming comprehensive report on the ground-water resources and geology of the reservations. The comprehensive report is to be published as a U.S. Geological Survey Professional Paper.

Purpose, Scope, and Organization of the Report

In 1946 the U.S. Geological Survey was asked by the Bureau of Indian Affairs to make a series of hydrologic investigations to help alleviate the water shortage at several localities. Later, in 1950, the U.S. Geological Survey in cooperation with the Bureau of Indian Affairs began a comprehensive investigation of the geology and ground-water resources of the Navajo and Hopi Indian Reservations, which occupy parts of northeastern Arizona, northwestern New Mexico, and southeastern Utah (fig. 1). The principal objectives of the investigation were as follows: (1) To determine the feasibility of developing ground-water supplies for stock, domestic, institutional, and industrial use in particular areas and at several-hundred well sites scattered throughout the reservations and in adjoining areas owned by the Navajo Tribe; (2) to compile an inventory of the existing ground-water supplies; (3) to make a comprehensive investigation of the geology and determine the hydrogeologic factors that control the occurrence and movement of ground water; and (4) to appraise the water potential for future development.

The basic geohydrologic data of the Navajo and Hopi Indian Reservations are reproduced separately in sections as Parts I, II, III, and IV of Arizona State Land Department Water Resources Report No. 12. Part I contains a compilation of the records of drilled wells, dug wells, and springs that were inventoried before 1957. Part II (this report) is a compilation of selected chemical analyses from the wells and springs that were sampled. Part III contains selected drillers' logs, lithologic logs, and stratigraphic sections. Part IV consists only of maps of the reservations showing the locations of the wells and springs listed in Parts I, II, and III. Information about other wells that were drilled after the completion of this study is available in the open files of the Geological Survey Ground Water Branch offices in Tucson and Holbrook, Arizona.

Personnel

The collection, compilation, and analysis of the data contained in this report were under the general supervision of A. N. Sayre, former chief, and O. M. Hackett, present chief, of the Ground Water Branch; and S. F. Turner, L. C. Halpenny, and J. W. Harshbarger, former district supervisors, and P. E. Dennis, present district supervisor, of the Ground Water Branch in Arizona. The collection of the data was begun under the direct supervision of Mr. Halpenny and was continued by Mr. Harshbarger.

Substantial contributions, including field inventory of the water developments, collection of water samples for chemical analysis, laboratory analysis of the samples, and geological correlations, were made by other personnel of the Navajo Project and the U.S. Geological Survey Quality of Water Branch, Albuquerque, New Mexico. The chemical analyses were done by A. M. Diaz, J. L. Hatchett, E. F. Williams, I. M. Gutierrez, J. P. Beverage, and H. E. Koester, under the direct supervision of J. D. Hem and J. M. Stow, former and present district chemists respectively of the Albuquerque district of the Quality of Water Branch. The water samples taken for chemical analysis were collected principally by J. P. Akers, J. T. Callahan, G. E. Davis, S. E. Galloway, E. L. Gillespie, H. A. Whitkind, W. F. Hardt, J. H. Irwin, C. A. Repenning, P. R. Stevens, and M. E. Cooley. The geological correlations were made by J. P. Akers and M. E. Cooley. The chemical analyses were typed by Mrs. Ruth Blubaugh and Mrs. Carol Jenkins.

Acknowledgments

The Geological Survey is grateful for the assistance, cooperation, and information given by the late J. J. Schwartz, former head of the Bureau of Indian Affairs water-development program for the Navajo Indians; by M. H. Miller, Bureau of Indian Affairs engineer; by Buster Kingsley, Bureau of Indian Affairs supervisor of the Hopi Indians; and by other personnel of the Bureau of Indian Affairs and the Navajo and Hopi Indian Tribes connected with the well-development program. The hydrologic information given the Geological Survey by the El Paso Natural Gas Co. and various religious missions and trading posts is greatly appreciated. Acknowledgment is due the many water-well drillers who conscientiously collected water samples during the drilling of new wells.

Land-Net System and Location of Wells and Springs

The Navajo and Hopi Indian Reservations are in the south-central section of the Colorado Plateau. The Navajo Indian Reservation occupies parts of Apache, Navajo, and Coconino Counties in

northeastern Arizona, San Juan and McKinley Counties in northwestern New Mexico, and San Juan County in southeastern Utah (fig. 1). The Hopi Indian Reservation is within the central part of the Navajo Indian Reservation in Arizona. The reservations comprise an area of about 25,000 square miles, which is about three times the size of the State of New Jersey.

The Navajo Indian Reservation is divided into 17 administrative districts, numbered 1 to 5 and 7 to 18, and the Hopi Indian Reservation comprises district 6 (fig. 1). District 19 is east of the reservation boundary in New Mexico. The reservations and adjoining area were not mapped in detail at the time of study, but 15-minute planimetric maps of the area had been made from aerial photographs. These maps were used for the geologic and hydrologic base maps and are arbitrarily numbered from 1 to 151, starting in the upper-right corner of the area and numbering consecutively in rows from right to left.

The types of ground-water developments sampled for chemical analysis are principally drilled wells, dug wells, and springs. The type of development and specific location of each are listed only in Part I, "Records of Ground-Water Supplies." The wells and springs are arranged in the numerical order of the 18 administrative districts of the Bureau of Indian Affairs and in accordance with the 15-minute quadrangles within each district. No data are included in this report from district 19, which is outside the reservation boundary in New Mexico.

Quality of the Ground Water

The chemical composition of natural ground water is influenced by its geologic environment, and this relationship between the formation and the chemical composition of its contained water was used by personnel as an aid in identifying strata yielding water to a particular well. The ground water in most of the area is classified as fair to poor and ranges from 500 to 2,000 ppm (parts per million) in dissolved-solids content. Locally, the ground water contains more than 4,000 ppm dissolved solids, but in other areas some water of excellent quality contains less than 250 ppm.

The water-bearing strata are referred to by their standard geologic names and are divided into formations and members. Some aquifers consist of combinations of formations and/or members. Figure 2 lists the stratigraphic names of the rocks that yield water to wells and springs in the Navajo and Hopi Indian Reservations.

There are quality differences from one formation to another and also within the same formation. For example, in some places water from the Coconino Sandstone is too highly mineralized for use. In other places, especially in recharge areas, water of excellent quality is available from the Coconino. In general, the great variation in the quality of the water from the several formations in the Navajo country is caused by the lithologic differences of the rocks, interformational movement between the water-bearing units, and ion exchange along the direction of ground-water movement.

The principal aquifer or aquifers that yield ground water to a development are shown in the "Remarks" column. The depths at which samples of water were taken of stratigraphic units other than the principal aquifer also are shown in this column. Samples obtained during the final bailing or pumping test of the well are indicated by the symbol "D," and those obtained before the well had been drilled to its total depth are indicated by the symbol "ID." Samples collected from a storage tank at the well are indicated by "T."

Expression of Results

The chemical analyses list the mineral constituents of the water in parts per million. Parts per million is the measure of the weight of one part of dissolved substance in one million parts of solution; 1 milligram of solute in 1 kilogram of solution. Perhaps some people may be more familiar with data expressed in percentage values, which is the same as parts per hundred. However, the use of percentage values for water analyses involves cumbersome decimals. To convert parts per million to percentage values, multiply parts per million by 10^{-4} or 0.0001. One percent is equivalent to 10,000 ppm. Hardness is often expressed as grains per U.S. gallon. To convert, multiply parts per million hardness by 0.0584.

Some techniques of interpretation require that chemical data be expressed in equivalents per million. Equivalents per million is a unit for expressing the concentration of chemical constituents in terms of the interreacting values of the electrically charged particles, or ions, in solution. One equivalent per million of a positively charged ion will react with one equivalent per million of a negatively charged ion. Parts per million is converted to equivalents per million by multiplying by the reciprocal of the combining weight of the ion as shown below.

Cations	Factor	Anions	Factor
Calcium (Ca^{++}).....	0.04990	Carbonate (CO_3^{--}).....	0.03333
Magnesium (Mg^{++})....	.08226	Bicarbonate (HCO_3^-)....	.01639
Sodium (Na^+).....	.04350	Sulfate (SO_4^{--}).....	.02082
Potassium (K^+).....	.02557	Chloride (Cl^-).....	.02821
		Fluoride (F^-).....	.05264
		Nitrate (NO_3^-).....	.01613

Source and Significance of Chemical Constituents in Water

Pure water probably does not occur naturally and the chemical composition of natural water is variable. Even the purest form—rainwater—contains dissolved gases and small amounts of sodium, chloride, and sulfate ions. The presence of dissolved gases, mainly carbon dioxide, helps the water to extract soluble material from rocks and unconsolidated deposits. The source and significance of the common minerals in ground water in the Navajo and Hopi Indian Reservations are discussed in the following paragraphs.

Silica (SiO_2). -- Silicon is found as silica in quartz, chert, and chalcedony or as silicates in feldspar and other minerals. Most of the silica in ordinary water is probably colloidal and does not affect the ionic balance in a water analysis. However, at high pH the silica may be present in the ionized state as calcium silicate. Colloidal silica is a good carrier of other material that may precipitate from solution. Waters high in silica form an exceedingly hard scale on porcelain fixtures, boilers, or other surfaces with which they may come in contact. The ground water of the reservations commonly has more than 15 ppm of silica and the maximum amount analyzed was 63 ppm. High silica content seems to be concentrated in water obtained from the alluvium, Chuska Sandstone, Bidahochi Formation, and volcanic rocks.

Iron (Fe).--Iron is available from practically all rocks and ground water may contain several parts per million. Upon exposure to air, the iron in water may oxidize and settle out as insoluble ferric hydroxide. Excessive amounts of iron cause an objectionable taste in water and will stain porcelain fixtures and fabrics washed in the water. Iron was recorded in only a few of the chemical analyses and it is listed in the column entitled "Remarks."

Calcium (Ca) and magnesium (Mg).--Calcium is present in all ground and surface waters of the reservations and is commonly the major cation present. Weathered limestone, dolomite, and rocks cemented by calcium carbonate yield calcium to water. The principal minerals of sedimentary rocks that yield calcium to ground water are gypsum ($\text{CaSO}_4 + 2\text{H}_2\text{O}$), calcite (CaCO_3), and dolomite ($\text{CaMg}(\text{CO}_3)_2$).

Magnesium is abundant in the carbonate rocks (dolomite) and is a typical constituent of some of the silicate minerals, such as olivine, pyroxenes, and micas, which are present as accessory minerals in sedimentary and volcanic rocks of the area. Magnesium usually is present in water in smaller amounts than calcium, but once in solution magnesium does not precipitate as readily as calcium.

The solubility of both calcium and magnesium is increased by the presence of carbon dioxide in the water.

Sodium (Na) and potassium (K).--All natural waters contain sodium and potassium, which are derived primarily from the weathering of feldspars and evaporites or secondarily from ion-exchange reactions between water and clay materials as ground water moves through sedimentary rocks. If large amounts of both ions are dissolved in the water, sodium will normally be present in much greater quantities than potassium. Sodium and potassium go easily into solution, but potassium is soon adsorbed by clays or used in the formation of mica-like minerals. High percentages of sodium give the water the property of softness, which is desirable for domestic supplies but undesirable for irrigation waters. Generally, in this report sodium and potassium are computed as sodium except for those analyses that indicate a significant amount of potassium.

Bicarbonate (HCO_3) and carbonate (CO_3).--Bicarbonate is the principal negative ion (anion) present in the ground water of the reservations. Ground waters that are in contact only with granitic rocks usually contain less than 50 ppm of bicarbonate, whereas the waters in contact with carbonate rocks or calcareous material of sedimentary rocks contain as much as 1,900 ppm.

Carbonate is present in relatively few natural waters. Theoretically, carbonate may be present only in water with a pH of more than 8.2. Some ground waters contain carbonate and some waters that have been treated with lime also contain carbonate.

Alkalinity in water is caused primarily by the presence of bicarbonates and carbonates, although other ions may also cause alkalinity. The property of alkalinity in water is its ability to neutralize acid.

Sulfate (SO_4).--The sulfate ion is produced by oxidation during the weathering of sulfide minerals and it is freed also by the weathering of minerals containing sulfate. Sulfate salts of calcium and magnesium cause the formation of hard scale in boilers. The presence of calcium sulfate (gypsum) in

irrigation water is desirable because of the favorable reactions with the soil. In fact, gypsum is often added to irrigation water or soil to prevent formation of "black alkali" or to reclaim alkali lands. Large concentrations of the sulfate ion can be tolerated by stock, unless it is accompanied by a large chloride-ion content. However, magnesium sulfate (Epsom salts) is objectionable in public supplies because of the laxative effect. The sulfate ion is the principal contaminating agent of water in the area.

Chloride (Cl).--Chloride is present in all natural water and is the most abundant of the halogen group of elements. Sedimentary rocks, especially those containing evaporite minerals, are an important source of chloride, which also occurs as the predominant ion in sea water. Chloride, therefore, may be found in porous rocks inundated by the sea. Within the Coconino Sandstone and sandstone aquifers of the Mesaverde Group, contamination by chloride occurs from intraformational leakage and by downdip movement of the ground water within an aquifer. Sodium is usually associated with large concentrations of chloride in water. Concentrations of more than 200 to 300 ppm of chloride impart a salty taste to the water.

Fluoride (F).--Fluoride is second to chloride as the most abundant of all the halogens and is usually present in igneous rocks as fluorite. Fluorite is resistant to weathering, but its solubility increases in the presence of carbon dioxide. Fluoride is present in evaporites, in clay and common soil minerals, and in volcanic rocks. Excessive concentrations of fluoride in drinking water are undesirable. According to the California State Water Pollution Control Board, water containing less than 0.9 to 1.0 ppm of fluoride seldom will cause mottled enamel in children and concentrations of less than 3 or 4 ppm are not likely to cause endemic cumulative fluorosis and skeletal effects in adults. Much of the ground water in the reservations has more than 1.0 ppm of fluoride and the maximum reported was 12 ppm.

Nitrate (NO_3).--Nitrogen in ground water and surface water comes from weathering of rocks and decay and oxidation of organic material. Nitrate nitrogen is the final oxidation product caused by the reaction of bacteria in the decay of plants and animals. Nitrate in the water from shallow dug wells is mainly of organic origin. The occurrence of nitrate in abundance in evaporites is rare. Large amounts of nitrate in drinking water may cause methemoglobinemia in infants (blue babies). It is recommended that waters containing more than 10 to 20 ppm of nitrate, expressed as nitrogen, should not be used for infant feeding (Comly, 1945). The presence of nitrate also may be an indication of pollution by sewage or other organic decomposition. Ordinarily, ground water from deep aquifers does not contain more than a few parts per million of nitrate.

Boron (B).--Boron occurs in igneous rocks and in sedimentary rocks as borates in marine evaporites, evaporites in closed basins, and evaporites connected with volcanic activity. Marine evaporites contain chiefly magnesium borates, whereas boron in evaporites in closed basins occurs as calcium borate. Volcanic sublimates contain boron as boric acid and various borates. Boron was determined in only a few of the chemical analyses and it is listed in the column entitled "Remarks."

Dissolved solids.--Dissolved solids is the total quantity of dissolved mineral matter in the water. The terms "dissolved solids (D.S.)" and "residue on evaporation at 180°C" are used synonymously in describing the amount of dissolved material in a unit volume of water. Ground water usually contains more dissolved solids than surface water. Part of the material reported as dissolved solids in colored waters is organic matter, which is not shown in the analyses.

Hardness.--Hardness, sometimes called the soap-consuming property of water, is caused mainly by calcium and magnesium. The hardness caused by the calcium and magnesium equivalent of the bicarbonate in water, is called carbonate or temporary hardness. This may be removed by boiling. Other salts of calcium and magnesium cause noncarbonate or permanent hardness. Hardness is a particularly troublesome property, and large sums of money are spent in softening waters for domestic and industrial use.

Percent sodium.--The term "percent sodium" is the ratio of sodium in the water to the total cations expressed as a percentage, with all the ion concentrations expressed as equivalents per million. Percent sodium is calculated as follows:

$$\text{Percent sodium} = \frac{\text{Na}^+}{\text{Na}^+ + \text{K}^+ + \text{Ca}^{++} + \text{Mg}^{++}} \times 100$$

In soils high concentrations of sodium tend to replace calcium and magnesium from the mineral and organic complexes, with the result that the physical properties of the soil are impaired and the soil becomes relatively impermeable.

Sodium-adsorption ratio (SAR).--SAR is a ratio for soil extracts and irrigation waters, used to express the relative activity of sodium ions in exchange reactions with the soil. It is used as an index of the sodium (alkali) hazard of an irrigation water.

Specific conductance.--The specific conductance of water is a measure of its capacity to conduct an electric current. The conductance varies with the concentration of the ions in solution and is a rough measure of the dissolved-solids content of the water.

pH.--The hydrogen-ion concentration of water is expressed in pH units. The pH denotes whether a water is basic or acidic. The pH of pure water is 7.0 and the pH of most natural waters varies from about 6.0 to slightly more than 8.0. However, except for one analysis which has a pH of 3.3, the ground waters in the reservations have pH values that range from 6.6 to 9.5. Waters with pH values less than 7.0 are acidic and tend to be corrosive, whereas waters with pH values more than 7.0 are basic and may form scales in pipes or boilers.

Literature Cited

- California State Water Pollution Control Board, 1952, Water-quality criteria: California State Water Pollution Control Board Pub. 3, 512 p.
- Comly, H. H., 1945, Cyanosis in infants caused by nitrates in well water: Am. Med. Assoc. Jour., v. 129.

Selected chemical analyses of the ground water in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah—Continued

Quad-range	Bureau of Indian Affairs field number or name	Date of collection	Remarks	Temperature (°F)	Silica (SiO ₂)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)	Carbonate (CO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Dissolved solids		Hardness as CaCO ₃		Percent sodium	Sodium-adsorption ratio (SAR)	Specific conductance (micro-mhos at 25°C)	pH	
																Parts per million	Tons per acre-foot	Calcium, magnesium	Non-carbonate					
DISTRICT 2—Continued																								
26	2A-93	3/24/55	Iron (Fe) total 1.7; Wingate (Lukachukai)	57	12	38	19	12	1.5	165	0	23	18	0.1	18	223	0.30	173	38	13	0.4	391	7.8	
	2T-316	8/18/54	Wingate (Lukachukai)	----	11	28	14		37	180	0	17	19	1.2	15	231	.31	128	0	38	1.4	403	---	
	2A-107	9/ 3/53	Navajo	60	15	28	11		2.1	127	0	6.8	5	.1	1.0	131	.18	115	11	4	.1	227	---	
	2A-108	7/22/54	Wingate (Lukachukai)	62	21	24	6.9		6.2	102	0	8.0	5.5	.4	1.5	124	.17	88	5	13	.3	192	---	
	40	2K-300	4/23/53	T; Navajo	----	14	39	6.2		3.0	128	0	9.7	5.0	.2	8.4	148	.20	123	18	5	.1	252	---
		2K-301	1/28/54	do.	----	11	32	4.7		6.9	118	0	8.0	2	.2	7.5	130	.18	100	3	13	.3	201	---
		2K-302	10/15/51	D; Navajo, Wingate (Lukachukai)	56	12	48	6.3		.2	152	0	8.6	4	.4	7.8	162	.22	146	22	0	.0	270	---
	2K-318	10/ /54	D; Navajo	----	----	----	----	----	----	161	0	----	8	----	5.4	----	----	128	0	----	----	303	---	
	2K-320	3/15/56	Navajo and Wingate (Lukachukai)	56	17	28	5.3		18	126	0	13	10	.2	2.7	157	.21	94	0	29	.8	250	8.2	
	2T-304	9/18/51	Navajo	57	14	31	5.4		6.4	113	0	11	4	.2	4.6	133	.18	100	7	12	.3	219	---	
Shonto 1	10/11/49	Alluvium	52	18	44	7.6		9.9	146	0	14	14	.0	11	190	.26	141	22	13	.4	317	---		
41	2A-40A	8/ 6/54	Navajo	64	15	32	3.7		8.5	119	0	4.7	5.5	.2	3.3	132	.18	95	0	16	.4	209	---	
	2A-41	8/ 6/54	do.	71	----	----	----	----	----	253	5	----	12	----	----	----	----	----	----	----	471	---		
	2C-14	8/ 7/54	do.	70	8.7	26	1.2		4.1	84	0	6.0	2	.2	.5	90	.12	70	1	11	.7	146	---	
	Shonto 2	3/20/50	do.	54	27	59	23		17	294	0	17	14	.4	.9	303	.41	242	0	14	.5	501	---	
	2A-13	3/20/50	T; Navajo	----	14	45	8.8		3.2	146	0	11	9	.0	15	178	.24	148	29	5	.1	299	---	
	2K-303	8/30/51	D; Navajo	----	15	40	5.9		8.5	150	0	6.0	7	.2	4.4	161	.22	124	2	13	.3	267	---	
	2K-319	9/ 3/54	Navajo	----	----	----	----	----	----	150	0	----	8	----	----	----	----	----	----	----	261	---		
	2T-317	5/23/52	do.	----	13	41	7.0		3.4	127	0	12	8	.1	13	160	.22	132	28	5	.1	267	---	
	2A-26	5/18/55	Iron (Fe) total 0.00; Navajo	62	6.7	24	3.2	2.6	4.0	84	0	8.1	2.8	.1	3.8	96	.13	73	4	7	.1	162	8.2	
	2A-12	7/27/54	Navajo	75	21	66	14		17	272	0	21	6	1.0	2.9	283	.38	222	0	14	.5	459	---	
57	2A-4	4/28/55	Landslide and talus	44	14	48	14		34	228	0	44	12	.5	.2	279	.38	178	0	29	1.1	465	7.5	
	2A-10	4/28/55	do.	46	----	----	----	----	----	267	0	----	26	----	2.1	----	----	112	0	----	----	685	7.6	
	2A-11	4/28/55	do.	51	14	48	12		65	242	0	72	24	.6	1.1	356	.48	170	0	45	2.2	582	7.4	
	2A-56	8/11/54	Toreva	71	17	298	96		149	241	0	1,200	10	.6	.3	1,890	2.57	1,140	940	22	1.9	2,250	---	
	2C-2	4/28/55	Landslide and talus	50	17	81	22		88	234	0	243	23	1.4	2.8	593	.81	292	101	39	2.2	892	7.7	

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Selected chemical analyses of the ground water in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah—Continued

Quad-range	Bureau of Indian Affairs field number or name	Date of collection	Remarks	Temperature (°F)	Silica (SiO ₂)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)	Carbonate (CO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Dissolved solids		Hardness as CaCO ₃		Percent sodium	Sodium-adsorption ratio (SAR)	Specific conductance (micro-mhos at 25°C)	pH	
																Parts per million	Tons per acre-foot	Calcium magnesium	Non-carbonate					
DISTRICT 11—Continued																								
36	11Y-75	7/18/50	Chinle (Shinarump)	64	13	0.8	3.1	80		196	0	18	6	0.2	0.4	218	0.30	14	0	92	9.1	352	---	
	11Y-47	8/ 4/54	Alluvium	68	25	29	7.6	133		306	0	108	18	.6	4.6	476	.65	104	0	74	5.7	745	---	
	11Y-80	8/ 4/54	do.	62	16	60	18	157		319	0	262	20	.6	.9	692	.94	224	0	60	4.5	1,040	---	
51	11Y-234	9/ 1/51	ID, 445 feet; Chinle (lower red)	---	15	40	12	84		317	0	54	11	.4	.6	373	.51	150	0	55	3.0	610	---	
		9/24/51	D; Chinle (Shinarump), De Chelly	---	10	10	7.5	140		343	0	59	11	.6	1.0	408	.55	56	0	84	8.1	669	---	
	Lukachukai T. P.	1/25/55	T; Chinle (Shinarump)	---	22	62	29	126		462	0	144	12	.6	.2	623	.85	274	0	50	3.3	975	---	
	Catholic Mission	7/29/49	Alluvium	55	---	---	---	---	---	500	0	---	54	---	---	---	---	---	---	---	---	991	---	
	11Y-3	8/27/54	Chuska	47	61	41	4.8	7.8		157	0	3.5	4.5	.2	.3	200	.27	122	0	12	.3	257	---	
	11Y-35	8/ 2/49	Chinle (lower red)	60	---	34	34	136		468	0	98	24	.4	.6	558	.76	225	0	57	3.9	919	---	
	11Y-37	8/27/54	Chuska	---	---	---	---	---	---	140	0	---	5.0	---	---	---	---	---	---	---	---	236	---	
	11Y-39	8/12/54	Alluvium	62	41	65	24	123		469	0	87	30	.4	12	613	.83	260	0	51	3.3	937	---	
	11Y-107	8/19/54	Chinle (Sonseia)	58	45	83	23	31		364	0	23	30	.2	3.0	417	.57	302	3	18	.8	675	---	
52	11K-237	6/ 8/53	D; De Chelly	---	10	126	46	17		381	0	204	7	2.0	.0	599	.81	504	192	7	.3	916	---	
	11K-239	9/10/54	do.	---	13	107	50	32		532	0	90	7	.6	.1	562	.76	472	36	13	.6	921	---	
	11K-249	8/23/56	De Chelly	64	---	---	---	---	---	341	0	---	7.0	---	---	---	---	558	278	---	---	982	7.0	
	11T-235	9/ 4/51	D; De Chelly	62	14	126	48	17		438	0	174	5	1.0	.2	601	.82	512	153	7	.3	956	---	
	11Y-58	8/25/54	Chinle (Shinarump)	61	15	131	38	35		382	0	220	11	.8	.2	639	.87	483	170	14	.7	945	---	
	11Y-69	8/ 2/49	De Chelly	---	15	40	50	38		332	0	97	9	.7	.1	413	.56	306	34	21	.9	681	---	
	11Y-78	7/29/49	T; Chinle (Shinarump), De Chelly	---	---	---	---	---	---	338	0	---	12	---	---	---	---	---	---	---	---	858	---	
	11Y-109	8/ 2/49	De Chelly	---	---	121	39	28		346	0	216	8	.7	.6	584	.79	462	179	11	.6	894	---	
	11Y-56	8/25/54	Alluvium	64	---	---	---	---	---	342	0	---	310	---	---	---	---	735	455	---	---	1,880	---	
	11Y-41	8/26/54	do.	65	63	18	12	540		1,000	49	278	52	1.2	.4	1,510	2.05	94	0	93	24	2,210	---	
	11Y-55	10/ 7/50	Chinle (Shinarump)	56	16	304	587	871		434	0	4,110	304	.8	1.7	6,410	8.72	3,170	2,820	37	6.7	6,950	---	
	11Y-72	8/25/54	De Chelly	52	---	139	42	---	---	348	0	10	---	---	---	---	---	520	234	---	---	1,010	---	
	11Y-85	8/26/54	Chinle (Sonseia)	62	19	9.9	3.6	342		740	0	127	31	.4	.5	897	1.22	40	0	95	24	1,390	---	
53	11Y-74	8/ 5/54	Chinle (Petrified Forest, upper)	68	15	6.4	1.7	310		512	0	127	100	1.0	3.7	817	1.11	23	0	97	28	1,320	---	
69	11Y-29A	8/18/54	Chuska	57	44	44	5.5	14		186	0	3.5	3.5	.2	.4	206	.28	132	0	18	.5	292	---	
70	11Y-34	8/19/54	Chinle (Shinarump), De Chelly	53	12	104	38	35		392	0	151	9	.4	.2	543	.74	416	94	15	.7	839	---	