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MEMO. ON WATER-SUPPLY INVESTIGATION AT SHIPROCK SCHOOL, NAVAJO INDIAN RESERVATION, SAN JUAN COUNTY, NEW MEXICO

By

J. T. Callahan and J. W. Harshbarger

United States
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Memorandum on water-supply investigation at Shiprock School, Navajo Indian Reservation, San Juan County, New Mexico

By

J. T. Callahan and J. W. Marshbarger

Prepared in cooperation with
the Bureau of Indian Affairs

Holbrook, Arizona
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Open-file report. Not reviewed for conformance with stratigraphic nomenclature and editorial standards of the Geological Survey.

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INTRODUCTION

At the request of the Navajo Agency, Bureau of Indian Affairs, a ground-water investigation was made for a proposed well at the new school at Shiprock, San Juan County, N. Mex. The investigation was started in 1952 and continued intermittently until 1954. This investigation was included as a part of the program of study of the ground-water resources of the Navajo and Hopi Indian Reservations now being made by the United States Geological Survey. The results of the Shiprock School investigation precede a complete report on the ground-water resources of the Navajo country. The work was financed by, and was in cooperation with, the Navajo Agency, Bureau of Indian Affairs.

The community of Shiprock is on the Navajo Indian Reservation in San Juan County, N. Mex., about 92 miles north of Gallup on U. S. Highway 666, and 30 miles west of Farmington on U. S. Highway 550 (fig. 1). The new school is approximately 2 miles north of the community of Shiprock. The population at the school will consist of approximately 800 pupils and faculty members. An additional 600 persons live in the community.

The present water supply for the community and school at Shiprock is obtained from an infiltration gallery in the gravels of the San Juan River. In 1952 approximately 125,000 gallons of water per day was pumped from the infiltration gallery for use by 950 persons. This is an average per-capita use of about 130 gallons per day. Using this figure as an estimate of future needs when the new school is in operation, 1,400 persons will require a total of

182,000 gallons per day. A pump in continuous operation would have to withdraw 126 gallons per minute (gpm) to meet this requirement. A water supply for the proposed 800 persons who will occupy the school would require the continuous pumping of 72 gpm. The construction of a drilled well for the purpose of obtaining a water supply for the new school has been considered by Indian Service officials. The geologic and hydrologic investigation of the Shiprock area was made to determine the feasibility of obtaining the water needed for the school from a deep well.

GEOLOGY

Stratigraphy

The community of Shiprock lies in the northwestern part of the San Juan structural basin, on the outcrop of the bluish-gray Mancos shale. The outcrop of the Mancos extends tens of miles to the north, south, and west. Locally, the formation is covered by thin layers of alluvial sands and gravels. The Mancos shale consists of an upper and a lower part of nearly homogeneous bluish-gray to black fissile carbonaceous shale, separated by the Gallup sandstone, which is a fine-grained sandstone. The Mancos shale contains numerous veinlets of gypsum which is somewhat soluble in water. None of the other formations listed in the stratigraphic section below are exposed at the land surface in the vicinity of Shiprock. The Dakota sandstone and older rocks are exposed in a north-south belt close to the Arizona-New Mexico State boundary. In the area of this report the Dakota sandstone consists of alternate beds of siltstone, sandstone, and granule conglomerate. The lower two-thirds of the formation is mostly conglomerate and sandstone. The Morrison and Summerville formations below are composed of fine-grained sandstone containing lesser amounts of siltstone and mudstone beds.

The stratigraphic section that would be encountered in a well at the Shiprock School is as follows:

Formation	Age	Water-bearing character	Thickness (feet)	Depth to base of formation (feet)
Alluvium	Recent	Non-water-bearing	20-40	20-40
Mancos shale (upper part)	Cretaceous	Non-water-bearing	400	420-440
Gallup sandstone	do.	Water-bearing	30-40	450-480
Mancos shale (lower part)	do.	Non-water-bearing	700	1,150-1,180
Dakota sandstone	do.	Water-bearing	150	1,300-1,330
Morrison formation	Jurassic	do.		
Brushy Basin member	do.	do.	160	1,460-1,490
Westwater Canyon member	do.	do.	170	1,630-1,660
Recapture member	do.	do.	230	1,860-1,890
Salt Wash member	do.	do.	190	2,050-2,080
Summerville formation	do.	do.	175	2,225-2,255
Todilto limestone	do.	Non-water-bearing	10	2,235-2,265
Entrada sandstone	do.	Water-bearing	200	2,435-2,465

Structure

Structurally, the town of Shiprock lies near the axis of a syncline which plunges to the north. The Hogback anticline, which lies southeast of Shiprock (pl. 1), is an elongated asymmetrical dome. It is approximately 5 miles long and 3 miles wide and the major axis trends a little east of north. The Rattlesnake and Toeito domes are similar structural features southwest of Shiprock; their major axes also trend a little east of north. The regional dip of the strata

is toward the east, and these structures are protuberances on the eastward-dipping strata.

The water-bearing sandstones are recharged along the flanks of the Carrizo Mountains and Beautiful Mountain (pl. 1), to the west and southwest of Shiprock. The geologic structure and the presence of alternating shale beds which act as confining layers cause the ground water to be under artesian pressure. The artesian pressure is sufficient to cause the water to flow from wells not only at the town of Shiprock but along the axes of both the Hogback anticline and the Rattlesnake dome.

GROUND-WATER SUPPLIES

Wells

A large number of existing wells have been drilled in the area surrounding Shiprock; most of them were oil and gas test wells. Many of these test wells were unsuccessful in obtaining oil or gas but have been converted into successful water wells. Other wells yielded only salt water and were abandoned. Water samples have been obtained from many of these test wells and analyses have been made to determine the chemical character of the water. From the results of these analyses it is possible to draw some conclusions regarding the quality of the water in the various formations in this area.

The sandstones in the Cretaceous rocks yield water to wells in the Shiprock area but the water contains relatively large amounts of dissolved solids and has sufficient hydrogen sulfide gas to cause an unpleasant odor and taste. Drillers' logs of oil tests in this area show several water-bearing strata in the Morrison and Summerville formations. However, the quality of the water in the Morrison and Summerville formations at Shiprock is not definitely known at the present time.

Within the Shiprock community at least three wells have been drilled. Well 12N-300, several hundred feet northeast of the District Supervisor's office, was drilled to a depth of 1,200 feet and penetrated the Dakota sandstone (table 1). According to the driller's log, the well produced salt water from the Gallup sandstone 225 feet below the land surface, water containing hydrogen sulfide from the Dakota sandstone at 1,038 feet, and water of poor quality at 1,122 feet. The well flowed 10 gallons per minute when completed, but it was abandoned because of the poor quality of the water. A chemical analysis of the water from well 12N-300, made in 1952, shows the water to be high in dissolved solids (table 2). A study of the well log indicates that most of the water issues from the Dakota sandstone.

Another well, 12N-300A, located within a mile of well 12N-300, was drilled to a reported depth of 2,170 feet in 1926. However, in 1952, it had a measured depth of only 1,717 feet. According to the driller's log this well penetrated the Mancos, Dakota, Morrison, and Summerville formations. The well flowed but was abandoned because the water was reported to be unfit to drink. A chemical analysis made in 1952 shows this water to be higher in dissolved solids, hardness, sulfate, and sodium and potassium (table 2) than the water from 12N-300. It is believed that this water is a mixture of waters from the Gallup sandstone, Mancos shale, Dakota sandstone, and Morrison formation, but it is impossible to determine which formation contributes most of the water and which aquifer, if any, produces water suitable for human consumption.

The character of the water obtained from the Gallup and Dakota sandstones in well 12N-300 indicates that these formations yield unpotable water at Shiprock. In order to arrive at some conclusion regarding the possibility of obtaining potable water from the Morrison and Summerville formations at Shiprock, the quality of water in the individual formations will be discussed.

Quality of Water

Gallup sandstone.--A seismic shot hole, OT-3, obtained flowing water from the Gallup sandstone on the north end of the Tocito dome (pl. 1), where the formation is exposed at the land surface. This structural feature lies south and a little west of Shiprock. The well is 27 feet deep and lies within the recharge area of the formation. The water contained 1,240 ppm of dissolved solids, of which 541 ppm was sulfate. Well 12N-32O, located about 3 miles north of shot hole OT-3, obtained water from the Gallup sandstone at a depth of 320 feet. This well is located down dip in a syncline, and the water of the Gallup sandstone was cemented off after water samples were obtained. This water contained 1,800 ppm of sulfate, a marked increase for such a short distance down dip from OT-3. Both this well and those wells at Shiprock are located in synclines, and the high dissolved-solids content may be due to solution of soluble minerals as the water moves in a down-dip direction from the area of recharge. It is possible that poor circulation exists within the synclinal troughs, and, as a result, the troughs have not been subjected to as much flushing as has the rest of the aquifer. The initial presence of the soluble minerals in the formation can be explained by the deposition of evaporites in a marine sandstone which lies between two marine claystone units.

Oil-test well OT-4, located about 6 miles north-northwest of well 12N-32O, was drilled on the northwest side of the Table Mesa anticline and obtained a water flow of 20 gpm from the Gallup sandstone. A sample of this water contained 2,440 ppm of dissolved solids, of which 1,370 ppm was sulfate and 707 ppm was sodium and potassium. This analysis is characteristic of the high sulfate content of water in the Gallup sandstone. This evidence and the driller's report of salt water in well 12N-30O indicates that the water present in the Gallup sandstone in the Shiprock area contains dissolved solids in amounts that would be undesirable for domestic use.

Dakota sandstone.--The water in the Dakota sandstone appears to differ in chemical constituents from water in the Gallup sandstone. Wells 12R-148 and 12K-317 produce water from the Dakota sandstone that is low in sulfate and high in bicarbonate. Well 12K-320 produced water from the Dakota sandstone from a depth of 1,400 feet that had these same characteristics. Water from the Dakota sandstone in well 12K-317 had the lowest sulfate and the highest bicarbonate content of any water encountered in that formation.

Well 12K-309 is reported to penetrate the Dakota sandstone. The water, however, is relatively high in sulfate and low in bicarbonate, and the water from well 12K-300 at Shiprock shows similar characteristics. Both these wells are farther from the recharge area than the three wells previously mentioned, and a change may be taking place in the chemical character of the water as it moves down the dip.

Dakota sandstone and Morrison formation.--Many of the wells in the Navajo country yield a mixture of waters from the Dakota sandstone and the underlying members of the Morrison formation. In some places good water is obtained from these wells; in others the mixture is unsuitable for domestic or stock purposes. Well 12K-300A at Shiprock produced water from the Dakota sandstone and the top part of the Morrison formation that is not suitable for human consumption.

Well OT-1, located in the SE 1/4 sec. 27, T. 31 N., R. 17 W., about 12 miles north and farther down dip from Shiprock, flowed at a reported 70 gpm from these two formations. The amount of water contributed by each formation and the depth of penetration into the Morrison formation are unknown. The water contained 3,500 ppm of sulfate, which shows an increase in the dissolved solids in a down-dip direction.

Well 12N-32D is located up dip from Shiprock. Four water samples were collected during the development of this well which represent water from the several rock units and a mixture of water of two formations. Water was obtained from the Dakota sandstone and the upper part of the Morrison formation at depths of 1,530 and 1,555 feet, respectively. The specific conductance (table 2) of these samples indicate that little difference exists between the waters. The total flow from the two zones was 5 gpm. At a depth of 1,625 feet the Westwater Canyon member of the Morrison formation had been partially penetrated, the flow increased to 17 gpm, and the quality of the water improved (table 2). Upon the completion of the well the flow had increased to about 60 gpm and the quality of the water had improved further (table 2). These results indicate that the quality in the lower part of the Morrison formation is better than the water in the upper part, at least in the vicinity of Table Mesa.

Morrison formation and underlying rocks.--Well 12S-8A, 20 miles south-southwest of Shiprock, was drilled by the Continental Oil Co. to a depth of 1,430 feet and penetrated the Morrison formation. All waters above the Morrison formation were cased off, and the well is reported to have flowed 75 gpm. The chemical analysis shows the water from this well to be low in dissolved solids, sulfate, and hardness (table 2). A well drilled in 1951 at the Sanastee Day School, 5 miles southwest of 12S-8A (pl. 1), penetrated the Morrison and Summerville formations and waters encountered in the formations above the Morrison formation were cemented off. Chemical analysis of this water shows it to be low in dissolved solids (table 2).

A test well 6 miles southeast of Shiprock, drilled by the Stanolind Oil Co., encountered water-bearing strata in the Mancos shale, Dakota sandstone, and Morrison formation. The well was cemented off to the top of the Morrison

formation, but unfortunately samples of water from the Morrison formation were not obtained. The well is reported to have flowed about 125 gallons per minute.

These results indicate that the lower part of the Morrison formation yields more and better water than does either the upper part of the formation or the Dakota sandstone.

On several occasions flowing water has been obtained from oil tests when the inflow of water has been so great as to halt drilling operations temporarily. A sample of water from the Entrada sandstone was obtained from oil test OT-2 in sec. 2, T. 29 N., R. 17 W., about 6 miles east and south and down dip from Shiprock. This water had a specific conductance of 1,510 micromhos, which is about one-third the conductance obtained for water from well 12K-300A at Shiprock. The Entrada sandstone was not penetrated in the Shiprock well; however, there are indications that water of similar or better chemical quality would be obtained at Shiprock from a depth between 2,200 and 2,500 feet below the land surface.

CONCLUSIONS

It is known that at Shiprock the waters in the Gallup sandstone and the Dakota sandstone are not suitable for human consumption. The quality of water in the lower members of the Morrison formation, the Summerville formation, and the Entrada sandstone cannot be predicted with certainty. However, the existing data from certain wells in the general area indicates that good water may be present in these formations in the Shiprock School area. The Westwater Canyon member of the Morrison yields the greatest quantity and the best quality of water to well 12K-320 at a depth between 1,625 and 1,800 feet. The Sanastee School well obtains good water from the Morrison and Summerville formations.

Well OT-2 obtained water from the Entrada sandstone that appears to have had a lower content of mineral constituents than does water from existing shallower wells at Shiprock.

A summation of the evidence available indicates that the drilling of a test well at the Shiprock School is warranted if it is desired to supplement the existing water supply. If a test well is drilled, it will be necessary to cement off, under pressure, waters in the Gallup sandstone, the Dakota sandstone, and the Brushy Basin member of the Morrison formation. It may be necessary also, to cement off water from the upper part of the Westwater Canyon member, and perhaps from the entire Morrison formation. The first length of casing could be cemented in place below the top of the Westwater Canyon member at a depth of about 1,600 feet. If the water below this point proves to be unsatisfactory, a second string of casing could be cemented at a depth of about 2,000 feet. It may be necessary to drill a well to a total depth of 2,500 feet in order to penetrate all the water-bearing strata of the Entrada sandstone.

The fluoride content of the water is a matter of importance inasmuch as the water would be used by young children. The content cannot be predicted; however, none of the few available analyses of water of good quality from the lower part of the Morrison formation and the Entrada sandstone show a fluoride content in excess of 1.5 ppm, the limit recommended by the Public Health Service.

Water encountered in any of the formations below the Gallup sandstone in all probability will flow at the land surface. The exact amount of water that may be obtained is not known, but the indications from existing wells are that the flow would be between 50 and 200 gpm.

Provisions should be made for the collection of drill cuttings at 10-foot intervals, and the collection of water samples for chemical analysis.

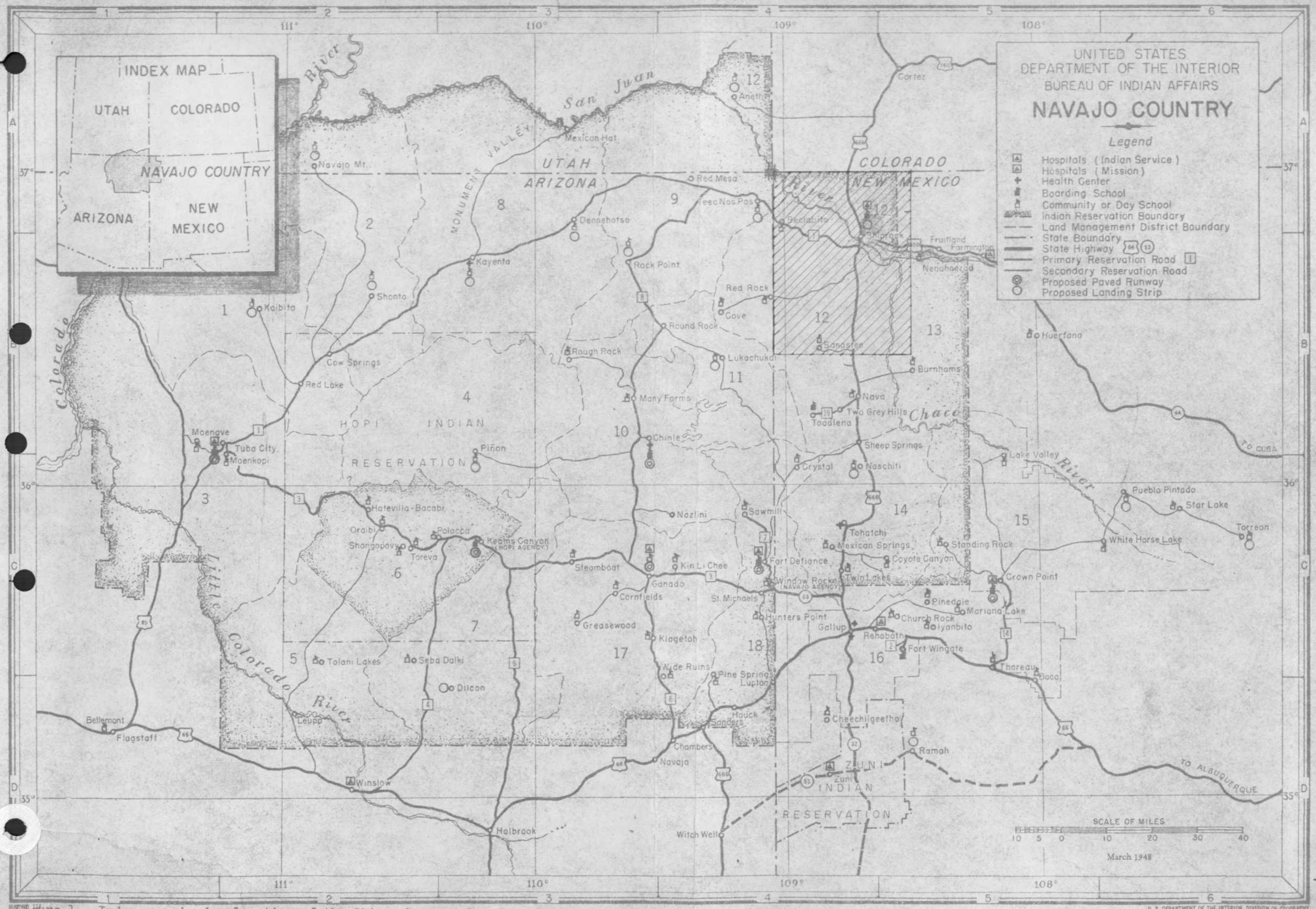
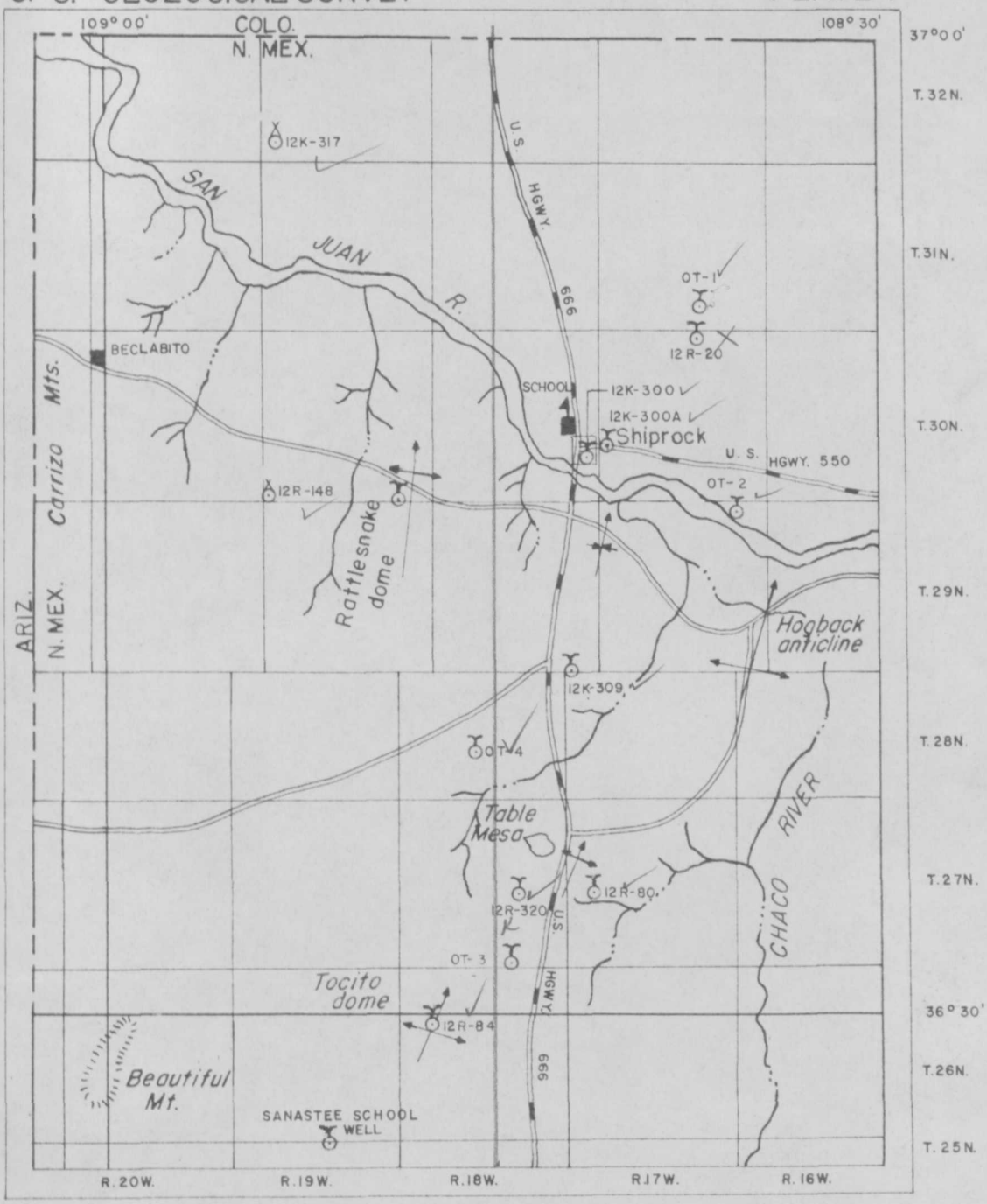


Figure 1.--Index map showing location of the Shiprock area, San Juan County, N. Mex.



EXPLANATION

OT-1 Flowing well (OT-oil test)

12K-317 Well with windmill

Anticline — Showing trace of axial plane

Syncline — and bearing and plunge of axis

Paved road

Graded road

MAP OF SHIPROCK AREA, SAN JUAN COUNTY, NEW MEXICO, SHOWING LOCATION OF SELECTED WELLS AND PRINCIPAL GEOLOGIC STRUCTURES

0 1 2 4 6 SCALE IN MILES

Table 1.--Water-bearing formations and discharge and depth of water wells in the Shiprock area, San Juan County, N. Mex.

Well number	Depth of well (feet)	Aquifer		Discharge (flow gpm)
OT-3	27	Gallup sandstone	0-27	1-5
OT-4	652	Gallup sandstone	620-652	20
12K-320 1/	520	Gallup sandstone Water level 75 feet	480-500	None
12R-148	695	Dakota sandstone		None
12R-204		Dakota sandstone (reported)		10
12K-300	1,200	Dakota sandstone		10
12K-309	1,640	Dakota sandstone	1,502-1,640	2
12K-317	874	Dakota sandstone		None
12K-320 1/	1,400	Dakota sandstone Cased to 840 feet	1,250-1,400	2
Rattlesnake	2,013 (plugged back)	Dakota sandstone		1
12R-84	1,430	Dakota sandstone and Morrison formation		75
12K-300A	1,717	Dakota sandstone and Morrison formation		100/
12K-320 1/	1,530	Dakota sandstone and Morrison formation		5
12K-320 1/	1,555	Dakota sandstone and Morrison formation Cased to 1,362 feet		5
12K-320 1/	1,625	Dakota sandstone and Morrison formation		17
12K-320	1,800	Dakota sandstone and Morrison formation		60
OT-1	1,860	Morrison formation	1,600-1,860	70
Sanastee School	1,240	Morrison formation and Summerville formation		35
OT-2	4,395	Entrada sandstone	2,160-2,195	20

1/ Water samples obtained during drilling operations. Total depth of well 1,800 feet.

Table 2.--Chemical analyses of ground-water in the Shiprock area, San Juan County, N. Mex.
(Analyses by Geological Survey)
(Parts per million except specific conductance and percent sodium)

Well number	Depth of well (feet)	Date of collection	Temp. (°F)	Specific conductance (micromhos at 25°C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+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
OT-3	27	1/7/54	60	1,870	25	19	11	398	312	20	541	71	2.1	0.2	1,240	92	90
OT-4	652	12/28/53		3,480	15	64	29	707	206	12	1,370	142	.3	.1	2,440	278	85
12K-320 1/	520	3/2/54		4,470				908	276	7	1,800	163				368	84
12R-148	695	6/27/52	69	2,670	11	5.5	2.0	617	763	17	17	482	4.8	.6	1,530	22	98
12R-204		8/10/49	83	6,640	17	146	28	1,530	254	0	3,210	170	2.1	.6	5,230	480	87
12K-300	1,200	7/19/52	76	4,150	7.0	2.0	.4	978	210	218	1,120	296	5.0	1.5	2,730	6	100
12K-309	1,640	8/10/49	61	2,440	14	6.0	1.7	548	271	11	831	74	1.0	.2	1,620	22	98
12K-317	874	8/6/53		2,470	16	5.2	3.2	660	1,550	39	7.8	65	10	.2	1,570	26	98
12K-320 1/	1,400	4/11/54		814	6.5			187	296	10	142	15	1.0	.8		25	94
Rattlesnake	2,013	6/27/52		3,150	13	19	3.1	692	167	6	978	280	1.3	1.0	2,080	60	96
12R-84	1,430	8/12/49	76	422	19	3.5	1.1	98	184	26	22	4	.6	.4	265	13	94
12K-300A	1,717	6/27/52	90	4,640	15	155	25	980	110	0	2,350	56	1.9	.1	3,640	490	81
12K-320 1/	1,530	4/21/54		1,290					163	70		32					
12K-320 1/	1,555	4/30/54		1,290	5.9			270	256	8	356	32	.4	.7		54	92
12K-320 1/	1,625	5/3/54		778	26	4.0	.9	176	226	16	160	11	1.0	.1	506	14	97
12K-320	1,800	12/7/54	60	389	18				146	47		5	.6	.0		2	
OT-1	1,860	6/5/53		7,600	12	182	33	1,760	218	33	3,500	375	1.4	.9	6,010	590	87
Sanastee Sch.	1,240	6/28/51	70	632	14	7.0	2.4	137	260	15	67	11	.4	.8	383	28	92
OT-2	4,395	5/11/54		1,510													

1/ Water samples obtained during drilling operations. Total depth of well 1,800 feet.