United States

Department of the Interior

Geological Survey

Water-Supply investigation at Navajo Mountain, Navajo Indian Reservation, San Juan County, Utah.

By

S. C. Brown, L. C. Halpenny, and H. A. Whitcomb

Salt Lake City, Utah

March 1949

49-59

INTRODUCTION

The Geological Survey has been studying the ground-water resources of the Navajo Indian Reservation since January 1948, particularly with respect to obtaining adequate water supplies for schools. The area in the vicinity of the Navajo Mountain school was investigated in July 1948.

Location

The Navajo Mountain school is located on the east side of Navajo Mountain, in southern San Juan County, Utah. The altitude of the school is about 6,100 feet above sea level. The school is about 2 miles north of the Arizona-Utah State line, and can be reached only from Arizona. The road to Navajo Mountain extends northeast from U. S. Highway 89 near Cameron, Arizona. Rainbow Lodge, the only settlement within 25 miles of the school, is located on the south side of Navajo Mountain, in Coconino County, Arizona.

Topography and drainage

Navajo Mountain is a roughly symmetrical dome. Drainage from the southeast, east, and northeast flanks enters Piute Creek, which flows into the San Juan River and thence into the Colorado. Drainage from the southwest, west, and northwest flanks enters the Colorado River directly. Deep canyons on the east, north, and west make the Navajo Mountain area inaccessible from all but the south side. The terrain is extremely rugged, and the elevation ranges from about 5,000 feet above sea level in Jackrabbit Canyon to 10,250 feet at the top of the mountain, a distance of less than 8 miles.

With respect to the broad outline of the mountain, Dutton1/ states:

> Far to the southeastward, upon the horizon, rises a gigantic dome of wonderful symmetric and simple form. It is the Navajo Mountain. Conceive a segment of a sphere cut off by a plane through the seventieth parallel of latitude and you have its form exactly. From whatsoever quarter it is viewed, it always presents the same profile. It is quite solitary, without even a foothill for society, and its very loneliness is impressive.

Gregory2/ continues the description:

> At nearer approach the sides are seen to be cut into vertical canyons and deep gorges by drainage lines. In places, particularly on the southeast, the outline is subdued because of the presence of enormous deposits of material in the form of fans, alluvial slopes, and rock streams. The less eroded parts of the top

1/ Dutton, C.E., Geology of the high plateau of Utah: U. S. Geog. and Geol. Survey Rocky Mtn. Region, pp. 290-291, 1880.

2/ Gregory, H.E., The Navajo Country: A geographic and hydrographic reconnaissance of parts of Arizona, New Mexico, and Utah:. U. S. Geol. Survey Water-Supply Paper 380, pp. 45-46, 1916.

> of the mountain present a plateau with flaring edges which are scalloped by canyon walls. The short canyons, with steep gradients, leading northward and northwestward removed about equal amounts of material, so that these sides of the mountain present a sloping plain. A stream leading southwest has cut far into the heart of the mass, so that the top presents the outlines of a gigantic horseshoe. The higher parts of the mountain consist of low ridges, imperfectly drained flats, small cliffs, and miniature canyons .... and areas acres in extent are covered with piles of angular blocks so large as to practically prohibit travel over them. The slopes of the minor ridges are strewn with boulders, and in three localities these fragments .... are arranged as rock flows, extending down the slope for 200 to 300 feet and forming at the base ridges with much the appearance of glacial moraines.

Problem

The existing water supply at the Navajo Mountain school is obtained from a well dug in the alluvial fill of the principal wash on the east side of the mountain. The well goes dry nearly every summer, and the school is extremely short of water part of each year. A deep well, drilled at the school in 1946, produced no water.

Field work

Field studies were made by S. C. Brown and H. A. Whitcomb, geologists, and G. A. Larua, student engineer, between July 9 and July 15, 1948. The studies, undertaken for the purpose of locating an adequate water supply, included an examination of all springs and wells within a radius of about 6 miles. The geologic section was studied to determine the advisability of drilling another deep well. The work was under the direct supervision of L. C. Halpenny, engineer in charge of Navajo work.

Acknowledgments

The assistance of Mrs. Elizabeth Eubanks, principal at Navajo Mountain school, is gratefully acknowledged. Mrs. Eubanks, through her friendly hospitality and invaluable knowledge of the area, made the field work much easier than was anticipated.

The quality-of-water section of this report was written by J. D. Hem, district chemist, Quality of Water Branch. The report was reviewed by H. E. Thomas, district geologist for ground-water investigations in Utah, who made a valuable contribution to the manuscript. C. B. Read, geologist, Fuels Section, Geologic Division, reviewed the report with respect to stratigraphy.

GEOLOGY AND ITS RELATION TO GROUND WATER

Most of the rocks in the region are of sedimentary origin, ranging from lower Permian to possible Upper Cretaceous age. Figure 1 is a cross section of the Navajo Mountain area, from west to east, showing the stratigraphic relations. It is believed by the present writers that the rocks older than the DeChelly sandstone member of the Cutler formation lie below practicable drilling depth. The section that follows contains descriptions of the DeChelly sandstone member and the overlying rocks, including brief discussions of their water-bearing properties. Statements on the possible occurrence of ground water in the lithologically more favorable beds are given in detail under the heading: "Possibilities for obtaining additional water."

The rocks that underlie the Chinle formation are not exposed in the Navajo Mountain area (see fig. 1), and the descriptions of these rocks are based on previous work by Baker.3/

Geologic formations and their water-bearing properties

Permian rocks

The DeChelly sandstone member of the Cutler formation is exposed in Monument Valley, where the sandstone is gray to tan and pinkish brown in color, medium- to fine-grained, poorly cemented, massive, and highly cross bedded. The subangular to well-rounded quartz grains appear to be largely of eolian deposition. The sandstone, where well exposed, characteristically displays well-rounded, remarkably cross bedded surfaces. The thickness of the member is estimated to be 75 to 100 feet in the area. The DeChelly sandstone member is known to be water bearing in many parts of the Navajo Country, but no wells have been drilled to the member in the vicinity of Navajo Mountain.

The DeChelly sandstone member is overlain by red beds which have been assigned to the Hoskinnini tongue of the Cutler formation. In Monument Valley, the sandy mudstones and siltstones of this tongue are deep red brown to maroon in color, with irregular streaks of gray. They are soft, shaly, and regularly bedded, and weather to nodular surfaces. It is estimated that the maximum thickness of the Hoskinnini tongue at Navajo Mountain does not exceed 50 feet. From the lithologic character, it is concluded that the Hoskinnini tongue of the Cutler formation is of little value as an aquifer.

Triassic rocks

The Lower Triassic Moenkopi formation overlies the Hoskinnini tongue of the Cutler formation. According to Baker,4/ the formation

3/ Baker, Arthur A., Geology of the Monument Valley-Navajo Mountain region, San Juan County, Utah: U. S. Geol. Survey Bull. 865, pp. 36-60, 1936.

4/ Baker, Arthur A., op. cit., p. 41.

consists of

> thin, evenly bedded, dark-brown to chocolate-brown sandy shale with a great many thin beds of red-brown ripple-marked sandstone and some irregularly bedded, blocky-weathering, platy to massive, red-brown, medium-grained sandstone containing lenses of grit.

The formation is not exposed in the Navajo Mountain area. The thickness is estimated to be from 130 to 340 feet. Water from the Moenkopi formation is almost universally of poor quality in the region, and in some areas is even unfit for livestock to drink.

The Shinarump conglomerate disconformably overlies the Moenkopi formation. The Shinarump conglomerate is essentially a gray fine- to coarse-grained quartz sandstone containing conglomerate lenses and interbedded shale. The more massive beds of sandstone contain scattered quartzite pebbles and are irregularly cross bedded. The thickness of the formation is variable throughout the region, ranging from 1 to 200 feet. The Shinarump conglomerate yields water to wells in those parts of the region where the formation is sufficiently thick and where structural conditions are favorable.

The Chinle formation conformably overlies the Shinarump conglomerate. In Piute Canyon and Jackrabbit Fork, east of the Navajo Mountain school, about 350 feet of the upper part of the Chinle formation is exposed. The total thickness of the formation is estimated to be about 900 feet in the area. The formation consists of variegated shales with thin beds of red to buff sandstone and light- to dark-gray limestone. The sandstones occur chiefly in the upper part of the formation. This formation is non-water bearing in the area.

Jurassic (?) and Jurassic rocks

The Glen Canyon group, of Jurassic (?) age, overlies the Chinle formation. The Wingate sandstone, the lower formation of the group, consists of buff fine- to medium-grained quartz sand. The sand grains are angular to rounded and are cemented with calcium carbonate. The sandstone is cross-bedded on a large scale, and weathers to deep-red cliffs which show numerous vertical joints. At the Navajo Mountain school the Wingate sandstone is 296 feet thick, as shown by the log of the test well (table 1). The well yielded about 1 gallon per minute from the lower part of the formation.

The Kayenta formation, which overlies the Wingate sandstone, is a buff to red irregularly bedded fine- to coarse-grained sandstone, with some interbedded shale, limestone, and conglomerate. The well log (table 1) shows this formation to be 203 feet thick at the school. No water was encountered in the formation at the well location, but the springs at Rainbow Lodge issue from a bedding plane about 30 feet below the top of the formation.

The Navajo sandstone is the upper formation of the Glen Canyon group, and overlies the Kayenta formation. The Navajo sandstone is composed of buff to gray quartz sand, the grains of which are medium-sized and subangular to rounded. The sand grains are loosely cemented with calcium carbonate. The sandstone is intricately cross bedded, with many tangential bedding planes. It has a maximum thickness of about 1,100 feet. Endischee Spring issues from rock debris, at or near the top of the Navajo sandstone. The contact between the sandstone and the overlying Carmel formation could not be accurately determined at the spring. Under more favorable structural conditions the Navajo sandstone probably would be a fair aquifer.

The San Rafael group of Jurassic age overlies the Navajo sandstone. Its lower unit, the Carmel formation, consists of interbedded red sandstone, shale, mudstone, and some thin beds of gray limestone. The total thickness is about 130 feet. The formation crops out high on the almost inaccessible flanks of Navajo Mountain. The Carmel formation is not considered a good aquifer in the area.

The Entrada sandstone of the San Rafael group lies conformably upon the Carmel formation. The Entrada sandstone is light brownish red to tan in color. It is fine- to medium-grained, massive, tangentially cross bedded, and forms the steep cliffs and upper slopes of Navajo Mountain. The total thickness is about 450 feet. War God Spring is reported to issue from bedding planes or joints in the Entrada sandstone, at an elevation of about 9,000 feet. The opening is reported to be obscured by rock debris. The outcrop area of the Entrada sandstone is not suitably located to receive much recharge, and therefore the formation is considered to be a poor aquifer in the Navajo Mountain area.

The Morrison formation, which overlies the Entrada sandstone, is comprised of gray to brown massive, cross-bedded sandstone, conglomerate, and thin lenses of green or red shale. The conglomerate pebbles consist of shale, variegated sandstone, chert, and quartz. The formation is about 475 feet thick and crops out as ridges and slopes near the top of Navajo Mountain. The Morrison formation is not considered a good aquifer in the area, although under more favorable conditions it probably would produce water.

Cretaceous or Jurassic rocks

The rock capping Navajo Mountain is a gray-white silicified conglomerate sandstone containing rounded pebbles of white quartz which range up to 3 inches in diameter. The rock overlies the Morrison formation, and is stratigraphically in the position occupied by the Dakota sandstone of Cretaceous age. In other parts of the region the Dakota sandstone is gray to brown, coarse-grained, and irregularly bedded. It is locally conglomeratic and contains some sandy and carbonaceous shale and impure coal. Baker5/ states that identification of the Dakota sandstone at the top of Navajo Mountain is questionable, and

5/ Baker, Arthur A., op. cit., p. 60.

that perhaps this rock should be included in the Morrison formation. However, the present writers believe that the rock resembles the general lithologic description of the Dakota sandstone more nearly than that of the Morrison formation. The rock does not yield water in the area.

Quaternary alluvium

Alluvium of Quaternary age is generally 5 to 30 feet thick in the washes that drain the Navajo Mountain. The alluvial fill near the school is poorly sorted material which contains boulders derived from the Navajo sandstone and younger formations. The fill is 20 to 25 feet thick and at present is the only source of ground water in the vicinity of the school.

Structure

Navajo Mountain is a large anticlinal dome with a maximum closure of at least 1,600 feet. The beds dip radially from the top of the mountain, with dips ranging from about 5° on the south side to about 20° on the northwest side. Piute Creek flows north along the axis of a syncline on the east side of the mountain. From Piute Creek the beds rise gently eastward toward Balanced Rock anticline, about 8 miles away. Eastward from the Balanced Rock anticline the beds dip into the Nokai syncline and then rise gently again to Hoskinnini Mesa, about 16 miles east of Piute Creek.

No faults were observed in the area.

POSSIBILITIES FOR OBTAINING ADDITIONAL WATER

Prior to the investigation it had been suggested that there were three possibilities of obtaining an adequate water supply at the Navajo Mountain school. These possibilities were: (1) To locate springs on Navajo Mountain which could be developed and would flow by gravity to the school; (2) to deepen the well that was drilled in 1946; and (3) to improve the recovery of ground water from the alluvial fill along the wash near the school. No other possibilities of obtaining water became apparent during the course of the investigation.

Springs

Inquiries were made of the few local residents as to the location of springs on Navajo Mountain. A guide was obtained and the mountain was climbed to study the springs and the stratigraphy. Only two springs--War God Spring and Hadischee Spring--are known to issue from the higher slopes of the mountain. A third, Rainbow Lodge Spring, occurs near the base of the mountain on the southwest side.

War God Spring is about 3 3/4 miles west of the school, at an elevation of about 9,000 feet, or about 3,000 feet higher than the school. An unsuccessful attempt was made to reach the spring during the investigation. The spring is reported to issue from the Entrada sandstone into a canyon which drains to the south. The present discharge is reported to be about 5 gallons per minute.

Gregory[6] reports that in 1910 the discharge was 25 gallons per minute, the temperature of the water was 47° F., and the quality was "excellent."

Endischee Spring flows into the same canyon as War God Spring, at an elevation of about 8,000 feet. The spring issues from the upper part of the Navajo sandstone, and the discharge on July 12, 1948, was estimated to be 7 to 10 gallons per minute. It is reported that the flow during the winter is about 25 gallons per minute. Gregory[6] states that in 1910 the discharge of Endischee Spring was about 3 gallons per minute. An analysis of the water is given in table 2.

The discharge from both these springs would be barely sufficient to supply Navajo Mountain school, and the cost of laying and maintaining a pipe line from the springs to the school would be large. The line would have to be buried to prevent freezing during the winter. The water from each of the springs sinks into the alluvial fill of the canyon and is discharged to the atmosphere within half a mile by evaporation and transpiration.

The springs at Rainbow Lodge issue from the Kayenta formation at an elevation of about 6,500 feet. The lodge is about 10 miles by road or about 6 miles by air southwest of the school. The total discharge of the springs was estimated to be 7 to 10 gallons per minute on July 12, 1948. All the water was being used for domestic or stock purposes, and therefore the springs could not be considered as a source of water for the school. An analysis of the water is given in table 2.

Deep well at school

The deep well drilled in 1946 produced about 1 1/4 gallons per minute from the Wingate sandstone. The bottom of the well was in the Chinle formation (see table 1). The geologic studies indicate that it probably would not be advisable to deepen the well, because structural conditions are unfavorable for the accumulation of ground water in the unexposed sedimentary rocks in the vicinity of the school.

There is a slight possibility, however, that the Shinarump conglomerate, if present in the vicinity of the school, is water bearing. The top of the formation may be expected at a depth of about 1,400 feet, which is nearly 700 feet lower than the altitude of the outcrop area. The outcrop area lies in a narrow belt along the axis of the Balanced Rock anticline, about 13 miles east of the school. However, the Piute Creek syncline, which plunges to the north, lies between the outcrop area and the school, and it is

[6] Gregory, H. E., op. cit., p. 157, 1916.

believed that most of the ground water moving west from the anticline drains north along the axis of the syncline. Although the Shinarump conglomerate may possibly be saturated at the school, there probably is little or no movement of ground water in that vicinity, and the residual salts in the formation probably have not been removed by flushing. Therefore, if ground water is encountered in the formation at the school it is likely to be highly mineralized.

The DeChelly sandstone member of the Cutler formation crops out in Nokai Creek, on the east side of the Balanced Rock anticline. As the formation dips eastward in that locality, there is no possibility that water entering the outcrop could move westward toward the school.

<u>Well or infiltration gallery in alluvium</u>

The dug well in the alluvium at the school is 20 feet deep. The bottom of the well is reported to be on the Navajo sandstone. The water level in the well fluctuates with the seasons, so that the well becomes dry in the summer when the creek ceases to flow. The well intercepts underflow of the creek, and when the water table is high the well will produce sufficient water for the school.

The underflow of the creek is estimated to range between 3,000 and 45,000 gallons per day, based on the following factors:

Gradient of water table:	400 feet per mile
Width of alluvial fill:	40 feet
Estimated average thickness of saturated portion of fill (range during year)	1 to 15 feet
Estimated average permeability of fill:	1,000 gallons per day per square foot at unit hydraulic gradient

An infiltration gallery probably would collect more water than the existing well, although even a gallery probably would fail to produce water during periods of little or no runoff. A low dam extending to bedrock, to stop underflow past the gallery, would raise the water table and increase the effectiveness of the gallery. The storage tank at Navajo Mountain is reported to hold 4,000 gallons, which is enough water for about a day at the normal rate of usage when the school is in operation. If the storage capacity were increased to 50,000 or 75,000 gallons, the school probably could be operated a few weeks longer each year. With an infiltration gallery, and with larger storage tanks, the runoff generally occurring in late spring might be sufficient to keep the school open until the normal closing date. The runoff in August probably would make sufficient water available to fill the storage tanks prior to September 1. Under existing conditions, the school opens a month late and closes a month early because of the water shortage.

QUALITY OF WATER

Analyses of four samples of water from the Navajo Mountain area are included in table 2. All the samples contain moderate amounts of dissolved matter, consisting mainly of calcium and bicarbonate.

The water from the well at the school is hard but satisfactory for domestic use. Samples from the other sources are of better quality.

CONCLUSIONS

1. The discharge of War God and Endischee Springs on Navajo Mountain is considered barely sufficient to supply the needs at the school. It is believed that the cost of developing the springs and piping water to the school would be prohibitive.

2. It is not considered advisable to deepen the 823-foot well at the school. If the Shinarump conglomerate is present in the area, there is a slight possibility of obtaining water from the formation, but the quality of the water probably would be poor.

3. The amount of ground water recovered from the alluvial fill at the school probably could be increased by constructing an underflow dam and an infiltration gallery across the creek.

4. The school probably could be kept open longer in the spring and opened earlier in the fall by increasing the water-storage capacity.

Table 1. Log of well drilled at Navajo Mountain school, August 1946. Diameter, 8 inches; uncased. Burt Cravath, driller. Well produced 1 1/4 gallons per minute from Wingate sandstone between 505 and 520 feet. Water level, 500 feet below top of casing. Abandoned as dry hole. Formations identification by S. C. Brown.

Material	Thickness (feet)	Depth (feet)
Alluvium		
Fill	4	4
Sand and boulders	32	36
Navajo sandstone		
Hard red sandstone	45	81
Kayenta formation		
Red shale	12	93
Red sandstone	97	190
Layers of dark-red sandstone and shale	94	284
Wingate sandstone		
Light-red sandstone	221	505
Red sandstone, water	15	520
Light-red sandstone	20	540
Chinle formation		
Red, gray and purple shale	30	570
Red flaky sandstone	120	690
Light-colored hard sandstone	18	708
Hard red sandstone	2	710
Red sandstone	7	717
Gray sandstone	3	720
Red sandstone	80	800
Red sticky shale	23	823
TOTAL DEPTH		823

Table 2. Analyses of water from Navajo Mountain area, Utah. Analyzed in Southwestern Laboratory of Geological Survey, Albuquerque, New Mexico.

(Parts per million except specific conductances)

Sample No.	Date of Collection 1948	Temperature °F.	Specific Conductance, (Micromhos @ 25° C.)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)
1	July 12	54	399	54	14	16
2	do.	62	222	26	10	7.6
3	do.	-	222	-	-	-
4	July 10	56	536	66	27	14

1. Endischee Spring, on Navajo Mountain. Discharge, 7 to 10 gallons per minute.

2. Domestic spring at Rainbow Lodge, Ariz., at base of Navajo Mountain. Discharge, 7 to 10 gallons per minute.

3. Stock spring at Rainbow Lodge. Discharge, ½ to 1 gallon per minute.

4. Dug well at Navajo Mountain school.

Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$
249	12	7	-	0.1	242	192
129	7.6	6	0	.9	136	106
130	-	5	-	-	-	-
335	16	10	0	.1	318	276