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Preliminary report on the availability of water in the Red Lake area, Navajo Indian Reservation, Arizona and New Mexico

By J. P. Akers, N. E. McClymonds, and J. W. Harshbarger

Prepared in cooperation with
the Navajo Tribe

Tucson, Arizona
February 1959

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PRELIMINARY REPORT ON THE AVAILABILITY OF WATER IN THE RED LAKE AREA, NAVAJO INDIAN RESERVATION, ARIZONA AND NEW MEXICO

By

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INTRODUCTION

The U. S. Geological Survey made a water-resources investigation of the Red Lake area about 11 miles north of Fort Defiance, Ariz., at the request of the Navajo Tribe. The purpose of the investigation was to determine the possibility of obtaining 1,000,000 gallons of water per day, from surface and (or) underground sources, for a proposed sawmill and a community of 3,000 people. The area of investigation lies between, and includes, Buell Park on the west and Todilto Park on the east (see topographic map).

The Red Lake area was mapped by the U. S. Geological Survey in 1950 through 1954 as part of the Navajo Ground Water Project, and in 1954 by Allen and Balk who also wrote a report on the mineral resources, including ground water, of the area. Allen and Balk's report contains data on specific wells and a general discussion of the individual aquifers in the Fort Defiance and Tohatchi quadrangles. However, none of the wells they discuss are within the area of the present investigation.

Fieldwork for the present investigation was started in March 1958 and consisted mostly of measuring the discharge of Whiskey and Crystal Creeks and the springs in Buell Park, and of test drilling selected areas. A reconnaissance was made of the geologic structure to determine the best sites for deep test wells. Work was hampered by unusually wet weather in March and April and little progress was made until May. Testing of wells continues at the present time (September 1958).

TOPOGRAPHY AND DRAINAGE

The major topographic features in the Red Lake area are the Defiance Plateau to the west, including Buell Park; the Black Creek valley in the central part; and Fuzzy Mountain and Todilto Park to the east. The Defiance Plateau is a timbered high tableland which extends for 100 miles along the eastern border of northern Arizona. Buell Park is 2 miles southwest of Red Lake and near the crest of the eastern slope of the Defiance Plateau. It is a circular depression of volcanic origin, about 2-1/2 miles in diameter; the edges range from 7,400 to 7,800 feet in altitude and the floor of the vent is about 7,200 feet above sea level. The Black Creek valley lies at an altitude of 7,070 feet, is 1 to 2 miles wide, and cuts across the investigated area in a north-south direction. The hogback east of the valley is formed by the resistant limestone ledges of the Owl Rock member of the Chinle formation and sheer red cliffs of the Entrada sandstone and Summerville formation. Todilto Park is about 4 miles east of Red Lake. This park is 5 miles long in a generally north-south direction and is up to 2-1/2 miles wide. Red cliffs of the Entrada sandstone and the Summerville formation surround the park except where they are cut by Tohdildonih Wash at the outlet.

The major area drains mainly to Black Creek, an intermittent stream flowing from north to south across the area. The major tributaries within the area are Buell Wash, which is mostly intermittent through Buell Park but is perennial for a short distance below the spring near the drainage outlet of the park; and Tohdildonih Wash, a perennial stream which originates in the Chuska Mountains east of the area. Water from Tohdildonih Wash is diverted into Red Lake.

A minor stream that comes off Fuzzy Mountain and traverses the south side of the volcanic plug known as Split Mesa loses its identity upon reaching the alluvial flats. However, this stream and its tributaries are in part the source for water in the wells penetrating alluvium south and west of Split Mesa. The underflow of this stream is supplemented by that in another unnamed wash which heads on the south side of Fuzzy Mountain, turns northward on the alluvial flats, and loses its identity before reaching the area west of Split Mesa. Underflow from Tohdildonih Wash also supplements the ground water in this vicinity by feeding water to what is probably its former channel east of the limestone hogback south of the Tohdildonih Wash Dam.

GEOLOGY

Structure

There are three main structural elements in the area: (1) the Defiance monocline on the west, (2) the Todilto anticline on the east, and (3) the intermediate Fuzzy Mountain syncline.

The anticlinal bend of the Defiance monocline is well defined and the strata dip toward the east as much as 20°. The Fuzzy Mountain syncline to the east is rather broad and flat. The strata forming the syncline have very gentle dips; however, the west limb dips more steeply than the east limb, and the syncline plunges southward under Fuzzy Mountain. The Todilto anticline trends about N. 25° E., diverging from the northerly trend of the Defiance monocline. It plunges gently toward the south and more steeply toward the north. It is egg shaped in plan view, the small end being to the northeast.

Sedimentary Rocks and Their Water-Bearing Properties

Consolidated sedimentary rocks in the Buell Park-Todilto Park area range in age from Permian to Cretaceous. They consist of a thick sequence of alternating shale and sandstone and minor amounts of conglomerate and limestone. Deposits of Quaternary alluvium along streams overlie the older bedrock. In general the older bedrock units are exposed to the west and the younger to the east.

Permian Rocks

Supai formation.--The Supai formation crops out along the western periphery of Buell Park and is present at depth in most of the area to the east. It consists of dark-red shale interbedded with dark-red fine- to medium-grained thin, flat-bedded sandstone and minor amounts of limestone. The thickness is not uniform, as the Supai was deposited on an erosion surface of considerable relief; however, it is believed to be as much as 1,000 feet in this area.

The Supai formation in much of the area contains water in the upper 250 feet, where it consists mostly of fine sand.

De Chelly sandstone.--Overlying the Supai formation is the De Chelly sandstone, which crops out along the eastern periphery of Buell Park and is present at depth in the rest of the area to the east. It consists of about 300 to 350 feet of light-red fine-grained massive sandstone exhibiting large-scale tangential crossbedding on its weathered surfaces. The De Chelly sandstone is water bearing in the Red Lake area.

Triassic Rocks

Chinle formation.--The Chinle formation, overlying the De Chelly sandstone, crops out along the sides of Black Creek valley and at the crest of the Todilto anticline. It is about 1,300 feet thick and comprises four units: (1) The Shinarump member at the base consists of about 100 feet of medium- to coarse-grained sandstone containing quartz, jasper, and quartzite pebbles. The Shinarump member is water bearing. (2) The lower red member above the Shinarump consists of red and purple claystone, siltstone, and conglomeratic sandstone. Some of the sandstone units in this member contain small amounts of water. (3) The Petrified Forest member is divided into lower and upper shaly parts by the intermediate Sonsela sandstone bed. The shaly parts are composed of varicolored claystone, siltstone, and fine-grained sandstone and contain no water. The Sonsela sandstone bed is an aquifer in this area. (4) The Owl Rock member at the top of the formation consists of alternating pink and green cherty limestone beds and pink claystone and siltstone; it is not water bearing.

Wingate sandstone.--The Wingate sandstone crops out in small exposures at the base of the cliffs in Todilto Park. It consists of about 265 feet of non-water-bearing orange-red siltstone and fine-grained sandstone.

Jurassic Rocks

Jurassic rocks crop out in this area in the cliffs at the eastern side of the Black Creek valley, in Todilto Park, and on the flanks of Fuzzy Mountain. They include the Entrada sandstone, the Todilto limestone, the Summerville formation, the Cow Springs sandstone, and the Morrison formation, and they consist of fine-grained light-red sandstone and shale. They are not considered a source for water in this area.

Cretaceous Rocks

Dakota sandstone.--The Dakota sandstone of Cretaceous age is present capping the uplands at the east edge of the area but is not a potential aquifer within the area.

Quaternary Alluvium

Quaternary alluvium, composed of gravel, sand, and silt, forms fairly extensive deposits along the streams in the area. It ranges in thickness from 30 to 75 feet along Tohdildonih Wash, about 60 to 90 feet between Red Lake and Frog Rock, and about 40 to 50 feet in the southeast quarter of Buell Park. The alluvium contains water in all these localities.

Igneous Rocks and Their Water-Bearing Properties

Most workers consider the igneous rocks in the Red Lake area to be of Tertiary age and assign them to the Pliocene epoch. All the igneous rocks in this area are of volcanic origin. They consist of two types, lava and lapilli tuff, of which only the lapilli tuff is important as a source of water.

Lapilli tuff forms the floor of Buell Park. It is gray green and contains fragments of igneous rock and angular and rounded pebbles of material derived from country rocks at depth. Most of the pebbles are composed of chert, quartzite, and slate; a few are composed of granite. The matrix is tuffaceous and contains abundant olivine and garnet crystals. Table 1 describes the rocks and their water-bearing properties.

Table 1.--Description of rocks and their water-bearing properties in the Red Lake area, Navajo Indian Reservation

Formation	Age	Thickness (feet)	Rock type	Water-bearing character
Alluvium	Quaternary	30-90	Sand, silt, and clay	Water-bearing
Lapilli tuff	Tertiary	-	-	Water-bearing
Dakota sandstone	Cretaceous	-	Sandstone	Not an aquifer in the area
Morrison formation				
Westwater Canyon member	Jurassic	260	Arkosic sandstone	Non-water-bearing in this area
Recapture member	Jurassic	330	Sandstone and clay	Non-water-bearing
Summerville formation	Jurassic	360	Sandstone and clay	Non-water-bearing
Todilto limestone	Jurassic	15	Sandstone and siltstone	Non-water-bearing
Entrada sandstone	Jurassic	280	Sandstone	Non-water-bearing
Wingate sandstone	Triassic	265	Siltstone and sandstone	Non-water-bearing
Chinle formation				
Owl Rock member	Triassic	250	Clay and limestone	Non-water-bearing
Upper shaly part of Petrified Forest member	Triassic	500	Claystone	Non-water-bearing
Sonsela sandstone bed	Triassic	30	Sandstone	Water-bearing
Lower shaly part of Petrified Forest member	Triassic	220	Claystone	Non-water-bearing
Lower red member	Triassic	200	Clay and siltstone	Non-water-bearing
Shinarump member	Triassic	50	Sandstone and conglomerate	Water-bearing
De Chelly sandstone	Permian	300	Sandstone	Water-bearing
Supai formation				
Upper part	Permian	250	Sandstone and claystone	Water-bearing
Lower part	Permian	750	Clay and siltstone	Non-water-bearing

SURFACE WATER

Gaging stations operated on Whiskey Creek in 1952 and 1953 and on Crystal Creek in 1949 to 1953 by the Irrigation Branch of the Bureau of Indian Affairs were reactivated during this study and operated as continuous-record stations by the Geological Survey. Monthly discharge of Whiskey and Crystal Creeks is listed in tables 2 and 3.

It is believed that the streamflow data, though meager, are complete enough to indicate the general magnitude of the discharge of Whiskey and Crystal Creeks. The combined flow of both creeks, averaged over the period of record, is greater than the required minimum of 1,000,000 gpd (gallons per day). However, the combined flow during the summer months would be less than 1 mgd (million gallons per day), and storage would be needed to make up the deficit. The period of record is incomplete, and great variance in streamflow may be expected. Also, these figures do not allow for seepage and evaporation losses, which would be considerable. Available data show that the discharge of Whiskey Creek in the years 1949 through 1951 was little more than half the average discharge for the years 1949 through 1953. It is possible that a prolonged drought, coupled with seepage and evaporation losses, would result in a critical water shortage even if an attempt were made to obtain all the water from the creeks.

Table 2.--Monthly discharge of Crystal Creek at Crystal, N. Mex., 1952-53[1] and 1958[2]

Year	Month	Average (cubic feet per second)	Average (million gallons per day)
1952	October	1.06	0.69
	November	1.36	.88
	December	1.77	1.14
1953	January	1.84	1.20
	February	4.38	2.84
	March	2.91	1.89
	April	3.29	2.13
	May	1.99	1.28
	June	1.02	.66
	July	1.65	1.07
	August	2.61	1.68
	September	3.19	2.06
Break in record			
1958	March*	2.85	1.84
	April	5.55	3.59
	May**	3.02	1.95
	June	.79	.51
	July	.53	.34
	August***	.56	.36

[1] Figures from records of the Bureau of Indian Affairs.
[2] Figures from records of the U. S. Geological Survey.

* 21 days only
** 15 days only
*** 15 days only

Table 3.--Monthly discharge of Whiskey Creek, 7 miles northwest of Crystal, N. Mex., 1949-53[1]

Year	Month	Average (cubic feet per second)	Average (million gallons per day)
1949	October	1.06	0.69
	November	1.36	.88
	December	1.77	1.14
Break in record			
1950	May	1.07	.69
	June	.79	.50
	July	1.33	.86
	August	.90	.58
	September	1.10	.71
	October	1.36	.88
	November	1.73	1.12
Break in record			
1951	May	1.43	.92
	June	.70	.45
	July	.65	.42
	August	1.13	.73
	September	.93	.60
	October	2.00	1.30
	November	2.43	1.57
	December	2.02	1.31
1952	January	2.25	1.45
	February	2.83	1.83
	March	2.60	1.68
	June	.42	.27
	July	.88	.56
	October	1.62	1.05
	November	3.41	2.20
	December	6.25	4.03
1953	January	2.63	1.70
	February	6.36	4.10
	March	9.21	5.95
	April	5.33	3.44
	May	2.38	1.54
	June	1.45	.94

[1] Figures from records of the Bureau of Indian Affairs.

If the water from both creeks were utilized, a system designed to deliver a maximum of 1 mgd of water to the sawmill site would require the installation of a minimum of 17 miles of pipeline (see map) and the construction of two dams. Water from Whiskey Creek would have to be lifted about 50 feet to a point about half a mile from the base of Little White Cone. From this point southward to the sawmill the water would flow by gravity. Water from a reservoir on Crystal Creek near Crystal, N. Mex., would flow by gravity to the sawmill site (see map). A chlorinator to disinfect the water and tanks to remove sediment would be required. The chemical quality of the water is very good (see section on Quality of Water).

In summary, two factors would have to be considered in using Whiskey and Crystal Creeks as a source of water for the proposed sawmill and sawmill community: (1) The runoff fluctuates widely, and a prolonged drought might result in a water shortage even if provision were made for all the surface storage capacity that conceivably might be economically feasible; (2) construction and maintenance of 17 miles of pipeline, two dams, and a water-purification system would be costly.

On the other hand, only one pump would be required in the system designed to deliver the water to the sawmill site. This would result in a considerable saving in power consumption over a system designed to supply water from ground-water sources. Also, the reservoirs on Whiskey and Crystal Creeks could serve as recreational areas both for the sawmill community and for sportsmen from other areas.

As the data on Whiskey and Crystal Creeks are not adequate to show conclusively whether the creeks would be reliable sources of water for a project as large as the sawmill, and as ground-water sources appear to be adequate, the creeks are not considered further in this report. However, should the need arise in the future for supplemental water, these creeks, with adequate storage, could be utilized.

GROUND WATER

Preliminary investigations indicate three areas from which ground water could be obtained in sufficient quantities for the proposed sawmill. These are: (1) along Tohdildonih Wash near the diversion dam, from alluvium; (2) on the southwest side of Red Lake, from the Shinarump member of the Chinle formation and the De Chelly sandstone; and (3) in Buell Park, from alluvium and volcanic material. The alluvium along Tohdildonih Wash and the alluvium and volcanic material in Buell Park were extensively tested by drilling wells. Both localities proved favorable for water development. Drilling of a deep test well to the Shinarump and De Chelly at the southwest edge of Red Lake is still in progress, and the yield and quality of water from this test hole are as yet undetermined.

The test drilling in each of these three areas is summarized as follows:

1. Tohdildonih Wash: Two test wells were drilled north of Tohdildonih Wash, just northeast of the diversion dam, in an old oxbow channel of the stream (see map). These two tests, numbered 18T-506 and 18T-507, penetrated silt and fine sand and yielded insufficient water for development for the sawmill project. Two other test holes (18T-512 and 18T-513) were drilled immediately south of the stream in this vicinity and encountered similar conditions.

Four more test holes (18T-508 through 18T-511) were drilled in what is considered an old channel of Tohdildonih Wash south of the dam. The alluvium in this channel was found to range from 44 to 83 feet in thickness, and about the lower 3 feet in each hole was found to consist of granule- to small pebble-sized gravel. The gravel in test hole 18T-511 yielded 45 gpm (gallons per minute) in a 16-1/2-hour test, with a drawdown of 52 feet from a static water level of 12.6 feet. The water was of good chemical quality, containing 328 ppm (parts per million) of dissolved solids.

The buried gravel channel was found to follow a course from the south side of Split Mesa to the south tip of the hogback south of the diversion dam and then westward (see geologic map). Four wells were drilled approximately 1,000 feet apart along this channel. These wells (18T-524 through 18T-527) are 32 inches in diameter, have 17.5-inch concrete casing, and are gravel packed. The lower 20 feet of the casing in each is perforated. Preliminary tests on these wells indicate that each is capable of yielding 200 gpm with about 40 feet of drawdown from static water levels of 12 to 23 feet.

A 96-hour pumping test on well 18T-525 indicates that the alluvium in this channel has a coefficient of transmissibility of about 22,000 gpd per foot, which indicates a moderately productive aquifer. The computed storage coefficient was about 0.03, indicating water-table conditions.

If, when the well field goes into production, the wells are pumped alternately, two at a time, it is believed that the field will sustain a yield of about 400 gpm, or roughly 600,000 gpd.

2. Red Lake: The deep test hole (18T-505) just east of the New Mexico-Arizona State line on the southeast margin of Red Lake is planned for a depth of about 1,200 feet, through the entire Shinarump member and De Chelly sandstone and into the Supai formation. Currently the hole is being drilled in the upper part of the aquifer. Difficulty with casing, which was set to about 680 feet at the approximate top of the aquifer, caused delay in the finishing of this well, so as yet it is untested. On September 8, 1953, it was down to slightly more than 800 feet and was flowing 4 gpm.

3. Buell Park: Six test holes were drilled in Buell Park. Near the spring in the southeast corner of the park a well (18T-514) was drilled to a total depth of 480 feet. This well produces from two zones of volcanic cinders at depths of 120 to 130 feet and 220 to 230 feet. It yielded 170 gpm in a 3-day test with a 50-foot drawdown from a static water level of 20.7 feet. The water is of good chemical quality, containing 464 ppm of dissolved solids. While the well was being tested, the flow from the spring decreased from 64 to 5 gpm. A production well (18T-523) of 10-inch diameter has since been drilled at this site, but it has not been tested.

The second test hole in Buell Park was located east of a plug of igneous rock (kimberlite) in the north-central part of the park. This well (18T-515) was drilled to 315 feet. It was tested at 30 gpm at a depth of 100 feet, below which no permeable materials were penetrated. This yield is considered insufficient for the sawmill project.

Four holes, originally drilled to test the alluvium along Buell Wash, were located across the alluvial flats immediately west of the arcuate dike near the east edge of the park. Three of these had insufficient yield; the fourth was drilled through the alluvium and penetrated volcanic cinder material similar to that in well 18T-514, but at a much shallower depth. The alluvial fill is 50 feet thick and the cinders 20 feet, from 50 to 70 feet. This well (18T-521) was drilled to a total depth of 123 feet and yielded 625 gpm for 72 hours with a drawdown of 28.5 feet from a static water level of 31.5 feet.

Extensive tests have yet to be run on the two production wells in Buell Park (18T-521 and 18T-523), but it is believed that at least 500 gpm, or about 700,000 gpd, can be obtained from this area.

Conclusion: Six wells, four southeast of Red Lake and two in Buell Park, are ready for production, except for the installation of pumps and construction of pipelines and storage tank. These wells should yield a combined total of about 900 gpm, or about 1,300,000 gpd. In addition, if the sawmill and community should expand beyond the present estimate, it is believed it would be possible to increase the output of the wells in Buell Park, possibly to double the figure of 500 gpm estimated for the two existing production wells. The wells in alluvium southeast of Red Lake probably cannot be pumped at a total rate greater than 400 gpm without adverse affect.

The deep test well 18T-505, when completed, will probably produce about 100 gpm; the drawdown cannot be estimated at this time. Should the drawdown be relatively small, it is not impossible that this well could produce as much as 200 gpm if the pump were set at a depth approaching 1,000 feet.

In emergencies, either the wells in Buell Park or those in the alluvium southeast of Red Lake could produce almost enough water for the sawmill project without supplementary aid, by drawing on storage in the deposits temporarily.

QUALITY OF WATER

The chemical quality of water in all the test wells and in Whiskey and Crystal Creeks is good. Although salty water was obtained from the Sonsela sandstone bed in well 18T-505, this bed is cased off and water from the Shinarump and De Chelly is expected to be of much better quality. Water from this deeper zone has not yet been analyzed. Analyses for test wells 18T-508 and 18T-511 should be indicative of the quality of water in the entire well field southeast of Red Lake. Water from production well 18T-523 in Buell Park should be practically identical in quality to that from test well 18T-514. Specific conductance measurements of water from wells 18T-515 and 18T-521 show that the water contains less dissolved solids than that from well 18T-514.

The following table gives the results of analyses made to date.

Table 4.--Chemical analyses of water from creeks and wells in the Red Lake area, Navajo Indian Reservation
(Analyses by U. S. Geological Survey. Chemical constituents in parts per million)

	Whiskey Creek	Crystal Creek	18T-505 (Sonsela)	18T-508	18T-511	18T-514
Temperature (°F)	-	-	52	52	52	53
Silica	30	20	6.4	5.2	8.6	25
Iron	-	-	-	.01	.14	-
Total iron	-	-	-	5.5	6.3	-
Calcium	51	37	14	58	54	24
Magnesium	5	5.9	1.7	12	9.7	45
Sodium and potassium	11	12	767	71	64	90
Bicarbonate	189	154	317	319	348	347
Carbonate	0	0	20	0	0	0
Sulfate	7.2	7.2	551	55	4.5	120
Chloride	5.5	6.0	590	20	16	19
Fluoride	.3	.5	2.7	.5	.4	.3
Nitrate	.4	.6	4.3	.2	.2	4.3
Dissolved solids:						
Parts per million	203	165	2,110	379	328	499
Tons per acre-foot	.28	.22	2.87	.52	.45	.68
Hardness as $CaCO_3$	148	117	42	194	174	245
Percent sodium	14	19	98	44	44	44
Sodium-adsorption ratio	.4	.5	51	2.2	2.1	2.5
Specific conductance (micromhos at 25°C)	315	264	3,450	625	557	791
pH	7.6	7.3	8.6	7.9	7.8	8.2

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