INTRODUCTION

The Navajo Indian Reservation in Utah and Arizona is situated in one of the most arid parts of the Western United States. Normal annual precipitation is less than 8 to about 10 in. over much of the region (Cooley and others, 1969). Generally, water supplies for residents on the Reservation come from wells and springs, but locally, these supplies are small and, in some areas, they are slightly to moderately saline and not suitable for domestic purposes (Naftz and Spangler, 1994). One such area where water supply is limited is Monument Valley, along the Utah-Arizona State line, in the northern part of the Navajo Indian Reservation (fig. 1).

The main issue identified by the Navajo Nation Department of Water Resources (DWR) concerns adequate water supply for the residents of the Monument Valley area. Additional water sources need to be developed locally to avoid having water piped into the area and to minimize haulage of water for domestic use. In addition, supplemental water supplies need to be developed to meet the demands of an increasing number of tourists. Because of these needs, the Navajo Nation DWR, in cooperation with the U.S. Geological Survey, investigated the hydrology of, and quality of water in, an alluvial aquifer along a tributary of Oljato Wash, near Oljato, Utah (fig. 2).

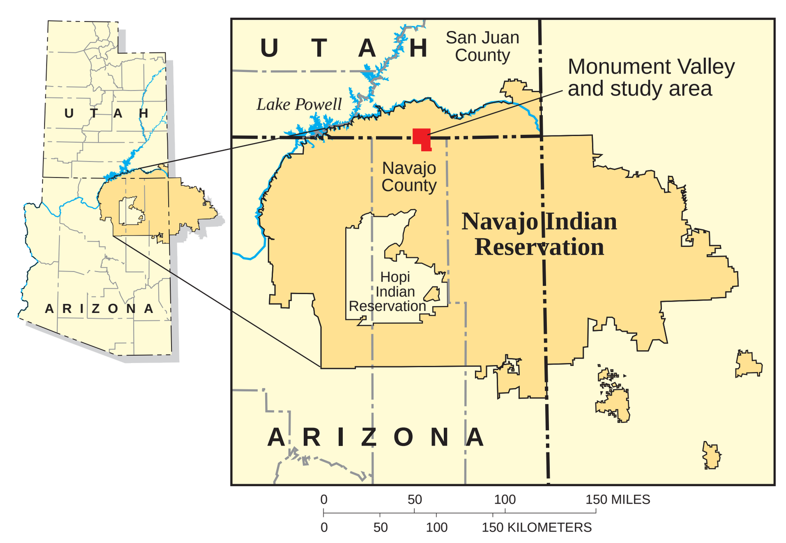

Figure 1. Location of Monument Valley and study area in San Juan County, Utah, and Navajo County, Arizona.

Previous Investigations

The last study to focus on water supply for the Navajo Nation that included the Monument Valley area began in 1950 and ended in the mid-1960s (Cooley and others, 1969). The principal objectives of that study were to inventory all wells and springs, investigate the geology and ground-water hydrology of sedimentary and igneous rocks in the area, and determine the feasibility of developing additional ground-water supplies. Geohydrologic data compiled during this investigation were published as a series of related reports by the Arizona State Land Department (Davis and others, 1963; Kister and Hatchett, 1963; Cooley and others, 1964; Cooley and others, 1966; and McGavock and others, 1966). A more specific investigation concerning geohydrology and water chemistry at abandoned uranium mines in the Monument Valley area was completed by Longsworth (1994).

Purpose and Scope

The purpose of this report is to describe (1) the composition and vertical and lateral extent of the alluvial deposits along an unnamed tributary of Oljato Wash, (2) the hydraulic characteristics of the aquifer contained within these deposits, (3) recharge to and discharge from the alluvial aquifer, and (4) the chemical quality of water in the aquifer.

Well records, water-use, water-quality, water-level, and aquifer-test data for this investigation were obtained from U.S. Geological Survey and Navajo Nation DWR data bases and from public water-supply system files. Aquifer data also were obtained from 15 monitoring wells drilled during the study, a multiple-well interference test completed in December 1996, single-well pumping tests for selected wells, and borehole-geophysical logs. Results of analysis of the multiple-well interference test were provided to the Navajo Nation DWR as a separate document (U.S. Geological Survey aquifer test, December 11-17, 1996). This report summarizes results of investigations done between October 1995 and October 1997.

Acknowledgments

The authors acknowledge the assistance of all those who helped contribute to the completion of this study. The U.S. Geological Survey, Water Resources Division, Western Region drill crew was responsible for completion of most monitoring wells. Several wells also were completed by Bayles Exploration, Blanding, Utah, and Quality Drilling, Mexican Hat, Utah. Archaeological surveys were done by the Navajo Nation Archaeology Department, Farmington, New Mexico, to obtain clearance for drilling sites. Appreciation is extended to the staff members of the Oljato Chapter of the Navajo Nation for their valuable assistance with regard to permitting, clearances, and help during drilling activities. In addition, the authors greatly appreciate the assistance of the local public water-supply systems managers in obtaining water samples and water levels and providing data for their wells.

Numbering System for Hydrologic-Data Sites

The local well-numbering system on the Navajo Indian Reservation is based on Bureau of Indian Affairs (BIA) administrative districts and numbered 15-minute quadrangles within each district. Well numbers consist of two parts. The first part is a number that designates the BIA district and a "K," "T," or another letter identifying the source of funds used in the drilling of the well; for wells drilled and inventories made before 1950, the first letter of the last name of the person who first inventoried the well or spring for the BIA is used. The letter "K" is used for wells drilled as part of the BIA drilling program, and the letter "T" is used for wells drilled as part of the Navajo Tribal Well Development Program. The second part of the BIA well number represents the order in which the drilled wells and the springs were inventoried in each district. Additional letters used at the end of some designations are obtained from the number of a nearby development that was inventoried previously. These letters are arranged consecutively beginning with "A."

In addition, monitoring wells drilled during this study are numbered consecutively in the order in which they were drilled, beginning with "OW-1" and ending with "OW-15," where "OW-3" indicates the third well drilled during the study. The location of all wells and springs inventoried also is expressed in latitude and longitude (degrees, minutes, seconds) and the corresponding Universal Transverse Mercator (UTM) coordinates (meters), and is presented in table 1.

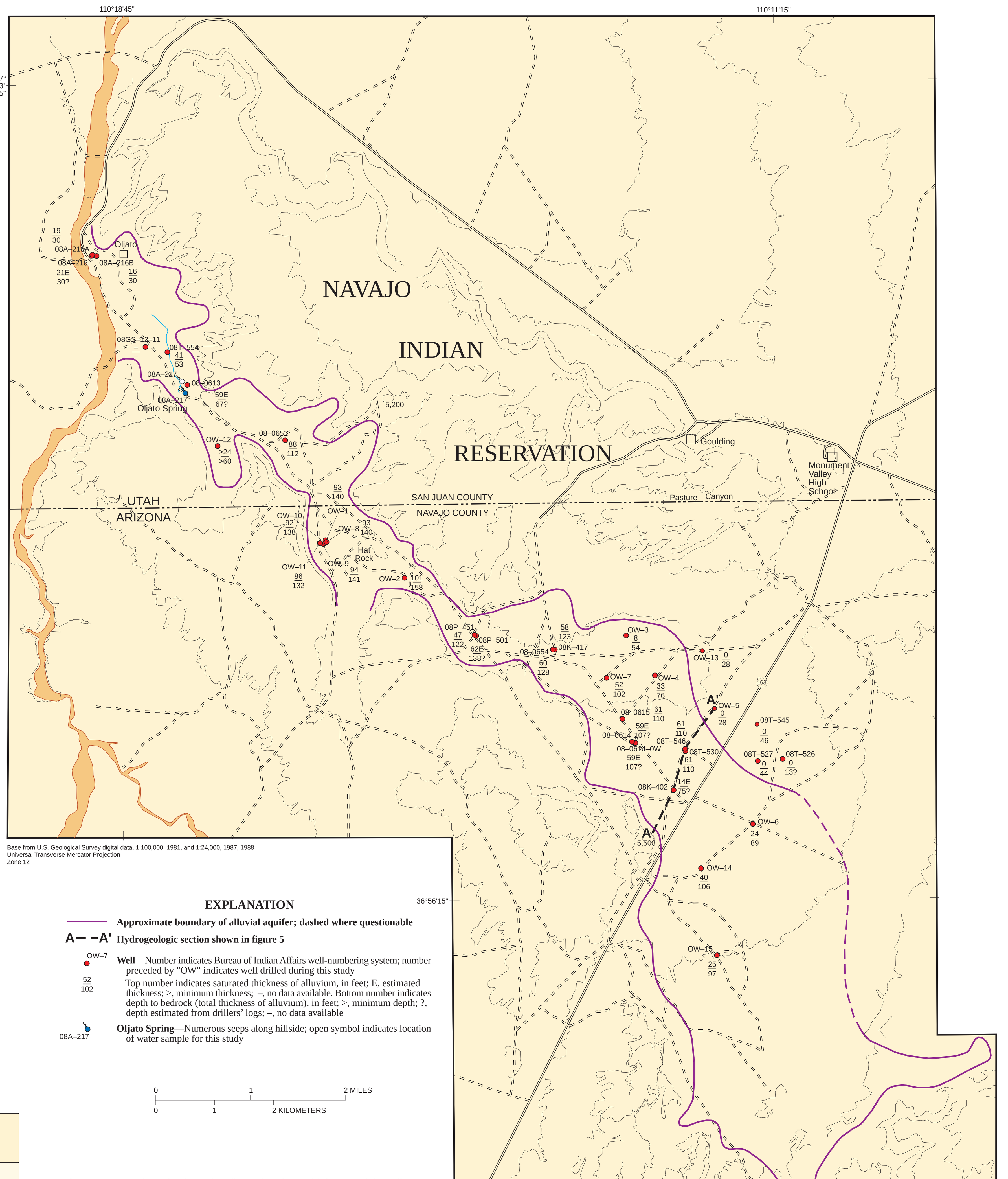

Figure 2. Location of selected wells and springs, thickness of the Oljato alluvial aquifer, and depth to bedrock, Monument Valley area, Utah and Arizona.

Table 1. Records of selected wells and a spring in the Monument Valley area, Utah and Arizona

[deg, degrees; min, minutes; sec, seconds; Do., ditto; ND, no data; NA, not applicable; <, less than stated value; ?, data uncertain]

Map number: Refer to numbering system for hydrologic-data sites; locations shown in figure 2.
UTM: Universal Transverse Mercator.
Altitude of land surface: In feet above sea level.
Perforated/screened/open interval: In feet below land surface.
Static water level: In feet below land surface; R, reported value.
Well yield: gal/min, gallons per minute.
Use of water: U, unused; P, public supply; S, stock.
Available information: D, driller's log; QW, water-quality data; L, lithologic log; G, geophysical log; P, aquifer/pumping-test data.

Map number	Latitude (deg/min/sec)	Longitude (deg/min/sec)	UTM coordinates, easting (meters)	UTM coordinates, northing (meters)	Altitude of land surface (feet)	Owner/ Operator	Date of well completion	Depth of well (feet)	Perforated/ screened/ open interval	Static water level (feet)		Date water level measured	Well yield (gal/min)	Use of water	Available information	Remarks
OW-1	365933	1101625	564651	4094097	5,096.48	Navajo Nation	07-17-96	158	100-140	47.09		09-23-97	ND	U	D,QW,L,G,P	Observation well
OW-2	365913	1101531	565985	4093483	5,137.85	Do.	07-17-96	177	118-158	56.72		09-23-97	<10	U	D,QW,L,G,P	Monitoring well
OW-3	365840	1101259	569737	4092505	5,192.84	Do.	07-17-96	55	20-54	45.91		09-23-97	ND	U	D,QW,L,G,P	Do.
OW-4	365818	1101240	570224	4091830	5,197.55	Do.	07-19-96	74	39-74	43.33		09-23-97	11	U	D,QW,L,G,P	Do.
OW-5	365800	1101159	571233	4091275	5,211.20	Do.	07-19-96	59	30-59	38.79		09-23-97	<1	U	D,QW,L,G	Completed in Organ Rock Tongue
OW-6	365656	1101134	571880	4089318	5,254.64	Do.	07-21-96	88	60-88	65.12		08-25-97	ND	U	D,QW,L,G	Monitoring well
OW-7	365817	1101313	569403	4091792	5,193.01	Do.	07-23-96	104	56-96	49.55		09-23-97	11	U	D,QW,L,G,P	Do.
OW-8	365933	1101625	564645	4094084	5,096.30	Do.	07-24-96	142	72-135	46.77		09-23-97	130	U	D,QW,L,G,P	Aquifer test well
OW-9	365933	1101625	564638	4094070	5,096.20	Do.	08-01-96	170	148-168	46.61		09-23-97	8	U	D,L,G,P	Completed in DeChelly Sandstone
OW-10	365933	1101626	564614	4094080	5,095.55	Do.	08-01-96	138	98-138	46.00		09-23-97	ND	U	D,L,G,P	Observation well
OW-11	365933	1101628	564554	4094071	5,095.32	Do.	08-01-96	129	89-129	45.64		09-23-97	ND	U	D,L.G,P	Do.
OW-12	370026	1101738	562822	4095710	5,030	Stanley Holiday	08-22-96	50	40-50	36.07		09-23-97	ND	U	D,L	Monitoring well
OW-13	365832	1101207	571025	4092246	5,200.62	Navajo Nation	08-25-97	50	NA	NA		NA	NA	NA	L	Plugged and abandoned
OW-14	365632	1101209	571004	4088568	5,266.62	Do.	08-27-97	107	75-105	66.33		09-23-97	10	U	D,QW,L,G,P	Monitoring well
OW-15	365545	1101159	571272	4087097	5,297.25	Do.	08-28-97	105	63-103	71.82		09-23-97	<5	U	D,QW,L,G,P	Do.
08A-216	370211	1101903	560690	4098930	4,838	Oljato Trading Post	10-48?	18	18	4	R	10-01-48	ND	U	D,QW	Abandoned windmill
										9.05		05-21-98				
08A-216A	370212	1101903	560700	4098950	4,840	Oljato Trading Post	07-51	100	31-100?	11	R	07-07-51	30	U	D,QW,L	Deepened to 130 feet in 1954?
										10.74		01-23-98				
08A-216B	370211	1101900	560773	4098924	4,840	Navajo Tribal Utility Authority	10-53	50	32-50?	12	R	10-29-54	30	P	QW,L,P	Public water supply
										14.0	R	08-02-90				
08A-217	370056	1101760	562275	4096620	4,960	Navajo Nation	NA	NA	NA	0		NA	20	S	QW	Oljato Spring
08K-402	365715	1101228	570540	4089890	5,245	Do.	03-14-39	123	113-123	55	R	03-14-39	<2	S	QW,L	Windmill; plumbed to 76.5 feet 5/98
										66.9	R	08-11-49				
										60.46		05-28-98				
08K-417	365833	1101348	568529	4092267	5,190	RGJ, Incorporated	06-47	137	ND	64.8	R	06-08-48	60-80	P	QW,L,P	Gouldings well
08P-451	365841	1101443	567170	4092516	5,180	Seventh Day Adventist Church	06-60	130	82-122	75.34		05-27-98	50	P	QW,L,P	Hospital/Mission well
08P-501	365841	1101442	567198	4092501	5,180	Do.	1967?	138	ND	75.84		05-27-98	12	P	L	Do.
08T-526	365732	1101113	572384	4090418	5,230	Navajo Nation	07-19-68	25	25	NA		NA	NA	U	L	Plugged and abandoned
08T-527	365731	1101130	571964	4090383	5,230	Do.	07-18-68	68	68	NA		NA	NA	U	L	Do.
08T-530	365737	1101220	570733	4090569	5,220	Parks and Recreation Department	12-75?	113	ND	49	R	12-24-75	ND	U	P	Movie Company well
										48.85		05-28-98				
08T-545	365751	1101130	571950	4091005	5,225	Navajo Nation	01-12-78	300	300?	60	R	01-12-78	<.5	U	L	Plugged and abandoned
08T-546	365738	1101220	570733	4090588	5,220	Parks and Recreation Department	03-01-78	120	80-110	49	R	03-01-78	42	P	QW,L,P	Tribal Park well
										50	R	04-29-97				
08T-554	370118	1101812	561971	4097300	4,920	Navajo Tribal Utility Authority	08-83	62	45-55	11.91	R	09-01-83	30	P	QW,L,P	Public water supply
08-0613	370100	1101759	562307	4096744	4,970	Indian Health Service	05-21-92	83	63-83	7.73		12-05-96	20-40	P	D,QW,L,P	Public water supply
08-0614	365742	1101256	569834	4090707	5,220	San Juan County School District	07-76	107	91-106	47.83		12-16-96	17	P	QW,L,P	High School well
										47.50		06-11-96				
08-0614-OW	365741	1101254	569892	4090689	5,213.49	Do.	1978?	85	ND	48.45		06-11-96	ND	U	P	Observation well
08-0615	365755	1101302	569673	4091093	5,200	Do.	01-30-78	111	ND	49.15		12-12-96	84	P	QW,L,P	High School well
08-0651	370029	1101652	563964	4095807	5,040	Gouldings	04-29-80	180	180	24.06		09-23-97	2	U	D,QW,L,P	
08-0654	365832	1101350	568486	4092234	5,190	RGJ, Incorporated	07-31-98	131	91-131	68.05		08-27-98	60-80	P	D,L,P	Gouldings well
08GS-12-11	370121	1101827	561600	4097389	4,900	Navajo Nation	04-15-67	<10	ND	<5			<5	S	ND	Moonlight well

Description of Study Area

The study area lies within the Monument Valley region and straddles the boundary between the States of Arizona and Utah, near the communities of Oljato and Goulding, Utah (figs. 1 and 2). The study area is within the Oljato Chapter of the Navajo Nation and includes about 21 mi² along an unnamed, northwest-trending tributary valley that joins Oljato Wash near Oljato, Utah (fig.2). The area is within the Colorado Plateau physiographic province and is characterized by mesas and buttes with intervening canyons and broad valleys. Land-surface altitude in the area ranges from about 4,800 ft above sea level along Oljato Wash to as much as 6,100 ft on Wetherill Mesa (fig. 2).

Many of the tributaries to Oljato Wash, a north-trending drainage to the San Juan River, are ephemeral, and surface-water flow in parts of Oljato Wash also is ephemeral. Surface drainage in much of the study area is poorly developed and integrated, particularly in the southeastern part of the valley where the landscape consists of stabilized dunes. Few perennial streams are present in the study area and surface flow generally occurs only after intense thunderstorms.

Annual precipitation in the study area averages about 8 in. (Cooley and others, 1969). Much of this precipitation comes from thunderstorms in late summer that provide 50 to 65 percent of the annual total (McDonald, 1956, fig. 7). Because the climate is arid, potential annual evaporation is much greater than precipitation. Daytime summer temperatures in the study area typically exceed 35°C. Vegetation is sparse, consisting of a desert scrub community in the valley and pinon-juniper on adjacent mesa tops (Cooley and others, 1969).

Geology

Unconsolidated alluvial deposits of Quaternary age are present along Oljato Wash and its tributaries (Cooley and others, 1969). In the study area, these deposits consist of interbedded clay, silt, sand, and gravel (fig. 3). The DeChelly Sandstone Member and Organ Rock Tongue of the Permian-age Cutler Formation underlie the alluvium in the northwestern part of the valley (Baker, 1936; Irwin and others, 1971). The Organ Rock Tongue is composed of interbedded mudstone, siltstone, and sandstone. In the southeastern part of the valley, the base of the DeChelly Sandstone is above land surface because rocks dip to the west, or has been removed by erosion, and the alluvium is directly underlain by the Organ Rock Tongue. On the basis of drillers' logs, this subsurface transition is present in the vicinity of well 08K-417 (fig. 2).

A profile from northwest to southeast across the study area (up valley) constructed using data from selected wells drilled through the alluvium to bedrock (fig. 3) shows that the upper part of the alluvium is generally finer grained than the lower part, which is predominantly sand and gravel. These sands and gravels provide the largest amount of water to wells. Natural gamma geophysical log responses also reflect the complex interbedding of fine and coarse materials within the alluvium that is not discernible using only lithologic descriptions based on drill cuttings (fig. 3). Because variations in lithologic character of these deposits are substantial throughout the study area, only generalized correlation of strata between wells can be done.

Variations in thickness of alluvial deposits (depth to bedrock) in the study area are shown in figures 2 and 3. Maximum known thickness of alluvium is 158 ft in well OW-2 near Hat Rock (fig. 2). Thickness of alluvium gradually decreases down valley toward Oljato, averaging only 30 to 60 ft. Up valley from Hat Rock, thickness of alluvium also decreases, and the maximum measured thickness is about 106 ft near Mystery Valley. Thicker alluvial deposits in the Hat Rock area could have resulted from input of fluvial sediments from areas to the south (fig. 2). Lithologic data from drillers' logs, in conjunction with well locations, indicate that the thickest alluvium probably is associated with one or more paleochannels. These buried channels, however, are not necessarily coincident with the present surface drainage.

HYDROLOGY OF THE ALLUVIAL AQUIFER

The principal aquifer in the study area is contained within the unconsolidated alluvial deposits that overlie the bedrock units throughout the valley. This aquifer herein is referred to as the "Oljato alluvial aquifer" to differentiate this aquifer from alluvial aquifers that are present along Oljato Wash and other tributaries. The alluvial deposits are unsaturated to partly saturated, except in downgradient areas near Oljato Wash, where the water table locally intersects the land surface. Several of the public-supply wells that yield water from the alluvium also are open to the upper part of the DeChelly Sandstone. Although these units are connected hydraulically, hydraulic conductivity of the DeChelly Sandstone is small compared with that of the overlying alluvium, and well yields from this unit generally are low (table 1).

Areal Extent, Thickness, and Hydraulic Properties

The Oljato alluvial aquifer is bounded physically by outcrops of the DeChelly Sandstone and Organ Rock Tongue along much of the valley. The alluvium also is not saturated in areas where these deposits are not thick enough to intercept the regional water table. The approximate areal extent of the alluvial aquifer as determined from well logs, water levels, and geology is about 9,500 acres (figs. 2 and 4). Downgradient, the aquifer merges with saturated alluvial deposits in Oljato Wash and likely thins to zero in upgradient areas (Mystery Valley), where the alluvium is presumed to pinch out against the bedrock boundaries of adjacent mesas and buttes (fig. 2).

Thickness of the aquifer is shown in figure 2. On the basis of measured water levels in 1996-97 and depth to bedrock, maximum thickness of the aquifer is 101 ft at well OW-2 near Hat Rock. Thickness of the aquifer decreases both downgradient and upgradient from this area (fig. 2). Thickness of the aquifer at well 08A-216B in Oljato is only 16 ft but averages about 58 ft in upgradient areas where most of the water-supply wells are located. At well OW-15 in the Mystery Valley area, thickness of the aquifer decreases to about 25 ft, although total thickness of the alluvium is almost 100 ft (fig. 3). Thickness of the aquifer also decreases rapidly toward valley margins in much of the area. Thickness of the aquifer at well OW-3, about 1,300 ft from the valley bedrock wall, is only about 8 ft (fig. 2).

A hydrogeologic section that includes wells 08K-402, 08T-546, and OW-5 (figs. 2 and 5) shows that, from well 08T-546, alluvial and aquifer thickness decrease rapidly to the northeast across the valley and toward the southwest. Thickness of alluvium at well 08T-546 (the Tribal Park well) is about 110 ft, of which about 61 ft is saturated. Thickness of the alluvium at well 08K-402, about 3,000 ft to the south, is about 75 ft, of which only about 14 ft is saturated. About 3,000 ft northeast of well 08T-546, the alluvium decreases in thickness to only about 28 ft at well OW-5 and is not saturated because regional water levels are below the base of the alluvium and in the underlying bedrock unit (figs. 4 and 5). The alluvium also is unsaturated in areas north, east, and southeast of well OW-5 (fig. 2). Most public-supply wells in this part of the study area, such as well 08T-546, appear to be aligned along a southeast-trending paleochannel(s) where aquifer thickness is greatest. Thus, an understanding of the hydrogeologic framework is important for successfully obtaining adequate water supplies in this area.

Transmissivity values reported and determined for selected wells in the Oljato alluvial aquifer range from less than 100 to as much as 2,800 ft²/d (table 2). Variations in transmissivity result from differences in aquifer thickness, hydraulic conductivity, and lithologic character of the alluvial deposits. Where aquifer thickness is large and alluvial deposits consist of predominantly coarse materials, transmissivity values can be high and well yields potentially large. Transmissivity determined from a multiple-well interference test near Hat Rock averages 1,250 ft²/d (table 2). Given a saturated thickness of 93 ft at this test site, hydraulic conductivity of the aquifer would be 13.4 ft/d. On the basis of this test (U.S. Geological Survey aquifer test, December 11-17, 1996), potential well yield in this area is at least 130 gal/min. Reported transmissivity of the aquifer in the vicinity of well 08T-554 averages 300 ft²/d (table 2). Although aquifer thickness at well OW-14 in the upgradient part of the study area is the same as that at well 08T-554 (fig. 2), results of analysis of a single-well test indicate a transmissivity of 70 to 100 ft²/d (table 2). Differences in transmissivity between these areas probably reflect differences in hydraulic conductivity of the alluvial deposits.

Specific-capacity values determined for selected wells also indicate that transmissivity of the alluvial aquifer varies substantially throughout the study area. Specific capacity ranges from 0.6 to 5.8 (gal/min)/ft of drawdown (table 2); larger values generally correspond with areas of high transmissivity. Specific capacity for well 08-0614 is 0.6 and transmissivity estimated from specific capacity is about 120 ft²/d (table 2). Specific capacity determined for well 08-0615 only 1,300 ft to the northwest, however, is 4.4 and transmissivity estimated from specific capacity is 940 to 1,100 ft²/d (table 2). Although thickness of the aquifer is about the same in both wells 08-0614 and 08-0615 (fig. 2), well yields are 17 and 84 gal/min, respectively (table 1).

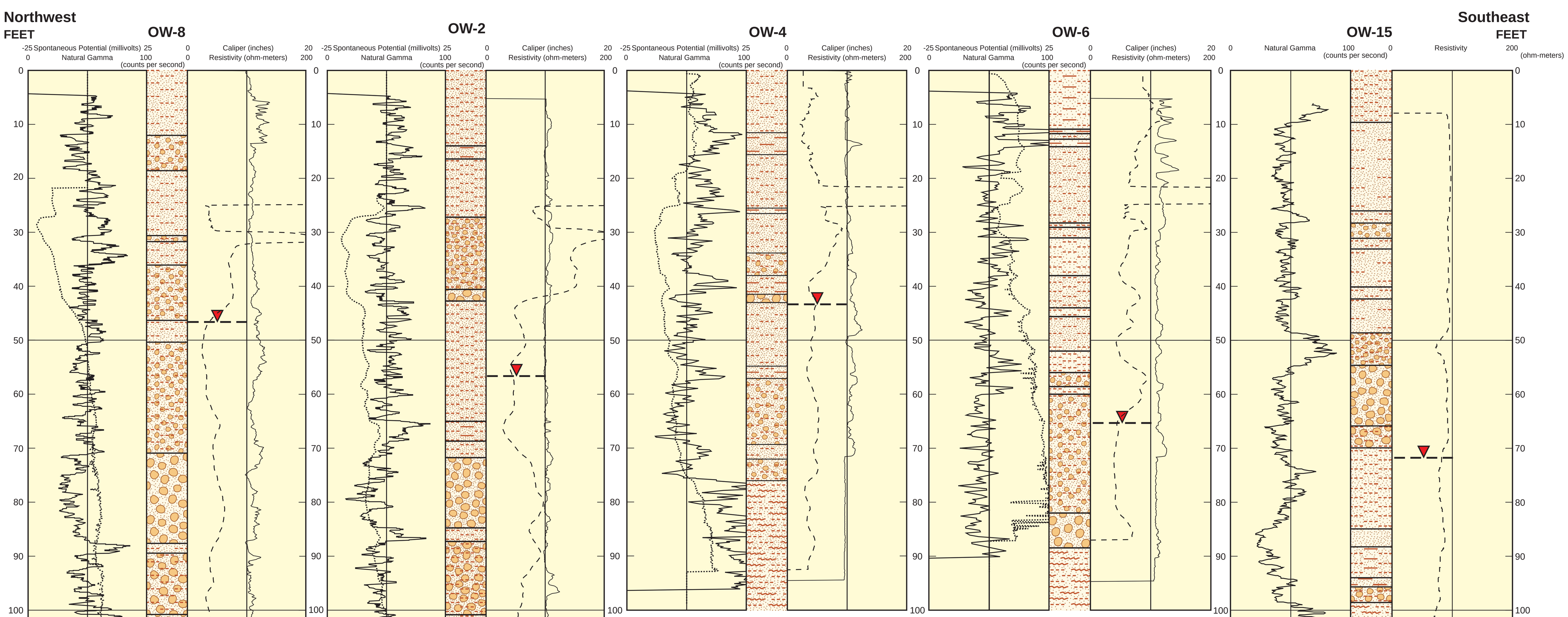

Figure 3. Diagrams showing correlation of natural gamma, spontaneous potential, resistivity, and caliper logs to stratigraphy for selected monitoring wells in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona.

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Hydrology and water quality of the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona

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