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HYDROLOGIC CHARACTERISTICS OF THE OJO ALAMO SANDSTONE, SAN JUAN BASIN, NEW MEXICO

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Abstract—The Ojo Alamo Sandstone is a Paleocene sandstone and shale formation that is utilized as an aquifer in the south and west portions of the inner San Juan Basin. This aquifer is sandwiched between the Kirtland Shale and the Nacimiento Formation, two units that seldom produce useful quantities of potable water. The Ojo Alamo Sandstone was deposited in alluvial fans and channels upon erosional surfaces of the Kirtland Shale. Sediments appear to have originated, at least in part, from southwestern Colorado. Yields of wells range from 5 to 350 gpm. Transmissivity values range from 0.05 to 470 ft^2/day. Specific capacities range from 0.02 to 5.2 gpm/ft. The most prolific water wells tapping this aquifer appear to be completed in channel-fill deposits. The aquifer is composed of multiple sands and penetration of all sands by water wells is essential for maximum production. The sands may be extremely friable and often cause difficulties in drilling, completing and producing wells. Improper well completions may result in sanding problems and low well efficiency.

INTRODUCTION

The Ojo Alamo Sandstone is a potable aquifer in the San Juan Basin. This formation crops out in the west, south and east sides of the inner San Juan Basin (Fig. 1). The aquifer is underlain by the Kirtland Shale, which contains localized and erratic producers of low-quality water. The overlying Nacimiento Formation is composed largely of fine-grained sediments that are also erratic producers of water. The Ojo Alamo Sandstone is significant in that it is the most laterally continuous aquifer and reliable water producer in the inner San Juan Basin.

GEOLOGIC SETTING

The Ojo Alamo Sandstone aquifer is located just above the Cretaceous-Tertiary boundary and unconformably overlies the Kirtland Shale in much of the San Juan Basin (Fassett and Hinds, 1971). It is conformably overlain by the Nacimiento Formation in most of the San

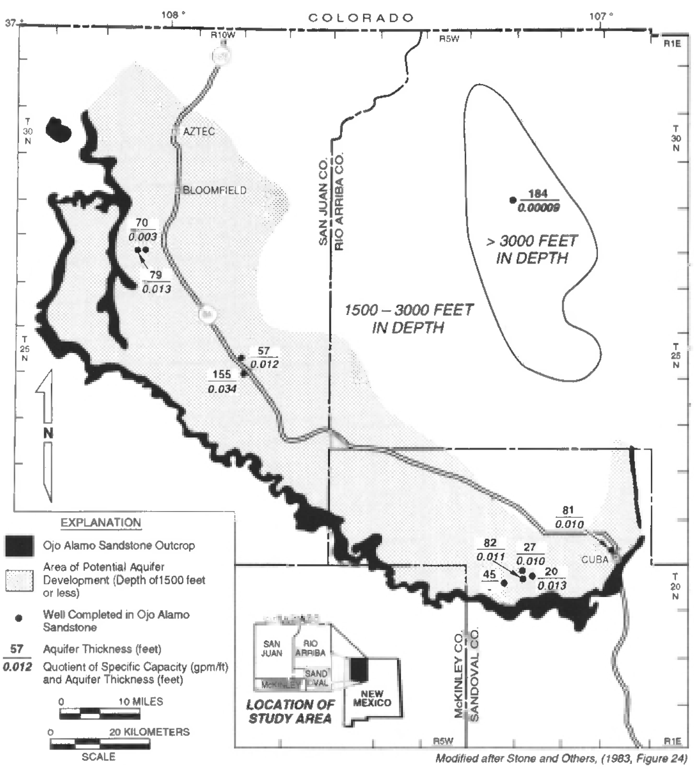

FIGURE 1. Map showing outcrop and area of potential development of the Ojo Alamo Sandstone, and locations and results of aquifer tests.

Juan Basin (Fassett and Hinds, 1971). The Nacimiento Formation was described by Stone et al. (1983) as interbedded black carbonaceous shales and white coarse-grained sandstones in the lower part and similar lithologies of more subdued color in the upper part.

The Ojo Alamo Sandstone is composed of interbedded sandstone, conglomeratic sandstone and shale. At the type locality, the unit is characterized by two ledge-forming conglomeratic sandstones with an intervening shale unit. The sandstone was described by Fassett and Hinds (1971) as poorly sorted coarse-grained arkosic sands containing an abundance of silicified wood (Stone et al., 1983, tables 8 and 9). Baltz and West (1967) described the formation on the Jicarilla Apache Reservation as multiple beds of medium- to very coarse-grained sandstone containing local lenses of gray shale. Locally, the Ojo Alamo contains several feet of pebble or cobble conglomerate.

Fassett (1966) and Hinds (1966) described large-scale channeling of 50 vertical feet or more at the base of the sandstone units. In some cases, the channels have been observed to truncate intervening shale units between the sandstone beds.

The thickness of the formation ranges from less than 20 ft to more than 400 ft in the San Juan Basin (Fassett and Hinds, 1971), but the average thickness is less than 175 ft (Stone et al., 1983, fig. 27). The aquifer crops out in the west, south and east sides of the inner San Juan Basin (Fig. 1). The aquifer persists at depth in the interior San Juan Basin as determined by deep oil and gas drilling.

The depositional environment of the Ojo Alamo Sandstone varies with location. Brimhall (1973) identified floodplains and channels as the two major depositional environments of this unit. Channel deposits are characterized by relatively thick and laterally limited accumulations of coarse, well-sorted sands and gravels. Floodplain deposits are thinner and of greater lateral extent; they are composed of finer grained sand deposits with more interbedded silts and clays.

HYDROLOGIC CHARACTERISTICS

The hydrology of the Ojo Alamo Sandstone has been studied by numerous workers in connection with investigations of ground-water resources of the San Juan Basin region. Baltz and West (1967) evaluated aquifers including the Ojo Alamo on the Jicarilla Apache Indian Reservation and adjacent areas. Cooley et al. (1969) studied the Ojo Alamo on the Navajo and Hopi Indian Reservations. Brimhall's (1973) study of the ground-water hydrology of Tertiary rocks in the San Juan Basin includes information on this aquifer. Geohydrology Associates, Inc. (1978) investigated aquifer units including the Ojo Alamo Sandstone in the San Juan Basin. Kelly (1981) evaluated the aquifer as part of a study of aquifer units associated with coal deposits in northwestern New Mexico.

The recharge area for the aquifer is the outcrop area shown in Fig. 1. Although the Ojo Alamo is relatively deep in much of the basin, it is an attractive target because it is laterally continuous and produces water of acceptable quality for most uses (Geohydrology Associates, Inc., unpubl. 1982). In much of its producing area, the aquifer is confined by the Nacimiento and contains water under artesian conditions.

The yields of water wells completed in the aquifer range from 5 gpm (gallons per minute) to 350 gpm. Specific capacities of the wells range from 0.2 gpm/ft to 5.2 gpm/ft; transmissivity ranges from a low of 0.05 ft^2/d (feet squared per day) to 470 ft^2/d. Table 1 is a summary of hydraulic parameters obtained from tests of wells completed in the aquifer.

The chemical quality of water in the Ojo Alamo Sandstone is quite variable, but generally acceptable for most uses near the outcrop-recharge area and where the depth is 1500 ft or less (Fig. 1). Within this area of potential development, the total dissolved solids range from about 500 mg/l (milligrams per liter) to about 2000 mg/l. The water typically is a sodium-bicarbonate/sulfate type.

CONTROLS ON PRODUCTIVITY

The quantity of water available from the Ojo Alamo Sandstone primarily depends upon aquifer thickness. The aquifer is thickest at paleochannels, and channel-fill deposits are characterized by conglomerates and well-sorted coarse-grained sands. These factors combine to make the aquifer most productive in and near buried paleochannels. Yields also depend to some extent upon well completion and development. Inefficient and/or partially penetrating wells do not allow full aquifer potential to be realized.

Fig. 1 shows the locations of selected wells from Table 1. This map illustrates the aquifer thickness and the quotient of specific capacity and aquifer thickness as a function of proximity to paleochannels. Although the data are scant, the values listed support the assertion that well productivity is dependent upon aquifer thickness. Anomalous values are indicated at wells located in SW1/4 sec. 36, T29N, R4W, NE 1/4 sec. 13, T27N, R12W and SW1/4 sec. 32, T25N, R9W. The low value located in SW1/4 sec. 36, T29N, R4W came from well tests that were conducted in conjunction with Project Gasbuggy (Mercer, 1969). The Project Gasbuggy site is located near the deepest part of the basin, where low permeability and high salinity are expected. The relationship between aquifer thickness and well productivity breaks down in this area; however, drilling depths for water wells are prohibitive here. One low-yielding well in NE1/4 sec. 13, T27N, R12W is offset by a much more productive well completed in a similar section of the Ojo Alamo Sandstone. The reason for poor yield from this well is not known.

The well located in SW1/4 sec. 32, T25N, R9W at Blanco Trading Post is the most prolific known producer in the Ojo Alamo aquifer. This well penetrated an unusually thick section of the aquifer. In addition, the ratio of specific capacity to aquifer thickness indicates that the aquifer is also unusually transmissive at this location.

Variation in productivity may be attributable to partial aquifer penetration of wells. Fig. 2 is a schematic diagram showing the completions of wells located at NW1/4 sec. 19, T25N, R9W (Dzilth-Na-O-Dith-Hle School Well No. 2) and SW1/4 sec. 32, T25N, R9W (Blanco Trading Post Well No. 1). The Dzilth-Na-O-Dith-Hle School Well No. 2 penetrated only 57 ft of Ojo Alamo Sandstone. It is unclear whether this well penetrated the entire aquifer or only the upper sand unit. The Blanco Trading Post Well penetrated 155 ft of Ojo Alamo Sandstone and had 128 ft of completed interval in the upper and lower sands (T. E. Kelly, unpubl. report for Yeargin Western Constructors, Inc., 1986).

Lack of well yield can be linked to well inefficiency. Analysis of a plot of pumping test recovery data obtained from Dzilth-Na-O-Dith-Hle School Well No. 2 indicates a transmissivity value of 185 ft^2/d (Fig. 3). A plot of pumping test drawdown data obtained from Blanco Trading Post Well No. 1 (Fig. 4) yields a transmissivity value of 470 ft^2/d. Factoring in the completed intervals of these two wells indicates that the hydraulic conductivities of the Ojo Alamo Sandstone at Dzilth School Well No. 2 and Blanco Trading Post Well No. 1 are 3.2 ft/d and 3.6 ft/d, respectively. Based upon the similarity of the hydraulic conductivities of these two wells, the ratios of specific capacities to

TABLE 1. Summary of aquifer and well coefficients obtained from tests of Ojo Alamo wells in the San Juan Basin.

Well Location	T	S	SC	h	SC/h	Source
Sec. 6, T20N, R3W.	57	0.0005	0.28	27	0.010	1
Sec. 7, T20N, R3W.	164	0.0067	0.93	82	0.011	1
Sec. 8, T20N, R3W.	425	0.0002	0.27	20	0.013	1
Sec.14, T20N, R4W.	---	------	----	45	-----	1
Sec.28, T21N, R1W.	234	------	0.82	81	0.010	2
Sec. 1, T23N, R9W.	140(?)	------	0.26	---	-----	3
Sec.19, T25N, R9W.	175	------	0.72	---	-----	3
Sec.19, T25N, R9W.	185	0.0030	0.68	57	0.012	4
Sec.32, T25N, R9W.	470	------	5.2	155	0.034	5
Sec.13, T27N, R12W.	155	0.0009	1.02	79	0.013	1
Sec.13, T27N, R12W.	88	0.0007	0.20	70	0.003	1
Sec.36, T29N, R4W.	0.05	------	0.003	179	0.00002	6
Sec.36, T29N, R4W.	0.39	------	0.016	184	0.00009	6
Sec.36, T31N, R2W.	5.3	------	0.02	---	-----	3

T--Transmissivity, square feet per day
S--Storativity, dimensionless
SC--Specific capacity, gallons per minute per foot
h--Assumed aquifer thickness, feet (from well completion)
SC/h--quotient of specific capacity and aquifer thickness (gpm/ft/ft)
Source--1: Brimhall, 1973
2: Bushman, F. X., unpubl. written communication, 1960
3: Stone et al., 1983
4: Edmonds, R. J., unpubl. report for Bureau of Indian Affairs, 1967
5: Kelly, T. E., unpubl. report for Yeargin Western Constructors, Inc., 1986
6: Mercer, 1969

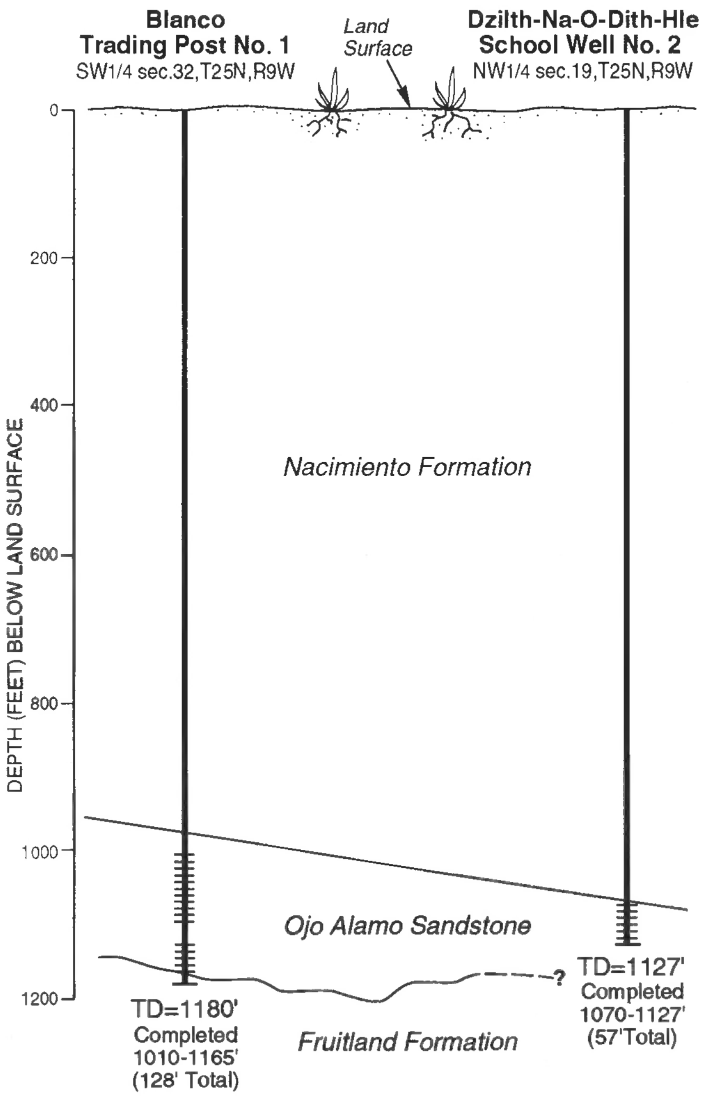

FIGURE 2. Comparison of well completions, Blanco Trading Post Well No. 1 and Dzilth-Na-O-Dith-Hle School Well No. 2.

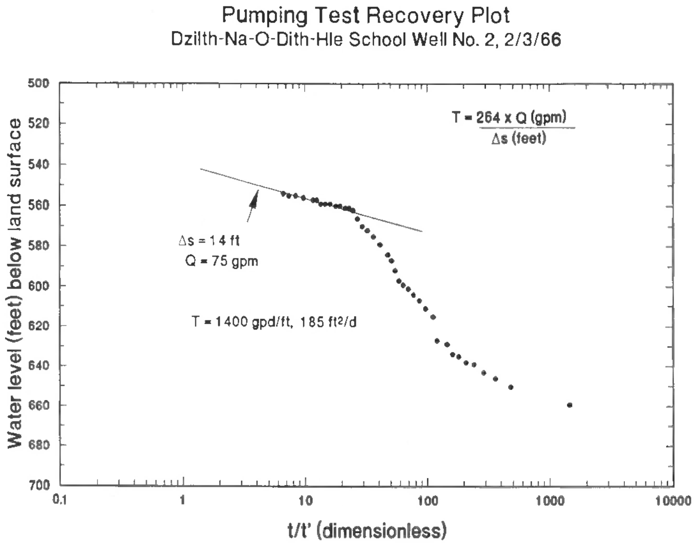

FIGURE 3. Pumping test recovery plot of Dzilth-Na-O-Dith-Hle School Well No. 2 (R. J. Edmonds, unpubl. report for Bureau of Indian Affairs, 1967).

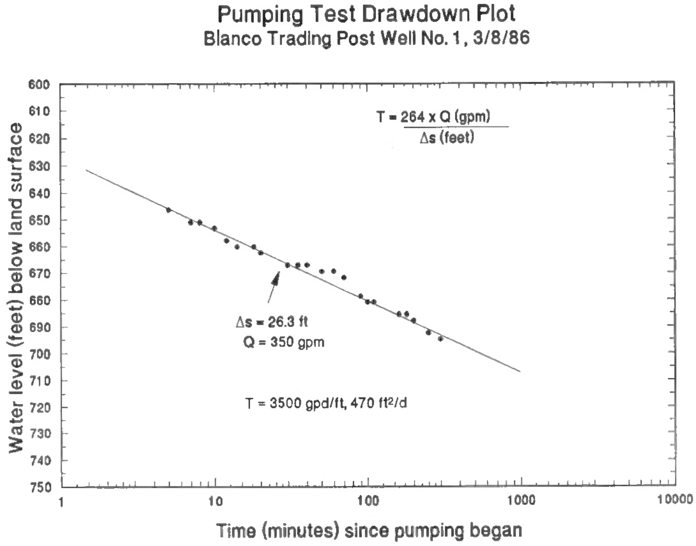

FIGURE 4. Pumping test drawdown plot of Blanco Trading Post Well No. 1 (Geohydrology Associates, Inc., unpubl. report for Yeargin Western Constructors, 1986).

aquifer thicknesses should be similar. Step drawdown data generated by R. J. Edmonds (unpubl. report for Bureau of Indian Affairs, 1967) for the Dzilth-Na-O-Dith-Hle School Well No. 2 was used in an analytical technique developed by Rorabaugh (1953) to calculate well efficiency. The Rorabaugh technique indicates that the Dzilth-Na-O-Dith-Hle School Well No. 2 is only 43% efficient at a pumping rate of 51 gpm (Table 2). Well efficiency could be in excess of 90%. Step-test data are not available for the Blanco Trading Post well, so a direct comparison of well efficiency cannot be made. Nonetheless, the productivity of Dzilth-Na-O-Dith-Hle School Well No. 2 appears to have been substantially reduced as a result of well inefficiency.

The Ojo Alamo aquifer is characterized by friable sands that tend to complicate drilling with hole instability. A major problem associated with completion of wells in this aquifer is the frequency of sanding that is known to occur (Geohydrology Associates, Inc., unpubl. 1982). The Dzilth-Na-O-Dith-Hle School Well No. 2 has a history of sanding problems that likely have contributed to low well efficiency (E. Arviso, unpubl. 1982).

SUMMARY

The Ojo Alamo Sandstone is an attractive target for ground-water development in the central part of the San Juan Basin, owing to its lateral continuity and the quality of available water. Water wells completed in the Ojo Alamo Sandstone yield between 5 gpm and 350 gpm. Specific capacities of water wells completed in the Ojo Alamo Sandstone range from 0.02 gpm/ft to 5.2 gpm/ft. Storativities range from 0.0067 to 0.0002. Productivity of the aquifer is best near buried paleochannels where thicker accumulations of well-sorted sand and gravel exist.

TABLE 2. Well performance data for Dzilth-Na-O-Dith-Hle School Well No. 2.

Q (gpm)	Formation head loss (ft)	Well head loss (ft)	Total head loss (ft)	Well efficiency (percent)
41	22.14	26.81	48.95	45
51	27.54	37.03	64.57	43
80	43.20	72.11	115.31	37

Formation head loss - Water level drawdown due to formation limits
Well head loss - Water level drawdown due to well limits
Total head loss - Total of formation head and well head losses

Well inefficiency has been linked to limited productivity in the Ojo Alamo aquifer. Partial well penetration is also a potential limiting factor to well productivity. Wells should fully penetrate the aquifer, and rigorous well design and completion techniques should be employed to minimize sanding problems and maximize water production.

ACKNOWLEDGMENTS

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STRATIGRAPHIC NOMENCLATURE CHART

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