TECHNICAL MEMORANDUM

To: John Conley and Andrea Felix, Enduring Resources

From: John Shomaker

Date: September 30, 2019

Subject: Results of pumping test, SJ-4301 POD4, July 12-14, 2019

INTRODUCTION

This memorandum will summarize the results of the pumping test of Enduring's Rincon Unit 2706-32F Water Supply Well, State Engineer Well No. SJ-4301 POD4, conducted on July 12-14, 2019 under an exploratory-well permit. This test provided data from which to estimate aquifer characteristics and to determine water quality. Daniel Apodaca of John Shomaker & Associates observed part of the testing. A spreadsheet showing the data collected by Enduring's contractors, with my additions, and which underlie the conclusions in this memorandum, should be submitted to the State Engineer with this memorandum but as a separate file. Logs and completion information for the well have been, or will be, submitted separately to the State Engineer by Enduring.

WELL COMPLETION

The producing unit in the well is the Entrada Sandstone. The overall perforated interval is 8,497 to 8,691 ft below ground level (bgl), significantly deeper than the 2,500-ft criterion for a deep, non-potable supply as referred to in Sec. 72-12-25 et seq. of the New Mexico Statutes (NMSA). Above the Entrada, the Todilto Limestone consists of a significant thickness of anhydrite and limestone beneath siltstone and mudstone. Below the Entrada are siltstone and mudstone of the Chinle Formation.

DESCRIPTION OF PUMPING TEST

Equipment and Procedure

The pump was a 500-hp, 58-stage submersible set at 2,751 ft bgl on 3-1/2-in. tubing. Water levels were measured by a pressure transducer integral with the pump, and also using an Echometer sonic water-level indicator from the surface Pressure transducer measurements of the head above the pump were taken at 1-minute intervals. The pumping rate was measured, in barrels, by a totalizing meter and recorded each hour; cumulative volume pumped was also measured. Pumped volumes were converted to gallons per minute (gpm) for purposes of interpretation. The water was discharged to a lined pond, to be stored for later use as permitted by the State Engineer.

Pumping Test Data

The pumping period was 720 min. The measured instantaneous pumping rate varied greatly throughout the test, from a minimum of about 11 gpm to a maximum of about 92 gpm. On the other hand, the cumulative volume increased fairly steadily, as shown by Figure 1, with an overall average rate of about 45 gpm. For the period later than about 270 min, the average rate was 41.6 gpm.

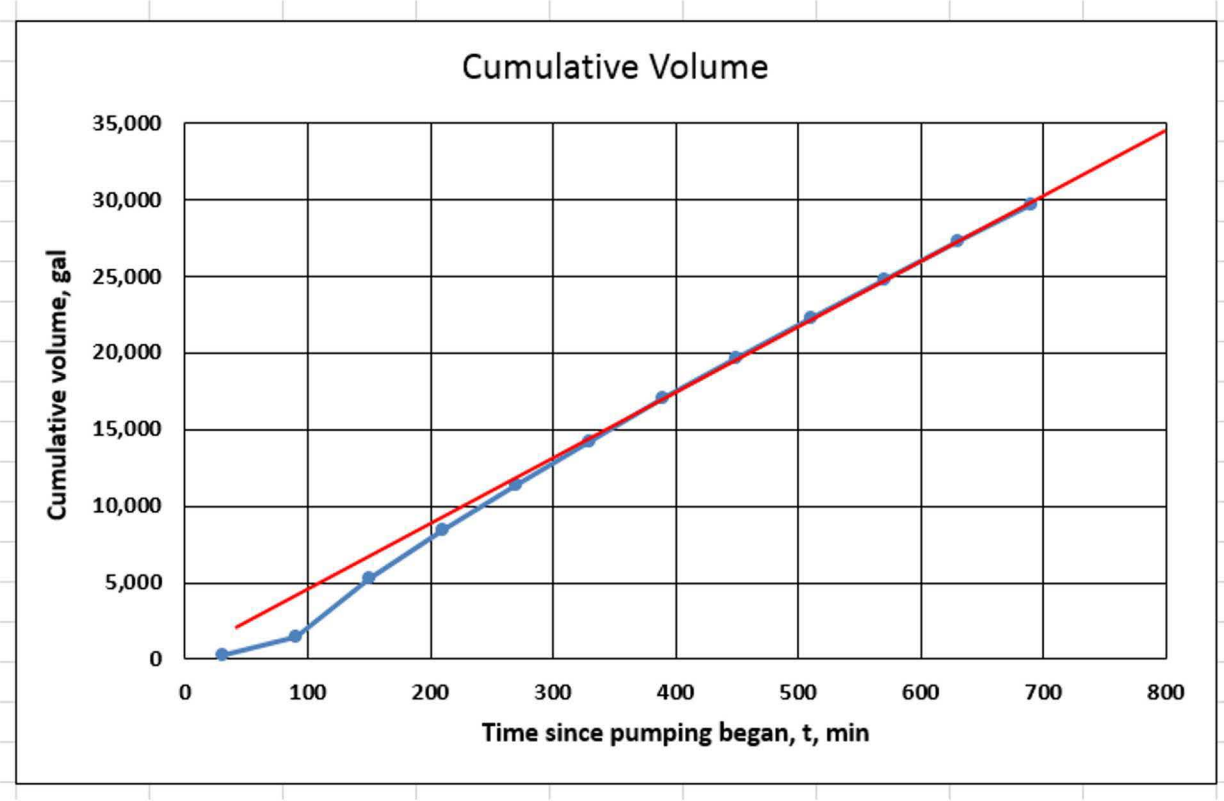

Figure 1. Cumulative volume pumped during the test of Enduring Resources Well SJ-4301 POD4, July 12-14, 2019.

Water levels measured during pumping are shown on a semi-logarithmic time scale in Figure 2. These were measured (in psi) by the transducer integral with the pump, and were calculated in Enduring's spreadsheet from the transducer setting depth at 2,751 ft bgl using a conversion factor of 2.31 feet of water per psi. Fluid-shot measurements were also taken, but did not appear to be reliable.

As of the final measurement at 720 min, the depth to water was calculated at 1,974 ft bgl. The recorded pre-pumping depth to water was 92 ft bgl. This is consistent with the pre-pumping depth to water measured at the beginning of later swabbing development on August 7, 2019, after the test itself. The drawdown between the final pumping water level and the estimated non-pumping water level is about 1,882 ft, leading to a specific capacity of about 0.022 gpm per foot of drawdown at the 41.6-gpm late-time pumping rate.

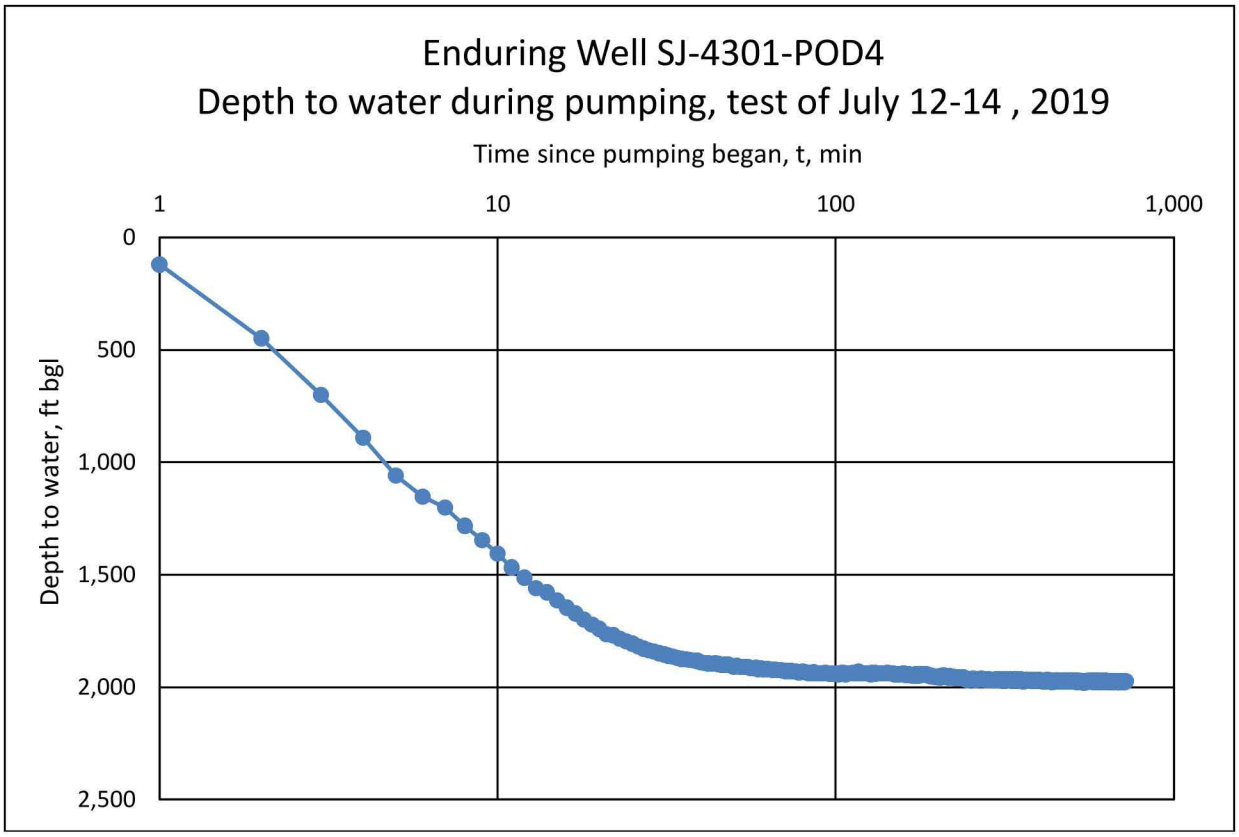

Figure 2. Depth to water during pumping from Enduring Resources Well SJ-4301 POD4, July 12-14, 2019.

Recovery measurements were taken for 2,169 min following the end of pumping. . The recovery measurements, plotted against the ratio t/t' (time since pumping began divided by time since pumping stopped), for analysis by the conventional Cooper-Jacob method[1] to determine confined-aquifer transmissivity, are shown as Figure 3.

[1] Cooper, H.H., and Jacob, C.E., 1946, A generalized graphical method for evaluating formation constants and summarizing well field history: American Geophysical Union Transactions, v. 27, pp. 526-534.

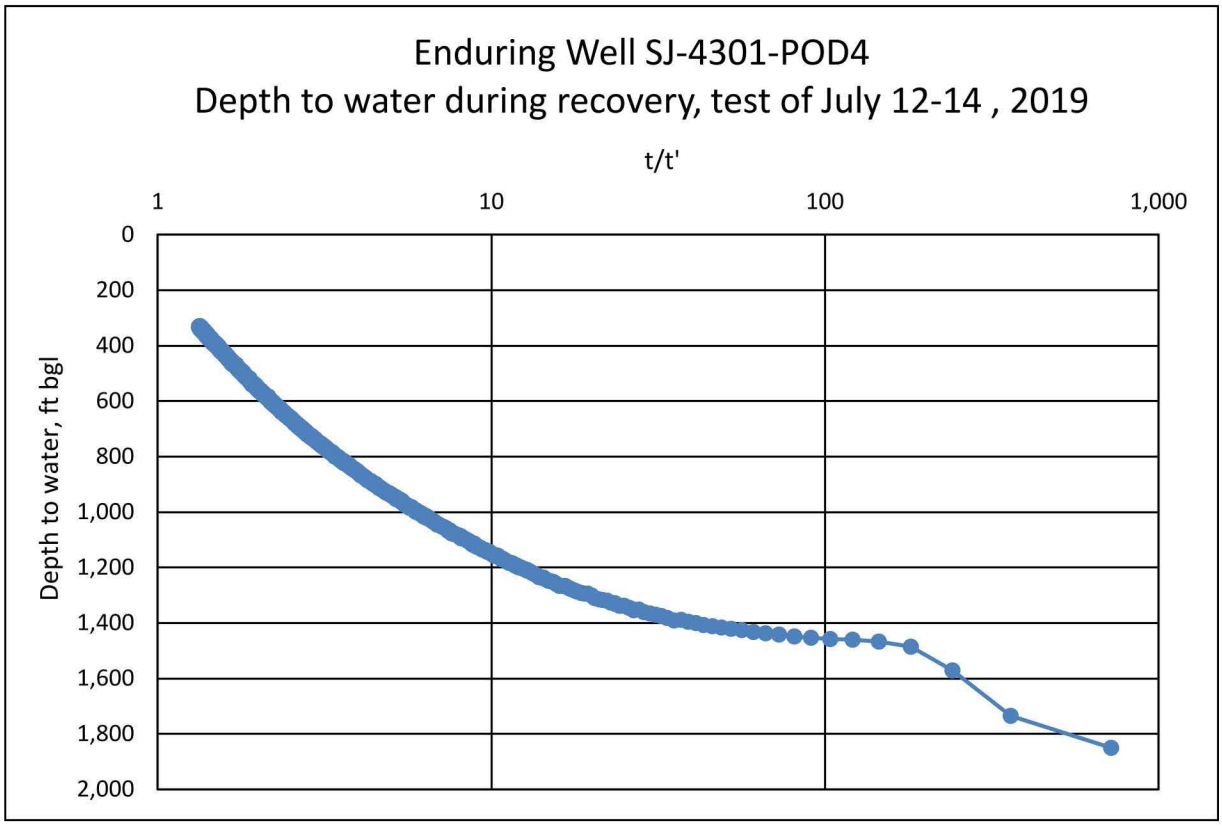

Figure 3. Depth to water during recovery after pumping ceased, measured by transducer at pump, test of Enduring Resources Well SJ-4301-POD4, July 12-14, 2019.

Aquifer Characteristics

The slope of the later part of the plot of water-level measurements during pumping, Figure 2, shown enlarged in Figure 4, allows for an interpretation of aquifer transmissivity by the Cooper-Jacob method. The slope, about 28.8 ft per log cycle, leads to a transmissivity of 381 gallons per day per foot (gpd/ft), or 51 ft^2/day. This transmissivity may be influenced by contribution of water by leakage into the Entrada Sandstone from the Chinle Formation below. The very large drawdown is not consistent with the calculated transmissivity, and suggests extremely low well-efficiency as will be discussed below.

The semilog recovery plot, Figure 3, appears to have a slope of about 1,250 ft per log cycle at times later than about 1,150 min after pumping stopped (t/t' = 2.63). This value would lead to a transmissivity of 9.5 gallons per day per foot (gpd/ft), equivalent to 1.3 ft^2/day, as calculated by the Cooper-Jacob method, if it were assumed that the points actually lie on a straight line and reflect conditions unaffected by casing storage. This is not consistent with the interpretation of the drawdown plot, and would lead to a theoretical specific capacity of 0.008 gpm per foot of drawdown, significantly lower than the observed value (0.022 gpm per foot). Because of the very low well-efficiency, water was continuing to contribute largely to casing storage during all of the period of recovery, and the recovery plot is not valid for interpretation of aquifer characteristics.

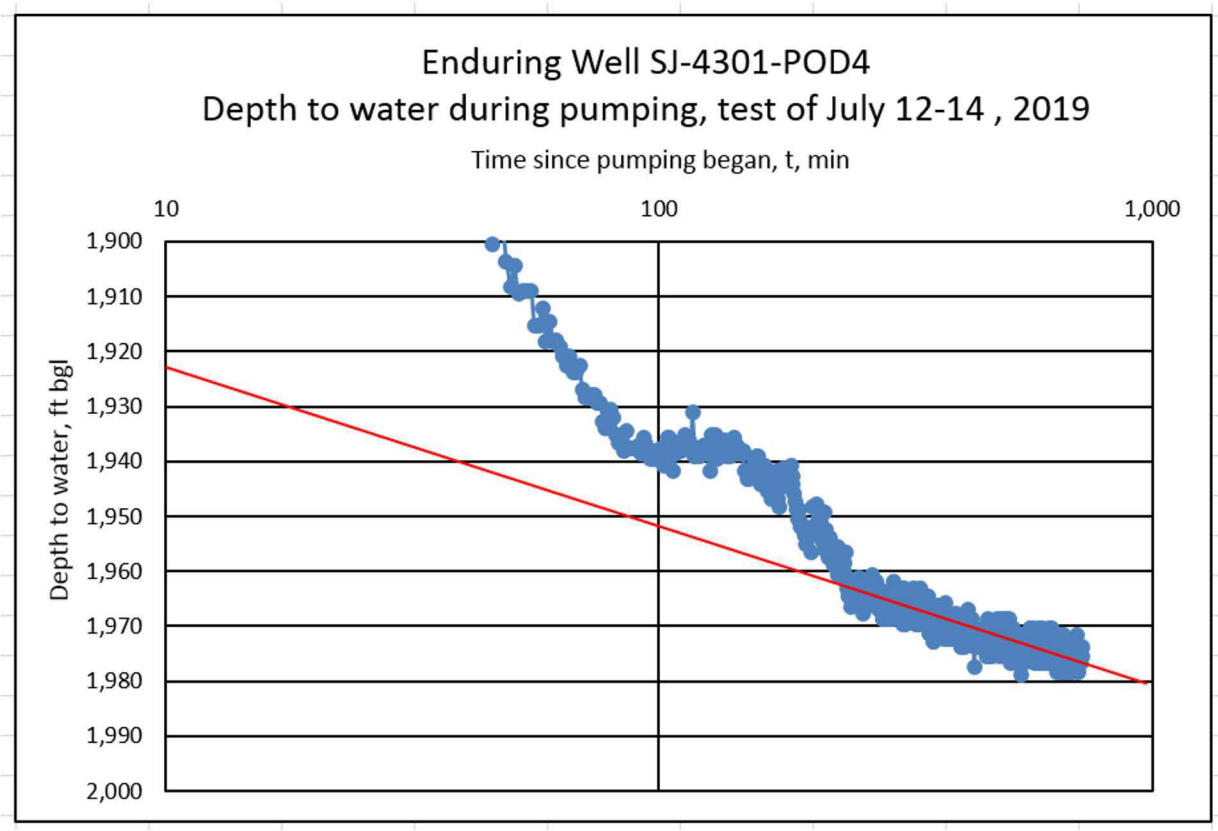

Figure 4. Depth to water during later part of pumping period, Enduring Resources Well SJ-4301 POD4, July 12-14, 2019 (enlarged segment of Figure 2).

A single-well test does not provide a reliable determination of storage coefficient, but a value based on the conventional assumption of 2 x 10^{-6} per foot of thickness (which is 194 ft, based on the overall perforated interval) for a confined aquifer, or 0.00039, would be appropriate for effects calculations.

The transmissivity of the Entrada Sandstone in Well SJ-4301 POD4 is less than, but not greatly different from, values calculated for the Cherokee & Pittsburg water wells and Enduring's Wells SJ-4301 POD1, -POD2, -POD3, and -POD5 completed in the Entrada Sandstone in the same part of the San Juan Basin, as shown in Table 1.

The theoretical specific capacity at the end of the pumping period is calculated from the transmissivity and storage coefficient, using the Theis equation,[2] at about 0.231 gpm per foot of drawdown. The efficiency of the well, expressed as the ratio of observed specific capacity (0.022 gpm/ft as discussed above) to the theoretical value appears to be about 10 percent. The actual efficiency may be somewhat less, in that there may be some contribution of water by leakage from the underlying Chinle Formation.

[2] Theis, C.V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage: American Geophysical Union Transactions, v. 16, pp. 519-524.

Table 1. Summary of aquifer characteristics, Enduring Resources Well SJ-4301 POD4, and comparison with existing Wells SJ-4301 POD1 through POD3 and POD5, and nearby Cherokee & Pittsburg Entrada Sandstone water wells.

	Cherokee & Pittsburg No. 2 Gallo Wash SJ-549-Expl. 1	Cherokee & Pittsburg No. 3 Gallo Wash SJ-549-Expl. 2	Enduring Resources Well SJ-4301 POD1	Enduring Resources Well SJ-4301 POD2
Location	SE/4 Sec. 16, T. 21 N., R. 9 W.	NW/4 Sec. 16, T. 21 N., R. 9 W.	NE/4 Sec. 16, T. 22 N., R. 7 W.	SW/4 Sec. 19 T. 23 N., R. 9 W.
Year drilled	1978	1978	2018	2019
Depth to top, Entrada, ft bgl	5,532	5,500	6,892	6,431
Entrada thickness, ft	162	211	215	189
Depth to water (proj.), ft bgl	23.3	6	411.5	near 0?
Water level elevation, ft	6,395	6,396	6,491	6,634
Pumping test rate, avg., gpm	402	616	189.7	217
Specific capacity, gpm per ft of drawdown	0.53	1.23	>0.62	1.18
Transmissivity, gpd/ft (ft^2/day)	980 (131)	1,145 (153)	780 (104)	4,010 (536)
Water temperature (as discharged), °F	144	144	137	144
Total dissolved solids, mg/L	10,630	10,200	9,430	8,680

	Enduring Resources Well SJ-4301 POD3	Enduring Resources Well SJ-4301 POD4	Enduring Resources Well SJ-4301 POD5
Location	SW/4 Sec. 24, T. 23 N., R. 9 W.	NW/4 Sec. 32, T. 27 N., R. 6 W.	SW/4 Sec. 20, T. 22 N., R. 6 W.
Year drilled	2019	2019	2019
Depth to top, Entrada, ft bgl	6,813	8,497 approx.	7,160
Entrada thickness, ft	164	194 approx.	143
Depth to water (proj.), ft bgl	375	92	647
Water level elevation, ft	6,438	6,508	6,414
Pumping test rate, avg., gpm	259.2	45.0	114.8
Specific capacity, gpm per ft of drawdown	0.32	0.022	0.17
Transmissivity, gpd/ft (ft^2/day)	660 (88)	381 (51)	548 (73.3)
Water temperature (as discharged), °F	165.7 (see note)	118 (see note)	136
Total dissolved solids, mg/L	8,990	10,800	10,800

Note: POD3 temperature is at pump, not as discharged. POD4 temperature is for last hour of test; temperature at pump was 133 °F.

WATER QUALITY

A sensor at the pump recorded temperature, which ranged from about 82°F to about 133°F, the upper limit probably representing the temperature of Entrada Sandstone formation water. The conductivity of the pumped water was measured periodically, and increased gradually from 6,020 µS/cm at 46.8°C (116.2°F) to about 13,570 µS/cm at 49.3°C (120.7°F) beginning about 3 hours after the start of pumping and peaking at about 5 hours, reflecting the fact that the drilling water in the casing had been entirely displaced by Entrada Formation water. Conductivity declined thereafter, however, and was in the range 10,600 to 10,980 µS/cm, at 47.1 to 48.5°C (116.8°F to 119.3°F) respectively, for the last three hours of the pumping period. The average temperature of the water discharged at the surface during the last hour of pumping was 118°F.

A set of water samples was collected at the end of the pumping period, and submitted to Hall Environmental Laboratory in Albuquerque for analysis. Total dissolved solids concentration is reported as 10,800 mg/L, significantly greater than the 1,000 mg/L minimum criterion for wells drilled under the provisions of Sec. 72-12-25 et seq., NMSA. Laboratory specific conductance was 19,000 µS/cm at 25°C. The charge-balance error was 2.0 percent, which is within the acceptable range. A summary of the analytical results is shown as Table 2. The complete Hall report will be submitted as a separate document.

Table 2. Image of summary page, Hall Environmental water-analysis report, Enduring Well SJ-4301 POD4, July 12, 2019.

Analytical Report
Lab Order **1907718**
Date Reported: **7/23/2019**

Hall Environmental Analysis Laboratory, Inc.

CLIENT: John Shomaker & Assoc. **Client Sample ID:** SJ 4301 Pod 4
Project: Enduring Resources **Collection Date:** 7/12/2019 8:25:00 PM
Lab ID: 1907718-001 **Matrix:** AQUEOUS **Received Date:** 7/15/2019 1:12:00 PM

Analyses	Result	RL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 300.0: ANIONS						Analyst:	**MRA**
Fluoride	ND	0.50		mg/L	5	7/16/2019 12:01:27 PM	R61437
Chloride	4700	250	*	mg/L	500	7/17/2019 5:30:48 PM	R61456
Bromide	7.1	0.50		mg/L	5	7/16/2019 12:01:27 PM	R61437
Phosphorus, Orthophosphate (As P)	ND	2.5	H	mg/L	5	7/16/2019 12:01:27 PM	R61437
Sulfate	1200	250	*	mg/L	500	7/17/2019 5:30:48 PM	R61456
Nitrate+Nitrite as N	ND	4.0		mg/L	20	7/17/2019 5:43:12 PM	R61456
SM2510B: SPECIFIC CONDUCTANCE						Analyst:	**JRR**
Conductivity	19000	25		µmhos/c	5	7/18/2019 3:19:42 PM	R61500
SM2320B: ALKALINITY						Analyst:	**JRR**
Bicarbonate (As CaCO3)	601.5	20.00		mg/L Ca	1	7/18/2019 12:22:04 PM	R61500
Carbonate (As CaCO3)	ND	2.000		mg/L Ca	1	7/18/2019 12:22:04 PM	R61500
Total Alkalinity (as CaCO3)	601.5	20.00		mg/L Ca	1	7/18/2019 12:22:04 PM	R61500
SM2540C MOD: TOTAL DISSOLVED SOLIDS						Analyst:	**KS**
Total Dissolved Solids	10800	200	*D	mg/L	1	7/17/2019 4:24:00 PM	46198
EPA METHOD 6010B: DISSOLVED METALS						Analyst:	**ELS**
Calcium	70	5.0		mg/L	5	7/18/2019 9:15:49 AM	A61476
Magnesium	9.5	5.0		mg/L	5	7/18/2019 9:15:49 AM	A61476
Potassium	83	5.0		mg/L	5	7/18/2019 9:15:49 AM	A61476
Sodium	3600	50		mg/L	50	7/18/2019 10:25:43 AM	A61476

EFFECTS OF PUMPING

The drawdown during pumping at the late-time rate of 41.6 gpm, the apparent 12-hour specific capacity of the well at about 0.022 gpm/ft, and the available drawdown to the top of the aquifer of 8,405 ft (top of perfs at 8,497 ft less non-pumping depth to water of 92 ft), indicate that the well could not produce at the annual rate of 942 ac-ft/yr (20,000 BWPD or 583 gpm) that is contemplated in the Notice of Intention. This does not appear to be because of aquifer characteristics, however, but is probably attributable to the low efficiency of the well.

It is possible that a conventional water-well completion, if the producing interval were drilled with air or clear water out from under cemented casing, and with slotted liner in open hole through the Entrada, would have an apparent efficiency near 100 percent. In some similar cases, the completion itself has an efficiency even greater than 100 percent, because well-development may increase the effective diameter beyond the nominal bit size, but the overall efficiency would be reduced by the friction loss in the casing as water moves up to the pump intake. Applying the values for transmissivity of 381 gpd/ft and storage coefficient of 0.00039, as described above, in the Theis equation leads to the predicted incremental drawdown effects within the Entrada Sandstone aquifer shown in Table 3.

The theoretically available drawdown between the non-pumping water level and the top of the aquifer is about 8,405 ft, as discussed above. If overall well efficiency were close to 100 percent, the pumping water levels would be the sum of the incremental drawdowns shown in Table 3 and the pre-pumping depth to water of 92 ft. Adding the 1-year drawdown to the projected non-pumping depth to water leads to a pumping water level at the end of one year of 3,339 ft. The actual drawdowns over time are likely to be less because of the effect of upward leakage, over a very large area, from the underlying Chinle Formation. On the other hand, drawdown interference due to pumping from other Entrada wells is not reflected in the values shown in Table 3.

Table 3. Theis-equation predicted incremental drawdown effect of pumping 942 ac-ft/yr (584 gpm) from a hypothetical, 100-percent efficient well at the location of Enduring Resources Well SJ-4301 POD4, based on the transmissivity and storage coefficient values described in text.

	Incremental drawdown, ft		
Distance	**1 year**	**10 years**	**40 years**
at well (r = 1 ft)	3,247	3,652	3,896
1,000 ft	822	1,226	1,469
1 mile	261	643	885
5 miles	18	134	335
10 miles	0	19	134

Although there will be large drawdown effects in the Entrada itself, no actual net depletion is likely to result from the proposed pumping because the water will be used as drilling water and in well stimulation for oil and gas production, and, except for minor

incidental losses, will be injected into petroleum-producing intervals shallower than the Entrada for well stimulation, or will be injected into salt-water disposal wells as produced water from the oil and gas wells. Almost all of the currently permitted San Juan Basin disposal wells are completed in the Entrada, and in some cases in additional, shallower zones.

District I
1625 N. French Dr., Hobbs, NM 88240
Phone:(575) 393-6161 Fax:(575) 393-0720
District II
811 S. First St., Artesia, NM 88210
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District III
1000 Rio Brazos Rd., Aztec, NM 87410
Phone:(505) 334-6178 Fax:(505) 334-6170
District IV
1220 S. St Francis Dr., Santa Fe, NM 87505
Phone:(505) 476-3470 Fax:(505) 476-3462

State of New Mexico
Energy, Minerals and Natural Resources
Oil Conservation Division
1220 S. St Francis Dr.
Santa Fe, NM 87505

CONDITIONS

Action 300696

CONDITIONS

Operator: NEW MEXICO ENERGY MINERALS & NATURAL RESOURCE 1220 S St Francis Dr Santa Fe , NM 87504	OGRID: 264235
	Action Number: 300696
	Action Type: [IM-SD] Well File Support Doc (ENG) (IM-AWF)

CONDITIONS

Created By	Condition	Condition Date
pgoetze	None	1/7/2024