Barton Springs
Edwards Aquifer
CONSERVATION DISTRICT

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Evaluation of the Potential for Unreasonable Impacts from the EP Well Field, Hays County, Texas

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Introduction

An application for a permit to produce 2.5 million gallons per day (MGD) of groundwater from the Middle Trinity Aquifer in central Hays County was submitted by Electro Purification LLC (EP) on July 13, 2017. In accordance with District rules, an applicant for a large-scale production permit must conduct an aquifer test and submit a hydrogeological report that provides findings and conclusions addressing the response of an aquifer to pumping over time. In particular, the report must evaluate the potential for “unreasonable impacts”, as defined by District rules to include:

1. Well interference related to one or more water wells ceasing to yield water at the ground surface;
2. Well interference related to a significant decrease in well yields that results in one or more water wells being unable to obtain either an authorized, historic, or usable volume or rate from a reasonably efficient water well;
3. Well interference related to the lowering of water levels below an economically feasible pumping lift or reasonable pump intake level; or
4. The degradation of groundwater quality such that the water is unusable or requires the installation of a treatment system.

Aquifer Science staff reviewed the hydrogeologic report in support of the application (WRGS, 2017a) and a subsequent addendum (WRGS, 2017b). Evaluations by Aquifer Science staff resulted in two previous technical memorandums that evaluated the aquifer-test data (BSEACD, 2017), and estimates of aquifer parameters (BSEACD, 2018).

This memo documents the District’s evaluations of the permit request for 2.5 MGD of groundwater and the potential for unreasonable impacts (PUI) to occur from the proposed pumping from the existing well field. This evaluation utilizes all existing aquifer-test information and makes some modeled projections of drawdown. The evaluation focuses on the extent and magnitude of well interference from drawdown that relate to determining PUI. It does not include impacts to springs or to the Desired Future Condition (DFC) which are a separate permitting consideration.

Aquifer Test Drawdown

The earliest BSEACD memo on this topic (BSEACD, 2017) describes the aquifer test and data collected, and concluded that the test and data were of excellent quality. The test had sufficient stress, duration, and response in observation wells to pumping that much was learned about the hydrogeologic barriers and interconnections of the system. In the second BSEACD memo (BSEACD, 2018), estimates of aquifer parameters were made with analytical solutions using aquifer test data. In that memo, we focused on evaluating drawdown that might produce interference in wells outside of the EP properties up to about 1-mile radial distance from the EP property.

Using the hydrogeologic principles of superposition, we added the measured drawdown attributed to all the EP pumping wells in the Middle Trinity Aquifer. Total aggregated drawdown was up to 212 ft. Results are summarized in **Table 1**. Drawdown was anisotropic and elongate along the fault and fracture trend of the area. In contrast, more distant wells located south and east of the Wimberley fault generally had little to no response to pumping. The drawdown contours shown in **Figure 1**, which interpolate between measured values, indicate aggregate drawdown produced by the aquifer test alone as greater than 500 ft in one of the EP wells and a large area. The drawdown contours in Figure 1 also indicate large areas, that includes many private wells, in which drawdown is greater than 300 ft.

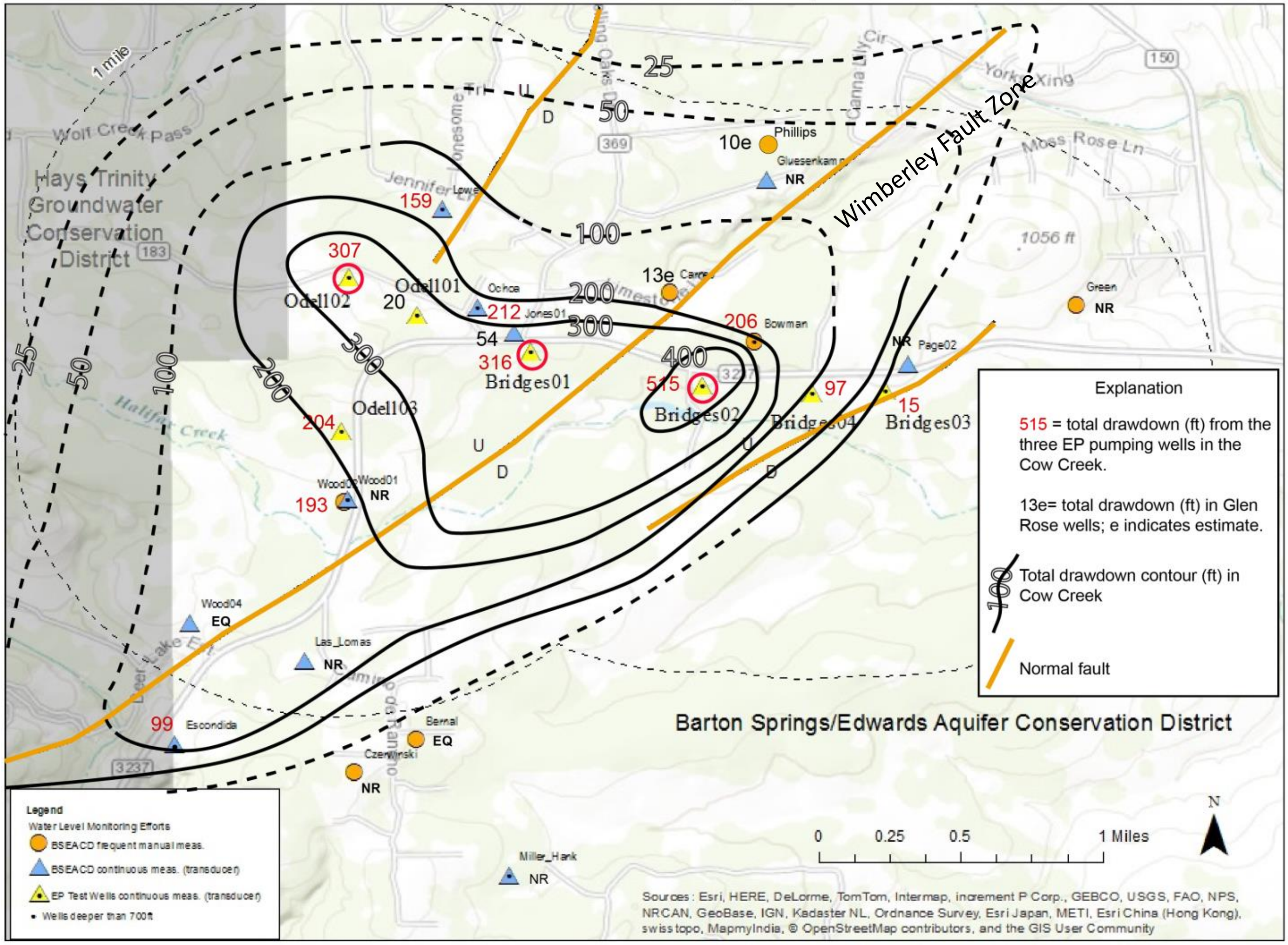

Figure 1. *Contours of total aggregate drawdown from the EP Aquifer Test in 2016-17. Figure from BSEACD, 2017.*

Table 1. *Summary of well construction, pump intake, and aggregate measured drawdown from the EP aquifer test. The observation wells are Middle Trinity (non-EP) observation wells.*

Well Name	*Well Depth (ft)*	*Pump Intake Depth (ft)*	*Static Water Level depth (ft)*****	*Aggregate Drawdown (ft)*	*Water above pump (ft) Pump – Static*	*Water relative to pump (ft) Pump – (Static + Drawdown)*
Bowman	850	700*	291	205	409	204
Woods #1	790	500	285	192	215	23
Ochoa	810	660	261	212	399	187
Lowe	860	760**	248	159	512	353
Escondida	930	460***	343e	99m	117	18

*According to Jolander Well Drilling records (personal communication 1/22/18).
**Anomalous depth: drilled and set pump after EP project proposed.
***depth of test pump (BGS, 2016), final completion unknown
****10/21/2016, relatively high conditions
e = estimate
m= minimum

Modeled Drawdown

In order to show the potential effects of long-term pumping and assess their unreasonable impacts outside the well field, in this present memo we modeled drawdown over longer time periods in five wells completed in the Middle Trinity. These wells were also used as observation wells during the 2016-2017 aquifer test. Aquifer and well parameters used in this evaluation are shown in **Table 2**. Aquifer parameters selected for this evaluation are from Table 6 of BSEACD (2018). The pumping rates used in the evaluation are proposed by WRGS (2017b). All pumping and observation wells are presumed to be isolated to the Cow Creek with similar construction.

Drawdown in each of the five observation wells was determined by using a spreadsheet with the Cooper and Jacob (1946) solution, or using the Theis (1935) forward modeling features within Aqtesolv (**Figures 2 and 3**). Both methods require aquifer parameters, pumping rate, elapsed time, and distance from each pumping well to the observation well **(Tables 2 and 3**). Both methods of estimating drawdown in these observation wells provide nearly identical results and are summarized in **Table 4** for 1-year and 7-year estimates. Modeled drawdown for 1 year ranges from 300 ft to 500 ft in the five observation wells. This is about 2.8 times more drawdown, on average, than measured during the short-term aquifer test. Accordingly, we find the 1-year model to provide realistic drawdown values.

Figure 4 illustrates the measured and modeled effects of pumping in the Lowe observation well relative to hydrogeologic units and well construction. Modeled results after 1 year of pumping indicate drawdown greater than 450 ft at this location, and water levels that approach the top of the Cow Creek unit (primary aquifer unit). Modeled estimates of drawdown at 7 years are below the bottom on the aquifer and not a realistic result (see Discussion).

Figure 5 is a map of the distribution of drawdown from the EP pumping wells after 1 year of pumping. The Theis model was used within Aqtesolv and assumed the parameters listed in **Table 2**. Grids of drawdown from each pumping well were combined in Surfer software and contoured using its kriging algorithm. Drawdown at the five observation wells are the same as listed in **Table 4**.

Table 2. *Aquifer parameters and pumping used in the individual well and regional drawdown assessment. Pumping values from WRGS (2017b) and aquifer parameters from BSEACD (2018, Table 6).*

	*Bridges #1**	*Bridges #2**	*Bridges #3***	*Bridges #4***	*Odell #1***	*Odell #2**	*Odell #3***
Pumping Rate (GPM)	645	148	48	66	95	560	175
Transmissivity (Ft2/d)	363	204	187	187	187	538	187
Storativity	9.45E-05	5.03E-05	4.82E-05	4.82E-05	4.82E-05	9.88E-05	4.82E-05
Fully Penetrating	yes	yes	yes	yes	yes	yes	yes
Radius of casing	0.448	0.448	0.448	0.448	0.448	0.448	0.448
Radius of borehole	0.41	0.41	0.41	0.41	0.41	0.41	0.41
X (ft)	-60	2730	5760	4620	-1840	-3030	-3000
Y (ft)	30	-620	-720	-730	630	1330	-1520

*Parameters from evaluation A-C, Table 6 BSEACD, 2018.
**Parameters from evaluation D, Table 6, BSEACD, 2018.

Table 3. *Distance between wells (ft) used in the Cooper-Jacob evaluation of drawdown from a pumping to observation well. Distances measured using Google Earth.*

	Bridges #1	***Bridges #2***	***Bridges #3***	***Bridges #4***	***Odell #1***	***Odell #2***	***Odell #3***
Bridges #1	0	2,870	5,900	4,640	1,930	3,200	3,370
Bridges #2	2,870	0	3,080	1,780	4,820	6,040	5,910
Bridges #3	5,800	5,780	0	1,200	7,730	8,930	8,880
Bridges #4	4,640	1,780	1,190	0	6,520	7,730	7,610
Odell #1	1,930	4,730	7,680	6,520	0	1,280	2,500
Odell #2	3,200	6,040	9,030	7,730	1,280	0	2,940
Odell #3	3,370	5,910	8,800	7,610	2,500	2,940	0
Bowman	3,600	1,160	2,300	1,310	5,480	6,620	6,910
Ochoa	1,150	3,910	6,860	5,600	970	2,150	3,150
Woods #1	4,070	6,100	8,980	7,750	3,670	4,180	1,270
Lowe	3,050	5,370	7,830	6,900	2,060	2,000	4,490
Escondida	8,670	10,250	12,600	11,680	8,240	8,450	5,790

Table 4. *Summary of modeled drawdown results from the seven EP pumping wells at five observation wells.*

A) Drawdown (ft)--1 year

	Bridges #1	**Bridges #2**	**Bridges #3**	**Bridges #4**	**Odell #1**	**Odell #2**	**Odell #3**	**Combined Drawdown (ft)**
Bowman	150	87	25	41	36	74	60	473
Ochoa	211	60	17	25	63	110	83	569
Woods #1	142	50	15	21	43	88	109	468
Lowe	158	53	16	23	52	112	73	487
Escondida	101	38	12	17	30	66	65	329

B) Drawdown (ft)--7 years

	Bridges #1	**Bridges #2**	**Bridges #3**	**Bridges #4**	**Odell #1**	**Odell #2**	**Odell #3**	**Combined Drawdown (ft)**
Bowman	201	109	33	51	51	105	88	638
Ochoa	265	82	24	35	78	141	111	736
Woods #1	195	72	22	32	58	119	137	635
Lowe	210	74	23	33	67	143	100	650
Escondida	155	60	20	28	45	97	93	498

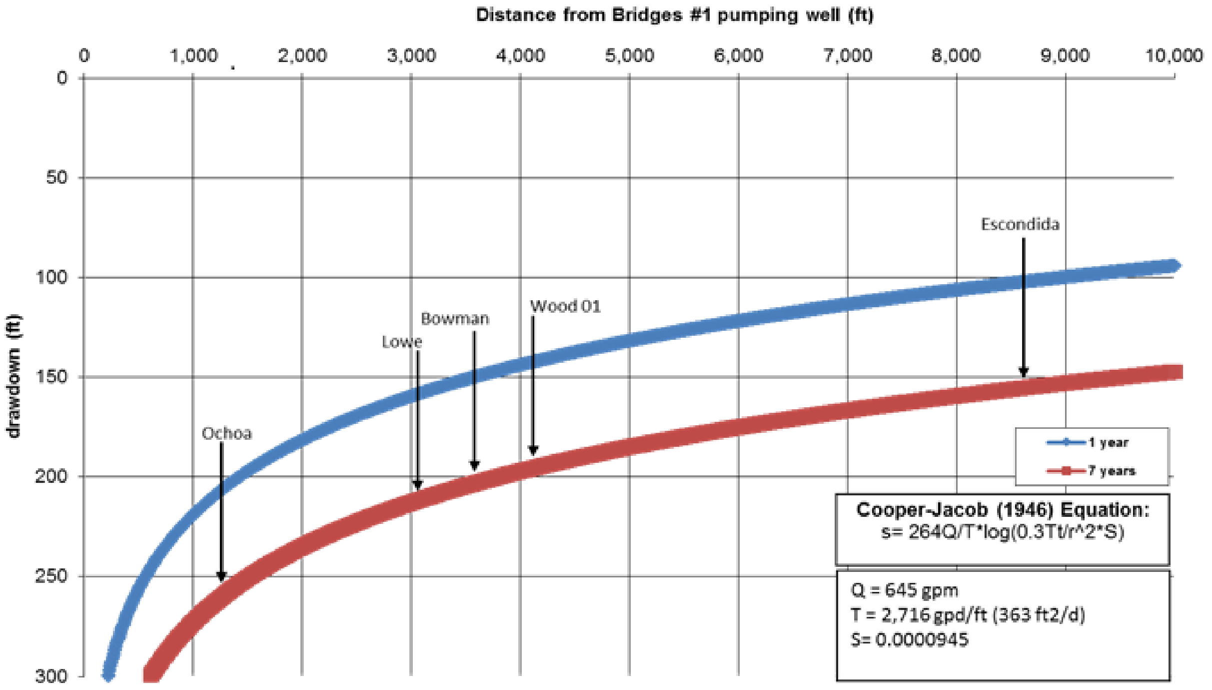

Figure 2. *Example of the theoretical distance vs drawdown curve from the Cooper-Jacob modification of the non-equilibrium equation. Pumping is from the Bridges #1 after 1 and 7 years showing the estimated drawdown at various distances from the pumping well corresponding to observation wells.*

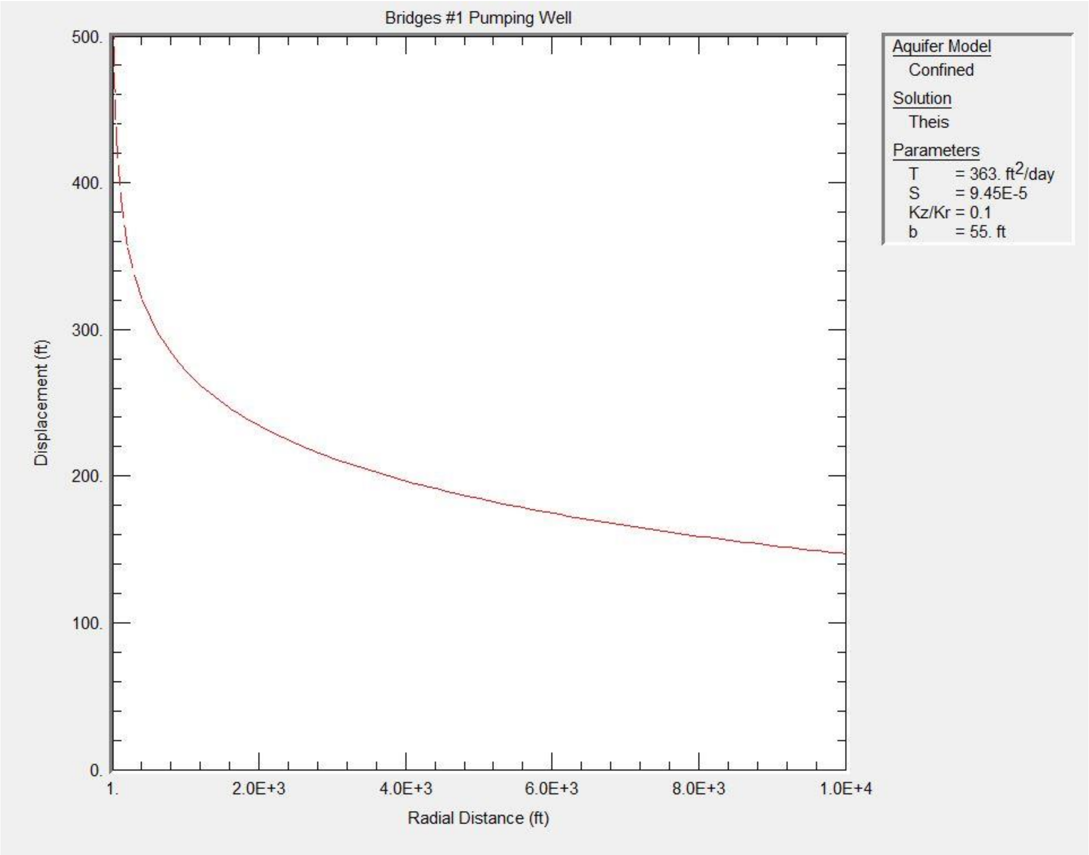

Figure 3. *Example of the theoretical distance vs drawdown curve from the Theis solution within Aqtesolv. In this diagram, pumping is from the Bridges #1 showing the estimated drawdown at a radial distance from the pumping well after 7 years.*

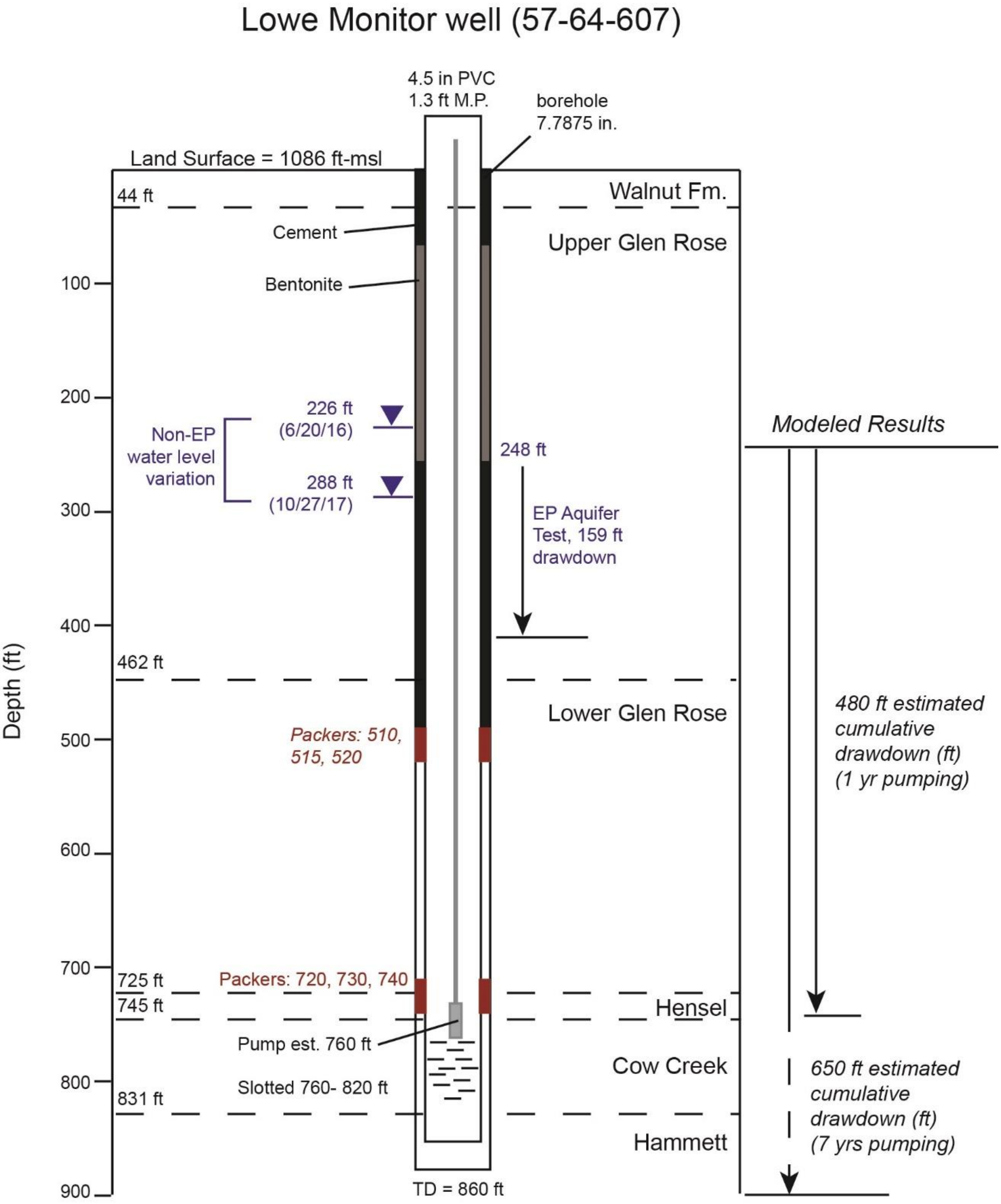

Figure 4. *Diagram of the Lowe monitor well with detailed hydrogeologic and well-construction data along with measured and modeled drawdown. A drawdown of 159 feet was measured in the Lowe well during the EP aquifer test. The diagram is very similar to the circumstances in Woods #1, with similar measured and modeled drawdown. The pump in the Woods #1 well is set to a depth of 500 ft and would cease to yield water sooner than the Lowe well.*

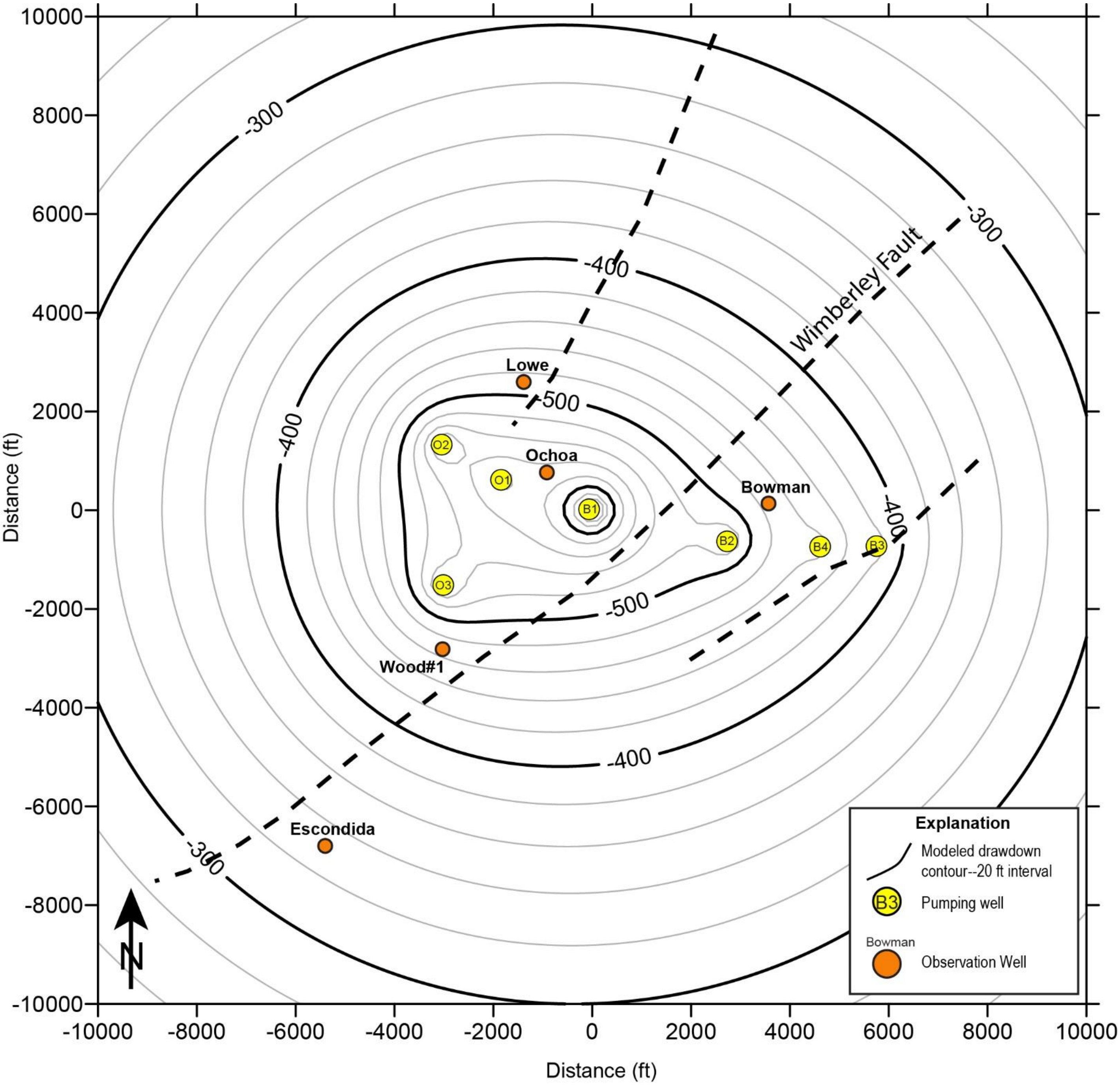

Figure 5. *Map of combined drawdown from pumping 2.5 MGD (1,700 gpm) after 1 year. Actual drawdown geometry would appear similar to Figure 1, with an elongate axis of drawdown trending along the area faults in a NE trend, and less drawdown east and south of the Wimberley fault. The results indicate drawdown of 400 ft or greater for a significant portion of the area surrounding the pumping wells.*

Table 5. *Summary of well construction, pump intake, and BSEACD modeled aggregate drawdown for Middle Trinity (non-EP) observation wells after 1 year.*

Well Name	*Well Depth (ft)*	*Pump Intake Depth (ft)*	*Static Water Level depth (ft)*	*Aggregate 1-yr Modeled Drawdown (ft)*	*Water level relative to pump (ft) Pump – (Static + model)*
Bowman	850	700	291	473	-64
Woods #1	790	500	259	569	-328*
Ochoa	810	660	258	468	-66
Lowe	860	760	247	487	26
Escondida	930	460	338	329	-207

**below the bottom of the well bore and likely top of the Cow Creek*

WRGS Modeling

WRGS (2017b) modeled drawdown for 1 and 7 years of pumping on a well-by-well basis using the average aquifer parameters estimated from a specified well pair, and then summed up the total drawdown. Results of the same five wells discussed above are summarized in **Tables 6 and 7**.

Table 6. *Summary of well construction, pump intake, and modeled aggregate drawdown for Middle Trinity (non-EP) observation wells after 1 year. Data summarized from WRGS (2017b).*

Well Name	*Well Depth (ft)*	*Pump Intake Depth (ft)*	*Static Water Level depth (ft)*	*Aggregate 1-yr Modeled Drawdown (ft)*	*Water level relative to pump (ft) Pump – (Static + model)*
Bowman	850	700	291	318	91
Woods #1	790	500	259	492	-251
Ochoa	810	660	258	534	-132*
Lowe	860	760	247	492	21
Escondida	930	460	338e	367	-245

**below the top of the Cow Creek*

Table 7. *Summary of well construction, pump intake, and modeled aggregate drawdown for Middle Trinity (non-EP) observation wells after 7 years. Data summarized from WRGS (2017b).*

Well Name	*Well Depth (ft)*	*Pump Intake Depth (ft)*	*Static Water Level depth (ft)*	*Aggregate 7-yr Modeled Drawdown (ft)*	*Water level relative to pump (ft) Pump – (Static + model)*
Bowman	850	700	291	430	-21
Woods #1	790	500	259	632	-391*
Ochoa	810	660	258	685	-283*
Lowe	860	760	247	661	-148*
Escondida	930	460	338e	496	-374

**below the bottom of the well bore and top of the Cow Creek*

GMA 10 Explanatory Report

Intera developed a transient analytic element modeling tool (TTIM code) to evaluate the effects of a variety of pumping scenarios on the groundwater resources of central Hays County (Intera, 2016; Oliver et al., 2017). The report is included as part of the Groundwater Management Area 10 Explanatory Report submitted to the Texas Water Development Board.

The TTIM model has uniform parameters and makes many of the same assumptions of other analytical models, but allows for a layered aquifer system and a better incorporation of a conceptual model. The model was calibrated with parameter estimation code (PEST) to the initial aquifer testing on the EP well field (WRGS, 2015).

All the modeling scenarios provide some insight into the potential response. However, one of the pumping scenarios (Scenario 3) limited the drawdown to the top of the Cow Creek in the well field—resulting in a yield of 901 gpm. This indicates that pumping of the well field at rates higher than this will begin de-watering the Cow Creek aquifer.

One important conclusion of the modeling work is that drawdown results and productivity of the EP wells are very sensitive to the Hensel vertical hydraulic conductivity (Kv). For example, using the Scenario 3 model simulations, if we assume a very low Kv (10^{-6}), the drawdown at the center of the EP field is estimated to be 422 ft in the Cow Creek and 3 ft in the Lower Glen Rose with a yield of 901 gpm. However, if we assume a high Kv (10^{-4}) for Scenario 3, the drawdown at the center of the EP field is estimated to be 423 ft in the Cow Creek, but 137 ft in the Lower Glen Rose with a yield of 1,069 gpm.

The report also presents a range of average drawdown for GMA 10 in Hays County. Similarly, the average drawdown and well productivity are very sensitive to the Hensel vertical hydraulic conductivity (Kv).

Discussion

When aggregated, the total drawdown during the aquifer test was up to 212 ft in non-EP Middle Trinity observation wells (**Table 1**). The drawdown contours shown in **Figure 1**, which interpolate between measured values, indicate drawdown up to 300 ft depending upon proximity to the EP wells and the Wimberley fault. Well interference can result in larger drawdown and the inability of the affected wells to produce water. Interference can cause the water level to be lowered below the pump or the bottom of the well, and the top and bottom of the aquifer. The aquifer test determined that after about a week of pumping at the requested volume, water levels could decline below a reasonable pump intake level (**Table 1**). Water levels in the Woods #1 and Escondida wells drew down to within 23 ft and 18 ft of the pump level, respectively. If we assume drought conditions with water levels being an additional 50 ft of lower, existing local well interference, and the appropriate depth of water needed above a pump intake to yield water, it is likely that these and other wells will cease to yield water. If those factors are considered, the number of impacted wells will likely increase in the vicinity of EP. The WRGS (2017b) report acknowledges these drawdown effects in the Woods #1 well and other Middle Trinity domestic wells that have pump settings less than 550-600 ft from the surface. Pump intake levels are likely to differ significantly among the wells in the area (**Table 1**).

It is uncommon, in the experience of the BSEACD, for an aquifer test to produce drawdown that indicates negative impacts to surrounding water-supply wells (without considering modeling results). This is likely due to the magnitude of the requested pumping rate and the compartmentalized nature of the Middle Trinity Aquifer (BSEACD, 2017, 2018).

Modeling results by the BSEACD (this memo) and WRGS (2017b) produce similar effects of drawdown on surrounding observation wells. Projecting the effects of drawdown after pumping for 1 year results in significant drawdown that approaches the top of the Cow Creek in the EP pumping and observation wells. The simulated drawdown from 1 year of pumping is sufficient to understand the potential effects of pumping for a long duration. Modeling 7 years of drawdown effectively shows de-watering of the Cow Creek, which would be an unreasonable impact. However, there is greater uncertainty in the results of the 7-year model runs compared with the 1-year runs.

A sustained lower water level within the Cow Creek could increase the capture of water from the overlying Lower Glen Rose. Some evidence of this is presented in BSEACD (2017, 2018) and is shown in **Appendix A**. For example, the Jones well, which is completed in the Upper Glen Rose, responded to the pumping of all three EP wells during the aquifer testing, for a combined total drawdown of 50 ft or 25% of its saturated borehole. Other wells completed into the Lower Glen Rose also responded to pumping during the aquifer test (BSEACD, 2017).

The magnitude of drawdown within the overlying units was modeled by Intera (2016). Results of the Intera (2016) modeling indicate the potential for significant drawdown in the overlying Lower Glen Rose if certain aquifer parameters within the Hensel are relatively high, which is locally supported by the aquifer test data (BSEACD, 2017). The effect of the hydraulic connection of the Cow Creek to the overlying units would be an increase in pumping yield; however, it would also cause drawdown in the overlying Lower and Upper Glen Rose and expand the potential drawdown impacts to other wells in the area.

The modeled drawdown could be considered a worst-case scenario of constant pumping with extreme drought, and with capture constrained. While the model scenario is for 1 year, the actual time to achieve those effects would likely be longer as the rate of pumping would be limited during a drought due to EP well interference with pumping wells, and other District-imposed drought conservation measures. Thus, while the model is for 1 year, the duration to achieve those modeled effects would likely take several years under those conditions.

Water-chemistry data were summarized in BSEACD (2017). The influence of pumping, and the associated head change, on the water quality of the aquifer is uncertain and in fact may be spatially variable. Data collected in the area, including during the aquifer test, indicates a variability of water quality depending upon the head conditions. In some cases water quality improves (lower TDS) with lower heads, and in other cases the water quality worsens, and TDS increases with lower heads (BSEACD, 2017). This probably relates to variable inter-formational flows between the Cow Creek and Lower Glen Rose aquifer units. The effects from the proposed pumping will be lower heads in a semi-permanent manner, such that the effects of low head conditions on water quality will be sustained. In some areas that may be an improvement, but in others it may worsen the water quality. There is presently not enough information to make a determination with high confidence of the overall effect of the proposed pumping on water quality in the area.

Conclusions

The aquifer test and evaluations of the hydrogeology and modeling of the EP well field indicate that the Cow Creek is a compartmentalized aquifer system with limits to its ability to yield water and to avoid unreasonable impacts from large pumping amounts. Evaluation of the aquifer-test data and modeling of the proposed pumping of 2.5 MGD of groundwater from the existing well field results in substantial drawdown in the Cow Creek and also possibly the Lower Glen Rose.

The assessment of the likelihood of Potentially Unreasonable Impacts from the EP well field under its proposed conditions is based on considering the following regulatory criteria:

1. Well interference that causes one or more wells to cease to yield water: This condition is very likely, without special permit conditions and avoidance measures.
2. Well interference that significantly decreases yield of other wells to the extent it prevents the wells from providing an authorized, historic, or usable amount or rate of water production: This condition is almost certain, without special permit conditions and avoidance measures.
3. Well interference that lowers the water levels below the physical or economically feasible level of pump intakes: This condition is almost certain, without special permit conditions and avoidance measures.
4. Degradation of water quality in other wells such that the native water is unusable for its current purpose: This condition is not determinable on the basis of existing information, but its likelihood is probably spatially variable.

The aquifer tests were conducted at a time when water levels were above average in central Hays County. When a factor of 50 ft, to account for severe drought conditions, is subtracted from the aggregate drawdown from the tests, resulting water levels would be such that the Woods #1 and Escondida wells would cease to produce water. Modeling has shown that with longer periods of pumping will cause even greater drawdown. Thus, we conclude that the proposed production of 2.5 MGD of groundwater from the existing EP wells has potential for unreasonable impacts.

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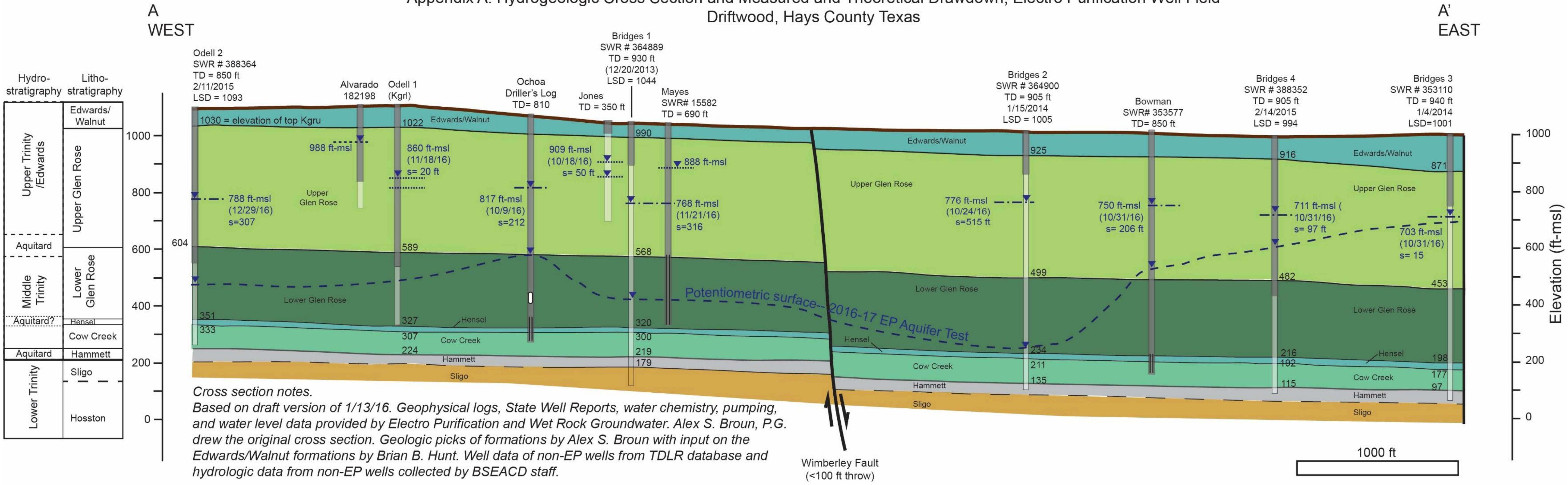
Wet Rock Geological Serivces (WRGS), 2017b, Administrative Completeness Review of a Production Permit Application by Electro Purification LLC, for authorization to produce groundwater from the Middle Trinity aquifer. Letter in response to BSEACD. December 14, 2017, 29p + appendices

Appendix A

The hydrogeologic cross section shown was constructed along the EP well field from west to east and provides key hydrogeologic information and context for discussion in this memo. Geologic information such as depth and thickness of the aquifer units were constructed with geophysical logs. Well construction and water levels (both static and drawdown indicated by “s”) are also indicated. The dashed potentiometric surface drawn on the cross section is the approximate level reached during 2016-17 aquifer test. The inset maps showing the measured contoured drawdown and the modeled drawdown after 1 year are provided for additional context of potential impacts.

Appendix A: Hydrogeologic Cross Section and Measured and Theoretical Drawdown, Electro Purification Well Field
Driftwood, Hays County Texas



Cross section notes.
Based on draft version of 1/13/16. Geophysical logs, State Well Reports, water chemistry, pumping, and water level data provided by Electro Purification and Wet Rock Groundwater. Alex S. Broun, P.G. drew the original cross section. Geologic picks of formations by Alex S. Broun with input on the Edwards/Walnut formations by Brian B. Hunt. Well data of non-EP wells from TDLR database and hydrologic data from non-EP wells collected by BSEACD staff.

Location map and contours of total drawdown from the EP Aquifer Test in 2016-17

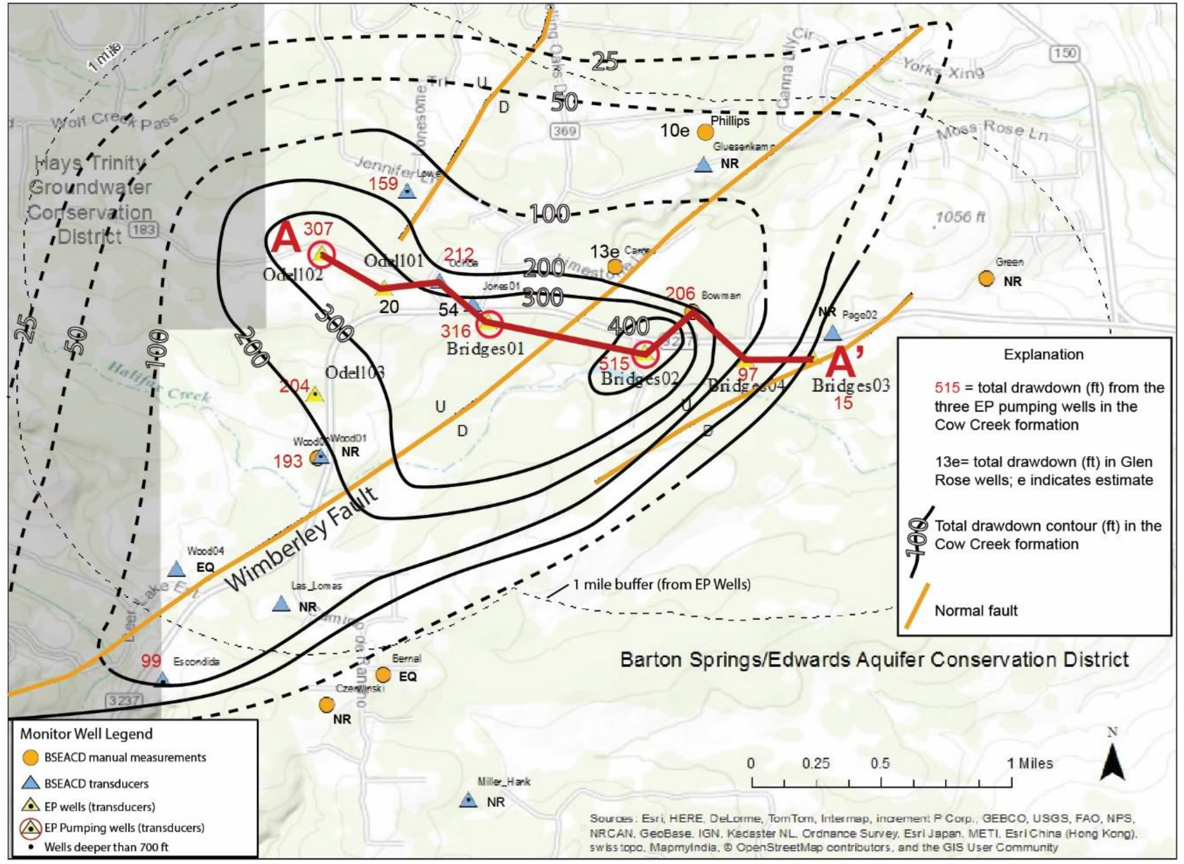


Figure modified from BSEACD, 2017.

Modeled drawdown (ft) of proposed 2.5 MGD after 1 year.