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August 6, 2020

Mr. Gary Westbrook
General Manager
Post Oak Savannah Groundwater Conservation District
Milano, TX 76556

RE: Technical Review of Beaver Creek WCID #1 Request of Exception to Spacing Requirements dated July 20, 2020 and Groundwater Modeling and Hydrogeology Report dated July 20, 2020

Dear Gary:

The purpose of this memo is to transmit INTERA's evaluation of Beaver Creek WCID #1 Hydrological Study of the drawdown impacts associated with their request for exception to spacing requirements.

The Beaver Creek WCID #1 Hydrological study uses the Theis equation to estimate the long-term (40-year) aquifer response associated with the following two production scenarios:

- **Scenario 1.** No Variance – production well instantaneous rates equal 100 gpm per well, and an annual production of 43 ac-ft/yr, per well.
- **Scenario 2.** Variance – production well instantaneous rates equal 175 gpm per well, and an annual production of 76 ac-ft/yr, per well.

Appendix A presents our evaluation of the Hydrological Study. The Hydrological Study determines that Scenario 2 would produce between 12.2 feet to 12.7 feet more drawdown in the Sparta Aquifer than would Scenario 1 for the properties adjacent to Beaver Creek land parcels where the proposed production wells are located. INTERA's analysis indicates that: 1)the Hydrological Study underestimated the storage coefficient for the Sparta Aquifer, which in turn caused the predicted drawdowns to be too high; and, 2) the increased drawdown associated with Scenario 2 is between 7.5 and 8.2 ft. Both set of analyses support the following statements regarding the increase in predicted drawdowns that would occur in the Sparta Aquifer underlying the lands closest to the proposed production well if the variance is granted.

- The additional drawdown is small compared to approximately 950 feet of available drawdown that currently exits above the top of the Sparta Aquifer underlying the adjacent properties
- The additional drawdown would have a de minimis effect on the ability to produce groundwater from the Sparta aquifer underlying the adjacent properties
- The additional drawdown would have negligible increase in the cost associated with pumping groundwater from the Sparta aquifer underlying the adjacent properties.

Please contact me if POSGCD has questions regarding our technical review.

Sincerely,

Steven C. Young
Principal Geoscientist

Attachment A
Technical Review of Beaver Creek WCID #1 Hydrological Study

In their letter to request an exception to well spacing requirements (Beaver Creek, 2020), Beaver Creek WCID #1 references a Hydrological Study performed by R.W. Harden and Associates (RWH&A) (R.W. Harden & Associates, 2020). INTERA's review of the Hydrological Study consists of the comments below.

Comment #1: In their Hydrological Study, R. W. Harden state:

> "RWH&A conducted analytical groundwater flow modeling using proprietary CAD-based software that utilizes the Theis equation to estimate the long-term (40-year) aquifer response associated with the two production scenarios:
>
> **Scenario 1.** No Variance – production well instantaneous rates equal 100 gpm per well, and an annual production of 43 ac-ft/yr, per well.
> **Scenario 2.** Variance – production well instantaneous rates equal 175 gpm per well, and an annual production of 76 ac-ft/yr, per well.
>
> The hydraulic parameters utilized for modeling purposes were obtained from the updated Central Carrizo Wilcox, Queen City and Sparta Groundwater Availability Model (GAM). Specifically, the aquifer transmissivity and storage parameters were obtained from Node 24531, and Node 24723 of Layer 3 of the GAM, which are summarized in Table 1."

Table 1. Aquifer Parameters from the Layer 3 of the GAM

Well ID	Cell Node (Row,Column)	Hydraulic Conductivity	Thickness	Transmissivity	Storage Coefficient
Well No. 1	24531 (R56,C131)	20 gal/day/ft^2	335 feet	6,700 gal/day/ft	5.5×10^{-7}
Well No. 2	24723 (R57,C132)	17.5 gal/day/ft^2	345 feet	6,000 gal/day/ft	5.18×10^{-7}

Note: hydraulic conductivity is presented in gallons per day per square foot (gal/day/ft^2), and transmissivity is presented in gallons per day per foot. Storage coefficient is unitless.

Response #1. Table A shows the hydrogeological parameters that INTERA extracted from the GAM for the Sparta aquifer at the location of the two proposed wells. The values for the thickness, hydraulic conductivity, and transmissivity agree with the values provided by RWH&A in their Table 1 above. However, there is a significant difference in the storage value. INTERA believes that RWH&A used the value specific storage from the GAM as the value for the storage coefficient to calculate drawdowns.

Table A. Hydrogeologic Parameters Extracted from the GAM by INTERA for the Sparta Aquifer

Well ID	Cell Node	Top (ft, msl)	Bottom (ft, msl)	Thickness (ft)	Hydraulic Conductivity (ft/dy)	Trans. (gal/dy/ft)	Specific Storage (1/ft)	Storage Coefficient
Well. No 1	24531	-685	-1016	331	19.8	6,561	5.56E-07	1.84E-04
Well No. 2	24723	-786	-1132	346	17.5	6,056	5.18E-07	1.79E-04
average	-	-735.5	-1074	338.5	18.7	6,309	5.37E-07	1.82E-04

Comment #2: In their Hydrological Study, R. W. Harden state:

> "Table 2 tabulates the maximum drawdown results of each modeling scenario at each adjacent property. It is important to note that as a result of either scenario, the aquifer will remain completely full of water and water levels will rise more than 650 feet above the top of the aquifer within the study area over the next 40 years, and likely longer"

Table 2. Drawdown Results within the Sparta Aquifer at Adjacent Properties

Well Location	*Parcel ID*	*Drawdown (feet) Scenario 1 (No Variance)*	*Drawdown (feet) Scenario 2 (Variance)*	*Owner Name*
Teal Lake Drive	30906	16.4	28.7	Porter, Ludessa
	30883	16.3	28.6	Boyd, Steven
	30884	16.7	29.3	Keimross 401(k) Profit Sharing Plan
	30880	16.7	29.3	Dotson, Jay
	30881	16.6	29.1	Cervera, Jose
	30877	16.4	28.8	Laws, Otis
	31057	16.8	29.5	Gonzalez, Amelia
	31022	16.9	29.5	Storm, Mical & Dawn
	31024	16.9	29.5	Pierre, Shawn
	31023	16.8	29.4	McMillan, Steve
	31026	16.6	29.0	Sabastian Flores and Maura Munoz
	31025	16.3	28.6	Cruz, Jose
	31126	16.5	28.9	Llamas, Silvia
Mallard Drive	31124	16.6	29.1	Abrey, John
	30613	17.0	29.7	Ammons, Tracy Lyn
	30617	16.8	29.3	Blackstock, Rodney
	30618	16.2	28.4	Canterberry, Jennifer & Marshall
	30776 North	16.7	29.3	Bartlett, Verna & Troy
	30776 South	16.3	28.6	Bartlett, Verna & Troy
	30766	16.6	29.0	Bartlett, Verna & Troy
	30767	16.3	28.6	Bartlett, Verna & Troy
	30418	16.5	28.8	McCoy, Jimmy & Janice
	30414	16.7	29.3	McCoy, Jimmy & Janice

Response #2a. INTERA simulated drawdowns for Scenario #1 and Scenario #2 using the public-available code call TTIM (Bakker, 2006, 2008, 2013). TTIM solves a form of the Theis equation in three dimensions. The Sparta aquifer was modeled using a uniform transmissivity value of 6,310 gal/ft/day and a uniform storage coefficient of 1.82 E-4. Figures 1 and 2 shows contours of the simulated drawdowns at the end of 40 years for Scenario #1 and Scenario #2. Figure 3 shows contours of the additional drawdown simulated in Scenario #2. Table B lists the simulated drawdowns for Scenario #1 and #2 by INTERA and by RWH&A in the Sparta Aquifer at the locations of the 23 land parcels closest to the proposed production wells.

The results in Table B show that INTERA simulated drawdown are less than the simulated drawdown produced by the RWH&A simulations.

Table B. Simulated Drawdowns at the Location of Property Parcels Closest to the Proposed Production Wells

Parcel ID	Name of Landowner	Drawdown (ft) Simulated by INTERA			Drawdown Simulated by R.W. Harden		
		Scenario 1	Scenario 2	Scenario #2 minus Scenario #1	Scenario 1	Scenario 2	Scenario #2 minus Scenario #1
30906	Porter, Ludessa	10.3	18.1	7.8	16.4	28.7	12.3
30883	Boyd, Steven	10.5	18.4	7.9	16.3	28.6	12.3
30884	Keimross 401(k) Profit Sharing	11	19.2	8.2	16.7	29.3	12.6
30880	Dotson, Jay	10.5	18.4	7.9	16.7	29.3	12.6
30881	Cervera, Jose	10.5	18.4	7.9	16.6	29.1	12.5
30877	Laws, Otis	10.3	18.1	7.8	16.4	28.8	12.4
31057	Gonzalez, Amelia	10.8	18.8	8.1	16.8	29.5	12.7
31022	Storm, Mical & Dawn	10.4	18.1	7.8	16.9	29.5	12.6
31024	Pierre, Shawn	10.3	18.1	7.7	16.9	29.5	12.6
31023	McMillan, Steve	10.3	18	7.7	16.8	29.4	12.6
31026	Sabastian Flores and Maura	10.3	18	7.7	16.6	29	12.4
31025	Cruz, Jose	10.1	17.7	7.6	16.3	28.6	12.3
31126	Llamas, Silvia	10.1	17.6	7.6	16.5	28.9	12.4
31124	Abrey, John	10.2	17.8	7.6	16.6	29.1	12.5
30613	Ammons, Tracy Lyn	10.6	18.5	7.9	17	29.7	12.7
30617	Blackstock, Rodney	10.6	18.6	8	16.8	29.3	12.5
30618	Canterberry, Jennifer & Marshall	10.2	17.8	7.6	16.2	28.4	12.2
30776	Bartlett, Verna & Troy	10.2	17.8	7.6	16.7	29.3	12.6
30776	Bartlett, Verna & Troy	10.2	17.8	7.6	16.3	28.6	12.3
30766	Bartlett, Verna & Troy	10.2	17.9	7.7	16.6	29	12.4
30767	Bartlett, Verna & Troy	10.1	17.7	7.6	16.3	28.6	12.3
30418	McCoy, Jimmy & Janice	10	17.5	7.5	16.5	28.8	12.3
30414	McCoy, Jimmy & Janice	10.5	18.4	7.9	16.7	29.3	12.6

Response #2b. In the vicinity of the proposed production well, the elevation of the top of the Sparta Aquifer is approximately 736 feet below sea level (see Table B). The average water level near the Sparta Aquifer near the proposed production wells is approximately 240 ft above sea level, or about 976 feet above the top of the Sparta Aquifer. RWH&A state that the water will rise more than 650 feet above the top of the aquifer within the study area over the next 40 years(see Comment #2). Based on INTERA calculations, the RWH&A discussion regarding the water level is true but perhaps a better evaluation the potential impact of the future drawdowns on the Sparta aquifer is that the water level is more than 950 feet instead of more than 650 feet above the top of the aquifer.

References:

Bakker, M. 2006. Analytic Element Modeling of Embedded Multiaquifer Domains. Ground Water, V. 44: No. 1, p. 81-85. Retrieved from https://info.ngwa.org/GWOL/pdf/061681212.pdf.

Bakker, M. 2010. TTim, a multi-aquifer transient analytic element model version 0.01. Delft University of Technology, 2010. ttim.googlecode.com

Bakker, M. 2013. Semi-analytic modeling of transient multi-layer flow with TTim. Hydrogeology Journal 21: 935-943

Beaver Creek Water Control & Improvement District No. 1 (Beaver Creek), 2020. Letter to Post Oak Savannah Groundwater Conservation District from James Dever, Reference: Request of Exception to the Spacing Requirements, July 20, 2020.

R. W. Harden & Associates, 2020. Technical Memorandum: Groundwater Modeling and Hydrogeologic Reporting from Liz Ferry to Brian Dobiyanski , July 20, 2020

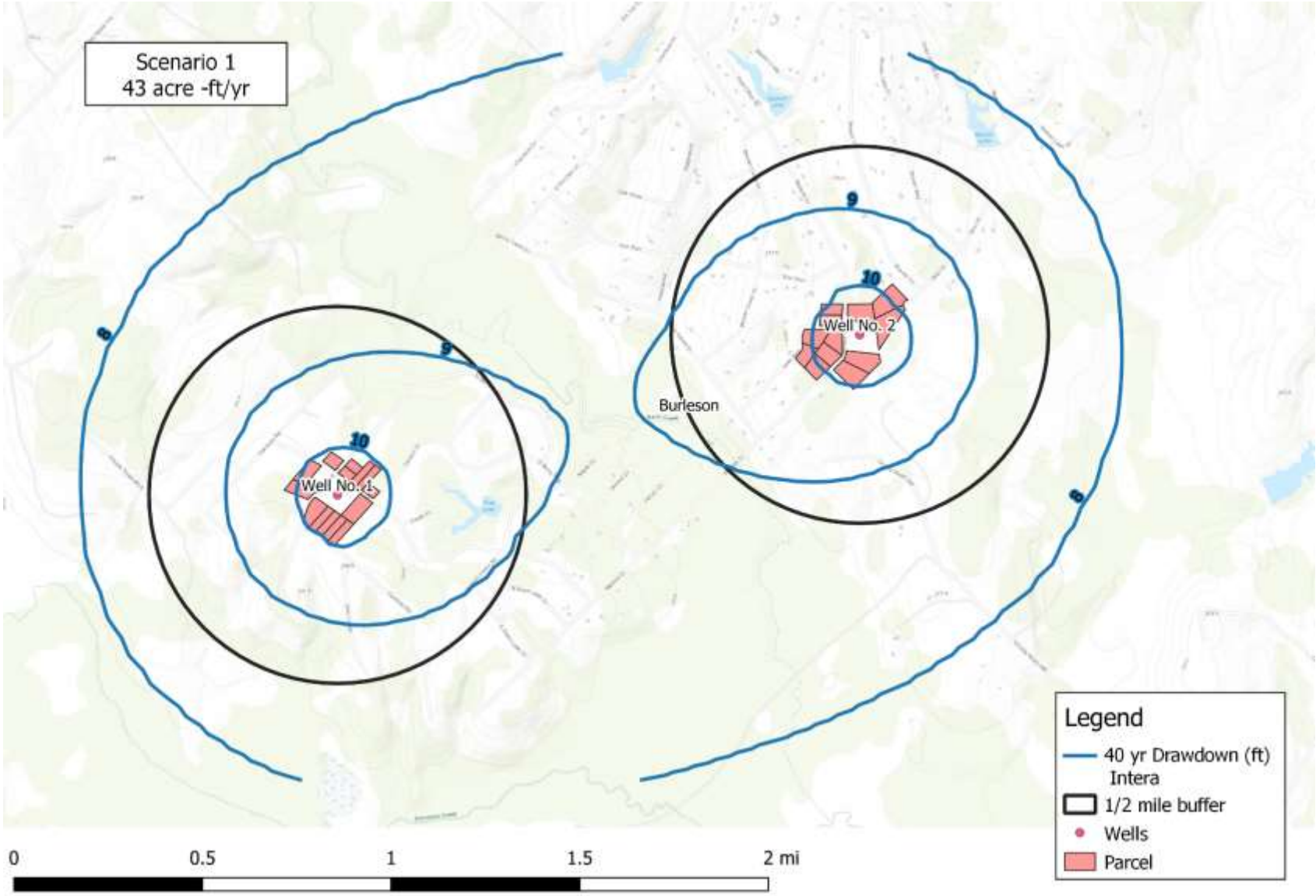

Figure 1. Estimated Drawdown after 40 years in the Sparta Aquifer after 40 years for Scenario #1

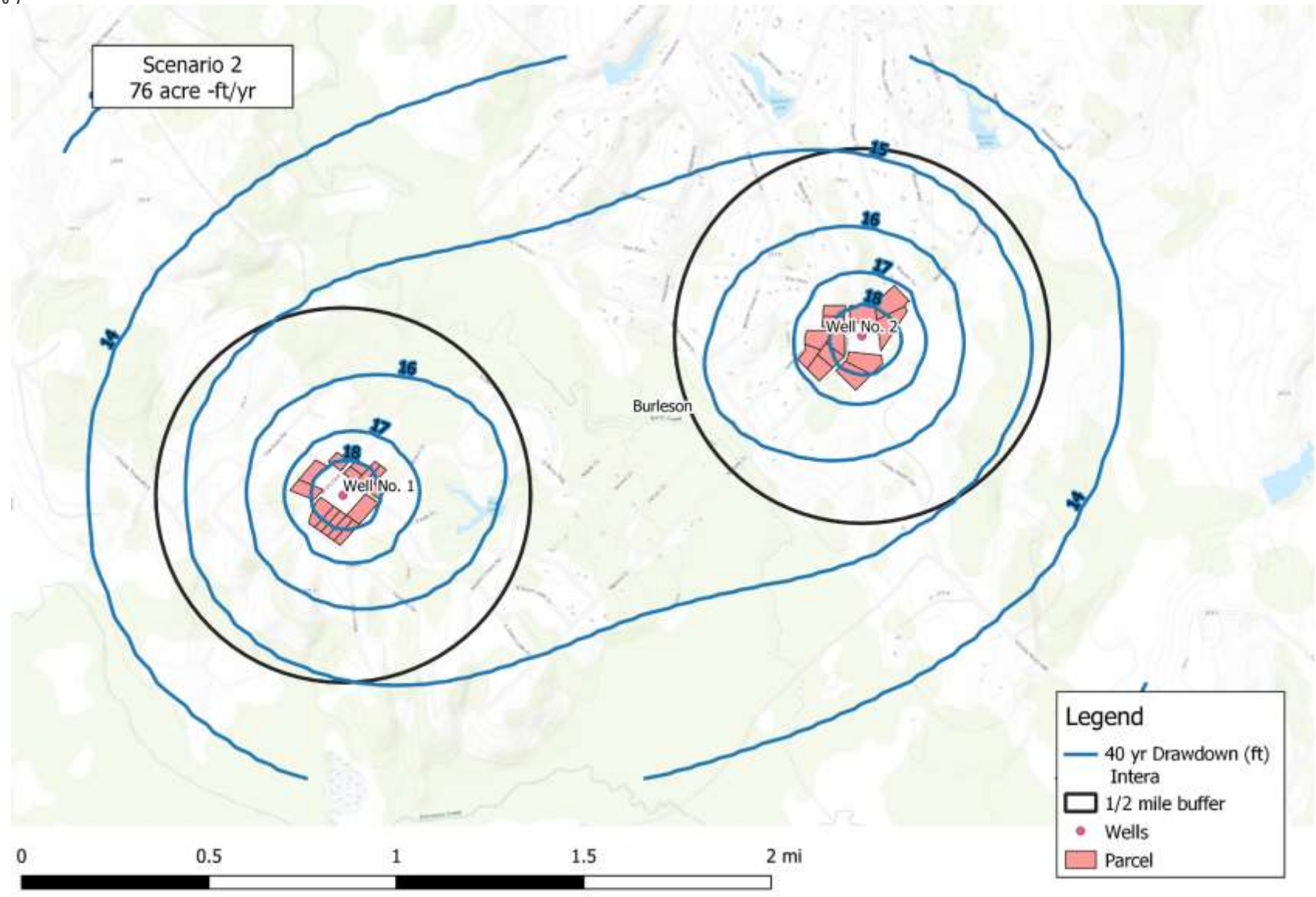

Figure 2. Estimated Drawdown after 40 years in the Sparta Aquifer after 40 years for Scenario #2

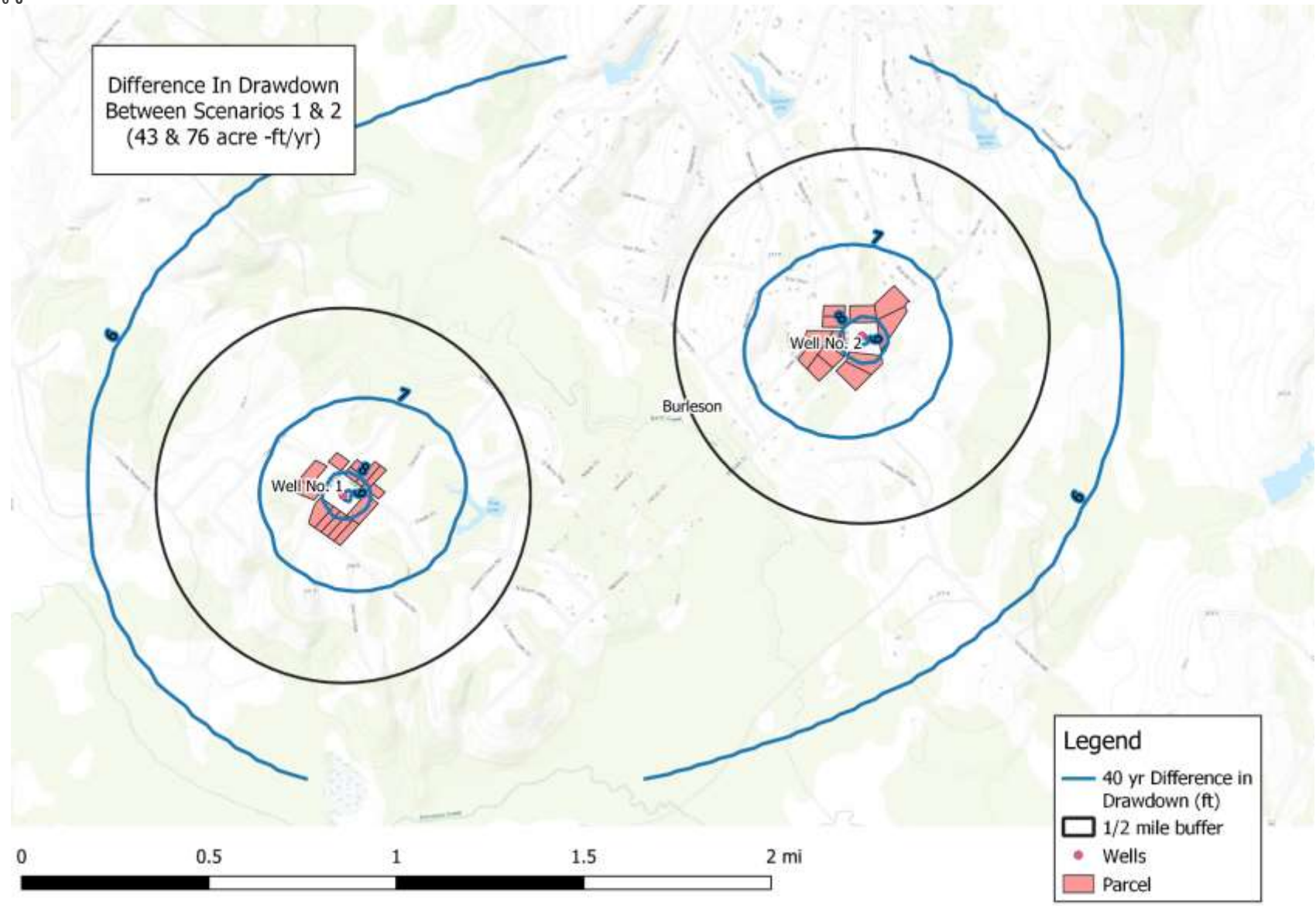

Figure 3. Estimated Difference in Drawdown between Scenarios #1 and #2 after 40 years in the Sparta Aquifer after 40 years.