NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES

La Cienega Groundwater Level Monitoring, Santa Fe County, New Mexico: 2020 Summary of Findings

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CONTENTS

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I. INTRODUCTION

Beginning in 2003, the New Mexico Bureau of Geology began a hydrogeological investigation of the Española Basin, with a special focus on the wetlands at La Cienega, Santa Fe County, New Mexico to better understand the inputs that support them (Johnson, 2009). The studies focused on linking the geology of the region and the groundwater flow to help understand the potential influences on the wetlands. The research showed that the primary aquifer that supports the wetlands in La Cienega is the Ancha Formation, which is overlying and connected to the Tesuque Formation. The eroded upper surface of the Tesuque Formation has a network of paleo-valleys that were incised by ancestral rivers. The Ancha Formation aquifer fills these valleys with coarse sediments that are highly transmissive. The wetlands are positioned on the southwestern edge of the Española Basin where the Tesuque and Ancha aquifers thin and pinch-out over older, low-permeability rock units. The thinning of the aquifer forces groundwater to the surface, where it discharges as springs and seeps that support the wetlands (Figure 1). Findings from this research showed that the groundwater feeding the wetlands is highly susceptible to regional influences such as pumping, drought, and land use changes. Both the Tesuque and the Ancha are productive aquifers that have been a source of water for the City of Santa Fe and several other large consumers. The report, using data collected from 2004 to 2013, found water levels in many wells in the primary aquifer around La Cienega had steadily declined since the 1970s (Figure 2) (Johnson et al., 2016).

As a follow up to hydrogeologic research performed by the New Mexico Bureau of Geology and Mineral Resources in recent years (summarized in Johnson, et al., 2016), a

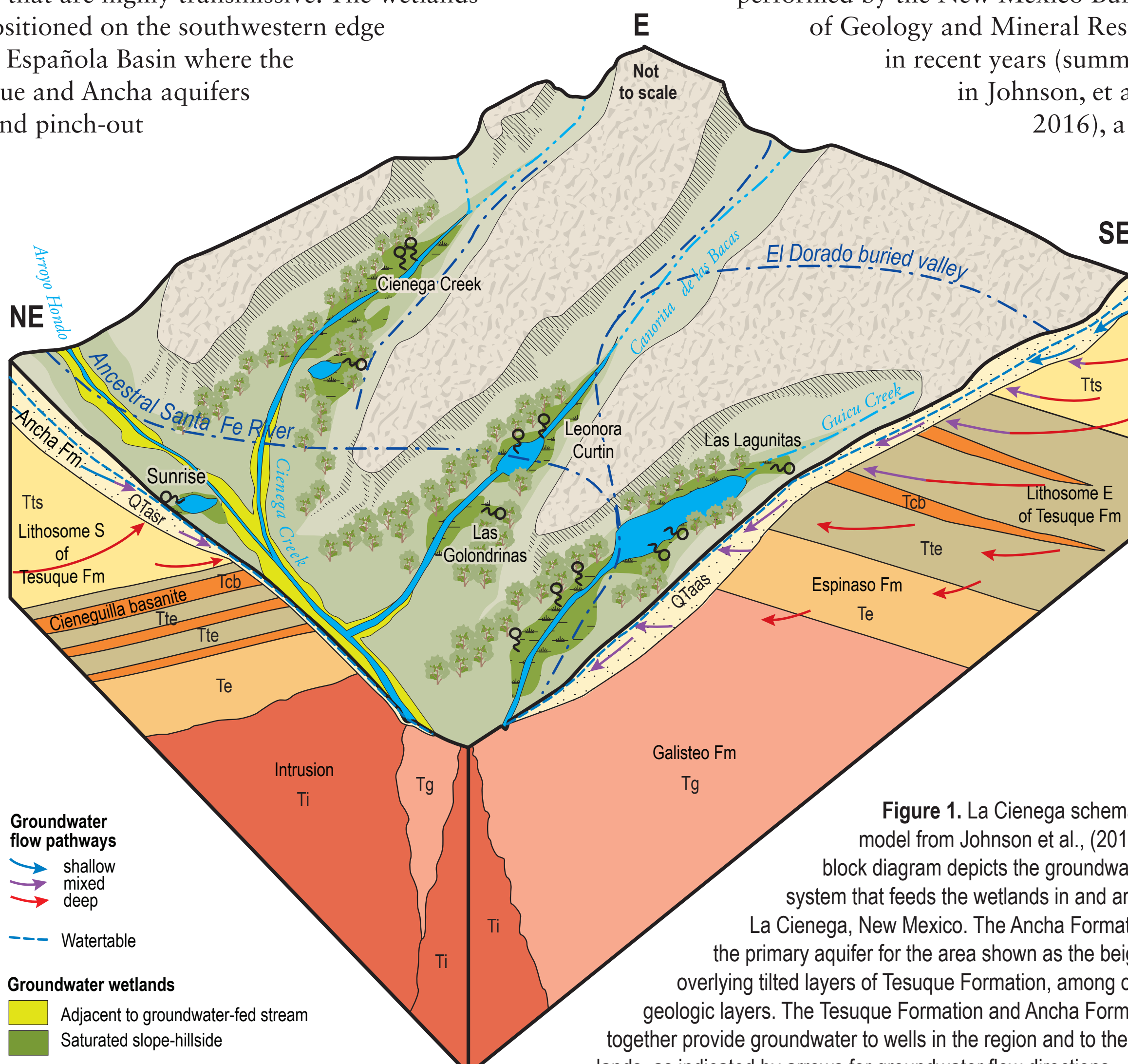
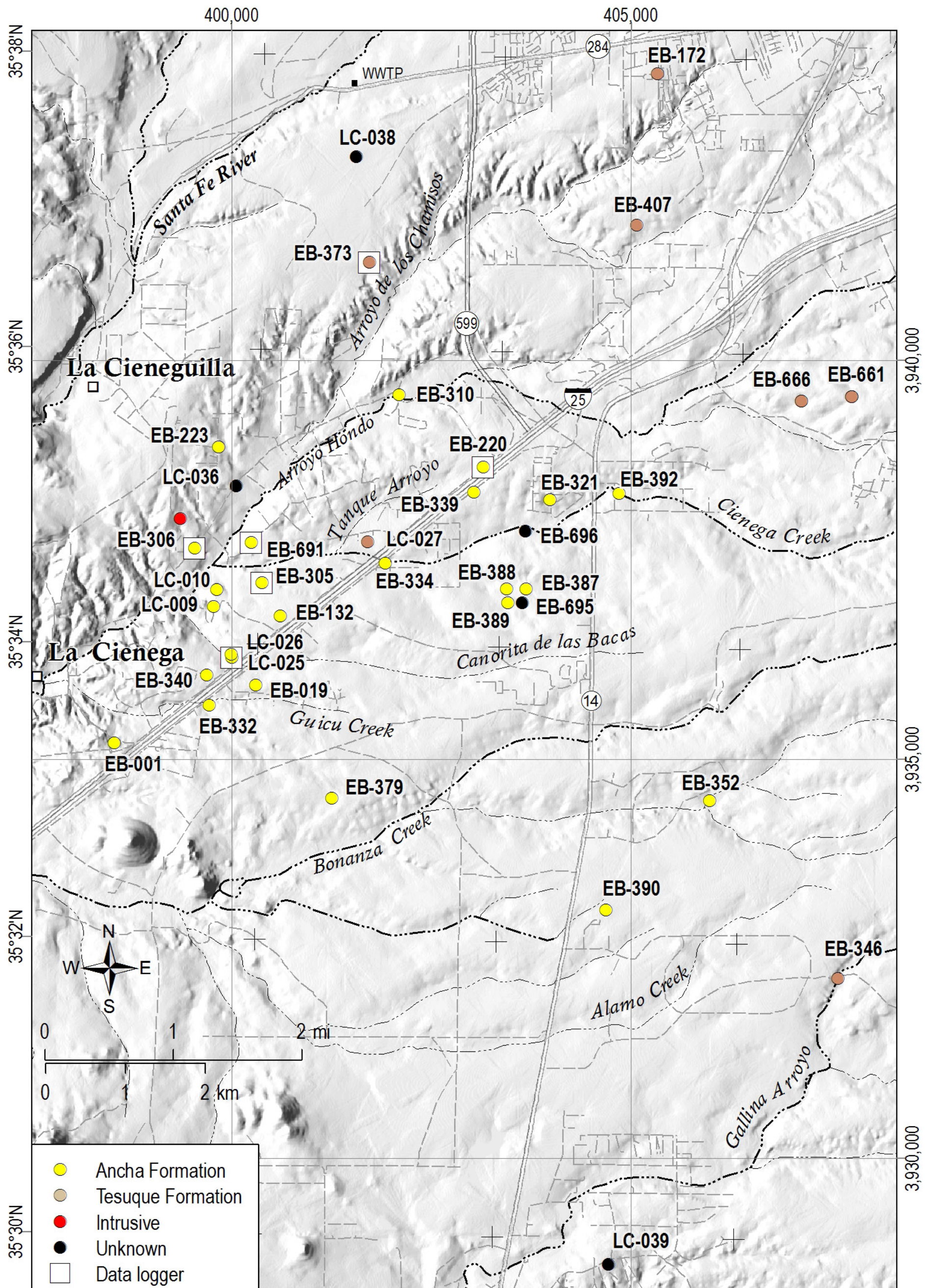


Figure 1. La Cienega schematic model from Johnson et al., (2016). This block diagram depicts the groundwater system that feeds the wetlands in and around La Cienega, New Mexico. The Ancha Formation, the primary aquifer for the area shown as the beige unit overlying tilted layers of Tesuque Formation, among other geologic layers. The Tesuque Formation and Ancha Formation together provide groundwater to wells in the region and to the wetlands, as indicated by arrows for groundwater flow directions.

groundwater monitoring network was implemented around La Cienega, Santa Fe County, New Mexico in the fall of 2015. Groundwater level monitoring provides an essential tool in groundwater management. The data can be used in the development of more accurate groundwater models, and can help with protection of groundwater resources. Measurements of changing groundwater levels also directly reflect changes in groundwater storage. Figure 3 shows the locations of the current wells in the monitoring network, with symbols color coded to the formation in which the wells are completed.

The long-term monitoring network in La Cienega has evolved over the years. The network was first established in 2015 to understand the seasonal trends experienced throughout the area (Mamer and Timmons, 2017; Mamer and Timmons, 2018a). The monitoring network was restructured in the spring of 2018 to more efficiently monitor the groundwater network, while still collecting valuable, usable data

Figure 2. Location of wells monitored for this project. Well points are color coded with the primary aquifer producing water. Most wells in this study are providing groundwater from the Ancha Formation, with a few on the margins of the study that produce water from the Tesuque Formation. In this region, groundwater is generally flowing toward the southwest.



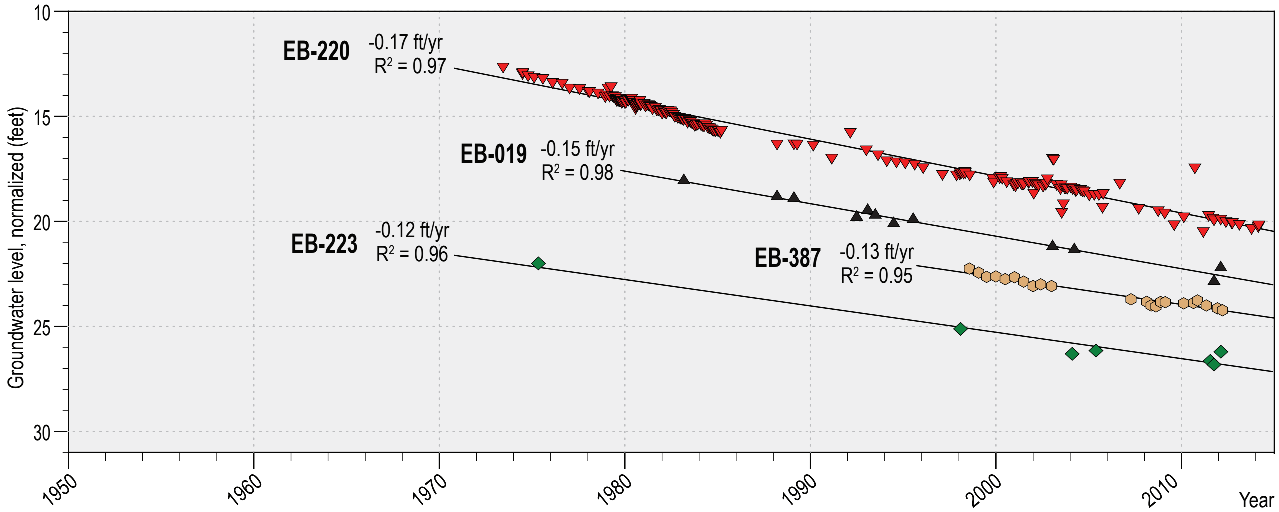


Figure 3. Modified figure from Johnson et al., (2016) that shows decline in groundwater hydrographs from shallow wells in the La Cienega over the past several decades. The rate of groundwater decline (ft/yr) is the slope of the regression line.

(Mamer and Timmons, 2018b; Mamer, 2019). The monitoring network has been measured once per year in late spring. As has been demonstrated in the previous monitoring reports, sampling during the spring period represents the highest groundwater level in many of the wells (Mamer and Timmons, 2017; Mamer and Timmons, 2018a; Mamer and Timmons, 2018b; Mamer, 2019). With the restructured network established in 2018 the spatial coverage of the monitoring network was expanded to the north and south to include 43 wells. The majority of the wells that were added were measured previously in 2015, and earlier in the 2003–2004 period of measurement. This report is a brief summary of the groundwater level monitoring activities in La Cienega, and updates regarding the 2020 measurements.

II. METHODS

In early May of 2020, the monitoring network for La Cienega was re-measured (Figure 3, Table 1). For this monitoring project, groundwater level measurements are made in existing domestic wells (with pumps), and open/unused wells (without pumps) throughout the La Cienega area. The project is made possible by the support of concerned land owners that have allowed the New Mexico Bureau of Geology to visit their wells and measure water levels, in some cases, for over 15 years. In 2020, three

Table 1. Inventory of wells that are part of the annual monitoring network, including location information and well construction. *Indicate wells that were added to the network from the previous bi-annual monitoring group. MP = Measuring point ("-" = below ground).

Site ID	Elevation (ft)	UTM easting NAD83	UTM northing NAD83	Well depth (ft)	MP height (ft)	Screen top (ft)	Screen bottom (ft)	Formation
EB-001*	6068	398529	3935208	221	0.5	47	221	Ancha Formation
EB-019	6139	400304	3935932	80	1	50	80	Ancha Formation
EB-132	6173	400609	3936794	135	-6.2	60	90	Ancha Formation
EB-172*	6459	405330	3943594	493	0.9	353	470	Tesuque Formation
EB-220	6259	403153	3938661	161	0.65	125	161	Ancha Formation
EB-223	6157	399840	3938918	100	0	40	95	Ancha Formation
EB-305	6121	400377	3937211	75	2	20	75	Ancha Formation
EB-306	6086	399537	3937647	43	1.8			Ancha Formation
EB-308*	6140	399358	3938016	103	2.6	73	103	Intrusive
EB-309*	6234	399896	3939990	300	1	120	280	Tesuque Formation
EB-310*	6176	402100	3939571	307	2.2	47	267	Ancha Formation
EB-321*	6261	403986	3938251	180	0.5	140	180	Ancha Formation
EB-332	6089	399720	3935678	160	0.45	80	140	Ancha Formation
EB-334	6146	401921	3937456	140	1.5	60	120	Ancha Formation
EB-339	6263	403035	3938347	200	2.09	160	200	Ancha Formation
EB-340	6136	399686	3936057	155	0.8			Ancha Formation
EB-346*	6340	407590	3932255	366	0.52	185	365	Tesuque Formation
EB-352*	6292	405988	3934482	152	1.29			Ancha Formation
EB-373	6262	401729	3941231	300	0.6			Tesuque Formation
EB-379*	6213	401253	3934512	227	0.67	137	227	Ancha Formation
EB-387	6225	403690	3937134	115	1.24			Ancha Formation
EB-388	6214	403442	3937136	91	1.43			Ancha Formation
EB-389	6234	403458	3936959	121	1.98			Ancha Formation
EB-390*	6302	404686	3933111	500	1.7	200	460	Ancha Formation
EB-392*	6262	404853	3938331	220	1.73	160	200	Ancha Formation
EB-407*	6369	405069	3941697	247	0.5			Tesuque Formation
EB-661*	6482	407765	3939546	620	2.75	580	620	Tesuque Formation
EB-662*	6482	407765	3939546	1140	2.74	1020	1140	Tesuque Formation
EB-663*	6482	407765	3939546	1580	2.79	1500	1580	Tesuque Formation
EB-666*	6418	407135	3939493	450	2.77	430	450	Tesuque Formation
EB-667*	6418	407135	3939493	1400	2.98	680	1360	Tesuque Formation
EB-691	6113	400249	3937717	180	1.75			Ancha Formation
EB-695	6242	403641	3936964	125	1.89			Unknown
EB-696	6216	403679	3937857	117	2.51			Unknown
LC-009	6084	399771	3936914	180	0.5			Ancha Formation
LC-010	6101	399811	3937131	180	0.9	160	180	Ancha Formation
LC-025	6086	400000	3936280	18	-0.35			Ancha Formation
LC-026	6086	399995	3936316	8	-0.5			Ancha Formation
LC-027*	6155	401705	3937727	102	-7.7			Tesuque Formation
LC-036	6111	400055	3938426		-6.1			Unknown
LC-038*	6323	401562	3942555	186	1.93	166	186	Unknown
LC-039*	6231	404716	3928667	295	-6.32	215	275	Unknown
LC-040*	6526	407004	3944472		1.47			Unknown

Table 2. Wells in La Cienega area monitoring network. Manual water level measurements collected during the early 2000s and the recent spring measurement periods. Depth to water is ft below land surface. * Indicate wells that were added to the network from the previous bi-annual monitoring group.

	Early 2000s		2015		2018		2019		2020	
Site ID	Date measured	Depth to water (ft)	Date measured	Depth to water (ft)	Date measured	Depth to water (ft)	Date measured	Depth to water (ft)	Date measured	Depth to water (ft)
EB-001*	3/24/04	48.41	4/14/15	48.03	4/9/18	48.03	4/17/19	48.02	5 /19/ 20	48.35
EB-016*	3/24/04	228.06	2/11/15	228.04						
EB-019	3/23/04	43.34	4/14/15	44.46	4/10/18	44.51	4/17/19	44.42	5 /19/ 20	44.64
EB-102*	3/31/04	60.35	2/18/15	62.07						
EB-115*	3/14/06	215.06	2/11/15	215.77						
EB-132	2/10/04	67.56	4/14/15	68.30	4/10/18	68.39	4/17/19	68.37	5 /19/ 20	68.44
EB-171*	3/31/05	347.26	2/20/15	344.53						
EB-172*	3/31/05	305.00			4/11/18	303.10	4/30/19	300.22	5 /19/ 20	300.09
EB-218*	3/25/04	264.03	2/11/15	232.12						
EB-220	3/18/04	131.39	2/11/15	133.15	4/9/18	132.85	4/17/19	132.79	5 /19/ 20	132.86
EB-222*	2/11/04	131.32	2/11/15	132.10						
EB-223	2/11/04	46.31	4/14/15	45.42	4/9/18	45.31	4/18/19	45.32	5 /19/ 20	45.30
EB-240*	5/12/05	435.49	2/17/15	437.12						
EB-305	1/9/04	22.17	4/13/15	22.78	4/9/18	22.78	4/17/19	22.81	5 /19/ 20	22.98
EB-306	2/10/04	19.40	3/16/15	18.97	4/9/18	18.72	4/18/19	18.74	5 /19/ 20	18.94
EB-308*	2/11/04	52.54	4/16/15	52.22	4/9/18	51.97	4/16/19	51.95	5 /19/ 20	51.96
EB-309*	2/11/04	106.50	4/16/15	104.76			4/16/19	104.48	5 /19/ 20	104.53
EB-310*	2/11/04	38.07	4/16/15	37.49	4/9/18	37.27	4/30/19	37.24	5 /19/ 20	37.42
EB-315	2/10/04	19.91	4/14/15	20.47						
EB-321*	2/20/04	132.89	4/13/15	132.17	4/10/18	132.10	4/16/19	132.02	5 /19/ 20	132.20
EB-332	2/21/04	30.00	4/14/15	8.83	4/10/18	8.75	4/17/19	8.62	5 /19/ 20	9.00
EB-334	2/27/04	38.42	4/13/15	39.65	4/10/18	39.63	4/17/19	39.61	5 /19/ 20	39.74
EB-336*	5/14/04	209.57	3/23/15	208.83						
EB-337*	5/14/04	203.87	3/23/15	201.21						
EB-338*	5/14/04	185.47	3/23/15	186.77						
EB-339	4/29/04	136.53	4/14/15	137.72	4/9/18	137.60			6 /2/ 20	137.80
EB-340	4/29/04	51.53	4/14/15	52.41	4/9/18	52.40	4/16/19	52.34	5 /19/ 20	52.52
EB-346*	6/3/04	151.77			5/4/18	132.37	4/16/19	132.83		
EB-352*	7/14/04	138.10	4/13/15	141.58	5/4/18	140.76	4/16/19	141.54		
EB-373	6/18/04	127.10	3/16/15	116.38	4/10/18	116.30	4/18/19	116.31	5 /19/ 20	117.15
EB-379*	6/24/04	101.77	4/13/15	103.15	4/11/18	103.33	4/17/19	103.34	5 /19/ 20	103.43
EB-387	4/12/07	98.47	4/13/15	98.95	4/9/18	98.87	4/16/19	98.64	5 /19/ 20	98.59
EB-388	4/12/07	88.95	4/13/15	88.99	4/9/18	88.92	4/16/19	88.81	5 /19/ 20	88.75
EB-389	4/12/07	107.94	4/13/15	108.39	4/9/18	108.31	4/16/19	108.10	5 /19/ 20	108.04
EB-390*	7/1/04	157.85			4/10/18	160.70	4/17/19	160.86	5 /19/ 20	161.00
EB-392*	7/15/04	125.21	4/13/15	125.26	4/9/18	125.21	4/16/19	125.23	5 /19/ 20	125.07
EB-407*	3/23/04	217.60	4/14/15	214.98	4/10/18	213.57	4/18/19	213.17	5 /19/ 20	212.29
EB-607*	3/28/06	198.65	3/26/15	200.18						
EB-661*	8/24/06	291.45	4/13/15	292.07	5/4/18	292.56	4/16/19	292.53		
EB-662*	8/24/06	290.70	4/13/15	290.58	5/4/18	290.78				
EB-663	8/24/06	286.71	4/13/15	282.67	5/4/18	280.05				

Table 2. Wells in La Cienega area monitoring network. Manual water level measurements collected during the early 2000s and the recent spring measurement periods. Depth to water is ft below land surface. * Indicate wells that were added to the network from the previous bi-annual monitoring group.—Continued.

	Early 2000s		2015		2018		2019		2020	
Site ID	Date measured	Depth to water (ft)	Date measured	Depth to water (ft)	Date measured	Depth to water (ft)	Date measured	Depth to water (ft)	Date measured	Depth to water (ft)
EB-666*	8/24/06	231.53	4/13/15	237.62	5/4/18	235.21	4/16/19	244.62		
EB-667*	8/24/06	246.62	4/13/15	245.20	5/4/18	245.55				
EB-691			3/16/15	23.21	4/10/18	23.10	4/17/19	23.02	5 /19/ 20	23.53
EB-695			4/13/15	110.54	4/9/18	110.43	4/16/19	110.17	5 /19/ 20	110.13
EB-696	4/12/07	89.75	4/13/15	91.55	4/9/18	91.57	4/16/19	91.56	5 /19/ 20	91.47
LC-009			4/14/15	15.79	4/9/18	16.07	4/16/19	14.42	5 /19/ 20	15.49
LC-010			4/14/15	16.10	4/9/18	16.05	4/16/19	16.28	5 /19/ 20	16.68
LC-025			3/16/15	7.87	4/9/18	7.97	4/17/19	7.90	5 /19/ 20	9.32
LC-026			3/16/15	8.02	4/9/18	6.44	4/17/19	6.48	5 /19/ 20	6.66
LC-027*					4/10/18	40.57	4/17/19	40.50	5 /19/ 20	40.74
LC-036			4/14/15	11.24	4/9/18	11.44	4/18/19	11.60	5 /19/ 20	11.28
LC-038*					4/9/18	171.18	4/18/19	171.93	5 /19/ 20	171.45
LC-039*					4/10/18	137.76	4/17/19	138.26	5 /19/ 20	138.6
LC-040*							4/18/19	363.94	5 /19/ 20	363.16

wells dropped out of the monitoring network in this measurement period. For domestic wells, water level measurements were made after the well had been off for at least 1 hour. Water levels were measured following the U.S. Geological Survey protocols for a steel tape measurement device with repeat measurements to within 0.02 feet. Open wells were measured using an electronic sounder probe, also with repeated measurements within 0.02 feet. All measurements reported are in units of feet, and are reported from below ground surface (bgs). Manual water level measurements from wells in the monitoring network are provided with this report in Table 2. Hydrographs showing the water level measurements over time are found in the Appendix 1.

Pressure transducers monitoring continuous changes in groundwater levels have been deployed in several wells since 2011 (EB-220, -306, LC-025, -026) (Table 3). Additional sites were instrumented in 2014 and 2015 (EB-305, -339, -373, -691). These instruments are VanEssen brand (Divers), and provide pressure readings, which are converted to water-level measurements collected every 12 hours. These are lengthy data records, and are available upon request. Hydrography produced from these records are discussed below. As these instruments age and reach the end of their lifetime, the data loggers have begun to fail; this has occurred in wells EB-339, EB-220, EB-305, EB-306, EB-373, and LC-026. When possible we have managed to replace the data loggers with spare units repurposed from other completed Aquifer Mapping projects.

Table 3. Well locations with continuous data recorders, and date of installation. See Figure 2 for locations.

Site ID	Date installed	Notes
EB-220	10/4/11	Instrument failed May 2020, not replaced
EB-305	6/4/15	Instrument failed April 2019, not replaced
EB-306	10/6/11	Instrument failed Sept. 2019, not replaced
EB-339	6/1/15	Lost from well April 2016, not replaced
EB-373	10/2/12	Instrument failed May 2020, not replaced
EB-691	5/27/14	Running, Replaced April 2019
LC-025	10/4/11	Running, Replaced April 2019
LC-026	10/4/11	Instrument failed Oct. 2017, not replaced

III. RESULTS

Continuous Data Records

As noted in Table 3, there were originally eight locations with pressure transducers monitoring groundwater level changes every 12 hours. At present there are only 2 remaining pressure transducers that are functioning correctly. These records are displayed in Figures 4–9. Locations of these wells are shown on Figure 3.

LC-025 is a shallow monitoring well that is 18 feet deep, and completed in the shallow Ancha Formation (Figures 1–2). The hydrograph shows a distinct seasonal fluctuation related to the growing season that is seen in numerous wells in the area, typically dropping 4 feet. (Figure 4). Water levels begin to recover after plants go dormant later in the fall, typically by mid-November. This well sees rapid recharge as noted in late 2013, where water levels rose 6 ft following a large storm event. This unit was replaced with a used data logger in April 2019 and is still functioning.

EB-373 is 300 feet deep, located near the Santa Fe airport, and is completed in the Tesuque Formation (Figure 2). This is the only well instrumented with a data logger with a consistent upward trend in the groundwater level (Figure 5) since the well was instrumented in late 2012. Wells in the area of the Santa Fe Airport were shut down in the mid-1990s, as the airport was connected to the City of Santa Fe water supply. These water supply changes may be influencing the water-level rise in the well. From 2012, when a pressure transducer was first deployed in the well, through mid-2016, water levels were rising at approximately 0.4 ft/yr. Since 2016, water level changes have remained steady. Where previously there was no noticeable seasonality to the water level trend there is now a very slight seasonality to the water level fluctuation. The muted seasonal trend is likely the result of summer pumping upgradient affecting the aquifer. The data loggers used in this well have had intermittent malfunctions and currently there is no device collecting data at this well.

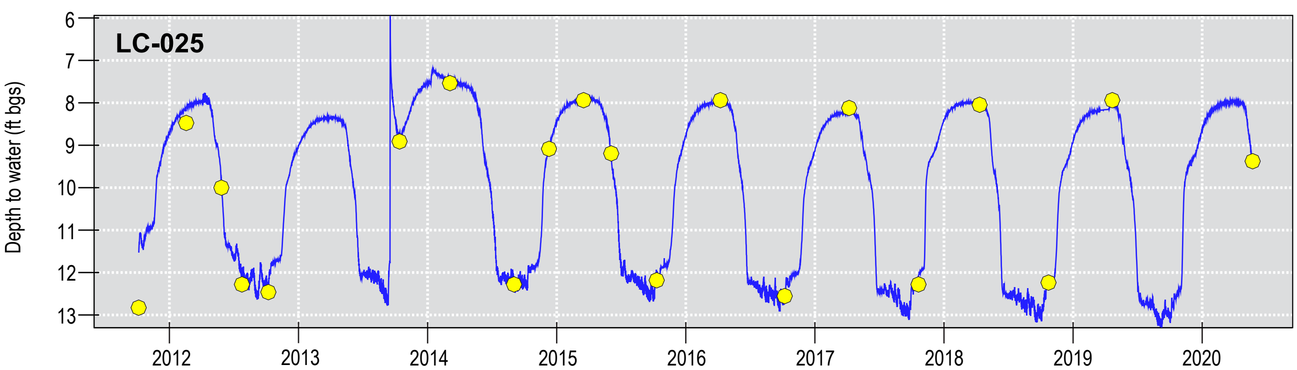


Figure 4. LC-025 is a shallow, 18 ft deep monitoring well, completed in the Ancha Formation. The spike in water level that occurs in September 2013 coincides with a significant precipitation event.

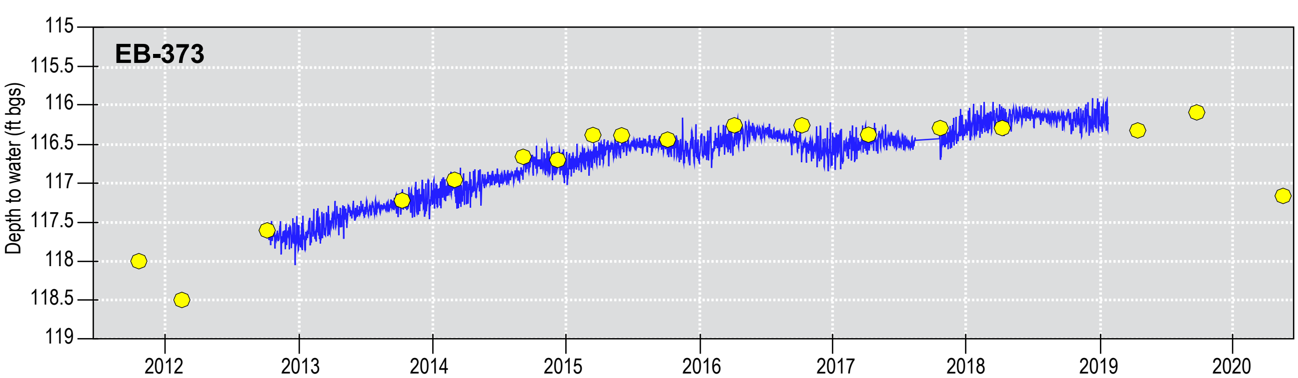


Figure 5. EB-373 is 300 ft deep, located near the Santa Fe airport, and completed in the Tesuque Formation.

EB-306 is a 43 foot deep well that is completed in the Ancha Formation (Figure 2). The water level time series recorded in this well shows a distinct seasonal fluctuation in the shallow water table likely related to evapotranspiration (Figure 6). The winter recovery, following the growing season, generally occurs at the end of September and since 2014 water levels have returned to approximately 18.8 feet below land surface. Once the growing period begins in late spring/early summer, the groundwater levels drop approximately 0.8 feet. The data loggers used in this well have had intermittent malfunctions and currently there is no device collecting data at this well.

EB-220 is a well completed in the Ancha Formation, with a total depth of 161 feet (Figure 2). This well has a long record of decline since the 1970s, on the order of roughly 0.2 ft/yr (Johnson et al., 2016) (Figure 3). Beginning in 2013, the water level began to recover. The peak winter water levels between 2013 and 2016 were consistently 0.1 feet higher each year (Figure 7). This recovery trend changed in 2017, as the winter high was 0.1 feet lower than the previous year. 2018, 2019, and 2020 have seen the recovery trend continue. This well also shows a muted water level response to seasonal changes; typically rising and falling approximately 0.25 feet. The seasonal fluctuation in this well is different from other wells in the area that respond quickly to the growing season. The signal in this well appears to be more muted or offset, likely the result of summer pumping upgradient affecting the aquifer. Typically the water level in this well does not fully recover until June, and doesn't fully decline until early January. The data loggers used in this well have had intermittent malfunctions and currently there is no device collecting data at this well.

EB-691 is a 180 foot deep pumping well completed in the Ancha Formation (Figure 2). Records of water levels measured when the well was pumping are shown by the dips in water levels (longer vertical lines), with water levels reaching 36 feet below land surface (Figure 8). The overall trend in the static water level of this well, as indicated by the level that the water level recovers to after pumping, shows that this well has a seasonal fluctuation of approximately 1 foot. Static water levels are close to 23 feet below land surface in the winter months, and approximately 24 feet below land surface during summer months. The data logger in this well died in August of 2018 and was replaced with a spare data logger when it was visited in spring of 2019, which is currently functioning correctly.

EB-305 is a 75 foot deep well completed in the Ancha Formation. The overall trend of water level change in this well reflects the seasonal decline common in other shallow Ancha Formation wells in the

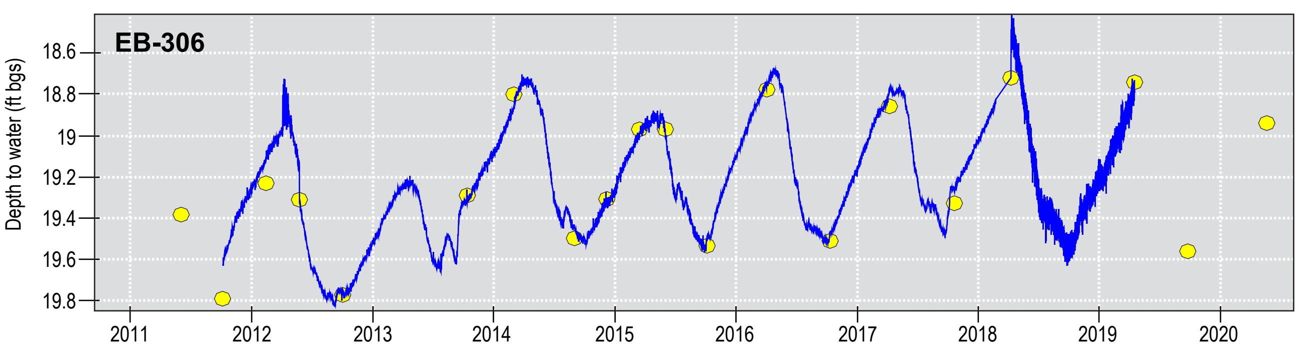


Figure 6. EB-306 is a 43 ft deep well completed in the Ancha Formation.

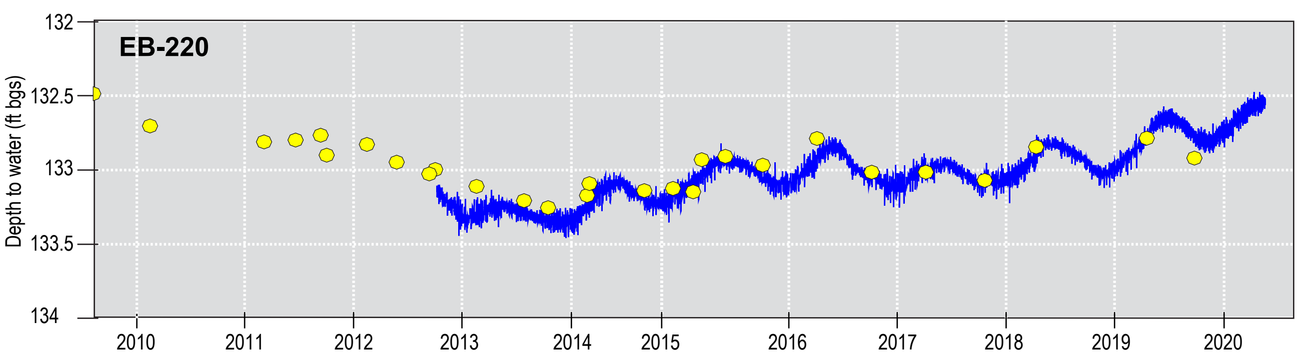


Figure 7. EB-220 is a well completed in the Ancha Formation, with a total depth of 161 ft.

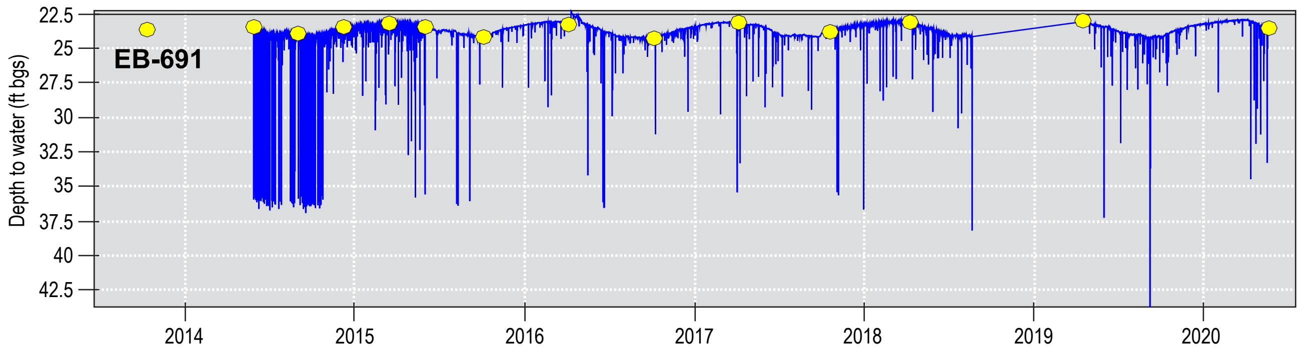


Figure 8. EB-691 is a 180 ft pumping well completed in the Ancha Formation. Water levels measured when the well was pumping are dramatically lower than the static water level, with water levels reaching 36 ft below land surface. The overall trend in the static water level of this well, indicated by the blue line of points, shows that this well reflects a seasonal fluctuation of approximately 1 ft.

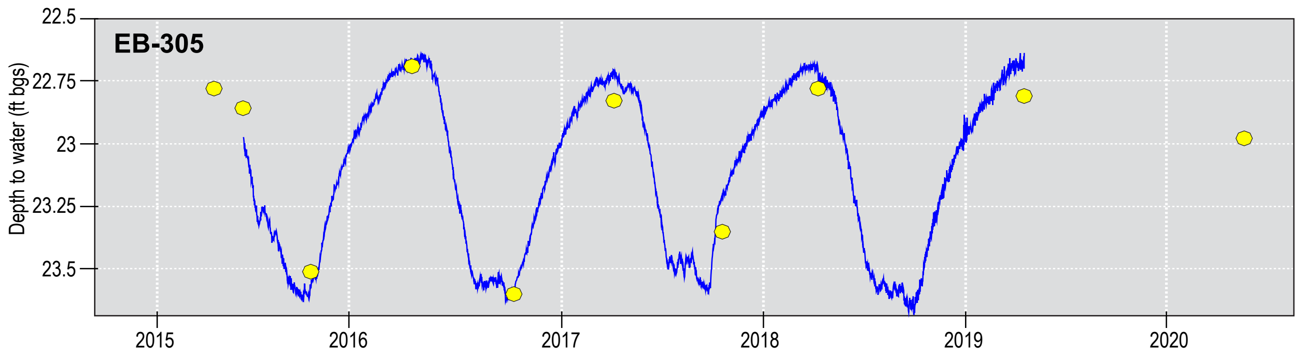


Figure 9. EB-305 is a 75 ft deep well completed in the Ancha Formation. Installed in June 2015.

region; rising and falling 1 foot between summer and winter seasons (Figure 9). A previous water level measurement from this well in January 2004 was 22.1 feet below land surface. This well has seasonal fluctuations, but there has been a long term decline in the overall water level at this well since it was measured in 2004. At present the well appears to be stable; recovering to approximately the same levels in the spring and decreasing to the same levels in the fall.

Analysis of 2020 Water Level Measurements

The most recent measurement of the monitoring network took place on May 19th, 2020. Previously, the monitoring network was visited during the first or second week of April. This was done for two main reasons. First, the water table is typically at its highest just before the spring growing season begins, when plants and trees begin to transpire and use water as they leaf out. Second, consistency in measurement timing is preferable when comparing water-level measurements annually. From our analysis of the continuous pressure transducer data we determined that we were still close to the peak water levels in several of the wells. Of the wells that were measured in 2020, the water level was higher in 32% of the wells than the 2019 water level. A total of 57% of wells measured in 2020 had water levels that were within 0.5 ft below the 2019 levels. In 11% of the wells measured water levels were more than 0.5 ft below the depth measured in 2019. The wells that recorded a drop in water level of more than a half foot were generally shallower wells; the depth to water was 42 ft on average. Those that dropped by less than a half foot were a little deeper wells, 68 ft, and wells that saw an increase in water levels since 2019 typically had the deepest depth to water on average, 143 ft (Figure 10). While it was not ideal to take measurements a month later than typical, the delayed measurement campaign did provide seasonal peak water levels or delayed.

Local Water Table Update

In 2009, Johnson et al., published a water table map of that area that extended from the Buckman well field to Lamy in the southeast. The map was produced using water levels measured from 2000 to 2005 and included the La Cienega area. The water table in the

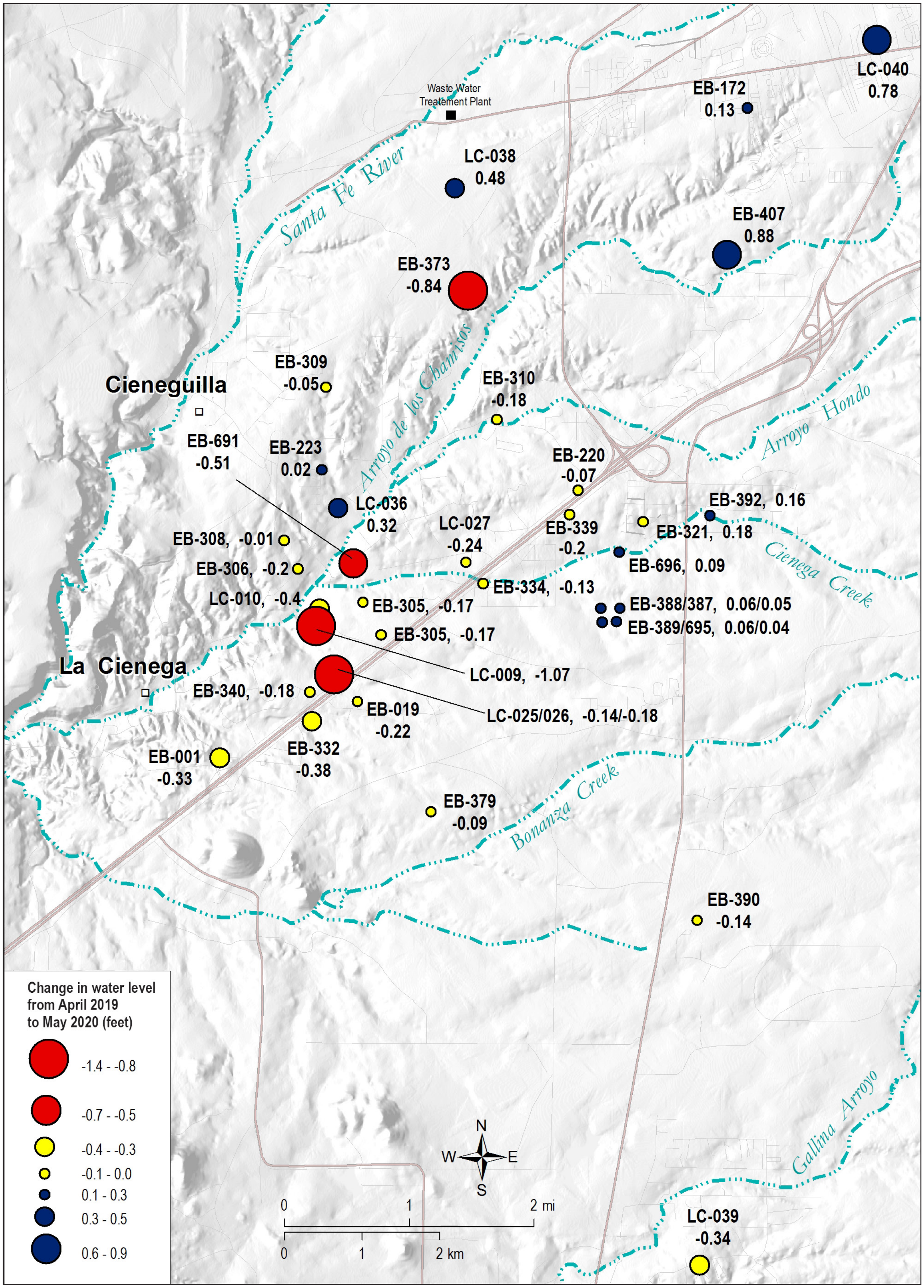


Figure 10. Change in water level between April 2019 and May 2020.

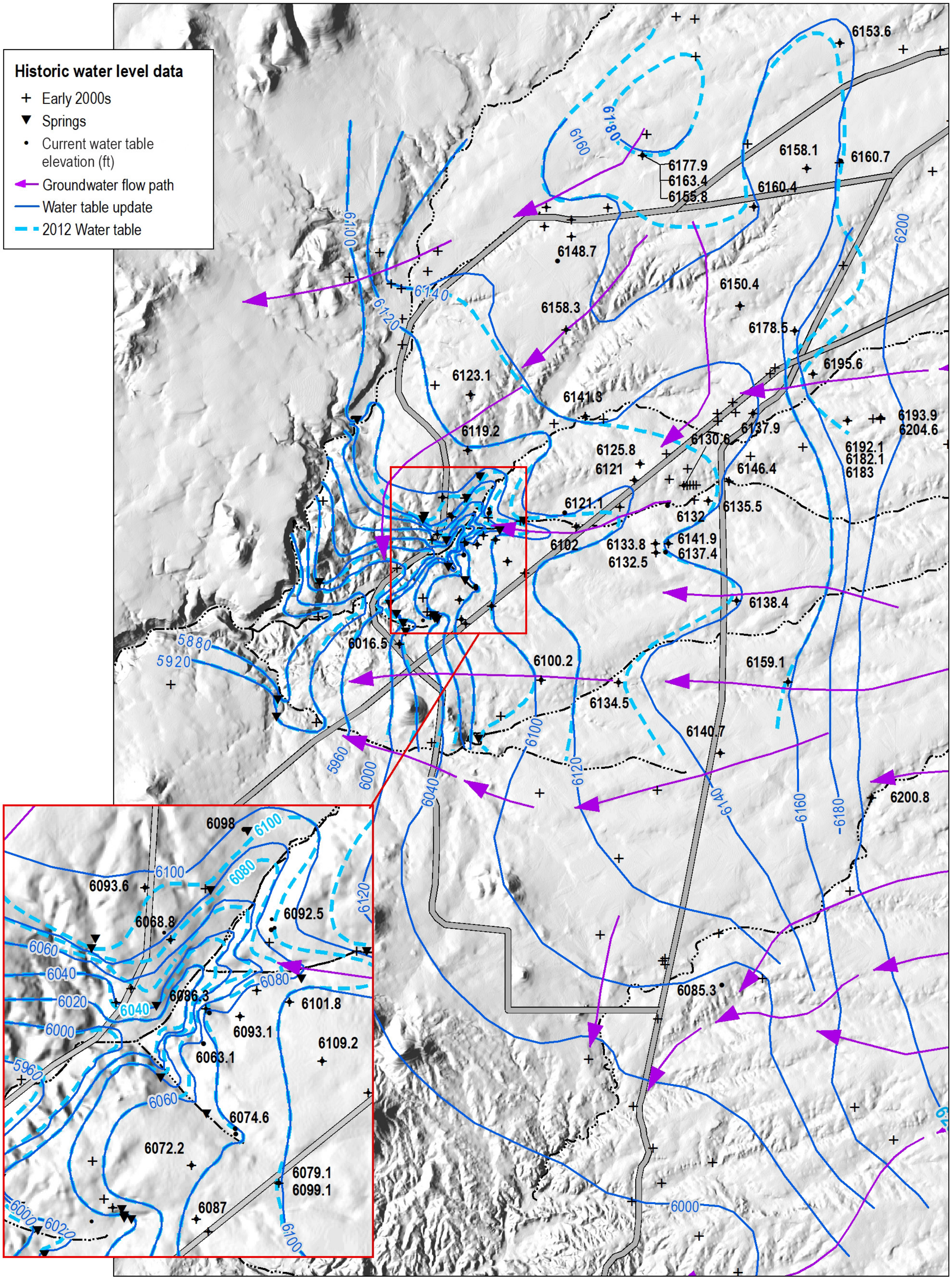


Figure 11. Water table map of the La Cienega area using water levels collected between 2015 to 2019. Modified from the water table map published by Johnson et al., (2016) using water level data collected from the early 2006, and 2012.

La Cienega area was further refined by Johnson et al., (2016) with measurements collected in 2012. As the long-term monitoring network in the area has expanded spatially, we determined that an updated water table map could be contoured for La Cienega using water-level data collected for this project's monitoring efforts. Using the 2012 water table map as a starting point, we mapped the water table elevation contours using the 2015–2020 dataset (Figure 11, previous page). The most significant changes have taken place in the region of the airport in the north. Water levels in this region have significantly recovered. For the most part, throughout the rest of the region, the water table has not significantly changed with only small adjustments. New flow paths for the region have been redrawn to reflect the changes to the local water table.

Long-term Trends

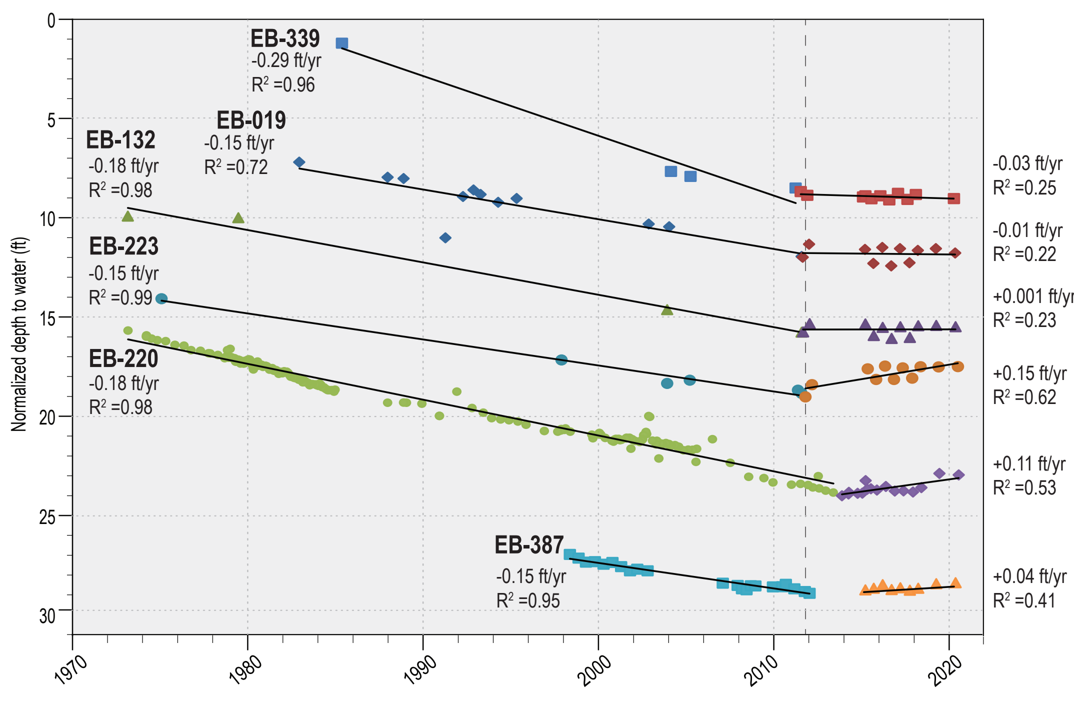
La Cienega area water levels have been monitored over the past several decades. Most wells in the monitoring network have records dating back 10 or more years. As was noted by Johnson et al. (2016), since the 1950s when some of the wells were first measured, water levels have been declining, between 0.12 and 0.23 ft/yr. On the hydrographs that were presented in Johnson et al., (2016) it was noted, however, that at the very end of the data collection period, early 2014, there did appear to be a slight rise in water levels (Figure 3). With the continued collection of data over the past four years the previously published hydrographs have been updated. Starting between 2010 and 2013, there has been a reversal in water-level trends in most wells in the La Cienega area and water levels are now stable or rising at several locations (Figure 12).

In order to detect long term spatial changes, the monitoring network was updated in 2018 to include wells that had previously been measured in the mid 2000s, in 2012, and again in 2015. We compared water levels from similar seasons (where possible) in 2004–2007 to measurements made during 2015 and again in 2018 (Table 2). To normalize changes in water levels between measurement periods, we calculated the feet of change per year over a given time period.

From analyzing the water level change maps we found a spatial trend in the long term water level data. Water levels northwest of the Cienega Creek and Arroyo Hondo, were found to be recovering (rising) from 2004 to present. The median change in water level per year in the NW region was close to neutral, 0.02 ft/yr, between 2004 and 2015. Between 2015 and 2018 water levels began to increase, closer to 0.1 ft/year (Figure 13, 14).

To the southeast, however, the decline in water levels from 2004 to 2015 were close to -0.1 ft/yr, (Figure 13). Since 2015, water levels in the southeastern portion of the study area have remained fairly

Figure 12. Groundwater hydrographs from four wells in the study area that show significant decline for several decades; between 0.29 and 0.15 ft per year. Starting in 2012 the rate of decline was significantly reduced in these wells; between 0.04 ft decline and 0.15 ft per year of recovery.



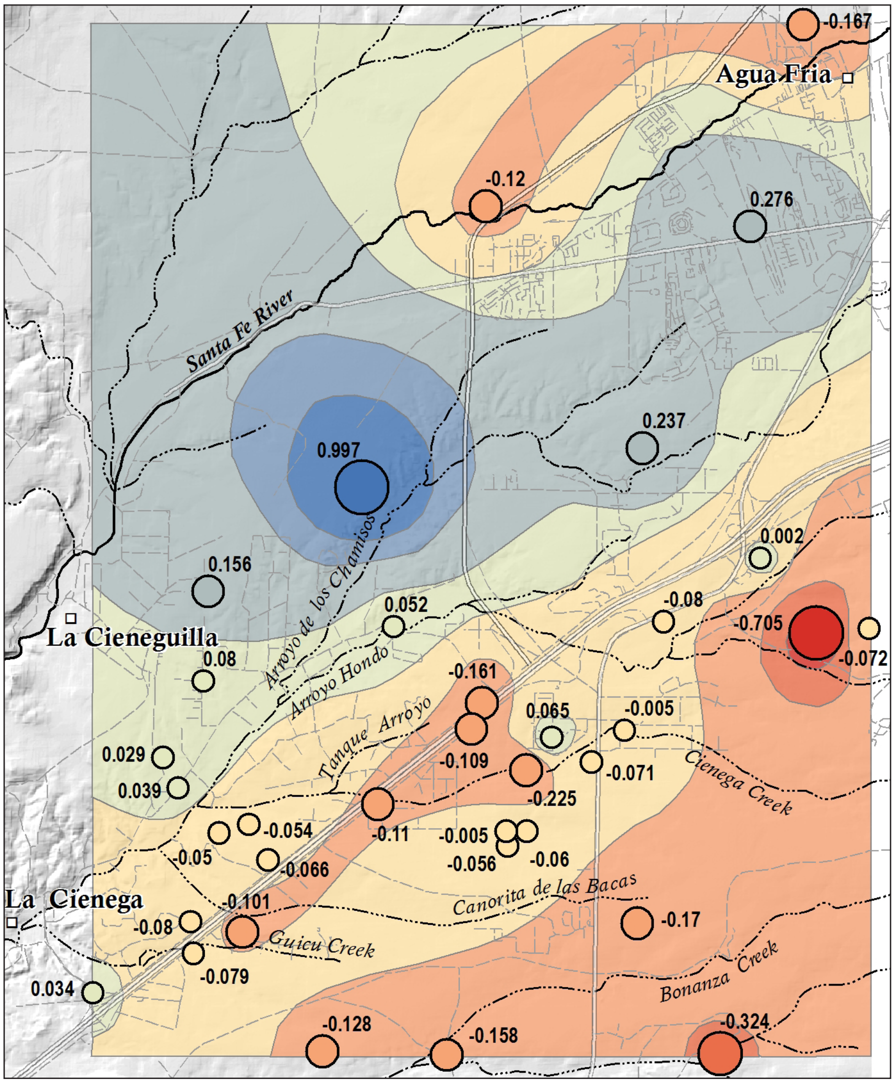


Figure 13. Rate of water level change (ft/year) from 2004–2006 to 2015.

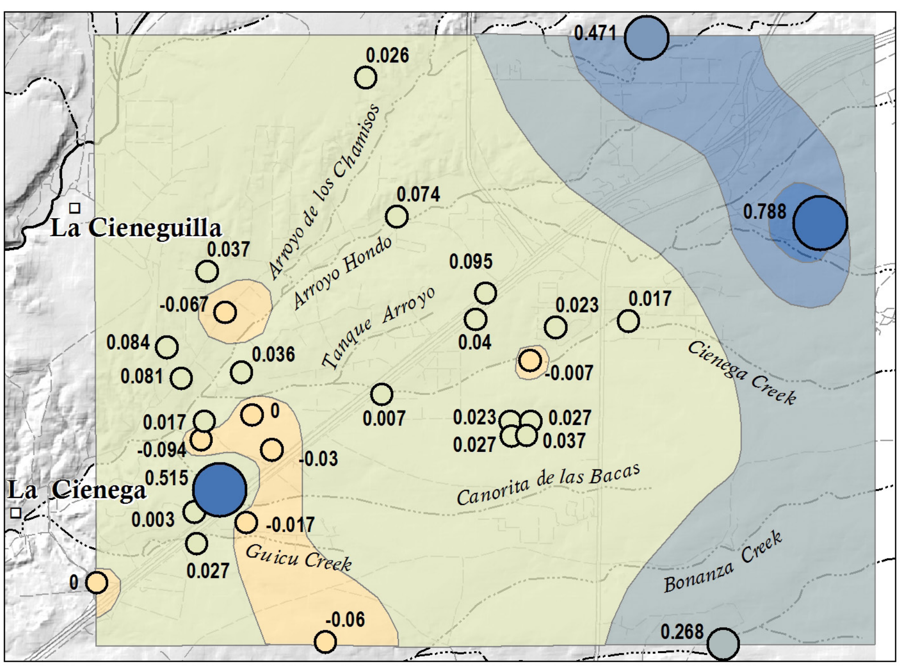


Figure 14. Rate of water level change (ft/year) from 2015 to 2018.

neutral, even showing some signs of recovering with a median rate of 0.02 ft/yr (Figure 14).

Using the updated water table map constructed using water levels collected during the late 2010s, groundwater flow paths in the area were drawn based on groundwater flow contours (Figure 11). The water level contours indicate that La Cienega is located at the termination of several flowpaths. These flowpaths originate from both the city of Santa Fe to the northeast, and the Eldorado region to the east. Regional land and water use changes in the region upgradient likely impact changes we observe in La Cienega.

Discussion of other Regional Datasets

Within the hydrologically up-gradient proximity to La Cienega, the U.S. Geological Survey maintains continuous data recorders in several nested piezometer well sets; Jail Well, NMOSE County and NMOSE Fairgrounds (Figures 15). Nested piezometers consist of a group of three wells that are drilled within close proximity to each other. Each well that is part of the nested piezometer grouping is completed at different depths; a shallow, a middle, and a deep well. This allows for analysis of the vertical gradient in an aquifer; the measure of groundwater flow in the 'Z' direction, up or down. The shallowest of these wells can be compared to the sites monitored in La Cienega. The results in the figures below show that regional groundwater levels in the Tesuque Formation aquifer are largely declining, with small seasonal rises superimposed on the overall downward trend (Figures 16–19). While the majority of the wells in La Cienega are screened in the Ancha Formation, the underlying Tesuque Formation is hydrologically connected to the Ancha in this area (Johnson et al., 2016), so tracking trends in both formations is essential.

The "Jail Well" is set of 3 nested piezometer; 340 ft, 640 ft, and 1,320 ft deep. The shallow and the middle piezometers are screened in the Ancha Formation and Tesuque Formation aquifers and relevant to the La Cienega monitoring network. The "Jail Well shallow piezometer" shows a groundwater decline from 2006 to 2014 of roughly 0.23 ft/yr (Figure 16). From 2014-2020, water levels have remained steady at around 200 ft bgs. The "Jail Well middle piezometer" shows consistent groundwater decline since 2009, approximately 0.4 ft/yr and is currently 123 ft/bgs (Figure 17). This set of nested piezometers shows an upward vertical gradient of 0.25 ft.

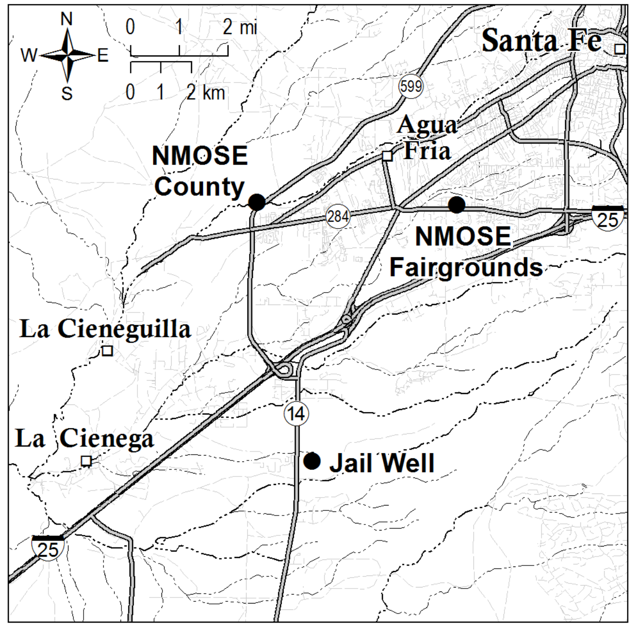


Figure 15. Map showing location of U.S. Geological Survey piezometer well sets. Wells discussed here include Jail Well, NMOSE County, and NMOSE Fairgrounds.

The "NMOSE County shallow piezometer" is 460 feet deep and was completed in the Tesuque Formation aquifer. It has a continuous decline from 2006 to 2018, dropping approximately 0.27 ft/yr (Figure 18). Currently the water level in this well is 187 ft/bgs. While the USGS has not updated the continuous water-level data at this site since 2019, manual water levels continue to be measured.

The "NMOSE Fairgrounds shallow piezometer" is 540 feet deep, completed in the Tesuque Formation aquifer. This well has a consistent groundwater decline of approximately 0.3 ft/yr (Figure 19). Currently the water level in this well is 161 ft/bgs. While the USGS has not updated the continuous water-level data at this site since 2019, manual water levels continue to be measured.

Upgradient Water Use Changes

As has been described above, water-level trends throughout the area experienced consistent declines from the 1970s till the early 2010s. Since roughly 2012, water levels in most of the wells in the La Cienega monitoring network show that the water table changes have stabilized, and in some cases, have begun to recover (Figure 12–14). While outside of the scope of this work, we are interested in better understanding the water use changes that occurred in

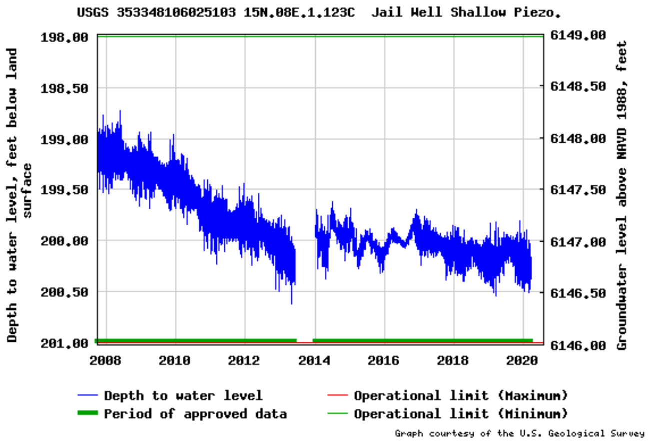


Figure 16. Jail Well Shallow piezometer. This well is 340 ft deep, completed in the bottom of the Ancha Formation and Tesuque Formation aquifers.

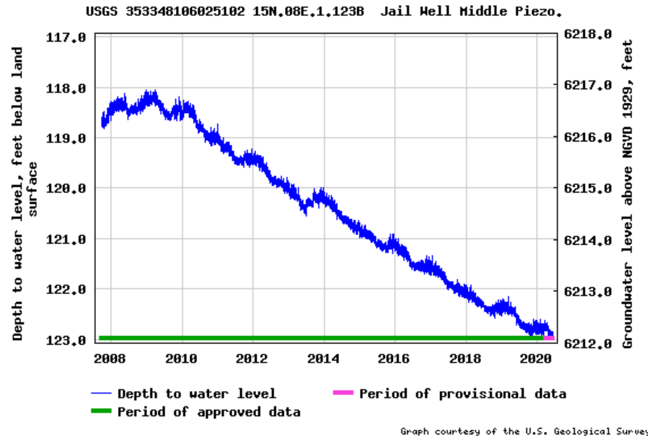


Figure 17. Jail Well middle piezometer. This well is 640 ft deep, completed in the Tesuque Formation aquifer.

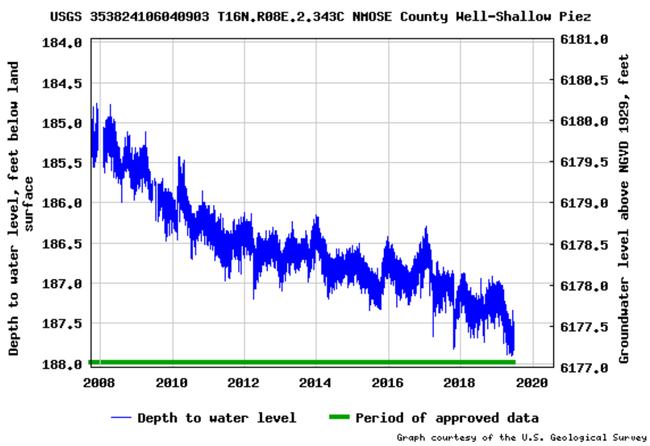


Figure 18. NMOSE County shallow piezometer. This well is 460 ft deep, completed in the Tesuque Formation aquifer.

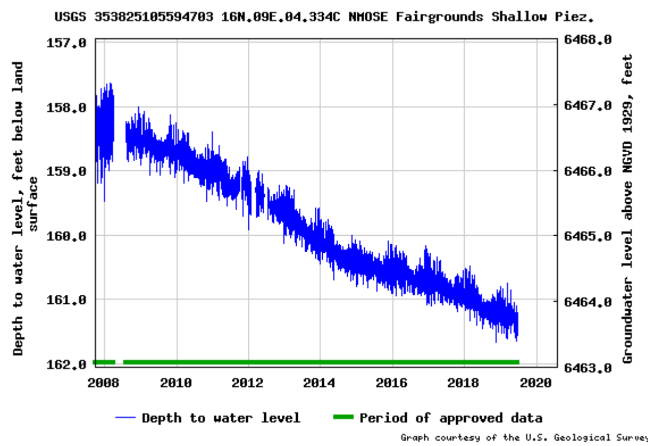


Figure 19. NMOSE Fairgrounds shallow piezometer. This well is 540 ft deep, completed in the Tesuque Formation aquifer.

the early 2010s that lead to this new trend in water levels. One of the most significant upgradient changes that has occurred in the area was the city of Santa Fe transitioning away from pumping groundwater and switching to San Juan/Chama water, and the Buckman Well field in 2011. Additionally, in 2013 the National Guard, State Penitentiary, and the Turquoise Trail Elementary school were connected to the Santa Fe County water pipeline, allowing them to stop pumping their wells. Another water use change that may be contributing to the down gradient trends seen at La Cienega is the Santa Fe Living River project. In 2012 Santa Fe passed an ordinance to maintain flow in the Santa Fe River. In addition to the positive aesthetic benefits of having an active river passing through Santa Fe, it also provides recharge to the aquifer that had been extensively pumped for decades. While it is difficult to quantify the impact that each of these upgradient water-use changes may have had on La Cienega, it does seem possible these changes have resulted in reduced groundwater level declines that have been observed.

IV. CONCLUSIONS

Results of this monitoring project in La Cienega highlight the importance of continued monitoring of groundwater levels in the region. Without regular measurements of groundwater, it is impossible to track changes in groundwater storage or recharge, effects of climate change, impacts of land use and water management choices or possible changes to groundwater flowpaths. The complexity of the groundwater system in and around La Cienega is indicated by the variety of results. As previous work (Johnson et al., 2016) and deeper groundwater monitoring sites in the Tesuque and Ancha Formation aquifers (i.e. USGS piezometers) have shown, there has been an overall trend of declining groundwater levels around La Cienega. Many of these declining trends have been ongoing since the 1970s. Superimposed on this trend, we also observe shallow groundwater fluctuations on a daily and seasonal time scale. Interestingly, in several of the shallow wells measured in this project that have extended water level records, we see a trend toward stabilizing water levels (i.e. EB-132) and even some recovery that started in the early 2010s (i.e., EB-223) (Appendix 1). We also see a rise in the Tesuque Formation aquifer at the Santa Fe Airport well (EB-373) (Appendix 1). This contradicts the NMOSE County shallow piezometer, which is also completed in the Tesuque Formation (though it is screened 260 feet deeper than EB-373 at the airport). At the NMOSE County shallow piezometer, the water level has dropped 3 feet since 2007. Measures to reduce the amount of groundwater pumping from the Ancha and Tesuque Formation aquifers, maintaining Santa Fe River flows, and other water conservation practices may be responsible for the observed slowing and changing rates of groundwater decline.

REFERENCES

City of Santa Fe Water Division, 2016 Annual Water Report.

Johnson, P., Koning, D., Timmons, S., Felix, B., 2008, Geochemical characterization of ground water in the southern Española Basin, Santa Fe, New Mexico: New Mexico Bureau of Geology, Open-file report 511.

Johnson, P., 2009, Water-level elevation contours and groundwater-flow conditions (2000 to 2005) for the Santa Fe Area, southern Española Basin, New Mexico: New Mexico Bureau of Geology, Open file report 520.

Johnson, P., Koning, D., 2012 Geologic and hydrologic maps of the Ancha Formation, Santa Fe County: New Mexico Bureau of Geology, Open-file Report 550.

Johnson, P., Koning, D., Timmons, S., Felix, B., 2016, Geology and Hydrology of Groundwater-Fed Springs and Wetlands at La Cienega, Santa Fe County, New Mexico: New Mexico Bureau of Geology, Bulletin 161.

Mamer, E., Timmons, S., 2017, La Cienega groundwater level monitoring, Santa Fe County, New Mexico: 2016 summary of findings: New Mexico Bureau of Geology, Open-file Report 590.

Mamer, E., Timmons, S., 2018a, La Cienega groundwater level monitoring, Santa Fe County, New Mexico: 2017 summary of findings: New Mexico Bureau of Geology, Open-file Report 600.

Mamer, E., Timmons, S., 2018b, La Cienega groundwater level monitoring, Santa Fe County, New Mexico: 2018 summary of findings: New Mexico Bureau of Geology, Open-file Report 602.

Mamer, E., 2019, La Cienega groundwater level monitoring, Santa Fe County, New Mexico: 2019 summary of findings: New Mexico Bureau of Geology, Open-file Report 604.

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