2018 ANNUAL GROUNDWATER REPORT

Prepared For

Camp Stanley Storage Activity
Boerne, Texas

Prepared By

PARSONS

Austin, Texas

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EXECUTIVE SUMMARY

This report provides an evaluation of results from groundwater monitoring conducted in 2018 at Camp Stanley Storage Activity (CSSA). Groundwater monitoring was performed on-post and off-post during the months of March, June, September, and December 2018. The CSSA groundwater monitoring program objectives are to determine groundwater flow direction and elevations, determine groundwater contaminant concentrations for characterization purposes, and identify meteorological and seasonal variations in physical and chemical properties. This report describes the physical and chemical characteristics of the groundwater monitoring results and changes occurring to the program during 2018.

- In 2011 one of the most severe droughts in central Texas history was recorded, followed by average to below average rainfall from 2012 to 2014, then record rainfall in 2015 and 2016. In 2017 the rainfall total dropped back below average about 8 inches. In 2018, rainfall measured at CSSA was 48.44 inches from the AOC-65 Weather Station (WS). This total was approximately 11 inches above the 30-year average of 37.06 inches for the Boerne weather station monitored by the National Weather Service (NWS). During the same timeframe, 41.20 inches of rain fell at the San Antonio International Airport.

- Quarterly rainfall was sporadic throughout 2018 with more than half of the yearly total 48.44 inches falling in the 3rd quarter (26.39 inches). April through June reported the lowest quarterly total of 4.03 inches from the AOC-65 WS. The most significant quarterly increase happened from July through September with the aquifer rising 167.71 feet. With the total rainfall being above average in 2018; the Middle Trinity aquifer sustained a net gain of 165.09 feet in the average elevation beneath CSSA and increased 101.88 feet above its 15-year average (2003-2018).

- Both on- and off-post groundwater samples were collected quarterly in 2018 (March, June, September, and December) in accordance with the approved CSSA Long-Term Monitoring Optimization (LTMO) program. This plan was updated in 2015 along with the project DQO's and approved by the TCEQ and EPA in May and April of 2016. The updated sampling schedule was implemented in September 2016 with most wells scheduled for sampling on a quarterly, 15-month, or 30-month interval. Results from March, June, and September 2018 have been reported in previous quarterly reports. December 2018 data is presented in this annual report.

- In 2018, a total of 33 samples were collected from 20 on-post wells. Contaminant concentrations above drinking water standards were detected at 2 on-post wells. Wells (CS-MW1-LGR and CS-MW36-LGR) exceeded drinking water standards for volatile organic compounds (VOCs). No wells exceeded drinking water standards for metals in 2018.

- A total of 34 samples were collected from Westbay zones in 2018. VOC concentrations above drinking water standards were detected in 12 zones at four Westbay locations.

- In 2018, a total of 42 samples were collected from 9 off-post wells and 6 granular activated carbon (GAC) wellhead treatment locations. VOC concentrations above drinking water standards were detected at two off-post wells (RFR-10 and RFR-11). RFR-10 and RFR-11 had GAC units installed at the wellheads in 2001. These GAC filtration units remove VOC contamination prior to use. Samples collected after the treatment systems at RFR-10 and RFR-11 (post-GAC samples) continue to show that all VOC are being removed from the well, and the treatment is effective. Off-post wells were not sampled for metals content as part of the groundwater program.

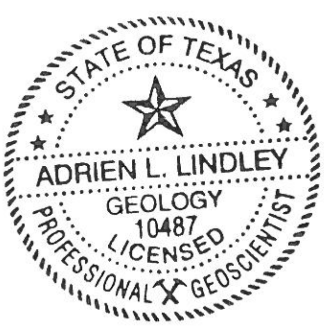
GEOSCIENTIST CERTIFICATION

2018 Annual Groundwater Monitoring Report

For

Department of the Army
Camp Stanley Storage Activity
Boerne, Texas

I, Adrien Lindley, P.G., hereby certify that the 2018 Annual Groundwater Monitoring Report for the Camp Stanley Storage Activity installation in Boerne, Texas accurately represents the site conditions of the subject area. This certification is limited only to geoscientific products contained in the subject report and is made on the basis of written and oral information provided by the Camp Stanley Storage Activity Environmental Office, laboratory data provided by APPL, and field data obtained during groundwater monitoring conducted at the site in 2018, and is true and accurate to the best of my knowledge and belief.



Adrien Lindley, P.G.
State of Texas
Geology License No. 10487

4/1/19
Date

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ACRONYMS AND ABBREVIATIONS

µg/L	Microgram Per Liter
§3008(h) Order	RCRA 3008(h) Administrative Order on Consent
AL	Action Level
AOC	Area of Concern
APPL	Agriculture and Priority Pollutants Laboratories, Inc.
BS	Bexar Shale
CC	Cow Creek
cis-1,2-DCE	*cis*-1,2-Dichloroethene
COC	Contaminants Of Concern
CSSA	Camp Stanley Storage Activity
DCP	Drought Contingency Plan
DQO	Data Quality Objectives
DVR	Data Validation Report
EXW	Extraction Well
GAC	Granular Activated Carbon
GPM	Gallons Per Minute
ISCO	In-Situ Chemical Oxidation
KSAT	San Antonio International Airport
LGR	Lower Glen Rose
LTMO	Long Term Monitoring Optimization
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MSL	Mean Sea Level
NCDC	National Climatic Data Center
NWS	National Weather Service
PCE	Tetrachloroethene
Plan	CSSA Off-Post Monitoring Program and Response Plan
QAPP	Quality Assurance Program Plan
RCRA	Resource Conservation and Recovery Act
RL	Reporting Limit
SAWS	San Antonio Water System
SCADA	Supervisory Control and Data Acquisition
SS	Secondary Standard
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
TCE	Trichloroethene
TCEQ	Texas Commission on Environmental Quality
TGRGCD	Trinity-Glen Rose Groundwater Conservation District

ACRONYMS AND ABBREVIATIONS *(continued)*

UGR	Upper Glen Rose
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WS	Weather Station

1.0 INTRODUCTION

This report provides an evaluation of results from groundwater monitoring conducted in 2018 at Camp Stanley Storage Activity (CSSA). Groundwater monitoring was performed on-post and off-post during the months of March, June, September, and December. All wells sampled in 2018 are shown on **Figure 1.1**. This report describes the physical and chemical characteristics of the groundwater monitoring results and changes occurring to the program throughout 2018.

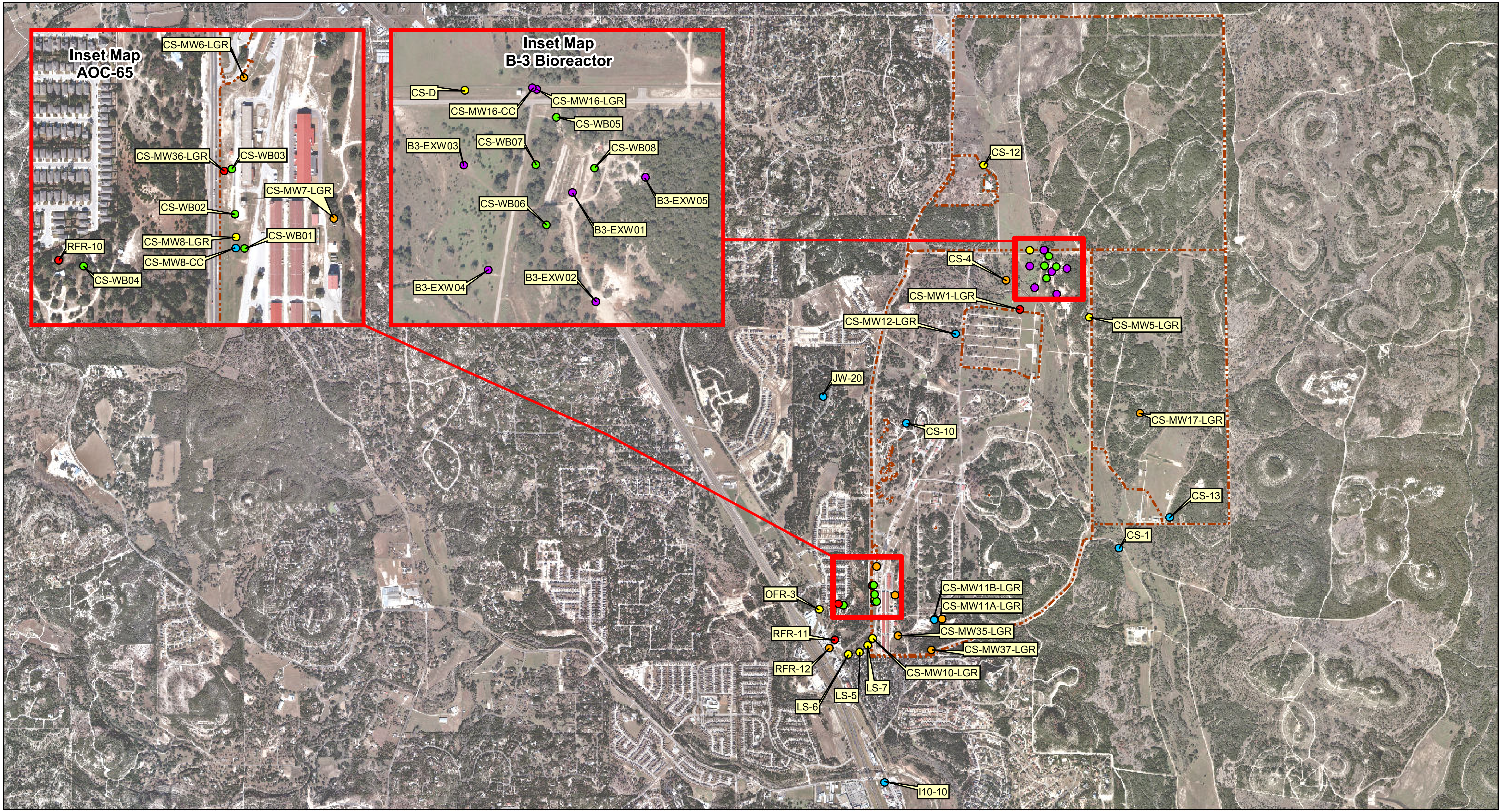
1.1 On-Post Groundwater Monitoring

The current objectives of the CSSA on-post groundwater monitoring program are to monitor groundwater flow direction trends and elevations, determine groundwater contaminant concentrations for characterization purposes, and identify meteorological and seasonal variations in physical and chemical properties of the groundwater. The objectives incorporate and comply with the Resource Conservation and Recovery Act (RCRA) §3008(h) Administrative Order on Consent (§3008(h) Order) issued by the United States Environmental Protection Agency (USEPA) on May 5, 1999.

On-post groundwater monitoring was initiated in 1992 in response to volatile organic compound (VOC) contamination detected in CSSA drinking water supply well CS-MW16-LGR and continued periodically until the current CSSA quarterly groundwater monitoring program for on-post wells was initiated in December 1999.

The CSSA groundwater monitoring program follows the provisions of the groundwater monitoring program *Final Data Quality Objectives (DQO) for the Groundwater Monitoring Program* (Parsons 2016a) in **Appendix A**, as well as the recommendations of the *Three-Tiered Long Term Monitoring Network Optimization Evaluation* (Parsons 2016b) which provided recommendations for sampling based on a long-term monitoring optimization (LTMO) study performed for the CSSA groundwater monitoring program. LTMO study sampling frequencies were initially implemented on-post in December 2005, as approved by the Texas Commission on Environmental Quality (TCEQ) and the USEPA. The LTMO evaluation was updated in 2010 using groundwater data from monitoring conducted between 2005 and 2009. It was approved by the TCEQ and USEPA and was implemented on- and off-post in June 2011 (**Appendix I**). The current versions of the LTMO and DQOs were updated with monitoring data collected between 2010 and 2014 and subsequently approved by the regulators for incorporation in the groundwater monitoring program in April and May 2016, respectively. Implementation of the latest revisions to the LTMO and DQOs began in September 2016 following approval from the USEPA and the TCEQ.

A comprehensive summary of the results from the 2018 on-post groundwater sampling events is presented in **Appendix B**. **Appendices C** and **D** present Westbay analytical results in tabular and graphical format, respectively. Abbreviated tables showing only the detected compounds are included in the groundwater results discussions in Section 2.2.1 of this report. **Appendix E** includes the potentiometric groundwater maps.



Aerial Photo Date: 2013

N
W E
S

0 0.5 1 2 Miles

- Wells with VOC concentrations > MCL
- Wells with VOC concentrations between RL and MCL
- Wells with VOC concentrations < RL
- Non-detect
- Mulit-port Westbay Wells
- Other wells
- Fence Line

Figure 1.1

2018 Sampled On-Post and Off-Post Groundwater Wells Camp Stanley Storage Activity

PARSONS

Off-post results for groundwater sampling and Granular Activated Carbon (GAC) maintenance are included as **Appendices F** and **G**. Laboratory data packages for 2018 were submitted to CSSA in electronic format separately from this report. **Appendix H** presents the associated data validation reports (DVR) for the December 2018 analytical package submittals. The March, June, and September DVRs are included with the quarterly groundwater reports.

1.2 Off-Post Groundwater Monitoring

The primary objective of the off-post groundwater monitoring program is to determine whether concentrations of VOCs detected in off-post public and private drinking water wells exceed safe drinking water standards. In off-post groundwater, the primary contaminants of concern (COC) are tetrachloroethene (PCE) and trichloroethene (TCE). A secondary objective of the off-post groundwater monitoring program is to determine the lateral and vertical extent of the contaminant plumes associated with past releases near Area of Concern (AOC)-65 or from Solid Waste Management Units (SWMU) B-3 and O-1. A third objective of the off-post groundwater monitoring program is to assess whether there are apparent trends in contaminant levels (decreasing or increasing) over time in the sampled wells.

CSSA was required by the §3008(h) Order to identify and locate both privately and publicly owned groundwater wells within ¼-mile of CSSA. The Offsite Well Survey Report (Parsons 2001) was submitted to fulfill this requirement. This survey was updated in 2010 to capture any new wells that have been added in the area and to extend the ¼-mile to ½-mile of CSSA (Parsons 2010). In total, 97 well locations are identified in the updated 2010 Well Survey. A total of 47 locations (45 active and 2 plugged) were identified within a ¼-mile radius, and another 39 locations (33 active and 6 plugged) are believed to exist between ¼ to ½-mile away from CSSA. Finally, a total of 11 locations (10 active and 1 plugged) were identified in a special interest area beyond the ½-mile survey that is considered to be downgradient of the CSSA VOC plumes.

After the 2010 Well Survey, the USEPA requested that CSSA identify additional wells beyond the ½-mile border to the south and west of the post. As a result, CSSA identified and added five wells that follow the Boerne Stage Road corridor, ranging in distance between 0.75 and 3 miles from CSSA. In accordance with the current DQO update, wells greater than 1.5 miles from CSSA or have a 5 year non-detect history are excluded from the sampling program. Some exceptions have been made to these stipulations based on proximity to the plume.

Additional background information regarding off-post private and public water supply wells is located in the ***CSSA Environmental Encyclopedia, Volume 5 Groundwater***. Some off-post wells were initially sampled in 1995 and quarterly sampling of off-post wells began in 2001 in accordance with the *Off-Post Monitoring Program and Response Plan* (CSSA 2002a) (Plan).

Under the Plan, the following criteria are used to determine the action levels for detected VOCs and to determine which off-post wells are sampled:

- If VOC contaminant levels are ≥90 percent of the maximum contaminant levels (MCL) based on preliminary data received from the laboratory and the well is used as a potable water source, the well will be taken offline and bottled water will be supplied within 24 hours after receipt of the data. For PCE and TCE, 90 percent of the MCL is 4.5 micrograms per liter (µg/L). A confirmation sample will be collected from the well within 14 days of receipt of the final validated analytical report. If the confirmation sample confirms COCs are at or above 90 percent of the MCLs, the well will be evaluated, and either installation of an appropriate method for wellhead treatment or connection to an alternative water source will be performed.
- If VOC contaminant levels are ≥80 but ≤90 percent of the MCL (>4.0 and <4.5 µg/L for PCE and TCE) during any single monitoring event based on preliminary data from the laboratory, and the well is used as a potable water source, it will be monitored monthly. If the monthly follow-up sampling confirms that COCs are ≥80 but ≤90 percent of the MCL, it will continue to be sampled monthly until the VOC levels fall below the 80 percent value.
- If any COC is detected at levels greater than or equal to the analytical method detection limit (MDL) (historically 0.06 µg/L for PCE and 0.05 µg/L for TCE), and <80 percent of the MCL, the well will be sampled on a quarterly basis. This sampling will be conducted concurrently with on-post sampling events and will be used to develop historical trends in the area. Quarterly sampling will continue for a minimum of 1 year, after which the sampling frequency will be reviewed and may be decreased.
- If COCs are not detected during the initial sampling event (i.e., no VOC contaminant levels above the MDL), further sampling of the well will be reconsidered. A well with no detectable VOCs may be removed from the sampling list. However, if analytical data suggest future plume migration could negatively influence the well, it will be re-sampled as needed. The well owner, USEPA, and TCEQ will be apprised of any re-sampling decisions regarding the non-detect wells.
- For locations where a wellhead treatment system has been installed, post-treatment samples will be collected and analyzed after initial system start-up and at 6-month intervals to confirm the system is effectively removing VOCs.

A comprehensive summary of the results from the 2018 off-post groundwater sampling events is presented in **Appendix F**. Abbreviated tables showing only the detected compounds are included in the groundwater results discussions in Section 2.2.2 of this report. **Appendix G** summarizes pre- and post-GAC filtration system sampling results.

The cumulative historical results from both on- and off-post groundwater monitoring are presented in summary tables located in the Introduction to the *On-Post and Off-Post Quarterly Groundwater Monitoring Program* (Tables 6 through 9), ***CSSA Environmental Encyclopedia, Volume 5 Groundwater.***

2.0 GROUNDWATER MONITORING RESULTS

2.1 Physical Characteristics

2.1.1 Water Level Measurements

Water level measurements were recorded during the March, June, September, and December 2018 events. A total of 56 water level measurements made from all monitoring wells and drinking water wells listed are in **Table 2.1**. Water levels from one off-post well (FO-20) are used to develop the northern perimeter of the gradient maps. Water levels were measured by either e-line indicator or collected from a permanently installed transducer.

Water level elevations and quarterly elevation changes are summarized in **Table 2.1**. The average groundwater elevation measurements for each of the Lower Glen Rose (LGR), Bexar Shale (BS), and Cow Creek (CC) intervals of the Middle Trinity aquifer are provided in **Table 2.2**. The averages were calculated using groundwater elevations from wells screened in only one of the three intervals. Water elevations from 5 wells completed with open boreholes over multiple formations were not used. Total precipitation recorded in 2018 was about 11.38 inches above the average annual for the area.

CSSA operates two weather stations to monitor and record climatic conditions across the post, although the B-3 WS was offline for sensor calibration and did not record a complete set of data for the year. For the purposes of this discussion, the CSSA precipitation record has been utilized from the AOC-65 WS located at the southwestern end of the inner cantonment. For longer term precipitation data, this report also utilizes precipitation data from the San Antonio International Airport (KSAT) because of the completeness and accuracy of the data.

The total amount of precipitation that fell in 2018 was 48.44 inches at the AOC-65 WS, which was significantly above 28.31 inches (B-3 WS) that fell in 2017. For the same 2018 time period, 41.20 inches of precipitation was measured at the KSAT location at the international airport. In 2017 the aquifer elevations were depleted due to below average rainfall. With a significantly above average rainfall year, the aquifer rebounded significantly in 2018. According to the National Weather Service (NWS), the 30-year average (1989-2018) for the Boerne, TX weather station is 37.06 inches.

The aquifer levels fell slightly during the first two quarters of 2018, which received 8.94 inches of rainfall for the 6-month period (AOC-65 WS). Less than an inch of rain fell in the months of January (0.40 inches), April (0.51 inches), and June (0.73 inches). As a result, quarterly groundwater monitoring showed average aquifer levels decreased by 6.77 feet from December 2017 to March 2018 and another 5.57 feet from March to June 2018. From July through September 26.39 inches of rain fell, allowing the aquifer to recover 167.71 feet. Most of this rain fell in September (18.88 inches). The final quarter of the year recorded an additional 13.11 inches of rainfall, allowing the aquifer to recover another 9.93 feet from September to December.

Table 2.1
Summary of Groundwater Elevations and Changes, 2018

Well ID	TOC elevation (ft MSL)	March 2018 Elevations	June 2018 Elevations	September 2018 Elevations	December 2018 Elevations	Groundwater Elevation Change: December 16 minus March 17	June minus March	September minus June	December minus September	Formations Screened: LGR	BS	CC
CS-1	**1169.27**	**905.17**	**896.66**	**1030.56**	**1049.95**	**15.55**	**-8.51**	**133.90**	**19.39**	**ALL**		
CS-2	**1237.59**	**980.17**	**980.11**	**1173.47**	**1135.06**	**-0.02**	**-0.06**	**193.36**	**-38.41**	**X**	**?**	
CS-3	1240.17	979.57	976.33	1160.97	1136.44	0.28	-3.24	184.64	-24.53	**X**		
CS-4	**1229.28**	**977.59**	**975.38**	**1160.44**	**1135.98**	**0.06**	**-2.21**	**185.06**	**-24.46**	**X**		
CS-10	**1331.51**	**951.21**	**948.27**	**1142.02**	**1137.71**	**-2.15**	**-2.94**	**193.75**	**-4.31**	**ALL**		
CS-12	**1274.09**	**996.63**	**984.93**	**1117.29**	**1124.41**	**9.72**	**-11.70**	**132.36**	**7.12**	**ALL**		
CS-13*	**1193.26**	**897.29**	**906.33**	**1054.49**	**1029.67**	**-32.17**	**9.04**	**148.16**	**-24.82**	**ALL**		
CS-D	1236.03	980.68	978.50	1153.18	1125.30	1.51	-2.18	174.68	-27.88	**X**		
CS-MWG-LGR	1328.14	1020.76	1010.04	1108.56	1134.26	7.42	-10.72	98.52	25.70	**X**		
CS-MWH-LGR*	1319.19	1021.17	1005.35	1082.84	1148.09	53.93	-15.82	77.49	65.25	**X**		
CS-I	1315.20	1014.17	1005.76	1120.22	1129.95	4.44	-8.41	114.46	9.73	**X**		
CS-MW1-LGR	1220.73	976.16	973.46	1157.35	1139.73	-1.57	-2.70	183.89	-17.62	**X**		
CS-MW1-BS	1221.09	975.01	976.07	1001.44	1110.06	-1.25	1.06	25.37	108.62		**X**	
CS-MW1-CC	1221.39	970.55	961.00	1042.08	1107.32	2.56	-9.55	81.08	65.24			**X**
CS-MW2-LGR	1237.08	974.00	970.83	1142.00	1142.27	-1.88	-3.17	171.17	0.27	**X**		
CS-MW2-CC	1240.11	965.08	963.46	999.19	1100.04	-1.28	-1.62	35.73	100.85			**X**
CS-MW3-LGR	1334.14	981.34	977.93	1123.15	1129.76	0.53	-3.41	145.22	6.61	**X**		
CS-MW4-LGR	1209.71	987.09	969.44	1177.10	1175.44	-15.41	-17.65	207.66	-1.66	**X**		
CS-MW5-LGR	1340.24	969.84	966.62	1126.70	1139.04	-1.73	-3.22	160.08	12.34	**X**		
CS-MW6-LGR	1232.25	945.21	934.84	1149.37	1134.70	-16.53	-10.37	214.53	-14.67	**X**		
CS-MW6-BS	1232.67	963.89	974.22	1084.05	1124.94	-18.38	10.33	109.83	40.89		**X**	
CS-MW6-CC	1233.21	926.86	922.04	1085.46	1125.17	-15.65	-4.82	163.42	39.71			**X**
CS-MW7-LGR	1202.27	930.77	923.60	1149.69	1130.74	-15.23	-7.17	226.09	-18.95	**X**		
CS-MW7-CC	1201.84	916.69	911.02	1100.15	1123.94	-19.81	-5.67	189.13	23.79			**X**
CS-MW8-LGR	1208.35	939.22	929.55	1146.60	1132.90	-18.49	-9.67	217.05	-13.70	**X**		
CS-MW8-CC	1206.13	918.95	913.32	1097.42	1124.29	-19.38	-5.63	184.10	26.87			**X**
CS-MW9-LGR	1257.27	991.22	986.27	1168.02	1135.68	3.45	-4.95	181.75	-32.34	**X**		
CS-MW9-BS	1256.73	990.48	988.05	1108.56	1132.71	2.21	-2.43	120.51	24.15		**X**	
CS-MW9-CC	1255.95	986.23	962.30	1074.83	1123.23	6.99	-23.93	112.53	48.40			**X**
CS-MW10-LGR	1189.53	901.29	892.66	1146.17	1127.43	-25.31	-8.63	253.51	-18.74	**X**		
CS-MW10-CC	1190.04	892.73	885.09	1137.09	1122.23	-24.69	-7.64	252.00	-14.86			**X**
CS-MW11A-LGR	1204.03	897.23	889.18	1145.03	1118.15	-26.80	-8.05	255.85	-26.88	**X**		
CS-MW11B-LGR	1203.52	dry	995.27	1011.13	1108.05	NA	NA	15.86	96.92	**X**		
CS-MW12-LGR	1259.07	974.33	970.60	1155.72	1139.02	-0.54	-3.73	185.12	-16.70	**X**		
CS-MW12-BS	1258.37	976.55	977.92	1038.30	1139.75	-0.83	1.37	60.38	101.45		**X**	
CS-MW12-CC	1257.31	978.62	962.94	1069.54	1122.01	3.78	-15.68	106.60	52.47			**X**
CS-MW16-LGR*	1244.60	980.67	978.58	1139.51	1067.70	2.60	-2.09	160.93	-71.81	**X**		
CS-MW16-CC*	1244.51	909.91	903.18	1038.32	1005.48	1.23	-6.73	135.14	-32.84			**X**
B3-EXW01	1245.26	977.68	974.04	1139.42	1127.66	5.87	-3.64	165.38	-11.76	**X**		
B3-EXW02	1249.66	977.28	974	1141.98	1137.02	2.83	-3.28	167.98	-4.96	**X**		
B3-EXW03	1235.11	975.31	973.33	1177.17	1135.32	0.48	-1.98	203.84	-41.85	**X**		
B3-EXW04	1228.46	978.23	975.64	1181.38	1139.74	0.92	-2.59	205.74	-41.64	**X**		
B3-EXW05*	1279.46	977.64	975.01	1131.6	1063.49	35.92	-2.63	156.59	-68.11	**X**		
CS-MW17-LGR	1257.01	936.8	933.39	1129.31	1128.57	-6.98	-3.41	195.92	-0.74	**X**		
CS-MW18-LGR	1283.61	942.43	938.61	1153.19	1136.49	-2.89	-3.82	214.58	-16.70	**X**		
CS-MW19-LGR	1255.53	957.05	953.35	1156.26	1145.04	-3.05	-3.70	202.91	-11.22	**X**		
CS-MW20-LGR	1209.42	958.27	952.65	1152.59	1147.50	-4.90	-5.62	199.94	-5.09	**X**		
CS-MW21-LGR	1184.53	935.86	932.77	1136.92	1132.73	-6.62	-3.09	204.15	-4.19	**X**		
CS-MW22-LGR	1280.49	912.44	914.89	1134.47	1131.82	-14.05	2.45	219.58	-2.65	**X**		
CS-MW23-LGR	1258.20	921.69	917.09	1152.47	1128.09	-15.26	-4.60	235.38	-24.38	**X**		
CS-MW24-LGR	1253.90	981.80	979.30	1165.81	1134.28	0.96	-2.50	186.51	-31.53	**X**		
CS-MW25-LGR	1293.01	988.57	984.25	1136.24	1129.34	1.69	-4.32	151.99	-6.90	**X**		
CS-MW35-LGR	1186.97	899.66	891.07	1146.09	1125.02	-25.99	-8.59	255.02	-21.07	**X**		
CS-MW36-LGR	1218.74	942.47	932.27	1147.64	1134.02	-18.54	-10.20	215.37	-13.62	**X**		
CS-MW37-LGR	1205.83	905.13	897.28	1142.93	1129.21	NA	-7.85	245.65	-13.72	**X**		
FO-20	**1327.00**	**1052.14**	**1029.47**	**1109.61**	**1150.27**	**14.18**	**-22.67**	**80.14**	**40.66**	**ALL**		
		Average groundwater elevation change (all wells minus pumpers):				**-6.77**	**-5.79**	**167.71**	**9.93**			
		Net change in average groundwater elevation since December 2017:				**165.09**						

Notes:

Bold wells: CS-2, CS-10, CS-12, CS-13, and FO-20 are open boreholes across more than one formational unit.

? = Exact screening information unknown for this well.

Shaded wells are routinely pumped for either domestic, livestock, or environmental remediation purposes, and therefore are not used in calculating statistics.

CS-1, CS-10, CS-12, and CS-13 are current drinking water wells.

CS-MW16-LGR, CS-MW16-CC, B3-EXW01 through B3-EXW05 pumps are cycling continuously to feed the B-3 Bioreactor.

* = submersible pump running at time of water level measurement.

Formational average groundwater elevation is calculated from non-pumping wells screened in only one formation.

All measurements given in feet.

NA = Data not available

Table 2.2
Summary of Groundwater Elevation by Formation, 2018

		2018 Groundwater Elevations				Formations Screened		
Well ID	**(ft MSL)**	**March**	**June**	**September**	**December**	**LGR**	**BS**	**CC**
CS-1	**1169.27**	**905.17**	**896.66**	**1030.56**	**1049.95**		**ALL**	
CS-2	**1237.59**	**980.17**	**980.11**	**1173.47**	**1135.06**	X	?	
CS-3	1240.17	979.57	976.33	1160.97	1136.44	X		
CS-4	**1229.28**	**977.59**	**975.38**	**1160.44**	**1135.98**	X		
CS-10	**1331.51**	**951.21**	**948.27**	**1142.02**	**1137.71**		**ALL**	
CS-12	**1274.09**	**996.63**	**984.93**	**1117.29**	**1124.41**		**ALL**	
CS-13*	**1193.26**	**897.29**	**906.33**	**1054.49**	**1029.67**		**ALL**	
CS-D	1236.03	980.68	978.50	1153.18	1125.30	X		
CS-MWG-LGR	1328.14	1020.76	1010.04	1108.56	1134.26	X		
CS-MWH-LGR*	1319.19	1021.17	1005.35	1082.84	1148.09	X		
CS-I	1315.20	1014.17	1005.76	1120.22	1129.95	X		
CS-MW1-LGR	1220.73	976.16	973.46	1157.35	1139.73	X		
CS-MW1-BS	1221.09	975.01	976.07	1001.44	1110.06		X	
CS-MW1-CC	1221.39	970.55	961.00	1042.08	1107.32			X
CS-MW2-LGR	1237.08	974.00	970.83	1142.00	1142.27	X		
CS-MW2-CC	1240.11	965.08	963.46	999.19	1100.04			X
CS-MW3-LGR	1334.14	981.34	977.93	1123.15	1129.76	X		
CS-MW4-LGR	1209.71	987.09	969.44	1177.10	1175.44	X		
CS-MW5-LGR	1340.24	969.84	966.62	1126.70	1139.04	X		
CS-MW6-LGR	1232.25	945.21	934.84	1149.37	1134.70	X		
CS-MW6-BS	1232.67	963.89	974.22	1084.05	1124.94		X	
CS-MW6-CC	1233.21	926.86	922.04	1085.46	1125.17			X
CS-MW7-LGR	1202.27	930.77	923.60	1149.69	1130.74	X		
CS-MW7-CC	1201.84	916.69	911.02	1100.15	1123.94			X
CS-MW8-LGR	1208.35	939.22	929.55	1146.60	1132.90	X		
CS-MW8-CC	1206.13	918.95	913.32	1097.42	1124.29			X
CS-MW9-LGR	1257.27	991.22	986.27	1168.02	1135.68	X		
CS-MW9-BS	1256.73	990.48	988.05	1108.56	1132.71		X	
CS-MW9-CC	1255.95	986.23	962.30	1074.83	1123.23			X
CS-MW10-LGR	1189.53	901.29	892.66	1146.17	1127.43	X		
CS-MW10-CC	1190.04	892.73	885.09	1137.09	1122.23			X
CS-MW11A-LGR	1204.03	897.23	889.18	1145.03	1118.15	X		
CS-MW11B-LGR	1203.52	dry	995.27	1011.13	1108.05	X		
CS-MW12-LGR	1259.07	974.33	970.60	1155.72	1139.02	X		
CS-MW12-BS	1258.37	976.55	977.92	1038.30	1139.75		X	
CS-MW12-CC	1257.31	978.62	962.94	1069.54	1122.01			X
CS-MW16-LGR*	1244.60	980.67	978.58	1139.51	1067.70	X		
CS-MW16-CC*	1244.51	909.91	903.18	1038.32	1005.48			X
B3-EXW01	1245.26	977.68	974.04	1139.42	1127.66	X		
B3-EXW02	1249.66	977.28	974	1141.98	1137.02	X		
B3-EXW03	1235.11	975.31	973.33	1177.17	1135.32	X		
B3-EXW04	1228.46	978.23	975.64	1181.38	1139.74	X		
B3-EXW05*	1279.46	977.64	975.01	1131.6	1063.49	X		
CS-MW17-LGR	1257.01	936.8	933.39	1129.31	1128.57	X		
CS-MW18-LGR	1283.61	942.43	938.61	1153.19	1136.49	X		
CS-MW19-LGR	1255.53	957.05	953.35	1156.26	1145.04	X		
CS-MW20-LGR	1209.42	958.27	952.65	1152.59	1147.50	X		
CS-MW21-LGR	1184.53	935.86	932.77	1136.92	1132.73	X		
CS-MW22-LGR	1280.49	912.44	914.89	1134.47	1131.82	X		
CS-MW23-LGR	1258.20	921.69	917.09	1152.47	1128.09	X		
CS-MW24-LGR	1253.90	981.80	979.30	1165.81	1134.28	X		
CS-MW25-LGR	1293.01	988.57	984.25	1136.24	1129.34	X		
CS-MW35-LGR	1186.97	899.66	891.07	1146.09	1125.02	X		
CS-MW36-LGR	1218.74	942.47	932.27	1147.64	1134.02	X		
CS-MW37-LGR	1205.83	905.13	897.28	1142.93	1129.21	X		
FO-20	**1327.00**	**1052.14**	**1029.47**	**1109.61**	**1150.27**		**ALL**	
Average groundwater elevation by formation, each event:	**LGR:**	**956.99**	**952.67**	**1141.66**	**1134.52**	**Average groundwater elevation by formation all of 2018:**		**1046.46**
	BS:	**976.48**	**979.07**	**1058.09**	**1126.87**			**1035.13**
	CC:	**944.46**	**935.15**	**1075.72**	**1118.53**			**1018.46**

Notes:

Bold wells: CS-2, CS-10, CS-12, CS-13, and FO-20 are open boreholes across more than one formational unit.

? = Exact screening information unknown for this well.

Shaded wells are routinely pumped for either domestic, livestock, or environmental remediation purposes, and therefore are not used in calculating statistics.

CS-1, CS-10, CS-12, and CS-13 are current drinking water wells.

CS-MW16-LGR, CS-MW16-CC, B3-EXW01 through B3-EXW05 pumps are cycling continuously to feed the B-3 Bioreactor.

* = submersible pump running at time of water level measurement.

Formational average groundwater elevation is calculated from non-pumping wells screened in only one formation.

All measurements given in feet.

NA = Data not available

Through all the hydrologic cycles of 2018, the overall groundwater levels in the Middle Trinity aquifer increased 165.09 feet from January through December 2018, as shown in **Table 2.1**. **Figure 2.1** presents a 16-year history of the quarterly groundwater elevation measurements in the LGR segment of the aquifer in relation to quarterly and annual precipitation measured at the KSAT weather station.

Based on 2018 quarterly aquifer level measurements, **Figure 2.2** shows the relationships of the water level in each portion of the aquifer at CSSA cluster wells (CS-MW1, CS-MW2, CS-MW6, CS-MW7, CS-MW8, CS-MW9, CS-MW10, and CS-MW12). The general trend in **Figure 2.2** shows that at an individual location, the head in the LGR well is typically greater than in the CC well. This was most prominent in September when the water table was rising due to historic rainfall. The amount of dissimilarity between water levels within a cluster is a good indicator of the degree of hydraulic separation between the formational units. Theoretically, intervals that are well connected hydraulically will have the same or very similar groundwater elevation. In prior years, the well clusters in the southern portion of the post (CS-MW6, CS-MW7, CS-MW8, and CS-MW10) show less hydraulic head separation between the LGR and CC production zones than cluster wells to the north (CS-MW1, CS-MW2, CS-MW9, and CS-MW12). In 2018, September showed the most hydraulic head separation throughout the post with the northern wells showing the most significant separation.

Under more favorable hydrologic conditions, the groundwater elevation in the BS typically falls between the LGR and CC elevations; this was only evident in one set of cluster wells in September 2018. As seen in **Figure 2.2**, when water levels decrease as they did in the first half of 2018, the BS groundwater elevation is generally higher than both of its counterparts. This phenomenon has been observed before in the cluster wells, and is attributed to the low draining potential of the less permeable BS matrix during continual aquifer declines. Conversely, during recharge events, the groundwater in the BS wells will lag behind the LGR and CC wells. This was depicted in cluster wells CS-MW1, CS-MW6, and CS-MW12 in September 2018 due to significant rainfall that quarter.

2.1.2 Weather Station and Transducer Data

Of the 56 wells listed on **Table 2.1**, 16 are equipped with transducers to continuously log groundwater levels and 11 are providing telemetry directly to the Supervisory Control and Data Acquisition (SCADA) system. As previously noted, two weather stations are in place at CSSA, B-3 WS is located next to the B3-EXW01 well in the north-central region of CSSA, and AOC-65 WS in the southwest corner of CSSA at AOC-65. Both weather stations record meteorological data, including precipitation, wind speed, wind direction, temperature, etc. The data are recorded to evaluate whether trends in rainfall and groundwater recharge. However, for the purposes of this report the data from the AOC-65 WS is used because it has the highest degree of accuracy and reliability.

Figure 2.1 - Average LGR Groundwater Elevations and Quarterly/Annual Precipitation

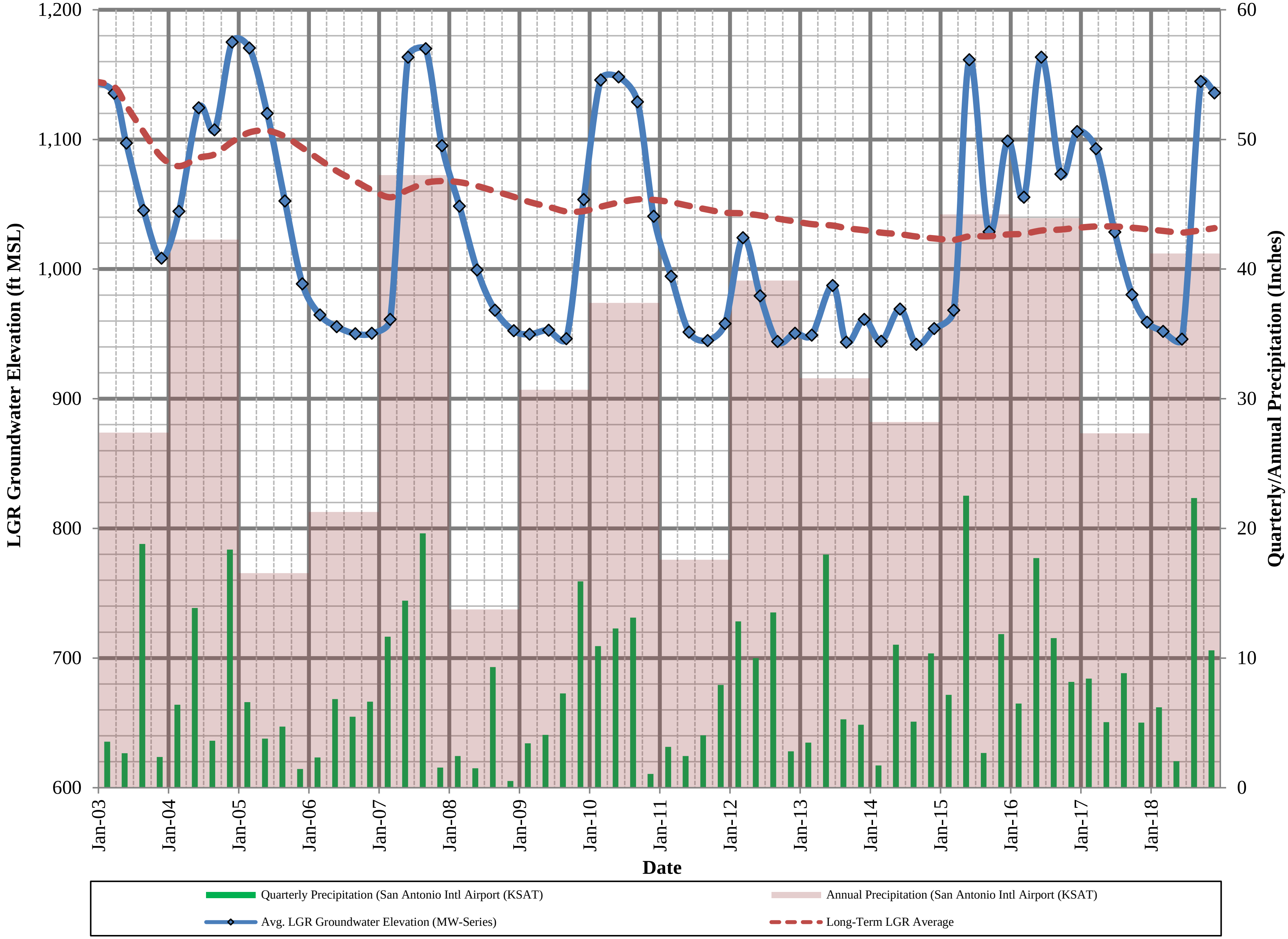
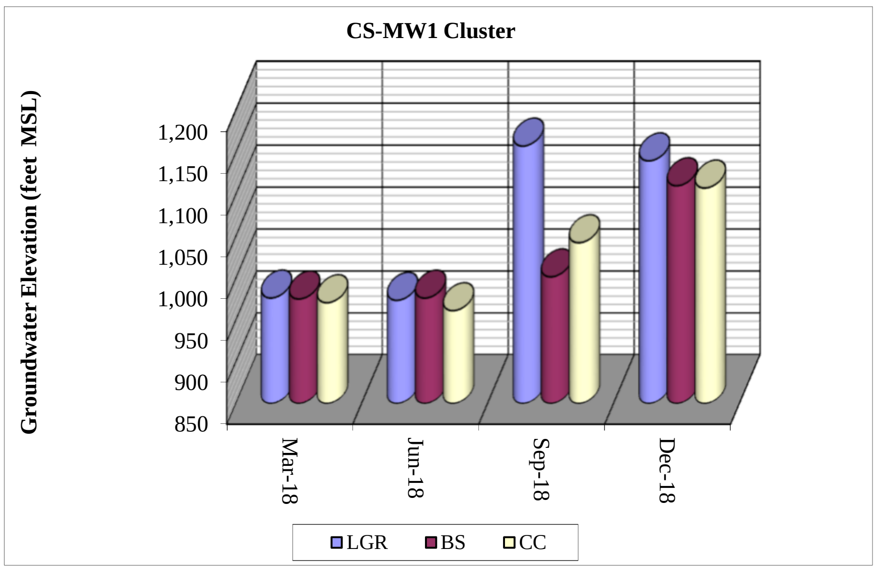
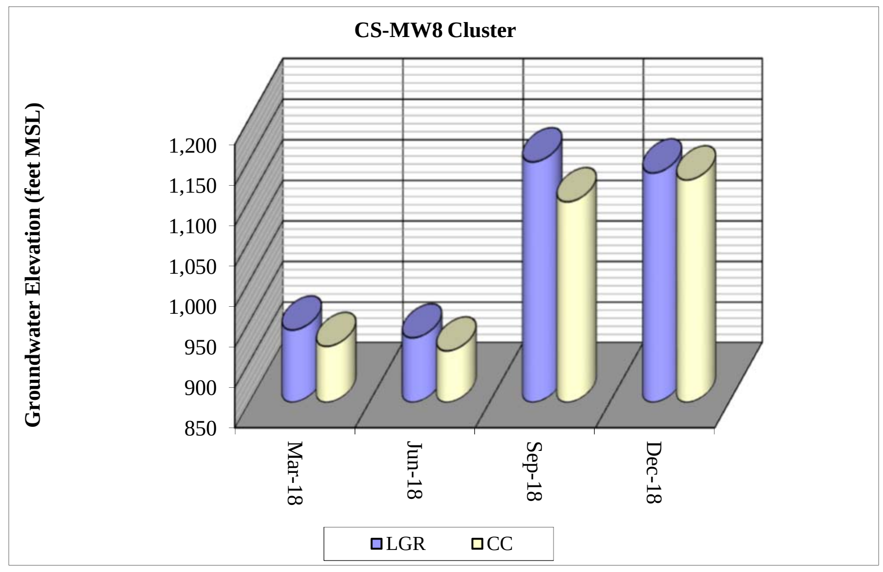
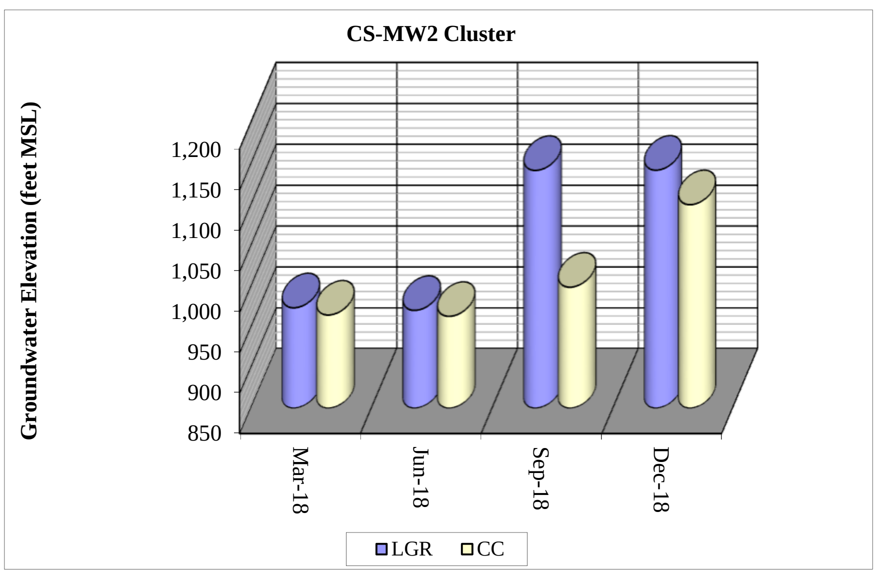
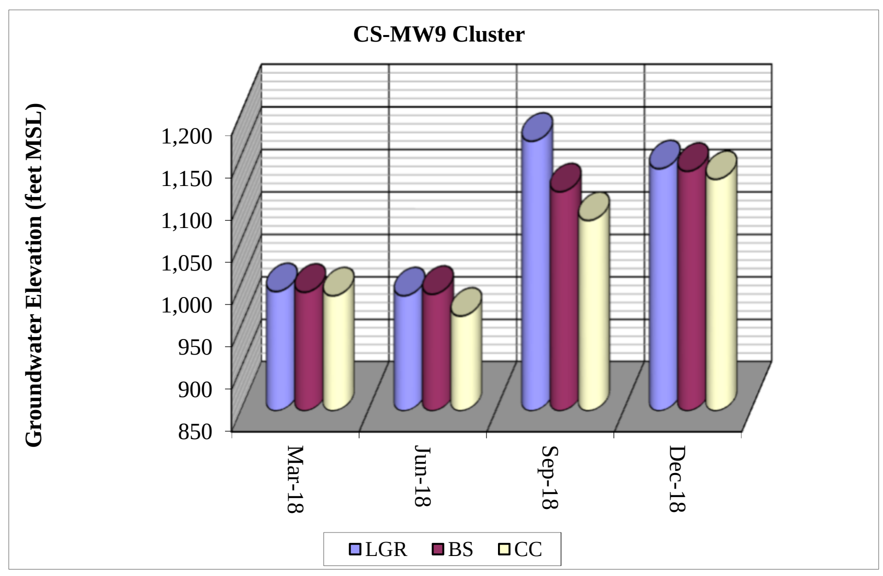


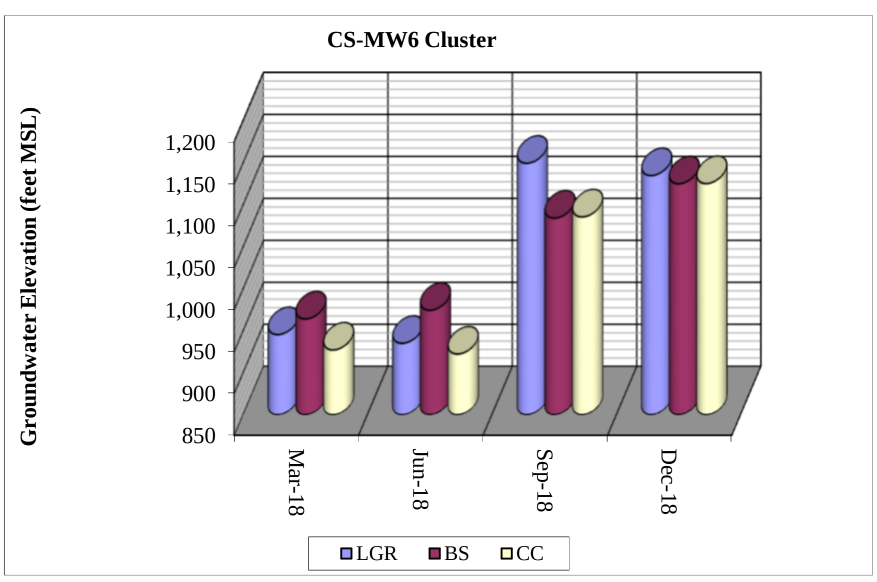
Figure 2.2
Comparison of Groundwater Elevations within Well Clusters

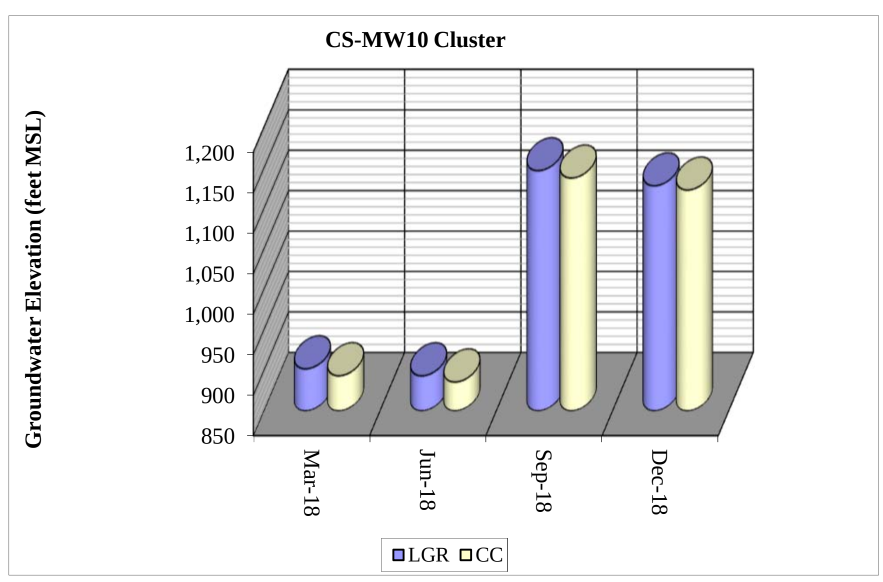


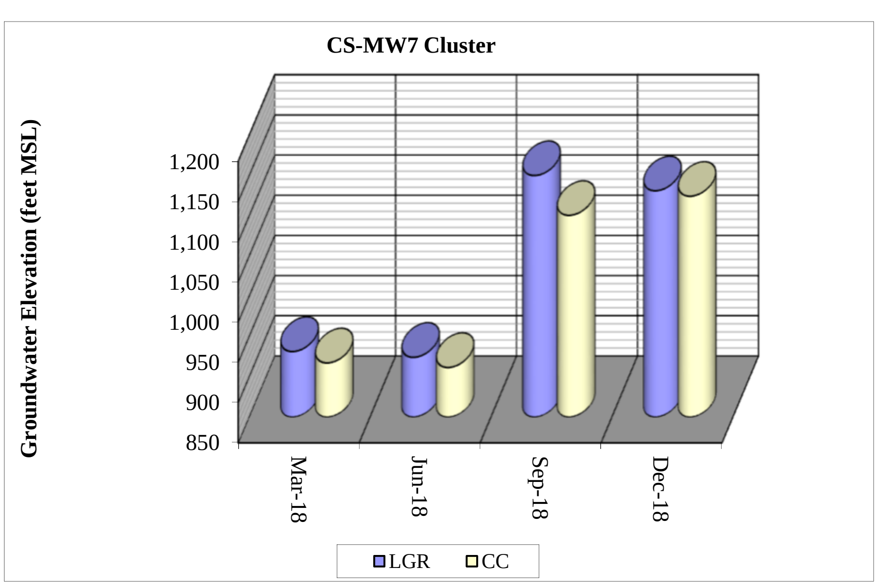


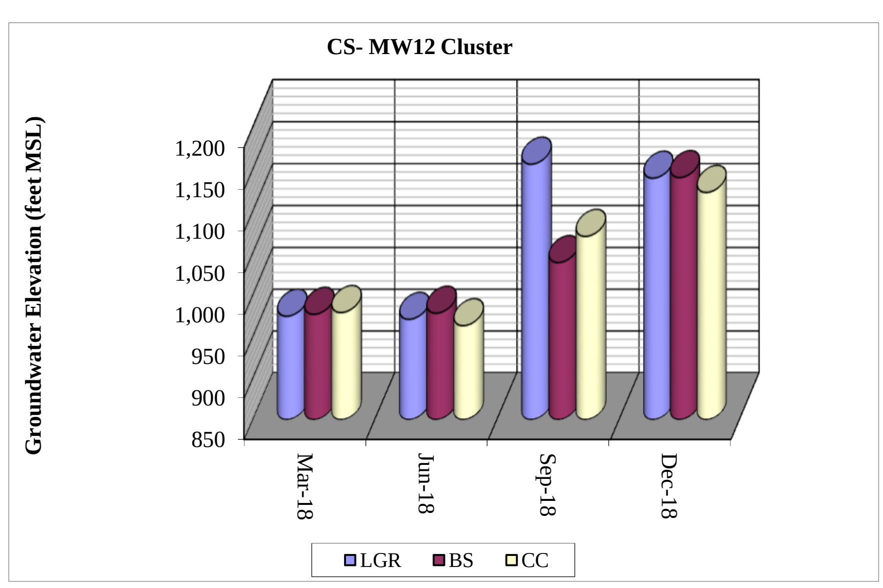












Continuous aquifer level data (January 1st through December 31st, 2018) collected from three wells screened within the LGR, and two wells screened within the CC are presented on **Figure 2.3** as well as the corresponding daily precipitation values. The wells presented in this figure are equipped with transducers set to record continuous water level measurements. The data from CS-MW4-LGR is incomplete due to transducer malfunction. Both CS-MW16-LGR and CS-MW16-CC are omitted from this graphic since they are actively pumping wells for the Bioreactor system, and therefore do not reflect static aquifer conditions. The active drinking water wells and the B3-EXW extraction wells were also omitted for the same reason. As in the past, the groundwater elevations indicate recharge of the LGR formation immediately after precipitation.

CSSA AOC-65 WS reported 106 rainfall events with a total precipitation of 48.44 inches. The rainfall in 2018 started off below average in January and February then picked up slightly in March. The rainfall dropped back off in April with 0.51 inches of rainfall, well below the 2.51 monthly average. The month of May had a rainfall total of 2.79 inches and June recorded 0.73 inches. The rain picked up in July with a total rainfall recorded of 6.46 inches. August recorded 1.05 inches, below the monthly average of 2.81 inches. September recorded 18.88 inches of rainfall, this month being the highest monthly rainfall total of the year. Above average rainfall continued to fall in October with 6.25 inches recorded. November and December also recorded above average rainfall, 3.01 and 3.85 inches respectively. July and September reported the highest monthly rainfall amounts and January had the lowest rainfall total recorded for the year. During the same timeframe, 41.20 inches of rainfall was measured at the San Antonio International Airport, and 42.99 inches of rainfall was measured in Boerne, TX.

Based upon 30-year precipitation data (1989-2018), 2018 rainfall totals at CSSA ended about 11.38 inches above the Boerne NWS weather station average of 37.06 inches. For the same timeframe, the San Antonio NWS weather station reports a 30-year average of 32.96, which was 15.48 inches below the CSSA AOC-65 WS recorded total. Currently the San Antonio Water System (SAWS) is in the ‘year-round’ drought restrictions and the Trinity Glen Rose Groundwater Conservation District (TGRGCD) also has ‘year-round’ conservation measures in effect.

Table 2.3 shows the total precipitation received each quarter, average groundwater elevations in each formation, the average groundwater elevation change in each formation, the approximate gradient, and approximate gradient flow direction for all monitoring events.

Referring back to **Figure 2.1**, the latter half of 2009 marked the end of a drought cycle that had begun at the end of 2006. Major precipitation events in August and September 2009 recharged the aquifer and began a trend that continued through May 2010. The aquifer surge experienced in the first five months was negated by a summer dry period through August 2010. Rainfall amounts declined September 2010 through September 2011, resulting in regional aquifer level decline of approximately 195 feet. There was an increase in rainfall late in 2011 but due to the already depressed aquifer the drought conditions persisted into 2012. Although an average amount of rain fell in 2012 and 2013, the aquifer rebound was minimal. The below average rainfall in 2014 allowed the aquifer to drop an additional 5 feet over the 12-month period. In 2015 above average rainfall allowed the aquifer to recover 140 feet, bringing the San Antonio area out of the severe drought that began in late 2010. With above average rainfall recorded again in 2016 the aquifer level continued to climb an additional 4.5 feet. The below average rainfall recorded in 2017 negated the gains from 2015 and 2016 and the aquifer dropped 147 feet over the 12-month period to levels similar to those experienced in last quarter of 2014 during the last drought cycle. Below average rainfall in the first two quarters of 2018 allowed the aquifer to drop an additional 13 feet. Record rains in September (wettest September on record for San Antonio) allowed the aquifer to rise nearly 200 feet during the latter part of the third quarter. Rains slackened in the fourth quarter and aquifer water levels fell slightly, ending the year at 1133.80 feet, slightly over 100 feet above the LGR long-term average groundwater elevation of 1030.61 feet.

Figure 2.3, Selected Wells Groundwater Elevations vs Precipitation Data

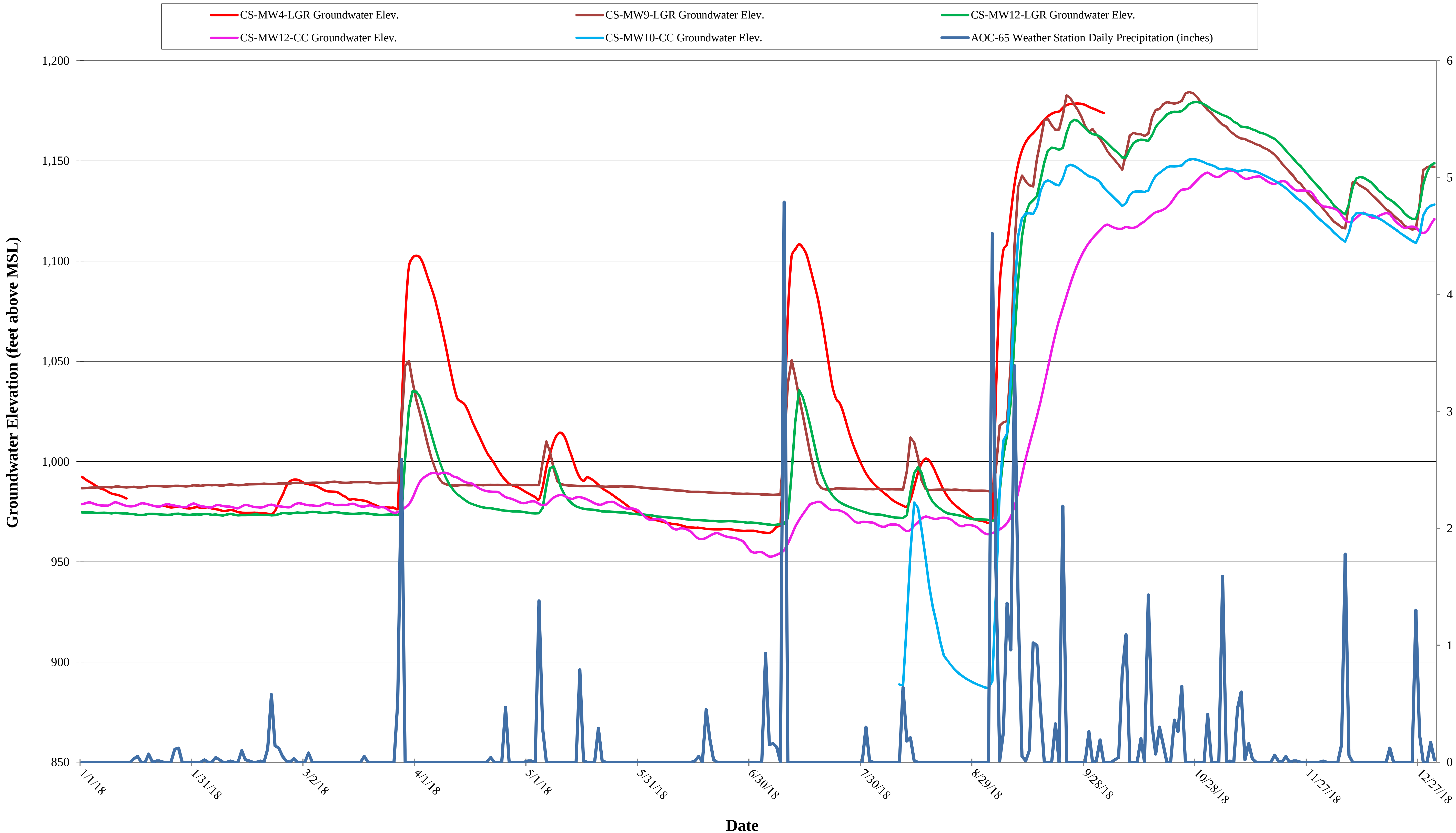


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Table 2.3
Precipitation, Groundwater Elevation and Gradient

Quarterly Report (Month, year)	Total Quarterly precipitation (inches) B-3 WS	Total Quarterly precipitation (inches) AOC-65 WS	Average GW elevation Change (feet)	CS-MW18-LGR GW Elevation Change (feet)	in each Formation (ft/MSL)			Approximate gradient (ft/ft)	Approximate gradient flow direction
					Lower Glen Rose	Bexar Shale	Cow Creek		
September-99	7.52	--	-188.4	--	979.80	--	--	0.007	Southwest
December-99	2.84	--	-4.9	--	973.10	--	--	0.004	Southwest
March-00	3.58	--	-9.3	--	970.94	--	--	0.009	South-southeast
June-00	11.1	--	11.77	--	976.27	--	--	0.006	Southeast
September-00	1.96	--	-6.34	--	967.03	--	--	0.006	Southeast
December-00	14.48	--	122.99	--	1118.59	--	--	0.005	South-southeast
March-01	10.13	--	53.19	--	1157.20	--	--	0.0125	Southeast
June-01	6.58	--	-47.5	--	1104.00	1106.85	1093.89	0.007	Southeast
September-01	14.73	--	23.96	--	1140.55	1098.18	1095.75	0.0067	Southeast
December-01	10.16	--	15.46	--	1149.68	1131.36	1125.63	0.0092	Southeast
March-02	2.25	--	-70.97	--	1077.91	1064.46	1059.27	0.0086	Southeast
June-02	4.46	--	-48.29	--	1030.51	1022.51	994.02	0.0137	South-southeast
September-02	30.98	--	104.5	--	1130.87	1129.21	1098.34	0.017	South-southeast
December-02	12.91	--	19.48	-2.84	1143.98	1148.26	1133.11	0.0061	South-southeast
March-03	6.22	6.68	-8.47	-1.99	1135.18	1140.52	1122.95	0.012	South-southeast
June-03	4.67	4.64	-41.08	-40.06	1097.87	1095.36	1069.02	0.0022	South-southwest
September-03	8.05	10.28	-52.85	-54.54	1046.77	1060.39	1025.61	0.0045	South-southwest
December-03	2.79	2.92	-32.85	-40.46	1011.38	1029.39	1002.07	0.0095	South-southwest
March-04	6.35	5.93	22.89	36.7	1043.68	1026.20	1017.98	0.0046	South-southwest
June-04	12.95	12.33	71.91	88.99	1121.80	1101.85	1074.56	0.0012	South-southwest
September-04	14.3	14.57	-8.05	-21.66	1106.43	1110.17	1074.96	0.003	South-southeast
December-04	21.04	23.12	63.07	76.62	1173.98	1159.46	1135.16	0.004	South-southeast
March-05	7.38	6.48	-6.47	-7.11	1168.46	1151.60	1127.58	0.00436	South-southeast
June-05	NA	5.29	-45.93	-61.3	1119.19	1125.27	1082.40	0.0041	South-southeast
September-05	NA	5.93	-61.24	-64.87	1054.88	1077.87	1033.65	0.0068	South-southwest
December-05	NA	2.41	-57.9	-69.24	994.23	1023.45	980.25	0.0054	South-southwest
March-06	2.52	1.11	-24.81	-33.89	974.10	990.23	948.80	0.0084	South-southwest
June-06	7.65	11.18	-9.46	-1.4	966.16	983.47	933.59	0.0104	South-southwest
September-06	3.42	3.12	-6.66	-4.81	961.07	979.78	922.34	0.0099	South
December-06	4.68	5.9	2.48	3.02	958.87	979.73	933.37	0.0099	South
March-07	9.83		14.53	-1.27	969.87	992.53	958.06	0.0079	South
June-07	11.99		182.09	234.13	1162.17	1119.36	1128.32	0.0016	Southeast
September-07	29.4		15.56	0.54	1168.77	1168.14	1154.47	0.0019	South
December-07	1.95		-70.45	-87.12	1095.68	1101.19	1088.93	0.0052	South-southeast
March-08	2.17	2.31	-42.45	-43.22	1050.23	1053.76	1047.78	0.0072	South
June-08	1.9	2.69	-51.71	-52.47	1002.44	1015.93	966.67	0.0047	South
September-08	6.06	6.95	-27.49	-45.80	976.18	991.62	953.41	0.0058	South
December-08	1.69	1.74	-15.48	-5.06	961.10	981.76	934.26	0.0080	South-southeast
March-09	2.58	3.16	-4.25	-2.15	957.48	973.36	916.24	0.0073	South-southeast
June-09	3.77	4.41	1.25	1.53	959.75	971.67	914.68	0.0059	South-southeast
September-09	NA	7.41	-7.76	-5.48	953.49	967.07	903.39	0.0054	South-southeast
December-09	NA	14.63	101.24	114.02	1051.77	1040.48	1026.64	0.00002	South
March-10	9.23	NA	91.51	100.05	1144.36	1128.84	1131.78	0.00052	South-southeast
June-10	NA	10.66	3.97	3.40	1147.52	1145.30	1114.38	0.00078	South-southeast
September-10	NA	10.91	-37.77	-15.95	1126.83	1070.13	1059.82	0.00085	South-southeast
December-10	NA	4.45	-63.93	-97.99	1045.26	1060.79	1011.76	0.00029	South-southeast
March-11	NA	2.57	-41.89	-52.73	997.07	1020.56	994.18	0.00314	South-southeast
June-11	0.91	0.83	-41.80	-46.77	957.42	983.63	917.00	0.00532	South-southeast
September-11	2.29	2.13	-8.81	-3.15	952.98	970.34	900.90	0.00533	South-southeast
December-11	9.85	11.71	14.73	8.05	963.15	972.51	922.89	0.00536	South-southeast
March-12	NA	8.58	57.04	75.20	1021.21	992.83	975.99	0.00066	South-southeast
June-12	NA	5.83	-30.83	-54.76	981.01	1012.98	964.88	0.00326	South-southeast
September-12	NA	9.95	-36.51	-26.02	952.92	975.91	909.63	0.00455	South-southeast
December-12	NA	7.12	8.92	4.15	957.47	984.75	930.15	0.00550	South-southeast
March-13	4.88	4.79	-2.93	-2.05	954.43	977.59	933.99	0.00605	South-southeast
June-13	12.26	9.57	34.90	24.00	989.52	999.66	974.67	0.00350	South-southeast
September-13	5.03	3.92	-43.40	-26.95	947.00	974.20	918.61	0.00541	South-southeast
December-13	11.84	10.92	16.28	7.70	964.12	974.92	939.82	0.00506	South-southeast
March-14	0.96	1.10	-12.81	-6.03	950.62	970.44	926.47	0.00620	South-southeast
June-14	8.73	8.03	22.53	11.46	972.10	984.11	960.81	0.00513	South-southeast
September-14	6.25	5.09	-26.88	-13.86	947.85	970.50	916.54	0.00550	South-southeast
December-14	9.34	7.38	11.64	7.35	958.45	974.38	935.08	0.00544	South-southeast

Table 2.3
Precipitation, Groundwater Elevation and Gradient

Quarterly Report (Month, year)	Total Quarterly precipitation (inches) B-3 WS	Total Quarterly precipitation (inches) AOC-65 WS	Average GW elevation Change (feet)	CS-MW18-LGR GW Elevation Change (feet)	in each Formation (ft/MSL)			Approximate gradient (ft/ft)	Approximate gradient flow direction
					Lower Glen Rose	Bexar Shale	Cow Creek		
March-15	7.95	5.52	14.41	4.62	971.61	986.23	955.73	0.00550	South-southeast
June-15	18.62	15.44	176.73	222.23	1162.97	1108.95	1115.04	0.00052*	South-southeast
September-15	6.76	3.66	-119.17	-147.45	1027.92	1055.29	1011.95	0.0053*	South-southeast
December-15	20.18	13.87	68.26	80.93	1100.39	1087.93	1083.84	0.00131	South-southeast
March-16	5.66	3.57	-43.11	-47.05	1054.01	1055.45	1045.55	0.00012*	South-southeast
June-16	NA	19.70	106.82	112.86	1165.70	1147.18	1143.07	0.00012	South-southeast
September-16	15.88	15.57	-85.26	-97.17	1073.18	1093.95	1070.35	0.00012	South-southeast
December-16	7.01	6.92	26.04	38.09	1105.84	1080.99	1091.31	0.00094	South-southeast
March-17	7.61	NA	-8.57	-15.45	1091.92	1100.58	1088.08	0.00131	South-southeast
June-17	6.86	5.31	-62.72	-70.29	1027.70	1048.68	1024.34	0.00106*	South-southeast
September-17	9.48	8.07	-48.78	-61.23	982.86	990.06	963.31	0.00362	South-southeast
December-17	4.36	4.33	-14.91	-17.19	964.68	981.05	952.90	0.00157	South-southeast
March-18	5.72	4.91	-6.77	-2.89	956.99	976.48	944.46	0.00725	South
June-18	NA	4.03	-5.79	-3.82	952.67	979.07	935.15	0.00679	South
September-18	26.36	26.39	167.71	214.58	1141.66	1058.09	1075.72	0.00326	Southeast
December-18	13.03	13.11	9.93	-16.70	1134.52	1126.87	1118.53	0.00613	South-southeast

GW = groundwater, ft MSL = feet above mean sea level, ft/ft = feet per foot, WS = weather station

NA = Data not available due to weather station outage.

2007 precipitation data was combined to fill in data gaps due to multiple weather station outages during SCADA installation.

* alternate wells were used in calculating gradient to generally describe the regional gradient

2.1.3 Potentiometric Data

The groundwater gradient/potentiometric surface figures presented in **Appendix E** incorporate measured groundwater elevations from the LGR, BS, and CC screened wells. Drought conditions, which began in 2010 and continued through 2014, were eased in 2015 following above-average precipitation, allowing the aquifer to return to normal conditions. The above-average precipitation trend continued through 2016 resulting in above-average aquifer water levels. Below average precipitation in 2017 resulted in aquifer water level declines throughout the year. By the end of 2017, aquifer water levels returned to those typically experienced during drought conditions and continued through the first half of 2018. Record rains in September 2018 resulted in above-average aquifer water levels that persisted through the remainder of the year. As shown in **Appendix E**, water levels at CSSA can vary greatly. This variability is associated with several factors:

- A low storage capacity for groundwater within the primary porosity (interstitial voids between grains) of the limestone matrix, which is inherent to carbonate mudstone aquifers. These aquifers with lower storage capacities are more susceptible to widely fluctuating groundwater levels (as compared to a well-sorted sand matrix). Within the Middle Trinity aquifer and other regional carbonate aquifers, their groundwater yield is mostly derived from secondary porosity features resulting from faults, fractures, and chemical dissolution of the bedrock (karst).
- Differences in well completion depths and formations screened;
- Differences in recharge rates due to increased secondary porosity associated with the Salado Creek area;
- Differences in recharge rates due to increased secondary porosity associated with local fault zones;
- Pumping from on- and off-post public and private water supply wells; and
- Locations of major faults or fractures.

2.1.4 Post-wide Flow Direction and Gradient

An average of the quarterly calculated LGR groundwater gradients in 2018 results in a flow direction to the south-southeast at 0.00573 ft/ft. In March and June 2018, flow direction was generally to the south with gradients of 0.00725 and 0.00679 ft/ft, respectively. Following the rains in September, elevated water levels and significant mounding at wells along Salado Creek is observed and flow direction turns more towards the southeast at 0.00326 ft/ft. In December, water levels have started to decline from the highs in September, and flow is generally to the south-southeast at 0.00613 ft/ft, though flow is interrupted by a cone of depression centered on the bioreactor and mounding at CS-MW4-LGR. General groundwater flow directions and average gradients calculated during past monitoring events are provided in **Table 2.3** for comparison.

<u>Lower Glen Rose</u>

The 2018 potentiometric surface maps for LGR-screened wells **(Appendices E.1, E.4, E.7** and **E.10)** exhibited a wide range of groundwater elevations. To illustrate, the average groundwater elevation in the LGR segment of the aquifer varied by more than 189 feet over the course of the year. Groundwater elevations are generally higher in the northern and central portions of CSSA and decrease to the south. This is consistent with the natural dip of the formations and the greater fault displacement in the southern portion of CSSA. The removal of well CS-G from the gridding process negates a mounding effect due to perched groundwater that is present at that well, and misleadingly disrupts the normal southerly and easterly components of the North Pasture. This well, along with open borehole completions in wells CS-D, CS-2, and CS-4 are not fully penetrating into the LGR, and therefore are not considered within these maps.

Between the December 2017 and March 2018 monitoring events, aquifer levels continued to decline following drier than average conditions in 2017 and moderately dry first quarter in 2018 culminating in an average 6.77-foot decline the first quarter of 2018. Water levels declined another 5.79 through the second quarter to an average elevation of 945.99 which is only 4 feet above the lowest average aquifer groundwater elevation recorded (491.98 feet in September 2014) during 16 years of monitoring. As shown in **Table 2.1**, aquifer levels rose dramatically late in the third quarter following record rains in September. The effect to the LGR elevation can be seen by comparing the June 2018 (**Appendix E.4)** and September 2018 (**Appendix E.7)**. The record rains experienced in September and early October ebbed through the last quarter and by December 2018 (**Appendix E.12**), LGR segment of the aquifer began to recede, ending the year at above the average level. Overall, the LGR segment gained approximately 170 feet of aquifer elevation over the 12-month period between December 2017 and December 2018.

A typical feature as seen in **Appendix E.1, E.7**, and **E.10** is the groundwater mounding effect centered on CS-MW4-LGR in the central portion of the base. This is a typical feature during non-drought conditions when the surrounding groundwater elevation is above approximately 970 feet mean sea level (MSL). Unlike the general trend at CSSA, groundwater flow appears to radiate outward from CS-MW4-LGR. Presumably this region has a strong hydraulic connection to significant perched water either associated with Salado Creek or the hillsides to the east. Throughout 2018 this feature is observed; however, the mounding is less significant in June as the surrounding water level approaches the 970 feet MSL mark.

Historical data has shown that this mounding effect can either be muted or completely removed under distressed aquifer levels. This muted effect is observed in June (**Appendix E.4**) as the average groundwater elevation approaches the elevation of the basal production zone of the aquifer. Groundwater mounding is also depicted at CS-B3-EXW04 in September (**Appendix E.7**), likely due to hydraulic connection with Salado Creek in this area and recharge via the creek bottom.

The groundwater drawdown due to the cyclic pumping of CS-MW16-LGR, B3-EXW01-LGR, B3-EXW02-LGR, B3-EXW03-LGR, B3-EXW04-LGR, B3-EXW05-LGR (Bioreactor System) is a recurring feature in the central portion of the post. In 2018, the cone of depression is observed only in December (**Appendix E.10**), however, this feature was observed throughout 2017. The operation of the bioreactor system and resultant groundwater "cone of depression" can vary due to combination of extraction wells actively pumping during the water level gauging effort. But as a collective system, they are effective in maintaining a zone of capture around the remediation system and re-injecting groundwater into the Bioreactor.

Depending on the current pumping rates at the time of measurement, groundwater in the vicinity of the Bioreactor may be depressed by as much as 50 to 150 feet, as measured between a currently active extraction well (EXW) and other surrounding wells (**Appendix E.10)**. In September (**Appendix E.7**), a cone of depression centered on well CS-MWH-LGR located in the northern portion of the post and a slight depression centered on water supply well CS-12 located within the inner cantonment are also observed.

Bexar Shale

Currently, groundwater head information is limited to four data points (CS-MW1-BS, CS-MW6-BS, CS-MW9-BS, and CS-MW12-BS). Given the paucity of well control, at best, the BS groundwater maps should be considered qualitative. The BS appears to have very limited groundwater that is likely associated with fracturing. Fractured bedrock such as this often results in discordant water levels between neighboring points and may not be a true indicator of flow direction. The appropriateness of preparing potentiometric surface maps for the BS is debatable, but these maps have been generated for completeness. Potentiometric maps for the Bexar Shale in 2017 are presented in **Appendices E.2, E.5, E.8** and **E.11**.

Compared to the LGR and CC segments, the BS aquitard fluctuates significantly less in response to both recharge and drought. After the 12-month period between December 2017 and December 2018, the BS segment had a net gain of 145.82 feet, whereas the LGR experienced a net gain of 170 feet. Historical data has shown for a given precipitation event, the BS water level will “peak” anywhere between 15 and 30 days after the LGR and CC has already crested for the same rain event.

From a historical perspective, the potentiometric surface maps for BS-screened wells often exhibit groundwater flow in multiple directions (**Appendix E.11**). Historically, these flow directions are to the south, east, and occasionally to the north. In 2018, the BS potentiometric surface gradients are generally to the south and southeast in March and June, and become more variable in September and December where flow directions are to the southeast in the northern portion of the post, to the east in the central portion of the post, and to the northeast in the southern part of the post in September, and mainly to the east in December.

Cow Creek

As with the BS, the post wide monitoring of the CC groundwater is limited due to the small number of wells completed only in the CC. Four of the nine CC wells are concentrated in the vicinity of AOC-65. In September, during its highest groundwater elevation of the year, the CC groundwater exhibited a northeasterly gradient in the southern portion of the post and easterly gradient in the central portion of the post (**Appendix E.9**). When groundwater was at its lowest elevations, in March and June 2018 (**Appendices E.3** and **F.6**), the predominant gradient was more strongly to the south with a visible cone of depression centered on the bioreactor recovery well CS-MW16-CC.

The effects of continuous pumping of CS-MW16-CC influence groundwater gradients significantly in the CC interval near the Bioreactor. The March and June 2018 potentiometric maps show the most significant induced gradients created as a result of routine pumping action at well CS-MW16-CC (**Appendix E.3 and E.6**). Prior studies have shown measurable pumping influence within the CC at distances of more than 2,000 feet from a CC pumping well, as measured at CS-MW1-CC.

The CC responds almost as quickly as the LGR to a recharge event, presumably because of direct infiltration on the outcrop areas to the north of CSSA. However, the recharge rate in the CC is somewhat slower than the LGR, and the crest of a precipitation response may come 15 days later than what is observed in the LGR. Typically, the CC aquifer elevation response to recharge or discharge is less than the LGR segment. After the 12-month period between December 2017 and December 2018, the net gain of the CC segment was 170.54 feet.

2.2 Chemical Characteristics

2.2.1 On-Post Analytical Results

The LTMO study implemented in December 2005, updated in 2010 and 2015, determines the frequency that on-post wells are sampled. An overview of sampling frequencies for on-post wells is given in **Table 2.4**. Thirty-three on-post samples from 20 wells were scheduled to be collected in 2018 (5 in March, 4 in June, 20 in September, and 4 in December). All 33 samples were collected.

The wells were sampled using either dedicated low-flow pumps, high capacity submersible pumps, or a dedicated solar-powered submersible pump (well CS-I). Samples were collected after field parameters (pH, temperature, conductivity) stabilized during well purging. Field parameters were recorded in the field logbook for each sampling event.

Groundwater samples were submitted to Agriculture & Priority Pollutants Laboratories, Inc. (APPL) of Clovis, California for analysis. The analytical program for on-post monitoring wells includes short-list VOC analysis and metals. The short list of VOC analytes included: *cis*-1.2-Dichloroethene (*cis*-1,2-DCE), PCE, TCE, and vinyl chloride. Drinking water wells were also sampled for the following metals: arsenic, barium, copper, chromium, cadmium, mercury, lead, and zinc.

Each sample is evaluated against either being qualitatively detected in trace amounts above the MDL [F-flagged data], quantitatively detected above the laboratory reporting limit (RL), or in exceedance of regulatory maximum contaminant level (MCL), action level (AL), or secondary standard (SS) comparison criteria. It is important to note that the RL value is significantly less than the promulgated groundwater standard criteria, and therefore the occurrence of a constituent above the RL does not necessarily indicate that there is an immediate concern, especially with the naturally occurring inorganics (metals) in groundwater. The only exception to this generalization is lead, where the RL (0.025 mg/L) is greater than the AL (0.015 mg/L).

2.2.1.2 On-Post Monitoring Wells with COC Detections above the MCL

Some wells sampled had concentrations detected that exceeded MCLs. The MCLs for some COCs were exceeded in wells CS-MW1-LGR and CS-MW36-LGR in 2018. The respective comparison criteria (MCLs, SS, or AL) for each compound are included in **Table 2.5**. The detected concentrations are summarized as follows:

- **CS-MW1-LGR –** This well was sampled once in 2018. PCE and TCE concentrations were above their MCLs in September. *Cis*-1,2-DCE was also detected below the MCL.
- **CS-MW36-LGR –** This well was sampled during the September event in 2018. PCE and TCE were above their MCLs and *cis*-1,2-DCE was below the MCL.

Table 2.4
Overview of On-Post Sampling for 2018

Count	Well ID	*Analytes*	*Last Sample Date*	*Mar-18*	*Jun-18*	*Sep-18 (15 month)*	*Dec-18*	*LTMO Sampling Frequency**
1	CS-MW1-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
2	CS-MW1-BS	VOCs	Dec-12	NS	NS	NS	NS	as needed
3	CS-MW1-CC	VOCs	Jun-17	NS	NS	NS	NS	30 months
4	CS-MW2-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
5	CS-MW2-CC	VOCs	Jun-17	NS	NS	NS	NS	30 months
6	CS-MW3-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
7	CS-MW4-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
8	CS-MW5-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
9	CS-MW6-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
10	CS-MW6-BS	VOCs	Dec-12	NS	NS	NS	NS	as needed
11	CS-MW6-CC	VOCs	Jun-17	NS	NS	NS	NS	30 months
12	CS-MW7-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
13	CS-MW7-CC	VOCs	Jun-17	NS	NS	NS	NS	30 months
14	CS-MW8-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
15	CS-MW8-CC	VOCs	Jun-17	NS	NS	S	NS	15 months
16	CS-MW9-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
17	CS-MW9-BS	VOCs	Dec-12	NS	NS	NS	NS	as needed
18	CS-MW9-CC	VOCs	Jun-17	NS	NS	NS	NS	30 months
19	CS-MW10-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
20	CS-MW10-CC	VOCs	Jun-17	NS	NS	NS	NS	30 months
21	CS-MW11A-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
22	CS-MW11B-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
23	CS-MW12-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
24	CS-MW12-BS	VOCs	Dec-12	NS	NS	NS	NS	as needed
25	CS-MW12-CC	VOCs	Jun-17	NS	NS	NS	NS	30 months
26	CW-MW17-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
27	CS-MW18-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
28	CS-MW19-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
29	CS-1	VOCs & metals (As,Ba,Cr, Cu,Cd,Hg,Pb,Zn)	Dec-17	S	S	S	S	Quarterly
30	CS-2	VOCs	Jun-17	NS	NS	NS	NS	30 months
31	CS-4	VOCs	Jun-17	NS	NS	S	NS	15 months
32	CS-10	VOCs & metals (As,Ba,Cr, Cu,Cd,Hg,Pb,Zn)	Dec-17	S	S	S	S	Quarterly
33	CS-12	VOCs & metals (As,Ba,Cr, Cu,Cd,Hg,Pb,Zn)	Dec-17	S	S	S	S	Quarterly
34	CS-13	VOCs & metals (As,Ba,Cr, Cu,Cd,Hg,Pb,Zn)	Dec-17	S	S	S	S	Quarterly
35	CS-D	VOCs	Jun-17	NS	NS	S	NS	15 months
36	CS-MWG-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
37	CS-MWH-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
38	CS-I	VOCs	Jun-17	NS	NS	NS	NS	30 months
39	CS-MW20-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
40	CS-MW21-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
41	CS-MW22-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
42	CS-MW23-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
43	CS-MW24-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
44	CS-MW25-LGR	VOCs	Jun-17	NS	NS	NS	NS	30 months
45	CS-MW35-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
46	CS-MW36-LGR	VOCs	Jun-17	NS	NS	S	NS	15 months
47	CS-MW37-LGR	VOCs	Dec-17	S	NS	S	NS	15 months

Notes/Abrreviations:
* New LTMO sampling frequency implemented September 2016. Metals analysis removed from monitoring wells and drinking water wells metals analysis remains the same.
S = Sample
NS = No Sample

Table 2.5
2018 On-post Groundwater COCs and Metals Analytical Results

Well ID		Sample Date	*cis* -1,2 DCE (ug/L)	PCE (ug/L)	TCE (ug/L)	Vinyl chloride (ug/L)
CS-1		3/14/2018	--	--	--	--
	Duplicate	3/14/2018	--	--	--	--
		6/11/2018	--	--	--	--
		9/7/2018	--	--	--	--
		12/3/2018	--	--	--	--
CS-4		9/7/2018	--	--	**0.47F**	--
CS-10		3/15/2018	--	--	--	--
		6/11/2018	--	--	--	--
		9/7/2018	--	--	--	--
		12/3/2018	--	--	--	--
CS-12		3/14/2018	--	--	--	--
		6/11/2018	--	--	--	--
	Duplicate	6/11/2018	--	--	--	--
		9/7/2018	--	--	--	--
	Duplicate	9/7/2018	--	--	--	--
		12/3/2018	--	**1.83**	--	--
		1/10/2019	--	--	--	--
CS-13		3/14/2018	--	--	--	--
		6/11/2018	--	--	--	--
		9/7/2018	--	--	--	--
		12/3/2018	--	--	--	--
	Duplicate	12/3/2018	--	--	--	--
CS-D		9/6/2018	**2.75**	**3.07**	**4.02**	--
CS-MW1-LGR		9/6/2018	**17.27**	**11.06**	**12.05**	--
CS-MW5-LGR		9/6/2018	**4.58**	**1.14F**	**2.73**	--
CS-MW6-LGR		9/5/2018	--	**0.88F**	--	--
CS-MW7-LGR		9/5/2018	--	**1.07F**	--	--
CS-MW8-LGR		9/5/2018	--	**2.44**	--	--
CS-MW8-CC		9/5/2018	--	--	--	--
CS-MW10-LGR		9/5/2018	--	**1.54**	**0.31F**	--
CS-MW11A-LGR		9/5/2018	--	**0.71F**	--	--
CS-MW11B-LGR		9/24/2018	--	--	--	--
CS-MW12-LGR		9/6/2018	--	--	--	--
CS-MW17-LGR		9/7/2018	--	**0.40F**	--	--
CS-MW35-LGR		9/5/2018	--	**0.58F**	--	--
	Duplicate	9/5/2018	--	**0.64F**	--	--
CS-MW36-LGR		9/5/2018	**0.56F**	**10.04**	**18.11**	--
CS-MW37-LGR		3/5/2018	--	--	--	--
		9/5/2018	--	**0.28F**	**0.36F**	--
Comparison Criteria						
Maximum Contaminant Level (MCL)			**70**	**5.0**	**5.0**	**2.0**
Reporting Limit (RL)			**1.2**	**1.4**	**1.0**	**1.1**
Method Detection Limit (MDL)			**0.07**	**0.06**	**0.05**	**0.08**

Bold (red)	Value ≥ MCL
Bold (blue)	MCL > Value ≥ RL
Bold	RL > Value > MDL

All samples were analyzed by APPL, Inc. using method SW8260B.
VOC data reported in ug/L & metals data reported in mg/L.

Abbreviations/Notes:

Duplicate	Field Duplicate
TCE	Trichloroethene
PCE	Tetrachloroethene
DCE	Dichloroethene

Data Qualifiers

-- = The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.
F = The analyte was positively identified but the associated numerical value is below the RL.

Table 2.5
2018 On-post Groundwater COCs and Metals Analytical Results

Well ID	Sample Date	Arsenic (mg/L)	Barium (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Mercury (mg/L)	Zinc (mg/L)
CS-1	3/14/2018	--	**0.0325**	--	**0.0070F**	**0.01**	**0.0037F**	--	**0.230J**
Duplicate	3/14/2018	--	**0.0332**	--	**0.0017F**	**0.007F**	--	--	**0.179J**
	6/11/2018	--	**0.0383**	--	**0.0017F**	**0.008F**	**0.0031F**	--	**0.19**
	9/7/2018	--	**0.0364**	--	**0.0015F**	**0.006F**	--	--	**0.197**
	12/3/2018	**0.00299F**	**0.0368**	--	--	**0.011**	--	--	**0.145**
CS-10	3/15/2018	--	**0.0398**	--	**0.0018F**	**0.008F**	**0.0022F**	--	**0.288**
	6/11/2018	--	**0.0414**	--	**0.0018F**	**0.025**	**0.0095F**	--	**0.629**
	9/7/2018	--	**0.0422**	--	**0.0011F**	--	--	--	**0.293**
	12/3/2018	**0.00120F**	**0.0386**	--	--	**0.012**	**0.0028F**	--	**0.436**
CS-12	3/14/2018	--	**0.0319**	--	**0.0018F**	--	**0.0023F**	--	**0.029F**
	6/11/2018	--	**0.0342**	--	**0.0012F**	--	--	--	**0.051**
Duplicate	6/11/2018	--	**0.0327**	--	**0.0019F**	**0.021**	**0.0024F**	--	**0.042F**
	9/7/2018	--	**0.035**	--	**0.0026F**	--	--	--	**0.029F**
Duplicate	9/7/2018	--	**0.034**	--	**0.0014F**	--	--	--	**0.018F**
	12/3/2018	**0.00297F**	**0.0312**	--	**0.0014F**	**0.013**	--	--	**0.070**
CS-13	3/14/2018	--	**0.0297**	--	**0.0022F**	--	--	--	**0.321**
	6/11/2018	--	**0.0315**	--	**0.0023F**	--	--	--	**0.487**
	9/7/2018	--	**0.0347**	--	**0.0015F**	**0.007F**	--	--	**0.398**
	12/3/2018	**0.00314F**	**0.0301**	--	--	**0.014**	**0.0056F**	--	**0.358J**
Duplicate	12/3/2018	**0.00422F**	**0.0293**	--	--	--	--	--	**0.261J**
Comparison Criteria									
Maximum Contaminant Level (MCL)		**0.01**	**2.0**	**0.005**	**0.1**	**1.3**	**0.015 (AL)**	**0.002**	**5.0 (SS)**
Reporting Limit (RL)		**0.03**	**0.005**	**0.007**	**0.01**	**0.01**	**0.025**	**0.001**	**0.05**
Method Detection Limit (MDL)		**0.00022**	**0.0003**	**0.0005**	**0.001**	**0.003**	**0.0019**	**0.0001**	**0.008**

Bold (red)	Value ≥ MCL
Bold (blue)	MCL > Value ≥ RL
Bold	RL > Value ≥ MDL

All samples were analyzed by APPL, Inc. using laboratory method SW8260B.
VOC data reported in µg/L & metals data reported in mg/L.

Abbreviations/Notes:

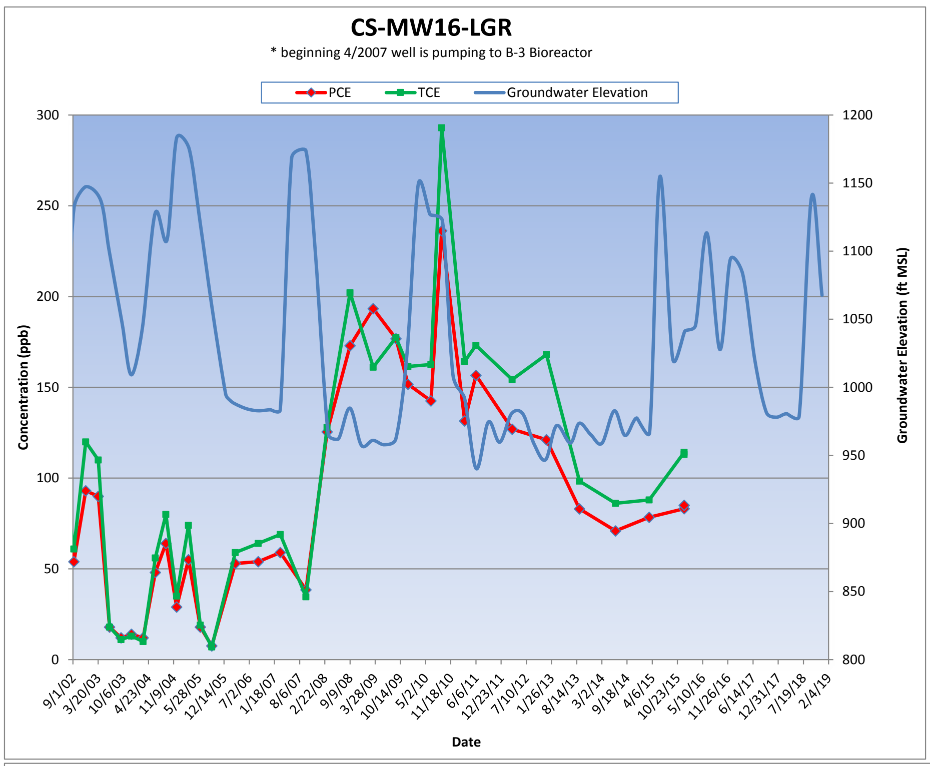
µg/L	micrograms per liter
mg/L	milligrams per liter
Duplicate	Field Duplicate
AL	Action Level
SS	Secondary Standard

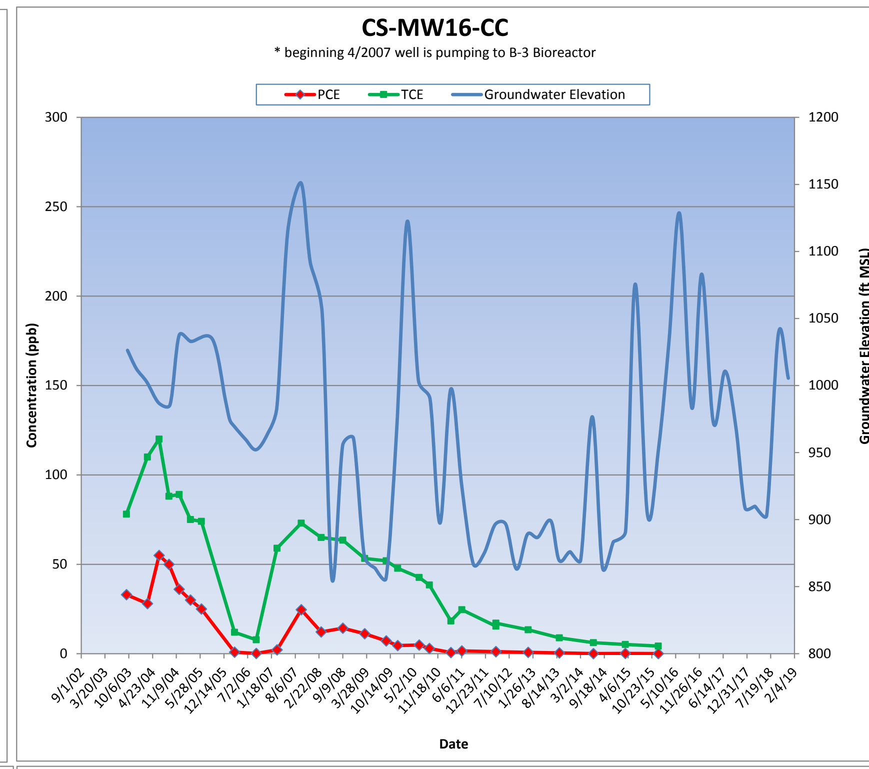
Data Qualifiers:

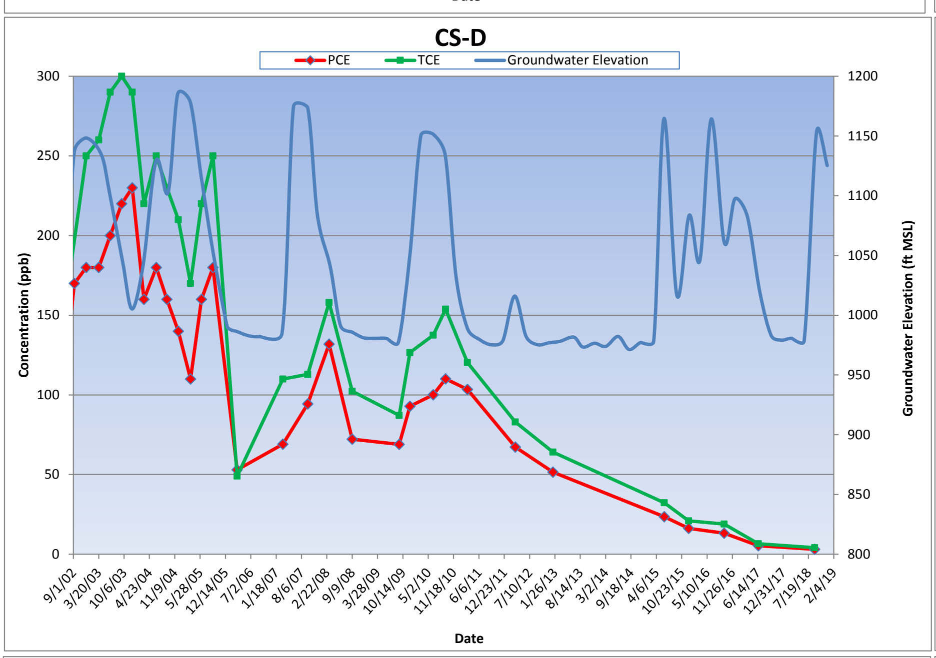
F = The analyte was positively identified but the associated numerical value is below the RL.
J = Analyte detected, concentration estimated.
-- = The analyte was analyzed for, but not detected. The associated numerical value is at or below The MDL.

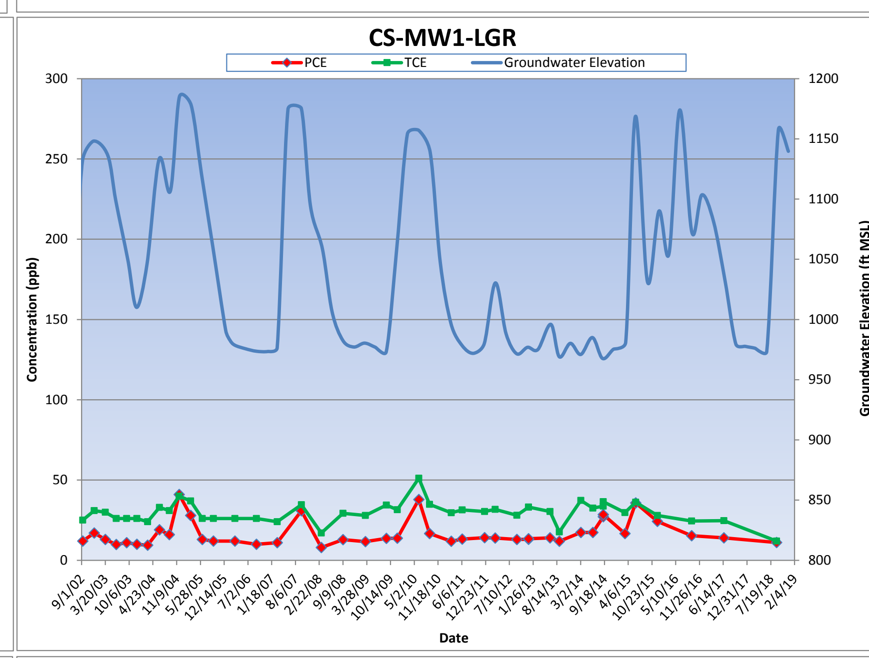
Concentration trends are illustrated on **Figure 2.4** for wells CS-MW16-LGR, CS-MW16-CC, CS-D, CS-MW1-LGR, CS-MW5-LGR, CS-MW36-LGR, and CS-4. These wells were selected because they have historical detections of PCE and TCE that approach and/or exceed MCLs. **Figure 2.4** also includes groundwater elevation data from each respective well to determine if there are correlations between VOC concentrations and water level. This figure suggests that CS-MW1-LGR has the most direct correlation between PCE/TCE concentration and groundwater recharge events. After that, discernible trends are less evident. Quarterly monitoring of CS-MW16-LGR and CS-D seems to indicate that increases in VOC concentrations lag recharge events by roughly six to nine months. CS-MW16-LGR and CS-MW16-CC have been removed from the groundwater monitoring program per the updated LTMO study and DQO's.

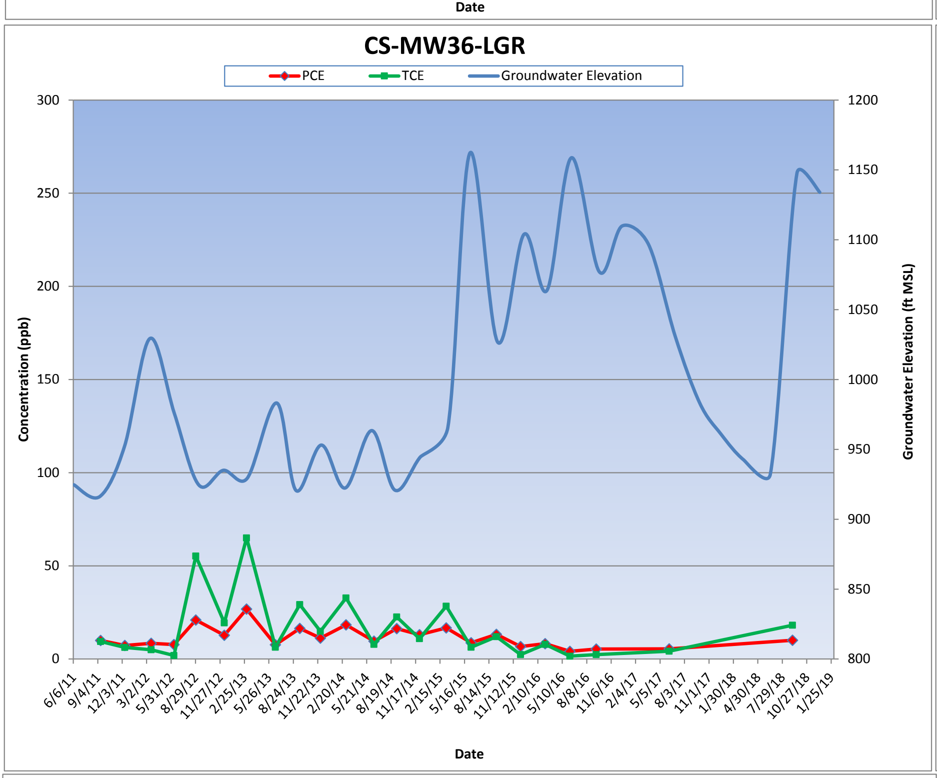
Figure 2.4
On-Post Cumulative Analytical vs. Groundwater Elevation

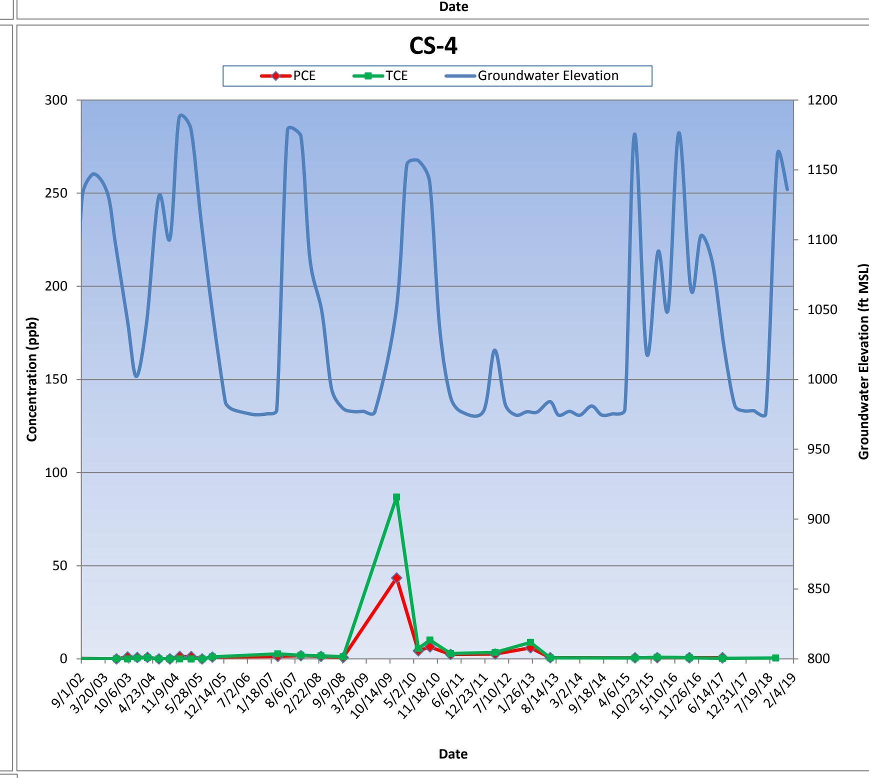


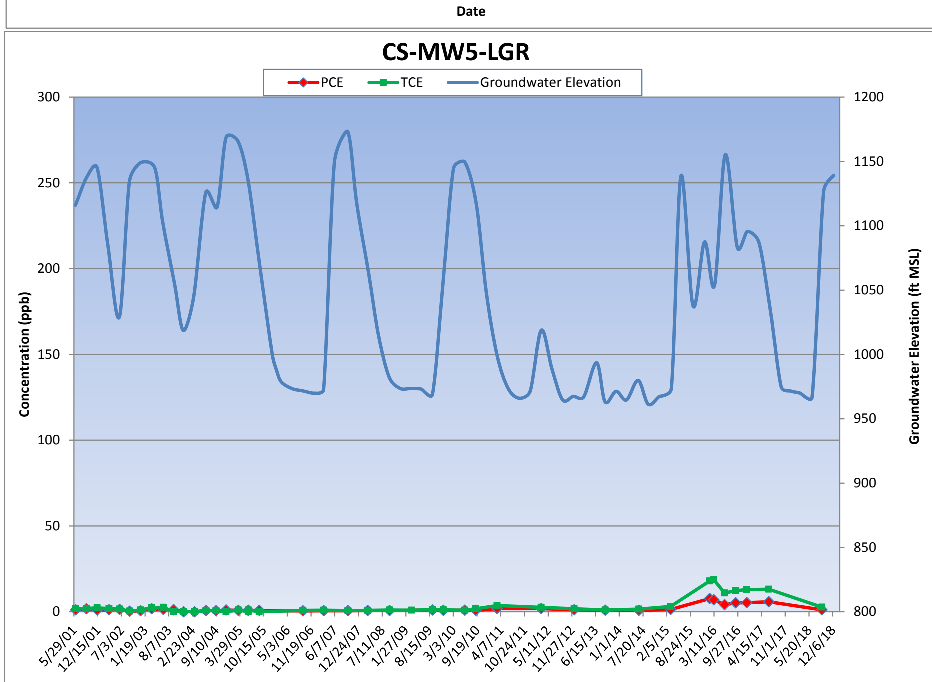












NOTE: Sampling dates are indicated by the squares on the trend line.

Notable trends in other wells appear to be related more to remedial activities than precipitation/recharge events. Concentrations at CS-MW16-CC decreased between March 2004 and June 2005 during a 15-month pump test of that well. Then concentrations increased in early 2007 during a time that roughly corresponds to the start-up of SWMU B-3 Bioreactor operations. Since that time, groundwater has been continually pumped from CS-MW16-CC and applied to the bioreactor as a remedial alternative. During that timeframe, VOC concentrations have steadily decreased, with little fluctuation attributable to precipitation. It is debatable whether the CS-MW36-LGR concentrations have responded to the in-situ chemical oxidation (ISCO) injections at AOC-65 in August 2012, May-June 2013, September-October 2014, and August-November 2015. The singular PCE/TCE peak at CS-4 has been attributed to the SWMU B-3 flood test in September 2009.

The VOC concentrations at CS-MW5-LGR have historically been below the MCLs since the well's inception in 2001. However, PCE, TCE, and *cis*-1,2-DCE all increased five-fold in 2016 and remained at these levels through 2017. In 2018, PCE and TCE fell back below their MCLs. The significant increase in contamination in well CS-MW5-LGR could be a result of the above average rainfall in 2015 and 2016. This area has not seen above average rainfall since before the historical drought of 2011. This, coupled with remedial activities at the SWMU B-3 bioreactor to the west of this well, may have contributed to this increase.

2.2.1.3 On-Post Monitoring Wells with COC Detections below the MCL

Groundwater monitoring results included wells where COCs were detected at levels below the applicable MCLs, SS, or ALs but above RLs. These included wells CS-D, CS-MW5-LGR, CS-MW8-LGR and CS-MW10-LGR. The detections below the MCLs/ALs but above RLs are summarized as follows:

- **CS-D –** This well was sampled in September 2018. PCE, TCE, and cis-1,2-DCE concentrations were above their RLs. The 2018 concentrations are the lowest seen in this well since sampling began in 1991.
- **CS-MW5-LGR –** This well was also sampled once in 2018. TCE and cis-1,2-DCE concentrations were above their RLs in September 2018. PCE was also detected below the RL. PCE and TCE concentrations were above the MCL from February 2016 through June 2017, this well has been monitored since June 2001.
- **CS-MW8-LGR** - PCE was detected in September 2018; above the RL but below the MCL.
- **CS-MW10-LGR –** PCE concentrations were detected below the MCL but above the RL in September 2018. A trace detection of TCE was also reported in this well below the RL.

2.2.1.4 On-Post Monitoring Wells with COC Detections below the Reporting Limits

The on-post results include detections in wells for which the analyte is identified, but at a concentration below the RL. These results are assigned an "F" flag under the CSSA Quality Assurance Project Plan (QAPP). In 2018, this included wells CS-4, CS-MW6-LGR, CS-MW7-LGR, CS-MW11A-LGR, CS-MW17-LGR, CS-MW35-LGR, and CS-MW37-LGR. Metals analysis was dropped from the schedule in September 2016 in accordance with the 2015 update to the LTMO study and DQO's. The detections below the reporting limit are summarized as follows:

- **CS-4 –** This well was sampled once in September 2018, and TCE was detected below the RL. This was the first time PCE has not been detected in this well since 1995.
- **CS-MW6-LGR** – This well was sampled once in 2018. PCE was detected below the RL in September 2018. This is only the fourth detection of PCE reported in this well since sampling began in 2001.
- **CS-MW7-LGR** – PCE was detected below the RL in September 2018. This was the highest concentration of PCE reported in this well to date.
- **CS-MW11A-LGR –** PCE was detected below the RL in September 2018.
- **CS-MW17-LGR –** PCE was detected below the RL in September 2018. PCE has been consistently detected in this well since monitoring began in 2002.
- **CS-MW35-LGR** – PCE was detected below the RL in September 2018. The field duplicated also reported a similar f-flagged detection of PCE.
- **CS-MW37-LGR** – PCE and TCE were detected, below the RLs, for the first time in September 2018. This well was also sampled in March 2018 with no COCs detected. Sampling of this well began in 2017.

2.2.1.5 On-Post Monitoring Wells with No COC Detections

Of the 16 monitoring wells sampled in 2018, 13 wells reported COC detections. A total of 3 wells (CS-MW8-CC, CS-MW11B-LGR, and CS-MW12-LGR) reported no VOC detections. In 2018 all scheduled samples were collected (**Table 2.4**). Details on the RL, MDLs, field duplicates, MCLs, etc., are described in the tables of detections (**Table 2.5**) and in **Appendix B**.

2.2.1.6 Drinking Water Supply Well Results

Four active CSSA drinking water supply wells (CS-1, CS-10, CS-12, and CS-13) were analyzed for VOCs and the 8 metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, and zinc) in 2018. Under the LTMO study, the drinking water supply wells are scheduled to be sampled quarterly (**Table 2.4 & Appendix B**). The detections are summarized as follows:

- **CS-1 –** No VOCs were detected during the 4 quarterly sampling events in 2018. Barium and zinc were above their applicable RLs in all four quarters. Copper was also above the RL in March and December. Arsenic, chromium, and lead were also detected below the RL in 2018.
- **CS-10** – No VOCs were detected during the four quarterly sampling events in 2018. Barium, copper, and zinc were detected above their RLs along with arsenic, chromium, and lead detected below their applicable RLs in 2018.
- **CS-12** – PCE was detected, above the RL, in December. An additional sample was collected in January 2019 to confirm the December 2018 PCE detection, the results were non-detect. The other three events reported no detections of VOCs in 2018. Barium, copper, and zinc were detected above their RLs along with arsenic, chromium, and lead detected below their applicable RLs in 2018.

- **CS-13 –** No VOCs were detected in this well in 2018. Barium, copper, and zinc were detected above their applicable RLs while arsenic, chromium, and lead were detected below their applicable RL's in 2018.

2.2.1.7 Westbay®-equipped Well Results

Eight wells equipped with the Westbay multi-port interval sampling equipment have been installed at CSSA. Four wells (CS-WB05, CS-WB06, CS-WB07, and CS-WB08) are sampled as part of the SWMU B-3 bioreactor treatability study and are not addressed in this report. The remaining four wells (CS-WB01, CS-WB02, CS-WB03, and CS-WB04) are part of the postwide groundwater monitoring program and are included in this report. Under the provisions of the groundwater monitoring DQOs and the 2015 updated LTMO study, the schedule for sampling CS-WB01, CS-WB02, CS-WB03, and CS-WB04 is every 15 months for the UGR and select LGR zones and every 30 months for the BS and CC zones. An overview of sampling frequencies for Westbay wells is given in **Table 2.6**.

Samples were collected from zones included in the 15-month schedule in September 2018. No samples were scheduled for collection in March, June, and December 2018. Samples were analyzed for PCE, TCE, *cis*-1,2-DCE, and vinyl chloride in September. All samples were analyzed by APPL. Per the DQOs, the Westbay data are used for screening purposes only, and therefore no quality assurance/quality control samples are collected with the Westbay samples. All intervals with detections of COCs are presented in **Table 2.7**. Full analytical results are presented in **Appendix C**. **Appendix D** illustrates the historical contaminant concentrations and groundwater elevations for each Westbay zone.

Additional samples were collected from the Westbay wells in conjunction with the normal quarterly groundwater monitoring in 2018. An ongoing ISCO treatability study is currently being conducted at AOC-65. The results of this effort are currently being tabulated and will be reported in a separate treatability study document.

Due to low groundwater elevations, certain zones (WB03-LGR-01, CS-WB03-LGR-02, and CS-WB04-LGR-01) could not be sampled in September because they were dry. CS-WB02-UGR-01 was not sampled due to a clogged sampling port and CS-WB04-LGR-05 was not sampled due to a non-operational sampling port. The remaining 33 zones scheduled for sampling contained water and were sampled. The Westbay-equipped wells are sampled using Westbay Instruments, Inc., equipment and sampling methods.

Table 2.6
Overview of Westbay Sampling for 2018

Westbay Interval	Last Sample Date	Mar-18	Jun-18	Sep-18 (15 month)	Dec-18	LTMO Sampling Frequency (as of Sept. 2016)
CS-WB01-UGR-01	Jun-16	NS	NS	S	NS	15 months
CS-WB01-LGR-01	Jun-17	NS	NS	S	NS	15 months
CS-WB01-LGR-02	Jun-17	NS	NS	S	NS	15 months
CS-WB01-LGR-03	Jun-17	NS	NS	S	NS	15 months
CS-WB01-LGR-04	Jun-17	NS	NS	S	NS	15 months
CS-WB01-LGR-05	Jun-17	NS	NS	S	NS	15 months
CS-WB01-LGR-06	Jun-17	NS	NS	S	NS	15 months
CS-WB01-LGR-07	Jun-17	NS	NS	S	NS	15 months
CS-WB01-LGR-08	Jun-17	NS	NS	S	NS	15 months
CS-WB01-LGR-09	Jun-17	NS	NS	S	NS	15 months
CS-WB02-UGR-01	Dec-04	NS	NS	clogged	NS	15 months
CS-WB02-LGR-01	Jun-16	NS	NS	S	NS	15 months
CS-WB02-LGR-02	Jun-16	NS	NS	S	NS	15 months
CS-WB02-LGR-03	Jun-17	NS	NS	S	NS	15 months
CS-WB02-LGR-04	Jun-17	NS	NS	S	NS	15 months
CS-WB02-LGR-05	Jun-17	NS	NS	S	NS	15 months
CS-WB02-LGR-06	Jun-17	NS	NS	S	NS	15 months
CS-WB02-LGR-07	Jun-17	NS	NS	S	NS	15 months
CS-WB02-LGR-08	Jun-17	NS	NS	S	NS	15 months
CS-WB02-LGR-09	Jun-17	NS	NS	S	NS	15 months
CS-WB03-UGR-01	Jun-17	NS	NS	S	NS	15 months
CS-WB03-LGR-01	Jun-17	NS	NS	NSWL	NS	15 months
CS-WB03-LGR-02	Jun-16	NS	NS	NSWL	NS	15 months
CS-WB03-LGR-03	Jun-17	NS	NS	S	NS	15 months
CS-WB03-LGR-04	Jun-17	NS	NS	S	NS	15 months
CS-WB03-LGR-05	Jun-17	NS	NS	S	NS	15 months
CS-WB03-LGR-06	Jun-17	NS	NS	S	NS	15 months
CS-WB03-LGR-07	Jun-17	NS	NS	S	NS	15 months
CS-WB03-LGR-08	Jun-17	NS	NS	S	NS	15 months
CS-WB03-LGR-09	Jun-17	NS	NS	S	NS	15 months
CS-WB04-UGR-01	Nov-04	NS	NS	NSWL	NS	15 months
CS-WB04-LGR-01	Jul-17	NS	NS	NS	NS	30 months
CS-WB04-LGR-02	Mar-10	NS	NS	NS	NS	30 months
CS-WB04-LGR-03	Jul-17	NS	NS	NS	NS	30 months
CS-WB04-LGR-04	Jul-17	NS	NS	NS	NS	30 months
CS-WB04-LGR-06	Jul-17	NS	NS	S	NS	15 months
CS-WB04-LGR-07	Jul-17	NS	NS	S	NS	15 months
CS-WB04-LGR-08	Jul-17	NS	NS	S	NS	15 months
CS-WB04-LGR-09	Jul-17	NS	NS	S	NS	15 months
CS-WB04-LGR-10	Jul-17	NS	NS	S	NS	15 months
CS-WB04-LGR-11	Jul-17	NS	NS	S	NS	15 months
CS-WB04-BS-01	Jul-17	NS	NS	NS	NS	30 months
CS-WB04-BS-02	Jul-17	NS	NS	NS	NS	30 months
CS-WB04-CC-01	Jul-17	NS	NS	NS	NS	30 months
CS-WB04-CC-02	Jul-17	NS	NS	NS	NS	30 months
CS-WB04-CC-03	Jul-17	NS	NS	NS	NS	30 months

Profiling performed quarterly, in conjunction with post wide water levels.
S = sample
NS = no sample
NSWL = no sample due to low water level

Table 2.7
2018 Westbay® Groundwater COCs Analytical Results

Well ID	Date Sampled	cis-1,2-DCE (cis-1,2-dichloroethene)	TCE (trichloroethene)	PCE (tetrachloroethene)	Vinyl Chloride
CS-WB01-UGR-01	9/11/2018	--	--	**1.29F**	--
CS-WB01-LGR-01	9/11/2018	--	--	**2.17**	--
CS-WB01-LGR-02	9/11/2018	--	**1.8**	**8.53**	--
CS-WB01-LGR-03	9/11/2018	--	**9.76**	**4.03**	--
CS-WB01-LGR-04	9/11/2018	**2.37**	--	--	--
CS-WB01-LGR-05	9/11/2018	--	--	--	--
CS-WB01-LGR-06	9/11/2018	**1.17F**	**4.08**	--	--
CS-WB01-LGR-07	9/11/2018	**0.22F**	**14.72**	**16.12**	--
CS-WB01-LGR-08	9/11/2018	**16.12**	**1.48**	**0.41F**	--
CS-WB01-LGR-09	9/11/2018	**0.36F**	**10.07**	**7.61**	--
CS-WB02-UGR-01	9/12/2018	port clogged			
CS-WB02-LGR-01	9/12/2018	--	--	**1.02F**	--
CS-WB02-LGR-02	9/12/2018	--	--	**1.46**	--
CS-WB02-LGR-03	9/12/2018	--	--	--	--
CS-WB02-LGR-04	9/12/2018	--	**4.63**	**2.72**	--
CS-WB02-LGR-05	9/12/2018	--	**1.45**	**0.85F**	--
CS-WB02-LGR-06	9/12/2018	--	**1.35**	**0.93F**	--
CS-WB02-LGR-07	9/12/2018	**0.60F**	**1.01**	--	--
CS-WB02-LGR-08	9/12/2018	**2.3**	--	--	--
CS-WB02-LGR-09	9/12/2018	--	**5.21**	**5.03**	--
CS-WB03-UGR-01	9/17/2018	**10.53**	**150.39J**	**10367.97*** **	--
CS-WB03-LGR-01	9/17/2018	Dry			
CS-WB03-LGR-02	9/17/2018	Dry			
CS-WB03-LGR-03	9/17/2018	--	**0.71F**	**3.86**	--
CS-WB03-LGR-04	9/17/2018	**0.52F**	**4.88**	**12.45**	--
CS-WB03-LGR-05	9/17/2018	**4.95**	**3.91**	**10.93**	--
CS-WB03-LGR-06	9/17/2018	**2.82**	--	--	--
CS-WB03-LGR-07	9/17/2018	**2.48**	**5.04**	**1.68**	--
CS-WB03-LGR-08	9/17/2018	**2.23**	--	--	--
CS-WB03-LGR-09	9/17/2018	--	**2.12**	**2.22**	--
CS-WB04-UGR-01	9/17/2018	Dry			
CS-WB04-LGR-01	9/17/2018	--	--	**0.87F**	--
CS-WB04-LGR-06	9/17/2018	**2.98**	**7.24**	**23.78**	--
CS-WB04-LGR-07	9/17/2018	**3.39**	**11.29**	**25.87**	--
CS-WB04-LGR-08	9/17/2018	--	**1.06**	**0.58F**	--
CS-WB04-LGR-09	9/17/2018	--	**5.51**	**7.36**	--
CS-WB04-LGR-10	9/17/2018	--	**0.47F**	**2.2**	--
CS-WB04-LGR-11	9/17/2018	--	--	**0.93F**	--
Comparison Criteria					
Method Detection Limit	**MDL**	**0.07**	**0.05**	**0.06**	**0.08**
Reporting Limit	**RL**	**1.2**	**1**	**1.4**	**1.1**
Max. Contaminant Level	**MCL**	**70**	**5**	**5**	**2**

BOLD	≥ MDL
BOLD (blue)	≥ RL
BOLD (red)	≥ MCL

Data Qualifiers
'--' indicates the result was non-detect.
F-The analyte was positively identified but the associated numerical value is below the RL.
J - Analyte detected, concentration estimated.
* dilution of 5 run for this sample.
** dilution of 50 run for this sample.
*** dilution of 200 run for this sample
All values are reported in µg/L.

The following Westbay intervals (shown in their general stratigraphic position) reported detections of PCE and/or TCE above the MCL in 2018.

CS-WB01	CS-WB02	CS-WB03	CS-WB04
-	-	• UGR-01	-
-	-	-	-
• LGR-02	-	-	-
• LGR-03	-	-	-
-	-	• LGR-04	-
-	-	• LGR-05	-
-	-	-	• LGR-06
• LGR-07	-	• LGR-07	• LGR-07
-	-	-	-
• LGR-09	• LGR-09	-	• LGR-09
			-
			-

Figures 2.5 and **2.6** present the September 2018 vertical distribution of the VOC plume within the multi-port wells for the most pervasive contaminants, PCE and TCE. The following discussion presents general observations that have been noted since the inception of Westbay monitoring at AOC-65.

In 2018, the VOC plume originating from AOC-65 is generally similar in concentration and distribution as in prior years. Near the source area (CS-WB03), the solvent contamination is persistent throughout the entire saturated thickness of the LGR excepting the LGR-06 and LGR-08 zones, with the greatest concentrations occurring nearest the land surface (UGR-01). Non-detections and trace detections of PCE within the LGR-08 zone and at WB02 in zones LGR-05, -06, and -07 result in two stratified lobes separated by the LGR-08 zone across the site and another lobe unconnected to the source area developed in the LGR-06 and LGR-07 zones to the south (WB01) and west (WB04) of the source area.

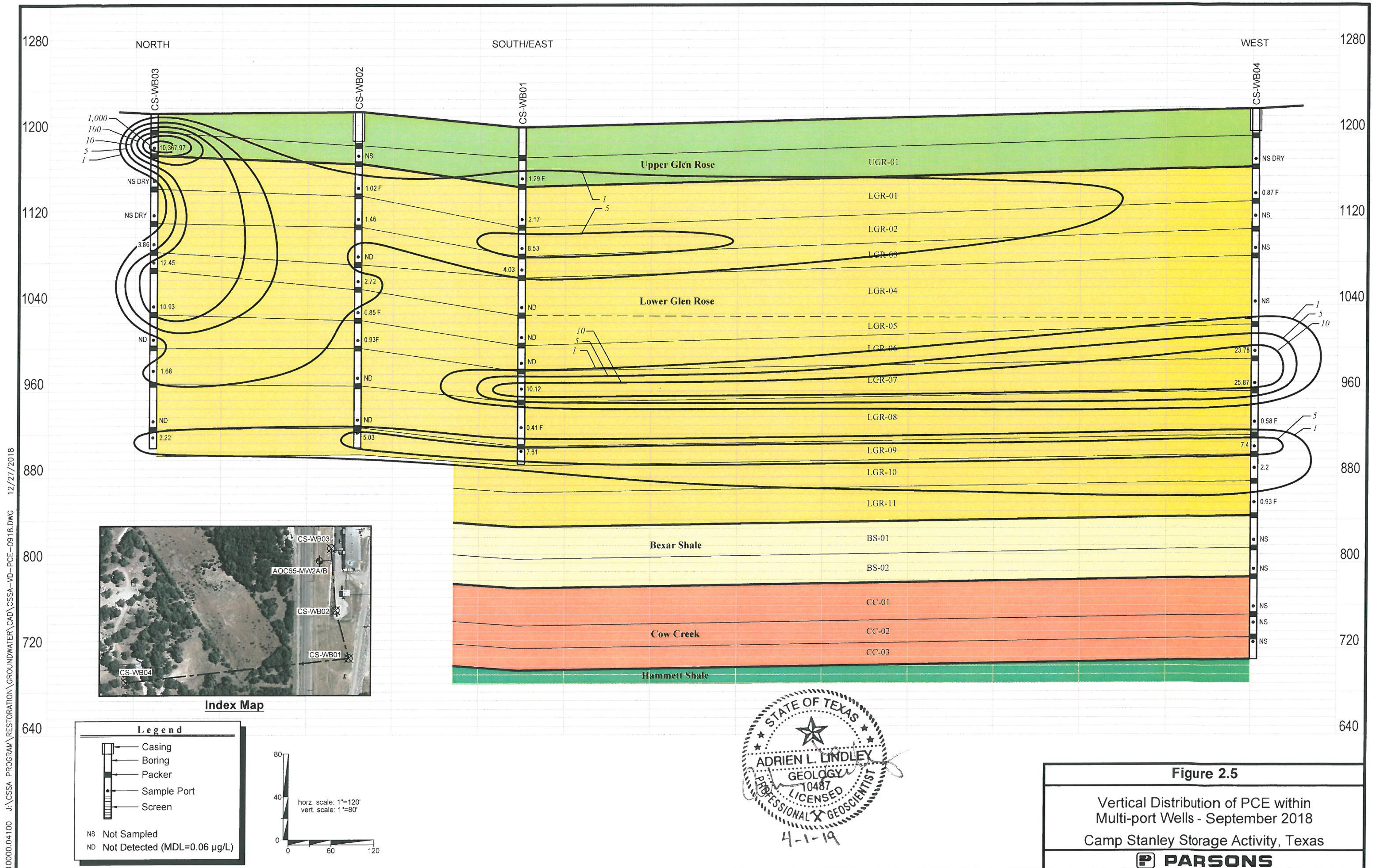


Figure 2.5

Vertical Distribution of PCE within Multi-port Wells - September 2018

Camp Stanley Storage Activity, Texas

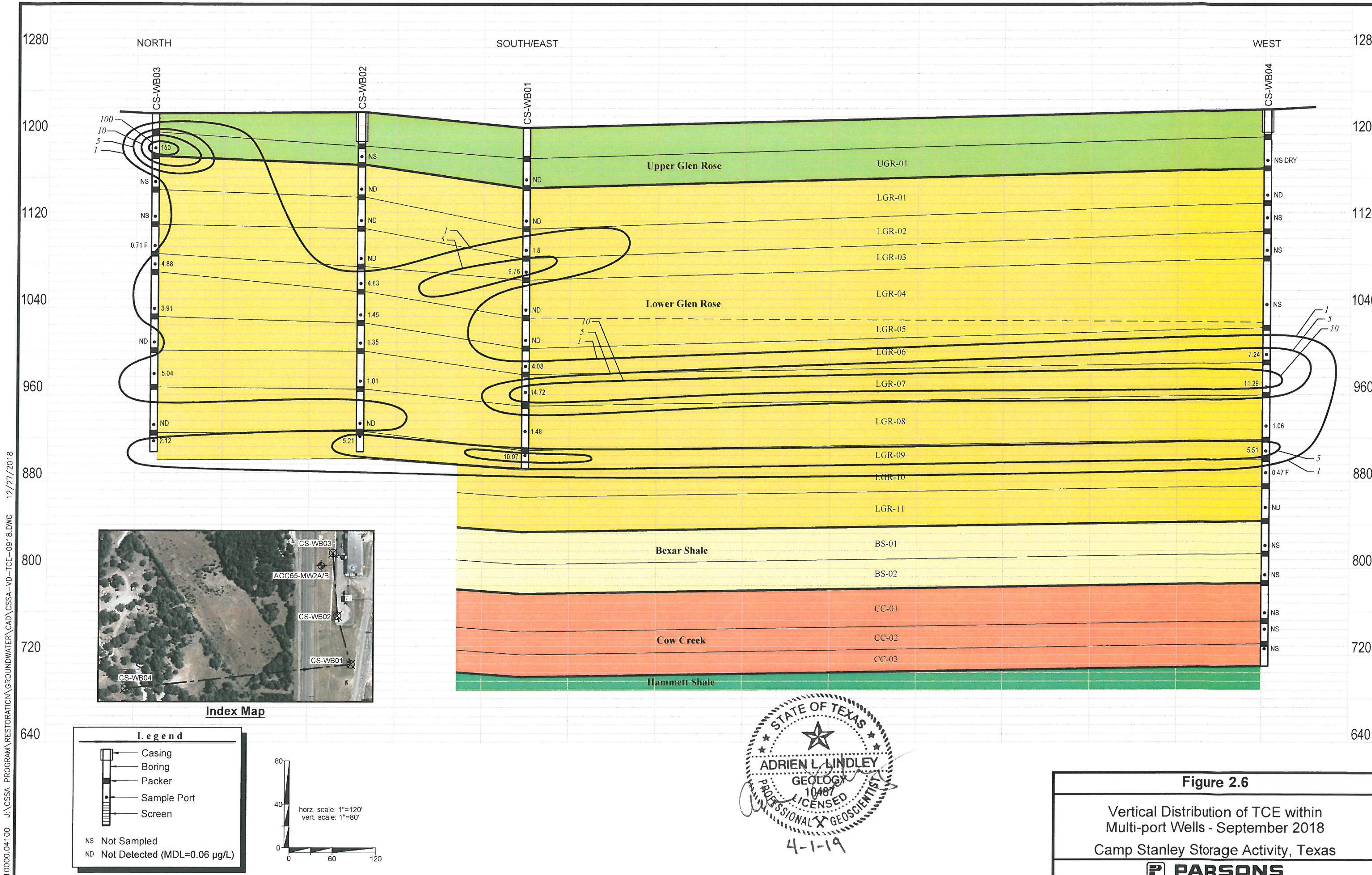


Figure 2.6

Vertical Distribution of TCE within Multi-port Wells - September 2018

Camp Stanley Storage Activity, Texas

CS-WB03 is located closest to the Building 90 source area, and consistently records the highest concentrations of contaminants (**Appendix D.3**). The upper zones (CS-BB03-LGR-01 and CS-WB03-LGR-02) are typically dry and have water only after significant rain. Because of frequent droughts and set sampling schedules, these zones have only been sampled 8-16 times since 2003. In September 2018, the zones CS-WB03-LGR-01 and -LGR-02 were dry. Contamination is still present in the UGR zone with a slight increase in concentration from June (9,356 µg/L) 2017 to September (10,368 µg/L) 2018. This level is well below the historical high concentration of 30,000 µg/L reported in March 2008. Zone -LGR-03 has had PCE and TCE concentrations above the MCL since the well was installed in 2003. In June 2016 these levels fell below the MCL and have been steadily decreasing since. In December 2011, *cis*-1,2-DCE was detected in zone CS-WB03-LGR-06. Since then there have been nine consecutive detections increasing in concentration and levels have ranged from 0.25 to 8.87 µg/L. In September 2018 the cis-1,2-DCE concentration dropped to 2.82 µg/L in zone -LGR-06. Zone -08 had no detection of PCE for the sixth consecutive time in the history of sampling this zone. Between May 2004 and September 2010, no *cis*-1,2-DCE had been reported in CS-WB03-LGR-09. Beginning in March 2011, a trace detection was reported in -LGR-09, followed by forteen consecutive sampling events that ranged in concentration between 0.20 µg/L and 45.73 µg/L. In 2016, 2017, and 2018 no detections of *cis*-1,2-DCE were reported in this zone. At the same time, PCE and TCE detections have fallen and stayed below the MCL. Since September 2012 PCE has dropped below the MCL and has showed a steady decline through 2013. In September 2018 PCE was 2.22 µg/L. The reason for these changes is likely a result of a biodegradation mechanism.

Historical results indicate that a persistent source of contamination still exists, and that periodic flushing by intense rainfall can mobilize these perched contaminants that are probably otherwise bound to the matrix during the rest of the year. Likewise, preliminary indications from the ISCO treatability study show that solvent contamination was mobilized/oxidized as a result of the study. Baseline samples in the WB03-UGR zone were less than 6 µg/L in July 2012. Thirty days after the initial injection, PCE concentrations were above 6,000 µg/L, and has persisted through September 2018. In 2018 the PCE concentrations in this zone increased slightly to 10,368 µg/L, up from 9,356 in June 2017.

CS-WB02 was installed nearly 300 feet south of CS-WB03 and the Building 90 source area. In general, most zones in 2018 showed PCE and TCE concentrations have remained similar to 2017 concentrations (**Appendix D.2**). Zones -LGR-01 and -LGR-02 were sampled in September 2018; both had PCE detections below the MCL. Zone -LGR-03 was non-detect for PCE and TCE for the first time since well sampling began in 2003. Zone -LGR-04 has had consistent TCE detections above the MCL since March 2006. These levels have been slowly decreasing since and fell below the MCL in June 2017 and remained below the MCL in September 2018. Zone -LGR-05 reported its first detection of *cis*-1,2-DCE in September 2015; it was still present in 2016 and 2017 but non-detect in 2018. Zone -LGR-08 began getting *cis*-1,2-DCE detections above the RL in September 2010; these detections have remained constant through September 2018. Zone -LGR-09 was the only zone in this well with PCE and TCE above the MCL in September 2018. The changes over the last couple of years do not follow the historic pattern seen after the ISCO injections in August 2012 and May-June 2013 which showed a significant increase in PCE approximately 3-4 months after the ISCO injections. The result is interesting because it initially implicated that there is a vertical conduit between the shallower ISCO injection zones (trench gallery and injection wells) and the deeper strata of CS-WB02-LGR-09. In 2015 and 2016 this theory could be complicated by above average rainfall following a severe drought in the area.

Multi-port well CS-WB01 is located approximately 500 feet south of CS-WB03 and the Building 90 source area. For all zones in this well historical PCE and TCE concentrations are present at concentrations less than 32 µg/L. Since mid-2005, there has been a general trend of increasing contaminant concentrations in zones CS-WB01-LGR-02 and -LGR-07. Initially, the -LGR-09 zone was following the same increasing trend beginning in 2005. In 2008 the overall concentrations began decreasing until 2015 where they began an upward trend. In 2016, PCE and TCE concentrations began dropping again into 2017 which reported no detection of PCE or TCE in -LGR-09. This was the first sampling event with PCE and TCE below the MCL since sampling began at this well in 2003. In September 2018 the PCE and TCE concentrations were back above the MCL similar to concentrations seen in September 2016. These noted increases seem to correspond with increases observed in several upgradient CS-WB02 zones, and may be associated with a “flushing” event in which a slug of contaminated groundwater is moving downgradient away from the source zone (**Appendix D.1**). At CS-WB01, the trend has been that TCE concentrations generally exceed PCE for most zones. The zone with the relatively highest concentration is typically –LGR-09. In 2016-17 zones -05, -06, and -08 reported their highest detection of *cis*-1,2-DCE to date, with zone –LGR-08 showing the most significant increase. The results of CS-WB01 indicate that the contamination becomes preferentially stratified such that greater contamination is found above and below zones LGR-04, -05, and -06, to the south and west. No discernible effect from the ISCO treatability study has been ascertained at CS-WB01.

Off-post at CS-WB04, trace detections of less than 2 µg/L PCE are generally reported in the LGR-02, LGR-03, LGR-04, and LGR-08 zones. WB04-LGR-05 has never been sampled due to an erroneous sample port installation. Since September 2006, TCE has been reported above the MCL in zones LGR-06 and LGR-07 at concentrations less than 21 µg/L and PCE has been above the MCL since 2008. In 2009, the concentration of PCE in both LGR-06 and LGR-07 more than doubled compared to September 2008. PCE in zone LGR-07 did fall back below the MCL in September 2015 and remained below the MCL through 2017. (**Appendix D.4**). In 2010, PCE in LGR-06 decreased from 33 µg/L to 11 µg/L while the LGR-07 PCE concentration decreased from 19 µg/L to 1.7 µg/L. But in 2011, the PCE concentration in LGR-06 increased to 28.76 µg/L, and zone LGR-07 also increased its PCE concentration to 24.41 µg/L. In June 2013, the increasing trend continued with PCE reaching a historical high of 39.18 µg/L in LGR-06. The levels in LGR-07 dropped slightly in 2013 and the levels remained similar in June and September 2013. In 2014, the increasing PCE trend reappeared in LGR-06 reaching another historic high in December 2014 (44.92 µg/L). Zone LGR-07 mimicked the LGR-06 zone but reaching its PCE historic high in June 2014 (32.86 µg/L). In March 2015, both of these zones reached another historic high concentration (55.08 µg/L in the -06 zone and 35.6 µg/L in the -07 zone) for PCE. In 2016, cis-1,2-DCE reached a historic high in zone LGR-07 (40.9 µg/L). In 2018 both PCE and TCE increased significantly in LGR-07 bringing concentrations back up above the MCL These trends in LGR-06 and -07 are evident on the graphs presented in **Appendix D.4**. These two zones have been the most dynamic of all the multiport zones monitored in this program, and are an indication that contaminant mass is migrating westward in these intervals.

Historically, the off-post zone with the most persistent contamination is CS-WB04-LGR-09. Nearly equivalent levels of PCE and TCE are found at concentrations that generally range above the MCL between 8 µg/L and 16 µg/L. In September 2018, LGR-09 fell back to the low end of this range, showing a decreasing trend since 2016. Zones LGR-10 (PCE = 7.47 µg/L) and LGR-11 (PCE = 444.82 µg/L) reported their first detection above the MCL in March 2015. In 2016 these concentrations had dropped back below the MCL and remained there in 2017 and 2018. Prior to September 2006, essentially no chlorinated solvents were detected in the CS-WB04-LGR-11 zone. Below this depth, any solvent contamination in the remainder of the BS and CC are at concentrations less than 2.0 µg/L. The only exception to this is zone CC-03 which reported PCE at 6.66 µg/L in September 2015.

The BS and CC zones at CS-WB04 are sampled every 30 months and were last sampled in June 2017. In prior years the BS and CC zones at CS-WB04 generally had little to no contamination present. In 2011, only trace detections of *cis*-1,2-DCE were reported in CS-WB04-BS-02 and –CC-01 intervals. But in 2012, the trace detections also included PCE in all five BS (2) and CC (3) zones. In March 2014 one zone showed a trace detection of *cis*-1,2-DCE (0.69F µg/L) in the –CC-01 interval. In September 2015, PCE was again detected in all five –BS and –CC zones. Zone CC-03 reported its highest detection of PCE to date (6.66 µg/L), with levels now above the MCL. *Cis*-1,2-DCE was also detected in all 3 –CC zones in September 2015. The BS and CC zones were not scheduled for sampling in 2016 but were sampled again in June 2017. PCE in the CC zones was back below the MCL and both BS zones reported no detections. The contention is that the trace contamination in the BS and CC at CS-WB04 is the result of the vertical mixing of contaminated LGR water within the nearby RFR-10 wellbore under a naturally downward vertical gradient. The last time VOCs have been seen distributed across most of the BS and CC zones was March 2009 and September 2012 when the aquifer was in a depressed condition.

2.2.2 Off-Post Analytical Results

The frequencies for sampling off-post wells in 2018 were determined by the updated *Three-Tiered Long Term Monitoring Network Optimization Evaluation* (Parsons 2015), in compliance with *The Plan*, and *DQOs for the Groundwater Monitoring Program* (Parsons 2015). These plans were updated in 2015 and new sampling frequencies were implemented in September 2016 after receiving TCEQ and EPA approval. An overview of sampling frequencies for off-post wells is given in **Table 2.8**. Forty-five off-post samples were collected from 9 wells during the 2018 quarterly monitoring events, and their locations are illustrated on **Figure 1.1**. One well (I10-2) was not sampled in 2018 due to pump outage. In September 2016 the 2015 updated LTMO study was implemented to sampling frequencies off-post. The TCEQ and EPA approval for implementing the LTMO off-post was received in April and May 2016 (see **Appendix I)**.

Off-post wells sampled during the quarterly monitoring events were selected based on previous sampling results and proximity to both the CSSA boundary and wells with detections of PCE and TCE. Public and private supply wells located west and south of CSSA were selected for these events. Samples were also collected from the off-post well GAC filtration systems after treatment during the March and September events.

Off-post wells sampled in 2018 included (see **Figure 1.1** for well locations):

- One well used by the general public along Interstate Highway 10 (I10-10);

- One privately-owned well in the Jackson Woods subdivision (JW-20);
- Three privately-owned wells in the Leon Springs Villa area (LS-5, LS-6, and LS-7);
- One well used by the general public on Old Fredericksburg Road (OFR-3);
- Three privately-owned wells in the Ralph Fair Road area (RFR-10, RFR-11, and RFR-12).

All wells were sampled from a tap located as close to the wellhead as possible. Most taps were installed by CSSA to obtain a representative groundwater sample before pressurization, storage, or the water supply distribution system. Water was purged to engage the well pump prior to sample collection. Conductivity, pH, and temperature readings were recorded to confirm adequate purging while the well was pumping. Purging measurements were recorded in the field logbook for each sampling event.

All groundwater samples were submitted to APPL for analysis. Groundwater samples were analyzed for the short list of VOCs (*cis*-1,2-DCE, PCE, TCE, and vinyl chloride) using SW-846 Method 8260B. Off-post wells are not analyzed for metals as part of the groundwater monitoring program.

The data packages containing the analytical results for the 2018 sampling events were reviewed and verified according to the guidelines outlined in the CSSA QAPP. After the data packages were received by Parsons, quarterly DVRs were submitted to CSSA as an attachment in the Quarterly Groundwater Reports. The December 2018 DVRs are included in **Appendix H.**

Based on historical detections, the lateral extent of VOC contamination above the MDL extends approximately 2.7 miles beyond the west boundary of CSSA (well SLD-01) and 0.4 miles to the south of CSSA (well LS-4). Information such as well depth, pump depth, and other pertinent data necessary to characterize the vertical extent of migration is not readily available for most off-post wells. However, the typical well construction for the area is open borehole completions that penetrate the full thickness of the Middle Trinity aquifer (LGR, BS, and CC).

Concentrations of VOCs detected in 2018 are presented in **Table 2.9**. Full analytical results from the 2018 sampling events are presented in **Appendix F**. Concentration trends are illustrated on **Figures 2.7 and 2.8** for wells LS-5, LS-6, LS-7, OFR-3, RFR-10, and RFR-11 for PCE and TCE. These wells were selected because they have had detections of PCE and TCE that approach and/or exceed MCLs. **Figure 2.7** includes precipitation data from the weather stations located at CSSA, AOC-65 WS and B-3 WS. This figure suggests VOC concentrations in OFR-3 and RFR-10 are very sensitive to significant rain events and that VOC concentrations in LS-5, LS-6, and LS-7 are less sensitive to rainfall.

Data from RFR-11 presents a mixed picture. From October 2001 through December 2007, RFR-11 VOC concentration peaks showed a good correlation to significant rainfall events, but after 2007, this correlation is less pronounced. It may be coincidental, but the changes in rainfall/VOC concentration correlations in RFR-11 happened when the San Antonio Water System (SAWS) abandoned pumping of the Bexar Met public supply wells in Leon Springs Villas (LS-1, LS-2, LS-3, LS-4). In late 2018 PCE and TCE concentrations in RFR-11 rose above the MCL for the first time since 2007. This could be due to significant rainfall in the later part of the year or the ongoing ISCO treatment at AOC-65 near CSSAs southern border fence line. **Figure 2.8** shows PCE and TCE concentrations with monthly water usage at each off-post well. The off-post GAC systems are equipped with flowmeters that track the gallons of water treated by the units. Data in this figure suggests little correlation between VOC concentrations and well pumping volumes.

Table 2-8
2018 Off-post Groundwater Sampling Rationale

Well ID	2018 Mar	Jun	Sept	Dec	Sampling Frequency
FO-J1	NS	NS	NS	NS	30 month
I10-2	NS	NA	NA	NA	exclude after June-18; pump out
I10-8	NS	NS	NS	NS	30 month
I10-10	NS	NS		NS	15 month
JW-7	NS	NS	NS	NS	30 month
JW-8	NS	NS	NS	NS	30 month
JW-20		NS		NS	exclude after Mar-19
LS-5					Quarterly
LS-5-A2		NS		NS	Biannually (Mar & Sept)
LS-6					Quarterly
LS-6-A2		NS		NS	Biannually (Mar & Sept)
LS-7					Quarterly
LS-7-A2		NS		NS	Biannually (Mar & Sept)
OFR-3					Quarterly
OFR-3-A2		NS		NS	Biannually (Mar & Sept)
RFR-10					Quarterly
RFR-10-A2		NS		NS	Biannually (Mar & Sept)
RFR-10-B2		NS		NS	Biannually (Mar & Sept)
RFR-11					Quarterly
RFR-11-A2		NS		NS	Biannually (Mar & Sept)
RFR-12	NS	NS		NS	15 month
RFR-14	NS	NS	NS	NS	30 month

LTMO has excluded the following wells from the program:

-Dec. 2015: BSR-03, FO-8, FO-17, FO-22, HS-2, HS-3, I10-5, I10-7, JW-6, JW-9, JW-12, JW-13, JW-14, JW-15, JW-26, JW-27, JW-28, JW-29, JW-30, JW-31, OW-HH1, OW-CE1, OW-MT2, OW-DAIRYWELL, OW-HH3, RFR-3, RFR-4, RFR-5, RFR-8, RFR-9, RFR-13, SLD-01, and SLD-02. OW-HH3, RFR-3, RFR-4, RFR-5, RFR-8, RFR-9, RFR-13, SLD-01, and SLD-02.

-Sept. 2016: JW-5, OW-HH2, and OW-BARNOWL.

-Sept. 2017: BSR-04 and HS-1.

The following wells have been plugged and abandoned: I10-4, I10-9, LS-1, LS-4, OFR-1,

VOCs detected are greater than 90% of the MCL. Sample monthly; quarterly after GAC installation.

VOCs detected are greater than 80% of the MCL. The well will be placed on a monthly sampling schedule until GAC installation then quarterly sampling after GAC installation.

VOCs detected are less than 80% of the MCL (<4.0 ppb and >0.06 ppb for PCE & <4.0 ppb >0.05 ppb for TCE). After four quarters of stable results the well can be removed from quarterly sampling.

No VOCs detected. Sample on an as needed basis.

This well has a GAC filtration unit installed by CSSA. Post GAC samples are collected every six months.
A1 - after GAC canister #1
A2 - after GAC canister #2

NS
Not sampled for that event.

NA
Not applicable, sample could not be collected due to pump outage or well access conflict.

Table 2.9
2018 Off-Post Groundwater COCs Analytical Results

Well ID	Sample Date	*cis*-1,2-DCE (ug/L)	PCE (ug/L)	TCE (ug/L)	Vinyl chloride (ug/L)
I10-10	9/10/2018	--	--	--	--
JW-20	3/20/2018	--	--	--	--
	9/12/2018	--	--	--	--
LS-5	3/6/2018	--	**1.05F**	**3.56**	--
Duplicate	3/6/2018	--	**0.98F**	**3.33**	--
	6/6/2018	--	**1.02F**	**3.57**	--
	9/13/2018	--	**0.79F**	**2.59**	--
	12/3/2018	--	**0.77F**	**3.10**	--
LS-5-A2	3/6/2018	--	--	--	--
	9/13/2018	--	--	--	--
LS-6	3/6/2018	--	**0.85F**	**2.4**	--
	6/6/2018	--	**0.61F**	**1.91**	--
	9/13/2018	--	**0.66F**	--	--
	12/3/2018	--	**0.87F**	--	**0.34F**
LS-6-A2	3/6/2018	--	--	--	--
	9/13/2018	--	--	--	--
LS-7	3/6/2018	--	**1.7**	**0.58F**	--
	6/6/2018	--	**1.43**	**0.53F**	--
	9/13/2018	--	**1.04F**	--	--
	12/3/2018	--	--	--	--
LS-7-A2	3/6/2018	--	--	--	--
	9/13/2018	--	--	--	--
OFR-3	3/6/2018	--	**4.79**	**2.85**	--
	6/6/2018	--	**4.78**	**3.85**	--
	9/13/2018	--	**2.30**	**1.72**	--
Duplicate	9/13/2018	--	**2.32**	**1.72**	--
	12/3/2018	--	--	--	--
OFR-3-A2	3/6/2018	--	--	--	--
	9/13/2018	--	--	--	--
RFR-10	3/6/2018	--	**8.22**	**4.51**	--
	6/6/2018	--	**10.84**	**6.1**	--
	9/13/2018	--	**4.45**	**2.6**	--
Duplicate	9/13/2018	--	**4.52**	**2.73**	--
	12/3/2018	--	**4.12**	**2.42**	--
RFR-10-A2	3/6/2018	--	--	--	--
	9/13/2018	--	--	--	--
RFR-10-B2	3/6/2018	--	--	--	--
	9/13/2018	--	--	--	--
RFR-11	3/6/2018	--	**0.69F**	**2.25**	--
	6/6/2018	--	**0.70F**	**2.25**	--
	9/13/2018	--	**3.06**	--	--
	12/3/2018	--	**8.73**	**4.96**	--
RFR-11-A2	3/6/2018	--	--	--	--
	9/13/2018	--	--	--	--
RFR-12	9/10/2018	--	**0.22F**	**0.82F**	--
Comparison Criteria					
Maximum Contaminant Level (MCL)		**70**	**5.0**	**5.0**	**2.0**
Reporting Limit (RL)		**1.2**	**1.4**	**1.0**	**1.1**
Method Detection Limit (MDL)		**0.07**	**0.06**	**0.05**	**0.08**

Bold (red)	Value ≥ MCL
Bold (blue)	MCL > Value ≥ RL
Bold	RL > Value > MDL

All samples were analyzed by APPL, Inc. using method SW8260B.
VOC data reported in ug/L & metals data reported in mg/L.

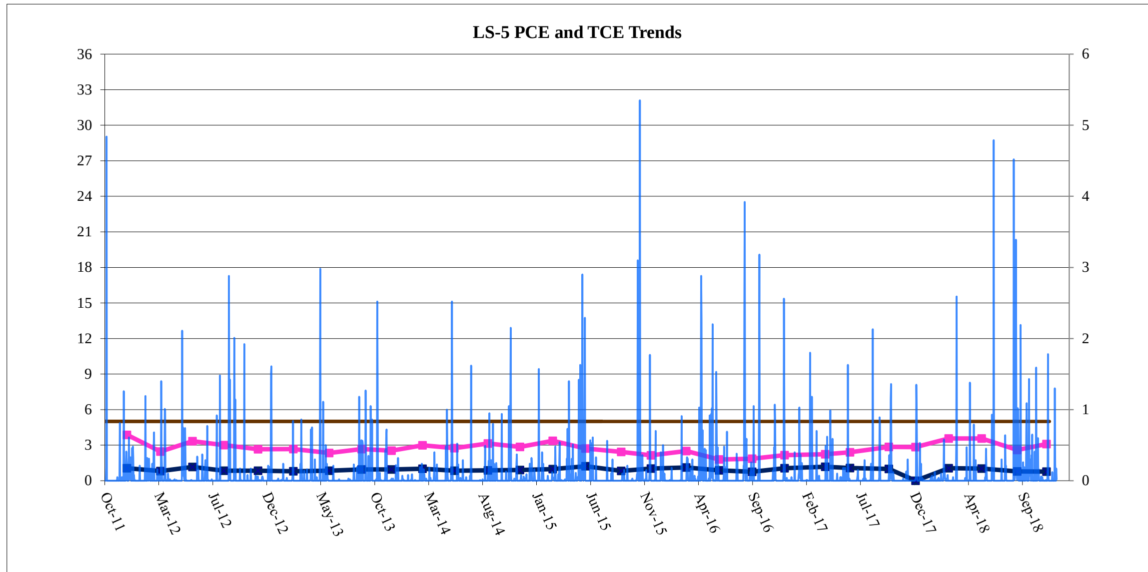
Abbreviations/Notes:

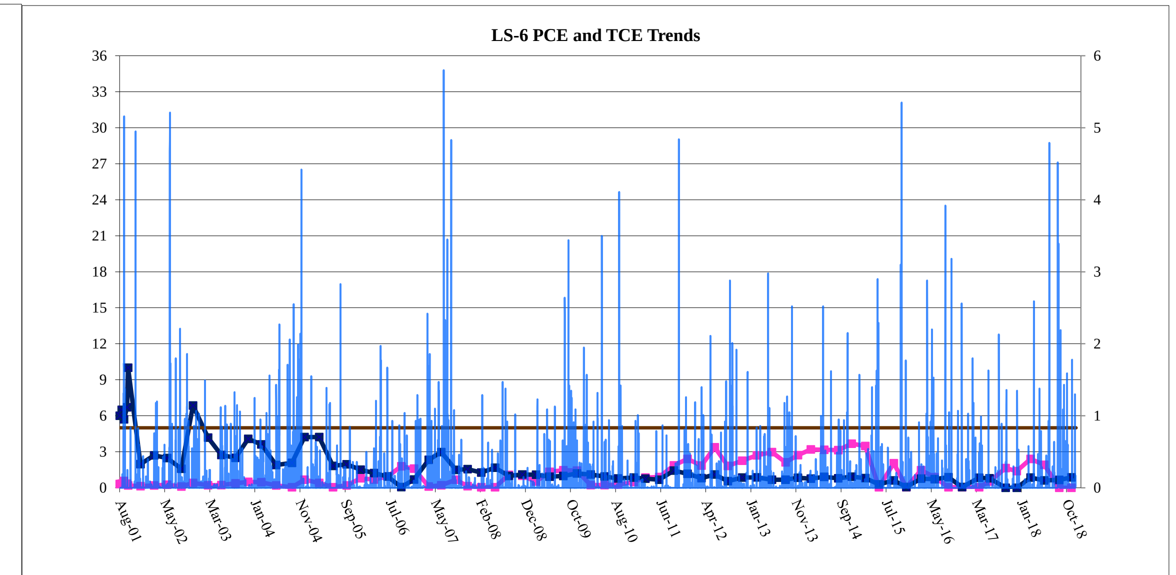
Duplicate	Field Duplicate
TCE	Trichloroethene
PCE	Tetrachloroethene
DCE	Dichloroethene

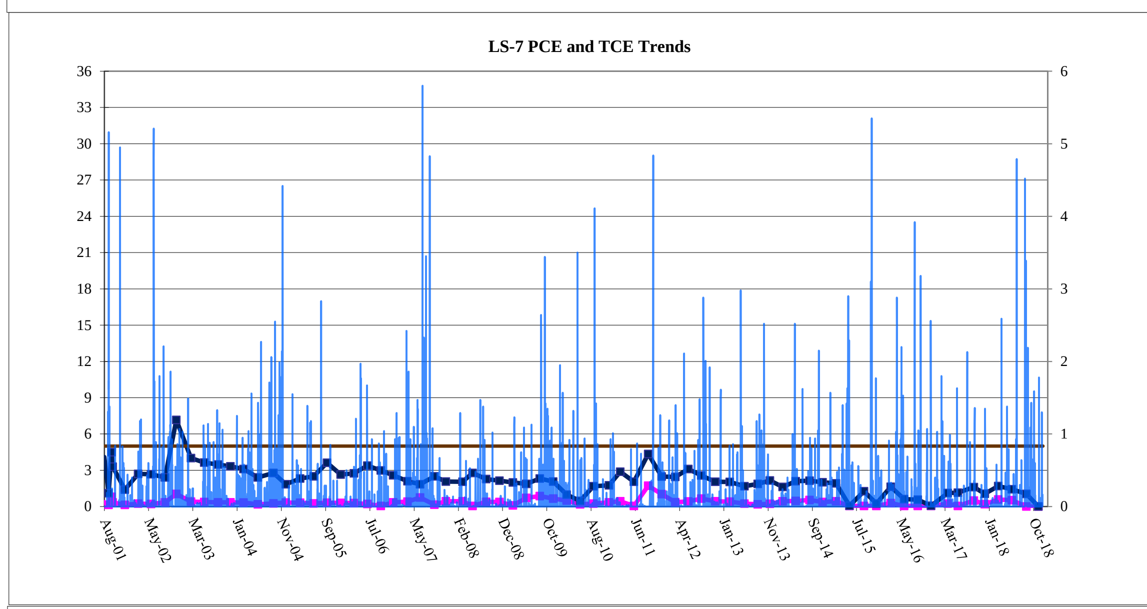
Data Qualifiers

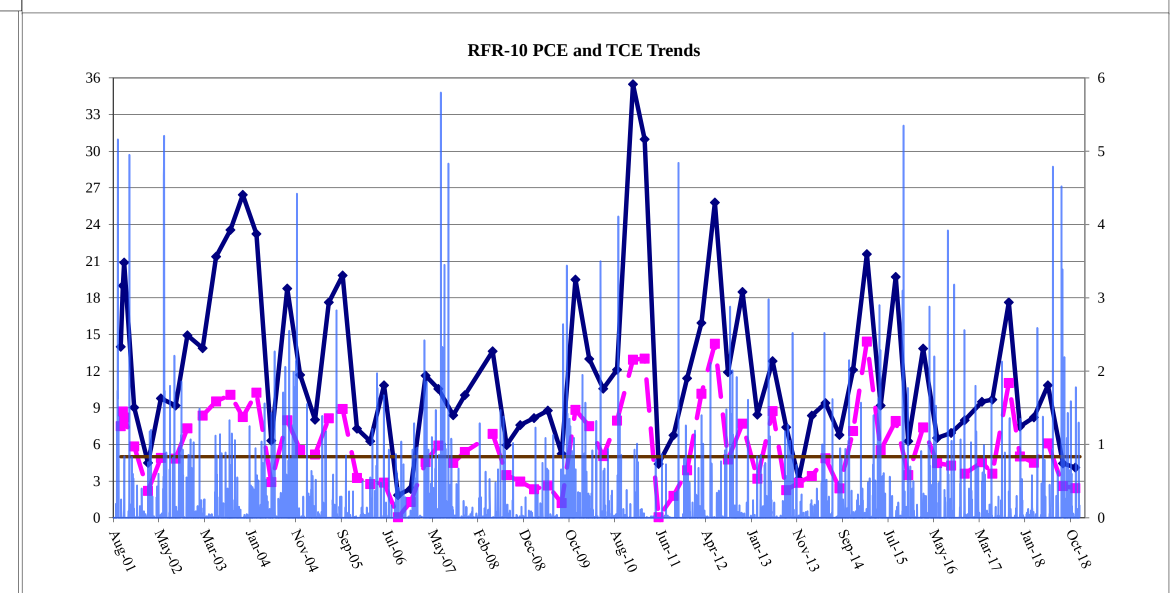
-- = The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.
F = The analyte was positively identified but the associated numerical value is below the RL.

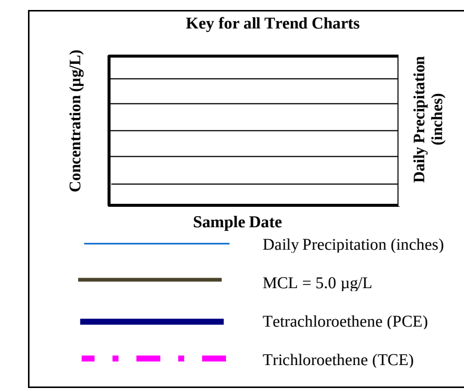
Figure 2.7
PCE and TCE Concentration Trends and Precipitation

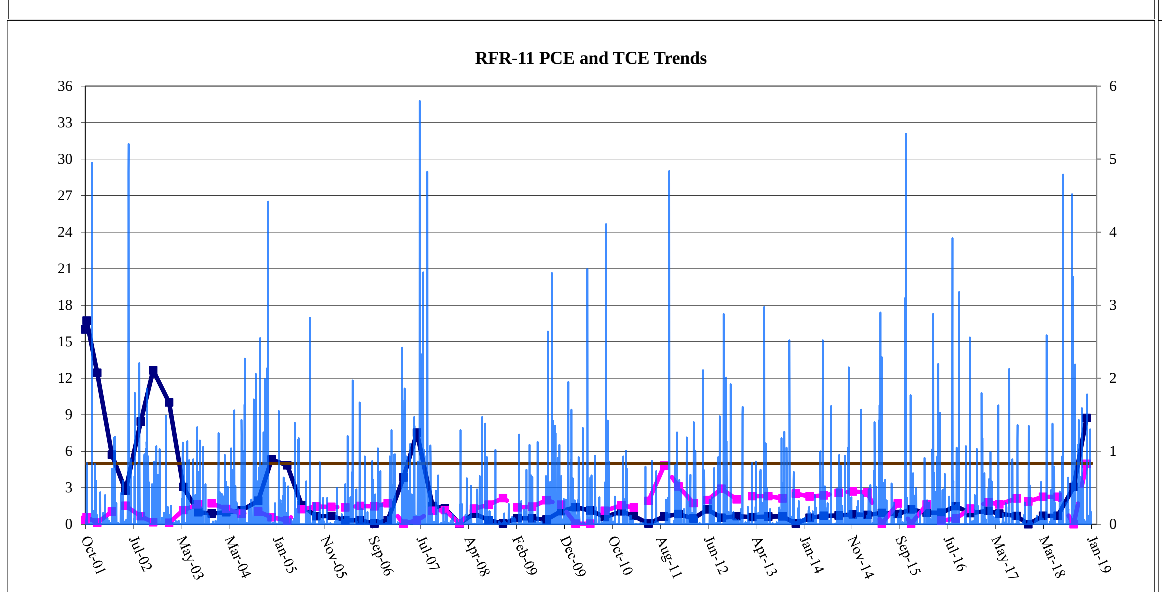












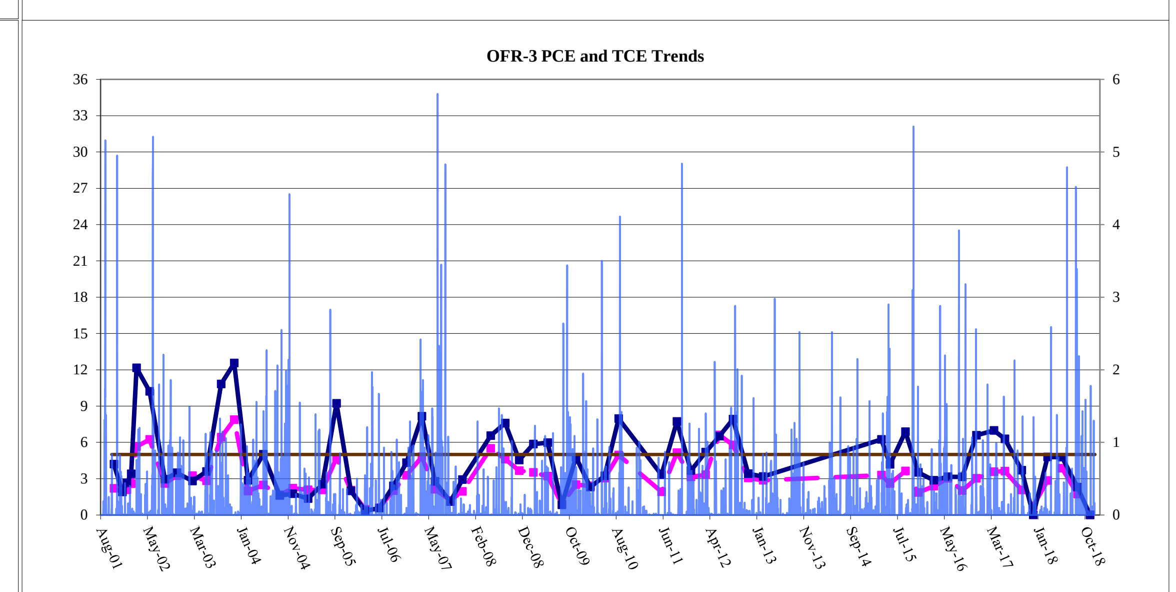
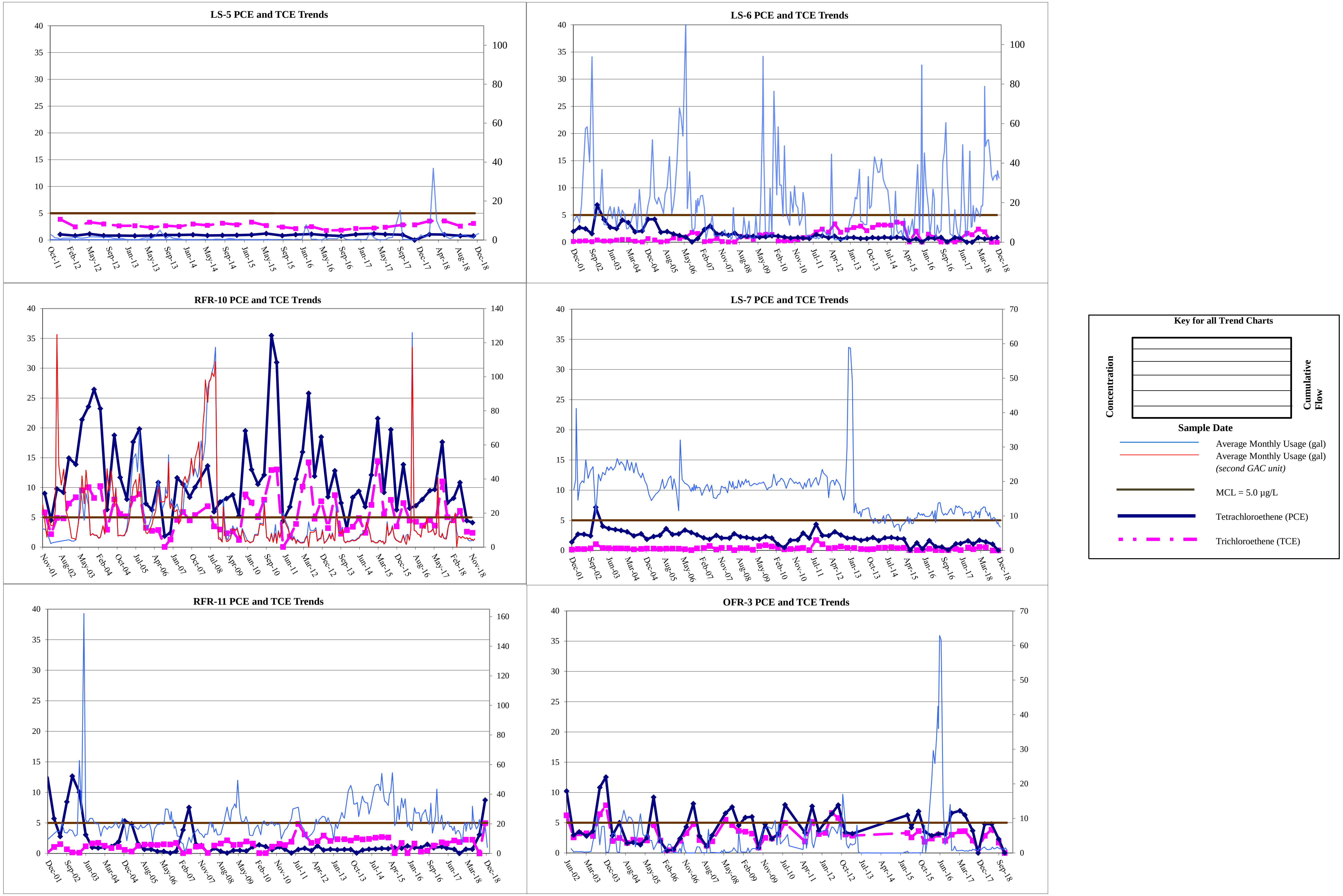


Figure 2.8
PCE and TCE Concentration Trends and Monthly Water Usage



2.2.2.1 Off-Post Wells with COC Detections above the MCL

During 2018, off-post wells RFR-10 and RFR-11 had raw water (pre-GAC) concentrations exceeding the MCL. Well RFR-10 concentrations exceeded the MCL for PCE during March and June 2018 sampling events and TCE also exceeded the MCL during the June event. Well RFR-11 exceeded the MCL for PCE during the December event. An evaluation of concentration trends through 2018 are included in **Figures 2.7 and 2.8**.

2.2.2.2 GAC Filtration Systems

All off-post drinking water wells that historically exceeded or approached MCLs have already been equipped with GAC filtration systems. These wells, and the date the filtration system was installed, are listed in **Table 2.10**. CSSA maintains and operates these GAC filtration systems at no cost or inconvenience to the well owners.

Table 2.10 GAC Filtration Systems Installed

Well	Date Installed
LS-6	August 2001
LS-7	August 2001
OFR-3	April 2002
RFR-10	October 2001
RFR-11	October 2001
LS-5	October 2011

Semi-annual post-GAC confirmation samples are collected from all wells equipped with GAC filtration systems (**Appendix G**). The samples confirm that the GAC filtration systems are working effectively and that VOCs are reduced to concentrations below the applicable drinking water MCLs.

Regular GAC maintenance/inspection occurs every 3 weeks. This task includes changing pre-filters and troubleshooting problems occurring with the systems. On March 5, 2018 and September 12, 2018, the carbon in the GAC filtration systems (LS-5, LS-6, LS-7, RFR-10, OFR-3, and RFR-11) was changed out.

2.2.2.3 Off-Post Wells with COC Detections below the MCL

Detections from all wells sampled off-post are presented in **Table 2.9** and complete 2018 results are included in **Appendix G**. The groundwater monitoring results include wells where COCs were detected at levels below applicable MCLs. These detections occurred in wells LS-5, LS-6, LS-7, and OFR-3. The detections below the MCL and above the RL are summarized as follows:

- **LS-5** – Concentration of TCE exceeded the RL in March, June, September, and December 2018. PCE was also detected below the RL during all four sampling events. This well is equipped with a GAC filtration system.
- **LS-6 –** Concentrations of TCE were above the RL in March and June and non detect in September and December 2018. PCE was detected in March, June, September, and

December as well but below the RL. Vinyl chloride was detected in December, also below the RL. This well is equipped with a GAC filtration system.

- **LS-7 –** Concentrations of PCE exceeded the RL in March and June 2018, fell below the RL in September and then non-detect in the December sampling event. Concentrations of TCE were also present in March and June but below the RL. This well is equipped with a GAC filtration system.
- **OFR-3 –** Concentrations of PCE and TCE were above the RL in the March, June, and September sampling events. No VOC detections were reported in December. This well is equipped with a GAC filtration system.

2.2.2.4 Off-Post Wells with COC Detections below the Reporting Limits

The off-post results include detections in wells for which the analyte is identified, but at a concentration below the RL. These results are assigned an "F" flag under the CSSA QAPP. In 2018, this included well RFR-12. The detections below the reporting limit are summarized as follows:

- **RFR-12 –** Concentrations of PCE and TCE detected below the RL in September 2018.

2.2.3 Isoconcentration Mapping

2.2.3.1 PCE, TCE, and cis-1,2-DCE

In annual reports prior to 2010, the maximum concentration detected during any quarterly event in the LGR wells (on-post and off-post) were contoured into isoconcentration contour maps for PCE, TCE, and *cis*-1,2-DCE. The reason for creating these "composite" maps resulted from the LTMO sampling frequency enacted in 2005. No single quarterly event included all of the wells in the sampling program. The LTMO program was updated in 2010 to include a "snapshot" sampling event in which all on- and off-post wells were sampled during the same event. These snapshot events began in September 2010, and occurred every 9 months. The 2015 update to the LTMO provides for a complete snapshot every 30 months with less inclusive events occurring every 15 months. The transition from the old to the new LTMO schedule began in late 2015 and was fully implemented in June of 2017 with the completion of the first 30-month snapshot event. Results from the September 2018 15-month event were utilized in generating plume isoconcentration contour maps.

Another development in the representation of contamination in groundwater came in March 2012. At the direction of the USEPA (**Appendix J**), isoconcentration maps depicting groundwater contamination will no longer present isoconcentration contour lines below the laboratory RL, which is considered quantifiable data. Trace detections of contamination (F-flagged) data reported by the lab are considered qualitative results and therefore are not suitable for demonstrating the extent of contaminant plumes. Results below the RL are still presented on the maps, but are not contained within an isoconcentration contour line. For the compounds reported, the RL (and lowest isoconcentration line) are as follows: *cis*-1,2-DCE (1.2 µg/L), PCE (1.4 µg/L), and TCE (1.0 µg/L).

To better represent the plume source areas, data from the Westbay wells were composited into the isoconcentration maps. Previously, only data from the deepest LGR zone were included in the isoconcentration maps, though, these data do not reflect the range of VOC concentrations observed in all zones within the LGR at each well. In Westbay wells CS-WB01 through CS-WB03 there are nine discrete sampling zones within the LGR and ten LGR zones in CS-WB04. Utilizing the highest concentration observed from any of the LGR zones in a single Westbay well is a more conservative approach to defining plume geometries. As an example, WB03 is located near the suspected source area at AOC-65. Typically, the PCE concentrations observed in the lowest zone (LGR-09) is less than 5 ppb (below the MCL), while zones LGR-05, -04, -02, and -01 all indicate the presence of PCE at or above the MCL. All zones of Westbay wells 01 through 04 have been incorporated in the groundwater monitoring program and are sampled according to the recommendations from the latest LTMO and all LGR zones scheduled were sampled in September of 2018 except for dry zones: LGR-01 and LGR-02 zones in CS-WB03. Data from all LGR zones from Westbay wells CS-WB01 through CS-WB04 sampled in September 2018 was reviewed, and the highest concentrations recorded for each well are included in the maps to help delineate Plume 2. The inclusion of data from zones other than LGR-09 does not appreciably affect the overall plume footprint, however, it does help define the core of the plume. The bioreactor extraction wells and LGR-04 zone of Westbay wells CS-WB05 through CS-WB08 were sampled in June 2018 as part of the SWMU B-3 Bioreactor operations and assist in delineating the central portion of Plume 1. The September 2018 isoconcentration maps are provided as **Figures 2.11, 2.12, and 2.13** and illustrate the extent of contamination as measured and inferred from analytical results.

The extent of COCs above the RL (approximately 1 µg/L) for each of PCE, TCE and *cis*-1,2-DCE can be determined by reviewing the set of figures generated for September 2018. 2018 PCE concentrations above 1.4 µg/L are detected on-post in wells CS-D, CS-MW1-LGR, CS-MW8-LGR, CS-MW10-LGR, CS-MW36-LGR, CS-B3-EXW01, B3-EXW02, B3-EXW-03, B3-EXW-04, and B3-EXW05. Additionally, in CS-WB01, zones LGR-01, LGR-02, LGR-03, LGR-07, and LGR-09; in CS-WB02, zones LGR-02, LGR-04, and LGR-09; in CS-WB03, zones LGR-03, LGR-04, LGR-05, LGR-07, and LGR-09; in CS-WB04, zones LGR-06, LGR-07, LGR-09, and LGR-10 and in the LGR-04 zones at wells CS-WB05 through CS-WB08 all indicated concentrations above the PCE RL of 1.4 µg/L (**Figure 2.11**). Off-post detections of PCE above 1.4 µg/L include OFR-3, RFR-10, RFR-11 and CS-WB04 zones LGR-06, LGR-07, -LGR-09, and -LGR-10.

TCE follows a similar pattern in September 2018 and has been detected above 1.0 µg/L in Plume 1 wells CS-D, CS-MW1-LGR, CS-MW5-LGR, CS-B3-EXW01, B3-EXW02, B3-EXW-03, B3-EXW-04, B3-EXW05, CS-MW16-LGR, and the LGR-04 zones from CS-WB05 through CS-WB08; and in Plume 2 wells CS-MW-36-LGR and CS-WB01 zones LGR-02, LGR-03, LGR-06, LGR-07, LGR-08, and LGR-09; CS-WB02 zones LGR-04, LGR-05, LGR-06, LGR-07, and LGR-09; and CS-WB03 zones LGR-04, LGR-05, LGR-07, and LGR-09 (**Figure 2.12**). Off-post wells with a TCE concentration reported above 1.0 µg/L include wells LS-5, OFR-3, RFR-10, RFR-11 and CS-WB04 zones -LGR-06, -LGR-07, -LGR-08, and -LGR-09.

In September 2018, *cis*-1,2-DCE was reported at levels above 1.2 µg/L in on-post wells CS-D, CS-MW1-LGR, CS-MW5-LGR, CS-B3-EXW01 through CS-EXW05 and CS-MW16-LGR and the LGR-04 zones of CS-WB05 through CS-WB08, and in CS-WB01-LGR-08, CS-WB02-LGR-08, and CS-WB03 zones LGR-05, LGR-06, -LGR-07, and -LGR-08. Off-post wells with a *cis*-1,2-DCE concentration reported above 1.2 µg/L only included Westbay well CS-WB04 zones -LGR-06, and -LGR-07 (**Figure 2.13**).

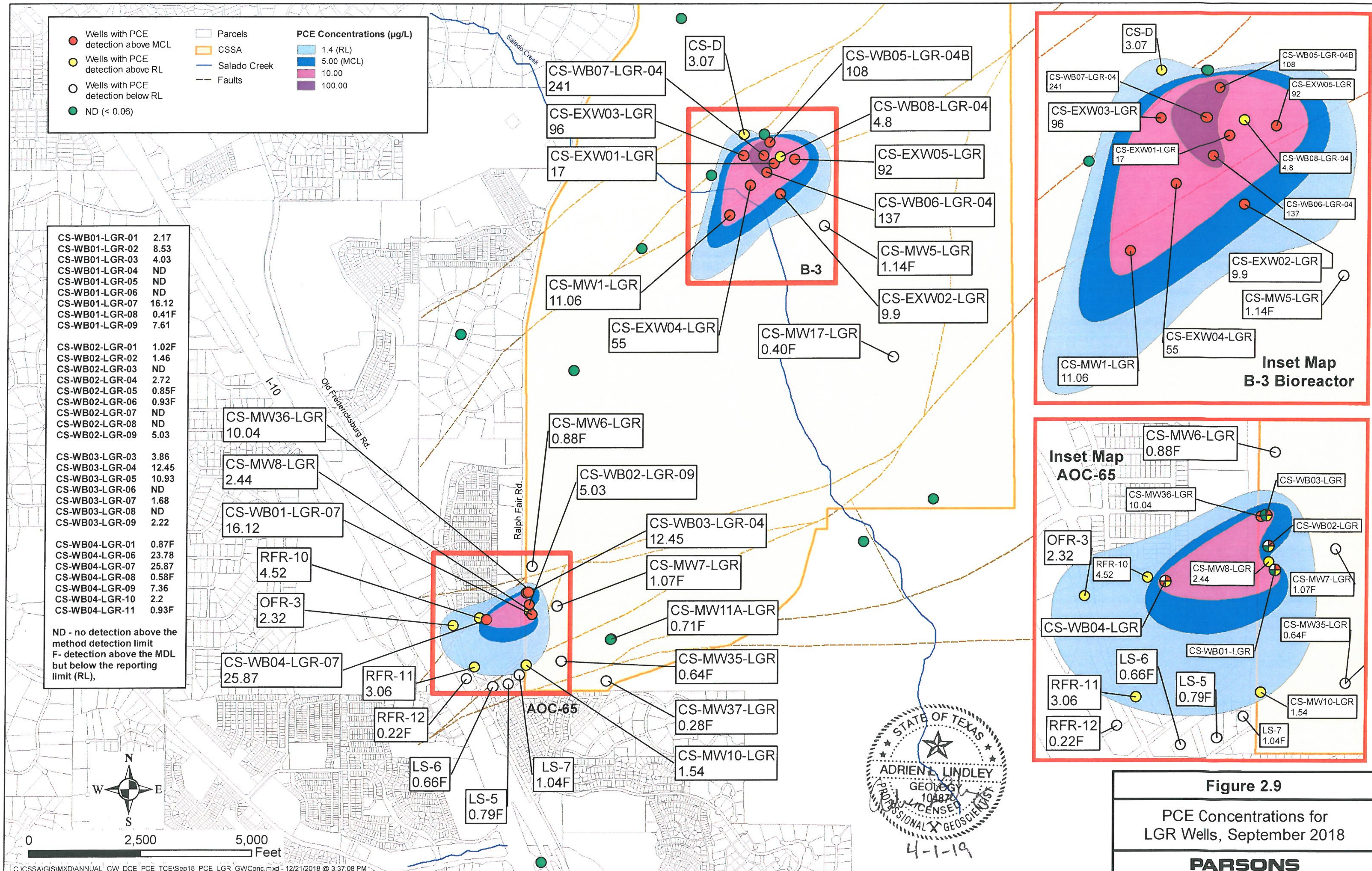


Figure 2.9

PCE Concentrations for LGR Wells, September 2018

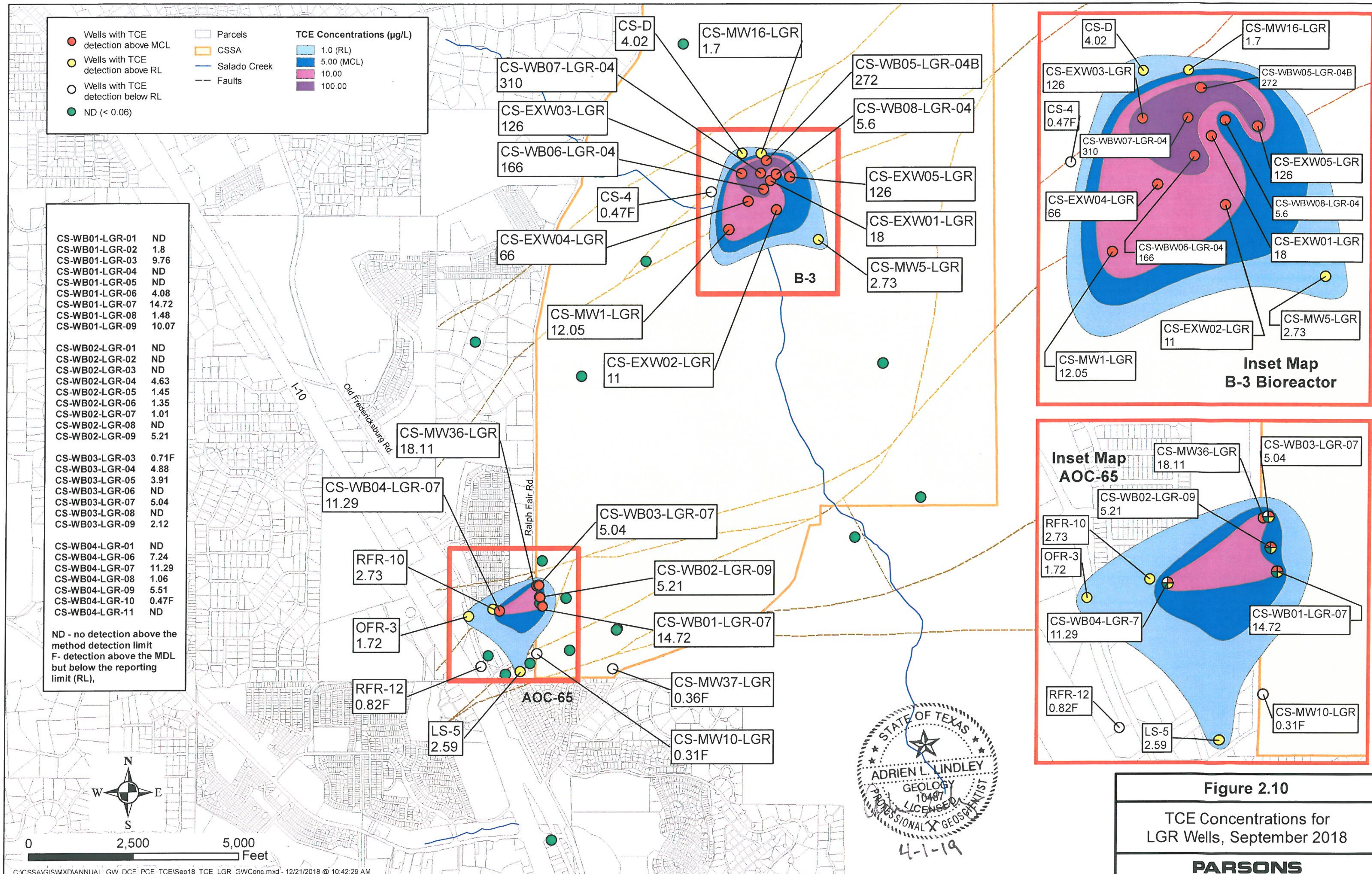


Figure 2.10

TCE Concentrations for LGR Wells, September 2018

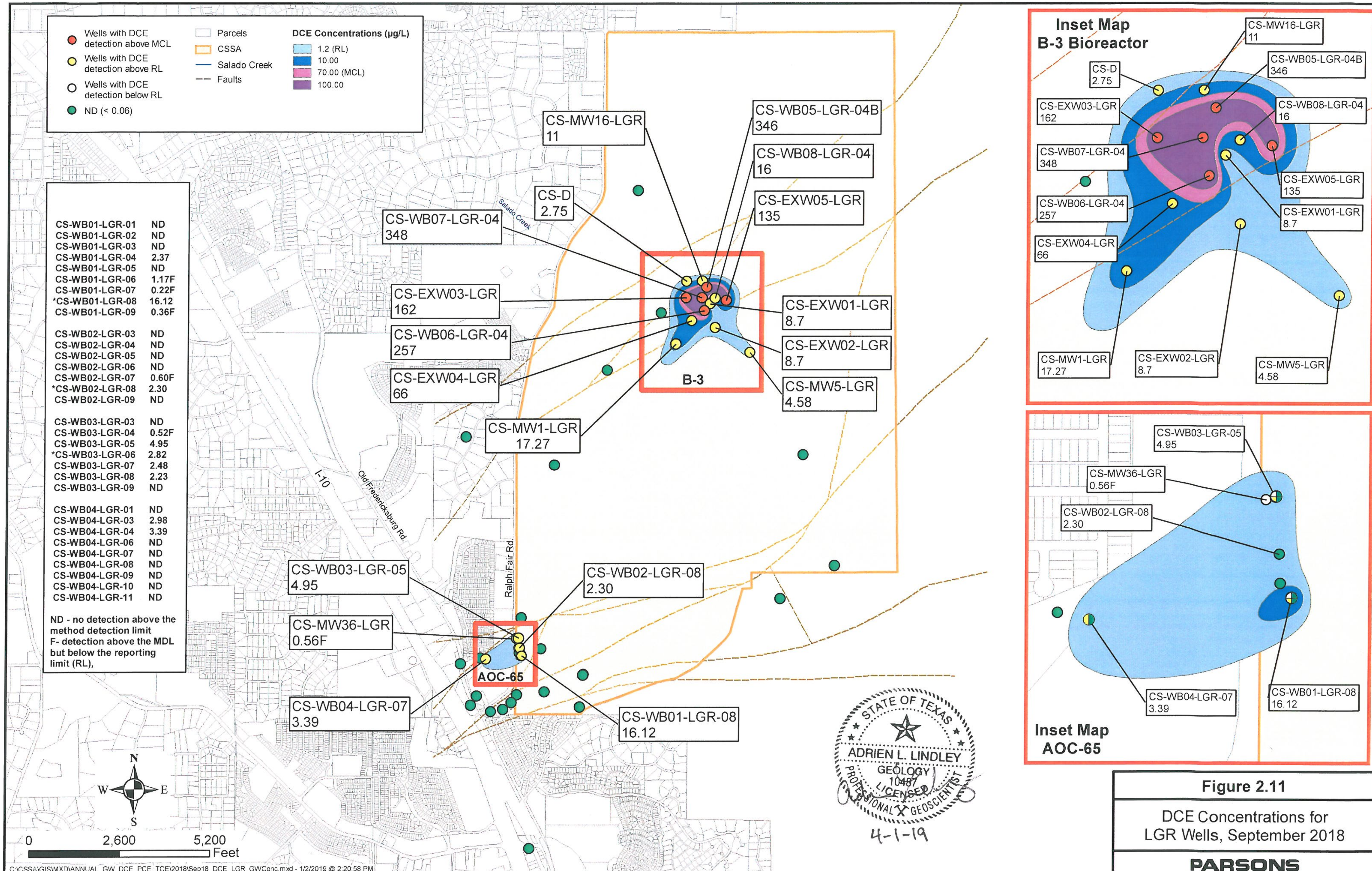


Figure 2.11

DCE Concentrations for LGR Wells, September 2018

Isoconcentration maps have also been prepared based on analytical data collected in 2006 through 2016. Those isoconcentration maps are available for review in the ***CSSA Environmental Encyclopedia, Volume 5 Groundwater***, in the *2006 through 2017 Annual Groundwater Reports*. In general, the 2018 plume extent is consistent with 2017 data and the geometry has changed slightly, accounting for the highest recorded concentrations in LGR zones.

Finally, the maximum annual concentrations detected near the LGR plume centers are generally stable in comparison to 2017. At Plume 1, VOC concentrations have slightly decreased at upgradient well CS-D, cross-gradient well CS-B3-EXW04, and down gradient wells CS-B3-EXW02, CS-MW1-LGR, and CS-MW5-LGR and increased at cross-gradient wells CS-B3-EXW03 and CS-B3-EXW05. Within Plume 2, the VOC concentrations have slightly decreased in well RFR-10 and decreased to non-detections at OFR-3 (downgradient off-post) and increased in CS-MW36-LGR (source area). Shallower source area monitoring points have noted increases in VOC concentrations at CS-WB03 and decreases in VOC concentrations at CS-WB02, presumably in response to the remedial efforts associated with the ISCO remedial actions or other hydrogeologic conditions (precipitation). See **Table 2.11** for comparison of the 2017 and 2018 data near the plume centers.

Table 2.11 Comparison of 2017 & 2018 PCE, TCE, and cis-1,2-DCE Max. Levels

	PCE		TCE		*cis*-1,2-DCE	
	2017	*2018*	*2017*	*2018*	*2017*	*2018*
B-3 Plume 1						
CS-D	5.32	3.07	6.56	4.02	4.47	2.75
CS-MW1-LGR	13.98	11.06	24.73	12.05	20.49	17.27
CS-4	0.61	ND	0.22	0.47	ND	ND
AOC-65 Plume 2						
RFR-10	17.63	10.84	11.03	6.1	0.37	ND
CS-MW36-LGR	5.43	10.04	4.20	18.11	ND	0.56
CS-WB02-LGR-09	7.14	5.03	6.82	5.21	ND	ND
CS-WB03-UGR-01	9,356	10,368	103.64	150	9.56	10.53

3.0 GROUNDWATER MONITORING PROGRAM CHANGES

3.1 Access Agreements Obtained in 2018

Access agreements are signed by off-post well owners to grant permission to CSSA to collect groundwater samples from each well. Well I10-10 returned an updated access agreement June 6, 2018. All other wells retained after the 2015 update to the LTMO study and DQO's have current access agreements in place.

3.2 Wells Added to or Removed From Program

Based on the 2015 update to the LTMO study and DQO's for the groundwater monitoring program 1 well was scheduled to be excluded from the program based on their history of non-detects. However, well I10-2 has experienced a pump outage since September 2016. CSSA would like to collect one final sample from this well before excluding it from the program. After contacting the well owner there are no plans to repair the I10-2 pump in the near future.

Well JW-20 will meet the 5 years of non-detect criteria in March 2019.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the evaluation of the on- and off-post groundwater monitoring program data collected in 2018, the following conclusions and recommendations can be made:

- On-post wells CS-MW1-LGR and CS-MW36-LGR all exceeded VOC MCLs in 2018 and should remain on the sampling schedule in the future.
- The four current drinking water wells had no metals detections above the MCL, SS, or AL in 2018.
- Twelve Westbay intervals had detections above the MCL in 2018. These intervals should remain on the 15-month sampling schedule in the future as recommended in the LTMO study.
- The Westbay wells at AOC-65 continue to indicate the strong presence of contamination near the source area (CS-WB03). Significant contamination above the MCLs continues to exist near-surface and in the lower-yielding upper strata of aquifer. The concentrations in the upper WB03-UGR-01 zone increased significantly in September 2012, likely due to the ISCO injection into the AOC-65 trench performed in August 2012. In May-June 2013, a larger scale ISCO injection was performed and the levels in this upper zone remained elevated. In September-October 2014, an even larger ISCO injection was performed and the VOC concentrations showed a steep decline in some intervals of the aquifer by December 2014. From August-September 2015 a smaller injection was performed using permanganate and injecting into newly installed infiltration cells in the road west of Building 90. This in turn significantly increased concentration in the upper WB03-UGR-01 zone. In December 2016 permanganate paraffin wax cylinders were installed in 6 select wells at AOC-65. The cylinders are infused with solid permanganate crystals which allow the permanganate to be released passively. This method allows permanganate treatment of groundwater under various (flood or drought) conditions. The 2017 and 2018 results indicate contamination levels remain steady. In October 2018 four additional candles were added to select wells. Future sampling results will determine the effectiveness of the slow release treatment. In most cases throughout the post, VOC contamination in the main portion of aquifer remains at concentrations below the MCLs.
- Off-post wells RFR-10 and RFR-11 exceeded the MCL for PCE and/or TCE in 2018. Wells OFR-3, RFR-10, LS-5, LS-6, LS-7, and RFR-11, are equipped with a GAC filtration system and should remain on the quarterly sampling schedule in the future. The GAC filtration systems will continue to be maintained by CSSA.
- **Figure 2.7** shows VOC concentrations in RFR-10 and OFR-3 are very sensitive to rainfall events while VOC concentrations in LS-5, LS-6, LS-7; and RFR-11 show less fluctuations after significant precipitation. This observation suggests RFR-10 and OFR-3 may be located along a fracture pattern that ties into the AOC-65 source area. PCE in well RFR-11 was above the MCL for the first time since 2007. This could be due to the above average rainfall in late 2018 and/or treatability study activities at AOC-65.

5.0 REFERENCES

CSSA 2002. *CSSA Quality Assurance Program Plan.*

CSSA 2002a. *Off-Post Monitoring Program and Response Plan.*

CSSA 2008. *CSSA Environmental Encyclopedia*, www.stanley.army.mil

Parsons 2001. *Offsite Well Survey Report*.

Parsons 2005. *Final Three-Tiered Long Term Monitoring Network Optimization Evaluation.*

Parsons 2006. *Final Data Quality Objectives for the Groundwater Monitoring Program.*

Parsons 2010. *Updated Off-Post Well Survey Report*.

Parsons 2016a. *Final Data Quality Objectives for the Groundwater Monitoring Program. Revised January 2016.*

Parsons 2016b. *2015 Update: Final Three-Tiered Long Term Monitoring Network Optimization Evaluation.*

NOAA, National Weather Service Forecast, Monthly/Annual/Average Precipitation Boerne and San Antonio (KSAT), Texas (1989 - 2018), http://nowdata.rcc-acis.org/ewx/

APPENDIX A

EVALUATION OF DATA QUALITY OBJECTIVES ATTAINMENT

ON-POST AND OFF-POST

Appendix A. On-Post Evaluation of Data Quality Objectives Attainment

Activity	Objectives	Action	Objective Attained?	Recommendations
Field Sampling	Conduct field sampling in accordance with procedures defined in the project work plan, SAP, QAPP, and HSP.	All sampling was conducted in accordance with the procedures described in the project plans.	Yes.	NA
Characterization of Environmental Setting (Hydrogeology)	Prepare water-level contour and/or potentiometric maps for each formation of the Middle Trinity Aquifer (3.5.3).	Potentiometric surface maps were prepared based on water levels measured in each of CSSA's wells screened in three formations in 2018.	To the extent possible with data available. Due to the limited data available and the fact that wells are completed across multiple water-bearing units, potentiometric maps should only be used for regional water flow direction, not local. Ongoing pumping in the CSSA area likely affects the natural groundwater flow direction.	As additional wells are installed screened in distinct formations, future evaluations will eliminate reliance on wells screened across multiple formations.
	Describe the flow system, including the vertical and horizontal components of flow (2.1.9).	Potentiometric maps were created using 2018 water level data, and horizontal flow direction was tentatively identified. Insufficient data are currently available to determine vertical component of flow.	As described above, due to the lack of aquifer-specific water level information, potentiometric surface maps should only be used as an estimate of regional flow direction.	Same as above.
	Define formation(s) in the Middle Trinity Aquifer are impacted by the VOC contaminants (2.1.3).	Quarterly groundwater monitoring provides information on Middle Trinity Aquifer impacts. Monitoring wells equipped with Westbay® - multi-port samplers are sampled by zone, the LGR zones are sampled every 15 months and the BS and CC zones are sampled every 30 months. Selected zones from these wells were sampled in 2018.	Yes.	Continue sampling.

Activity	Objectives	Action	Objective Attained?	Recommendations
	Identify any temporal changes in hydraulic gradients due to seasonal influences (2.1.5).	Downloaded data from continuous-reading transducer in wells: CS-MW4-LGR, CS-MW9-LGR, CS-MW12-LGR, CS-MW12-CC, and CS-MW10-CC. Data was also downloaded from the northern and southern continuous-reading weather stations B-3 WS and AOC-65 WS. Water levels will be graphed from selected wells against precipitation through 2018 and will be included in this annual groundwater report.	Yes.	Continue collection of transducer data and possibly install transducers in other cluster wells.
Contamination Characterization (Groundwater Contamination)	Characterize the horizontal and vertical extent of any immiscible or dissolved plume(s) originating from the Facility (3.1.2).	Samples for laboratory analysis were collected from 20 of 47 CSSA wells. All 33 samples scheduled to be collected in 2018 were collected.	The horizontal and vertical extent of groundwater contamination is continuously monitored.	Continue groundwater monitoring and construct additional wells as necessary.
	Determine the horizontal and vertical concentration profiles of all constituents of concern (COCs) in the groundwater that are measured by USEPA-approved procedures (3.1.2). COCs are those chemicals that have been detected in groundwater in the past and their daughter (breakdown) products.	Samples were analyzed for the selected VOCs using USEPA method SW8260B. Drinking water wells were also sampled for metals (As, Ba, Cr, Cu, Cd, Hg, Pb, Zn). Analyses were conducted in accordance with the AFCEE QAPP and approved variances. All RLs were below MCLs, as listed below: **ANALYTE** / **RL (µg/L)** / **MCL (µg/L)** *cis*-1,2-DCE / 1.2 / 70 Vinyl Chloride / 1.1 / 2 PCE / 1.4 / 5 TCE / 1.0 / 5	Yes.	Continue sampling.

Activity	Objectives	Action	Objective Attained?	Recommendations
Contamination Characterization (Groundwater Contamination) (Continued)		**ANALYTE** / **RL (µg/L)** / **MCL (µg/L)** Arsenic / 30 / 10 Barium / 5 / 2000 Chromium / 10 / 100 Copper / 10 / 1300 (AL) Zinc / 50 / 5000 (SS) Cadmium / 7 / 5 Lead / 25 / 15 (AL) Mercury / 1 / 2		
	Meet AFCEE QAPP quality assurance requirements.	Samples were analyzed in accordance with the CSSA QAPP and approved variances. Parsons chemists verified all data and performed data validation according to the CSSA QAPP and approved variances.	Yes.	NA
		All data flagged with a "U", "J", "M", and "F" are usable for characterizing contamination. All "R" flagged data are considered unusable.	Yes.	NA
		An MDL study for arsenic, cadmium, and lead was not performed within a year of the analyses, as required by the AFCEE QAPP.	The laboratory performed new MDL studies in February 2001 for these metals and the new MDL values were found to be almost identical to the previous MDLs and all met the associated AFCEE QAPP requirements. MDLs for these three metals are well below MCLs. In addition, the laboratory performed daily calibrations and RL verifications for these metals, both of which demonstrate the laboratory's ability to detect and quantitate these metals at RL levels. These daily analyses also indicate that concentrations above the laboratory RL for these compounds were not affected by the expired MDL study.	Use results for groundwater characterization purposes.

Activity	Objectives	Action	Objective Attained?	Recommendations
Remediation	Determine goals and create cost-effective and technologically appropriate methods for remediation (2.2.1).	Continued data collection will provide analytical results for accomplishing this objective.	Ongoing.	Continue sampling and evaluation, including quarterly groundwater monitoring teleconferences to address remediation.
	Determine placement of new wells for monitoring (2.3.1, 3.6)	Sampling frequency and sample locations to be monitored (including any new wells) will be based on trend data from monitoring event(s) (3.1.5).	Ongoing.	Continue quarterly groundwater teleconferences to discuss sampling frequency and placement of new monitor wells.
Project schedule/ Reporting	Produce a quarterly monitoring project schedule as a road map for sampling, analysis, validation, verification, reviews, and reports.	Prepare schedules and sampling guidelines prior to each quarterly sampling event.	Yes.	Continue sampling schedule preparation each quarter.

Appendix A Off-Post Evaluation of Data Quality Objectives Attainment

Activity	Objectives	Action	Objective Attained?	Recommendations
Field Sampling	Conduct field sampling in accordance with procedures defined in the project work plan, SAP, QAPP, and HSP.	All sampling was conducted in accordance with the procedures described in the project plans.	Yes	NA
Contamination Characterization (Groundwater Contamination)	Determine the potential extent of off-post contamination (§2.3.1 of the DQOs for the Groundwater Contamination Investigation, revised 2015).	Samples for laboratory analysis were collected from selected off-post public and private wells, which are located within a ½ mile radius of CSSA. Also, selected wells outside the ½ mile radius were sampled at the request of the EPA.	Partially	Continue sampling wells in accordance with the LTMO study recommendations. If significant changes are seen in contaminant concentrations then consider adding wells in the vicinity back to the sampling schedule to track any plume movement.
	Meet CSSA QAPP quality assurance requirements.	Samples were analyzed in accordance with the CSSA QAPP and approved variances. Parsons chemists verified all data and performed data validation according to the CSSA QAPP and approved variances.	Yes	NA
		All data flagged with a "U", "M", and "J" are usable for characterizing contamination.	Yes	NA

Activity	Objectives	Action	Objective Attained?	Recommendations
	Evaluate CSSA monitoring program and expand as necessary (§2.3.1 of the DQOs for the Groundwater Contamination Investigation, revised 2015). Determine locations of future monitoring locations.	Evaluation of data collected is ongoing and is reported in this annual groundwater report and will be reported in future quarterly groundwater reports. Additional information covering the CSSA monitoring program is available in Volume 5, CSSA Environmental Encyclopedia.	Yes	Continue data evaluation and quarterly teleconferences for evaluation of the monitoring program. Each teleconference/planning session covers expansion of the quarterly monitoring program, if necessary.
Project schedule/ Reporting	The quarterly monitoring project schedule shall provide a schedule for sampling, analysis, validation, verification, reviews, and reports for monitoring events off-post.	A schedule for sampling, analysis, validation, verification, data review and reports are provided in this annual groundwater report and will be reported in future quarterly groundwater reports. Additional information covering the CSSA monitoring program is available in Volume 5, CSSA Environmental Encyclopedia.	Yes	Continue quarterly and annual reporting to include a schedule for sampling, analysis, validation, verification, data review and data reports.

Activity	Objectives	Action	Objective Attained?	Recommendations
Remediation	Evaluate the effectiveness of GACs (§3.2.3) and install as needed (§3.2.5 both of the DQOs for the Groundwater Contamination Investigation, revised 2015).	Perform maintenance as needed. Install new GACs as needed.	Yes	Maintenance to the off-post GAC systems to be continued by Parsons' personnel approximately every 3 weeks. Semi annual (or as needed) maintenance to the off-post GAC systems by additional subcontractors to continue. Evaluations of future sampling results for installation of new GAC systems will occur as needed.

APPENDIX B

2018 QUARTERLY ON-POST GROUNDWATER ANALYTICAL RESULTS

Appendix B
2018 Quarterly On-Post Groundwater Monitoring Analytical Results, VOCs

Well ID	Sample Date	*cis*-1,2 DCE (ug/L)	PCE (ug/L)	TCE (ug/L)	Vinyl chloride (ug/L)	pH	Temp. (deg. C)	Specific Conductivity (mS)
						Field Measurements		
CS-1	3/14/2018	0.07U	0.06U	0.05U	0.08U	7.20	21.33	0.540
Duplicate	3/14/2018	0.07U	0.06U	0.05U	0.08U	7.20	21.33	0.540
	6/11/2018	0.07U	0.06U	0.05U	0.08U	7.26	22.22	0.546
	9/7/2018	0.07U	0.06U	0.05U	0.08U	7.17	21.92	0.542
	12/3/2018	0.07U	0.06U	0.05U	0.08U	7.16	21.79	0.588
CS-4	9/7/2018	0.07U	0.06U	**0.47F**	0.08U	6.91	21.37	0.539
CS-10	3/15/2018	0.07U	0.06U	0.05U	0.08U	7.15	21.85	0.721
	6/11/2018	0.07U	0.06U	0.05U	0.08U	7.17	23.10	0.593
	9/7/2018	0.07U	0.06U	0.05U	0.08U	7.15	23.10	0.494
	12/3/2018	0.07U	0.06U	0.05U	0.08U	7.23	22.26	0.597
CS-12	3/14/2018	0.07U	0.06U	0.05U	0.08U	7.23	22.08	0.532
	6/11/2018	0.07U	0.06U	0.05U	0.08U	7.22	22.15	0.519
Duplicate	6/11/2018	0.07U	0.06U	0.05U	0.08U	7.22	22.15	0.519
	9/7/2018	0.07U	0.06U	0.05U	0.08U	7.21	22.24	0.432
Duplicate	9/7/2018	0.07U	0.06U	0.05U	0.08U	7.21	22.24	0.432
	12/3/2018	0.07U	**1.83**	0.05U	0.08U	7.18	22.14	0.538
	1/10/2019	0.07U	0.06U	0.05U	0.08U	7.17	22.08	0.526
CS-13	3/14/2018	0.07U	0.06U	0.05U	0.08U	7.27	21.77	0.703
	6/11/2018	0.07U	0.06U	0.05U	0.08U	7.25	23.37	0.687
	9/7/2018	0.07U	0.06U	0.05U	0.08U	7.24	22.86	0.562
	12/3/2018	0.07U	0.06U	0.05U	0.08U	7.23	21.99	0.690
Duplicate	12/3/2018	0.07U	0.06U	0.05U	0.08U	7.23	21.99	0.690
CS-D	9/6/2018	**2.75**	**3.07**	**4.02**	0.08U	7.13	22.39	0.491
CS-MW1-LGR	9/6/2018	**17.27**	**11.06**	**12.05**	0.08U	7.09	21.64	0.536
CS-MW5-LGR	9/6/2018	**4.58**	**1.14F**	**2.73**	0.08U	7.04	22.48	0.500
CS-MW6-LGR	9/5/2018	0.07U	**0.88F**	0.05U	0.08U	6.92	22.84	0.608
CS-MW7-LGR	9/5/2018	0.07U	**1.07F**	0.05U	0.08U	6.84	22.62	0.674
CS-MW8-LGR	9/5/2018	0.07U	**2.44**	0.05U	0.08U	7.03	22.71	0.640
CS-MW8-CC	9/5/2018	0.07U	0.06U	0.05U	0.08U	7.17	22.51	0.830
CS-MW10-LGR	9/5/2018	0.07U	**1.54**	**0.31F**	0.08U	6.81	23.36	0.653
CS-MW11A-LGR	9/5/2018	0.07U	**0.71F**	0.05U	0.08U	6.81	23.09	0.590
CS-MW11B-LGR	9/24/2018	0.07U	0.06U	0.05U	0.08U	6.97	22.27	0.543
CS-MW12-LGR	9/6/2018	0.07U	0.06U	0.05U	0.08U	7.15	23.26	0.513
CS-MW17-LGR	9/7/2018	0.07U	**0.40F**	0.05U	0.08U	7.39	21.79	0.347
CS-MW35-LGR	9/5/2018	0.07U	**0.58F**	0.05U	0.08U	6.67	22.10	0.692
Duplicate	9/5/2018	0.07U	**0.64F**	0.05U	0.08U	6.67	22.10	0.692
CS-MW36-LGR	9/5/2018	**0.56F**	**10.04**	**18.11**	0.08U	6.88	23.99	0.636
CS-MW37-LGR	3/5/2018	0.07U	0.06U	0.05U	0.08U	7.21	21.36	0.566
	9/5/2018	0.07U	**0.28F**	**0.36F**	0.08U	6.97	22.10	0.587
Comparison Criteria								
Maximum Contaminant Level (MCL)		**70**	**5.0**	**5.0**	**2.0**			
Reporting Limit (RL)		**1.2**	**1.4**	**1.0**	**1.1**			
Method Detection Limit (MDL)		**0.07**	**0.06**	**0.05**	**0.08**			

Bold (red)	Value ≥ MCL
Bold (blue)	MCL > Value ≥ RL
Bold	RL > Value > MDL

All samples were analyzed by APPL, Inc. using method SW8260B.
VOC data reported in ug/L & metals data reported in mg/L.

Abbreviations/Notes:

mS	millisiemans
µg/L	micrograms per liter
mg/L	milligrams per liter
deg. C	degrees Celsius
Duplicate	Field Duplicate
TCE	Trichloroethene
PCE	Tetrachloroethene
DCE	Dichloroethene

Data Qualifiers

NA = Analyte not analyzed
U-The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.
F-The analyte was positively identified but the associated numerical value is below the RL.

Appendix B
2018 Quarterly On-post Groundwater Analytical Results, Metals

Well ID	Sample Date	Arsenic (mg/L)	Barium (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Mercury (mg/L)	Zinc (mg/L)
CS-1	3/14/2018	0.00022U	**0.0325**	0.0005U	**0.0070F**	**0.01**	**0.0037F**	0.0001U	**0.230J**
Duplicate	3/14/2018	0.00022U	**0.0332**	0.0005U	**0.0017F**	**0.007F**	0.0019U	0.0001U	**0.179J**
	6/11/2018	0.00022U	**0.0383**	0.0005U	**0.0017F**	**0.008F**	**0.0031F**	0.0001U	**0.19**
	9/7/2018	0.00022U	**0.0364**	0.0005U	**0.0015F**	**0.006F**	0.0019U	0.0001U	**0.197**
	12/3/2018	**0.00299F**	**0.0368**	0.0005U	0.0010U	**0.011**	0.0019U	0.0001U	**0.145**
CS-10	3/15/2018	0.00022U	**0.0398**	0.0005U	**0.0018F**	**0.008F**	**0.0022F**	0.0001U	**0.288**
	6/11/2018	0.00022U	**0.0414**	0.0005U	**0.0018F**	**0.025**	**0.0095F**	0.0001U	**0.629**
	9/7/2018	0.00022U	**0.0422**	0.0005U	**0.0011F**	0.003U	0.0019U	0.0001U	**0.293**
	12/3/2018	**0.00120F**	**0.0386**	0.0005U	0.0010U	**0.012**	**0.0028F**	0.0001U	**0.436**
CS-12	3/14/2018	0.00022U	**0.0319**	0.0005U	**0.0018F**	0.003U	**0.0023F**	0.0001U	**0.029F**
	6/11/2018	0.00022U	**0.0342**	0.0005U	**0.0012F**	0.003U	0.0019U	0.0001U	**0.051**
Duplicate	6/11/2018	0.00022U	**0.0327**	0.0005U	**0.0019F**	**0.021**	**0.0024F**	0.0001U	**0.042F**
	9/7/2018	0.00022U	**0.035**	0.0005U	**0.0026F**	0.003U	0.0019U	0.0001U	**0.029F**
Duplicate	9/7/2018	0.00022U	**0.034**	0.0005U	**0.0014F**	0.003U	0.0019U	0.0001U	**0.018F**
	12/3/2018	**0.00297F**	**0.0312**	0.0005U	**0.0014F**	**0.013**	0.0019U	0.0001U	**0.070**
CS-13	3/14/2018	0.00022U	**0.0297**	0.0005U	**0.0022F**	0.003U	0.0019U	0.0001U	**0.321**
	6/11/2018	0.00022U	**0.0315**	0.0005U	**0.0023F**	0.003U	0.0019U	0.0001U	**0.487**
	9/7/2018	0.00022U	**0.0347**	0.0005U	**0.0015F**	**0.007F**	0.0019U	0.0001U	**0.398**
	12/3/2018	**0.00314F**	**0.0301**	0.0005U	0.0010U	**0.014**	**0.0056F**	0.0001U	**0.358J**
Duplicate	12/3/2018	**0.00422F**	**0.0293**	0.0005U	0.0010U	0.003U	0.0019U	0.0001U	**0.261J**
Comparison Criteria									
Maximum Contaminant Level (MCL)		0.01	2.0	0.005	0.1	1.3	0.015 (AL)	0.002	5.0 (SS)
Reporting Limit (RL)		0.03	0.005	0.007	0.01	0.01	0.025	0.001	0.05
Method Detection Limit (MDL)		0.00022	0.0003	0.0005	0.001	0.003	0.0019	0.0001	0.008

Bold (red)	Value ≥ MCL
Bold (blue)	MCL > Value ≥ RL
Bold	RL > Value ≥ MDL

All samples were analyzed by APPL, Inc. using laboratory method SW8260B.
VOC data reported in µg/L & metals data reported in mg/L.

Abbreviations/Notes:

µg/L	micrograms per liter
mg/L	milligrams per liter
Duplicate	Field Duplicate
AL	Action Level
SS	Secondary Standard

Data Qualifiers:

NA = Analyte not analyzed
F-The analyte was positively identified but the associated numerical value is below the RL.
J - Analyte detected, concentration estimated.
M - Matrix effect present.
U-The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.

APPENDIX C

2018 WESTBAY® ANALYTICAL RESULTS

Appendix C
2018 Westbay® Analytical Results

Well ID	Date Sampled	cis-1,2-DCE (cis-1,2-dichloroethene)	TCE (trichloroethene)	PCE (tetrachloroethene)	Vinyl Chloride
CS-WB01-UGR-01	9/11/2018	0.07U	0.05U	**1.29F**	0.08U
CS-WB01-LGR-01	9/11/2018	0.07U	0.05U	**2.17**	0.08U
CS-WB01-LGR-02	9/11/2018	0.07U	**1.8**	**8.53**	0.08U
CS-WB01-LGR-03	9/11/2018	0.07U	**9.76**	**4.03**	0.08U
CS-WB01-LGR-04	9/11/2018	**2.37**	0.05U	0.06U	0.08U
CS-WB01-LGR-05	9/11/2018	0.07U	0.05U	0.06U	0.08U
CS-WB01-LGR-06	9/11/2018	**1.17F**	**4.08**	0.06U	0.08U
CS-WB01-LGR-07	9/11/2018	**0.22F**	**14.72**	**16.12**	0.08U
CS-WB01-LGR-08	9/11/2018	**16.12**	**1.48**	**0.41F**	0.08U
CS-WB01-LGR-09	9/11/2018	**0.36F**	**10.07**	**7.61**	0.08U
CS-WB02-UGR-01	9/12/2018	port clogged			
CS-WB02-LGR-01	9/12/2018	0.07U	0.05U	**1.02F**	0.08U
CS-WB02-LGR-02	9/12/2018	0.07U	0.05U	**1.46**	0.08U
CS-WB02-LGR-03	9/12/2018	0.07U	0.05U	0.06U	0.08U
CS-WB02-LGR-04	9/12/2018	0.07U	**4.63**	**2.72**	0.08U
CS-WB02-LGR-05	9/12/2018	0.07U	**1.45**	**0.85F**	0.08U
CS-WB02-LGR-06	9/12/2018	0.07U	**1.35**	**0.93F**	0.08U
CS-WB02-LGR-07	9/12/2018	**0.60F**	**1.01**	0.06U	0.08U
CS-WB02-LGR-08	9/12/2018	**2.3**	0.05U	0.06U	0.08U
CS-WB02-LGR-09	9/12/2018	0.07U	**5.21**	**5.03**	0.08U
CS-WB03-UGR-01	9/17/2018	**10.53**	**150.39J**	**10367.97*** **	0.08U
CS-WB03-LGR-01	9/17/2018	Dry			
CS-WB03-LGR-02	9/17/2018	Dry			
CS-WB03-LGR-03	9/17/2018	0.07U	**0.71F**	**3.86**	0.08U
CS-WB03-LGR-04	9/17/2018	**0.52F**	**4.88**	**12.45**	0.08U
CS-WB03-LGR-05	9/17/2018	**4.95**	**3.91**	**10.93**	0.08U
CS-WB03-LGR-06	9/17/2018	**2.82**	0.05U	0.06U	0.08U
CS-WB03-LGR-07	9/17/2018	**2.48**	**5.04**	**1.68**	0.08U
CS-WB03-LGR-08	9/17/2018	**2.23**	0.05U	0.06U	0.08U
CS-WB03-LGR-09	9/17/2018	0.07U	**2.12**	**2.22**	0.08U
CS-WB04-UGR-01	9/17/2018	Dry			
CS-WB04-LGR-01	9/17/2018	0.07U	0.05U	**0.87F**	0.08U
CS-WB04-LGR-06	9/17/2018	**2.98**	**7.24**	**23.78**	0.08U
CS-WB04-LGR-07	9/17/2018	**3.39**	**11.29**	**25.87**	0.08U
CS-WB04-LGR-08	9/17/2018	0.07U	**1.06**	**0.58F**	0.08U
CS-WB04-LGR-09	9/17/2018	0.07U	**5.51**	**7.36**	0.08U
CS-WB04-LGR-10	9/17/2018	0.07U	**0.47F**	**2.2**	0.08U
CS-WB04-LGR-11	9/17/2018	0.07U	0.05U	**0.93F**	0.08U
Comparison Criteria					
Method Detection Limit	**MDL**	**0.07**	**0.05**	**0.06**	**0.08**
Reporting Limit	**RL**	**1.2**	**1**	**1.4**	**1.1**
Max. Contaminant Level	**MCL**	**70**	**5**	**5**	**2**

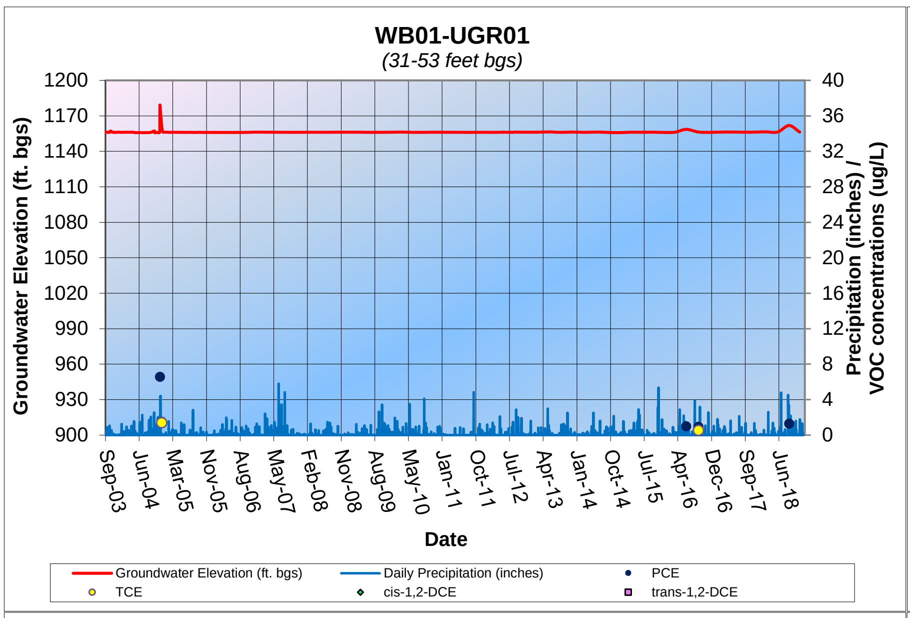
BOLD	≥ MDL
BOLD (blue)	≥ RL
BOLD (red)	≥ MCL

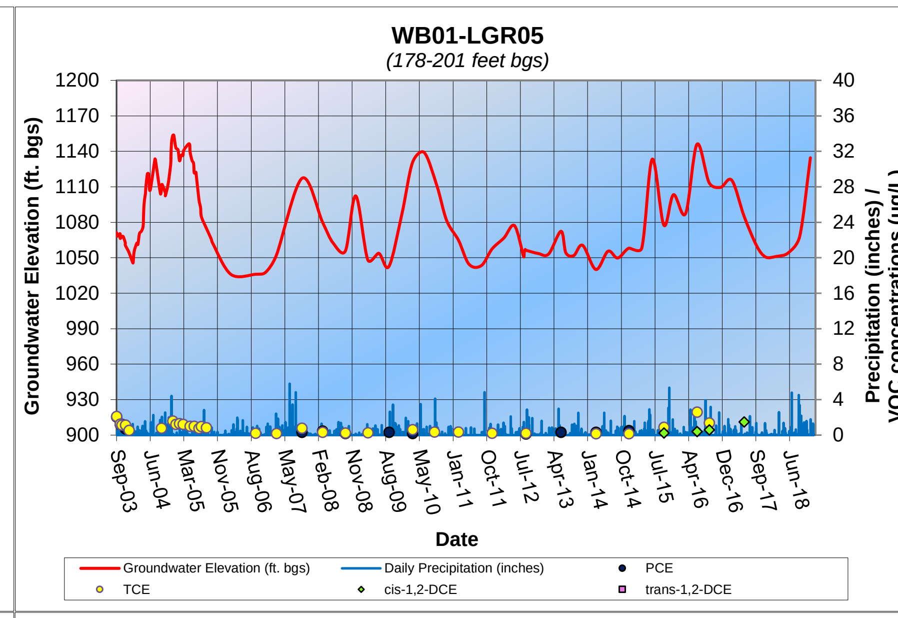
Data Qualifiers
F-The analyte was positively identified but the associated numerical value is below the RL.
U-The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.
J - Analyte detected, concentration estimated.
* dilution of 5 run for this sample.
** dilution of 50 run for this sample.
*** dilution of 200 run for this sample
All values are reported in µg/L.

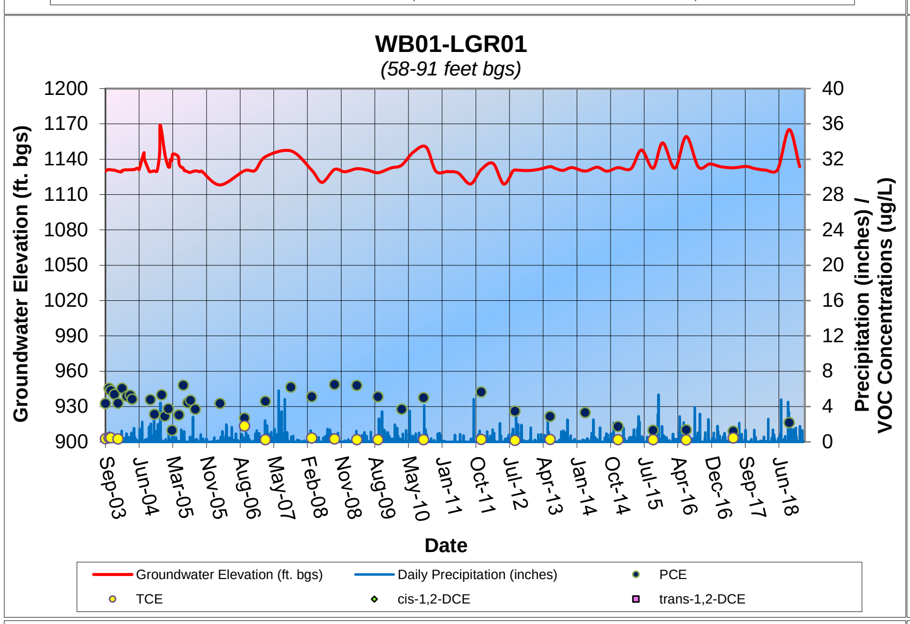
APPENDIX D

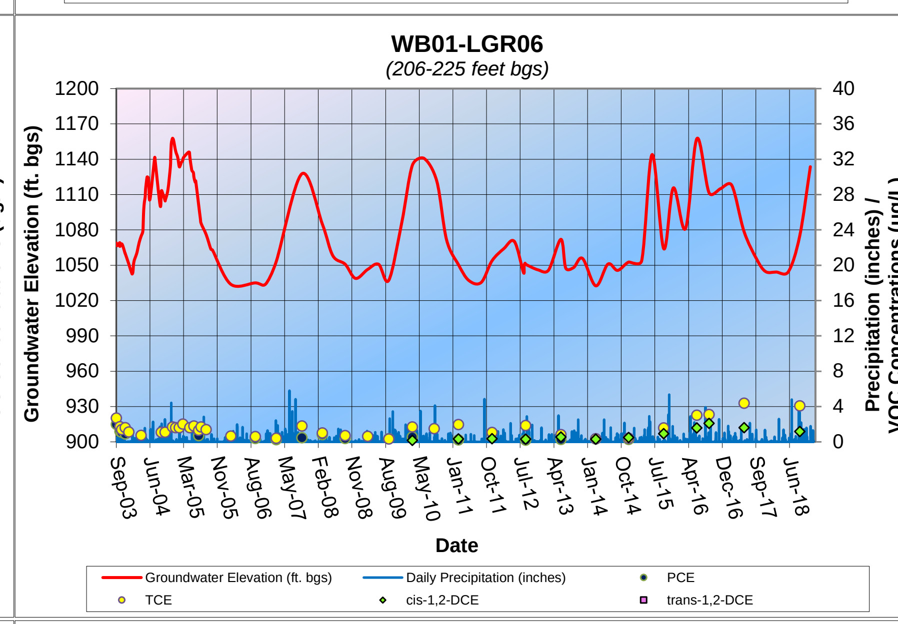
CUMULATIVE WESTBAY® ANALYTICAL GRAPHS

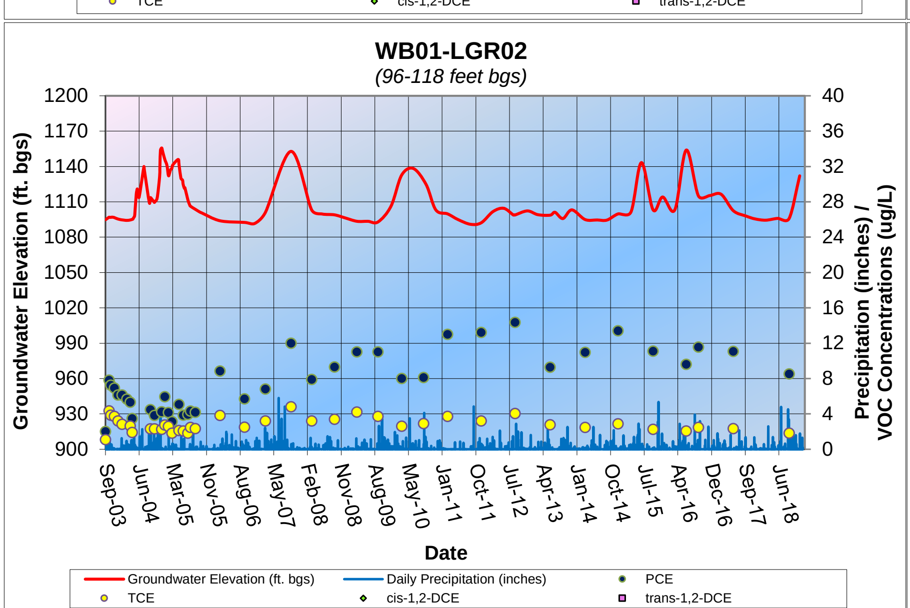
Appendix D.1 - CS-WB01 Culmulative VOC Concentrations, Groundwater Level, and Precipitation

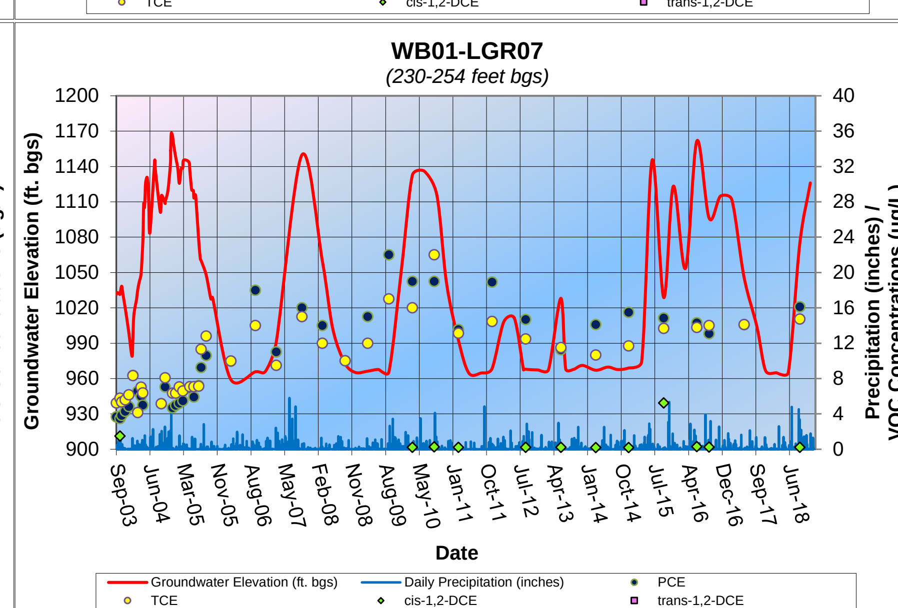


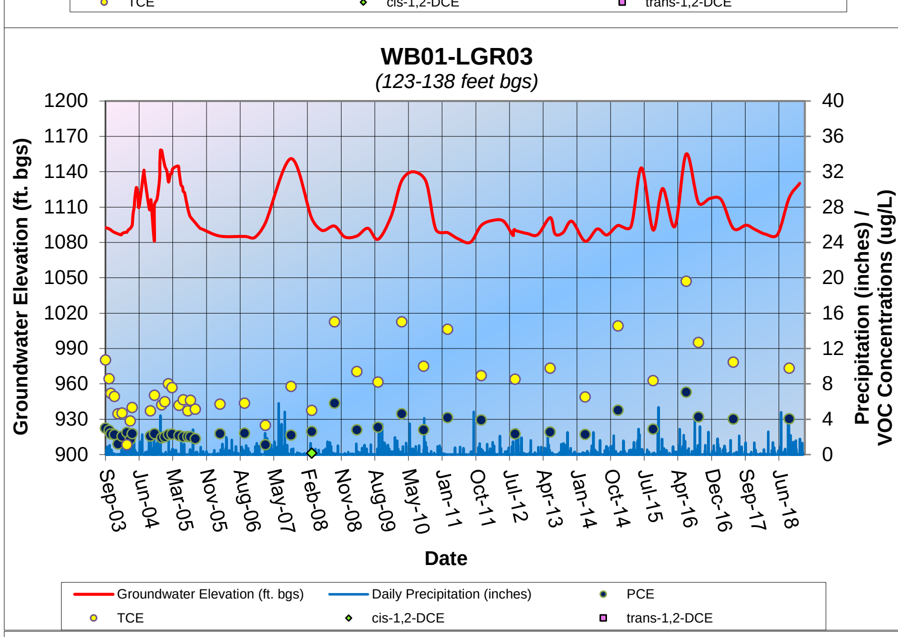


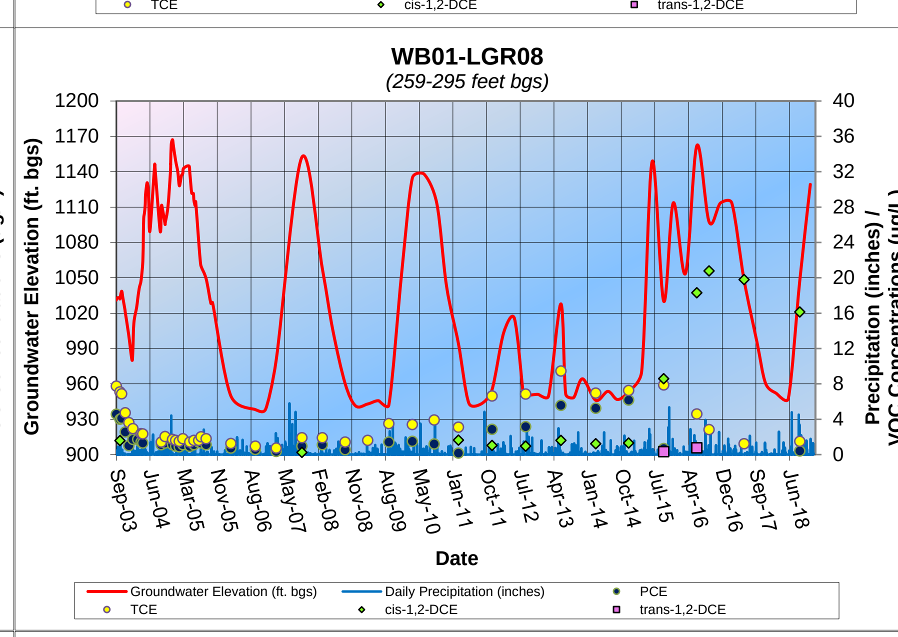


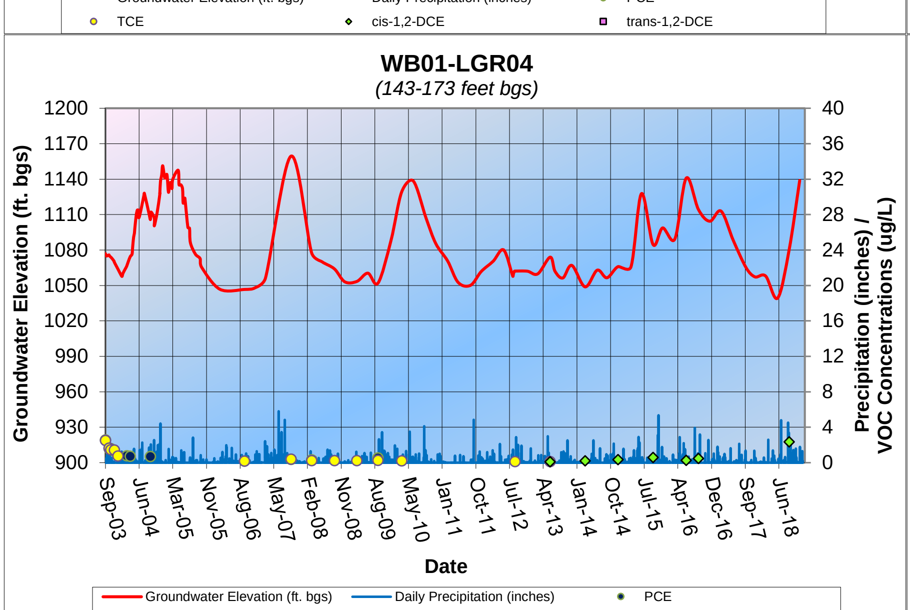


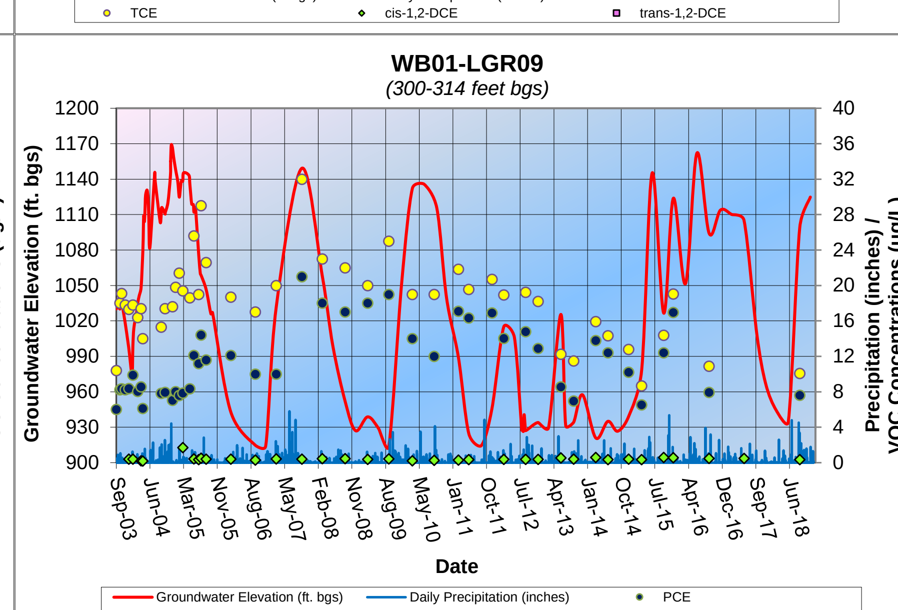




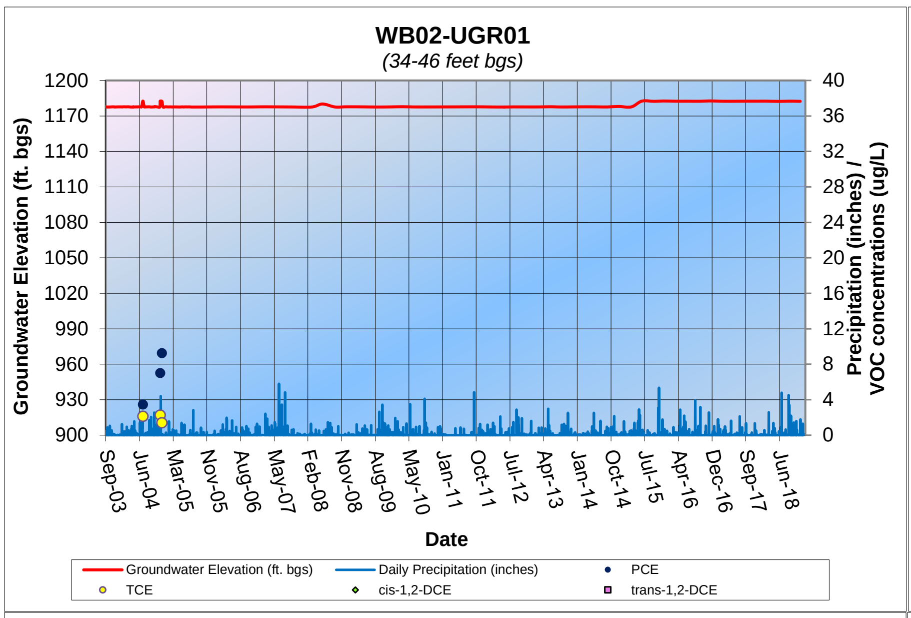


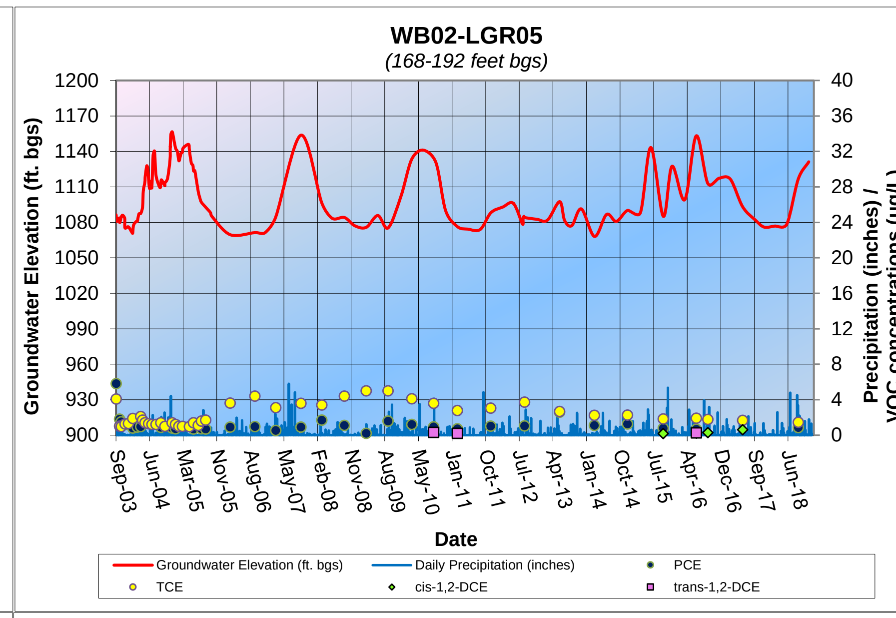


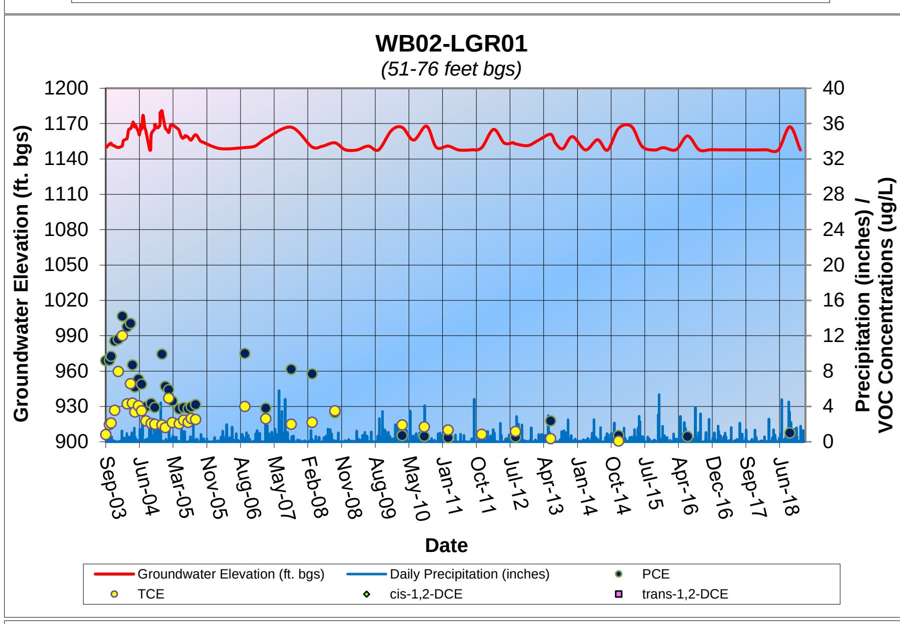


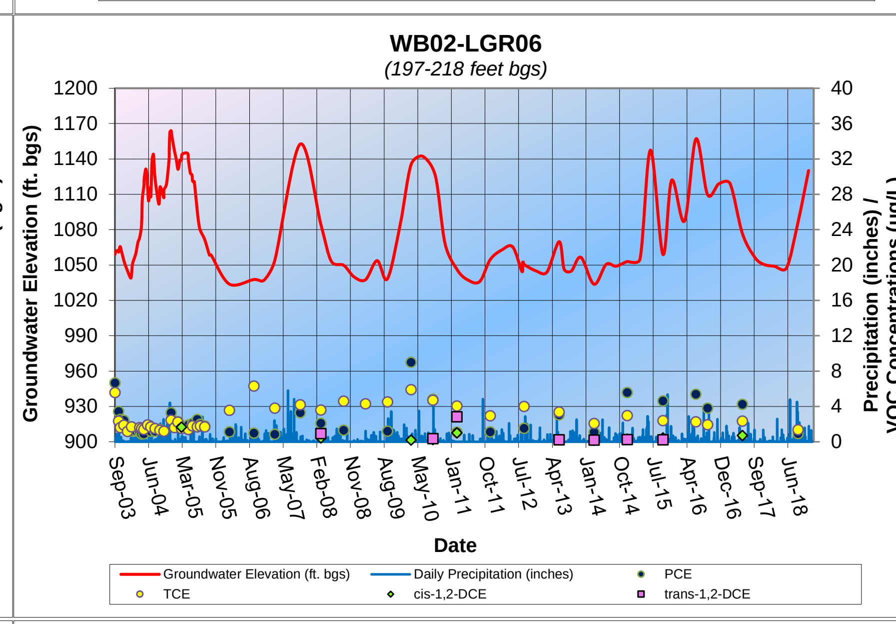


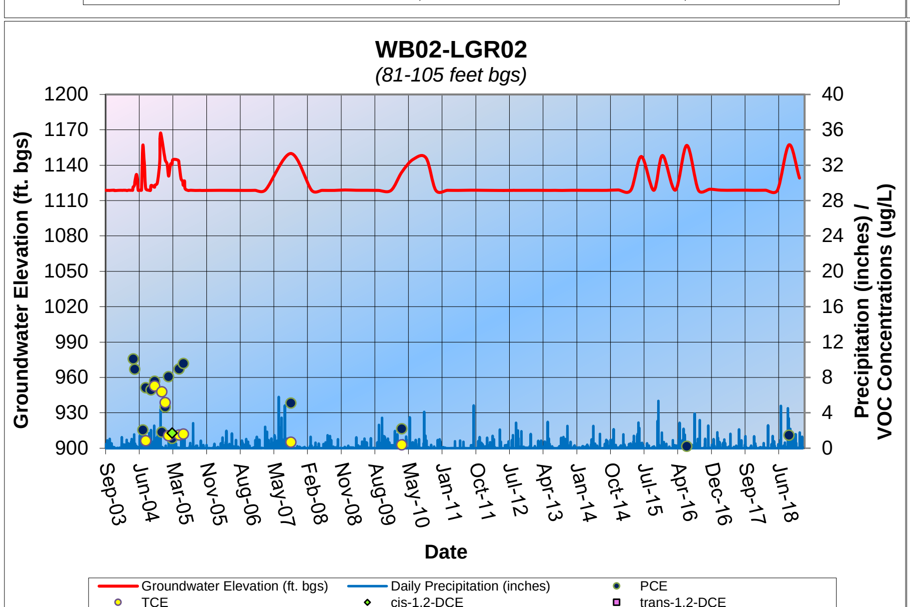
Appendix D.2 - CS-WB02 Culmulative VOC Concentrations, Groundwater Level, and Precipitation

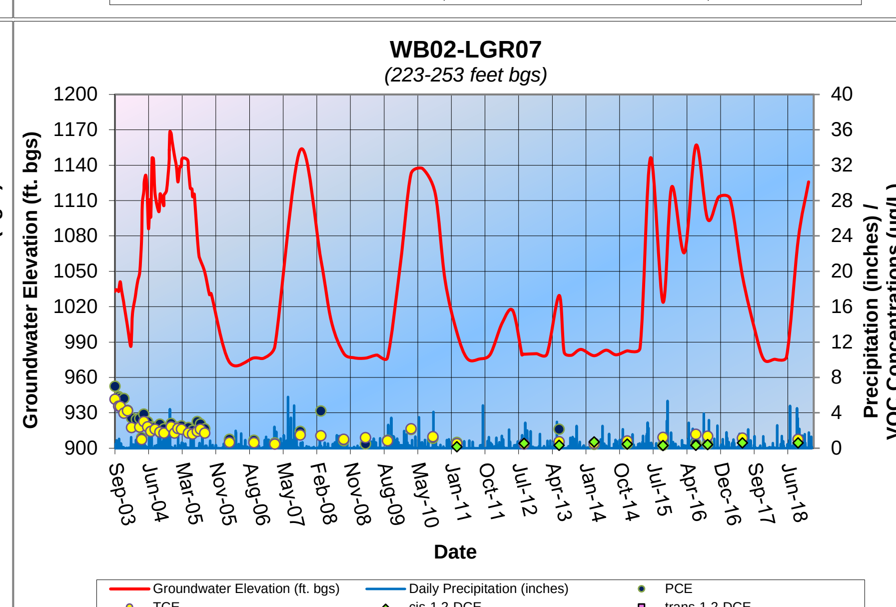


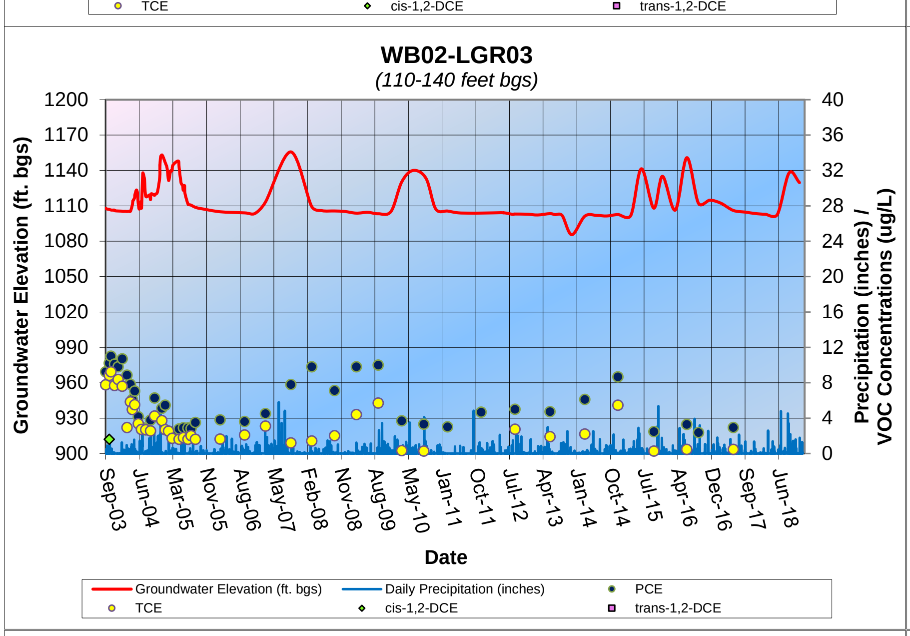


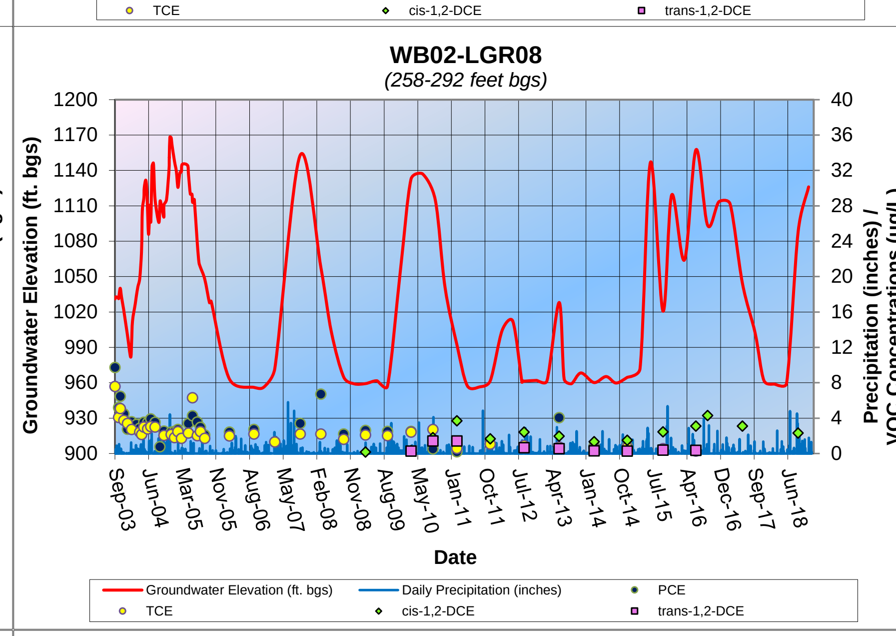


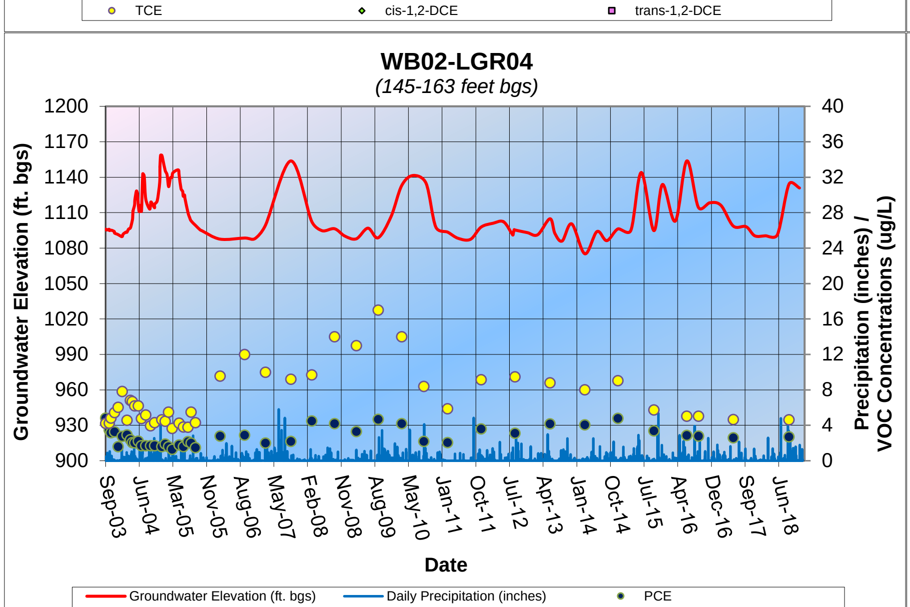


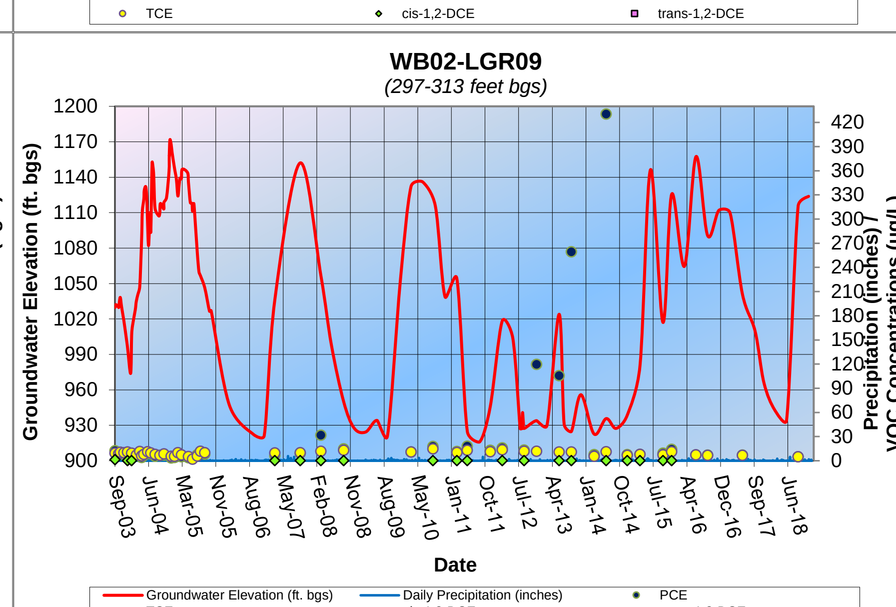






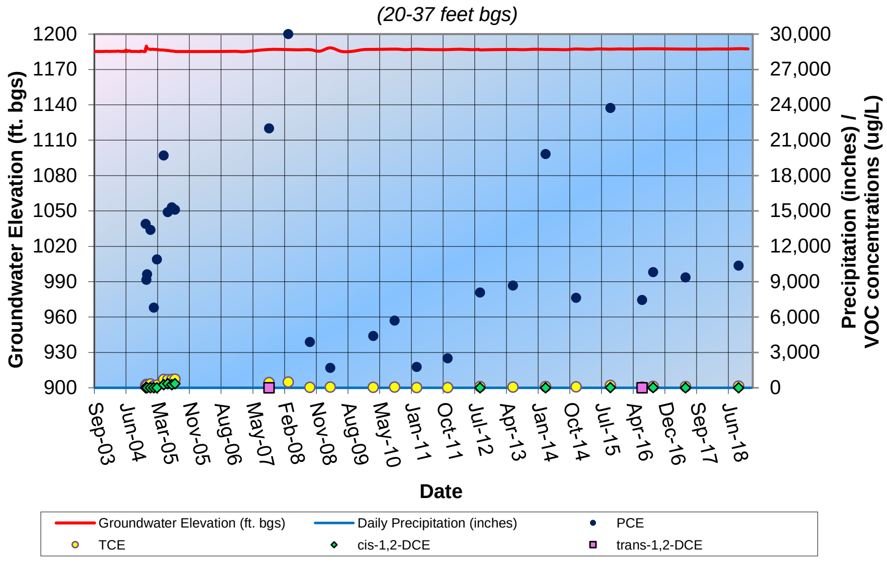




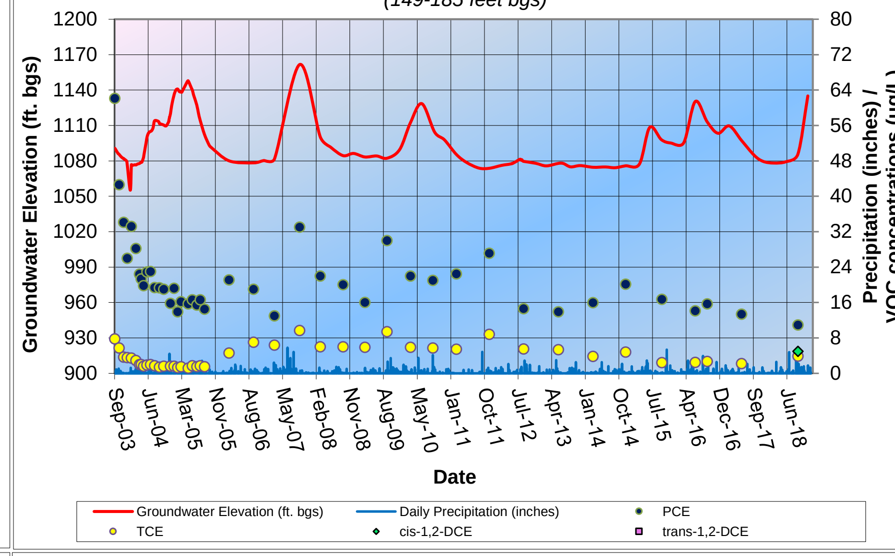


Appendix D.3 - CS-WB03 Culmulative VOC Concentrations, Groundwater Level, and Precipitation

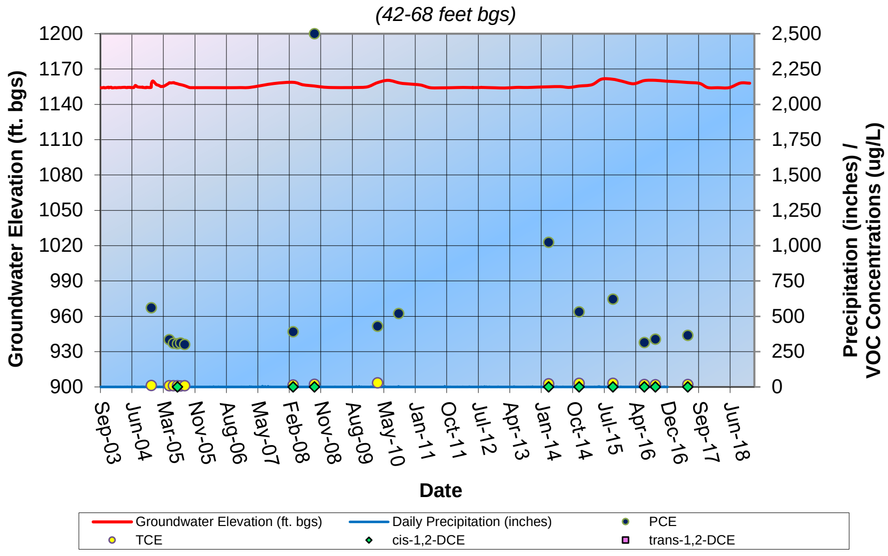
WB03-UGR01
(20-37 feet bgs)



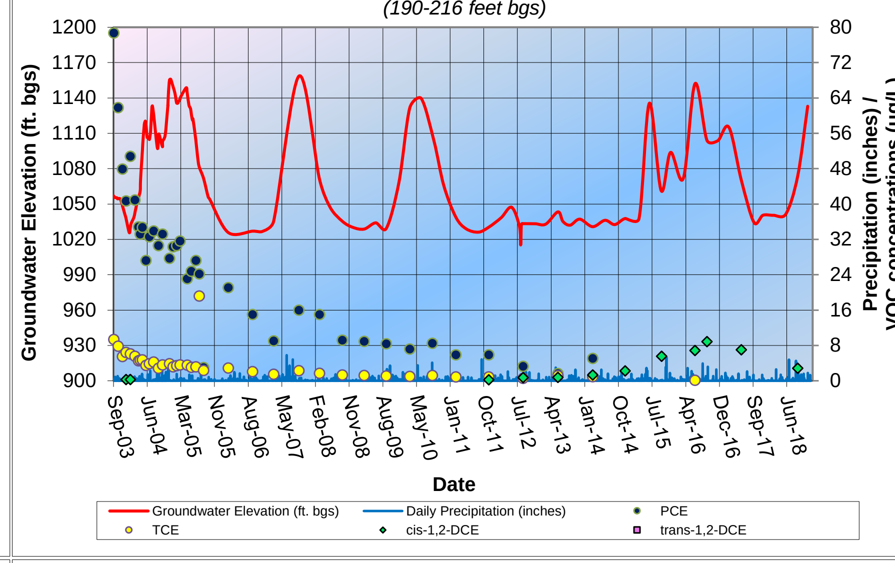
WB03-LGR05
(149-185 feet bgs)



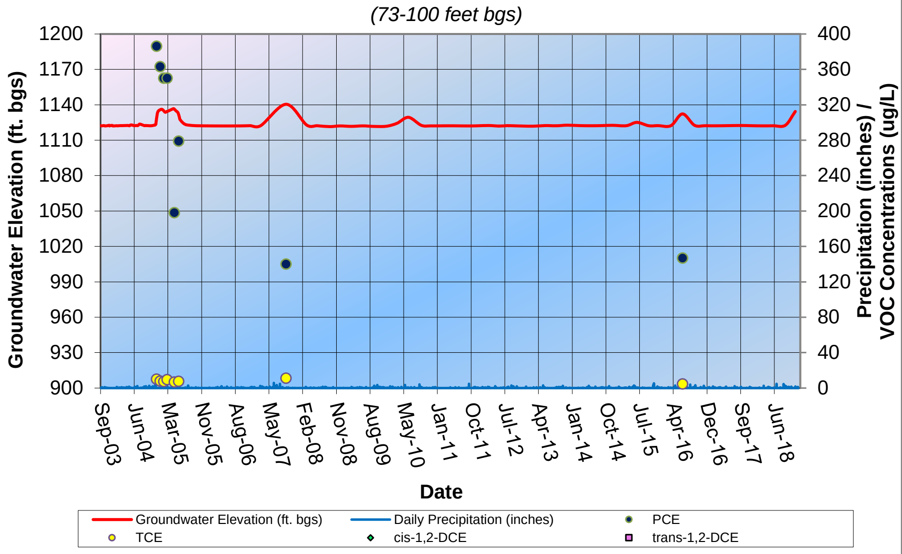
WB03-LGR01
(42-68 feet bgs)



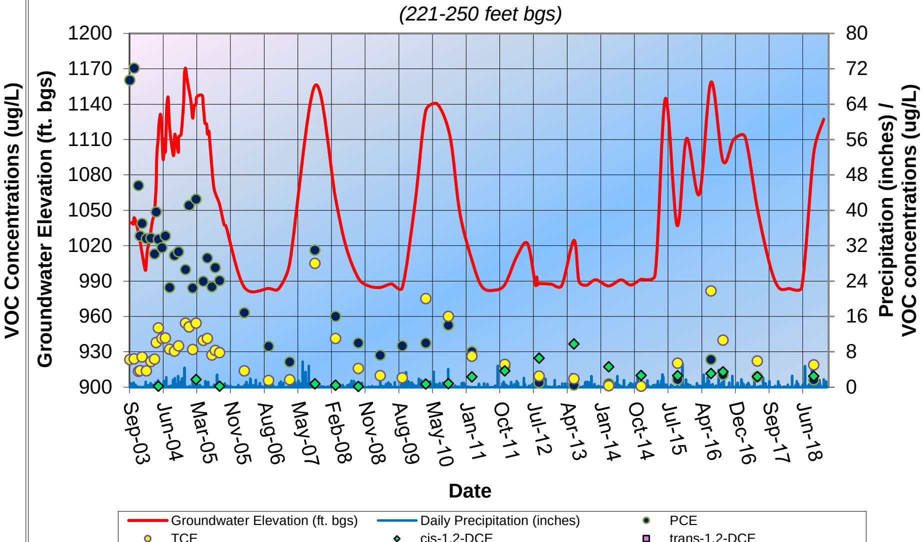
WB03-LGR06
(190-216 feet bgs)



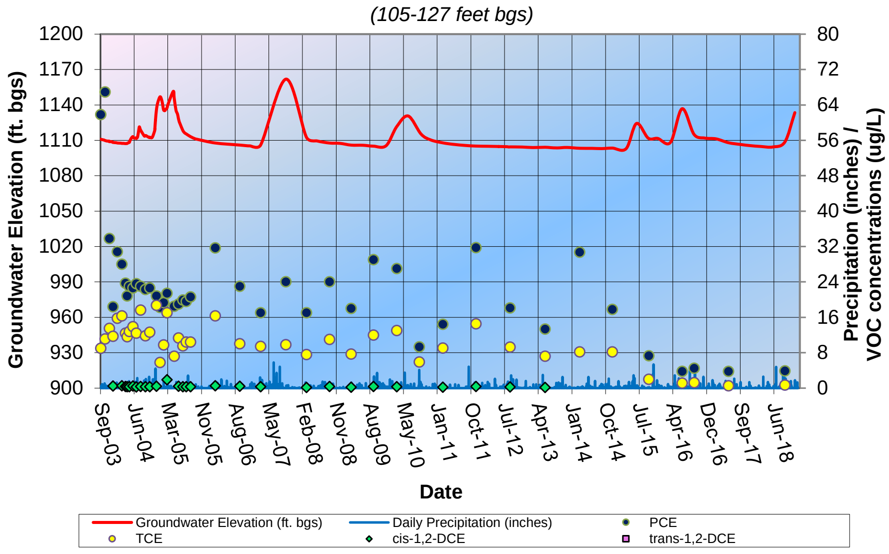
WB03-LGR02
(73-100 feet bgs)



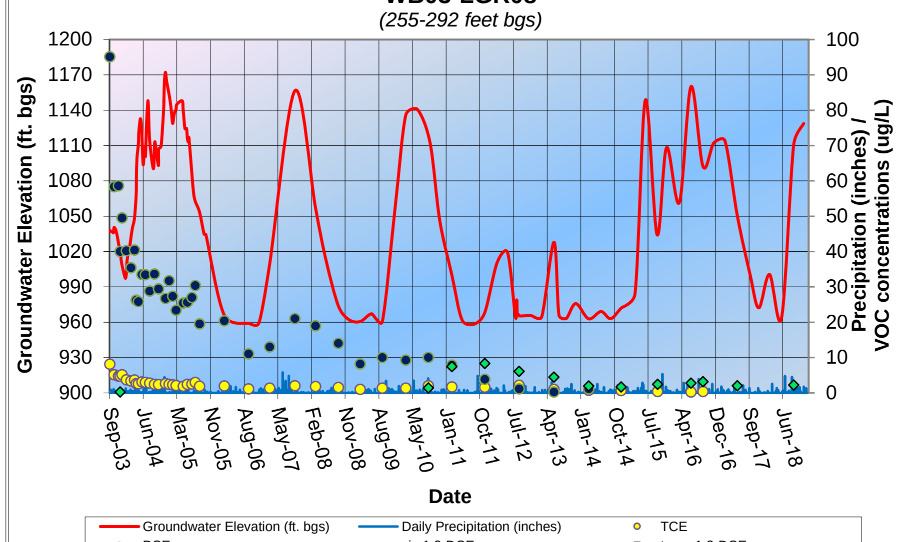
WB03-LGR07
(221-250 feet bgs)



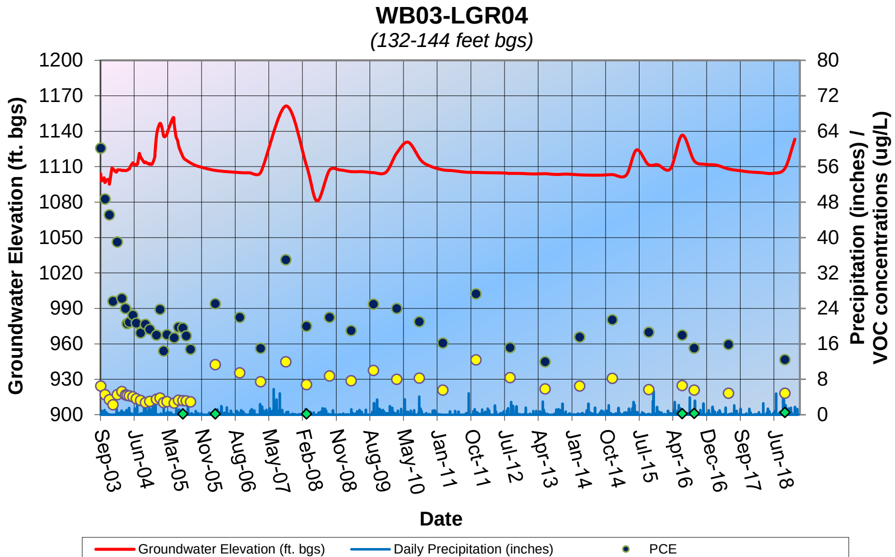
WB03-LGR03
(105-127 feet bgs)



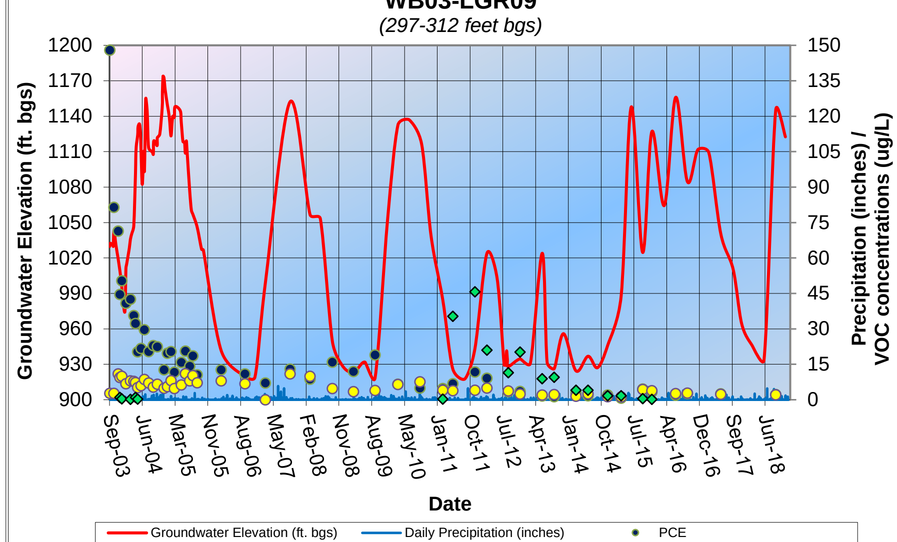
WB03-LGR08
(255-292 feet bgs)



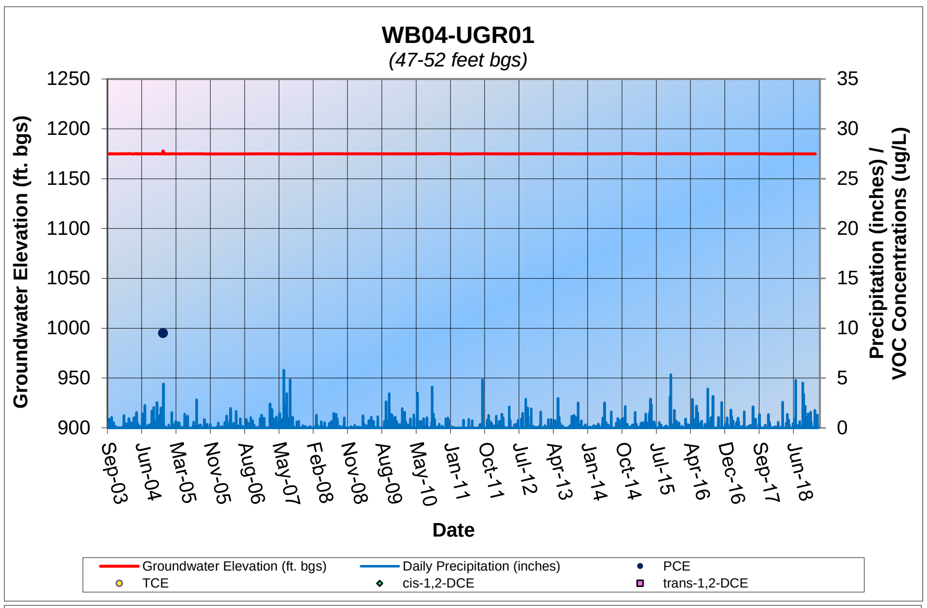
WB03-LGR04
(132-144 feet bgs)

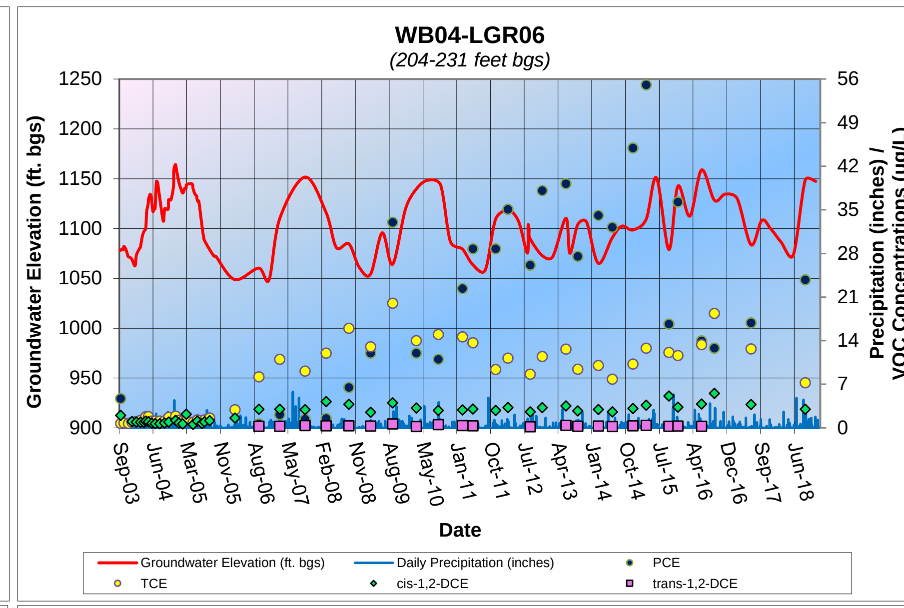


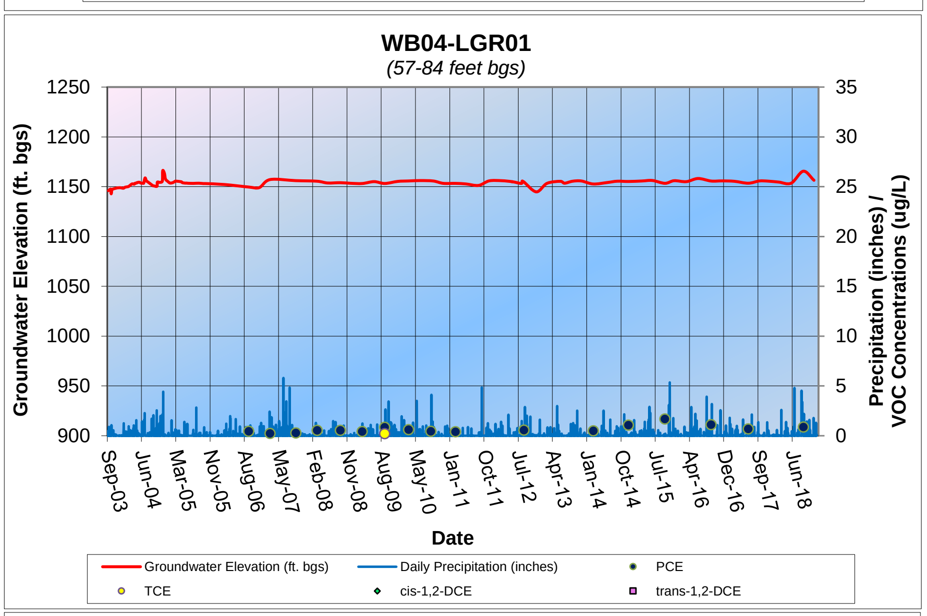
WB03-LGR09
(297-312 feet bgs)

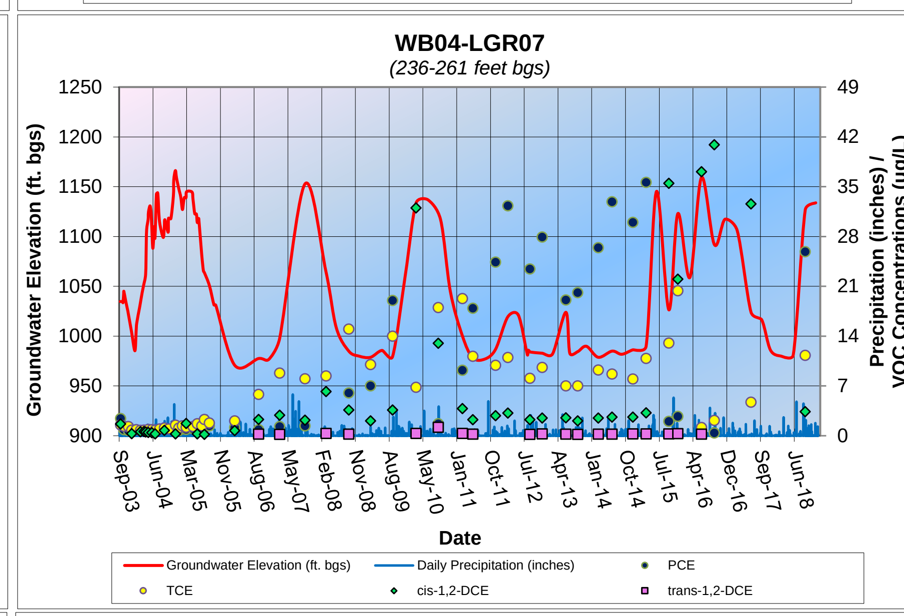


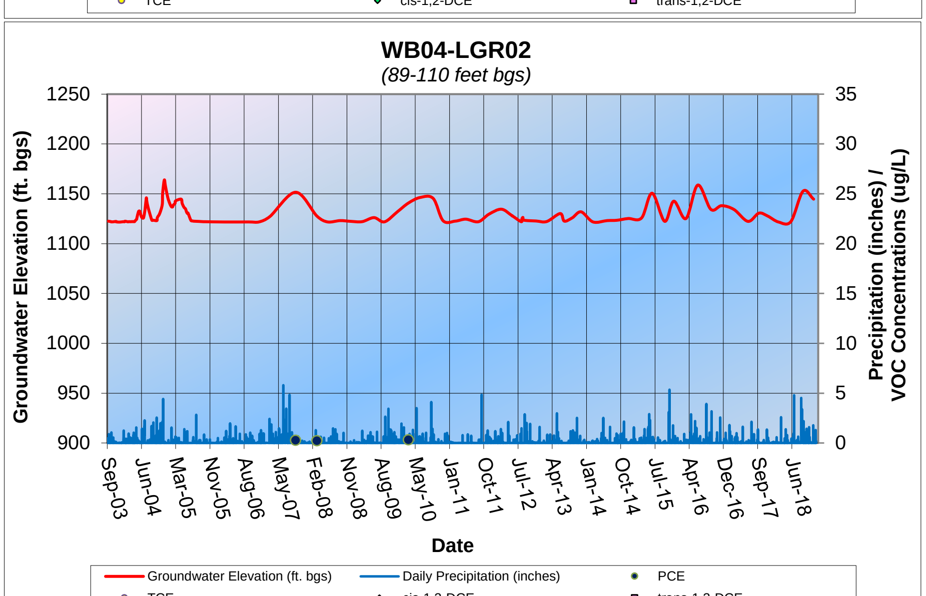
Appendix D.4 - CS-WB04 Culmulative VOC Concentrations, Groundwater Level, and Precipitation

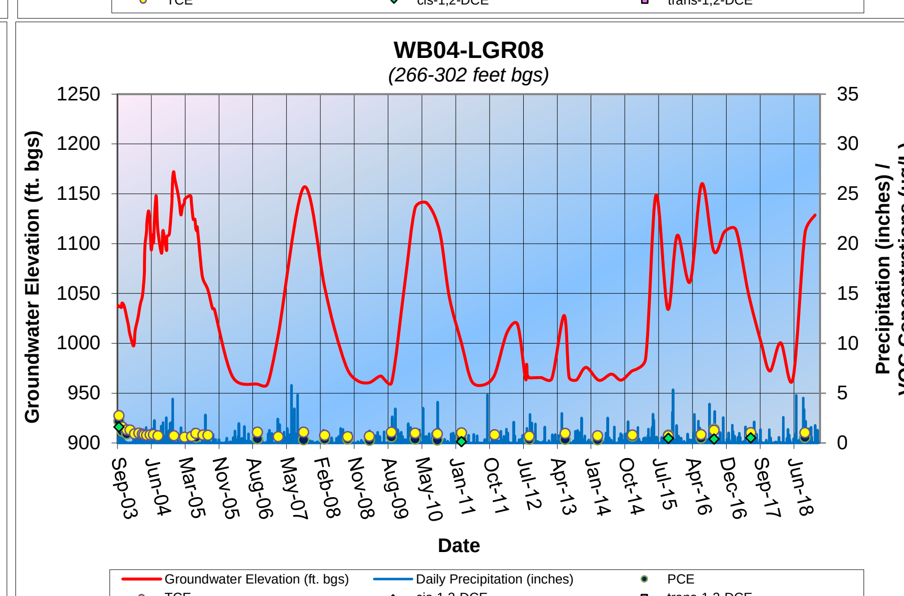


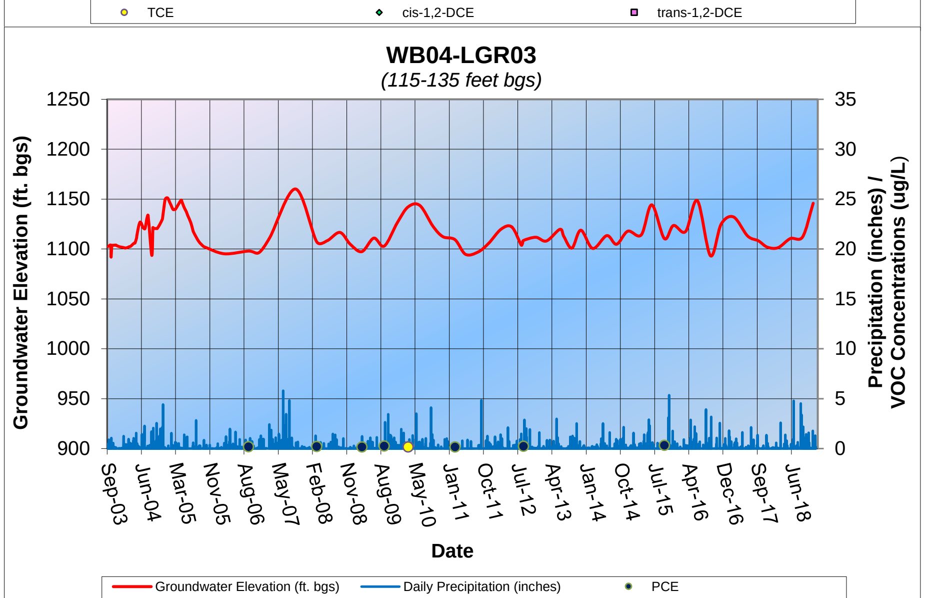


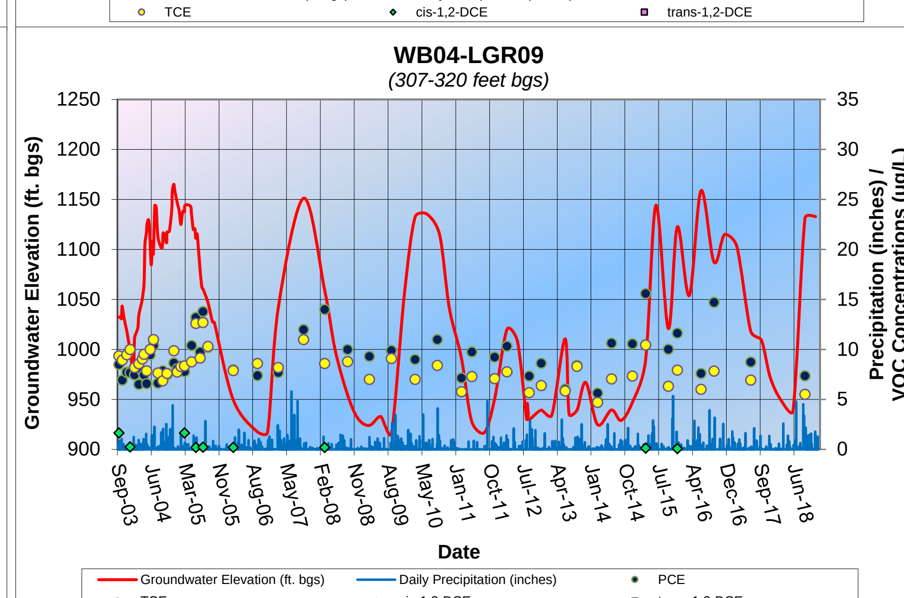


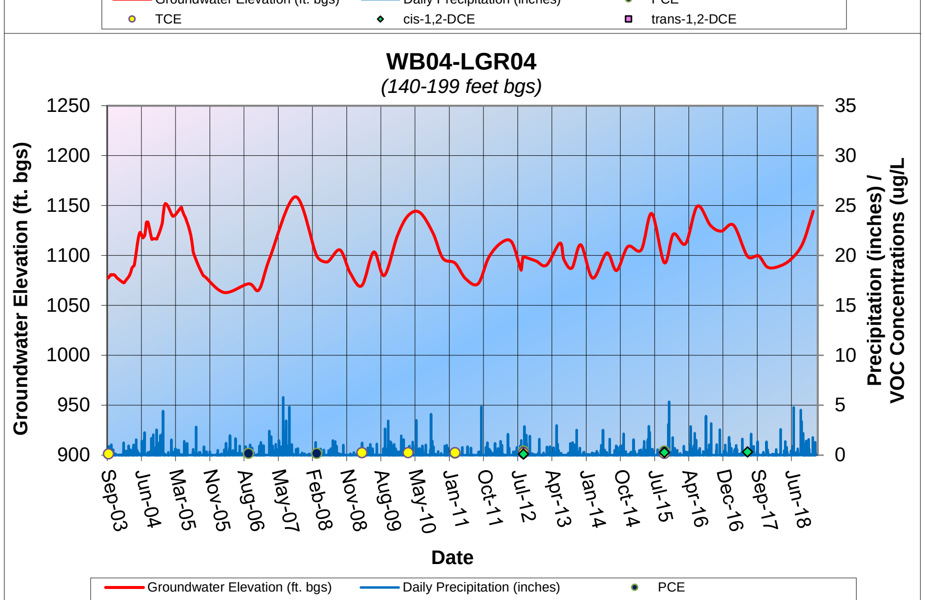


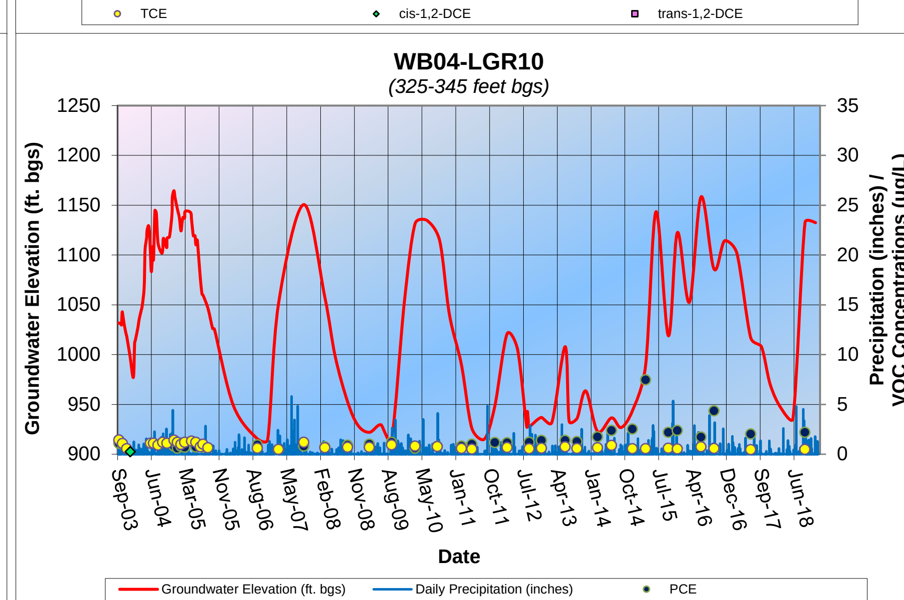




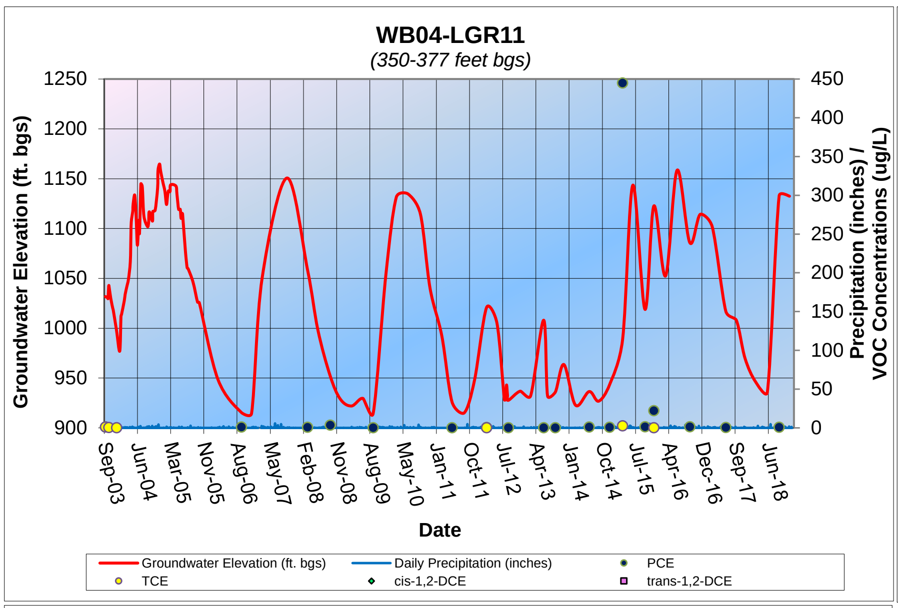


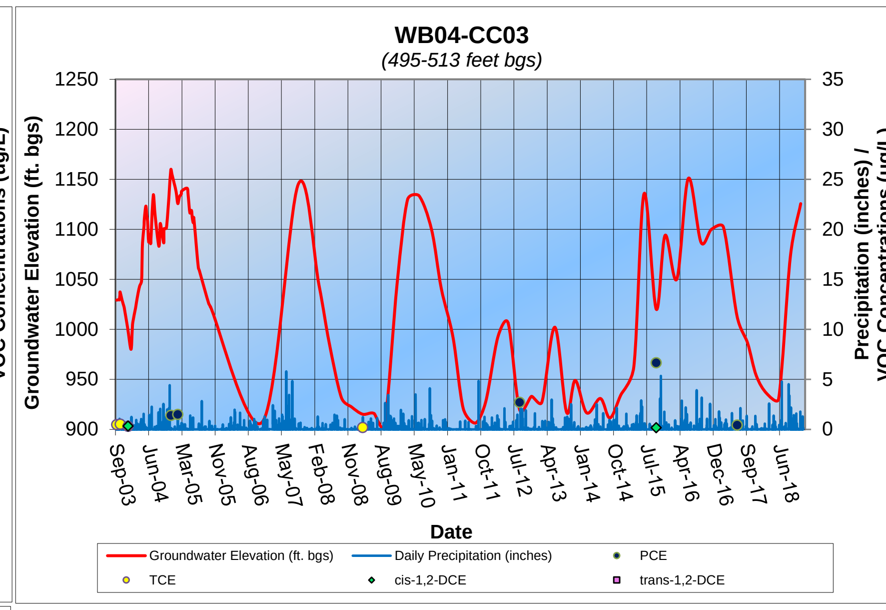


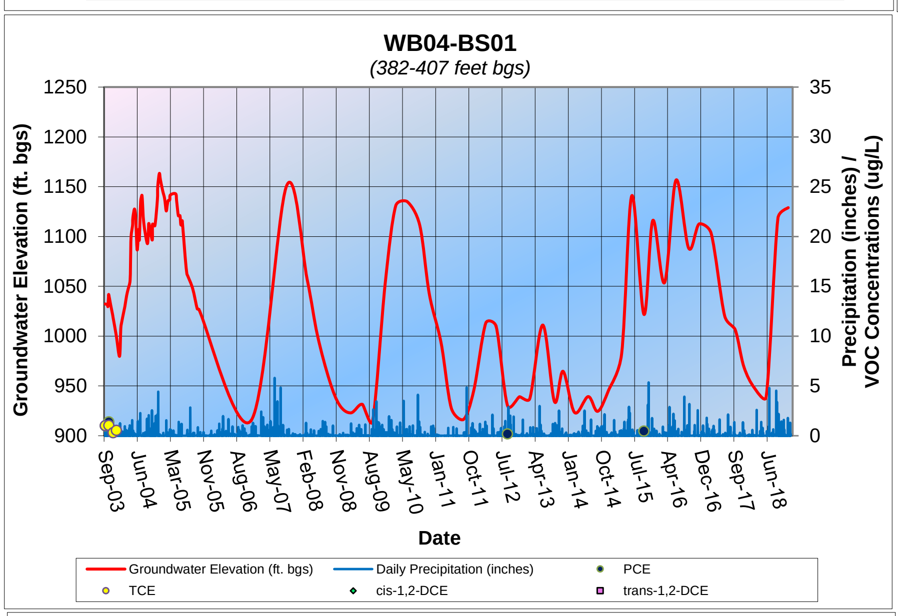


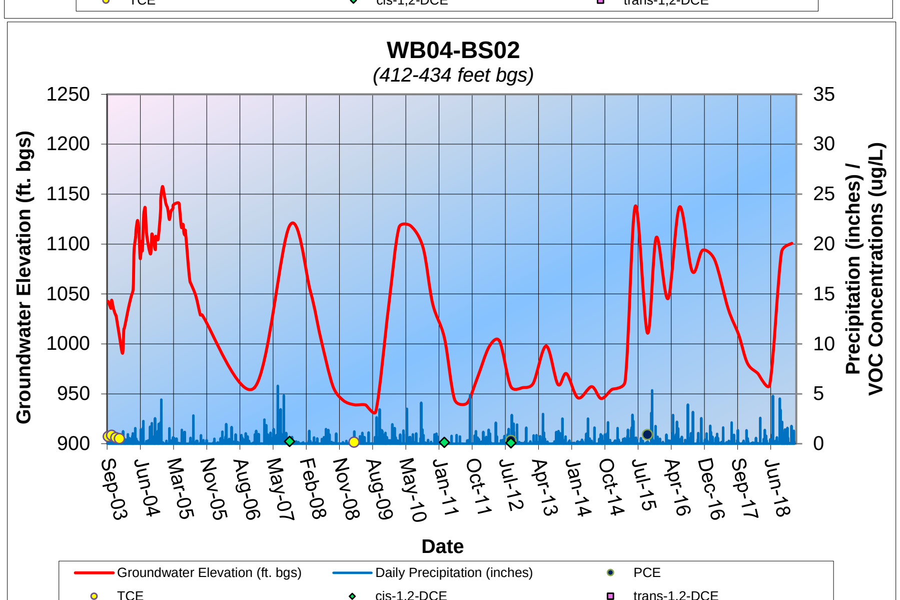


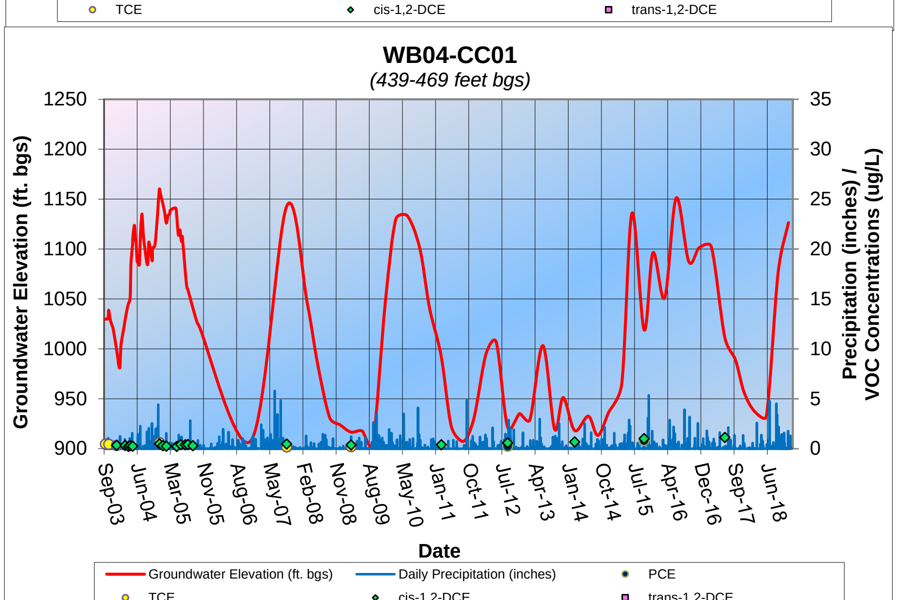
Appendix D.4 - CS-WB04 Culmulative VOC Concentrations, Groundwater Level, and Precipitation

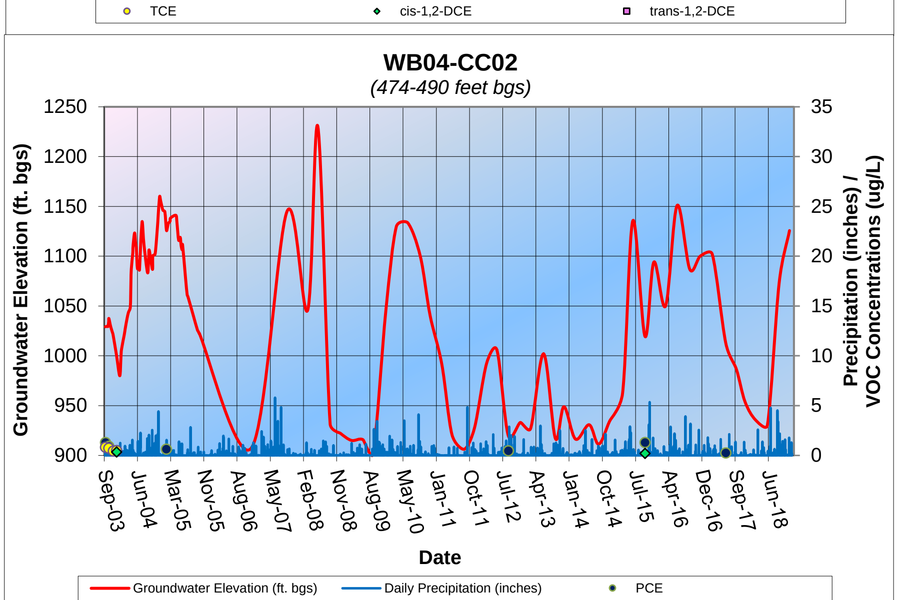






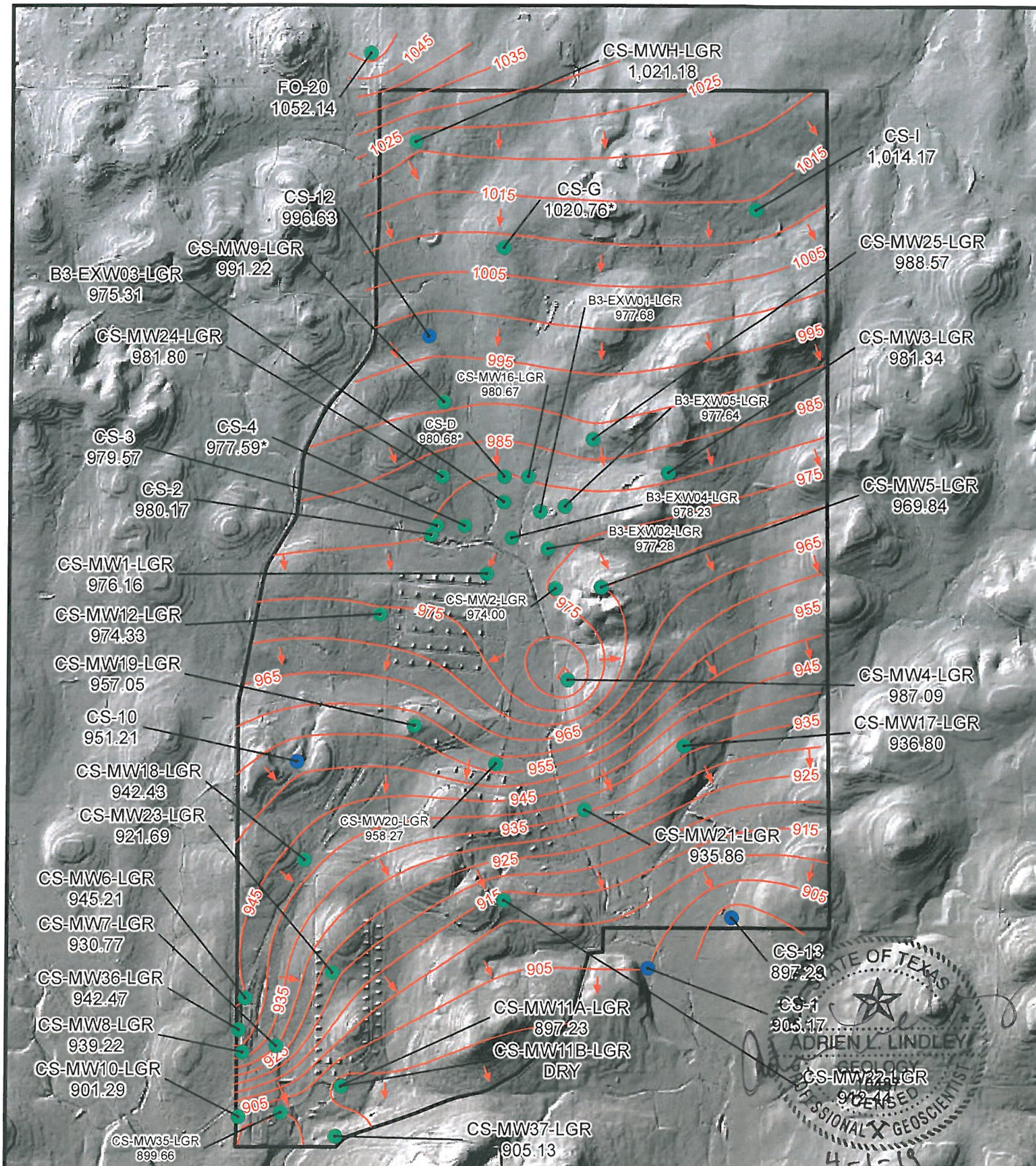






APPENDIX E

POTENTIOMETRIC MAPS FOR MARCH, JUNE, SEPTEMBER, DECEMBER 2018



N

0 0.5 Miles

Flow direction

Outer fence

LGR Groundwater Contours

LGR Wells and groundwater elevation (ft above msl)

Drinking water wells (may be completed in LGR, BS, and/or CC)

* Not a fully penetrating well into LGR. Groundwater elevation not used in contouring

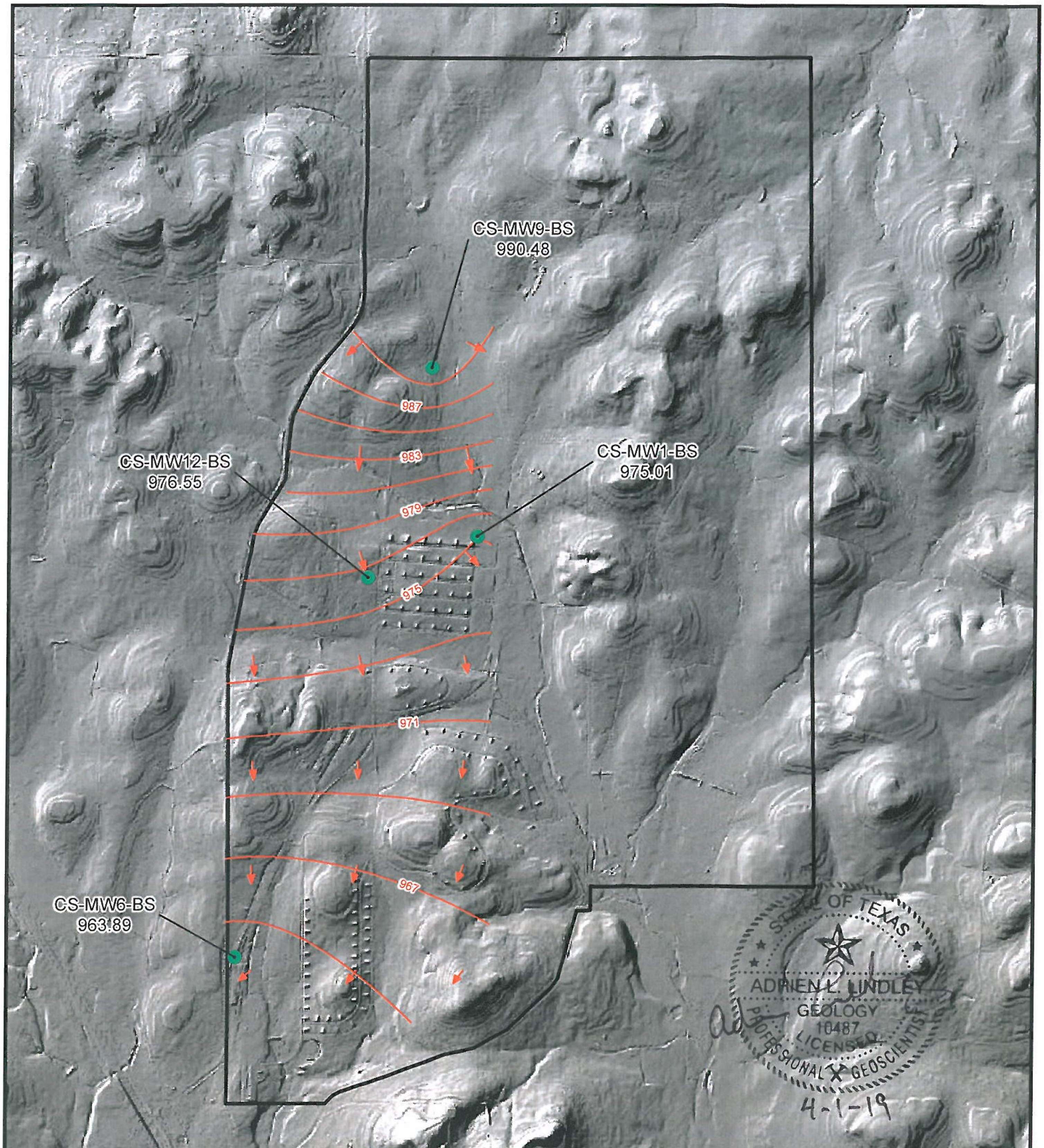
C:\CSSA\GIS\GW_POTENTIOMETRIC\MAR2018\Mar18_potentiometric_lgr.mxd - 5/7/2018 @ 11:52:40 AM

Figure E.1

March 2018 Potentiometric Surface Map, LGR Wells

Camp Stanley Storage Activity

PARSONS



N

0 0.5 Miles

Flow direction
Outer fence
BS Groundwater Contours
BS Wells and groundwater elevation (ft above msl)

Figure E.2

March 2018 Potentiometric Surface Map, BS Wells

Camp Stanley Storage Activity

PARSONS

C:\CSSA\GIS\GW_POTENTIOMETRIC\MAR2018\Mar18_potentiometric_bs.mxd - 5/7/2018 @ 12:10:34 PM

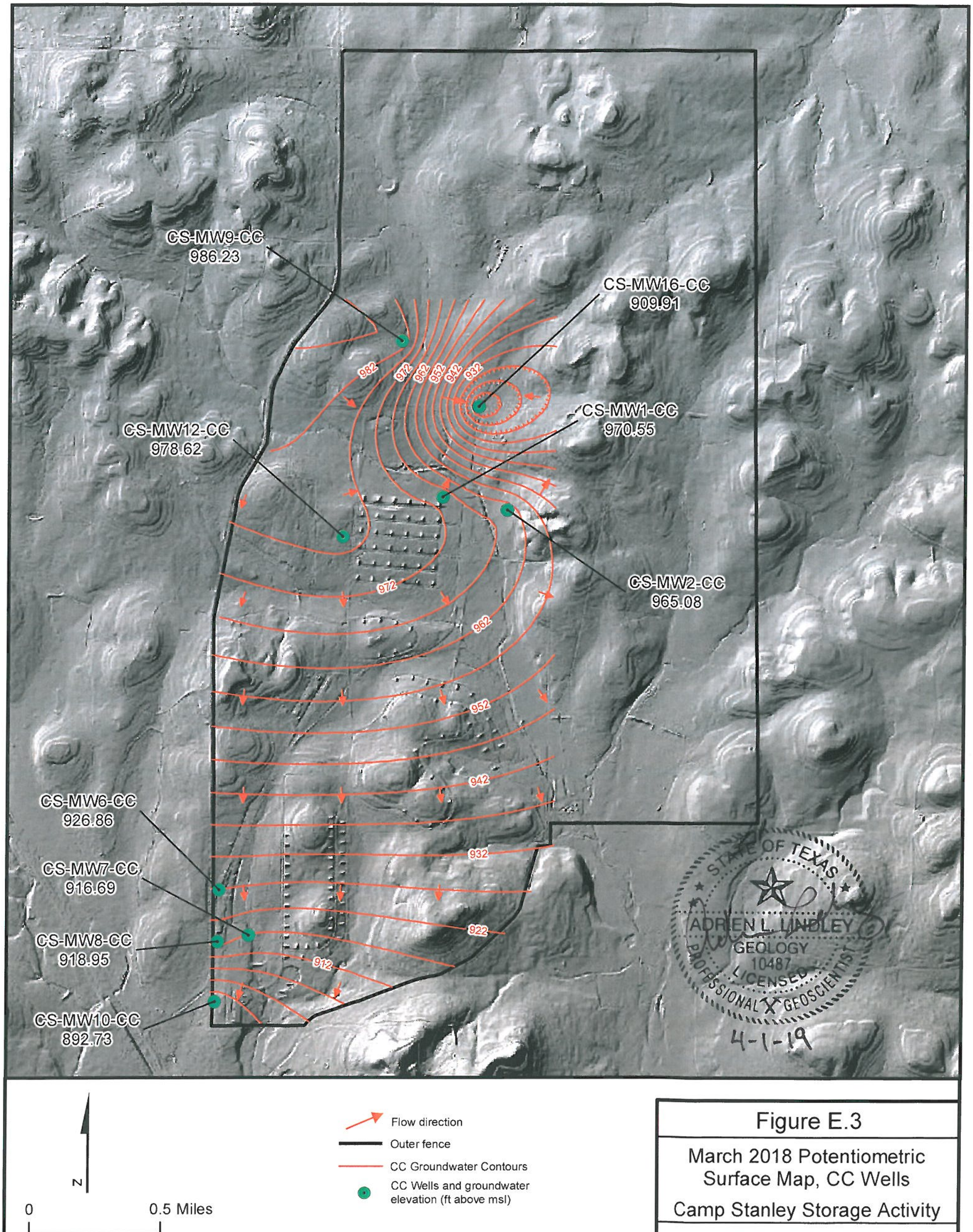


Figure E.3

March 2018 Potentiometric Surface Map, CC Wells

Camp Stanley Storage Activity

PARSONS

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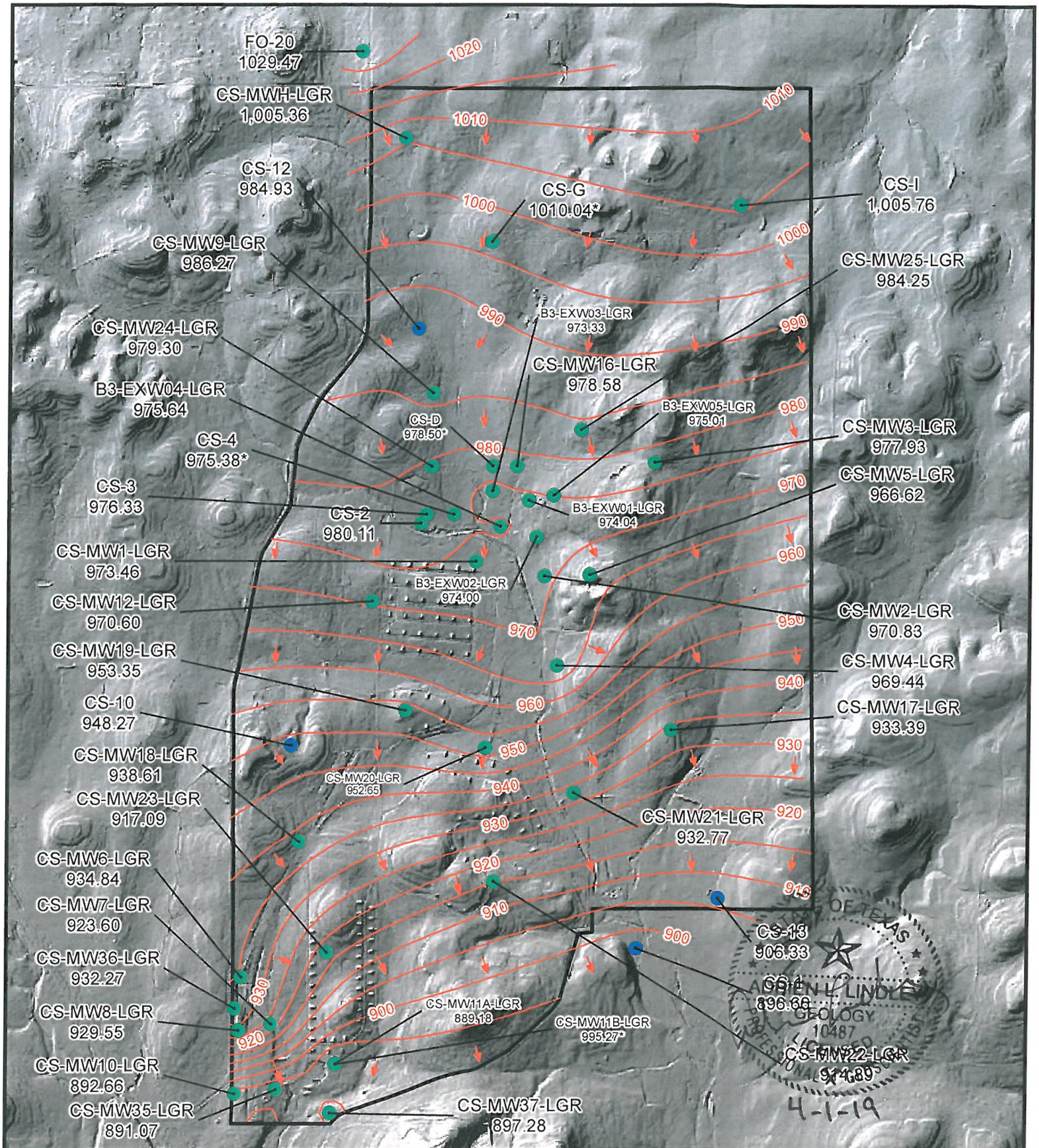

N

0 0.5 Miles

Flow direction
Outer fence
LGR Groundwater Contours
LGR Wells and groundwater elevation (ft above msl)
Drinking water wells (may be completed in LGR, BS, and/or CC)

* Not a fully penetrating well into LGR. Groundwater elevation not used in contouring

C:\CSSA\GIS\GW_POTENTIOMETRIC\JUN2018\Jun18_potentiometric_lgr.mxd - 7/25/2018 @ 5:19:35 PM

Figure E.4

June 2018 Potentiometric Surface Map, LGR Wells

Camp Stanley Storage Activity

PARSONS

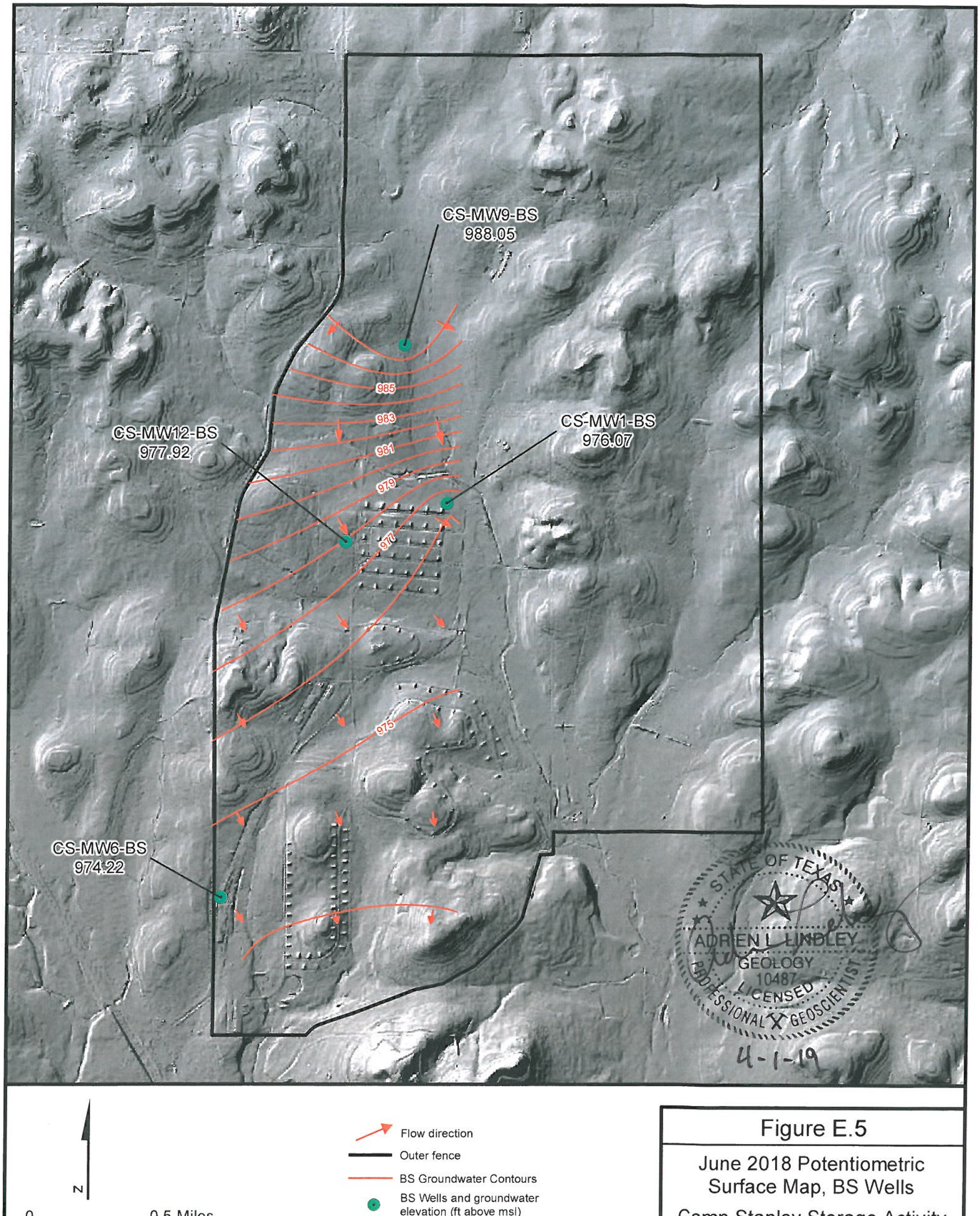

Figure E.5

June 2018 Potentiometric Surface Map, BS Wells

Camp Stanley Storage Activity

PARSONS

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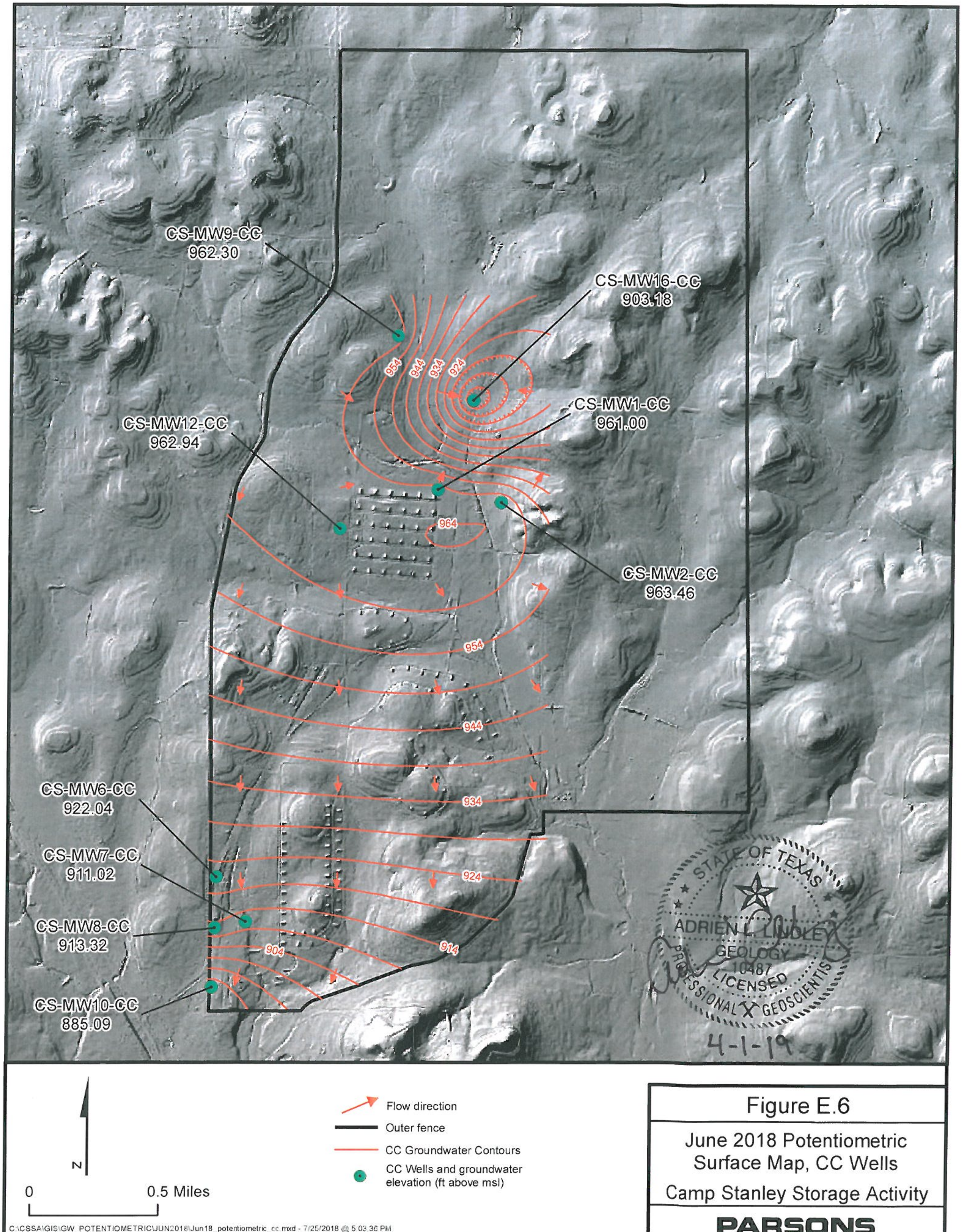

Figure E.6

June 2018 Potentiometric Surface Map, CC Wells

Camp Stanley Storage Activity

PARSONS

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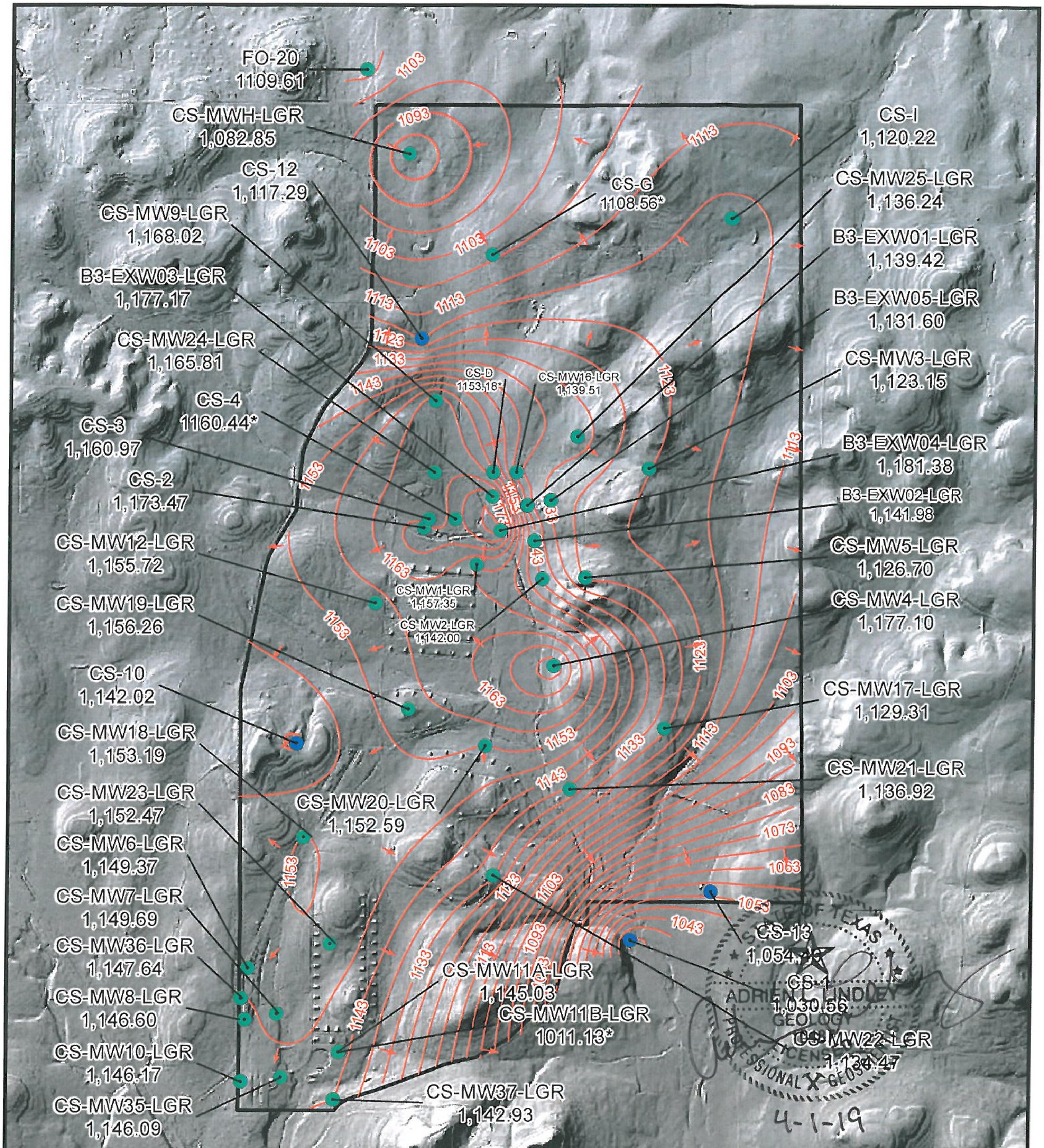

Flow direction

Outer fence

LGR Groundwater Contours

LGR Wells and groundwater elevation (ft above msl)

Drinking water wells (may be completed in LGR, BS, and/or CC)

N

0 0.5 Miles

* Not a fully penetrating well into LGR. Groundwater elevation not used in contouring

Figure E.7

September 2018 Potentiometric Surface Map, LGR Wells

Camp Stanley Storage Activity

PARSONS

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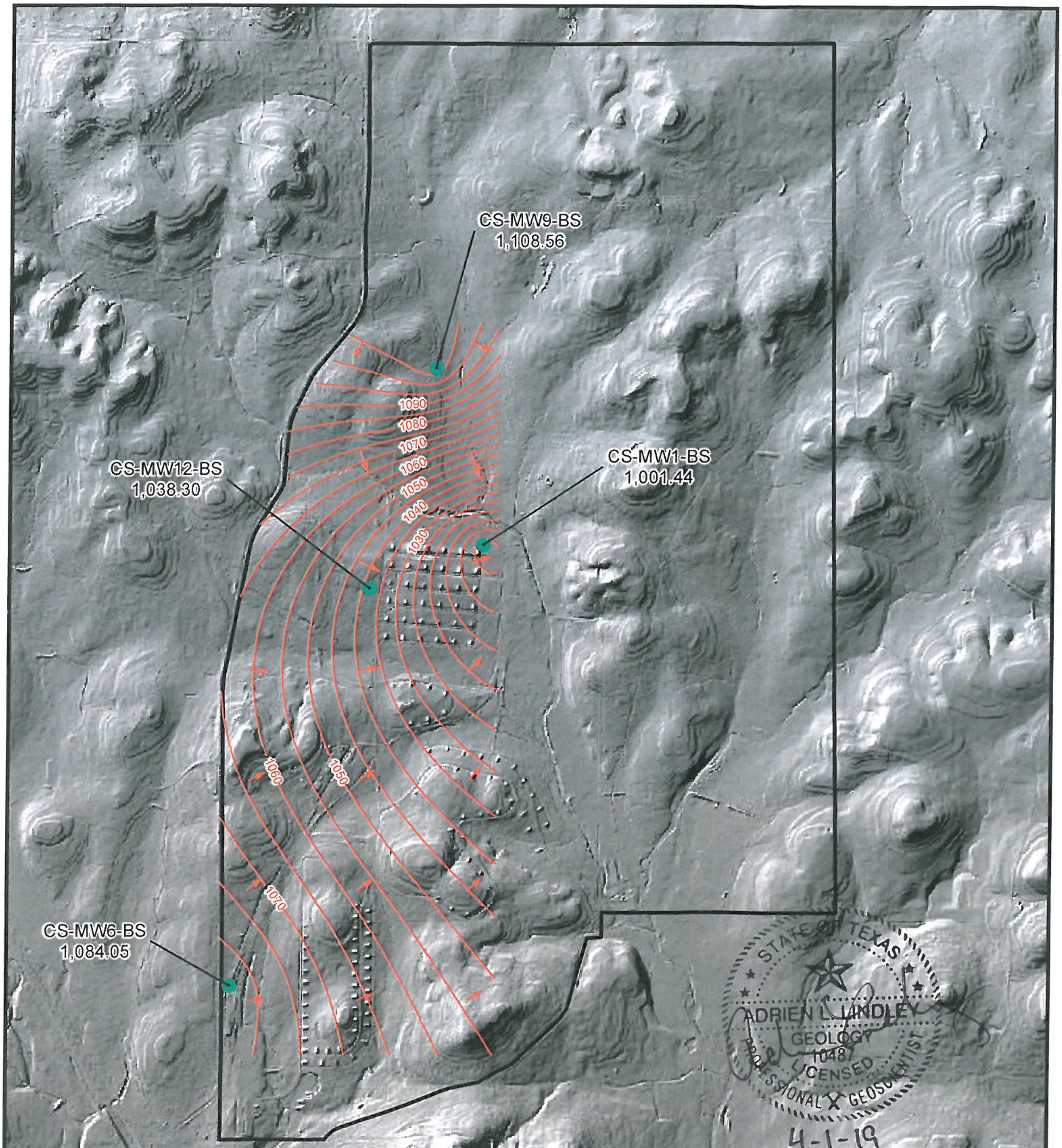


N

0 0.5 Miles

Flow direction

Outer fence

BS Groundwater Contours

BS Wells and groundwater elevation (ft above msl)

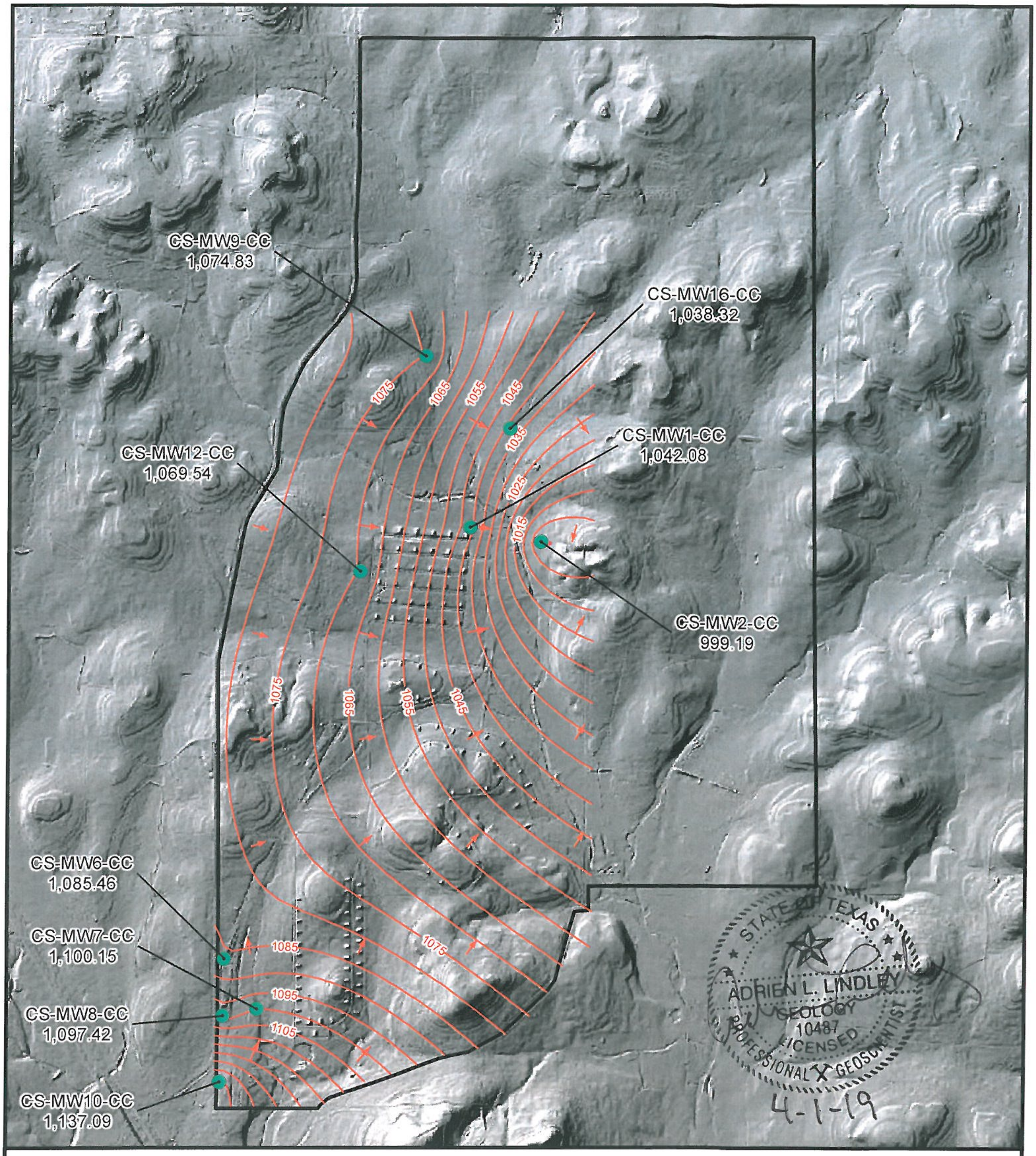
Figure E.8

September 2018 Potentiometric Surface Map, BS Wells

Camp Stanley Storage Activity

PARSONS

C:\CSSA\GIS\GW_POTENTIOMETRIC\SEP2018\Sep18_potentiometric_bs.mxd - 10/24/2018 @ 7:25:26 AM



N

0 0.5 Miles

Flow direction

Outer fence

CC Groundwater Contours

CC Wells and groundwater elevation (ft above msl)

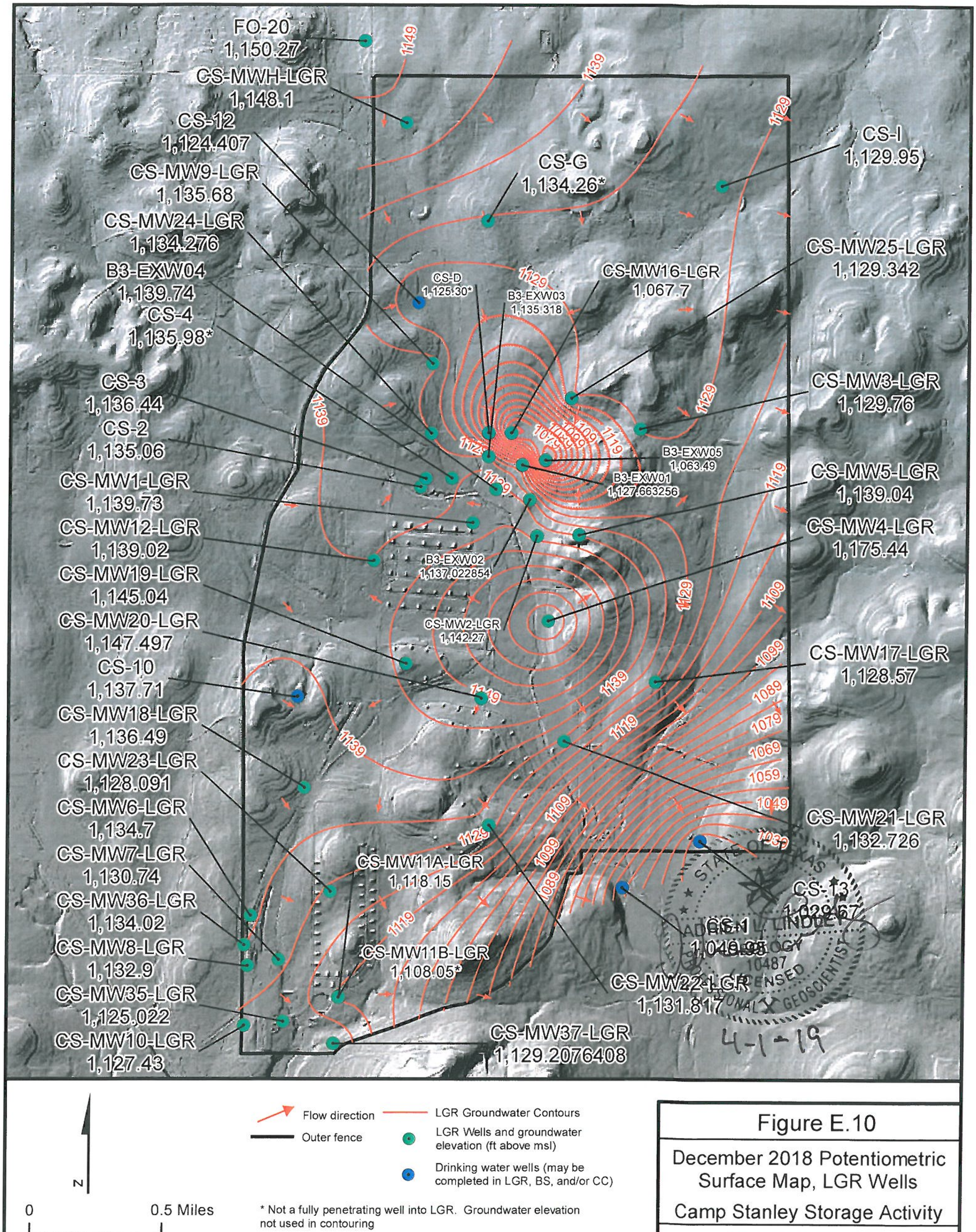
C:\CSSA\GIS\GW_POTENTIOMETRIC\SEP2018\Sep18_potentiometric_cc.mxd - 10/24/2018 @ 7:24:03 AM

Figure E.9

September 2018 Potentiometric Surface Map, CC Wells

Camp Stanley Storage Activity

PARSONS



Flow direction

LGR Groundwater Contours

Outer fence

LGR Wells and groundwater elevation (ft above msl)

Drinking water wells (may be completed in LGR, BS, and/or CC)

* Not a fully penetrating well into LGR. Groundwater elevation not used in contouring

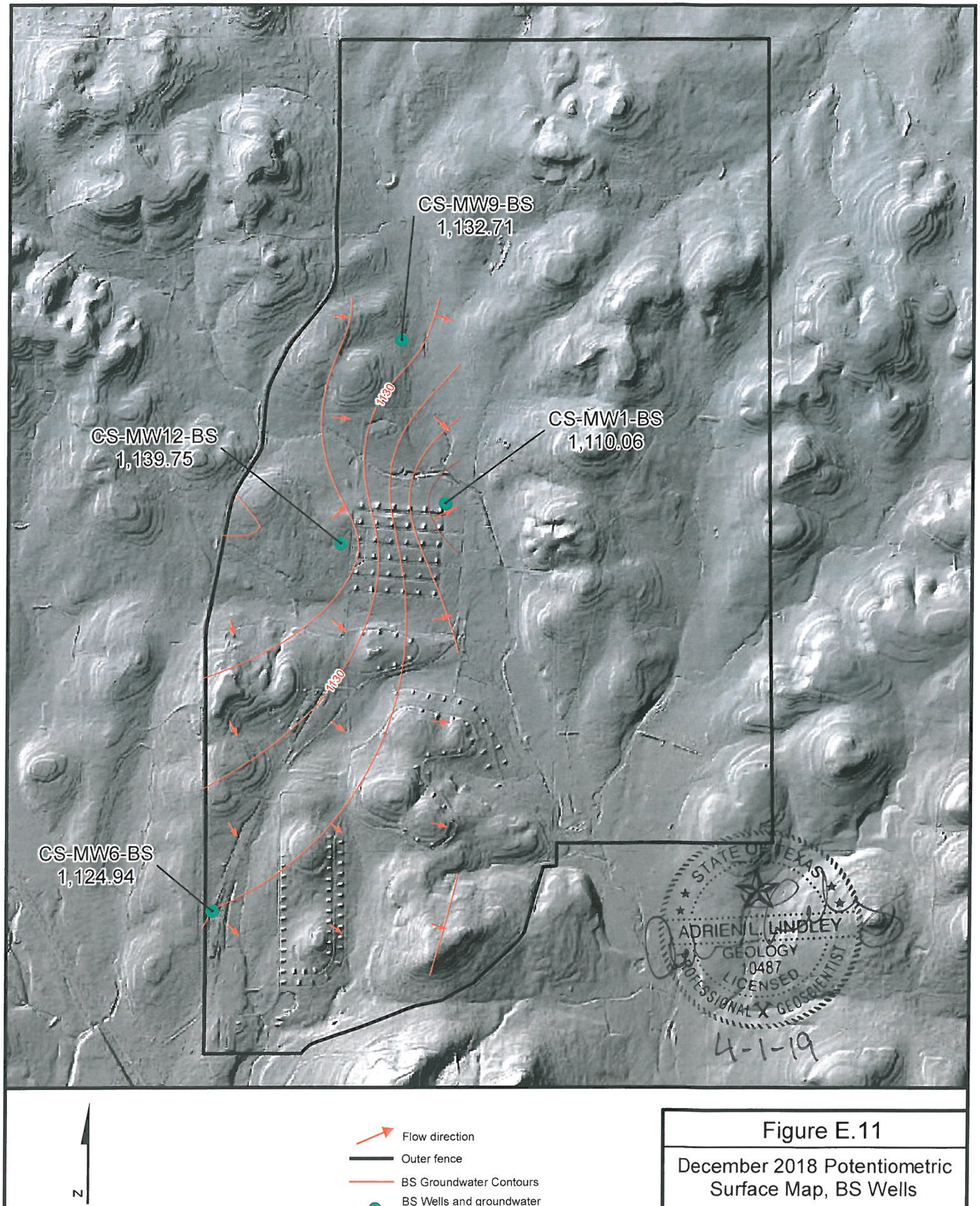
Figure E.10

December 2018 Potentiometric Surface Map, LGR Wells

Camp Stanley Storage Activity

PARSONS

C:\CSSA\GIS\GW_POTENTIOMETRIC\DEC2018\Dec18_potentiometric_lgr.mxd - 3/6/2019 @ 6:44:06 PM



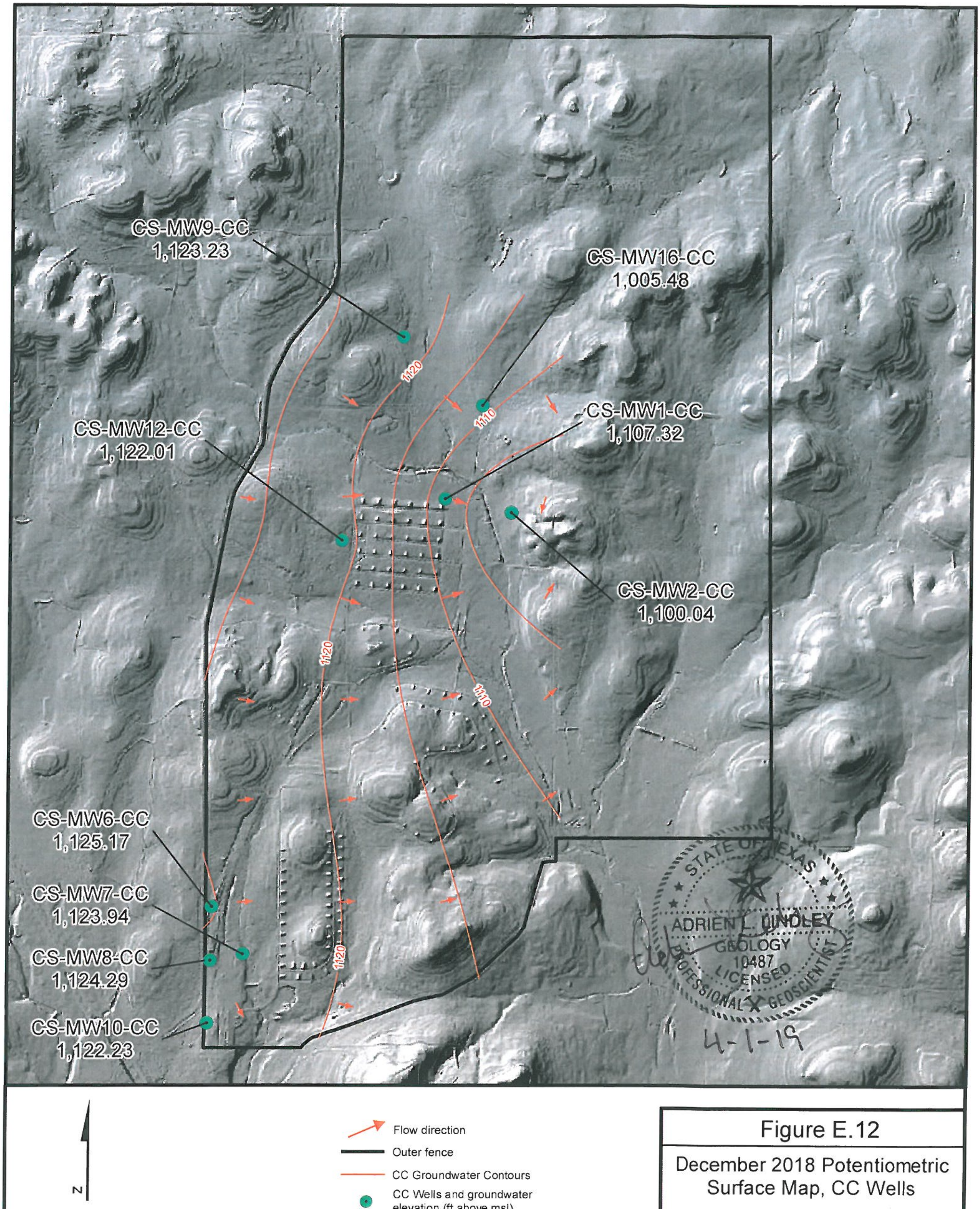
C:\CSSA\GIS\GW_POTENTIOMETRIC\DEC2018\Dec18_potentiometric_bs.mxd - 3/7/2019 @ 10:29:42 AM

Figure E.11

December 2018 Potentiometric Surface Map, BS Wells

Camp Stanley Storage Activity

PARSONS



C:\CSSA\GIS\GW_POTENTIOMETRIC\DEC2018\Dec18_potentiometric_cc.mxd - 3/7/2019 @ 10:13:29 AM

Figure E.12

December 2018 Potentiometric Surface Map, CC Wells

Camp Stanley Storage Activity

PARSONS

APPENDIX F

2018 QUARTERLY OFF-POST GROUNDWATER ANALYTICAL RESULTS

Appendix F
2018 Quarterly Off-Post Groundwater Monitoring Analytical Results

Well ID	Sample Date	*cis*-1,2-DCE (ug/L)	PCE (ug/L)	TCE (ug/L)	Vinyl chloride (ug/L)	pH	Temperature (°C)	Specific Conductivity (mS)
						Field Measurements		
I10-10	9/10/2018	0.07U	0.06U	0.05U	0.08U	7.11	22.68	0.542
JW-20	3/20/2018	0.07U	0.06U	0.05U	0.08U	6.97	21.19	0.724
	9/12/2018	0.07U	0.06U	0.05U	0.08U	7.19	21.38	0.533
LS-5	3/6/2018	0.07U	**1.05F**	**3.56**	0.08U	6.97	22.49	0.630
Duplicate	3/6/2018	0.07U	**0.98F**	**3.33**	0.08U	6.97	22.49	0.630
	6/6/2018	0.07U	**1.02F**	**3.57**	0.08U	6.99	22.61	0.652
	9/13/2018	0.07U	**0.79F**	**2.59**	0.08U	6.95	22.52	0.57
	12/3/2018	0.07U	**0.77F**	**3.10**	0.08U	6.94	22.40	0.667
LS-5-A2	3/6/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
	9/13/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
LS-6	3/6/2018	0.07U	**0.85F**	**2.4**	0.08U	6.93	22.40	0.639
	6/6/2018	0.07U	**0.61F**	**1.91**	0.08U	6.92	22.25	0.668
	9/13/2018	0.07U	**0.66F**	0.05U	0.08U	6.64	22.09	0.682
	12/3/2018	0.07U	**0.87F**	0.05U	**0.34F**	6.74	21.74	0.741
LS-6-A2	3/6/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
	9/13/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
LS-7	3/6/2018	0.07U	**1.7**	**0.58F**	0.08U	6.85	22.54	0.648
	6/6/2018	0.07U	**1.43**	**0.53F**	0.08U	6.89	22.75	0.675
	9/13/2018	0.07U	**1.04F**	0.05U	0.08U	6.73	22.44	0.603
	12/3/2018	0.07U	0.06U	0.05U	0.08U	6.76	22.01	0.667
LS-7-A2	3/6/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
	9/13/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
OFR-3	3/6/2018	0.07U	**4.79**	**2.85**	0.08U	7.05	24.30	0.582
	6/6/2018	0.07U	**4.78**	**3.85**	0.08U	7.02	23.38	0.605
	9/13/2018	0.07U	**2.30**	**1.72**	0.08U	7.02	23.07	0.512
Duplicate	9/13/2018	0.07U	**2.32**	**1.72**	0.08U	7.02	23.07	0.512
	12/3/2018	0.07U	0.06U	0.05U	0.08U	6.98	22.98	0.605
OFR-3-A2	3/6/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
	9/13/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
RFR-10	3/6/2018	0.07U	**8.22**	**4.51**	0.08U	6.98	22.57	0.630
	6/6/2018	0.07U	**10.84**	**6.1**	0.08U	7.00	22.53	0.659
	9/13/2018	0.07U	**4.45**	**2.6**	0.08U	7.00	22.45	0.556
Duplicate	9/13/2018	0.07U	**4.52**	**2.73**	0.08U	7.00	22.45	0.556
	12/3/2018	0.07U	**4.12**	**2.42**	0.08U	6.97	22.81	0.679
RFR-10-A2	3/6/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
	9/13/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
RFR-10-B2	3/6/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
	9/13/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
RFR-11	3/6/2018	0.07U	**0.69F**	**2.25**	0.08U	7.03	23.47	0.597
	6/6/2018	0.07U	**0.70F**	**2.25**	0.08U	7.02	24.22	0.622
	9/13/2018	0.07U	**3.06**	0.05U	0.08U	6.67	21.94	0.755
	12/3/2018	0.07U	**8.73**	**4.96**	0.08U	6.74	22.71	0.921

Appendix F
2018 Quarterly Off-Post Groundwater Monitoring Analytical Results

Well ID	Sample Date	*cis*-1,2-DCE (ug/L)	PCE (ug/L)	TCE (ug/L)	Vinyl chloride (ug/L)	pH	Temperature (°C)	Specific Conductivity (mS)
						Field Measurements		
RFR-11-A2	3/6/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
	9/13/2018	0.07U	0.06U	0.05U	0.08U	NA	NA	NA
RFR-12	9/10/2018	0.07U	**0.22F**	**0.82F**	0.08U	7.03	22.72	0.527
Comparison Criteria								
Maximum Contaminant Level (MCL)		**70**	**5.0**	**5.0**	**2.0**			
Reporting Limit (RL)		**1.2**	**1.4**	**1.0**	**1.1**			
Method Detection Limit (MDL)		**0.07**	**0.06**	**0.05**	**0.08**			

Bold (red)	Value ≥ MCL
Bold (blue)	MCL > Value ≥ RL
Bold	RL > Value > MDL

All samples were analyzed by APPL, Inc. using method SW8260B.
VOC data reported in ug/L & metals data reported in mg/L.

Abbreviations/Notes:

mS	millisiemans
µg/L	micrograms per liter
mg/L	milligrams per liter
deg. C	degrees Celsius
Duplicate	Field Duplicate
TCE	Trichloroethene
PCE	Tetrachloroethene
DCE	Dichloroethene

Data Qualifiers

NA = Not Applicable
U-The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.
F-The analyte was positively identified but the associated numerical value is below the RL.

APPENDIX G

PRE- AND POST-GAC SAMPLE COMPARISONS FOR WELLS LS-5, LS-6, LS-7, OFR-3, RFR-10, AND RFR-11

APPENDIX G

PRE- AND POST-GAC SAMPLE COMPARISONS FOR WELLS LS-5, LS-6, LS-7, RFR-10, RFR-11, AND OFR-3

LS-5				
	PCE (µg/L)		TCE (µg/L)	
Date	**Pre**	**Post**	**Pre**	**Post**
3/6/18	1.05F	ND	3.56	ND
3/6/18 FD	0.98F	NA	3.33	NA
6/6/18	1.02F	NA	3.57	NA
9/13/18	0.79F	ND	2.59	ND
12/3/18	0.77F	NA	3.10	NA

LS-6				
	PCE (µg/L)		TCE (µg/L)	
Date	**Pre**	**Post**	**Pre**	**Post**
3/6/18	0.85F	ND	2.4	ND
6/6/18	0.61F	NA	1.91	NA
9/13/18	0.66F	ND	ND	ND
12/3/18	0.87F	NA	ND	NA

LS-7				
	PCE (µg/L)		TCE (µg/L)	
Date	**Pre**	**Post**	**Pre**	**Post**
3/6/18	1.7	ND	0.58F	ND
6/6/18	1.43	NA	0.53F	NA
9/13/18	1.04F	ND	ND	ND
12/3/18	ND	NA	ND	NA

RFR-10				
	PCE (µg/L)		TCE (µg/L)	
Date	**Pre**	**Post**	**Pre**	**Post**
3/6/18	**8.22**	ND/ND	4.51	ND/ND
6/6/18	**10.84**	NA	**6.1**	NA
9/13/18	4.45	ND/ND	2.6	ND/ND
9/13/18 FD	4.52	NA	2.73	NA
12/3/18	4.12	NA	2.42	NA

RFR-11				
	PCE (µg/L)		TCE (µg/L)	
Date	**Pre**	**Post**	**Pre**	**Post**
3/6/18	0.69F	ND	2.25	ND
6/6/18	0.70F	NA	2.25	NA
9/13/18	3.06	ND	ND	ND
12/3/18	**8.73**	NA	4.96	NA

OFR-3				
	PCE (µg/L)		TCE (µg/L)	
Date	**Pre**	**Post**	**Pre**	**Post**
3/6/18	4.79	ND	2.85	ND
6/6/18	4.78	NA	3.85	NA
9/13/18	2.30	ND	1.72	ND
9/13/18 FD	2.32	NA	1.72	NA
12/3/18	ND	NA	ND	NA

NA – not applicable (post-GAC not sampled during this event)
ND – indicates analyte was not detected at or above the MDL.
FD – field duplicate.

APPENDIX H

DECEMBER 2018
DATA VERIFICATION REPORTS

SDG 87573
SDG 87845

DATA VERIFICATION SUMMARY REPORT

for groundwater samples collected from

CAMP STANLEY STORAGE ACTIVITY

BOERNE, TEXAS

Data Verification by: Sandra de las Fuentes
Parsons - Austin

INTRODUCTION

The following data verification summary report covers water samples and the associated field quality control (QC) samples collected from Camp Stanley Storage Activity (CSSA) on December 3, 2018. The samples were assigned to the following Sample Delivery Group (SDG).

87573

The samples were analyzed for the following parameters: volatile organic compounds by SW8260B, metals by SW6010B, and mercury by SW7470A. The field QC samples associated with this SDG was one field duplicate (FD), one set of matrix spike/matrix spike duplicate (MS/MSD), and one trip blank (TB) sample. No ambient blanks were collected. During the initiation of this project, it was determined that ambient blanks were not necessary due to the absence of a source at these sites.

All samples were collected by Parsons and analyzed by APPL, Inc. following the procedures outlined in the Statement of Work and CSSA QAPP, Version 1.0. Samples in this SDG were shipped to the laboratory in a single cooler, which was received by the laboratory at a temperature of 1.5ºC.

SAMPLE IDs AND REQUESTED PARAMETERS

Sample ID	Matrix	VOCs	Metals	Mercury	Comments
TB-1	Water	X			Trip blank
LS-7	Water	X			
LS-6	Water	X			
LS-5	Water	X			
OFR-3	Water	X			
RFR-10	Water	X			
RFR-11	Water	X			
CS-12	Water	X	X	X	MS/MSD
CS-13	Water	X	X	X	

Sample ID	Matrix	VOCs	Metals	Mercury	Comments
CS-13FD	Water	X	X	X	Field duplicate of CS-13
CS-1	Water	X	X	X	
CS-10	Water	X	X	X	

EXTRACTION, ANALYTICAL, AND REPORTING DETAILS

Parameter	Matrix	Prep Method	Analytical Method	Units
VOCS	WATER	SW5030B	SW8260B	µg/L
Metals	WATER	3010A	SW6010B	mg/L
Mercury	WATER	SW7470A	SW7470A	mg/L

EVALUATION CRITERIA

The data submitted by the laboratory has been reviewed and verified following the guidelines outlined in the CSSA QAPP, Version 1.0. Information reviewed in the data package included sample results; field and laboratory quality control samples; calibrations; case narratives; raw data; chain-of-custody (COC) forms and the sample receipt checklist. The findings presented in this report are based on the reviewed information, and whether the guidelines in the CSSA QAPP, Version 1.0, were met.

VOLATILES

General

The volatiles portion of this data package consisted of fourteen (14) water samples that include ten (10) groundwater samples, one (1) field duplicate, one (1) MS/MSD pair and one (1) trip blank. All samples were collected on December 3, 2018 and analyzed for a reduced list of VOCs which included: *cis*-1,2-dichloroethene, tetrachloroethene, trichloroethene, and vinyl chloride.

The VOC analyses were performed using United States Environmental Protection Agency (USEPA) SW846 Method 8260B. The samples were analyzed in three analytical batches, #235815, #235825 and #235876 under two initial calibrations (ICALs). All samples were analyzed following the procedures outlined in the CSSA QAPP and were prepared and analyzed within the holding time required by the method. All analyses were performed undiluted.

Accuracy

Accuracy was evaluated using the percent recovery (%R) obtained from the three laboratory control spike (LCS) samples, MS/MSD, and the surrogate spikes. Sample CS-12 was designated as the MS/MSD on the COC.

All LCS, MS/MSD, and surrogate spike recoveries were within acceptance criteria.

Precision

Precision was evaluated using the relative percent difference (RPD) obtained from the MS/MSD results. Precision was further evaluated by comparing the field duplicate analyte results. Sample CS-13FD was collected and analyzed as the field duplicate of CS-13.

All MS/MSD RPDs were within acceptance criteria, except as follows: cis-1,2-DCE had an RPD of 22 with a criterion of 20. Since this analyte was not detected in the sample spiked, no corrective action was required.

All FD/parent sample results were non-detect; therefore, RPD could not be evaluated.

Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represents actual site conditions. Representativeness has been evaluated by:

- Comparing the COC procedures to those described in the CSSA QAPP;
- Comparing actual analytical procedures to those described in the CSSA QAPP;
- Evaluating holding times; and
- Examining laboratory blank and TB for cross contamination of samples during sample collection, transportation, and analysis.

All samples in this data package were analyzed following the COC and the analytical procedures described in the CSSA QAPP, Version 1.0. All samples were prepared and analyzed within the holding time required by the method.

- All instrument performance check criteria were met.
- All initial calibration criteria were met.
- All initial calibration verification (ICV) criteria were met. The ICV was prepared using a secondary source standard. All second source verification criteria were met.
- All continuing calibration verification (CCV) criteria were met.
- All internal standard criteria were met.

There were three method blanks associated with the VOC analyses in this SDG. The MBs were non-detect for all target VOCs.

There was one trip blank sample associated with the VOC analyses in this SDG. The TB was non-detect for all target VOCs.

Completeness

Completeness has been evaluated in accordance with the CSSA QAPP. The number of usable results has been divided by the number of possible individual analyte results and expressed as a percentage to determine the completeness of the data set.

All VOC results for the samples in this SDG were considered usable. The completeness for this SDG is 100%, which meets the minimum acceptance criteria of 95%.

ICP-AES METALS

General

The ICP-AES portion of this SDG consisted of seven (7) water samples that includes five (4) groundwater samples, one (1) field duplicate and one (1) MS/MSD pair. All samples were collected on December 3, 2018. All samples were analyzed for arsenic, barium, cadmium, chromium, copper, lead, and zinc.

The ICP-AES metals analyses were performed using USEPA SW846 Method 6010B. All samples were analyzed following the procedures outlined in the CSSA QAPP and were prepared and analyzed within the holding time required by the method.

The samples for ICP-AES metals were digested in batch #235872. All analyses were performed undiluted.

Accuracy

Accuracy was evaluated using the percent recovery obtained from the LCS, MS and MSD. CS-12 was designated as the parent sample for the MS/MSD analyses.

All LCS, MS, and MSD recoveries were within acceptance.

Precision

Precision was measured based on the %RPD of MS/MSD results and parent/FD sample results. Sample CS-13FD was collected and analyzed as the field duplicate of CS-13.

All RPDs were compliant for the MS/MSD.

Barium and Zinc were detected above the reporting limit (RL), as follows:

Metal	Parent (mg/L)	FD (mg/L)	%RPD	Criteria (RPD)
Barium	0.0301	0.0293	2.7	≤20
Zinc	0.358	0.261	31	

Zinc results were qualified as estimated ('J') in the parent and FD samples due to the RPD exceedance.

Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represents actual site conditions. Representativeness has been evaluated by:

- Comparing the COC procedures to those described in the CSSA QAPP;
- Comparing actual analytical procedures to those described in the CSSA QAPP;
- Evaluating preservation and holding times; and
- Examining laboratory blank for cross contamination of samples during analysis.

All samples were analyzed following the COC and the analytical procedures described in the CSSA QAPP, Version 1.0, prepared and analyzed within the holding time required by the method.

- All initial calibration criteria were met.
- All second source verification criteria were met. The ICV was prepared using a secondary source.
- All CCV criteria were met.
- All interference check (ICSA/ICSAB) criteria were met.
- Dilution test (DT) was analyzed on same sample as the MS/MSD (CS-12) and was not applicable since all target metals met criteria in the MS/MSD.
- Post digestion spike (PDS) was analyzed on the same sample as the MS/MSD and DT. All target metals met criteria in the MS/MSD; therefore, the PDS analysis was not applicable.
- The initial calibration blank (ICB) and two of the continuing calibration blank (CCB) samples reported trace amounts of copper. No corrective action was necessary since qualifiers are only applied when blank results are above the reporting limits.

One method blank and several calibration blanks were analyzed in association with the ICP-AES analyses in this SDG. The method blank was free of target metals at or above the RL.

Completeness

Completeness has been evaluated by comparing the total number of samples collected with the total number of samples with valid analytical data.

All ICP-AES metals results for the samples in this SDG were considered usable. The completeness for the ICP metals portion of this SDG is 100%, which meets the minimum acceptance criteria of 95%.

MERCURY

General

The mercury portion of this SDG consisted of seven (7) water samples that includes five (4) groundwater samples, one (1) field duplicate and one (1) MS/MSD pair. All samples were collected on December 3, 2018 and were analyzed for mercury.

The mercury analyses were performed using USEPA SW846 Method 7470A. These samples were analyzed following the procedures outlined in the CSSA QAPP, prepared and analyzed within the holding time required by the method.

The mercury samples were prepared in batch #236189. The analyses were performed undiluted.

Accuracy

Accuracy was evaluated using the percent recovery obtained from the LCS, MS, and MSD. CS-10 was designated as the parent sample for the MS/MSD analyses.

All LCS, MS, and MSD recoveries were within acceptance.

Precision

Precision was measured based on the %RPD of MS/MSD results and parent/FD sample results. Sample CS-13FD was collected and analyzed as the field duplicate of CS-13.

The %RPD of MS/MSD was compliant.

Mercury was not detected in the parent or FD sample.

Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represents actual site conditions. Representativeness has been evaluated by:

- Comparing the COC procedures to those described in the CSSA QAPP;
- Comparing actual analytical procedures to those described in the CSSA QAPP;
- Evaluating holding times; and
- Examining laboratory blanks for cross contamination of samples during analysis.

All samples were analyzed following the COC and the analytical procedures described in the CSSA QAPP, prepared and analyzed within the holding times required by the method.

- All initial calibration criteria were met.
- All second source verification criteria were met. The ICV was prepared using a secondary source.
- All calibration verification criteria were met.

There was one method blank and several calibration blanks associated with the mercury analyses in this SDG. All blanks were free of mercury at or above the RL.

Completeness

Completeness has been evaluated by comparing the total number of samples collected with the total number of samples with valid analytical data.

Mercury result for the samples in this SDG was considered usable. The completeness for the mercury portion of this SDG is 100%, which meets the minimum acceptance criteria of 95%.

DATA VERIFICATION SUMMARY REPORT

for groundwater samples collected from

CAMP STANLEY STORAGE ACTIVITY

BOERNE, TEXAS

Data Verification by: Sandra de las Fuentes
Parsons - Austin

INTRODUCTION

The following data verification summary report covers one water sample collected from Camp Stanley Storage Activity (CSSA) on January 10, 2019. The sample was assigned to the following Sample Delivery Group (SDG).

87845

There was a trip blank sample associated with this SDG. During the initiation of this project, it was determined that ambient blanks were not necessary due to the absence of a source at these sites.

All samples were collected by Parsons and analyzed by APPL, Inc. following the procedures outlined in the Statement of Work and CSSA QAPP, Version 1.0. Samples in this SDG were shipped to the laboratory in one cooler, which was received by the laboratory at a temperature of 1.5ºC.

SAMPLE IDs AND REQUESTED PARAMETERS

Sample ID	Matrix	VOCs	Comments
TB-1	Water	X	Trip blank
CS-12	Water	X	

EXTRACTION, ANALYTICAL, AND REPORTING DETAILS

Parameter	Matrix	Prep Method	Analytical Method	Units
VOCS	WATER	SW5030B	SW8260B	µg/L

EVALUATION CRITERIA

The data submitted by the laboratory has been reviewed and verified following the guidelines outlined in the CSSA QAPP, Version 1.0. Information reviewed in the data package included sample results; field and laboratory quality control samples; calibrations; case narratives; raw data; chain-of-custody (COC) forms and the sample receipt checklist. The findings presented in this report are based on the reviewed information, and whether the guidelines in the CSSA QAPP, Version 1.0, were met.

VOLATILES

General

The volatiles portion of this data package consisted of one (1) groundwater sample, and one (1) trip blank sample. Both samples were collected on January 10, 2019 and analyzed for a reduced list of VOCs which included: *cis*-1,2-dichloroethene, tetrachloroethene, trichloroethene, and vinyl chloride.

The VOC analyses were performed using United States Environmental Protection Agency (USEPA) SW846 Method 8260B. The samples were analyzed in analytical batch #236687 under one initial calibration (ICAL). All samples were analyzed following the procedures outlined in the CSSA QAPP and were prepared and analyzed within the holding time required by the method. All analyses were performed undiluted.

Accuracy

Accuracy was evaluated using the percent recovery (%R) obtained from the laboratory control spike (LCS) sample and the surrogate spikes.

All LCS and surrogate spike recoveries were within acceptance criteria.

Precision

Precision could not be evaluated due to the lack of duplicate analyses involved in this SDG.

Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represents actual site conditions. Representativeness has been evaluated by:

- Comparing the COC procedures to those described in the CSSA QAPP;
- Comparing actual analytical procedures to those described in the CSSA QAPP;
- Evaluating holding times; and
- Examining laboratory blank and TB for cross contamination of samples during sample collection, transportation, and analysis.

All samples in this data package were analyzed following the COC and the analytical procedures described in the CSSA QAPP, Version 1.0. All samples were prepared and analyzed within the holding time required by the method.

- All instrument performance check criteria were met.
- All initial calibration criteria were met.
- All initial calibration verification (ICV) criteria were met. The ICV was prepared using a secondary source standard. All second source verification criteria were met.

- All continuing calibration verification (CCV) criteria were met.
- All internal standard criteria were met.

There was one method blank and one trip blank associated with the VOC analyses in this SDG. The blanks were non-detect for all target VOCs.

Completeness

Completeness has been evaluated in accordance with the CSSA QAPP. The number of usable results has been divided by the number of possible individual analyte results and expressed as a percentage to determine the completeness of the data set.

All VOC results for the samples in this SDG were considered usable. The completeness for this SDG is 100%, which meets the minimum acceptance criteria of 95%.

APPENDIX I

LTMO AND DQO REGULATOR APPROVAL CORRESPONDENCE

March 22, 2011
April 22, 2016
April 29, 2016

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

March 22, 2011

Camp Stanley Storage Activity
ATTN: Mr. Gabriel Moreno-Fergusson
25800 Ralph Fair Road
Boerne, TX 78015-4800

Re: Approval – "Three-Tiered Long Term Monitoring Network Optimization Evaluation and Data Quality Objectives for the Groundwater Monitoring Program", dated November 23, 2011
Camp Stanley Storage Activity (CSSA), Boerne, TX
TCEQ Solid Waste Registration (SWR) No. 69026
RN 100662840; CN 602728206; EPA ID No. TX2210020739

Dear Mr. Moreno-Fergusson:

The Texas Commission on Environmental Quality (TCEQ) has completed the review of the above mentioned report. In accordance with the final Resource Conservation and Recovery Act (RCRA) Section 3008(h) Administrative Order on Consent (Order) for CSSA, the Environmental Protection Agency (EPA) approved the entitled report on February 16, 2011, along with the recommendations. Based on the information provided, the TCEQ approves the LTMO evaluation recommendations and data quality objectives (DQOs).

Questions concerning this letter should be directed to my attention at 512.239.2572 or via email at kcoulter@tceq.state.tx.us. Thank you for your continued cooperation.

Sincerely,

Kirk Coulter, P.G., Project Manager
Corrective Action Team 1, VCP-CA Section
Remediation Division

KEC/jdm

cc: Mr. Greg Lyssy, U.S. EPA Region 6, 1445 Ross Ave (6SF-LT), Dallas, TX 75202-2733
Ms. Julie Burdey, Parsons Inc., 8000 Centre Park Drive, Suite 200, Austin, TX 78754
Mr. Joel Anderson, Waste Program Manager, TCEQ Region 13 Office, San Antonio, TX

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

April 22, 2016

Mr. Jason Shirley
Installation Manager
Camp Stanley Storage Activity
25800 Ralph Fair Road
Boerne, TX 78015

Re: Approval
- *Three-Tiered Long Term Monitoring Network Optimization Evaluation*, dated January 11, 2016
- *Data Quality Objectives - Groundwater Monitoring Program*, dated February 2, 2016
- *Synopsis of Metals Detections in Camp Stanley Groundwater – Compendium Document to the 2015 Data Quality Objectives and Long-Term Monitoring Optimization Documents*, dated January 28, 2016

Camp Stanley Storage Activity, Boerne, Texas
TCEQ SWR No. 69026, CN602728206, RN100662840
EPA ID No. TX2210020739

Dear Mr. Shirley:

The Texas Commission on Environmental Quality (TCEQ) has reviewed the above-referenced submittals. The reports were submitted in accordance with the final Resource Conservation and Recovery Act (RCRA) §3008(h) Administrative Order on Consent (Order) for Camp Stanley Storage Activity, dated May 5, 1999. The reports provide adequate documentation and rationale to support the recommendations and revisions contained therein. The TCEQ approves the Three-Tiered Long Term Monitoring Network Optimization Evaluation, Data Quality Objectives (DQOs) – Groundwater Monitoring, and Synopsis of Metals Detections in Camp Stanley Groundwater as submitted with the following comment:

- The groundwater monitoring DQOs were revised such that the volatile organic compound (VOC) list was reduced from six compounds to four [dropping 1,1-dichloroethene (1-1-DCE) and *trans*-1,2-dichloroethene (trans-1,2-DCE) while retaining tetrachloroethene, trichloroethene, and *cis*-1,2-dichloroethene (*cis*-1,2-DCE)]. If future groundwater analytical results document significant increases in *cis*-1,2,-DCE, the TCEQ requests that CSSA consider evaluating whether 1,1-DCE and *trans*-1,2-DCE should again be added to VOC analyte list.

Questions concerning this letter should be directed to me at (512) 239-6526. Thank you for your continued cooperation.

Sincerely,

Amanda Pirani, P.G., Project Manager
Team 1, VCP-CA Section
Remediation Division
Texas Commission on Environmental Quality

AP/mdh

cc: Ms. Felicia Kraintz, Environmental Program Manager, Camp Stanley Storage Activity (PDF)
Mr. Greg Lyssy, Senior Project Manager, U.S. EPA, Region 6 (PDF)
Ms. Julie Burdey, P.G., Parsons (PDF)
Mr. Jorge Salazar, Federal Facilities Coordinator, TCEQ Region 13 Office (PDF)
Mr. Cameron Lopez, Waste Program Manager, TCEQ Region 13 Office (PDF)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 Ross Avenue, Suite 1200
Dallas, Texas 75202-2733

Transmitted via email

April 29, 2016

Mr. Jason D. Shirley
Installation Manager
Camp Stanley Storage Activity
25800 Ralph Fair Road
Boerne, TX 78015-4800

RE: *RCRA Three Tiered Long Term Monitoring Network Optimization Evaluation*
Camp Stanley Storage Activity, Boerne, Texas

Dear Mr. Shirley:

The Three Tiered Long Term Monitoring Network Optimization (LTMO) Evaluation, dated January 11, 2016, for Camp Stanley Storage Activity (CSSA), has been reviewed by the U.S. EPA (EPA) in accordance with the final Resource Conservation and Recovery Act (RCRA) § 3008(h) Administrative Order on Consent for CSSA, (Order) Docket No. RCRA-VI 002(h)99-H FY99, dated May 5, 1999.

The purpose of the LTMO Evaluation is to ensure that the groundwater monitoring program adequately addresses the monitoring requirements of the remedial actions at the Site, both temporally and spatially. CSSA has been collecting groundwater data since 1991, and has optimized the monitoring program several times to ensure that an adequate monitoring program is in place. The proposed sampling schedule in the LTMO Evaluation meets the temporal and spatial objectives of the CSSA groundwater monitoring program and is hereby approved.

If you have any questions, please feel to contact me at 214-665-8317 or via e-mail at lyssy.gregory@epa.gov.

Sincerely,

Greg J. Lyssy

Greg J. Lyssy
Senior Project Manager
RCRA Corrective Action Section (6MM-RC)

cc: Felicia Kraintz, CSSA
Amanda Pirani, TCEQ
Jorge Salazar, TCEQ
Laurie King, EPA
Julie Burdey, Parsons

APPENDIX J

USEPA CONSTITUENT CONCENTRATION MAPS LETTER

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 Ross Avenue, Suite 1200
Dallas, Texas 75202-2733

Transmitted via e-mail

February 13, 2012

MEMORANDUM

FROM: *Greg J. Lyssy*
Senior Project Manager
Federal Facilities Section (6PD-F)

TO: Gabriel Moreno-Ferguson
CSSA

CC: Kirk Coulter
TCEQ

RE: **CSSA Constituent Concentration Maps**

This Memo is written pursuant to our meeting on January 24, 2012, and as a follow-up to the discussions on the graphical depiction of analytical data in groundwater plume maps, and in accordance with the final Resource Conservation and Recovery Act (RCRA), Section 3008(h) Administrative Order on Consent (Order) for Camp Stanley Storage Activity (CSSA), Docket No. RCRA-VI 002(h)99-H FY99, dated May 5, 1999.

Historically, CSSA has created groundwater plume delineation maps utilizing all analytical data, including historical data points as well as data points that are near or at the method detection limit of the constituents. Preparing plume maps utilizing data points that are in the part per trillion range (and several orders of magnitude below the Maximum Contaminant Levels (MCLs)) may create a misleading graphical representation of the actual plume size.

In order to have consistency on plume maps across different facilities, it is my recommendation that CSSA create a groundwater plume map at the MCL (or appropriate regulatory level if there is not an MCL) for the constituents of concern (COCs). In addition, CSSA should also create a groundwater plume map that depicts isoconcentrations at 20% of the MCL.

If desired, CSSA may create a ***base*** groundwater plume map using data near the method detection limit, but that map ***must*** contain qualifying information on the data that was used to create the map.

Groundwater monitoring of the plume at CSSA is required, and will continue to be required, as long as the Order is in place and there are COCs in the groundwater.

If CSSA, or your technical consultants, have any questions regarding this Memo, please do not hesitate to call me at 214.665.8317, or I may be contacted via e-mail at *lyssy.gregory@epa.gov*.