

Evaluation of Wyckoff Groundwater Level Data January 1, 2018 through March 31, 2018

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This memorandum summarizes the Wyckoff groundwater level results for the January 1 through March 31, 2018 (Quarter 1) monitoring period and evaluates the data to support the determination on whether upper aquifer hydraulic containment was achieved for the quarterly monitoring period.

Summary/Recommendations

- The upper aquifer recovery wells and groundwater treatment system operated 24 hours per day, 7 days per week, except for temporary shutdowns due to low water levels, power outages, weather conditions, and maintenance.
- Hydraulic containment was maintained at all but two well pairs over the 90-day monitoring period, with the lower aquifer to upper aquifer groundwater elevation ratios ranging from 1.03 to 1.53 for Quarter 1. A ratio of greater than 1.0 indicates hydraulic containment was maintained. Hydraulic containment was not maintained for well pairs CW-13/VG-4L and CW08/P-4L during the Quarter 1 - 2018 period.
- The groundwater elevation data from the transducers in the 10 well pairs will be downloaded again on June 30, 2018 to maintain a quarterly data evaluation schedule consistent with that used in the definition of hydraulic containment.
- New transducer cables were installed at three locations during the first week of January 2018, following damage during vegetation clearing operations in September 2017. Transducer calibration was necessary after installation of the new transducer cables. All in-use transducers at the site were calibrated on March 1, 2018. Calibration events are conducted annually to confirm accurate water level measurements.

Water Level Data Collection

The January 1 through March 31, 2018 period represents the next consecutive 90-day quarterly monitoring interval following the Quarter 4 (July 1 through December 31, 2017) evaluation presented in *Evaluation of Wyckoff Groundwater Level Data July 1 through December 31, 2017* (CH2M Memorandum, January 25, 2018). The locations of the monitoring wells are shown on Figure 1 and the wells with transducers are listed in Table 1. Model 705 KPSI™ Level and Pressure Transducers are installed in 22

upper aquifer wells and 18 lower aquifer wells and were last calibrated in March 2018. All recorded water level data are available in e-format upon request.

On September 20, 2017 transducer cables for two upper aquifer wells (VG-2U and CW08) and one lower aquifer well (VG-4L) were damaged during vegetation clearing by a U.S. Environmental Protection Agency subcontractor. The transducer cable for lower aquifer well VG-2L was damaged on October 5, 2017. Data for these wells were unavailable for the Quarter 4 - 2017 monitoring period and the beginning of the Quarter 1 - 2018 monitoring period. Data collection at these three wells resumed on January 9, 2018. The transducer cables at these locations were replaced during the first week of January 2018.

Between the evening of February 18 and the morning of February 20, 2018 the transducers did not record water level data at any of the well pairs due to a power outage at the site.

Table 1 – Wells with Transducers and Upper Aquifer/Lower Aquifer Well Pairings, January 1 through March 31, 2018

Well Pairs for Vertical Gradient Evaluation			Other Wells with Transducers	
Upper Aquifer		Lower Aquifer Well ID		
Well ID	Compartment		Lower Aquifer Well ID	Upper Aquifer Recovery Wells ^a
MW14	1	CW05	E-02b	CW09
MW18	1	02CDMW01	E-04b	P-1L
PO03	1	99CDMW02A	E-06b	P-2L
CW03	2/3	CW02	E-07b	P-3L
VG-2U	2/3	VG-2L	MW-21	P-5L
VG-3U	2/3	VG-3L	RPW-1	P-6L
VG-5U	1	VG-5L	RPW-2	PZ03
PO13	1	VG-1L	RPW-4	SE02
CW13	1	VG-4L	RPW-5	
CW08	1	P-4L	RPW-6	
			PW-8	
			PW-9	

^a All upper aquifer recovery wells are screened across Compartments 1/2/3 except MW-21, which is screened in Compartment 1.
^b The E-0x series of wells are located within the Pilot Test sheet pile wall.

Groundwater Treatment Plant Operations

The groundwater treatment plant (GWTP) and all nine of the upper aquifer extraction wells operated 24 hours per day, 7 days per week during Quarter 1, as conditions permitted. Several extraction well shutdowns occurred during the monitoring period due to low water levels, power outages, adverse weather conditions (e.g. wind/freeze), or maintenance. The dates during which the extraction wells were shut down for periods greater than 24 hours are listed in Table 2. These periods are graphically overlain with the rainfall records and are shown in Figure 3. For the Quarter 1 monitoring period (January 1 through March 31, 2018), 11.71-inches of rainfall was recorded.

The total volume of water extracted from the upper aquifer was 5,077,106 gallons during the 90-day monitoring period, equating to an average pumping rate of approximately 39 gpm for the 90 days where

all or portions of the wellfield were in operation. [Note, when fully operating, and upper aquifer water levels allow, the system can pump about 72 gpm.]

Table 2 – Former Process Area (FPA) Extraction Well Pump Shutdown Periods Greater than 1 Day

Offline Dates	Wells	Reason
December 8, 2017 – January 11, 2018	PW-9	Low water level
January 11 – January 12, 2018	PW-1, PW-2, PW-4, PW-5, PW-6, PW-8, PW-9, EW-2, EW-6	Shutdown in preparation for expected wind storm
February 7, 2018 – beyond Quarter 1	PW-9	Low water level
February 10 – February 14, 2018	PW-1, PW-2, PW-4, PW-5, PW-6, PW-8, EW-2, EW-6	Pumps off due to site power issues
February 14 – February 16, 2018	PW-1, PW-2, PW-4, PW-5, PW-6, PW-8	Pumps off due to expected freezing temperatures
February 16 – March 1, 2018	EW-2, EW-6	Pumps off due to expected freezing temperatures
March 9 – March 12, 2018	PW-1, PW-2, PW-4, PW-5, PW-8, EW-2	Pumps off for carbon change out
March 9, 2018 – beyond Quarter 1	PW-6, EW-6	Pumps off for carbon change out

Hydraulic Containment Evaluation

Upper aquifer hydraulic containment at the Wyckoff site is evaluated using water level data from 10 upper and lower aquifer well pairs as shown in Table 1 (See Figure 1 for the well locations). Hydrographs for each of the 10 well pairs have been prepared and are presented in Figures 2a through 2j. Seven of the upper aquifer wells are screened in Compartment 1 while three upper aquifer wells are screened in Compartment 2/3.

Hydraulic containment at each well pair is evaluated by first calculating the average groundwater elevations in the upper and lower aquifers using the water elevation data recorded every 15 minutes during the monitoring period. Then the average upper and lower aquifer groundwater elevations at each well pair are compared relative to each other. If the average lower aquifer groundwater elevation is greater than the average upper aquifer groundwater elevation at the well pair, an upward (positive) vertical gradient is indicated. Additionally, if an upward vertical gradient is present, the ratio of the average lower aquifer water elevation to the average upper aquifer water elevation for that well pair is greater than 1.0 for the duration of the monitoring period, and a hydraulic containment maintained determination is made.

Additional evaluations are conducted through examination of the short-term periods when downward hydraulic gradients occur. Groundwater elevations for each well pair are compared at each 15-minute recording, and the summary statistics: average, maximum, and minimum difference in groundwater elevation for each well pair are calculated, along with a duration analysis for negative (downward) gradients. The duration analysis includes the number of downward gradients observed during the

monitoring period, their average duration (hours), and the cumulative duration (days and percent) for the monitoring period. A downward vertical gradient is indicated when the difference between the lower and upper aquifer groundwater elevations at each 15-minute recording have a negative value (e.g. average upper aquifer groundwater elevation greater than the average lower aquifer groundwater elevation).

The summary statistics and hydraulic containment evaluation data for the well pairs are summarized in Table 3. Table 3 is based on the 90-day monitoring period (Quarter 1) from January 1 through March 31, 2018, which corresponds to the quarterly period used for assessing hydraulic containment. The table presents the average groundwater elevations for each well pair, the ratio of the average lower aquifer to upper aquifer groundwater elevation, the average and range of ratios observed, and summary statistics for negative vertical gradient conditions (compared at each 15-minute recording) between the upper and lower aquifers.

Based on the information presented in Table 3, the following determinations were made:

- The average lower aquifer to upper aquifer groundwater elevation ratios were greater than 1.0 at 8 of the 10 well pairs for the 90-day monitoring period, indicating hydraulic containment was maintained at these 8 locations.
- Negative vertical gradients were observed at 8 of the 10 monitoring well pairs. Downward (negative) vertical gradient events typically occur during the lowest semidiurnal tide period when the lower aquifer groundwater elevation declines below the upper aquifer groundwater elevation (see Figures 2a through 2j). Groundwater elevations in the upper aquifer Compartment 2/3 and all lower aquifer wells are strongly influenced by daily tidal fluctuations while water levels in the upper aquifer Compartment 1 wells show much less tidal influence.
- Negative vertical gradients occurred in 8 of the 10 well pairs as a series of short-duration downward gradient periods. The average duration of the downward gradient periods was between 4 and 5 hours each at five well pair locations, and between 6 and 11 hours each at the remaining three well pair locations.
- At seven of the eight locations where negative gradients were observed (MW14/CW05, MW18/02CDMW01, PO03/99CDMW02A, VG-5U/VG-5L, PO13/VG-1L, CW13/VG-4L and CW08/P-4L), the upper aquifer well is screened in Compartment 1, and at the eighth location (CW03/CW02) the upper aquifer well is screened in Compartment 2/3. The remaining two well pairs (VG-2U/VG-2L and VG-3U/VG-3L) did not have any downward gradients during the current reporting period. The upper aquifer well at these two well pair locations is screened in Compartment 2/3.
- At 1 of the 10 well pairs (MW18/02CDMW01), the total negative gradient duration for the 90-day period was 3.3% (3 days). Three of the 10 well pairs (MW14/CW05, PO03/99CDMW02A, and CW02/CW03) had durations between 10.6% and 19.5% (9.5 to 17.5 days), three well pairs (VG-5U/VG-5L, PO13/VG-1L, and CW13/VG-4L) had durations between 26.7% and 42.2% (24 to 38 days), while the remaining well pair (CW08/P-4L) had a total duration of 50.7% (45.7 days) of the 90-day monitoring period. CW08/P-4L also had the highest total negative gradient duration during the Quarter 2 - 2017 and Quarter 3 - 2017 monitoring periods of 2017. The frequency of downward gradients at well pair CW08/P-4L is unusual in that this well pair is located a similar distance (190 ft) from production well RPW2 as is VG-3U/VG-3L which had no negative gradient events.
- Maximum downward flow gradients occurred at seven well pairs on January 30 and 31, 2018 when the extraction wells were in full operation, following precipitation amounts of 1.11 and

0.98 inches on January 29 and 30, 2018, respectively, and when minus tides up to -2.79 feet mean lower low water (MLLW) occurred. One well pair had a maximum negative flow gradient occurrence on February 25, 2018 when three extraction wells were shut down and when minus tides up to -0.53 feet MLLW occurred.

Summary

During the Quarter 1 monitoring period, hydraulic containment was maintained at eight of the ten well pairs. Hydraulic containment was not maintained at well pairs CW13/VG-4L and CW08/P-4L.

Negative hydraulic gradient events occurred in 8 of the 10 well pairs over the Quarter 1 monitoring period. The maximum observed negative gradients, for the Quarter 1 period, occurred for 7 of the 10 well pairs on January 30 and 31, 2018 when the well field was in full operation, following two daily precipitation totals of up to 1.11 inches, and when minus tides up to -2.79 ft MLLW occurred. The remaining well pair (MW18/CDMW01) had a maximum negative flow gradient on February 25, 2018 when three extraction wells were shut down and when minus tides up to -0.53 feet MLLW occurred (Figure 3).

During extraction well shutdown events, water levels in some of the upper aquifer well locations recovered quickly showing a general increase between 0.5 to 3 feet (Figures 2a through 2j).

Table 3
Summary of Groundwater Elevation Data by Well Pair
January 1 through March 31, 2018

Well Pair	Upper Aquifer Average Groundwater Elevation (ft. MLLW)	Lower Aquifer Average Groundwater Elevation (ft. MLLW)	Ratio (Avg Lower Aq WL / Avg Upper Aq WL) ^a	Summary Statistics Short Term Comparison - Water Level Difference between the Upper and Lower Aquifer wells (ft)			Duration Analysis – Downward (neg.) Gradient			
				Average	Max	Min	Number of Neg Grad Events	Average Duration of Neg Grad (hours)	Total Duration of Neg Grad (days)	Percent Duration of 92-day Monitoring Period ^b
MW14/CW05	9.09	10.52	1.16	1.43	4.49	-2.86	94	4	17.5	19.5%
MW18/02CDMW01	6.72	10.29	1.53	3.58	7.95	-1.82	16	4	3.0	3.3%
PO03/99CDMW02A	8.55	10.63	1.24	2.08	5.52	-2.73	54	5	10.2	11.3%
CW03/CW02	8.09	9.75	1.20	1.66	4.16	-1.54	56	4	9.5	10.6%
VG-2U/VG-2L	8.48	9.63	1.14	1.16	2.01	0.34	none			
VG-3U/VG-3L	8.08	11.01	1.36	2.92	4.93	0.22	none			
VG-5U/VG-5L	11.71	12.07	1.03	0.36	3.03	-3.35	122	6	31.2	34.7%
PO13/VG-1L	9.06	10.10	1.12	12.07	4.41	-3.86	110	5	24.0	26.7%
CW13/VG-4L	13.75	12.27	0.89	-1.48	2.10	-7.05	80	11	38.0	42.2%
CW08/P-4L	10.61	10.03	0.95	-0.58	2.78	-5.68	141	8	45.7	50.7%

Notes:

^a Ratio > 1 = Hydraulic Containment was Achieved

^b Percent Duration of Monitoring Period = total duration of negative gradient in days divided by the number of calendar days in the monitoring period

Figures

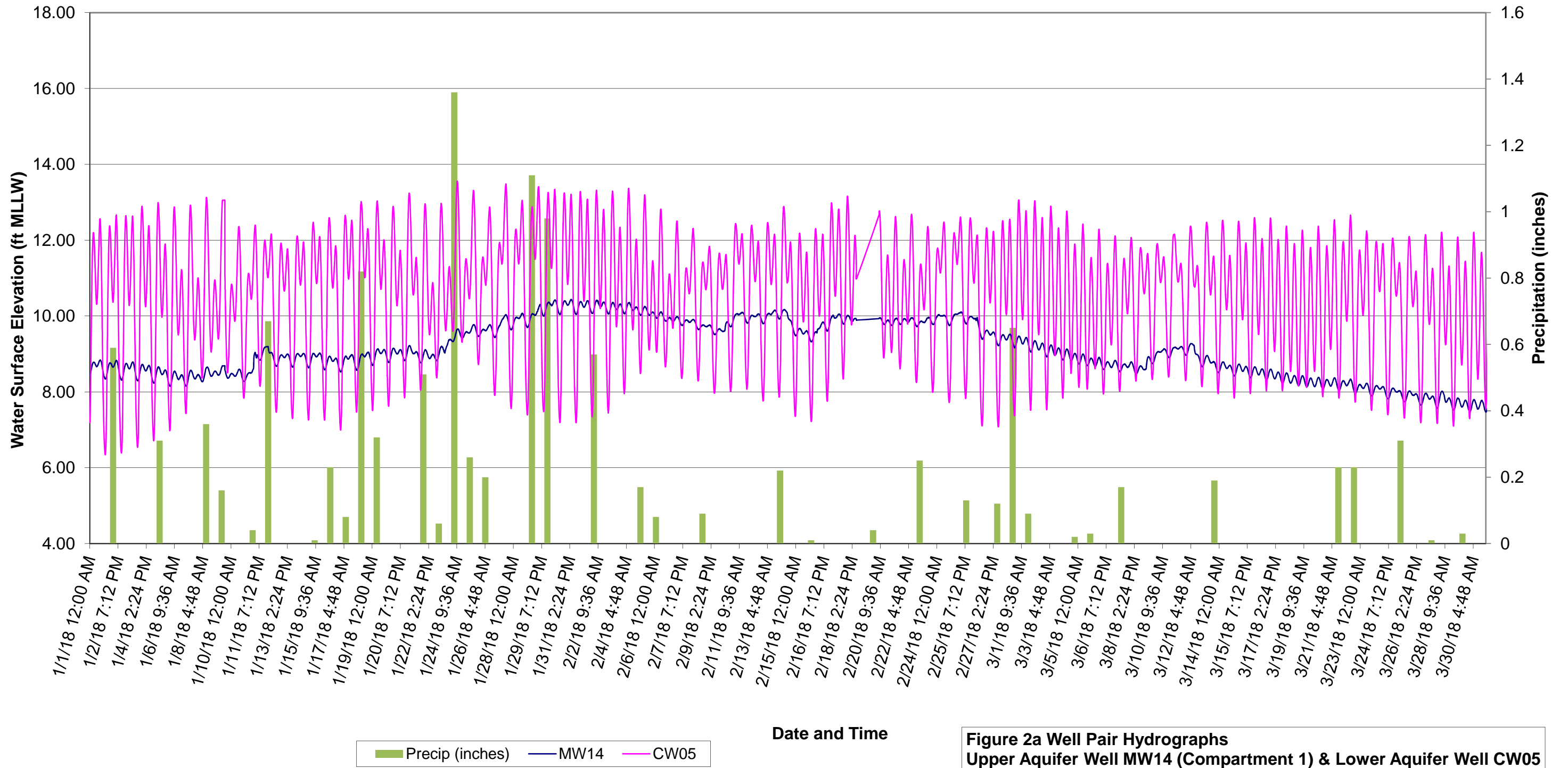
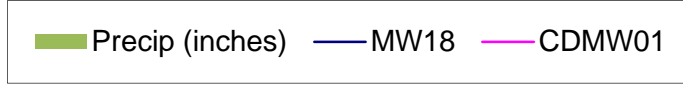
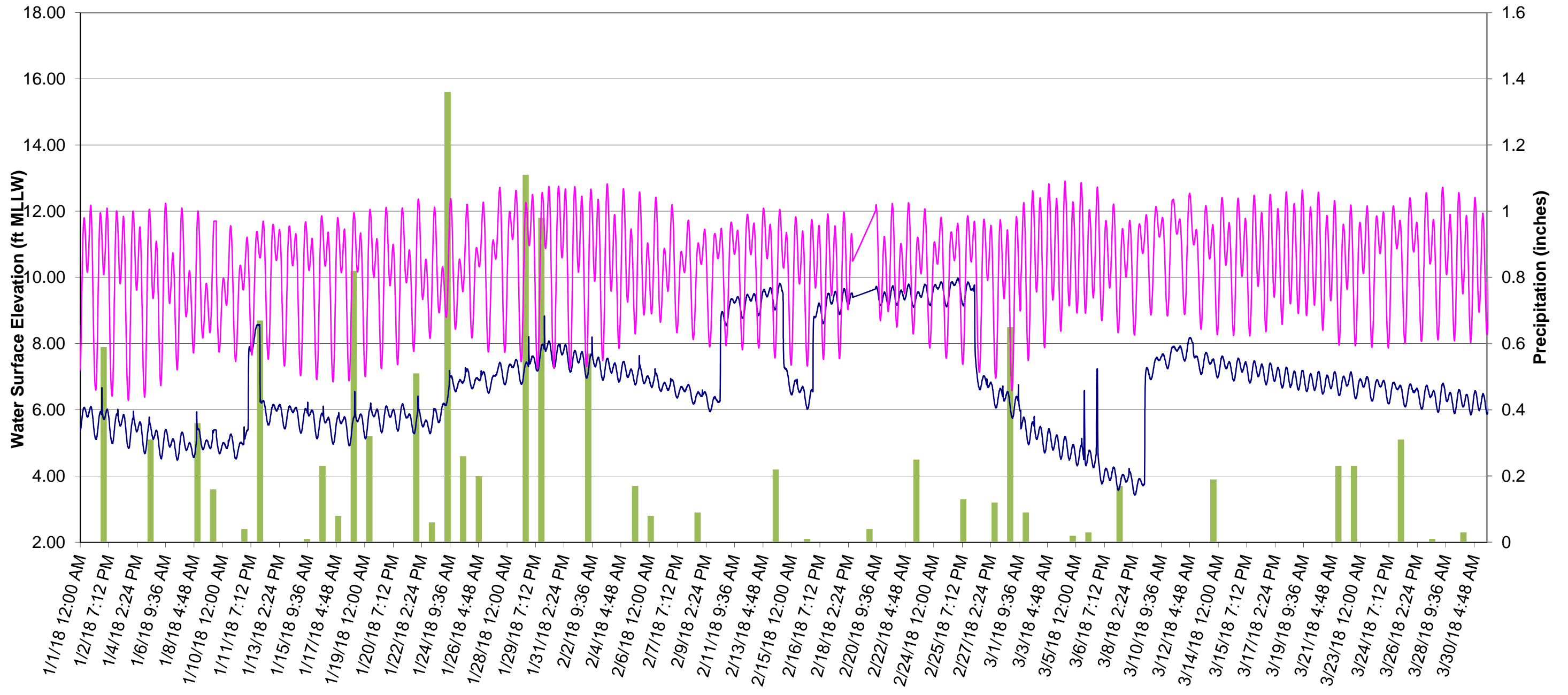
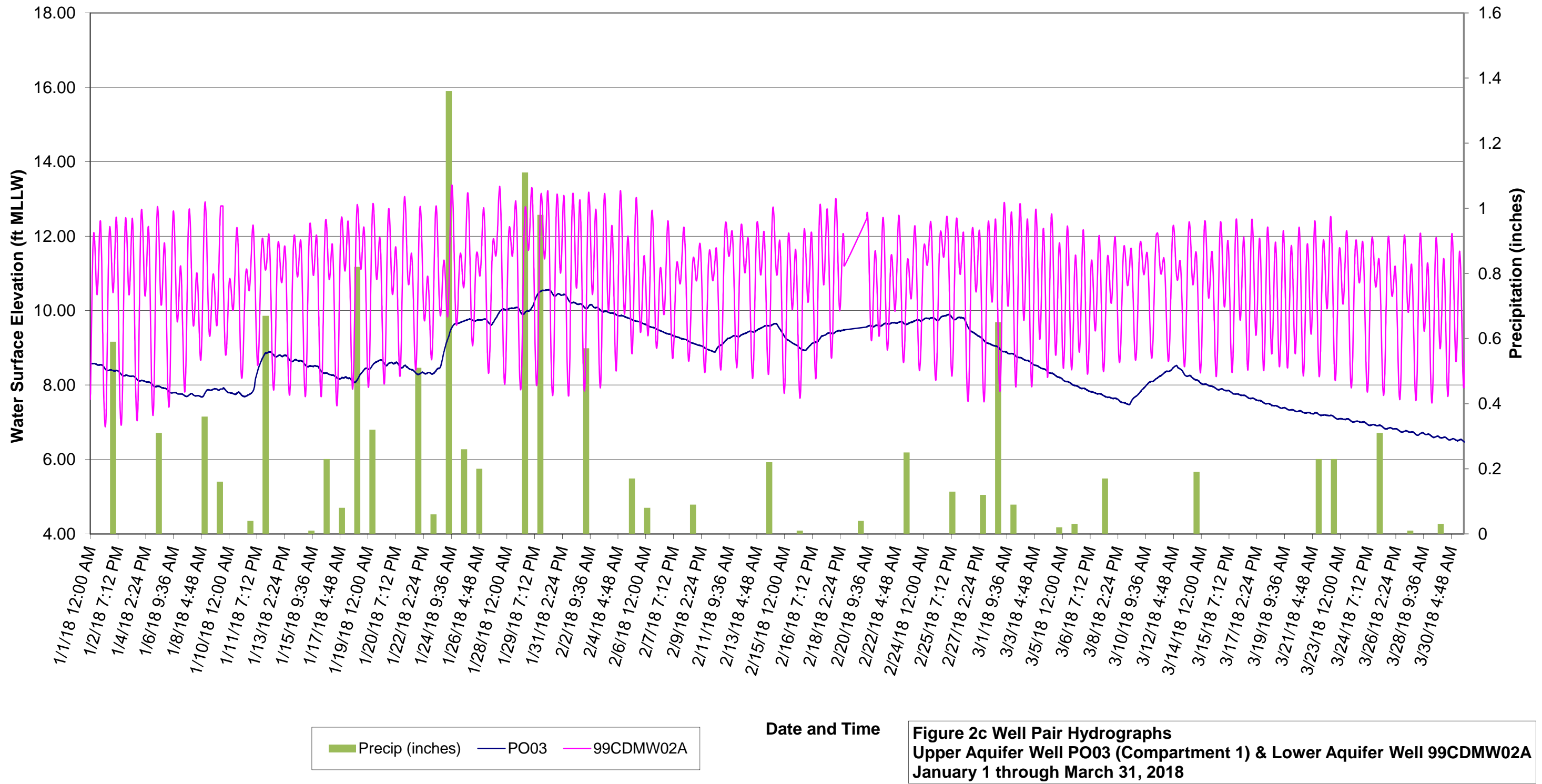


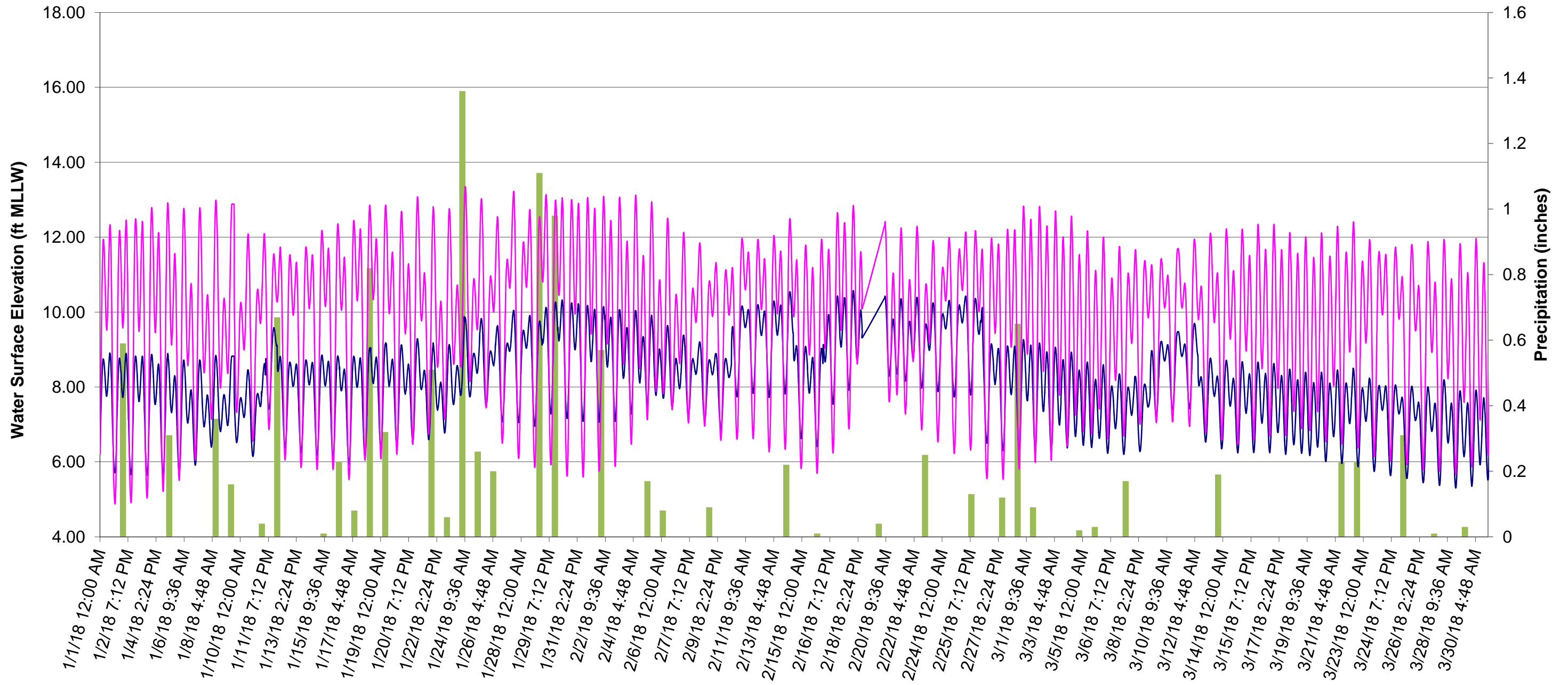
Figure 2a Well Pair Hydrographs
Upper Aquifer Well MW14 (Compartment 1) & Lower Aquifer Well CW05
January 1 through March 31, 2018



Date and Time

**Figure 2b Well Pair Hydrographs
Upper Aquifer Well MW18 (Compartment 1) & Lower Aquifer Well 02CDMW01
January 1 through March 31, 2018**

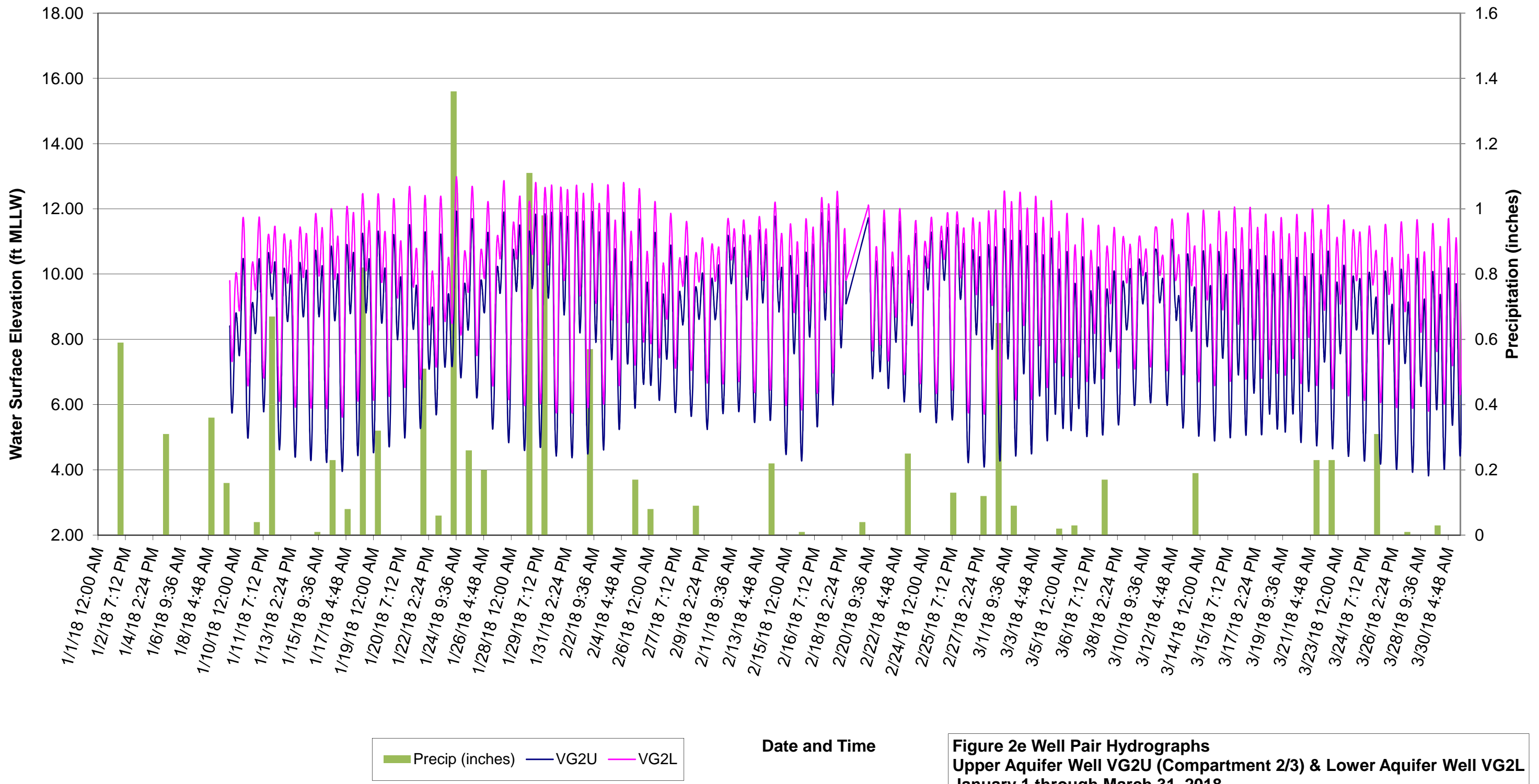


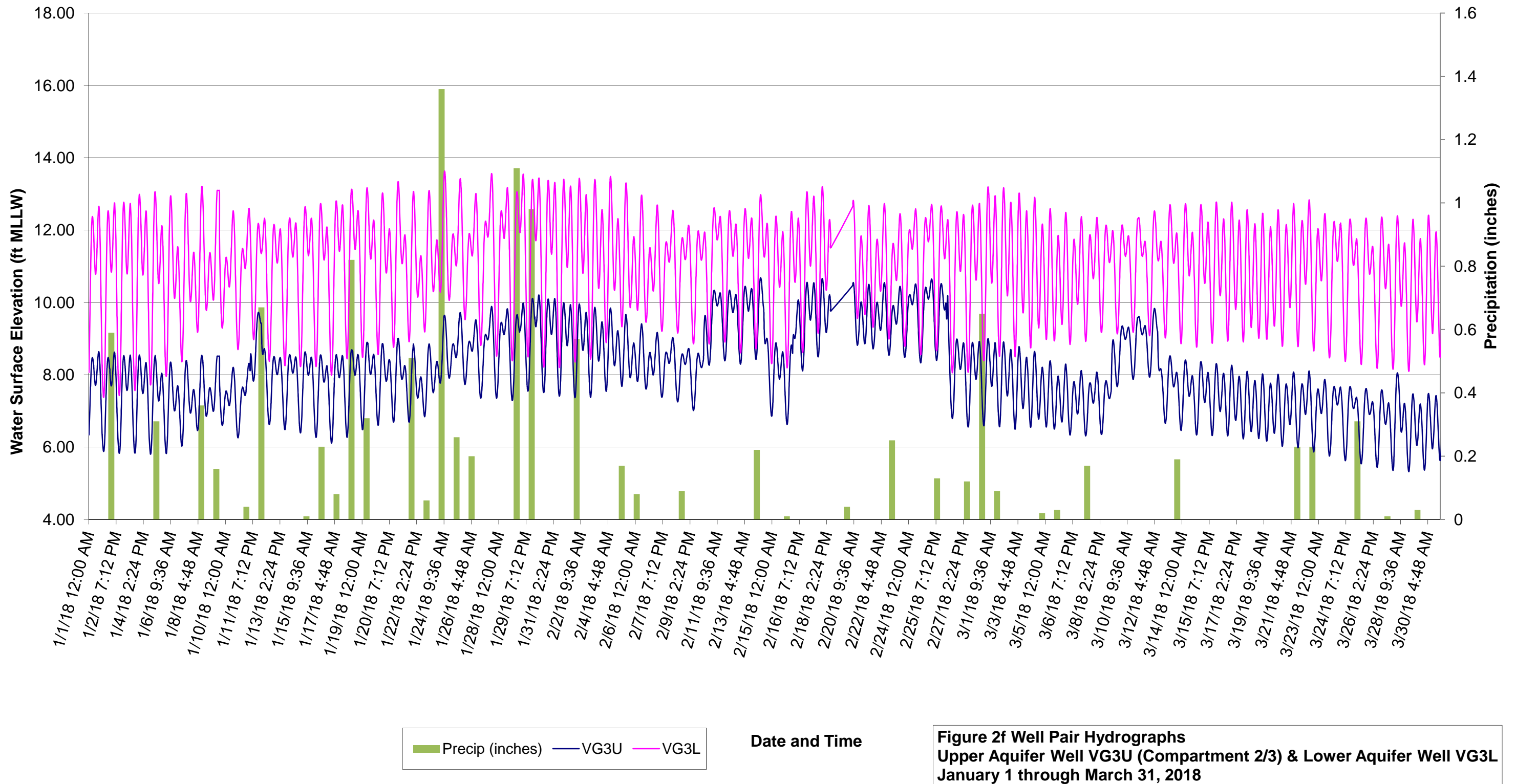


■ Precip (inches)
 — CW03
 — CW02

Date and Time

Figure 2d Well Pair Hydrographs
Upper Aquifer Well CW03 (Compartment 2/3) & Lower Aquifer Well CW02
January 1 through March 31, 2018





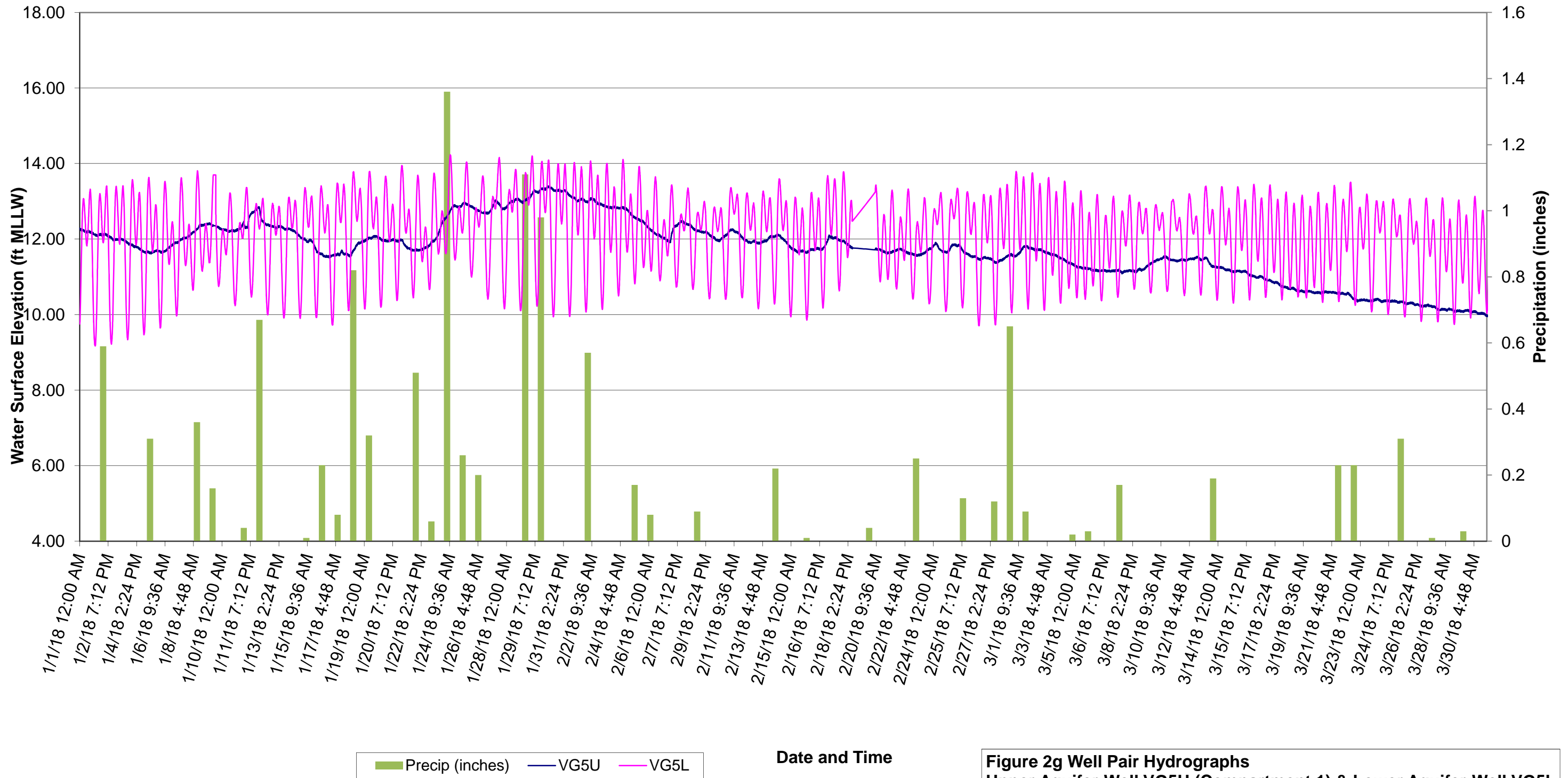
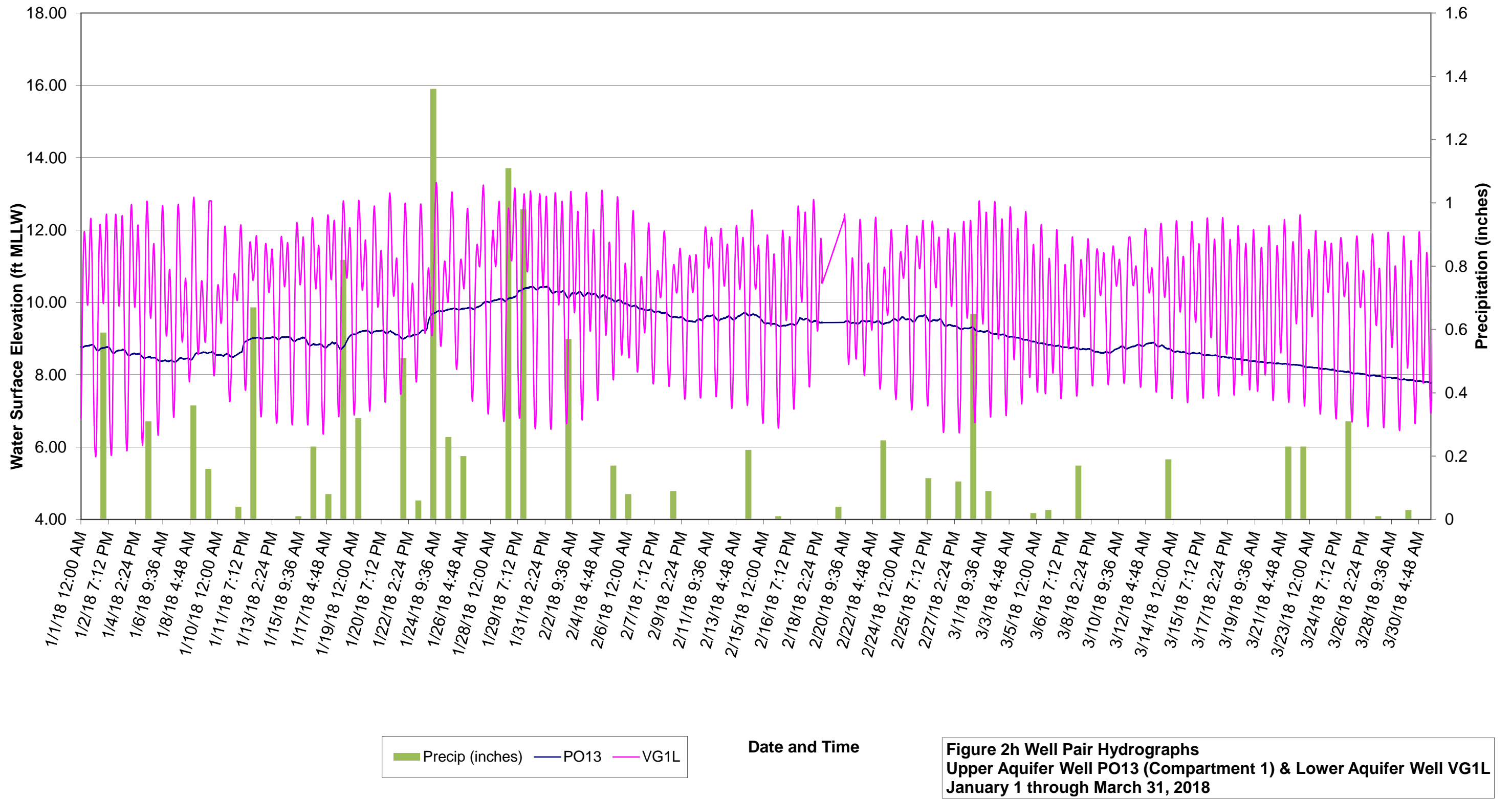
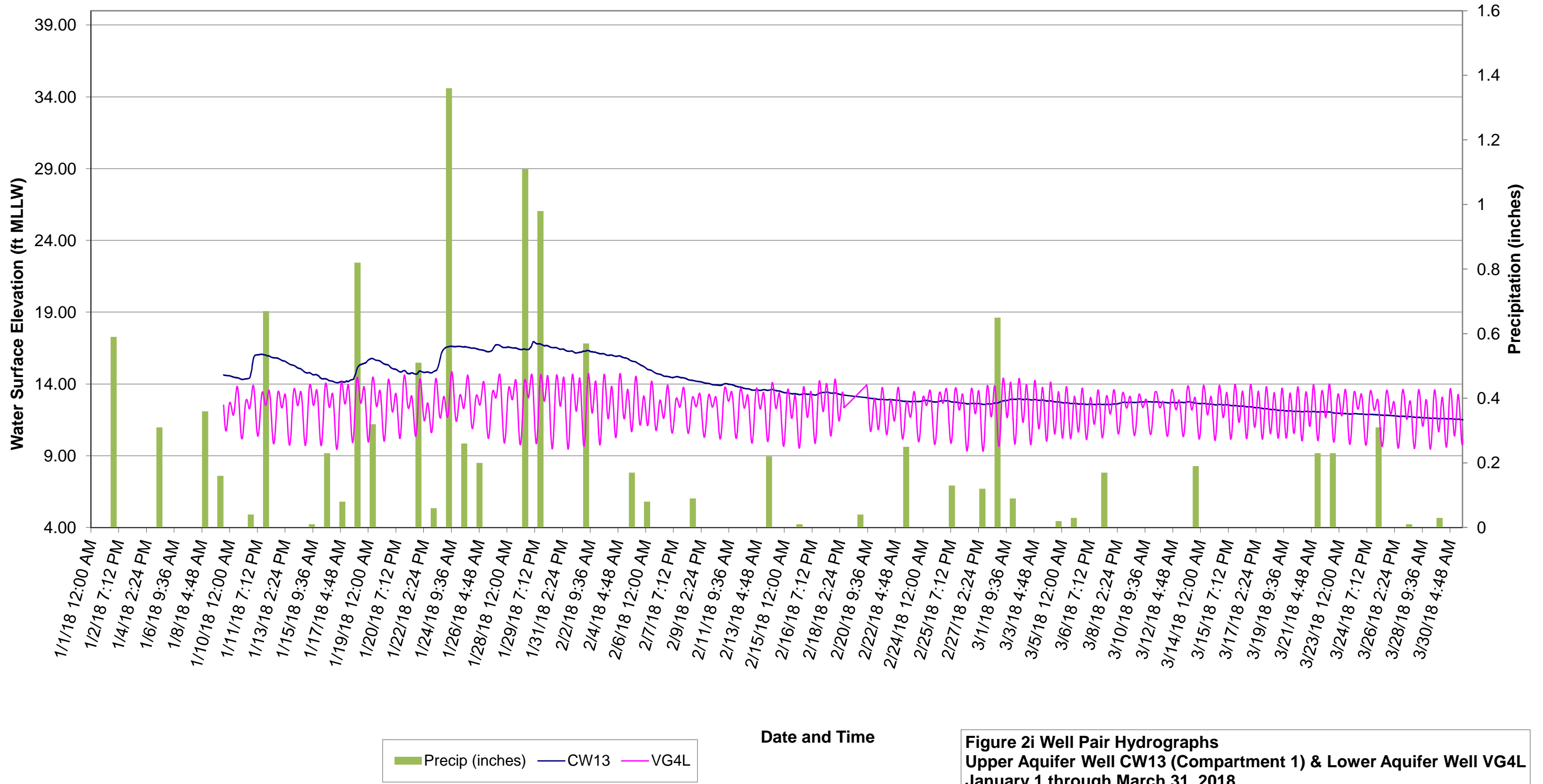
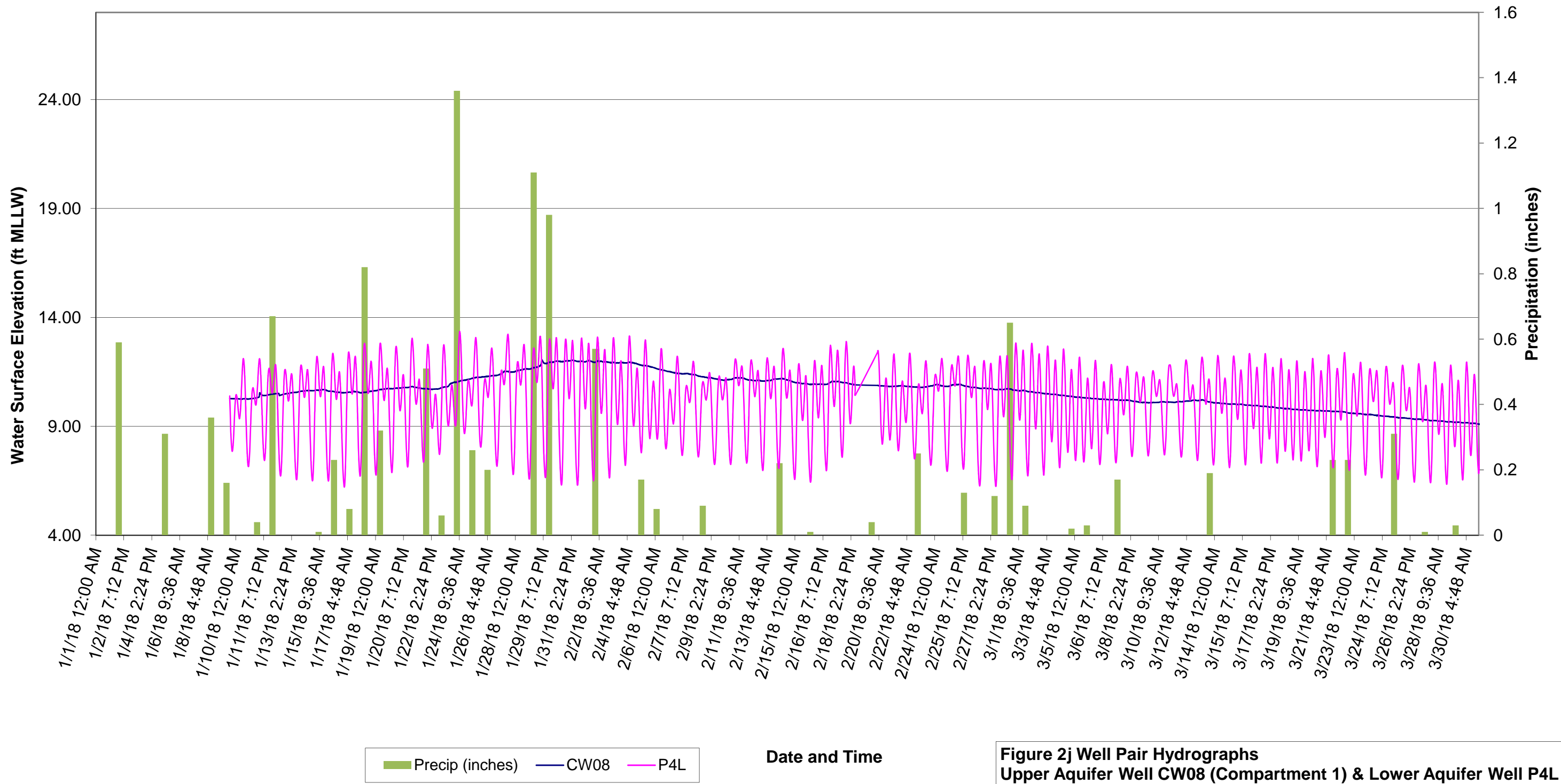


Figure 2g Well Pair Hydrographs
Upper Aquifer Well VG5U (Compartment 1) & Lower Aquifer Well VG5L
January 1 through March 31, 2018







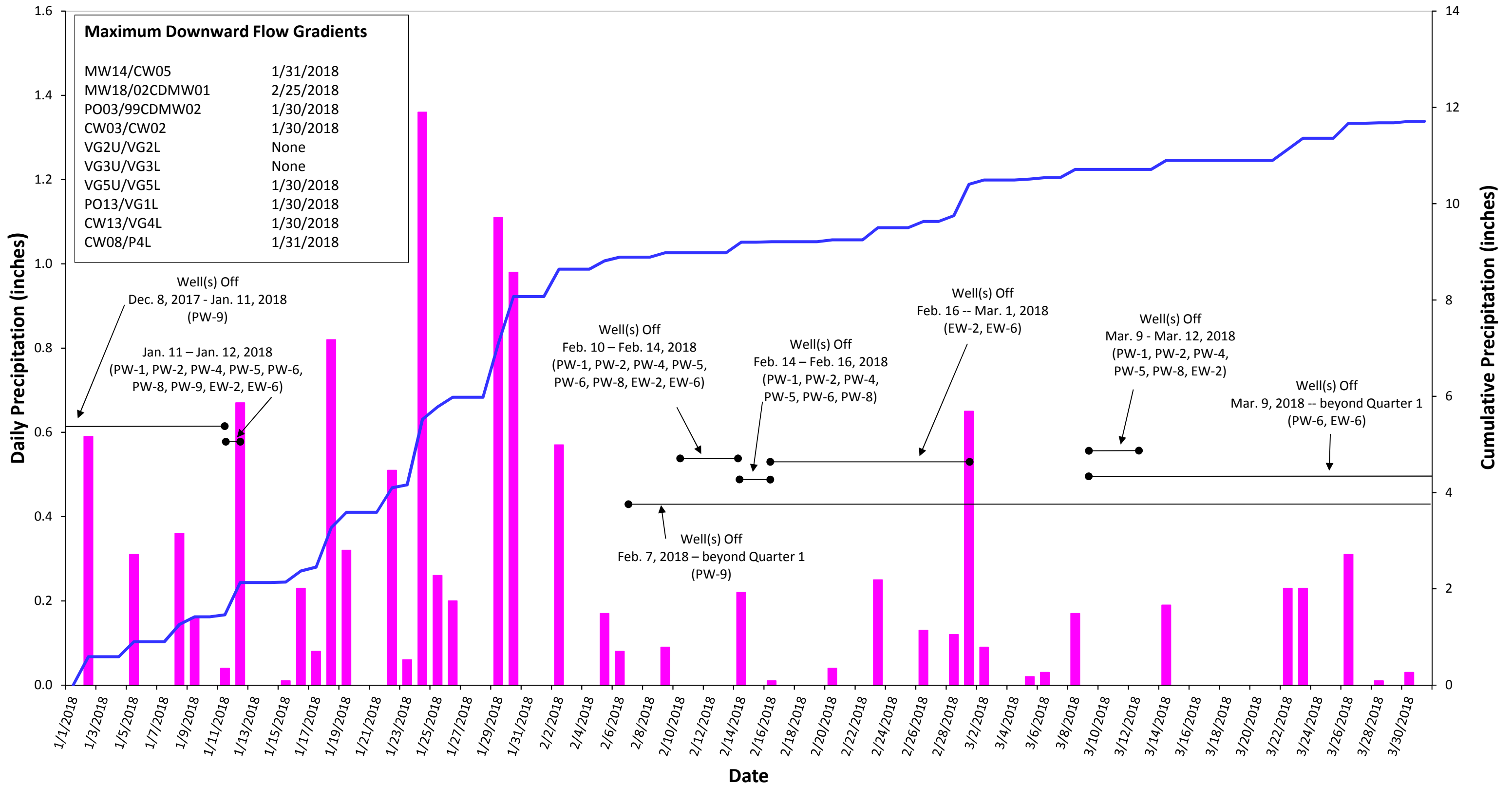


Figure 3 Wyckoff Site Precipitation, Well Field Shutdown, and Max Downward Flow Potential Summary January 1 through March 31, 2018

