

Comanche Station No Aquifer Determination Memorandum

Date: Tuesday, January 30, 2018

To: Jennifer McCarter, Public Service Company of Colorado

From: Matt Rohr, HDR, Inc.

Subject: Comanche Station No Aquifer Determination

1 Introduction

The U.S. Environmental Protection Agency's (EPA's) final Coal Combustion Residuals (CCR) Rule establishes comprehensive a set of requirements for the management and disposal of CCR (or coal ash) in landfills and surface impoundments by electric utilities. Comanche Station, located in Pueblo, Colorado (Figure 1) is owned and operated by Public Service Company of Colorado (PSCo), an Xcel Energy Company. Comanchev Station has two active CCR units, an impoundment (Bottom Ash Pond) and an Ash Disposal Facility (landfill) (Figure 2) subject to the CCR Rule.

Per the CCR Rule, groundwater monitoring is required to monitor potential impacts to the uppermost aquifer. PSCo has implemented groundwater monitoring pursuant to the Comanche Groundwater Monitoring System Certification (HDR, 2016). PSCo has characterized hydrogeologic conditions at the site in multiple previous investigations. Prior studies indicate the properties of the shallow perched water beneath the site are not consistent with the definition of an "aquifer." Despite the lack of an aquifer, PSCo implemented groundwater monitoring as defined in the CCR Rule to establish baseline characteristics of the shallow perched water where present. The monitoring program was designed to be compliant with the CCR Rule; however, it is not required, nor is it possible, based on the definition of aquifer within the Rule. Subsequent sections will present the definition of an aquifer, as presented in the Rule, and provide the site conditions relevant to that definition.

Eight rounds of samples from around the landfill and around the impoundments were collected where water was encountered before October 17, 2017 as specified under CCR Rule Part 257.94. An additional 9th sampling event was also completed. Typically the water quality collected from monitoring wells located upgradient of the CCR facilities would be compiled and statistically analyzed to develop background threshold values (BTV) for each constituent of interest (COI) at each CCR facility. However, there is no laterally continuous water table across the site and no gradient associated with the perched water underlying the CCR regulated facilities. Therefore no wells could be identified as upgradient, and BTVs could not be established. Therefore, this No Aquifer Determination Memorandum is provided in lieu of an

Annual Report to document the nine sample events performed and to describe the hydrogeologic site conditions relative to the definition of an aquifer.

2 Facility Description

Comanche Station is a coal-fired plant consisting of three generating units (Units 1, 2, and 3). Comanche Station currently has two CCR units subject to the CCR Rule, the Bottom Ash Pond and the Landfill (Figure 2). Additional non-CCR ponds at the facility include process water, settling, polishing, and raw water storage ponds. These additional ponds do not manage CCR, and therefore are not subject to the CCR Rule.

The CCR landfill, also known as the CCR Ash Disposal Facility (Figure 2), is an approximately 280-acre ash monofill consisting of eight permitted disposal cells. Currently, disposal is occurring in one 40-acre cell (Cell 1) in the southeast corner of the permitted landfill, which was constructed with a clay liner (Xcel Energy, 2005). Fly ash from all three units is collected in silos for disposal in the landfill. Bottom ash is also disposed in the on-site landfill. Water treatment sludge (lime from an on-site treatment system), process water pond sediment, coal impurities, and excavation soils are also permitted for disposal at the landfill (Tetra Tech, 2015). Cell 2 is being constructed in late 2017 with disposal operations expected to commence in early 2018.

Bottom ash generated from Units 1 and 2 is sluiced to the Bottom Ash Pond for dewatering and temporary storage. Bottom ash solids are routinely excavated from the impoundment and either beneficially used off-site or transported to the landfill for disposal. Bottom ash is removed from Unit 3 dry via a submerged flight conveyor (SFC) and does not go into the bottom ash pond; it is transported dry either to off-site beneficial use or to the landfill for disposal. According to historic documents, the impoundment was constructed in 1972 with a three-foot thick clay liner; however, this liner does not meet the requirements of the CCR Rule (HDR, 2016). The primary influent to the CCR impoundment is bottom ash sluiced from Units 1 and 2. Additional influent sources include continuous deionization softeners waste, brine and rinse, and activated carbon filter backwash and brine (Tetra Tech, 2012). The CCR impoundment effluent discharges to the polishing pond immediately east of the Bottom Ash Pond (Figure 2).

2.1 Hydrogeology

Comanche Station is underlain by unconsolidated colluvium consisting of stiff clays and silts. Typical colluvium thickness is less than 20 feet but has been found to range between 5 and 75 feet across the site (Woodward-Clyde, 1987; URS, 2005). The colluvium is underlain by the Pierre Shale, the uppermost bedrock at the Comanche Station. A water table does not exist regionally in the Pierre Shale (Tetra Tech, 2013). Underlying the approximate 1,450 feet of shale bedrock deposits is the Dakota Sandstone, the uppermost bedrock aquifer in this region (Tetra Tech, 2012).

The shallow unconsolidated colluvium deposits beneath Comanche Station are predominantly unsaturated, with some isolated areas of perched water (GeoTrans, Inc. 2009). Previous studies have reported that a continuous water table does not appear to exist in the colluvium above the thick Pierre Shale bedrock (Xcel Energy, 2005; Tetra Tech, 2012; GeoTrans, Inc., 2009). The

bedrock contact surface does not appear to have a consistent gradient across the site for perched water to flow across site-wide (GeoTrans, 2009). According to GeoTrans (2009), shallow perched water detected in the colluvium deposits beneath the site is not laterally extensive or continuous across the site.

Observations made by HDR during well drilling and the background groundwater sample events for compliance with the CCR Rule indicate that HDR's site conceptual model is consistent with previous reports, that shallow perched water is occurring as a result of localized surface infiltration. Surface water infiltration from precipitation and/or snow melt collects in topographic lows in the bedrock surface or migrates vertically into low-permeability bedrock that is almost 1,500 feet thick.

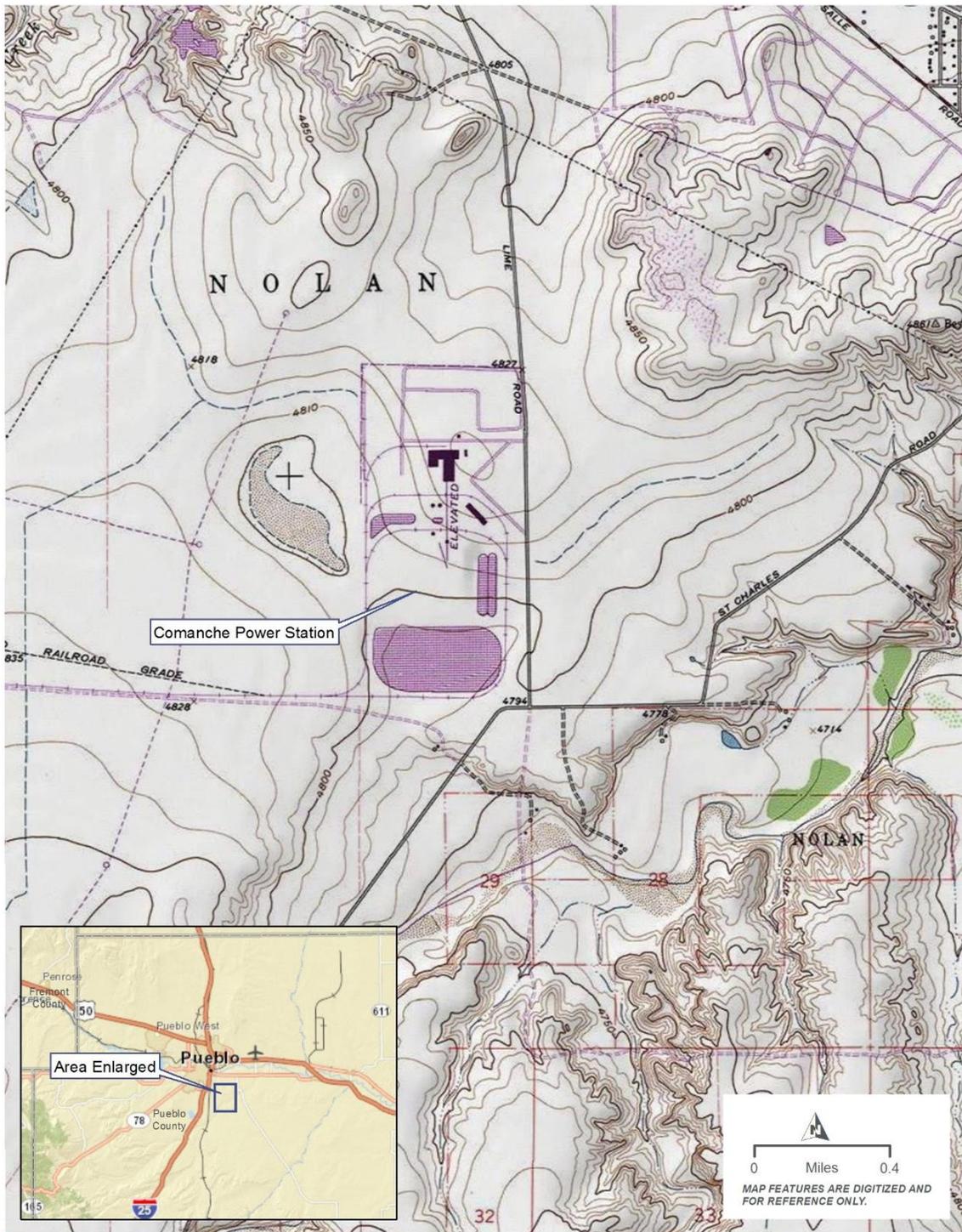
2.2 Monitoring Well Network

2.2.1 Landfill

Four existing monitoring wells (MW-1, MW-2, MW-3, and MW-4) around the perimeter of the landfill are monitored for compliance with the CCR Rule. The well locations are shown on Figure 2. Due to the presence of intermittent shallow perched water in the colluvium deposits beneath the site and the significant depth to the regional water table, a wet/dry monitoring well design was deemed appropriate for the monitoring wells. Wells MW-1, MW-2, MW-3, and MW-4 are screened at the colluvium/bedrock contact and are constructed with a two-foot sump consisting of blank casing below the well screen to capture infiltrating perched shallow water. Well construction details are described in the Groundwater Monitoring Certification (HDR, 2016a).

2.2.2 Impoundments

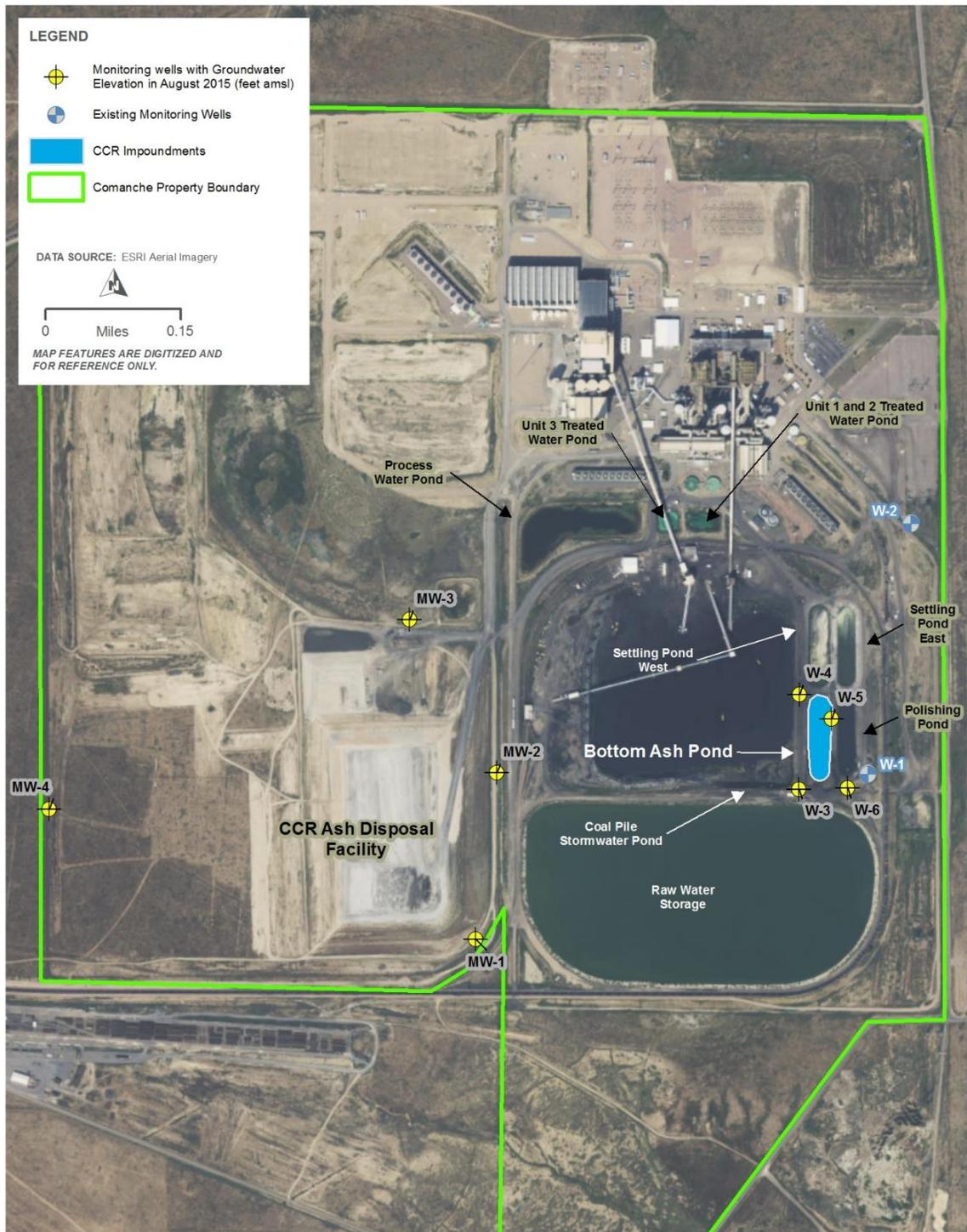
Monitoring wells W-3, W-4, W-5, and W-6 surround the CCR impoundment in order to monitor perched water quality immediately surrounding the Bottom Ash Pond. Due to the presence of intermittent shallow (perched) water in the colluvium deposits beneath the site and the significant depth to the regional groundwater table, a wet/dry monitoring well design was deemed appropriate for the monitoring wells. Wells W-4, W-5, and W-6 are screened at the colluvium/bedrock contact and incorporate a two-foot sump consisting of blank casing below the well screen to capture infiltrating perched water. Well construction details are described in the Groundwater Monitoring Certification (HDR, 2016a). In addition to the CCR monitoring wells, there are two wells (W-1 and W-2) in the vicinity of the impoundments that were previously installed under a separate monitoring program. Water levels in these two wells were used to evaluate ground water elevations around the impoundments, as discussed in Section 6.0.



  **COMANCHE POWER STATION**
PUEBLO COUNTY, CO

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Figure 1. Vicinity map for Comanche Station.



COMANCHE POWER STATION
 PUEBLO COUNTY, CO

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Figure 2. Comanche Station – CCR unit and monitoring well location map.

3 Monitoring Methods

3.1 Monitoring Frequency

Per the CCR Rule, eight “background” groundwater sampling events and one detection monitoring event were completed before October 17, 2017 from the wells designated as the CCR monitoring well network. Although many of these wells were either dry and/or were observed to contain perch water they were sampled and tested in a manner consistent with the CCR Rule as discussed above. The CCR groundwater sampling program for Comanche Station has been designed so that sampling was conducted on a quarterly basis between fourth quarter 2015 and third quarter 2017 for background monitoring. The first detection monitoring event was completed after background sampling had been completed. Sampling was completed on the following dates:

- ✓ December 2-17, 2015
- ✓ February 29-March 17, 2016
- ✓ May 3-June 1, 2016
- ✓ August 23-September 15, 2016
- ✓ November 8-29, 2016
- ✓ February 14-March 10, 2017
- ✓ May 10-23, 2017
- ✓ July 6-20, 2017
- ✓ August 16-30, 20-17

3.2 Water Levels and Sample Collection

Water levels were recorded for each well prior to sample collection. Water quality samples were collected from each of the eight monitoring wells. Sample collection protocols followed the Groundwater Sample Collection Standard Operating Procedure (SOP) (HDR, 2015). The water samples were collected using a submersible Geotech SS Geosub pump, and the pump and hose were decontaminated between wells following protocols outlined in the Sampling SOP. Water samples were delivered under chain of custody to Test America in Denver, Colorado.

3.3 Analytical Testing

Groundwater samples were analyzed for the parameters shown in Table , which include all of the parameters in Appendices III and IV of CCR Rule Part 257. In addition to the parameters listed in Table 1, each sample was also analyzed for total suspended solids (TSS).



Table 2. Groundwater quality parameters

Appendix III constituents for detection monitoring	Appendix IV constituents for assessment monitoring
Boron	Antimony
Calcium	Arsenic
Chloride	Barium
Fluoride	Beryllium
pH	Cadmium
Sulfate	Chromium
Total dissolved solids (TDS)	Cobalt
Additional Parameters	Fluoride
TSS	Lead
	Lithium
	Mercury
	Molybdenum
	Selenium
	Thallium
	Radium 226 and 228 combined

4 Data Validation and Usability

Data validation was conducted to eliminate data that did not meet validation criteria, minimize suspect analytical data, and designate a data qualifier for any data quality limitation discovered. Data validation was performed by the HDR project chemist on each data package received from the analytical laboratory. All data validation was performed per the Data Management and Statistical Protocol Plan for Compliance with the Coal Combustion Residuals Rule document (HDR, 2016b). The validation completed by the HDR project chemist, included a review of field quality control (QC), lab QC, and analytical samples, along with calibration information. Quality control analyses on laboratory control samples, matrix spike/duplicate samples, and field duplicate samples were performed, per required quota.

5 Data Management

The project data manager inputs data from field data forms into an Excel database, specifically recording static water level data, field parameter values, and general pertinent field observations. The project database manager acquires the electronic field database from the data manager and the laboratory electronic data deliverable (EDD) files after receiving notification from the validator that the data validation process was complete. EDDs comprise three individual files that contain sample information, analytical results, and analytical batch information.

The database manager downloads the validated EDDs to a local server for processing and review. Review includes ensuring that the EDD files conform to the required structure and

language of the database. Certain fields within the EDD files have regulated language that must correspond to the lookup/valid value reference tables contained in the database, which helps to ensure that data are coded and stored uniformly within the database; this is known as parity. Adjustments are made, as necessary, to ensure that all samples and data flags are properly set in the EDD. Once review is complete and the EDD passes a final check using an EQUIS Data Processor program, the files are uploaded into an EQUIS database for the project where data can be provided to the Statistician for use in ProUCL. Ultimately the database is exported to Manages, PSCo's chosen database, and delivered to the PSCo Project Manager.

6 Water Levels and Flow Direction

HDR attempted to measure water levels in eight monitoring wells quarterly between fourth quarter 2015 and third quarter 2017, for both the landfill and impoundment CCR facilities. Monitoring wells MW-1 through MW-4 surround the landfill. Wells MW-1, MW-2, and MW-4 were observed to be dry each quarter, consistent with previous studies. Well MW-3 was sampled each quarter after purging dry and allowing the well to slowly recharge. The water level in MW-3 was consistent through the year, varying a maximum 1.25 feet, and remained at and very near the colluvium/bedrock contact. This resulted in samples being collected primarily in the sump portion of the well, not within the screened interval.

Monitoring wells W-3 through W-6 surround the bottom ash impoundment. The water level in well W-4 was below the screened interval within the sump of the well during all sample events. Wells on the east side of the impoundment had up to nine-foot higher water elevation than W-3 on the west side of the impoundment (W-4 only captures water in the sump). The water levels in wells surrounding the impoundment display variability, where some water levels are increasing, while others are decreasing over the same period.

After the initial four monitoring events HDR recommended that existing monitoring wells W-1 and W-2 also be monitored. Starting in Q1 2017, HDR monitored water levels and field parameters in wells W-1 and W-2 (Figure 2). Well W-1 is located very near the CCR impoundment and is screened across the colluvium/bedrock contact. Water levels in W-1 increase seasonally with snowmelt. Perched groundwater elevations in W-1 (4,783 to 4,791 feet) are below the bedrock elevation (approximately 4,793 feet) encountered during drilling; therefore the well may be acting like a sump. Both the topography and bedrock elevations are more than 20 feet higher at well W-2, which is also screened across the colluvium/bedrock contact. The well was seasonally dry, which is consistent with PSCo's previous monitoring program data. Bi-annual water level measurements obtained under this program show that the well W-2 has been found dry since 2006.

The data collected indicates that a continuous water table does not exist under the regulated CCR units. Therefore, a potentiometric contour map of the water levels cannot be developed, wells cannot be identified as upgradient, and background water quality cannot be established. Each of the wells that were not dry and able to be sampled, appear to be independently recharged by localized infiltration from surface water.



Table 1. Groundwater elevations in monitoring wells at Comanche Station

Site	Well ID	Water elevation (ft amsl) December 2015	Water elevation (ft amsl) February 2016	Water elevation (ft amsl) May 2016	Water elevation (ft amsl) August 2016	Water elevation (ft amsl) November 2016	Water elevation (ft amsl) February 2017	Water elevation (ft amsl) May 2017	Water elevation (ft amsl) July 2017	Water elevation (ft amsl) August 2017	Casing elevation (ft amsl)	CCR facility
Comanche	MW-1	dry	dry	dry	dry	dry	dry	dry	dry	dry	4806.73	Landfill
Comanche	MW-2	dry	dry	dry	dry	dry	dry	dry	dry	dry	4800.45	Landfill
Comanche	MW-3	4788.85	4788.55	4788.52	4789.55	4789.17	4788.41	4788.47	4789.28	4789.8	4798.45	Landfill
Comanche	MW-4	dry	dry	dry	dry	dry	dry	dry	dry	dry	4826.47	Landfill
Comanche	W-3	4791.46	4791.21	4792.46	4791.77	4790.85	4791.19	4791.25	4791.61	4792.29	4807.41	Impoundment
Comanche	W-4	4789.67*	4794.57*	4787.74*	4791.03*	4789.07*	4784.82*	4787.94*	4786.57*	4786.07*	4812.47*	Impoundment
Comanche	W-5	4795.13	4796.09	4795.89	4797.04	4797.34	4797.14	4796.62	4797.06	4796.71	4807.46	Impoundment
Comanche	W-6	4796.51	4796.59	4794.44	4795.11	4799.21	4794.36	4793.61	4792.68	4787.19	4811.89	Impoundment
Comanche	W-1	nm	nm	nm	nm	nm	4783.51	4790.97	4791.25	4791.07	4801.37	None
Comanche	W-2	nm	nm	nm	nm	nm	dry	4818.24	4815.69	4815.39	4829.09	None

*All W-4 water elevations are within the well sump below the screened interval, not in the screened interval. The bottom of the screened interval is just below the top of the bedrock such that groundwater flowing laterally across the top of the bedrock surface would flow into the well sump. A water table within the colluvium would have water levels within the screened interval.

NM=not measured

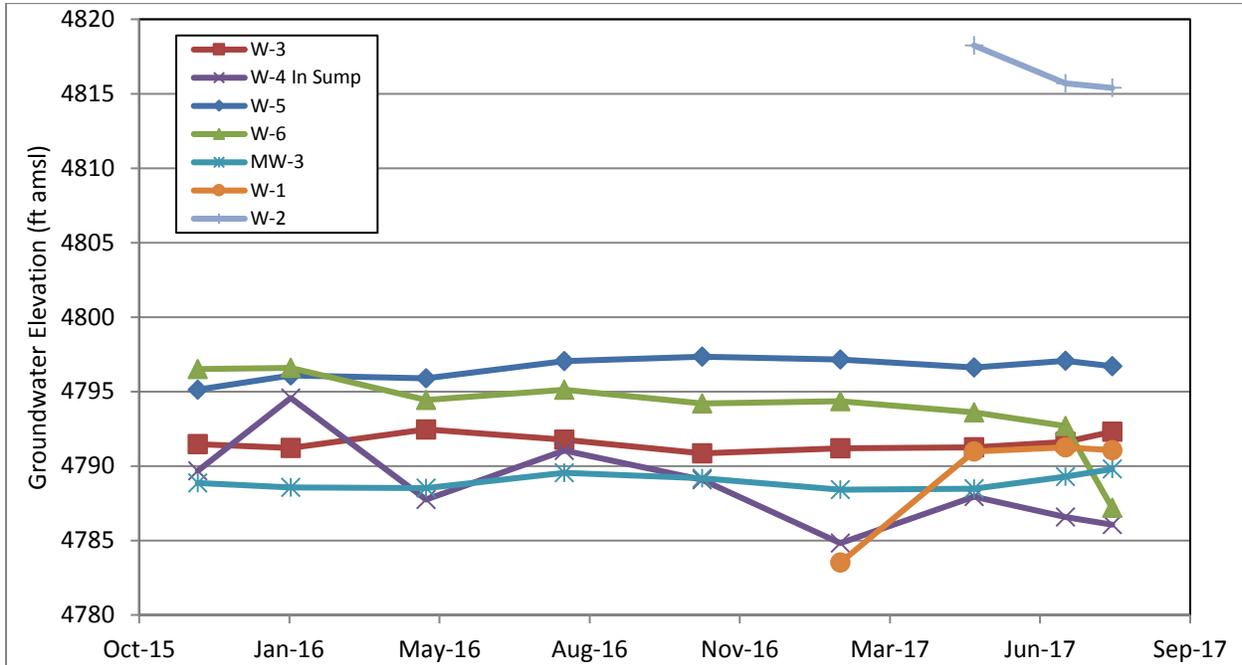


Figure 3. Groundwater elevations at wells observed each quarter.

7 No Aquifer Determination

The CCR Rule requires that the groundwater monitoring be conducted on the uppermost aquifer at each site with a regulated CCR facility. The definition of an aquifer, from the CCR Rule (40 CFR 257.53), is a geologic formation, group of formations, or portion of a formation capable of transmitting water fast enough to yield usable quantities of groundwater to wells or springs.

- Usable quantity can be defined as a sufficient amount of water to supply a single family home. Many states would require a well between 0.5 and 5 gallons per minute depending on available storage. A well that yields 5 gpm or more is capable of meeting the peak-day demand and the average day demand for a home. For wells that yield less than 5 gpm, it is necessary to store a sufficient volume of water in the well and in the pressure tank for the home to meet peak demands. The lower the well yield the more storage is required, but a well with yield less than 0.5 gpm is not recommended for use.
 - Slug testing to obtain hydraulic conductivity measurement was not performed at the three new Comanche Station wells because the well screens were not installed at the bottom of the well. Each well has a sump and the water level measured in the well is towards the bottom of the screen at approximately the screen/sump boundary. However, Woodward Clyde (1987) installed 10 to 30 foot deep test holes at the site for permeability (hydraulic conductivity) testing. These holes were dry and soil samples were sent to a laboratory for geotechnical testing. Laboratory results showed calculated permeability of 10^{-6} to 10^{-7} cm/sec.



- The thickness of the saturated colluvium varies between zero (W-4) and 12 feet (W-3) beneath the CCR impoundment. The colluvium beneath the landfill is dry in most wells at the waste boundary and the saturated thickness appears to be very thin at MW-3, where water levels are very near the top of the bedrock. This very thin saturated thickness would not allow for the drawdown that occurs in low permeability material when a water supply well is pumped. This was observed during the pumping associated with water quality sampling, described below.
- During well sampling, only one well (W-3) was (on some sample events) sampled immediately after the well was purged. Most wells would purge dry rapidly and would not recharge with sufficient volume for sample collection until the following day (MW-3, W-5, and W-6). One well (W-4) would purge dry and take weeks for a couple of liters to accumulate in the well sump for sampling and analysis. Table 3 provides a description of the sampling recharge observations, which further reflect the low permeability. The yield of a well in the colluvium would be less than 0.5 gpm and not capable of supplying a single-family home with water.

Table 2. Well recharge observations from sampling events

Well	Purge and recharge observation from sampling events	Estimated rate of well recharge after sample purge to each two-inch well
MW-1	Well dry	
MW-2	Well dry	
MW-3	Purges dry, but some events will recharge enough to sample the same day as the purge and other events it will recharge enough to sample by the following day	~<0.002 – 0.007 gpm
MW-4	Well dry	
W-3	Some events can sample same day as purge and will not purge dry, other events it will recharge the next day.	~<0.002 - 0.2 gpm
W-4	Well sump was purged dry, takes ~3 weeks before enough volume accumulates in the well sump for lab sample	~0.07 ml/min
W-5	Purges dry, recovers the next day	~<0.002 gpm
W-6	Purges dry, recovers the next day	~<0.002 gpm

- In addition to the low permeability observed in each well with available water, the lack of consistency across the site in water levels and well recharge, and even between the wells immediately surrounding the CCR impoundment implies that each of the wells at the site is responding to localized surface water infiltration. The water levels in wells surrounding the impoundment display variability, where some water levels are increasing, while others are decreasing over the same period. This is not indicative of an aquifer system where all wells within the same

vicinity would exhibit similar water level trends (absent of local pumping wells or recharge areas).

- There is insufficient usable quantity of water in the Comanche colluvium based on the observations provided above. Another definition of “usable” may apply to the water quality. The State of Colorado maintains drinking water standards for different classifications of groundwater: Domestic Use, Agricultural Use, Surface Water Quality Protection, Potentially Usable Quality, and Limited Use and Quality. Groundwater is classified “Limited Use and Quality” when TDS levels are equal to or in excess of 10,000 milligrams per liter (mg/l). TDS in groundwater sampled at Comanche was between 4,900 and 77,000 mg/L, with an average of 43,515 mg/L. Only four of 39 samples were below 10,000 mg/L and only at well W-3. Therefore, the perched shallow groundwater at Comanche would be classified as Limited Use and Quality.
- The fact that three of the four monitoring wells surrounding the ADF facility have been dry for the past 25 years of monitoring supports the conclusion that a laterally continuous saturated zone is not present in the area of the landfill (Tetra Tech, 2013). A feasibility investigation of the landfill area by Woodward-Clyde (1987) included installation of 10 borings and no perched groundwater was encountered in any of the 10 borings. In addition, historical investigative borings in the vicinity of the plant site to the north of the landfill did not encounter saturated conditions in the colluvium or Pierre Shale at depths of over 70 feet (Woodward Clyde 1987). In 2005, six borings were installed to the west and northwest of the landfill as part of the Unit 3 design. Four of the six borings encountered thin zones of perched groundwater within the upper Pierre Shale or immediately above the bedrock in a silty-sand deposit (URS, 2005). The difference in elevation for the perched groundwater surface ranged over approximately 12 feet. The distribution of borings with perched groundwater and range of perched groundwater elevation indicated that the perched groundwater was not laterally continuous (URS, 2005).
- The colluvium is underlain by the Pierre Shale, the uppermost bedrock at the Comanche Station. A water table does not exist regionally in the Pierre Shale (Tetra Tech, 2013). Underlying the approximate 1,450 feet of shale bedrock is the Dakota Sandstone, the regional aquifer in this area (Tetra Tech, 2012). Therefore, the uppermost aquifer beneath the Comanche Site is the Dakota Sandstone at a depth of over 1,450 feet. Any seepage from CCR units to the uppermost aquifer would have to infiltrate through 1,450 feet of the Pierre Shale, with a measured hydraulic conductivity of 3×10^{-10} to 3×10^{-7} cm/sec. Geotrans (2009) estimated groundwater travel time through the shale deposits to take approximately 13,000 years to migrate through the Pierre Shale deposits before water from the impoundments would reach the Dakota Sandstone Aquifer. Therefore, all studies completed at the Comanche site have concluded that the shale deposits beneath the site are effectively impermeable.

With regard to horizontal flow of perched water, the distance from the surface impoundment to the St. Charles River, the nearest receptor for the colluvium, is



approximately 4,000 feet. The potential for lateral migration of perched water in the colluvium is less than 10 feet per year.

Based on the forgoing, the perched groundwater in the colluvium at Comanche does not qualify as an aquifer because its yield is too low, TDS concentrations are too high, perched groundwater is not laterally continuous, and it is not a current water supply source. Therefore, the site does not appear to qualify as a site that requires groundwater monitoring under the CCR Rule, and in fact it is not possible to implement the groundwater monitoring program as defined under the CCR Rule. However, PSCo will continue to monitor the wells in the program through water level monitoring on a semi-annual basis. No additional reports for CCR Rule compliance are anticipated unless a change in the site conditions or groundwater conceptual site model are detected through the continued water level monitoring.

8 References

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Certification

Comanche Station No Aquifer Determination for Review of Compliance with the Coal Combustion Residuals Rule

I hereby certify to the best of my knowledge that the information provided herein is accurate and the determination of a no aquifer system is based upon the data collected for CCR Rule compliance.

I am duly licensed Professional Engineer under the laws of the State of Colorado.



Matthew Rohr, PE
Colorado PE License 0053467
License renewal date October 31, 2019