Comanche Station, Pueblo, Colorado

Groundwater Monitoring System Certification

for Compliance with the Coal Combustion Residuals (CCR) Rule

Comanche Station

Xcel Energy

August 1, 2016

Updated June 18, 2018

Table of Contents

List of Tables

List of Figures

Table of Abbreviations and Acronyms

Abbreviation	Definition
ADF	Ash Disposal Facility
CCR	Coal Combustion Residuals
EPA	U.S. Environmental Protection Agency
TSS	Total Suspended Solids

CERTIFICATION

Groundwater Monitoring System for Compliance

With the Coal Combustion Residuals Rule

Public Service Company of Colorado

Comanche Station, Pueblo, Colorado

I hereby certify that the groundwater monitoring system at Comanche Station is designed and constructed to meet the performance standard in Section 91 of 40 CFR Part 257; and that the groundwater monitoring system, including the number and spacing of monitoring wells as described herein, is designed and constructed to meet this performance standard for all active CCR units.

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

Matthew M. Rohr, PE (Colorado PE 0053467)

License Renewal Date October 31, 2019

1.0 Introduction

The U.S. Environmental Protection Agency's (EPA's) final Coal Combustion Residuals (CCR) Rule establishes a comprehensive 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. Comanche Station has two CCR units subject to the CCR Rule: an impoundment (Bottom Ash Pond) and a landfill (Ash Disposal Facility; ADF) (**Figure 2**).

This document supports compliance with the CCR Rule by demonstrating that the groundwater monitoring system at Comanche Station meets the requirements outlined in Section § 257.91 of the Rule, which states:

- Section § 257.91(f): *'The owner or operation must obtain a certification from a qualified professional engineer stating that the groundwater monitoring system has been designed and constructed to meet requirements of this section* [§257.91]. *If the groundwater monitoring system includes the minimum number of monitoring wells specified in paragraph (c)(1) of this section* [Section § 257.91], *the certification must document the basis supporting this determination*.'

Table 1 summarizes components required by groundwater monitoring systems, per the CCR Rule and the professional engineer's certification of compliance with these requirements. The remainder of this document provides information to support certification for the groundwater monitoring system for the two CCR units at Comanche Station.

Table 1. Summary of 40 CFR Section § 257.91 Groundwater Monitoring System Requirements and Site-Specific Compliance

Groundwater Monitoring System Requirements	Compliance with Requirement
(a) *Performance standard.* The owner or operator of a CCR unit must install a groundwater monitoring system that consists of a sufficient number of wells, installed at appropriate locations and depths, to yield groundwater samples from the uppermost aquifer that: (1) Accurately represent the quality of background groundwater that has not been affected by leakage from a CCR unit. A determination of background quality may include sampling of wells that are not hydraulically upgradient of the CCR management area where: (i) Hydrogeologic conditions do not allow the owner or operator of the CCR unit to determine what wells are hydraulically upgradient; or (ii) Sampling at other wells will provide an indication of background groundwater quality that is as representative or more representative than that provided by the upgradient wells; and (2) Accurately represent the quality of groundwater passing the waste boundary of the CCR unit. The downgradient monitoring system must be installed at the waste boundary that ensures detection of groundwater contamination in the uppermost aquifer. All potential contaminant pathways must be monitored.	**Yes.** While there is no aquifer at the Comanche site, a groundwater monitoring system has been established that includes the minimum number of wells at appropriate locations and depths to yield groundwater samples surrounding each CCR facility. See Sections 3 and 4.

Table 1. Summary of 40 CFR Section § 257.91 Groundwater Monitoring System Requirements and Site-Specific Compliance	
Groundwater Monitoring System Requirements	**Compliance with Requirement**
(b) The number, spacing, and depths of monitoring systems shall be determined based upon site-specific technical information that must include thorough characterization of: (1) Aquifer thickness, groundwater flow rate, groundwater flow direction including seasonal and temporal fluctuations in groundwater flow; and (2) Saturated and unsaturated geologic units and fill materials overlying the uppermost aquifer, materials comprising the uppermost aquifer, and materials comprising the confining unit defining the lower boundary of the uppermost aquifer, including, but not limited to, thicknesses, stratigraphy, lithology, hydraulic conductivities, porosities and effective porosities.	**Yes.** The monitoring system was designed based on results of technical, site-specific data, including (b)(1) and (b)(2). See Sections 3 and 4.
(c) The groundwater monitoring system must include the minimum number of monitoring wells necessary to meet the performance standards specified in paragraph (a) of this section, based on the site-specific information specified in paragraph (b) of this section. The groundwater monitoring system must contain: (1) A minimum of one upgradient and three downgradient monitoring wells; and (2) Additional monitoring wells as necessary to accurately represent the quality of background groundwater that has not been affected by leakage from the CCR unit and the quality of groundwater passing the waste boundary of the CCR unit.	**Yes.** While there is perched groundwater in some locations, the hydraulic gradient cannot be determined at the site because there is no laterally continuous aquifer at the site. Upgradient versus downgradient wells cannot be determined without a laterally continuous water table. Monitoring wells that meet the performance standards are located at each CCR unit (four wells surrounding the impoundment and six wells surrounding the landfill) in compliance with the CCR Rule. The wells are located such that all possible conditions are represented in the collection of shallow groundwater surrounding each CCR unit. See Section 4.
(d) The owner or operator of multiple CCR units may install a multiunit groundwater monitoring system instead of separate groundwater monitoring systems for each CCR unit. (1) The multiunit groundwater monitoring system must be equally as capable of detecting monitored constituents at the waste boundary of the CCR unit as the individual groundwater monitoring system specified in paragraphs (a) through (c) of this section for each CCR unit based on the following factors:(i) Number, spacing, and orientation of each CCR unit; (ii) Hydrogeologic setting; (iii) Site history; and (iv) Engineering design of the CCR unit. (2) If the owner or operator elects to install a multiunit groundwater monitoring system, and if the multiunit system includes at least one existing unlined CCR surface impoundment as determined by §257.71(a), and if at any time after October 19, 2015 the owner or operator determines in any sampling event that the concentrations of one or more constituents listed in appendix IV to this part are detected at statistically significant levels above the groundwater protection standard established under §257.95(h) for the multiunit system, then all unlined CCR surface impoundments comprising the multiunit groundwater monitoring system are subject to the closure requirements under §257.101(a) to retrofit or close.	There is no multiunit monitoring system at Comanche. See Sections 2 and 4.

Table 1. Summary of 40 CFR Section § 257.91 Groundwater Monitoring System Requirements and Site-Specific Compliance

Groundwater Monitoring System Requirements	Compliance with Requirement
(e) Monitoring wells must be cased in a manner that maintains the integrity of the monitoring well borehole. This casing must be screened or perforated and packed with gravel or sand, where necessary, to enable collection of groundwater samples. The annular space (*i.e.,* the space between the borehole and well casing) above the sampling depth must be sealed to prevent contamination of samples and the groundwater. (1) The owner or operator of the CCR unit must document and include in the operating record the design, installation, development, and decommissioning of any monitoring wells, piezometers and other measurement, sampling, and analytical devices. The qualified professional engineer must be given access to this documentation when completing the groundwater monitoring system certification required under paragraph (f) of this section. (2) The monitoring wells, piezometers, and other measurement, sampling, and analytical devices must be operated and maintained so that they perform to the design specifications throughout the life of the monitoring program.	**Yes.** Well design meets requirements (e). See Section 4. Groundwater monitoring system will be operated and maintained per (e)(2).
(f) The owner or operator must obtain a certification from a qualified professional engineer stating that the groundwater monitoring system has been designed and constructed to meet the requirements of this section. If the groundwater monitoring system includes the minimum number of monitoring wells specified in paragraph (c)(1) of this section, the certification must document the basis supporting this determination.	**Yes.** System designed and constructed to meet the requirements of Section §257.91. Technical information to support certification and number of wells, per (c)(1). See Sections 2.0, 3.0 and 4.0.

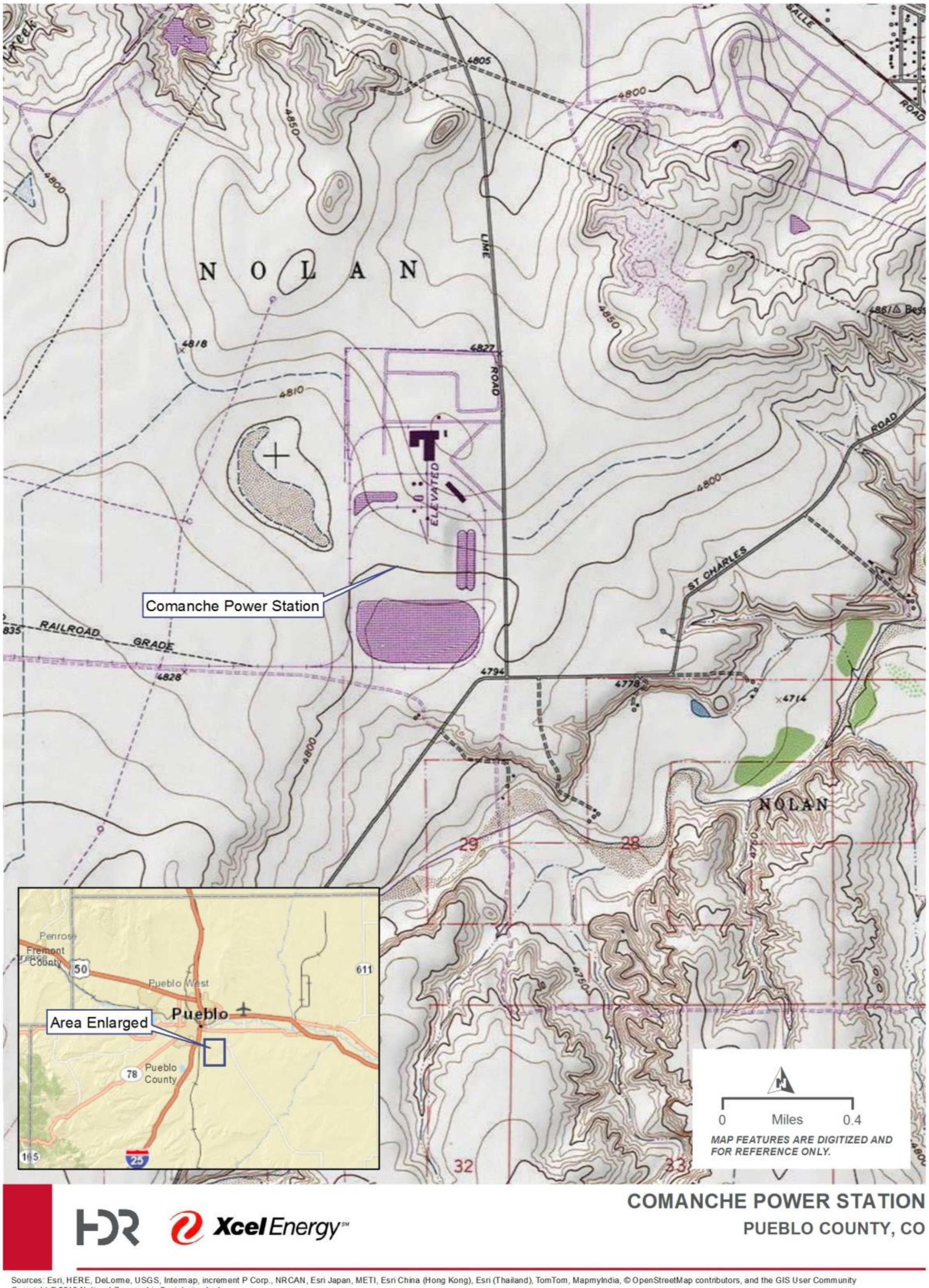

Figure 1. Vicinity Map for Comanche Station

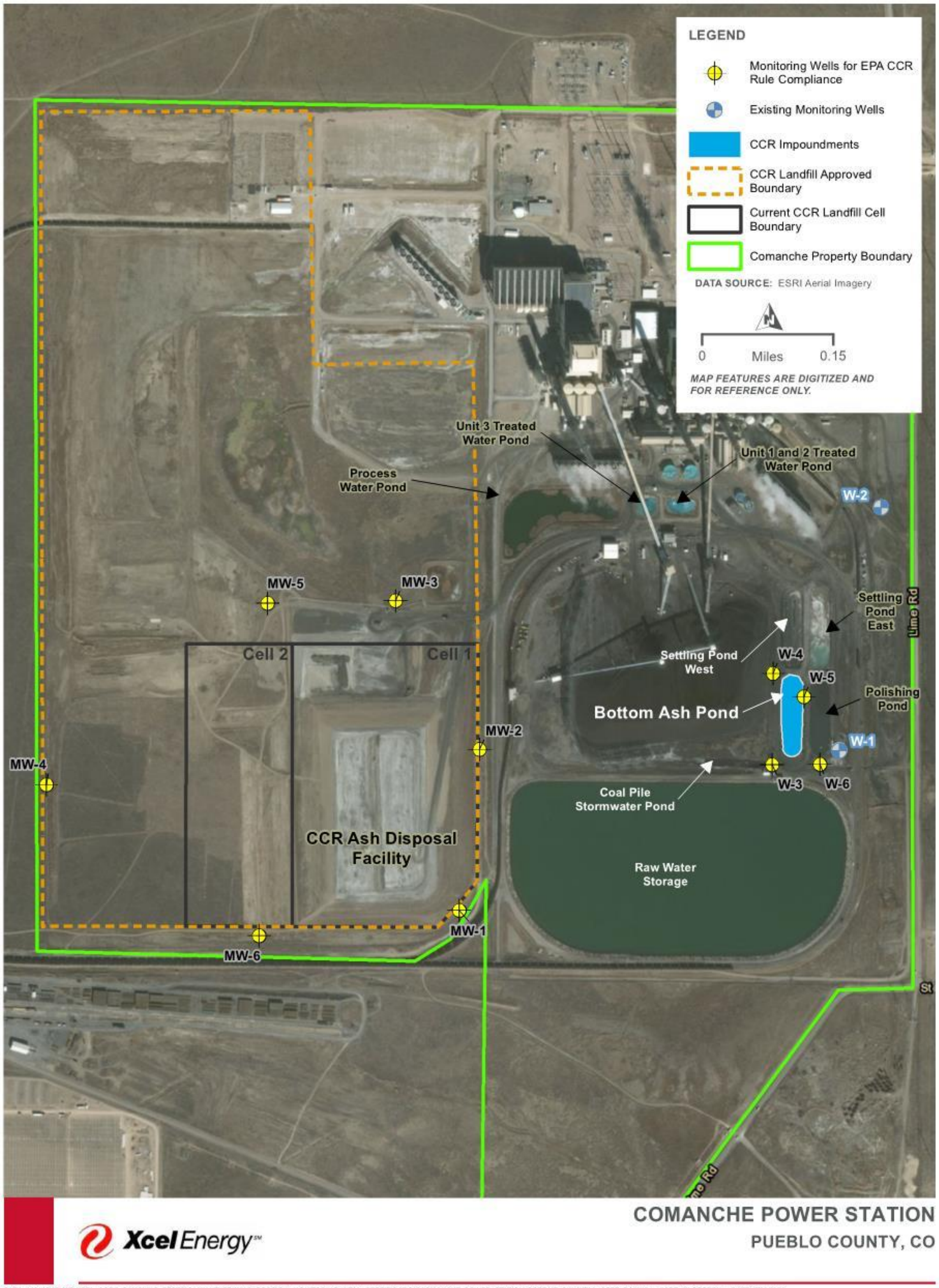

Figure 2. Comanche Station – CCR Units and Monitoring Well Location Map

2.0 Facility Description

Comanche Station is a coal-fired plant consisting of three units (Units 1, 2, 3) that burn Powder River Basin coal. Unit 1 was built in 1973, Unit 2 was built in 1975, and Unit 3 was built in 2010 (Tetra Tech, 2012). Comanche Station currently has two CCR units subject to the CCR Rule: a landfill and an impoundment (**Figure 2**). The sections that follow provide a brief description of the CCR units.

Additional ponds at the facility include process water, settling, polishing, and raw water storage ponds. These units do not hold CCR, and therefore are not considered CCR units, in compliance with the CCR Rule:

> *"CCR surface impoundments do not include units generally referred to as cooling water ponds, process water ponds, wastewater treatment ponds, storm water holding ponds, or aeration ponds. These units are not designed to hold an accumulation of CCR, and in fact, do not generally contain significant amounts of CCR."*

2.1 CCR Landfill

The CCR landfill, also know as the CCR Ash Disposal Facility (**Figure 2**), is an approximately 280-acre engineered ash monofill consisting of eight permitted disposal cells. Currently, disposal is occurring in one 40-acre cell in the southeast corner of the permitted landfill, which was constructed with a clay liner (Xcel Energy, 2005). The additional disposal cells will be constructed in phases as needed to contain ash and waste from power generating activities. Fly ash from all three units is collected in silos for disposal in the landfill. Bottom ash is also permitted to be disposed in the on-site landfill, if needed. 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). Construction of Cell 2 was completed in early 2018 and disposal operations will commence later in 2018.

2.2 CCR Impoundment

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. The impoundment is 513 feet long by 138 feet wide and 26 feet deep with a surface area of 1.6 acres. The primary influent to the CCR impoundment is sluiced bottom ash. Additional influent sources include continuous deionization softeners waste, brine and rinse, and activated carbon filter backwash and brine (Tetra Tech, 2013). The CCR impoundment effluent discharges to the polishing pond immediately east of the Bottom Ash Pond (**Figure 2**).

3.0 Site Hydrogeology/Geology

Prior investigation reports are available documenting hydrogeologic and geotechnical studies completed at the Comanche Station. These include:

- Feasibility Investigation, Two Ash Disposal Areas (Woodward-Clyde Consultants, 1987);
- Geotechnical Investigation, Unit 3 (URS, 2005);
- Coal Ash Disposal Facility Design and Operations Plan (Xcel Energy, 2005);
- Surface Water Impoundment Infiltration Characterization Analysis (GeoTrans, Inc., 2009);
- Inventory and Preliminary Classification Report, Waste Impoundments (Tetra Tech, 2012);
- Sitewide Monitoring Plan, Ash Disposal Facility (Tetra Tech, 2014); and
- Engineering Design and Operations Plan, Ash Disposal Facility (Tetra Tech, 2015).

Comanche Station is underlain by unconsolidated colluvium consisting of stiff clays and silts, with interbedded sand and gravel west and northwest of CCR landfill. Typical colluvium thickness is less than 20 feet but ranges between 5 and 75 feet (Woodward-Clyde, 1987; URS, 2005). The Pierre Shale is 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 deposits is the Dakota Sandstone, the uppermost bedrock aquifer in this area (Tetra Tech, 2012).

Because a water table does not appear to exist in the colluvium, there is no measureable horizontal groundwater flow direction or hydraulic gradient at the site. A potential south-southeasterly flow gradient is assumed based on the ground surface topography, which slopes to the south-southeast towards the St. Charles River. The alluvial aquifers associated with the Arkansas River (north), the St. Charles River (south), and Salt Creek (west) do not extend beneath the site (Xcel Energy, 2005).

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 surface does not appear to have a consistent gradient across the site for perched water to flow in one direction across the site (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 groundwater sample events for compliance with the CCR Rule indicate that HDR’s site conceptual model is consistent with previous reports which conclude 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. Because of the lack of a site-wide water table in the colluvium a groundwater flow direction cannot be determined. Lateral flow of perched groundwater likely follows the bedrock surface topography.

Given the lack of a laterally extensive shallow groundwater system in the colluvium deposits beneath the site and the great depth of the uppermost aquifer (Dakota Sandstone), a wet/dry monitoring well system (includes a well sump) has been selected to help characterize the hydrogeology of the limited perched groundwater and to be consistent with the well design (approved by the Colorado Department of Public Health and Environment) of the groundwater monitoring program for State permitting compliance.

4.0 Monitoring Wells

The CCR Rule requires, at a minimum, one upgradient and three downgradient monitoring wells per CCR unit to be completed in the uppermost aquifer. Section 257.9 of the Rule states that the operator: *"…may install a multiunit groundwater monitoring system instead of separate groundwater monitoring systems for each CCR unit."* In addition, the CCR Rule states that downgradient monitoring wells should be installed to: *"accurately represent the quality of groundwater passing the waste boundary of the CCR unit. The downgradient monitoring system must be installed at the waste boundary that ensures detection of groundwater contamination in the uppermost aquifer."*

Based on the CCR requirements, hydrogeological data, and site visits, ten monitoring wells have been identified for CCR compliance, six at the landfill and four at the impoundment **(Figure 2)**.

<u>Landfill/ADF</u>
Tetra Tech (2014) documented four existing monitoring wells (MW-1, MW-2, MW-3, and MW-4) that surround the ADF. The well locations are shown on **Figure 2**. Given the lack of a laterally extensive shallow groundwater system in the colluvium deposits beneath the site and the great depth to the regional potentiometric surface, a wet/dry monitoring well design was deemed appropriate for the monitoring wells. Wells MW-1, MW-2, MW-3, and MW-4 incorporate a 2-foot sump consisting of blank casing below the well screen that captures infiltrating perched water that otherwise would be too minimal along the bedrock surface to sample.

Two new wells, MW-5 and MW-6 were installed in August 2017 for CCR compliance to serve as additional monitoring wells for the ADF, including the newly constructed Cell 2. Wells MW-5 and MW-6 incorporate 10-foot and 5-foot sumps consisting of blank casing below the well screen (and bedrock surface) that captures infiltrating perched water.

The six monitoring wells (MW-1 through MW-6) that surround the ADF meet the requirements of the CCR Rule for groundwater monitoring. Because of the lack of a water table in the colluvium across the site in monitored wells, a groundwater flow direction cannot be determined. However, the facility is surrounded by monitoring wells (**Figure 2**); therefore, all possible conditions will be represented in the collection of shallow groundwater. Upgradient and downgradient wells cannot be designated based upon the lack of groundwater flow direction. The well MW-3 is located north of the ADF in a low lying area. MW-3 periodically contains 1.5 to 2 feet of water in the sump, likely due to infiltration of surface water runoff during high precipitation events. Well MW-5 is also located north of the ADF and monitored water levels are right at the bedrock surface and sampled water is that which accumulates in the sump. The wells MW-1, MW-2, MW-4 are located southeast, east, and west, respectively, from the facility. Historically, MW-1, MW-2, and MW-4 have been dry. Well MW-6 typically has water in the screened interval. Well MW-6 was drilled in a location where colluvium thickness and depth to bedrock are greater than other well locations and according to boring logs and bedrock mapping is located in a paleo-channel or similar bedrock low where perched water may collect.

<u>Impoundment/Bottom Ash Pond</u>

In 1997, monitoring well W-3 was installed near the CCR impoundment and the nearby settling and polishing ponds to investigate the presence or absence of perched water and the integrity of the 3-foot thick pond liner systems (GeoTrans, Inc. 2009). W-3 contains perched water, however it was concluded that the source of perched water was not the surface impoundments (GeoTrans, Inc. 2009).

Based on the CCR requirements, hydrogeological data, and site visits, the existing well W-3 meets the requirements of the CCR Rule for groundwater monitoring and serves as a monitoring well. Three new wells, W-4, W-5, and W-6 were sited for CCR compliance to serve as the additional monitoring wells. As with the landfill/ADF wells, because of the lack of water table in the colluvium, it is not possible to designate upgradient and downgradient wells.

4.1 Well Construction

The boreholes for monitoring wells were drilled by a licensed well driller. Each well is constructed with 2-inch diameter, Schedule 40 PVC casing and screen with 0.010-inch screen slots. Between 5 and 20 feet of screen was installed in each well. Where perched water was not encountered, the well screen was placed approximately 5 feet above the top of the bedrock contact to intersect the colluvium-bedrock contact (unless the contact was too shallow). To capture infiltrating perched water[1], 10-foot long sumps consisting of blank casing were placed beneath the screens to be consistent with Colorado Department of Public Health and Environment well design recommendations (Tetra Tech, 2014).

Well construction included 10-20 washed silica sand for the filter pack approximately 5 feet above the well screen. Annular seals of coated bentonite pellets extend from the top of the filter pack to the surface and were hydrated after placement. Monitoring wells were developed and surveyed.

[1] Previously constructed wells W-1, W-2, and W-3 incorporated a 2-foot sump to capture infiltrating perched water. Due to the lack of a laterally extensive shallow groundwater system in the colluvium deposits beneath the site and the depth of the uppermost aquifer (Dakota Sandstone), a wet/dry monitoring well system is an effective way to detect changes in perched groundwater conditions and/or potential contaminants from the ash landfill and CCR impoundment.

Table 2. Monitoring Well Construction

Well I.D.	Northing (UTM NAD 83 Zone 13, meters)	Easting (UTM NAD 83 Zone 13, meters)	Elevation TOC (ft)	Well Total Depth (ft bgs)	Screen Interval (ft bgs)	Well Stickup (ft)	Well Type	Static WL (ft amsl) March 2016	Well Permit Number	Depth to Water (ft BTOC)	Approximate Depth of Pierre Shale if encountered (ft BGS)
MW-1	4228054.61	536733.11	4806.73	11 (2 ft sump)	4-9	1.89	2-inch PVC	dry	32282	dry	9
MW-2	4228350.96	536770.80	4800.45	13 (2 ft sump)	6-11	1.65	2-inch PVC	dry	32283	dry	10
MW-3	4228624.19	536615.92	4798.45	11 (2 ft sump)	4-9	1.67	2-inch PVC	4788.85	32284	9.9	7
MW-4	4228286.31	535973.39	4826.47	29 (2 ft sump)	7-27	2.42	2-inch PVC	dry	32285	dry	27
MW-5	4228619.73	536379.92	4806.97	36.0 (10 ft sump)	16-26	2.43	2-inch PVC	4779.30*	Not available yet	27.67	24
MW-6	4228008.02	536363.95	4823.08	42.0 (5 ft sump)	27-37	2.23	2-inch PVC	4793.04*	Not available yet	30.04	35
W-3	4228322.28	537309.21	4807.41	29 (no sump)	14-29	1.04	2-inch PVC	4791.46	210286	16.2	29
W-4	4228491.35	537310.48	4812.47	23.4 (10 ft sump)	3.4-13.4	3.63	2-inch PVC	4789.67	299843	22.8	14
W-5	4228323.54	537396.38	4807.46	23.5 (10 ft sump)	3.5-13.5	3.83	2-inch PVC	4795.13	299844	12.33	14
W-6	4228447.93	537367.35	4811.89	25 (10 ft sump)	5-15	3.90	2-inch PVC	4796.51	299845	15.38	15

Notes:
TOC = top of casing
BTOC = below top of casing
BGS = below ground surface
amsl = above mean sea level
*Measured August 2017

5.0 Water Levels and Flow Direction

HDR attempted to measure water levels in ten monitoring wells between fourth quarter 2015 and fourth quarter 2017, for both the landfill and impoundment CCR facilities. Monitoring wells MW-1 through MW-6 surround the landfill. Wells MW-1 through MW-4 surround Cell 1 of the landfill and were monitored quarterly between fourth quarter 2015 and third quarter 2017. Wells MW-5 and MW-6 were constructed in August 2017 to monitor Cell 2 of the landfill. To collect eight background samples prior to waste disposal in Cell 2, all six landfill wells were monitored eight times between August 2017 and December 2017. **Table 3** provides the water elevation data collected by HDR and **Figure 3** is a graph of the same data. Wells MW-1, MW-2, and MW-4 were observed to be dry each sample event, consistent with previous studies over many years. Well MW-3 was sampled during each event after purging dry and allowing the well to slowly recharge. The water level in MW-3 was consistent through the year 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. The water level in MW-5 was consistently at or immediately below the colluvium/bedrock contact. Thus samples collected from MW-5 were also from the sump portion of the well, not within the screened interval in the colluvium. Samples collected from MW-6 were obtained from the screened interval, but represent localized perched water.

Monitoring wells W-3 through W-6 surround the bottom ash impoundment and were monitored quarterly between fourth quarter 2015 and third quarter 2017. The water level in well W-4 was below the screened interval within the sump of the well during all sample events. Wells W-5 and W-6 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.

Table 3. Groundwater elevations in monitoring wells at Comanche Station

Site	**Comanche Station**											
CCR facility	**Landfill**						**Impoundment**				**None**	
Well ID	**MW-1**	**MW-2**	**MW-3**	**MW-4**	**MW-5**	**MW-6**	**W-3**	**W-4**	**W-5**	**W-6**	**W-1**	**W-2**
Date	**Water elevation (ft amsl)**											
Dec-15	Dry	dry	4788.85	dry	not installed	not installed	4791.46	4789.67*	4795.13	4796.51	nm	nm
Feb-16	Dry	dry	4788.55	dry	not installed	not installed	4791.21	4794.57*	4796.09	4796.59	nm	nm
May-16	Dry	dry	4788.52	dry	not installed	not installed	4792.46	4787.74*	4795.89	4794.44	nm	nm
Aug-16	Dry	dry	4789.55	dry	not installed	not installed	4791.77	4791.03*	4797.04	4795.11	nm	nm
Nov-16	Dry	dry	4789.17	dry	not installed	not installed	4790.85	4789.07*	4797.34	4799.21	nm	nm
Feb-17	Dry	dry	4788.41	dry	not installed	not installed	4791.19	4784.82*	4797.14	4794.36	4783.51	dry
May-17	Dry	dry	4788.47	dry	not installed	not installed	4791.25	4787.94*	4796.62	4793.61	4790.97	4818.24
Jul-17	Dry	dry	4789.28	dry	not installed	not installed	4791.61	4786.57*	4797.06	4792.68	4791.25	4815.69
Aug-17	Dry	dry	4789.80	dry	nm	4792.88	4792.29	4786.07*	4796.71	4787.19	4791.07	4815.39
9/13/2017	Dry	dry	4790.03	dry	4779.3*	4793.04	nm	nm	nm	nm	nm	nm
10/16/2017	Dry	dry	4789.90	dry	4779.27*	4792.93	nm	nm	nm	nm	nm	nm
10/30/2017	Dry	dry	4789.91	dry	4779.32*	4792.88	nm	nm	nm	nm	nm	nm
11/13/2017	Dry	dry	4789.93	dry	4779.35*	4792.91	nm	nm	nm	nm	nm	nm
11/28/2017	Dry	dry	4789.73	dry	4779.35*	4792.71	nm	nm	nm	nm	nm	nm
12/4/2017	Dry	dry	4790.00	dry	4779.43*	4792.85	nm	nm	nm	nm	nm	nm
12/18/2017	Dry	dry	4789.96	dry	4779.52*	4792.84	nm	nm	nm	nm	nm	nm

*****All W-4 water elevations are within the well sump below the screened interval, not in the screened interval. All MW-5 water elevations are right at the well sump/screen contact just 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

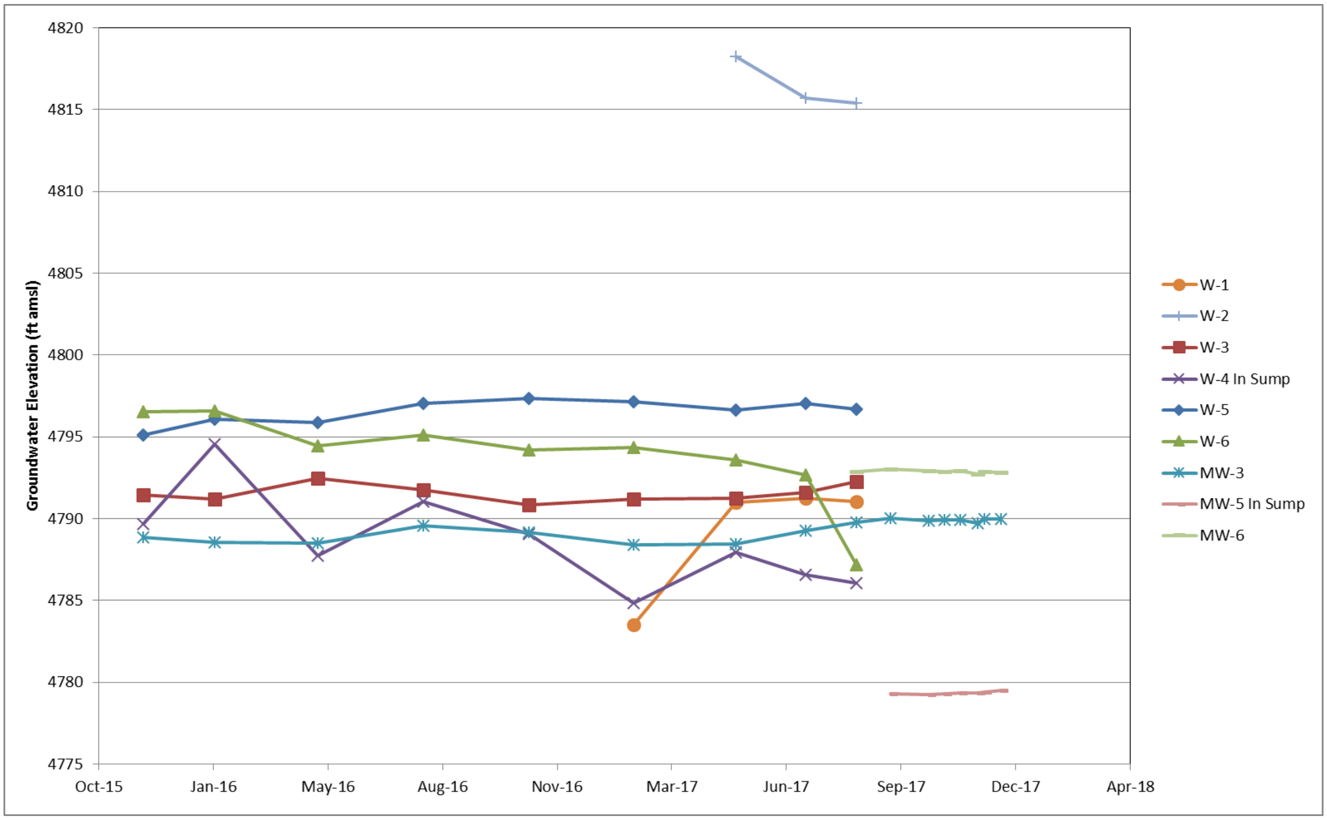

Figure 3. Groundwater elevations at wells observed each quarter.

To understand the system it is critical to review the construction of each well and the elevation of the consolidated bedrock at each well while reviewing the water level data. Thus, a fence diagram was prepared (**Figure 4**) to illustrate the relationship between bedrock and water levels and the variability of the bedrock elevation and water elevation at the site. **Figure 4** is not a cross section across the site and thus subsurface units are not connected. 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 thus 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.

6.0 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." The following bullets address the groundwater character at the Comanche site relative to the definition of an aquifer.

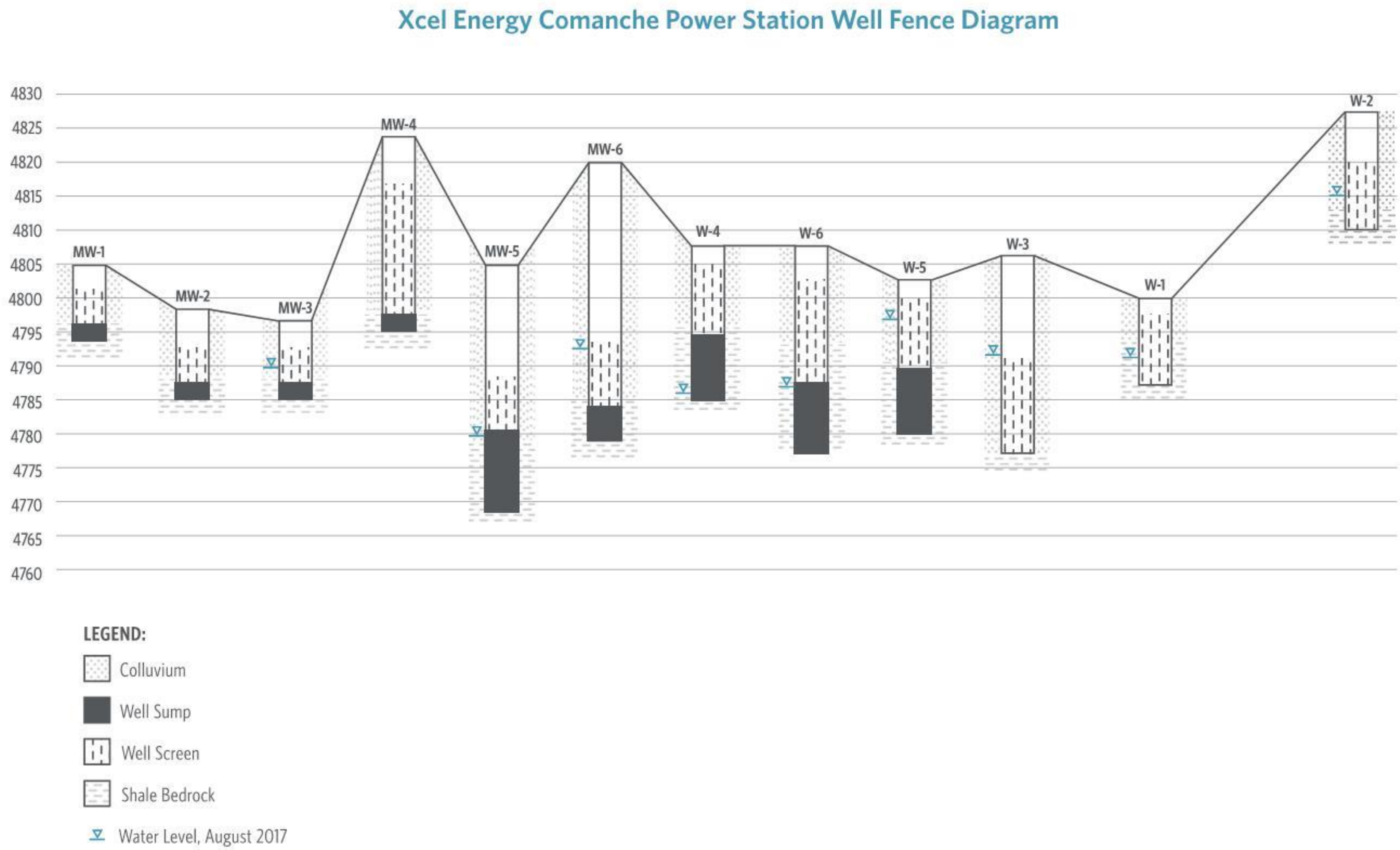

Figure 4. Well fence diagram illustrates the lack of laterally continuous water table, the bedrock surface variability, and where water collects in well sumps. This is not a cross-section.

- 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 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 most wells 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 testing. These holes were dry and soil samples were sent to a laboratory for geotechnical testing. The colluvium had laboratory calculated permeability results 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 and MW-5, where water levels are at or very near the top of the bedrock. Only one well, MW-6, around the landfill has saturated colluvium. The very thin saturated thickness in most wells 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 wells W-3 and MW-6 can be sampled immediately after the well is purged. Most of the wells purge dry very rapidly and recharge very slowly, with sufficient volume for sample collection the following day (MW-3, MW-5, W-5, and W-6). One well, W-4, purges 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 4. 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	Well sump purges dry and some events will recharge enough to sample later the same day but typically it will recharge enough to sample by the following day	~<0.002 – 0.007 gpm
MW-4	Well dry	
MW-5	Well sump purges dry and takes days to recharge, often not enough water available to collect sample volume requested by laboratory	~<0.002 – 0.007 gpm
MW-6	Can sample same day as purge and will not purge dry.	>0.2 gpm*
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

*Well has not purged dry like all other wells so the rate of recharge of this well is unknown.

- 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.

- Three of the six monitoring wells surrounding the landfill facility have been dry for the past 25 years of monitoring, which 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 of 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 vertical 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. Therefore it would take approximately 400 years for perched groundwater under the site to travel to the St. Charles River.

7.0 Groundwater Monitoring

Sampling was conducted at a frequency compliant with CCR Part 257.94. Eight rounds of well sampling were completed before October 17, 2017. These samples were collected to represent background water quality sampling as required in the CCR Rule; however as described in Section 5.0 there is no consistent water table under the site to determine upgradient versus downgradient wells and therefore no background water quality could be established for either CCR facility. Groundwater sampling was conducted quarterly between fourth quarter 2015 and third quarter 2017 at wells W3 through W6 around the impoundment and MW-1 through MW-4 of the landfill. Groundwater sampling was conducted between August and December 2017 at wells around the landfill for the background water quality for construction of the landfill Cell 2. Groundwater quality sampling was conducted in all CCR monitoring wells unless wells were dry. In accordance with the CCR Rule, groundwater samples were not field filtered. The field parameters of turbidity, pH, and temperature were measured using an YSI Professional Plus (or an equivalent) portable water quality instrument that has been calibrated prior to use.

Analytical testing of groundwater samples for background was performed by TestAmerica or other EPA certified laboratory. Samples were analyzed for the parameters shown on **Table 3**, which include all of the parameters in Appendices III and IV of Part 257 for the initial eight background sample events, plus Total Suspended Solids (TSS). For quality control, one field duplicate sample and one field equipment blank sample will be collected for each sample event. The laboratory analyzed matrix spike/matrix spike duplicates at a rate of 5 percent, per laboratory quality control standards.

Table 5. Groundwater Quality Parameters
Appendix III Constituents for Detection Monitoring
Boron
Calcium
Chloride
Fluoride
pH
Sulfate
Total Dissolved Solids (TDS)
Appendix IV Constituents for Assessment Monitoring
Antimony
Arsenic
Barium
Beryllium
Cadmium
Chromium
Cobalt
Fluoride
Lead
Lithium
Mercury
Molybdenum
Selenium
Thallium
Radium 226 and 228 combined
Additional Parameters
Total Suspended Solids (TSS)

Due to the lack of a continuous shallow groundwater system in the colluvium beneath the site, up-gradient and down-gradient flow directions cannot be determined. Additionally, the colluvium under the site is incapable of transmitting water fast enough to yield usable quantities of groundwater to wells or springs, and therefore does not meet the definition of an aquifer. Given these factors, hydrogeologic conditions at the site do not meet the criteria necessary to implement groundwater monitoring under the CCR Rule. However, PSCo will continue to monitor the wells in the program through water level monitoring on a semi-annual basis, which will be reassessed each year.

8.0 Reporting

The CCR Rule 297.90(e) identifies the reporting requirements for the groundwater monitoring program for the CCR units. The annual reporting documents will be developed no later than January 31, 2018 and annually thereafter. Annual reports will summarize key monitoring actions completed, describe any problems encountered, discuss actions to resolve the problems, and project key activities for the upcoming year. For CCR compliance, PSCo will file the report in the facility operating record.

PSCo will comply with the CCR Rule recordkeeping requirements specified in § 257.105(h), notification requirements specified in § 257.106(h), and internet requirements specified in § 257.107(h).

9.0 References

GeoTrans, Inc., 2009. Surface Water Impoundment Infiltration Characterization Analysis, Public Service Company of Colorado, Comanche Station, Pueblo, Colorado. December 1, 2009.

Tetra Tech, 2012. Inventory and Preliminary Classification Report, Waste Impoundments, Comanche Station, Pueblo, Colorado. November 1, 2012.

Tetra Tech, 2013. Closure Plan, Type A Waste Impoundments, Comanche Station, Pueblo, Colorado. June 28, 2013.

Tetra Tech, 2014. Sitewide Monitoring Plan, Ash Disposal Facility, Comanche Station, Pueblo, Colorado. August 29, 2014.

Tetra Tech, 2015. Engineering Design and Operations Plan, Ash Disposal Facility, Comanche Station, Pueblo, Colorado. January 13, 2015.

URS, 2005. Geotechnical Investigation, Unit 3, Comanche Station, Pueblo, Colorado. March 2, 2005.

Woodward-Clyde Consultants, 1987. Feasibility Investigation, Two Ash Disposal Areas for Comanche Power Station, Pueblo, Colorado. March 1987.

Xcel Energy, 2005. Comanche Station Coal Ash Disposal Facility Design and Operations Plan. August 24, 2005.