Groundwater Monitoring Program for More's Lake

Columbia Water & Light Department

Columbia Municipal Power Plant
Project No. 93647

August 2017
Revision 1: February 2018

Groundwater Monitoring Program for More's Lake

prepared for

Columbia Water & Light Department
Columbia Municipal Power Plant
Columbia, Missouri

Project No. 93647

August 2017
Revision 1: February 2018

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
°F	Degrees Fahrenheit
ASTM	American Society of Testing and Materials
CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
COPC	Constituents of Potential Concern
GMP	Groundwater Monitoring Program
NAVD	North American Vertical Datum
NRCS	Natural Resource Conservation Service
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation Recovery Act
SAP	Sampling and Analysis Plan
Site	Columbia Municipal Power Plant located in Columbia, Missouri
SSI	Statistically Significant Increase
Inactive CCR Unit	Inactive CCR Surface Impoundment at Columbia Municipal Power Plant
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

1.0 INTRODUCTION

This Groundwater Monitoring Program (GMP) has been prepared by Burns and McDonnell Engineering Company (Burns & McDonnell) to establish procedures for groundwater monitoring at the coal combustion residual (CCR) Inactive Surface Impoundment (referred to as "inactive CCR Unit") for Columbia Water & Light Department (CWLD), Columbia Municipal Power Plant (CMPP) located in Columbia, Missouri (Site). The inactive CCR Unit is located directly north of the facility within the property boundaries of CMPP. Topographic and aerial photographic site vicinity maps illustrating the location of the inactive CCR Unit are provided as Figures 1 and 2, respectively. The City of Columbia is planning a clean closure of the inactive CCR Unit.

1.1 Purpose

This GMP has been prepared to support compliance with groundwater monitoring requirements published by the United States Environmental Protection Agency (USEPA) in the *Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule*, dated April 17, 2015 (USEPA, 2015), and the *Hazardous and Solid Waste Management System: Disposal of Coal Combustion Residuals From Electric Utilities; Extension of Compliance Deadlines for Certain Inactive Surface Impoundments; Response to Partial Vacatur*, dated August 5, 2016 (USEPA, 2016), collectively referred to herein as the "CCR Final Rule."

1.2 CCR Final Rule Program

The CCR Final Rule is found in 40 Code of Federal Regulations (CFR) Part 257 and was published by the USEPA to regulate the disposal CCR as solid waste under subtitle D of the Resource Conservation and Recovery Act (RCRA). This CCR Final Rule applies to all CCR generating electric utility facilities and independent power producers that fall within the North American Industry Classification System code 221112.

This CCR Final Rule established nationally applicable minimum criteria for the safe disposal of CCR in landfills and surface impoundments. CCR includes fly ash, bottom ash, boiler slag, and flue gas desulfurization materials. The CCR Final Rule applies to owners and operators of new, existing, and/or laterally expanded landfills and surface impoundments that dispose or otherwise engage in solid waste management of CCR. In June 2016, a United States Court of Appeals granted a settlement between utility industry and environmental groups that removed the effects of the "early closure" provisions for inactive surface impoundments under the USEPA CCR rule (40 CFR §257). With this rule change, all inactive CCR surface impoundments must now comply with all of the rule requirements applicable to

existing/active CCR surface impoundments (location criteria; design and operating requirements; air criteria; inspection requirements; groundwater monitoring and corrective action; closure and post-closure care; and recordkeeping, notification and publicly accessible internet site requirements). The requirements of the CCR Final Rule also apply to CCR units located off-site of the electric utilities' or independent power producers' facilities that receive CCR for disposal (i.e., public or private landfills).

The CCR Final Rule requires CCR units implement groundwater monitoring system (40 CFR §257.91) and program (40 CFR §257.93-§257.95) that are capable of detecting CCR impacts on the groundwater quality, if any, underlying each utility waste landfill and/or surface impoundment. The groundwater monitoring system must consist of a sufficient number of appropriately located wells (at minimum, one upgradient and three downgradient wells) capable of monitoring the quality of background groundwater and the quality of groundwater passing the CCR waste boundary. Monitoring wells must be installed in order to yield representative groundwater samples from the uppermost aquifer. The CCR Final Rule requires groundwater sampling at utility CCR-waste landfills/impoundments for specific CCR chemical constituents of potential concern (COPCs). The CCR rule requires operators of inactive surface impoundments (i.e., More's Lake) to implement groundwater monitoring programs prior to April 17, 2019 that are capable of detecting releases to shallow groundwater. To meet this requirement, owners must install well networks and conduct eight rounds of background monitoring prior to April 17, 2019. If the groundwater monitoring system demonstrates a verified exceedance of a groundwater protection standard for any of the identified CCR COPCs, the owner or operator must initiate corrective action.

1.3 Rationale

There is one inactive CCR Unit associated with CMPP, which consist of one surface impoundment (More's Lake). However, More's Lake was inactive by October 2015 and CWLD is currently performing closure activities for this inactive surface impoundment planned to be completed by April 17, 2019. As discussed previously in Section 1.2, the effects of the "early closure" provisions for inactive surface impoundments have been removed from the Final Rule so that inactive surface impoundments must now comply with all of the rule requirements applicable to existing/active CCR surface impoundments. Due to this recent rule change that no longer allows "early closure" provisions for inactive surface impoundments, the inactive CCR Unit has until April 17, 2019 to comply with groundwater monitoring requirements.

Based on the review of the existing monitoring well networks and current approach to groundwater monitoring at More's Lake, the following actions were/are needed to support compliance with the CCR Final Rule:

1. Additional monitoring wells were installed to represent the quality of background groundwater that has not been affected by potential leakage from the CCR unit and the quality of groundwater passing through the boundary of the inactive CCR unit.

2. Establish sampling procedures for the collection of low-flow groundwater samples from the inactive CCR Unit monitoring well network. Low-flow groundwater sampling procedures for the inactive CCR Unit are provided in the *Groundwater Sampling and Analysis Plan* (SAP) included as Appendix A to this GMP.

3. Collection of eight rounds of groundwater samples to establish background conditions for water quality parameters listed in the CCR Final Rule and MDNR CCR White Paper. Baseline groundwater sampling will be performed to establish background conditions at the inactive CCR Unit.

4. Development of detection and assessment (as needed) monitoring frameworks to be applied to the inactive CCR unit once background sampling is completed.

This GMP includes an overview of the methods and approaches to groundwater sampling, laboratory analyses, statistical analysis, and groundwater data reporting. Groundwater sampling and analysis of newly installed wells and existing monitoring wells will be conducted in accordance with the field procedures presented in the SAP included as Appendix A which has been prepared by Burns & McDonnell to support compliance with the CCR Final Rule requirements.

1.4 Overview

This GMP describes the hydrogeological setting of the inactive CCR Unit, monitoring network, compliance monitoring frequencies for each monitoring point, monitoring parameters, sampling methods, and statistical methods of analysis. This GMP will serve as guidance for personnel performing monitoring of the inactive CCR Unit. The GMP is organized in sections as summarized below:

Section 2.0 Site Setting and History - Section 2.0 summarizes the location and setting of the inactive CCR Unit at the CMPP.

Section 3.0 Hydrogeological Setting - Section 3.0 presents the geology and hydrogeology of the region and the Site. The groundwater monitoring program is designed to detect a release from the inactive CCR Unit and is based on regional and site-specific hydrogeological characteristics.

Section 4.0 Groundwater Monitoring - Section 4.0 presents a description of the groundwater monitoring well network and approach to background, detection, and assessment (if necessary) monitoring required by the CCR Final Rule. Field procedures for groundwater sampling are detailed in the SAP included as Appendix A to this GMP.

Section 5.0 Statistical Analysis - Section 5.0 outlines the applied statistical methodologies for detecting a release from a CCR management area and monitoring any releases that may occur.

Section 6.0 Groundwater Monitoring Reports - Section 6.0 lists the submittals required by the CCR Final Rule.

Section 7.0 References - Section 7.0 includes a bibliography for references made within this GMP.

1.5 Modifications to Groundwater Monitoring Program

It should be noted that the existing monitoring well network may undergo periodic re-evaluation in the future that could result in either the addition or deletion of wells from the groundwater sampling network and changes in groundwater sampling methods. Groundwater sampling parameters may also be adjusted, following the review of data. Therefore, as changes to the groundwater monitoring network, sampling methodology, and analytical parameters occur, this GMP will be updated appropriately. Changes to the GMP will be documented in the operating record in accordance with the record keeping requirements presented in 40 CFR 257.105 and 257.107.

2.0 SITE SETTING AND HISTORY

This section of the GMP summarizes the location, setting, and history of the inactive CCR Unit at the CMPP and the history of utility CCR disposal within the inactive CCR Unit. Information presented in this section was cited from previous CMPP hydrogeologic investigations.

2.1 Facility Description and History

The CMPP facility is owned and operated by the City of Columbia Water & Light Department. The CMPP is located at 1501 Business Loop 70 East, Columbia, Missouri in Boone County, Missouri, illustrated in Figures 1 and 2. The CMPP facility occupies approximately 25.4 acres and is situated in the Southeast ¼, of the Southwest ¼, of Section 6, in Township 48 North, Range 12 West, at a latitude of 38.964917° N and longitude of 92.317027° W.

The facility is bound on the east by residential while the north, west, and south are bound by mixed industrial, commercial, and residential (Figure 2). The CMPP is located approximately 950 feet (0.18 miles) east of an unnamed intermittent tributary of Bear Creek, about 2,150 feet (0.41 miles) northwest of an unnamed intermittent tributary of Hinkson Creek, and approximately 5,750 feet (1.09 miles) northeast of Flat Branch Creek. Bear Creek and Hinkson Creek are approximately 4,100 feet (0.78 miles) northwest and 4,500 feet (0.85 miles) southeast of the CMPP, respectively.

The CMPP has one CCR unit that is comprised of an inactive surface impoundment that formerly received CCR from facility operations. The original surface impoundment, known locally as More's Lake, was constructed as a farm pond no later than 1896, prior to being used for CCR disposal. The first power production at the CMPP occurred around 1914. Through the years, the impoundment was used as a settling pond for CCR material, receiving sluiced bottom ash, fly ash, boiler blow-down, cooling tower blow-down, and storm water runoff from the CMPP. The impoundment ceased receipt of CCR in 2015, in accordance with the Federal CCR Rule (40 CFR §257.53), allowing it to be classified as an inactive Surface Impoundment.

The inactive Surface Impoundment area is situated at the northern portion of the CMPP facility, within the property boundary, as shown on Figures 1 and 2. The impoundment is not lined and covers about 7.0 acres. The impoundment is operated under MDNR Permit No. 0004979. The base elevation of the inactive surface impoundment is around 745 feet amsl based on test pits dug in the fall of 2016 (Burns & McDonnell, 2016).

The City intends to clean close the surface impoundment by the complete removal of CCR material in accordance with the CCR Federal Rule (40 CFR §257.100(b)(5)) and Federal regulations.

2.2 Physiographic Region

Boone County, Missouri is in the Glaciated Region of the Central Lowland Interior Plains physiographic province region. This area is part of the Dissected Till Plains physiographic unit that was glaciated, uplifted, and subsequently eroded into a flat-to-rolling terrain that slopes gently toward the Missouri and Mississippi River Valleys. The main topographic features of the county are the deeply incised valleys of the Missouri River and its tributaries. The Missouri River Valley is 0.2 to 0.7 miles wide in some areas and defines the southern boundary of Boone County and marks the southern extent of continental glacial deposits. The CMPP facility is situated near the middle of Columbia, Missouri and is approximately 40 miles upstream of the confluence of the Missouri and Osage Rivers.

In the City of Columbia, the prominent tributaries of the Missouri River are Perche Creek, Hinkson Creek, and Flat Branch Creek. Along these and other creeks in the area can be found large valleys, cliffs, and cave systems such as that in Rock Bridge State Park located south of the city (approximately 6 miles south of the inactive CCR Unit). These creeks are largely responsible for numerous stream valleys giving Columbia hilly terrain similar to the Ozarks while also having prairie flatland typical of northern Missouri. Columbia also operates several greenbelts with trails and parks throughout town.

2.3 Climate

Columbia, Missouri lies within the humid continental zone and generally has hot summers, cold winters, and wet springs. Average annual precipitation is approximately 45 inches. May and June are generally the wettest months while December and January are the driest. Average high monthly temperatures range from 40.1 degrees Fahrenheit (ºF) in January to 88.9 ºF in July. Average low monthly temperatures range from 22.6 ºF in January to 69.3 ºF in July (High Plains Regional Climate Center, 2017).

3.0 HYDROGEOLOGIC SETTING

Hydrogeology is defined as the geology of groundwater, with emphasis on the chemistry and movement of the groundwater. Information presented in this section was obtained from review of the United States Geological Survey (USGS) *Groundwater Atlas of the United States: Kansas, Missouri, Nebraska* (Miller and Appel, 1997), *Geology of Boone County, Missouri* (Unkleskbay, 1952), Missouri Department of Natural Resources (MDNR) Well Information Management System (WIMS), Missouri Geological Survey (MGS) Geosciences Technical Resource Assessment Tool (GeoSTRAT), MGS Geologic Well Logs of Missouri database, and a Geotechnical Engineering Report for City of Columbia for Mores Lake Dam Global Stability Analysis (Crockett Geotechnical Testing Lab, 2014).

3.1 Regional Geology

Missouri is located on the North American craton (or Laurentia) and is an area that has been tectonically stable throughout most of geologic time. The regional geology consists of a thick cover of sediments and sedimentary rocks (Quaternary-age to Cambrian-age) deposited on top of older metamorphic and igneous rocks (Precambrian-age) that form the "crystalline basement complex" (basement rocks) or foundation of the continental crust. The region has undergone some deformation with faults and up-warps and down-warps on the surface of the crystalline basement rocks. In Missouri, most notable structural deformation features are the St. Francois Mountains in southeastern Missouri and the Ozark Uplift (dome) in central Missouri that are related to up-warping of the basement rocks. Basement rocks are exposed only in the St. Francois Mountains of southeastern Missouri at more than 1,000 feet above sea level and buried to depths of as much as 6,000 feet below sea level in southwestern Kansas. Sediments were deposited on the surface of the basement rocks and lithified into sedimentary rocks during diagenesis. The thick deposits of sedimentary rocks in the region predominately consist of limestone and dolomite and interbedded sequences of shale, sandstone, and coal. In most of the region north of the Missouri River, the sedimentary rocks are overlain by unconsolidated to semi-consolidated sediments consisting of glacial drift, loess, colluvium, and alluvium.

3.1.1 Faults and Seismic Activity

The Federal CCR Rule requires new CCR landfills, new and existing CCR surface impoundments, and any lateral expansion of these facilities that engage in the disposal of CCR generated by electric utilities and independent power producers not to be located within 200 feet of the outermost damage zone of a Holocene era fault, which includes all faults active within the last 11,700 years and up to the present. According to data extracted from the USGS Interactive Fault Map displaying locations of Quaternary-age faults in the United States (http://earthquake.usgs.gov/hazards/qfaults/), the nearest Holocene era fault is

the Thebes Gap Faults and the Reelfoot scarp and New Madrid Seismic Zone which is located approximately 190 and 220 miles away, respectively. The Thebes Gap Faults generally run northeast-southwest and is south of Cape Girardeau, Missouri. The New Madrid Seismic Zone generally run northeast-southwest and is west of New Madrid, Missouri. According to the Interactive Fault Map, the fault is approximately 70 miles and has been active in the last 15,000 years.

Additional data review using the MGS GeoSTRAT database, identified the following structural features and pre-Holocene faults in the vicinity of the inactive CCR Unit:

- Browns Station Anticline – approximately 7 miles north of the inactive CCR Unit;
- Fox Hollow Fault and Monocline, Bonne Femme Creek graben, Sapp monocline – approximately 9 miles south of the inactive CCR Unit;
- Fish Creek Anticline – approximately 11.5 miles west of the inactive CCR Unit; and
- Woodlandville Fault – approximately 12 miles northwest of the inactive CCR Unit.

As outlined in the preamble to the Federal CCR Rule, a seismic impact zone is defined as "an area having a 2% or greater probability that the maximum expected horizontal acceleration, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10 g in 50 years." Burns & McDonnell reviewed available data from United States Geological Survey Earthquake Hazards Program (http://earthquake.usgs.gov/hazards/apps/) in order to determine the maximum expected horizontal acceleration for the CMMP inactive CCR surface impoundment. According to data extracted from the USGS website, the maximum expected horizontal acceleration in the vicinity of the CMPP site is 0.06-0.10 g, which is at and below the 0.10 g requirement of the CCR rule. Therefore, the inactive CCR impoundment at the CMPP is not located within a seismic impact zone and consequently is not violating the location restriction standards with respect to seismic impact zones as described in §257.63 of the CCR Rule. The USGS hazard map supports that there is a low likelihood of intense seismic activity within the nearby vicinity of the CMPP, being that the area is outside of a seismic impact zone.

3.2 Regional Hydrogeology

The principal aquifers in the region include the Ozark Plateau Aquifer system and the Mississippi and Cambrian-Ordovician aquifers. In Missouri, north of the Missouri River, the rocks of the Mississippi and Cambrian-Ordovician aquifers and confining units are stratigraphically equivalent with rocks of the Ozark Plateaus Aquifer system south of the Missouri River. Although these different aquifers are

stratigraphically equivalent, generally there is little or no hydraulic connection between them since the Missouri River is a discharge area for both aquifers. In some areas, these aquifers underlie parts of surficial aquifer systems (i.e. glacial-drift or stream-valley aquifers). Areas with overlying glacial till provide a confining layer/cap to the aquifer system where only small to moderate amounts of water can be obtained from wells completed in areas of confining units or having no principal aquifer. Groundwater flow throughout the region is largely driven by topography and is highly variable in response to regional points of groundwater discharge (e.g., springs, streams, rivers, and shallow stream/river valley alluvial aquifers). Groundwater in aquifers locally move from topographically high recharge areas to regional points of groundwater discharge or localized discharges at surface (e.g., seeps and water supply wells).

3.2.1 Surficial Aquifers

The surficial aquifers are composed of Quaternary-age unconsolidated sediments that provide water for shallow water supply wells and consist primarily of material deposited during multiple advances of continental glaciers from the north. The massive ice sheets planed off and incorporated soil and rock fragments as large as boulders during advances and redistributed these materials on the eroded land surface as water- or ice-laid deposits (or both) during retreats. Surficial aquifers present are composed of glacial outwash, coarse-grained glacial-lake sediment, and coarse- and fine-grained alluvium (some of which may be buried in some places beneath fine-grain sediments). Because of the shallow depth, ease of recharge, and short groundwater flow system, surficial aquifers supply much of the base flow of streams. The hydraulic connection to streams is proportional to the permeability of the deposits. Most of the water in the surficial aquifer system is under unconfined conditions. Groundwater quantity and quality varies considerably in physical and chemical properties depending on the geological formations associated with the aquifer from which the water is taken. Recharge of the surficial aquifers is primarily from precipitation. However, a lesser amount of recharge is provided by infiltration from hydraulically connected stream/rivers (i.e., Missouri River) during high flow conditions, bedrock adjacent to and underlying the alluvium, and downward leakage of water from streams, other than the Missouri River, flowing across the alluvium. The volume of water supplied by precipitation and the volume of recharge that occurs from other streams as they cross the stream/river-valley alluvium depends greatly on the hydrologic characteristics of the shallow alluvial materials. In areas where surficial materials are sandy and permeable, the amount of recharge water is significant. Where there is a clay or silt cap overlying the more permeable deposits, the recharge is less.

Surficial aquifers can be used in farmstead, irrigation, domestic, and industrial applications. The regional surficial aquifer system includes stream-valley aquifers and glacial-drift aquifers.

3.2.1.1 Glacial-Drift Aquifers

The maximum southern extent of the continental glaciers and glacial-drift deposits was approximately positioned at the present location of the Missouri River in Missouri and just south of the Kansas River in northeastern Kansas. The thickness of glacial drift generally is 50 to 200 feet but locally is greater than 300 feet in eastern Missouri and 400 feet in western Missouri and northeastern Kansas (Miller and Appel, 1997). Meltwater created an extensive stream network in front of the advancing ice, and the streams deposited gravel, sand, and finer sediments as alluvium along the courses of preglacial bedrock valleys. The glacial deposits are generally complex interbedding of fine- and coarse-grained sediments. The complex interbedding of permeable (coarse-grained) and poorly permeable (fine-grained) sediments in the glacial-drift aquifers results in a large number of local confining units. Accordingly, water in these aquifers can be under unconfined conditions in some places and confined conditions in other places. Glacial stream channels may have been filled with coarse grained sediments at the bottom and finer grained and less permeable silt, clay, or till at the top resulting in buried channel or buried valley aquifers under confined or semiconfined conditions.

Although deposits of glacial drift extend over wide areas, most were laid down directly by the ice; are fine grained, poorly sorted, or both; and, therefore, yield only small amounts of water to wells. The glacial-drift aquifers are a primary source of water for supply wells that usually penetrate beds of coarse-grained material (sand and gravel). Yields of shallow water supply wells screened within glacial-drift aquifers are highly variable. Wells screened in predominately fine-grained glacial deposits typically provide low yields and rely on large diameter wells for storage. Glacial-drift aquifers typically do not yield suitable water for a public water supply, unless hydraulically connected to streams or stream-valley aquifers.

Groundwater movement in glacial-drift aquifers generally move along short flow paths to the nearest surface-water body, where it discharges. A small amount of groundwater percolates downward and may infiltrate underlying bedrock aquifers, if hydraulically connected.

3.2.1.2 Stream-Valley Aquifers

Alluvial materials deposited along major rivers/streams in the Missouri River Valley provide another source for surficial aquifers. Alluvium is composed of clay, silt, fine to coarse sand, and fine to medium gravel. The size of the alluvium materials typically increases with depth; finer-grained materials directly underlie the land surface, and coarser sands and gravels are found at depth. The alluvium is generally the thickest toward the center part of the valley near the river, but there are instances where the thickest materials are near a valley wall. Water supply wells in major alluvial aquifers can produce high yields of

good-quality water from properly constructed wells in coarse-grained sands and gravels with high permeability.

3.2.2 Bedrock Aquifers

The uppermost regional bedrock aquifers consist of permeable hydrogeologic units of the Ozark Plateaus aquifer system and the Mississippian aquifer. The presence and thickness of the uppermost bedrock aquifers vary locally where it has been eroded (e.g., river and/or glaciers).

3.2.2.1 Ozark Plateaus Aquifer System

The Ozark Plateaus Aquifer system underlies most of central and southern Missouri and consists of three aquifers, separated by two confining units, comprised of Mississippian-age and older rocks. The water-yielding rocks in these aquifers are primarily limestones and dolomites with some sandstones and chert. The confining units within the aquifer system are primarily shale but also consist of limestone, dolomite, and sandstone with minimal permeability and provide hydraulic separation between aquifers. Where these confining units contain more shale, the vertical movement of water between aquifers is more effectively restricted. The hydrogeologic units of the Ozark Plateaus Aquifer system are also equivalent to aquifers and confining units north of the Missouri River in Missouri that include the Mississippi and Cambrian-Ordovician aquifers.

3.2.2.2 Mississippian Aquifer

The Mississippi Aquifer underlies Missouri north of the Missouri River and consist of stratigraphically equivalent rocks of the uppermost aquifer of Ozark Plateaus aquifer system (Springfield Plateau aquifer) situated south of the Missouri River. Limited information indicates that the Mississippi and Springfield Plateau aquifers have little or no hydraulic connection due to the Missouri River serving as both a boundary and discharge area between the two aquifers. The base of the aquifer is bound by a confining unit (equivalent to Ozark Confining Unit rocks) while the top of the aquifer is typically overlain with overburden materials consisting of either glacial till or alluvium.

3.2.2.3 Cambrian-Ordovician Aquifer

The Cambrian-Ordovician aquifer underlies Missouri north of the Missouri River and consists of stratigraphically equivalent rocks that form a part of the middle aquifer (Ozark aquifer) of the Ozark Plateaus aquifer system. The degree to which these aquifers are hydraulically connected is not fully known but is considered hydraulically connected in some places. However, where the Missouri River serves as both a boundary and discharge area for the two aquifers they are considered hydraulically separate. The aquifer consists predominately of carbonate rocks (dolomite and limestone) with some

sandstone and is bound by confining units at the top (equivalent to Ozark Confining Unit rocks) and bottom (equivalent to St. Francis Confining Unit rocks). Because of these confining units, groundwater in the Cambrian-Ordovician aquifer is confined in most places. The lowermost aquifer of the Ozark Plateaus aquifer system (St. Francis Aquifer) is equivalent to a poorly known, unnamed minor aquifer in northern Missouri.

One CMPP production water supply well is located in the northeast corner of the CMPP property, approximately 200 feet northeast of the inactive CCR Unit, and is identified in the MDNR Public Drinking Water Supply System (PDWSS) as Old Well #4, Bowling Street (W4, Well ID #14074). This well serves as the CMPP's main source of cooling water and backup source of boiler make-up water with a total well depth of 1,505 feet below ground surface (elevation of 723 ft below mean sea level) and is screened in the Cambrian-Ordovician aquifer.

A majority of the City's bedrock water supply wells are screened deep within the Cambrian-Ordovician aquifer.

3.3 Local Hydrogeology

Based on review of available drill logs, the CMMP overlies both surficial and bedrock aquifers. The surficial aquifer is composed of glacial-drift and serves as the uppermost water-bearing zone at the site. This glacial-drift aquifer is comprised predominately of clay with sand and fine gravel to clayey sand with gravel and occasional cobbles and boulders. The glacial-drift materials that make suitable aquifers are those composed of permeable coarse-grained sediments (sands and gravels), while glacial-drift composed of fine-grain sediments (clays) are typically poorly permeable and yield small amounts of water to wells. A drill log from a former deep water supply well located in the northwest corner of the CMMP, identified as City of Columbia Well #10 (formerly known as Old Well #4), was obtained from the MGS Geologic Well Logs of Missouri database and indicated the glacial-drift to be approximately 65 feet thick. According to the drill log, the base of the glacial-drift is bound by approximately 15 feet of limey shale and bentonite-rich clay that overlies Mississippian-age carbonate rocks (limestones and dolomites). Based on the drill logs, these carbonate rocks form the Mississippi aquifer and include the Keokuk-Burlington Limestone formations. These hydrogeologic units are stratigraphically equivalent to those that compose the lower portions of the Springfield Plateau aquifer (the uppermost aquifer in the Ozark Aquifer system), located south of the Missouri River. The primary groundwater source of public water supply wells in the area is located deep in the subsurface within limestones/dolomites of the Cambrian-Ordovician aquifer. Near the Missouri River, the major groundwater source of water supply wells is surficial aquifers consisting of alluvium along the river.

Based on the water level data obtained during monitoring well installation activities, the estimated groundwater movement generally flows in a western direction. The overall groundwater movement within the glacial drift (uppermost water bearing zone) at the Site is inferred as flowing west-southwest toward the Missouri River.

3.4 Soil

Based on a review of available information provided by the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) web soil survey and the NRCS and USDA Soil Survey of Boone County, Missouri the primary mapped soil unit in the vicinity of the inactive CCR Surface Impoundment (More's Lake) includes the Urban land-harvester complex and Keswick-Urban land complex. The Urban land-harvester complex usually forms on ridges on uplands (2 to 9 percent slopes) from fine-silty loess. A typical soil profile consists of 0-30 inches of silty clay loam, 30-60 inches of clay loam. These soils are moderately well drained with very high runoff rate. The Keswick-Urban land complex usually form on hills or uplands (5 to 9 percent slopes) from loess over clayey till. A typical soil profile consists of 0-7 inches of silt loam, 7-20 inches of clay, and 20-60 inches of clay loam. These soils are moderately well drained with very high runoff rate.

3.5 Existing Groundwater Monitoring Well Network

The currently defined groundwater monitoring network at the inactive CCR Unit is summarized in Table 1 and illustrated on Figure 3, respectively. The defined groundwater sampling monitoring well network consists of eight (8) newly installed Monitoring Wells MW-1, MW-2, MW-3, MW-4, MW-5, MW-6, MW-7, and MW-8 and two (2) existing Piezometers PZ-2 and PZ-6. Four other existing piezometers (PZ-1, PZ-3, PZ-4, and PZ-5) are not included in the groundwater sampling monitoring well network but will be used for recording water level and total depth measurements during sampling events. Well construction details of the monitoring well network for the inactive CCR Unit are summarized on Table 2, respectively.

Additional groundwater monitoring well installations may be required in the future at the inactive CCR Unit based on but not limited to the following:

- To enhance post closure detection monitoring or improve the groundwater monitoring system.
- Support compliance with the CCR Final Rule.

In the event additional monitoring well installations are needed, a Site-specific Work Plan will be developed to identify the scope and rationale for new monitoring wells.

4.0 GROUNDWATER MONITORING

This section of the GMP presents a description of the approach to groundwater monitoring at the inactive CCR Unit developed in accordance with the requirements of the CCR Final Rule. Groundwater samples will be collected using low-flow sampling techniques following procedures presented in the SAP (see Appendix A). The SAP includes sampling schedules, analytical parameters, and laboratory performance criteria and Quality Assurance (QA) / Quality Control (QC) requirements. Sampling and analysis of these monitoring wells are to support compliance with the CCR Final Rule requiring implementation of a groundwater monitoring system and program that are capable of detecting CCR impacts on the quality of groundwater underlying the CCR unit in the uppermost aquifer.

4.1 Inactive CCR Unit Monitoring Network Description

The defined monitoring well network at the inactive CCR Unit includes 14 monitoring wells and was discussed previously in Section 3.5 (see Table 1 and 2). All network monitoring wells are located along the perimeter of the inactive CCR Unit, outside the former footprint of CCR. The locations of these monitoring wells are illustrated on Figure 3.

4.2 Monitoring Well Inspection and Maintenance Program

Well inspections are performed during all planned groundwater monitoring events. The condition of the monitoring wells and surrounding area is observed and recorded by the sampling team in accordance with field procedures presented in the SAP (see Appendix A). Any required maintenance activities would be conducted in a timely manner, optimally prior to the next groundwater monitoring event.

The groundwater monitoring wells will be inspected and maintained throughout the inactive life and post-closure care period of the CCR unit. Per the Final Rule requirements (§257.90[c]), if at the end of the post-closure care period the owner or operator of the CCR unit is operating under assessment groundwater monitoring, the owner or operator must continue to conduct post-closure care until the owner or operator returns to detection groundwater monitoring.

4.3 Groundwater Monitoring Schedule

Groundwater sampling and gauging events at CMPP will be performed semi-annually, and is anticipated to occur during the months of May and October. The sampling schedule is an estimate and may be adjusted to accommodate sampling requirements.

Any newly installed monitoring wells, or existing wells without established background values will be sampled to obtain eight (8) independent and qualified background sample sets as discussed in Section 4.5.

Once eight acceptable samples are obtained, the wells will be incorporated into the groundwater monitoring network and will follow the semi-annual sampling and analysis schedule under the detection monitoring program as described in Section 4.6.

4.4 Groundwater Sampling Field Activities

A description for the common field procedures to be used during groundwater sampling and analysis events are presented in the SAP (refer to Appendix A). Groundwater monitoring activities include:

- Monitoring well integrity inspections
- Monitoring well maintenance (if necessary)
- Water level and total well depth measurements
- Monitoring well purging and sample collection
- Field QA/QC groundwater sample collection
- Analysis of groundwater samples
- Monitoring well re-development (if necessary)
- Decontamination procedures
- Disposition of excess sample volume and decontamination water
- Sample custody and documentation procedures
- Sample container handling, packaging, and shipping
- QA/QC procedures

4.5 Background Groundwater Sampling

For inactive CCR units, any newly installed monitoring wells and existing wells without established background values will be sampled to collect a minimum of eight (8) independent and qualified initial background samples no later than April 17, 2019 to allow for statistical evaluation (40 CFR 257.94[b]). The collected background groundwater samples are analyzed for both Detection and Assessment Monitoring parameters listed in Appendix III and IV, respectively of the CCR Final Rule (40 CFR 257) and MDNR CCR water quality standard parameters, see Table 3. In accordance with the CCR Final Rule, the first background window for existing CCR units will be established so that eight rounds of data are collected prior to April 17, 2019. Groundwater sampling will be performed in accordance with field procedures presented in the SAP (see Appendix A).

For new CCR landfills and surface impoundments, and all lateral expansions of CCR units, a minimum of eight (8) independent samples for each background well will be collected and analyzed for both Detection and Assessment Monitoring parameters during the first six (6) months of sampling (40 CFR 257.94[b]).

Once eight samples are obtained from each monitoring well, background populations will be established and detection monitoring will be initiated as presented in Section 4.6. Procedures for establishing and updating background data populations are presented in Sections 5.2 and 5.3, respectively.

4.6 Detection Monitoring Program

The detection monitoring program includes background groundwater sampling discussed in Section 4.5. Once background groundwater quality has been established for a well in the monitoring well network, subsequent groundwater samples will be collected on a semi-annual basis for detection monitoring. It is anticipated that groundwater sampling will be performed in the months of May and October. A surface water sample will also be collected from the inactive ash pond during each groundwater monitoring event following the procedures presented in the SAP. It should be noted that the surface water sample is not required per the CCR Final Rule and may not be used in reporting. Groundwater and surface water samples will be collected and analyzed for Detection Monitoring Parameters listed in Appendix III of the CCR Final Rule (40 CFR 257) and MDNR CCR water quality standard parameters following the groundwater sampling field procedures presented in the SAP (see Appendix A).

Following each sampling event, analytical results will be statistically evaluated to determine whether or not data from the most recent monitoring event is indicative of a release to groundwater from the inactive CCR unit using one or more of the methods presented in Section 5.0 and outlined in 40 CFR 257.93 (f) (1 through 5). In the event the statistical results are indicative of a potential release by observing a statistically significant increase (SSI) over established background levels, resampling will be performed within 90 days to verify the SSI result as discussed in Section 4.6.1.

4.6.1 Verification Sampling

In the event one or more of the constituents listed in Appendix III of the CCR Final Rule or MDNR CCR water quality standard parameter has statistical results indicative of a potential impact (detected SSI over background levels), resampling will be performed within 90 days of observing the SSI to verify the result is not due to error in sampling, analysis, or statistical evaluation or demonstrate that a source other than the inactive CCR unit caused the SSI. If the verification sampling result is confirmed as an SSI over background conditions (spatial and/or temporal), the facility will enter into a period of assessment monitoring (see Section 4.7). If the initial SSI is not confirmed, the owner or operator of the CCR unit may continue with a detection monitoring program. If a successful demonstration is not completed within the 90-day period, the owner or operator of the CCR unit will initiate an assessment monitoring program (see Section 4.7). The owner or operator will also include the demonstration in the annual groundwater monitoring and corrective action report required by § 257.90(e).

4.7 Assessment Monitoring

If a verified SSI is observed in one or more of the constituents listed in Appendix III of the CCR Final Rule and MDNR CCR water quality standard parameters (as demonstrated by verification sampling [see Section 4.6.1]) or a successful demonstration is not completed within 90 days of observing the initial SSI, the owner or operator will initiate assessment monitoring program. Within 90 days of triggering an assessment monitoring program, the owner or operator of the inactive CCR unit will collect groundwater samples from each well in the sampling network for the parameters presented in Appendix III and Appendix IV of the CCR Final Rule and MDNR CCR water quality standard parameters. Both Appendix III and Appendix IV parameters will be analyzed on a semiannual frequency during subsequent monitoring events. Groundwater protection standards will be established for all parameters detected during assessment and detection monitoring pursuant to 40 CFR 257.95(h). The groundwater protection standard will be:

1. The MCL, for constituents for which an MCL has been established under §141.62 and §141.66;
2. The background concentration established from wells in accordance with §257.91, for constituents for which an MCL has not been established; or
3. The background concentration established from wells in accordance with §257.91, for constituents for which the background level is higher than the MCL.

Once initiated, assessment monitoring will continue until one of the following scenarios is observed:

1. If all of the detected Appendix III or IV and MDNR CCR water quality constituents are detected at levels below background levels using the statistical procedures presented in Section 5.0 and 40 CFR 257.93(g), for two consecutive sampling events, a notification will be prepared stating that detection monitoring will be resumed as outlined in Section 4.6.

2. If one or more Appendix III or IV and MDNR CCR water quality constituents is detected at levels above background values, but at concentrations below the established groundwater protection standard, assessment monitoring will continue as outlined above.

3. If one or more Appendix III or IV and MDNR CCR water quality constituents is detected at levels above the groundwater protection standard using the statistical procedures presented in Section 5.0 and 40 CFR 257.93(g), a notification will be prepared for incorporation into the operating record, and the following activities will ensue:

a. Characterize the nature and extent of the release through the installation of additional monitoring wells and additional groundwater sampling and analysis as presented in 40 CFR 257.95 (g) (1).

b. Notify any adjacent property owners of releases that extend outside of the facility boundary as presented in 40 CFR 257.95 (g) (2).

c. Within 90 days of any of the constituents listed in Appendix IV of the Final Rule having a verified SSI exceeding groundwater protection standards the owner or operator will either:

    i. Initiate an assessment of corrective action measures as required by 40 CFR 257.96; or

    ii. Demonstrate that a source other than the CCR unit caused the contamination, or that the SSI resulted from laboratory error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. If a successful demonstration is made, the owner or operator will continue monitoring in accordance with the assessment monitoring program, and may return to detection monitoring if the constituents in Appendices III and IV of the Final Rule and MDNR CCR water quality standards are at or below background as specified in 40 CFR 257.95 (e). If it cannot be demonstrated that a source other than the CCR unit caused the contamination, or that the statistically significant increase resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater, assessment of corrective measures will be performed. Requirements for assessing corrective measures and selecting a remedy are presented in 40 CFR 257.96 and 40 CFR 257.97, respectively, and are not covered by this document.

5.0 STATISTICAL ANALYSIS

5.1 Introduction

The groundwater monitoring data collected in accordance with this GMP will be statistically evaluated for background, detection, and assessment (as needed) monitoring (as presented in Sections 4.5, 4.6, and 4.7, respectively). The statistical methods used to evaluate the project data will be determined following the collection of background samples (see Section 4.5) and establishment of background populations for each well/constituent pair (see Section 5.2). After establishing background populations, future data assessment may use the statistical methods presented in 40 CFR 257.93 (f) and listed in Section 5.4. When selecting statistical methods to be used in evaluating groundwater monitoring data, certification from a qualified professional engineer will be obtained stating that the selected statistical method is appropriate for evaluating the groundwater monitoring data for the CCR management area. The certification will include a narrative description of the statistical method selected and may be included in future groundwater monitoring reports or in the operational record. The selected statistical test will be conducted separately for each constituent in each monitoring well. Statistical analysis will be performed in accordance with USEPA's *Unified Guidance for Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* dated March 2009. The commercially available *Sanitas for Groundwater*© (or similar) software program will be used to perform the statistical data evaluation.

5.2 Establishing Background Data

Once the minimum of eight background data have been collected, a statistical background window will be established for each analyte. This background window will include the data used to assess subsequent sample results for Detection monitoring and Assessment monitoring (if necessary), as presented in Sections 4.6 and 4.7, respectively. Prior to establishing the initial background window, the eight rounds of data will be assessed to identify any potentially erroneous data points that could lead to erroneous statistical results. This may be done using outlier and trend tests as described in the following sections. Outlier analyses are used to identify data points that are erroneously high and not representative of the naturally occurring conditions. Trend tests provide information about apparent data trends that may be present in the dataset. While it is not anticipated that any of the eight quarterly background samples will be omitted from the background window, outliers and data points that result in trending data will be omitted from the background window during routine updates. Procedures for updating the background window are presented in Section 5.3.

5.2.1 Outlier Analysis

Occasionally, an inconsistent large or small value may be observed in the data due to sampling, laboratory, transportation, transcription errors, or even by chance alone. If such erroneous values (either too high or too low) are included in the statistical calculations, it may result in an artificial increase in the magnitude of an established statistical limit and a corresponding increase in the false negative rate of the statistical test (i.e., concluding that there is not site impact when in fact there is). Outlier tests are typically performed when updating the background window to account for these potential erroneous values that would result in an artificial increase or decrease in a statistically calculated background.

Generally, the one-third outlier option is used to evaluate the data. This screening tool is more conservative in that a broader concentration range is allowed before a data point is classified as an outlier. In this calculation, the median value of the previous background window is calculated and the outlier(s) in question is compared to three times/one third this value. If the outlier in question is outside this calculated value, the result is considered an outlier and flagged as an outlier in the statistical database and excluded from the statistical calculations until the next background update (or if a change in concentrations is noted in future sampling events [i.e., increase in concentration observed on Time Series plots]). Any data points flagged as outliers will be re-evaluated during future monitoring events, and/or during the next background update, to determine if it is still an outlier. No data points will be permanently "deleted" from the statistical database.

5.2.2 Trend Tests

A trend is a general increase or decrease in data concentrations over time. A trend test can be used to determine if a trend is statistically significant at a specified level of confidence. A Sen's Slope/Mann-Kendall trend test is generally utilized to determine if a significant trend exists in the data. This method of trend test is not greatly affected by gross data errors or outliers.

Trend tests will be performed when updating the background window. Any data exhibiting trends are not generally included in the background update. For instances in which a trend is noted, the background window for the monitoring well/constituent pair in question is typically then updated at a later date. The trend will be further evaluated as more data are collected before the data is added to the background. No data points are removed from the statistical database based on trending data. Visual observations of the time series plots can also provide an "at a glance" check for possible trends. Trends in constituent concentrations can be naturally occurring, or caused by the landfill or other site activities. Because of this, some historical or early data may be excluded from statistical calculations if Site conditions have changed over time. Additionally, if trends are noted, a secondary statistical test may be utilized to determine if the

"old" and "new" data are similar. This test is the Mann-Whitney (Wilcoxson Rank Sum) test, which is essentially a t-test to determine if the two populations (old data vs new data) are similar.

5.3 Updating Background Datasets

The background window will be updated bi-annually (every two years) to increase the number of data points in the background dataset and add statistical power to the groundwater evaluations performed. When updating the background window, outlier and trend analyses will be performed as presented in Sections 5.2.1 and 5.2.2. These tests will be performed using the proposed new background window which will include a combination of the previous background window and the new samples to be incorporated into the new background window. If the addition of new data results in a statistically significant increasing trend, these points will not be incorporated into the background window to prevent the inclusion of data that may be the result of a release from the inactive CCR unit. Outlier tests will be performed to determine whether or not any individual data point may by a one-time atypical result that is not indicative of natural site conditions. Data points identified as outliers will be omitted from the background window provided the minimum requirement of eight independent datasets can be achieved by the resulting background population.

5.4 Statistical Methodologies

While the statistical methods used to evaluate the project data will be determined following the collection of background samples and establishment of background populations for each well, the following methods are presented in 40 CFR 257.93 (f) and may be used in future data assessments:

- Parametric Analysis of Variance
- Analysis of Variance Based on Ranks
- Tolerance / Prediction Limits
- Control Chart

5.4.1 Parametric Analysis of Variance

A parametric analysis of variance followed by multiple comparison procedures to identify statistically significant evidence of contamination. The method will include estimation and testing of the contrasts between each compliance well's mean and the background mean levels for each constituent.

5.4.2 Analysis of Variance Based on Ranks

An analysis of variance based on ranks followed by multiple comparison procedures to identify statistically significant evidence of contamination. The method will include estimation and testing of the contrasts between each compliance well's median and the background median levels for each constituent.

5.4.3 Tolerance / Prediction Limits

A tolerance or prediction interval procedure, in which an interval for each constituent is established from the distribution of the background data and the level of each constituent in each compliance well is compared to the upper tolerance or prediction limit.

5.4.4 Control Chart

A control chart approach that gives control limits for each constituent.

5.4.5 Other Statistical Methodologies

Another statistical test method that meets the performance standards of 40 CFR 257.92 (g).

6.0 MONITORING WELL ABANDONMENT ACTIVITIES

6.1 Monitoring Well Abandonment

In the event that a monitoring well is no longer being used or needed as part of the groundwater monitoring system, or is damaged, the well will be properly abandoned and plugged. Monitoring well abandonment activities will be conducted by a Missouri-licensed driller or MDNR-certified well contractor, and work will be required to be performed in accordance with all Missouri statues and regulations regarding well abandonment and plugging and following procedures in the SAP (refer to Appendix A).

7.0 REPORTING

7.1 Groundwater Monitoring Memos

Upon completion of each sampling event and after receiving the laboratory results, a groundwater monitoring memo will be prepared for submission to CWLD for internal use only that summarizes basic information regarding the sampling event and summarizes the groundwater analytical results. The information and results presented in these memos will be used in preparing the annual Groundwater Monitoring and Corrective Action Report in accordance the CCR Final Rule 40 CFR 257.90(e).

7.2 Annual Groundwater Monitoring and Corrective Action Reports

Upon completion of the background monitoring for the inactive CCR unit, the initial groundwater monitoring and corrective action report will be prepared by August 1, 2019 and annually thereafter. For new CCR units and all lateral expansion of CCR units, the initial annual groundwater and corrective action report will be prepared no later than January 31 of the year following the calendar year a groundwater monitoring system has been established for such CCR unit (collection of eight representative groundwater samples to establish initial background conditions), and annually thereafter.

The annual reports will document the status of the groundwater monitoring and corrective action program for the CCR unit, summarize key actions completed, describe any problems encountered, discuss actions to resolve the problems, and identify key project activities for the upcoming year. At a minimum, the annual groundwater monitoring and corrective action report will contain the following information, to the extent available:

- Narrative of current sampling round
- Well integrity inspection results
- Well maintenance activities performed (if any)
- Site vicinity and monitoring well location maps
- Groundwater depths and elevations
- Annual total well depths and elevations
- Potentiometric surface maps and discussion of groundwater gradients
- Copies of groundwater monitoring field documents
- Copies of laboratory analytical reports with QA/QC results and lab qualifiers (if any)
- Data validation results (perform State I data review at minimum)
- Summary data table of groundwater field parameters and laboratory results
- Statistical analysis results

- Analytical results maps prepared as necessary to summarize the distribution of significant detections of compounds
- Identify any SSIs or Areas of Concern (if any)
- Narrative discussion of any transition between monitoring programs (detection/assessment)
- Discussion of any monitoring wells that were installed or decommissioned during the previous reporting period
- Recommendations for subsequent groundwater monitoring event, transition between monitoring program and/or status of corrective action, if required

7.3 Record Keeping and Public Reporting

In accordance with the Final Rule requirements, these annual reports will be placed in the facility's operating record no later than August 1, 2019 (and annually thereafter) as required by 40 CFR §257.105(h) and posted to CWLD's publicly accessible Internet website in accordance with 40 CFR §257.107(h).

In addition to the annual groundwater monitoring and corrective action reports, additional records and certifications presented in 40 CFR 257.105(h) will be maintained by CWLD in the operating record for compliance with the CCR Final Rule. While not all of these items will be posted by CWLD to their publicly accessible Internet website, these additional record keeping requirements may include:

- Documentation of the design, installation and decommissioning of any monitoring wells, piezometers, and other measurements, sampling, and analytical devices.
- The groundwater monitoring system certification required by 40 CFR 257.91(e) (1).
- The selection of a statistical method certification.
- The notification of the establishment of an assessment monitoring program, if required.
- The results of Appendix III and Appendix IV or MDNR CCR water quality standard constituents.
- The notification of returning to the detection monitoring program, if required.
- Notification of detecting one or more Appendix IV or MDNR CCR water quality standard constituents at statistically significant levels above the groundwater protection standard.
- Notification of initiating corrective measures requirements, if required.
- The completed assessment of corrective measures, if required.
- Documentation recording the public meeting for the corrective measures assessment, if required.
- The semiannual report(s) describing progress in selecting and designing the remedy and the selection of remedy report, if required.
- Notification of completing the remedy, if required.

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TABLES

Table 1
Summary of Groundwater Monitoring Well Network
Columbia Water Light Department - Columbia Municipal Power Plant
Columbia, Missouri

Closed Surface Impoundment	Sample[1,2,3]	Water Level Gauging[4]	Annual Total Well Depth Gauging[5]
MW-1	X	X	X
MW-2	X	X	X
MW-3	X	X	X
MW-4	X	X	X
MW-5	X	X	X
MW-6	X	X	X
MW-7	X	X	X
MW-8	X	X	X
PZ-1		X	X
PZ-2	X	X	X
PZ-3		X	X
PZ-4		X	X
PZ-5		X	X
PZ-6		X	X

Notes:

1. Background Sampling: For existing CCR unit(s), any newly installed wells and existing wells without established background values are initially sampled to collect a minimum of 8 independent and qualified samples no later than April 17, 2019. For new CCR units and all lateral expansions of CCR units, a minimum of 8 independent and qualified initial background samples will be collected for each background well during the first 6 months of sampling. Background groundwater samples will be analyzed for Detection and Assessment Monitoring parameters listed in Appendix III and IV of the CCR Final Rule, respectively. Additional groundwater parameters will include those listed in MDNR's CCR Storage and Disposal in Missouri, Division of Environmental Quality white paper.The analytical parameters are summarized in Table 3 of the GMP and Table 2 of the SAP (see Appendix A of GMP).

2. Detection Monitoring: Once 8 background samples are obtained from each monitoring well and background populations established, semi-annual detection monitoring will be initiated during months of May and October. Detection Monitoring parameters listed in Appendix III of the CCR Final Rule and MDNR white paper are summarized in Table 2 of the SAP (see Appendix A of GMP).

3. Assessment Monitoring: In the event that a verified SSI is observed in one or more of the Detection Monitoring constituents listed in Appendix III or a successful demonstration is not completed within 90 days of observing the SSI, the owner or operator will initiate assessment monitoring. Within 90 day of triggering assessment monitoring, and semi-annual thereafter, groundwater samples would be collected from each well in the sampling network for the Assessment Monitoring parameters listed in Appendix III and Appendix IV of the federal CCR rule. Detection and Assessment Monitoring parameters are summarized in Table 2 of the SAP (see Appendix A of GMP).

4. Water levels measurements will be recorded using the proceedures presented in the SAP during each planned sampling event prior to collecting groundwater samples. Water level measurements will be obtained within a period of time short enough to avoid temporal variations in groundwater flow which could preclude accurate determination of groundwater flow rate and direction (i.e., < 24 hours).

5. Total well depths will be measured annually at the groundwater monitoring network using the proceedures presented in the SAP. Total well depth measurements will be compared to well construction depths to assess whether or not sediment is present and evaluate screen occlusion. For wells without dedicated pumps, total well depths will be measured during water level gauging prior to sampling activities. For wells with dedicated pumps, total well depths will be measured immediately following the sampling activities to prevent the sampling technician from surging the wells prior to sampling when removing the dedicated pumps. Another option for measuring total well depths to avoid removing pumps form the wells may be using a steel tape measure that can slide down the side of the well past the pump. Following approximately 2 years of background sampling, the frequency of measuring total well depths may be adjusted based on review of collected data.

Table 2
Summary of Monitoring Well Network Construction Details
Columbia Water Light Department - Columbia Municipal Power Plant
Columbia, Missouri

Well Identification	Well Location		Ground Surface Elevation (feet NAVD88)	Top of Casing Elevation (feet NAVD88)	Total Well Depth (feet bTOC)	Well Screen Length (feet)	Screened Interval			
							Top	Bottom	Top	Bottom
	Northing	Easting					(feet bTOC)		(feet NAVD88)	
MW-1	1309.61	595.26	770.20	769.82	42.87	10.00	32.50	42.50	737.32	727.32
MW-2	1283.14	982.64	781.80	781.03	52.96	10.00	42.59	52.59	738.44	728.44
MW-3	908.83	1035.37	781.62	781.13	49.58	10.00	39.21	49.21	741.92	731.92
MW-4	674.69	1040.37	785.39	785.02	57.16	10.01	46.78	56.79	738.24	728.23
MW-5	691.74	731.12	770.08	769.61	41.18	10.01	30.80	40.81	738.81	728.80
MW-6	690.15	349.67	770.47	770.07	41.83	10.01	31.45	41.46	738.62	728.61
MW-7	748.88	78.48	762.67	762.23	33.46	10.01	23.08	33.09	739.15	729.14
MW-8	1243.32	192.84	753.46	753.09	27.92	10.01	17.54	27.55	735.55	725.54
PZ-1	897.15	159.71	771.46	770.78	20.00	15.00	5.00	20.00	765.78	750.78
PZ-2	906.03	81.89	756.19	755.91	19.80	15.00	4.80	19.80	751.11	736.11
PZ-3	1056.64	223.33	770.77	769.94	20.00	15.00	5.00	20.00	764.94	749.94
PZ-4	1150.48	119.48	752.40	752.06	20.13	15.00	5.13	20.13	746.93	731.93
PZ-5	1179.83	338.16	771.01	770.02	20.00	15.00	5.00	20.00	765.02	750.02
PZ-6	1264.67	300.25	755.87	755.60	20.16	15.00	5.16	20.16	750.44	735.44

Notes:

bTOC = Below top of casing.

ft = feet

NAVD = North American Vertical Datum of 1988.

Northing and Easting well locations in Missouri State Plane coordinate system.

PZ-1 through PZ-6 construction details taken from historical drilling logs and construction forms.

Table 3
Background Groundwater Sampling
Columbia Water Light Department - Columbia Municipal Power Plant
Columbia, Missouri

Soil Boring Identification	Chemical Testing												Field Parameters				
	Metals	Calcium	Chloride	Sulfate	Fluoride	Hardness	COD	pH	TDS	TOC	TOX	Radium 226+228	pH	Temperature	Specific Conductance	ORP	DO
MW-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MW-2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MW-3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MW-4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MW-5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MW-6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MW-7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MW-8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PZ-2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Duplicate	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Matrix Spike	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Matrix Spike Duplicate	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total Samples	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**
8 Events	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**

Notes:

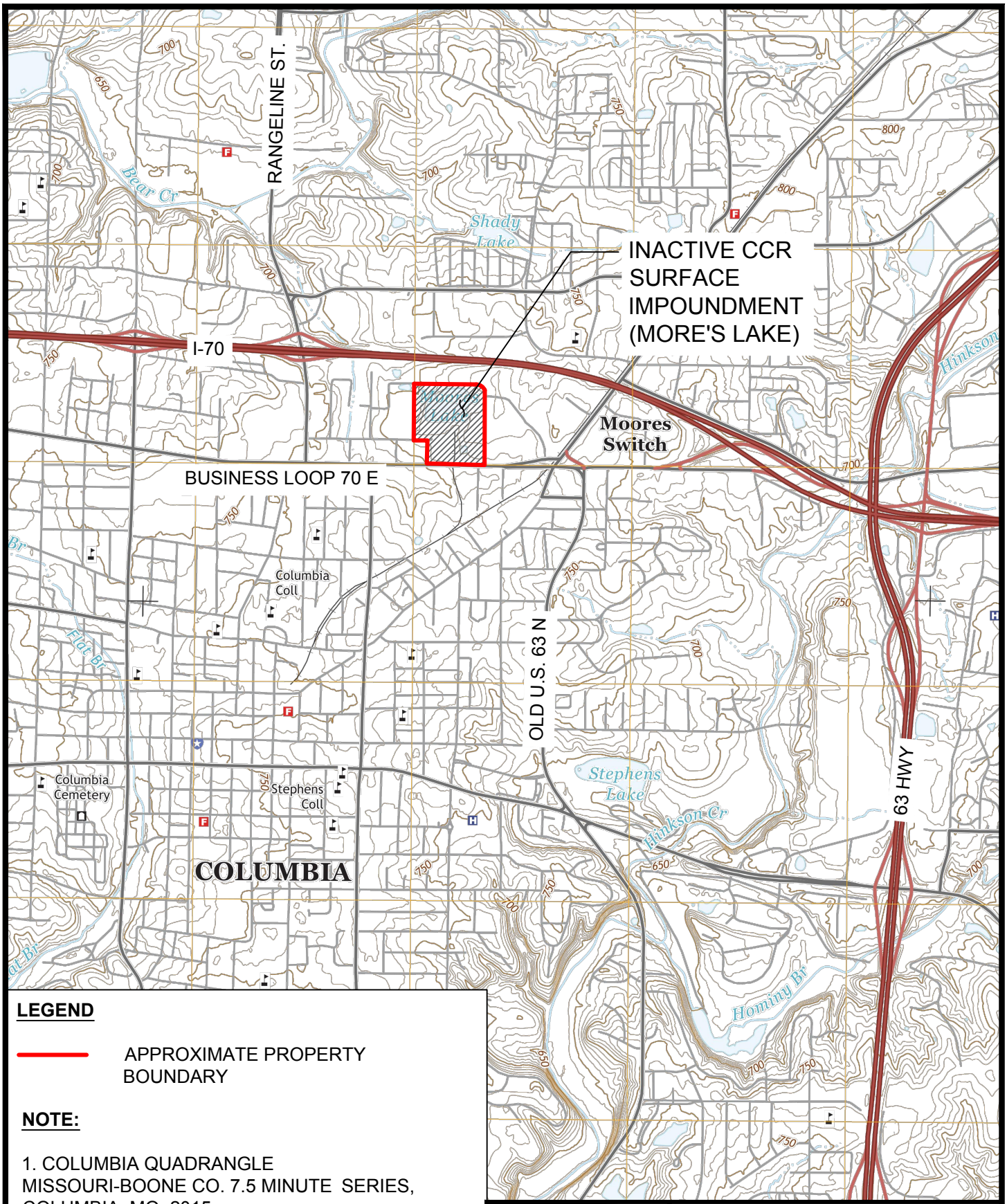
Groundwater sampling will be performed on a quarterly basis for two years so that eight rounds of background data are obtained prior to April 17, 2019. If necessary, more frequent sampling and analysis may be performed to obtain the eight independent background samples prior to April 17, 2019. Groundwater sampling will be performed in accordance with the Sampling and Analysis Plan (SAP) included in the Groundwater Monitoring Program (GMP).

One (1) duplicate, one (1) matrix spike (MS), and one (1) matrix spike duplicate (MSD) will be collected during each background sampling event.

COD - chemical oxygen demand
TDS - total dissolved solids
TOC - total organic carbon
TOX - total organic halogens

Metals - RCRA 8 (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), Boron, Aluminum, Antimony, Beryllium, Chromium III, Chromium VI, Cobalt, Iron, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Sodium, Thallium, and Zinc.

FIGURES



LEGEND

APPROXIMATE PROPERTY BOUNDARY

NOTE:

1. COLUMBIA QUADRANGLE MISSOURI-BOONE CO. 7.5 MINUTE SERIES, COLUMBIA, MO, 2015.
2. CONTOUR INTERVAL 10 FEET.

N

0 2000' 4000'

SCALE IN FEET

BURNS McDONNELL

FIGURE 1
SITE VICINITY TOPOGRAPHIC MAP
COLUMBIA MUNICIPAL POWER PLANT COLUMBIA, MO

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LEGEND

APPROXIMATE PROPERTY BOUNDARY

NOTE:

1. COLUMBIA QUADRANGLE MISSOURI-BOONE CO. 7.5 MINUTE SERIES, COLUMBIA, MO, 2015.

N

0 2000' 4000'

SCALE IN FEET

BURNS McDONNELL

FIGURE 2
SITE VICINITY AERIAL MAP
COLUMBIA MUNICIPAL POWER PLANT COLUMBIA, MO

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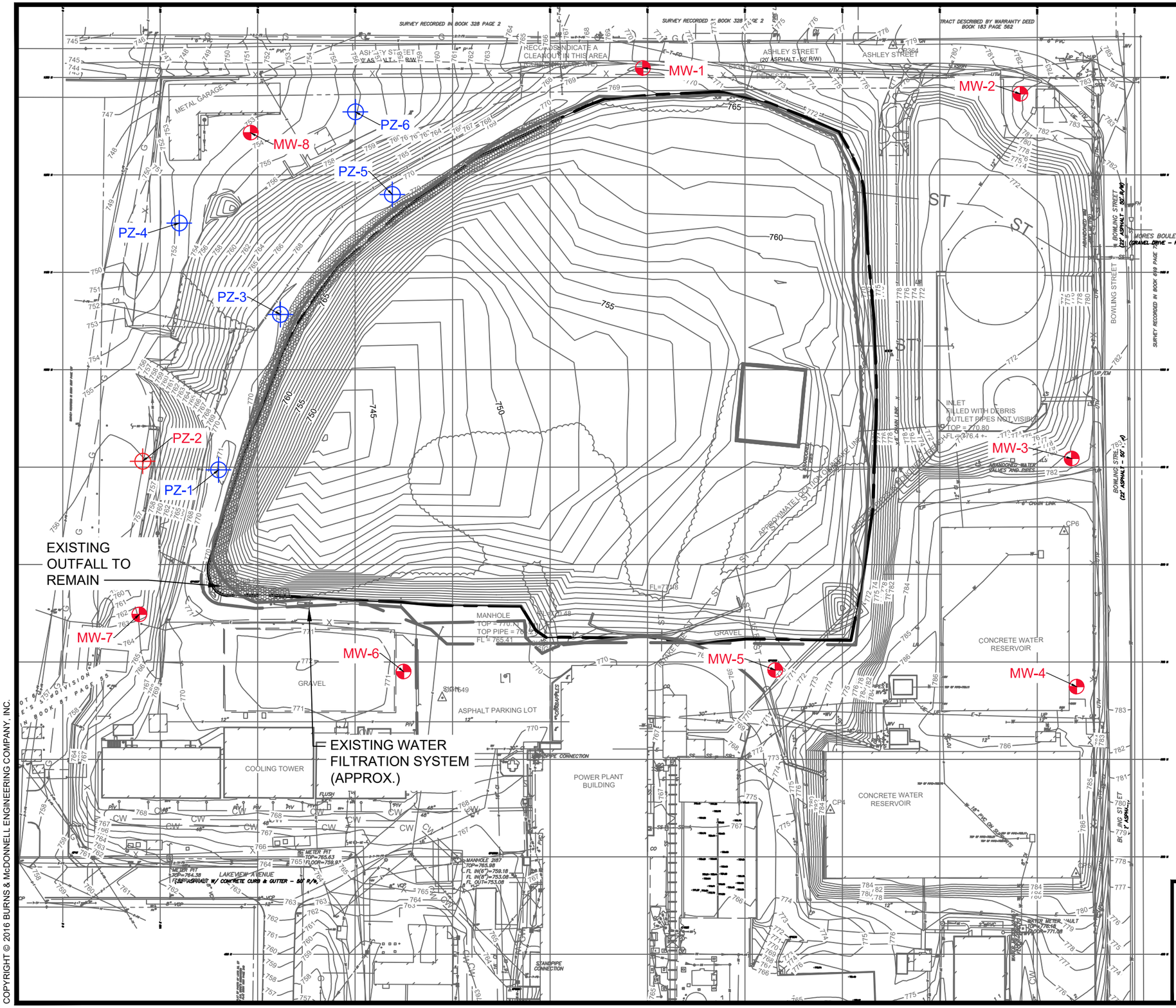

LEGEND

- PIEZOMETER
- MONITORING WELL
- USED FOR WATER LEVEL OR TOTAL DEPTH ONLY
- APPROXIMATE PROPERTY BOUNDARY

NOTE:

1. COLUMBIA QUADRANGLE MISSOURI-BOONE CO. 7.5 MINUTE SERIES, COLUMBIA, MO, 2015.
2. CONTOUR INTERVAL 1 FEET.
3. WELLS COLORED IN RED ARE INCLUDED IN THE SAMPLING NETWORK.

N

0 100' 200'

SCALE IN FEET

BURNS McDONNELL

FIGURE 3
MONITORING WELL NETWORK
COLUMBIA MUNICIPAL POWER PLANT
COLUMBIA, MISSOURI

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Z:\CLIENTS\ENS\COLUMBIAMO\93647_MORESLAKE\DESIGN\CADD\DWGS\GROUNDWATER WORK PLAN\FIG3-MONITORING WELL LOCATIONS.DWG DHINEMAN

APPENDIX A – GROUNDWATER SAMPLING AND ANALYSIS PLAN

Groundwater Sampling and Analysis Plan for More's Lake

Columbia Water & Light

Columbia Municipal Power Plant
Project No. 93647

August 2017
Revision 1: February 2018

Groundwater Sampling and Analysis Plan for More's Lake

prepared for

Columbia Water & Light
Columbia Municipal Power Plant
Columbia, Missouri

Project No. 93647

August 2017
Revision 1: February 2018

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

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INDEX AND CERTIFICATION

Columbia Water & Light
Groundwater
Sampling and Analysis Plan
for
More's Lake
Project No. 93647

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Certification

I hereby certify, as a Professional Engineer, and Registered Geologist in the state of Missouri, that the information in this document was assembled under my direct personal charge. This report is not intended or represented to be suitable for reuse by the Columbia Water & Light or others without specific verification or adaptation by the Engineer/Geologist.

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2/6/2018

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
°C	Degrees Celsius
ASTM	American Society of Testing and Materials
CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
CMPP	Columbia Municipal Power Plant
COPC	Constituents of Potential Concern
CWLD	Columbia Water & Light Department
DO	Dissolved Oxygen
DQO	Data Quality Objective
EDD	Electronic Data Deliverable
GMP	Groundwater Monitoring Program
LCS	Laboratory Control Sample
MCL	Maximum Contaminant Level
mg/L	Milligrams Per Liter
mL/min	Milliliters Per Minute
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NELAP	National Environmental Laboratory Accreditation Program
NFGI	National Functional Guidelines for Inorganic Data Review
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Units

Abbreviation	Term/Phrase/Name
ORP	Oxidation Reduction Potential
PARCC	Precision, Accuracy, Representativeness, Completeness, and Comparability
PPE	Personal Protective Equipment
PQL	Practical Quantitation Limit
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
R	Data Qualified as Unusable or Rejected
RCRA	Resource Conservation Recovery Act
REC	Percent Recovery
RL	Reporting Limit
RPD	Relative Percent Difference
SA	Spike Added
SAP	Sampling and Analysis Plan
Site	Columbia Municipal Power Plant located in Columbia, Missouri
SR	Sample Results
SSR	Spike Sample Results
Inactive CCR Unit	Inactive CCR Surface Impoundment at Columbia Municipal Power Plant
USEPA	United States Environmental Protection Agency

1.0 INTRODUCTION

This Sampling and Analysis Plan (SAP) has been prepared by Burns and McDonnell Engineering Company (Burns & McDonnell) to establish procedures for monitoring well installation and groundwater monitoring at the inactive coal combustion residual (CCR) Inactive Surface Impoundment (referred to as "inactive CCR Unit") for Columbia Water & Light Department (CWLD) Columbia Municipal Power Plant (CMPP) located in Columbia, Missouri (Site). Topographic and aerial photographic site vicinity maps illustrating the location of the inactive CCR Unit are provided as Figures 1 and 2, respectively. The currently defined groundwater monitoring network at the inactive CCR Unit is summarized in Tables 1 and 2 of the Groundwater Monitoring Plan (GMP) and illustrated on Figure 3, respectively.

1.1 Purpose

This SAP has been prepared to present groundwater monitoring procedures to support compliance with the requirements included in the United States Environmental Protection Agency (USEPA) *Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule*, dated April 17, 2015 (USEPA, 2015), and the *Hazardous and Solid Waste Management System: Disposal of Coal Combustion Residuals From Electric Utilities; Extension of Compliance Deadlines for Certain Inactive Surface Impoundments; Response to Partial Vacatur*, dated August 5, 2016 (USEPA, 2016), collectively referred to herein as the "CCR Final Rule."

1.2 CCR Final Rule Program

The CCR Final Rule is found in 40 Code of Federal Regulations (CFR) Parts 257 and 261 and was published by EPA to regulate the disposal of CCR as solid waste under subtitle D of the Resource Conservation and Recovery Act (RCRA). This final rule is effective on October 19, 2015 and applies to all CCR generating electric utility facilities and independent power producers that fall within the North American Industry Classification System (NAICS) code 221112.

This CCR Final Rule established nationally applicable minimum criteria for the safe disposal of CCR in landfills and surface impoundments. CCR includes fly ash, bottom ash, boiler slag, and flue gas desulfurization materials. The CCR Final Rule applies to owners and operators of new, existing, and/or laterally expanded landfills and surface impoundments that dispose or otherwise engage in solid waste management of CCR. In June 2016, a United States Court of Appeals granted a settlement between utility industry and environmental groups that removed the effects of the "early closure" provisions for inactive surface impoundments under the USEPA CCR rule (40 CFR §257). With this rule change, all inactive CCR surface impoundments must now comply with all of the rule requirements applicable to

existing/active CCR surface impoundments (location criteria; design and operating requirements; air criteria; inspection requirements; groundwater monitoring and corrective action; closure and post-closure care; and recordkeeping, notification and publicly accessible internet site requirements). The requirements of the CCR Final Rule also apply to CCR units located off-site of the electric utilities' or independent power producers' facilities that receive CCR for disposal (i.e., public or private landfills).

The CCR Final Rule requires CCR units implement groundwater monitoring system (40 CFR §257.91) and program (40 CFR §257.93-§257.95) that are capable of detecting CCR impacts on the groundwater quality, if any, underlying each utility waste landfill and/or surface impoundment. The groundwater monitoring system must consist of a sufficient number of appropriately located wells (at minimum, one upgradient and three downgradient wells) capable of monitoring the quality of background groundwater and the quality of groundwater passing the CCR waste boundary. Monitoring wells must be installed in order to yield representative groundwater samples from the uppermost aquifer. The CCR Final Rule requires groundwater sampling at utility CCR-waste landfills/impoundments for specific CCR chemical constituents of potential concern (COPCs). The CCR rule requires operators of inactive surface impoundments (i.e., More's Lake) to implement groundwater monitoring programs prior to April 17, 2019 that are capable of detecting releases to shallow groundwater. To meet this requirement, owners must install well networks and conduct eight rounds of background monitoring prior to April 17, 2019. If the groundwater monitoring system demonstrates a verified exceedance of a groundwater protection standard for any of the identified CCR COPCs, the owner or operator must initiate corrective action.

1.3 Rationale

This SAP is prepared to support for compliance with groundwater monitoring requirements in the CCR Final Rule.

There is one inactive CCR Unit associated with CMPP, which consist of the inactive surface impoundment (More's Lake). However, More's Lake was inactive by October 2015 and CWLD is currently performing closure activities for this inactive surface impoundment planned to be completed by April 17, 2019. As discussed previously in Section 1.2, the effects of the "early closure" provisions for inactive surface impoundments have been removed from the Final Rule so that inactive surface impoundments must now comply with all of the rule requirements applicable to existing/active CCR surface impoundments. Due to this recent rule change that no longer allows "early closure" provisions for inactive surface impoundments, the inactive CCR Unit has until April 17, 2019 to comply with groundwater monitoring requirements.

While not specified in the CCR Final Rule, a surface water sample will be collected from the inactive ash pond during each groundwater sampling event for analyses of the parameters sampled from each groundwater monitoring well.

This SAP includes an overview of the field activities and procedures for groundwater and surface water sampling and analysis activities.

1.4 Overview

This SAP presents procedures for the sampling and analysis of groundwater monitoring wells at the CMPP inactive CCR Unit. The SAP will serve as guidance for personnel performing groundwater monitoring of the inactive CCR Unit and is organized in sections as summarized below:

Section 2.0 Field Procedures - Section 2.0 presents a description of the field procedures to be used during groundwater and surface water sampling activities.

Section 3.0 Quality Assurance/Quality Control (QA/QC) - Section 3.0 details the methods that will be used so that only valid data are used in determining whether or not impacts to groundwater are present. This section describes the laboratory QA/QC procedures, analyte reporting limits, and analytical methodologies.

Section 4.0 References - Section 4.0 includes a bibliography for references made within this SAP.

1.5 Modification to Sampling and Analysis Plan

It should be noted that the existing monitoring well network may undergo periodic re-evaluation in the future that could result in either the addition or deletion of wells from the groundwater sampling network and changes in groundwater sampling methods. Groundwater and surface water sampling parameters may also be adjusted, following the review of data. Therefore, as changes to the groundwater monitoring network, sampling methodology, and analytical parameters occur, this SAP will be updated appropriately. Changes to the SAP will be documented in the operating record in accordance with the record keeping requirements presented in 40 CFR 257.105 and 257.107.

2.0 FIELD PROCEDURES

This section of the SAP presents a description for common field procedures to be used during monitoring well installation and groundwater and surface water sampling activities.

2.1 Overview

Groundwater samples will be collected to establish background groundwater quality and determine if the inactive CCR Unit has impacted the uppermost shallow groundwater quality. Proper sampling procedures are an important and fundamental aspect in an effective monitoring program. Groundwater sampling at the inactive CCR Unit will be accomplished by personnel trained in proper sampling protocol.

Groundwater sampling at the CCR unit will consist of five basic field activities: performing well integrity inspections, collecting water level and total well depth measurements, obtaining field measurements of select parameters, collecting groundwater samples, and submitting collected samples for laboratory analysis. Well maintenance and redevelopment may also be included in the field activities, as needed.

For the inactive CCR Unit, any newly installed monitoring wells (or existing wells without established background values) will be sampled to collect a minimum of eight (8) independent and qualified initial background samples no later than April 17, 2019 to allow for statistical evaluation. For new CCR landfills and surface impoundments, and all lateral expansions of CCR units, a minimum of eight (8) independent samples for each background well will be collected and analyzed for both Detection and Assessment Monitoring parameters during the first six (6) months of sampling (40 CFR 257.94[b]). Following background sampling, the wells will be incorporated into the groundwater monitoring network and will follow a semi-annual sampling and analysis schedule for detection or assessment (as needed) monitoring basis (during approximately May and October of each year) as described in the GMP.

Additional monitoring well installations may be required in the future to enhance detection monitoring or improve the groundwater monitoring system to support compliance with the CCR Final Rule. Monitoring well installation activities typically consist of five basic field activities: drilling, logging of subsurface samples, well installation and construction, well development, and well maintenance. In the event additional monitoring well installations are needed, a Site-specific Work Plan will be developed.

2.2 Personnel

Groundwater sampling activities at inactive CCR Unit will be performed in the field by a qualified technician familiar with the GMP and this SAP. All samples collected will be sent by the sampling

technician to an off-site National Environmental Laboratory Accreditation Program (NELAP) certified commercial laboratory for analysis using the procedures presented below.

2.3 Health and Safety

Personnel will conduct operations in accordance with promulgated Occupational Safety and Health Administration (OSHA) regulations and the CWLD and Burns & McDonnell Safety and Health Programs. Minimum field personnel protective equipment (PPE) will include steel-toed boots, hard hat, safety glasses, gloves, long pants, short sleeves, and hearing protection.

2.4 Groundwater Sampling Procedures

2.4.1 Sampling Frequency

For the inactive CCR Unit where background sampling for newly installed monitoring wells and/or existing wells without established background values is required, those wells will be sampled to obtain a minimum of eight independent and qualified initial background samples no later than April 17, 2019 to allow for statistical evaluation. The currently defined groundwater monitoring network at the inactive CCR Unit (More's Lake) is illustrated on Figure 3. For new CCR landfills and surface impoundments, and all lateral expansions of CCR units, a minimum of eight (8) independent samples for each background well will be collected and analyzed for both Detection and Assessment Monitoring parameters during the first six (6) months of sampling (40 CFR 257.94[b]).

Once eight background samples are obtained from the monitoring wells, background populations will be established and the wells will be incorporated into a semi-annual sampling schedule (approximately May and October).

2.4.2 Pre-Sampling Activities

Prior to beginning field activities, the project manager and the field sampling team will contact a selected NELAP certified commercial laboratory, schedule the sampling event, and arrange for laboratory-prepared bottles with appropriate preservatives to be obtained. The sampling team will pre-schedule the necessary sampling equipment which is anticipated to include:

- Necessary Field Paperwork
- Pneumatic Bladder Pump Control Box
- Compressed Gas Canister(s) (carbon dioxide or nitrogen)
- Pressure regulator and associated air line
- Electronic Water Level Indicator

- Multi-Parameter Meter with Flow-Through Cell
- Turbidity Meter
- Thermometer
- Calibration Standards
- Plastic Sheeting and Trash Bags
- Five-Gallon Buckets
- Disposable Gloves
- Calculator
- Decontamination Equipment
- Sample Cooler and Ice
- Sample Bottles (with appropriate preservatives)
- Weighted steel tape for total well depth measurements
- Camera for documenting well conditions or any maintenance issues

Equipment for field instruments will be calibrated in accordance with manufacturers' procedures. Calibration results will be documented in the field logbook or on field calibration forms. Sampling will not commence until all sampling equipment and supplies are on site.

2.4.3 Well Integrity Inspection

Each monitoring well will be inspected prior to the start of sampling events during the collection of water level measurements (refer to Section 2.4.5). Items to be inspected will include condition of the well pad, well cover, and bumper posts (if any); presence of excessive vegetation; presence of erosional features or the indication of ponding of water near the well; condition of the polyvinyl chloride (PVC) casing and well cap, condition of well label, and inspection of dedicated bladder pump well cap. The integrity of the dedicated bladder pumps and associated tubing will be evaluated during sampling and will be inspected (if necessary) based on field observations during sampling. Screen occlusion will be measured annually during total well depth gauging. The results of the well inspection will be documented in the field logbook or Field Groundwater Sampling Data Form (or equivalent) found in Appendix A. If a maintenance item is noted that could compromise the integrity of the groundwater sample, then a sample will not be collected until well maintenance has been conducted.

2.4.4 Well Maintenance

All well maintenance items noted in the field inspection (Section 2.4.3) or identified by CWLD will be corrected prior to the next sampling event by CWLD or their groundwater sampling contractor. Well

maintenance items such as painting, labeling, erosion control, and vegetation management may be conducted on a yearly basis if the deficiency will not affect the groundwater sampling. Major repairs or alteration of a monitoring well will be corrected prior to the next sampling event and will be conducted by a Missouri-licensed or MDNR-certified well contractor per Missouri regulations, if necessary. An account of monitoring well repairs will be generated by CWLD or contractor and placed in the operational record in accordance with the record keeping requirements presented in 40 CFR 257.105(h) and/or submitted to MDNR.

2.4.5 Water Level and Total Well Depth Measurements

Water levels measurements will be collected from the monitoring well network associated with the inactive CCR Unit during each planned sampling event prior to collecting groundwater samples. An electronic water level meter will be used to collect water level measurements. Groundwater elevations in monitoring wells must be measured within a period of time short enough to avoid temporal variations in groundwater flow which could preclude accurate determination of groundwater flow rate and direction (i.e., less than 24 hours). Total well depths will be measured annually at the groundwater monitoring network using a weighted steel tape or equivalent to measure and compare to the well construction depths to assess whether sediment is present and evaluate screen occlusion. For wells without dedicated pumps, total well depths will be measured during water level gauging prior to sampling activities. For wells with dedicated pumps, total well depths will be measured immediately following the sampling activities to prevent the sampling technician from disturbing sediment in the wells prior to sampling when removing the dedicated pumps. Another option for measuring total well depths to avoid removing pumps from the wells may be using a steel tape measure that can slide down the side of the well past the pump. Following two (2) years of sampling, the frequency of measuring total well depths may be adjusted based on review of collected data. Disposable nitrile or latex gloves will be worn during all water level and total well depth measurements and changed in between well locations. In monitoring wells with watertight caps, water level measurements taken immediately after the caps are removed will be repeated at regular intervals until the readings stabilize. As an alternative method, wells with unstable water levels after removing the caps may be opened to vent to atmospheric pressure for approximately 30 minutes prior to measuring water levels.

All groundwater levels will be measured to the surveyed reference mark (notch) on the top of the well casing. If no reference mark is present, the water level will be measured to the top of the casing on the north side of the well and the position measured to marked with a permanent marker on the outside of the casing. The following procedure will be used to measure groundwater levels and total well depths at each well:

1. Decontaminate the water level meter cable and probe in accordance with Section 2.10 of this SAP.
2. Turn on the water level meter and push the instrument test button to check the batteries.
3. Lower the water level meter probe into the monitoring well by pulling the cable from the hand-held reel until the indicator light and/or audible signal responds.
4. Move the cable up and down while observing the indicator. Note the exact length of cable extended from the tip of the probe sensor to the top of the well casing at the reference point when the probe sensor indicates the groundwater/air interface. Record the cable length to the nearest 0.01 foot, monitoring well number, time, and date of the measurement in a field logbook or appropriate form (Appendix A).
5. Once a year (annually), total well depths will be gauged. This will be performed following the collection of groundwater samples at wells with dedicated pumps to prevent disturbing sediment in the well immediately before sampling. After the groundwater sample has been collected, measure the total well depth by gently lowering the probe to the bottom of the well. Add the length of the distance between the end of the probe and the probe sensor to the total well depth measurement if applicable. Record the total well depth measured at the top of the well casing at the reference point to the nearest 0.01 foot in a field logbook or appropriate form. When removing bladder pumps and tubing from a well to measure total well depth, care shall be taken so that the equipment does not come in contact with the ground or other surfaces that could contaminate the equipment. Following total well depth measurement, inspect bladder pump and associated tubing prior to reinserting equipment down well. Prior to reinsertion of the pump system down the well, triple rinse the outside of the pump with distilled water and wipe the outside of the pump and tubing with a clean, dry, disposable towel. Another option for measuring total well depths to avoid removing pumps from the wells may be using a steel tape measure that can slide down the side of the well past the pump.
6. Decontaminate the probe and cable (see Section 2.10) prior to measuring the next well.
7. Obtain all groundwater elevation measurements within 24 hours.

Water level elevations will be compared with previous water level elevations for that monitoring well whenever possible. If a large difference in water level elevation (> 3 feet) is noted between measurements, the water level will be re-measured. If the re-measurement provides the same result, the inconsistency will be noted in the field logbook and evaluated during reporting with continued monitoring in subsequent sampling events.

The total well depth measurement of the well will be compared with the constructed total well depth. A lesser total well depth measurement is an indication that sediment is accumulating in the well. Wells will be re-developed whenever more than 10 percent of the effective well screen is occluded by sediments or records indicate a change in well yield and/or turbidity. Well redevelopment procedures will follow those discussed in Section 2.7 of this document.

2.4.6 Monitoring Well Purging and Sample Collection

2.4.6.1 Methodology

The overall objective in groundwater sampling is to collect a sample that is representative of the formation water for the parameters being tested. Sampling methods, equipment and procedures that are employed during sampling are designed and selected to accomplish this objective. Groundwater samples will not be field filtered prior to analysis. Disposable nitrile or latex gloves will be worn during all sampling procedures and changed in between well locations. Some of the concerns that arise in sampling a groundwater well are:

- Removing or avoiding stagnant non-representative water in the well
- Minimizing turbulent flow through the filter pack and screen, in order to avoid mobilizing solids
- Avoiding disturbance of any sediment that has collected at the bottom of the well
- Avoiding unnecessary agitation of the sampled water

The preferred method of sampling will be to use low-flow procedures with a dedicated bladder pump. For low recovery wells (if present), which do not support the stable water level requirement of standard low-flow sampling procedures, the preferred method of sampling will be the minimum-purge procedures using a dedicated bladder pump (see Section 2.4.6.4).

2.4.6.2 Field Indicator and Stabilization Parameters

Some of the sampling methods presented below depend on stabilization of field indicator parameters before the collection of sample water begins. The field parameters are measured and recorded every five minutes in the field logbook or on sample collection forms during well purging and immediately before collection of the sample. Even with methods that do not depend on parameter stabilization, field parameters are to be measured if possible. A summary of the stabilization requirements and field parameters is provided in Section 2.4.6.3 and Table 1, respectively.

The instruments used to measure field parameters will be calibrated and operated according to manufacturer's recommendations. The calibration will be checked at a minimum before each day of

sampling and often enough to maintain accurate readings. The pH probe on the multi-parameter meter will be checked at the beginning of each day using three standard buffer solutions, with a pH of 4, 7, and 10. Instrument calibration will be recorded in the field logbook or on field calibration forms.

When a flow-through cell is being used, multi-parameter sensors are contained within the flow-through chamber and measurements are made during purging. The sample line is disconnected from the flow-through cell prior to sampling, so samples are never collected downstream of the flow-through cell. Care will be taken to ensure that no air is introduced into the flow-through cell system through loose fittings. The flow-through cell will be decontaminated between use at each monitoring well by triple rinsing with distilled water.

The following physical and chemical parameters will be recorded when using a flow-through cell:

- Water temperature
- pH
- Specific conductance
- Dissolved oxygen (DO)
- Oxidation reduction potential (ORP)
- Turbidity - may also be recorded from a separate instrument outside of the flow-through cell by collecting groundwater from the sample line.

2.4.6.3 Well Purging and Sample Collection

Well purging and sampling using a dedicated bladder pump system will follow standard procedures for low-flow purging and sampling.

The following procedure will be followed during purging and sampling using a submersible bladder pump:

1. After opening the well, obtain a water level measurement. The water level probe is left in the well so that the well level can be checked regularly during pumping to monitor the drawdown. If the water level is below the top of the pump (probe is stopped at the pump before contacting water) note this in the field logbook; the well likely cannot be sampled with the pump.
2. Connect the charge line to a portable controller. Connect the controller to a compressed gas cylinder (nitrogen or carbon dioxide). Connect the pump discharge tube so that the sample water goes into the flow-through cell and is discharged into a bucket. A container with volumetric markings (i.e., liquid measuring cup) will be used to periodically collect discharge water prior to

entering the bucket to measure and monitor flow rates. Protect the field measurement apparatus from the effects of ambient temperature, wind and sun as necessary to minimize their influence on readings.

3. Operate the pump at a discharge rate that is low enough that the water level stabilizes with minimal drawdown and that is practical for purging and sampling. For wells in which the original water level is above the top of the screen (and therefore stagnant water overlies representative formation quality water) the drawdown shall generally not exceed 25 percent of the distance between the pump intake and the top of the screen (American Society of Testing and Materials [ASTM], D6771-02). If a stable water level cannot be achieved by reducing the pump rate, then the sampling personnel will switch to the minimum purge procedures used for low-recovery wells (see Section 2.4.6.4).
4. Purge the well until at least three pump assembly volumes (the volume within the pump and the tubing) have been discharged.
5. Document discharge rate, water level, and field parameters at least every five minutes and immediately before sample collection. Continue purging until at least three (3) consecutive field parameter measurements have stabilized using the following criteria:
    - ± 0.2 degrees Celsius (°C) for temperature;
    - ± 0.2 standard units for pH measurements;
    - ± 3 percent for specific conductance;
    - ± 10 percent for DO measurements greater than 2.0 milligrams per liter (mg/L) and ± 0.2 mg/L for DO measurements less than 2.0 mg/L;
    - ± 20 millivolts for ORP;
    - ≤ 5 Nephelometric Turbidity Units (NTUs) for turbidity;
        - If the well does not, or has a history of not, achieving 5 NTUs, use ±10% for values greater than 5 NTUs (USEPA, 2010[a]).
    - Stable water level (water level readings do not decrease over three consecutive measurements; acceptable for the water level to remain unchanged or to increase) with minimal drawdown.
        - Minimal drawdown may be difficult to achieve under some conditions due to geologic heterogeneities within the screened interval, and may require adjustment based on site-specific conditions and historical purging and drawdown data from the well. It is far more important to achieve a stabilized water level in a well during

purging than to achieve a particular drawdown value, as each well is hydrogeologically unique and thus will respond differently to pumping.

- In the event that the water level has not stabilized with minimal drawdown, then groundwater samples will be collected per the methods described in Section 2.4.6.4 Minimum Purge/Sampling of Low Yield Wells.

6. Disconnect the flow-through cell before sampling and record total gallons purged.
7. Decrease pump rate to no more than 500 milliliters per minute (mL/min) for sampling. Collect and preserve samples (where applicable).
8. Clear water from the top of the sample line by pressurizing the frost-protection airline if applicable.

Once the field parameters have stabilized and sampling begins, the discharge rate can be decreased if necessary, but is not subsequently increased. Maintaining the purge rate while sampling reduces the time the water collected for sensitive analytes is exposed to the atmosphere. However, discharge rates while sampling shall not exceed 500 mL/min. Wells should be sampled immediately after purging if possible, but can be sampled up to 24 hours after purging if required. Groundwater samples will not be field filtered prior to analysis.

2.4.6.4 Minimum Purge/Sampling of Low Yield Wells

The minimum purge method for sampling wells with a bladder pump is appropriate for wells that do not recharge adequately to maintain a stable water level while pumping as slowly as is practical, typically no slower than 100 mL/min. The method is intended to collect samples from the water within the screened interval, while avoiding any stagnant water that may exist in the casing above the screened interval.

The procedures for the minimum purge method are similar to the above described procedures for standard sampling with a bladder pump, with the following differences:

- The pump is operated at a low discharge rate, typically no lower than 100 mL/min, in order to minimize any disturbance of sediment in the well screen.
- Stabilization of water level does not occur.
- Measurement of field parameters will be recorded during purging and before sample collection if possible. If the volume of water in the well will be limited by the volume required to fill all sample bottles, then field parameters will be measured after sampling is complete if there is sufficient water and accurate readings can be obtained.

- The volume of water in the well casing and filter pack will be calculated. A determination will be made based on the calculated well volume if there is sufficient volume to measure and record field parameters prior to sampling.
- Sample collection can begin as soon as three pump assembly volumes (pump and tubing) of groundwater have been discharged. This is the minimum required purge, however more water volume will be removed if possible based on the calculated volume and water column height.
- For wells in which the original water level is above the top of the screen, sample collection will need to occur before or be suspended when the water level has been drawn down by the distance between the pump intake and the top of the screen, minus a safety margin of about 2 feet (Nielsen, 2002). This approximate 2-foot safety margin is to avoid drawing in stagnant water that is originally above the screened interval. Record the water level at the maximum drawdown.
    - As an example: In a monitoring well with ten feet of screen and the pump intake two feet from the bottom, the maximum draw down distance is six feet (eight feet from the pump intake to the top of the screen minus the two feet safety margin).
- For wells in which the original water level is within the screened interval, the water may be drawn down to about the level of the top of the pump as a practical limit during sampling. Record the water level at the maximum drawdown.
- It may be necessary to reduce the sample bottle volumes to the minimum required by the laboratory for analysis, the project manager and laboratory will be contacted to acquire the minimum volume requirements for each analysis and to ensure it is appropriate for the project.
- If sample collection cannot be completed, allow the well to recharge for approximately 24 hours and reattempt sample collection (maximum of one attempt).

2.5 Groundwater Quality Control Samples

Quality control samples will consist of duplicate, matrix spike (MS), and matrix spike duplicate (MSD). Duplicate samples will be collected at a rate of 1 for every 10 samples and MS/MSDs will be collected at a rate of 1 for every 20 samples. At a minimum, one duplicate, one MS, and one MSD will be obtained for every sampling event.

2.5.1 Duplicate Samples

Duplicate samples will be obtained at the same time and analyzed for the same set of parameters as the project sample it is intended to duplicate. If the potential for limited volume at low recovery wells exist, it may be necessary to collect duplicates on a per analyte basis per well (i.e., the total metals duplicate may come from one monitoring well while the anions duplicate may come from another monitoring well). The

original and duplicate samples will be placed in identical containers and preserved in the same manner. Duplicate samples will be identified with unique sample identification numbers so as to be blind to the analytical laboratory (i.e., DUP-1, DUP-2). The well locations where duplicates are collected will be documented in the field logbook and/or on the Field Groundwater Sampling Data Form (or similar) found in Appendix A.

2.5.2 Matrix Spike and Matrix Spike Duplicates

Groundwater samples for the MS/MSD will be collected in triplicate including the project sample. Due to the larger sample volume needed, MS/MSDs will typically be collected from monitoring wells with adequate recharge/recovery (not collected from low recovery wells). If insufficient volume is present at the monitoring well for sampling, it may be necessary to collect the MS/MSD on a per analyte basis per well (i.e., the total metals MS/MSD may come from one monitoring well while the anions MS/MSD is collected from another). The three samples will be identified as the project sample (well identification), the MS, and the MSD. Well locations where MS/MSDs are collected will be documented in the field logbook and/or on the Field Groundwater Sampling Data Form (or similar) found in Appendix A.

2.6 Analysis of Groundwater Samples

All groundwater samples collected will be analyzed by a NELAP certified commercial laboratory. Groundwater samples will not be field filtered prior to analysis. Background groundwater samples collected will be analyzed for both Detection and Assessment Monitoring parameters in accordance with Appendix III and IV of the federal CCR Rule and additional MDNR CCR water quality standard parameters. Following background sampling, subsequent groundwater samples will be analyzed for either Detection or Assessment Monitoring based on groundwater results and statistical analysis. Table 2 lists the specific parameters and analytical methods to be used when analyzing groundwater samples for Detection, Assessment, and MDNR CCR water quality standards. The table includes an analyte summary along with specific holding times, preservatives, and sample container requirements. The practical quantitation limit (PQL) for each analyte will be either at or below:

1. The Maximum Contaminant Level (MCL), for constituents for which an MCL has been established under §141.62 and §141.66;
2. The background concentration established from wells in accordance with §257.91, for constituents for which an MCL has not been established; or
3. The background concentration established from wells in accordance with §257.91, for constituents for which the background level is higher than the MCL.

2.7 Monitoring Well Re-Development

Well re-development will be performed on existing monitoring wells in which more than 10 percent of the effective screen is occluded or records indicate a change in turbidity and/or well yield. Re-development will be performed to remove fine-grained material from the well and the filter pack near the screen and will be accomplished by surging and pumping the monitoring wells using a submersible pump, surge block, and/or weighted bailer. The screen will be surged from the bottom to the top by gently raising and lowering the pump surge block, and/or weighted bailer over a one- to two-foot interval, then lowering the object and repeating this procedure. A pump will then be placed near the bottom of the screen and groundwater pumped to remove the displaced fines. This process will be repeated until the development parameters are met. Sediment and volume of water removed will be monitored and recorded on a regular basis until development is complete.

The pH, conductivity, temperature, and turbidity of the water will be recorded before beginning development. The initial static water level and total well depth of the monitoring well will be measured and recorded, and the volume of standing water in the borehole calculated. These water quality parameters will be reevaluated as development continues. Development of the monitoring well will be considered complete when all of the following requirements are met:

- Field measurements of pH, specific conductivity, and temperature have stabilized such that three consecutive measurements taken not less than one borehole volume apart are within 10 percent of each other for the temperature and specific conductivity, and within 0.1 standard units for pH.
- Field measurements of turbidity are less than 5 NTUs or $\pm$10% for values greater than 5 NTUs (USEPA, 2010[a]).

Development of monitoring wells will be recorded on the Well Development Form (or similar) found in Appendix A.

2.8 Monitoring Well Abandonment

In the event that a monitoring well is no longer being used or needed as part of the groundwater monitoring system, or is damaged, it will be properly abandoned and plugged. Monitoring well abandonment activities will be conducted by a Missouri-licensed driller or MDNR-certified well contractor, and work will be required to be performed in accordance with all Missouri statues and regulations regarding well abandonment and plugging.

Abandoned monitoring wells will be inspected prior to plugging operations to ensure there are no obstructions that may interfere with plugging operations. All pumps, sampling equipment, debris, or other

material (if any) in the well shall be removed. Measurements of the total well depth and depth to groundwater will be measured prior to plugging and photographs taken to document the current state of the well.

The protective well casing, concrete pad, and bollards (if present) will be removed. The riser pipe and well screen will then be removed from the borehole if possible. If the riser pipe and screen cannot be removed, then approval for a variance to plug the well in place will be obtained from MDNR prior to continuing the well abandonment. Certain situations may require over-drilling of the riser and screen pipe for removal, this will be determined on a case by case basis. Monitoring wells will be plugged using high-solids bentonite or cement-bentonite grout slurry. High-solids bentonite grout slurry will consist of bentonite powder and water premixed according to manufacturer's instructions. Portland cement and bentonite powder combined with water mixed to the manufacturer's instructions will be used if bentonite-cement grout is specified. The grout slurry will be introduced via pressure grouting using a side-discharging tremie pipe from the bottom of the well or boring to fill the boring or well up to approximately two (2) feet below ground surface. The tremie pipe is withdrawn as the hole is filled while keeping the bottom of the tremie pipe submerged in the grouting material at all times to prevent the development of air pockets. In unstable borehole situations, the grout slurry will be emplaced simultaneously while the riser and screen are removed (the bottom cap of the well will be knocked off to allow flow through). If the well pipe cannot be removed then the top of well riser pipe will be removed to a depth of three (3) feet below ground surface. Clean soil will be placed on top of the plugged boring or well and graded so that surface water is directed away from the abandoned well location.

After well plugging is complete a Well Plugging Registration Record (Form 780-1603) will be completed and submitted to MDNR within 60 days.

2.9 Surface Water Sampling Procedures

A surface water sample will also be collected from the inactive ash pond following the procedures presented in the SAP. It should be noted that the surface water sample is not required per the CCR Final Rule. The results of surface water sampling may be used to further evaluate potential and confirmed SSIs, but are not required to be included in annual groundwater monitoring reports.

2.9.1 Sampling Frequency

A surface water sample will be collected from the inactive ash pond during each groundwater sampling event.

2.9.2 Water Level Measurements

Water levels measurements will be collected from the inactive ash pond using the pond level staff gauge located in the southwest corner of the pond.

2.9.3 Surface Water Sampling

The surface water samples will be collected from the side of the pond using either a disposable bailer attached to a rope or a long ladle dipper. If easily accessible, samples may be collected directly from the pond.

Discrete surface water samples will be collected following the following steps:

1. Record the water level of the pond in the field logbook.

2. Measure the field water quality parameters of the surface water. Field parameters are summarized in Table 3. Document whether field measurements taken in-situ or ex-situ. Record results and observations of water characteristics (e.g., turbidity, color, odor) in the field logbook.

3. When possible, fill unpreserved sample containers directly from the pond without the use of intermediate containers, by submerging the sample container in the water with the cap in place, taking care to minimize surface or sediment disturbance. Remove the cap and allow the container to fill slowly and continuously using the cap to regulate the speed of water entering the container. Replace the cap after the container is filled and before removing the container from the water. Take care to ensure any preservative is not lost during filling of sample bottles. If using a bailer or long ladle dipper, collect the sample with as little disturbance as possible, then decant the liquid directly into the sample containers.

4. Place the surface water in appropriate sample containers, label, and place immediately in a cooler with ice. Some samples may require additional preservative added to the container to obtain a pH of <2 for laboratory analysis.

5. Record a general description of the sample in the field logbook, including the location and depth of collection from the top of water. This may include marking the sample location on a site figure.

6. Decontaminate non-disposable sampling equipment prior to the start of the sampling event and between samples (see Section 2.10).

7. Enter the appropriate sampling information on the chain of custody (COC) and field logbook (see Section 2.12.3).

8. Pack the samples for shipping (see Section 2.13).

2.9.4 Surface Water Analysis

Surface water samples will be analyzed for the same set of parameters as groundwater. During background groundwater sampling, surface water samples will be analyzed for both Detection and Assessment Monitoring parameters in accordance with Appendix III and IV of the federal CCR Rule and additional MDNR CCR water quality standard parameters. Following background groundwater sampling, subsequent surface water samples will be analyzed for the federal CCR Rule Appendix III Detection and Appendix IV Assessment Monitoring parameters. Table 2 lists the specific parameters and analytical methods to be used when analyzing surface water samples for Detection, Assessment, and MDNR CCR water quality standards. The table includes an analyte summary along with specific holding times, preservatives, and sample container requirements.

2.10 Decontamination of Groundwater Sampling Equipment

All non-disposable and non-dedicated tools which contact the sample will be decontaminated prior to the collection of each sample. Decontamination solutions will be kept in labeled, plastic, spray bottles. Disposable nitrile or latex gloves will be worn during all decontamination procedures and changed in between well locations. As dedicated sampling devices will be used at this Site, the water level meter and the field measurement meters are the only pieces of equipment that will require decontamination.

The water level meter will be decontaminated according to the following procedure:

1. Rinse the tape and probe of the water level indicator with a detergent solution. The solution shall consist of 1 tablespoon of non-phosphate detergent per gallon of water.
2. Remove any dirt with a paper towel.
3. Triple rinse the tape and probe with distilled water.
4. Upon completion of sampling, allow the tape and probe of the water level indicator to air dry.
5. Store the equipment covered with plastic between events.

The probe portions of the field measurement meters for pH, conductivity, and temperature will be decontaminated by triple rinsing with distilled water.

2.11 Disposition of Excess Sample Volume and Decontamination Water

Excess liquid volume from monitoring well sampling that includes non-contaminated purged groundwater and decontamination fluids can be discharged to the ground surface. If a monitoring well is determined to have contamination present in the groundwater, appropriate actions will be taken to containerize and properly dispose of any excess sample volume at direction of CWLD.

All other general waste generated, including all disposable personal protective equipment (PPE), rope, bailers, paper towels, empty water bottles, etc., will be placed in trash bags. The trash bags will be placed in an appropriate solid waste receptacle.

2.12 Sample Custody and Documentation Procedures

Each sample or field measurement must be properly documented to facilitate timely, correct, and complete analyses and support actions concerning the Site. The documentation system provides a means to identify, track, and monitor each individual sample from the point of collection through final reporting of the data. Specific documentation requirements are described in the following sections.

2.12.1 Documentation Procedures

A suitable work area will be established with sufficient space available for processing forms and packaging samples. After all sample documentation has been completed and before the samples are prepared for shipping, the groundwater sampling technician (or a field team member if applicable) will cross check the data on all forms and labels and compare the data to the logbook and field data sheet entries.

The following procedure is given as a general reference for completing the sample documentation:

1. Determine the samples to be packaged and shipped that day and the laboratory to be used.
2. Complete a shipping bill (if applicable) and enter the shipping record number in the field logbook.
3. Complete a chain of custody record.
4. Prepare samples for shipment.
5. Complete all necessary field forms.

2.12.2 Field Logbook Record

All information pertinent to the groundwater sampling events will be recorded either in a bound logbook with consecutively numbered pages or on appropriate forms. All entries in logbooks will be made in indelible ink, and corrections will consist of line out deletions that are initialed and dated. The person

responsible for the entries will sign and date each page (or entry) after entering it in the logbook. Blank spaces will be crossed through with single diagonal line and initialed by the person recording the data.

No general rules can specify the exact information that must be entered in a logbook for a particular site. However, the logbook will contain sufficient information so that sampling activities can be reconstructed, if necessary. Logbooks will be kept in a field team member's possession or a secure place during the investigation. Following the sampling event, logbooks will become part of the project file. Copies of the logbook will be included in representative groundwater sampling or corrective action reports.

A list of typical field logbook entries is as follows:

- Date
- Weather conditions
- Names of field members
- Names of observers
- Calibration record of field test equipment
- Monitoring well number
- Well inspection information including: condition of the well pad, casing, well identification, protective casing, well lock, and reference mark
- Water level and total well depth measurements with measurement technique
- Well purge equipment and technique
- Purge volume and time
- Initial and subsequent field measurements for each well volume of groundwater removed
- Identification number of sample
- Time of collection
- Sample withdrawal procedure/equipment
- Types and number of sample containers
- Parameters requested for analyses
- Preservatives used
- Sample description (color, odor, etc.)
- Field observations on sampling event
- Sample shipment information, name of carrier, air bill number, shipment date and time
- Any deviations from the SAP and/or GMP

As an alternative example, a Field Groundwater Sampling Data Form, as found in Appendix A (or similar), may be used to record the details associated with the sampling event. Use of sampling forms should be noted in the field logbook at the beginning of each field day.

2.12.3 Chain of Custody Record

The chain of custody record will be employed as physical evidence of sample custody. The sampler will complete a chain of custody record to accompany each sample shipment from the field to the laboratory. The custody record will be completed using waterproof ink. Corrections will be made by drawing a line through, initialing, and dating the error and entering the correct information. Erasures will not be permissible. The following typical information is to be included in the chain of custody record:

- Sample identification numbers
- Signatures of samplers
- Date and time of collection
- Sample type
- Identification of monitoring well
- Number and type of containers
- Parameters requested for analysis
- Signatures of persons involved in the chain of possession
- Inclusive dates and times of possession
- Notations regarding compromise of sample integrity, such as broken seals, bottles, etc.
- Notation regarding the presence or absence of ice when the cooler is opened at the laboratory.

After completing a chain of custody record using the above procedure, the original signature (top) copy of the record will be sealed in a plastic bag (with any other sample documentation) and secured to the inside lid of the cooler. Laboratory personnel will sign the chain of custody and a copy will be included in the analytical data package. An example of a typical chain of custody is provided in Appendix A.

2.12.4 Sample Labels

Each sample removed from the Site and transferred to a laboratory for analysis will be identified with a sample label containing specific information regarding the sample. Each completed sample identification label will be securely fastened to the sample container. All sample labels will be completed in indelible ink and the well identification may be marked on the sample container lid. As an alternative, the sample labels may be covered in clear plastic tape. An example sample label is provided in Appendix A.

2.12.5 Custody Seals

Custody seals will be used to preserve the integrity of the sample from the time the cooler is packed until it is opened in the laboratory. Seals must be attached so that it is necessary to break the seals to open the cooler. All samples for the Site will be shipped in coolers. Each cooler will usually be sealed on two opposite sides with custody seals. As long as custody records are sealed inside the sample cooler and custody seals remain intact, commercial carriers are not required to sign the custody form. An example custody seal is provided in Appendix A.

2.12.6 Electronic Field Records

When available, electronic field records may be used to document field procedures provided the types of information presented above are captured and the final record is as, or more, secure than hard copy records. Electronic field records may include, but are not limited to, spreadsheets, electronic pdfs, and proprietary tools developed to support project needs.

2.13 Sample Container Handling, Packaging, and Shipping

Sample packaging and shipping procedures are based on USEPA specifications, as well as United States Department of Transportation regulations (49 CFR Parts 172 and 173). Samples will be packed and shipped according to the requirements for low hazard level samples. All samples will be packaged and transported within one day of collection.

During field activities, loose samples will be handled in the same manner as packed samples. The samples, after being obtained and labeled, will be wrapped with protective packing material or stored in foam/bubble envelopes. At all times, ice in double sealable plastic bags will be kept in the cooler to reduce the temperature of the samples as quickly as possible. Ice will be replenished as needed. The steps outlined below will be followed to pack samples:

1. Arrange sample containers in groups by sample number.
2. Arrange containers in front of the assigned coolers.
3. Pack the containers in the foam/bubble envelopes provided with the jars or wrap each glass sample container with protective packing material. Tape the packing material to the containers and secure in place.
4. Place approximately 2 inches of packing material in the bottom of the cooler for cushioning. Place a plastic bag inside the cooler on top of the packing material.
5. Place sample containers inside the plastic bag in the cooler.
6. Seal the plastic bag with tape.

7. Fill the remaining cooler space with ice packaged in double sealed plastic gallon bags.
8. Separate copies of forms. Seal paper copies in a large, sealable, plastic bag and tape to the inside lid of the cooler.
9. Close the lid of the cooler. Tape the cooler drain shut if applicable. Tape the cooler shut on both ends, making several revolutions with the strapping tape. Do not cover labels.
10. Place the shipping bill with the contracted laboratory's address on top of the cooler.
11. Affix custody seals over lid openings (front right and back left corners of cooler). Cover seals with clear, plastic tape.
12. Record the time the cooler is relinquished to an overnight delivery service in the field logbook.
13. Maintain a file of all sample documentation.

3.0 QUALITY ASSURANCE/QUALITY CONTROL

Data collected during groundwater monitoring activities will be used to evaluate the groundwater quality surrounding the inactive Surface Impoundment. To satisfy this use, analytical data should meet the requirements outlined in USEPA's *Test Methods for Evaluating Solid Waste* (SW-846, 1997) or equivalent analytical procedures. To provide the proper level of confidence, it is critical that only valid data are used. To this end, field and laboratory QA/QC procedures have been established. This chapter presents the data quality objectives (DQOs), field and laboratory QA/QC requirements, and data validation components.

3.1 Data Quality Objectives

Precision, accuracy, representativeness, completeness, and comparability (PARCC) are all aspects of data quality and should be assessed when evaluating whether or not data is fit for use in reporting.

3.1.1 Precision

Precision is a measure of the reproducibility of the measurements made under a set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements compared to their average value. Precision is assessed by evaluating duplicate sample results and can be expressed as the relative percent difference (RPD) as follows:

$$RPD = \frac{|(D_1 - D_2)|}{(D_1 + D_2)/2} \times 100$$

Where: D_1 = Original Sample Value

D_2 = Duplicate Sample Value

If variability of a group of measurements is not present compared to their average value, the RPD equals zero.

Precision QC procedures for field measurements consist of taking multiple readings. For analyses requiring the use of an off-site commercial laboratory, both overall and analytical precision are examined. Field duplicates will be collected to evaluate the overall precision of field sampling and laboratory analytical methods. Precision for field duplicate samples is evaluated based on guidelines presented in the USEPA *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (NFGI) [USEPA, 2010(b)]. The precision goal for the field duplicate RPD is < 20%.

Analytical precision is assessed from MS/MSD results. The sample collector will collect extra sample material from certain sample locations at the minimum duplicate sample frequency specified by Chapter 1

of SW-846 (i.e., once every 20 samples). At least one MS/MSD sample set will be collected during each sampling event. Sample material from these locations will be designated on the chain of custody form as requiring laboratory MS/MSD analyses.

The precision goals for duplicate analyses are modeled on the criteria of RPD < 20% for inorganic laboratory duplicates presented in the NFGI.

3.1.2 Accuracy

Accuracy measures the bias of a measurement system. Possible sources of errors include the sampling process, field contamination, preservation, handling, sample matrix, sample preparation, and analytical techniques. QC procedures for field measurements consist of initial and periodic instrument calibrations for accuracy.

Interferences from the sample matrix or errors introduced by the analytical process may be assessed by examining the surrogate, laboratory control sample (LCS), and MS spike sample results. For spike samples, accuracy is expressed in terms of percent recovery (REC), which measures the degree of agreement between a measurement and its true value. The REC is calculated as follows:

$$REC = \frac{|(SSR - SR)|}{SA} \times 100$$

Where: SSR = Spike Sample Results

SR = Sample Results (assumed to be zero for surrogates)

SA = Spike Added

Perfect accuracy is defined as 100 REC.

Spike sample results will be compared to QC criteria established in the applicable analytical methods or to laboratory developed QC criteria, as appropriate. It is possible for spike RECs to be significantly below their minimum QC limits. Such hyposensitivity, as defined by the NFGI, includes the following examples:

- Inorganic MS REC values below 30 percent
- Inorganic LCS REC values below 50 percent

In such cases, some or all of the associated field sample results may not meet the accuracy DQO because the possibility of false negatives exists.

3.1.3 Representativeness

Representativeness qualitatively expresses the degree to which sample analytical results precisely and accurately represent Site conditions. The representativeness DQO was considered during the planning stages and is reflected in several aspects of the sampling approach: number of samples, sample locations, sampling techniques, and analytical parameters.

Analytical results will fail to meet the representativeness DQO if gross precision or accuracy QC inconsistencies exist.

3.1.4 Completeness

Completeness defines the percentage of completed measurements judged to be valid. Sufficient amounts of valid data must be generated to make technical decisions. Field completeness is assessed by comparing the number of samples collected to the number of samples planned for collection. Laboratory completeness is assessed by comparing the number of samples with valid data to the number submitted for chemical analysis. Laboratory completeness is reduced by the following mechanisms:

- Data were qualified as unusable (R) during data validation based on gross precision or accuracy QC inconsistencies
- Holding times were exceeded

Minimum completeness objectives are 80 percent for field and laboratory completeness.

3.1.5 Comparability

Comparability qualitatively expresses how data developed during the groundwater sampling activities compares with applicable criteria. Data collected during the sampling events can be considered comparable to other sampling event data collected following the sampling procedures outlined in this SAP and analyzed using the same methods from SW 846 or USEPA methods as noted on Table 2.

3.2 Laboratory QA/QC

The laboratory will provide analytical and QC results in Level II Data package to contain the following:

- Narrative
- Sample Results (including reporting limits)
- Batch-specific QC results (including method blanks, laboratory control/matrix spikes, and/or laboratory duplicates at a minimum)
- QC Sample Associations

- Chain-of-Custody

Any QA/QC requirements listed above that are more stringent than the laboratory's normal QA/QC procedures should be applied by the laboratory to the groundwater data to be collected. A copy of the laboratory QA/QC plan will be maintained in the project files.

3.3 Field QA/QC

Field QA/QC procedures were previously discussed in the sampling procedures and DQO sections. In summary, field QA/QC procedures include the following activities:

- Maintaining field logs and field notebooks
- Calibrating field instruments
- Taking multiple readings of field measurements
- Collecting material for QC samples (e.g., MS/MSD, field duplicate) at the minimum
- Preparing and handling QC sample material in the same manner as field samples
- Cross check data on all sample labels and field forms and compare the data to the logbooks, field data sheet entries, and chain-of-custody

3.4 Data Validation

Data validation procedures determine whether individual project data are useable, useable with qualifications, or unusable. Data validation activities will be conducted in a staged approach. The validation effort will increase beyond Stage I to more in-depth reviews if inconsistencies with the data are noted. The following sections describe the data validation procedure.

3.4.1 Stage I Review

Stage I data review will be conducted for each analytical data package that is used. A chemist will perform the Stage I data review. The following items will be reviewed during Stage I:

- Sample Collection and Analysis - Verify that the appropriate samples were collected for the sampling event and the laboratory provided results for all required analyses.
- Target Compounds - Verify that the samples were analyzed for the correct compounds and the appropriate compound names were provided.
- Analytical Reporting Limits (RLs) - Verify that the RLs meet project requirements.
- Laboratory Data Package - Verify that the laboratory analytical hard copy is complete and correct.

- Electronic Data Deliverable (EDD) - Verify that the laboratory electronic deliverable is complete and correct.
- Sample Preservation - Verify that samples were appropriately preserved.
- Holding Times - Verify that analytical holding times were met.
- Duplicates - Verify that field duplicates were collected and assess data precision based on guidelines presented in NFGI.
- Case Narrative - If provided by lab, review case narratives for any analytical inconsistencies encountered at the lab, and note any impact of these inconsistencies.

3.4.2 Stage II Review

Stage II data review will occur if inconsistencies with the data are noted. Inconsistencies could include noted outlier data when comparing the data set to historical results or expectations for the site. Outlier data might include: unexpected detect or non-detect results for target constituents, new constituents showing statistically significant increases, data that are unexpected when compared to historical results, or data that exceeds MCLs. During Stage II review, the questionable result will be reviewed for achievement of any method-specific QA/QC criteria. In general, this review will involve examination of the following additional items:

- Laboratory Control Samples
- Surrogates
- MS/MSDs

Data qualifiers, if necessary, will be added to the data in accordance with procedures outlined in the NFGI.

3.4.3 Stage III Review

Stage III data review is performed at the request of the CWLD Project Manager. This request will generally be made if significant analytical inconsistencies are noted during Stage II review. The project chemist performing the Stage I and II reviews will advise the CWLD Project Manager when such inconsistencies are noted. Stage III review requires evaluation of the entire data set for achievement of any method-specific QA/QC criteria. In general, this review involves examination of the following additional items for the entire data set:

- Laboratory Control Samples
- Surrogates

- MS/MSDs

Data qualifiers, if necessary, will be added to the data in accordance with procedures outlined in the NFGI.

4.0 REFERENCES

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USEPA, 2015, *Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule*, 40 CFR Parts 257 and 261, Federal Register, Vol. 80, No. 74, April 17, 2015, http://www.gpo.gov/fdsys/pkg/FR-2015-04-17/pdf/2015-00257.pdf.

TABLES

Table 1
Groundwater Field Parameters
Columbia Water & Light Department - Columbia Municipal Power Plant
Columbia, Missouri

Groundwater Field Parameters
Static Water Level
pH*
Groundwater Temperature*
Specific Conductance*
Turbidity*
Total gallons purged
Oxidation-Reduction Potential (ORP)*
Dissolved Oxygen (DO)*

Notes:

* Measurements collected using low-flow purging/sampling procedures with flow-through cell equipped with multi-parameter meter. If necessary, turbidity measurements may be collected ex-situ from the groundwater discharge line.

Table 2
Laboratory Analysis of Groundwater and Surface Water
Columbia Water & Light Department - Columbia Municipal Power Plant
Columbia, Missouri

CCR Groudwater and Surface Water Monitoring Constituents*				
Constituent	**Analytical Method**	**Sample Container**	**Sample Preservation**	**Holding Time**
Organics / Water Quality				
Sulfate*	EPA Method 300.0	250 mL, HDPE or glass	None required, Cool to 4°C	Analyzed--28 days
Total Organic Carbon (TOC)	SM310B,C,D or EPA Method 9060A	Glass	pH<2 H_2SO_4 or HCl; ≤6°C	Analyzed--28 days
Total Organic Halogens (TOX)	SM5320 or EPA Method 9020/9021	Glass; no headspace	≤6°C	Analyzed--14 days
Inorganics / Water Quality				
Chemical Oxygen Demand (COD)	SM5220C,D, 410.4, or Hach 8000	HDPE or glass	pH<2 H_2SO_4; ≤6°C	Analyzed--28 days
Chloride*	EPA Method 300.0	250 mL, HDPE or glass	None required, Cool to 4°C	Analyzed--28 days
Fluoride*-**	EPA Method 300.0 or 300.1	250 mL, HDPE or glass	None required	Analyzed--28 days
pH*	SM 4500 H-B	100 mL, HDPE or glass	None required	Analyzed -- 24 hrs
Hardness, as CaCO3	SM2370B,C/130.1	HDPE or glass	pH<2 HNO_3	Analyzed--6 months
Total Dissolved Solids (TDS)*	SM 2540 C	1 L, HDPE or glass	None required, Cool to 4°C	Analyzed -- 7 days
Metals, Total				
Aluminum Antimony** Arsenic** Barium** Beryllium** Boron* Cadmium** Calcium* Chromium** **Chromium III** Cobalt** **Copper** **Iron** Lead** Lithium** **Magnesium** **Manganese** Molybdenum** **Nickel** Selenium** **Silver** **Sodium** Thallium** **Zinc**	SW-846 6010B or SW-846 6020	500 mL, HDPE or glass	Nitric Acid (HNO_3) pH<2 Cool to 4°C	Analyzed--6 months
Chromium VI	7196, 218.6, or SM3500Cr -C,D	HDPE or glass	≤6°C	**Analyzed -- 24 hours**
Mercury**	EPA 7470 or 245.1	250 mL, HDPE or glass	Nitric Acid (HNO_3) pH<2 Cool to 4°C	Analyzed--28 days
Radionuclides				
Radium 226**	EPA 903.0	1.0 L, HDPE or glass	Nitric Acid (HNO_3) pH<2	Analyzed--6 months
Radium 228**				

Notes:

*Constituents included in USEPA CCR Rule, Appendix III (Detection Monitoring) to 40 CFR Part 257.

**Constituents included in USEPA CCR Rule, Appendix IV (Assessment Monitoring) to 40 CFR Part 257.

Bold Constituent = exclusive MDNR groundwater quality monitoring parameter listed in MDNR CCR Storage and Disposal Sites in Missouri, Division of Environmental Quality (MDNR white paper).

Noted analytical method(s) and sample container(s) are for typical method requirements. These may vary slightly by method updates and/or laboratory sample volume preferences.

HDPE = high density polyethylene
HNO_3 = nitric acid

Table 3
Surface Water Field Indicator Parameters
Columbia Water & Light Department - Columbia Municipal Power Plant
Columbia, Missouri

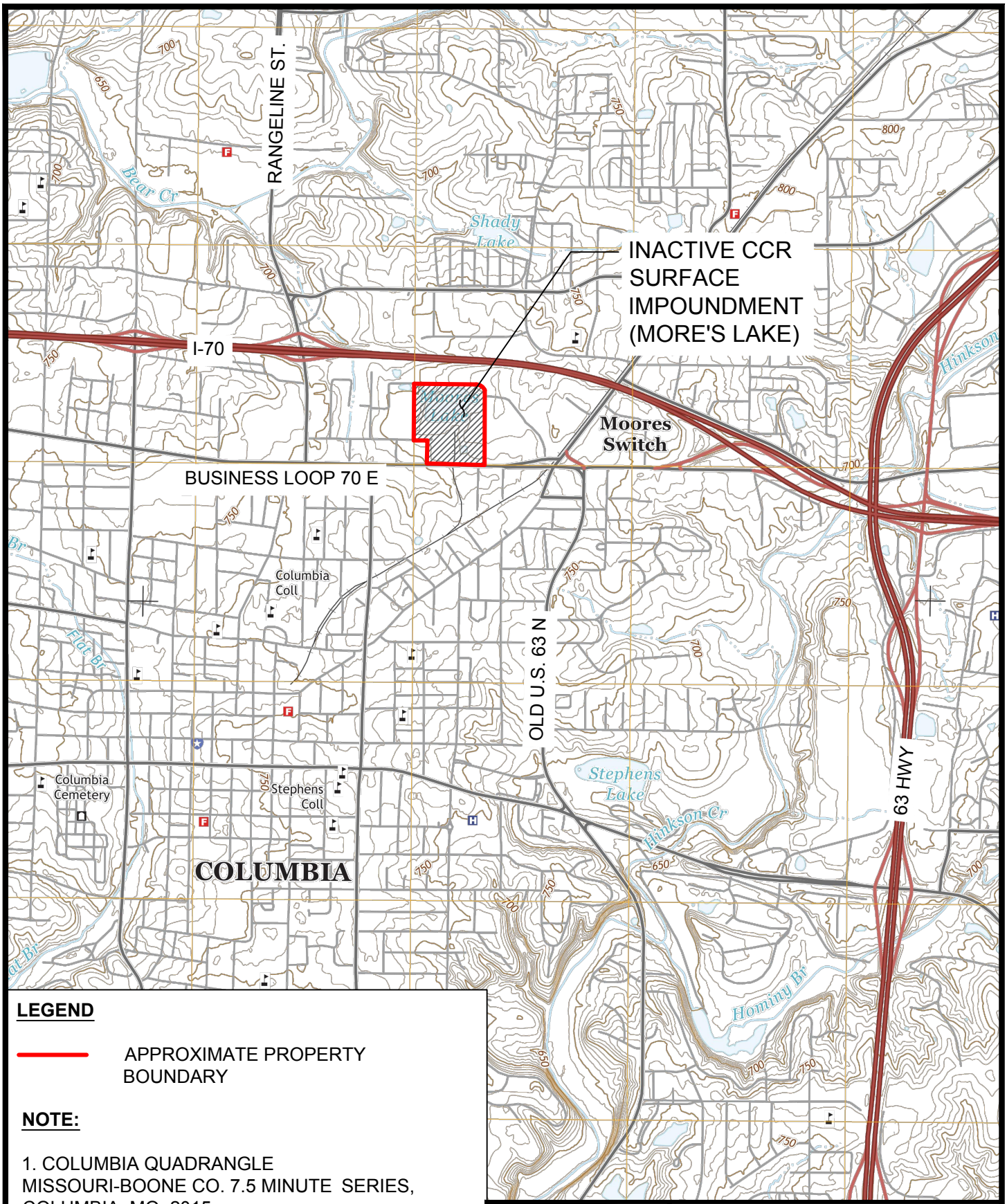
Surface Water Field Indicator Parameters
Pond Water Level [2]
pH [3]
Groundwater Temperature [3]
Specific Conductance [3]
Turbidity [3]
Total gallons purged
Oxidation-Reduction Potential (ORP) [3]
Dissolved Oxygen (DO) [3]

1. Surface water samples collected from inactive ash pond.

2. Pond water level measurements collected from gauge staff located in southwest corner of pond.

3. Field water quality measurements collected using the low-flow multi-parameter meter in-situ directly from surface water. If necessary, field measurements may be collected ex-situ from the pond.

FIGURES



LEGEND

APPROXIMATE PROPERTY BOUNDARY

NOTE:

1. COLUMBIA QUADRANGLE MISSOURI-BOONE CO. 7.5 MINUTE SERIES, COLUMBIA, MO, 2015.
2. CONTOUR INTERVAL 10 FEET.

N

0 2000' 4000'

SCALE IN FEET

BURNS McDONNELL

FIGURE 1
SITE VICINITY TOPOGRAPHIC MAP
COLUMBIA MUNICIPAL POWER PLANT COLUMBIA, MO

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LEGEND

APPROXIMATE PROPERTY BOUNDARY

NOTE:

1. COLUMBIA QUADRANGLE MISSOURI-BOONE CO. 7.5 MINUTE SERIES, COLUMBIA, MO, 2015.

N

0 2000' 4000'

SCALE IN FEET

BURNS McDONNELL

FIGURE 2
SITE VICINITY AERIAL MAP
COLUMBIA MUNICIPAL POWER PLANT COLUMBIA, MO

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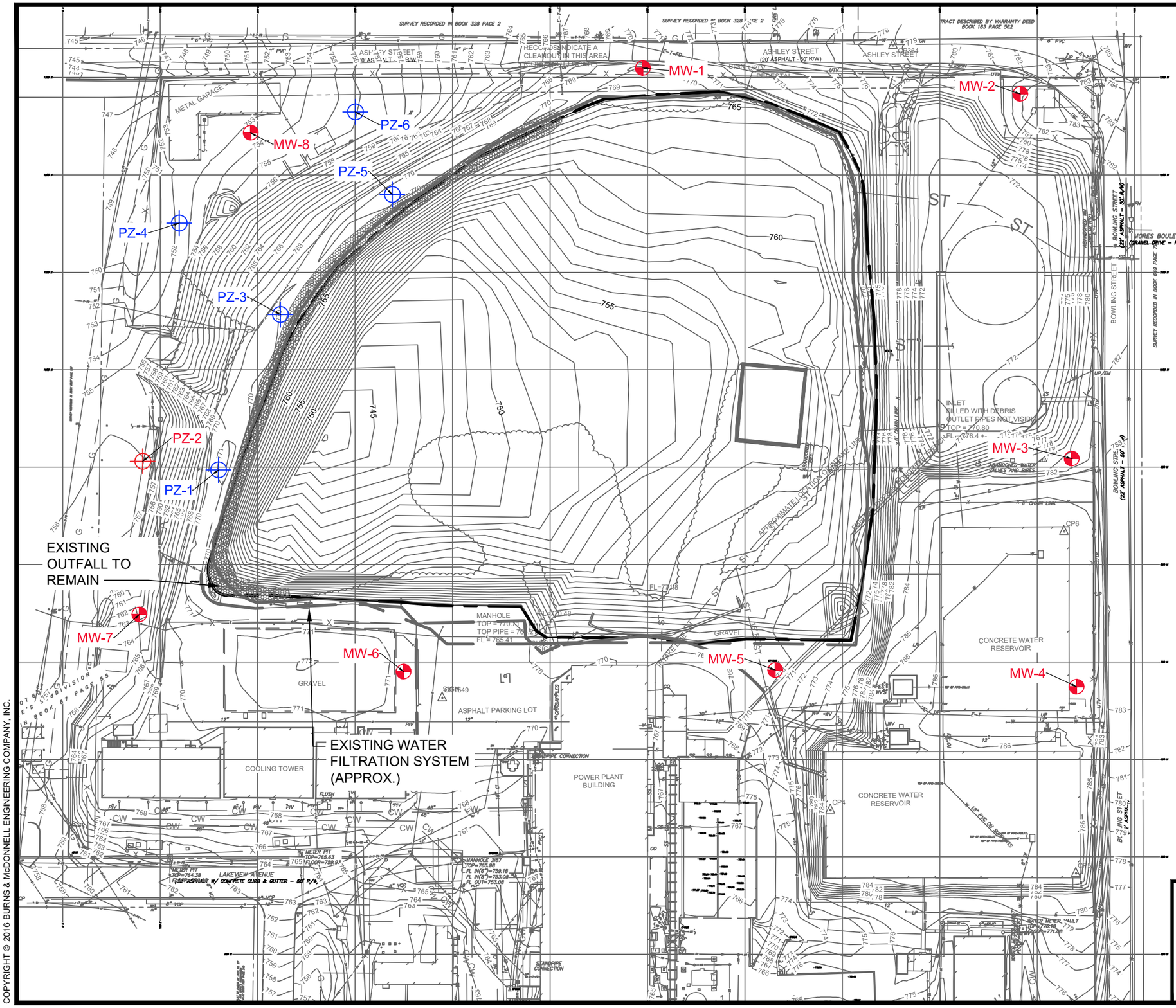

LEGEND

- PIEZOMETER
- MONITORING WELL
- USED FOR WATER LEVEL OR TOTAL DEPTH ONLY
- APPROXIMATE PROPERTY BOUNDARY

NOTE:

1. COLUMBIA QUADRANGLE MISSOURI-BOONE CO. 7.5 MINUTE SERIES, COLUMBIA, MO, 2015.
2. CONTOUR INTERVAL 1 FEET.
3. WELLS COLORED IN RED ARE INCLUDED IN THE SAMPLING NETWORK.

N

0 100' 200'

SCALE IN FEET

BURNS McDONNELL

FIGURE 3
MONITORING WELL NETWORK
COLUMBIA MUNICIPAL POWER PLANT
COLUMBIA, MISSOURI

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Z:\CLIENTS\ENS\COLUMBIAMO\93647_MORESLAKE\DESIGN\CADD\DWGS\GROUNDWATER WORK PLAN\FIG3-MONITORING WELL LOCATIONS.DWG DHINEMAN

APPENDIX A – FIELD DOCUMENTATION

FIELD GROUND-WATER SAMPLING DATA FORM

DATE:_____ SITE:_____ PROJECT _____

WEATHER: _____ WELL DIAMETER (inches)_____

WELL IDENTIFICATION

MW-1

DEPTH TO WATER (ft bTOC):_____

WELL TOTAL DEPTH (ft bTOC):_____

DEPTH TO TOP OF PUMP (ft bTOC):_____

DEPTH TO TOP OF WELL SCREEN (ft bTOC): **32.50**

WATER LEVEL ABOVE WELL SCREEN (Yes/No?):_____

*Limit water level drawdown per SAP

PURGING:

SATURATED WELL CASING VOLUME CALCULATION:_____ft of water in casing X 0.1632 gallon/foot = _____ total gallons/casing volume

*Well casing volume calculation for 2-inch diameter well

SATURATED FILTER PACK VOLUME: [_____ft of water in filter pack X 2.777 gallons/foot - Casing Volume] X 0.30 = _____ total gallons

*MW-1 filter pack thickness = 13.13 ft; Saturated flter pack volume calculation for 8.25-inch diameter well borehole and assume 30% porosity

Equipment Used: Dedicated Bladder Pump Nondedicated Bladder Pump Bailer Other:_____

Time (24 hr)	Amount Purged (gals)	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)
Continued on back (circle one) yes / no									

Well Purged Below Top of Pump? (Y/N):_____ Time to Recharge:_____ Depth to Water (ft bTOC):_____

SAMPLING Equipment Used: Same as Above Other:_____

Sample Time (24 hr)	Total Purged (gals)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)	Obs.

FINAL DEPTH TO WATER (ft bTOC): _____ TIME FINAL DEPTH TAKEN: _____

SAMPLE ID: _____ SAMPLE FOR QC: _____

PARAMETERS REQUESTD FOR ANALYSIS: _____

IDW PURGE WATER TOTAL (gal): _____ FLOW THROUGH CELL MODEL #: _____

Well Condition	**Remarks**
Concrete Pad?	
Bumper Posts?	
Protective Casing?	
Paint and Label?	
Lock?	
Well Casing?	
Reference Point?	

Field Sampler(s) Name(s):_____

	NAME	SIGNATURE	DATE
PREPARED:	_____	_____	_____
REVIEWED:	_____	_____	_____

FIELD GROUND-WATER SAMPLING DATA FORM (continued)

WELL IDENTIFICATION

MW-1

Time (24 hr)	Amount Purged	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)

COMMENTS

FIELD GROUND-WATER SAMPLING DATA FORM

DATE:_____ SITE:_____ PROJECT _____

WEATHER: _____ WELL DIAMETER (inches)_____

WELL IDENTIFICATION

MW-2

DEPTH TO WATER (ft bTOC):_____

WELL TOTAL DEPTH (ft bTOC):_____

DEPTH TO TOP OF PUMP (ft bTOC):_____

DEPTH TO TOP OF WELL SCREEN (ft bTOC): **42.59**

WATER LEVEL ABOVE WELL SCREEN (Yes/No?):_____

*Limit water level drawdown per SAP

PURGING:

SATURATED WELL CASING VOLUME CALCULATION:_____ft of water in casing X 0.1632 gallon/foot = _____ total gallons/casing volume

*Well casing volume calculation for 2-inch diameter well

SATURATED FILTER PACK VOLUME: [_____ft of water in filter pack X 2.777 gallons/foot - Casing Volume] X 0.30 = _____ total gallons

*MW-2 filter pack thickness = 13.13 ft; Saturated flter pack volume calculation for 8.25-inch diameter well borehole and assume 30% porosity

Equipment Used: Dedicated Bladder Pump Nondedicated Bladder Pump Bailer Other:_____

Time (24 hr)	Amount Purged (gals)	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)
Continued on back (circle one) yes / no									

Well Purged Below Top of Pump? (Y/N):_____ Time to Recharge:_____ Depth to Water (ft bTOC):_____

SAMPLING Equipment Used: Same as Above Other:_____

Sample Time (24 hr)	Total Purged (gals)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)	Obs.

FINAL DEPTH TO WATER (ft bTOC): _____ TIME FINAL DEPTH TAKEN: _____

SAMPLE ID: _____ SAMPLE FOR QC: _____

PARAMETERS REQUESTD FOR ANALYSIS: _____

IDW PURGE WATER TOTAL (gal): _____ FLOW THROUGH CELL MODEL #: _____

Well Condition	**Remarks**
Concrete Pad?	
Bumper Posts?	
Protective Casing?	
Paint and Label?	
Lock?	
Well Casing?	
Reference Point?	

Field Sampler(s) Name(s):_____

	NAME	SIGNATURE	DATE
PREPARED:	_____	_____	_____
REVIEWED:	_____	_____	_____

FIELD GROUND-WATER SAMPLING DATA FORM (continued)

WELL IDENTIFICATION

MW-2

Time (24 hr)	Amount Purged	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)

COMMENTS

FIELD GROUND-WATER SAMPLING DATA FORM

DATE:_____ SITE:_____ PROJECT _____

WEATHER: _____ WELL DIAMETER (inches)_____

WELL IDENTIFICATION

MW-3

DEPTH TO WATER (ft bTOC):_____

WELL TOTAL DEPTH (ft bTOC):_____

DEPTH TO TOP OF PUMP (ft bTOC):_____

DEPTH TO TOP OF WELL SCREEN (ft bTOC): **39.21**

WATER LEVEL ABOVE WELL SCREEN (Yes/No?):_____

*Limit water level drawdown per SAP

PURGING:

SATURATED WELL CASING VOLUME CALCULATION:_____ft of water in casing X 0.1632 gallon/foot = _____ total gallons/casing volume

*Well casing volume calculation for 2-inch diameter well

SATURATED FILTER PACK VOLUME: [_____ft of water in filter pack X 2.777 gallons/foot - Casing Volume] X 0.30 = _____ total gallons

*MW-3 filter pack thickness = 13.06 ft; Saturated flter pack volume calculation for 8.25-inch diameter well borehole and assume 30% porosity

Equipment Used: Dedicated Bladder Pump Nondedicated Bladder Pump Bailer Other:_____

Time (24 hr)	Amount Purged (gals)	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)
Continued on back (circle one) yes / no									

Well Purged Below Top of Pump? (Y/N):_____ Time to Recharge:_____ Depth to Water (ft bTOC):_____

SAMPLING Equipment Used: Same as Above Other:_____

Sample Time (24 hr)	Total Purged (gals)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)	Obs.

FINAL DEPTH TO WATER (ft bTOC): _____ TIME FINAL DEPTH TAKEN: _____

SAMPLE ID: _____ SAMPLE FOR QC: _____

PARAMETERS REQUESTD FOR ANALYSIS: _____

IDW PURGE WATER TOTAL (gal): _____ FLOW THROUGH CELL MODEL #: _____

Well Condition	**Remarks**
Concrete Pad?	
Bumper Posts?	
Protective Casing?	
Paint and Label?	
Lock?	
Well Casing?	
Reference Point?	

Field Sampler(s) Name(s):_____

	NAME	SIGNATURE	DATE
PREPARED:	_____	_____	_____
REVIEWED:	_____	_____	_____

FIELD GROUND-WATER SAMPLING DATA FORM (continued)

WELL IDENTIFICATION

MW-3

Time (24 hr)	Amount Purged	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)

COMMENTS

FIELD GROUND-WATER SAMPLING DATA FORM

DATE:_____ SITE:_____ PROJECT _____

WEATHER: _____ WELL DIAMETER (inches)_____

WELL IDENTIFICATION

MW-4

DEPTH TO WATER (ft bTOC):_____

WELL TOTAL DEPTH (ft bTOC):_____

DEPTH TO TOP OF PUMP (ft bTOC):_____

DEPTH TO TOP OF WELL SCREEN (ft bTOC): **46.78**

WATER LEVEL ABOVE WELL SCREEN (Yes/No?):_____

*Limit water level drawdown per SAP

PURGING:

SATURATED WELL CASING VOLUME CALCULATION:_____ft of water in casing X 0.1632 gallon/foot = _____ total gallons/casing volume

*Well casing volume calculation for 2-inch diameter well

SATURATED FILTER PACK VOLUME: [_____ft of water in filter pack X 2.777 gallons/foot - Casing Volume] X 0.30 = _____ total gallons

*MW-4 filter pack thickness = 13.03 ft; Saturated flter pack volume calculation for 8.25-inch diameter well borehole and assume 30% porosity

Equipment Used: Dedicated Bladder Pump Nondedicated Bladder Pump Bailer Other:_____

Time (24 hr)	Amount Purged (gals)	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)
Continued on back (circle one) yes / no									

Well Purged Below Top of Pump? (Y/N):_____ Time to Recharge:_____ Depth to Water (ft bTOC):_____

SAMPLING Equipment Used: Same as Above Other:_____

Sample Time (24 hr)	Total Purged (gals)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)	Obs.

FINAL DEPTH TO WATER (ft bTOC): _____ TIME FINAL DEPTH TAKEN: _____

SAMPLE ID: _____ SAMPLE FOR QC: _____

PARAMETERS REQUESTD FOR ANALYSIS: _____

IDW PURGE WATER TOTAL (gal): _____ FLOW THROUGH CELL MODEL #: _____

Well Condition	**Remarks**
Concrete Pad?	
Bumper Posts?	
Protective Casing?	
Paint and Label?	
Lock?	
Well Casing?	
Reference Point?	

Field Sampler(s) Name(s):_____

	NAME	SIGNATURE	DATE
PREPARED:	_____	_____	_____
REVIEWED:	_____	_____	_____

FIELD GROUND-WATER SAMPLING DATA FORM (continued)

WELL IDENTIFICATION

MW-4

Time (24 hr)	Amount Purged	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)

COMMENTS

FIELD GROUND-WATER SAMPLING DATA FORM

DATE:_____ SITE:_____ PROJECT _____

WEATHER: _____ WELL DIAMETER (inches)_____

WELL IDENTIFICATION

MW-5

DEPTH TO WATER (ft bTOC):_____

WELL TOTAL DEPTH (ft bTOC):_____

DEPTH TO TOP OF PUMP (ft bTOC):_____

DEPTH TO TOP OF WELL SCREEN (ft bTOC): **30.80** WATER LEVEL ABOVE WELL SCREEN (Yes/No?):_____

*Limit water level drawdown per SAP

PURGING:

SATURATED WELL CASING VOLUME CALCULATION:_____ft of water in casing X 0.1632 gallon/foot = _____ total gallons/casing volume

*Well casing volume calculation for 2-inch diameter well

SATURATED FILTER PACK VOLUME: [_____ft of water in filter pack X 2.777 gallons/foot - Casing Volume] X 0.30 = _____ total gallons

*MW-5 filter pack thickness = 13.11 ft; Saturated flter pack volume calculation for 8.25-inch diameter well borehole and assume 30% porosity

Equipment Used: Dedicated Bladder Pump Nondedicated Bladder Pump Bailer Other:_____

Time (24 hr)	Amount Purged (gals)	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)
Continued on back (circle one) yes / no									

Well Purged Below Top of Pump? (Y/N):_____ Time to Recharge:_____ Depth to Water (ft bTOC):_____

SAMPLING Equipment Used: Same as Above Other:_____

Sample Time (24 hr)	Total Purged (gals)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)	Obs.

FINAL DEPTH TO WATER (ft bTOC): _____ TIME FINAL DEPTH TAKEN: _____

SAMPLE ID: _____ SAMPLE FOR QC: _____

PARAMETERS REQUESTD FOR ANALYSIS: _____

IDW PURGE WATER TOTAL (gal): _____ FLOW THROUGH CELL MODEL #: _____

Well Condition	**Remarks**
Concrete Pad?	
Bumper Posts?	
Protective Casing?	
Paint and Label?	
Lock?	
Well Casing?	
Reference Point?	

Field Sampler(s) Name(s):_____

	NAME	SIGNATURE	DATE
PREPARED:	_____	_____	_____
REVIEWED:	_____	_____	_____

FIELD GROUND-WATER SAMPLING DATA FORM (continued)

WELL IDENTIFICATION

MW-5

Time (24 hr)	Amount Purged	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)

COMMENTS

FIELD GROUND-WATER SAMPLING DATA FORM

DATE:_____ SITE:_____ PROJECT _____

WEATHER: _____ WELL DIAMETER (inches)_____

WELL IDENTIFICATION

MW-6

DEPTH TO WATER (ft bTOC):_____

WELL TOTAL DEPTH (ft bTOC):_____

DEPTH TO TOP OF PUMP (ft bTOC):_____

DEPTH TO TOP OF WELL SCREEN (ft bTOC): **31.45** WATER LEVEL ABOVE WELL SCREEN (Yes/No?):_____

*Limit water level drawdown per SAP

PURGING:

SATURATED WELL CASING VOLUME CALCULATION:_____ft of water in casing X 0.1632 gallon/foot = _____ total gallons/casing volume

*Well casing volume calculation for 2-inch diameter well

SATURATED FILTER PACK VOLUME: [_____ft of water in filter pack X 2.777 gallons/foot - Casing Volume] X 0.30 = _____ total gallons

*MW-6 filter pack thickness = 13.06 ft; Saturated flter pack volume calculation for 8.25-inch diameter well borehole and assume 30% porosity

Equipment Used: Dedicated Bladder Pump Nondedicated Bladder Pump Bailer Other:_____

Time (24 hr)	Amount Purged (gals)	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)
Continued on back (circle one) yes / no									

Well Purged Below Top of Pump? (Y/N):_____ Time to Recharge:_____ Depth to Water (ft bTOC):_____

SAMPLING Equipment Used: Same as Above Other:_____

Sample Time (24 hr)	Total Purged (gals)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)	Obs.

FINAL DEPTH TO WATER (ft bTOC): _____ TIME FINAL DEPTH TAKEN: _____

SAMPLE ID: _____ SAMPLE FOR QC: _____

PARAMETERS REQUESTD FOR ANALYSIS: _____

IDW PURGE WATER TOTAL (gal): _____ FLOW THROUGH CELL MODEL #: _____

Well Condition	**Remarks**
Concrete Pad?	
Bumper Posts?	
Protective Casing?	
Paint and Label?	
Lock?	
Well Casing?	
Reference Point?	

Field Sampler(s) Name(s):_____

	NAME	SIGNATURE	DATE
PREPARED:	_____	_____	_____
REVIEWED:	_____	_____	_____

FIELD GROUND-WATER SAMPLING DATA FORM (continued)

WELL IDENTIFICATION

MW-6

Time (24 hr)	Amount Purged	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)

COMMENTS

FIELD GROUND-WATER SAMPLING DATA FORM

DATE:_____ SITE:_____ PROJECT _____

WEATHER: _____ WELL DIAMETER (inches)_____

WELL IDENTIFICATION

MW-7

DEPTH TO WATER (ft bTOC):_____

WELL TOTAL DEPTH (ft bTOC):_____

DEPTH TO TOP OF PUMP (ft bTOC):_____

DEPTH TO TOP OF WELL SCREEN (ft bTOC): **23.08** WATER LEVEL ABOVE WELL SCREEN (Yes/No?):_____

*Limit water level drawdown per SAP

PURGING:

SATURATED WELL CASING VOLUME CALCULATION:_____ft of water in casing X 0.1632 gallon/foot = _____ total gallons/casing volume

*Well casing volume calculation for 2-inch diameter well

SATURATED FILTER PACK VOLUME: [_____ft of water in filter pack X 2.777 gallons/foot - Casing Volume] X 0.30 = _____ total gallons

*MW-7 filter pack thickness = 13.02 ft; Saturated flter pack volume calculation for 8.25-inch diameter well borehole and assume 30% porosity

Equipment Used: Dedicated Bladder Pump Nondedicated Bladder Pump Bailer Other:_____

Time (24 hr)	Amount Purged (gals)	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)
Continued on back (circle one) yes / no									

Well Purged Below Top of Pump? (Y/N):_____ Time to Recharge:_____ Depth to Water (ft bTOC):_____

SAMPLING Equipment Used: Same as Above Other:_____

Sample Time (24 hr)	Total Purged (gals)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)	Obs.

FINAL DEPTH TO WATER (ft bTOC): _____ TIME FINAL DEPTH TAKEN: _____

SAMPLE ID: _____ SAMPLE FOR QC: _____

PARAMETERS REQUESTD FOR ANALYSIS: _____

IDW PURGE WATER TOTAL (gal): _____ FLOW THROUGH CELL MODEL #: _____

Well Condition	**Remarks**
Concrete Pad?	
Bumper Posts?	
Protective Casing?	
Paint and Label?	
Lock?	
Well Casing?	
Reference Point?	

Field Sampler(s) Name(s):_____

	NAME	SIGNATURE	DATE
PREPARED:	_____	_____	_____
REVIEWED:	_____	_____	_____

FIELD GROUND-WATER SAMPLING DATA FORM (continued)

WELL IDENTIFICATION

MW-7

Time (24 hr)	Amount Purged	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)

COMMENTS

FIELD GROUND-WATER SAMPLING DATA FORM

DATE:_____ SITE:_____ PROJECT _____

WEATHER: _____ WELL DIAMETER (inches)_____

WELL IDENTIFICATION

MW-8

DEPTH TO WATER (ft bTOC):_____

WELL TOTAL DEPTH (ft bTOC):_____

DEPTH TO TOP OF PUMP (ft bTOC):_____

DEPTH TO TOP OF WELL SCREEN (ft bTOC): **17.54** WATER LEVEL ABOVE WELL SCREEN (Yes/No?):_____

*Limit water level drawdown per SAP

PURGING:

SATURATED WELL CASING VOLUME CALCULATION:_____ft of water in casing X 0.1632 gallon/foot = _____ total gallons/casing volume

*Well casing volume calculation for 2-inch diameter well

SATURATED FILTER PACK VOLUME: [_____ft of water in filter pack X 2.777 gallons/foot - Casing Volume] X 0.30 = _____ total gallons

*MW-8 filter pack thickness = 13.09 ft; Saturated flter pack volume calculation for 8.25-inch diameter well borehole and assume 30% porosity

Equipment Used: Dedicated Bladder Pump Nondedicated Bladder Pump Bailer Other:_____

Time (24 hr)	Amount Purged (gals)	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)
Continued on back (circle one) yes / no									

Well Purged Below Top of Pump? (Y/N):_____ Time to Recharge:_____ Depth to Water (ft bTOC):_____

SAMPLING Equipment Used: Same as Above Other:_____

Sample Time (24 hr)	Total Purged (gals)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)	Obs.

FINAL DEPTH TO WATER (ft bTOC): _____ TIME FINAL DEPTH TAKEN: _____

SAMPLE ID: _____ SAMPLE FOR QC: _____

PARAMETERS REQUESTD FOR ANALYSIS: _____

IDW PURGE WATER TOTAL (gal): _____ FLOW THROUGH CELL MODEL #: _____

Well Condition	**Remarks**
Concrete Pad?	
Bumper Posts?	
Protective Casing?	
Paint and Label?	
Lock?	
Well Casing?	
Reference Point?	

Field Sampler(s) Name(s):_____

	NAME	SIGNATURE	DATE
PREPARED:	_____	_____	_____
REVIEWED:	_____	_____	_____

FIELD GROUND-WATER SAMPLING DATA FORM (continued)

WELL IDENTIFICATION

MW-8

Time (24 hr)	Amount Purged	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)

COMMENTS

FIELD GROUND-WATER SAMPLING DATA FORM

DATE:_____ SITE:_____ PROJECT _____

WEATHER: _____ WELL DIAMETER (inches)_____

WELL IDENTIFICATION

PZ-2

DEPTH TO WATER (ft bTOC):_____

WELL TOTAL DEPTH (ft bTOC):_____

DEPTH TO TOP OF PUMP (ft bTOC):_____

DEPTH TO TOP OF WELL SCREEN (ft bTOC): **4.80** WATER LEVEL ABOVE WELL SCREEN (Yes/No?):_____

*Limit water level drawdown per SAP

PURGING:

SATURATED WELL CASING VOLUME CALCULATION:_____ft of water in casing X 0.1632 gallon/foot = _____ total gallons/casing volume

*Well casing volume calculation for 2-inch diameter well

SATURATED FILTER PACK VOLUME: [_____ft of water in filter pack X 2.777 gallons/foot - Casing Volume] X 0.30 = _____ total gallons

*PZ-2filter pack thickness = 17.00 ft; Saturated flter pack volume calculation for 8.25-inch diameter well borehole and assume 30% porosity

Equipment Used: Dedicated Bladder Pump Nondedicated Bladder Pump Bailer Other:_____

Time (24 hr)	Amount Purged (gals)	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)
Continued on back (circle one) yes / no									

Well Purged Below Top of Pump? (Y/N):_____ Time to Recharge:_____ Depth to Water (ft bTOC):_____

SAMPLING Equipment Used: Same as Above Other:_____

Sample Time (24 hr)	Total Purged (gals)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)	Obs.

FINAL DEPTH TO WATER (ft bTOC): _____ TIME FINAL DEPTH TAKEN: _____

SAMPLE ID: _____ SAMPLE FOR QC: _____

PARAMETERS REQUESTD FOR ANALYSIS: _____

IDW PURGE WATER TOTAL (gal): _____ FLOW THROUGH CELL MODEL #: _____

Well Condition	**Remarks**
Concrete Pad?	
Bumper Posts?	
Protective Casing?	
Paint and Label?	
Lock?	
Well Casing?	
Reference Point?	

Field Sampler(s) Name(s):_____

	NAME	SIGNATURE	DATE
PREPARED:	_____	_____	_____
REVIEWED:	_____	_____	_____

FIELD GROUND-WATER SAMPLING DATA FORM (continued)

WELL IDENTIFICATION

PZ-2

Time (24 hr)	Amount Purged	Flow Rate (ml/min)	pH	Temp (C)	Conductivity (mS/cm)	Turbidity (NTUs)	ORP (mV)	D.O. (mg/L)	Depth to Water (ft TOC)

COMMENTS

Observed Water Level Form

Project Number:	Well Number:

Facility Name:	Ground Surface Elevation (GS):
Location: N E	Top of Pipe Elevation (TOP):
	Reference Point Elevation (RP):

Date Drilling Began:		Total Depth of Boring:	feet from
Date Drilling Completed:		Total Depth of Well:	feet from
Drilling Type:		Depth to Top of Screen:	feet from
Date Well Installed:		Length of Casing Screened:	feet

Remarks:

Date	Time	By Whom	Depth to Water*	Water Level El.	Total Depth*	Remarks**
			from		from	
			from		from	
			from		from	
			from		from	
			from		from	
			from		from	
			from		from	
			from		from	
			from		from	
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			from		from	
			from		from	
			from		from	
			from		from	
			from		from	
			from		from	

* Depth noted from Ground Surface (GS), Top of Pipe (TOP), or Reference Point (RP)
** e.g. Added or removed water, began pumping, took samples

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Well Development Form

Project Name:	Project Number:	SW File Number:	Well Name:

Project Information			Elevation of Piezometer
Facility Name:			Ground Surface Elevation (GS):
Location:	N	E	Top of Casing Elevation (TOC):
Location in Decimal Degrees:	LatDD:	LongDD:	Measuring Point Elevation (MP):

Well Information		Well Volume Calculation
Date Drilled:		
Borehole Depth:	feet from	
Casing Depth:	feet from	
Depth to Top of Screen:	feet from	
Depth to Bottom of Screen:	feet from	
Filter Top Depth:	feet from	
Filter Bottom Depth:	feet from	
Length of Casing Screened:	feet	1 well volume (gallons) = intial height of water column (ft) x 0.0408 x (casing diameter (in))^2
Type of Formation Screened:		intial height of water column (ft) = total depth (ft) - intial depth to water (ft)

Development Method				
Equipment:				Drilling Methods:
Surge		Bail		
Airlift		Pump		

Observations During Development

Date	Time	Depth to Water* (ft)	Total Depth* (ft)	Fluid Removed Gallons	Fluid Removed Total	Temp. (degrees F)	pH (units)	S.C. (mS/cm)	Tubidity (NTU)	Fluid Appearance and Remarks (color, odor, etc.)

*from TOC unles otherwise noted in Remarks

Well Development Form (Continuation)

Project Name:	Project Number:	Piezometer Number:

Observations During Well Development

Date	Time	Depth to Water* (ft)	Total Depth* (ft)	Fluid Removed Gallons	Fluid Removed Total	Temp. (degrees F)	pH (units)	S.C. (µS/cm)	Fluid Appearance and Remarks (turbidity, color, odor, etc.)

*from TOC unles otherwise noted in Remarks

CHAIN-OF-CUSTODY RECORD

PROJ. NO.	PROJECT NAME
SAMPLERS: (Signature)	

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CON-TAINERS							REMARKS

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks	

Typical Chain of Custody

Route to		Analysis
Sample Number:		
Medium Sampled:		
Date Sampled:		
Time Sampled:		
Preservative:		
Sample Personnel:		
Sample Personnel:		

Typical Sample Label

Company:	Sample Personnel
	Signature
	Signature
	Date

Typical Custody Seal

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