2019 Annual Groundwater Monitoring and Corrective Action Report

Laramie River Station
Wheatland, Wyoming

Basin Electric Power Cooperative

Project number: 60577052

January 31, 2020

Basin Electric Power Cooperative
Bismarck, North Dakota

Quality information

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Revision	Revision date	Details	Authorized	Name	Position

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List of Acronyms

ACM	Assessment of Corrective Actions
ASD	Alternative Source Demonstration
Basin	Basin Electric Power Cooperative
bgs	below ground surface
CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
FGD	Flue Gas Desulfurization
ft	feet
ft/d	feet per day
GWPS	groundwater protection standard
LRS	Laramie River Station
MCL	maximum contaminant level
MW	megawatt
RCRA	Resource Conservation and Recovery Act
SSI	statistically significant increase
SSL	statistically significant level
TDS	total dissolved solids
UPL	upper prediction limit
USGS	U.S. Geological Survey
95LCL	95 percent lower confidence limit

1. Introduction

On behalf of Basin Electric Power Cooperative, (Basin), AECOM has prepared this 2019 annual report documenting groundwater monitoring and corrective action for the Coal Combustion Residuals (CCR) units at Basin's Laramie River Station (LRS).

Chapter 1.0 provides background information on the LRS power generating facility, its CCR unit(s) and their physical setting including geology, hydrology and groundwater conditions. Chapter 2.0 summarizes CCR groundwater monitoring activities conducted prior to 2019. Chapter 3.0 summarizes the groundwater monitoring and corrective action activities completed in 2019, and references attachments to this report that contain detailed documentation of those activities. Chapter 4.0 provides some general information regarding the LRS CCR program and actions planned for 2020. Chapter 5.0 presents a summary and conclusions from CCR groundwater monitoring in 2019 and statistical analysis of the results. Chapter 6.0 lists references cited in this report.

Regulatory Background

The CCR rule (Chapter 40 of the Code of Federal Regulations (CFR) Part 257 Subpart D) became effective on October 19, 2015 and established standards for the disposal of CCR in landfills and surface impoundments (CCR units). In particular, the rule set forth groundwater monitoring and corrective action requirements for CCR units. The rule includes the requirement for an "annual groundwater monitoring and corrective action report" (annual report), with the annual report for 2019 due by January 31, 2020. The annual report is intended to document the status of the groundwater monitoring and corrective action program for each CCR unit, summarize key actions completed in the previous year, and project key activities for the upcoming year. This report is the third annual report for LRS, and includes activities performed in calendar year 2019.

Facility Location and Operational History

LRS, located east of Wheatland, Wyoming (**Figure 1-1**), is one of the largest consumer-operated, regional, joint power supply ventures in the United States. LRS is a coal-based generating station located in Platte County east of Wheatland, Wyoming. The plant consists of three power generating units with a total power output capacity of 1,710 megawatts (MW):

- Unit 1, with a rating of 570 MW, which began operating in 1980;
- Unit 2, with a rating of 570 net MW, which began operating in 1981; and
- Unit 3, with a rating of 570 net MW, which began operating in 1982.

CCR produced at LRS includes fly ash, bottom ash, and flue gas desulfurization (FGD) waste.

CCR Unit Description

CCR is disposed at LRS in the following CCR units monitored as individual units or as multi-units:

- Bottom Ash Pond 1
- Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill (multi-unit)
- Emergency Holding Ponds (multi-unit)

The ash landfill and three bottom ash ponds are located near the western edge of the site, west of the LRS generating units and office complex (**Figure 1-2**). The two emergency holding ponds are located north of the generating units in the northeastern part of the site. The landfill and ash ponds were permitted in 1978 and began receiving coal ash in 1980. The emergency holding ponds were subsequently incorporated due to disposal of FGD materials. Basin reported that in 2018 the landfill received approximately 335,000 tons of solid waste, including fly ash, FGD waste, and a minor contribution of solid debris. The landfill is currently accessed via a haul road running generally east to west along the south side of the landfill.

Physical Setting

The geological and hydrogeological setting is important to understanding the groundwater environment in the vicinity of the LRS. The geologic history of Platte County is similar to most areas within the Front Range of the Rocky Mountains. Platte County is underlain by marine and continental deposits of limestone, conglomerate, sandstone, siltstone, shale, and unconsolidated sediments. Deposits range in thickness up to 10,000 feet (ft) in the east central and southeastern parts of the county. Precambrian rocks generally make up the mountainous areas, Paleozoic and Mesozoic rocks adjoin the older formations, and Tertiary and Quaternary period rocks underlie most of the county east of the Laramie Range (U.S. Geological Survey [USGS] 1960). The Laramide Orogeny was a period of mountain building active in the county approximately 70 million years ago marking the beginning of the Laramie Range and the Hartville Uplift, a structural divide separating the southern Powder River Basin from the northern Denver Basin. During the Cenozoic Era, streams eroded the eastern side of the range depositing silts, sands, and gravels of the Brule and Arikaree Formations that underlie the Wheatland area including LRS.

Precipitation landing on the eastern flank of the Laramie Range supplies surface water to perennial and ephemeral streams that flow east towards the basin. Most surface water west of Wheatland eventually joins with the Laramie River continuing east before discharging into the Platte River near Fort Laramie. Groundwater near Wheatland is recharged primarily through infiltration of rain and melt water on the eastern flank of the Laramie Range, and through infiltration of irrigation water during the spring, summer, and fall months. Some groundwater in the saturated zones eventually returns to the land surface through seeps and springs, or is discharged by wells and evapotranspiration; however, the majority flows into surface streams. Alluvial drainages bounding the eastern (Wheatland Creek) and western portions (Chugwater Creek) of the facility transport surface water generally northward, discharging to the Laramie River (USGS 1960). Some groundwater within these regions percolates into the Arikaree Formation which holds the uppermost aquifer beneath the LRS facility.

The LRS facility is underlain by a 5 to 30 ft thick section of Quaternary sediments that overlies the Arikaree Formation. The Arikaree Formation is comprised primarily of loosely to moderately cemented very fine to fine grained sandstone with interbedded silts and clays. A lower unit consists of lenses of loosely to well-cemented red to gray coarse sandstone interbedded with lenses of well-cemented conglomerate. A basal conglomerate lies unconformably upon the underlying Brule Formation in many places throughout Platte County (USGS 1960). A review of the geologic logs generated during the drilling of the onsite water supply well (Forell-Baumgardner No. 2) suggests the Brule Formation is approximately 820 ft below ground surface (bgs) in the western portions of the facility. Based on this information, the local thickness of the Arikaree Formation onsite is approximately 790 ft thick.

The lithologic characteristics of the Arikaree Formation beneath the LRS are generally consistent, although there are slight differences in the degree of cementation and induration, and minor variations in grain size. Few fractures were noted in borehole soil cores obtained during monitoring well network installation. Interbeds with higher silt and clay content, coupled with greater cementation generate thin discontinuous perched groundwater horizons that are interpreted to hold only seasonal groundwater. The perched groundwater would tend to percolate downward to what is interpreted as the uppermost aquifer based on data obtained during monitoring well installation and aquifer testing. The uppermost aquifer is present at a depth of approximately 95 ft bgs in the southwestern portion of the facility, and slopes generally north towards the Laramie River. The hydraulic gradient for the uppermost aquifer beneath the facility appears to be controlled dominantly through topographic features and enhanced infiltration zones in permeable shallow alluvium. A representative potentiometric surface map from the most recent Assessment Monitoring event conducted in October 2019 is presented in **Figure 1-2**. Data from aquifer pump testing conducted at the facility in 2016 were used to estimate hydraulic conductivities, which range from 0.65 feet per day (ft/d) to 3.12 ft/d, with an average of 1.40 ft/d. Aquifer slug tests were also performed on eight other wells, with resulting hydraulic conductivities ranging from 0.45 ft/d to 6.28 ft/d, with an average of 2.16 ft/d.

2. CCR Groundwater Monitoring Activities Prior to 2019

The regulatory process for CCR groundwater monitoring and corrective action is established by 40 CFR §§ 257.90 through 257.98. The process includes a phased approach to groundwater monitoring, leading (if applicable) to the establishment of groundwater protection standards (GWPSs) for each CCR unit. Exceedances of the GWPSs that are determined to be statistically significant can trigger requirements for additional groundwater characterization and corrective action assessment followed by corrective action implementation. The following paragraphs provide a brief summary of CCR groundwater monitoring activities performed prior to 2019. CCR groundwater monitoring activities performed in 2019 are discussed in Chapter 3.

Groundwater monitoring at LRS is performed using a network of monitoring wells that includes both wells to monitor background water quality that is not potentially influenced by the presence of the CCR unit, and wells placed at the downgradient boundary of the CCR units (**Figure 2-1**). The hydrostratigraphic positions of the CCR monitoring wells selected for sampling background and downgradient groundwater quality for each LRS CCR unit or multi-unit prior to 2019 is summarized below:

CCR unit/multi-unit	Background wells	Downgradient wells
Bottom Ash Pond 1	MW-52B, MW-53B	MW-49B, MW-21B, MW-38B
Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill	MW-39B, MW-32B	MW-36B, MW-37B, MW-20B, MW-14BR, MW-40B, MW-52B, MW-53B
Emergency Holding Ponds	MW-41B, MW-42B, MW-43B	MW-44B, MW-45B, MW-46B, MW-47B

The following eight monitoring wells were also included in the CCR monitoring network for the purpose of measuring groundwater elevations and evaluating groundwater flow direction and velocity in the vicinity of the bottom ash ponds and landfill:

- MW-22B, MW-23B, MW-33B, MW-34B, MW-35B, MW-48B, MW-50B, MW-51B.

Detection Monitoring was initiated in August 2016, which involved sampling groundwater for Part 257 Appendix III and IV constituents over eight Baseline Detection Monitoring events.

Baseline Detection Monitoring events were performed in general accordance with procedures established in the site-specific Sampling and Analysis Plan (AECOM 2018a), which is included in the facility's Operating Record. The Sampling and Analysis Plan describes the procedures for equipment calibration, monitoring well water level measurement, monitoring well purging and sampling, sample custody, sample shipping, laboratory analysis and documentation requirements for each groundwater sample submitted. The results of detection monitoring at LRS were presented and discussed in the First Annual Groundwater Monitoring and Corrective Action Report, 2016-2017 (AECOM 2018b).

If a statistically significant increase (SSI) of any Appendix III constituent relative to background conditions was detected in the downgradient monitoring wells and could not be demonstrated to be associated with a source other than the CCR unit, then the CCR rule required that groundwater monitoring transition from the Detection Monitoring phase to the Assessment Monitoring phase. The results of Detection Monitoring identified the following Appendix III SSIs:

- Bottom Ash Pond 1 SSIs – boron, calcium, chloride, sulfate and total dissolved solids (TDS)
- Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill SSIs – fluoride and chloride
- Emergency Holding Ponds SSI – fluoride.

Basin implemented an Assessment Monitoring program for the two CCR multi-units (Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill; Emergency Holding Ponds) in the spring of 2018 based on the results of Detection Monitoring. The initial Assessment Monitoring event for the two multi-units was conducted in April 2018 and included analysis of groundwater samples for constituents listed in Part 257 Appendix IV.

Basin elected to conduct an Alternative Source Demonstration (ASD) investigation to evaluate whether an alternative source could explain the SSIs identified for Bottom Ash Pond 1 during Detection Monitoring. This ASD investigation involved the following activities:

- Analyzing soil samples collected from shallow soil borings at ten locations near Bottom Ash Pond 1, and
- Performing groundwater modeling to evaluate potential constituent migration pathways and transport times from potential source areas to one of the downgradient wells for Bottom Ash Pond 1.

The ASD investigation could not confirm an alternative source; therefore, Basin initiated an Assessment Monitoring program for Bottom Ash Pond 1 and completed the initial Assessment Monitoring event in June 2018.

The following Appendix IV constituents were detected during the initial Assessment Monitoring of both CCR multi-units: barium, chromium, fluoride, lithium, molybdenum, radium-226 and -228 (combined), and selenium. The Appendix IV constituents detected during initial Assessment Monitoring of Bottom Ash Pond 1 included barium, chromium, cobalt, fluoride, lithium, molybdenum and selenium.

Because one or more Appendix IV constituents were detected during the initial Assessment Monitoring event for all three CCR units/multi-units at LRS, the CCR rule required that a second, verification Assessment Monitoring event be performed for each unit/multi-unit. Verification Assessment Monitoring was performed in June 2018 for the two multi-units and in October 2018 for Bottom Ash Pond 1. Verification monitoring for each unit/multi-unit involved analysis for Appendix III constituents plus the Appendix IV constituents detected during initial Assessment Monitoring.

The results of Assessment Monitoring conducted in 2018 were presented in the 2018 Annual Groundwater Monitoring and Corrective Action Report (AECOM 2019a).

The CCR rule requires that concentrations of Appendix III and Appendix IV constituents detected in downgradient wells during Assessment Monitoring be compared to background concentrations using the statistical procedures in § 257.93(g). The rule also requires the establishment of GWPSs in accordance with § 257.95(h) for each Appendix IV constituent detected in downgradient wells during Assessment Monitoring. If a GWPS is exceeded in one or more downgradient wells at statistically significant levels (SSLs), the rule requires additional groundwater characterization and an Assessment of Corrective Measures unless the SSLs can be attributed to a source other than the CCR unit or attributed to an error in sampling, statistical evaluation, or to natural variation in groundwater quality.

Assessment Monitoring of Bottom Ash Pond 1 found that lithium and molybdenum concentrations in monitoring well MW-38B exceeded GWPSs at an SSL. Although selenium concentrations in monitoring wells MW-21B and MW-38B exceeded the GWPS by direct comparison, their 95 percent lower confidence limit (95LCL) did not exceed the GWPS. Basin concluded the available data indicate that the SSLs associated with Bottom Ash Pond 1 could not be attributed to a source other than the CCR unit or attributed to error in sampling, statistical evaluation, or natural variation in groundwater quality. Therefore, Basin performed additional groundwater characterization and an Assessment of Corrective Measures for Bottom Ash Pond 1, which is discussed in **Chapter 3**.

Assessment Monitoring in 2018 of the Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill multi-unit found that concentrations of Appendix IV constituents chromium, fluoride, and selenium exhibited SSIs above background values, but all concentrations were below GWPSs. Therefore, Assessment Monitoring of this multi-unit is required on a semi-annual basis per the requirements of § 257.95. Assessment monitoring of the Emergency Holding Ponds multi-unit found that Appendix IV constituents chromium, fluoride, and selenium exhibited SSIs above background values but below GWPSs. Therefore, semi-annual Assessment Monitoring of this multi-unit is also required. The results of semi-annual Assessment Monitoring subsequently completed in 2019 are also discussed in **Chapter 3**.

3. CCR Groundwater Monitoring and Corrective Action Activities in 2019

This chapter summarizes the activities conducted at LRS in 2019 to comply with the groundwater requirements of the CCR rule:

- Additional groundwater characterization of Bottom Ash Pond 1
- Groundwater Assessment Monitoring activities for all CCR units
  - monitoring system evaluation
  - groundwater sampling
  - laboratory analysis
  - statistical analysis of the monitoring results
- Assessment of Corrective Measures for Bottom Ash Pond 1

These activities are discussed below.

Groundwater Characterization of Bottom Ash Pond 1

Groundwater characterization activities were performed in the spring of 2019 to evaluate the nature and extent of groundwater impacted by a release of CCR from Bottom Ash Pond 1 that has resulted in the exceedance of GWPSs for lithium and molybdenum. The characterization activities were designed to also support selection and implementation of a remedy to attain GWPSs. The activities involved installation and sampling of four monitoring wells (MW-38C, MW-54B, MW-55B, MW-56B) downgradient of Bottom Ash Pond 1 at the locations illustrated in **Figure 2-1**:

- MW-38C was installed near MW-38B to evaluate the nature and vertical extent of groundwater impacts near MW-38B. The total depth of MW-38C was 130 ft bgs.
- MW-54B was installed to evaluate groundwater quality of the uppermost aquifer at the facility boundary. The total depth of MW-54B was 25 ft bgs.
- MW-55B was installed northeast of MW-21B to evaluate the nature and downgradient extent of groundwater impacts north of MW-38B. The total depth of MW-55B was 70 ft bgs.
- MW-56B was installed east of MW-21B to evaluate the nature and lateral extent of groundwater impacts northeast of MW-38B. The total depth of MW-56B was 79 ft bgs.

Groundwater samples from the four wells were analyzed for Appendix III parameters, the following Appendix IV parameters - barium, chromium, cobalt, fluoride, lithium, molybdenum, and selenium, and the geochemical parameters alkalinity, magnesium, and sodium. None of the results (**Appendix A, Table 2**) exceeded the GWPSs for lithium, molybdenum, or the other Appendix IV constituents detected during Assessment Monitoring in 2018. These results, combined with results from past Assessment Monitoring, reasonably defined the extent of groundwater impacted by lithium and molybdenum attributed to Bottom Ash Pond 1. The data suggest that the horizontal extent of groundwater with lithium and molybdenum concentrations exceeding GWPSs extends from Bottom Ash Pond 1 downgradient to MW-38B but not as far as MW-55B or MW-56B. Similarly, the vertical extent of groundwater exceeding GWPSs extends from the surface of the uppermost aquifer at MW-38B to possibly below the bottom of the screened interval of MW-38B (75 ft bgs), but not as deep as the screened interval of MW-38C (114 ft – 125 ft bgs). Overall, the data enhanced understanding of relevant site conditions and will assist in selecting and implementing a remedy.

Assessment Monitoring Activities

Monitoring System Evaluation

As described in the CCR Groundwater Monitoring System Report (AECOM 2017), monitoring wells were installed around the CCR unit/multi-units at LRS to: (1) facilitate collection of representative groundwater samples from the uppermost aquifer, and (2) accurately measure water table elevations to support evaluation of groundwater gradient and flow direction (**Figure 1-2**). All monitoring wells comprising the LRS CCR monitoring system, except for MW-23B, were found to be in good condition during the Assessment Monitoring events conducted in 2019. Damage to the surface casing of MW-23B was discovered in 2019, presumably due to impact with a vehicle or construction machinery. This well was used for water level measurements to aid in determining groundwater flow direction and velocity. The remaining wells that comprise the CCR monitoring network are adequate for this purpose, therefore Basin does not plan to replace MW-23B. It will be properly repaired or abandoned per WDEQ/EPA guidance in 2020.

Following additional groundwater characterization of Bottom Ash Pond 1 in the spring of 2019, Basin elected to incorporate the four newly installed monitoring wells into the Assessment Monitoring program. Water level measurements and groundwater quality samples will be collected from MW-38C during Assessment Monitoring events, and water level measurements will also be taken at MW-54B, MW-55B and MW-56B.

Analysis of potentiometric surface maps constructed using the depth to groundwater measurements obtained in 2019 during groundwater Assessment Monitoring indicates the direction of groundwater flow is generally to the northeast, consistent with previous data collected during Detection and Assessment Monitoring from 2016 through 2018, and supports the design of the well network (**Figure 1-2**) to monitor background groundwater quality and the quality of groundwater downgradient of the CCR units.

Groundwater Sampling and Analysis

Groundwater assessment monitoring was performed at LRS in June and October 2019 for the three CCR unit/multi-units. Monitoring activities included collecting groundwater samples from the wells listed below:

CCR unit/multi-unit	Background wells	Downgradient wells
Bottom Ash Pond 1	MW-52B, MW-53B	MW-21B, MW-38B, MW-38C*, MW-49B
Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill (multi-unit)	MW-39B, MW-32B	MW-36B, MW-37B, MW-20B, MW-14BR, MW-40B, MW-52B, MW-53B
Emergency Holding Ponds (multi-unit)	MW-41B, MW-42B, MW-43B	MW-44B, MW-45B, MW-46B, MW-47B

* MW-38C, installed in April 2019, was added to the Assessment Monitoring program as a downgradient compliance well for Bottom Ash Pond 1.

Water levels were also measured in the following monitoring wells for the purpose of evaluating groundwater flow direction and velocity:

- MW-22B, MW-33B, MW-34B, MW-35B, MW-48B, MW-50B, MW-51B, MW-54B, MW-55B, MW-56B.

Assessment Monitoring sampling and analysis was performed in general accordance with procedures established in the Sampling and Analysis Plan (AECOM 2018a). The results are presented in **Attachment A**, which also includes a representative potentiometric surface map for the uppermost aquifer, inferred groundwater flow direction and estimated velocities, and a tabulated summary of field measurements and laboratory analytical data.

Statistical Procedures and Analysis

The CCR rule requires that concentrations of Appendix III and Appendix IV constituents detected in downgradient wells during Assessment Monitoring be compared to background concentrations using the statistical procedures in § 257.93(g). The rule also requires the establishment of GWPSs for each Appendix IV constituent detected in downgradient wells during Assessment Monitoring. The detected concentrations are then compared to the GWPSs for each constituent, which are either:

- The federal Safe Drinking Water Act maximum contaminant level (MCL),

- Concentrations for cobalt, lead, lithium and molybdenum specified in § 257.95(h)(2), or
- The background concentration (upper prediction limit) if it is higher than the MCL or concentration specified in § 257.95(h)(2).

The statistical analysis procedures and results from 2019 Assessment Monitoring for each LRS CCR unit/multi-unit are discussed below.

Bottom Ash Pond 1

Appendix III and Appendix IV groundwater quality data from Bottom Ash Pond 1 Assessment Monitoring were evaluated using an interwell approach that statistically compared constituent concentrations at downgradient monitoring wells to those present at background monitoring wells. The statistical analyses were performed in accordance with the Statistical Method Certification and Statistical Methodology presented in the CCR Groundwater Monitoring System Report (AECOM 2017).

Prediction limits (i.e., parametric or nonparametric) were developed for each constituent based on the frequency of non-detect values and whether the background data for that constituent exhibited a normal, lognormal, or nonparametric distribution. For the statistical analysis, non-detect values were represented as one-half the detection limit. No outliers were identified in the background data. Analytical data from the background monitoring wells were used to develop an upper prediction limit (UPL) for the Appendix III and Appendix IV background data at 95 percent confidence or better. Data from each downgradient compliance monitoring well were compared to the UPL to identify SSIs over background. Mann-Kendall trend analysis was used to identify statistically significant increasing trends for constituents with SSIs. ProUCL Version 5.1 was used to store the data and run the statistical analyses. Constituents exhibiting a SSI over the background UPL were further evaluated to determine whether they are present at SSLs relative to GWPS established under § 257.95(d)(2). SSLs were identified by calculating the 95LCL for the constituents exhibiting SSIs over background at the downgradient compliance wells at each CCR unit and comparing the 95LCL to the established GWPS. A constituent is present at an SSL above the GWPS if the 95LCL is greater than the GWPS.

Table 3-1 summarizes the statistically determined background UPLs of each Appendix III and Appendix IV constituent for Bottom Ash Pond 1. **Table 3-1** also identifies applicable Appendix IV GWPSs, whether each Appendix IV constituent concentration measured in the downgradient wells exceeds the GWPS by direct comparison, and if constituent concentrations are present at an SSL above the GWPS. Lithium and molybdenum at monitoring well MW-38B exceed their respective GWPSs at an SSL. While selenium concentrations at monitoring well MW-21B exceeds the GWPS by direct comparison, it is not an SSL because the 95LCL does not exceed the GWPS. Therefore, Assessment Monitoring of this CCR unit will continue on a semi-annual basis per the requirements of § 257.95.

Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill Multi-unit

Statistical analyses of Appendix III and Appendix IV groundwater quality data for the Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill multi-unit were performed in a manner similar to that described above for Bottom Ash Pond 1. **Table 3-2** summarizes the statistically determined background UPLs of each Appendix III and Appendix IV constituent for the Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill multi-unit. **Table 3-2** also identifies applicable Appendix IV GWPSs, whether each Appendix IV constituent concentration measured in the downgradient wells exceeds a GWPS by direct comparison, and if the constituent concentrations are present at an SSL above the GWPS. Assessment Monitoring of this multi-unit in 2019 found that concentrations of some Appendix IV constituents (chromium, fluoride, selenium) exhibited SSIs above background values at selected monitoring wells but were below the GWPSs (**Table 3-2**). Therefore, Assessment Monitoring of this multi-unit will continue on a semi-annual basis per the requirements of § 257.95.

Emergency Holding Ponds

Statistical analyses of Appendix III and Appendix IV groundwater quality data for the Emergency Holding Ponds multi-unit were also performed consistent with the methodology described above for Bottom Ash Pond 1. **Table 3-3** summarizes the statistically determined background UPLs of each Appendix III and IV constituent for the Emergency Holding Ponds multi-unit. **Table 3-3** also identifies applicable Appendix IV GWPSs, whether or not each Appendix IV constituent concentration measured in the downgradient wells exceeds a GWPS by direct comparison, and if the constituent concentrations are present at an SSL above the GWPS. Assessment Monitoring of the Emergency

Holding Ponds multi-unit found that concentrations of one Appendix IV constituent (barium) exhibited an SSI above the background value but was below the GWPSs (**Table 3-3**). Therefore, Assessment Monitoring of this multi-unit will continue on at least a semi-annual basis per the requirements of § 257.95.

Assessment of Corrective Measures for Bottom Ash Pond 1

Groundwater Assessment Monitoring of Bottom Ash Pond 1 identified lithium and molybdenum at SSLs above GWPSs. The exceedance of GWPSs triggered requirements for the assessment, selection and implementation of corrective measures to prevent further releases of hazardous constituents, remediate any releases and restore the affected area. Basin completed an Assessment of Corrective Measures (ACM) in 2019 (AECOM 2019b). The ACM focused on identifying and evaluating groundwater corrective measures to address the dissolved lithium and molybdenum in groundwater downgradient of Bottom Ash Pond 1.

Potentially applicable corrective measures were identified based on the nature and extent of groundwater impacts and site-specific geological and hydrogeological characteristics. Screening was performed by evaluating each corrective measure against the criteria of effectiveness, technical implementability and relative cost. Those that were deemed ineffective and/or had significant implementation concerns were rejected from further consideration. Natural attenuation, groundwater extraction, and long-term monitoring passed the screening step and were assembled into the following two corrective measures alternatives for further detailed evaluation:

- Alternative A: Natural Attenuation and Long-Term Monitoring
- Alternative B: Groundwater Extraction, Onsite Reuse or Disposal and Long-Term Monitoring

The two alternatives were evaluated against the requirements specified in 40 §§ CFR 257.96 and 257.97, broadly categorized under the criterion of effectiveness, implementability and cost. The results of the Assessment of Corrective Measures, including an evaluation of the two alternatives, are presented in the Assessment of Corrective Measures (AECOM, 2019b).

4. General Information

The following subsections summarize any problems encountered in the LRS CCR program through 2019, resolutions to those problems (if needed), and upcoming actions planned for 2020.

Problems Encountered

No problems were encountered during the 2019 monitoring period, other than the discovery of the damage to MW-23B. MW-23B has been removed from the CCR monitoring network because MW-23B was only used for groundwater level measurements and the remaining CCR monitoring wells provide sufficient water level data to adequately evaluate flow direction and velocity.

Actions Planned for 2020

Basin plans on continuing the Assessment Monitoring program for the three CCR unit/multi-units at LRS in 2020. The Assessment Monitoring program will include semi-annual groundwater sampling events and the required statistical evaluations. Basin also plans to select a remedy based on the Assessment of Corrective Measures for Bottom Ash Pond 1. Any notifications required by 40 CFR § 257.95 (e) or (g) will be transmitted accordingly. Basin will prepare a semiannual report describing the progress in selecting and designing the remedy. Upon selection of a remedy, Basin will prepare a final report describing the selected remedy and how it meets the required standards specified in § 257.97(b). Basin will initiate remedial activities within 90 days of selecting a remedy under § 257.97.

5. Summary and Conclusions

Groundwater characterization activities, two rounds of groundwater Assessment Monitoring, and an Assessment of Corrective Measures were performed at LRS in 2019. Statistical analysis of the Assessment Monitoring results identified an SSI for at least one Appendix III constituent for each LRS CCR unit/multi-units, therefore Assessment Monitoring will be performed on a semi-annual basis in 2020 for all LRS CCR unit/multi-units. Basin will also select and implement a remedy to address Appendix IV SSLs for lithium and molybdenum associated with Bottom Ash Pond 1, and continue to comply with CCR rule notification, reporting, and certification requirements.

6. References

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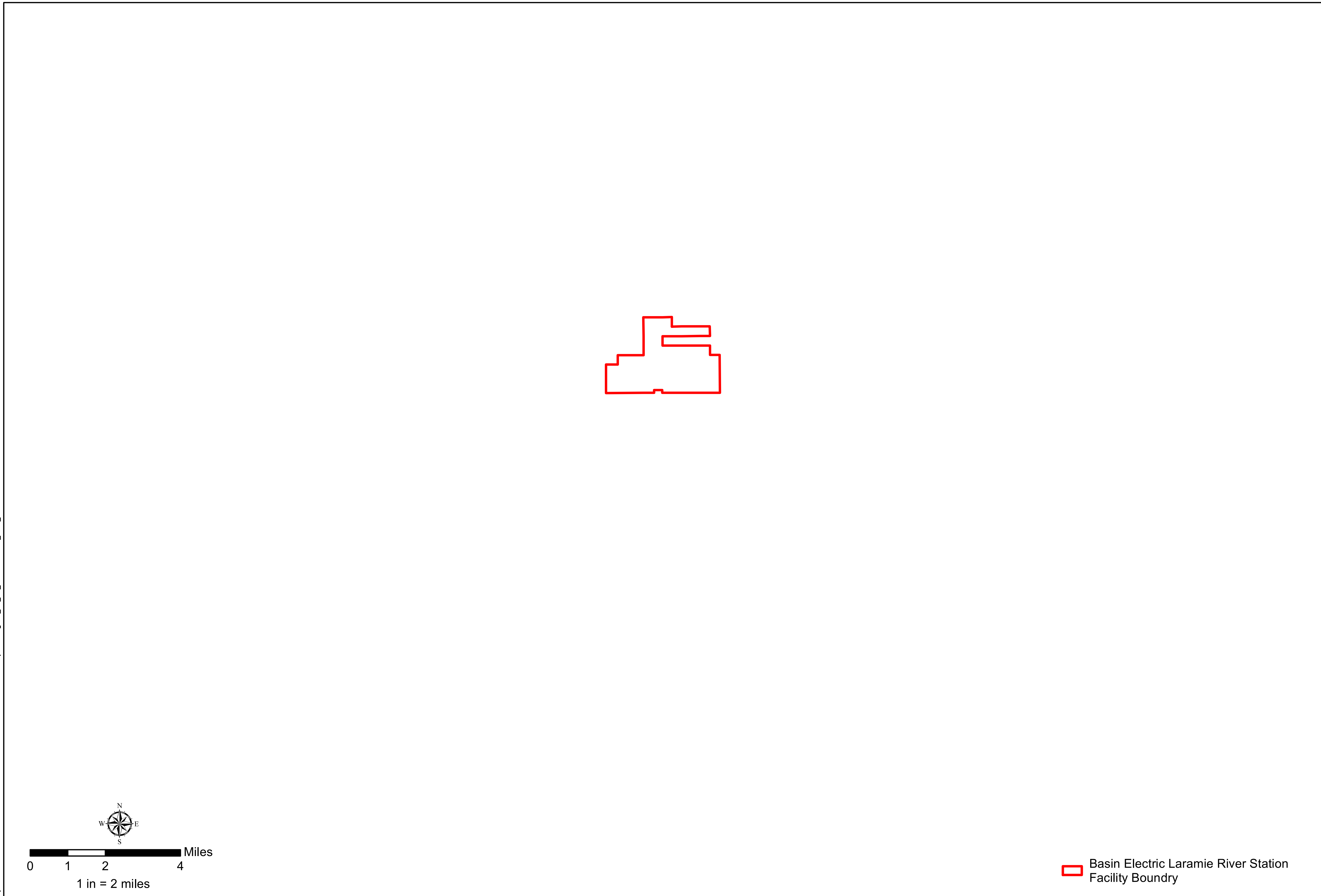
Figures



Site Location Map

Basin Electric
Laramie River Station
Platte County, Wyoming
Project No.: 60506860 Date: 09/28/2016

AECOM
Figure: 1-1

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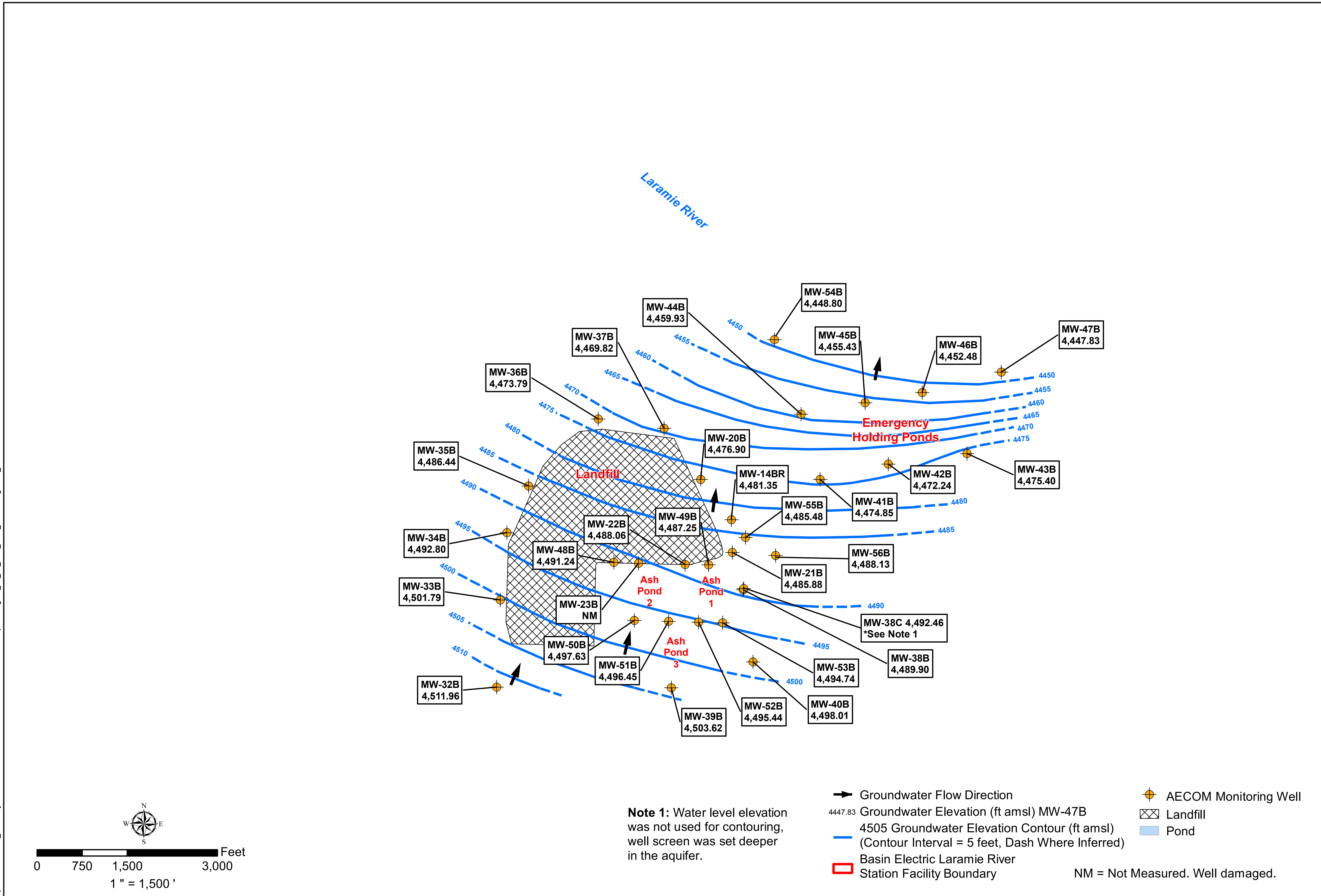

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Potentiometric Surface Map
October 21-23, 2019

Figure: 1-2

Basin Electric
Laramie River Station
Platte County, Wyoming
Project No.: 60577052 Date: 11/5/2019

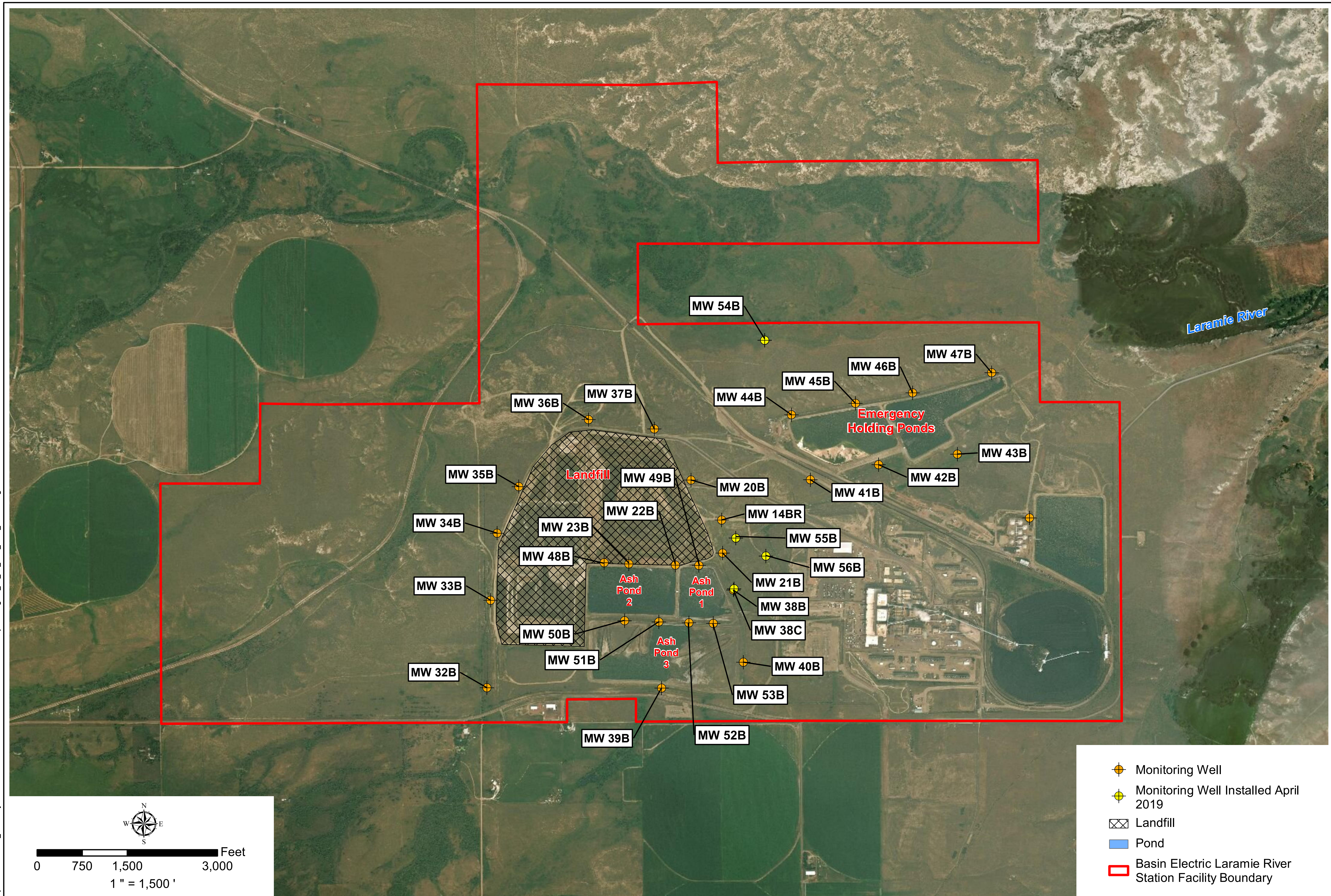

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Figure: 2-1

LRS CCR Monitoring Well Network

Basin Electric
Laramie River Station
Platte County, Wyoming
Project No.: 60577052 Date: 6/28/2019

Tables

Table 3-1 Statistical Analysis Methods and Results - Bottom Ash Pond 1

Parameter (units)	Number of Samples	Percent Nondetects	Normal or Lognormal Distribution?	Statistical Test	Background UPL	GWPS Basis	GWPS	SSI Above Background?	Exceeds GWPS?	SSL Above GWPS?
Appendix III										
Boron (mg/L)	24	42	No/No	Nonparametric	0.17	----	----	Yes (MW-38B)	----	----
Calcium (mg/L)	24	0	Yes/Yes	Parametric	180	----	----	Yes (MW-21B, MW-38B)	----	----
Chloride (mg/L)	24	0	Yes/No	Parametric	46.8	----	----	Yes (MW-21B, MW-38B)	----	----
Fluoride (mg/L)	26	46	No/No	Nonparametric	1.33	----	----	No	----	----
pH (std units)	20	24	No/Yes	Parametric	8.86	----	----	No	----	----
Sulfate (mg/L)	24	0	No/No	Nonparametric	499	----	----	Yes (MW-21B, MW-38B)	----	----
TDS (mg/L)	24	0	Yes/Yes	Parametric	1,178	----	----	Yes (MW-21B, MW-38B)	----	----
Appendix IV										
Antimony (mg/L)	22	100	No/No	MDL	0.002	----	----	No	----	----
Arsenic (mg/L)	22	100	No/No	MDL	0.005	----	----	No	----	----
Barium (mg/L)	26	0	No/Yes	Parametric	0.197	----	----	No	----	----
Beryllium (mg/L)	22	100	No/No	MDL	0.001	----	----	No	----	----
Cadmium (mg/L)	22	100	No/No	MDL	0.001	----	----	No	----	----
Chromium (mg/L)	26	65	No/No	Nonparametric	0.011	MCL	0.1	Yes (MW-21B)	No	No
Cobalt (mg/L)	24	83	No/No	Nonparametric	0.004	----	----	No	----	----
Fluoride (mg/L)	26	46	No/No	Nonparametric	1.33	----	----	No	----	----
Lead (mg/L)	22	95	No/No	Nonparametric	0.004	----	----	No	----	----
Lithium (mg/L)	26	0	Yes/Yes	Parametric	0.056	§257.95(h)(3)	0.056	Yes (MW-38B)	Yes (MW-38B)	Yes (MW-38B)
Mercury (mg/L)	22	100	No/No	MDL	0.0002	----	----	No	----	----
Molybdenum (mg/L)	26	0	Yes/Yes	Parametric	0.016	§257.95(h)(2)	0.1	Yes (MW-21B, MW-38B)	Yes (MW-38B)	Yes (MW-38B)
Radium 226+228 (pCi/L)	22	73	No/Yes	Nonparametric	1.09	----	----	No	----	----
Selenium (mg/L)	26	77	No/No	Nonparametric	0.009	MCL	0.05	Yes (MW-21B, MW-38B)	Yes (MW-21B)	No
Thallium (mg/L)	22	100	No/No	Nonparametric	0.001	----	----	No	----	----

UPL - upper prediction limit
GWPS - groundwater protection standard
SSI - statistically signficiant increase
SSL - statistically significant level (95LCL exceeds GWPS)
MCL - maximum contaminant level
mg/L - milligram per liter
pCi/L - picocuries per liter
MDL - UPL set at maximum Method Detection Limit

Table 3-2 Statistical Analysis Methods and Results - Ash Pond 2, Ash Pond 3, Ash Landfill Multiunit

Parameter (units)	Number of Samples	Percent Nondetects	Normal or Lognormal Distribution?	Statistical Test	Background UPL	GWPS Basis	GWPS	SSI Above Background?	Exceeds GWPS?	SSL Above GWPS?
Appendix III										
Boron (mg/L)	22	0	No/No	Nonparametric	0.31	----	----	No	----	----
Calcium (mg/L)	22	0	Yes/Yes	Parametric	211	----	----	Yes (MW-20B)	----	----
Chloride (mg/L)	22	0	No/No	Nonparametric	94.3	----	----	Yes (MW-20B)	----	----
Fluoride (mg/L)	24	17	No/No	Nonparametric	0.79	----	----	Yes (MW-20B, MW-53B)	----	----
pH (std units)	22	0	No/No	Nonparametric	6.37/7.78	----	----	Yes (MW-53B)	----	----
Sulfate (mg/L)	22	0	No/No	Nonparametric	877	----	----	No	----	----
TDS (mg/L)	22	0	No/No	Nonparametric	1,830	----	----	No	----	----
Appendix IV										
Antimony (mg/L)	22	100	No/No	MDL	0.002	----	----	No	----	----
Arsenic (mg/L)	22	95	No/No	MDL	0.006	----	----	No	----	----
Barium (mg/L)	24	0	No/Yes	Parametric	0.197	----	----	No	----	----
Beryllium (mg/L)	22	100	No/No	MDL	0.001	----	----	No	----	----
Cadmium (mg/L)	22	100	No/No	MDL	0.001	----	----	No	----	----
Chromium (mg/L)	24	96	No/No	Nonparametric	0.002	MCL	0.1	Yes (MW-14BR)	No	No
Cobalt (mg/L)	20	85	No/No	Nonparametric	0.003	----	----	No	----	----
Fluoride (mg/L)	24	17	No/No	Nonparametric	0.79	MCL	4	Yes (MW-53B)	No	No
Lead (mg/L)	22	100	No/No	Nonparametric	0.001	----	----	No	----	----
Lithium (mg/L)	24	0	Yes/Yes	Parametric	0.087	----	----	No	----	----
Mercury (mg/L)	22	100	No/No	MDL	0.0002	----	----	No	----	----
Molybdenum (mg/L)	24	8	No/Yes	Parametric	0.052	----	----	No	----	----
Radium 226+228 (pCi/L)	24	33	Yes/Yes	Nonparametric	1.175	----	----	No	----	----
Selenium (mg/L)	24	100	No/No	Nonparametric	0.005	MCL	0.05	Yes (MW-14BR, MW-37B,MW-40B,MW-53B)	No	No
Thallium (mg/L)	22	100	No/No	Nonparametric	0.001	----	----	No	----	----

UPL - upper prediction limit
GWPS - groundwater protection standard
SSI - statistically signficiant increase
SSL - statistically significant level (95LCL exceeds GWPS)
MCL - maximum contaminant level
mg/L - milligram per liter
pCi/L - picocuries per liter
MDL - UPL set at maximum Method Detection Limit

Table 3-3 Statistical Analysis Methods and Results - Emergency Holding Ponds

Parameter (units)	Number of Samples	Percent Nondetects	Normal or Lognormal Distribution?	Statistical Test	Background UPL	GWPS Basis	GWPS	SSI Above Background?	Exceeds GWPS?	SSL Above GWPS?
Appendix III										
Boron (mg/L)	33	0	No/No	Nonparametric	1.07	----	----	No	----	----
Calcium (mg/L)	33	0	Yes/No	Parametric	494	----	----	No	----	----
Chloride (mg/L)	33	0	No/No	Nonparametric	320	----	----	No	----	----
Fluoride (mg/L)	36	86	No/No	Nonparametric	0.74	----	----	No	----	----
pH (std units)	32	0	No/No	Nonparametric	6.45/7.85	----	----	No	----	----
Sulfate (mg/L)	33	6	No/No	Nonparametric	2,200	----	----	No	----	----
TDS (mg/L)	33	0	No/No	Nonparametric	4,000	----	----	No	----	----
Appendix IV										
Antimony (mg/L)	30	100	No/No	MDL	0.002	----	----	No	----	----
Arsenic (mg/L)	30	100	No/No	MDL	0.005	----	----	No	----	----
Barium (mg/L)	36	0	No/Yes	Parametric	0.197	MCL	2	Yes (MW-46B, MW-47B)	No	No
Beryllium (mg/L)	30	100	No/No	MDL	0.001	----	----	No	----	----
Cadmium (mg/L)	30	100	No/No	MDL	0.001	----	----	No	----	----
Chromium (mg/L)	36	19	No/Yes	Parametric	0.011	----	----	No	----	----
Cobalt (mg/L)	30	87	No/No	Nonparametric	0.002	----	----	No	----	----
Fluoride (mg/L)	36	86	No/No	Nonparametric	0.74	----	----	No	----	----
Lead (mg/L)	30	100	No/No	Nonparametric	0.001	----	----	No	----	----
Lithium (mg/L)	36	0	Yes/Yes	Parametric	0.088	----	----	No	----	----
Mercury (mg/L)	30	100	No/No	MDL	0.0002	----	----	No	----	----
Molybdenum (mg/L)	30	0	No/No	Nonparametric	0.180	----	----	No	----	----
Radium 226+228 (pCi/L)	36	56	No/Yes	Nonparametric	1.020	----	----	No	----	----
Selenium (mg/L)	36	53	No/No	Nonparametric	0.012	----	----	No	----	----
Thallium (mg/L)	30	100	No/No	Nonparametric	0.001	----	----	No	----	----

UPL - upper prediction limit
GWPS - groundwater protection standard
SSI - statistically signficiant increase
SSL - statistically significant level (95LCL exceeds GWPS)
MCL - maximum contaminant level
mg/L - milligram per liter
pCi/L - picocuries per liter
MDL - UPL set at maximum Method Detection Limit

Attachment A

Sampling and Analysis Report, 2016-2017

AECOM Imagine it. Delivered.

2019 Sampling and Analysis Report CCR Monitoring Program

Laramie River Station
Wheatland, Wyoming

Basin Electric Power Cooperative

January 31, 2020

Prepared for:

Basin Electric Power Cooperative
Bismarck, North Dakota

Prepared by:

AECOM
1601 Prospect Park Way
Fort Collins, CO 80525
aecom.com

Project number: 60577052

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List of Appendices

List of Acronyms

CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
LRS	Laramie River Station
QA/QC	quality assurance/quality control
USEPA	United States Environmental Protection Agency

1. Introduction

On behalf of Basin Electric Power Cooperative (Basin), AECOM Technical Services, Inc. (AECOM) prepared this Coal Combustion Residuals (CCR) Groundwater Sampling and Analysis Report for the Basin Laramie River Station (LRS).

This Sampling and Analysis Report was prepared to present the results of sampling and analysis of groundwater conducted per the monitoring requirements of the United States Environmental Protection Agency (USEPA) CCR rule (Chapter 40 of the Code of Federal Regulations (CFR), §§ 257.90 to 257.98).

The following three CCR unit/multi-units are present at LRS:

- Bottom Ash Pond 1
- Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill (multi-unit)
- Emergency Holding Ponds (multi-unit)

Groundwater characterization activities were performed in the spring of 2019 to evaluate the nature and extent of groundwater impacted by a release of CCR from Bottom Ash Pond 1 that has resulted in the exceedance of GWPSs for lithium and molybdenum. The characterization activities were designed to also support selection and implementation of a remedy to attain GWPSs.

Semi-annual groundwater Assessment Monitoring was also performed at LRS in June and October 2019 for the three CCR unit/multi-units. Assessment Monitoring involves groundwater level measurements, collection of groundwater samples from CCR monitoring wells, and analysis for Part 257 Appendix III and selected Appendix IV parameters.

2. Groundwater Flow

As required by 40 CFR § 257.93(c), groundwater elevations were measured in each well prior to purging each time groundwater was sampled. The groundwater measurements, presented in **Table 1**, were used to create potentiometric surface maps for the uppermost aquifer for the baseline monitoring events. The resulting potentiometric surface maps (contained in the operating record) were used to evaluate the direction of groundwater flow and hydraulic gradient for each subject CCR unit/multi-unit. **Figure 1** represents a potentiometric surface map constructed using measurements taken on October 21-23, 2019 and shows inferred groundwater flow directions for each CCR unit/multi-unit. This potentiometric map is generally consistent with the groundwater flow patterns observed during the other CCR monitoring events performed at LRS since monitoring began in 2016. Groundwater flow velocities were calculated for each unit/multi-unit using measurements from the semi-annual Assessment Monitoring events in June and October 2019, as presented in **Appendix I** and summarized below:

	Calculated Seepage Velocities (ft/day)		
CCR unit/multi-unit	**Minimum**	**Maximum**	**Geometric Mean**
Bottom Ash Pond 1	0.029	0.46	0.12
Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill	0.013	2.5	0.18
Emergency Holding Ponds	0.044	2.9	0.36

Based on the groundwater flow conditions documented in this chapter, the relative function of the monitoring wells employed in the LRS CCR groundwater monitoring system is as follows:

CCR unit/multi-unit	Background wells	Downgradient wells
Bottom Ash Pond 1	MW-52B, MW-53B	MW-49B, MW-21B, MW-38B, MW-38C*
Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill	MW-39B, MW-32B	MW-36B, MW-37B, MW-20B, MW-14BR, MW-40B, MW-52B, MW-53B
Emergency Holding Ponds	MW-41B, MW-42B, MW-43B	MW-44B, MW-45B, MW-46B, MW-47B

* MW-38C was added to the monitoring system following its installation during groundwater characterization activities in the spring of 2019.

The following ten monitoring wells are also included in the LRS CCR monitoring system for the purpose of measuring groundwater elevations and evaluating groundwater flow direction and velocity in the vicinity of the bottom ash ponds and landfill: MW-22B, MW-33B, MW-34B, MW-35B, MW-48B, MW-50B, MW-51B, MW-54B, MW-55B, and MW-56B. MW-54B, MW-55B, and MW-56B were added to the list of wells to be measured following their installation during groundwater characterization activities in the spring of 2019.

3. Groundwater Quality

TestAmerica provided laboratory reports following each monitoring event presenting the results of laboratory analysis. The laboratory reports are included in the operating record and were reviewed against the chain-of-custody forms and for compliance with maximum holding times and project-required methods. The reported analytical results were reviewed and verified by an AECOM data validator/chemist using USEPA guidelines (USEPA 2017). Data validation concluded that field and laboratory precision, field and laboratory accuracy, method compliance, and data set completeness were acceptable based on the data reported. No data were missing or rejected, and all reported data are suitable for their intended use as reported with the clarifications and qualifications noted. Data validation reports were prepared for each monitoring event and are included in the operating record. The validated results were compiled into summary form as presented in **Tables 2, 3** and **4** for the two semi-annual assessment monitoring events in 2019. The first semi-annual event in June 2019 involved the laboratory analysis of samples for Appendix III parameters and those Appendix IV parameters detected in the previous Assessment Monitoring event. The second semi-annual event in October 2019 involved analysis for Appendix III and all Appendix IV parameters.

Table 5 contains the results of quality assurance/quality control (QA/QC) field blank samples collected during the groundwater monitoring events conducted in 2019. **Table 6** presents the validated results for monitoring wells installed as part of the groundwater characterization monitoring event that was conducted in April 2019 in support of corrective measures assessment.

Figures

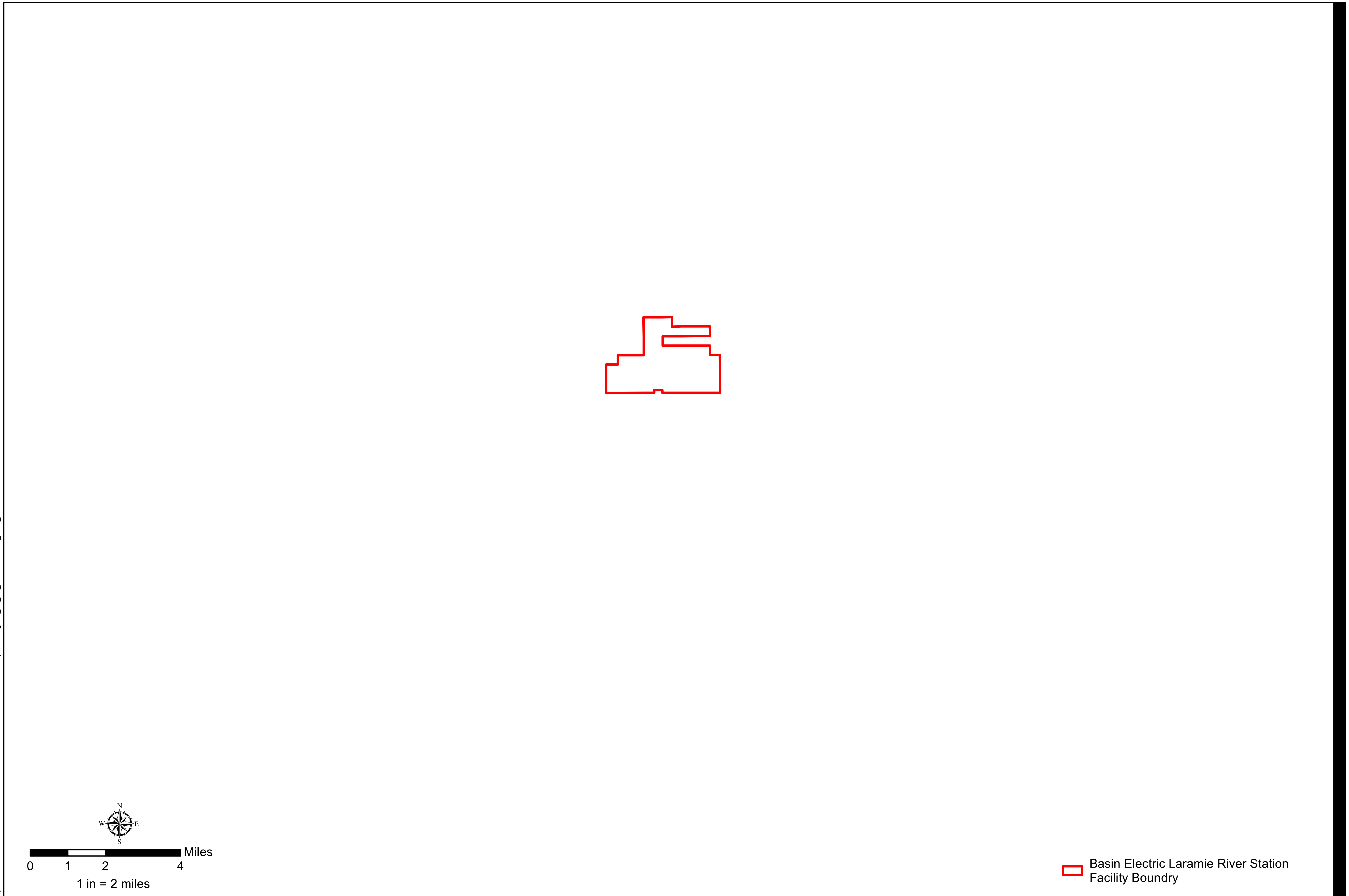


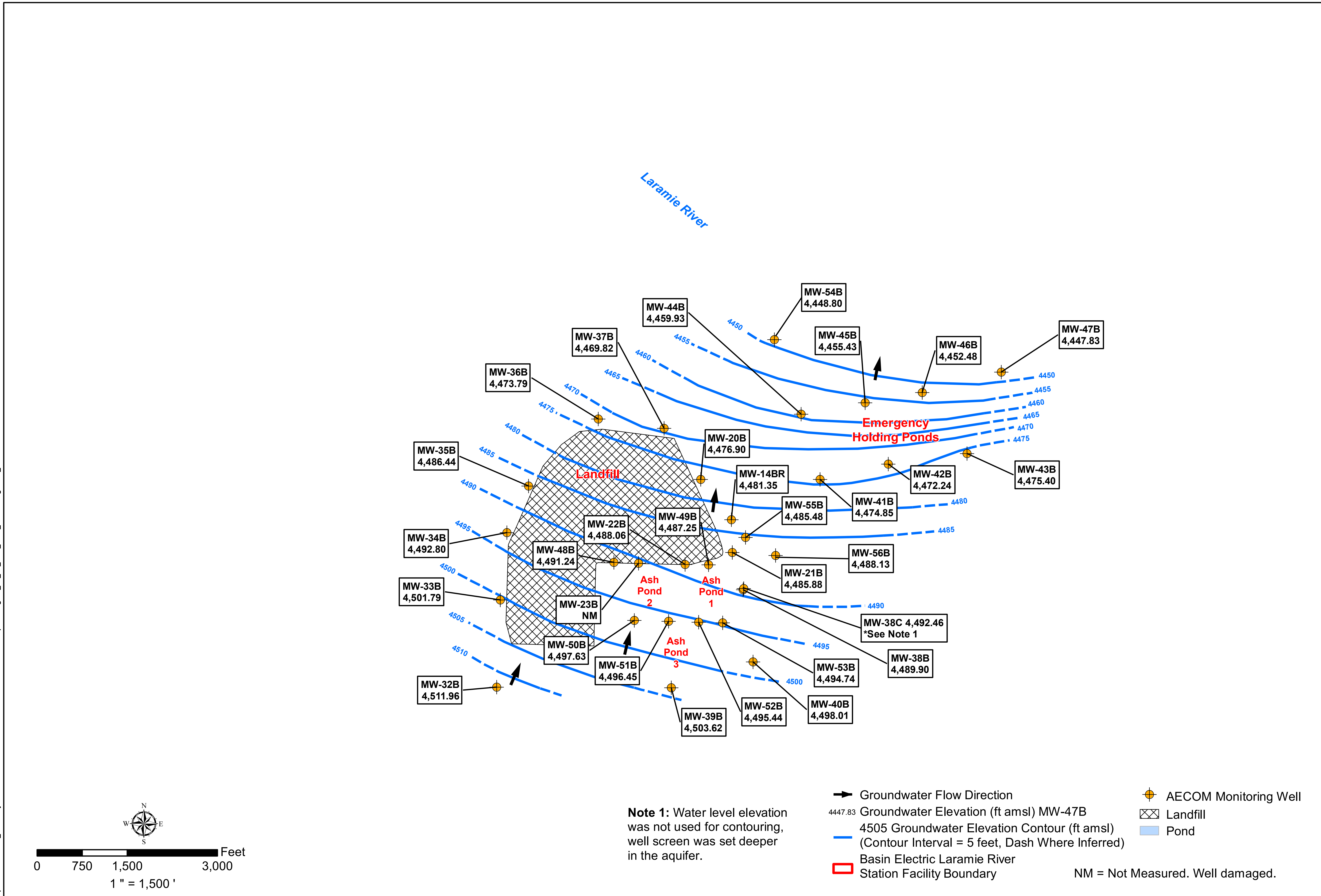
Figure: 1-1

AECOM

Site Location Map

Basin Electric
Laramie River Station
Platte County, Wyoming
Project No.: 60506860 Date: 09/28/2016

Filepath: W:\60506860 Basin Electric LRS CCR\900-CAD GIS\920-GIS-Graphics\Figure_01_01_BasinElectric_LRS_SiteLocation.mxd

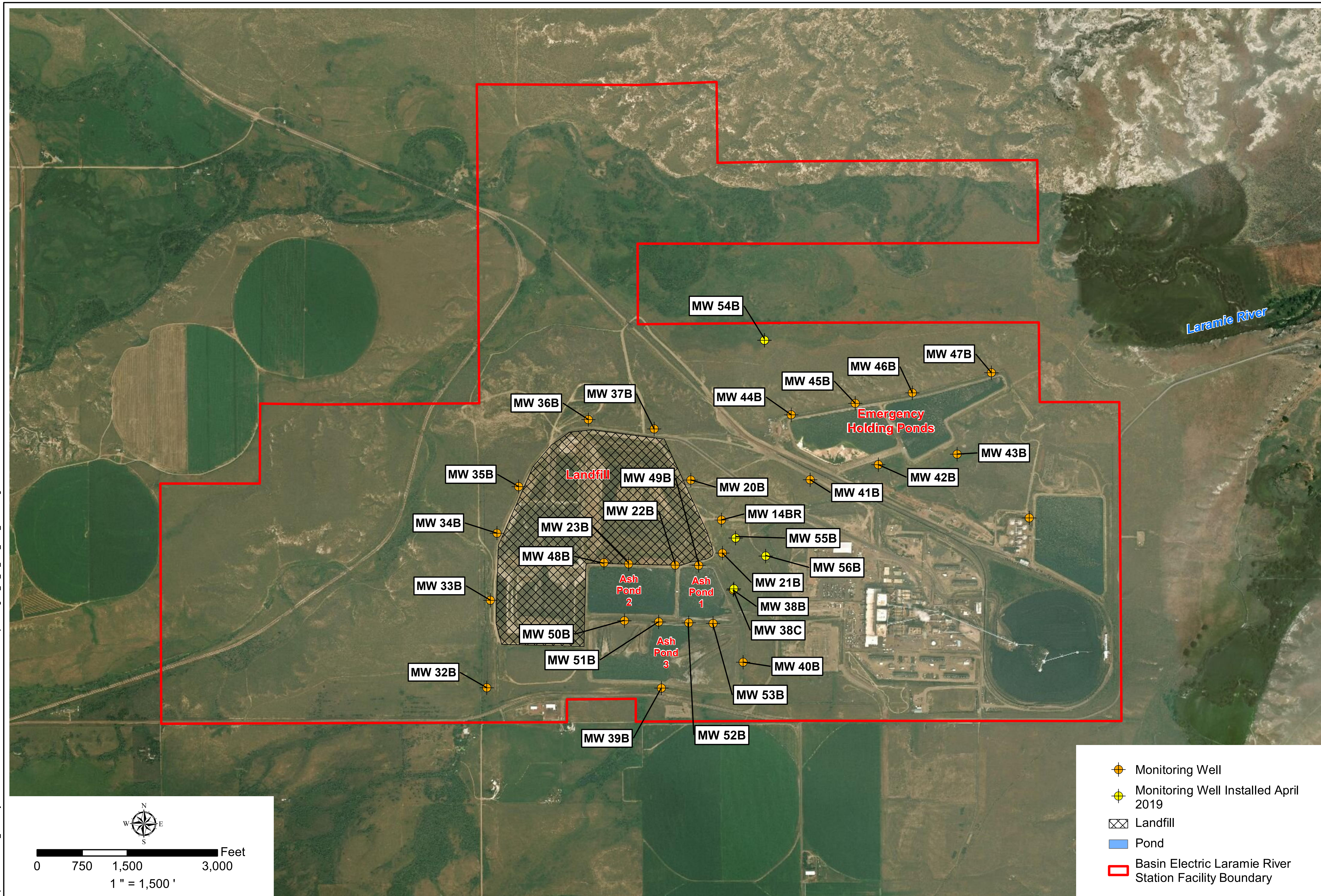


Potentiometric Surface Map
October 21-23, 2019

Basin Electric
Laramie River Station
Platte County, Wyoming
Project No.: 60577052 Date: 11/5/2019

Figure: 1-2

Filepath: M:\Denver_GIS\Projects\60506860 Basin Electric LRS CCR\920-GIS-Graphics\Figure_03_01_LRS_CCR_MonitoringWells_October2019.mxd



AECOM

Figure: 2-1

LRS CCR Monitoring Well Network

Basin Electric
Laramie River Station
Platte County, Wyoming
Project No.: 60577052 Date: 6/28/2019

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Tables

Table 1 Groundwater Level Measurements and Elevations

Location ID	Top of Casing Elevation (feet amsl)	April 16, 2019			June 4-6, 2019			October 21-23, 2019		
		Date	Depth To Water (feet)	Water Level Elevation (feet amsl)	Date	Depth To Water (feet)	Water Level Elevation (feet amsl)	Date	Depth To Water (feet)	Water Level Elevation (feet amsl)
MW-14BR	4537.90	4/16/2019	56.90	4481.00	6/5/2019	56.84	4481.06	10/21/2019	56.55	4481.35
MW-20B	4535.47	4/16/2019	58.93	4476.54	6/5/2019	58.82	4476.65	10/21/2019	58.57	4476.90
MW-21B	4539.58	4/16/2019	54.03	4485.55	6/4/2019	54.04	4485.54	10/22/2019	53.70	4485.88
MW-22B	4569.21	NM	NM	NM	6/5/2019	81.52	4487.69	10/22/2019	81.15	4488.06
MW-23B	4569.48	NM	NM	NM	6/5/2019	NM	NM	10/22/2019	NM	NM
MW-32B	4567.11	4/16/2019	55.51	4511.60	6/5/2019	55.42	4511.69	10/23/2019	55.15	4511.96
MW-33B	4566.61	4/16/2019	65.33	4501.28	6/5/2019	65.45	4501.16	10/22/2019	64.82	4501.79
MW-34B	4554.72	4/16/2019	62.63	4492.09	6/5/2019	62.56	4492.16	10/22/2019	61.92	4492.80
MW-35B	4548.67	4/16/2019	62.84	4485.83	6/5/2019	62.73	4485.94	10/22/2019	62.23	4486.44
MW-36B	4532.44	4/16/2019	59.07	4473.37	6/6/2019	58.87	4473.57	10/23/2019	58.65	4473.79
MW-37B	4530.37	4/16/2019	61.04	4469.33	6/6/2019	60.84	4469.53	10/23/2019	60.55	4469.82
MW-38B	4547.48	NM	NM	NM	6/5/2019	57.98	4489.50	10/22/2019	57.58	4489.90
MW-38C	4547.48	4/16/2019	57.41	4492.04	6/5/2019	57.35	4492.10	10/22/2019	56.99	4492.46
MW-39B	4581.45	NM	NM	NM	6/5/2019	78.04	4503.41	10/23/2019	77.83	4503.62
MW-40B	4589.59	NM	NM	NM	6/5/2019	91.81	4497.78	10/23/2019	91.58	4498.01
MW-41B	4529.64	4/16/2019	55.49	4474.15	6/4/2019	55.50	4474.14	10/21/2019	54.79	4474.85
MW-42B	4515.83	4/16/2019	45.52	4470.31	6/4/2019	45.31	4470.52	10/21/2019	43.59	4472.24
MW-43B	4501.44	4/16/2019	32.12	4469.32	6/4/2019	27.87	4473.57	10/21/2019	26.04	4475.40
MW-44B	4529.39	4/16/2019	70.03	4459.36	6/4/2019	69.73	4459.66	10/21/2019	69.46	4459.93
MW-45B	4530.92	4/16/2019	76.13	4454.79	6/4/2019	75.77	4455.15	10/22/2019	75.49	4455.43
MW-46B	4527.72	4/16/2019	76.11	4451.61	6/4/2019	75.79	4451.93	10/21/2019	75.24	4452.48
MW-47B	4522.60	4/16/2019	75.76	4446.84	6/4/2019	75.47	4447.13	10/21/2019	74.77	4447.83
MW-48B	4568.66	NM	NM	NM	6/5/2019	78.13	4490.53	10/22/2019	77.42	4491.24
MW-49B	4564.36	NM	NM	NM	6/4/2019	77.45	4486.91	10/22/2019	77.11	4487.25
MW-50B	4588.34	NM	NM	NM	6/5/2019	91.23	4497.11	10/22/2019	90.71	4497.63
MW-51B	4588.90	NM	NM	NM	6/5/2019	92.95	4495.95	10/22/2019	92.45	4496.45
MW-52B	4589.60	NM	NM	NM	6/5/2019	94.51	4495.09	10/22/2019	94.16	4495.44
MW-53B	4589.23	NM	NM	NM	6/5/2019	94.85	4494.38	10/22/2019	94.49	4494.74
MW-54B	4454.80	4/16/2019	5.17	4449.63	6/4/2019	4.42	4450.38	10/21/2019	6.00	4448.80
MW-55B	4532.37	4/16/2019	47.36	4485.01	6/5/2019	47.31	4485.06	10/22/2019	46.89	4485.48
MW-56B	4541.95	4/16/2019	54.60	4487.35	6/5/2019	54.51	4487.44	10/22/2019	53.82	4488.13

Notes:
TOC = top of casing
amsl = above mean sea level
NM = not measured
Geodetic Datum: North American Datum of 1983 (NAD 83)
Vertical Datum: North American Verical Datum of 1988 (NAVD 88)

Table 2 Groundwater Analytical Data – Bottom Ash Pond 1

				Appendix III Constituents							Appendix IV Constituents														
		Analyte Name		Boron	Calcium	Chloride	Fluoride	pH	Sulfate	TDS	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Fluoride	Lead	Lithium	Mercury	Molybdenum	Radium 226/228	Selenium	Thallium
		Unit		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pCi/L	mg/L	mg/L
Relative Location	MW ID	Date	Type																						
Background	MW-52B	6/5/2019	N	0.152	169	42.8	0.500 U	6.94	493	1120	----	----	0.0750	----	----	0.00200 U	0.00100 U	0.500 U	----	.0467	----	0.00417	----	0.00500 U	----
Background	MW-52B	10/22/2019	N	0.154	174	39.3 J	0.500 UJ	7.55	471 J	1040	0.00200 U	0.00500 U	0.0752 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.500 UJ	0.00100 U	.0403	0.000200 U	0.00418	0.775	0.00500 U	0.00100 U
Background	MW-53B	6/5/2019	N	0.1 U	104	45.7	1.08	7.2	247	699	----	----	0.0451	----	----	0.00200 U	0.00100 U	1.08	----	.0375	----	0.00563	----	0.00854	----
Background	MW-53B	10/22/2019	N	0.1 U	102	47.0 J	0.919 J	7.81	222 J	686	0.00200 U	0.00500 U	0.0477 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.919 J	0.00100 U	.0317	0.000200 U	0.00606	0.595 U	0.00935	0.00100 U
Downgradient	MW-21B	6/4/2019	N	0.179	286	317	0.522	7.31	729	1690	----	----	0.0392	----	----	0.0303	0.00100 U	0.522	----	.0448	----	0.0157	----	0.0531	----
Downgradient	MW-21B	10/22/2019	N	0.179	280	276	0.574	7.59	707	1690	0.00200 U	0.00500 U	0.0426 J+	0.00100 U	0.00100 U	0.0272	0.00100 U	0.574	0.00100 U	.0394	0.000200 U	0.0163	0.441 U	0.0529	0.00100 U
Downgradient	MW-38B	6/5/2019	FD	3.45	651	312	2.50 U	----	3590	5940	----	----	0.0152	----	----	0.00728	0.00100 U	2.50 U	----	.147	----	0.212	----	0.0117	----
Downgradient	MW-38B	6/5/2019	N	3.7	652	366	2.50 U	6.71	4040	6450	----	----	0.0155	----	----	0.00744	0.00100 U	2.50 U	----	.156	----	0.223	----	0.0118	----
Downgradient	MW-38B	10/22/2019	N	3.22	558	357	0.500 U	7.37	5050	8330	0.00200 U	0.00500 U	0.0190 J+	0.00100 U	0.00100 U	0.00804	0.00100 U	0.500 U	0.00100 U	0.138	0.000200 U	0.216	0.424 U	0.0104	0.00100 U
Downgradient	MW-38C	4/16/2019	FD	0.14 J-	98	93 J	1.7	----	310	800	----	----	0.050 J-	----	----	0.0020	0.0010 UJ	1.7	----	0.047	----	0.025 J-	----	0.0050 U	----
Downgradient	MW-38C	4/16/2019	N	0.13 J-	94	47 J	0.89	7.53	320	760	----	----	0.051 J-	----	----	0.0020 U	0.0010 UJ	0.89	----	0.052	----	0.027 J-	----	0.0051	----
Downgradient	MW-38C	10/22/2019	N	0.1 U	99	28.6	0.524	7.57	209	603	0.00200 U	0.00500 U	0.0481 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.524	0.00100 U	.0268	0.000200 U	0.0116	0.414 U	0.00593	0.00100 U
Downgradient	MW-49B	6/4/2019	N	0.168	133	36.8	0.500 U	7.72	436	1030	----	----	0.0779	----	----	0.00200 U	0.00100 U	0.500 U	----	.0407	----	0.00579	----	0.00500 U	----
Downgradient	MW-49B	10/22/2019	N	0.16	145	35.7 J	0.500 UJ	7.73	426 J	970	0.00200 U	0.00500 U	0.0744 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.500 UJ	0.00100 U	.0448	0.000200 U	0.00472	0.605 U	0.00500 U	0.00100 U

Notes:
MW ID - monitoring well identifier
mg/L - milligram per liter
U - undetected at the reporting limit/concentration
UJ - undetected, reporting limit is estimated
J - estimated concentration
J+ - estimated concentration, high bias indicated
FD - field duplicate
N - primary sample

Table 3 Groundwater Analytical Data - Bottom Ash Pond 2, Bottom Ash Pond 3, Ash Landfill

			Analyte Name	Appendix III Constituents						
			Analyte Name	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	TDS
			Unit	mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
Relative Location	MW ID	Date	Type							
Background	MW-32B	6/5/2019	N	0.293	202	94.3	0.500 U	6.61	877	1830
Background	MW-32B	10/23/2019	N	0.295	198	89.5	0.500 U	7.36	840	1780
Background	MW-39B	6/5/2019	N	0.189	197	49.9	0.500 U	6.71	602	1340
Background	MW-39B	10/23/2019	N	0.183	191	45.8	0.500 U	7.26	542	1310
Downgradient	MW-14BR	6/5/2019	N	0.145	147	74.3	0.500 U	6.94	296	793
Downgradient	MW-14BR	10/21/2019	N	0.15	162	81.1 J	0.500 UJ	7.76	304 J	814
Downgradient	MW-20B	6/5/2019	N	0.219	143	51.2	0.664	7.06	421	985
Downgradient	MW-20B	10/21/2019	N	0.212	135	46.5 J	0.608 J	7.74	392 J	936
Downgradient	MW-20B	10/22/2019	N	0.179	280	276	0.574	7.59	707	1690
Downgradient	MW-36B	6/6/2019	N	0.1 U	144	46.4	0.500 U	7.34	427	930
Downgradient	MW-36B	10/23/2019	FD	0.1 U	135	43.0	0.506	----	386	912
Downgradient	MW-36B	10/23/2019	N	0.1 U	147	43.2	0.522	7.6	377	910
Downgradient	MW-37B	6/6/2019	N	0.153	210	96.7	0.500 U	7.34	586	1230
Downgradient	MW-37B	10/23/2019	N	0.154	201	88.2	0.500 U	7.57	517	1190
Downgradient	MW-40B	6/5/2019	N	0.163	146	36.9	0.793	7.1	374	924
Downgradient	MW-40B	10/23/2019	N	0.164	137	32.4	0.697	7.7	331	884
Downgradient	MW-52B	6/5/2019	N	0.152	169	42.8	0.500 U	6.94	493	1120
Downgradient	MW-52B	10/22/2019	N	0.154	174	39.3 J	0.500 UJ	7.55	471 J	1040
Downgradient	MW-53B	6/5/2019	N	0.1 U	104	45.7	1.08	7.2	247	699
Downgradient	MW-53B	10/22/2019	N	0.1 U	102	47.0 J	0.919 J	7.81	222 J	686

			Analyte Name	Appendix IV Constituents															
			Analyte Name	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Fluoride	Lead	Lithium	Mercury	Molybdenum	Radium 226/228	Selenium	Thallium	
			Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pCi/L	mg/L	mg/L	
Relative Location	MW ID	Date	Type																
Background	MW-32B	6/5/2019	N	----	----	0.0349	----	----	0.00200 U	----	0.500 U	----	.0837	----	0.00358	0.580 U	0.00500 U	----	
Background	MW-32B	10/23/2019	N	0.00200 U	0.00500 U	0.0323 J+	0.00100 U	0.00100 U	0.00245	0.00100 U	0.500 U	0.00100 U	.0739	0.000200 U	0.00389	0.414 U	0.00500 U	0.00100 U	
Background	MW-39B	6/5/2019	N	----	----	0.0402	----	----	0.00200 U	----	0.500 U	----	.0704	----	0.00966	0.508 U	0.00500 U	----	
Background	MW-39B	10/23/2019	N	0.00200 U	0.00500 U	0.0380 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.500 U	0.00100 U	.0565	0.000200 U	0.00683	0.452	0.00500 U	0.00100 U	
Downgradient	MW-14BR	6/5/2019	N	----	----	0.0357	----	----	0.0110	----	0.500 U	----	.0239	----	0.00729	0.472 U	0.00602	----	
Downgradient	MW-14BR	10/21/2019	N	0.00200 U	0.00500 U	0.0396 J+	0.00100 U	0.00100 U	0.0162	0.00100 U	0.500 UJ	0.00100 U	.0285	0.000200 U	0.00806	0.478 U	0.00906	0.00100 U	
Downgradient	MW-20B	6/5/2019	N	----	----	0.0529	----	----	0.00200 U	----	0.664	----	.0332	----	0.00701	0.433 U	0.00500 U	----	
Downgradient	MW-20B	10/21/2019	N	0.00200 U	0.00500 U	0.0551 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.608 J	0.00100 U	.0261	0.000200 U	0.00805	0.441 U	0.00500 U	0.00100 U	
Downgradient	MW-20B	10/22/2019	N	0.00200 U	0.00500 U	0.0426 J+	0.00100 U	0.00100 U	0.0272	0.00100 U	0.574	0.00100 U	.0394	0.000200 U	0.0163	0.441 U	0.0529	0.00100 U	
Downgradient	MW-36B	6/6/2019	N	----	----	0.0543	----	----	0.00200 U	----	0.500 U	----	.0317	----	0.00610	0.441 U	0.00500 U	----	
Downgradient	MW-36B	10/23/2019	FD	0.00200 U	0.00500 U	0.0613 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.506	0.00100 U	.0355	0.000200 U	0.00667	0.525 U	0.00500 U	0.00100 U	
Downgradient	MW-36B	10/23/2019	N	0.00200 U	0.00500 U	0.0623 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.522	0.00100 U	.0262	0.000200 U	0.00703	0.403 U	0.00500 U	0.00100 U	
Downgradient	MW-37B	6/6/2019	N	----	----	0.0737	----	----	0.00258	----	0.500 U	----	.0364	----	0.0315	0.487 U	0.00547	----	
Downgradient	MW-37B	10/23/2019	N	0.00200 U	0.00500 U	0.0669 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.500 U	0.00100 U	.0326	0.000200 U	0.0317	0.506	0.00545	0.00100 U	
Downgradient	MW-40B	6/5/2019	N	----	----	0.0317	----	----	0.00200 U	----	0.793	----	.049	----	0.00735	0.467 U	0.00672	----	
Downgradient	MW-40B	10/23/2019	N	0.00200 U	0.00500 U	0.0302 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.697	0.00100 U	.0464	0.000200 U	0.00670	0.463 U	0.00609	0.00100 U	
Downgradient	MW-52B	6/5/2019	N	----	----	0.0750	----	----	0.00200 U	0.00100 U	0.500 U	----	.0467	----	0.00417	----	0.00500 U	----	
Downgradient	MW-52B	10/22/2019	N	0.00200 U	0.00500 U	0.0752 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.500 UJ	0.00100 U	.0403	0.000200 U	0.00418	0.775	0.00500 U	0.00100 U	
Downgradient	MW-53B	6/5/2019	N	----	----	0.0451	----	----	0.00200 U	0.00100 U	1.08	----	.0375	----	0.00563	----	0.00854	----	
Downgradient	MW-53B	10/22/2019	N	0.00200 U	0.00500 U	0.0477 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.919 J	0.00100 U	.0317	0.000200 U	0.00606	0.595 U	0.00935	0.00100 U	

Notes:
MW ID - monitoring well identifier
mg/L - milligram per liter
U - undetected at the reporting limit/concentration
J+ - estimated concentration, high bias indicated
J - estimated concentration
UJ - undetected, reporting limit is estimated
FD - field duplicate
N - primary sample
MW ID - monitoring well identifier

Table 4 Groundwater Analytical Data - Emergency Holding Ponds

Relative Location	MW ID	Date	Type	Boron (mg/L)	Calcium (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	pH (SU)	Sulfate (mg/L)	TDS (mg/L)
				Appendix III Constituents						
Background	MW-41B	6/4/2019	N	0.714	396	277	1.00 U	7.35	2030	3400
		10/21/2019	N	0.862	333	200 J	0.500 UJ	7.58	1480 J	2800
	MW-42B	6/4/2019	N	0.897	413	297	1.00 U	7.39	2120	3470
		10/21/2019	N	0.89	332	203 J	0.500 UJ	7.66	1470 J	2700
	MW-43B	6/4/2019	N	0.319	146	81.7	0.500 U	7.36	611	1170
		10/21/2019	N	0.32	172	67.6 J	0.500 UJ	7.44	663 J	1290
Downgradient	MW-44B	6/4/2019	N	0.1 U	171	62.8	0.655	7.42	440	1010
		10/21/2019	N	0.1	166	57.9 J	0.593 J	7.64	405 J	1010
	MW-45B	6/4/2019	N	0.183	148	51.5	0.809	7.51	353	863
		10/22/2019	N	0.184	146	44.7	0.671	7.57	320	822
	MW-46B	6/4/2019	N	0.1 U	85	23.6	0.500 U	7.26	178	567
		10/21/2019	N	0.1 U	87.2	29.8 J	0.537 J	7.53	188 J	564
	MW-47B	6/4/2019	N	0.138	132	25.1	0.500 U	7.23	291	1790
		10/21/2019	N	0.147	132	29.5 J	0.500 UJ	7.47	305 J	756

Relative Location	MW ID	Date	Type	Antimony (mg/L)	Arsenic (mg/L)	Barium (mg/L)	Beryllium (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Cobalt (mg/L)	Fluoride (mg/L)	Lead (mg/L)	Lithium (mg/L)	Mercury (mg/L)	Molybdenum (mg/L)	Radium 226/228 (pCi/L)	Selenium (mg/L)	Thallium (mg/L)
				Appendix IV Constituents														
Background	MW-41B	6/4/2019	N	----	----	0.0320	----	----	0.00282	----	1.00 U	----	.0731	----	0.0970	0.483 U	0.00611	----
		10/21/2019	N	0.00200 U	0.00500 U	0.0273 J+	0.00100 U	0.00100 U	0.00314	0.00114	0.500 UJ	0.00100 U	.0601	0.000200 U	0.132	0.547 U	0.00638	0.00100 U
	MW-42B	6/4/2019	N	----	----	0.0316	----	----	0.00272	----	1.00 U	----	.0765	----	0.138	0.413 U	0.00699	----
		10/21/2019	N	0.00200 U	0.00500 U	0.0219 J+	0.00100 U	0.00100 U	0.00235	0.00100 U	0.500 UJ	0.00100 U	.0561	0.000200 U	0.106	0.478 U	0.00998	0.00100 U
	MW-43B	6/4/2019	N	----	----	0.0390	----	----	0.00200 U	----	0.500 U	----	.035	----	0.0196	0.457 U	0.00500 U	----
		10/21/2019	N	0.00200 U	0.00500 U	0.0440 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.500 UJ	0.00100 U	.0328	0.000200 U	0.0208	0.971	0.00500 U	0.00100 U
Downgradient	MW-44B	6/4/2019	N	----	----	0.0556	----	----	0.00821	----	0.655	----	.0362	----	0.00641	0.565 U	0.00512	----
		10/21/2019	N	0.00200 U	0.00500 U	0.0516 J+	0.00100 U	0.00100 U	0.00792	0.00100 U	0.593 J	0.00100 U	.0306	0.000200 U	0.00645	0.614 U	0.00574	0.00100 U
	MW-45B	6/4/2019	N	----	----	0.0488	----	----	0.00200 U	----	0.809	----	.0368	----	0.00836	0.521 U	0.00827	----
		10/22/2019	N	0.00200 U	0.00500 U	0.0488 J+	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.671	0.00100 U	.0278	0.000200 U	0.00827	0.627	0.00921	0.00100 U
	MW-46B	6/4/2019	N	----	----	0.0607	----	----	0.00875	----	0.500 U	----	0.0200	----	0.00486	0.397 U	0.00500 U	----
		10/21/2019	N	0.00200 U	0.00500 U	0.0614 J+	0.00100 U	0.00100 U	0.00903	0.00100 U	0.537 J	0.00100 U	.0231	0.000200 U	0.00473	0.450 U	0.00500 U	0.00100 U
	MW-47B	6/4/2019	N	----	----	0.0826	----	----	0.00493	----	0.500 U	----	0.0303	----	0.00657	0.576 U	0.00500 U	----
		10/21/2019	N	0.00200 U	0.00500 U	0.0809 J+	0.00100 U	0.00100 U	0.00486	0.00100 U	0.500 UJ	0.00100 U	0.0219	0.000200 U	0.00673	0.592	0.00500 U	0.00100 U

Notes:
MW ID - monitoring well identifier
mg/L - milligram per liter
U - undetected at the reporting limit/concentration
J+ - estimated concentration, high bias indicated
J - estimated concentration
UJ - undetected, reporting limit is estimated
FD - field duplicate
N - primary sample

Table 5 Groundwater Analytical Data - Field Blanks

			Appendix III Constituents						Appendix IV Constituents														
		Analyte Name	Boron	Calcium	Chloride	Fluoride	Sulfate	TDS	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Fluoride	Lead	Lithium	Mercury	Molybdenum	Radium 226/228	Selenium	Thallium
		Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pCi/L	mg/L	mg/L
Sample ID	Date	Type																					
FB-1	4/16/2019	FB	0.100 U	0.200 U	3.00 U	0.500 U	5.00 U	10.0 U	----	----	0.00100 U	----	----	0.00200 U	0.0010 U	0.500 U	----	0.0200 U	----	0.00200 U	----	0.00500 U	----
FB-01	6/5/2019	FB	0.100 U	0.200 U	3.00 U	0.500 U	5.00 U	10.0 U	----	----	0.00100 U	----	----	0.00200 U	----	0.500 U	----	0.0200 U	----	0.00200 U	----	0.00500 U	----
FB-01	10/23/2019	FB	0.100 U	0.200 U	3.00 U	0.500 U	5.00 U	10.0 U	0.00200 U	0.00500 U	0.00100 U	0.00100 U	0.00100 U	0.00200 U	0.00100 U	0.500 U	0.00100 U	0.0200 U	0.000200 U	0.00200 U	0.485 U	0.00500 U	0.00100 U

Notes:

mg/L - milligram per liter

U - undetected at the reporting limit/concentration

J+ - estimated concentration, high bias indicated

FB - field blank

Table 6 Groundwater Analytical Data – Bottom Ash Pond 1 Groundwater Characterization Activities, Spring 2019

			Appendix III Constituents							Appendix IV Constituents							Geochemical Parameters		
		Analyte Name	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	TDS	Barium	Chromium	Cobalt	Fluoride	Lithium	Molybdenum	Selenium	Sodium	Magnesium	Total Alkalinity
		Unit	mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L as CaCO3
MW ID	Date	Type																	
MW-38C	4/16/2019	N	0.135 J-	94.3	47.2 J	0.893	7.53	320	755	0.0509 J-	0.0020 U	0.0010 UJ	0.893	0.0515	0.0268 J-	0.00513	55.9	34.8	197
MW-38C	4/16/2019	FD	0.137 J-	97.9	92.8 J	1.67	7.53	310	796	0.0500 J-	0.00200	0.00100 UJ	1.67	0.0471	0.0254 J-	0.00500 U	57.1	36.2	199
MW-54B	4/16/2019	N	0.100 UJ	44.4	17.5 J	0.918	7.69	95.6	398	0.0491 J-	0.00341	0.0010 UJ	0.92	0.0200 U	0.00507 J-	0.00608	21.3	16.5	149
MW-55B	4/16/2019	N	0.146 J-	106	85.3 J	0.842	7.65	320	853	0.125 J-	0.00808	0.00143 J-	0.842	0.0362	0.0164 J-	0.0252	33.7	43.4	160
MW-56B	4/16/2019	N	0.100 UJ	101	37.7 J	0.963	7.60	320	789	0.0840 J-	0.00463	0.00106 J-	0.963	0.0345	0.0160 J-	0.0187	27.6	37.9	168

Notes:
MW ID - monitoring well identifier
mg/L - milligram per liter
U - undetected at the reporting limit/concentration
UJ - undetected, reporting limit is estimated
J - estimated concentration, indeterminate bias indicated
J- - estimated concentration, low bias indicated
FD - field duplicate
N - primary sample

Appendix I

Groundwater Flow Calculations

Project:	Laramie River Station	CCR Unit:	Bottom Ash Pond 1	Background Wells:	MW-52B, MW-53B
Calculations by:	Gregg Somermeyer	Checked by:	Chris Ahrendt	Downgradient Wells:	MW-49B, MW-21B, MW-38B
Date:	1/10/2020	Date:	1/13/2020		

Hydrualic Gradient (i, ft/ft)

$$i = -{}^{dh}/_{dl}$$

where, i= hydraulic gradient
dh= change in hydraulic head between upgradient and downgradient locations
dl= horizontal distance between upgradient and downgradient locations, parallel to flow (perpendicular to potentiometric contours)

Date	Upgradient WL elevation (ft MSL)	Downgradient WL Elevation (ft MSL)	dh (ft)	dl (ft)	i (ft/ft)
June 2019	4495	4486.91	8.09	917	0.0088
October 2019	4495	4487.25	7.75	927	0.0084
				Minimum	0.0084
				Maximum	0.0088
				Average	0.0086

Hydraulic Conductivity (K, ft/d)

K, from slug and pumping tests		
Minimum	1.04	ft/day
Maximum	1.04	ft/day
Average (geomean)	1.04	ft/day

Specific Yield, Effective Porosity

Specific Yield, Effective Porosity	
Minimum	0.02
Maximum	0.3
Average	0.15

Note: Effective porosity/specific yield is based on literature values from Arikaree Formation literature and textbook values for sandstone

Seepage Velocity

$$v_s = {}^{-K * i}/_{n_e}$$

where, v_s= seepage velocity, feet per day (ft/d)
K= hydraulic conductivity, feet per day (ft/d)
i= hydraulic gradient, feet per foot (ft/ft)
n_e= effective porosity/specific yield, unitless

Calculated Seepage Velocities (ft/day)				
	K (ft/day)	i (ft/ft)	n_e	v_s (ft/day)
Minimum	1.04	0.0084	0.30	0.029
Maximum	1.04	0.0088	0.02	0.46
			Geometric Mean	0.12

Project:	Laramie River Station	CCR Unit:	Bottom Ash Ponds 2&3 and Ash Landfill	Background Wells:	MW-39B, MW-32B
Calculations by:	Gregg Somermeyer	Checked by:	Chris Ahrendt	Downgradient Wells:	MW-36B, MW-37B, MW-20B, MW-14BR, MW-40B, MW-52B, MW-53B
Date:	1/10/2020	Date:	1/13/2020		

Hydrualic Gradient (i, ft/ft)

$$i = -{}^{dh}/_{dl}$$

where, i= hydraulic gradient
dh= change in hydraulic head between upgradient and downgradient locations
dl= horizontal distance between upgradient and downgradient locations, parallel to flow (perpendicular to potentiometric contours)

Summary Table - Hydraulic Gradient

Date	Vector	Upgradient WL elevation (ft MSL)	Downgradient WL Elevation (ft MSL)	dh (ft)	dl (ft)	i (ft/ft)	Average i (ft/ft)
June 1, 2019	Vector 1 (32B)	4510.00	4473.57	36.43	4671	0.0078	0.0078
	Vector 2 (39B)	4505.00	4487.69	17.31	2345	0.0074	
	Vector 3 (48B)	4500.00	4469.53	30.47	3711	0.0082	
October 2019	Vector 1 (32B)	4511.96	4473.79	38.17	4770	0.0080	0.0081
	Vector 2 (39B)	4505.00	4488.06	16.94	2105	0.0080	
	Vector 3 (48B)	4500.00	4469.82	30.18	3710	0.0081	
						Minimum	0.0078
						Maximum	0.0081
						Average	0.0079

Hydraulic Conductivity (K, ft/d)

K from slug and pumping tests conducted at site		
Minimum	0.50	ft/day
Maximum	6.16	ft/day
Average (geomean)	1.54	ft/day

Specific Yield, Effective Porosity

Specific Yield, Effective Porosity	
Minimum	0.02
Maximum	0.3
Average	0.15

Note: Effective porosity/specific yield is based on literature values from Arikaree Formation literature and textbook values for sandstone

Seepage Velocity

$$v_s = {}^{-K * i}/_{n_e}$$

where, v_s= seepage velocity, feet per day (ft/d)
K= hydraulic conductivity, feet per day (ft/d)
i= hydraulic gradient, feet per foot (ft/ft)
n_e= effective porosity/specific yield, unitless

Calculated Seepage Velocities (ft/day)				
	K (ft/day)	i (ft/ft)	n_e	v_s (ft/day)
Minimum	0.50	0.0078	0.30	0.013
Maximum	6.16	0.0081	0.02	2.5
			Geometric Mean	0.18

Project: Laramie River Station
Calculations by: Gregg Somermeyer
Date: 1/10/2020

CCR Unit: Emergency Holding Ponds
Checked by: Chris Ahrendt
Date: 1/13/2020

Background Wells: MW-41B, MW-42B, MW-43B
Downgradient Wells: MW-44B, MW-45B, MW-46B, MW-47B

Hydrualic Gradient (i, ft/ft)

Governing Equation:
(Hydrualic Gradient)

$$i = -{}^{dh}/_{dl}$$

where, i= hydraulic gradient
dh= change in hydraulic head between upgradient and downgradient locations
dl= horizontal distance between upgradient and downgradient locations, parallel to flow (perpendicular to potentiometric contours)

Calculation Table

Date	Vector	Upgradient WL elevation (ft MSL)	Downgradient WL Elevation (ft MSL)	dh (ft)	dl (ft)	i (ft/ft)	Average i (ft/ft)
June 2019	Vector 1 (42B)	4470.52	4455.00	15.52	1027	0.0151	0.0176
	Vector 2 (43B)	4473.57	4450.00	23.57	1175	0.0201	
October 2019	Vector 1 (42B)	4472.24	4455.00	17.24	1081	0.0159	0.0188
	Vector 2 (43B)	4475.40	4450.00	25.40	1178	0.0216	
						Minimum	0.0176
						Maximum	0.0188
						Average	0.0182

Hydraulic Conductivity (K, ft/d)

K from slug and pumping tests conducted at site		
Minimum	0.75	ft/day
Maximum	3.12	ft/day
Average (geomean)	1.31	ft/day

Specific Yield, Effective Porosity

Specific Yield, Effective Porosity	
Minimum	0.02
Maximum	0.3
Average	0.15

Note: Effective porosity/specific yield is based on literature values from Arikaree Formation literature and textbook values for sandstone

Seepage Velocity

$$v_s = {}^{-K \, * \, i}/_{n_e}$$

where, v_s= seepage velocity, feet per day (ft/d)
K= hydraulic conductivity, feet per day (ft/d)
i= hydraulic gradient, feet per foot (ft/ft)
n_e= effective porosity/specific yield, unitless

Calculated Seepage Velocities (ft/day)				
	K (ft/day)	i (ft/ft)	n_e	v_s (ft/day)
Minimum	0.75	0.0176	0.30	0.04
Maximum	3.12	0.0188	0.02	2.9
			Geometric Mean	0.36