# Placement Above the Uppermost Aquifer Determination

## *Lewis & Clark Station*

Prepared for
Montana-Dakota Utilities Co.

October 2018

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# Placement Above the Uppermost Aquifer Determination
# Lewis & Clark Station

## October 2018

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## Certifications

I hereby certify that this Placement Above the Uppermost Aquifer Determination for the Lewis & Clark Station meets the requirements of the Coal Combustion Residuals Rule 40 CFR 257 Subpart D and the requirements of 40 CFR §257.60. Furthermore, I certify that the constructed elevation of the base of the CCR unit complies with the alternative separation distance above the uppermost aquifer established in this report.

Paul T. Swenson
Barr Engineering Co.
MT Registration Number 12805PE

Dated this 17th day of October 2018

# 1.0 Introduction

Montana-Dakota Utilities Co. (MDU) operates the Lewis & Clark Station (Lewis & Clark), a coal-fired steam-electric generating plant, near Sidney, Montana to produce electrical energy. Coal combustion residuals (CCR) is a by-product of plant operation. Management of CCR produced by electric utilities is subject to the requirements of 40 CFR 257 Subpart D, Disposal of Coal Combustion Residuals From Electric Utilities (CCR Rule).

Flue-gas desulfurization solids and fly ash are captured by the plant's air quality control equipment, which is then slurried to a surface impoundment known as the Scrubber Ponds for settling and further management. The Scrubber Ponds are subdivided into the East and West Scrubber Ponds, a single, multi-unit CCR unit, which has been designated an existing surface impoundment under the CCR Rule.

US Environmental Protection Agency (US EPA) 40 CFR Parts 257 and 261, Disposal of Coal Combustion Residuals From Electric Utilities (CCR Rule), requires a separation between the base of existing and new CCR surface impoundments and the upper limit of the uppermost aquifer in §257.60. The CCR Rule requires a separation of no less than five feet unless a demonstration is made for an alternative, site-specific groundwater separation requirement. The base of the CCR unit is defined as the bottom surface of the CCR unit liner.

## 1.1 Purpose

This report demonstrates compliance with an alternative separation distance between the base of the Scrubber Ponds and the upper limit of the uppermost aquifer under the CCR Rule. Analysis of groundwater separation requirements contained in US EPA 40 CFR Part 257, as it applies to the Lewis & Clark Station Scrubber Ponds and site conditions at the Scrubber Ponds, is included in this report to support the demonstration. This demonstration includes evaluation of historic groundwater elevation records collected from site monitoring wells and other site factors that may affect potential groundwater elevations.

## 1.2 Conclusion

Based on review of available site data, an alternative separation distance between the base of the Scrubber Ponds and the upper limit of the uppermost aquifer (also referred to in the preamble of the rule and this memorandum as the wet season water table) is appropriate under the CCR Rule. We conclude that the appropriate separation distance for all portions of the base of the CCR unit and the uppermost aquifer, taking into account normal fluctuations in groundwater elevations (including the seasonal high water table) is a minimum of two feet. Furthermore, we conclude that the base of the CCR unit complies with the alternative separation distance established in this report. Therefore, we conclude that there will not be "an intermittent, recurring, or sustained hydraulic connection" between any portion of the base of the CCR unit and the uppermost aquifer, per 40 CFR §257.60(a).

# 2.0 Demonstration

This section describes the data analysis and other considerations used to demonstrate that an intermittent, recurring, or sustained hydraulic connection between any portion of the base of the CCR unit and the uppermost aquifer due to normal fluctuations in groundwater elevations (including groundwater elevations during the wet season) will not occur and the existing CCR unit base elevation meets the minimum separation requirements.

## 2.1 Data Analysis

Available groundwater elevation measurements for wells around the Scrubber Ponds were reviewed for data analysis. Monitoring wells around the Scrubber Ponds (identified below in this section) are shown on Figure 1. Groundwater elevation measurements were included in the analysis if the following conditions were satisfied:

- The recorded depth to water measurement was available for review.
- The water level measurement was recorded from the uppermost aquifer. For example, monitoring well MW-210 shown on Figure 1 is not screened in the uppermost aquifer.
- More than five water level measurements (i.e., observations) should be available for review to assess the dataset for statistical significance. For example, monitoring well MW-120 shown on Figure 1 was installed in 2018 and only two water level measurements have been collected.

When these criteria were taken into account, all wells within 500 feet of the Scrubber Ponds, except for MW-120 and MW-210, were used in this analysis.

To ensure that our analysis accounted for fluctuations in the wet season water table, we performed a statistical analysis on the groundwater elevation data to determine the potential range of groundwater elevations at the Scrubber Ponds.

Any statistical analysis needs to be conducted on a dataset that is consistent within itself. A key aspect of groundwater elevation analysis is the basis of the measurements. Wells were surveyed by Uintah Engineering and Land Surveying in August 2015 to establish a common datum for all monitoring wells used in this analysis. Validity of the water elevation data was assessed by examining historic field data sheets that also recorded the total depth of the wells. All valid depth to groundwater measurements were adjusted to the North American Vertical Datum of 1988 (NAVD88) and only reliable data were used in the statistical analysis conducted to prepare this report.

The period of record for data used in the analysis varied by well, depending on when the well was installed and availability of information to verify that a common datum was used for all measurements from each monitoring well. The longest period of record began in June 2009 and ended in June 2018 (MW-102, MW-106, MW-110, and MW-111), with between 24 to 26 measurements at each well. The next longest period (MW-101, MW-103, MW-105, MW-107, MW-108, MW-109, and MW-116) began in June 2013 and ended in May 2018 with 14 to 17 measurements at each well. The shortest period of record

(MW-117, MW-118, and MW-119) began in March 2016 and ended in August 2018 with 12 to 13 measurements at each well.

Table 1 lists the wells for which groundwater elevation measurements were included in the statistical analysis. Statistical analysis was conducted using ProUCL, a statistical software package published by the US EPA (2017), to verify the normality of the data. Once the data was determined to be normally distributed, ProUCL was used to determine the mean and standard of deviation for groundwater elevations at each monitoring well.

Nearly the entire distribution of a normal population (99.74 percent) is captured within three times the standard of deviation above and below the mean of the population. The upper limit of the mean plus three times the standard of deviation is taken to be the upper limit of the uppermost aquifer for purposes of complying with requirements in the rule.

It was found that the location exhibiting the highest groundwater elevations near the Scrubber Ponds is at monitoring well MW-101. Groundwater elevations at this well are the highest of the monitoring wells that are in close proximity to the Scrubber Ponds (see Table 1). Sixteen groundwater elevation measurements are available at well MW-101, covering a time frame of June 2013 through May 2018. The mean groundwater elevation at well MW-101 is 1916.95 feet NAVD88, with a standard of deviation of 0.47 foot. The mean elevation plus three times the standard of deviation is approximately elevation 1918.4 feet NAVD88.

## 2.2 Application of Data and Analysis

The rule requires a buffer between the upper limit of the uppermost aquifer and the base of the CCR unit, but allows for establishing a site-specific standard, as described above.

This report demonstrates that a dimension of two feet is an appropriate separation to establish the buffer. Two feet is greater than three times the standard of deviation at 13 of the 14 wells on which the statistical analysis was conducted, meaning that it allows more than double the normally distributed groundwater elevation deviation from the mean elevation. Three times the standard of deviation at monitoring well MW-116 is 2.87 feet. Monitoring well MW-116 is greater than 500 feet from the Scrubber Ponds, is located in a topographic low area northeast of the Sewage Pond, and does not affect our understanding of the groundwater table below the Scrubber Ponds.

Establishing a two-foot buffer satisfies the criterion that "there will not be an intermittent, recurring, or sustained hydraulic connection between any portion of the base of the CCR unit and the uppermost aquifer due to normal fluctuations in groundwater elevations." When a buffer of two feet is added to the statistical analysis presented in Section 2.1 (mean elevation plus three times the standard of deviation), a top of buffer elevation of 1920.4 feet NAVD88 at MW-101 is justified. Top of buffer in this document refers to the surface that is defined by the mean elevation at each well, plus three times the standard of deviation at each well, plus two feet.

### 2.2.1 Site Geology

A consideration in establishing a site-specific groundwater separation standard is how site geology may affect groundwater conditions. The Lewis & Clark Station Groundwater Characterization and Monitoring report (Barr, February 2015) included monitoring well and soil boring logs previously completed by MDU, pilot boring logs completed in 2011 by Barr, and a geological and hydrogeological description of the Site. Figure 2 shows the location of cross-section A-A'. Monitoring well logs (MW-101, MW-103, MW-105, MW-107, and MW-109) are shown on the geological cross-section (Figure 2). The monitoring well, soil boring, and pilot boring logs encountered geological unconsolidated alluvial deposits underlain by bedrock inferred to be the Fort Union Formation. The geology shown on Figure 2 is defined as follows:

- **Fill.** Non-native material, which was placed in a controlled fashion.
- **Fine Alluvium and Coarse Alluvium.** Silt and clay (fine) unconsolidated alluvial deposits and sand and gravel (coarse) unconsolidated deposits.
- **Silt/Siltstone and Clay/Claystone Bedrock.** A dark gray consolidated deposit interbedded with seams of lignite inferred to be bedrock (Fort Union Formation).

Groundwater flow beneath the Scrubber Ponds primarily occurs within the alluvium because this unit is more permeable than the underlying bedrock.

### 2.2.2 Site Hydrology and Hydrogeology

Surficial waterbodies on or near the Site include the Scrubber Ponds, the Sewage Lagoon, the Water Retention Pond, Drainage Ditch #12, and the Yellowstone River, as shown on Figure 1. The Scrubber Ponds are described above. The Sewage Lagoon and Water Retention Pond are located north and northeast of the Scrubber Ponds. Drainage Ditch #12 is located north of the Scrubber Ponds, running east toward the Yellowstone River. The Yellowstone River is located south and east of the Scrubber Ponds and runs from southwest to northeast.

The drainage ditch and the river offer little aquifer recharge capacity since they likely form hydraulic flow boundaries. Recharge either occurs from precipitation directly on the site or groundwater flow from a relatively narrow zone west and south of the site with fairly flat topography.

#### 2.2.2.1 Groundwater Elevations

A hydrograph of historical groundwater elevations collected from the monitoring wells surrounding the Scrubber Ponds for the period of 2009 through 2018 is included on Figure 3. The hydrograph shows groundwater elevations roughly rise and fall concurrently, which indicates hydrologic connection among the wells.

#### 2.2.2.2 Groundwater Flow

A groundwater contour map was created using the mean groundwater elevation plus three times the standard of deviation for the wells shown on Figure 1. Groundwater flow is to the north toward Drainage

Ditch #12 and to the east toward the Yellowstone River. A USGS stream gage (06329500) in the Yellowstone River and a stream gage installed in Drainage Ditch #12 were used to determine the range of water elevations in the river and in the ditch, respectively (Figure 1).

Characteristics of the subsurface hydraulic conductivities have been collected and analyzed. Slug test results for monitoring wells MW-110 (upgradient) and MW-111 (downgradient) are provided in Appendix 1 and are shown in Table 2.

The hydraulic conductivity of the alluvium deposits in eastern Montana, based on published data, ranges from about 1 x $10^{-2}$ cm/sec to 1 x $10^{-4}$ cm/sec (Smith et al., 2000). The hydraulic conductivities determined using slug-in and slug-out tests, ranging from 1.3 x $10^{-3}$ to 8.8 x $10^{-4}$, are within the published data range for a clean to silty sand. Therefore, soils at the site are anticipated to readily drain and limit the amount of fluctuation in groundwater elevations.

As shown on Figure 1, the groundwater surface exhibits a downward gradient from MW-101 toward the footprint of the Scrubber Ponds.

## 2.3 Other Considerations Supporting the Site-Specific Standard

Other factors that contribute to the determination presented in this memorandum include:

- The Scrubber Ponds are located on a strip of high ground between the Yellowstone River on one side and an irrigation/drainage ditch on the other. Both the river and the ditch provide low-elevation drains for site groundwater, limiting groundwater surface fluctuation under the ponds. Floods on the Yellowstone River and in the irrigation ditch will not have a significant impact on groundwater elevations under the Scrubber Ponds. Since extreme events (the flood of record and the 100-year flood elevation) will not significantly affect groundwater elevations, lesser events will have little influence on groundwater elevations, providing assurance that there "will not be an intermittent, recurring, or sustained hydraulic connection between any portion of the base of the CCR unit and the uppermost aquifer due to normal fluctuations in groundwater elevations." Figure 2 provides a cross-section of the site to illustrate the comparative elevations. Information on surface water around the plant site includes:
    - The US National Oceanic and Atmospheric Administration, Nation Weather Service and US Geologic Survey (USGS) maintain a gaging station on the Yellowstone River adjacent to the Lewis & Clark Station. The record flood at the Sidney USGS gage, based on gage period of record (1911 to present), is elevation 1907.0 feet NAVD88, much lower than the minimum CCR unit base elevations shown on Figure 4. It is also much lower than the mean groundwater elevation in wells nearest the Scrubber Ponds [ranging from 1914.07 (MW-102) to 1916.95 (MW-101) feet MSL, or a separation of seven to ten feet lower than mean groundwater], meaning that floods on the river will have little impact on groundwater elevations under the Scrubber Ponds.

- Flood elevations for the ditch are not documented; however, the ditch thalweg is approximately elevation 1909 feet NAVD88 (significantly lower than the minimum CCR unit base elevation and groundwater under the Scrubber Ponds). The ditch is high enough for water to drain to the river even under high river flood conditions. Floods along the ditch would only result from local hydrologic events and would have a relatively short duration. This again leads to the conclusion that floods will not have a significant impact on groundwater elevations under the Scrubber Ponds.

- Federal Emergency Management Administration (FEMA) information for the Sidney area was reviewed. FEMA has not prepared a detailed flood insurance risk map (FIRM) study for the plant site. The nearest location where a FIRM shows a detailed study flood elevation is at the confluence of Lone Tree Creek with the Yellowstone River, approximately 1½ miles to the east of the plant site. The 100-year flood at the confluence is 1907 feet NAVD88. The 100-year flood adjacent to the Scrubber Ponds would be somewhat higher than this and still much lower the CCR unit base elevation and site groundwater elevations.

- Recharge to the aquifer at the Scrubber Ponds can only come from precipitation at the site and groundwater flow from a relatively narrow source to the south and west of the Scrubber Ponds. Since the area south and west of the site is approximately at the same elevation as the site, little gradient is available to drive groundwater to the site, so groundwater flow toward the Scrubber Ponds is likely to be slow.

- The lower component of the composite liner is constructed from low permeability material that would not readily transmit water (thus creating a hydraulic connection) to the waste unless it were below groundwater for a period of years. Based on the information provided in this summary, such groundwater conditions have not occurred in the history of recorded data for the Yellowstone River or at the site.

- The CCR Rule frequently points to generally accepted good engineering practice as the standard for design and evaluation of CCR units. A basis to establish generally accepted good engineering practice for groundwater separation at Lewis & Clark Station is to apply relevant State of Montana regulatory requirements for similar facilities. While Montana issues Montana Pollutant Discharge Elimination System (MPDES) permits for water discharges from CCR surface impoundments, the state does not issue solid waste or lined pond permits or licenses for CCR units. For solid waste facilities that are permitted by the state, the rules require that there be an "adequate" separation between the liner and groundwater. Adequate is taken to mean essentially the same requirement as stated in the CCR Rule, that there "will not be an intermittent, recurring, or sustained hydraulic connection between" any portion of the solid waste facility and groundwater.

- To further aid in understanding acceptable separation requirements, the groundwater separation standard for Montana-licensed industrial solid waste facilities was reviewed for guidance. The Montana rules state that there must be "adequate" separation between groundwater and the landfill liner. Adequate separation is taken here to mean that the separation will prevent contact between groundwater and the solid waste facility liner under normal conditions, similar to the intent of the requirements established in the CCR Rule. Therefore, state solid waste facility license requirements would support a site-specific separation standard.

# 3.0 Existing CCR Unit Base Elevation Determination

Base elevations for the existing Scrubber Ponds surface impoundment at Lewis & Clark and contours depicting the top of the buffer are shown on Figure 4. Base of CCR unit elevations and contours were developed from record surveys. The buffer contours were developed by creating a three-dimensional model based on the calculated top of buffer elevation at each of the wells, as described above.

As shown on this figure, six locations have been identified as the critical locations to examine in determining whether the base of the CCR unit is positioned above the top of the buffer. The locations are at the ends of the north and south flume wall in each of the ponds (the lowest elevations in each of the ponds), and the corner of each pond to the south of the flumes. As shown on the figure, the surveyed base of the CCR unit is compared to the top of buffer surface; the base of the CCR unit is at least 0.7 foot higher than the top of buffer. Greater separation exists at all other locations within the Scrubber Ponds. Therefore, the base of the CCR unit has been demonstrated to be constructed at elevations that exceed the minimum required to satisfy separation requirements established in this report.

# 4.0 Summary of Analysis

This section provides a summary of the key results of the site and groundwater analysis.

- The period of record used for the groundwater data analysis was at least four years and as many as nine years, with at least ten measurements collected for each of the wells that are nearest the Scrubber Ponds and therefore most critical to establishing a design water table.
- The standard of deviation for the well (MW-101) is 0.47 foot. Three times the standard of deviation (which covers nearly the entire normal groundwater elevation distribution) is 1.41 feet.
- The Yellowstone River south of the Scrubber Ponds and the irrigation ditch north of the Scrubber Ponds are located at elevations that are lower than the mean groundwater elevations in the monitoring wells near the Scrubber Ponds, thus providing a location for groundwater to discharge even in flood conditions.
- Flood elevations on the Yellowstone River are seven to ten feet lower than mean groundwater around the Scrubber Ponds.
- Site geologic conditions include soils with a hydraulic conductivity of $1.3 \times 10^{-3}$ to $8.8 \times 10^{-4}$ cm/sec, which is a relatively hydraulically conductive soil, meaning that groundwater readily flows to drains (the ditch and the Yellowstone River) and limits the amount of fluctuation in groundwater elevations.
- Hydrogeologic conditions at the site offer little aquifer recharge capacity. Recharge either occurs from precipitation directly on the site or groundwater flow from a relatively narrow zone west and south of the site with fairly flat topography.
- The proposed two-foot buffer establishes a minimum base of CCR unit elevation surface that more than doubles the range of normal distribution of groundwater elevations that might be expected (approximately three times the standard of deviation).
- State rules for similar facilities require that separation to groundwater be “adequate,” a requirement that is considered in establishing the generally accepted good engineering practice for facilities in the region around Lewis & Clark Station.

As a result of these observations and analyses, a site-specific groundwater separation standard including a two-foot buffer above the mean groundwater elevation plus three times the standard of deviation is sufficient to demonstrate there will not be an intermittent, recurring, or sustained hydraulic connection between any portion of the base of the CCR unit and the uppermost aquifer due to normal fluctuations in groundwater elevations (including the seasonal high water table) between the base of the CCR unit and the upper limit of the uppermost aquifer at the Scrubber Ponds. With the minimum elevations for the base of the CCR unit compared to the top of buffer elevations shown on Figure 4, the unit meets the separation requirements for site-specific conditions established in this report.

# 5.0 References

Barr Engineering Co., 2015. Lewis & Clark Station Groundwater Characterization and Monitoring. Prepared for Montana Dakota Utilities, February 2015.

Smith et al., 2000. Ground-water resources of the Lower Yellowstone River Area: Dawson, Fallon, Prairie, Richland, and Wibaux Counties, Montana Part A – Descriptive Overview and Basic Data. Montana Bureau of Mines and Geology.

US EPA, 2017. Statistical Software ProUCL 5.1.00 for Environmental Applications for Data Sets with and without Nondetect Observations < https://www.epa.gov/land-research/proucl-software

USGS, 2017. Yellowstone River near Sidney MT, USGS Current Conditions For Montana, *Gage* 0632950022 March 2017.< https://waterdata.usgs.gov/mt/nwis/uv?> https://waterdata.usgs.gov/mt/nwis/uv?cb_00065=on&format=html&site_no=06329500&period=&begin_date=2017-03-23&end_date=2017-03-30

# Tables

## Table 1 Groundwater Elevation Statistical Analysis

| Description | Mean | Standard Deviation | Mean Plus 3 x Standard Deviation | Observations (n) |
|---|---|---|---|---|
| MW-101 | 1916.95 | 0.47 | 1918.4 | 16 |
| MW-102 | 1914.07 | 0.60 | 1915.9 | 24 |
| MW-103 | 1916.65 | 0.41 | 1917.9 | 17 |
| MW-105 | 1915.56 | 0.35 | 1916.6 | 16 |
| MW-106 | 1915.21 | 0.32 | 1916.2 | 24 |
| MW-107 | 1916.22 | 0.30 | 1917.1 | 16 |
| MW-108 | 1900.36 | 0.44 | 1901.7 | 16 |
| MW-109 | 1916.17 | 0.41 | 1917.4 | 17 |
| MW-110 | 1917.06 | 0.47 | 1918.5 | 26 |
| MW-111 | 1915.04 | 0.31 | 1916.0 | 25 |
| MW-116 | 1906.53 | 0.96 | 1909.4 | 14 |
| MW-117 | 1914.14 | 0.55 | 1915.8 | 13 |
| MW-118 | 1915.36 | 0.21 | 1916.0 | 12 |
| MW-119 | 1917.14 | 0.42 | 1918.4 | 12 |

Note:

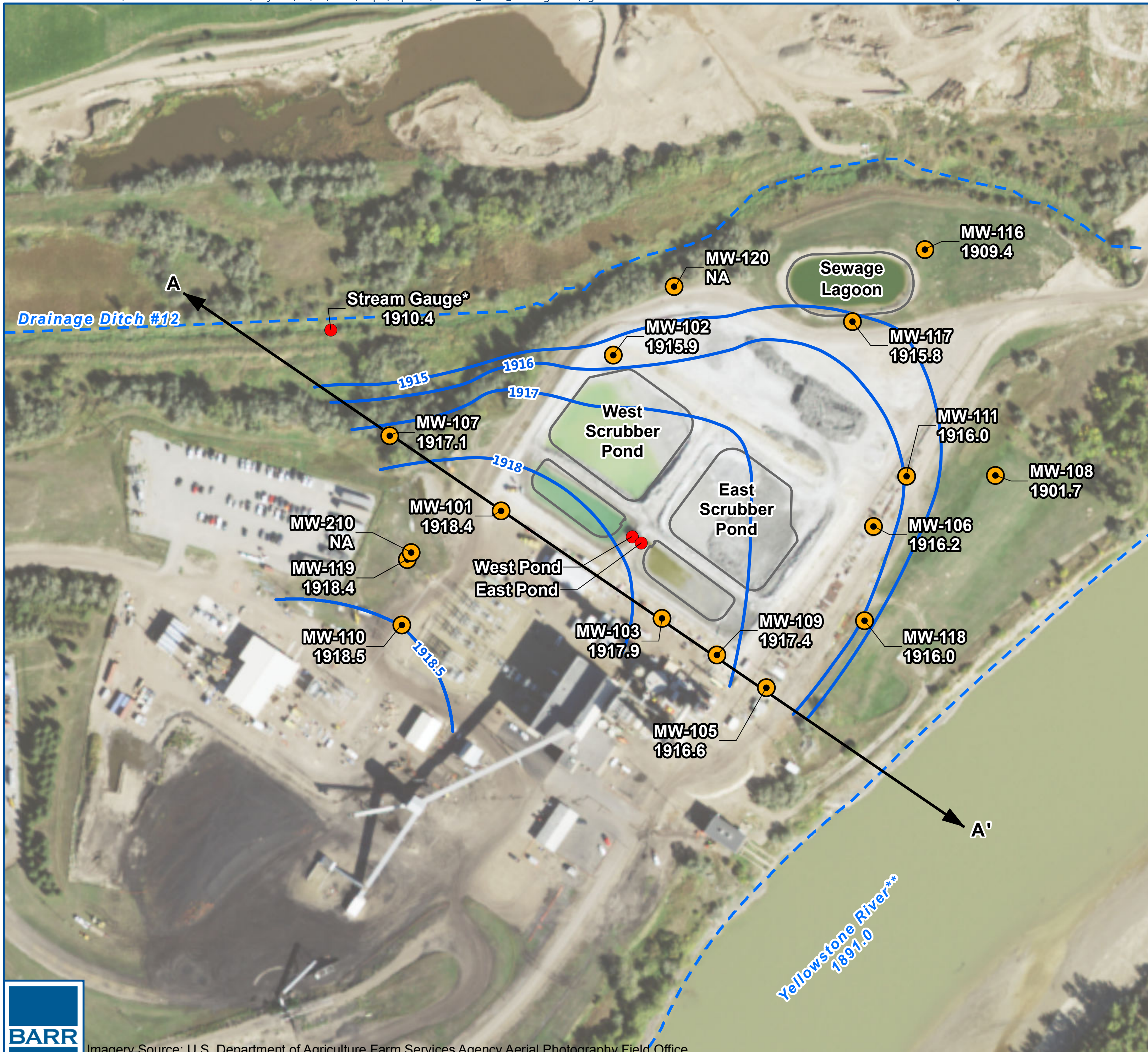
MW-120 was recently installed and < 5 observations have been recorded, therefore is not shown.

MW-210 does not monitor the uppermost aquifer, therefore is not shown.

**Table 2 Slug Test Results**

| Well | Monitored Unit | Hydraulic Conductivity Slug-In (cm/s) | Hydraulic Conductivity Slug-Out (cm/s) |
|---|---|---|---|
| MW-110 | Water table, upgradient | $1.3x10^{-3}$ | $1.5x10^{-3}$ |
| MW-111 | Water table, downgradient | $1.6x10^{-3}$ | $8.8x10^{-4}$ |

# Figures




Gauge Location

Monitoring Well Location

Cross Section Location

Groundwater Contours (ft. MSL)

Stream/River

Ponds

Note:

* Stream gauge measured on 7/28/2016

** Average elevation obtained from historical and present data from nearby USGS gaging station.

NA - Not available. Less than 5 water levels available or is a deep monitoring well

Projected groundwater elevations found by taking the mean elevation plus three times the standard deviation.

Groundwater elevations use available data from 6/22/09 to 8/27/2018. See Well Hydrograph on Figure 3 for the groundwater elevation record.

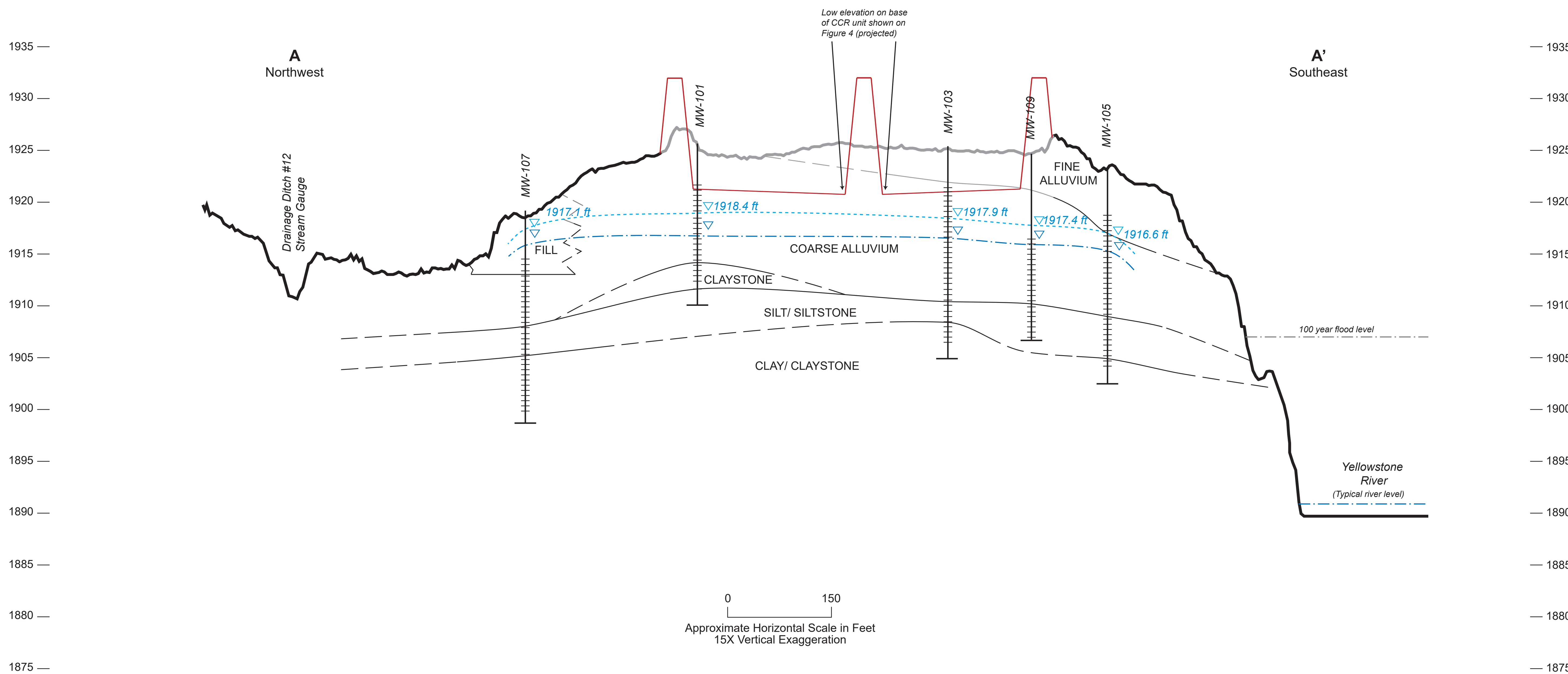
Projected groundwater contours not shown below elevation 1915 ft.

0 125 250

Feet

MEAN + 3STD GROUNDWATER ELEVATIONS
Lewis and Clark Station
Montana Dakota Utilities
Richland County, Montana

FIGURE 1




LEGEND

- Geologic Contact
- Inferred Geologic Contact
- Approximate Average Water table + 3x Standard Deviation
- Approximate Average Water table
- Monitoring Well Screen
- Soil Boring/Piezometer
- Record Base of Retrofit Scrubber Ponds

***Notes:***

*-Stream gauge location adjusted to the East for clarity of presentation.*

*-Elevation data based on NAVD88.*

*-River elevation based on USGS stream gauge 06329500.*

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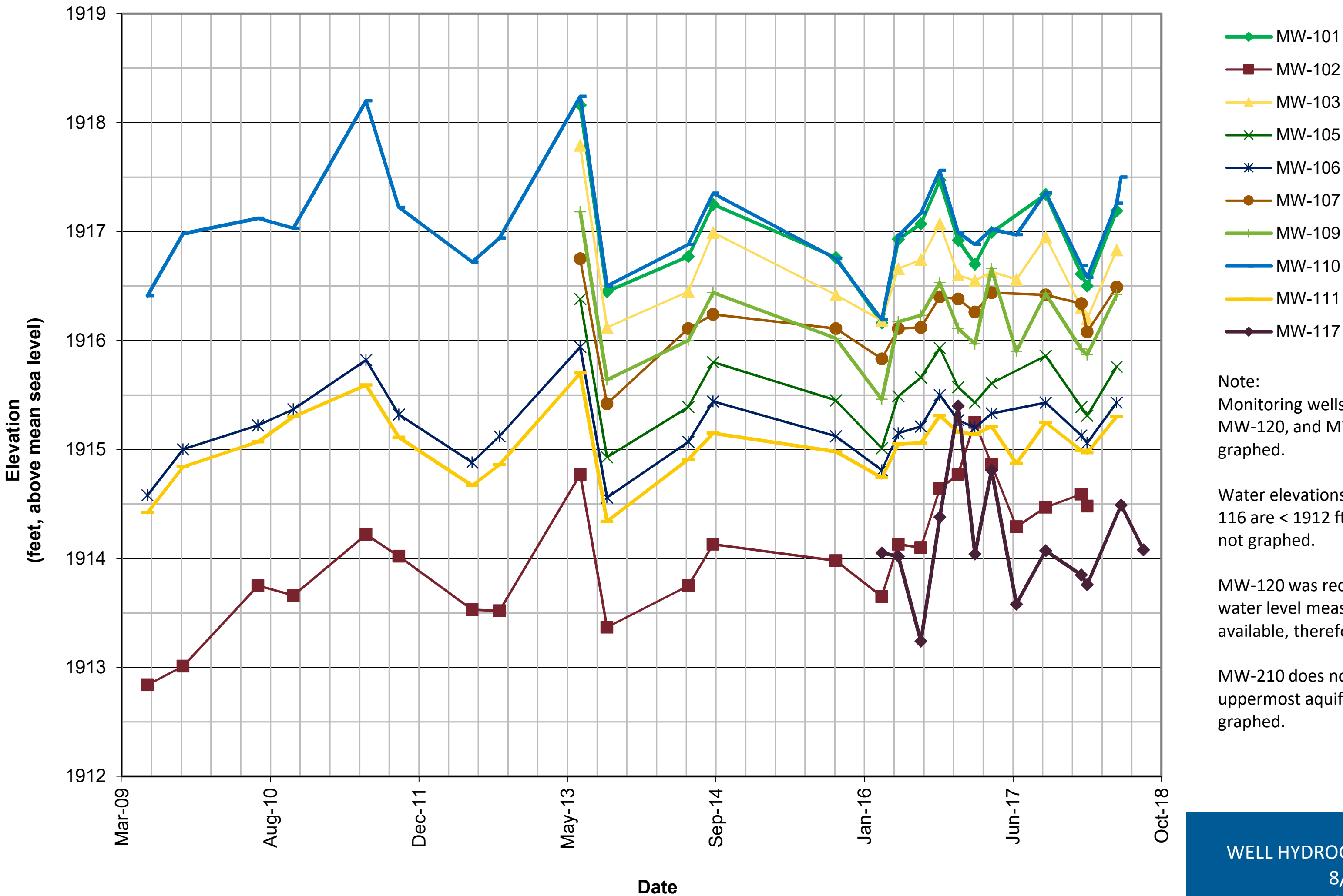
GEOLOGIC CROSS SECTION A-A'
Lewis & Clark Station
Montana Dakota Utilities
Richland County, Montana




Note:
Monitoring wells MW-108, MW-116, MW-120, and MW-210 are not graphed.

Water elevations in MW-108 and MW-116 are < 1912 ft MSL, therefore are not graphed.

MW-120 was recently installed and < 5 water level measurements are available, therefore is not graphed.

MW-210 does not monitor the uppermost aquifer, therefore is not graphed.

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WELL HYDROGRAPH (6/22/09 to 8/27/18)
Lewis & Clark Station
Sidney, MT
Montana Dakota Utilities

FIGURE 3

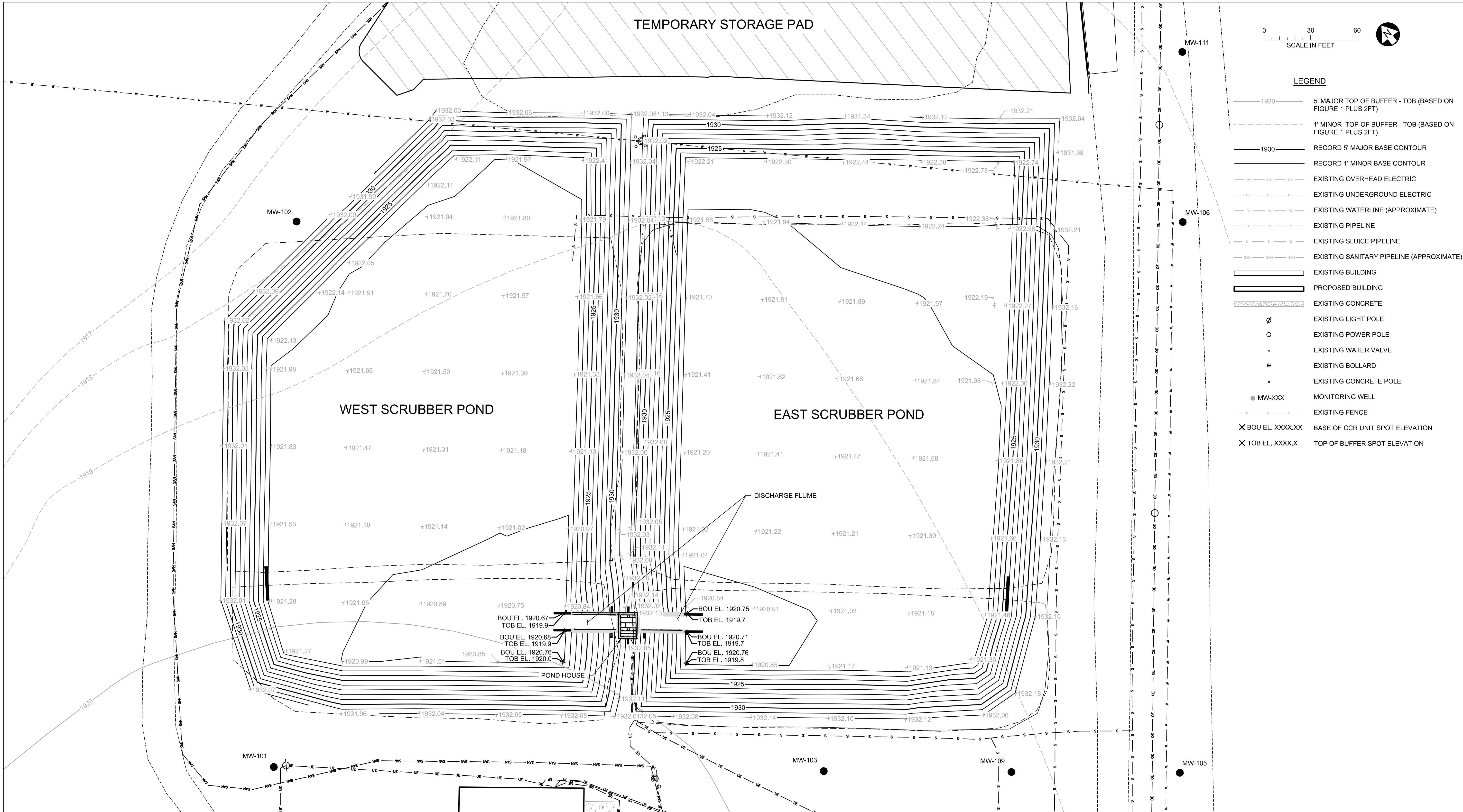


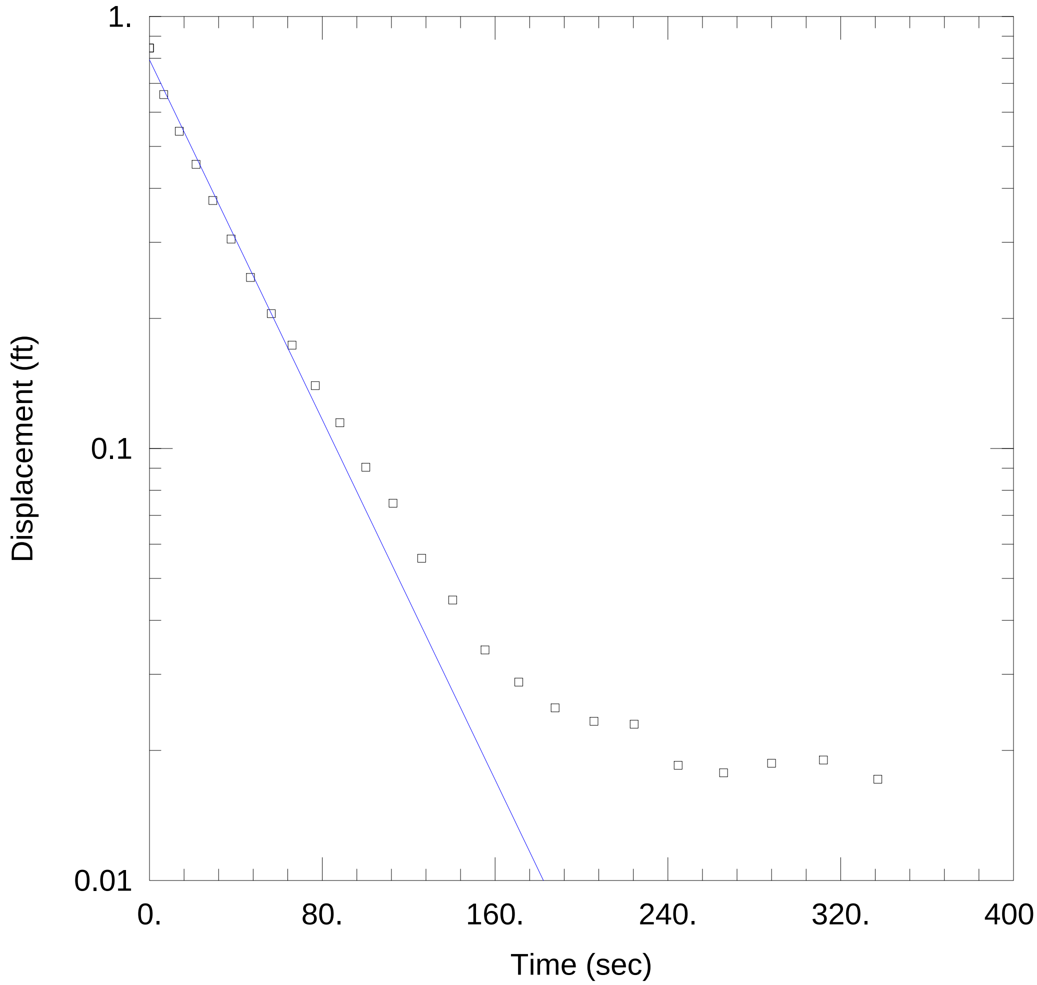

FIGURE 4
RECORD BASE OF CCR UNIT

LEWIS AND CLARK STATION
MONTANA-DAKOTA UTILITIES
RICHLAND COUNTY, MONTANA

# Appendices

# Appendix 1

## Slug Test Results




MW-110 FALLING HEAD SLUG TEST (SLUG-IN)

Data Set: \...\MW-110 Slug IN.aqt
Date: 08/10/16 Time: 10:56:35

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: MDU
Project: 26411005
Location: Sidney, MT
Test Well: MW-110
Test Date: Feb 11, 2016

AQUIFER DATA

Saturated Thickness: 6.62 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW-110)

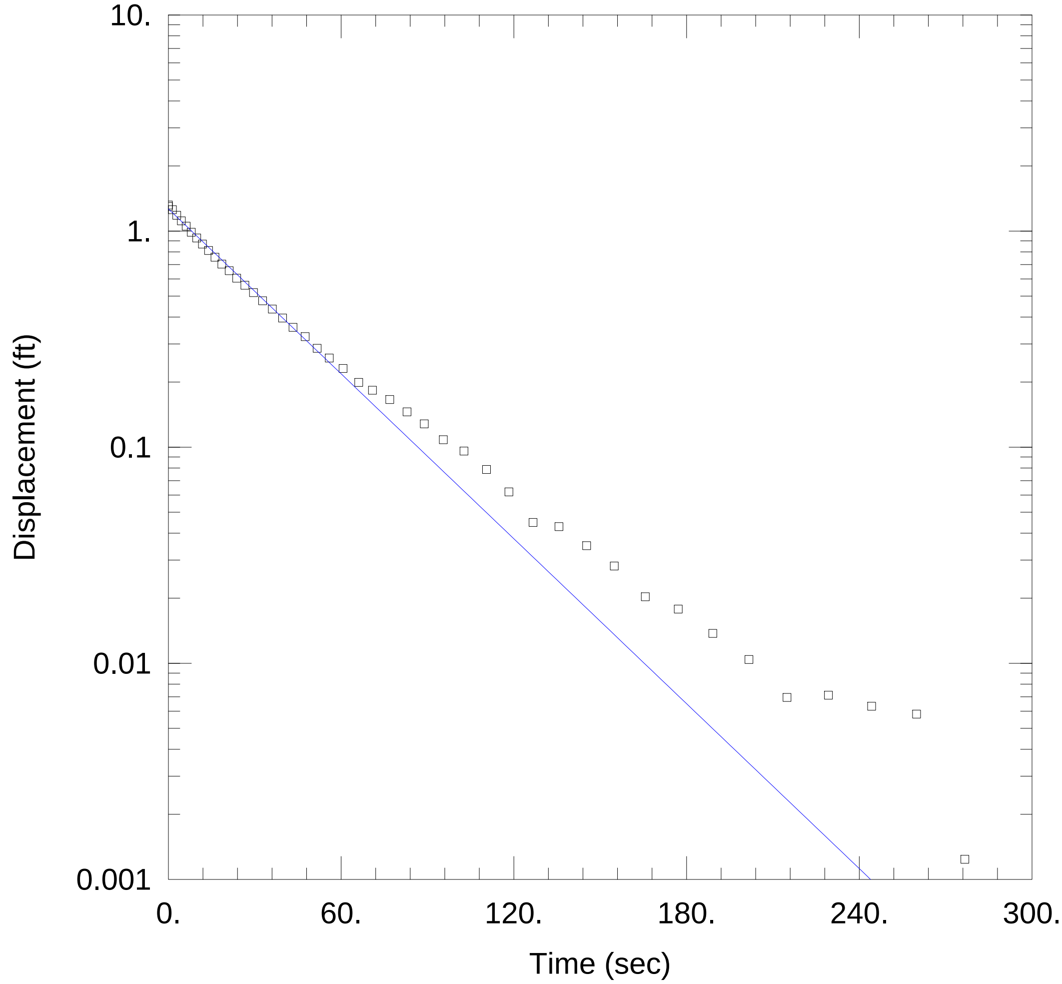
Initial Displacement: 0.845 ft
Total Well Penetration Depth: 6.62 ft
Casing Radius: 0.083 ft

Static Water Column Height: 6.62 ft
Screen Length: 6.62 ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.00128 cm/sec y0 = 0.7935 ft




MW-110 RISING HEAD SLUG TEST (SLUG-OUT)

Data Set: \...\MW-110 Slug Out.aqt
Date: 08/10/16 Time: 10:58:17

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: MDU
Project: 26411005
Location: Sidney, MT
Test Well: MW-110
Test Date: Feb 11, 2016

AQUIFER DATA

Saturated Thickness: 6.62 ft
Anisotropy Ratio (Kz/Kr): 1.

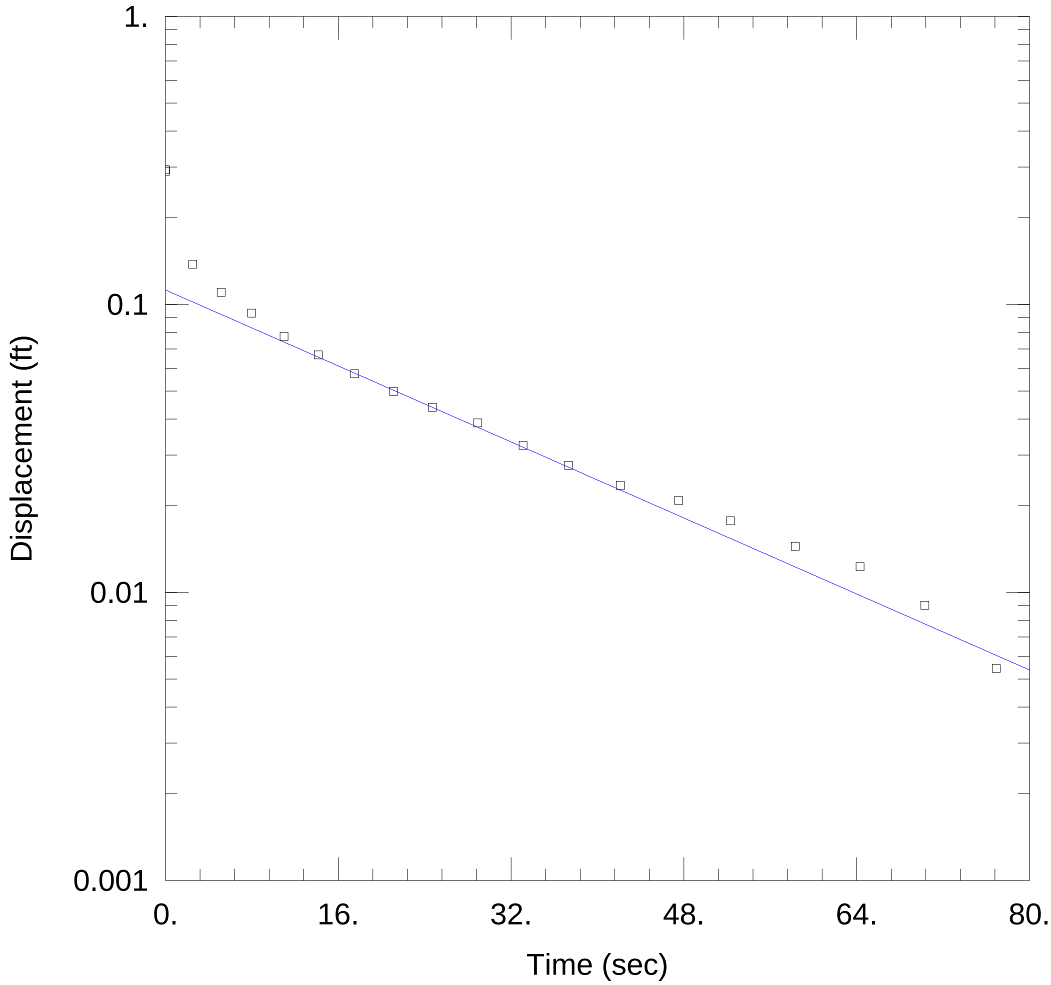
WELL DATA (MW-110)

Initial Displacement: 1.3 ft
Total Well Penetration Depth: 6.62 ft
Casing Radius: 0.083 ft
Static Water Column Height: 6.62 ft
Screen Length: 6.62 ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.001563 cm/sec
y0 = 1.266 ft




MW-111 FALLING HEAD SLUG TEST (SLUG-IN)

Data Set: \...\MW-111 Slug In.aqt
Date: 08/10/16
Time: 11:07:08

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: MDU
Project: 26411005
Location: Sidney, MT
Test Well: MW-111
Test Date: Feb 11, 2016

AQUIFER DATA

Saturated Thickness: 9.21 ft
Anisotropy Ratio (Kz/Kr): 1.

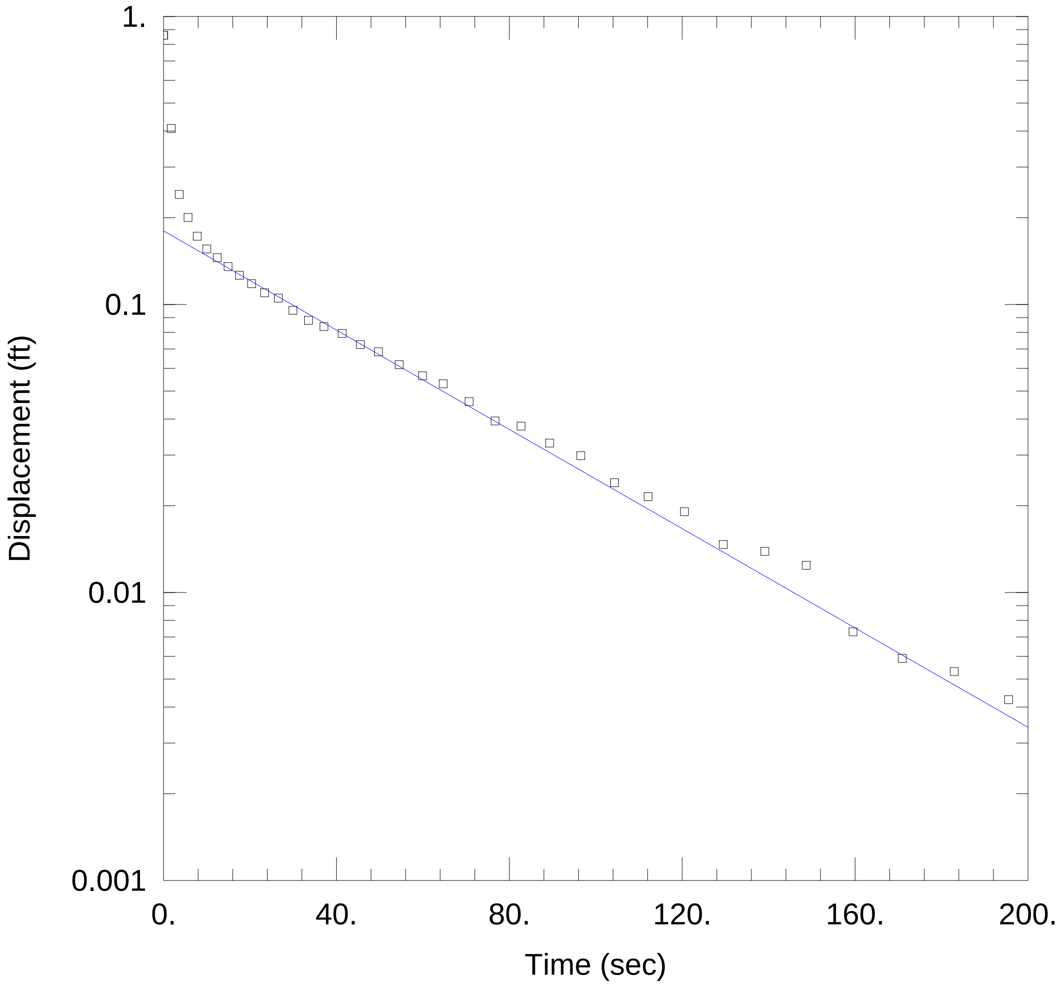
WELL DATA (MW-111)

Initial Displacement: 0.29 ft
Total Well Penetration Depth: 9.21 ft
Casing Radius: 0.08612 ft
Static Water Column Height: 9.21 ft
Screen Length: 9.21 ft
Well Radius: 0.08612 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.001677 cm/sec
y0 = 0.1123 ft




MW-111 RISING HEAD SLUG TEST (SLUG-OUT)

Data Set: \...\MW-111 Slug Out.aqt
Date: 08/10/16
Time: 10:52:00

PROJECT INFORMATION

Company: Barr Engineering Co.
Client: MDU
Project: 26411005
Location: Sidney, MT
Test Well: MW-111
Test Date: Feb 11, 2016

AQUIFER DATA

Saturated Thickness: 9.21 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW-111)

Initial Displacement: 0.86 ft
Total Well Penetration Depth: 9.21 ft
Casing Radius: 0.08612 ft
Static Water Column Height: 9.21 ft
Screen Length: 9.21 ft
Well Radius: 0.08612 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.0008762 cm/sec
y0 = 0.18 ft