GOLDER

# TECHNICAL MEMORANDUM

**DATE** March 29, 2019 **Project No.** 1531406

**TO** Renee Cipriano
Schiff Hardin LLP

**CC** Ameren Missouri, Haley and Aldrich

**FROM** Golder Associates – Jeffrey Ingram, RG,
Joanna Moreno, PH (GW)

**GROUNDWATER AND GEOCHEMICAL MODELING SUMMARY UPDATES FOR THE RUSH ISLAND ENERGY CENTER CORRECTIVE MEASURES ASSESSMENT**

## 1.0 INTRODUCTION

Golder Associates Inc. (Golder) is pleased to submit this Technical Memorandum summarizing updated modeling and investigation results. In January of 2019 Golder submitted a detailed modeling Technical Memorandum entitled "*Groundwater and Geochemical Modeling Summary for Ameren Rush Island Energy Center Corrective Measures Assessment*". This current Technical Memorandum provides modeling and investigation updates for the January 2019 Technical Memorandum (Golder 2019a) based on comments and requests from Schiff Hardin, Ameren Missouri (Ameren), and Haley and Aldrich.

## 2.0 GROUNDWATER FLOW MODEL

### 2.1 Closure Scenario Groundwater Model Predictions

The calibrated model described in the Golder (2019a) Technical Memorandum was used to predict flow from the RCPA, flow rates in the alluvium, flows to/from the river, and to optimize recovery well placement and pumping rates for alternative closure scenarios. These scenarios are similar to those in the 2019 Golder report, however, these scenarios use a 18-inch thick 1 x $10^{-7}$ centimeter per second (cm/s) Cap with a 6-inch soil cover resulting in 1-inch per year infiltration, whereas the previous report detailed model runs using a 1 x $10^{-6}$ cm/s Cap of the same thickness resulting in 7 inches per year of infiltration to the RCPA. The scenarios modeled are summarized below in Table 1 and Figures 1-6.

**Table 1: Summary of Steady-State Groundwater Model Predictions for Future Scenarios**

| Future Prediction Model Scenario | Reference Figure | Mississippi River Stage (ft amsl) | Number of Wells | Well Pumping Rate (gpm) | Total Pumping Rate (gpm) | Slurry Wall? | Inward Hydraulic Gradient from Mississippi River toward the RCPA? |
|---|---|---|---|---|---|---|---|
| RCPA Cap of 18-inch thick 1 x $10^{-7}$ cm/s with a 6-inch soil cover (RCPA Cap) | Figure 1 | 366 | -- | -- | -- | No | No |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| RCPA Cap, Hydraulic Containment with Pumping Wells #1 | Figure 2 | 366 | 6 | 2.8 | 16.8 | No | Yes |
| RCPA Cap, Hydraulic Containment with Pumping Wells #2 | Figure 3 | 366 | 6 | 1.6 | 9.6 | No | No |
| RCPA Cap, Hydraulic Containment with Pumping Wells #3 | Figure 4 | 374.2 | 6 | 3.5 | 21.0 | No | Yes |
| RCPA Cap, Hydraulic Containment with Slurry Wall and Pumping Wells #1 | Figure 5 | 366 | 6 | 2.3 | 13.8 | Yes | Yes |
| RCPA Cap, Hydraulic Containment with Slurry Wall and Pumping Wells #2 | Figure 6 | 374.2 | 6 | 2.8 | 16.8 | Yes | Yes |

**Notes:**

1) cm/s = centimeters per second.
2) ft amsl = feet above mean sea level.
3) gpm = gallons per minute.
4) In all future model scenarios, the RCPA was modeled as drained, inactive, and capped with RCPA recharge of 1-inch/year based on Haley & Aldrich 2018 HELP model net infiltration prediction for 1 x $10^{-7}$ cm/s soil cover.
5) Mississippi River stage of 366 ft amsl is the steady-state equivalent river stage and 374.2 ft amsl is the long-term average river stage calculated from 1983 to 2017.
6) Hydraulic head control was predicted using proposed pumping wells placed at approximately 1000 foot spacing. Each proposed well is simulated to screen very shallow alluvium to the base of the intermediate alluvium.
7) RCPA hydraulic containment was evaluated using predicted flow velocity vectors and predicted pumping well capture of particles distributed along the outside edge of the RCPA in each model ash layer (Golder 2019).
8) The proposed slurry wall was modeled as constructed along the east side of the RCPA from the very shallow alluvium to the base of the deep alluvium/top of bedrock, 2 feet thick, and a hydraulic conductivity of 1 x $10^{-6}$ cm/s.

The reduction in pumping rates between the scenarios with a 1 x $10^{-6}$ cap in the Golder 2019 report and those displayed above with a 1 x $10^{-7}$ cap are due to the reduction in infiltration through the cap. Based on the Haley and Aldrich (2018) HELP model, there is a reduction from 7-inches per year (1 x $10^{-6}$ cap) to 1-inch per year (1 x $10^{-7}$ cap). This 86% reduction in infiltration to the RCPA reduces the pumping rates required by 70-85%.

## 2.2 Model Estimates of Flow Around the RCPA Based on Ash K

Model estimates of groundwater flow into and around the RCPA varies with the assumed hydraulic conductivity of the RCPA ash. The horizontal hydraulic conductivity of the RCPA ash was estimated to be 3.0 x $10^{-3}$ cm/sec based on slug testing results and the model calibration process (Golder 2019a). Table 2 below displays the change in flow into and around the RCPA based on different ash hydraulic conductivity values. As shown on Table 2, if the horizontal conductivity of the ash is decreased by an order of magnitude, the model simulations show that there would be no flow into the RCPA from the alluvial aquifer and that all groundwater flowing from upgradient of the RCPA would preferentially flow around the RCPA. Example particle pathways that display this preferential flow pattern around the RCPA are provided in Figure 7. No upgradient groundwater is simulated to flow into the RCPA with the lower horizontal conductivity values because the lower conductivity ash causes a small amount of mounding in the RCPA (estimated to be 0.05 to 0.3 feet).

**Table 2: Model Estimates of Flow Around vs Into the RCPA Based on Ash Conductivity**

| Horizontal Hydraulic Conductivity (Kx,Ky) of RCPA Ash | Vertical Hydraulic Conductivity (Kz) of RCPA Ash | Flow Around the RCPA | Flow Through the RCPA | Percent Flow Around RCPA | Percent Flow Through the RCPA |
|---|---|---|---|---|---|
| Centimeter per Second | | Gallons per Minute | | Percent | |
| $3.0 \times 10^{-3}$ | $9.8 \times 10^{-5}$ | 3.6 | 0.2 | 94.7% | 5.3% |
| $3.0 \times 10^{-4}$ | $9.8 \times 10^{-5}$ | 4.1 | 0.0 | 100.0% | 0.0% |
| $3.0 \times 10^{-5}$ | $9.8 \times 10^{-5}$ | 4.2 | 0.0 | 100.0% | 0.0% |

**Notes:**

1) In all future model scenarios, the RCPA was modeled as drained, inactive, and with the RCPA cap resulting in an infiltration rate of 1-inch/year to the RCPA based on Haley & Aldrich 2018 HELP model net infiltration prediction for $1 \times 10^{-7}$ cm/s cap.
2) Mississippi River stage of 366 ft amsl is the steady-state equivalent river stage used in each of the model scenarios.

## 3.0 GEOCHEMICAL MODELING UPDATES

The PHAST geochemical model used in the Golder 2019 Technical Memorandum was updated to incorporate the use of an 18-inch thick $1 \times 10^{-7}$ cap with 6-inches of soil cover instead of a $1 \times 10^{-6}$ cap of the same thickness. Figures 8-14 compare the concentration over time between a $1 \times 10^{-6}$ and a $1 \times 10^{-7}$ cap at locations described in the Golder 2019 report (Golder 2019a).

## 4.0 WATER LEVELS

Periodic water levels have been collected in the pore-water within the RCPA and in the alluvial aquifer around the RCPA. Figure 15 displays the locations of where groundwater and pore-water elevation measurements were obtained and the results from these measurements are provided in Table 3.

**Tables:**



**Figures:**

Figure 2 - Steady-State Groundwater Model Predictions - Capped RCPA With Six Proposed Pumping Wells, River Stage 366 Feet AMSL

Figure 3 - Steady-State Groundwater Model Predictions - Capped RCPA with Six Proposed Pumping Wells, River Stage 366 Feet AMSL, No Inward HYD Gradient

Figure 4 - Steady-State Groundwater Model Predictions - Capped RCPA with Six Proposed Pumping Wells, Long-Term Ave River Stage 374.2 Feet AMSL

Figure 5 - Steady-State Groundwater Model Predictions - Capped RCPA with Slurry Wall and Proposed Pumping Wells, River Stage 366 Feet AMSL

Figure 6 - Steady-State Groundwater Model Predictions - Capped RCPA with Slurry Wall and Proposed Pumping Wells, Long-Term Average River Stage

Figure 7 - Particle Flow Paths Around the RCPA

Figure 8 – Time Series Plot – Average Concentrations at Location 1

Figure 9 – Time Series Plot – Average Concentrations at Location 2

Figure 10 – Time Series Plot – Average Concentrations at Location 3

Figure 11 – Time Series Plot – Average Concentrations at Location 4

Figure 12 – Time Series Plot – Average Concentrations at Location 5

Figure 13 – Time Series Plot – Average Concentrations at Location 6

Figure 14 – Time Series Plot – Average Concentrations at Location 7

Figure 15 – Groundwater Elevation Measurement Location Map

**References**

Golder 2019a. Groundwater and Geochemical Modeling Summary for the Rush Island Energy Center Corrective Measures Assessment. Technical Memorandum, January 2019.

Haley and Aldrich 2018. HELP Model results for different cap scenarios.

# Tables

# Table 3
## Summary of Groundwater Elevation Monitoring Results
## Rush Island Energy Center
## Jefferson County, Missouri

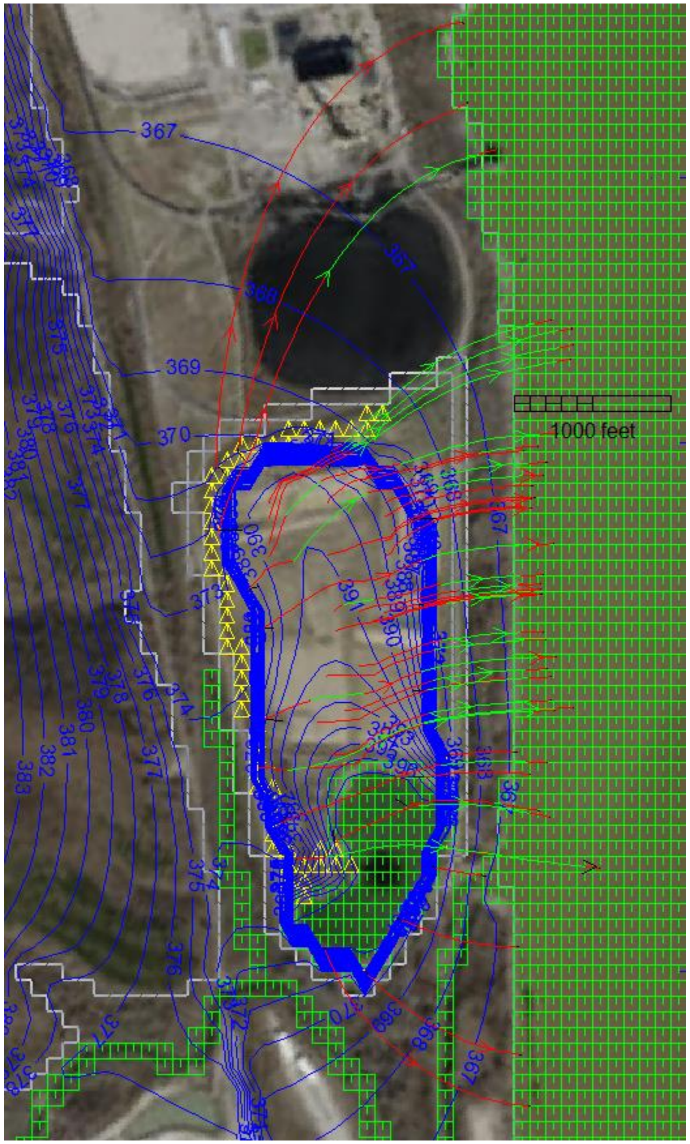
| Well ID | Location | | Top of Casing | Ground Surface Elevation | Ground Water Elevation Measurements - 1/10/2018 | | Ground Water Elevation Measurements - 4/2/2018 | | Ground Water Elevation Measurements - 5/24/2018 | | Ground Water Elevation Measurements - 6/22/2018 | | Ground Water Elevation Measurements - 7/19/2018 | | Ground Water Elevation Measurements - 8/20/2018 | | Ground Water Elevation Measurements - 9/25/2018 | | Ground Water Elevation Measurements - 11/1/2018 | | Ground Water Elevation Measurements - 12/5/2018 | | Ground Water Elevation Measurements - 1/4/2019 | | Ground Water Elevation Measurements - 2/25/2019 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Northing | Easting | FT MSL[2] | FT MSL[2] | DTW[3] | GWE[4] | DTW[3] | GWE[4] | DTW[3] | GWE[4] | DTW[3] | GWE[4] | DTW[3] | GWE[4] | DTW[3] | GWE[4] | DTW[3] | GWE[4] | DTW[3] | GWE[4] | DTW[3] | GWE[4] | DTW[3] | GWE[4] | DTW[3] | GWE[4] |
| CCR RULE MONITORING WELLS | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-MW-1 | 835,384.2 | 889,832.5 | 395.52 | 393.50 | 35.91 | 359.61 | 15.40 | 380.12 | 11.53 | 383.99 | 17.45 | 378.07 | 17.03 | 378.49 | 24.98 | 370.54 | 17.35 | 378.17 | 11.61 | 383.91 | 11.81 | 383.71 | 10.07 | 385.45 | 16.19 | 379.33 |
| R-MW-2 | 834,261.5 | 890,364.1 | 393.87 | 391.70 | 33.42 | 360.45 | 13.87 | 380.00 | 9.96 | 383.91 | 15.95 | 377.92 | 15.73 | 378.14 | 23.53 | 370.34 | 16.07 | 377.80 | 10.31 | 383.56 | 10.19 | 383.68 | 8.49 | 385.38 | 14.91 | 378.96 |
| R-MW-3 | 833,178.4 | 890,892.7 | 391.38 | 389.20 | 31.38 | 360.00 | 11.55 | 379.83 | 7.53 | 383.85 | 13.60 | 377.78 | 13.53 | 377.85 | 21.30 | 370.08 | 13.87 | 377.51 | 8.04 | 383.34 | 7.79 | 383.59 | 6.08 | 385.30 | 12.19 | 379.19 |
| R-MW-4 | 831,647.5 | 890,830.5 | 392.78 | 390.80 | 32.30 | 360.48 | 12.89 | 379.89 | 9.10 | 383.68 | 14.98 | 377.80 | 14.64 | 378.14 | 22.35 | 370.43 | 12.94 | 379.84 | 9.29 | 383.49 | 9.71 | 383.07 | 7.51 | 385.27 | 13.63 | 379.15 |
| R-MW-5 | 831,994.9 | 889,984.5 | 390.36 | 388.00 | 28.93 | 361.43 | 10.86 | 379.50 | 6.40 | 383.96 | 12.25 | 378.11 | 11.78 | 378.58 | 19.27 | 371.09 | 12.06 | 378.30 | 6.54 | 383.82 | 7.24 | 383.12 | 4.87 | 385.49 | 10.83 | 379.53 |
| R-MW-6 | 833,111.0 | 888,977.0 | 402.71 | 401.10 | 40.26 | 362.45 | 20.84 | 381.87 | 18.27 | 384.44 | 24.50 | 378.21 | 24.29 | 378.42 | 30.35 | 372.36 | 23.56 | 379.15 | 18.29 | 384.42 | 19.46 | 383.25 | 17.11 | 385.60 | 21.62 | 381.09 |
| R-MW-7 | 834,476.8 | 888,483.3 | 407.95 | 406.10 | 45.28 | 362.67 | 27.62 | 380.33 | 24.33 | 383.62 | 29.64 | 378.31 | 28.23 | 379.72 | 36.48 | 371.47 | 28.33 | 379.62 | 23.48 | 384.47 | 25.23 | 382.72 | 22.82 | 385.13 | 28.89 | 379.06 |
| R-MW-B1 | 837,602.1 | 887,903.9 | 411.61 | 409.60 | 51.69 | 359.92 | 31.50 | 380.11 | 28.01 | 383.60 | 33.50 | 378.11 | 31.81 | 379.80 | 40.51 | 371.10 | 32.01 | 379.60 | 27.21 | 384.40 | 28.69 | 382.92 | 26.24 | 385.37 | 32.10 | 379.51 |
| R-MW-B2 | 837,801.7 | 885,337.2 | 397.85 | 395.90 | 35.44 | 362.41 | 17.80 | 380.05 | 14.55 | 383.30 | 19.59 | 378.26 | 17.10 | 380.75 | 29.50 | 368.35 | 16.69 | 381.16 | 12.36 | 385.49 | 15.07 | 382.78 | 12.23 | 385.62 | 17.09 | 380.76 |
| NATURE AND EXTENT MONITORING WELLS | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-P-01S | 831,422.3 | 890,858.9 | 387.62 | 385.69 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3.74 | 383.88 | 4.68 | 382.94 | 2.24 | 385.38 | - | - |
| R-P-03D | 831,686.3 | 890,369.8 | 391.65 | 389.34 | - | - | - | - | 7.81 | 383.84 | 13.50 | 378.15 | 13.05 | 378.60 | 20.61 | 371.04 | 13.33 | 378.32 | 7.75 | 383.90 | 8.36 | 383.29 | 6.04 | 385.61 | - | - |
| R-P-03S | 831,690.9 | 890,352.1 | 391.68 | 389.48 | - | - | - | - | 7.80 | 383.88 | 13.50 | 378.18 | 13.01 | 378.67 | 20.52 | 371.16 | 12.52 | 379.16 | 7.65 | 384.03 | 8.54 | 383.14 | 6.10 | 385.58 | - | - |
| R-P-05I | 832,295.4 | 889,756.1 | 390.07 | 387.87 | - | - | - | - | 5.83 | 384.24 | 11.69 | 378.38 | 11.16 | 378.91 | 18.63 | 371.44 | 11.41 | 378.66 | 5.95 | 384.12 | 6.67 | 383.40 | 4.31 | 385.76 | - | - |
| R-P-05S | 832,317.6 | 889,749.7 | 392.50 | 390.05 | - | - | - | - | 8.25 | 384.25 | 14.09 | 378.41 | 13.71 | 378.79 | 20.87 | 371.63 | 12.81 | 379.69 | 8.34 | 384.16 | 9.12 | 383.38 | 6.69 | 385.81 | - | - |
| R-P-08D | 833,687.5 | 888,715.1 | 404.61 | 401.77 | - | - | - | - | 20.58 | 384.03 | 26.25 | 378.36 | 25.07 | 379.54 | 32.97 | 371.64 | 25.22 | 379.39 | 20.04 | 384.57 | 21.61 | 383.00 | 19.01 | 385.60 | - | - |
| R-P-08S | 833,692.6 | 888,711.1 | 404.79 | 402.03 | - | - | - | - | 20.74 | 384.05 | 25.87 | 378.92 | 23.69 | 381.10 | 30.66 | 374.13 | 22.65 | 382.14 | 18.33 | 386.46 | 21.95 | 382.84 | 19.57 | 385.22 | - | - |
| R-P-10S | 834,545.1 | 888,099.0 | 407.23 | 404.83 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 22.16 | 385.07 | 24.39 | 382.84 | 21.37 | 385.86 | - | - |
| R-P-13D | 834,992.6 | 889,105.8 | 410.40 | 408.52 | - | - | - | - | 26.59 | 383.81 | 32.25 | 378.15 | 31.21 | 379.19 | 39.42 | 370.98 | 31.46 | 378.94 | 26.21 | 384.19 | 27.24 | 383.16 | 25.04 | 385.36 | - | - |
| R-P-13I | 834,995.2 | 889,110.6 | 410.52 | 408.57 | - | - | - | - | 26.63 | 383.89 | 32.30 | 378.22 | 31.25 | 379.27 | 39.42 | 371.10 | 31.36 | 379.16 | 26.11 | 384.41 | 27.33 | 383.19 | 25.08 | 385.44 | - | - |
| R-P-13S | 835,005.5 | 889,108.3 | 411.62 | 409.25 | - | - | - | - | 27.77 | 383.85 | 33.40 | 378.22 | 32.26 | 379.36 | 40.47 | 371.15 | 32.44 | 379.18 | 27.26 | 384.36 | 28.46 | 383.16 | 26.28 | 385.34 | - | - |
| R-P-17D | 834,718.8 | 890,158.3 | 395.56 | 392.62 | - | - | - | - | 11.43 | 384.13 | 17.44 | 378.12 | 17.19 | 378.37 | 25.03 | 370.53 | 17.51 | 378.05 | 11.77 | 383.79 | 11.61 | 383.95 | 9.96 | 385.60 | - | - |
| R-P-17I | 834,744.2 | 890,148.9 | 394.86 | 392.53 | - | - | - | - | 12.06 | 382.80 | 16.72 | 378.14 | 16.44 | 378.42 | 24.28 | 370.58 | 14.16 | 380.70 | 11.03 | 383.83 | 11.00 | 383.86 | 9.29 | 385.57 | - | - |
| R-P-17S | 834,736.7 | 890,152.8 | 394.65 | 392.49 | - | - | - | - | 10.71 | 383.94 | 15.75 | 378.90 | 14.24 | 380.41 | 18.65 | 376.00 | 16.79 | 377.86 | 6.96 | 387.69 | 10.96 | 383.69 | 10.48 | 384.17 | - | - |
| R-P-19D | 833,915.6 | 890,552.2 | 392.08 | 390.31 | - | - | - | - | 8.46 | 383.62 | 14.50 | 377.58 | 14.32 | 377.76 | 22.10 | 369.98 | 14.68 | 377.40 | 8.89 | 383.19 | 9.70 | 382.38 | 7.01 | 385.07 | - | - |
| R-P-19I | 833,911.3 | 890,550.6 | 392.75 | 390.24 | - | - | - | - | 8.11 | 384.64 | 14.14 | 378.61 | 13.94 | 378.81 | 21.72 | 371.03 | 14.30 | 378.45 | 8.51 | 384.24 | 8.37 | 384.38 | 6.66 | 386.09 | - | - |
| R-P-19S | 833,919.0 | 890,546.4 | 393.31 | 390.58 | - | - | - | - | 9.67 | 383.64 | 15.32 | 377.99 | 14.86 | 378.45 | 22.68 | 370.63 | 15.21 | 378.10 | 9.10 | 384.21 | 9.94 | 383.37 | 8.15 | 385.16 | - | - |
| R-P-21D | 832,902.9 | 891,031.2 | 393.39 | 391.04 | - | - | - | - | 9.39 | 384.00 | 15.48 | 377.91 | 15.38 | 378.01 | 23.16 | 370.23 | 15.73 | 377.66 | 9.93 | 383.46 | 9.63 | 383.76 | 7.89 | 385.50 | - | - |
| R-P-21I | 832,904.2 | 891,027.0 | 393.53 | 391.19 | - | - | - | - | 9.43 | 384.10 | 15.51 | 378.02 | 15.41 | 378.12 | 23.20 | 370.33 | 15.74 | 377.79 | 9.95 | 383.58 | 9.68 | 383.85 | 7.94 | 385.59 | - | - |
| R-P-21S | 832,898.0 | 891,024.7 | 393.87 | 391.45 | - | - | - | - | 10.24 | 383.63 | 16.07 | 377.80 | 16.77 | 377.10 | 23.48 | 370.39 | 16.02 | 377.85 | 9.91 | 383.96 | 10.59 | 383.28 | 8.73 | 385.14 | - | - |
| R-P-22D | 832,278.2 | 891,018.7 | 393.76 | 391.63 | - | - | - | - | 9.86 | 383.90 | 15.84 | 377.92 | 15.61 | 378.15 | 23.46 | 370.30 | 15.93 | 377.83 | 10.26 | 383.50 | 10.25 | 383.51 | 8.33 | 385.43 | - | - |
| R-P-22I | 832,272.1 | 891,018.0 | 393.52 | 391.59 | - | - | - | - | 9.66 | 383.86 | 15.67 | 377.85 | 15.44 | 378.08 | 23.27 | 370.25 | 15.75 | 377.77 | 10.03 | 383.49 | 10.11 | 383.41 | 8.15 | 385.37 | - | - |
| R-P-22S | 832,277.0 | 891,007.6 | 394.30 | 392.15 | - | - | - | - | 10.46 | 383.84 | 16.39 | 377.91 | 15.93 | 378.37 | 23.89 | 370.41 | 16.19 | 378.11 | 10.60 | 383.70 | 11.12 | 383.18 | 9.01 | 385.29 | - | - |
| R-P-29D | 837,804.9 | 885,389.1 | 398.27 | 396.23 | - | - | - | - | 14.73 | 383.54 | 19.76 | 378.51 | 17.28 | 380.99 | 25.68 | 372.59 | 16.86 | 381.41 | 12.54 | 385.73 | 15.23 | 383.04 | 12.39 | 385.88 | - | - |
| R-P-29S | 837,797.9 | 885,383.8 | 399.11 | 397.02 | - | - | - | - | 16.42 | 382.69 | 20.52 | 378.59 | 17.63 | 381.48 | 24.35 | 374.76 | 16.72 | 382.39 | 13.36 | 385.75 | 16.08 | 383.03 | 13.65 | 385.46 | - | - |
| R-P-30S | 836,606.9 | 889,007.8 | 407.75 | 407.98 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 25.20 | 382.55 | 24.53 | 383.22 | 22.60 | 385.15 | - | - |
| R-P-31S | 835,629.4 | 887,488.1 | 408.68 | 406.08 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 22.31 | 386.37 | 25.38 | 383.30 | 22.48 | 386.20 | - | - |
| PORE-WATER MONITORING WELLS | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-P-27S | 834,319.5 | 888,680.9 | 413.23 | 410.33 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 14.91 | 398.32 | 18.87 | 394.36 | 18.09 | 395.14 | - | - |
| R-P-28S | 834,788.3 | 889,594.3 | 413.34 | 410.86 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 21.35 | 391.99 | 23.80 | 389.54 | 25.51 | 387.83 | - | - |
| Pond Gauge | 890854* | 832689* | NA | NA | NA | 388.5 | NA | 398.0 | NA | 398.0 | NA | 396.0 | NA | 394.0 | NA | 395.0 | NA | 396.0 | NA | 394.0 | NA | 394.5 | NA | 394.0 | NA | 390.5 |
| Mississippi River[7] | 888823* | 837705* | NA | NA | NA | 361.20 | NA | 380.94 | NA | 385.38 | NA | 379.40 | NA | 379.41 | NA | 371.69 | NA | 379.08 | NA | 384.79 | NA | 385.29 | NA | 386.72 | NA | 380.56 |

Notes:
1.) * - Mississippi River and Pond gauge location is estimated.
2.) MSL - Feet above mean sea level.
3.) DTW - Depth to water measured in feet below top of casing.
4.) GWE - Groundwater elevation measured in feet above mean sea level.
5.) Horizontal Datum: State Plane Coordinates NAD83 (2000) Missouri East Zone feet.
6.) Vertical Datum: NAVD88 feet.
7.) Mississippi River gage elevation provided by Ameren
8.) NA - Not Applicable
9.) "-" - Ground water elevation measurement not collected.

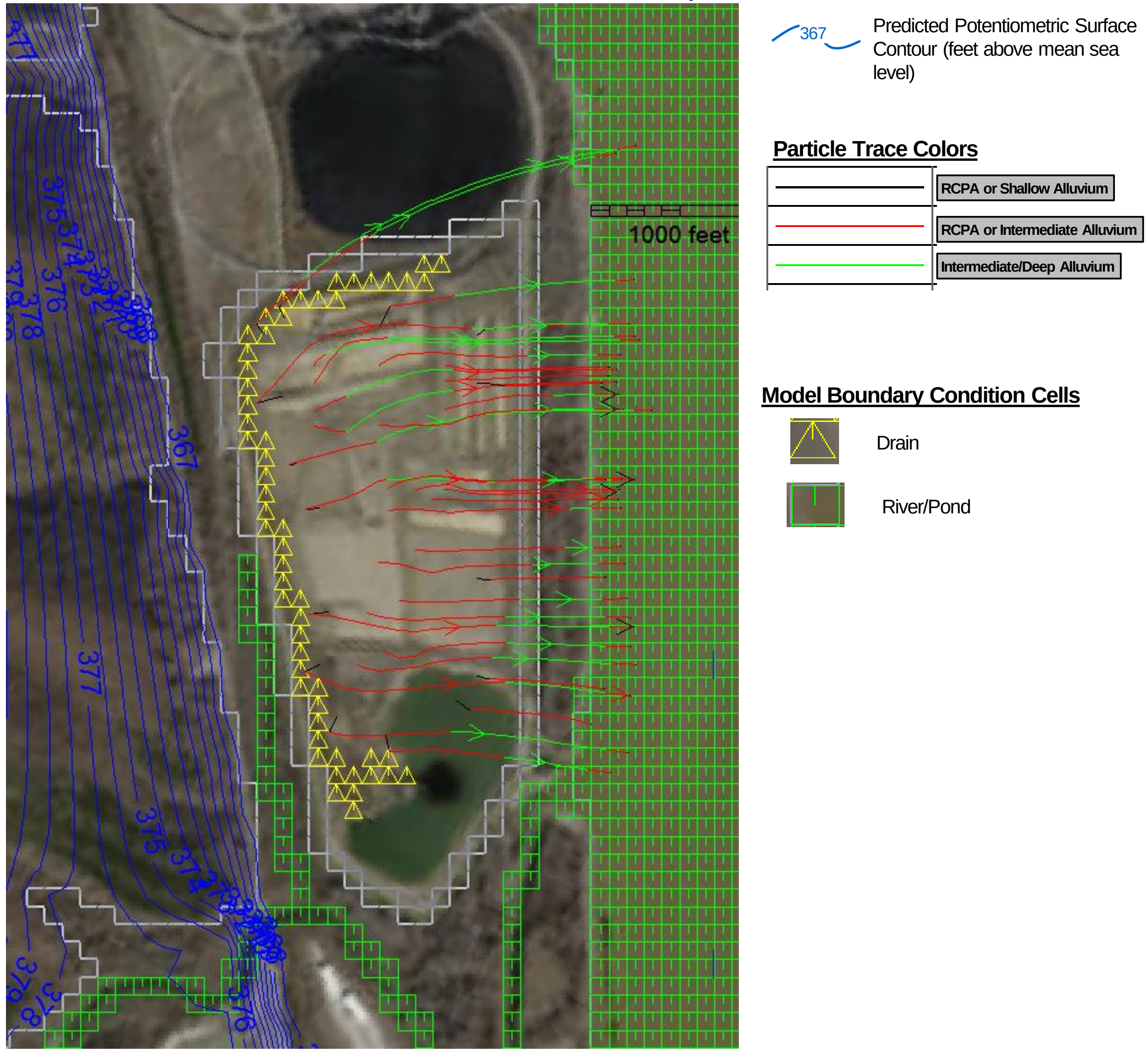
Prepared By: EMS
Checked by: JAP
Reveiwed By: MNH

# Figures

## Predicted Historical Condition: No Cap




## Predicted Future Condition: 1 x $10^{-7}$ cm/s Cap




NOTE(S)

1. Steady-state groundwater model predictions.
2. Mississippi River at steady-state equivalent river stage of 366 feet above mean sea level.
3. Particles distributed along the outside edge of the RCPA in each model ash layer. See Figure GW-1 for details on starting particle locations.
4. No Cap model includes 87.6 inches/year recharge to the RCPA.
5. Cap model includes 1.0 inch/year recharge to the RCPA based on Haley & Aldrich 2018 HELP model net infiltration prediction for 1 x $10^{-7}$ cm/s soil cover.

CLIENT

AMEREN MISSOURI
RUSH ISLAND ENERGY CENTER

Ameren

CONSULTANT

GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2019-03-26 |
| PREPARED | RT |
| DESIGN | RT |
| REVIEW | JM |
| APPROVED | MNH |

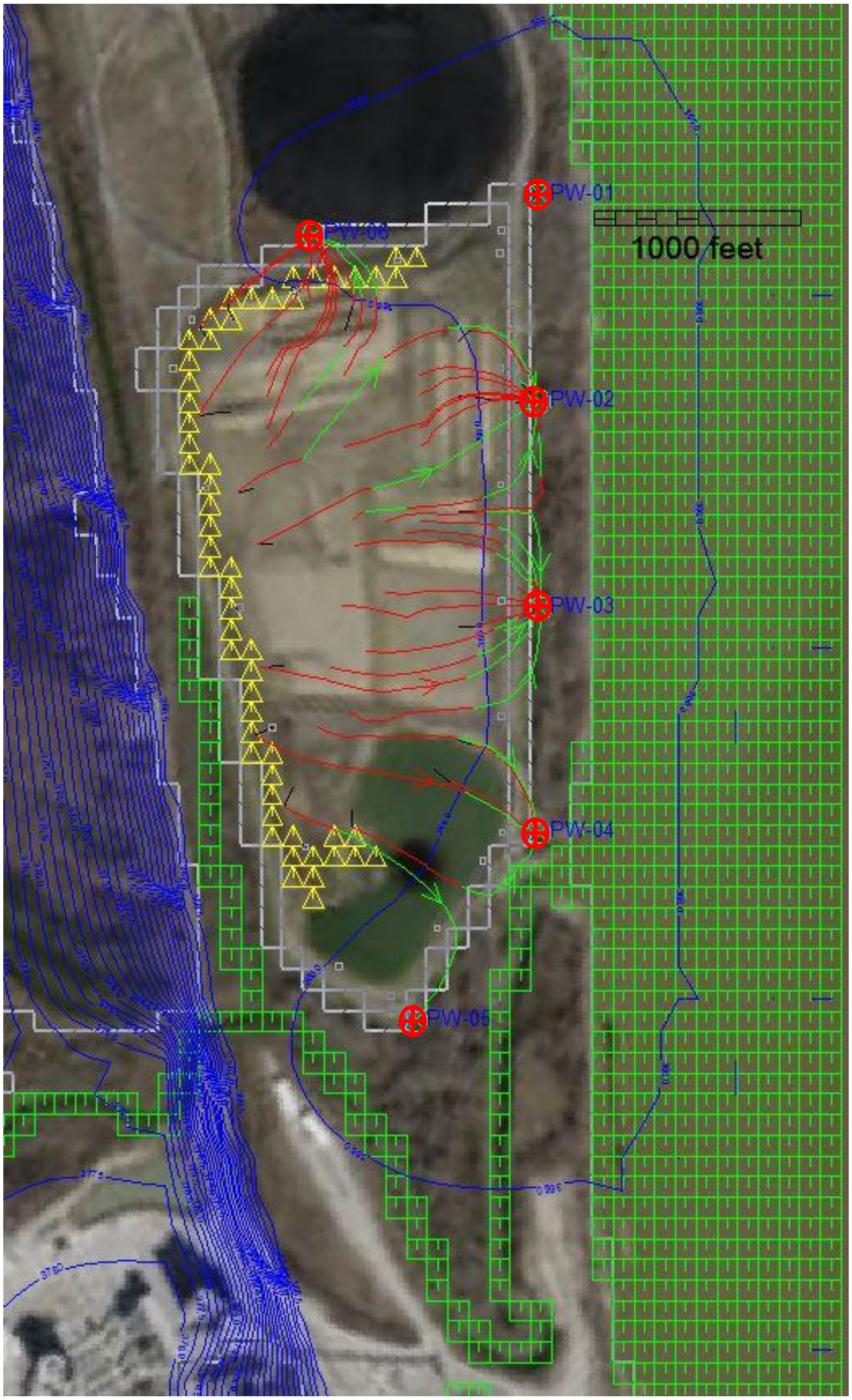
PROJECT

GROUNDWATER MONITORING PROGRAM

TITLE

**STEADY-STATE GROUNDWATER MODEL PREDICTIONS HISTORICAL (NO CAP) AND FUTURE (WITH CAP) CONDITIONS WITH FORWARD PARTICLE FLOW PATHS**

| PROJECT No. | REV. | FIGURE |
|---|---|---|
| 1531406 | A | 1 |




367 Predicted Potentiometric Surface Contour (feet above mean sea level)

**Particle Trace Colors**

| | |
|---|---|
| (black line) | RCPA or Shallow Alluvium |
| (red line) | RCPA or Intermediate Alluvium |
| (green line) | Intermediate/Deep Alluvium |

**Proposed Pumping Wells for Hydraulic Containment**

PW-01 Proposed Pumping Well

6 Proposed Pumping Wells
Approx. 1000 foot spacing
Screened from Very Shallow Alluvium to Intermediate Alluvium
Upward Vertical Hydraulic Gradient predicted in Deep Alluvium near each well

Predicted hydraulic containment of RCPA particles and inward hydraulic gradient from the Mississippi River toward the RCPA maintained based on:
Each Well Pumping Rate = **2.8 gpm**
Total Pumping Rate = **16.8 gpm**

**Model Boundary Condition Cells**

Drain

River

NOTE(S)
1. Steady-state groundwater model predictions.
2. Mississippi River at steady-state equivalent river stage of 366 feet above mean sea level.
3. Particles distributed along the outside edge of the RCPA in each model ash layer. See Figure Golder 2019 Technical Memorandum for details on starting particle locations.
4. Cap model includes 1.0 inch/year recharge to the RCPA based on Haley & Aldrich 2018 HELP model net infiltration prediction for 1 x $10^{-7}$ cm/s soil cover.

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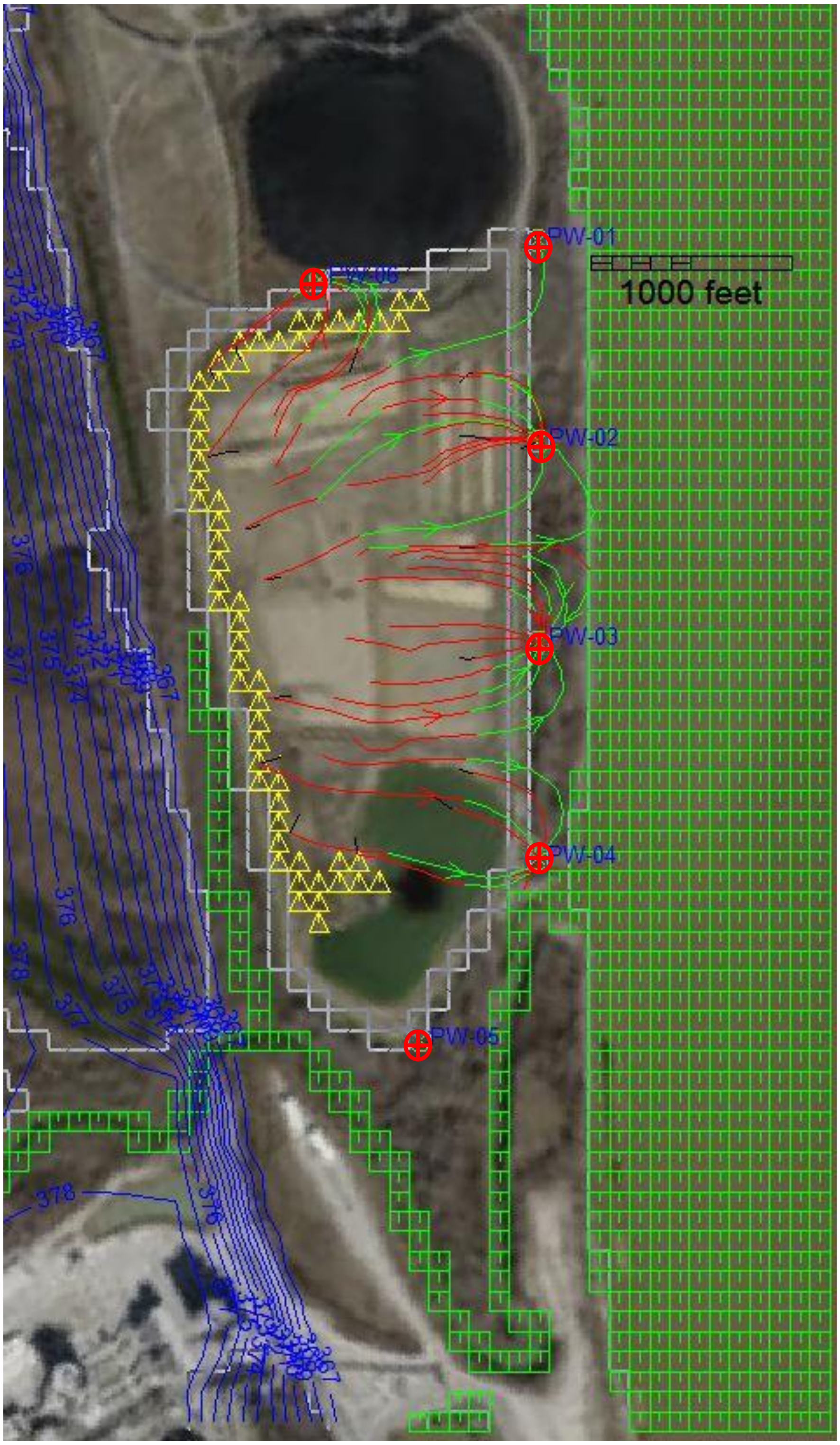
| PREPARED | JSI |
| DESIGNED | RT |
| REVIEWED | JM |
| APPROVED | MNH |

TITLE
**STEADY-STATE GROUNDWATER MODEL PREDICTIONS CAPPED RCPA WITH SIX PROPOSED PUMPING WELLS, RIVER STAGE 366 FEET AMSL**

PROJECT NO. **1531406** REV. **A** FIGURE **2**




367 Predicted Potentiometric Surface Contour (feet above mean sea level)

**Particle Trace Colors**

- RCPA or Shallow Alluvium
- RCPA or Intermediate Alluvium
- Intermediate/Deep Alluvium

**Proposed Pumping Wells for Hydraulic Containment**

PW-01 Proposed Pumping Well

6 Proposed Pumping Wells
Approx. 1000 foot spacing
Screened from Very Shallow Alluvium to Intermediate Alluvium
Upward Vertical Hydraulic Gradient predicted in Deep Alluvium near each well

Predicted hydraulic containment of RCPA particles based on:
Each Well Pumping Rate = **1.6 gpm**
Total Pumping Rate = **9.6 gpm**

**Inward hydraulic gradient** from the Mississippi River toward the RCPA **not maintained**

**Model Boundary Condition Cells**

- Drain
- River

NOTE(S)
1. Steady-state groundwater model predictions.
2. Mississippi River at steady-state equivalent river stage of 366 feet above mean sea level.
3. Particles distributed along the outside edge of the RCPA in each model ash layer. See Golder (2019) Technical Memorandum for details on starting particle locations.
4. Cap model includes 1.0 inch/year recharge to the RCPA based on Haley & Aldrich 2018 HELP model net infiltration prediction for $1 \times 10^{-7}$ cm/s soil cover.

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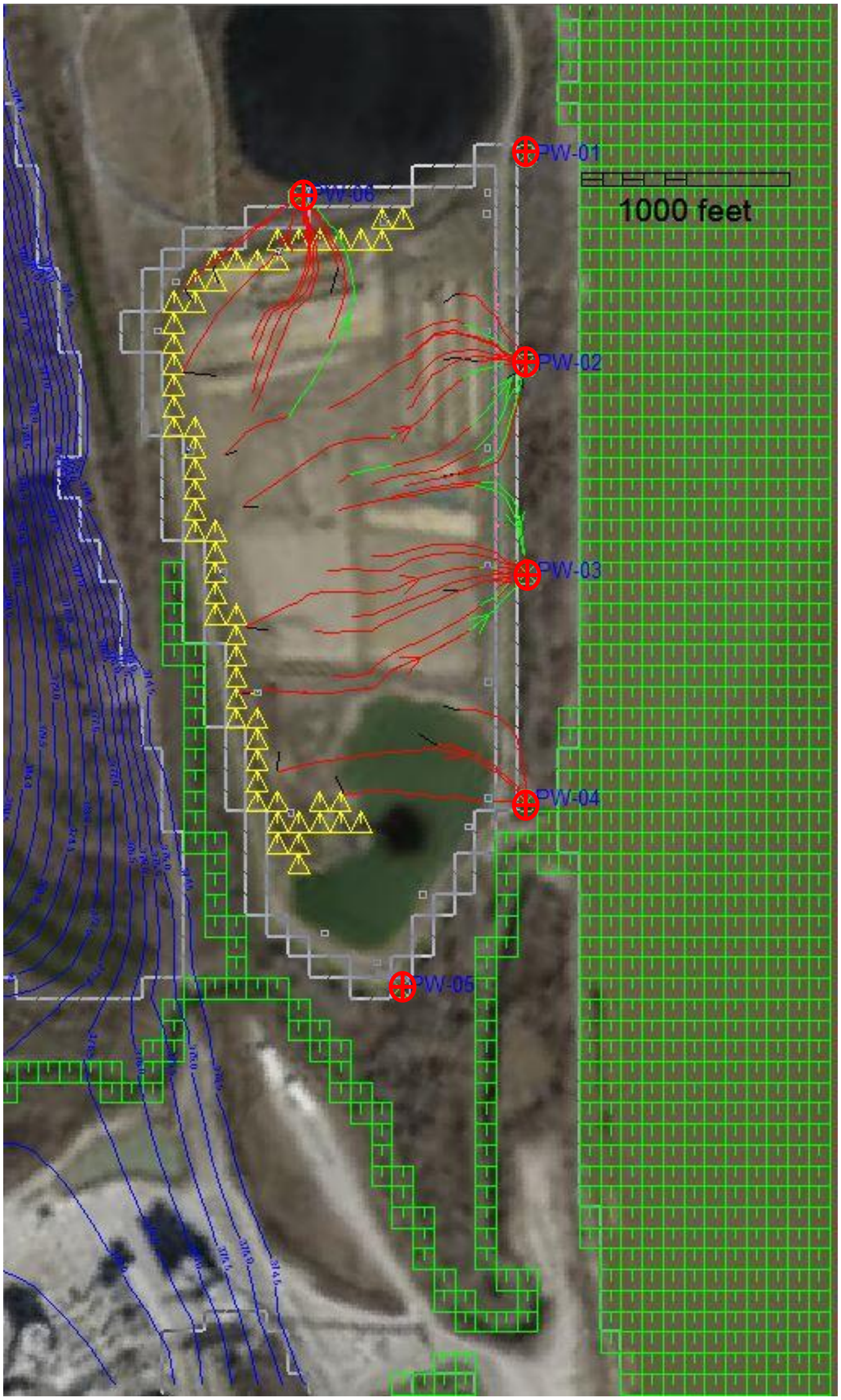
| CONSULTANT<br>GOLDER | YYYY-MM-DD: 2019-03-26<br>PREPARED: JSI<br>DESIGNED: RT<br>REVIEWED: JM<br>APPROVED: MNH | TITLE<br>**STEADY-STATE GROUNDWATER MODEL PREDICTIONS CAPPED RCPA WITH SIX PROPOSED PUMPING WELLS, RIVER STAGE 366 FEET AMSL, NO INWARD HYD GRADIENT** | |
| | | PROJECT NO. **1531406** | REV. **A** FIGURE **3** |




367 Predicted Potentiometric Surface Contour (feet above mean sea level)

**Particle Trace Colors**

| | |
|---|---|
| black line | RCPA or Shallow Alluvium |
| red line | RCPA or Intermediate Alluvium |
| green line | Intermediate/Deep Alluvium |

**Proposed Pumping Wells for Hydraulic Containment**

PW-01 Proposed Pumping Well

6 Proposed Pumping Wells
Approx. 1000 foot spacing
Screened from Very Shallow Alluvium to Intermediate Alluvium
Upward Vertical Hydraulic Gradient predicted in Deep Alluvium near each well

Predicted hydraulic containment of RCPA particles and inward hydraulic gradient from the Mississippi River toward the RCPA maintained based on:
Each Well Pumping Rate = **3.5 gpm**
Total Pumping Rate = **21.0 gpm**

**Model Boundary Condition Cells**

Drain

River

NOTE(S)
1. Steady-state groundwater model predictions.
2. Mississippi River at long-term average river stage of 374.2 feet above mean sea level.
3. Particles distributed along the outside edge of the RCPA in each model ash layer. See Golder (2019) Technical Memorandum for details on starting particle locations.
4. Cap model includes 1.0 inches/year recharge to the RCPA based on Haley & Aldrich 2018 HELP model net infiltration prediction for 1 x $10^{-7}$ cm/s soil cover.

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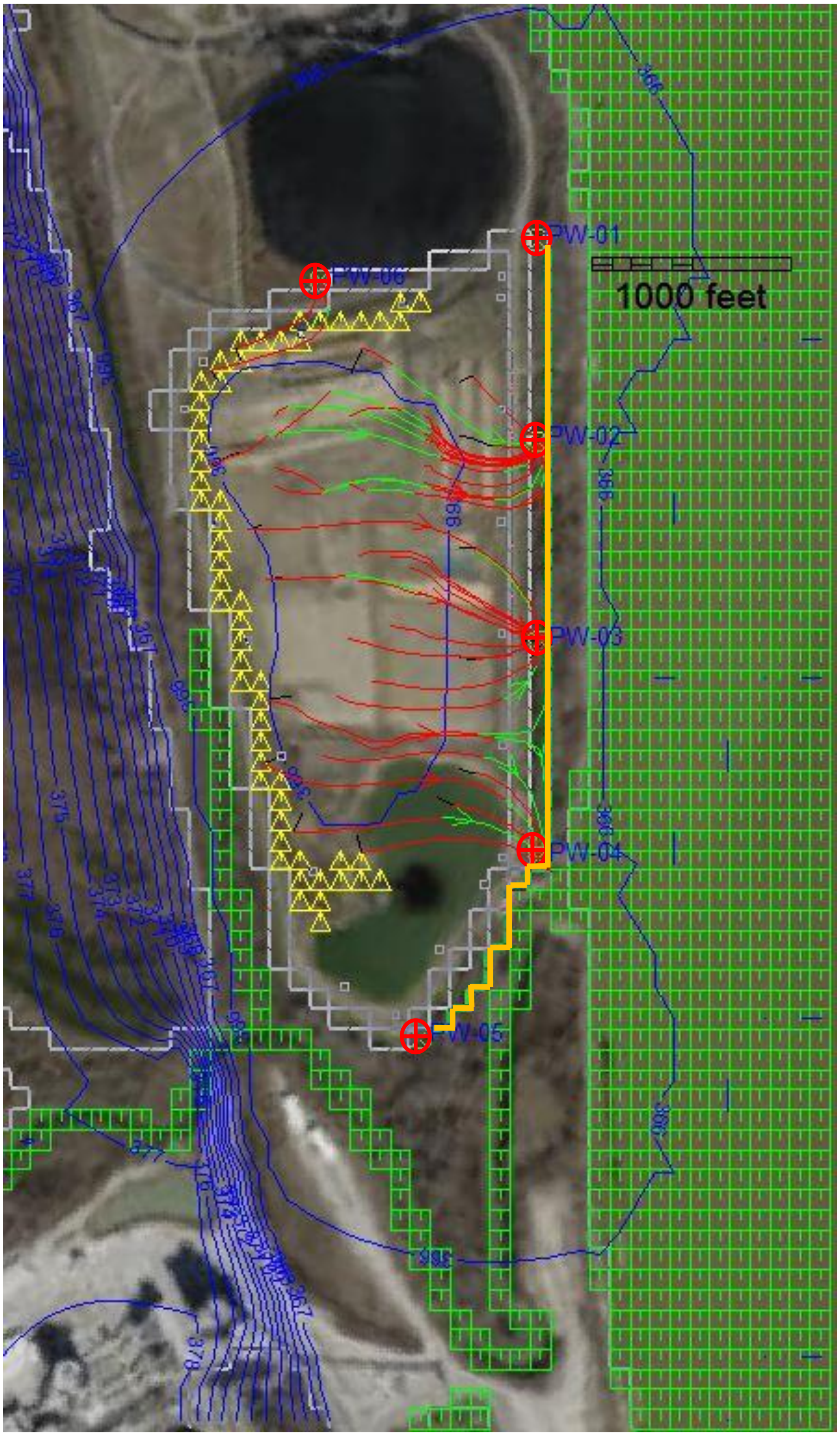
| PREPARED | JSI |
| DESIGNED | RT |
| REVIEWED | JM |
| APPROVED | MNH |

TITLE
**STEADY-STATE GROUNDWATER MODEL PREDICTIONS CAPPED RCPA WITH SIX PROPOSED PUMPING WELLS, LONG-TERM AVG RIVER STAGE 374.2 FEET AMSL**

| PROJECT NO. | REV. | FIGURE |
|---|---|---|
| **1531406** | **A** | **4** |




367 Predicted Potentiometric Surface Contour (feet above mean sea level)

**Particle Trace Colors**

| | |
|---|---|
| (black line) | RCPA or Shallow Alluvium |
| (red line) | RCPA or Intermediate Alluvium |
| (green line) | Intermediate/Deep Alluvium |

**Proposed Pumping Wells for Hydraulic Containment**

PW-01 Proposed Pumping Well

6 Proposed Pumping Wells
Approx. 1000 foot spacing
Screened from Very Shallow Alluvium to Intermediate Alluvium
Upward Vertical Hydraulic Gradient predicted in Deep Alluvium near each well

Predicted hydraulic containment of RCPA particles and inward hydraulic gradient from the Mississippi River toward the RCPA maintained based on:
Proposed Slurry Wall
Each Well Pumping Rate = **2.3 gpm**
Total Pumping Rate = **13.8 gpm**

**Model Boundary Condition Cells**

Drain

River

Proposed Slurry Wall
Constructed from Very Shallow Alluvium to Deep Alluvium/ Top of Bedrock
2 foot thick wall
Hydraulic Conductivity = 1 x $10^{-6}$ cm/s

NOTE(S)
1. Steady-state groundwater model predictions.
2. Mississippi River at steady-state equivalent river stage of 366 feet above mean sea level.
3. Particles distributed along the outside edge of the RCPA in each model ash layer. See Golder (2019) Technical Memorandum for details on starting particle locations.
4. Cap model includes 1.0 inches/year recharge to the RCPA based on Haley & Aldrich 2018 HELP model net infiltration prediction for 1 x $10^{-7}$ cm/s soil cover.

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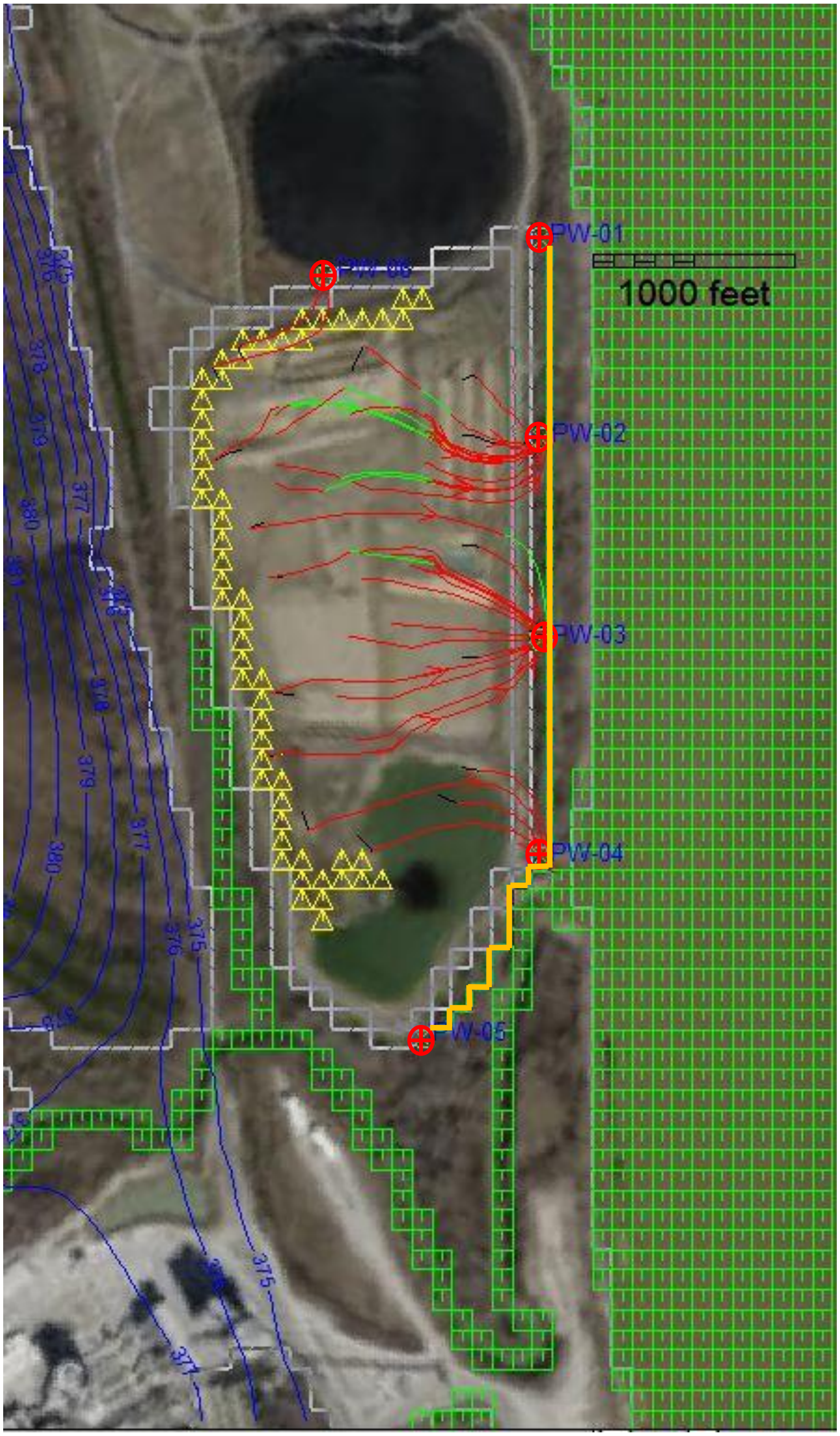
| REVIEWED | JM |
| APPROVED | MNH |

TITLE
**STEADY-STATE GROUNDWATER MODEL PREDICTIONS CAPPED RCPA WITH SLURRY WALL AND PROPOSED PUMPING WELLS, RIVER STAGE 366 FEET AMSL**

| PROJECT NO. | REV. | FIGURE |
|---|---|---|
| **1531406** | **A** | **5** |




367 Predicted Potentiometric Surface Contour (feet above mean sea level)

**Particle Trace Colors**

| | |
|---|---|
| (black line) | RCPA or Shallow Alluvium |
| (red line) | RCPA or Intermediate Alluvium |
| (green line) | Intermediate/Deep Alluvium |

**Proposed Pumping Wells for Hydraulic Containment**

PW-01 Proposed Pumping Well

6 Proposed Pumping Wells
Approx. 1000 foot spacing
Screened from Very Shallow Alluvium to Intermediate Alluvium
Upward Vertical Hydraulic Gradient predicted in Deep Alluvium near each well

Predicted hydraulic containment of RCPA particles and inward hydraulic gradient from the Mississippi River toward the RCPA maintained based on:
Proposed Slurry Wall
Each Well Pumping Rate = **2.8 gpm**
Total Pumping Rate = **16.8 gpm**

**Model Boundary Condition Cells**

Drain

River

Proposed Slurry Wall
Constructed from Very Shallow Alluvium to Deep Alluvium/ Top of Bedrock
2 foot thick wall
Hydraulic Conductivity = 1 x $10^{-6}$ cm/s

NOTE(S)
1. Steady-state groundwater model predictions.
2. Mississippi River at long-term average river stage of 374.2 feet above mean sea level..
3. Particles distributed along the outside edge of the RCPA in each model ash layer. See Golder (2019) Technical Memorandum for details on starting particle locations.
4. Cap model includes 1.0 inches/year recharge to the RCPA based on Haley & Aldrich 2018 HELP model net infiltration prediction for 1 x $10^{-7}$ cm/s soil cover.

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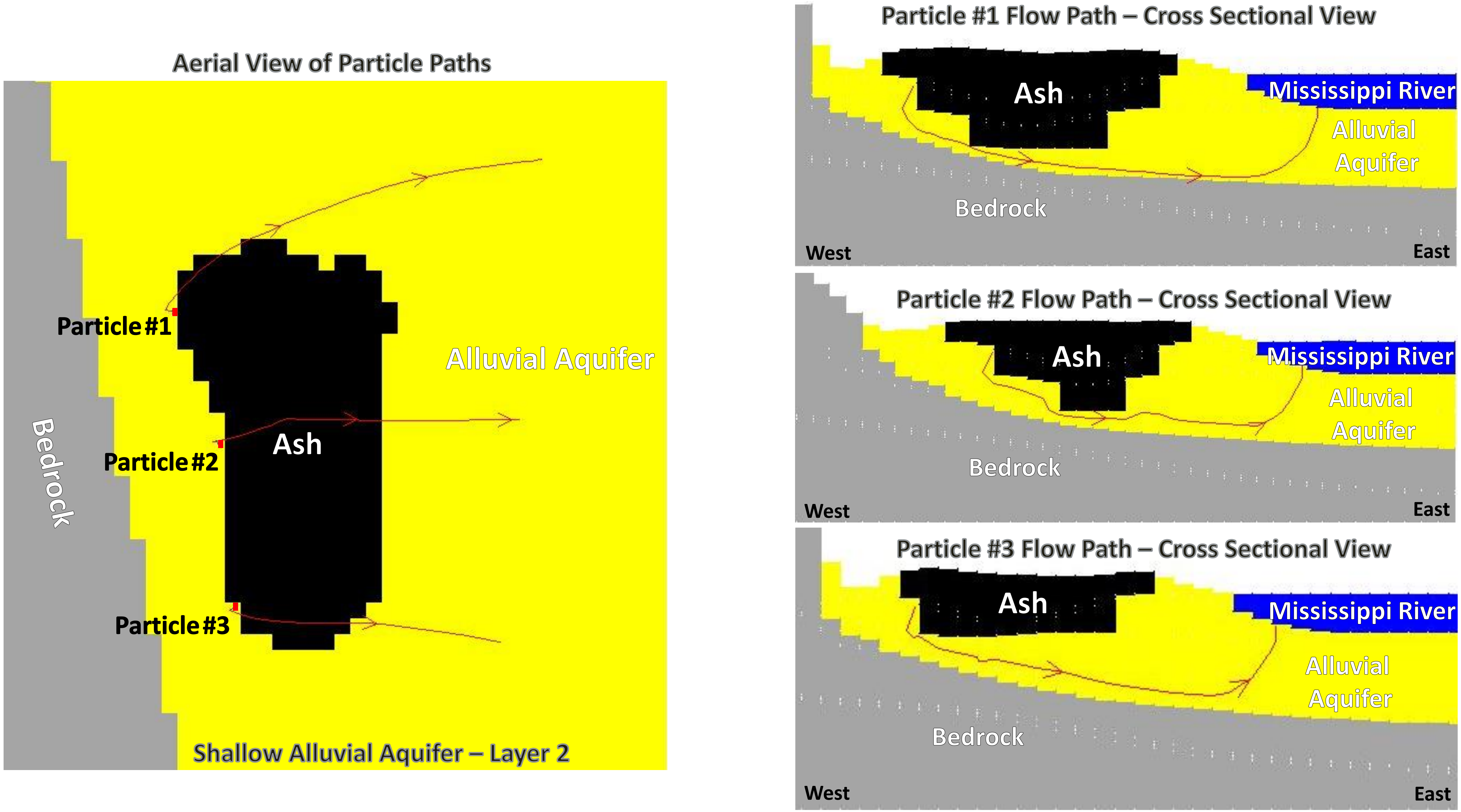
| APPROVED | MNH |

TITLE
**STEADY-STATE GROUNDWATER MODEL PREDICTIONS CAPPED RCPA WITH SLURRY WALL AND PROPOSED PUMPING WELLS, LONG-TERM AVG RIVER STAGE**

PROJECT NO. **1531406** REV. **A** FIGURE **6**




NOTE(S)

1) In this steady state scenario, the RCPA was modeled as drained, inactive, and capped with a infiltration rate to the RCPA of 1-inch/year based on Haley & Aldrich 2018 HELP model.
2) A Mississippi River stage of 366 ft amsl is the steady-state equivalent river stage used.
3) Particles display forward tracking with starting points at the top of layer 2 (Shallow Alluvial Aquifer).
4) Aerial view displays Layer 2 (Shallow Alluvial Aquifer).
5) Model displays results using the ash conductivities displayed in the Golder 2019 Technical memorandum with a kx,ky value of $3 \times 10^{-3}$ centimeters per second and a kz value of $9.8 \times 10^{-4}$ centimeters per second.

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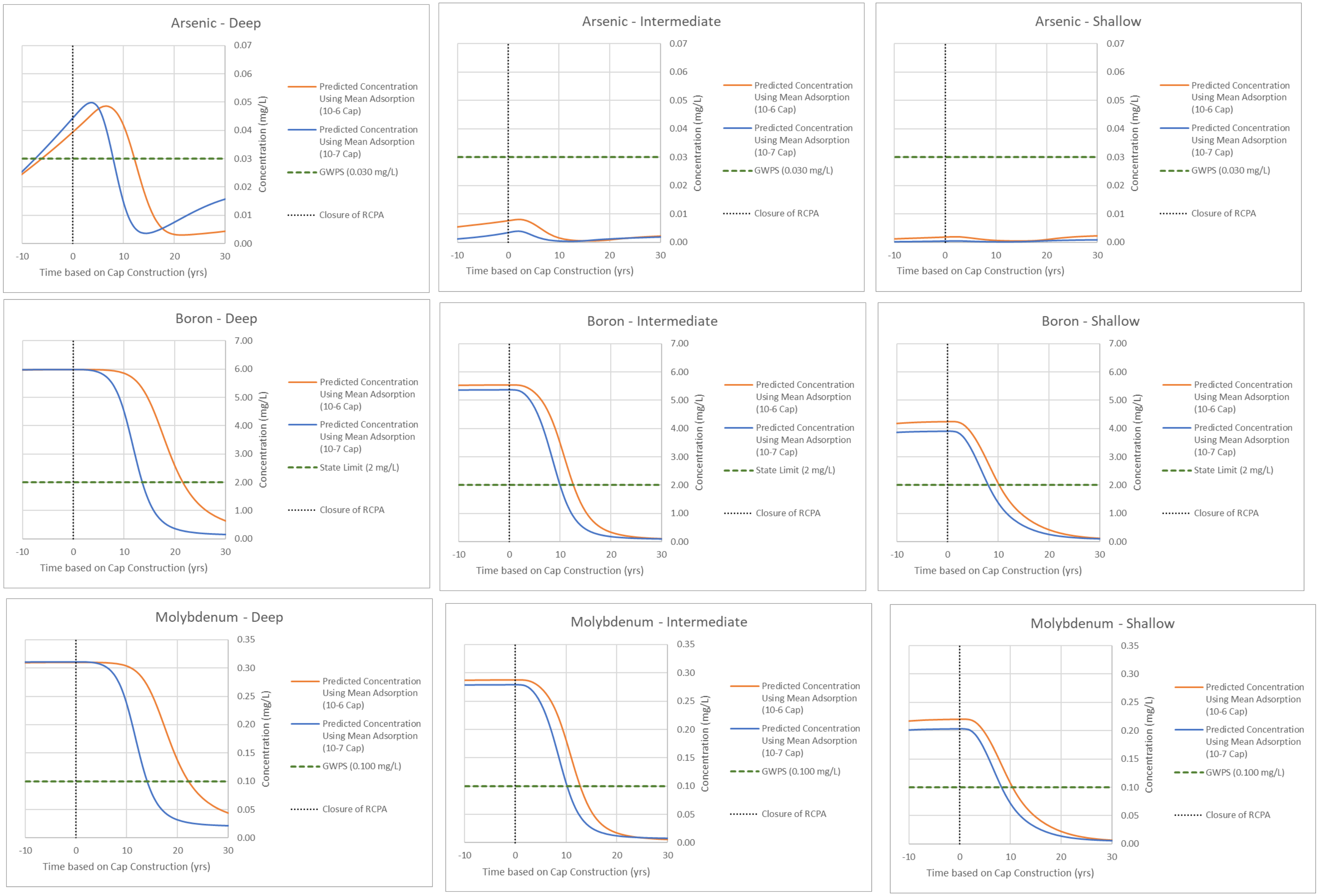
| DESIGN | JSI |
| REVIEW | JM |
| APPROVED | MNH |

PROJECT
GROUNDWATER MONITORING PROGRAM

TITLE
Particle Flow Paths Around the RCPA

PROJECT No. 1531406
Rev 0
Figure 7




NOTE(S)

1) GWPS – Groundwater Protection Standard. This is a site specific value.
2) mg/L – milligrams per liter.
3) "$10^{-6}$ Cap" = $1x10^{-6}$ centimeter per second cap hydraulic conductivity.
4) "$10^{-7}$ Cap" = $1x10^{-7}$ centimeter per second cap hydraulic conductivity.

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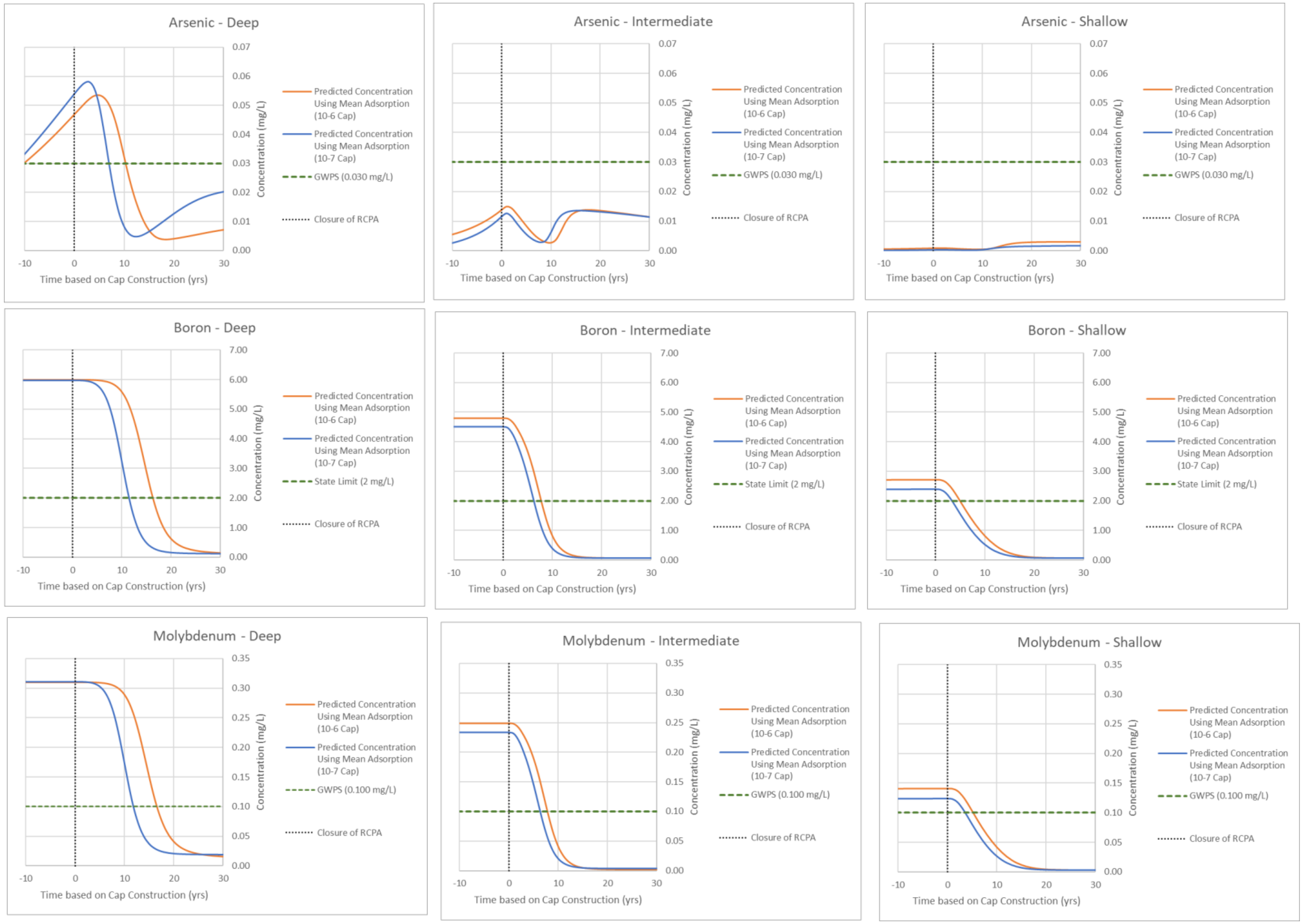
| DESIGN | MSG |
| REVIEW | MSG |
| APPROVED | MNH |

PROJECT
GROUNDWATER MONITORING PROGRAM

TITLE
**Time Series Plot**
**Average Concentrations at Location 1**

PROJECT No. **1531406**
REV **A**
Figure **8**




NOTE(S)

1) GWPS – Groundwater Protection Standard. This is a site specific value.
2) mg/L – milligrams per liter.
3) "$10^{-6}$ Cap" = $1x10^{-6}$ centimeter per second cap hydraulic conductivity.
4) "$10^{-7}$ Cap" = $1x10^{-7}$ centimeter per second cap hydraulic conductivity.

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PROJECT

GROUNDWATER MONITORING PROGRAM

TITLE

**Time Series Plot**
**Average Concentrations at Location 2**

| PROJECT No. | REV | Figure |
|---|---|---|
| 1531406 | A | 9 |

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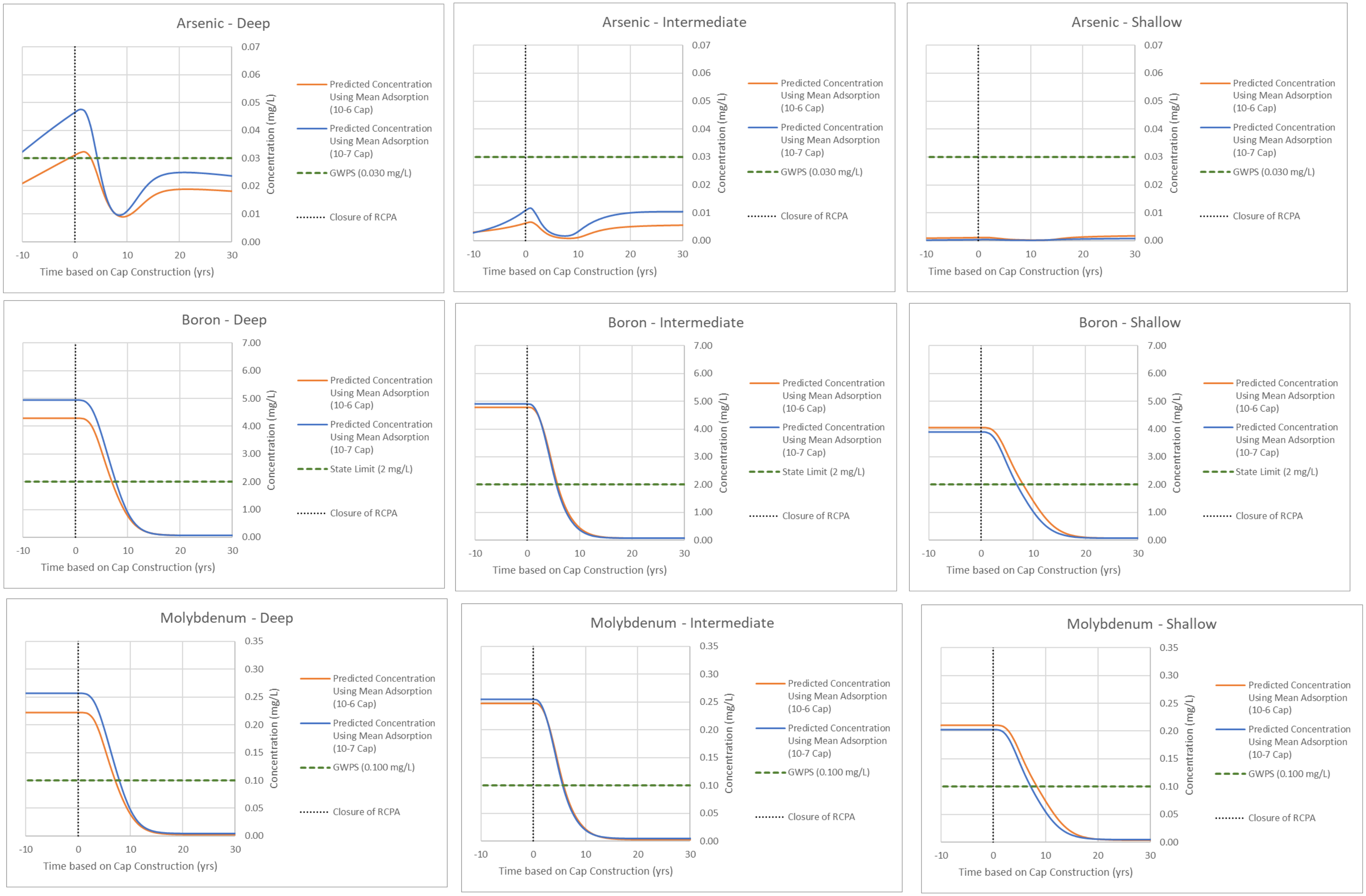


NOTE(S)

1) GWPS – Groundwater Protection Standard. This is a site specific value.
2) mg/L – milligrams per liter.
3) "$10^{-6}$ Cap" = $1x10^{-6}$ centimeter per second cap hydraulic conductivity.
4) "$10^{-7}$ Cap" = $1x10^{-7}$ centimeter per second cap hydraulic conductivity.

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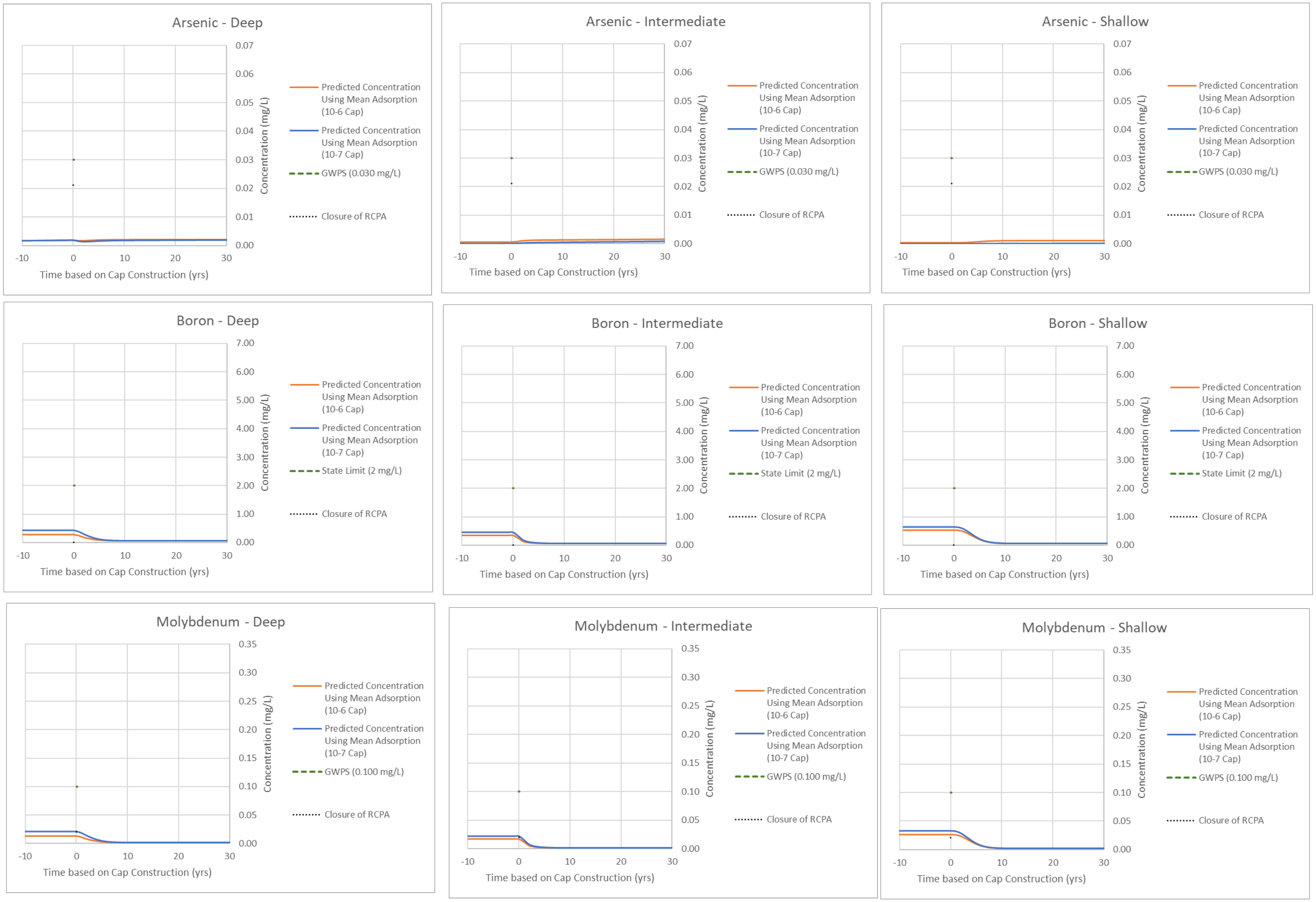
PROJECT
GROUNDWATER MONITORING PROGRAM

TITLE
**Time Series Plot**
**Average Concentrations at Location 3**

| PROJECT No. | REV | Figure |
|---|---|---|
| 1531406 | A | 10 |




NOTE(S)

1) GWPS – Groundwater Protection Standard. This is a site specific value.
2) mg/L – milligrams per liter.
3) "$10^{-6}$ Cap" = $1x10^{-6}$ centimeter per second cap hydraulic conductivity.
4) "$10^{-7}$ Cap" = $1x10^{-7}$ centimeter per second cap hydraulic conductivity.

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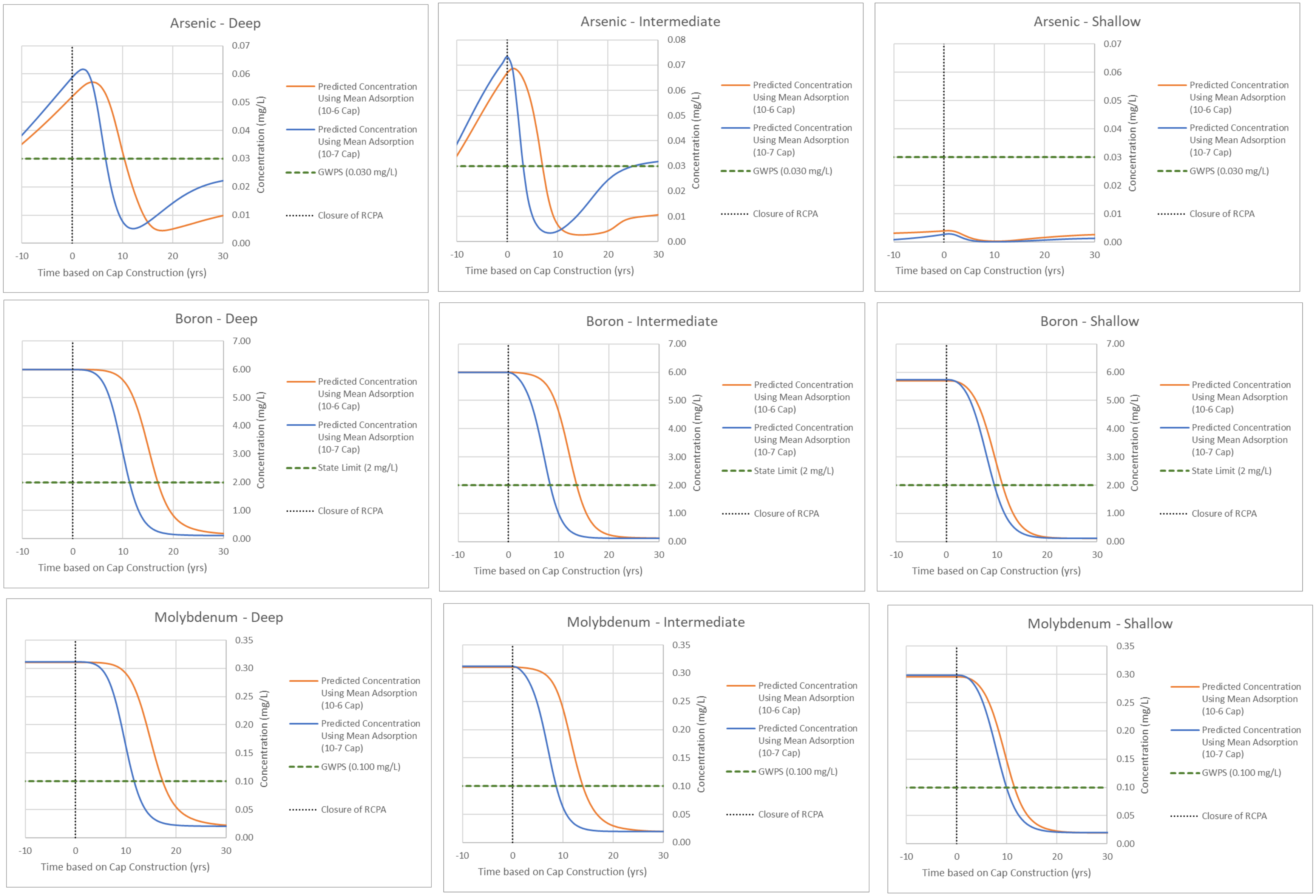
| REVIEW | MSG |
| APPROVED | MNH |

PROJECT
GROUNDWATER MONITORING PROGRAM

TITLE
**Time Series Plot**
**Average Concentrations at Location 4**

PROJECT No. **1531406** REV **A** Figure **11**




NOTE(S)

1) GWPS – Groundwater Protection Standard. This is a site specific value.
2) mg/L – milligrams per liter.
3) “$10^{-6}$ Cap” = $1x10^{-6}$ centimeter per second cap hydraulic conductivity.
4) “$10^{-7}$ Cap” = $1x10^{-7}$ centimeter per second cap hydraulic conductivity.

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| REVIEW | MSG |
| APPROVED | MNH |

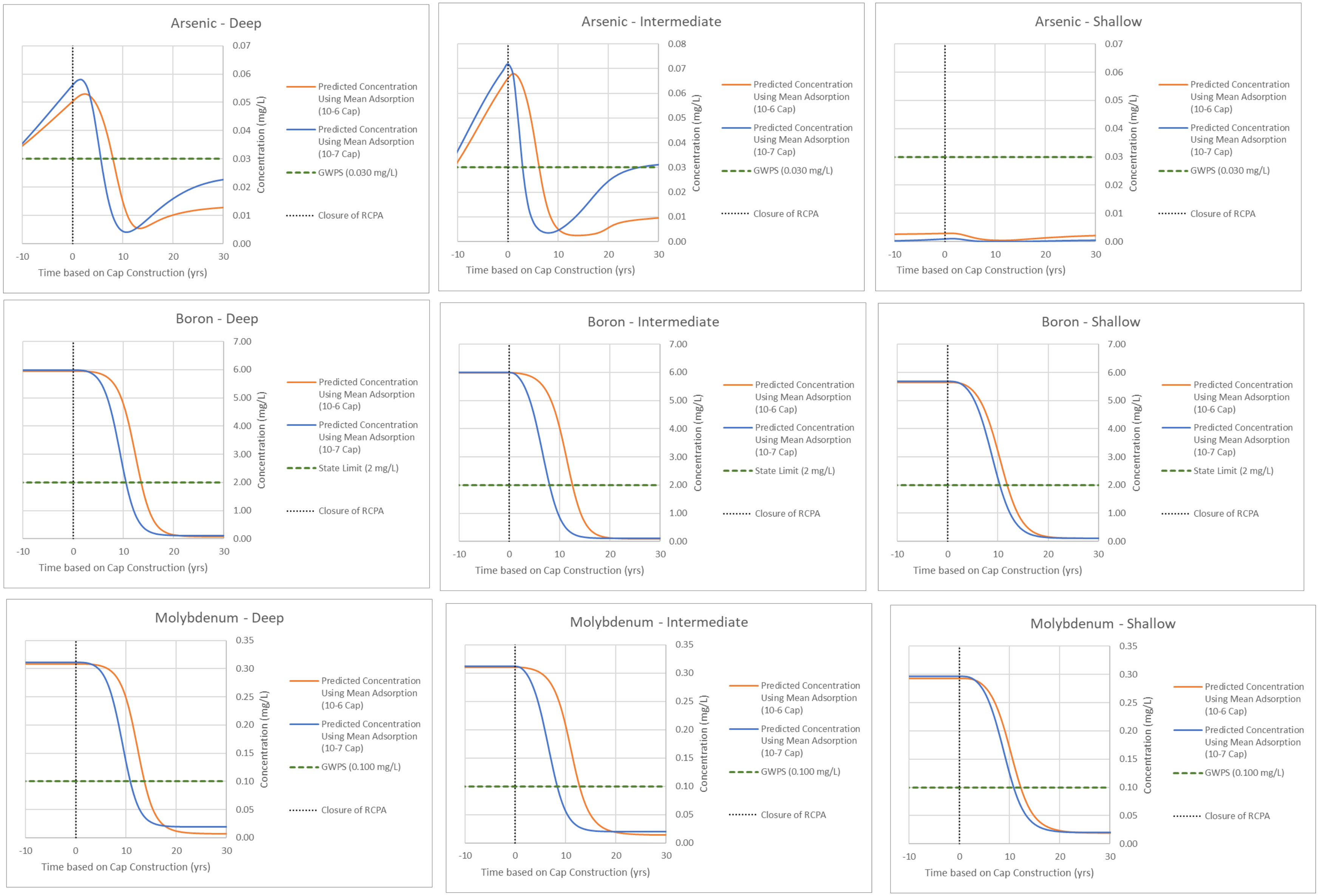
PROJECT

GROUNDWATER MONITORING PROGRAM

TITLE

**Time Series Plot**
**Average Concentrations at Location 5**

| PROJECT No. | REV | Figure |
|---|---|---|
| 1531406 | A | 12 |




NOTE(S)

1) GWPS – Groundwater Protection Standard. This is a site specific value.
2) mg/L – milligrams per liter.
3) "$10^{-6}$ Cap" = $1\times10^{-6}$ centimeter per second cap hydraulic conductivity.
4) "$10^{-7}$ Cap" = $1\times10^{-7}$ centimeter per second cap hydraulic conductivity.

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| PREPARED | EMS |
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| REVIEW | MSG |
| APPROVED | MNH |

PROJECT
GROUNDWATER MONITORING PROGRAM

TITLE
**Time Series Plot**
**Average Concentrations at Location 6**

| PROJECT No. | REV | Figure |
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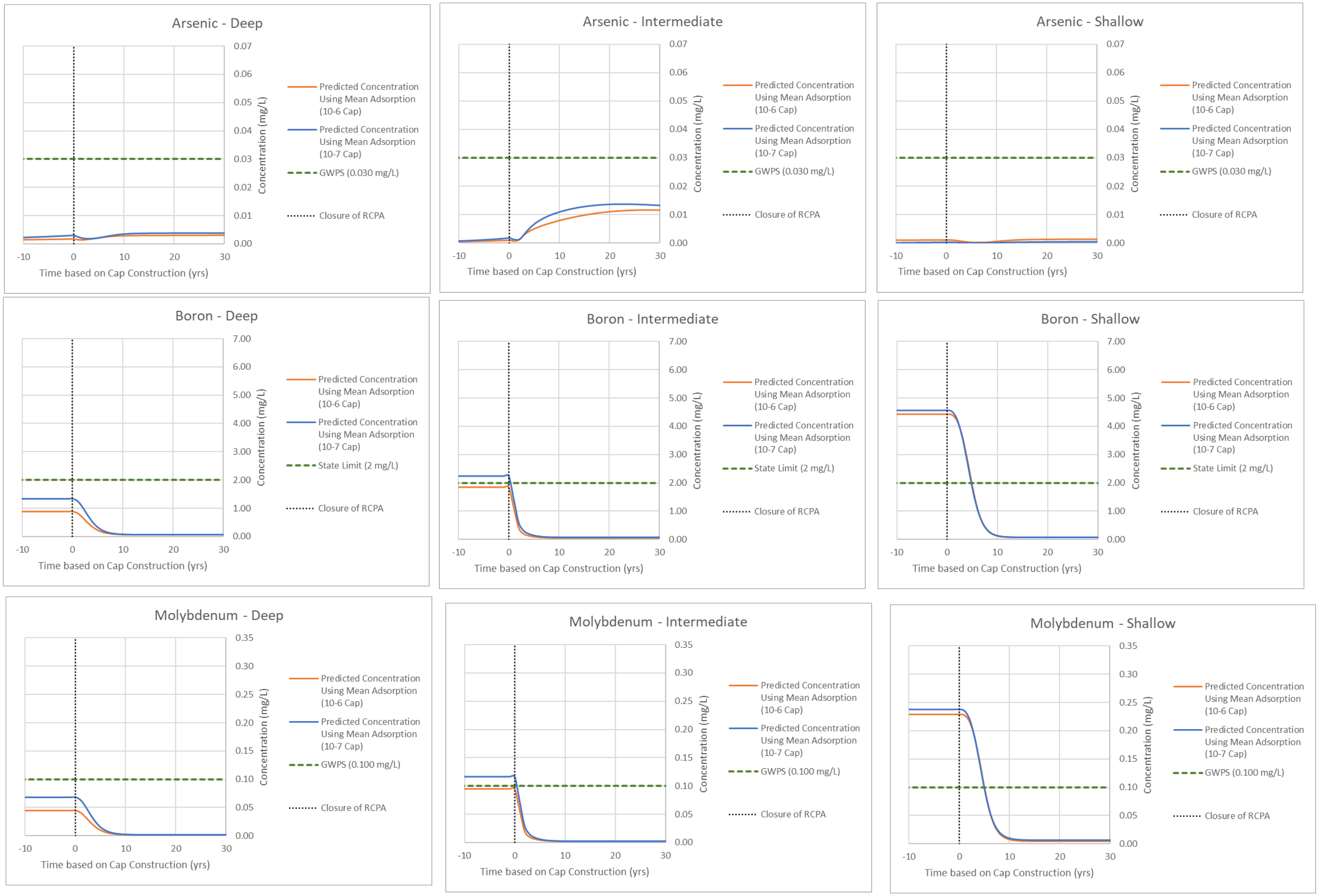
| 1531406 | A | 13 |




NOTE(S)

1) GWPS – Groundwater Protection Standard. This is a site specific value.
2) mg/L – milligrams per liter.
3) "$10^{-6}$ Cap" = $1 \times 10^{-6}$ centimeter per second cap hydraulic conductivity.
4) "$10^{-7}$ Cap" = $1 \times 10^{-7}$ centimeter per second cap hydraulic conductivity.

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| DESIGN | MSG |
| REVIEW | MSG |
| APPROVED | MNH |

PROJECT
GROUNDWATER MONITORING PROGRAM

TITLE
**Time Series Plot**
**Average Concentrations at Location 7**

| PROJECT No. | REV | Figure |
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**LEGEND**

- Rush Island Energy Center Property Boundary
- RCPA Surface Impoundment
- RCPA CCR Rule Monitoring Well Location
- Existing Monitoring Well Used for Nature and Extent
- Pore-water Monitoring Well

**NOTES**

1. ALL LOCATIONS AND BOUNDARIES ARE APPROXIMATE. SOME PIEZOMETER LOCATIONS OFFSET FOR CLARITY PURPOSES.

**REFERENCE**

1.) AMEREN MISSOURI RUSH ISLAND ENERGY CENTER, RUSH ISLAND PROPERTY CONTROL MAP, JANUARY 2012.
2.) NRT 2014, NATURAL RESOURCE TECHNOLOGY, RUSH ISLAND IMPOUNDMENT POND CLOSURE GROUNDWATER MONITORING AND SAMPLING PLAN, MARCH 4, 2014.
3.) COORDINATE SYSTEM: NAD 1983 STATEPLANE MISSOURI EAST FIPS 2401 FEET.

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PROJECT
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TITLE
**GROUNDWATER ELEVATION MEASUREMENT LOCATION MAP**

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| YYYY-MM-DD | 2019-03-26 |
| PREPARED | JSI |
| DESIGN | JSI |
| REVIEW | EMS |
| APPROVED | MNH |

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