Using Stabilized Flue Gas Desulfurization Material to Reclaim Highwalls and Mitigate Acid Mine Drainage

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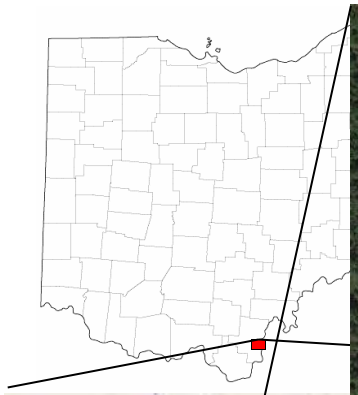
Stingy Run Fly Ash Impoundment



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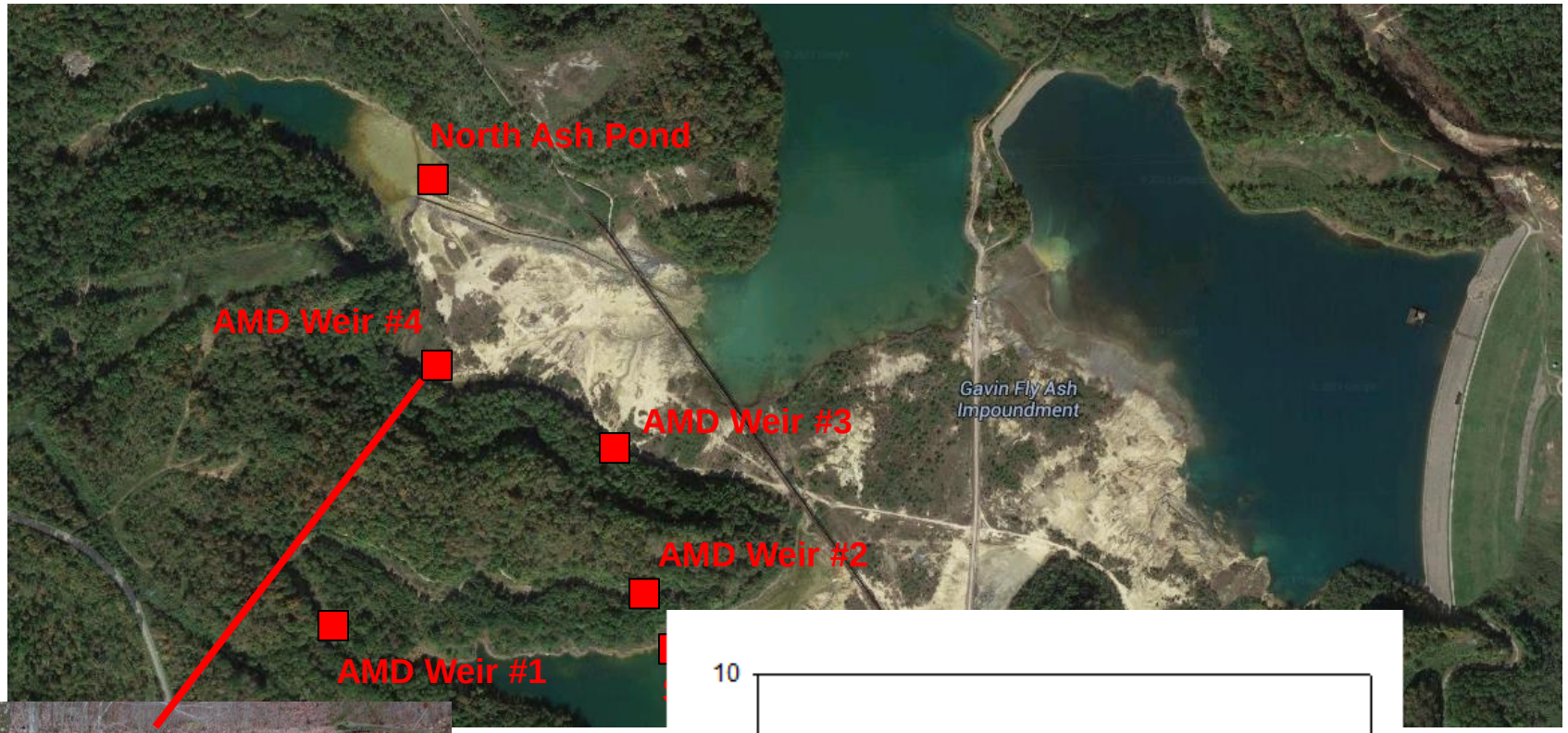
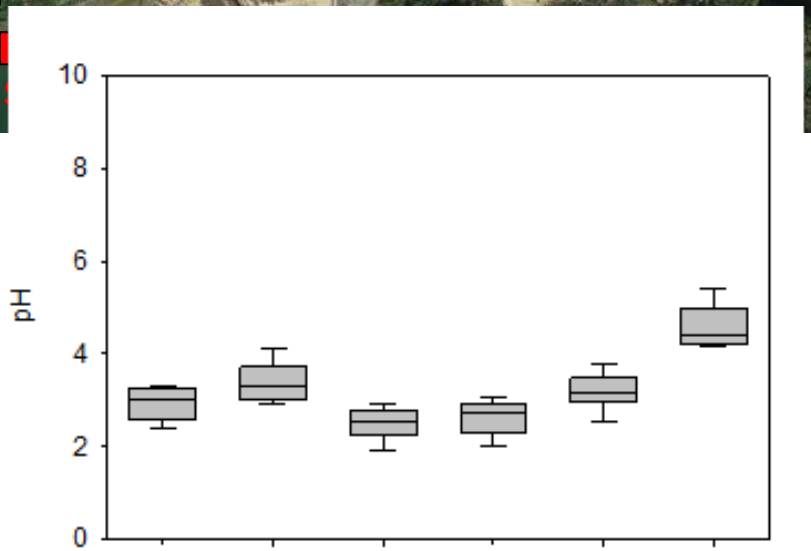


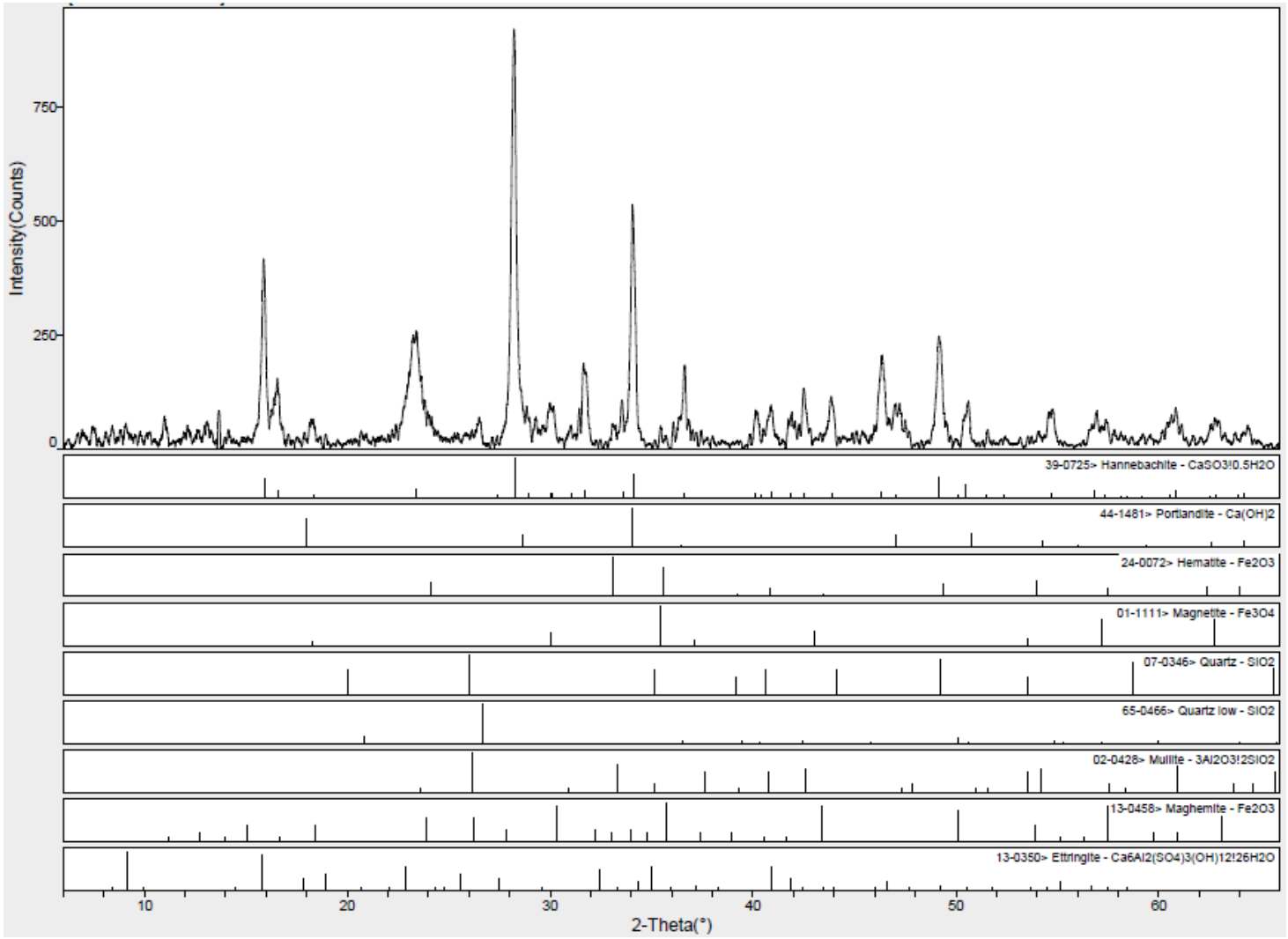


Highwalls and Pits Around Stingy Run Impoundment

Reclamation using Fixated FGD Material

- Utilizing large volume of fixated flue gas desulfurization materials
  - FGD by-product (calcium sulfite) stabilized with fly ash and lime
- Goals
  - Encapsulate acid mine drainage (AMD) producing materials
  - Neutralize AMD
  - Re-contour highwalls
- Approaches
  - Year I: field investigation; laboratory test; bench-scale study; numerical analysis of design approaches; background water monitoring
  - Year II and III: permitting, water quality monitoring, construction of the demonstration project

Mineral Composition of Gavin Stablized FGD Material



Hannebachite ($CaSO_3$ 0.5 H_2O)

Portlandite ($Ca(OH)_3$)

Hematite (Fe_2O_3)

Magnetite (Fe_3O4)

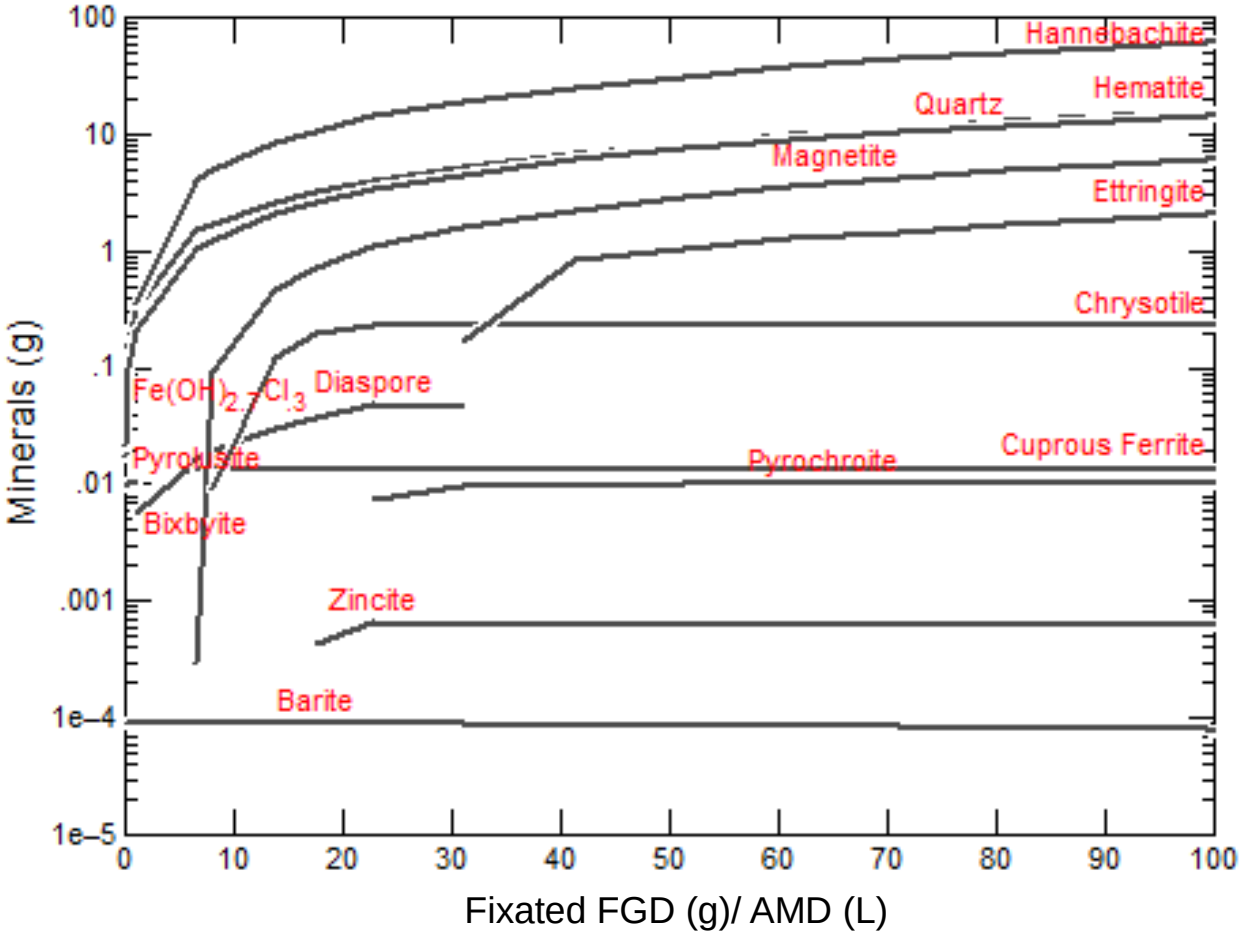
Quartz (SiO_2)

Mullite ($3Al_2O_3$ $2SiO_2$)

Maghemite (Fe_2O_3)

Ettringite ($Ca_6Al_2(SO_4)_3(OH)_{12}.26H_2O$)

Chemical Reactions between AMD and Stabilized FGD Material



- Neutralization of AMD
  - Portlandite

$$Ca(OH)_2 + 2H^+ \rightarrow Ca^{2+} + 2H_2O$$

  - Ettringite

$$C_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O + 12H^+ \rightarrow 2Al^{3+} + 6Ca^{2+} + 3SO_4^{-2} + 38H_2O$$

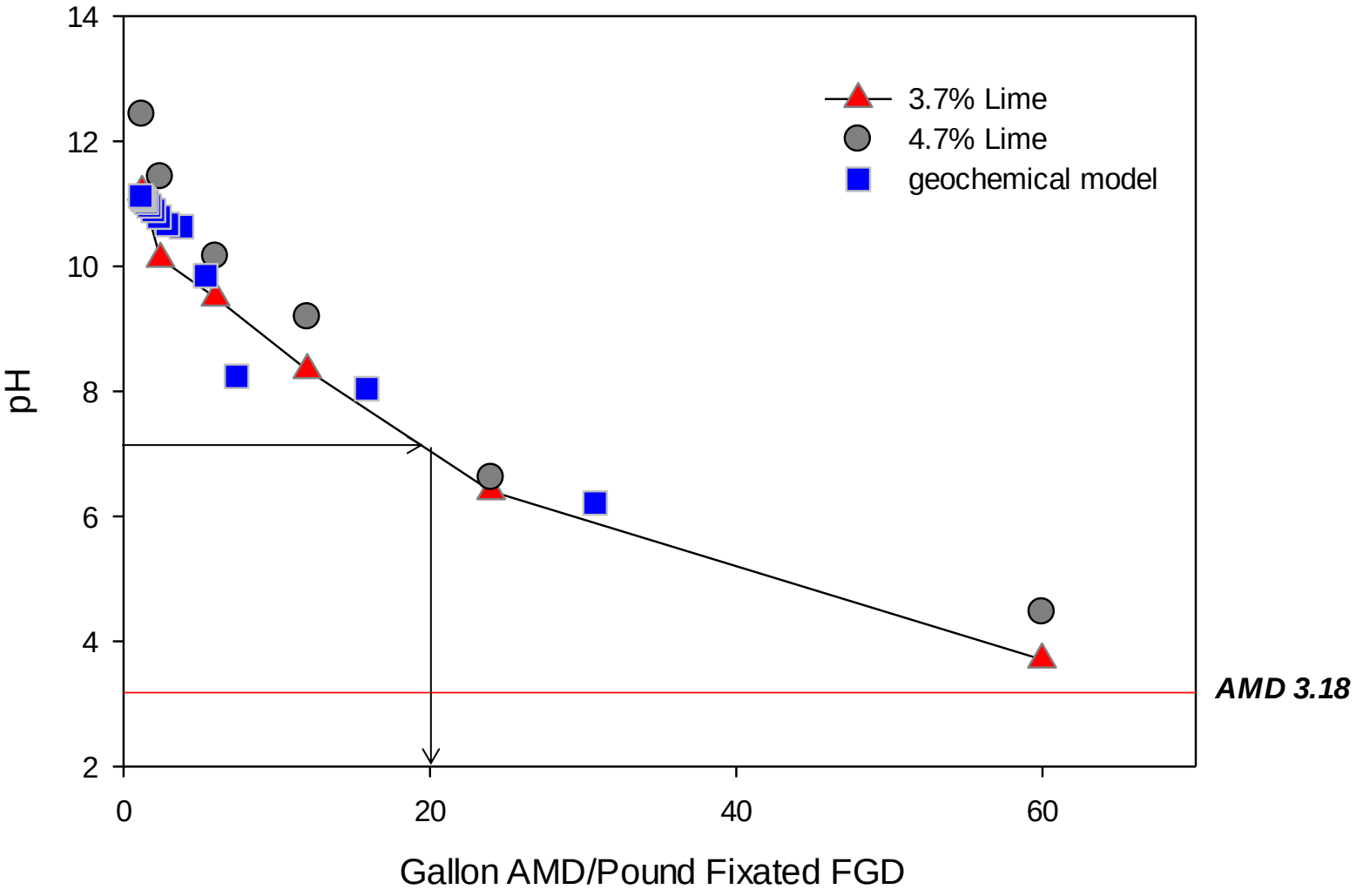
  - Iron oxides

$$Fe_2O_3 + 6H^+ \rightarrow 2Fe^{3+} + 6H_2O$$

$$Fe_3O_4 + 8H^+ \rightarrow 2Fe^{3+} + Fe^{2+} + 8H_2O$$

  - Carbonates
- Formation of potential secondary minerals
  - Iron hydroxides, Chrysotile ($Mg_3Si_2O_5$), diaspore ($AlHO_2$), bixbyite (Mn_2O_3), barite ($BaSO_4$)

Neutralization Capacity



Reclamation using Fixated FGD Material

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- Objectives
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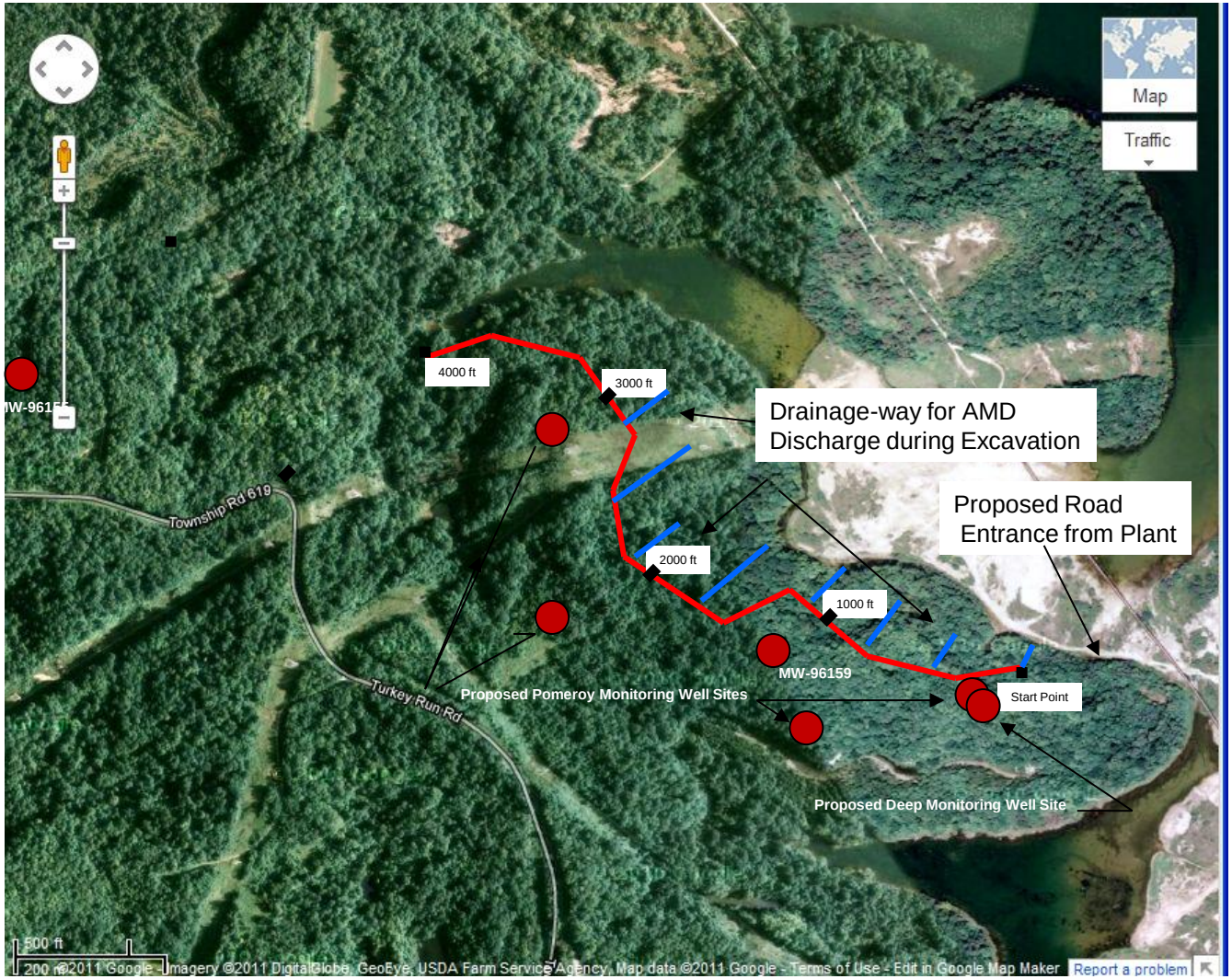
Full-scale Demonstration



Scale:

Approximate Highwall Location

1000 ft Approximate Measurement of Distance

Reclamation using Fixated FGD Material

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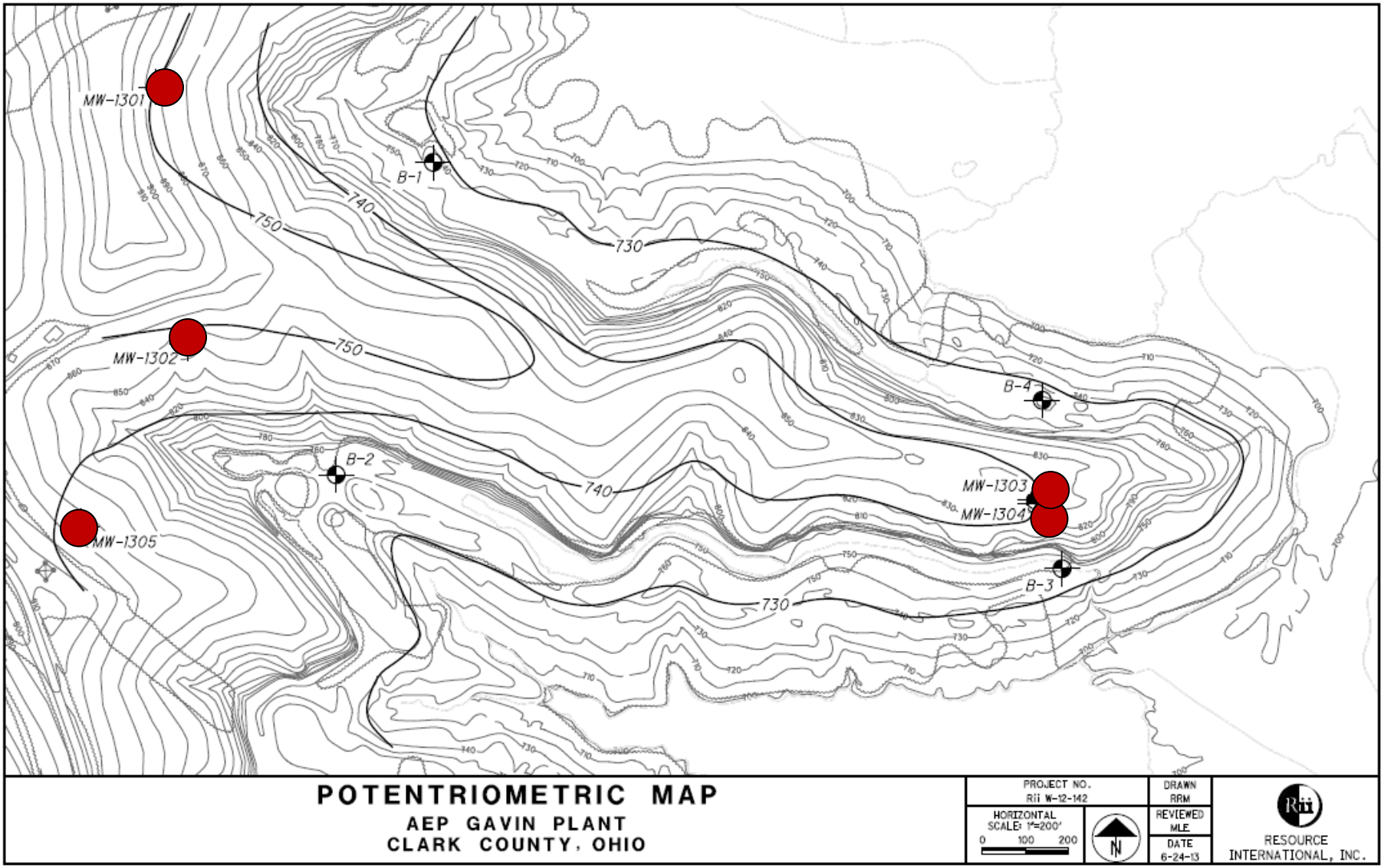
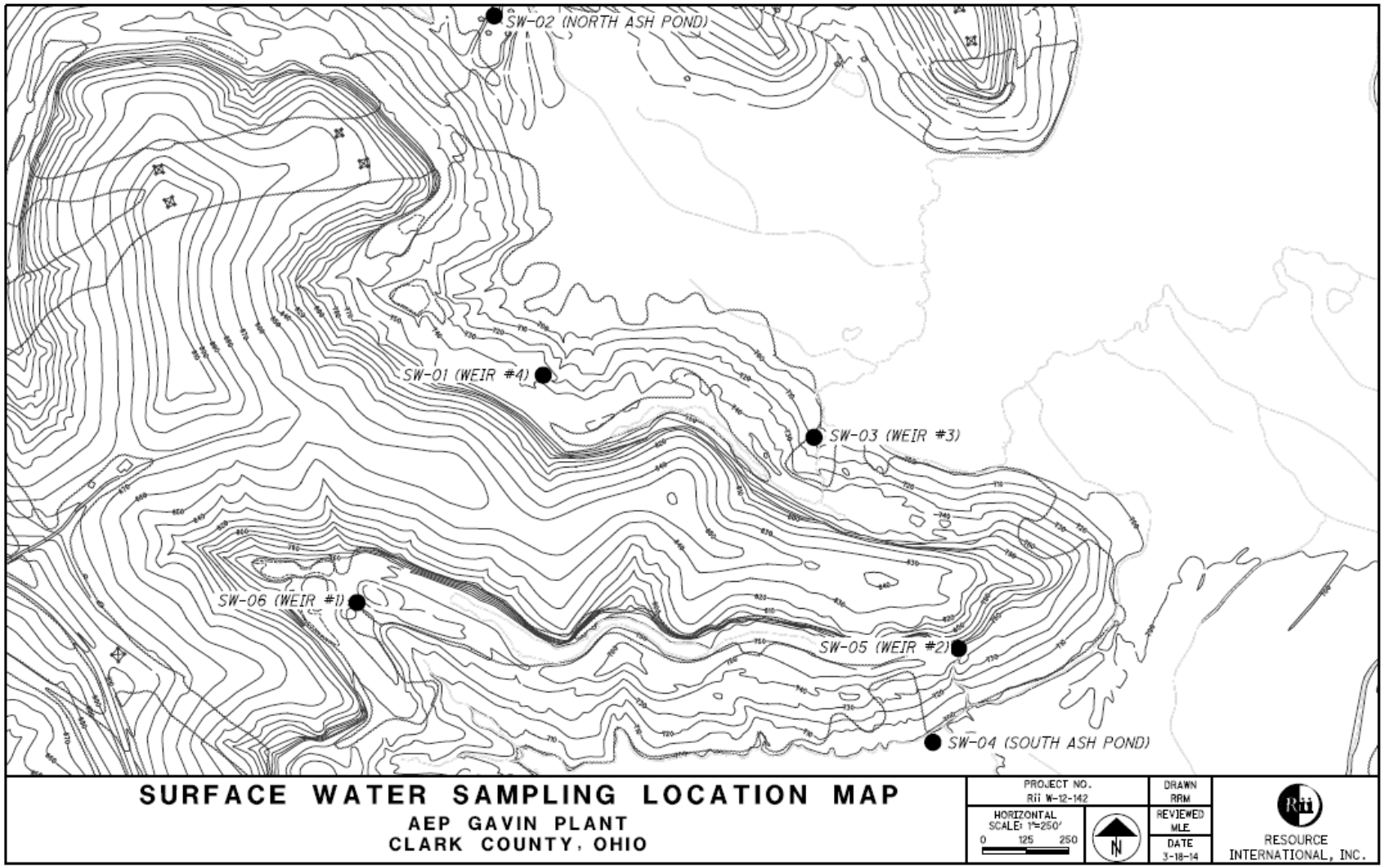
- Goals
  - Encapsulate acid mine drainage (AMD) producing materials
  - Neutralize AMD
  - Re-contour highwalls
- Approaches
  - Laboratory test: batch and column leaching studies, development of geochemical kinetic model
  - Bench-scale study: effectiveness of different reclamation design, numerical analysis of design approaches.
  - Field: water monitoring and full-scale demonstration

Water Quality Monitoring

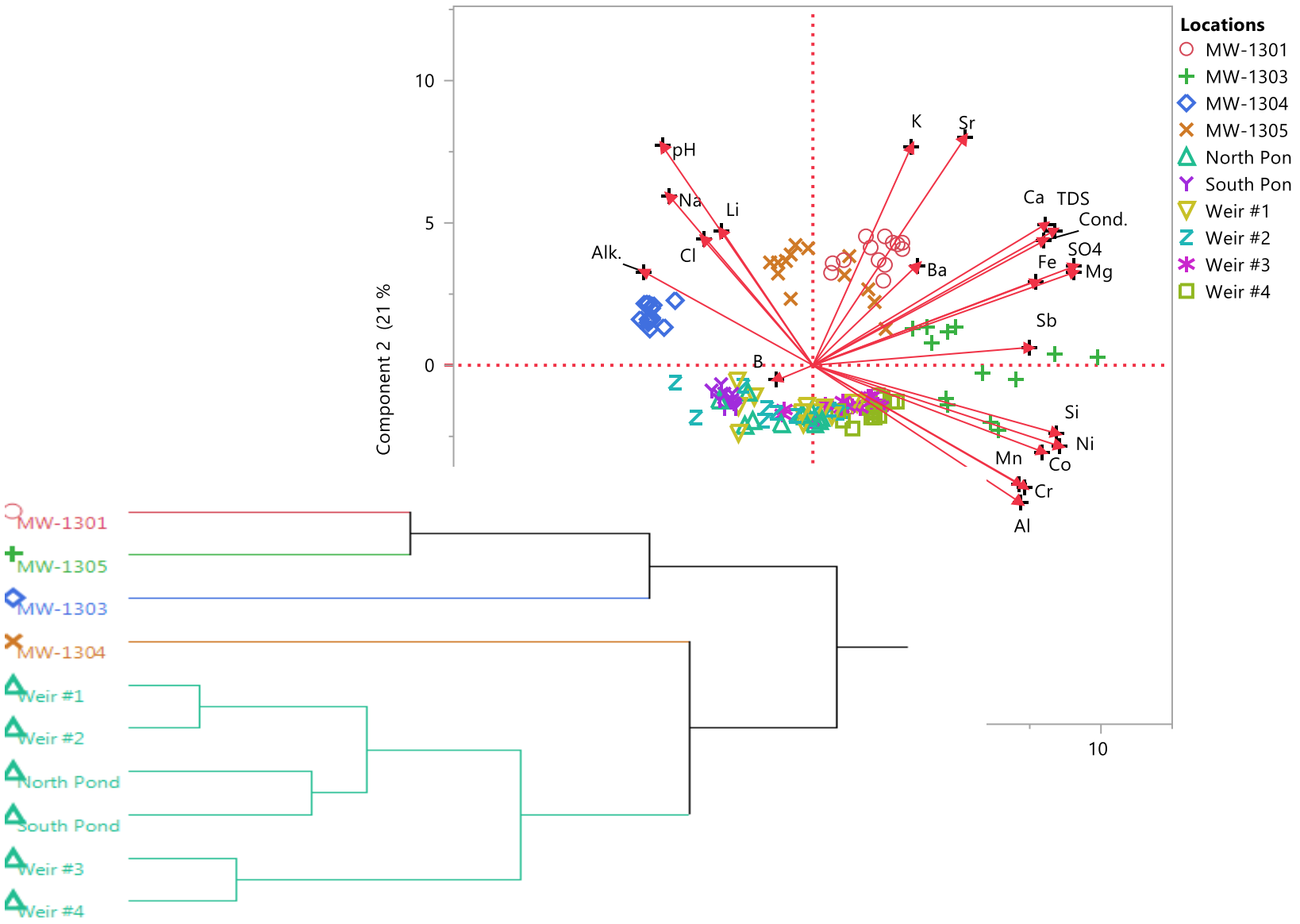
Groundwater Monitoring



Surface Water Monitoring



Background Water Quality

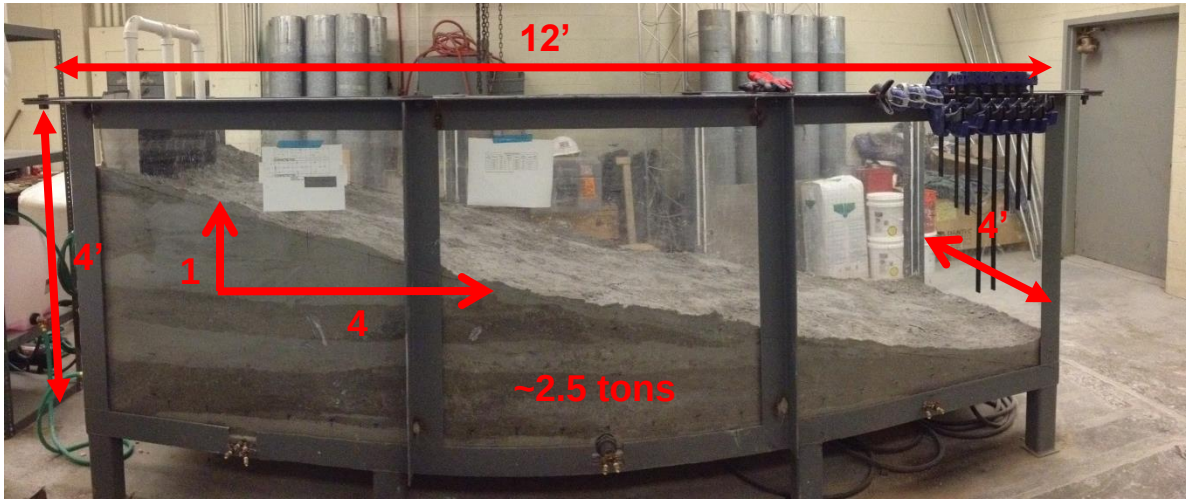


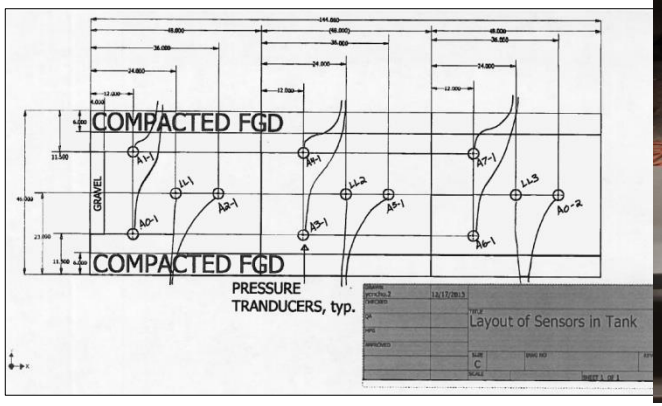
Bench Scale Testing

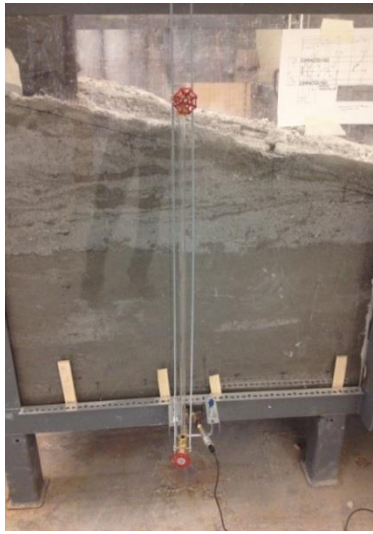
Objective: **Calibrate geotechnical and geochemical models to be used for full-scale demonstration project design**

- Assessment of AMD infiltration in absence and presence of coal drain

Bench Scale Testing





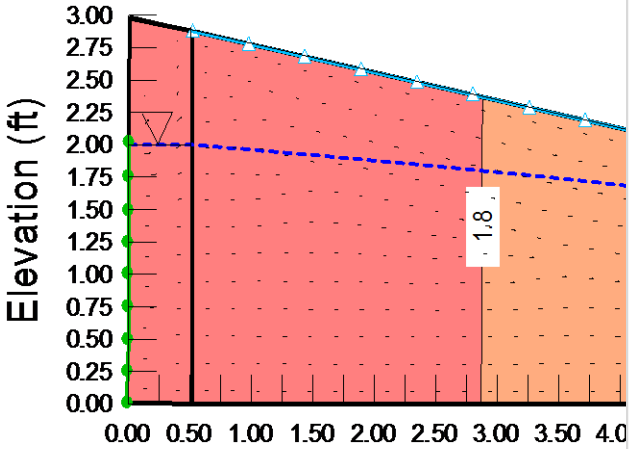


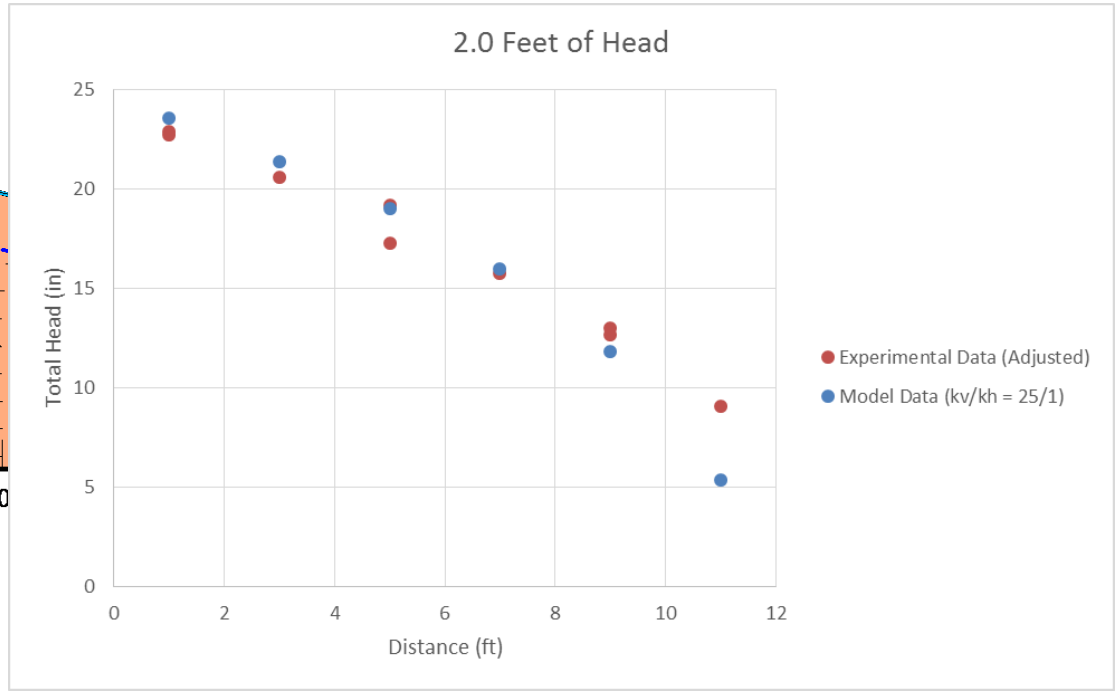
Bench Scale Model Configurations Tested

	Parameters	Results
Test 1	FGD dumped Water, No Geotextile - Transducers at bottom	Calibrated model for effective permeability ratio (steady state modelling)
Test 2	FGD dumped Water, Geotextile (1ft long, 1ft height from bottom) - Transducers above and below geotextile	Flow rates increased significantly
Test 3	FGD lightly compacted AMD, No Geotextile - Transducers at bottom	Calibrated model for effective permeability (transient modelling) for lightly compacted FGD
Test 4	FGD lightly compacted AMD, Geotextile (1ft long, 0.5ft height from bottom) - Transducers at bottom	The presence of Geotextile does not decrease the flow rate
Test 5	FGD well compacted AMD, No Geotextile - Transducers at bottom	Short Term- Calibrated model for effective permeability (transient modelling) for well compacted FGD Long Term (In progress)-Change of AMD property with longer contact time

Geotechnical Modeling

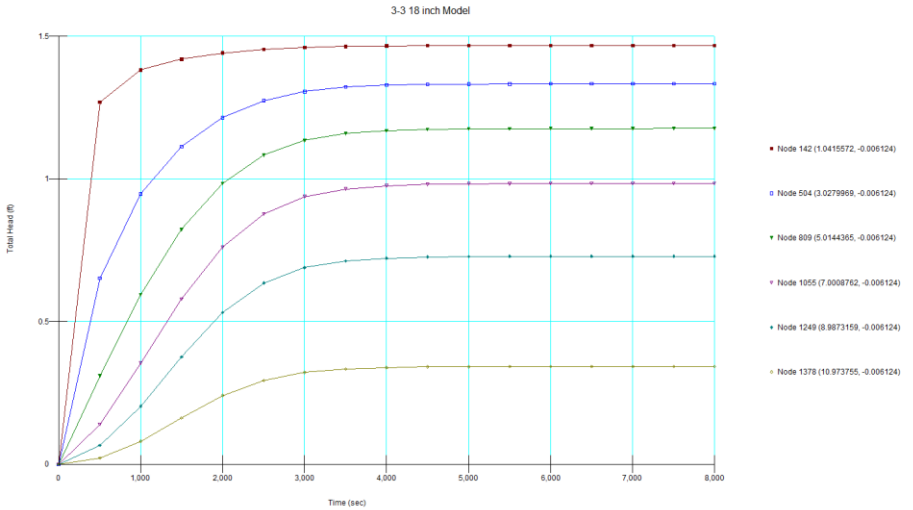
- Seep/w is used to predict flow of water through FGD with and without geotextile
- Steady-State Analysis
  - Calibrated model for effective permeability ratio using Steady-State Analysis (Test 1)

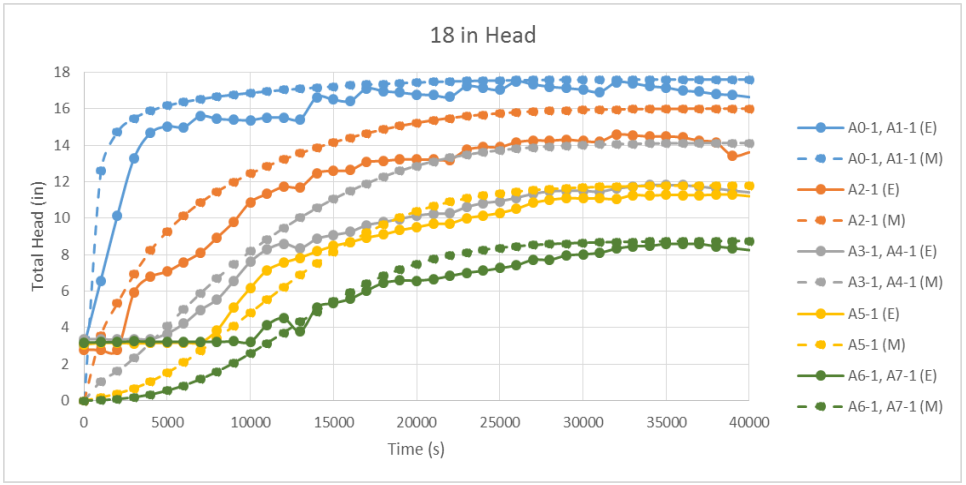




Geotechnical Modeling

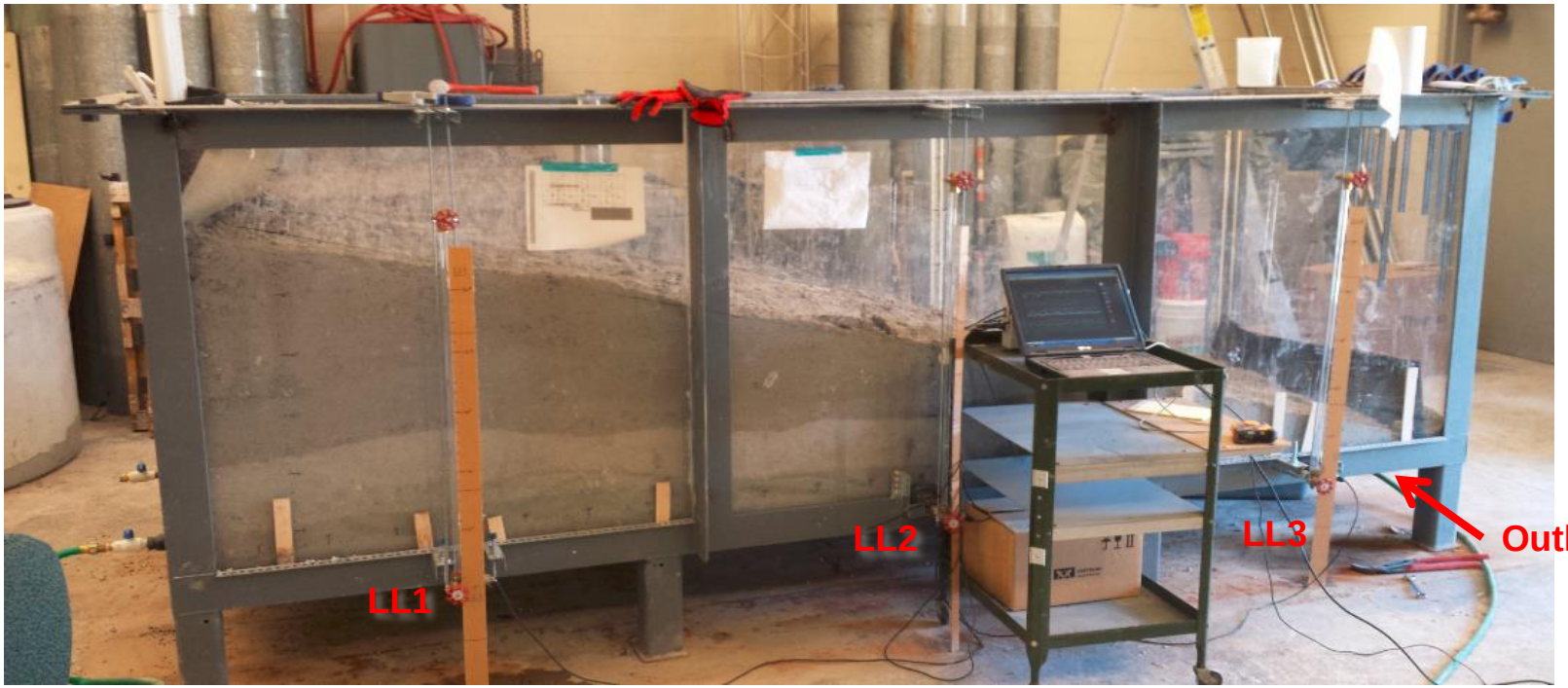
- Transient Analysis
  - Effective horizontal permeability (8×10^{-3} cm/sec) with lightly compacted FGD (Test 3)
  - Effective horizontal permeability (8×10^{-4} cm/sec) with well compacted FGD (Test 5 short term)
    - Significantly increased the time taken for AMD to reach steady-state





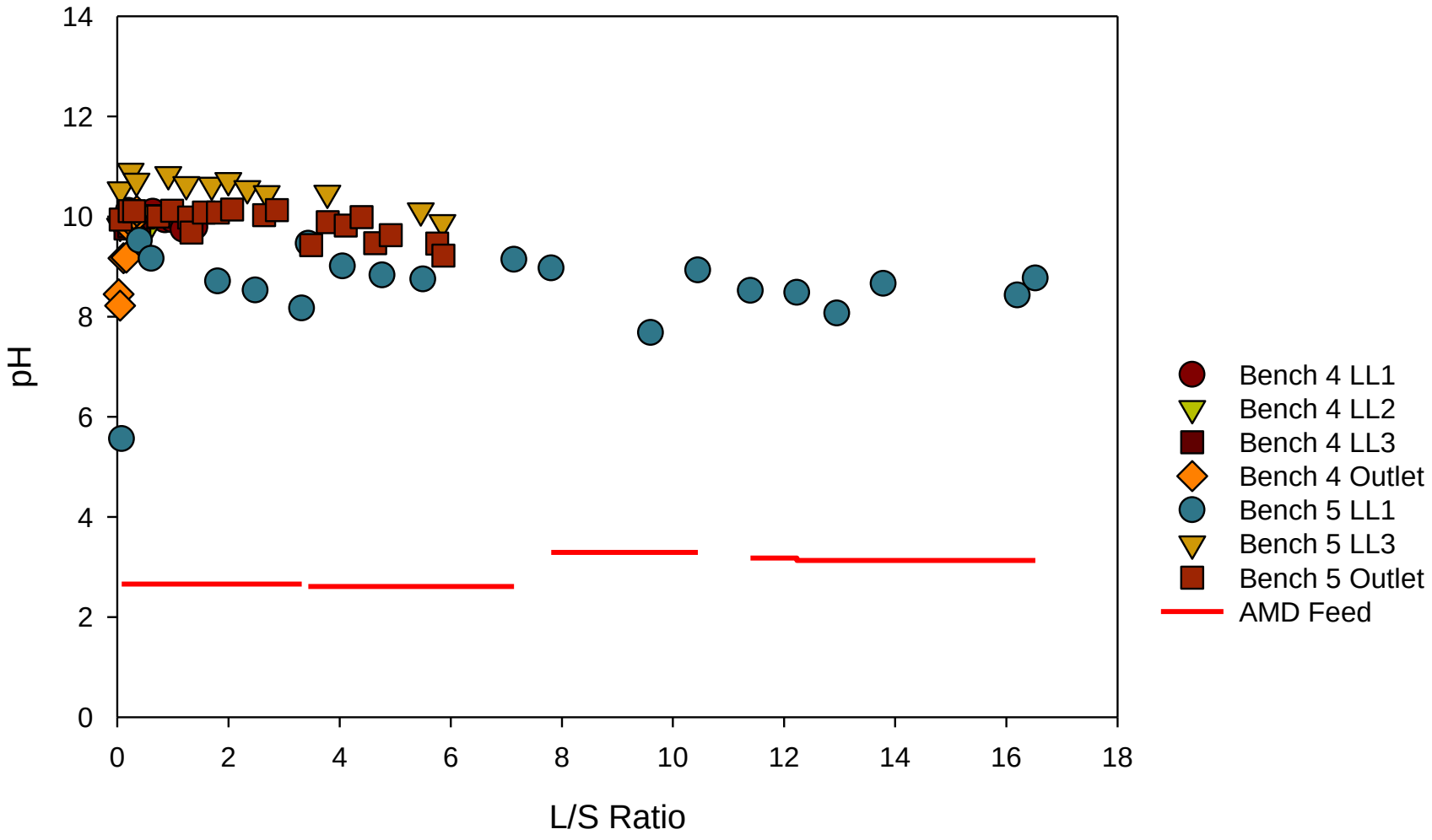
Change of AMD Hydrochemical Property

- Bench Scale-Tests 4 and 5



  - Using AMD collected from the site
  - 24” head at the inlet
  - Samples are collected from LL1, LL2, LL3, and/or outlet

Change of AMD Hydrochemical Property

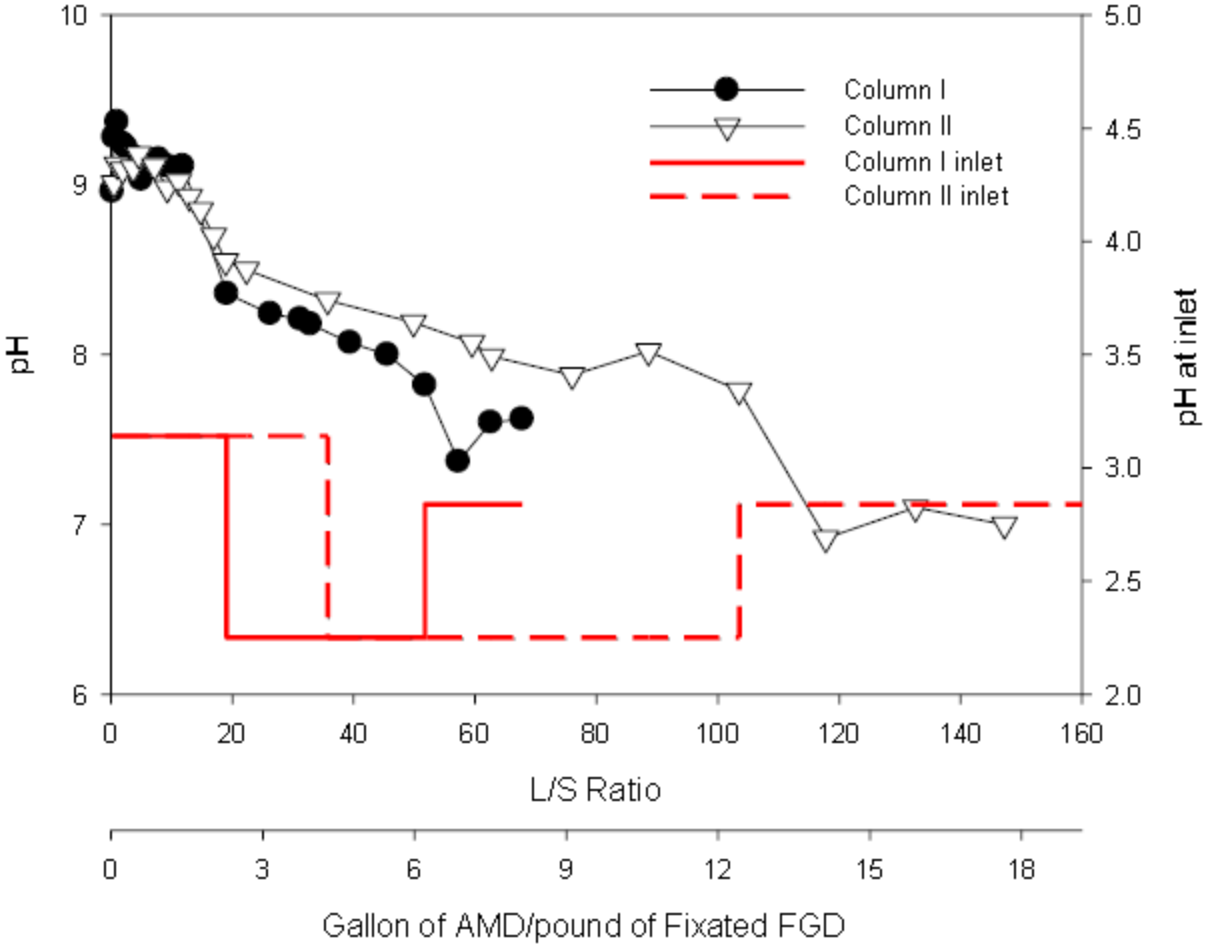


Laboratory Column Testing

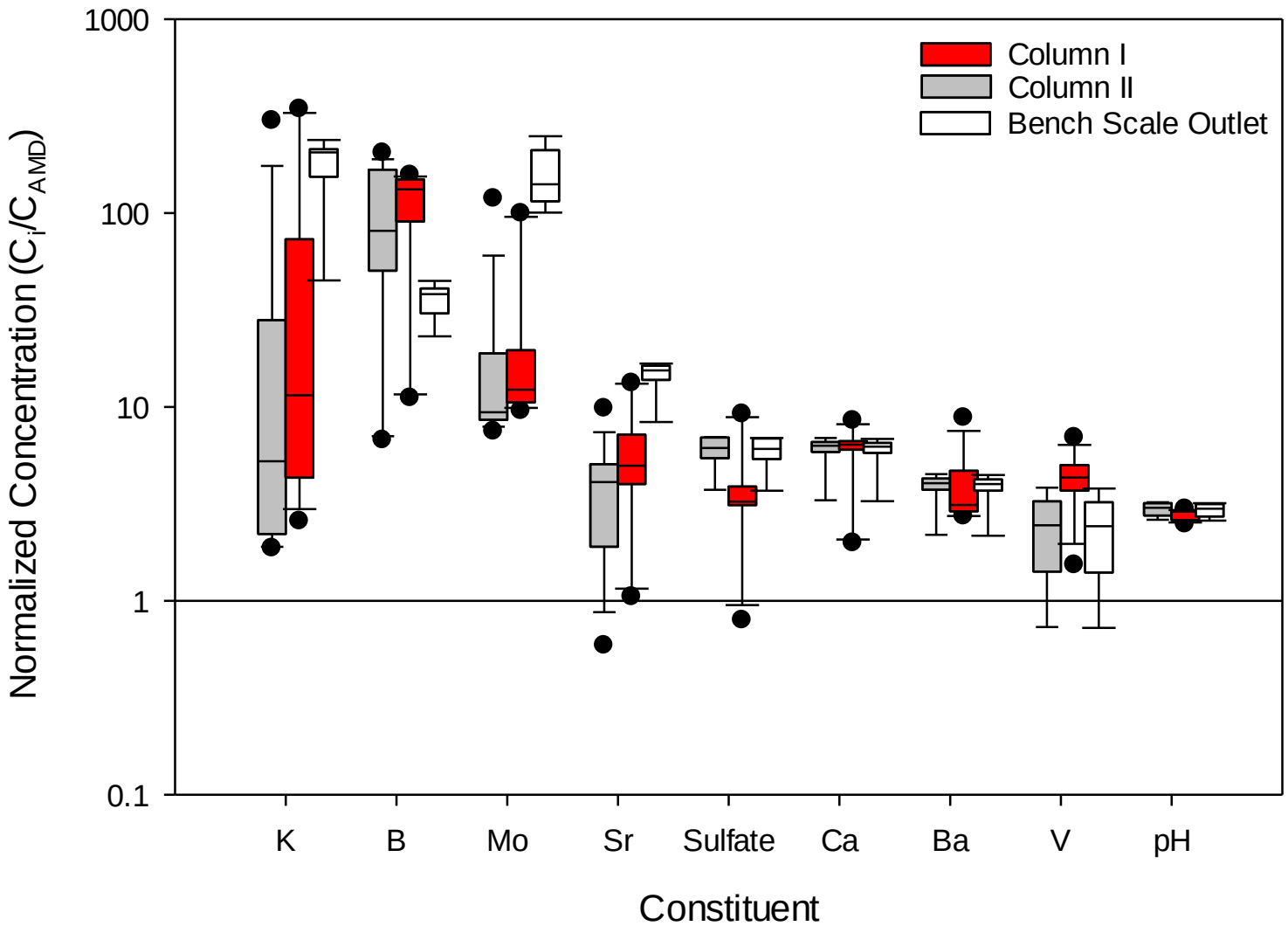
- Simulate AMD neutralization process under similar percolation condition as reclamation
- Two columns with different L/S flow rates
  - Column I: ~1.0 L/S per day
  - Column II: ~2.0 L/S per day
- Monitoring change of AMD water quality with extended L/S ratio
- Temporal trend can be described by coupling solute transport and geochemical models.

Change of AMD pH after Contacting Fixated FGD Material in Flow Through Column Test

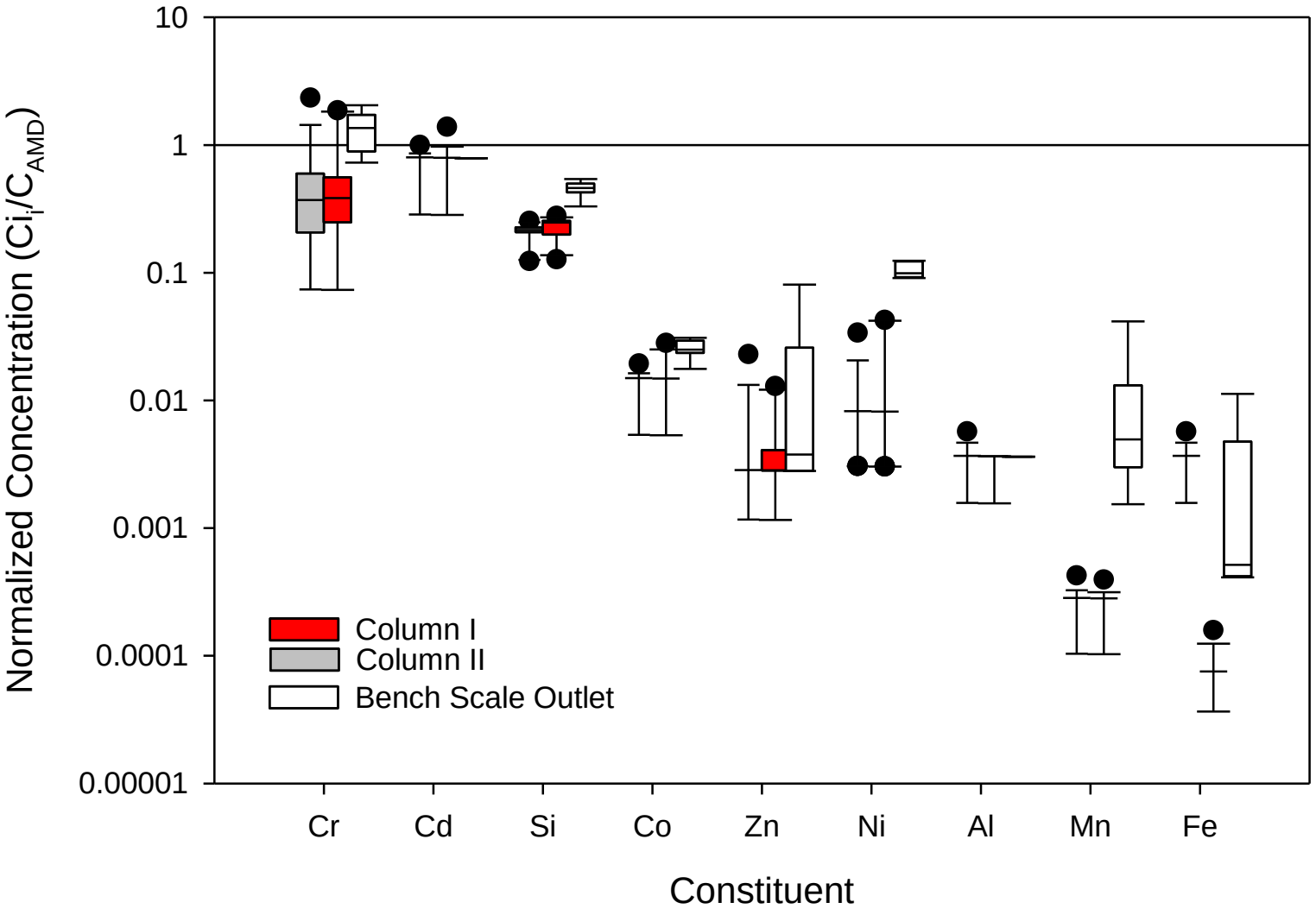
as a Function of L/S Ratio



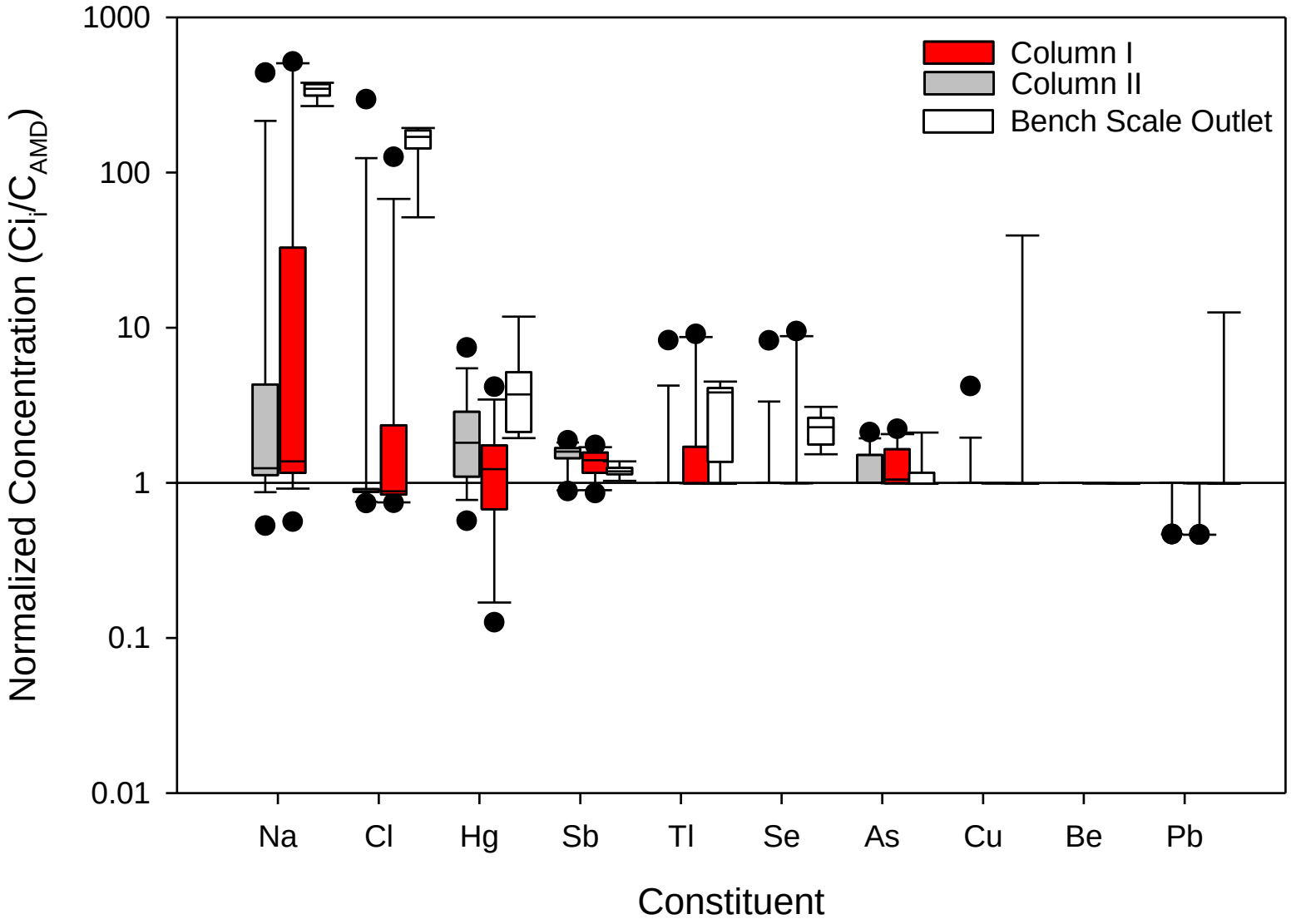
Constituents with Elevated Levels

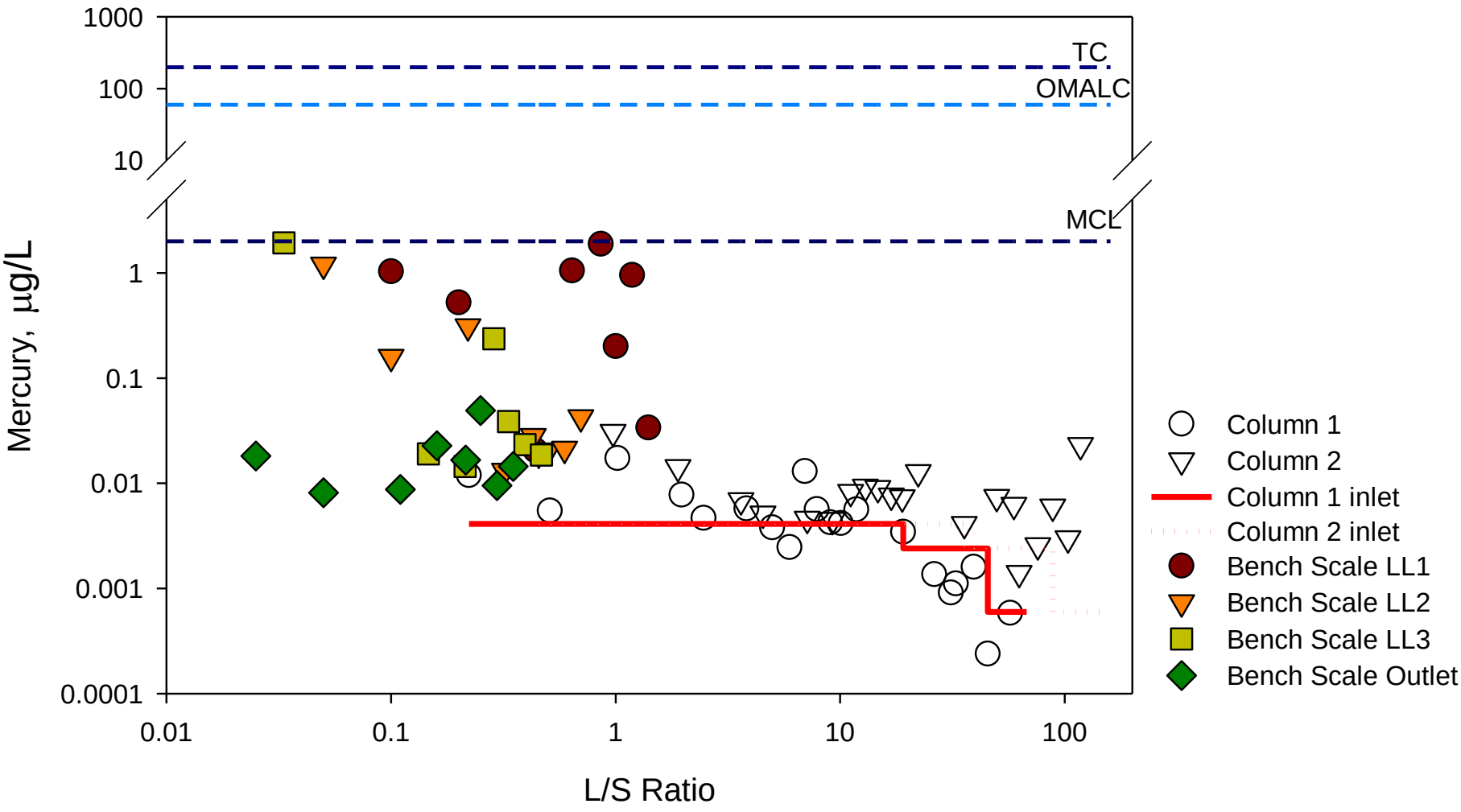


Elements with Decreased Concentration



Elements Showing First Flush Phenomenon




1000
100
10
1
0.1
0.01
0.001
0.0001
TC
OMALC
MCL
Mercury, µg/L
0.01
0.1
1
10
100
L/S Ratio
Column 1
Column 2
Column 1 inlet
Column 2 inlet
Bench Scale LL1
Bench Scale LL2
Bench Scale LL3
Bench Scale Outlet

Summary

- Stablized FGD material can be effective in neutralizing AMD
  - One pound of Gavin fixated FGD material is able to neutralize approximately 20 gallons of AMD (~160 L/S)
- Geotechnical Modeling
  - V/H permeability ratio
  - Effective horizontal permeability ($\mathbf{8 \times 10^{-4}}$ cm/sec) with well compacted FGD
- Concentrations of COI
  - As, B, Pb, Hg, Mo, Se, and Tl exceeded MCL/DWEL during the early stage
  - Sb was constantly higher than MCL
  - All of the concentrations of COIs are lower than either Ohio Maximum Acceptable Leaching Concentration and/or EPA's Toxicity level

Future Work

- Laboratory column test
  - Examine the environmental response beyond the neutralization capacity of the fixated FGD material
  - Coupling solute transport and geochemical kinetic models
    - Using data from column tests
    - Verified with bench-scale testing
    - Used to estimate the concentrations of COI for full-scale demonstration
- Bench-scale reclamation module
  - Model site specific demo project cross sections
- Full-scale demonstration
  - Permit application
  - Reclamation
  - Water quality monitoring/data analysis

Coal Combustion Products Program

Ohio State's Coal Combustion Products Program focuses on sustainable, high-volume beneficial uses of coal combustion products (CCPs), primarily from sulfur dioxide scrubbing processes, in construction, reclamation, infrastructure rehabilitation, manufacturing and agricultural applications. This program advances the beneficial uses of CCPs from sulfur dioxide scrubbing processes as well as more traditional byproducts, including fly ash, bottom ash, boiler slag and fluidized-bed combustor ash. Re-use of CCPs provides a low-cost raw construction material; extends the life of landfills, and lessens the need for new ones; and helps keep energy production costs in check.

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Funded by the Ohio Coal Development Office, Ohio State University, Ohio coal-fired utilities, ash marketers, private businesses and trade and farming organizations, the Coal Combustion Products Program improves and discovers technically sound, environmentally friendly and commercially competitive uses of CCPs in many interdisciplinary sustainable applications.

The program aids the CCP industry through research, education, technology transfer and outreach in its efforts to:

- expand uses in proven areas, such as highway and agricultural applications;
- remove or reduce regulatory and perceptual barriers to use;
- develop new or under-used large-volume market applications, such as mine land reclamation; and
- place greater emphasis on sulfate and sulfite flue gas desulfurization byproducts utilization.

More than 500 animal feeding pads in more than 12 Ohio counties are made from coal combustion products, including feeding pads at The Wilds in Muskingum County.

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To learn more, visit ccp.osu.edu.

Possible deposit of black bixbyite (MnO2)

Possible white barite deposit

Deposit of iron oxide

Comparison of Column and Bench Scale