Bench-scale evaluation of the effectiveness of pond closure using in situ soil stabilization

Agenda

1. Program team
2. Project background and why ISS
3. Bench program overview
4. Key findings/conclusions
5. Q&A

Program team

NiSource

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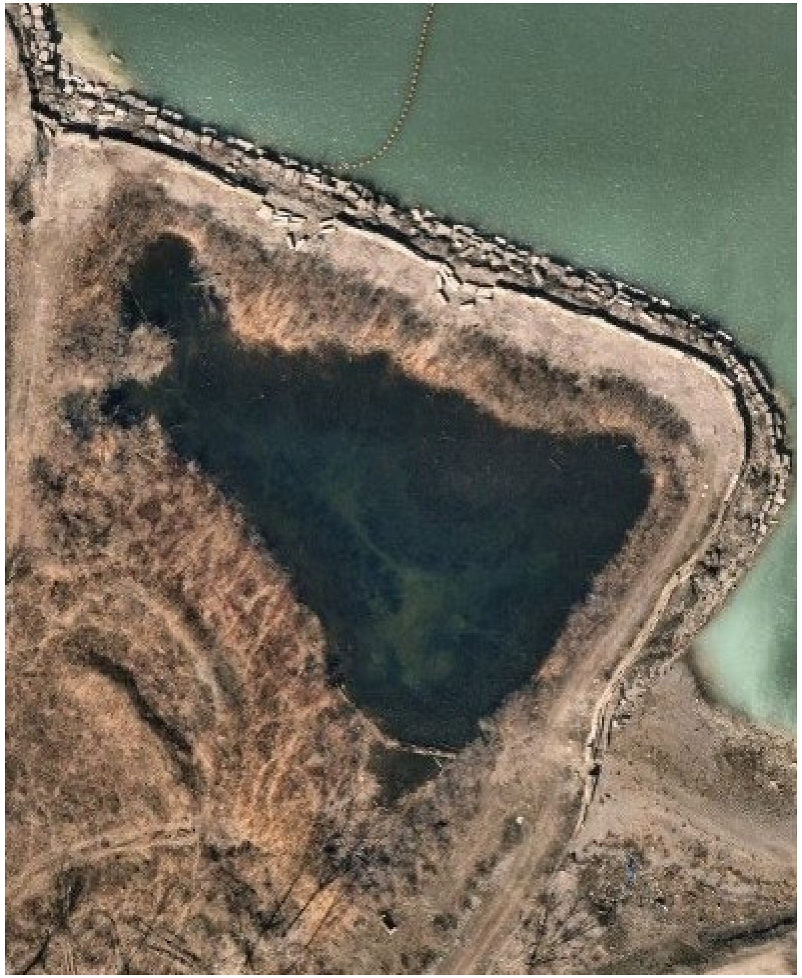
Project background and why ISS

- Four-acre ash pond, approximately 75,000 cubic yards of ash
  - Aerial extent and volume determined through several phases of investigation (test pits and test borings)
  - Ash found up to 25 feet deep
- Closure-by-removal approach was evaluated; however, challenging Site conditions made it difficult to achieve a performance standard to document removal
- Site conditions would necessitate either extensive surface and groundwater control or dredging
- Closure-in-place using ISS is advantageous from a cost and schedule perspective

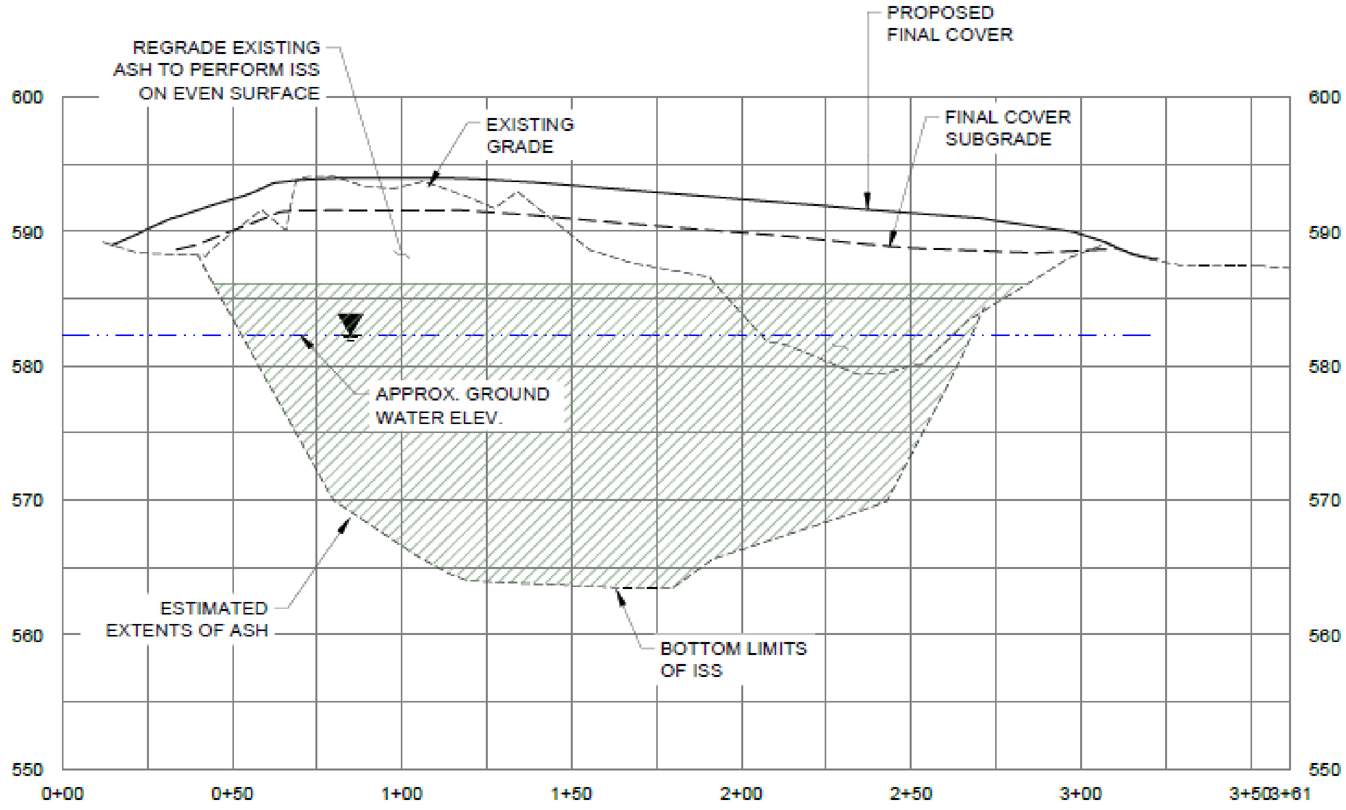
Project setting and challenging site conditions

- Remote location in the northern Midwest
- Limited access
- Proximate to surface water
- Shallow water table
- Groundwater and surface water control challenges
- Surrounding heavy-industrial land use



Bench program overview

- Limited industry data available for this application
- The goal of the program: to demonstrate that application of ISS is feasible and will result in reduced metals concentrations in Site groundwater
- Program included physical and analytical testing performed in sequence
- Followed by a mass flux evaluation for metals
- This work started in June 2020 with the collection of field samples and was completed in March 2022



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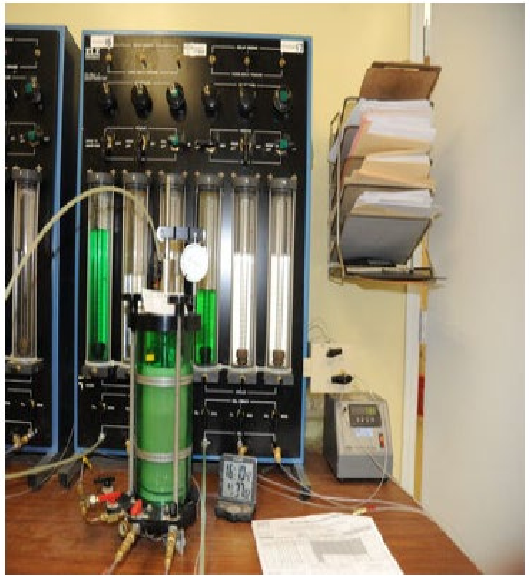
Bench program: physical testing and analysis

Goal: Physical testing was to evaluate if the performance goals can be achieved, and to provide data on which reagents may perform better.

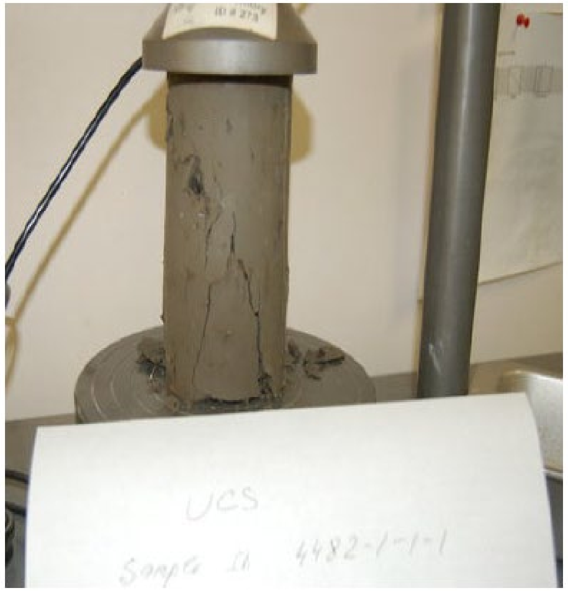
- Testing performed:
  - ASTM D 1633 – Compressive strength
  - ASTM D 5084 – Hydraulic conductivity
- Testing at 7, 14, 28, 56, and 109-day intervals
- Project performance goals:
  - Unconfined compressive strength: 50 psi
  - Hydraulic conductivity: 1.0 x 10^{-5} cm/sec



Flexible Wall Permeability

ASTM D 5084

Photo Courtesy of TEST, LLC



UCS Test for Soil / Cement Mix

ASTM D 1633

Photo Courtesy of TEST, LLC

Testing performed by Timely Engineering Soils Test, LLC (TEST), Tucker, GA

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Bench program: reagents and mix designs

Additives	Portland Cement (%)	Blast Furnace Slag (%)	Cement Kiln Dust (%)	Bentonite (%)
Mix 1	3	7	--	--
Mix 2	4.5	10.5	--	--
Mix 3	1.5	3.5	--	--
Mix 4	3	7	--	1
Mix 5	2	6	6	--

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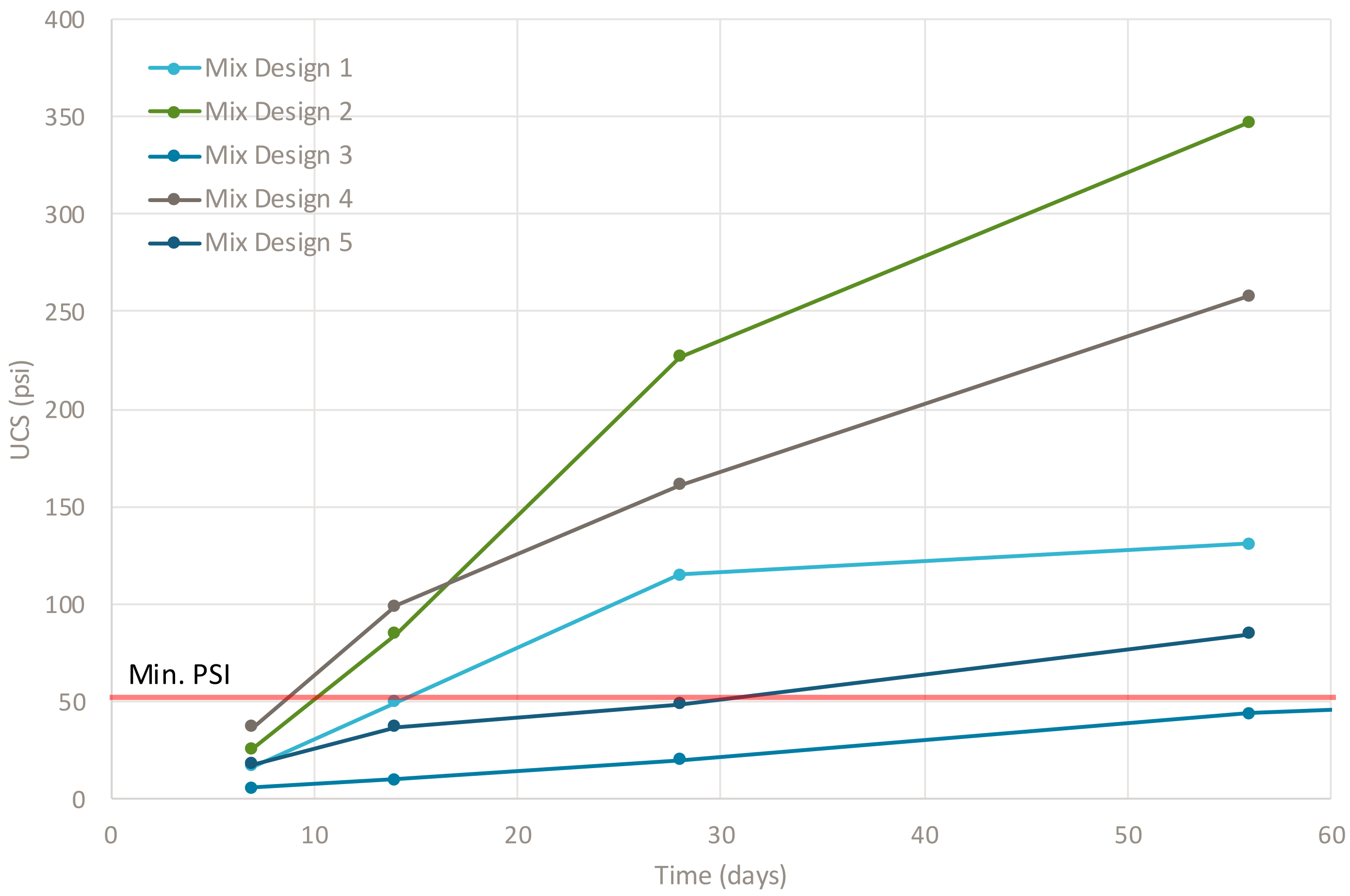
Unconfined compressive strength results



At 28 days, three of the five mix designs exceed 50 psi

At 56 days, four of the five mix designs exceeded 50 psi

Greater addition of Portland Cement resulted in increased strength

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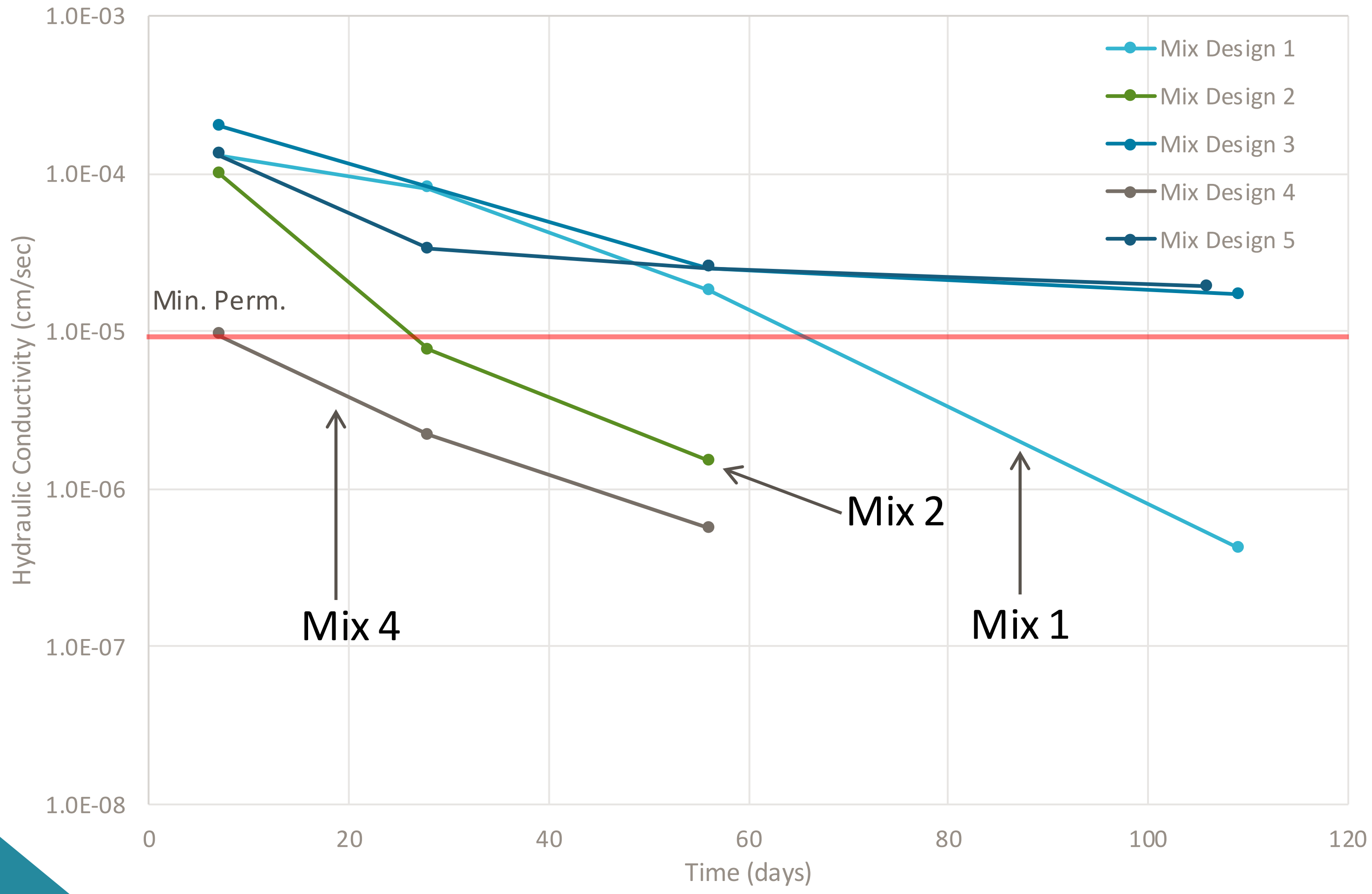
Hydraulic conductivity (permeability) results



At 28 and 56 days, two of the five mix designs met the project performance goal for hydraulic conductivity of less than 1 x 10^{-5} cm/sec:

- Mix 2 - 4.5% PC and 10.5% BFS
- Mix 4 - 3% PC, 7% BFS, and 1% Bentonite

At 109 days, one additional mix design met the project performance goal:

- Mix 1 - 3% PC and 7% BFS

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Summary of physical testing results

Mix design number	Sample curing time (days)	Unconfined compressive strength (psi)	Hydraulic conductivity (cm/sec)
1	28	115	8.0×10^{-5}
1	56	131	1.8×10^{-5}
2	28	227	7.6×10^{-6}
2	56	347	1.5×10^{-6}
3	28	20	Nor analyzed
3	56	44	2.5×10^{-5}
4	28	161	2.2×10^{-6}
4	56	258	5.6×10^{-7}
5	28	49	3.3×10^{-5}
5	56	85	2.5×10^{-5}

Note: psi = pound-force per square inch; cm/sec = centimeters per second

Bench evaluation of metals leachability - overview

- Leachability evaluation completed following physical testing program
- Laboratory testing program was set up to assess post-ISS flux of metals from the monolith to groundwater
- Performance goals:
  - No net increase in metals leaching from the stabilized monolith
  - Overall reduction in groundwater metals concentrations
- Evaluated for antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, lead, lithium, mercury, molybdenum, nickel, radium, selenium, silver, and thallium (requested by the regulator)

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Bench evaluation of metals leachability - overview

Three new mix designs for this evaluation:

- Mix A – 1.5% PC, 3.5% BFS, 0.5% bentonite
- Mix B – 4.5% PC, 10.5% BFS, 1% bentonite
- Mix C – 3% PC, 7% BFS, 2% bentonite

The following tests and evaluations were completed on these three mix designs:

1. Additional physical testing and sample prep. (i.e., molds) by TEST;
2. Initial analytical phase using modified Synthetic Precipitation Leaching Procedure (SPLP) testing by Test America/Eurofins Pittsburgh, PA lab
3. Secondary analytical phase using Leachability Environmental Assessment Framework (LEAF) testing (also by TA/Eurofins); and
4. Mass flux evaluation for metals

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Bench evaluation of metals leachability – physical testing results

Strength and hydraulic conductivity testing results evaluated at 28 days by TEST

Mix	Strength (psi)	Hydraulic conductivity (cm/sec)
Mix A 1.5% PC, 3.5% BFS, 0.5% bentonite	14	6.7×10^{-5}
Mix B 4.5% PC, 10.5% BFS, 1% bentonite	161	5.9×10^{-6}
Mix C 3% PC, 7% BFS, 2% bentonite	93	1.7×10^{-6}

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Bench evaluation of metals leachability: SPLP testing

- SPLP testing performed as the “first cut” of this evaluation due to quicker turnaround and lower cost than LEAF testing
- SPLP method considered more aggressive than LEAF with potentially more conservative results
- Method prep. modified from sample pulverization to a non-destructive tumble method
- Both barium and molybdenum concentrations increased following stabilization in each mix design compared to untreated sample of ash
- As a result, LEAF testing was advanced

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Bench evaluation of metals leachability: LEAF testing

- LEAF test method 1315 for monoliths
- This method consists of placing a solidified sample in a water bath, extracting the water, and running analysis at a specified interval:
  - 2, 24, and 48 hours; and
  - 7, 14, 28, 42, 49, and 63 days
- Results varied by mix design and reagents used:
  - Barium, boron, lithium, molybdenum, nickel, and selenium detected in leachate within the range of historic GW concentrations for the Site
- As a result, mass flux was evaluated in accordance with Interstate Technology Regulatory Council (ITRC) and EPA guidance documents

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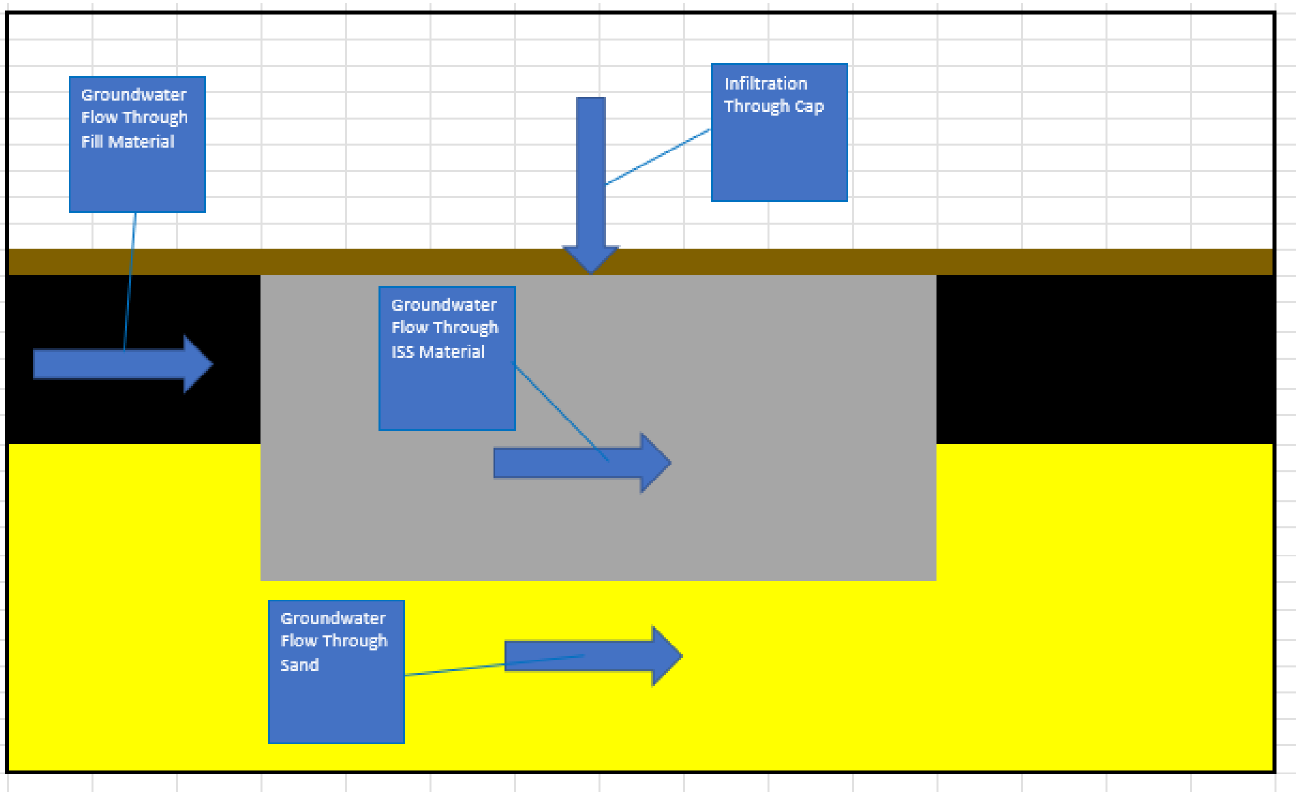
Bench evaluation of metals leachability: mass flux evaluation

- Mass flux evaluation performed at the ninth LEAF testing interval – 63 days
- This evaluation includes:
  - Cross-sectional area of the ISS monolith perpendicular to groundwater flow
  - Surface area of the ISS monolith
  - Site groundwater flow rate and direction
  - Infiltration through cap
  - Groundwater flow through different soils and materials
- Dilution attenuation factor (DAF) applied to the post-ISS GW concentrations



$$DAF = \frac{\text{groundwater flow through fill material + groundwater flow through sand}}{\text{infiltration through cap + groundwater flow through ISS monolith}}$$

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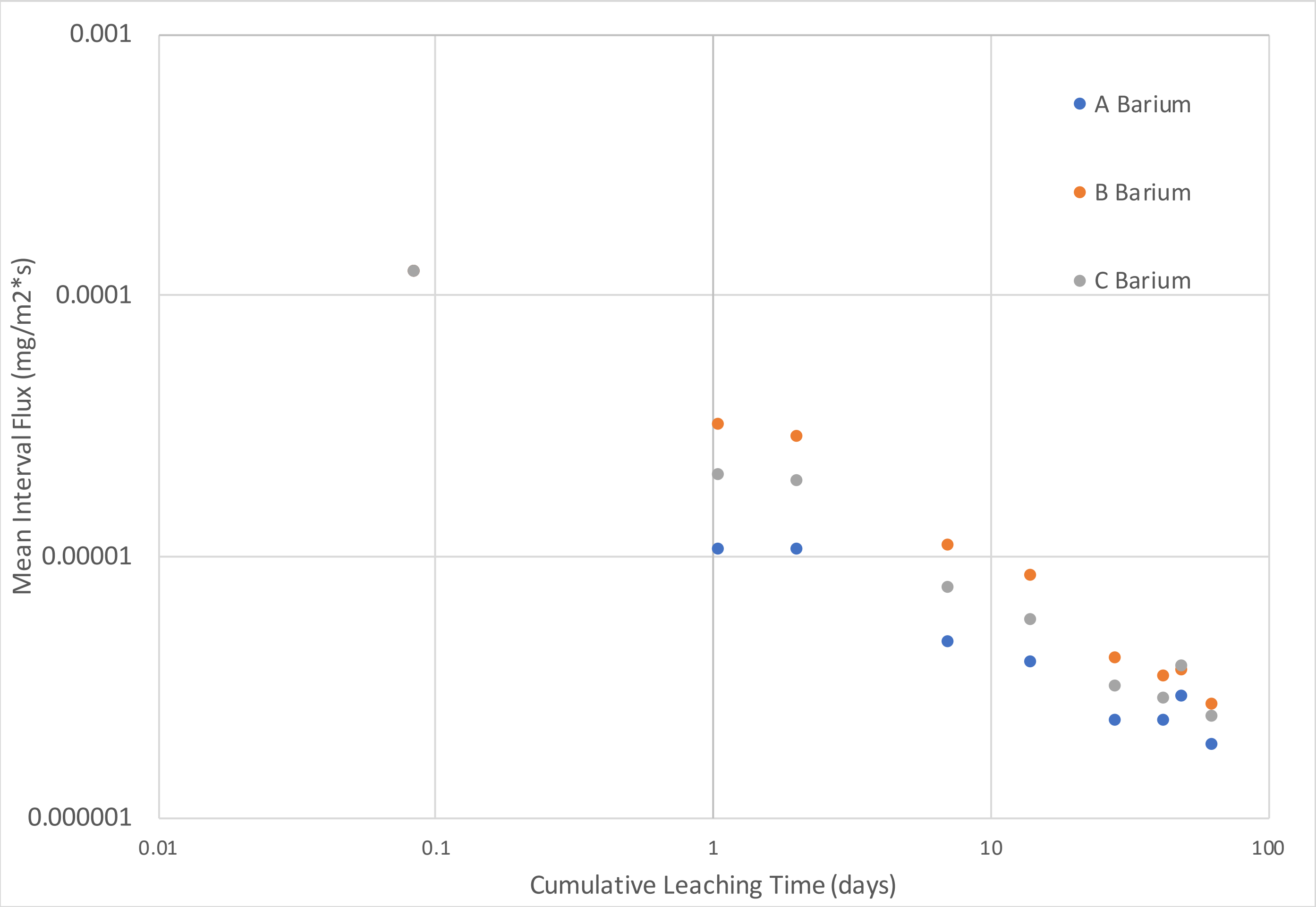
Interval flux graph example - barium



Interval flux graphs were prepared for each compound detected in the LEAF testing

Mass flux rates decrease with time

Flux evaluation outcome

- A wide range of mix designs will result in a decrease in flux of metals compared to existing conditions
- Greater than 99% reduction in post-ISS groundwater metal concentrations in each sample

Sample location and mix design	Compound	Unconfined compressive strength at 28 days (psi)	Hydraulic conductivity at 28 days (cm/sec)	Pre-ISS concentration in groundwater (µg/L)	Post-ISS concentration in groundwater (µg/L)	Percent reduction (%)
TP-27 A	Barium	14	$6.7*10^{-5}$	43.85	0.00513	99.988
TP-27 A	Boron	14	$6.7*10^{-5}$	800	0.0493	99.994
TP-27 A	Lithium	14	$6.7*10^{-5}$	125	0.00197	99.998
TP-27 A	Molybdenum	14	$6.7*10^{-5}$	37.5	0.00162	99.996
TP-27 A	Nickel	14	$6.7*10^{-5}$	Not applicable	0.000197	Not applicable
TP-27 A	Selenium	14	$6.7*10^{-5}$	4.45	0.000986	99.978
TP-27 B	Barium	161	$5.9*10^{-6}$	43.85	0.00730	99.983
TP-27 B	Lithium	161	$5.9*10^{-6}$	125	0.00237	99.998
TP-27 B	Molybdenum	161	$5.9*10^{-6}$	37.5	0.000986	99.997
TP-27 C	Barium	93	$1.7*10^{-6}$	43.85	0.00651	99.985
TP-27 C	Molybdenum	93	$1.7*10^{-6}$	37.5	0.00217	99.994
TP-27 C	Selenium	93	$1.7*10^{-6}$	4.45	0.000986	99.978

Note: cm/sec = centimeters per second; µg/L = micrograms per liter; psi = pounds per square inch

Conclusions – physical testing

- The use of ISS for the closure of the subject ash pond is feasible
- The bench data helped the project team understand the relationship of unconfined compressive strength and hydraulic conductivity over time in the various mix designs
- Mix reagents generally performed as expected
- Some reagents performed better than others for this application:
  - Addition of bentonite helped achieve hydraulic conductivity performance goal
  - Locally available CKD showed no benefit to meeting performance goals
  - The use of other reagents may be possible

Conclusions – leachability evaluation

- Leachability and flux evaluation demonstrates that post-ISS flux of metals from the ISS monolith to adjacent groundwater is less compared to existing conditions
  - Achieved by the reduction in permeability and leaching potential of the ash following ISS
  - Metals leaching can be greatly decreased through the use of mix designs meeting a hydraulic conductivity range of 1.0×10^{-5} to 1.0×10^{-6} cm/sec.
- In conclusion, ISS can result in long-term reduction of metals leaching

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Next steps

- Work plan approval pending
- Construction slated for 2022/2023
- The bench data will be used to optimize a mix design during additional bench-scale testing by the contractor
- Contractor testing will optimize costs and improve constructability using the results of this investigation completed to date

Summary

- Limited bench data available for ISS implementation and ash pond closures
- In the case of the subject project, ISS offered significant schedule and cost savings
- ISS Pre-Design Bench Program demonstrated that readily available reagents could be used to achieve performance goals
- Community benefits to ISS approach
  - Decrease in imported backfill quantities
  - No transportation and disposal
  - Lower carbon footprint

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with any questions