In-Situ Nitrate and Selenium Reduction/Stabilization within Waste Rock

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Problem Statement

- Metal and coal mine waste rock releases Se and other co-contaminants (As, Cd, Fe, CN, NO_3, SO_4, etc.).
- Nitrates are released into these waters from residual blasting compounds.
  - NO_3 is the preferred electron acceptor;
  - NO_3 needs to be removed prior to Se removal;
  - In situ denitrification decreases the size of the required active water treatment facility and helps stabilize metals.

The Electro-Biochemical Reactor

- Low voltage (1-3 Volts potential) provides:
  - Electrons and electron acceptor environments for controlled contaminant removal environment
  - Compensation for inefficient and fluctuating electron availability through nutrient metabolism
- 1 mA provides 6.24 x 10^{15} electrons/second
  - Replaces excess nutrients
  - Produces much less TSS (bio-solids)
- As a comparison, other electrons donors (nutrients) provide electrons only under metabolism

Selenium Reduction

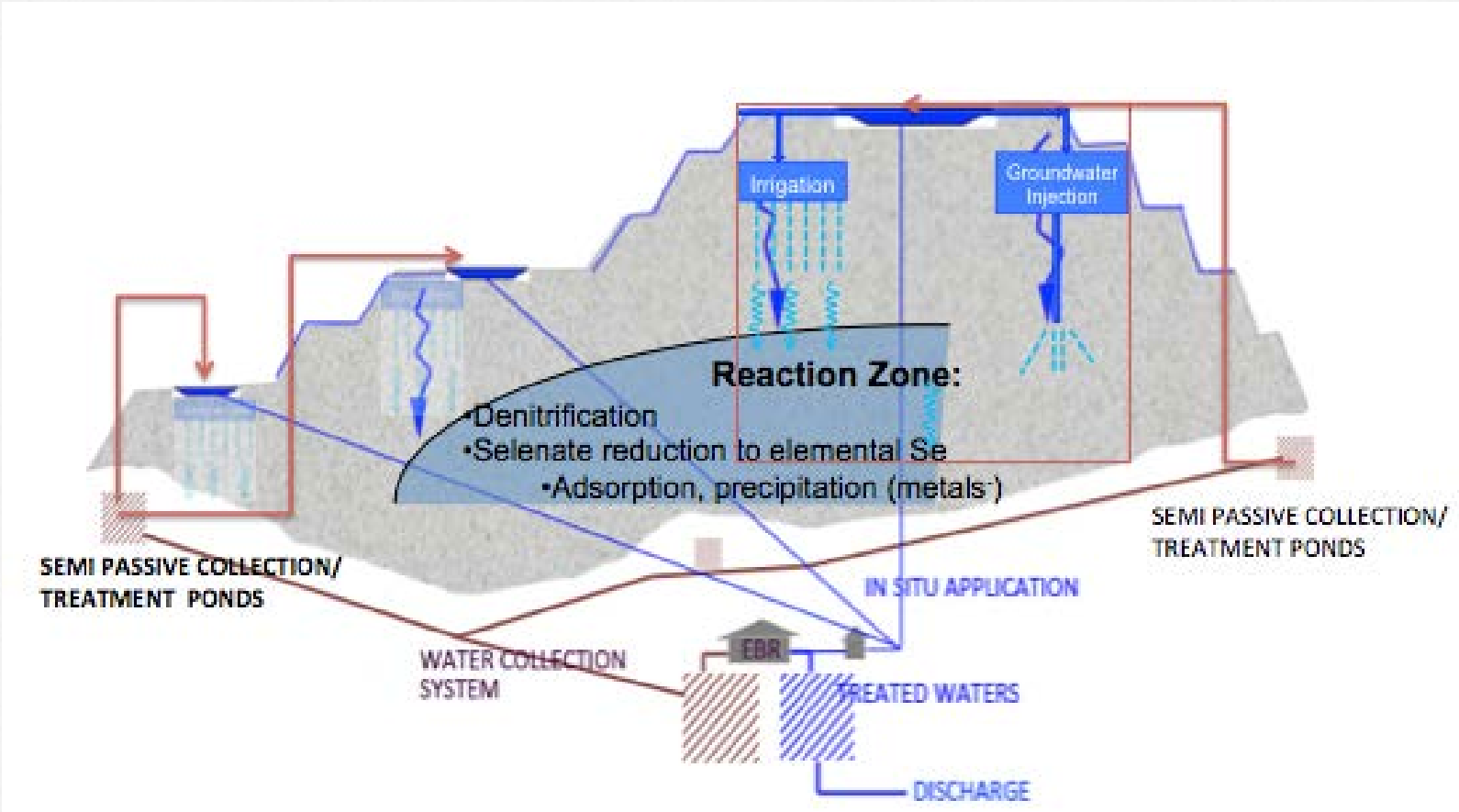
$SeO_4^{2-} + 3H^+ + \mathbf{2e^-} <-> HSeO_3^- + H_2O$

$HSeO_3^- + 5H^+ + \mathbf{4e^-} <-> Se_{(s)} + 3H_2O$

Results: EBR Performance

	Parameter	Ave. Influent	Ave. Effluent
Water A	NO_3-N [mg/L]	11.0	<0.1
	Se [µg/L]	355	1.2
Water B	NO_3-N [mg/L]	16.4	<0.1
	Se [µg/L]	35.0	1.4
Water C	NO_3-N [mg/L]	37.0	1.0
	Se [µg/L]	531	1.4
Water D	NO_3-N [mg/L]	50.0	2.0
	Se [µg/L]	105	0.5
Water E	NO_3-N [mg/L]	170	<0.1
	Se [µg/L]	186	1.2

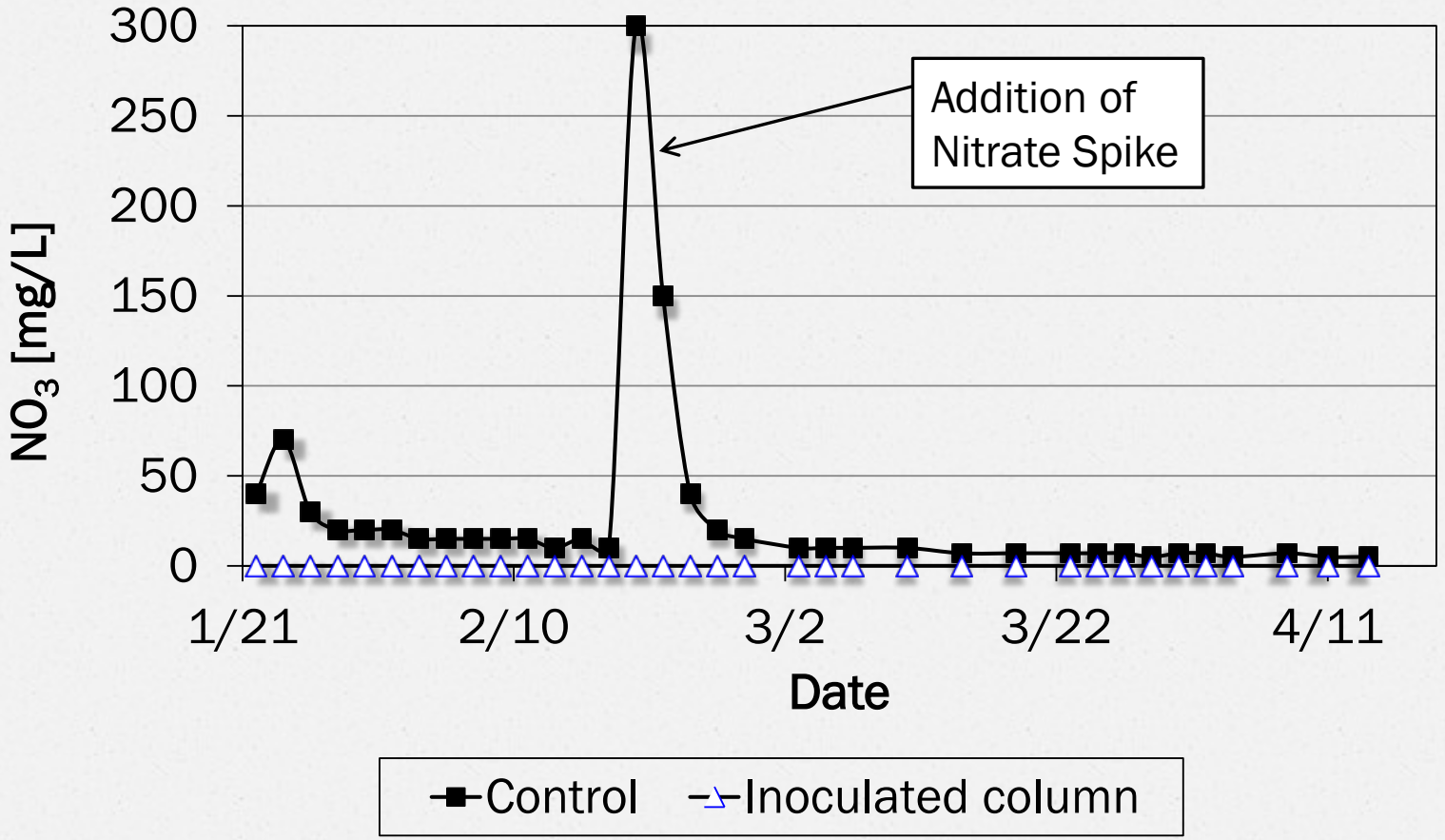
Concept: EBR + In Situ



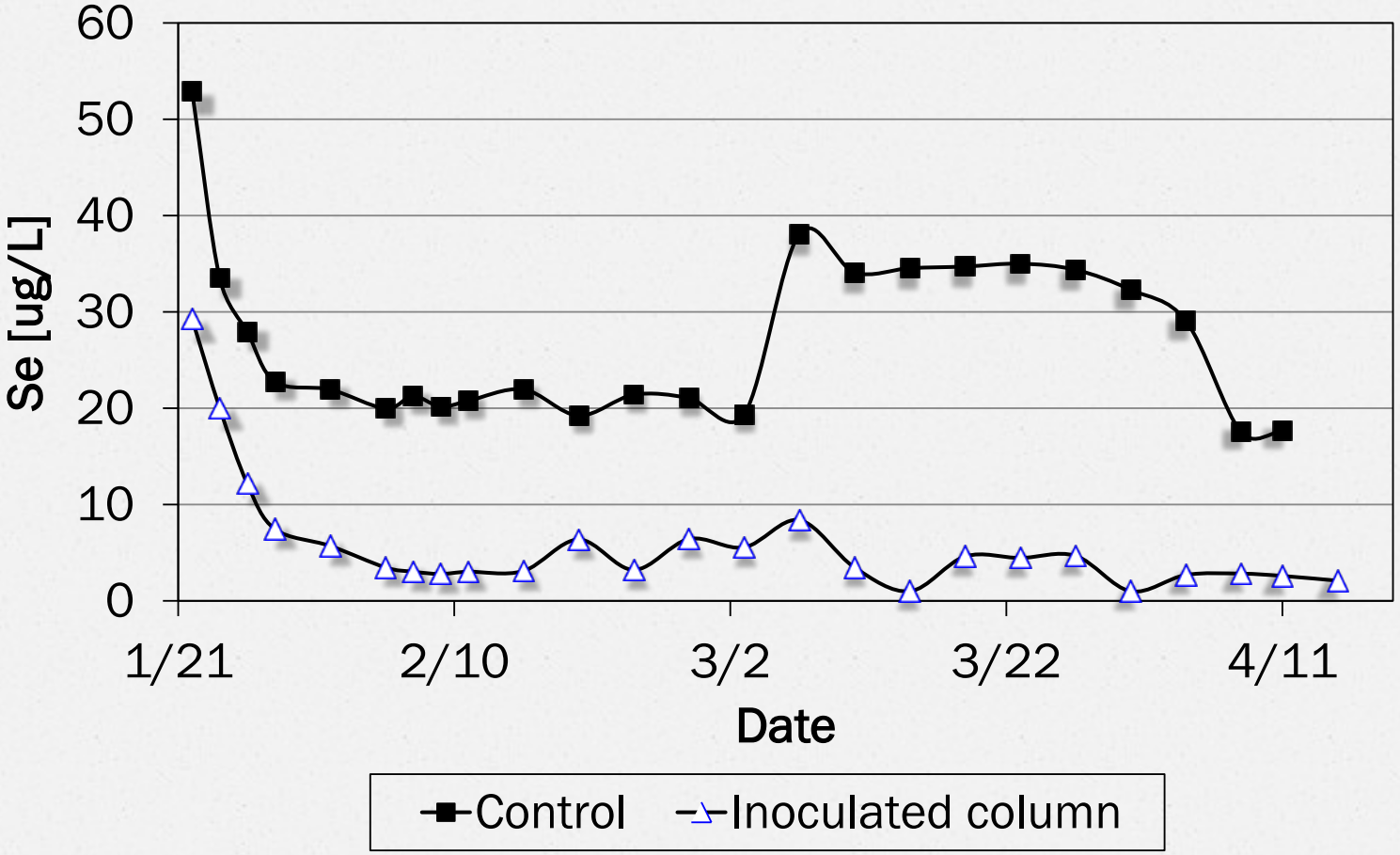
Results: EBR + In Situ

- Three bench-scale columns:
  - EBR, treating mine waters, was used to produce an amended microbial inoculum for the in-situ column nitrate/selenium reduction tests;
  - A control, down-flow column filled with coal waste rock source materials was used to determine baseline selenium and nitrate elution rates; and
  - A down-flow column filled with coal waste rock source materials was inoculated periodically with EBR amended effluents to evaluate in-situ denitrification and selenium reduction/stabilization.

Results: EBR + In Situ



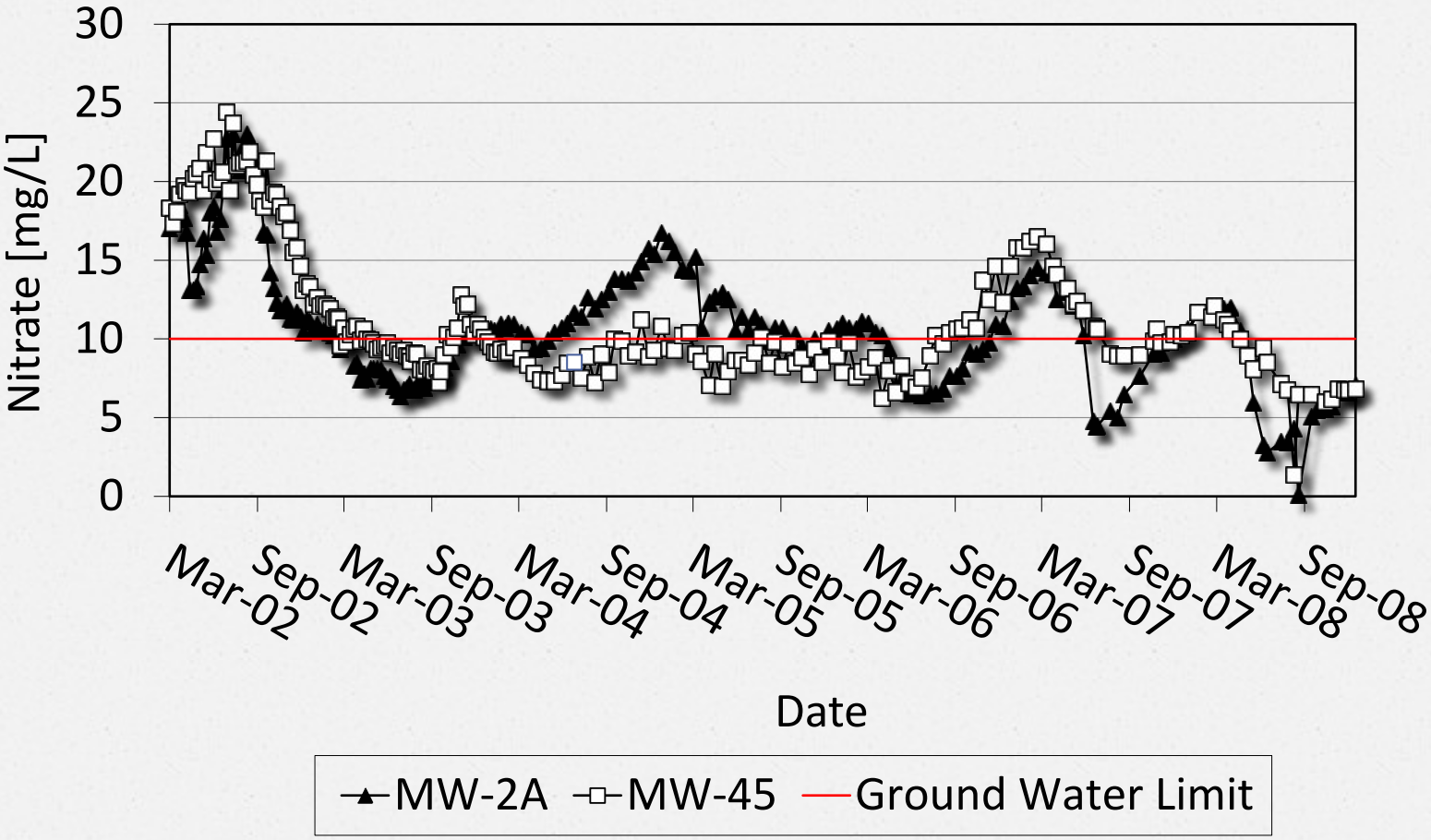
Results: EBR + In Situ



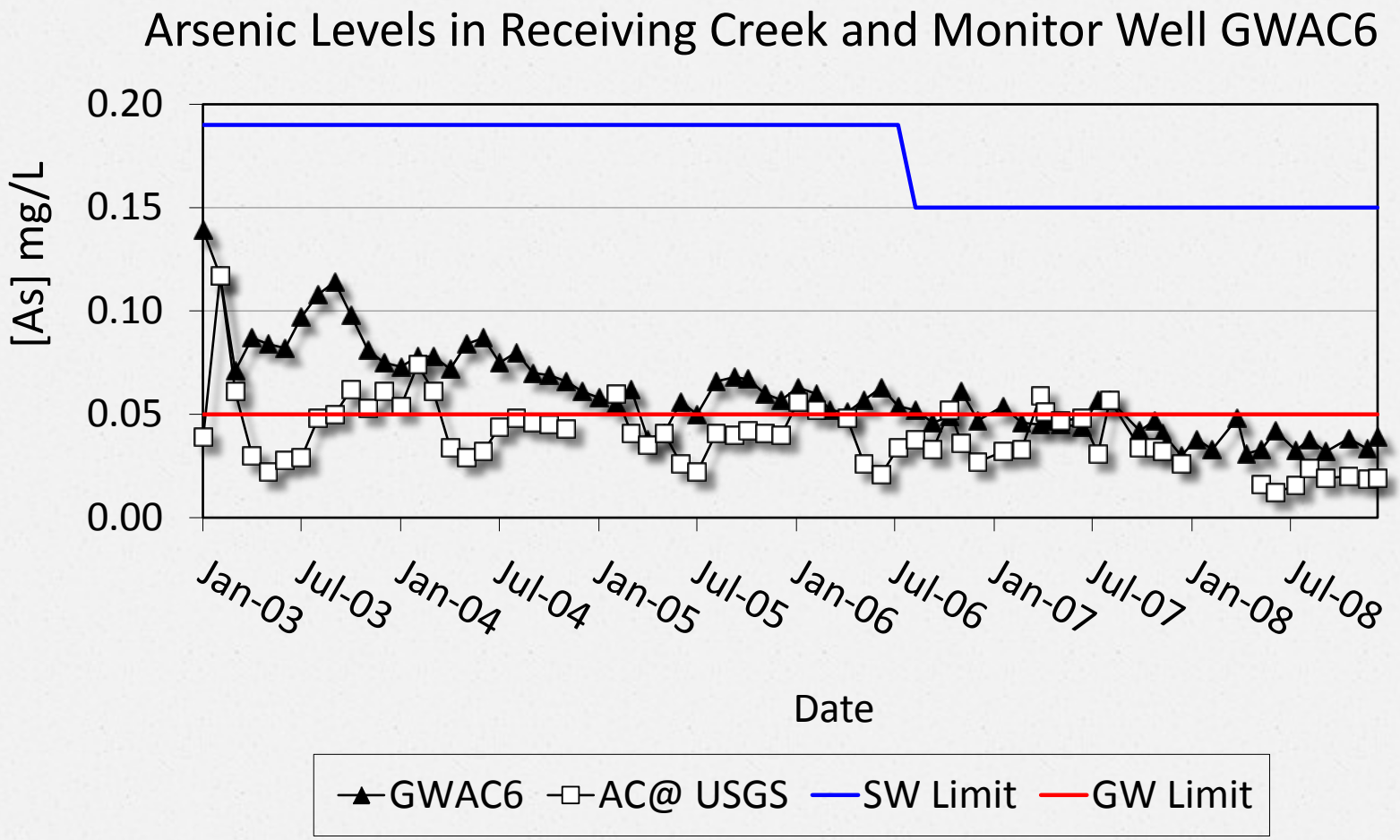
In Situ: Hardrock Mining

- Example successful implementation:
  - Wharf gold mine
  - Located in the Black Hills, SD
  - Open pit, heap leach operation

In Situ: Hardrock Mining



In Situ: Hardrock Mining



EBR + In Situ: Hardrock Mining

- Current full-scale implementation:
  - Landusky Mine
  - Located in the Little Rocky Mountains, MT
  - Closed mine
  - Open pit, heap leaching operation


Landusky Site
In Situ Biotreatment
EBR Biotreatment Facility
Semi-passive Biotreatments
Pump-back Ponds for Biotreatment Facility
Biological Post-treatment
Chemical Treatment Plant

Conclusions: Coal Mines

- Effective management approaches for water treatment should include in situ denitrification treatments to reduce nitrate loads;
  - Significantly reduce active treatment CAPEX and OPEX costs;
  - Demonstrated complete nitrate removal from waste rock at bench-scale;
  - Significant Se reduction and stabilization within the source materials (from 27 pbb to below 4 ppb).

Conclusions: Hardrock Mines

- Treatment of nitrate-N at ranges from 60 to 320 mg/L
  - All sites treated to near or below discharge criteria
  - Sites within two properties have been removed from company inventory - treated to below State closure criteria
- Treatment and stabilization of As
  - Treated to below discharge criteria - <10 µg/L
- Treatment and stabilization of Se
  - Plume treated from ~16 mg/L to <1 mg/L
- Treatment times ranged from 1 to 4 years

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Thank You

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