

Progress on Translating (“Scaling”) Laboratory Weathering Tests on Mine Wastes to Full Scale Facilities

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Acknowledgements

- Avanti Kitsault Mine
- Cameco Corporation
- Teck
- Thompson Creek Mining
- Walter Energy
- Yellowhead Mining
- Our colleagues

What We'll Cover

- What do we mean by scaling?
- Overview of weathering and leaching.
- Scaling of weathering rates.
- Scaling of leaching processes.
- Observations of scaling.

Why does this matter?

- Laboratory test results are used to make water chemistry predictions
- Predictions are used as inputs into downstream water quality assessments.
- Water chemistry predictions are also used to make mine design decisions
 - Under- or over-prediction can be costly.

What Do We Mean By Scaling?

Mineralogy
 10^{-6} kg grains

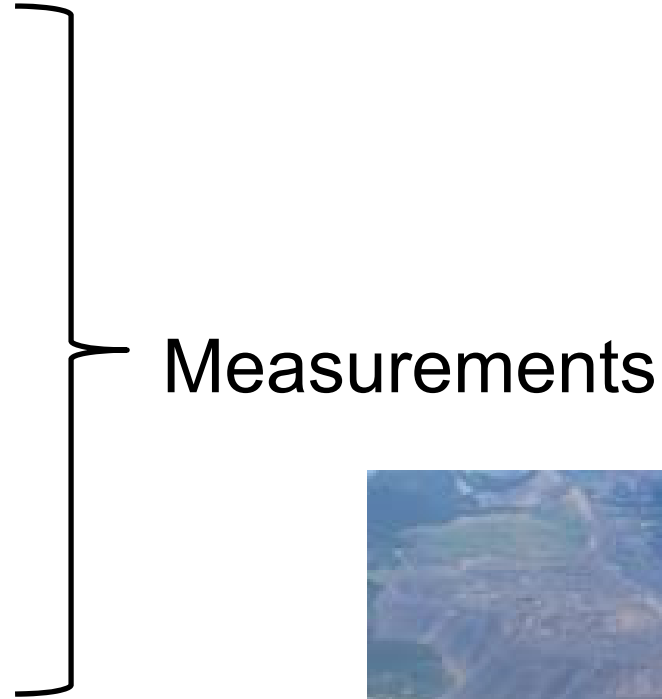


Static tests
 10^{-3} kg sample



Shake Flasks
0.1 kg sample

Kinetic Tests
1 kg sample

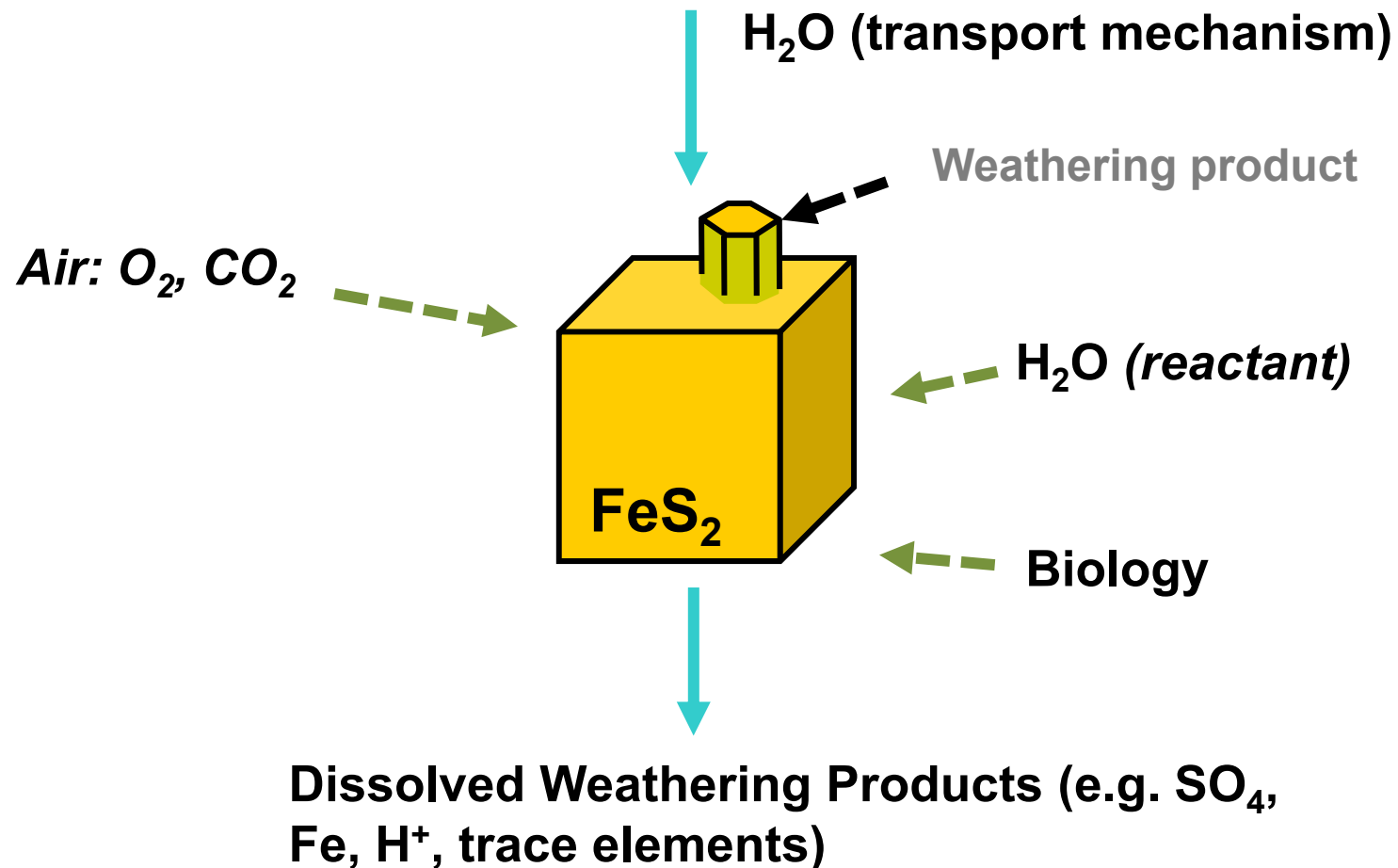


Scaling?

Predictions (Forecasts) of
water chemistry

Full Scale
 10^{12} kg dump

Overview of weathering and leaching – example, pyrite (FeS_2) oxidation



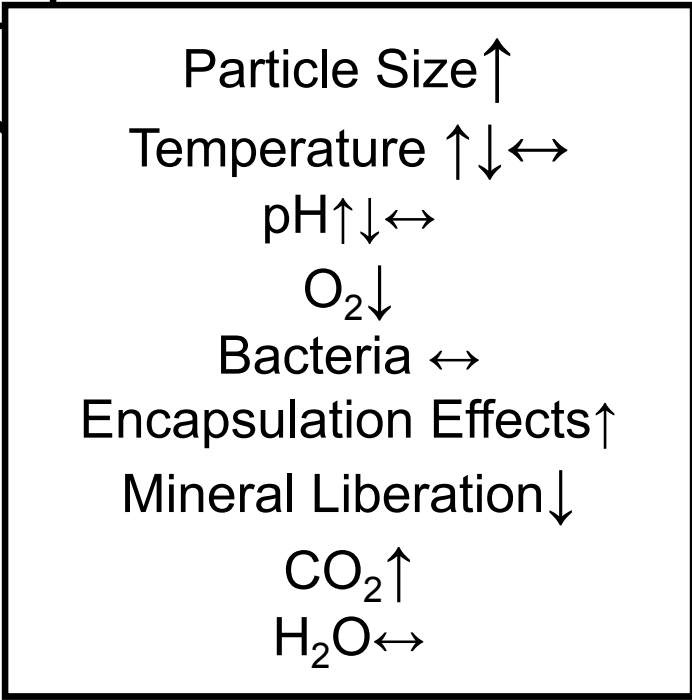
Processes Requiring Scaling

- Rate of conversion of primary minerals to weathering products
- Leaching processes
 - Solubility of weathering products.
 - Leaching efficiency.

Scaling of Weathering Rates (eg mg/kg/time step)



Kinetic Tests
1 kg sample



Full Scale
10¹² kg dump

Legend:

Arrows show direction of change between scales
For example, particles are larger (↑) at full scale

Scaling of Weathering Rates

- General expectation is that in most settings, weathering rates are lower under site conditions due to:
 - Coarser materials.
 - Lower availability of oxygen.
 - Lower temperatures (for Canada at least)
- Predictions based on:
 - $\text{Rate}_{\text{site}} = \text{Rate}_{\text{lab}} \times f_{\text{particle size}} \times f_{\text{O}_2} \times f_{\text{temperature}}$

Scaling of Leaching Processes



Kinetic Tests
1 kg sample

Liquid-to-solid ratio (L/kg) ↓
Leachate Contact Time ↑
CO₂ ↑
Temperature ↑ ↓ ↔
Coarse Particles ↑
Mineral Exposure ↓
O₂ (redox sensitive parameters) ↓ ↔ ↑



Full Scale
10¹² kg dump

Contact Ratios:
Kinetic tests – 10⁰ L/kg
Full Scale – 10⁻³ L/kg

Scaling of Leaching Processes

- Lower liquid-to-solid ratios under site conditions are a **primary** consideration:
 - Typically expect measured concentrations [C] to be higher under site conditions but not exclusively.
- Higher CO₂ may also be important
 - Lowers pH which affects solubility

Scaling of Leaching Processes

- Therefore, $[C]_{\text{Site, Measured}} > [C]_{\text{lab, measured}}$
 - $[C]$ generally increases as liquid-to-solid ratio decreases.
- If we combine rate and leach ratio scaling:
 - $[C]_{\text{Site, Predicted}} > [C]_{\text{Site, Measured}}$
- Why?
 - Due to secondary mineral solubility limits.
 - Kinetics of solubility

Observation of Scaling Effects

- Sites with comprehensive monitoring data and kinetic tests at different scales now allow evaluation of scaling effects.
- Challenging to separate weathering rates and leaching processes due to linkages.
- Evaluation of weathering rate scaling is typically done with sulphate because it is:
 - Linked to sulphide oxidation.
 - Readily leached.
 - Solubility controls are well understood.

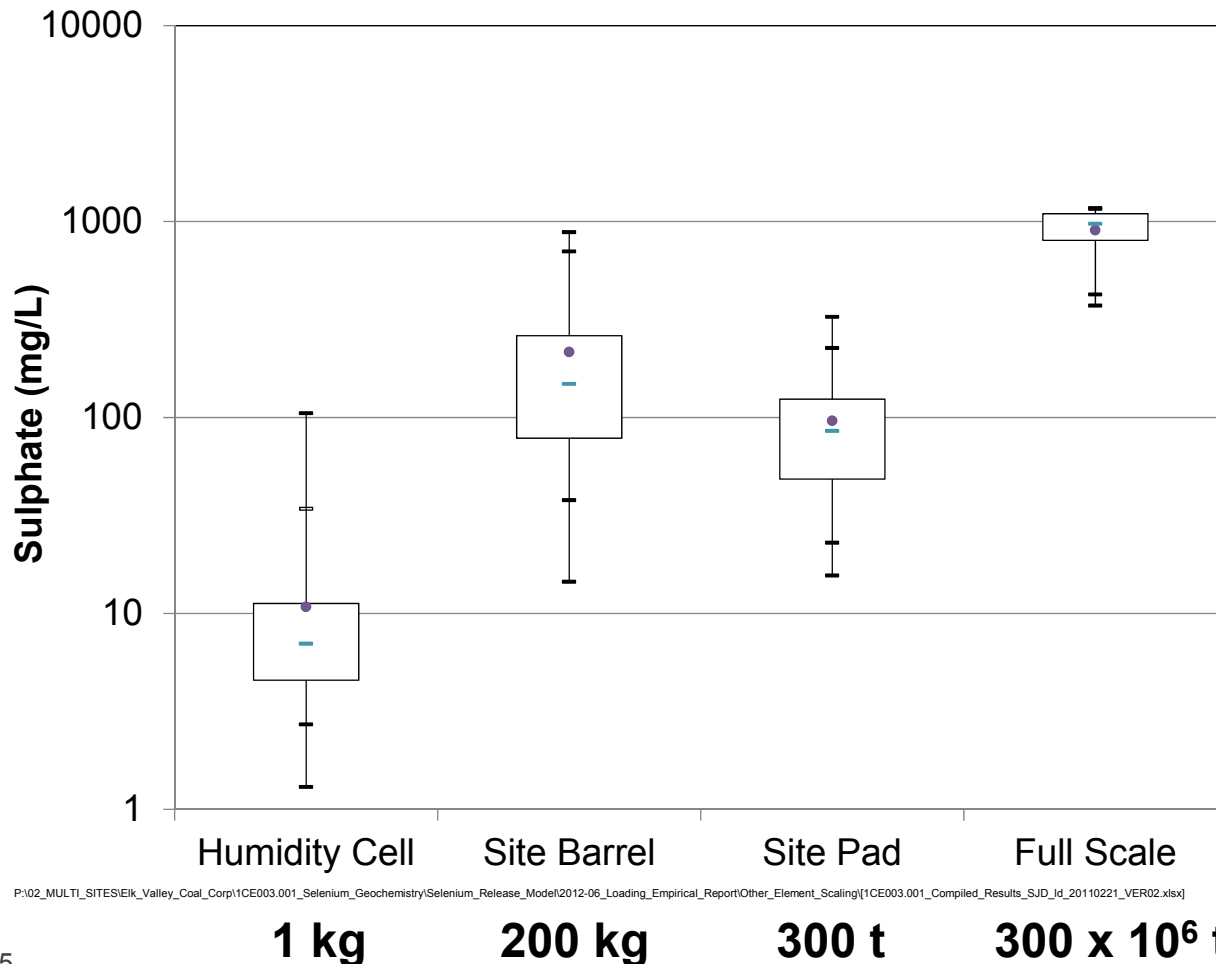
Observation of Scaling Effects

- Waste rock weathering rate (R) scaling for sulphate.

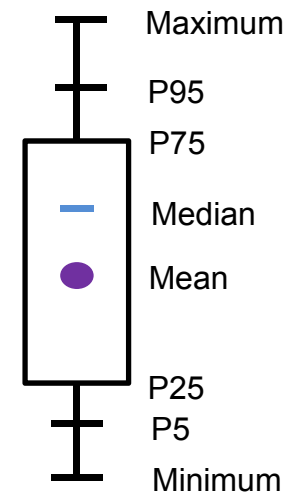
Company	Deposit Type	R _{lab} Basis	R _{site} Basis	R _{site} /R _{lab}
Teck, Walter Energy	Open pit coal	Humidity cells	Full Scale	0.01 to 0.03
Avanti Kitsault, Thompson Creek (Endako)	Molybdenum porphyries	Humidity cells	Full Scale	0.04 to 0.1
Yellowhead Mining (Harper Creek)	Volcanogenic sulphide	Humidity cells	Barrels	0.2
Cameco (Rabbit Lake B-Zone)	Unconformity-associated uranium	Humidity cells	Full scale	0.02
Closed site	Sedex	Humidity cells	Full scale	0.02

Observation of Scaling Effects

- Leaching Scaling – comparison of concentrations at different scales of testing



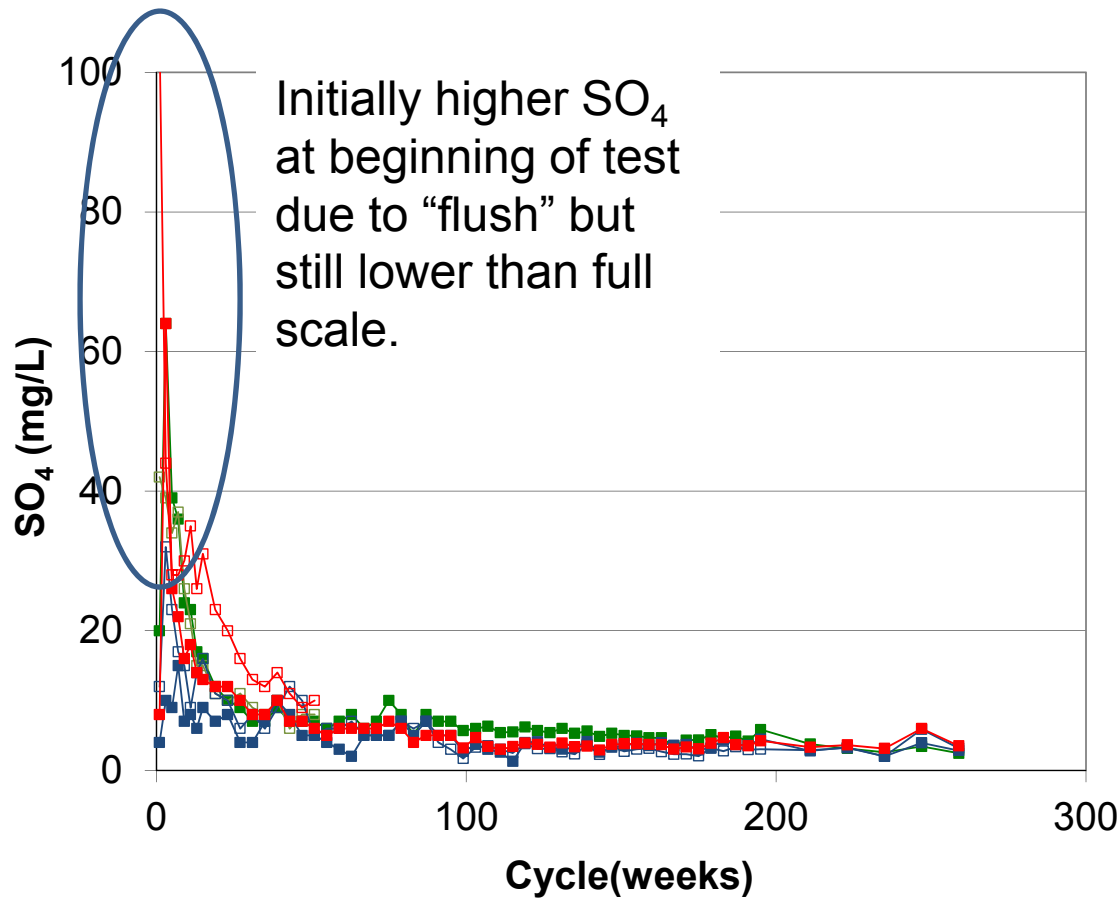
Coal mine waste rock, 0.1% total sulfur, basic drainage.



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Observation of Scaling Effects

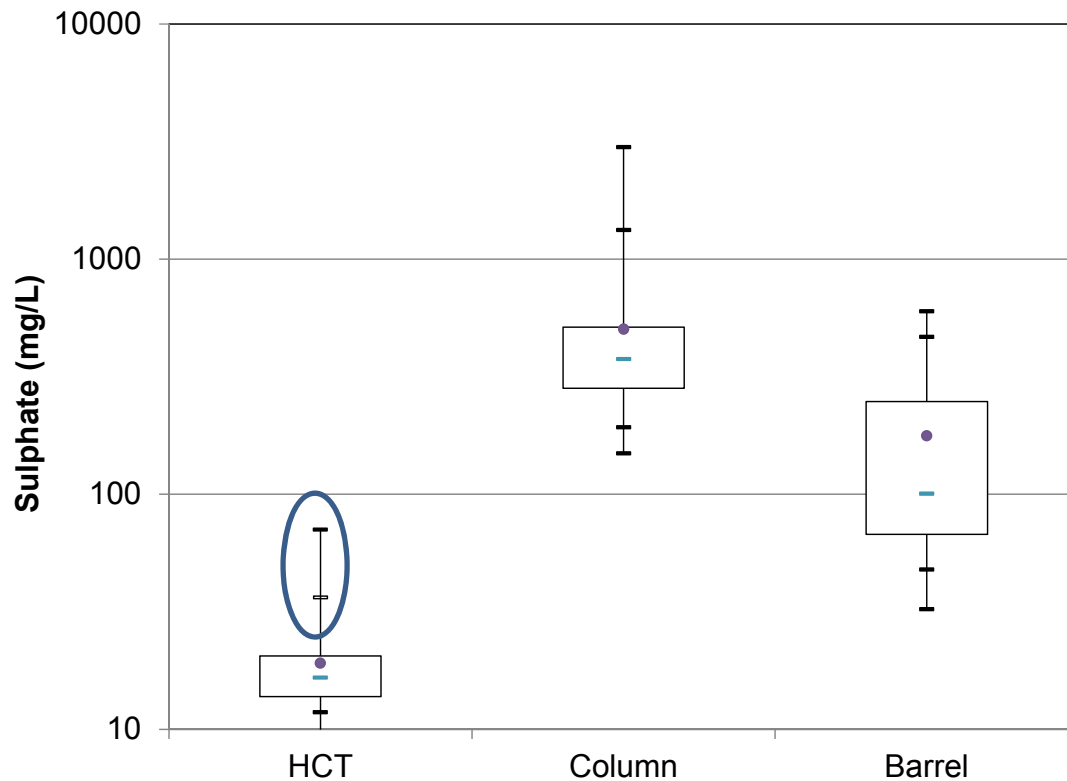
- Humidity cell detail



Coal mine waste rock, 0.1% total sulfur, basic drainage.

Observation of Scaling Effects

- Leaching Scaling – comparison of concentrations at different scales of testing



Harper Creek Project

Column run at low liquid-to-solid to match barrel

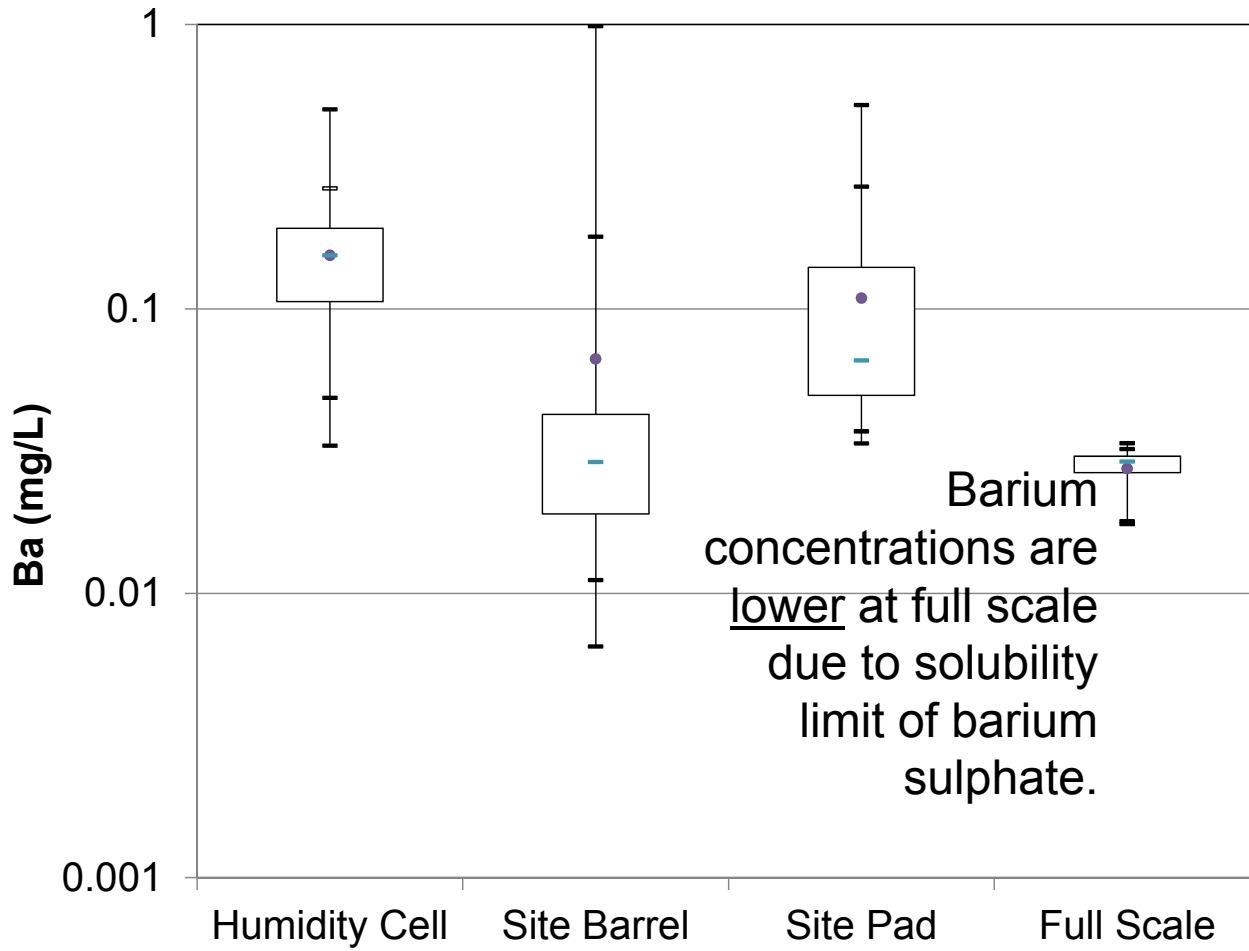
P:\01_SITES\Harper_Creek\1CY003.001_MLARD_Feasibility&EA\800_On_Site_Kinetic_Testing\1CY003.001_MLARD_

1 kg

10 kg

300 kg

Observation of Scaling Effects



Coal mine waste rock, 0.1% total sulfur, basic drainage.

Barium concentrations are lower at full scale due to solubility limit of barium sulphate.

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Conclusions

- Laboratory test data cannot be used directly without considering factors affecting weathering rates and leaching processes.
- Growing body of site data shows that:
 - A site-specific approach is always needed.
 - Weathering rates are often lower under site conditions than shown in laboratory tests.
 - Concentrations from laboratory scale tests must be evaluated for effects of liquid-to-solid ratios and weathering mineral solubility.