Hemmera
An Ausenco Company

Case Study: Pilot Scale In-Situ Remediation of Dissolved Metals Plume

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October 2020

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2. Conceptual Site Model & Remedial Design
3. Bench Scale Testing
4. Pilot Scale Injections
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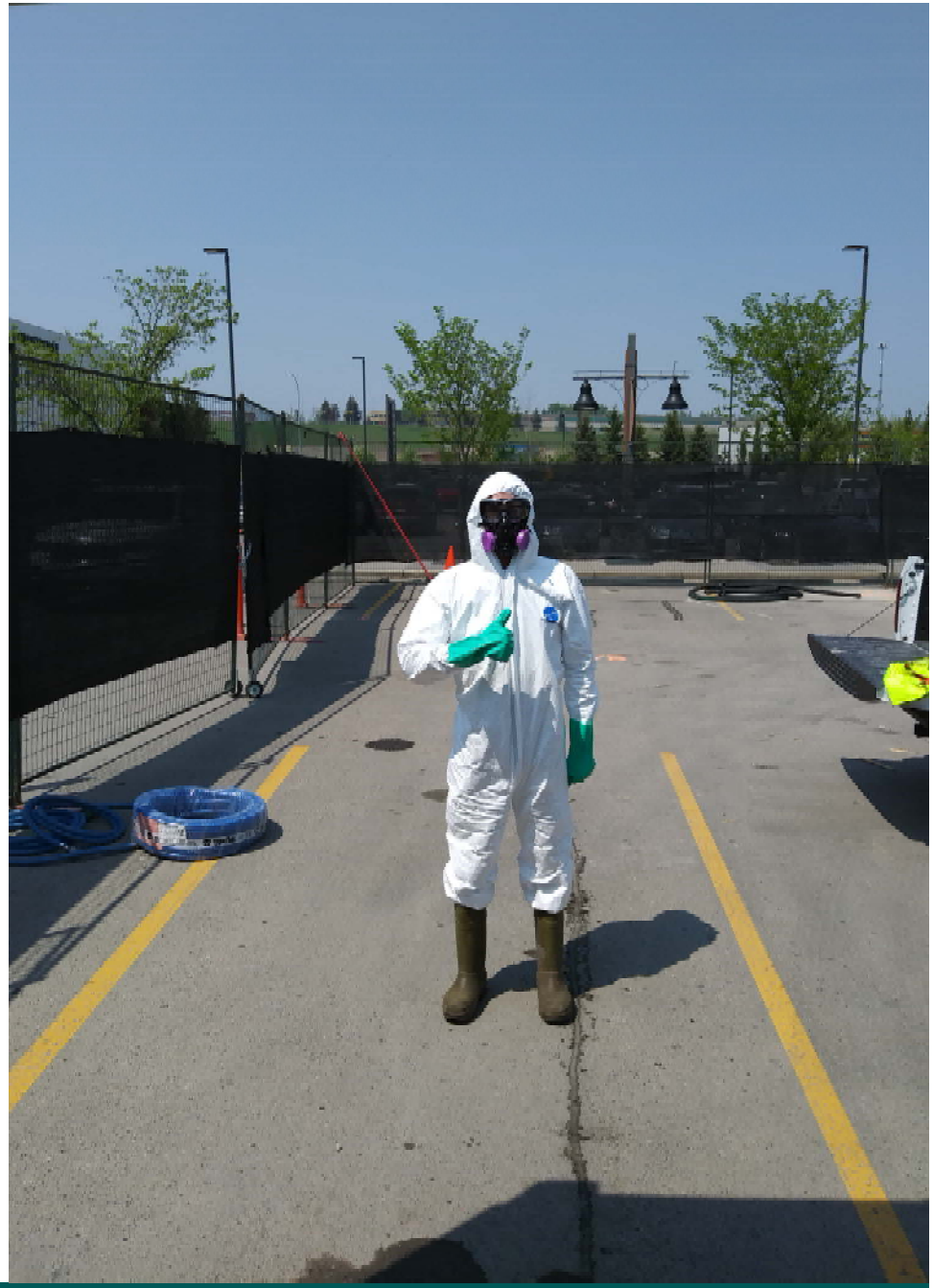

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Site History & Investigations

Site History

- Former Industrial Site
- Copper used as a catalyst
- Spent catalyst dumped into the ground
- Decommissioned in late 1980's
- Investigation and remediation since early 1990's

Site Investigations

Copper Plume ~700 m long defined by 4 wells	
2015 Hemmera SSI	Identified new hot spot 3x higher concentration Soil mineralogy analysis (BCR 701/modified Tessier) 500 mg-Fe/kg-soil; ~30% limestone
Porewater sampling	Copper reaching river at ~7x guideline
Toxicity Testing	Currently at effects threshold
Geochemical Model using PHREEQCI	Concentrations expected to increase ~10x
Remediation required	
How to remediate dissolved metals?	

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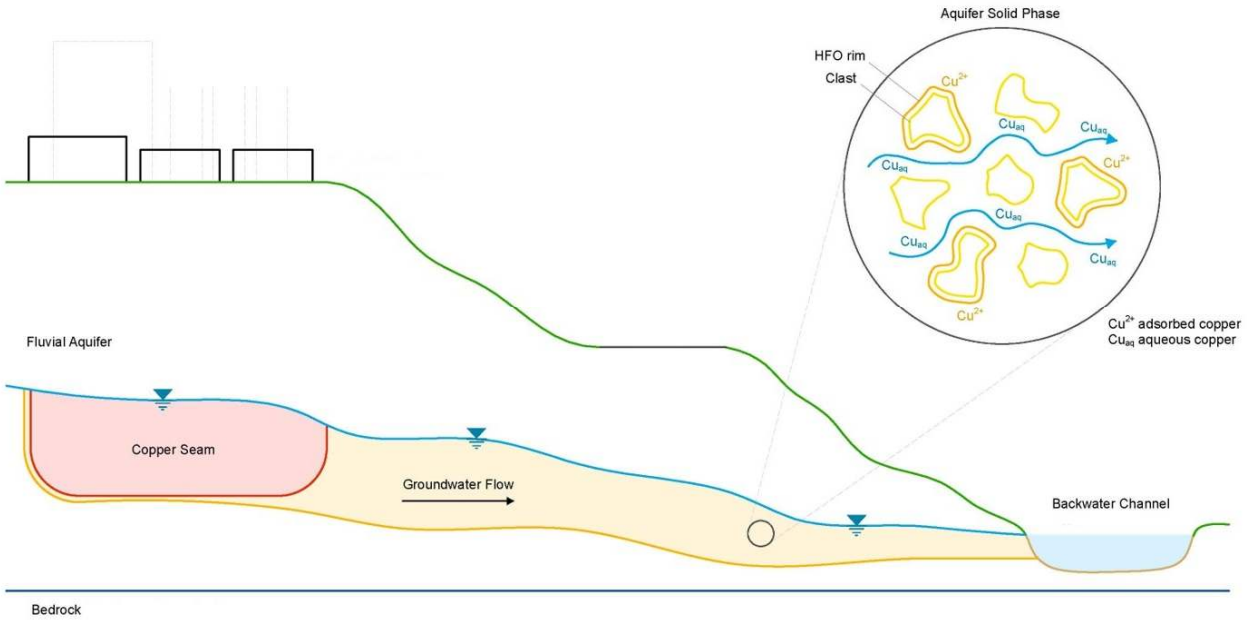
Conceptual Site Model



Hydrogeological Site Conceptual Model

- Glacial Outwash (Gravel and Cobble)
- High K (>10^{-3} m/s)
- Underlain by low K bedrock
- Entire thickness impacted
- No impacts in bedrock

Geochemical Behaviour of Copper

- Dominant species is cupric i.e. Cu(II)
- Adsorbs onto hydrous ferric oxide/iron oxyhydroxides
  - HFO for short
- Competition for adsorption sites

General Affinity of Dissolved Species for $Fe(OH)_3$

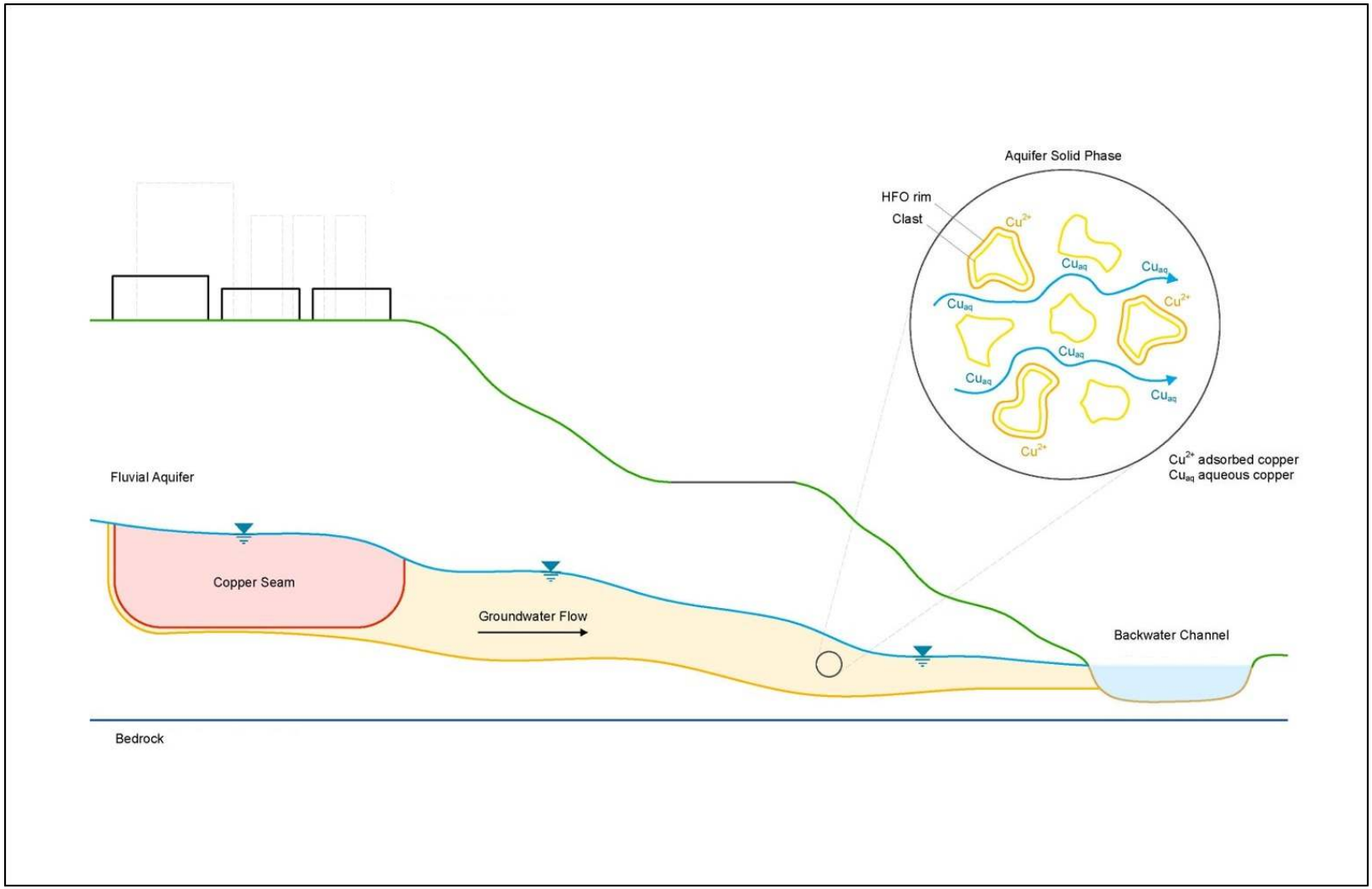
$As^{5+} = Cu^{2+} = Be^{2+} = Pb^{2+} = PO_4^{3-}$

$> Zn^{2+} > Cd^{2+} > As^{3+} > Ni^{2+} > SO_4^{2-}$

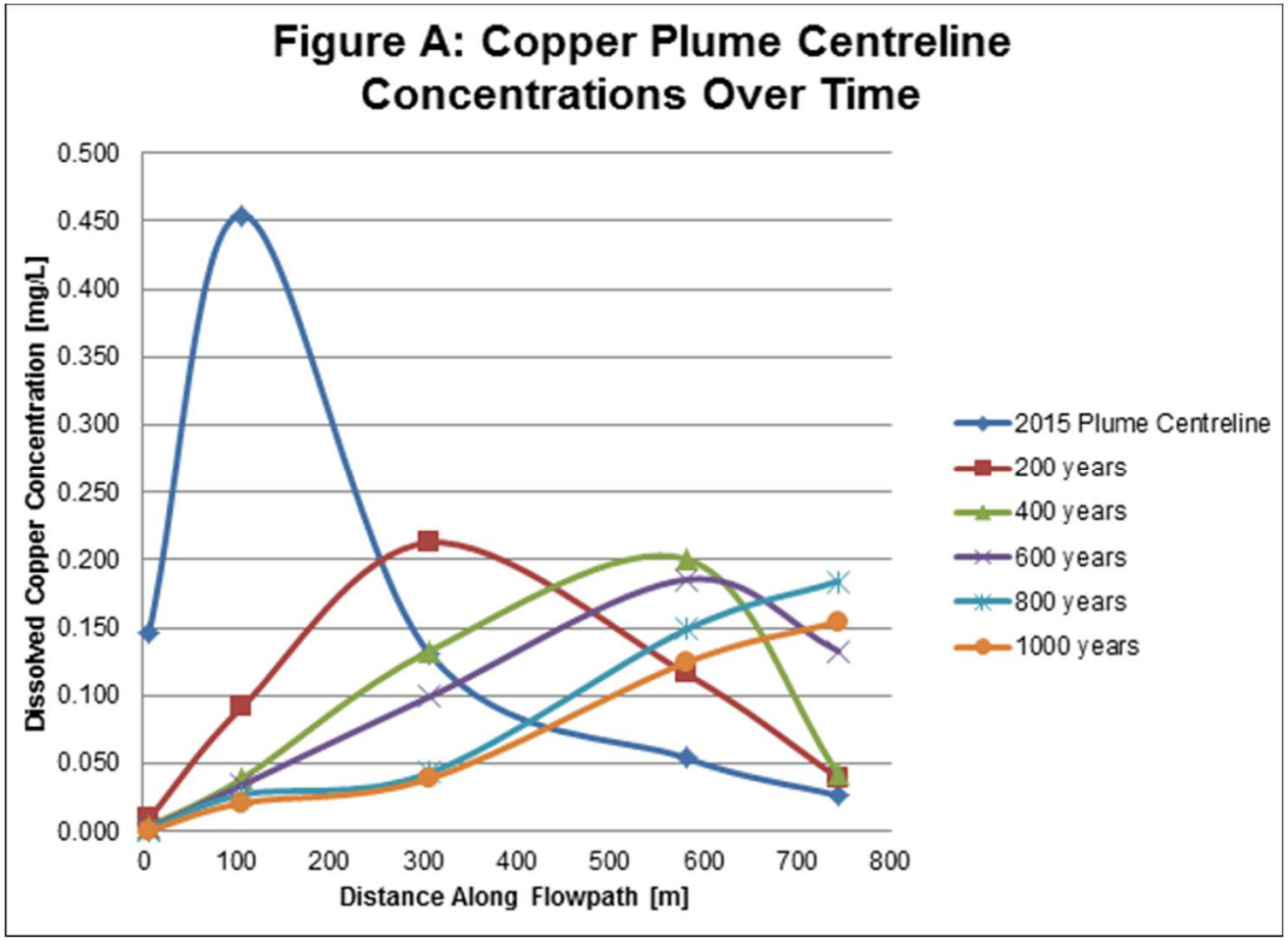
$>> Ba^{2+} >> Ca^{2+} >> B^{3+}$

Arsenate (As^{5+}) most strongly adsorbed, boron least strongly adsorbed

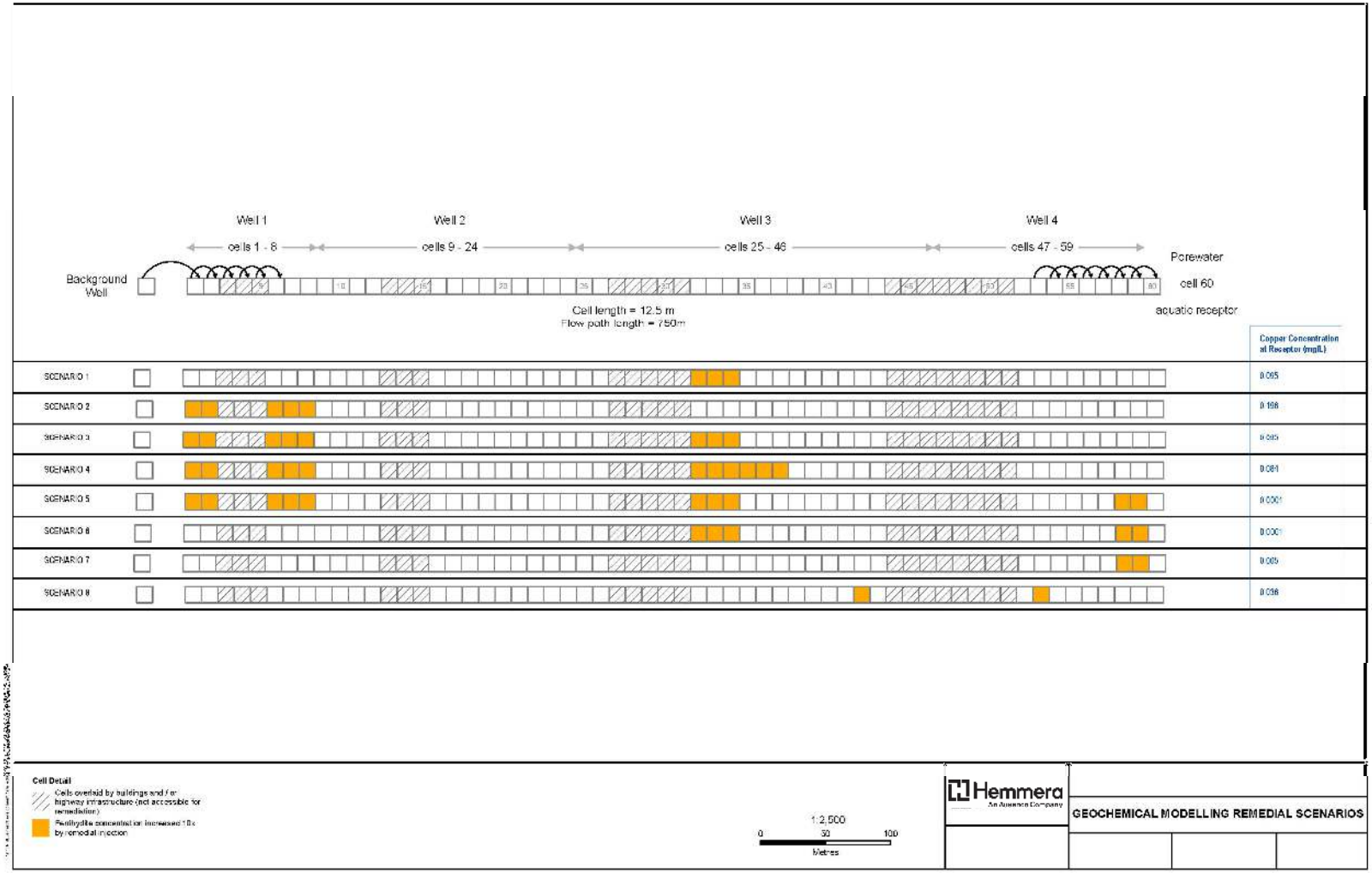
Conceptual Site Model – Copper Plume



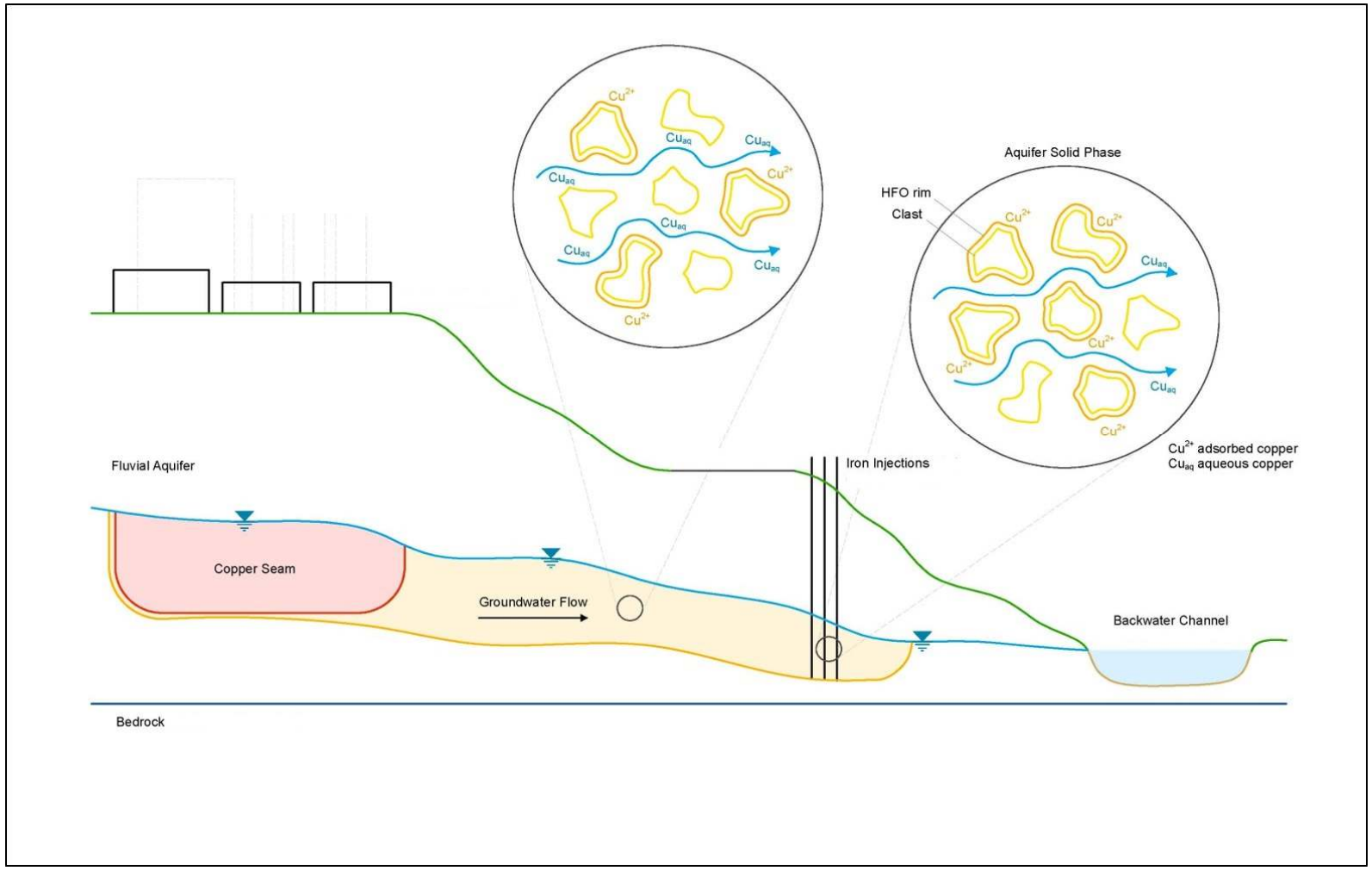
Conceptual Site Model – Copper Desorption/Adsorption



Conceptual Site Model – Remedial Simulations



Conceptual Site Model – Copper Remediation



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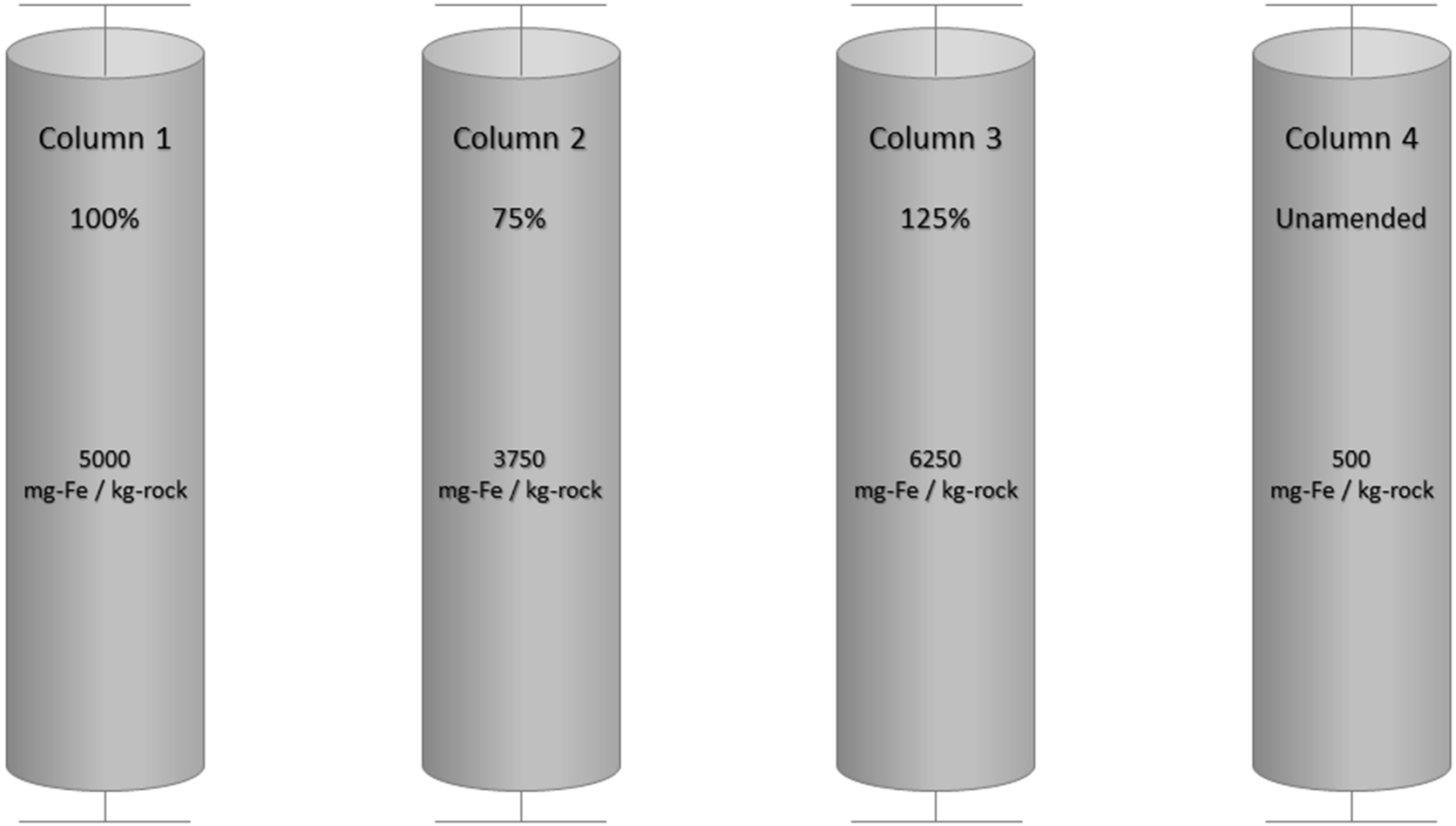
Bench Scale Testing

Bench Scale Testing - Columns



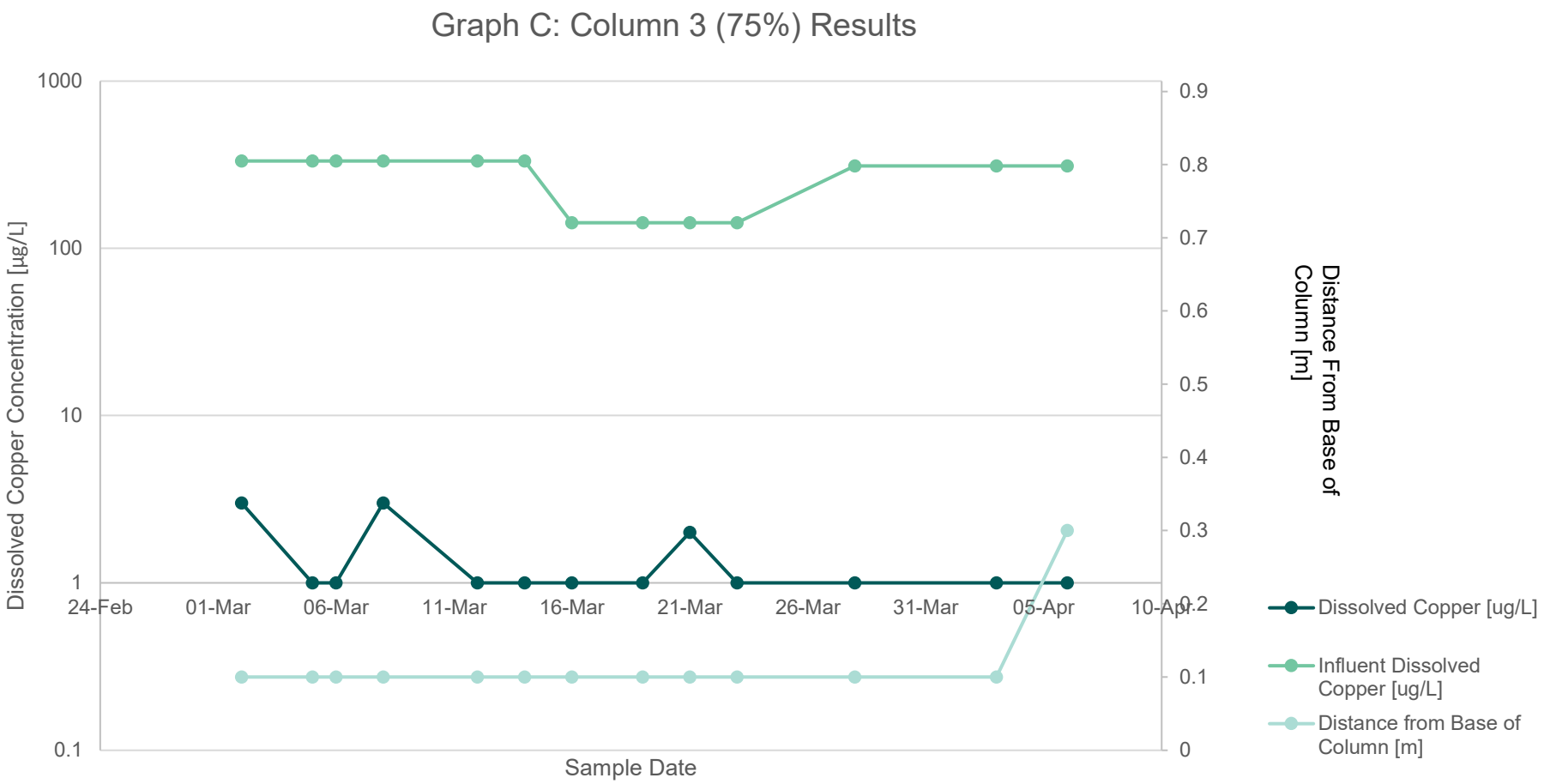
Columns	6.5” x 3’ 16.5 cm x 91.44 cm

Bench Scale Testing – Iron Recipe

+

=

Bench Scale Testing Program Results



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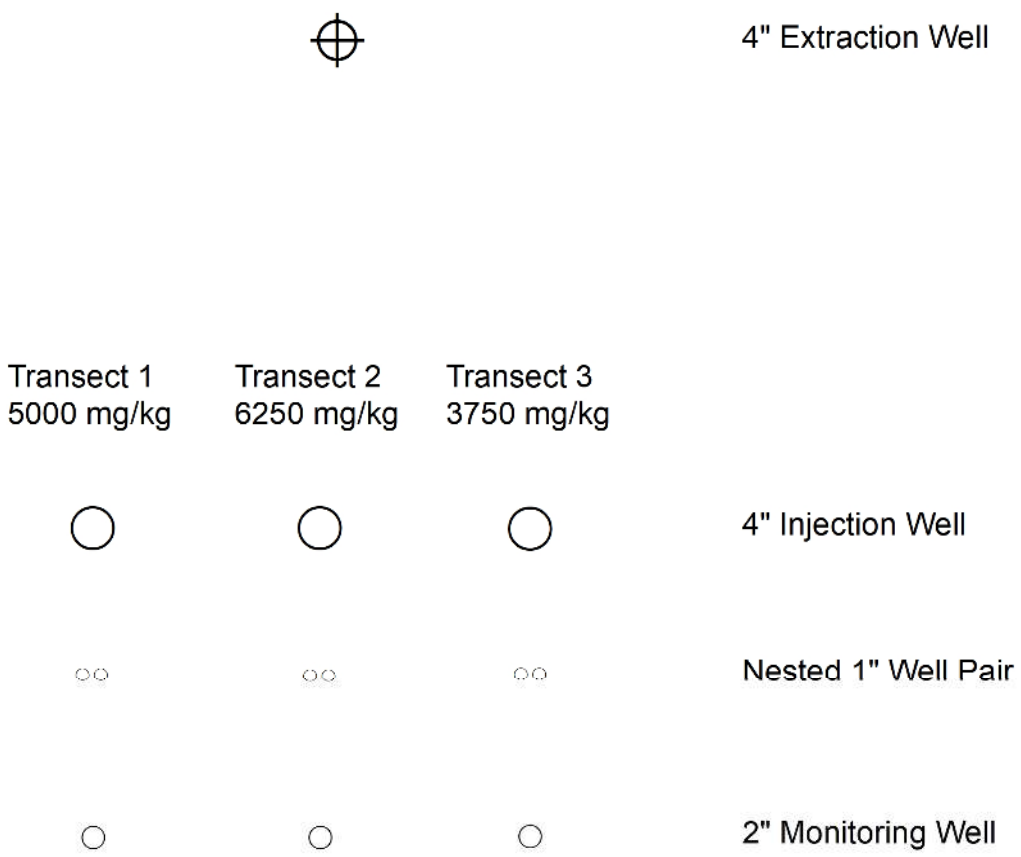
Pilot Scale Injections

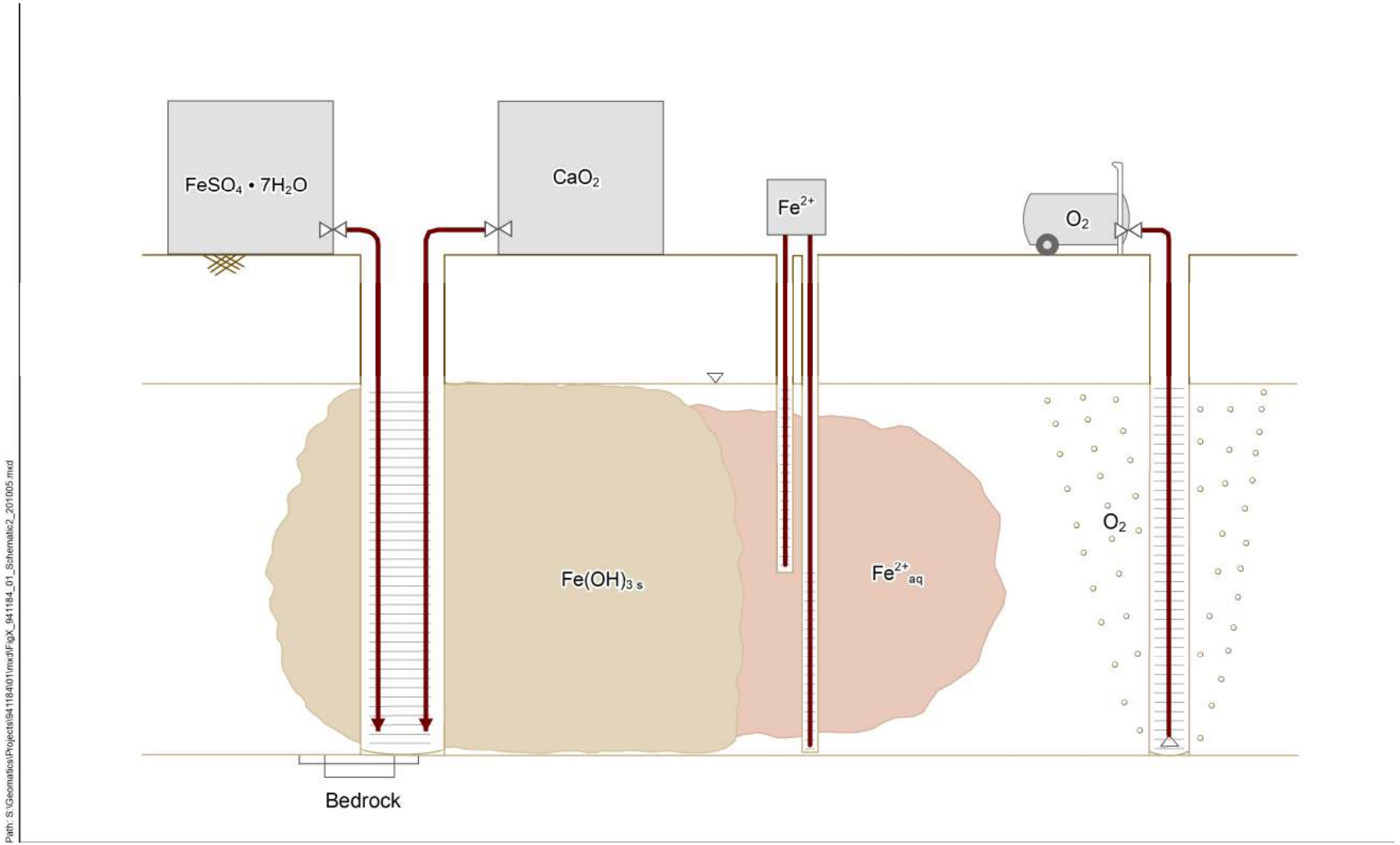
Pilot Scale Injections

- 1 m3 calcium peroxide
- 0.5 m3 groundwater
- 1 m3 ferrous sulphate
- 0.5 m3 groundwater

- HACH monitoring for ferrous iron



Pilot Scale Injections



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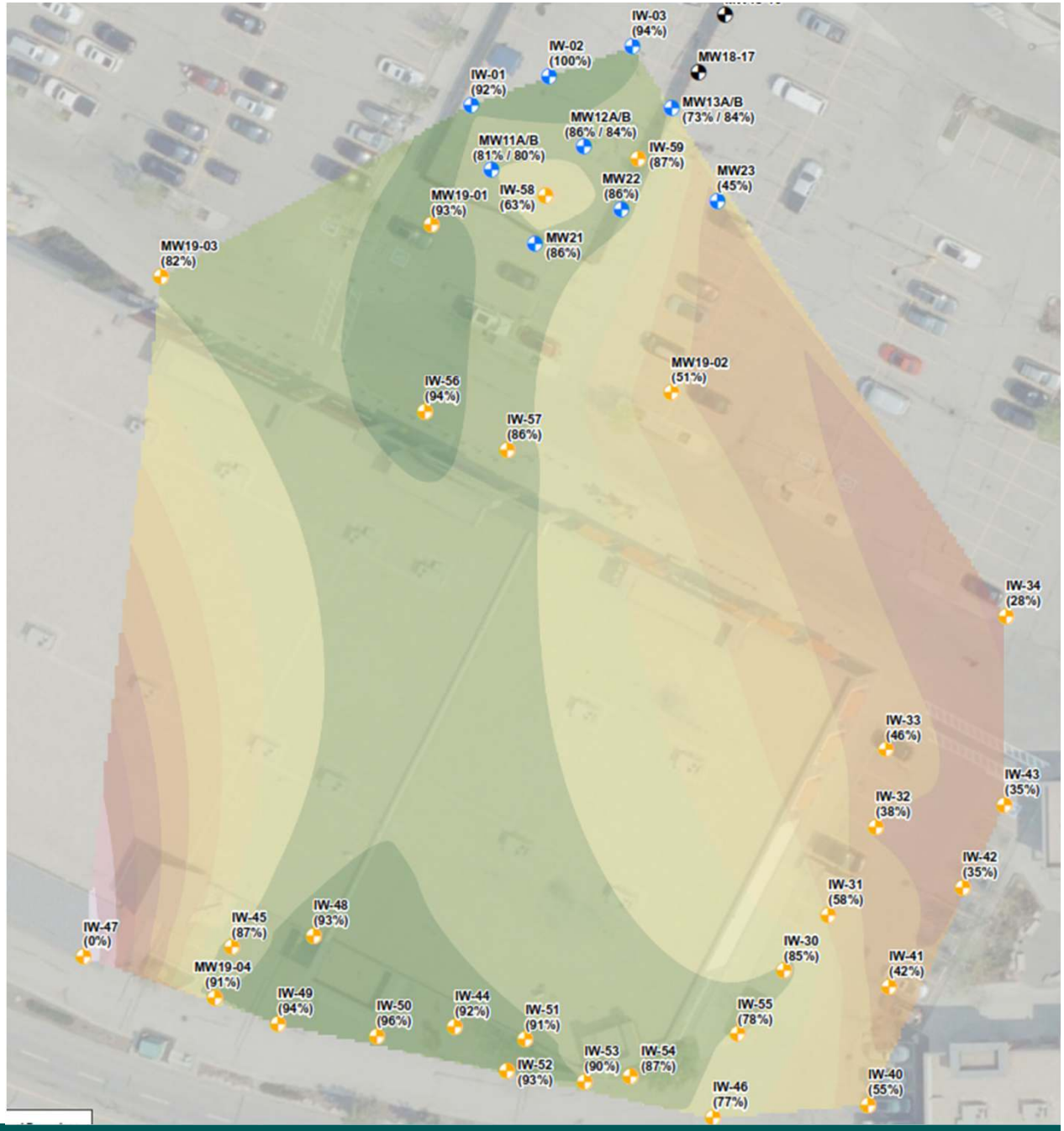
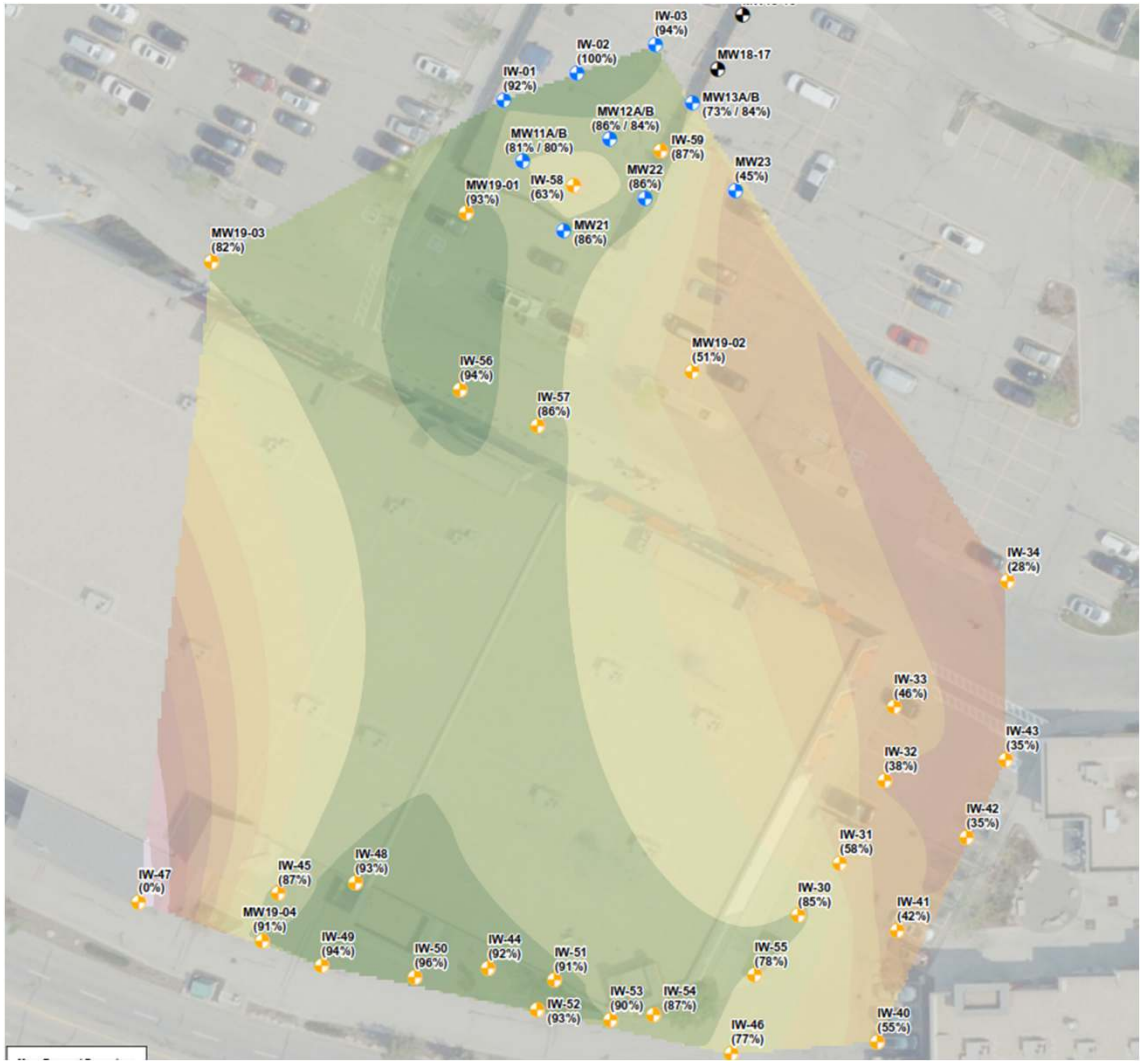
Results & Interpretation



Results and Interpretation

- Digital data collection
- Dashboard
- Percent Removal



Results and Interpretation

- Confirmatory Tessier analysis
- Target HFO not reached (Fraction 3)
  - Max 3,040 mg-Fe/kg-soil
- Target dissolved Cu reached
  - Min dissolved Cu <0.006 mg/L
- Dissolved Cu did not rebound – stays adsorbed (Fraction 1)
  - Consistent with Tessier results
- Results suggest more stable iron-oxides precipitated (Fraction 4)

Fraction 1. Exchangeable. Numerous studies (*15–23*) performed on sediments or on their major constituents (clays, hydrated oxides of iron and manganese, humic acids) have demonstrated the adsorption of trace metals; changes in water ionic composition (e.g., in estuarine waters) are likely to affect sorption–desorption processes.

Fraction 2. Bound to Carbonates. Several workers (*9, 11, 24, 25*) have shown that significant trace metal concentrations can be associated with sediment carbonates; this fraction would be susceptible to changes of pH.

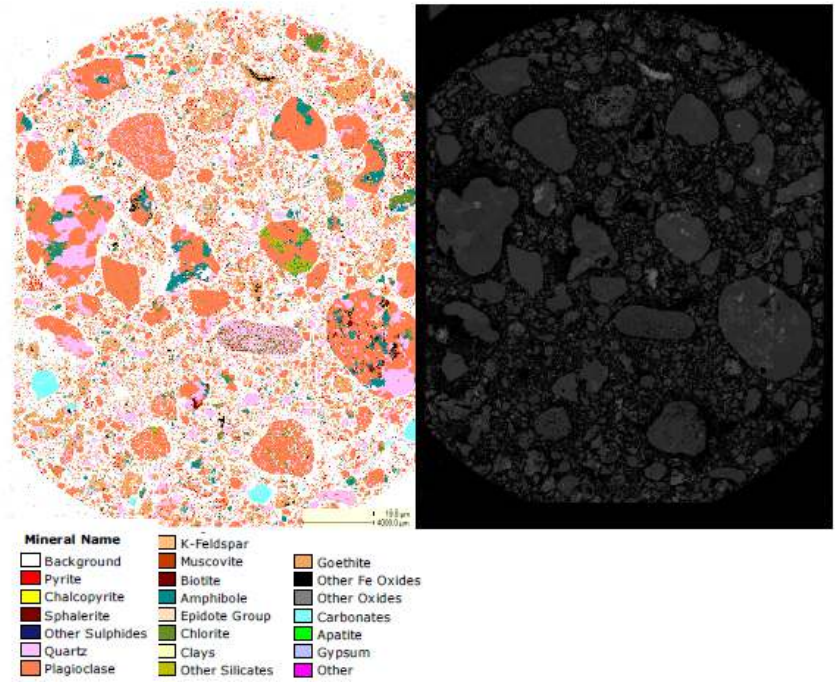
Fraction 3. Bound to Iron and Manganese Oxides. It is well established (*26*) that iron and manganese oxides exist as nodules, concretions, cement between particles, or simply as a coating on particles; these oxides are excellent scavengers for trace metals and are thermodynamically unstable under anoxic conditions (i.e., low Eh).

Fraction 4. Bound to Organic Matter. Trace metals may be bound to various forms of organic matter: living organisms, detritus, coatings on mineral particles, etc. The complexation and peptization properties of natural organic matter (notably humic and fulvic acids) are well recognized, as is the phenomenon of bioaccumulation in certain living organisms. Under oxidizing conditions in natural waters, organic matter can be degraded, leading to a release of soluble trace metals.

Run at pH 2

Geochemical Conclusions

- Initially colloidal, crystalline overtime
- Coprecipitation
- Copper concentrations stable
- HFO insoluble at prevailing pH/ORP
- No acidic/reducing sources up-gradient
- Sustainable



Lessons Learned

MOBILE COLLOIDS/SHEAR

3750 MG/KG TARGET

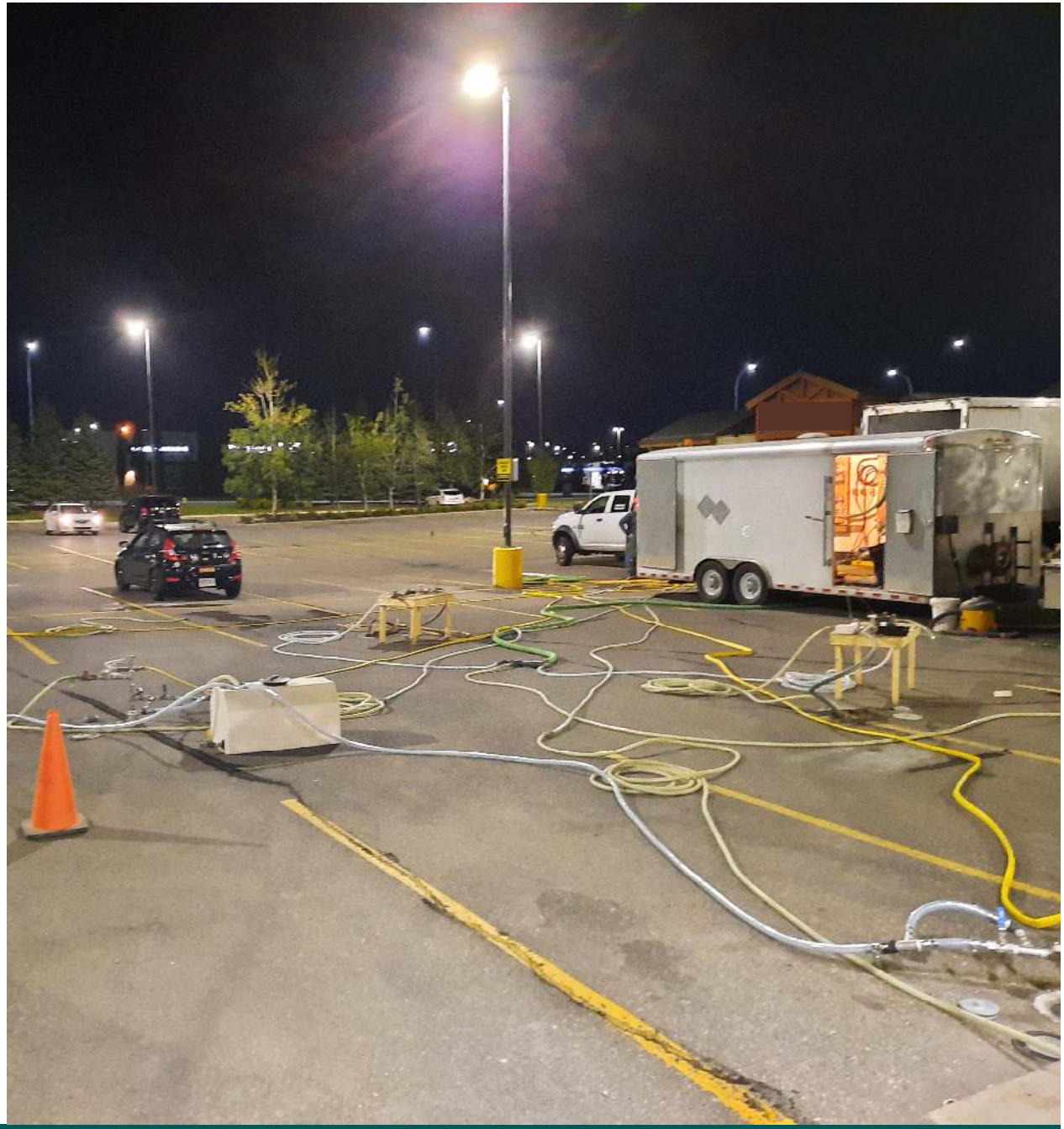
Lessons Learned

MORE AGGRESSIVE OXIDANT

HIGHER DOSING

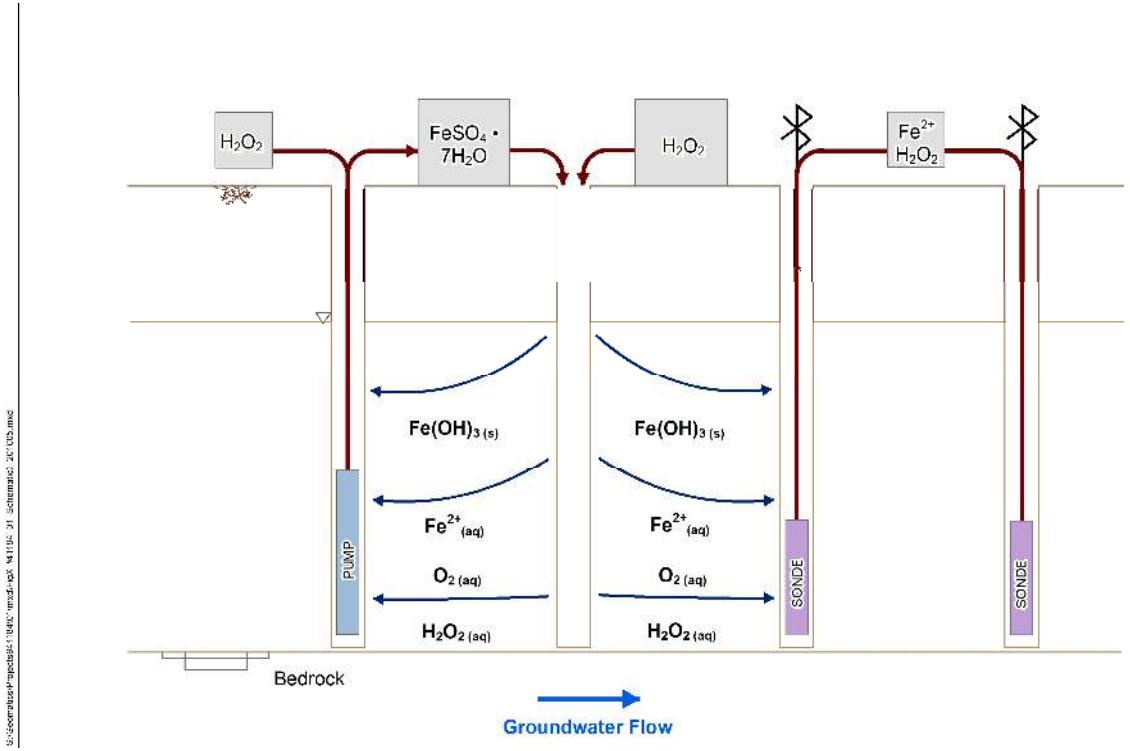
6

Next Steps



Next Steps

- Full scale injections ongoing
- Performance verification to follow
  - HFO concentration
  - Percent Cu removal
  - Porewater sampling
- RemTech 2021?



Questions?

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