

ACCESSING DIFFICULT GEOLOGY FOR CHARACTERIZATION AND INJECTION USING THE NEW GEOTAP™ METHOD

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Remediation & GeoTAP

- In-situ remediation success requires proper reagent:
 - Longevity
 - Dosing
 - **Contact**
- DPT or Packers are not always options (formation)
- Injection well problems?
 - Mass location
 - Lithology
 - Injectate, e.g. slurry

- Refusal?
 - Gravel/cobble zones
 - Glacial till
 - Weathered bedrock/PWR/Saprolite
 - Historic fill
 - Clay
 - Flowing sands
- Drill it like BR; inject it like OB
- Combined with bedrock remediation?

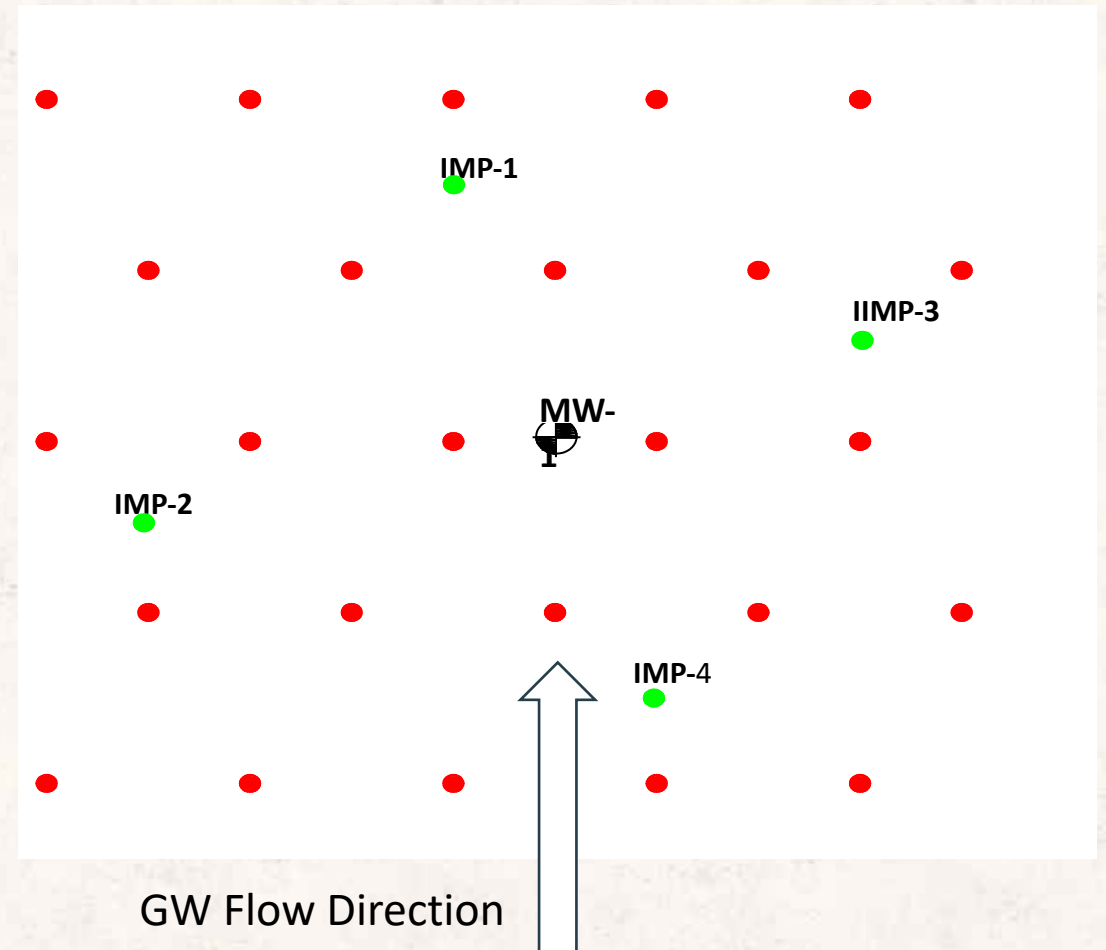


GeoTAP™ Technique

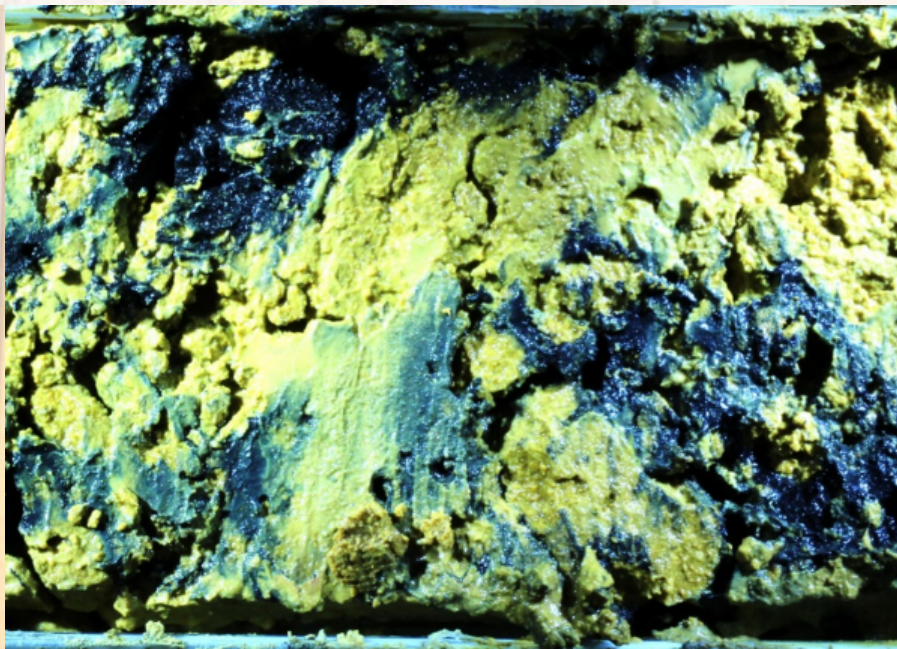
- Pre-drill each injection location to target depth
 - Augers (HSA, SSA)
 - **Sonic (log lithology)**
- Engineered bentonite backfill
 - Build in lifts
 - Sequential hydration
- DPT through bentonite column
- High energy injection
- Emplace reactant/reagent within native lithology
 - Geology still dictates injection tip, pressure, and flow
 - Radial mixing
 - Fracturing
- 60+ sites in various geologies/regions completed to date

GeoTAP™ Design

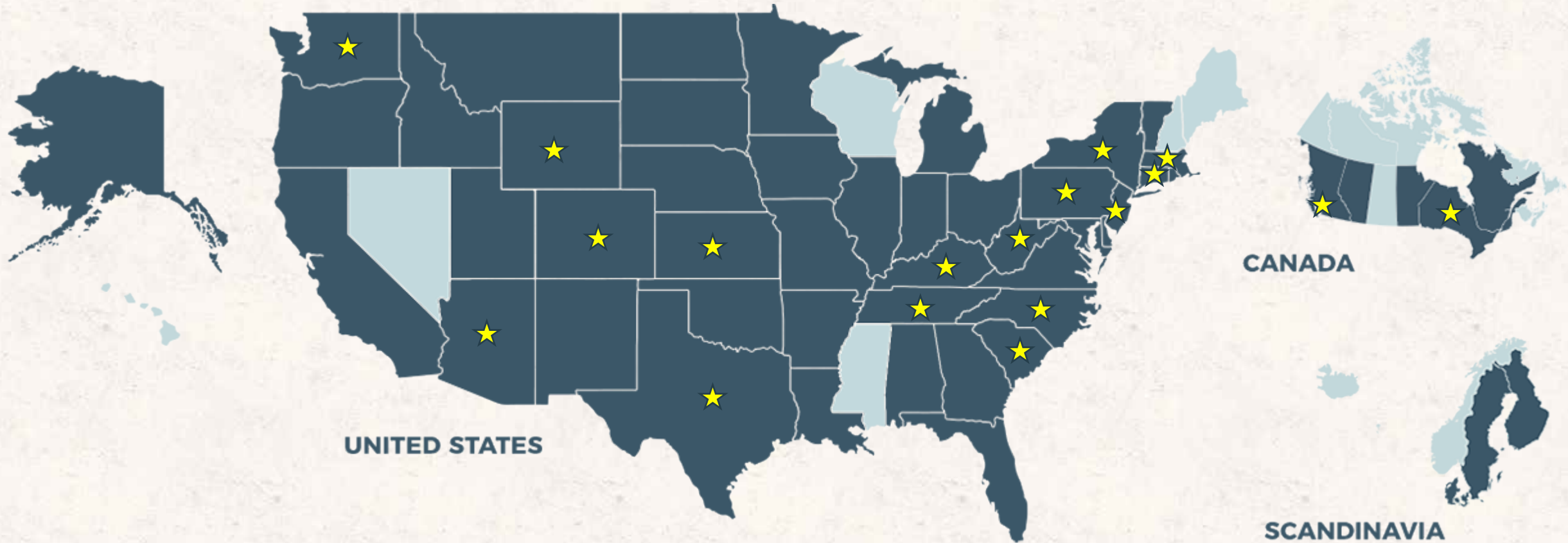
- Triangular grid pattern
- Spacing is a function of:
 - Depth
 - Lithology
 - Shot volume
- Does not supplant injection spacing requirements



Distribution Examples



GeoTAP™ Applications



Reagent Design Considerations

SLURRIES (~10 to 300 um) ("pollen to sand")

- BOS 100[®]
- CAT 100
- BOS 200[®]/BOS 200+[®]
- Activated Carbon (GAC, PAC)
- FerroBlack[®]
- FlouroSorb[®]
- Organoclay[®]
- ZVI
- CaSO₄
- Oxides
- Iron Sulfides

AQUEOUS & COLLOIDAL (<10um) ("soot to red blood cells")

- MgSO₄
- Persulfates
- Peroxides/MFR
- CaCO₃
- Colloidal Carbon (LAC)
- Drawbacks
 - Wash-out
 - Low rock matrix interaction
 - Composition
 - Dilute
 - Solids
 - Multiple injection events



Site Example: Setting & Challenges

- Northeast U.S.
- Large hexavalent chromium plume
- Earlier remediation phases (T&D, P&T, etc.)
- Zones
 - Tight, silty sand
 - Silty sand with gravel
 - Glacial till
- Consistent Access?
 - Difficult to impossible
 - Depths up to 90 ft-bgs.
- Installation
 - Soil mixing?
 - Fracturing?
 - High energy radial mixing?
 - Contemporary modification to a PRB?

Injection Equipment & Process

- Roto-sonic (“sonic”) drilling technology
 - Expeditious advancement
 - Logging soils
 - Complete vertical soil profile
 - Full transect span evaluation
 - Photographs
 - Succinct top and bottom intervals
 - Piezometer installation
 - 3 per transect
 - Distribution monitoring
- GeoTAP
- Schedule
 - Sonic drilling and backfill activities: 5 weeks
 - Conducted with a 4-week lead time

RDC

- Soil and groundwater samples
- Evaluate mass and mass flux
- 30-year lifespan
 - Requirement
 - Flow between transects
- Significant mass of reactant required
- Loading Calculations
 - lb./ft³
 - Transect specific
 - Depth specific
 - Dictated transect spacing (15 to 30 ft. centers)



Equipment



Soil Logging (Transects)



Injectate

FerroBlack

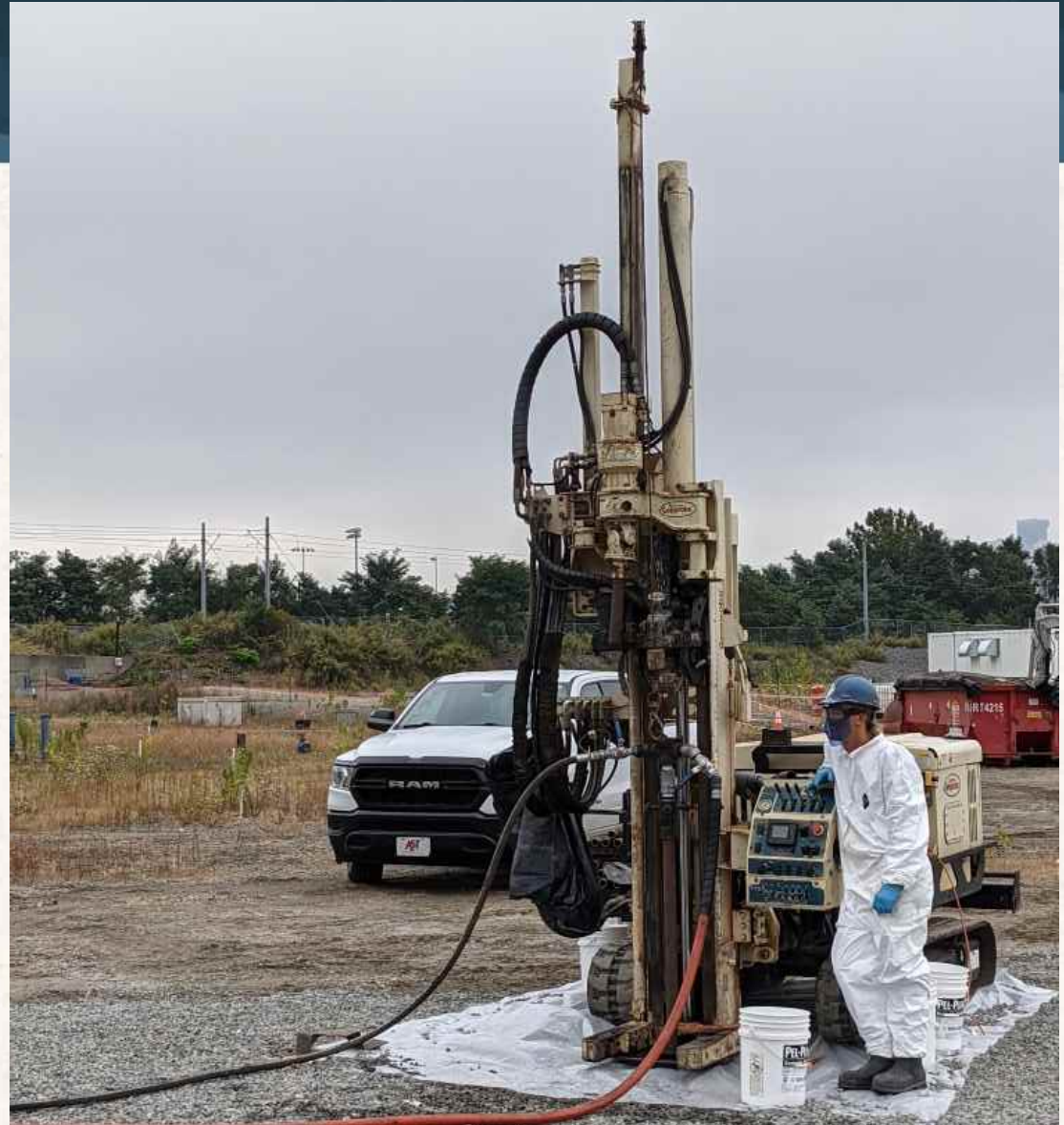
- Mackinawite-structured ferrous sulfides
 - Mixed-valence iron sulfide
 - Different stoichiometric ratios (Fe/S)
 - Different “surface charges”
 - Multiple mechanisms
- Immediate reductions
- Viscous slurry (~12.1 lb./gal)
 - pH ↑
 - ORP ↓
- *In Situ* or Manufactured?
 - Sulfate Reducing Microorganisms (SRM) + iron (biotic)
 - Synthesized (chemical reactor)



Injections (DPT & Triplex)

- DPT rig (7822DT)
- 2.25” injection rods, pre-strung hose (AST design)
- Geology-specific injection tip (AST design)
- Depth: 40 to 90 ft-bgs. (range)
- High-flow/high-energy Triplex injection system
 - Flow rates up to 280 gpm
 - Sustained injection pressures up to 2,000 psig.
 - Controlled distribution power – not a sledgehammer!

Equipment (Triplex & DPT)



Triplex (Varied Flow Rates)



Various Flow Rates

20 gpm, 60 gpm

120 gpm, 250 gpm

Installation

Summary

- ~34,600 gal of FerroBlack
- Five transects, totaling 2,340 linear ft (lf)
- 4 weeks of injection activities.
- Injectate distribution assessment
 - Transducers in existing monitoring wells and piezometers
 - Monitoring
 - Changes in groundwater geochemistry
 - Changes in water table
 - Colorimetric evaluation
 - Visual confirmation

Optimization

- Deep
 - 50 to 200 psig
 - One 300-gallon shot
- Shallow
 - 50 to 80 psig
 - Sequential shots of 200 and 100 gallons.
- Groundwater monitoring continues at the site to evaluate performance

Lessons Learned

- Initial design
 - Based on previous experience
 - Injecting slurries up to ~180 ft-bgs.
- In Field
 - Distribution at moderate energy?
 - Triplex vs. other pumps?
 - Energy
 - Duration
 - Preferential pathways- planning and management
 - Former sheet pile
 - Former wells
 - Former investigatory borings
 - Former canal





Thank You

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