USING MULTIPLE AMENDMENTS AND DELIVERY METHODS TO TREAT EXTENSIVE PCE IMPACTS IN COMPLEX SOIL AND BEDROCK MATRICES

Eleventh International Conference
on Remediation of Chlorinated and
Recalcitrant Compounds

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Palm Springs, California

BATTELLE

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Presented by *Remediation Risk Reduction, LLC*

Agenda

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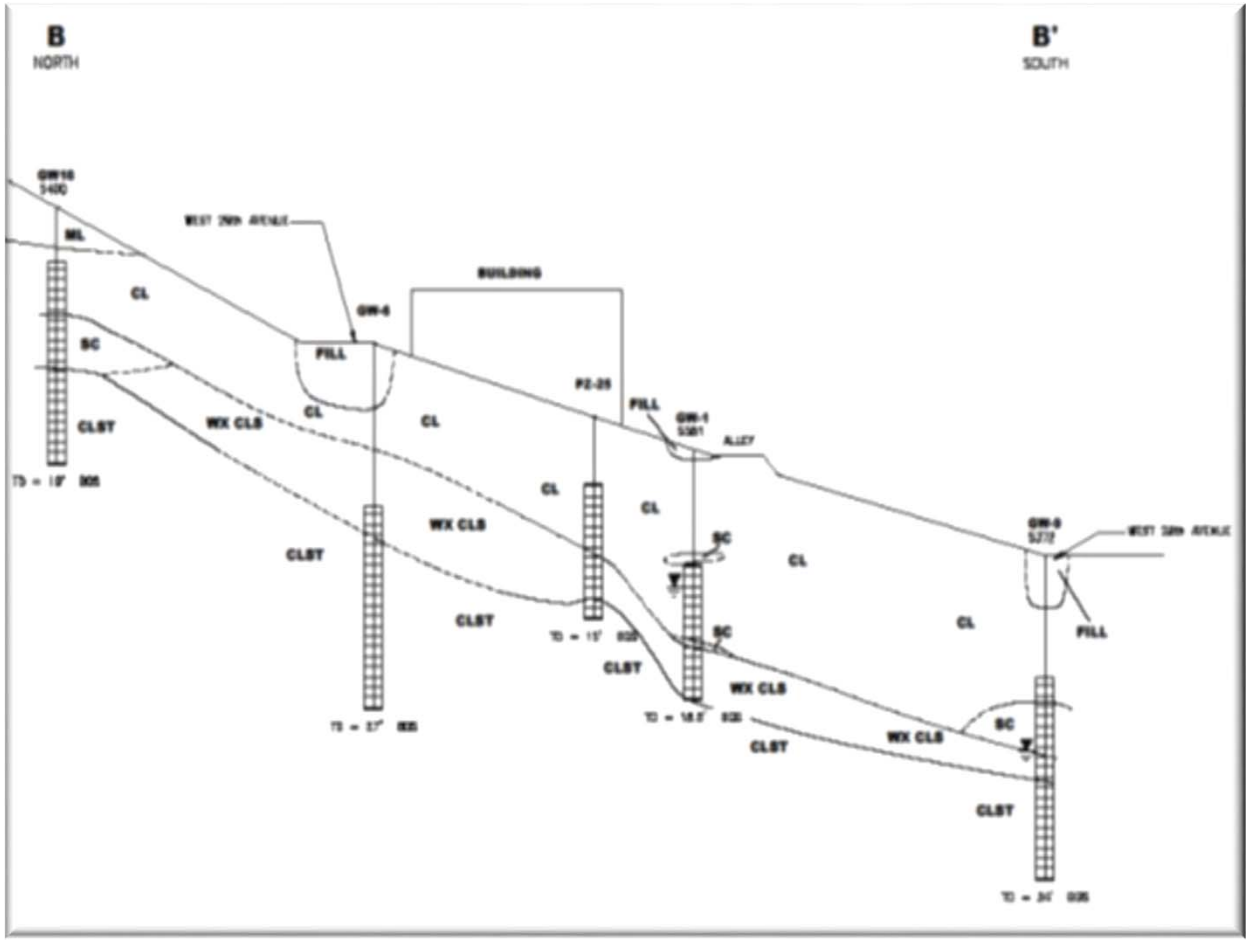
- Background
- Assessment
  - Hydrology Study
  - Specialized Drilling
- Conceptual Site Model
  - Delineation of Nature & Extent of Impacts
  - Mass Flux & Mass Discharge
- Remedial Approach
  - Stage 1: Excavation
  - Stage 2: BOS 100®
  - Stage 3: Sodium Permanganate
- Performance Monitoring
- Final Results
- Lessons Learned

Background

Setting:

- Former dry cleaner, PCE tank removed in the 1990's
- Matrix includes low-permeability residuum overlying incised and fractured claystone and sandstone
- DNAPL extends to depths 40 feet below unconfined water table



Background

Setting:

- Plume is largely overlain by residential community; hence, posing IAQ risks of fugitive emissions
- Paleo-channels and steep gradient result in dissolved-phase plume to extend more than 1/4-mile downgradient from the source
- there is also an upgradient source of PCE
- Voluntary Clean-up Program
- Risk-based targets per oncoming mass discharge and IAQ findings

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Background

Conditions:

- Soil impacts ranged up to **18,708,000 µg/kg PCE** (up to **35,175 µg/kg TCE**)
- Groundwater impacts ranged up to **184,000 µg/L PCE**
- Apparent **DNAPL in bedrock**

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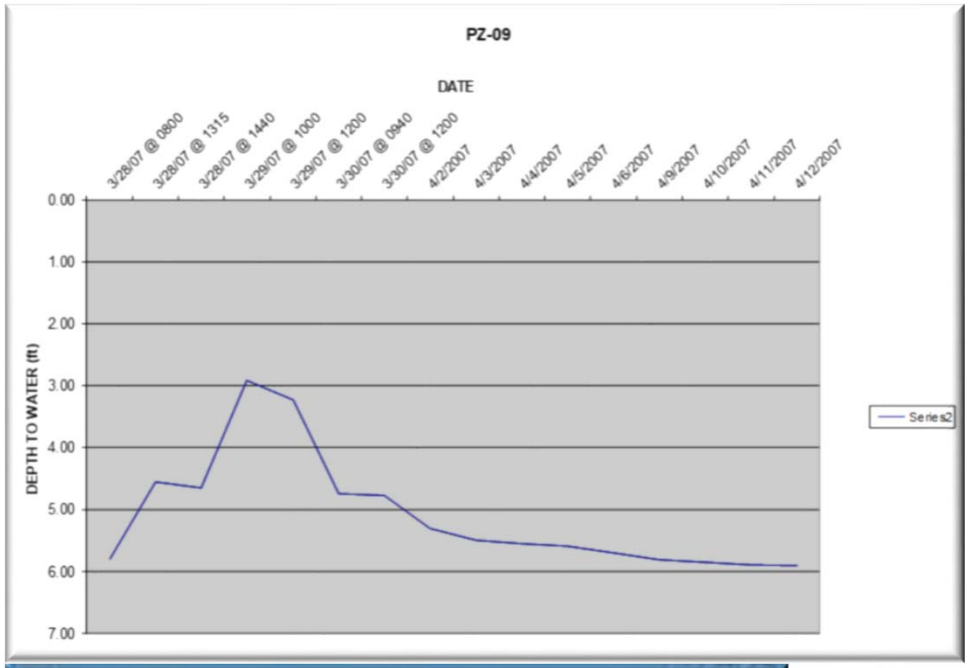
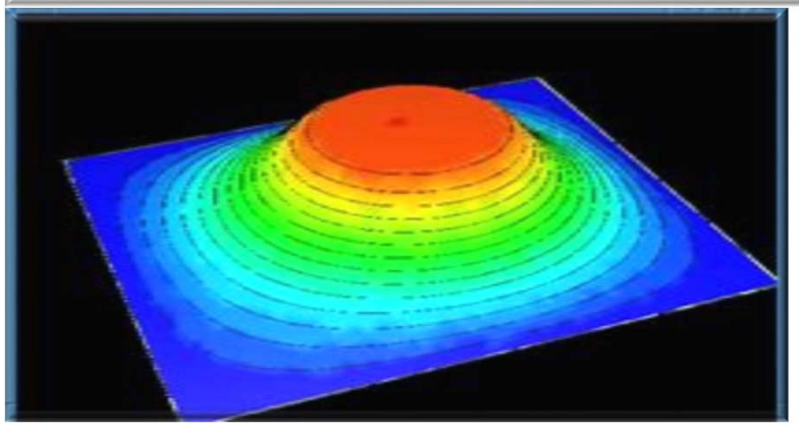
Assessment

Hydraulic Study:

- **Mounding**: Compare total-fluid injection volume with estimated native matrix pore-water volume to evaluate displacement potential
- for more accuracy, installed transducers in wells at different radial distances from injection point to calculate hydraulic-head changes
  - Transducers in 8 Wells
  - Manual measurements at 18 other locations daily for 1 week, then weekly for 3 weeks, then monthly for 2 months **(Total = 3 months)**





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Assessment

Specialized Drilling:

- Drilled from 1st floor, down through basement
- Angled borings for injection wells (discussed further in "Remedial Approach, Stage 3" slide)

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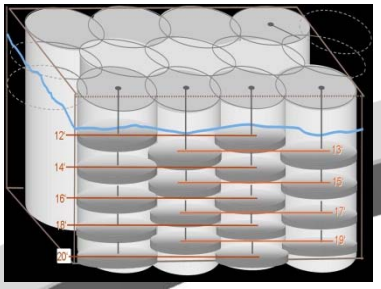
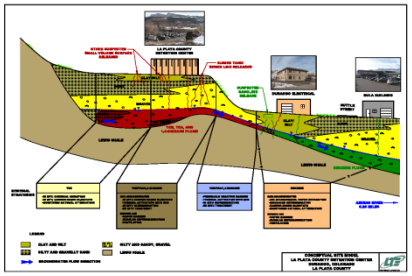
Conceptual Site Model

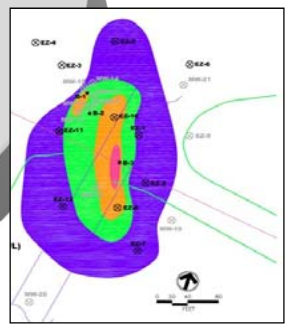
Installation / Treatment



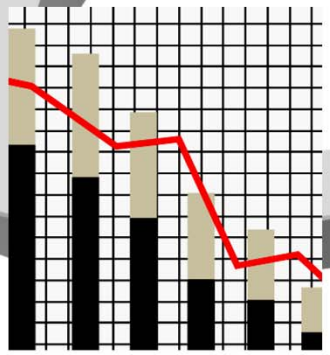
Design



Conceptual Site Model



Evaluation / Delineation



Performance Monitoring

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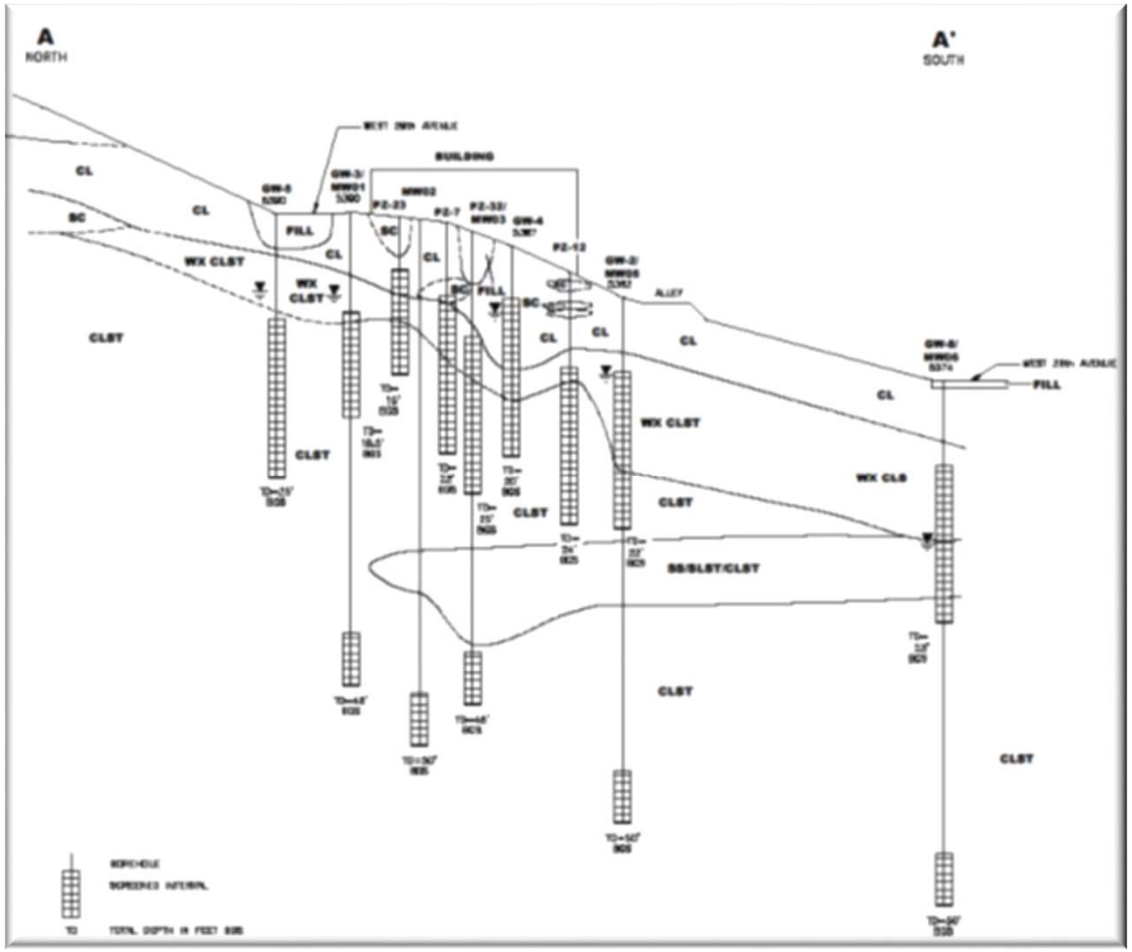
Conceptual Site Model

Delineation:

- Completed 42 Soil Borings, Continuously Sampled
- Installed 21 Wells
- Cross-sectional transects for **accurate conceptual site model**



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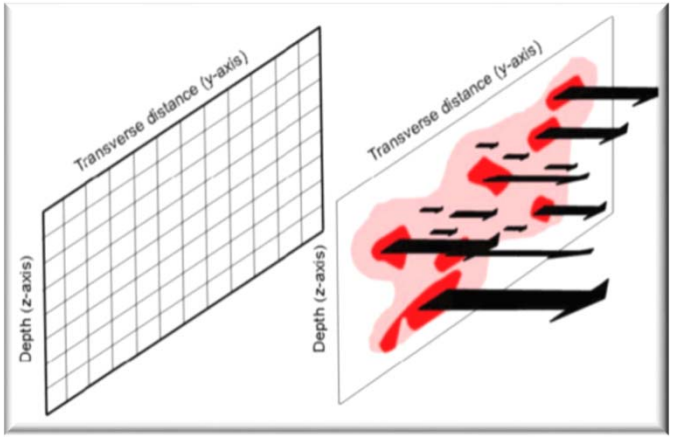
Conceptual Site Model

Mass Flux & Mass Discharge:



- Mass flux used to identify variability in solute concentrations and transmissive zones transporting bulk of mass
- Mass discharge measurements used to ensure target levels maintained at downgradient transects
- Evaluate plume architecture (solute distribution dictated by heterogeneity)
- Evaluate plume strength (contaminant mass moving per unit time)

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Remedial Approach

Stage 1: Excavation

- 120 yd^3 (25.5' X 25.5' X 5')
- Up to **6,200 µg/kg PCE**

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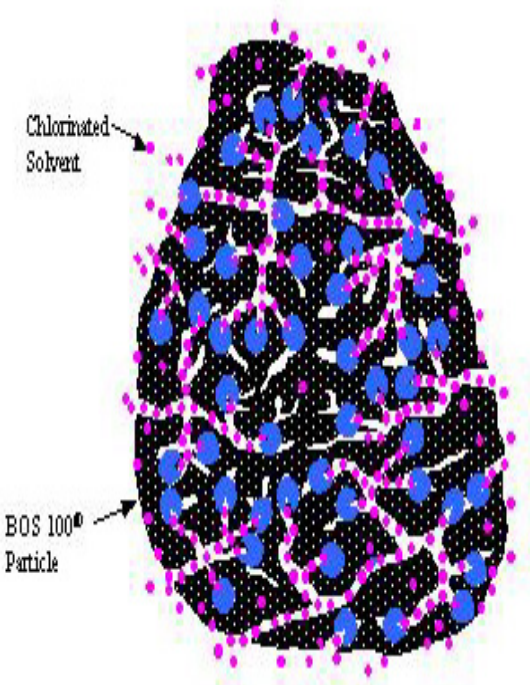
Remedial Approach

Stage 2: BOS 100® is granular activated carbon impregnated with nano-scale, reactive iron

- **Indiscriminate** - activated carbon removes virtually all organics, whether in vapor, solid, or aqueous phase
- Efficient destruction of chlorinated solvents via **reductive dechlorination**
- Effective in the **saturated** and **unsaturated** zones
- **Works in multiple site conditions** - despite pH, dissolved O_2 levels, microbial or substrate deficiencies



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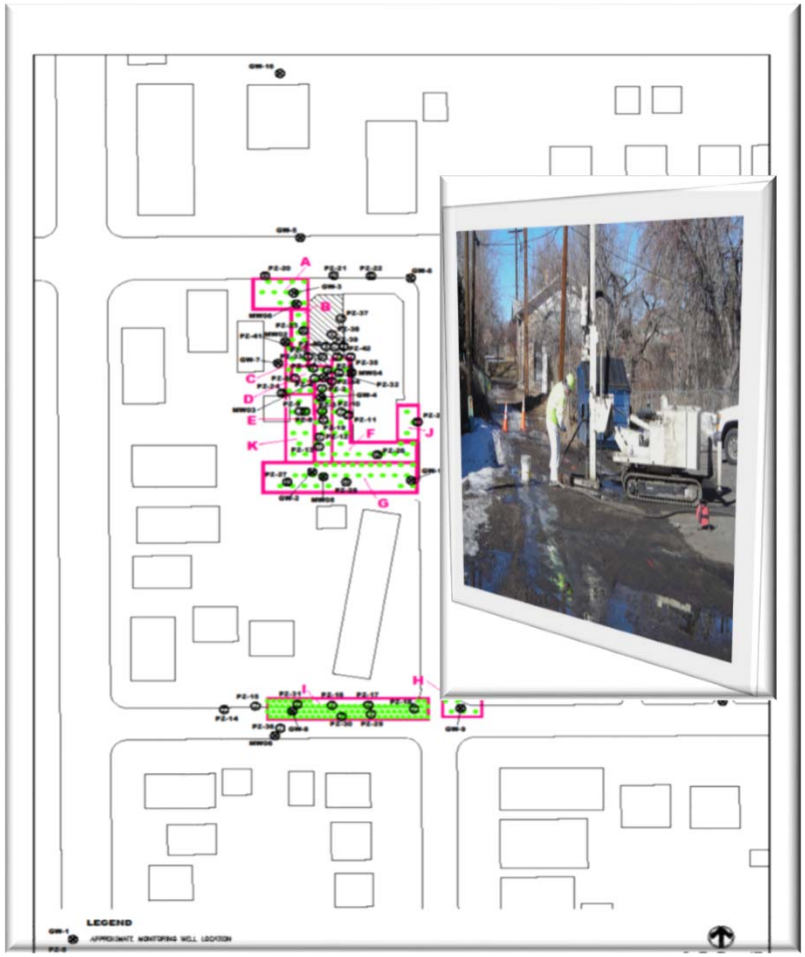
Remedial Approach

Stage 2: BOS 100® Injection

- Pilot Testing (Phase I, II, and III)
- **Round 1: Full Scale**
  - 102 onsite injection locations, to 7’ - 21’ depth, including a permeable reactive barrier (PRB) at the property boundary
  - 120 offsite injection locations, to 10’ - 19’ depth, creating another PRB downgradient



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Remedial Approach

Stage 2: BOS 100® Injection

- **Round 2: Extending the PRBs Deeper**
  - Auger drilled, packer-assembly to inject at 6 onsite locations to 45’
  - 24 offsite injection locations, to 25’

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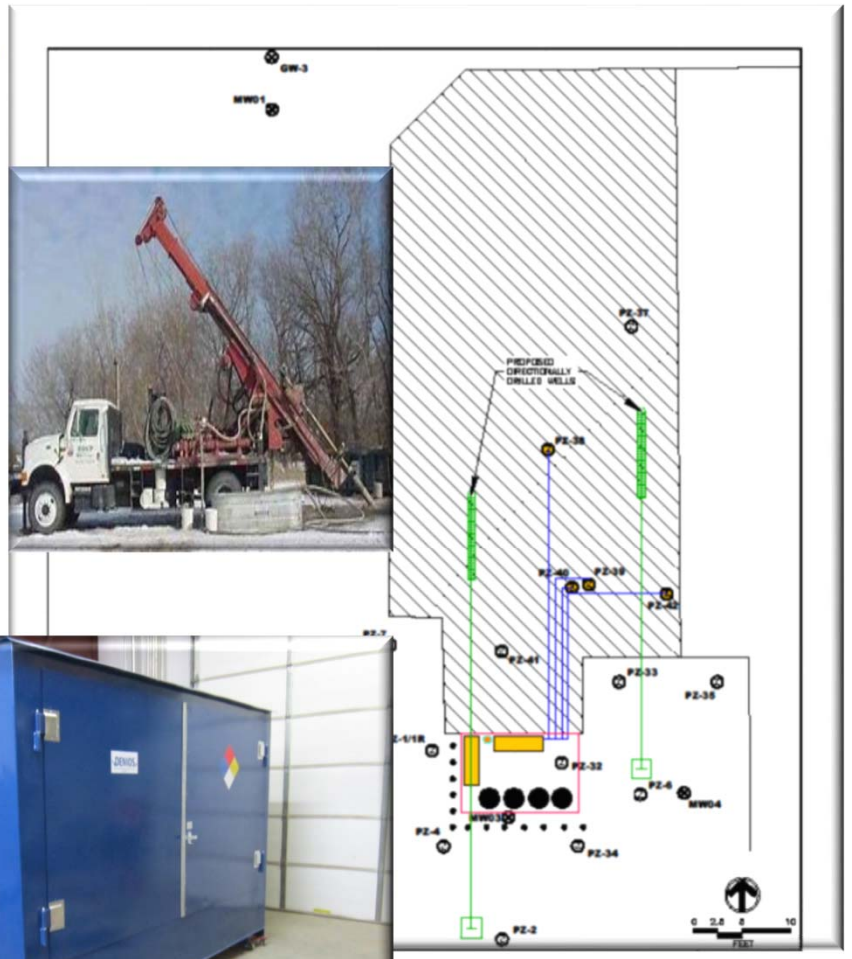
Remedial Approach

Stage 3: Sodium Permanganate

- **Robust Infiltration Gallery**
  - Angled injection wells to access deeper targets beneath the building
  - System also plumbed to 4 existing wells installed through basement floor



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Performance Monitoring

Methodologies:

- GW sampling before, during, and after injection to monitor remedy performance
- Next-day results allowed for "nimble" design revisions
- M_d calculated periodically to monitor mass reduction (diminished plume strength over time) ensuring property-boundary compliance
- Continuous confirmatory soil borings to document solute mass reduction (especially in DNAPL areas)
- Forensic drilling to observe if BOS 100® seams present

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Performance Monitoring

Mass Flux & Mass Discharge:

- Transect method used for J and M_d in and just downgradient of source and along plume to evaluate remedy performance
- Seepage velocity at individual wells using equilibrium flow-rates from low-flow sampling and associated PCE analytical results
- J spatial and temporal variations can be significant due to variations in conc's and GW flow magnitude and direction
- M_d can only vary over time since only a single value for entire transect

Average Seepage Velocity (v) of Fine-Grained Alluvium	2.35E-07 cm/sec
Average Seepage Velocity (v) of Coarse-Grained Alluvium	2.19E-06 cm/sec
Average Hydraulic Gradient	0.0035 (unitless)
Average Mass Flux From Source Area (Pre-Treatment)	682,185 mg/m^2/year
TCE Mass Discharge From Source Area (Pre-Treatment)	138 kg/year
Average Mass Flux From Source Area (Post-Treatment)	31,984 mg/m^2/year
TCE Mass Discharge From Source Area (Post-Treatment)	6 kg/year
Mass Flux Percent Reduction	**95.31 %**

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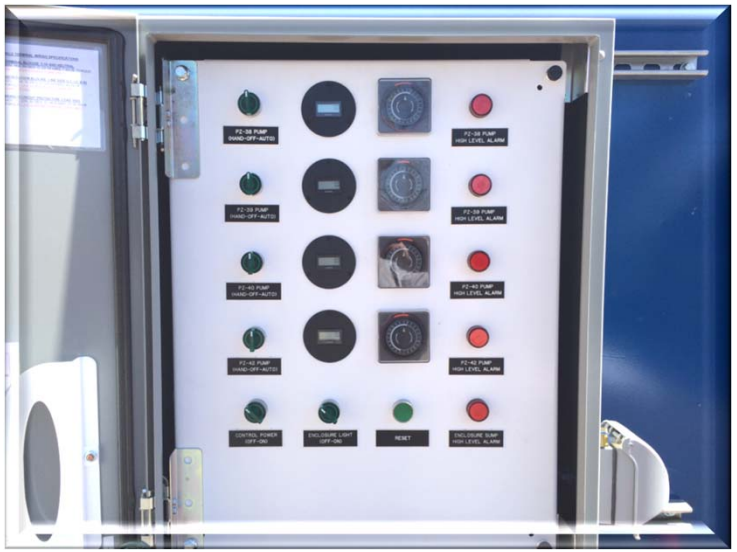
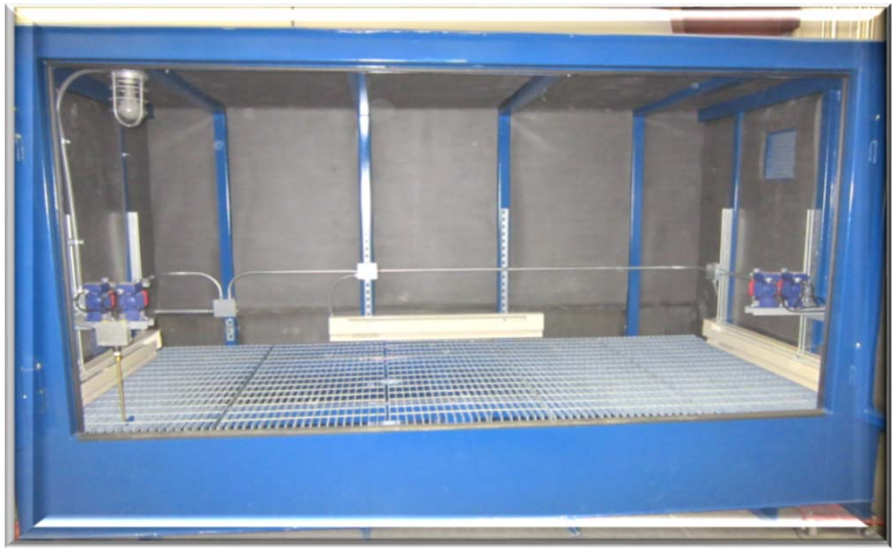
Performance Monitoring

Sodium Permanganate System:

- Fully instrumented dispensing system
- Adjustable flow controllers
- Dosing pumps





- Sodium permanganate tote storage

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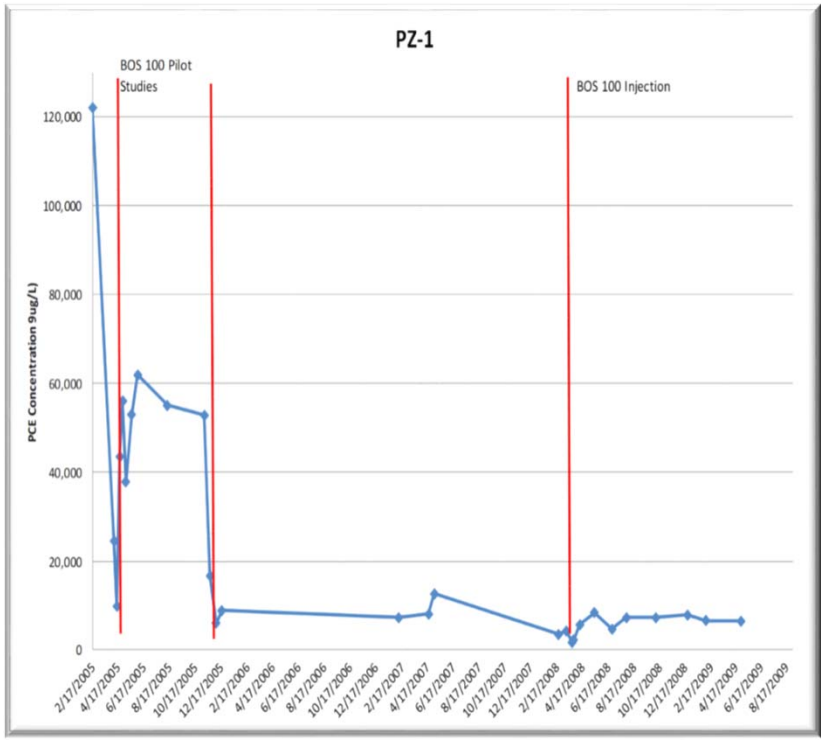
Final Results

Once the Dust Settled:

- To date (4 months after final remedy was installed), PCE impacts have been reduced from concentrations up to 18,708,000 µg/kg in soil and 184,000 µg/L in groundwater, **to near risk-based target levels**
- A **NO ACTION DETERMINATION** for the site will be obtained, once voluntary clean-up objectives have been met



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Lessons Learned

- The project has been successful because of the effectiveness of the **trident approach:**
  - soil excavation in the source and adjacent areas
  - continual delivery of sodium permanganate to treat source-area groundwater and DNAPL
  - the stalwart presence of BOS 100® within the dissolved-phase plume and in PRBs at strategic locations at the property boundary and offsite

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"Remediation is only expensive when it doesn't work"

Questions