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YOUR EXPERT SOURCE FOR COMPLETE SOIL AND GROUNDWATER REMEDIATION

Lessons Learned from Pre-Application Assessments at *In Situ* Remediation Sites

Brett Hicks—Ohio Valley District Manager

2019 Great Lakes Environmental Remediation and Redevelopment Conference

OVERVIEW

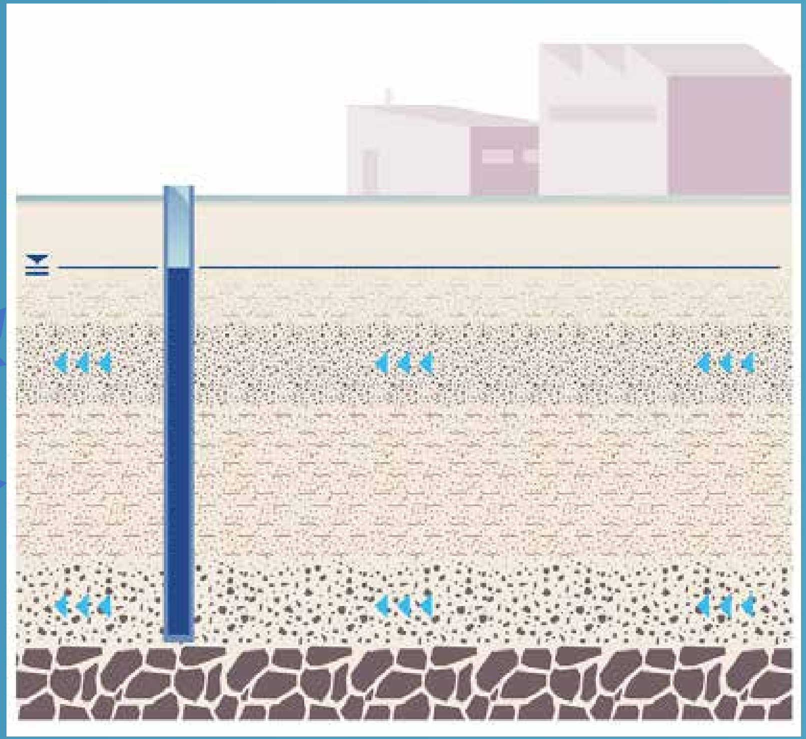
1. Fundamentals of Contaminant Distribution
2. Design Verification- What it is and Why we do it
3. Case Study
4. Analysis of Design Verification Program: N=43 Sites

Fundamentals of Contaminant Distribution

- Vertical and Lateral relationships between fine- and coarse-grained units
  - Determination of vertical and lateral relationships between low and high Kh zones are critical
- Organization and Position of COC Storage Units and Transport Units
  - Fine grained units - storage
  - Coarse grained units – transport
- Sand Content “Plumbing”
  - How much
  - How well sorted
  - What is its positional orientation

Higher permeability zones
“Freeways”

Lower permeability zones
“Parking lots”



Fundamentals of Contaminant Distribution:

- **Mass Storage**
  - The relationship of fine and coarse grained unit organization plays large role in plume shape.

- **COC distribution is controlled by soil type positional relationships**
  - Determination of vertical and lateral relationships between low and high Kh zones are critical
  - Remediation is site specific
    - Based on a sites specific aquifer characteristics
    - Often unique to the site

Design Verification-What?

- What is Design Verification?
  - Pre-application field-verification of remedial design parameters
  - High-density based identification of Contaminant Transport Zones
  - Increases reagent emplacement accuracy - maximum flux-interception

- Objective: Maximize reagent-contaminant contact
  - Field-verification of remedial design parameters & delivery rates
  - Identification of contaminant transport strata and distribution
  - Ensure accurate, efficient placement of reagents for maximum flux-interception and performance

Design Verification Process – Why?

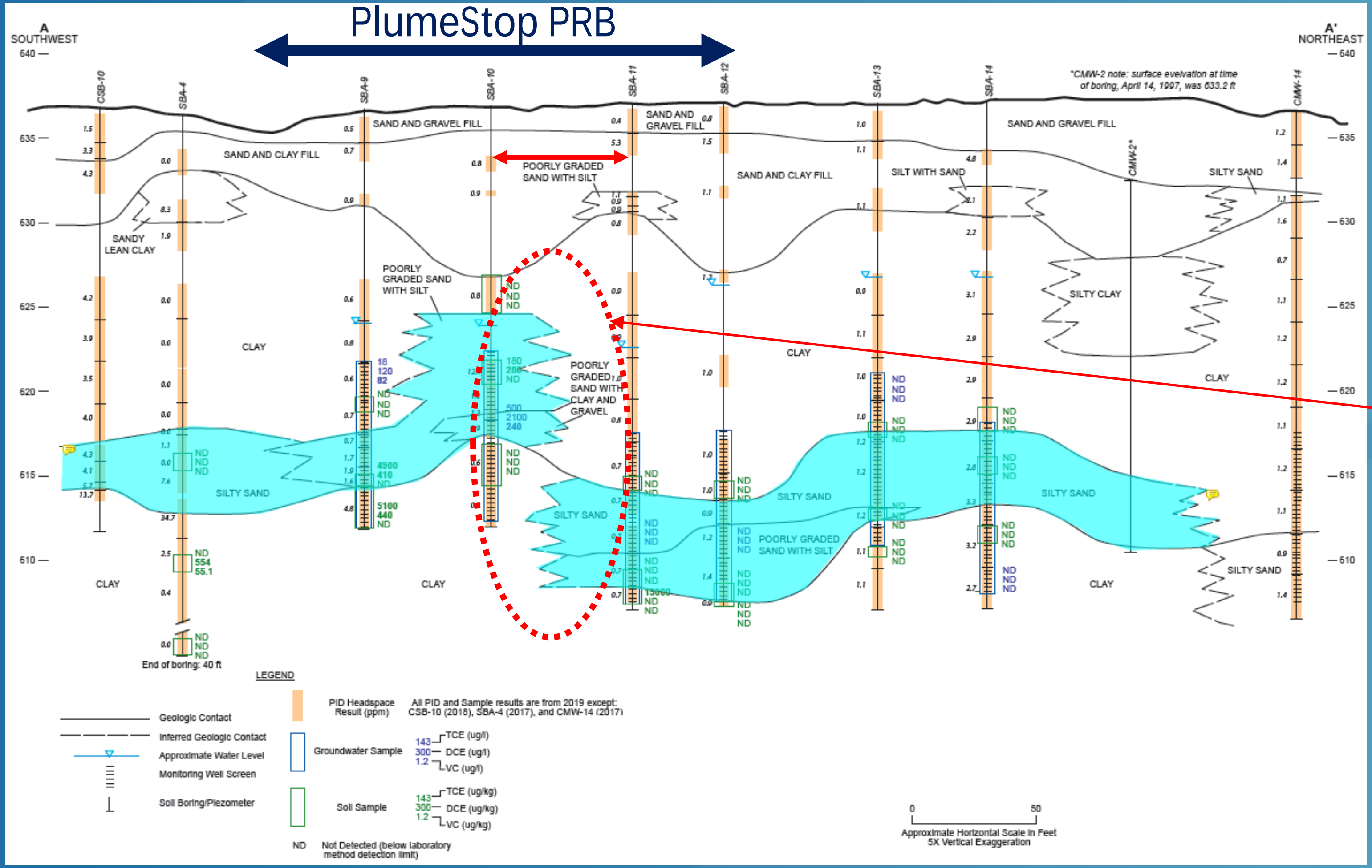
Site Assessments have different objectives than DVT, such as:

- Nature and Extent, Plume Boundaries
- Liability and Risk, Sensitive Receptors

DVT improves remedial outcome by increasing site resolution :

- Focusing on identifying position of COC mass and high flux zones
  - -Emphasis on identification of principal impacted units
  - -Provides greater reagent-COC contact = improved performance

Design Verification = Scaling for Remediation



X-Section – 600 ft long

Plumestop PRB ~200 ft long covering Sand Unit – Aqua Color

Focus: Circled Area

Q: Is Sand Layer Broken or Continuous?

~60 feet long section of PRB

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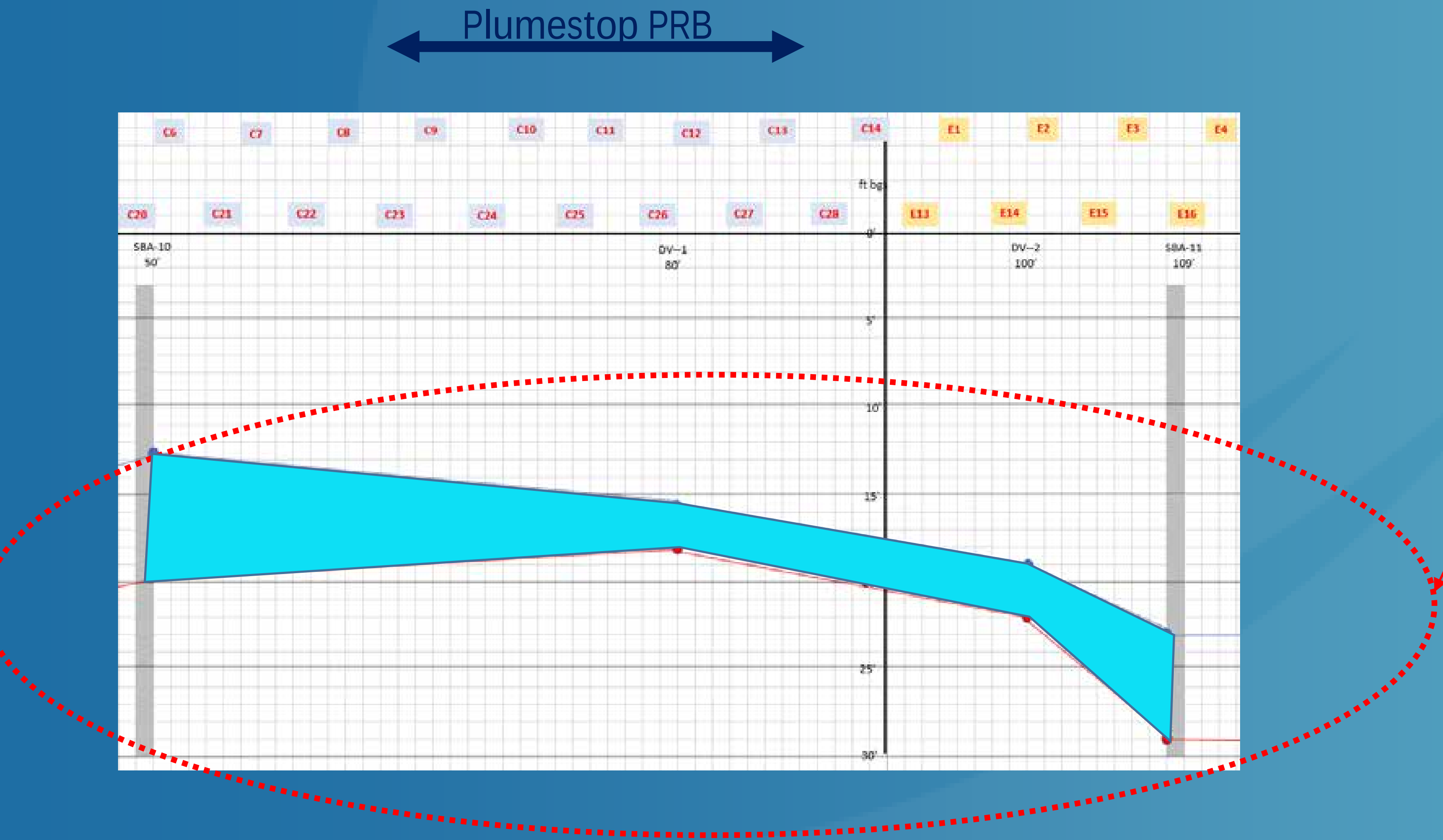
Design Verification = Scaling for Remediation



Sand Unit – Aqua Color

Q. Is Layer Broken or Continuous?

A. At finer scale we can see that sand unit dives but continuous.

Individualized injection point depths needed

Design Verification: Tools Box

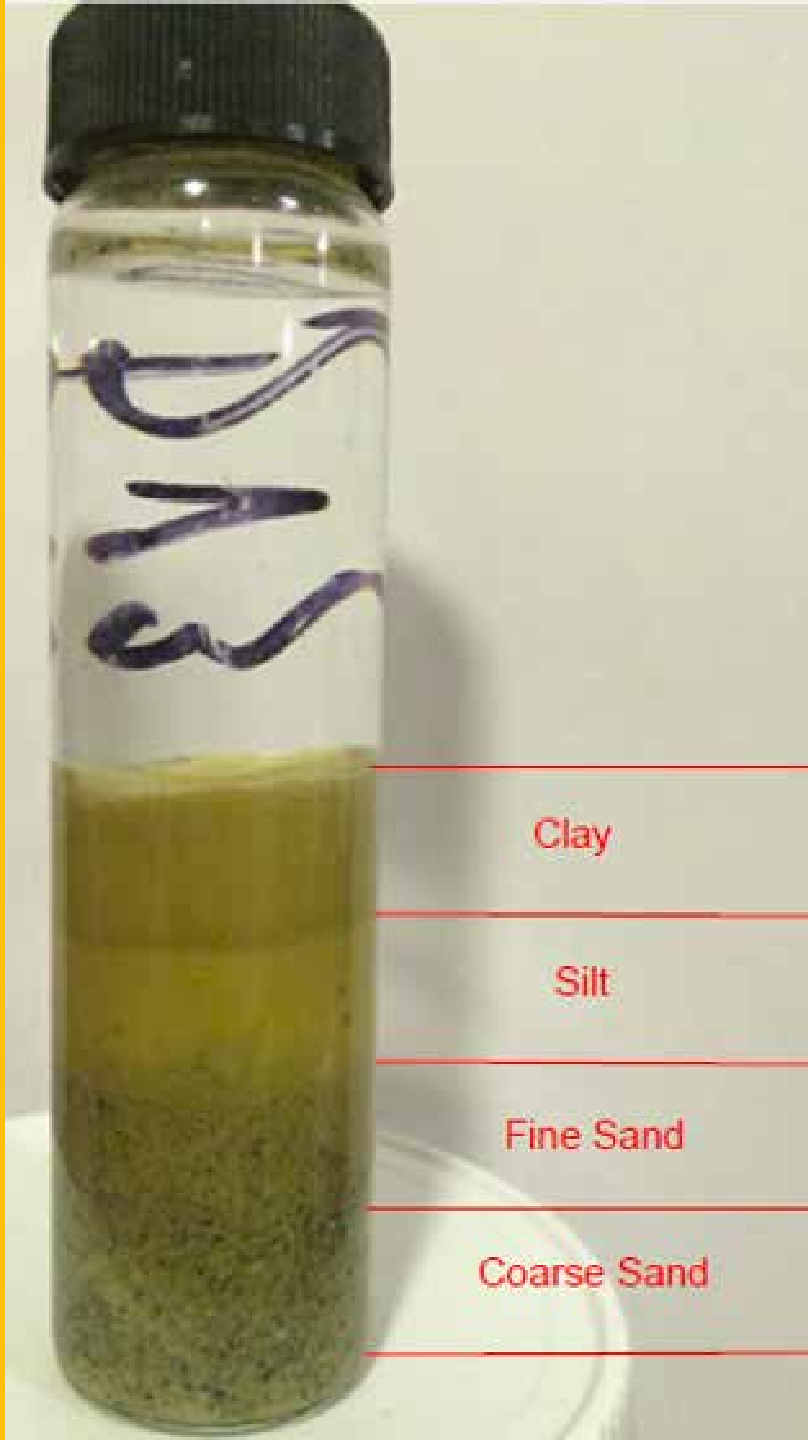
- Continuous Soil Core Logging
- Soil Contaminant Analysis
- Settling Tubes
- Clear Water Injection
- Passive Flux Meter

Continuous Core Logging

- **Physical Characteristics**
  - Moisture content
  - Contaminant: e.g. odor, staining, PID
- **Grain Size:**
  - % clay- silt-
  - % fine- medium- coarse- sand/gravel
- **Gradation:**
  - coarsening upward vs. fining upward
- **Soil contaminant analysis:**
  - Identify contaminant concentrations within flow pathways

Design Verification: Soil Settling Tubes

- Field Technique provides semi-quantitative data to trained Field Geologist
- Visual Determination
  - Sand, Silt, Clay
  - Soil particle size %
  - Sand: grain size and sorting
- Simple Rapid Reliable
- Decreases Subjectivity
  - e.g. Silty sand silty clayey sand etc.
- High density, 1 foot vertical interval



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Design Verification: Clear water injection test

- Documents acceptance rates and volumes
  - Vertical TTZ's interval
- Assists in application decisions
  - Direct Push Injection
    - Top-down vs Bottom-up
  - Injection wells
    - Screened Intervals
- Data collected often differs greatly from the estimated K_h based volume

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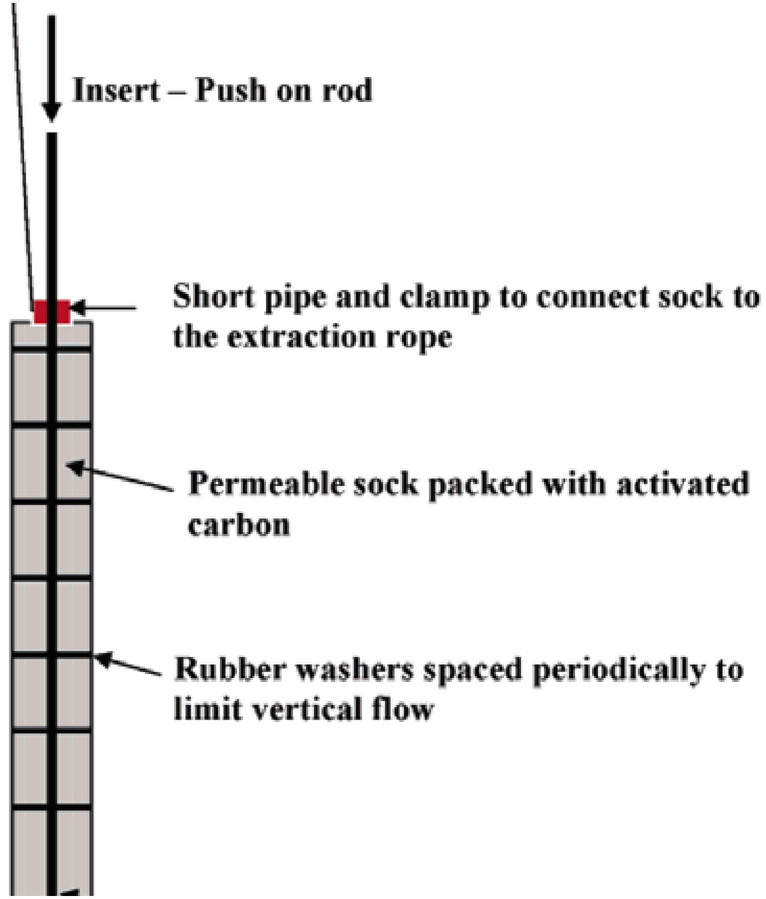
Design Verification: Unknown Velocity?

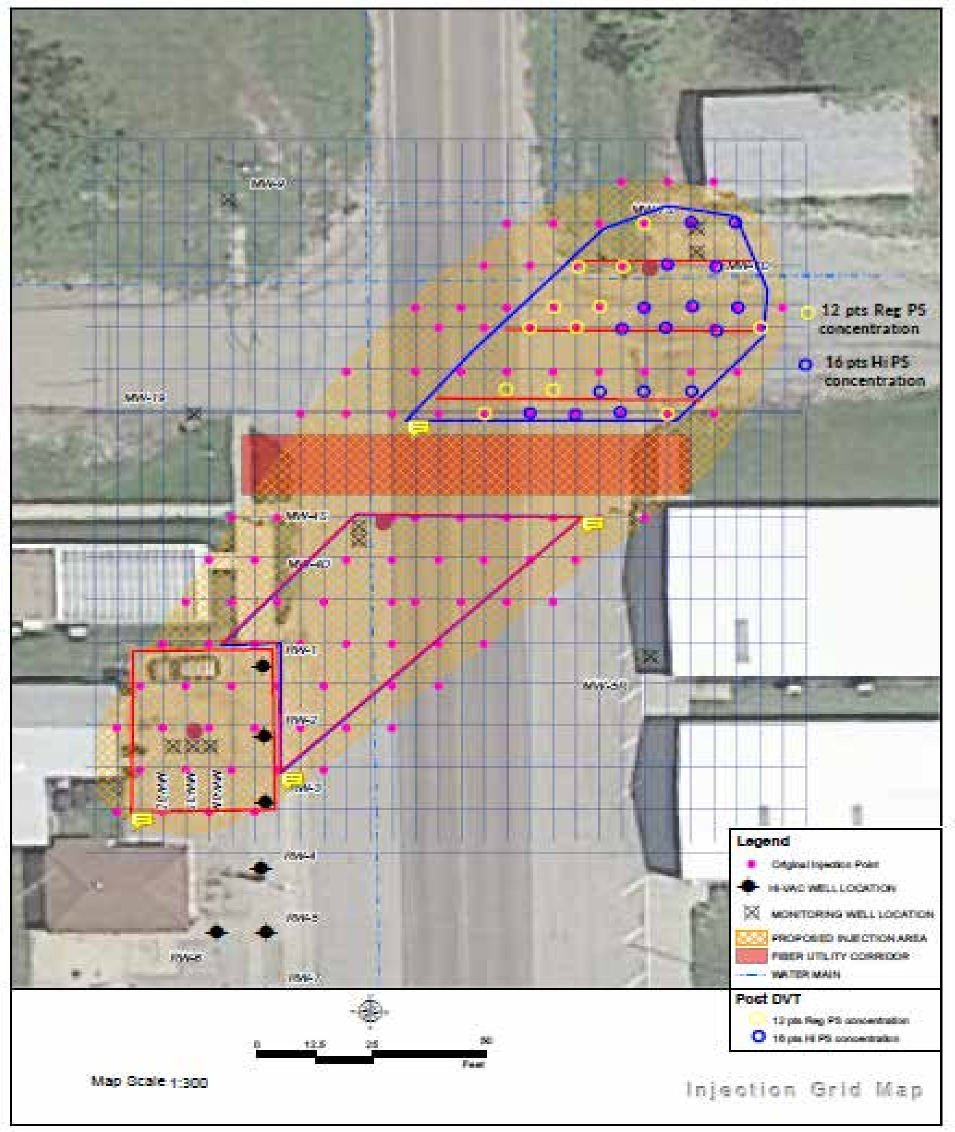
- Passive Flux Meters (PFM's) can answer this ?
  - Self Contained Permeable Unit – Designed to be Inserted into 2 or 4 inch Well
  - Filled with a Permeable Sorbent (Carbon)
    - Accumulates contaminant
      based on flow and concentration
  - Carbon pre-loaded with multiple tracers – known sorption (Kd)
    - Loses tracer based on groundwater velocity and flux convergence calculations



Case Study: Hydrocarbon Site

Former UST Site: TPH/BTEX

- **Remedial Strategy:**
  - Direct Push Injection Methods
  - ISCO - source/mid-plume/grid
  - Sorption + Bio - distal plume/barrier
- **DV Objectives:**
  - Identify sand units present
    - vertically/laterally
  - Confirm/Determine
    - contaminant mass distribution
    - hydraulic accommodation rates volumes



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Case Study: DVT Soil Logging

Detailed Soil Examination Results

- Identified increased sand units
- Identified COC transport units
- Identified increased TPH levels in distal section of the plume

Case Study: Design/Application Modifications

Varied Reagent Solution % and Volumes based on:

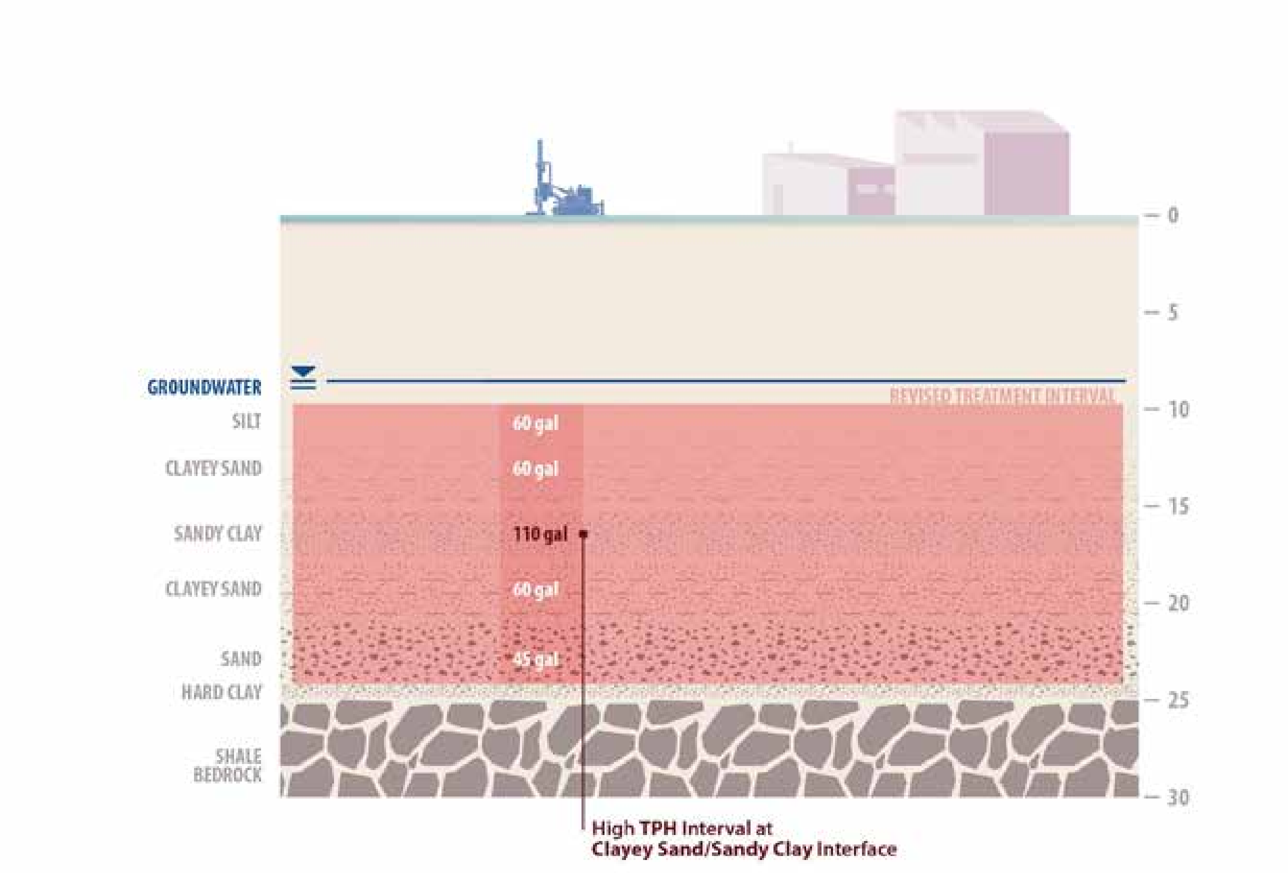
- Injection Tests

Increased TTZ vertical interval based on:

- Continuous Core logs
- COC analysis

Decreased TTZ laterally based on:

- Continuous Core Logs
- COC Analysis



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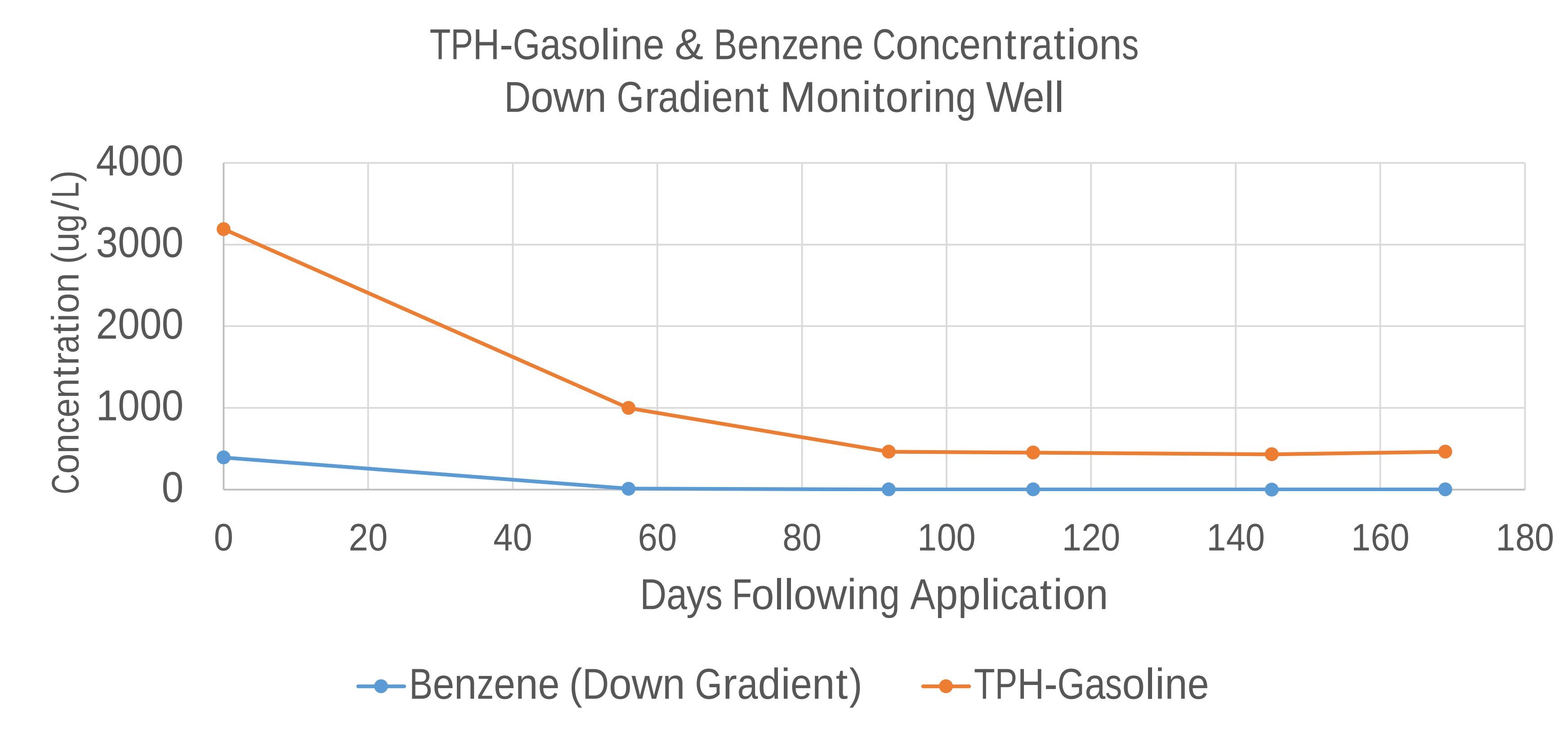
Case Study Results

- Redistribution of the original remedial solution mass via a site specific optimized program
- Reallocation
    - TTZ foot print reduced
    - Source Area – No Change
    - Mid-Plume – 20%
    - Distal Plume - 25%
  - Remedial Solution quantities based on COC mass ID in DVT
  - Remedial Solution % modified - focus on transport units
  - Improved the Application Methods

Case Study: Post-application results



Design Verification: Analysis

- **Project Population**
  - 43 Sites

- **Project Design Approach**
  - 33 % source areas
  - 67 % mid- to distal- plume

Design Verification: Analysis

- Contaminant Type
  - 35% Petroleum
  - 61% CVOC's
  - 4% Comingled

- General Soil Type
  - 50% Fine grained (Clays & Silts)
  - 50% Coarse grained (Sand & Gravel)

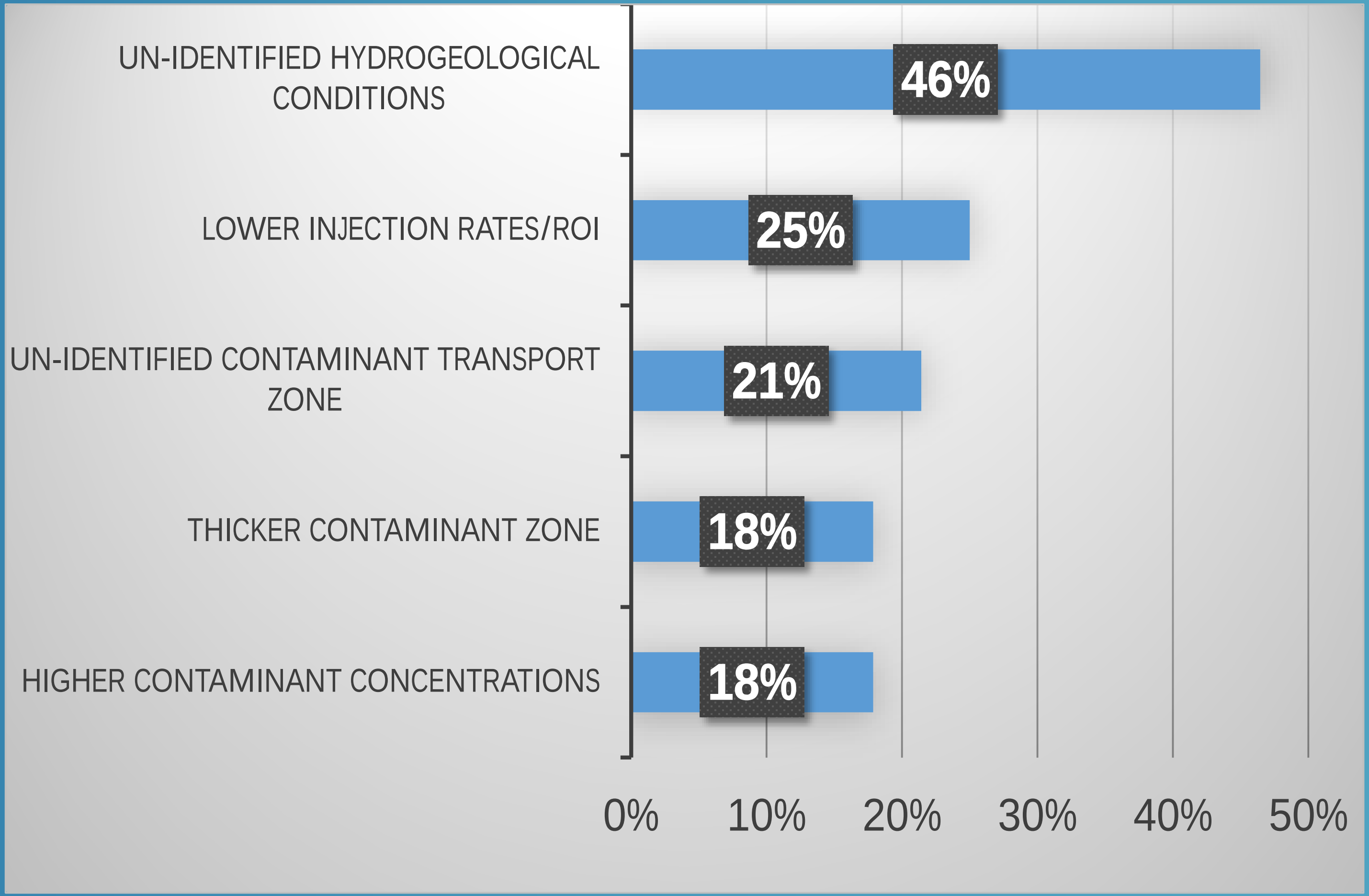
ANALYSIS OF TECHNICAL BLINDSPOTS

What's the outcome?

- ~80% of tests to date have found unanticipated results (technical blind spots)

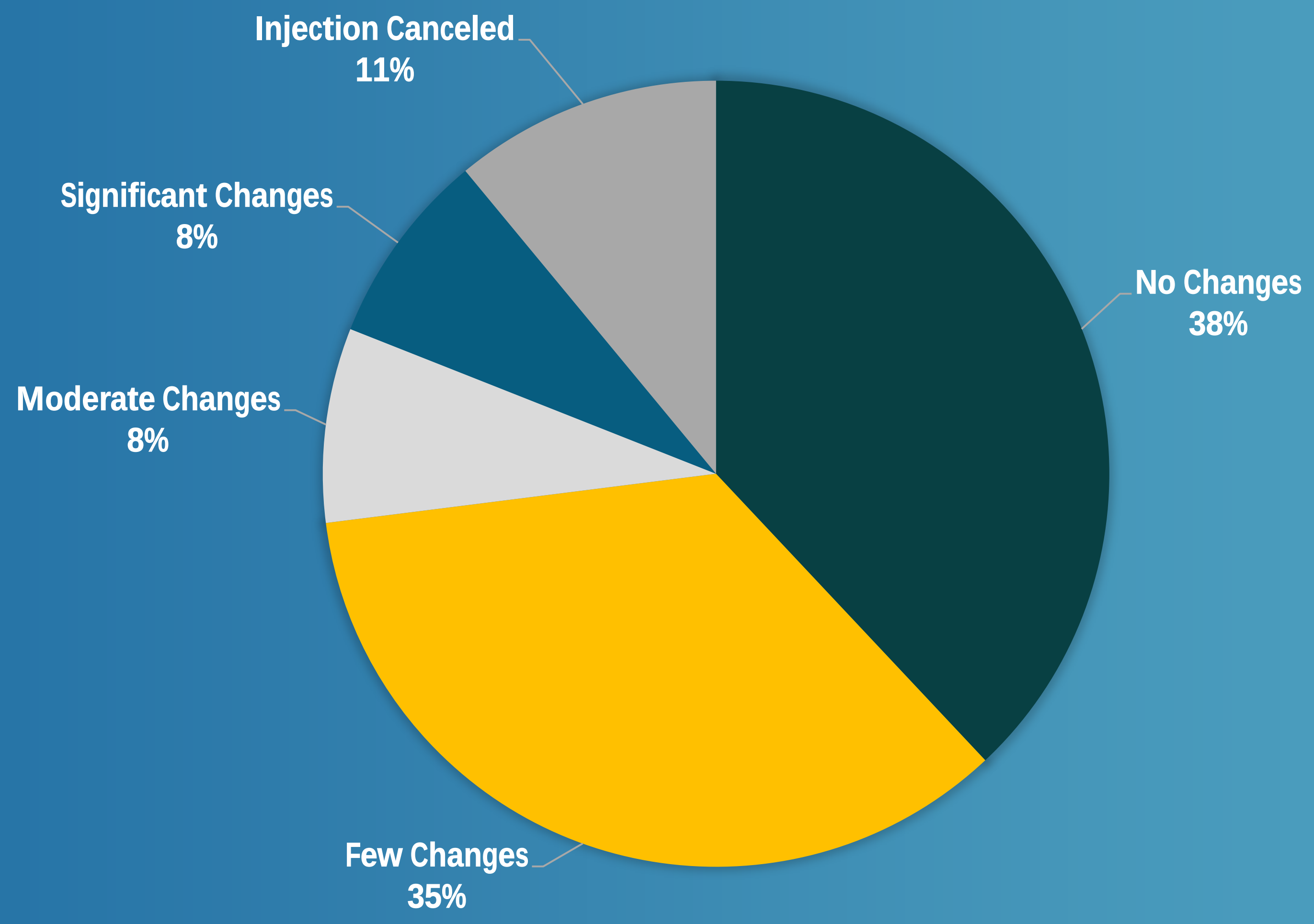
- 62% of preliminary designs were modified / refined

- Most of design changes have been cost-neutral



DESIGN VERIFICIATION

Design Changes



Design Verification Lessons Learned: Conclusions

- Depositional Processes have a significant control COC distribution
  - Depositional processes are predicable and non-random
  - DV data provides additional remedial insight into these processes
- Improves
  - Predictability
  - Implementation Time/Efficiency
  - Early ID Technical Blind Spots/Problems
  - Enhances final design and application program outcomes

QUESTIONS?