COMBINED IN SITU TREATMENT METHODS AND TECHNOLOGIES REDUCE MASS AT LARGE DNAPL SOLVENT SITE

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Acknowledgements

- Remediation Products, Inc. (RPI)
- Carus Corporation
- Linebach-Funkhouser, Inc. (PM Russell Brooks, P.G.)

Site Background

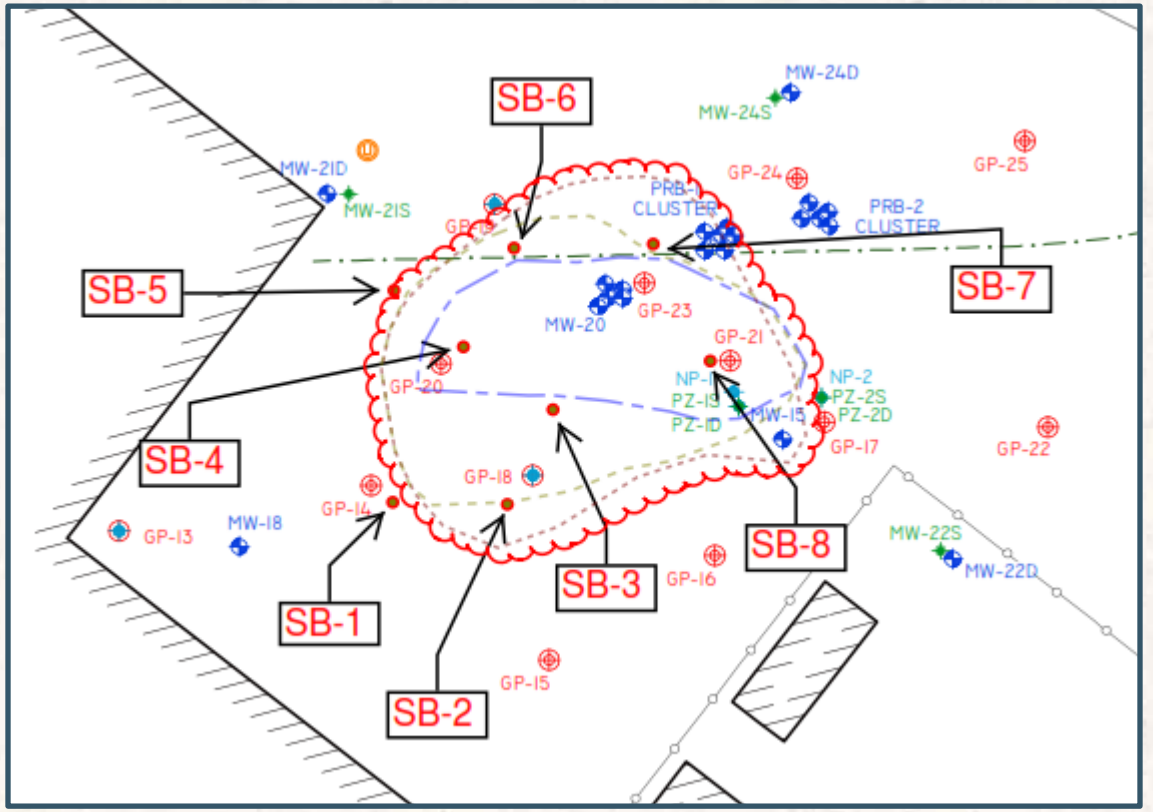
- Confidential Site
- Historical Industrial Property that utilized chlorinated solvents for equipment maintenance from the 1950's to 1970's
- Materials are suspected to have been discharged to drainpipes which allowed for the migration
- Site is still active with existing utilities and various structures
- The site geology consist of interbedded sands, silts and clays
- Groundwater table at ~15 ft bgs

Project Timeline

- RDC (2013)
- GAC impregnated w/ ZVI injected PRB (2014)
- ISCO Soil Mixing (2015)
- RDC #2 (2020)
- GAC impregnated w/ ZVI + ERD injected (2020)

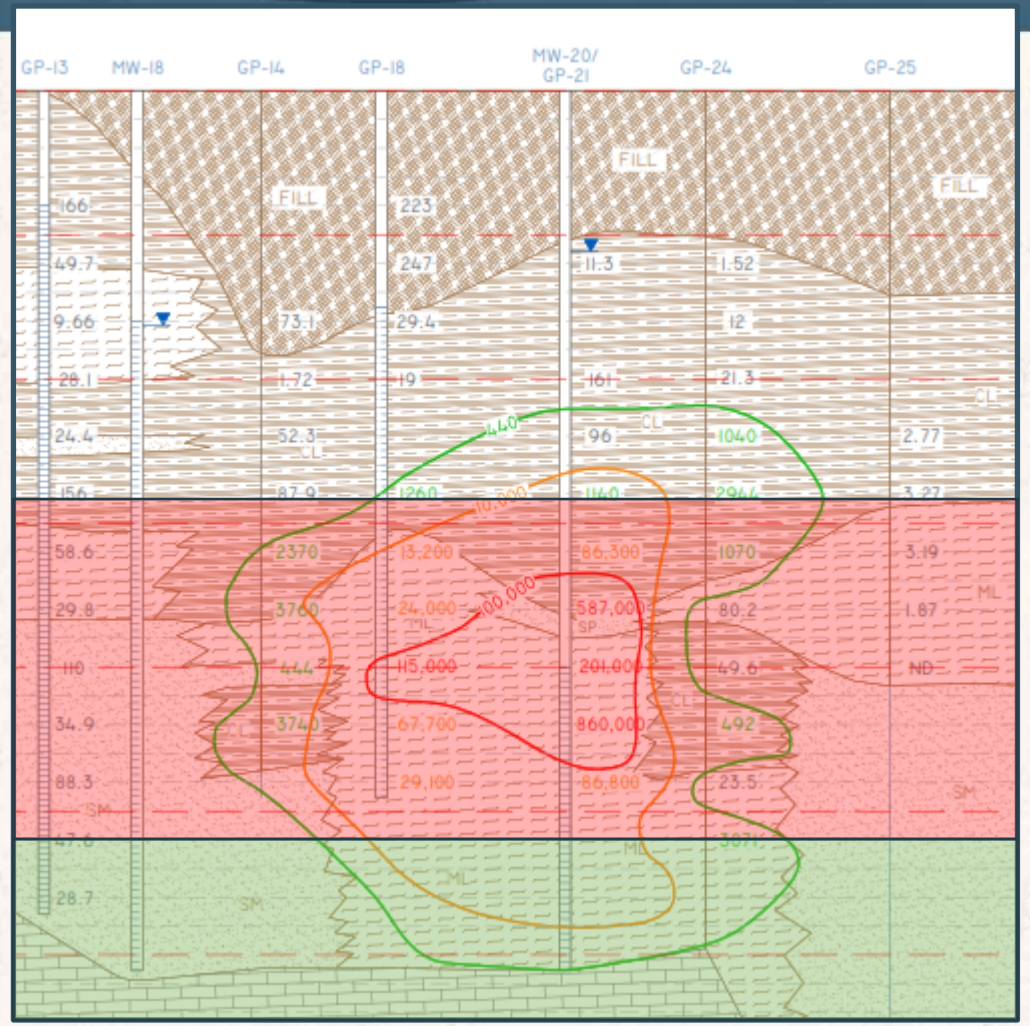
Remedial Design Characterization (RDC)

- Detailed understanding of vertical and horizontal distribution of speciated and total mass
  - 26 soil borings, 186 samples
  - 31 gw samples (nested implants)
  - HPT used to identify transmissive zones
- RPI Project Support lab (Denver) ran soil and water analytical at no cost (pre and post remediation)



RDC Findings

- DNAPL source area
- Unsaturated and saturated impacts (8-46 ft bgs)
- Groundwater table at ~15 ft bgs
- $[TCE]_{gw}$ as high as 730 mg/L
- $[TCE]_{soil}$ as high as 5,350 mg/kg

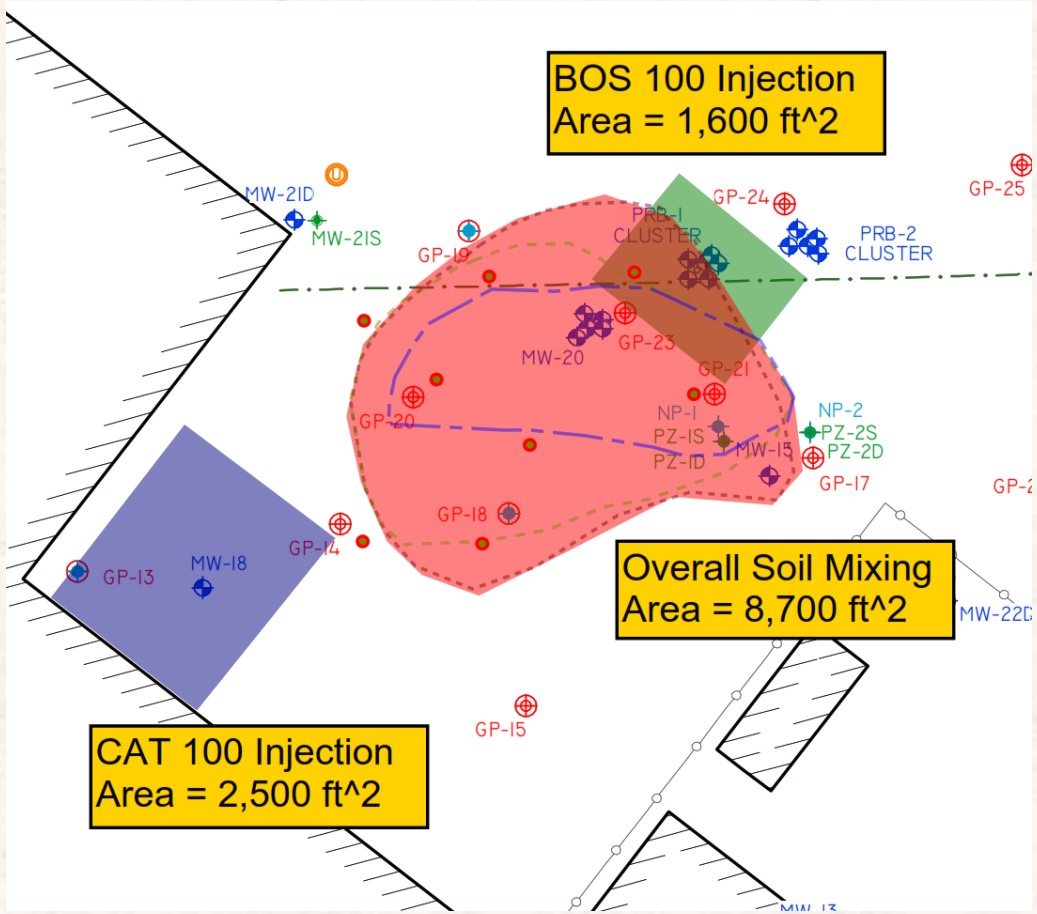


Approx. Soil Mixing Horizon (14-26 ft)

Approx. PRB Horizon (26 ft to refusal, max = 46 ft)

Technologies Selected

- BOS 100® (RPI)
  - Activated carbon impregnated with metallic iron (6.5% w/w)
  - Abiotic β-elimination pathway
  - Objective = 5 ppb at property boundary
- Sodium Permanganate (RemOx-L® Carus)
  - Delivered as 40% w/w liquid and diluted onsite
  - Objective = 125 mg/kg TCE soil
- CAT 100 (RPI)
  - BOS 100 + Electron Donor + Yeast Extract + Bacteria
  - Objective = Mass reduction

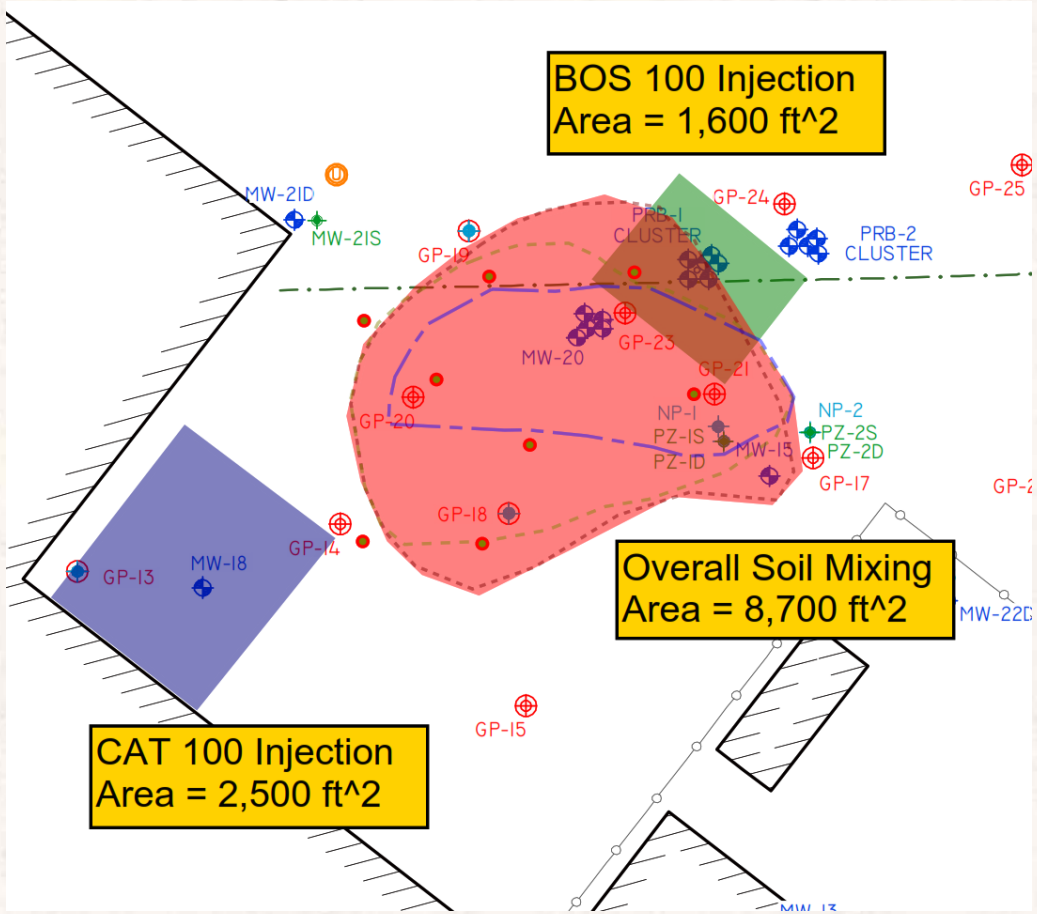


PRB Design

- Original design (pre-RDC)
  - TCE concentration of 350 mg/L (MW-20)
  - K = 1.65 10^{-5} cm/s (MW-20 slug test)
  - Injection interval = 15-30 ft bgs
- Modified design (post-RDC)
  - Injection interval = 26-46 ft bgs
  - Mass in shallow zone (<26 ft) was significant and the system would be iron limited, leading to a shorter PRB life
  - Alternate options for shallow mass treatment would need to be considered

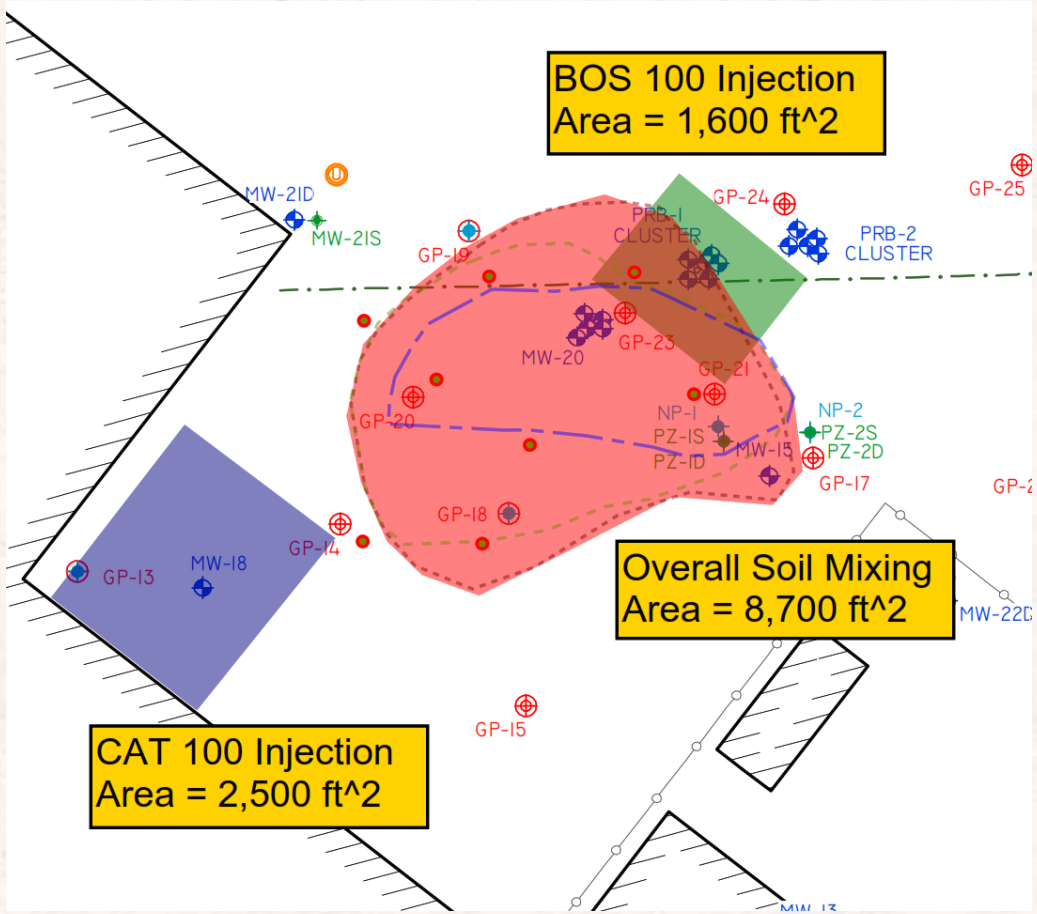
BOS 100 PRB Installation

- 4,200 pounds of BOS 100 were applied in a 40 ft by 40 ft area from a depth of 26 feet to 46 feet bgs (0.25-1 lb BOS 100®/gal slurry)
- 28 DPT injection points on 7.5-ft centers (with alternating elevations at each injection point)
- Cluster monitoring points PRB-1 and PRB-2 were utilized to evaluate the effectiveness of the pilot test from May 2014 to September 2015
- PRB-1 was within treatment area and PRB-2 was outside the treatment area
- Note PRB wells were destroyed during soil mixing operations
- Wells destroyed during soil mixing operations



Soil Mixing Design

- 54,000 lbs of RemOx-L® was selected for treatment of 2,830 cubic yards of soil
- Included excavation of 7,000 cubic yards of overburden to access the 14 to 26 ft treatment zone
- 43 grid blocks (~12 ft by ~12 ft by ~10 ft) were treated in place

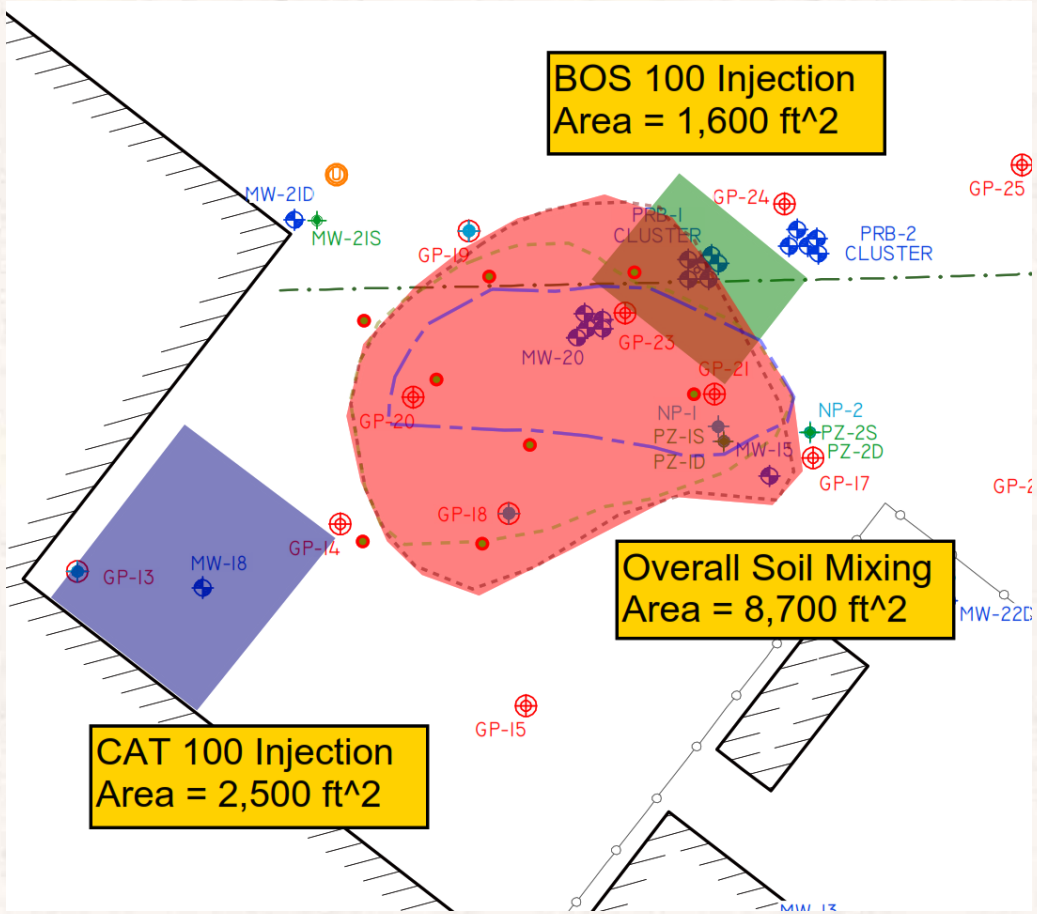


Soil Mixing – Real Time and Post Project Sampling

- Performance sampling was conducted in real time (24 hr TAT at our Denver lab)
  - 31 of 43 blocks were below the 125 ppm target after one pass
  - After treatment the average concentration was 92 ppm which is a 92% reduction from initial average concentration of 1,126 ppm
- Post Treatment Monitoring
  - Reinstallation of groundwater monitoring well in treatment area (MW-20)
  - Confirmation sampling of soil utilizing DPT. Samples were collected at 2 ft vertical intervals at 4 locations across the treatment area.

Source Area Application

- 16,000 pounds of CAT 100 were applied in a 2,500 ft^2 area from a depth of 8 ft to 30 ft bgs. Reagent was injected at 69 points on 6-ft centers



BOS 100 Results

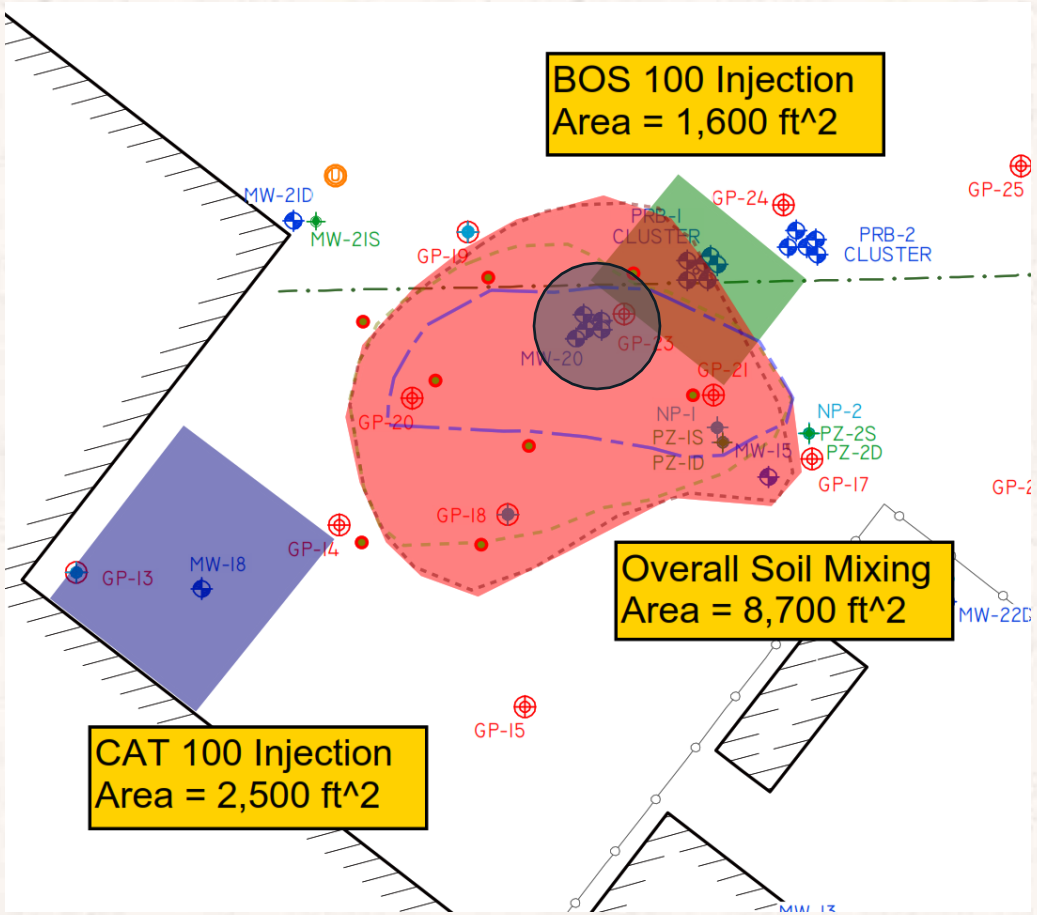
- PRB-1 Cluster = 5 Channels
- PRB-2 Cluster = 4 Channels
- Avg values presented
- Max TCE detection in PRB-2 Cluster = 6 ppb

ISCO Soil Mixing Results - Soil

Soil Mixing Area - Soil		
Baseline (Sept 2015)	Post Application (Dec 2016)	% Reduction
1,126 mg/kg (avg)	SB-1 - 16.75 mg/kg	98.5%
	SB-2 - 56.45 mg/kg	95.0%
	SB-3 - 12.08 mg/kg	99.0%
	SB-4 - 56.42 mg/kg	95.0%

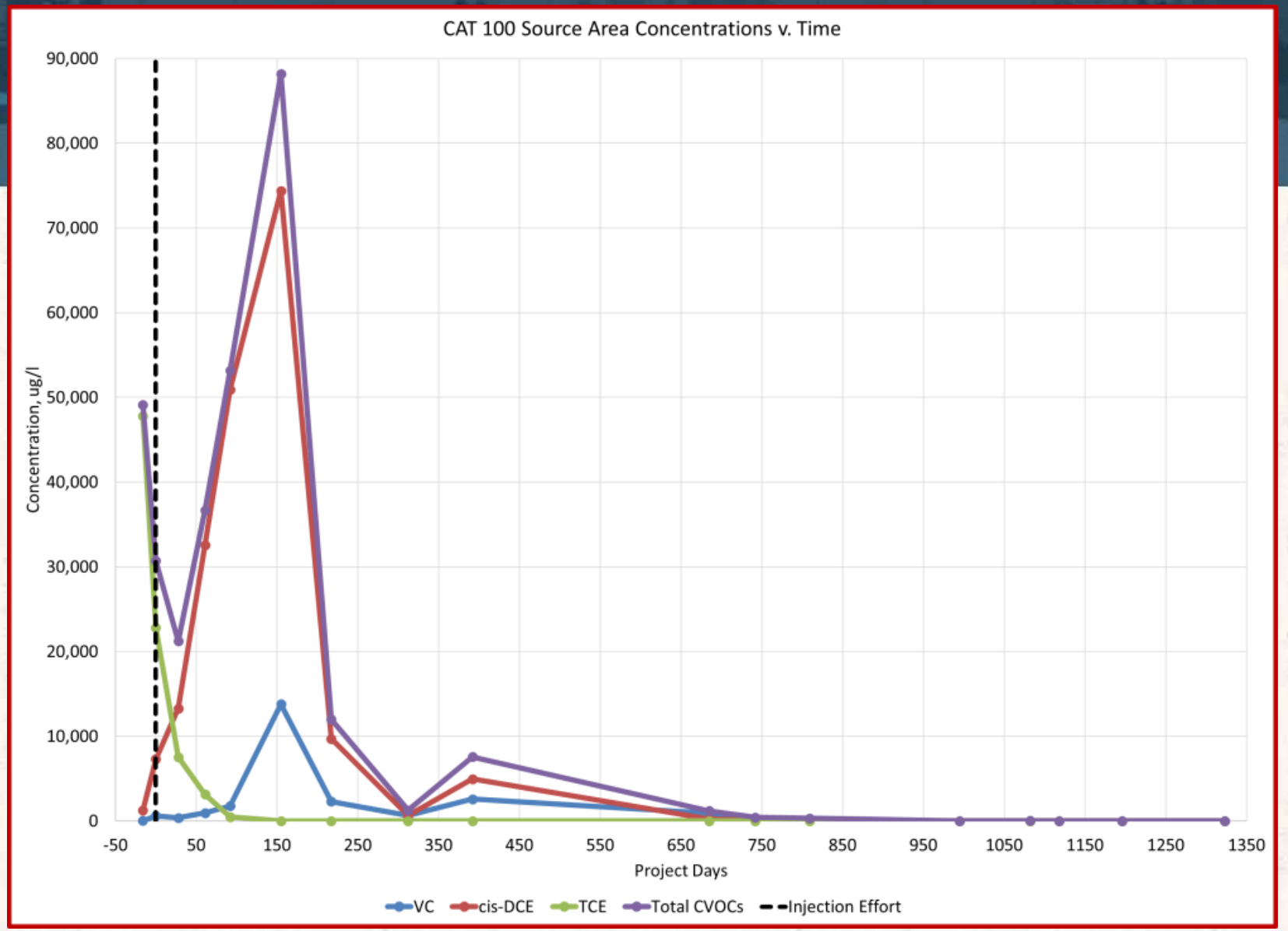
- Of the 20 samples collected only 1 sample was above the 125 mg/kg goal at a concentration of 133 mg/kg.

ISCO Soil Mixing Results - Groundwater



Soil Mixing Area - Groundwater	
Date	MW-20 TCE Concentration, mg/L
7/21/2014	730
10/21/2014	660
9/1/2015	519
Soil Mixing Operations + Well Replacement	
12/12/2016	9.21
3/14/2017	3.36
6/21/2017	1.16
11/2/2017	2.37
7/31/2020	2.90
7/18/2022	0.70
4/17/2023	2.00
Percent Reduction	**99.4%**

CAT 100 Results



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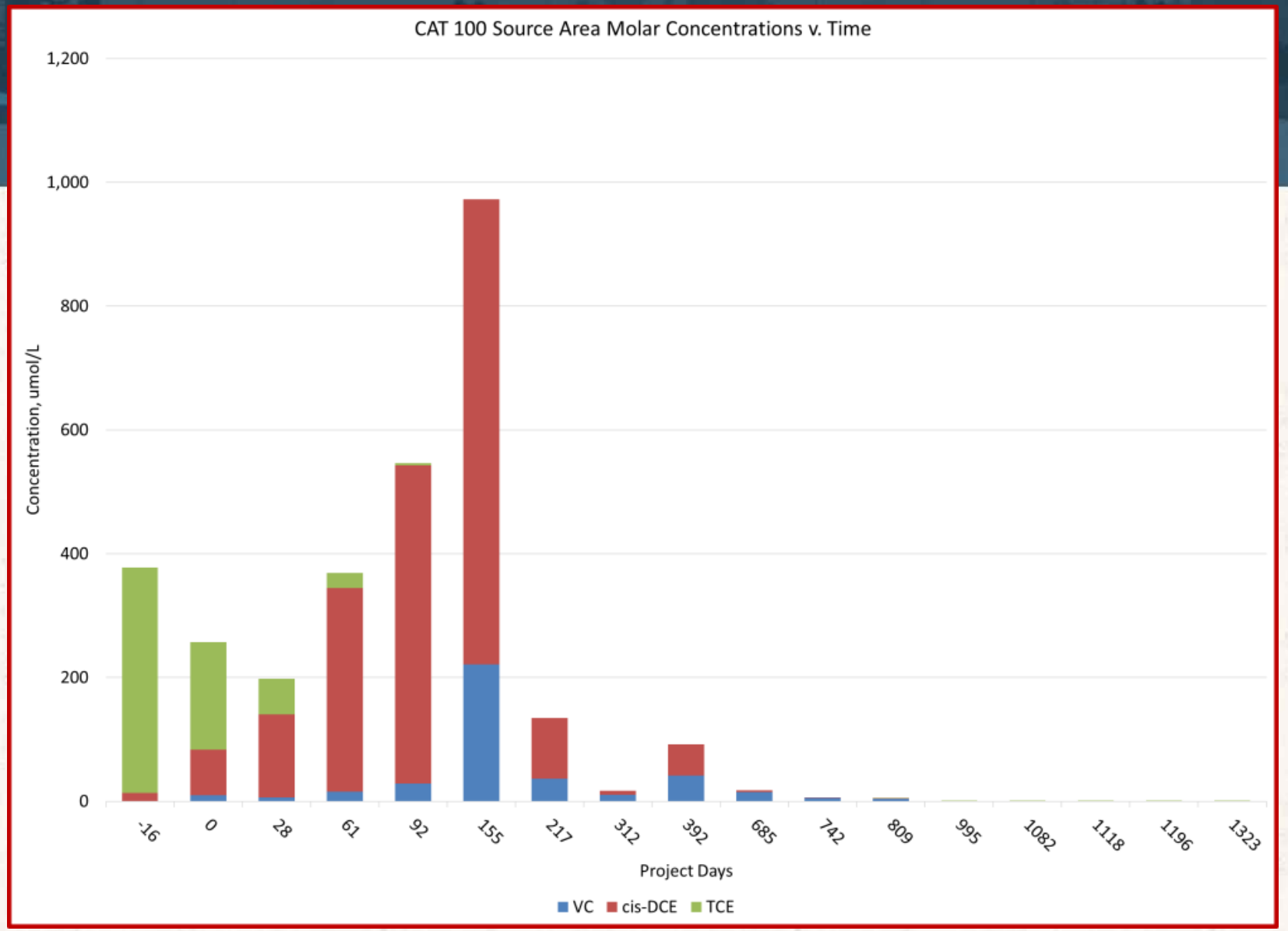

Summary

- RDC process critical to CSM development and technology selection
- Multiple technologies (ISCR, ISCO, and ERD) were used to successfully reduce source mass multiple OOMs and limit downgradient mass flux
- Total price to client ~$800k

Thank you for your time. Questions?

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