



ADAPTIVE ISCO INJECTION STRATEGY FOR DNAPL SOURCE ZONE TREATMENT

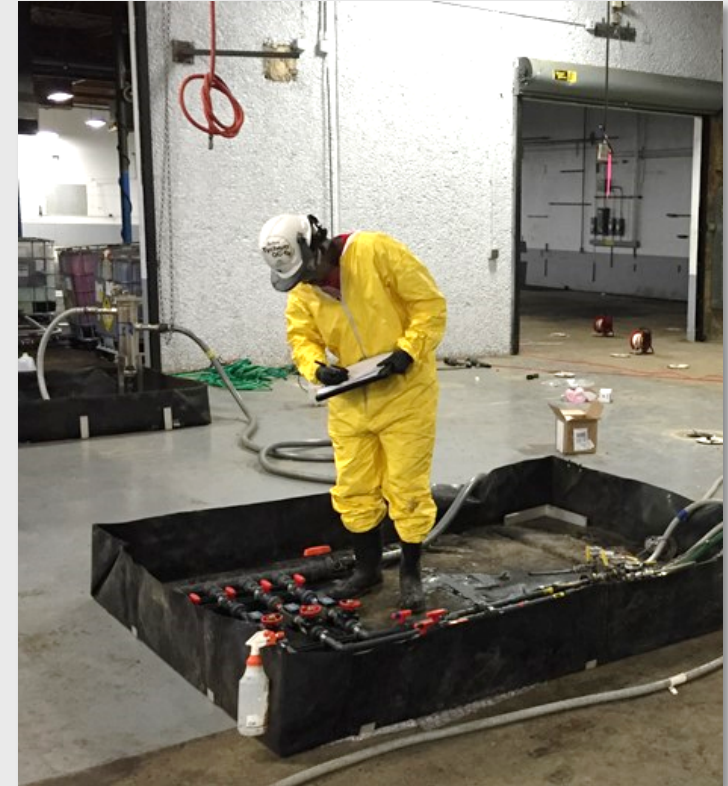
BATTELLE CHLORCON 2024



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ACKNOWLEDGEMENT OF PROJECT TEAM

- Trihydro – Kyle McDonald, Wilson Clayton, Kigen Limo, Michael Sweetenham
- Client
- Project Owner



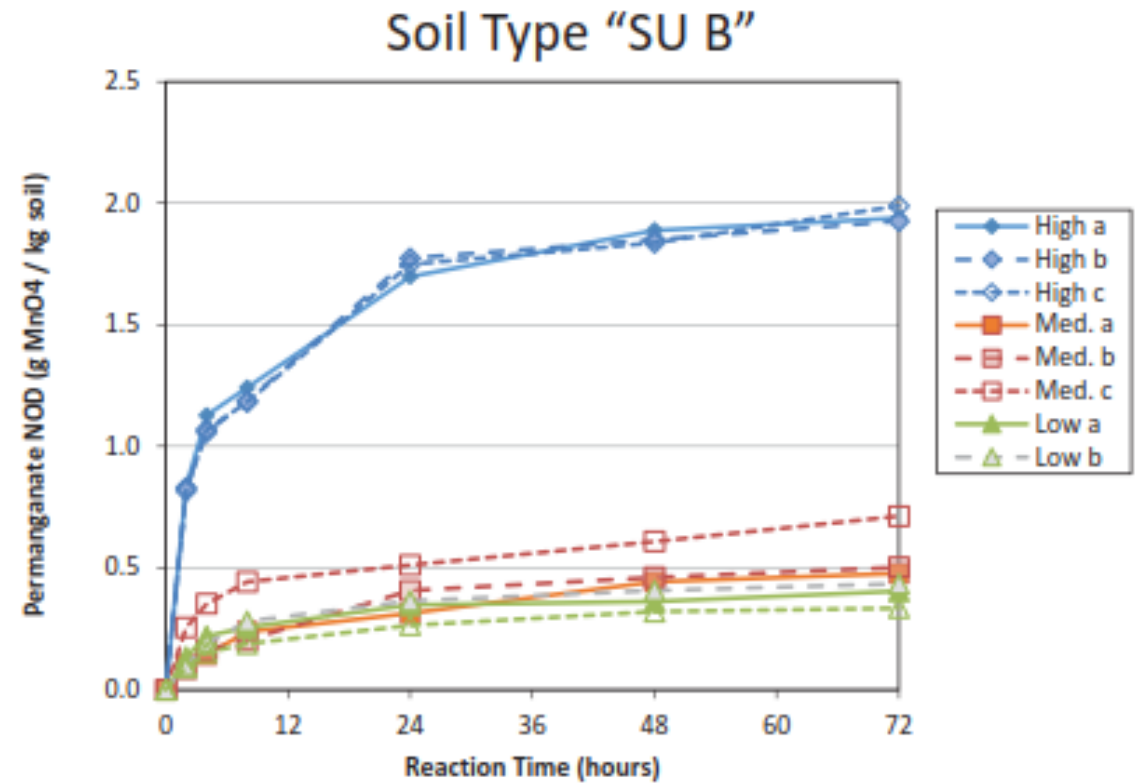
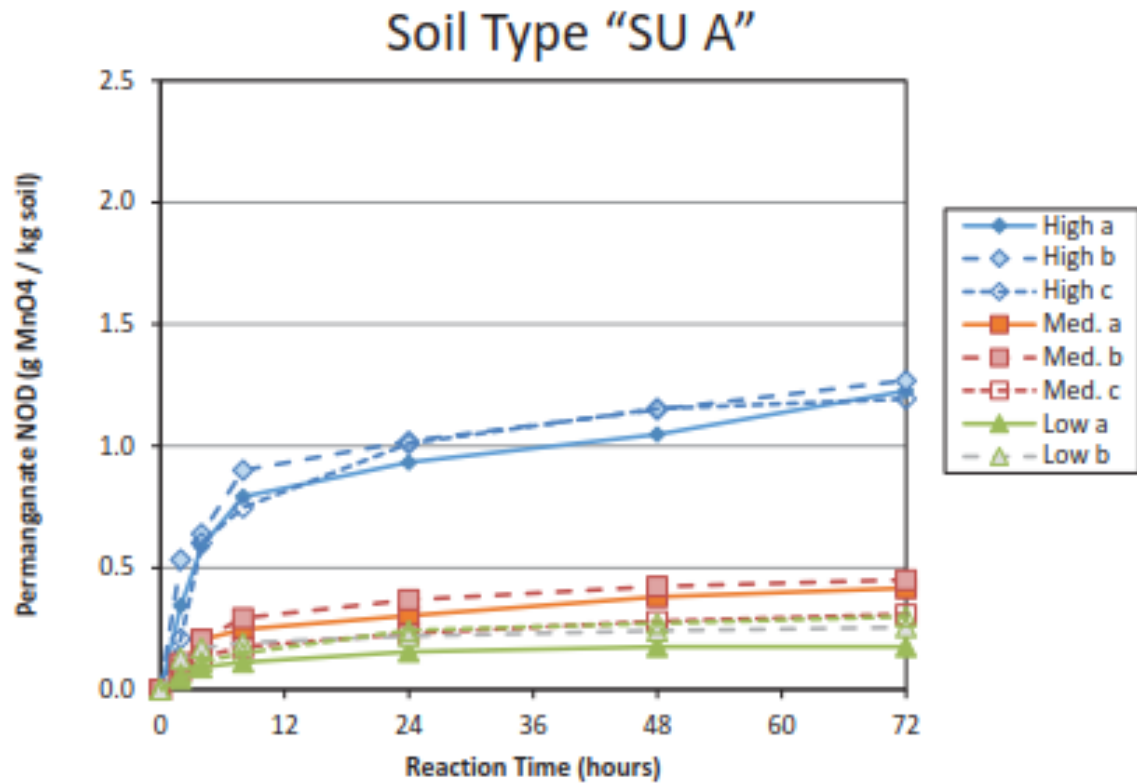
A photograph of a manufacturing facility floor. In the foreground, there are two metal stands with various hoses and equipment attached to them. A red bucket is visible under the left stand. The floor is concrete and has several circular manhole covers. In the background, there are large industrial machines with yellow safety railings and orange traffic cones. The scene is cluttered with various tools, bags, and equipment.

Manufacturing Facility
TCE up to 300,000 ug/L
Silt and Fine Sand

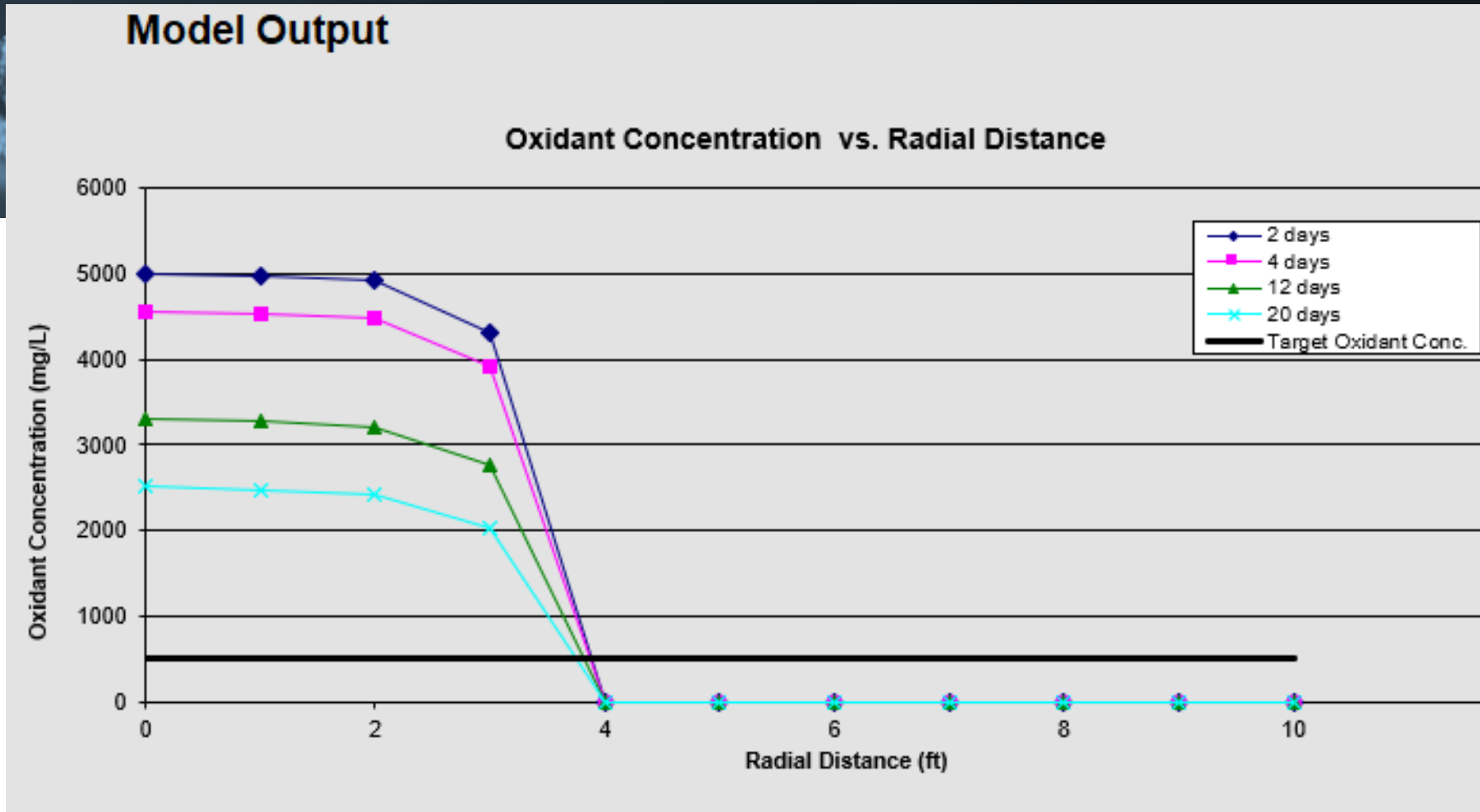
Rapid Mass Reduction 10,000 ug/L Endpoint Permanganate



KINETIC NATURAL OXIDANT DEMAND TEST

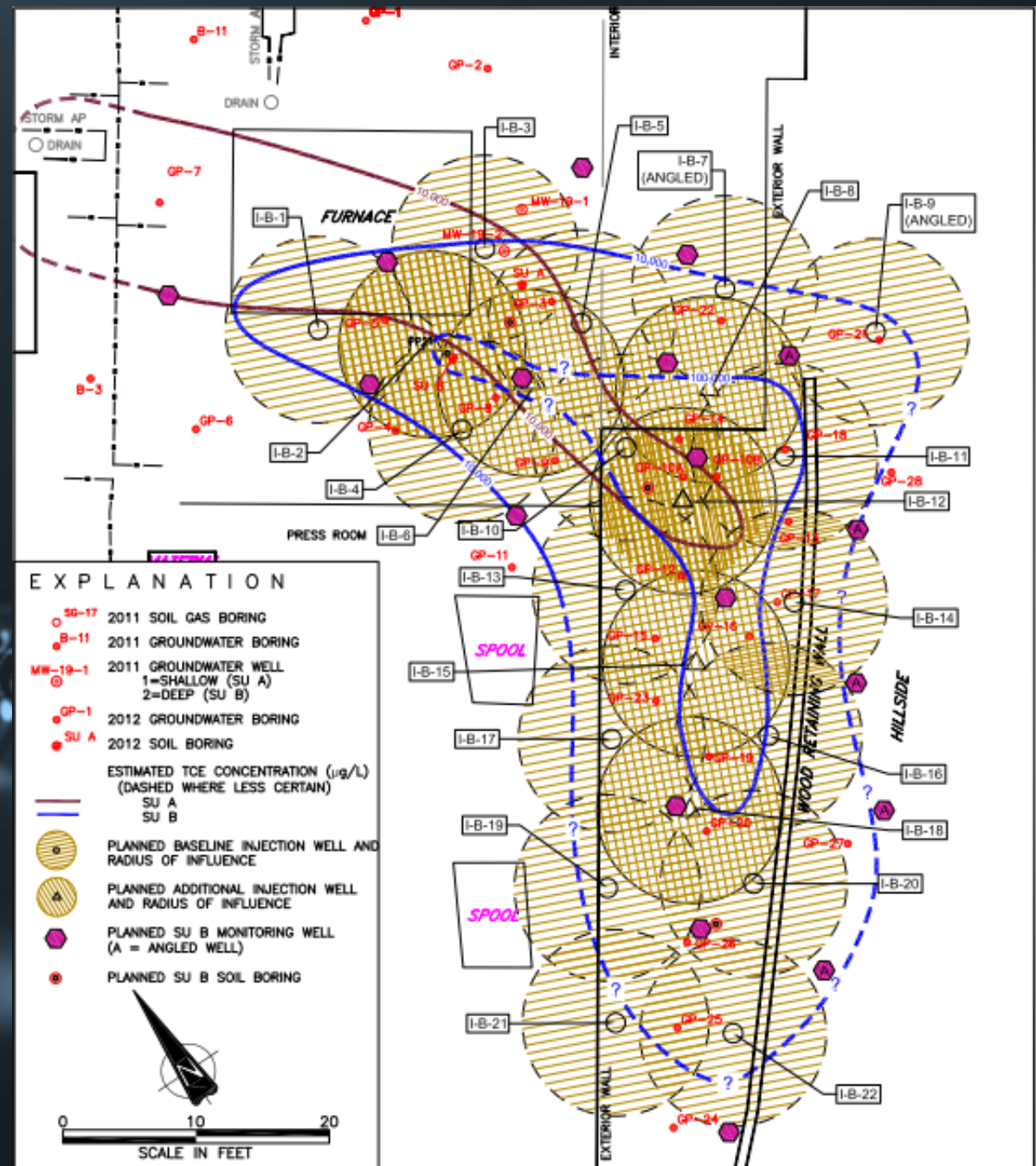


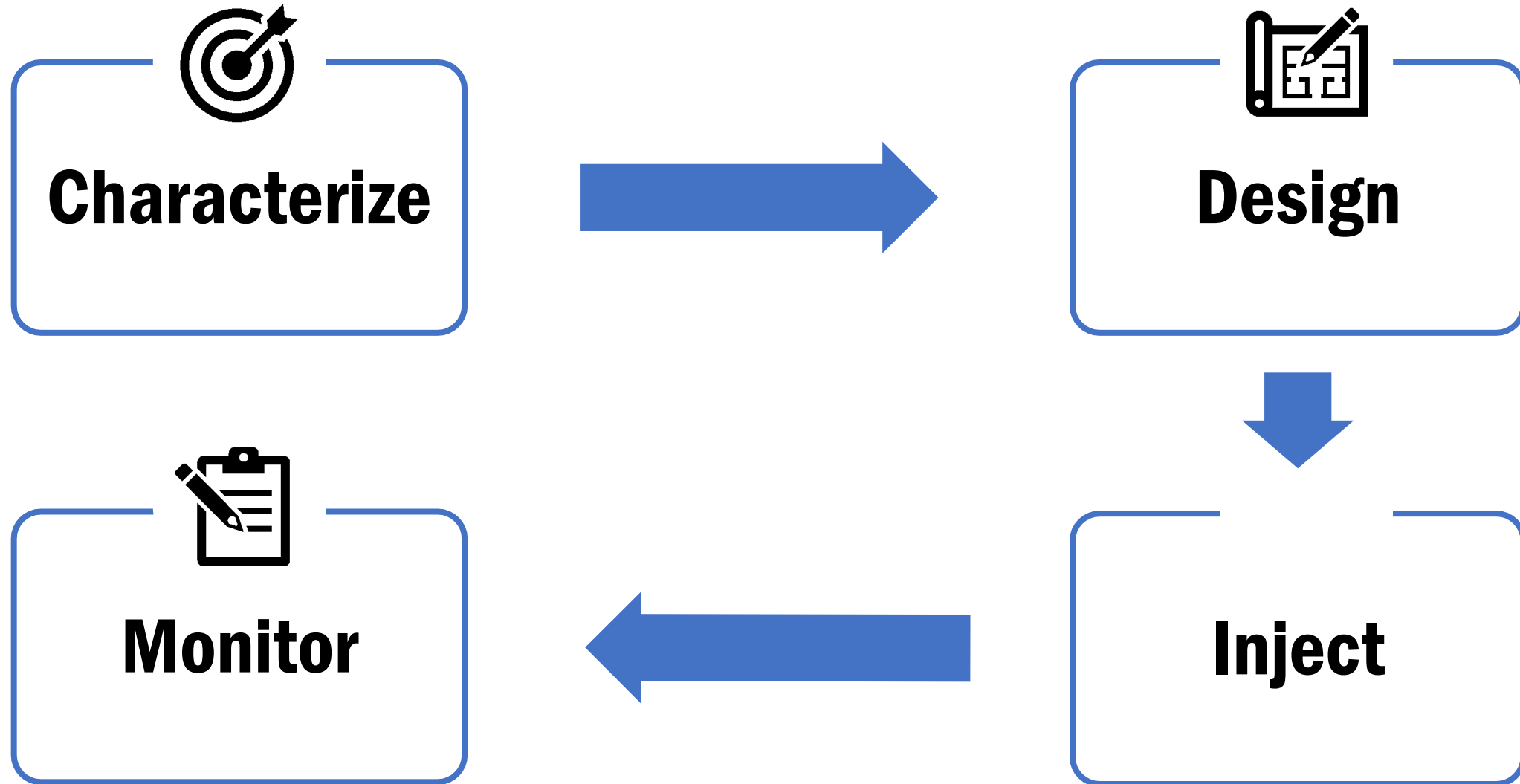
CONCEPTUAL DESIGN FOR ISCO (CDISCO) DESIGN TOOL



<https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/ER-200626>

- 1.4 to 1.7 g permanganate / kg soil
- 7-ft ROI – CDISCO modeling
- 10-ft injection centers
- Fill in wells where TCE > 100,000 µg/L
- 1.37 ePV SU B
- Tightly spaced monitoring network





INJECTION ROUND 1

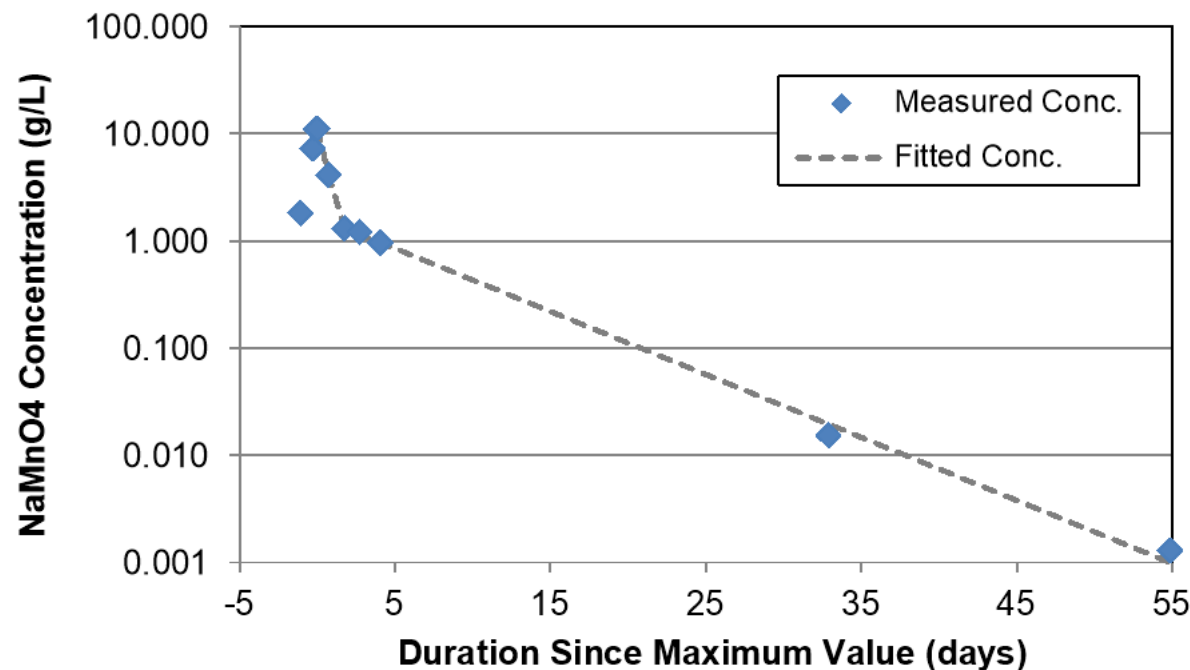
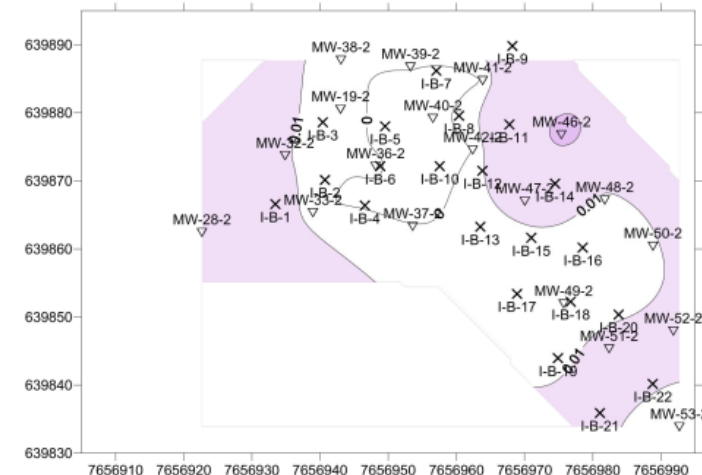
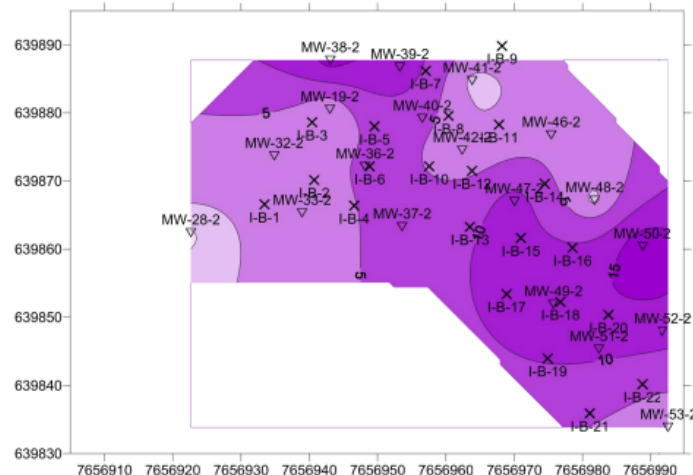
- 22,000 gallons of 22 g/L sodium permanganate (NaMnO_4)
- 13 wells in SU A & 22 wells in SU B
- Target concentration and volumes ~ Actual
- Injection sequence predetermined



MONITORING ROUND 1

- Samples collected from injection manifold
- Samples collected from monitoring wells using peristaltic pump
- Qualitative analysis based on color
- Serial logarithmic dilution for quantitative analysis with Hach Colorimeter





WHY MONITOR REAL TIME?

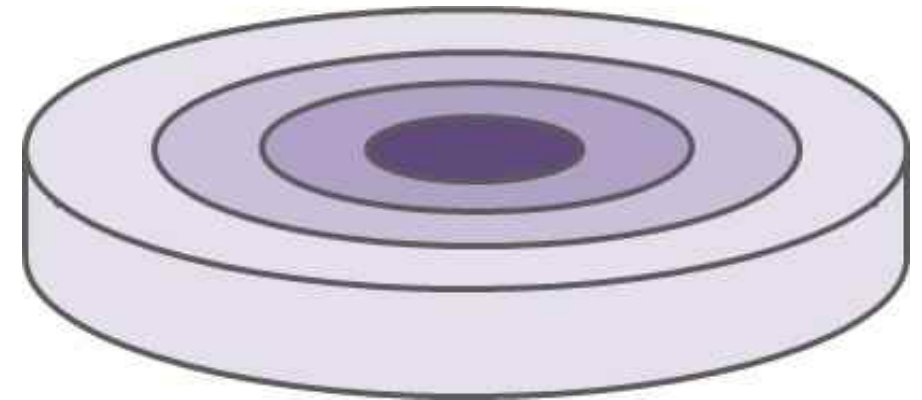
- Homogeneous?
- $K_v/K_h = 0.1$?
- Perfect ROI and cylinders?
- Easy to displace > 1 ePV?
- Constant concentrations and reaction rates?
- Assume robust design is correct and proceed?



WHY MONITOR REAL TIME?

ROUND 1 KEY TAKEAWAYS

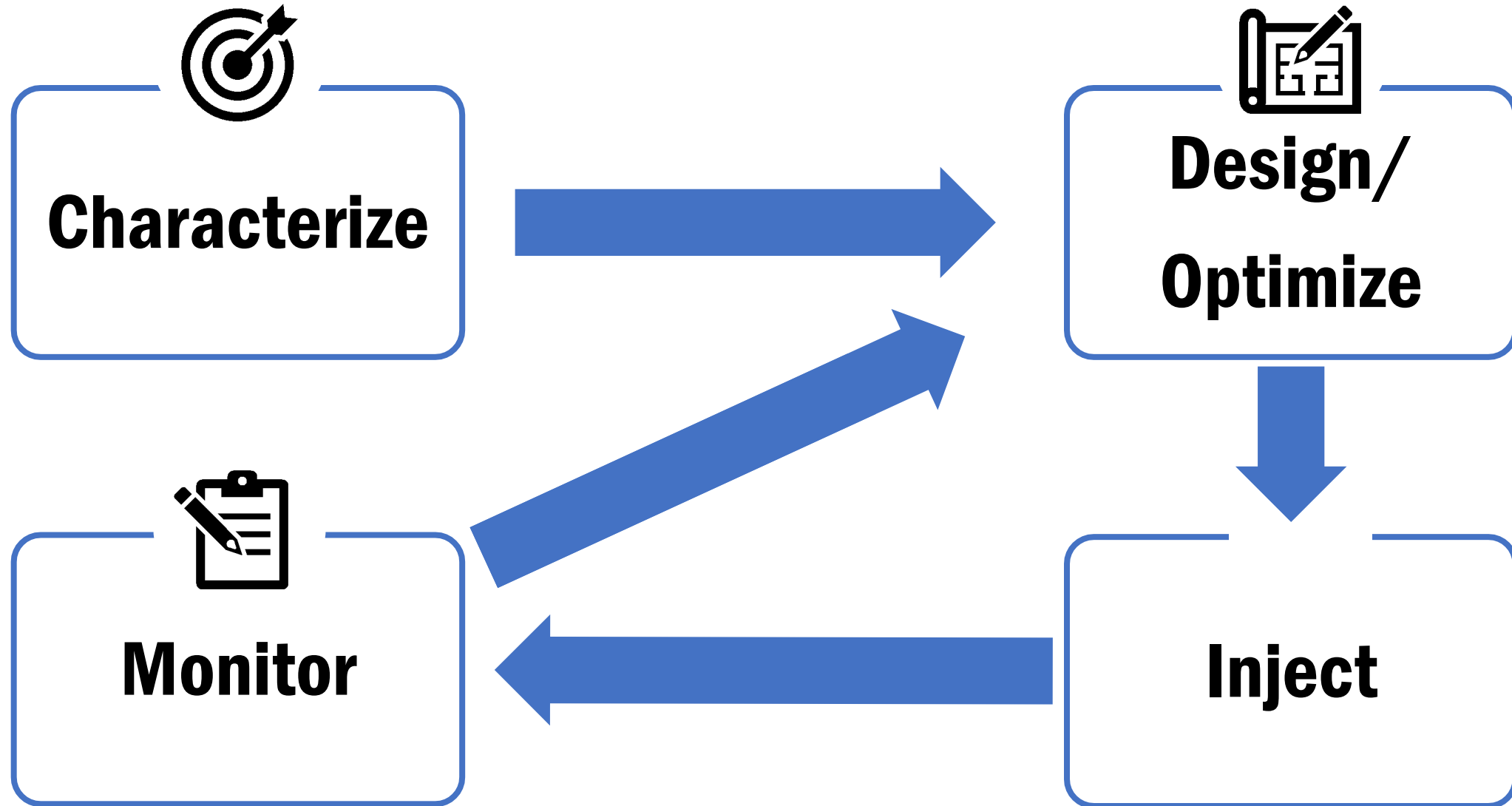
- Homogeneous?
- $K_v/K_h = 0.1$? *NaMnO₄ in SU A prior to injection*
- Perfect ROI and cylinders? *Variable ROI and upward migration*
- Easy to displace > 1 ePV? *Surfacing*
- Constant concentrations and reaction rates?
Variable kinetics
- Assume robust design is correct and proceed?
Optimize with real-time monitoring



INJECTION ROUND 2

- Injected 23,000 gallons at NaMnO₄ concentration from 15 to 44 g/L
- 12 wells in SU A and 20 wells in SU B





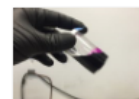
INJECTION ROUND 2

- Started in SU B (deeper zone)
- Evaluated real-time ROI and reaction kinetics
- Optimized oxidant delivery by adjusting sequence and volumes
- Delivered oxidant to under-treated areas
- TBD wells with extra time, permanganate, and budget to optimize





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IMG_1459.JPG



IMG_1460.JPG



IMG_1463.JPG



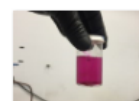
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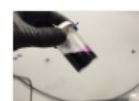
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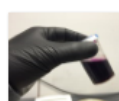
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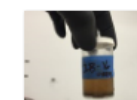
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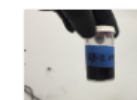
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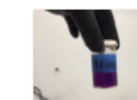
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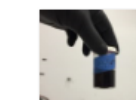
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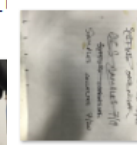
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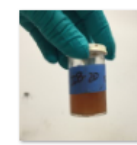
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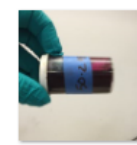
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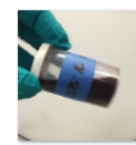
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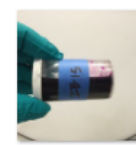
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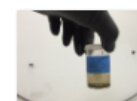
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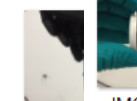
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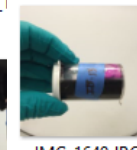
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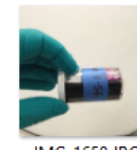
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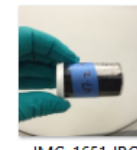
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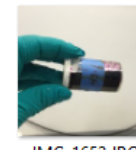
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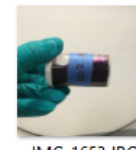
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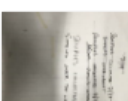
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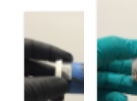
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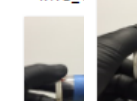
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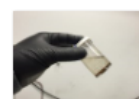
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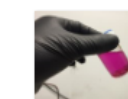
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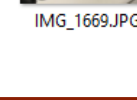
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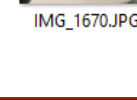
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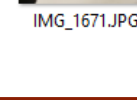
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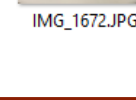
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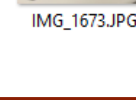
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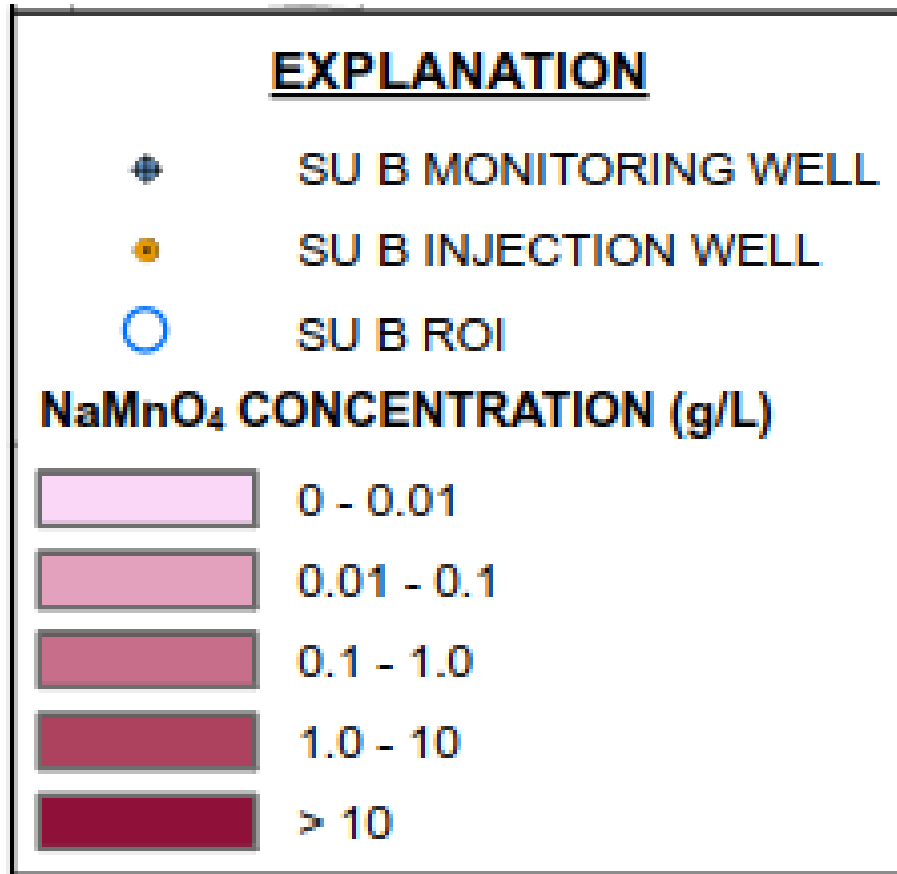
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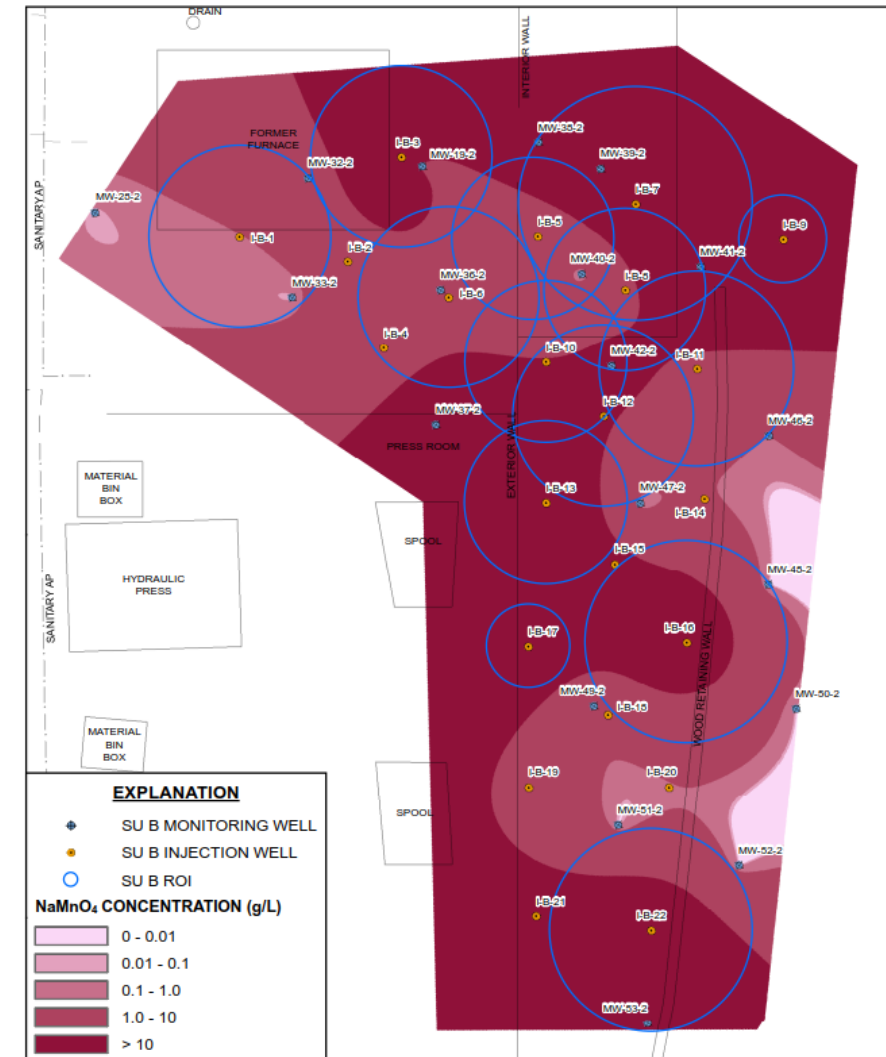
KEY OBSERVATIONS- INJECTION ROUND 2

SU A



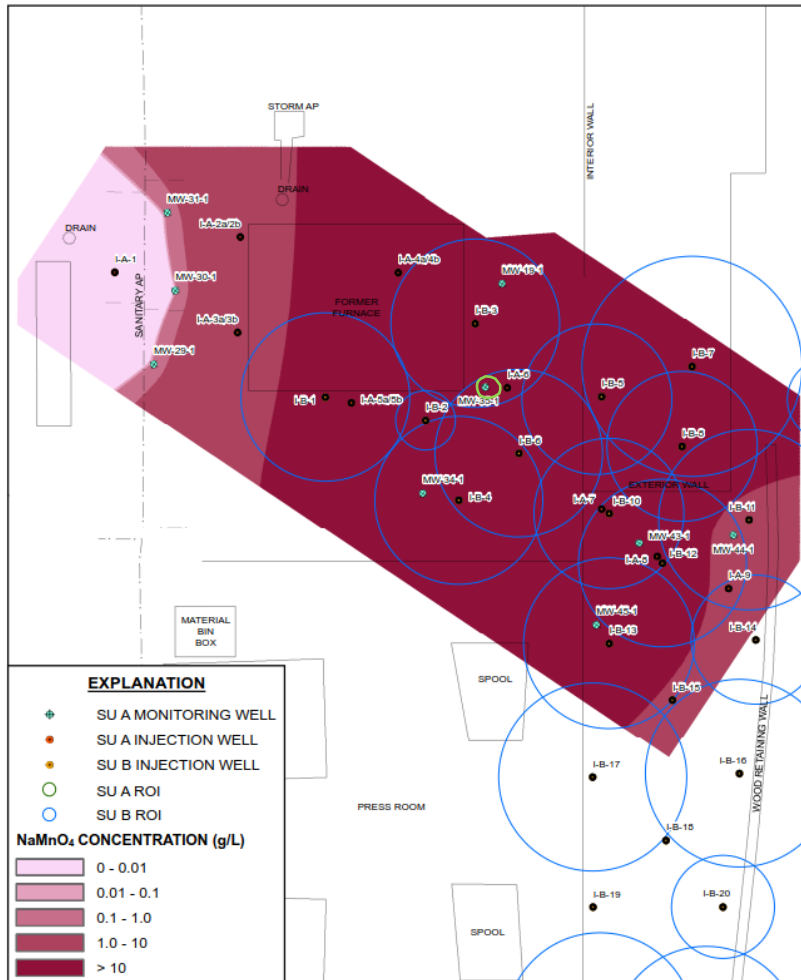
Day 3

SU B



KEY OBSERVATIONS– INJECTION ROUND 2

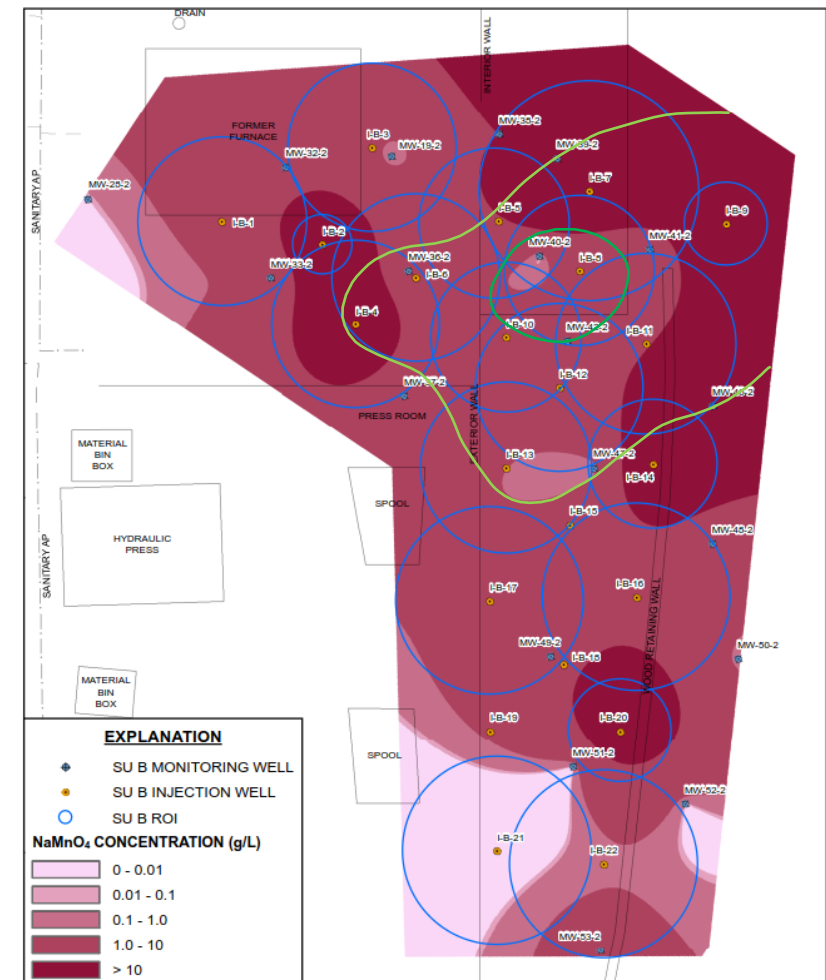
SU A



Day 4

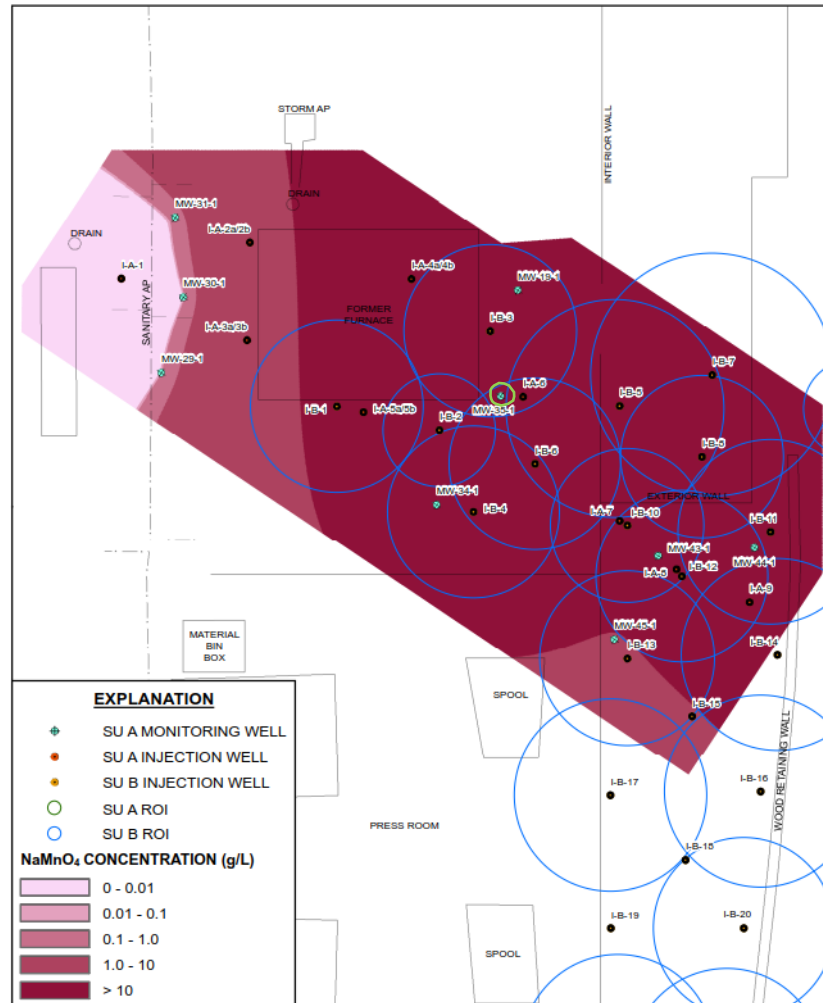


SU B



KEY OBSERVATIONS- INJECTION ROUND 2

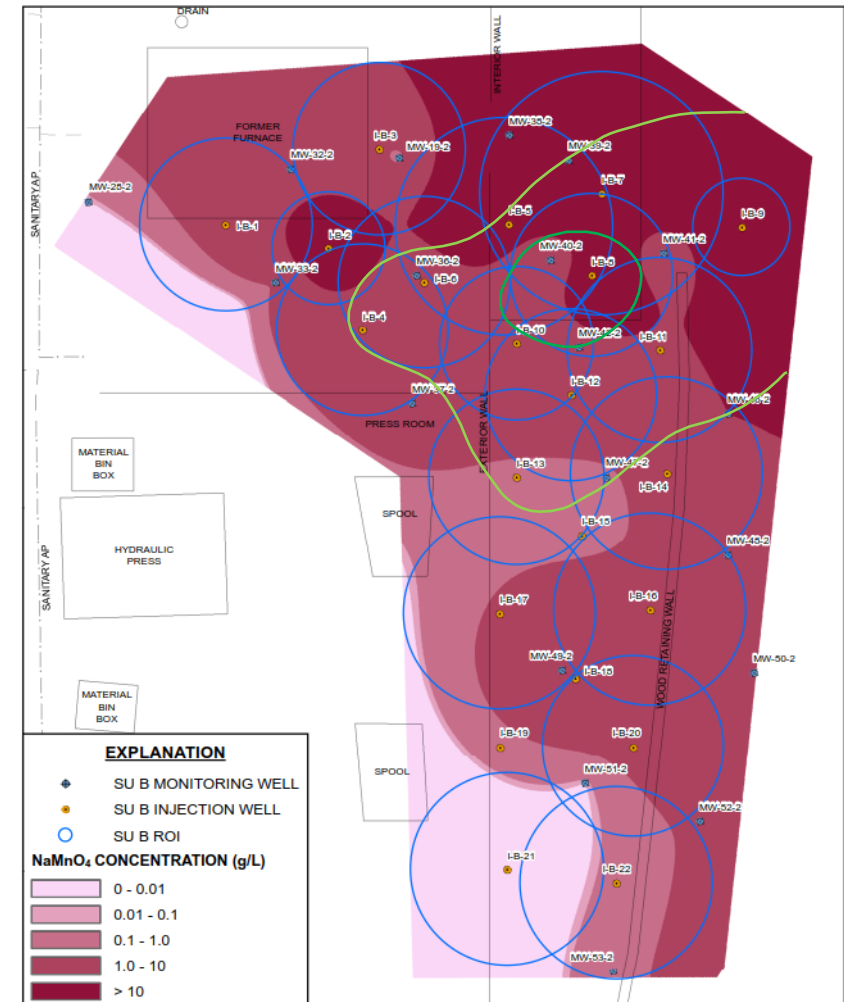
SU A



Day 5

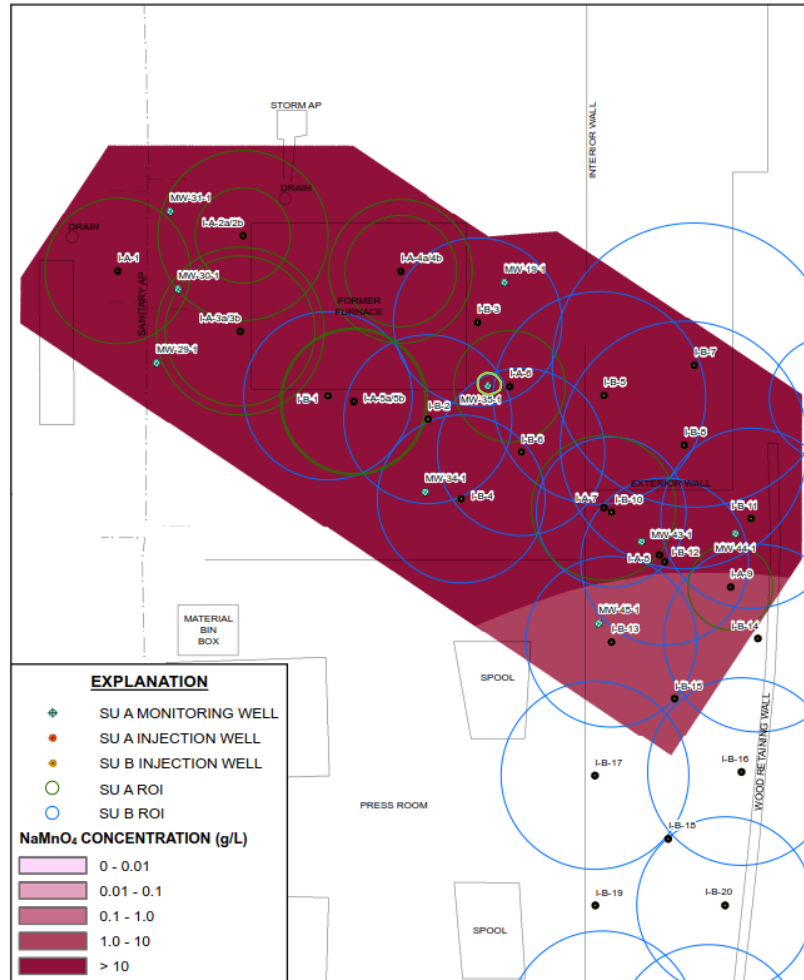
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SU B



KEY OBSERVATIONS- INJECTION ROUND 2

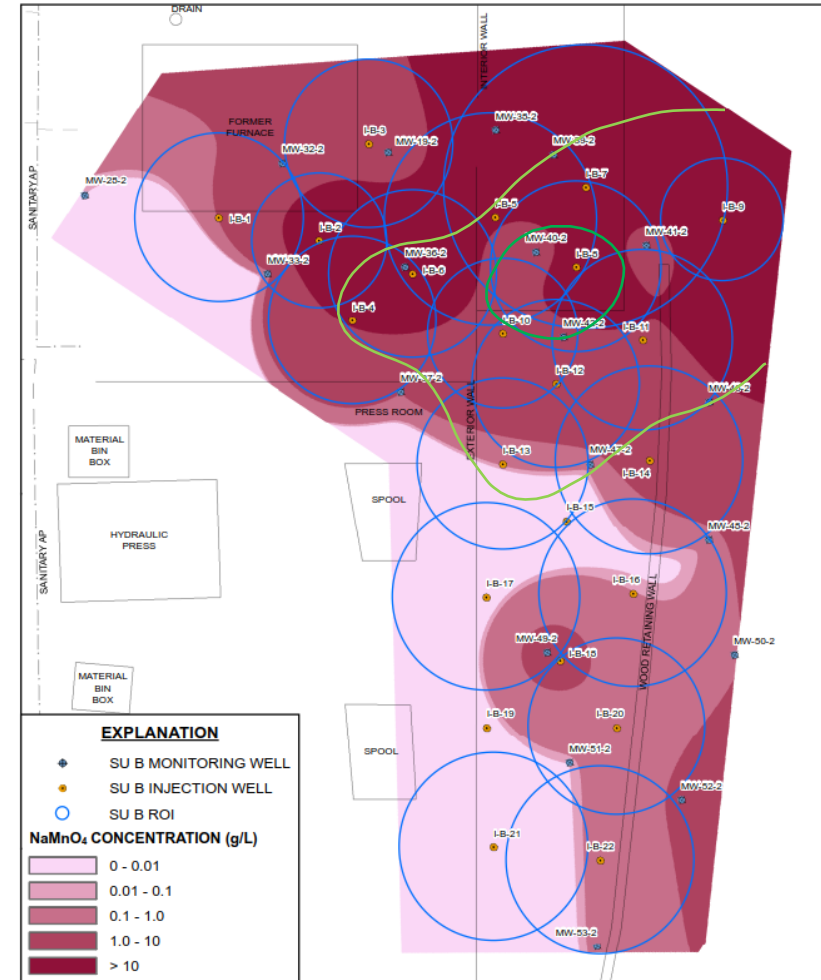
SU A



Day 7

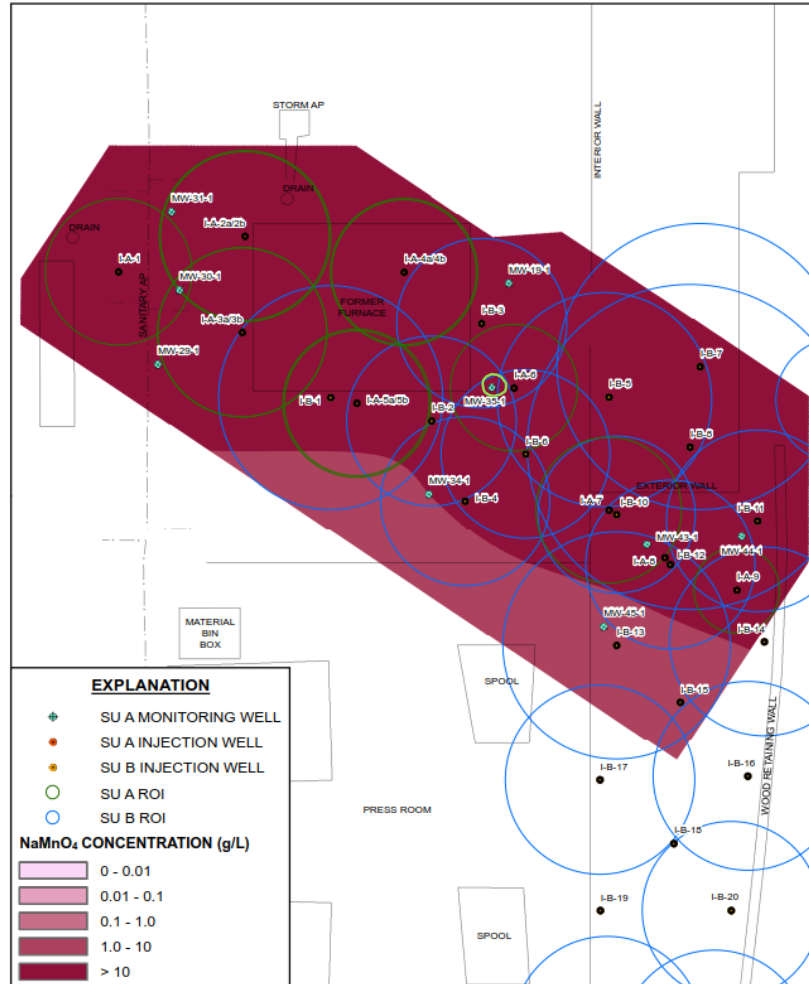
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KEY OBSERVATIONS- INJECTION ROUND 2

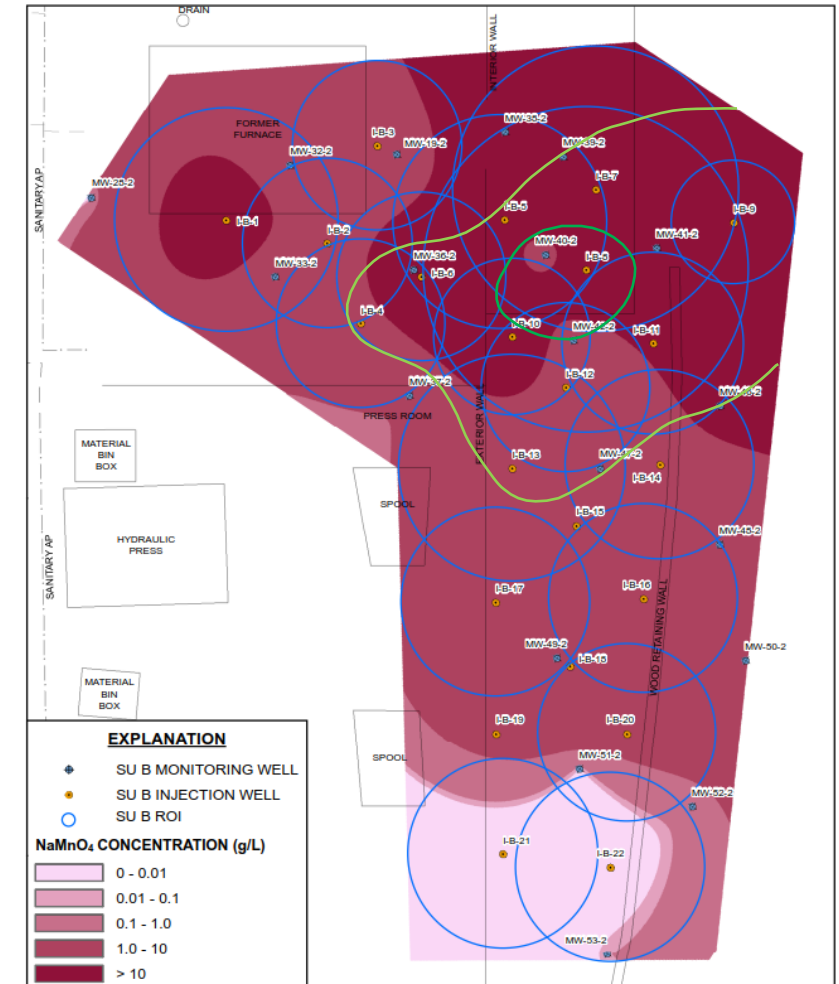
SU A



Day 8

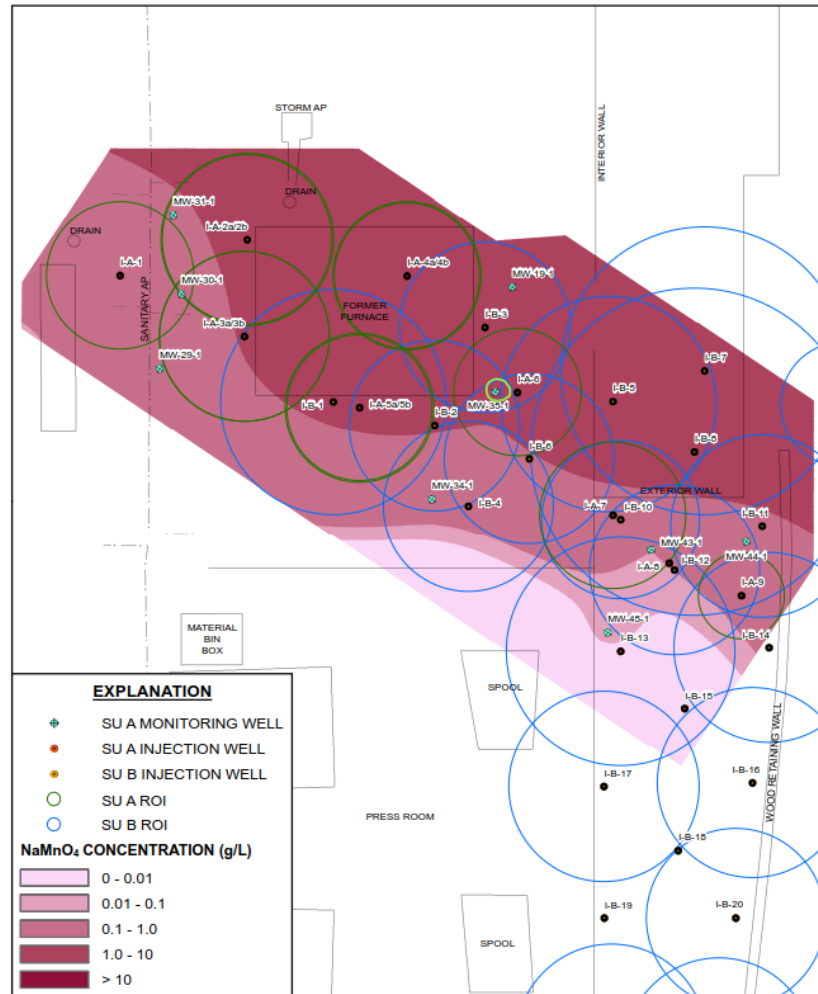


SU B



KEY OBSERVATIONS- INJECTION ROUND 2

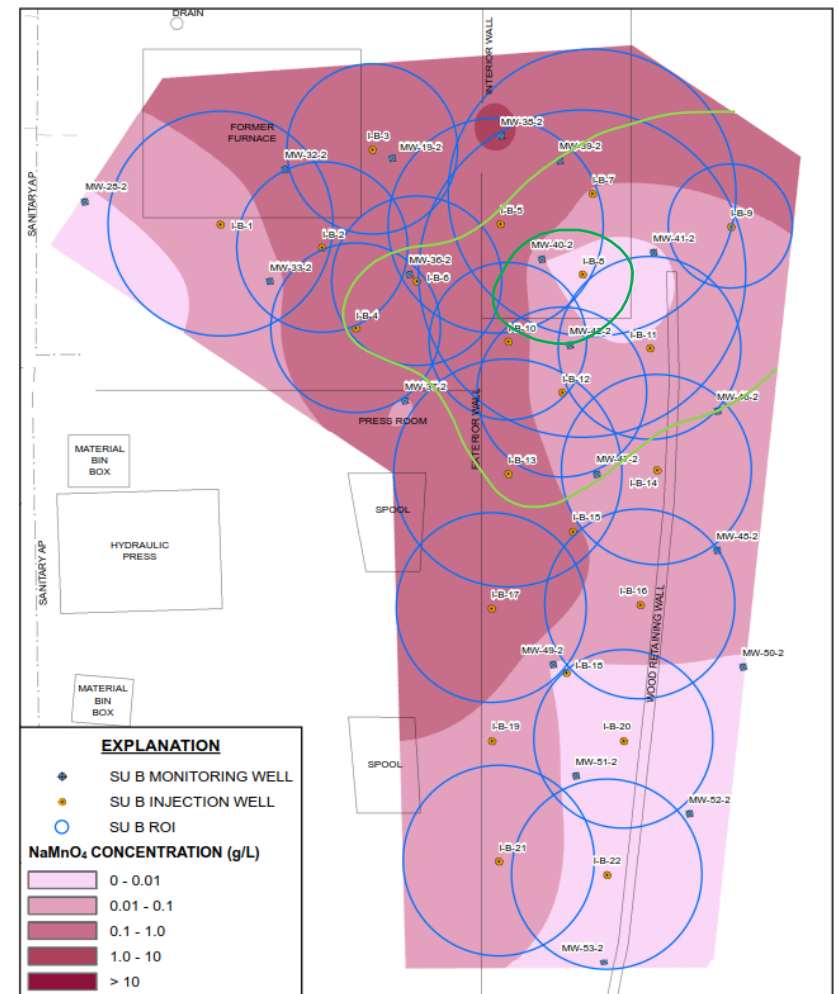
SU A



Day 49

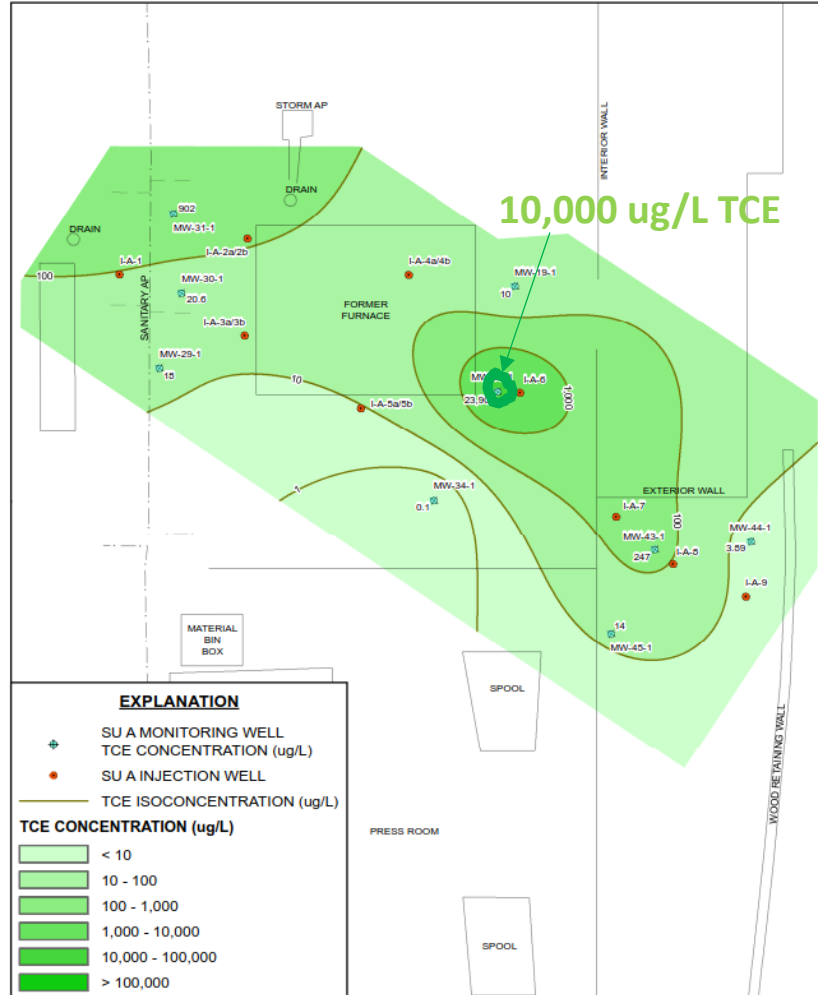


SU B



TCE RESULTS- INJECTION ROUND 2

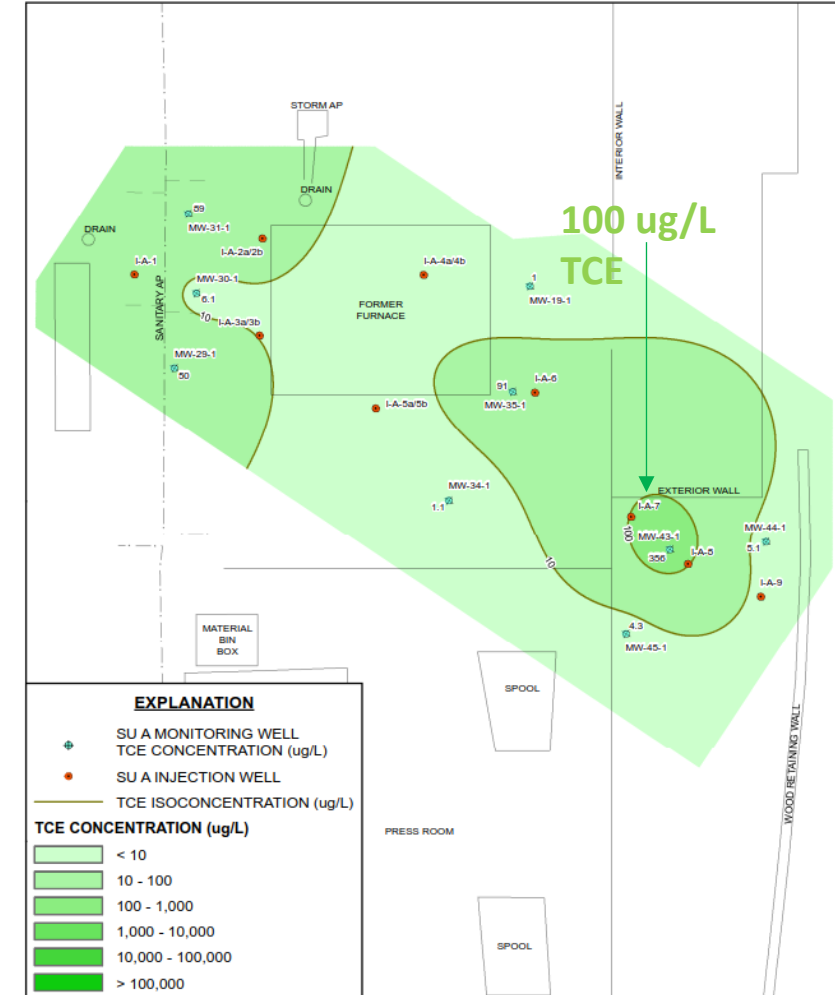
PRE ISCO ROUND 2



SU A

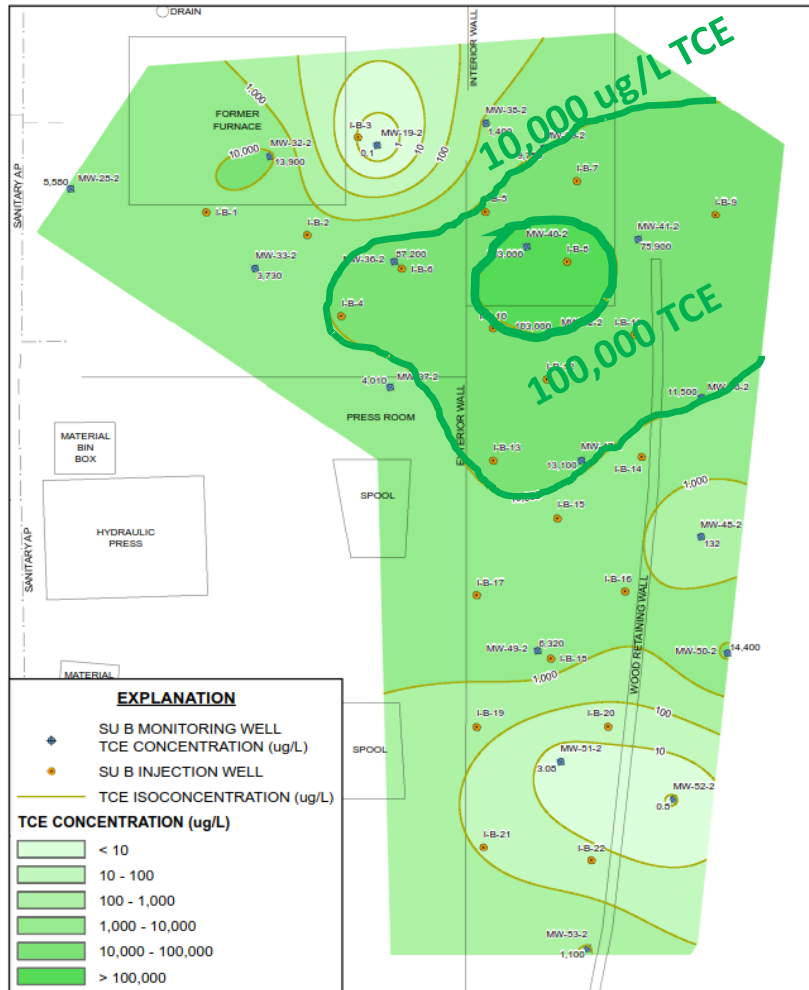
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POST ISCO ROUND 2



TCE RESULTS- INJECTION ROUND 2

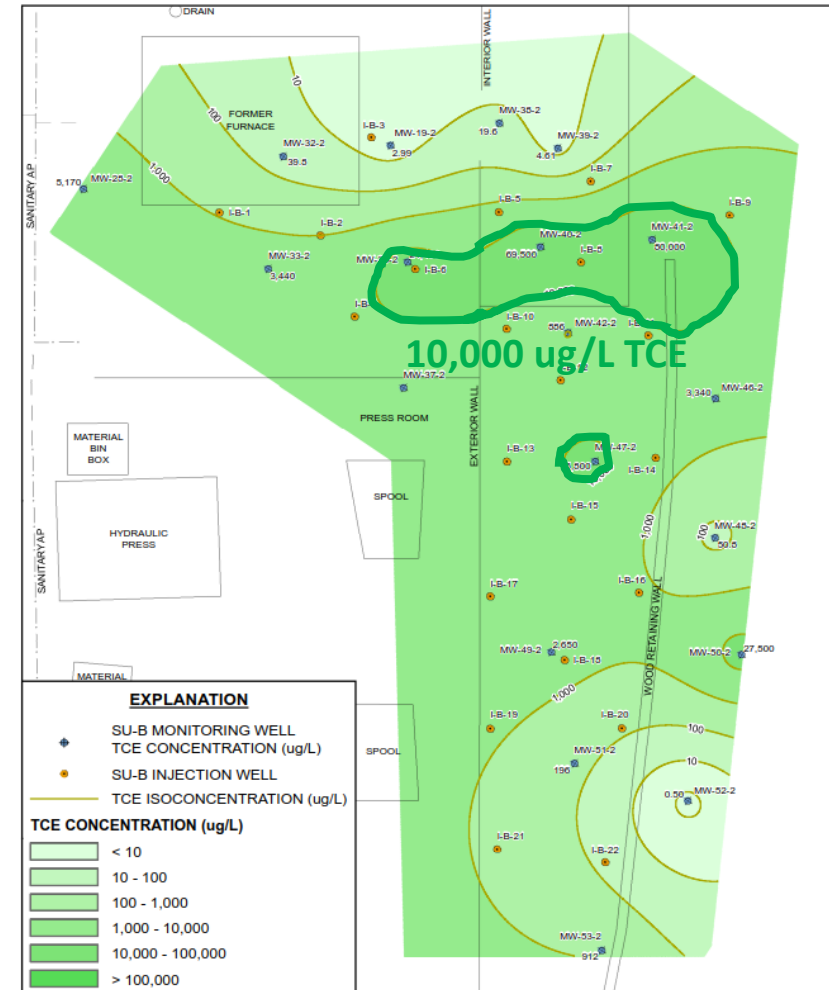
PRE ISCO ROUND 2



SU B

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POST ISCO ROUND 2



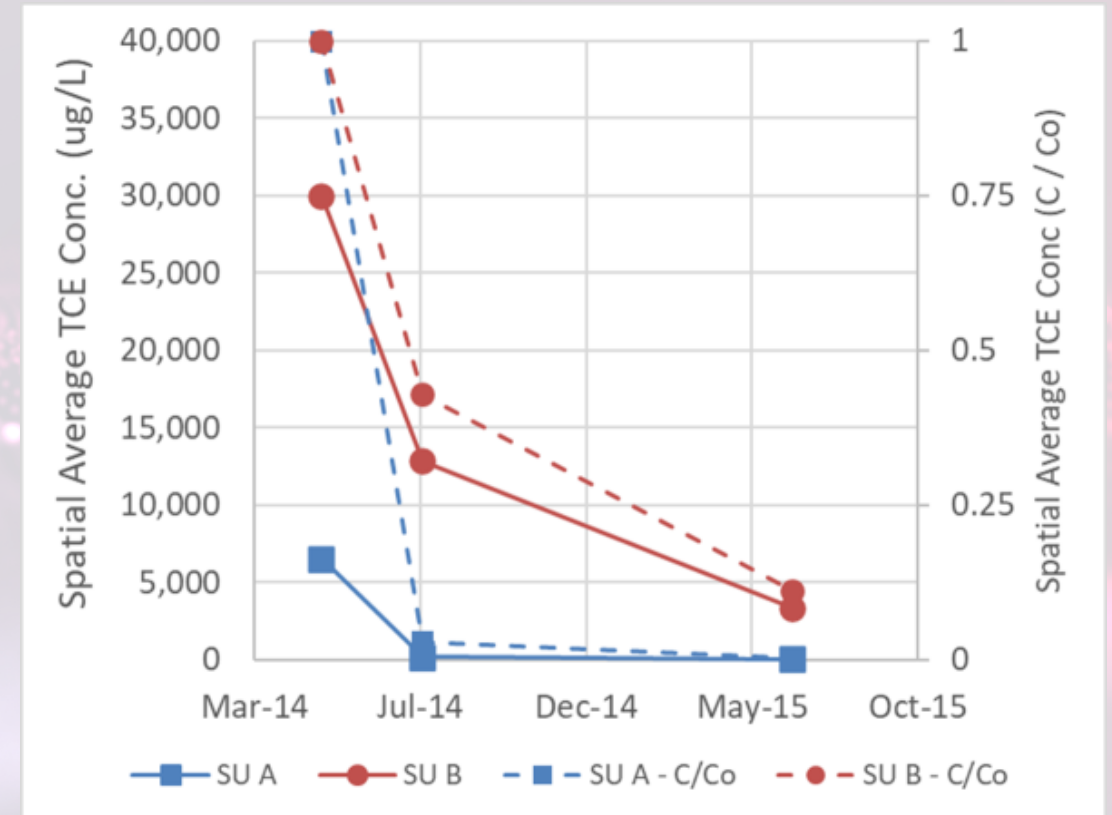
TCE RESULTS

SU A:

- 97% Treatment Rnd 1
- 99+% Rnd 2

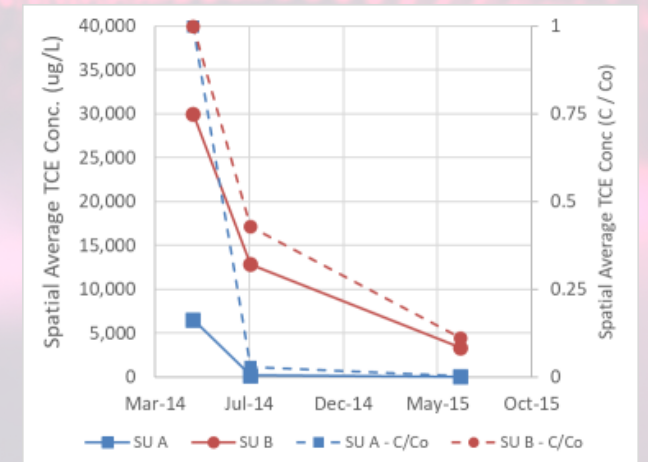
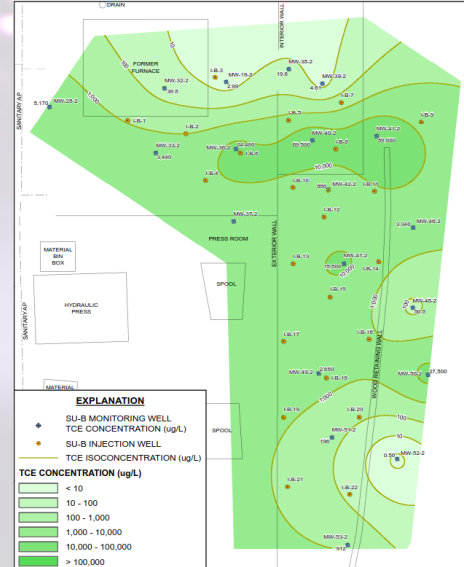
SU B:

- 57% Rnd 1
- 89% Rnd 2



SUMMARY

- Permanganate injection monitored real time
- Injection approach optimized based on data
- Additional focus to key areas
- Concentration reductions 90% in most impacted zone and 99% in periphery





QUESTIONS



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