Techniques for Evaluating the In Situ Injection Process

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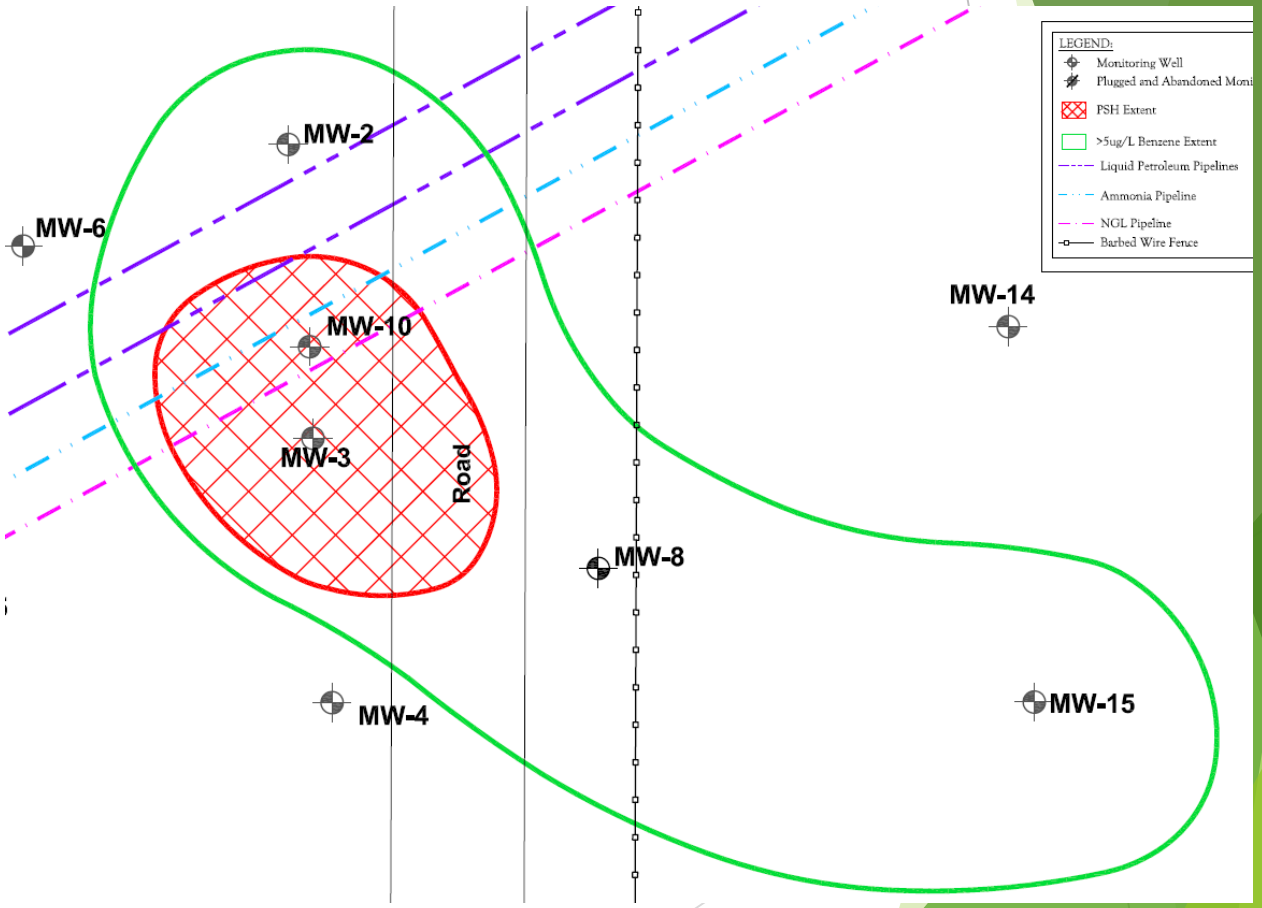
Site Background

- Natural gas liquids (NGL) pipeline release in an agricultural field
- 19,000 square foot plume with ~3,500 square feet of phase separated hydrocarbons (PSH)
- Knew very little about the subsurface of the site before work began

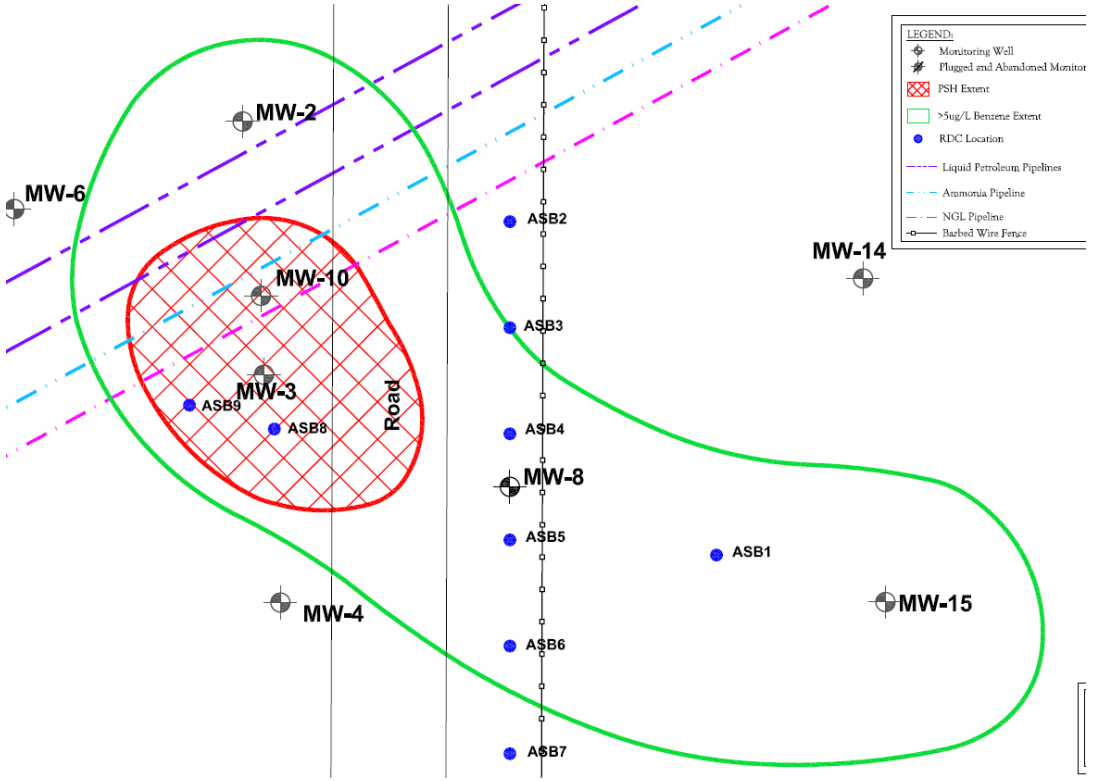


Remediation Plan

- Selection of product and installation technique was done by others
- Remediation Products Inc BOS-200®
  - Activated carbon product that is the consistency of flour
- Installed using Direct Push Technology (DPT)
  - Slurry – High pressure & flow
  - Top down technique

Remediation Design Characterization (RDC)

- Not typical to have so little information
- Arrived on site & spent the first 2 days taking continuous soil and grab groundwater samples in 9 locations throughout the plume



RDC Results/Changes

- Injection loadings were tailored to the varying concentrations found across the vertical treatment zone.
- Realized that the vertical treatment zone is in sand and not clay like we had originally thought.

Planned injection Depth (ft bgs)	Original Product Loading (pounds)	Soil Benzene Concentration (mg/Kg)	Final Product Loadings (pounds)
15 or 16	75	37.9	75
17 or 18	75	48.2	75
19 or 20	75	0.061	35
21 or 22	75	0.041	25

Injections Begin

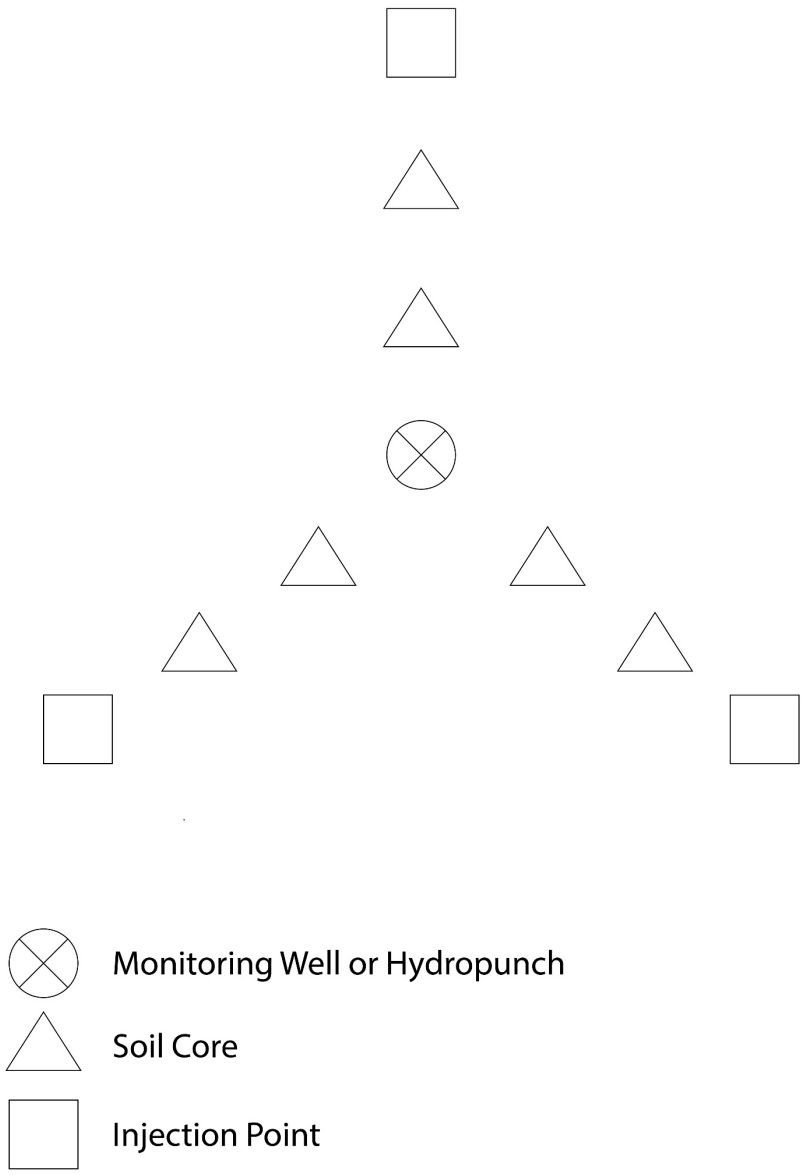
- Downgradient edge of plume
  - Dissolved contamination only
- 10 foot triangular grid
- First injection point is directly adjacent to a monitoring well
  - ~5 feet from well based on grid spacing
- Finish first injection point and purge the nearby monitoring well looking for activated carbon
- No carbon

Injections Begin

- Decide to move to adjacent injection point that is ~5 feet from the monitoring well
- Finish injections in second point and purge well
- Still no carbon
- Complete 3rd injection point near well and purge to look for carbon
- Still no carbon
- Ask client for permission to take more soil cores

Continuous Soil Samples

- Took several continuous soil samples between the injection points and the monitoring well
- Broke each core apart and visually inspected for evidence of carbon
- Continuous soils were taken 1 foot and 3 feet from each injection borehole for a total of 6 sample locations
- Carbon is seen in the 1 foot cores but not the 3 foot



Basic Procedure

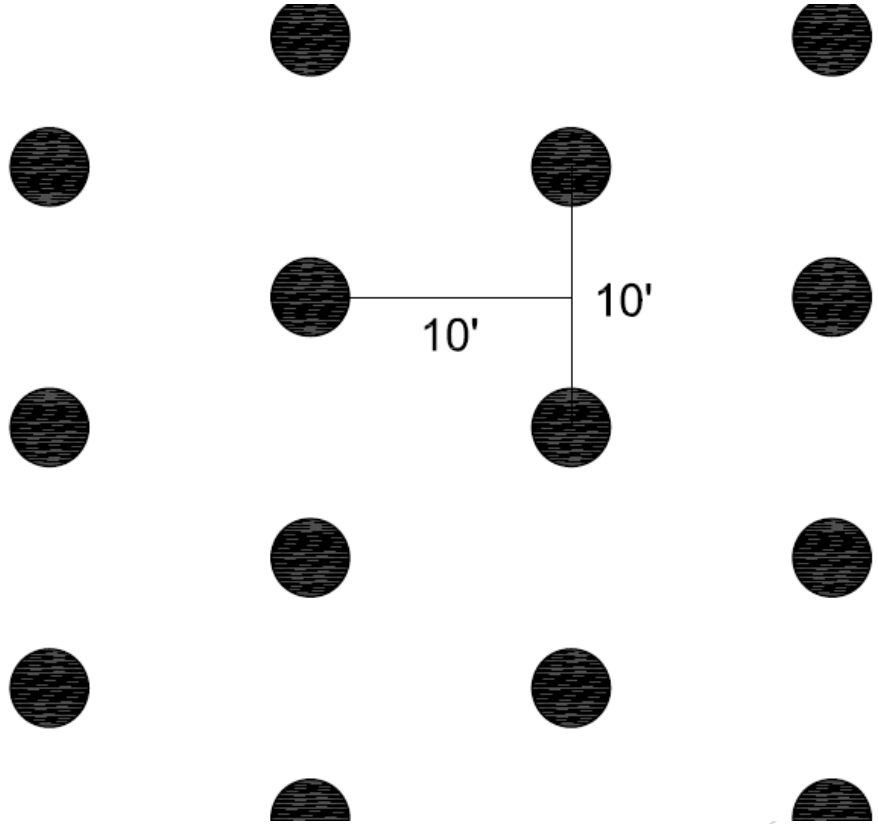
- Continue to purge groundwater and take continuous soils
- Change 1 of the following each time:
  - Slurry Volume
  - Grid Spacing
  - Pump/Flow Rate
  - Slurry Density
  - Exit Velocity/Injection Tips

Volume

- Can be increased or decreased by ~25% without changing injection grid
- Started with 50 gallon shots
- Went as high as 60 gallons and as low as 30 gallons
    - Surfacing became an issue as we increased the volume

Grid Spacing

- Originally started with 10 foot triangular grid
- Most of the site was completed using a 7.5 foot triangular grid
- One small area was done using a 5 foot triangular grid



Pump/Flow Rate

- Arrived on site with a pump capable of pumping at 35 gallons per minute
- Switched injection trucks out for a truck with dual pumps that was capable of pumping at 70 gallons per minute

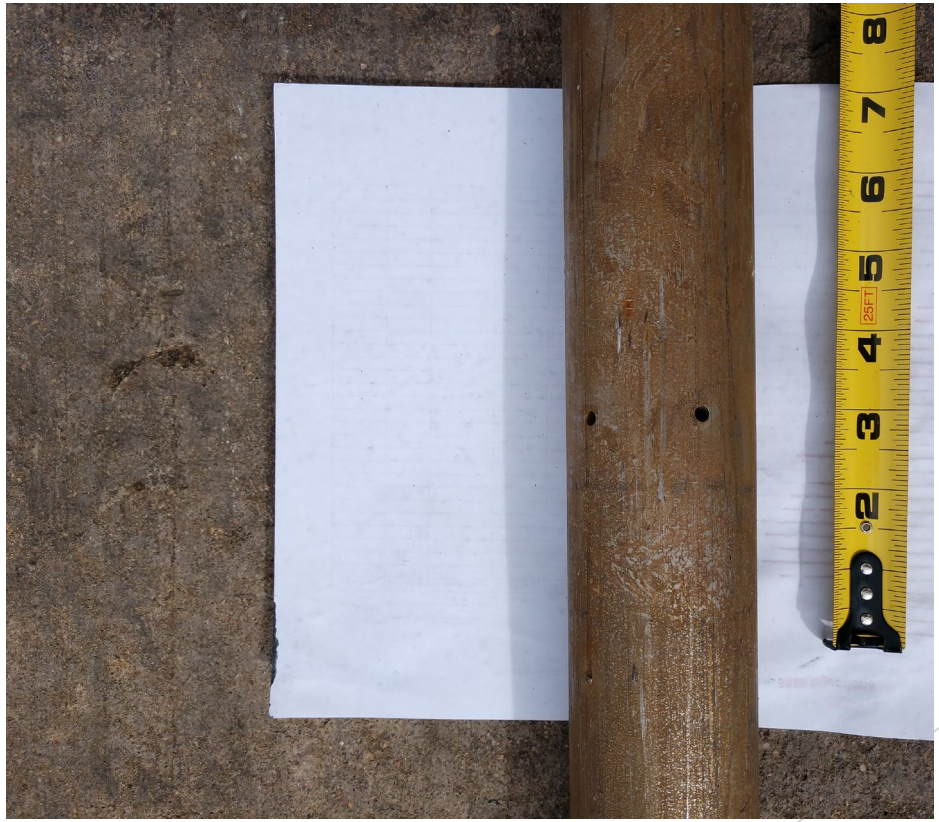
Pounds of BOS-200®	Gallons of Water	Density (pounds/ gallon)
25	50	0.50
25	60	0.42
25	40	0.63
12.5	40	0.31
12.5	35	0.36
12.5	30	0.42

Density

- Started with 25 pounds in 50 gallons
- Increased to 25 pounds in 60 gallons
- Surfaced
- Settled on 12.5 pounds in 30 gallons

Exit Velocity

- Dependent on the injection tip
- Had been experimenting with this on other sites
- Size & number of holes on tip
- Started with 6 point tip
- Ended with 9 point tip with 1/18” injection holes



Injection Tips

1. Our first custom tip for a project in flowing sugar sands
2. Holes are angled down to help combat surfacing – used on clay sites
3. Holes are at varying angles to increase distribution – used on sand sites
4. The original tip – easily plugged

Successful Combination

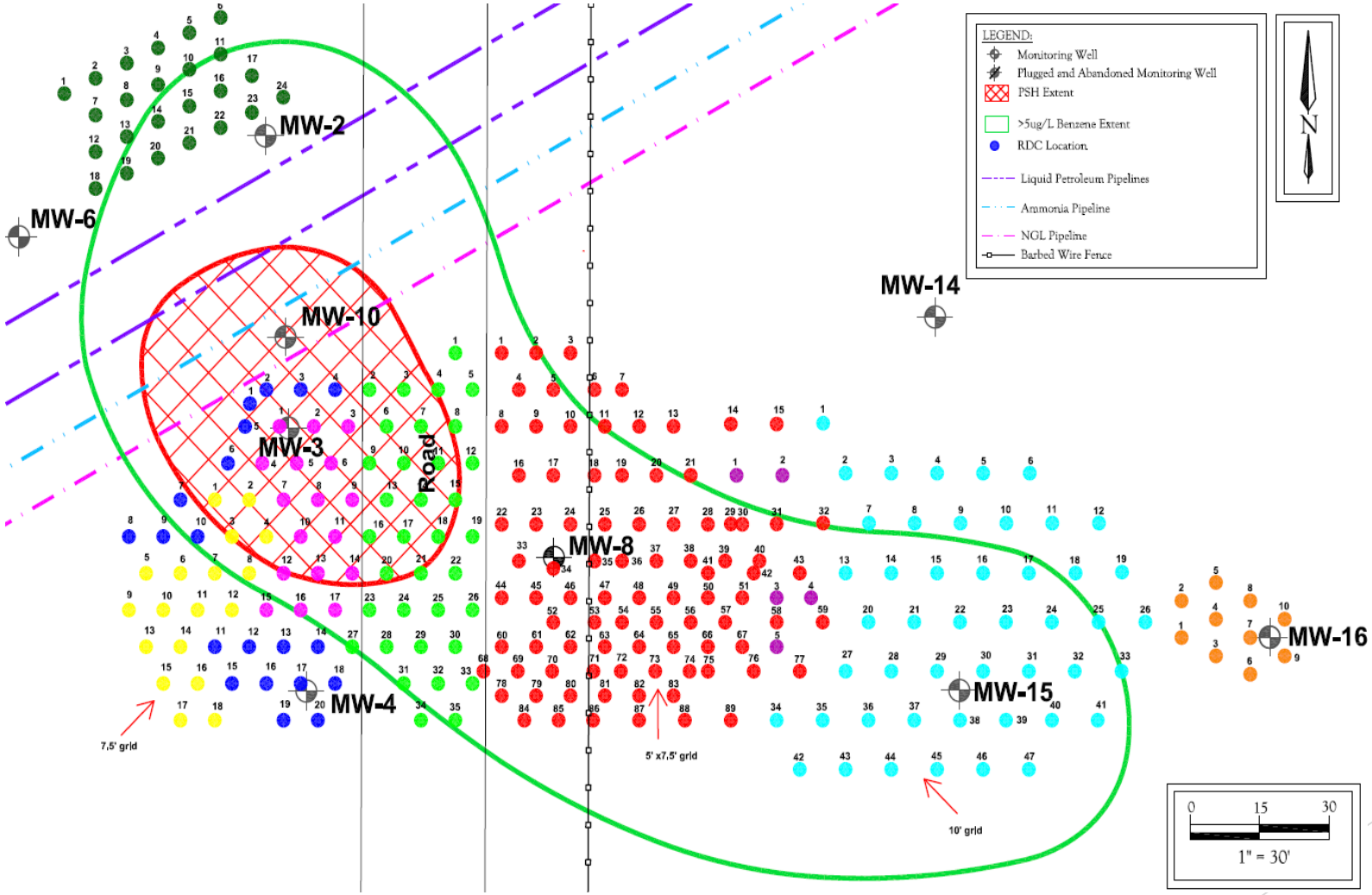
- Volume – 30 gallon shots
- Spacing – 7.5 foot grid
- Pump rate – 70 gpm
- Density – 0.4 pounds/gallon
- Exit velocity – increased by using smaller holes

Not a Linear Process!

More Changes

- Client gave permission to perform the same procedure several times as we progressed through the installation
- In one area, testing indicated the ROI was not being met
- One more change:
  - The grid spacing was decreased to a 5 foot grid
- No changes were needed to the volume, density, exit velocity, or pumping rate.

Final Site Map



Final Result

- Many changes were ultimately made to our approach to each job
  - Ask questions about the lithology so we bring the right types of tips
  - Adjust the volume, density, and flow to combat surfacing
  - Monitor the groundwater for signs of impact
  - Lack of surfacing may also be a clue that the ROI is not being achieved
  - Take soils for more information