



# Barrier Reinjection of Emulsified Vegetable Oil within a Bedrock Aquifer and Innovative Monitoring Methods

*Prepared by:*

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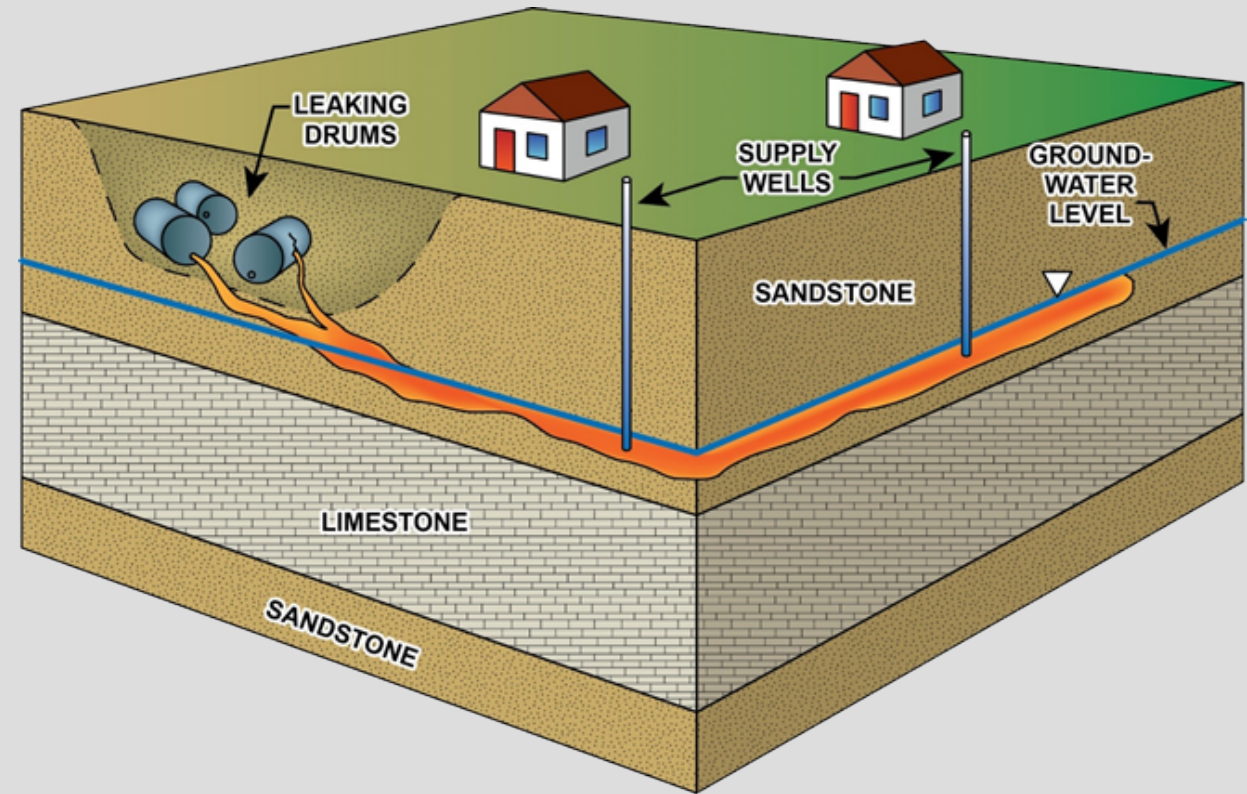
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# Background Information

- TCE Plume originated from an unpermitted dump
- 226-acre TCE and *cis*-1,2-DCE Groundwater Plume
- Groundwater plume 0.5 miles wide and 1 mile long
- Sandstone Bedrock Aquifer
- Depth to Groundwater 50 ft bgs at Barrier
- Public and Private Supply Wells Impacted



# EVO Barrier - Wells

- Remedy - In Situ Bioremediation to address the Core of the Plume
- Groundwater flow southeast
- Barrier 300 feet in length and 20 feet wide
- 15 Injection Wells spaced 20 feet apart – Schedule 80 PVC – Screen cut to provide optimal length for the remedy
- Screen length averages 15 feet
- 5 Performance Assessment Wells – Schedule 40 PVC

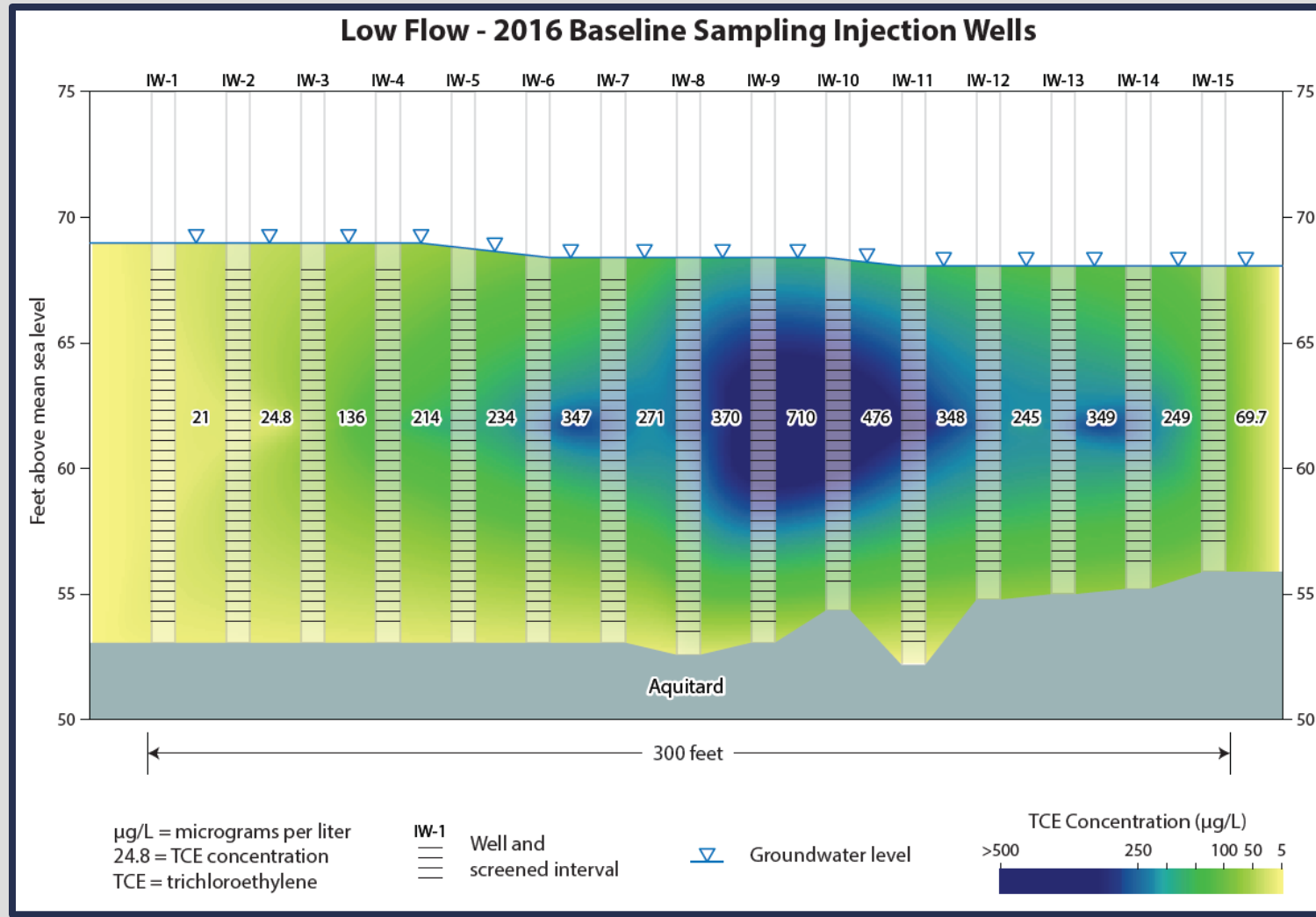


# Injection History



- **Three Injections of Emulsified Vegetable Oil (EVO)**
  - ◆ 1<sup>st</sup> Injection – April 2016
  - ◆ 2<sup>nd</sup> Injection – November 2017
  - ◆ 3<sup>rd</sup> Injection – August 2020
- **Adjusted pH with sodium bicarbonate after first and second injections**
  - ◆ After 1<sup>st</sup> Injection – May 2016
  - ◆ After 2<sup>nd</sup> Injection – March 2018
- **Baseline Sampling Conducted prior to First Injection**

# Baseline Sampling of Injection Wells Low Flow

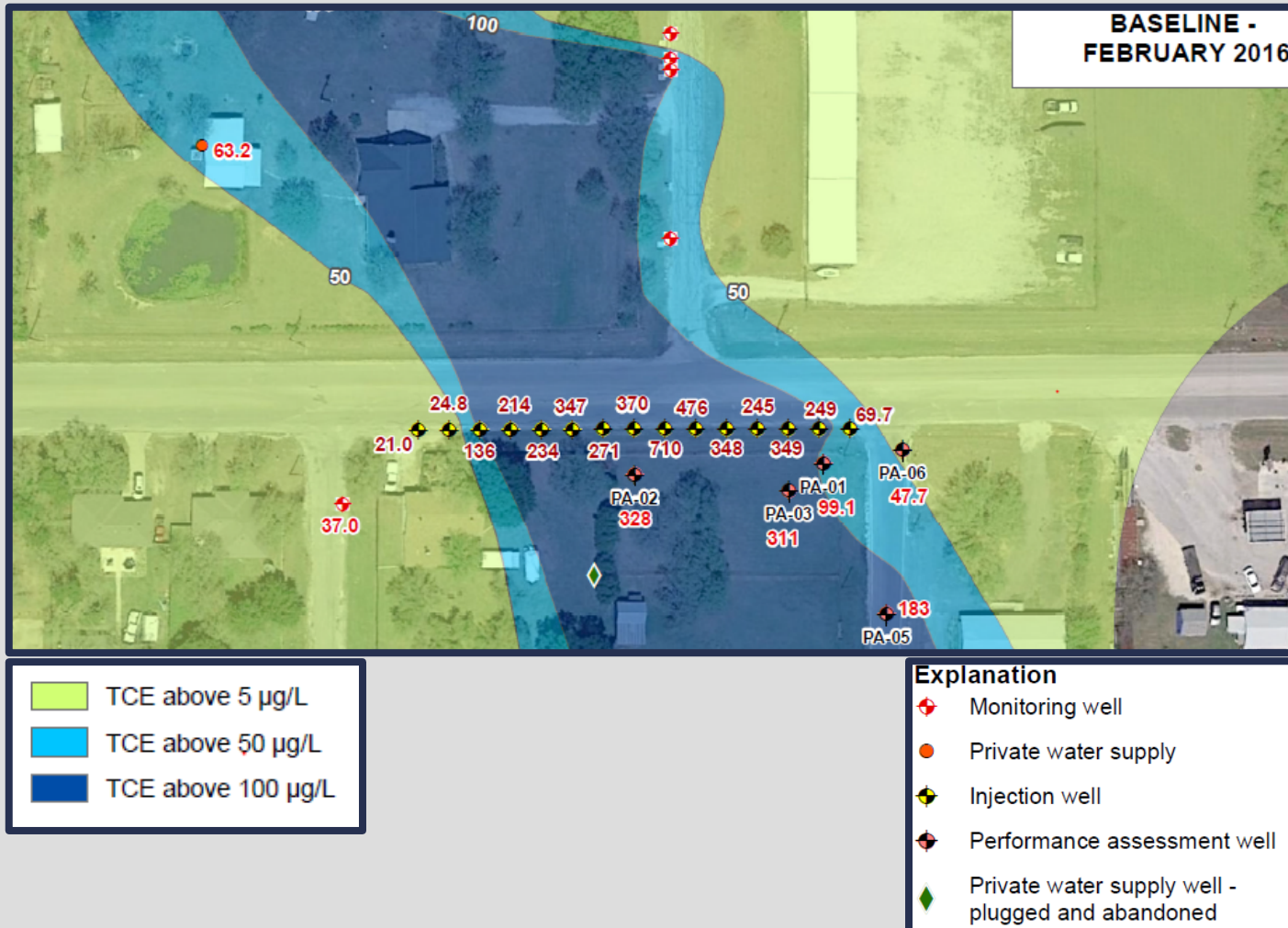


## ■ Low Flow

- ◆ VOCs, dissolved gases, metals (arsenic, iron, manganese), sulfate, nitrate, TOC, TDS
- ◆ Obtain a single groundwater sample
- ◆ Sampling take up to 1.5 hours per well
- ◆ Decontamination of Equipment between wells
- ◆ Generates purge/decon water – investigation-derived waste (IDW)

# 1<sup>st</sup> EVO Injection – 2016

## Baseline Conditions



## 1<sup>st</sup> Injection –EVO

- Initial Injection April 2016 – Terra Systems SRS-FR and TSI-DC Bioaugmentation
- Total injected 6,645 gallons – SRS-FR/water mixture.
- Injection completed under gravity through a metered and valved manifold via 1-inch drop pipes set below the water table.
- No packers used
- Flows ranged from 3 to 14 gpm. Formation readily accepted amendment.
- 16,610 gallons of flush water was injected under gravity at 9 to 14 gpm.

# Performance Assessment Sampling for EVO Barrier

- ◆ Performance Assessment Wells – Sampled using **passive sampling devices** 30, 60, 90, 120, 150, 240, 340, 400-days for same sample suite. Subsequent injections quarterly, then semi-annual.
- ◆ **VOCs and Dissolved Gases** – using Eon Products Passive Diffusion Bags (PDBs) at various intervals (4)
- ◆ **Metals (Arsenic, Iron, Manganese), Sulfate, Nitrate, TOC, TDS** – using Eon Products Dual Membrane Samplers (DMPDBs) one interval middle of screen – multiple samplers
- ◆ Injection and Performance Assessment Wells – **Downhole Water Quality Meter**

# Passive Diffusion Samplers

## EON Products Inc. states:

- PDBs – What is a PDB – 18–20-inches in length semi-permeable, polyethylene membranes. Filled with deionized water.
- Deployed on weighted tether.
- VOC – contaminant molecules dissolved in water will naturally flow from areas of higher concentration to lower concentration if there is a pathway through which molecules can move.
- PDBs deployed 2–3 weeks ahead of sampling to equilibrate
- Can purchase prefilled or fill yourself.



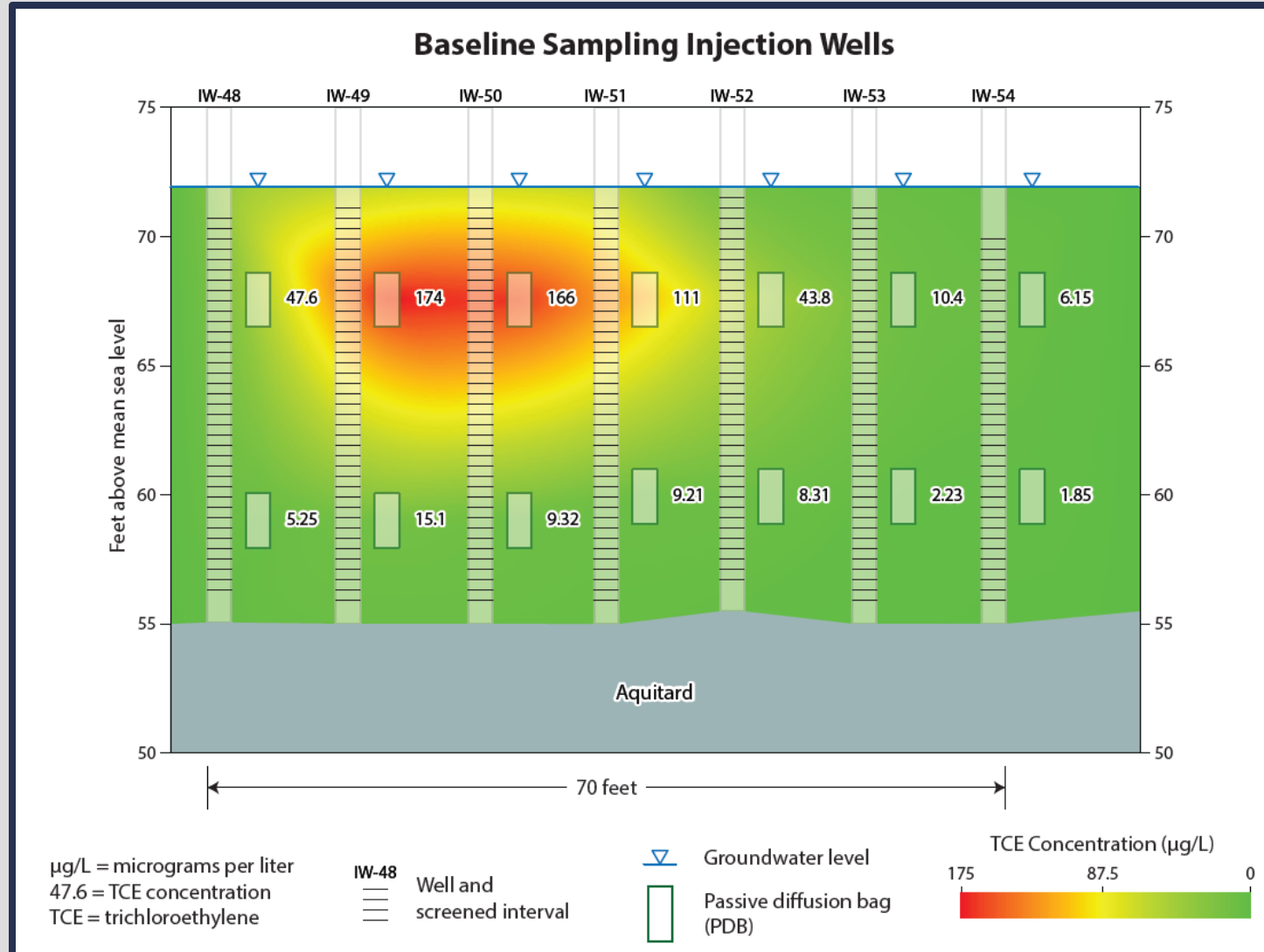
# Dual Membrane Passive Diffusion Samplers

## EON Products Inc states:

- DMPDBs – Two separate semi-permeable membranes around a single sample chamber allows any molecule dissolved in groundwater to diffuse into the DMPDBs.
- Bottom membrane identical to PDB, the upper membrane is hydrophilic and has larger pores to enable a wide range of molecules to diffuse into the sampler
- You fill with deionized water.
- 1.75-inch diameter lengths up to 28-inch
- Deployed 2–3 weeks equilibrate

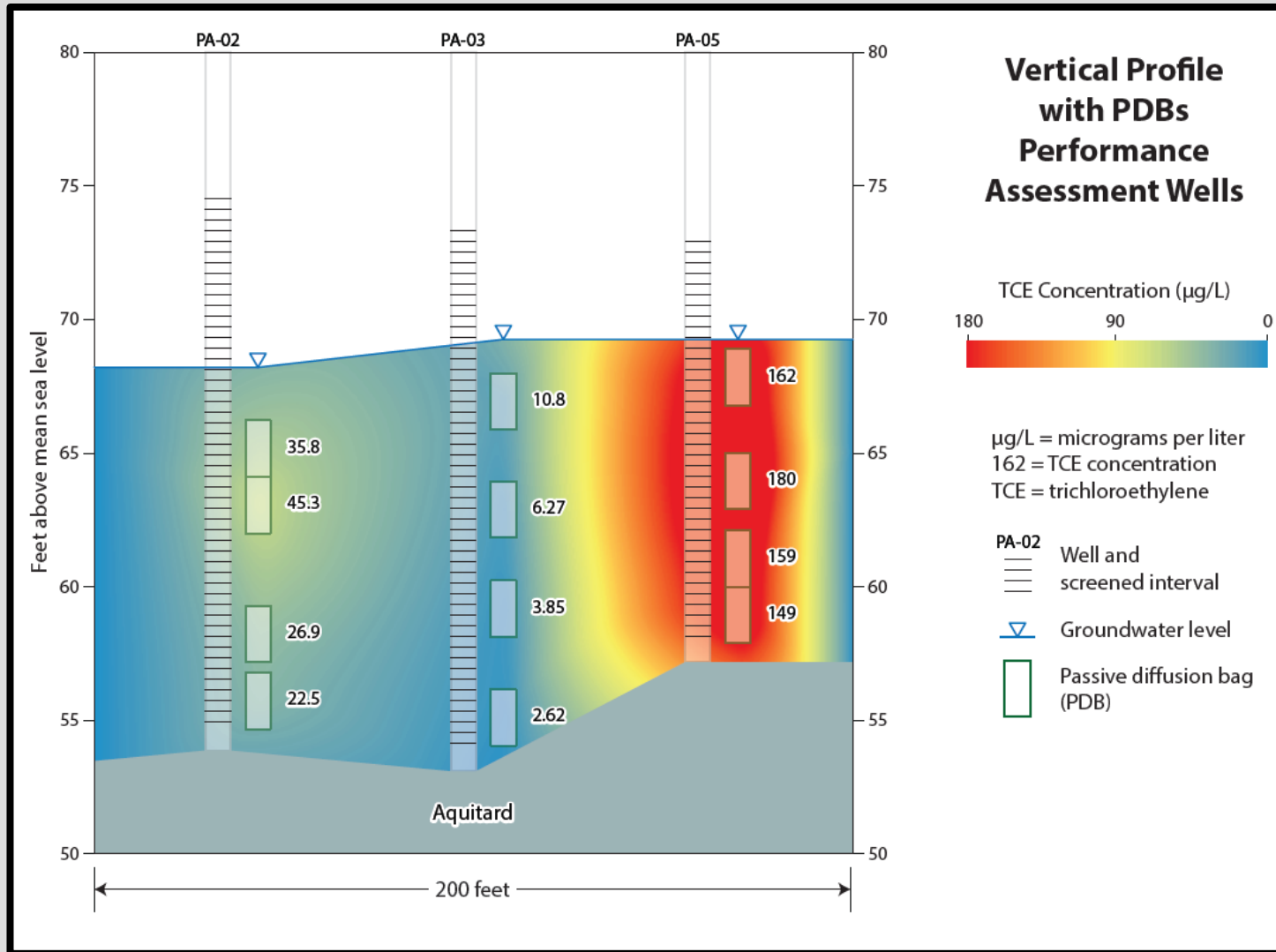


# Baseline Sampling of Injection Wells PDBs



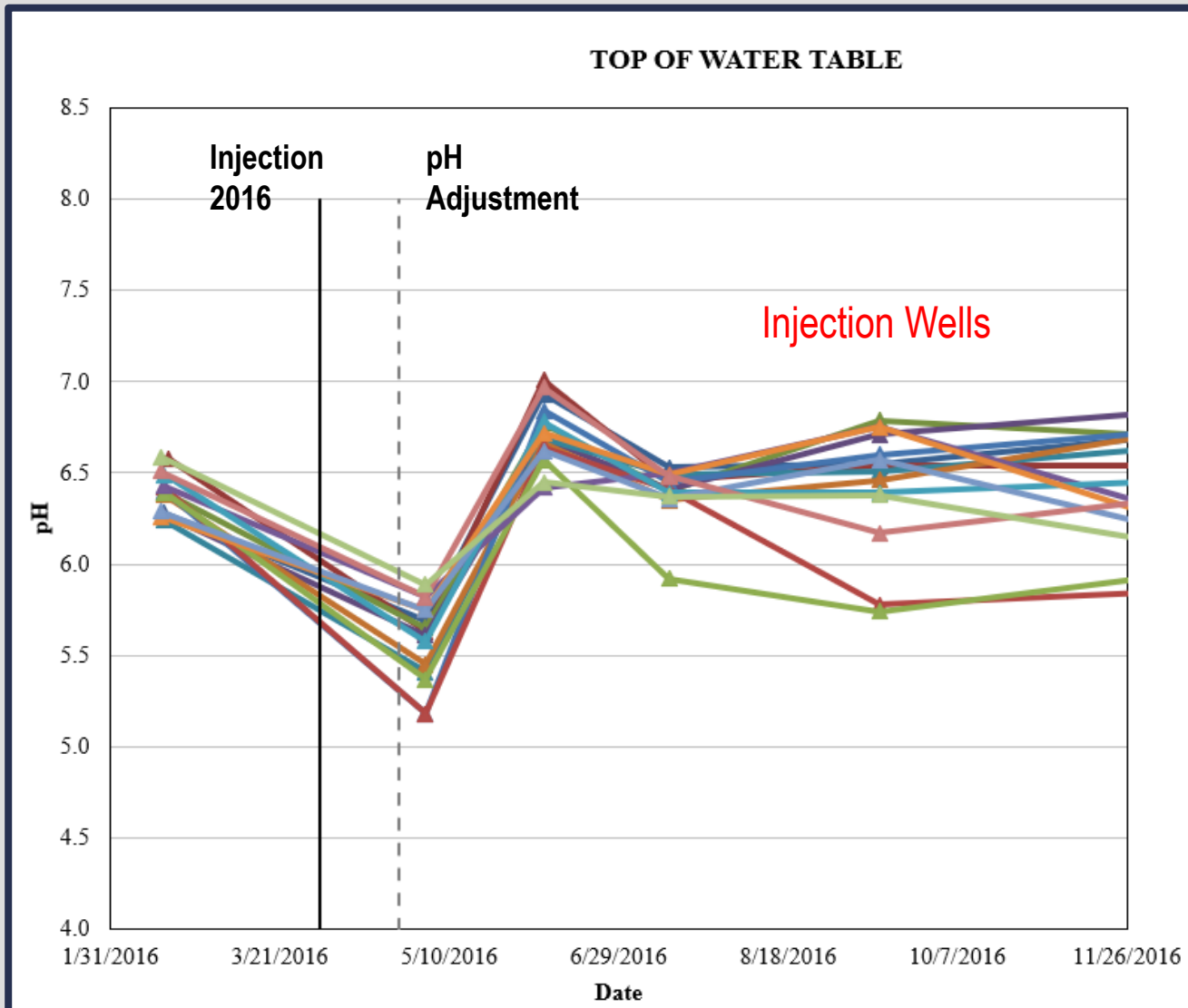
- **Passive Sampling of Barrier added after First Barrier**
- **Obtained two groundwater sample per well**
  - ◆ **Vertical profile – Contamination present at top of aquifer**
  - ◆ **Generates less investigation derived waste purge water**
  - ◆ **Sample time 30–45 minutes**

# Performance Assessment Wells PDBs



- Performance Assessment Sampling July 2016 103 - Days after First Injection
- Obtained four groundwater sample for vertical profile

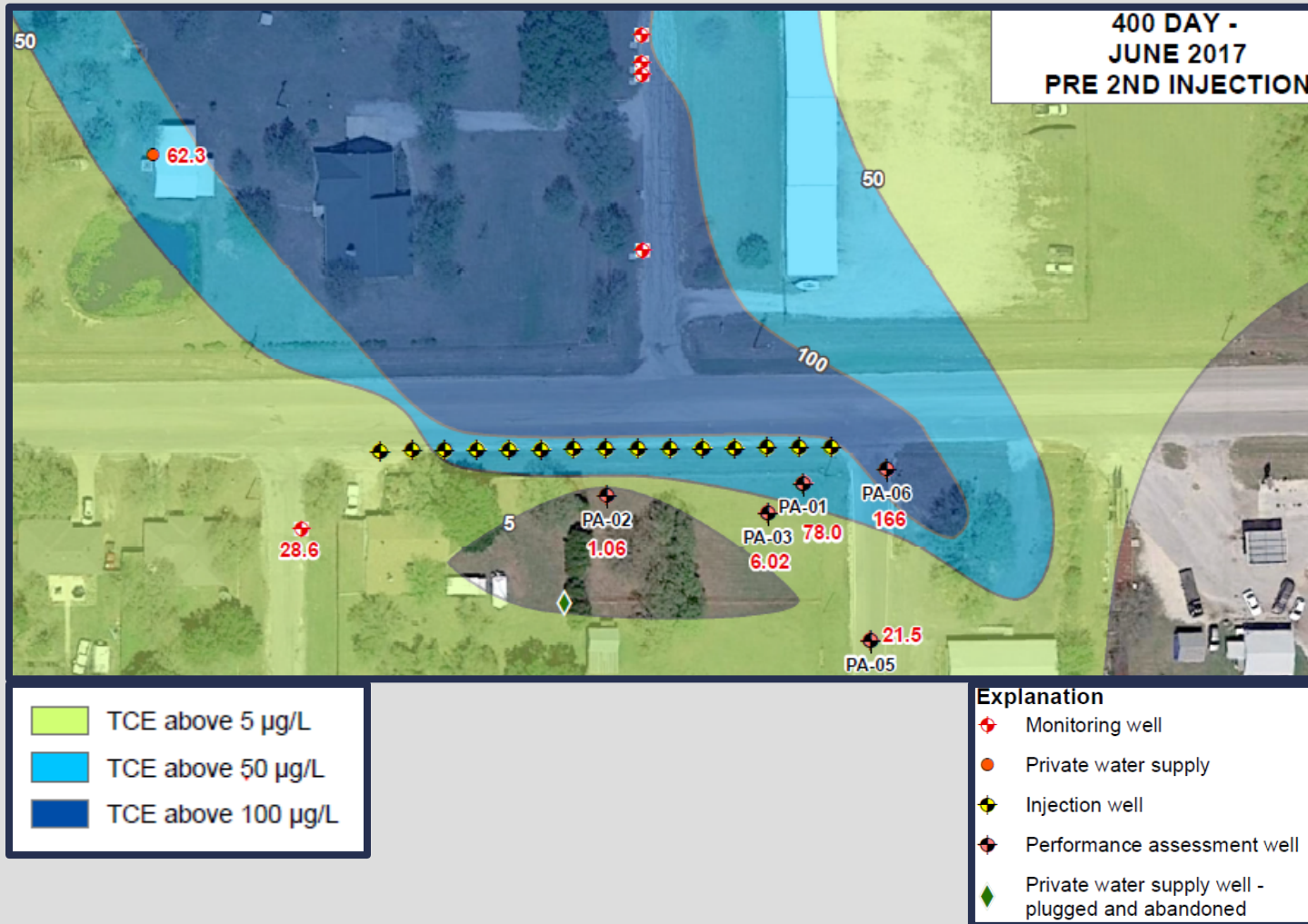
# Down Hole Meter and pH Adjustment



- After 1<sup>st</sup> Injection pH dropped rapidly below 6.
- Had to adjust pH with injection of sodium bicarbonate.
- Downhole Water Quality Meter essential in providing us information on the Injection Wells



# Performance 400 days After 1<sup>st</sup> Injection

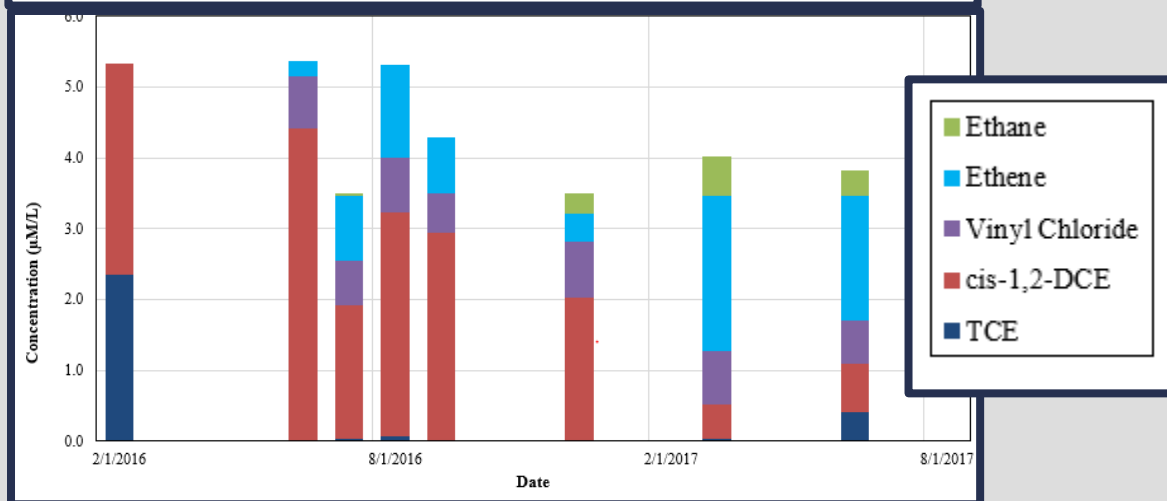
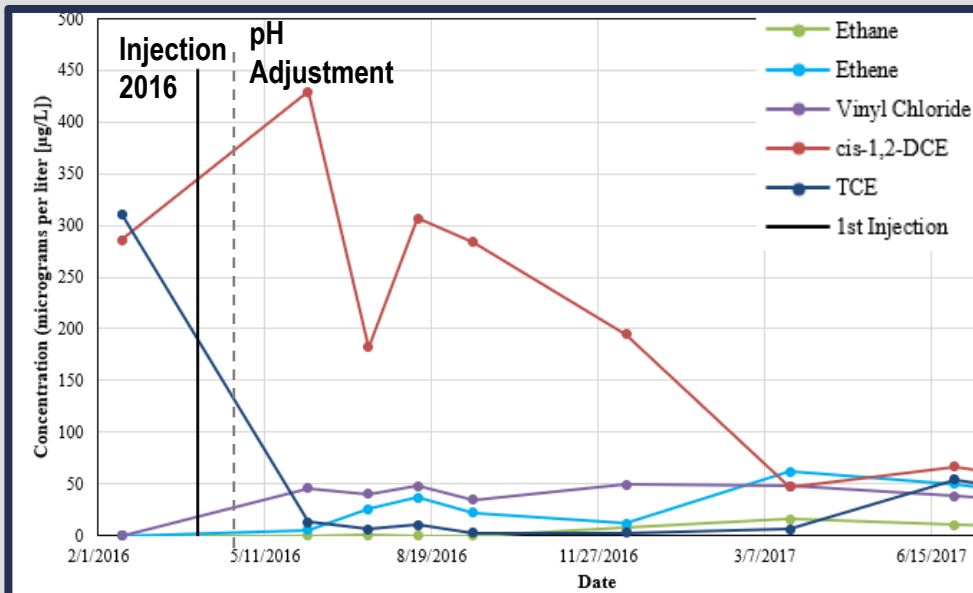


## Increasing Concentrations

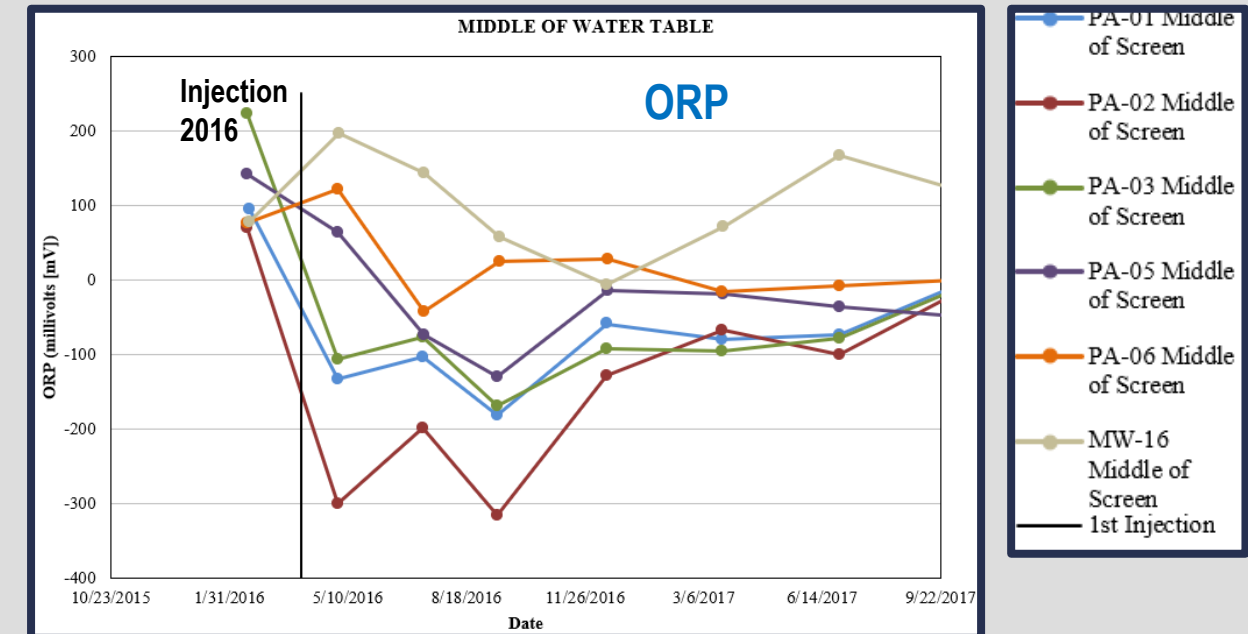
- TCE concentrations increasing in several PA wells
- TCE concentrations in PA-06 increasing and plume moving around barrier.
- Second injection proposed to maintain barrier

# TCE Concentrations June 2017 – 453 Days After 1<sup>st</sup> Injection

## RDC CONCENTRATION TRENDS FOR WELL INTERVAL PA-03-68



- In 2 PA wells (PA-01 and PA-03) TCE concentrations begin to increase
- ORP increasing
- TOC decreasing in four PA wells



# Second Injection

## Second Injection – Emulsified Vegetable Oil (EVO)

- Second Injection October 2017 – SRS-SD and TSI-DC
- Well Reconditioning
  - ◆ Wells checked to see if wells screens clogged
  - ◆ Wells checked for EVO by products (ferrous sulfide, biomass, and organics)
  - ◆ Wells bailed to remove by products
  - ◆ Hot water mixed with dish soap poured in well then bail and surge the wells.



Heating water to clean wells

# Second EVO Injection Continued



Injection

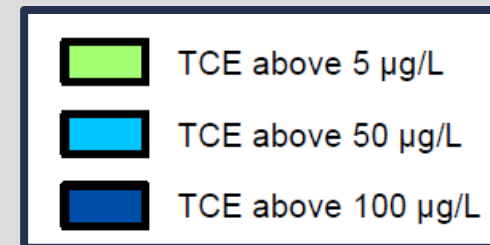
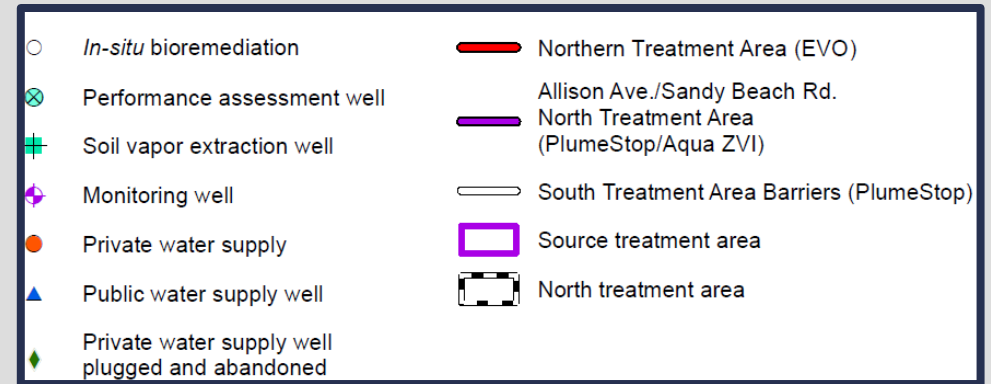
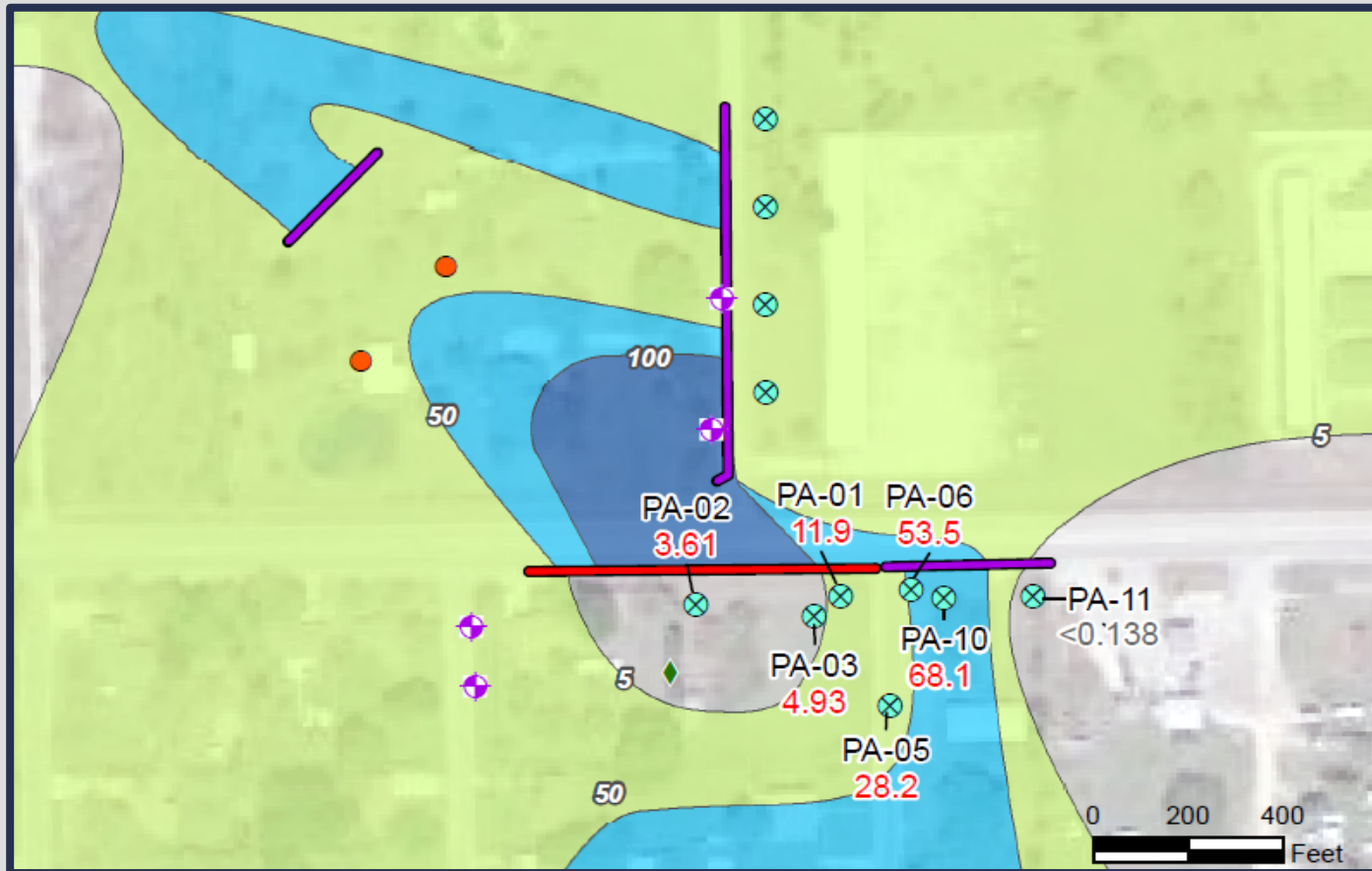


Surfacing

## Second Injection – Emulsified Vegetable Oil (EVO)

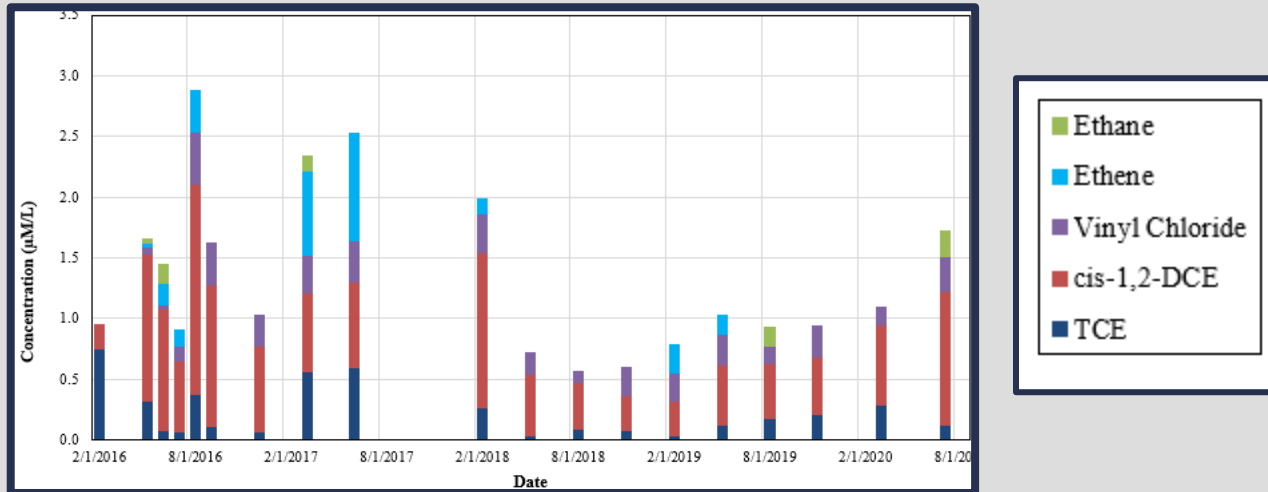
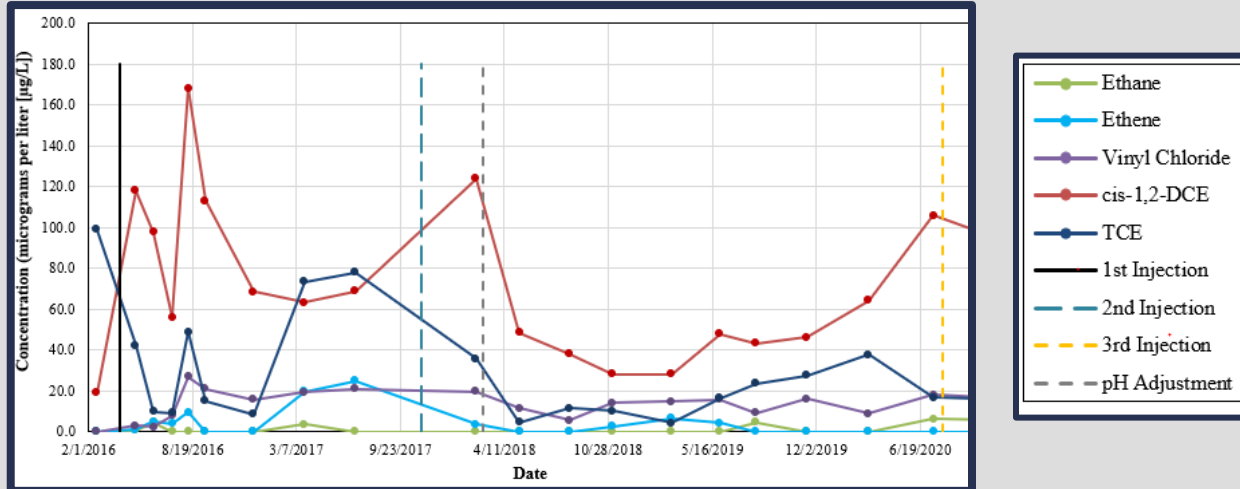
- Total injected 19,689 gallons – SRS-SD/water mixture. Volume increased for better distribution.
- Injection completed via gravity or under low pressure using inflatable packers.
- Flows ranged from 1 to 11 gpm. Flow reduced as injection proceeded.
- 48,255 gallons of flush water was injected volume increased to reduce retention of EVO in injection wells.
- Surfacing of chase water in one ISB well – ISB-05.

# 985 Days (2.7 Years) after Second Injection



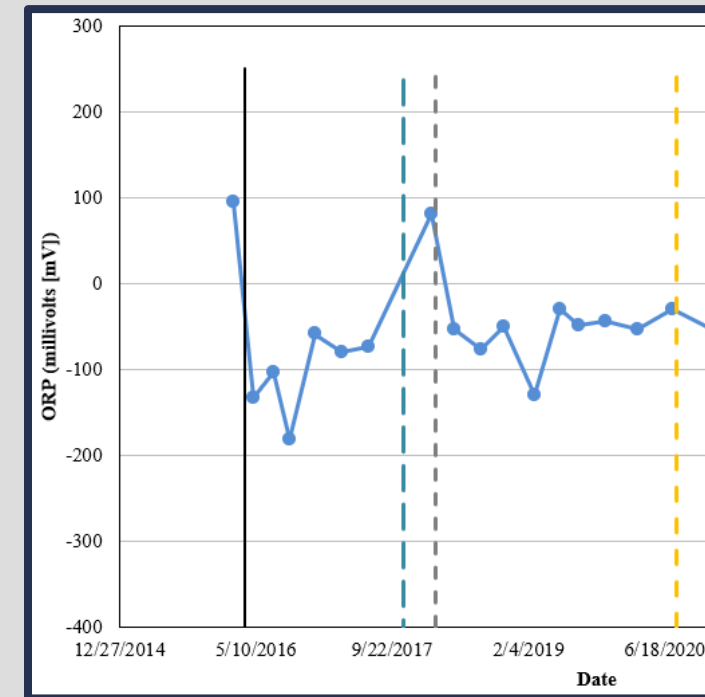
# Performance 985 Days (2.7 Years) After Second Injection

RDC CONCENTRATION TRENDS FOR WELL INTERVAL PA-01-68



July 2020 PA-01 – 24 feet from Barrier

- TCE concentrations increasing trend
- ORP value increasing
- Nitrate and Sulfate decreasing



# Third EVO Injection

## Third Injection – Emulsified Vegetable Oil (EVO)

- Third Injection August 2020 – SRS-FRL
- Well Reconditioning
  - ◆ Two Wells (ISB-05 and ISB-11) were obstructed with solids at the water table. Stainless steel bailer used to break through solids.
  - ◆ Wells bailed and surged
  - ◆ Hydro-jetting with steam and dishwashing soap the entire length of the screen
  - ◆ Then each well was redeveloped with a submersible pump.



Jetting tool



Bailing

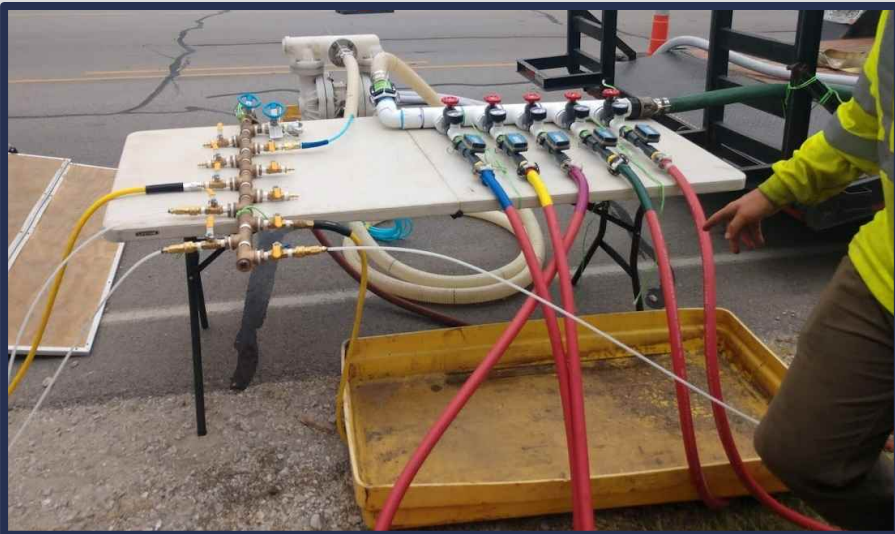
# Third EVO Injection



Injection lines  
and manifold

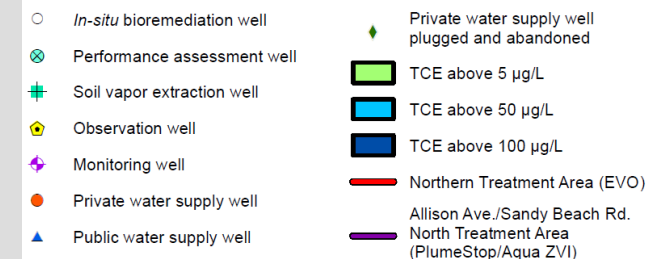
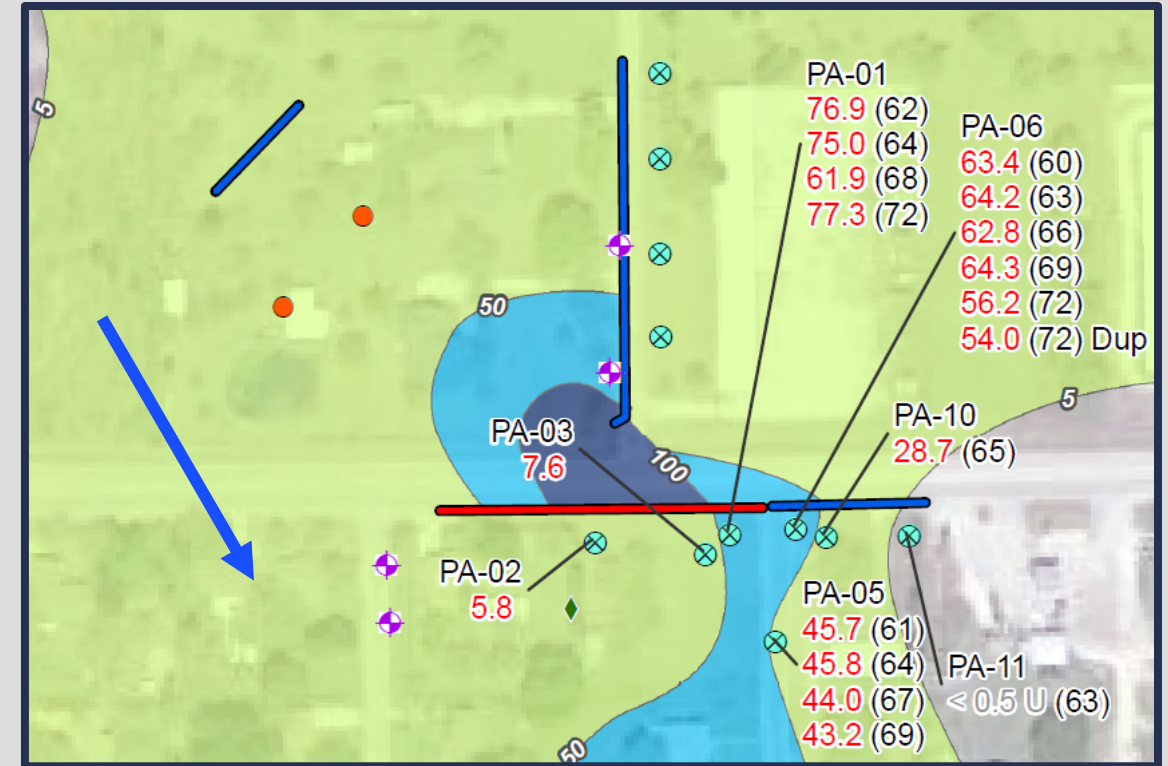
## Third Injection – Emulsified Vegetable Oil (EVO)

- Total injected 7,520 gallons – SRS-FRL/water mixture.
- Injection completed under pressure using inflatable packers – 1-inch drop pipe.
- Flows ranged from 0.25 to 14 gpm.
- Four wells did not readily accept EVO, as a result EVO was gravity flowed at 0.25 gpm.
- Not all wells took full volume.
- 16,965 gallons of flush water was injected volume increased to reduce retention of EVO in injection wells. Five wells did not take full volume of chase water.



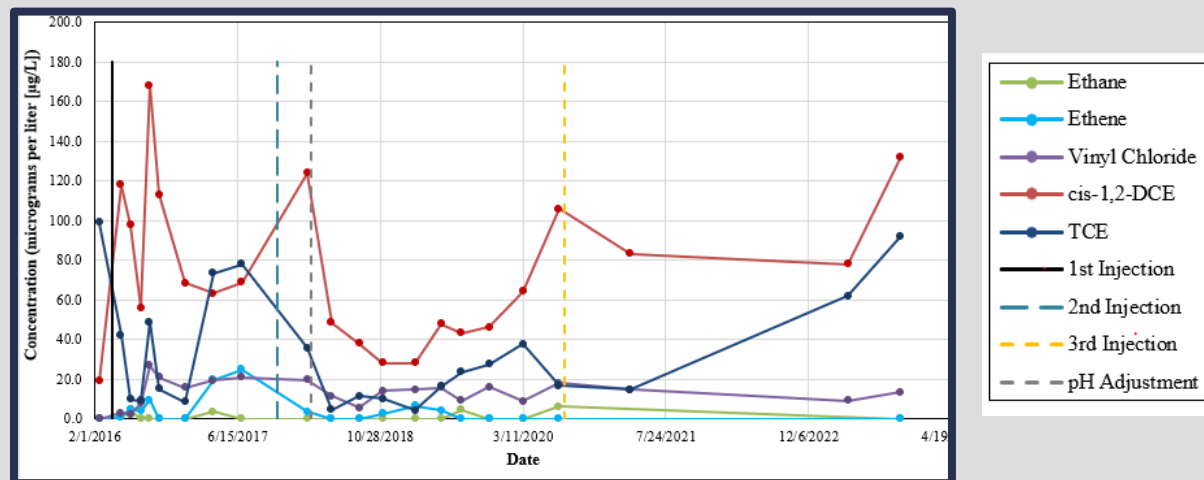
# TCE Concentrations 2023 – 4.4 Years after 3<sup>rd</sup> Injection

- TCE concentrations increasing downgradient of EVO barrier
- Ten of Fifteen Injection wells are plugged.



# Performance 1781 Days (4.9 Years) After Third Injection

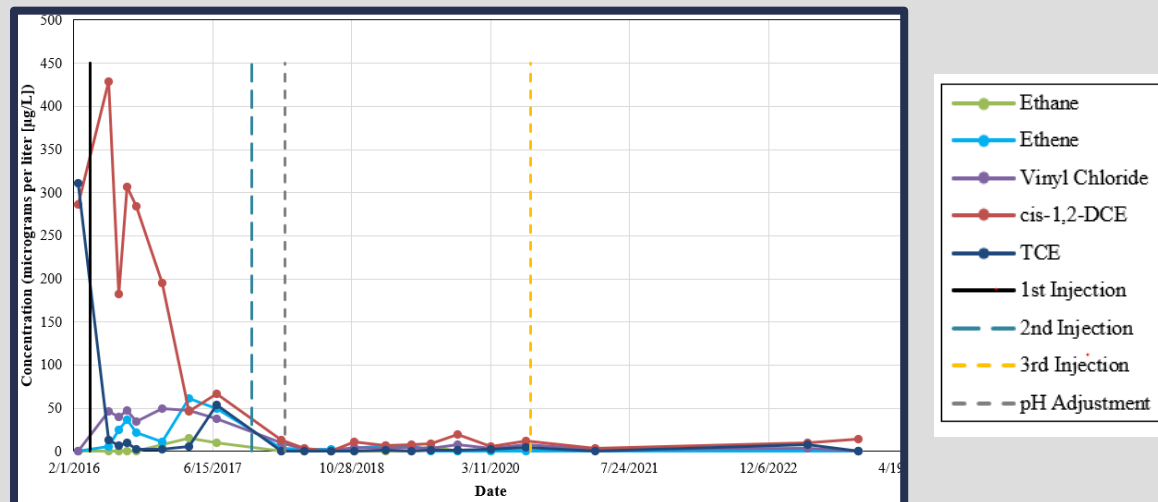
## RDC CONCENTRATION TRENDS FOR WELL INTERVAL PA-01-68



## October 2023 PA-01 – 24 feet from Barrier

- TCE concentrations increasing
- No ethane or ethene
- ORP value increasing
- Sulfate increasing
- TOC below 10 µg/L
- Insufficient substrate to support biodegradation of the VOCs

## RDC CONCENTRATION TRENDS FOR WELL INTERVAL PA-03-68



## October 2023 PA-03 – 65 Feet from Barrier

- TCE concentrations remain unchanged
- ORP value remaining the same
- Nitrate and Sulfate remaining low
- TOC above 10 µg/L
- Sufficient substrate to support biodegradation of the VOCs

# Conclusions

- **Reinjection**
  - ◆ Second injection would probably been best if we jetted the wells and redeveloped prior to injection.
  - ◆ Currently Wells are clogged, do not think we can do another injection.
- **Passive sampling devices provided:**
  - ◆ Quicker Sampling Time – half the time to sample than low flow – this leads to cost savings to project
  - ◆ Less IDW
  - ◆ Vertical profile
- **Downhole Meter provided:**
  - ◆ Information on barrier – when to adjust pH
  - ◆ Information on performance assessment wells

# Questions

