

CHLORINATED SOLVENT DAUGHTER PRODUCT MANAGEMENT AND EXPEDITED REMEDIATION

Mike Mazzaresse

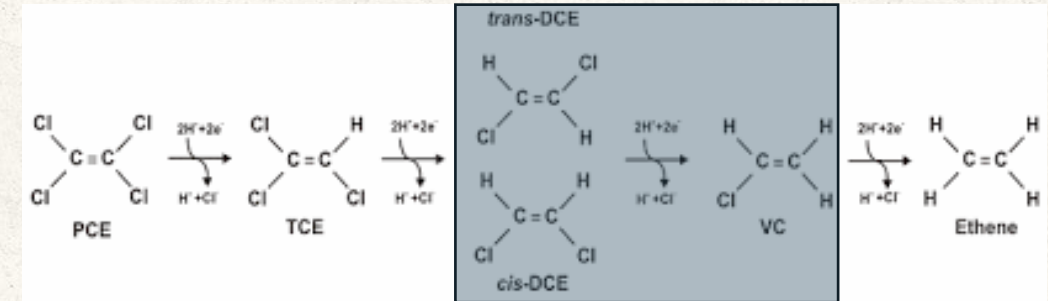
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Daughter Product Generation/Remediation

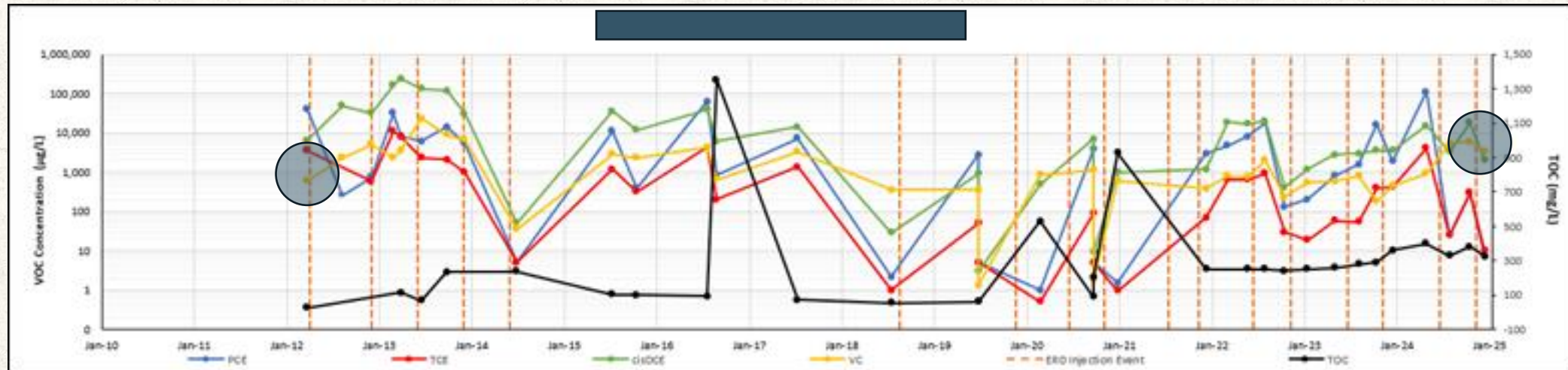
- Chlorinated volatile organic compounds (CVOCs) are common contaminants that tend to persist in the subsurface
- Daughter products are generated where an electron donor is introduced or where sufficient natural organic carbon is present in the aquifer
- For sites where either perchloroethylene (PCE) or trichloroethylene (TCE) is the parent compound, the degradation products are primarily cis-1,2-dichloroethylene (DCE) and/or vinyl chloride (VC)
- For source areas, significant daughter product concentrations can be generated and can persist for extended periods of time, even decades



Why Do They Persist?

- There are many reasons why daughter products do not degrade naturally or post-enhanced reductive dechlorination (ERD) remediation:
 - Geochemistry
 - Microbiology
 - Lack of sufficient organic carbon
 - Distribution of remedial amendment
 - Incomplete CSM
 - Poor design/capture

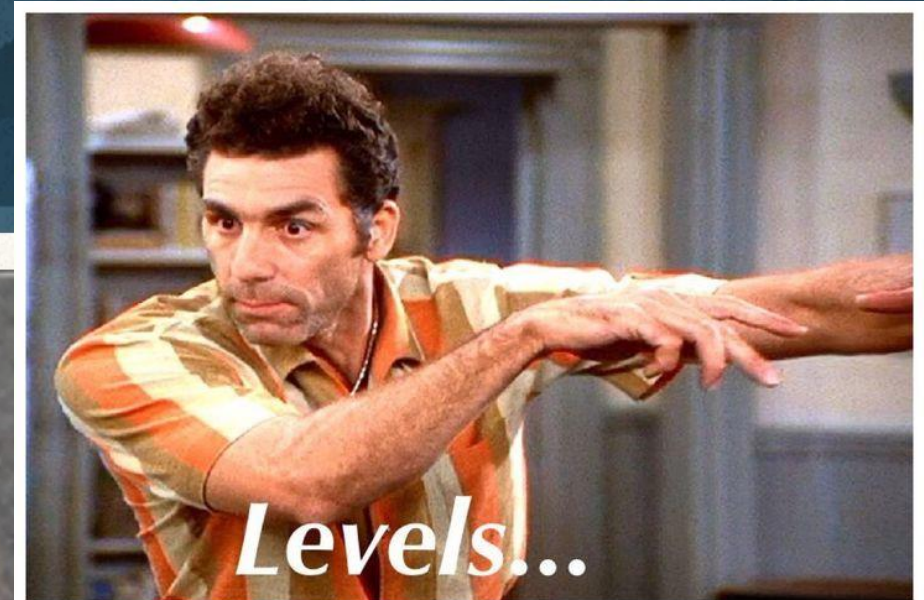
So, what's the definition of insanity?



- 17 injection events over ~13 years
- “We think there may be some mass sorbed into the clay confining unit”

Characterization options/levels

- Nature and Extent
 - Defines vertical and horizontal extent
 - Helps develop preliminary remediation plan(s)
 - Typically weighted towards groundwater
 - Limited source area saturated soil data
 - Should NOT be used for final remedial design
- High-Resolution Site Characterization (HRSC)
 - Rapid **qualitative** data collection
 - Helps to define “the box”
 - Need to understand limitations
- Remedial Design Characterization (RDC)
 - Spatially and vertically dense soil and groundwater sampling
- qHRSC
 - **Quantitative** HRSC
 - Combines all data into 3-D model(s)



Let's Dig Into Some Project Examples

- All sites to be discussed:
 - Source area treatment
 - Unconsolidated soil/weathered bedrock (example 3)
 - Shallow (<15 m) DPT slurry injection
 - Pre-injection high density sampling was performed
 - Most had some level of microbiological assessment work performed
 - Abiotic degradation PRB downgradient of treatment area(s) => Important to consider

Technology Highlights

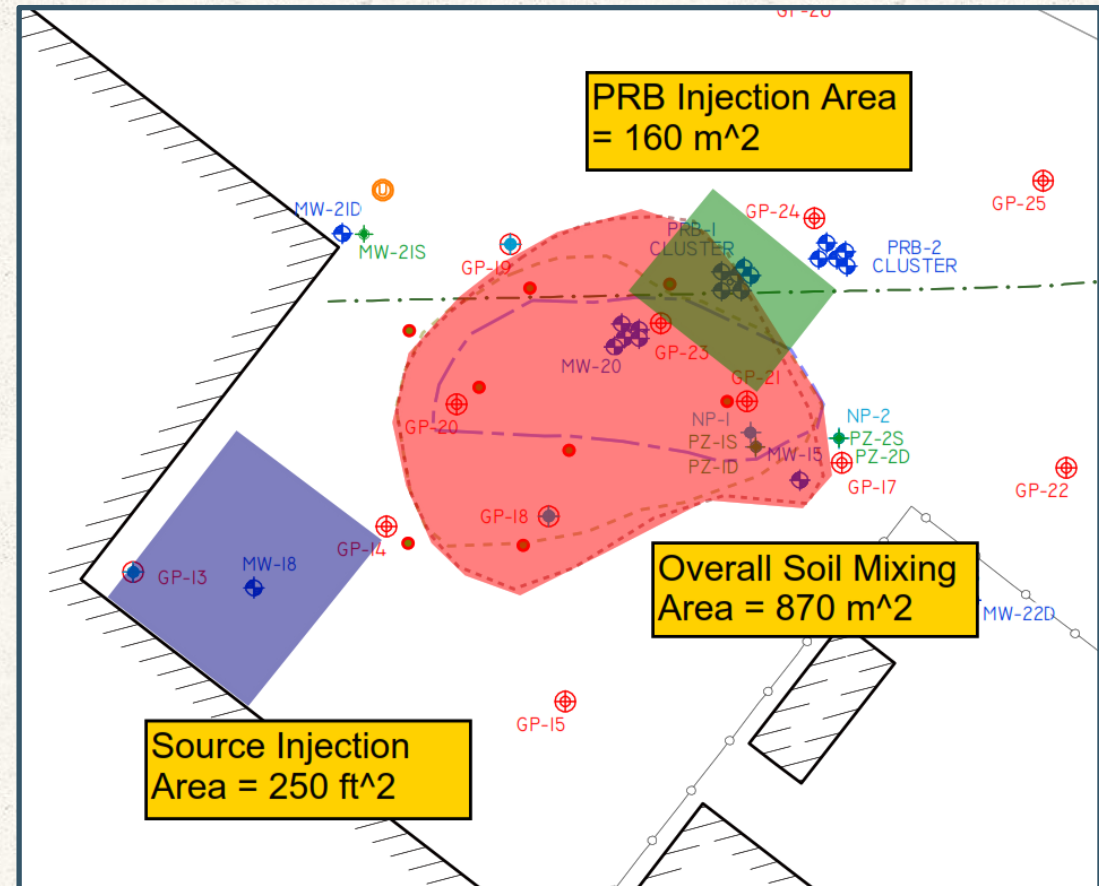
- Key Elements
 - Granular activated carbon (GAC) impregnated with metallic iron (abiotic degradation)
 - Electron donor – food grade starch or chitin
 - One set of microorganisms designed to degrade CVOCs
 - Second set of microorganisms designed to break down the electron donor
 - Nutrients (yeast extract or pea fiber)
 - Quantities of “ingredients” are tailored for each project site

Project Sites We Are Going to Review

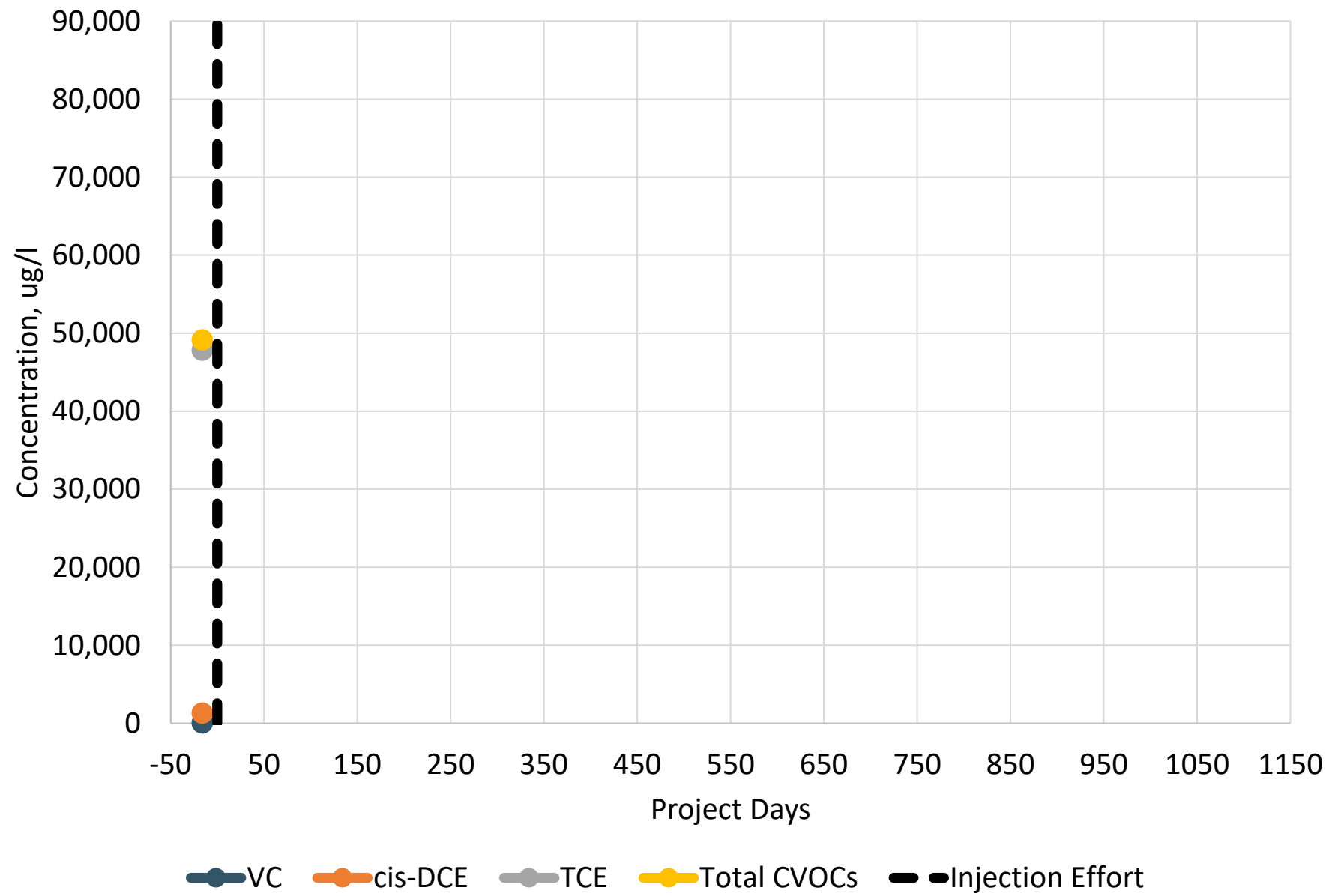
- #1. Elevated parent compounds relative to daughter concentrations
 - Sites with no natural dechlorination or ERD
- #2. Elevated daughter concentrations relative to parent
 - Sites with natural degradation or ERD performed
- #3. Large site with elevated concentrations of both parent and daughter products
 - This site highlights the importance of the high-density sampling

Site #1 - Source Area Application

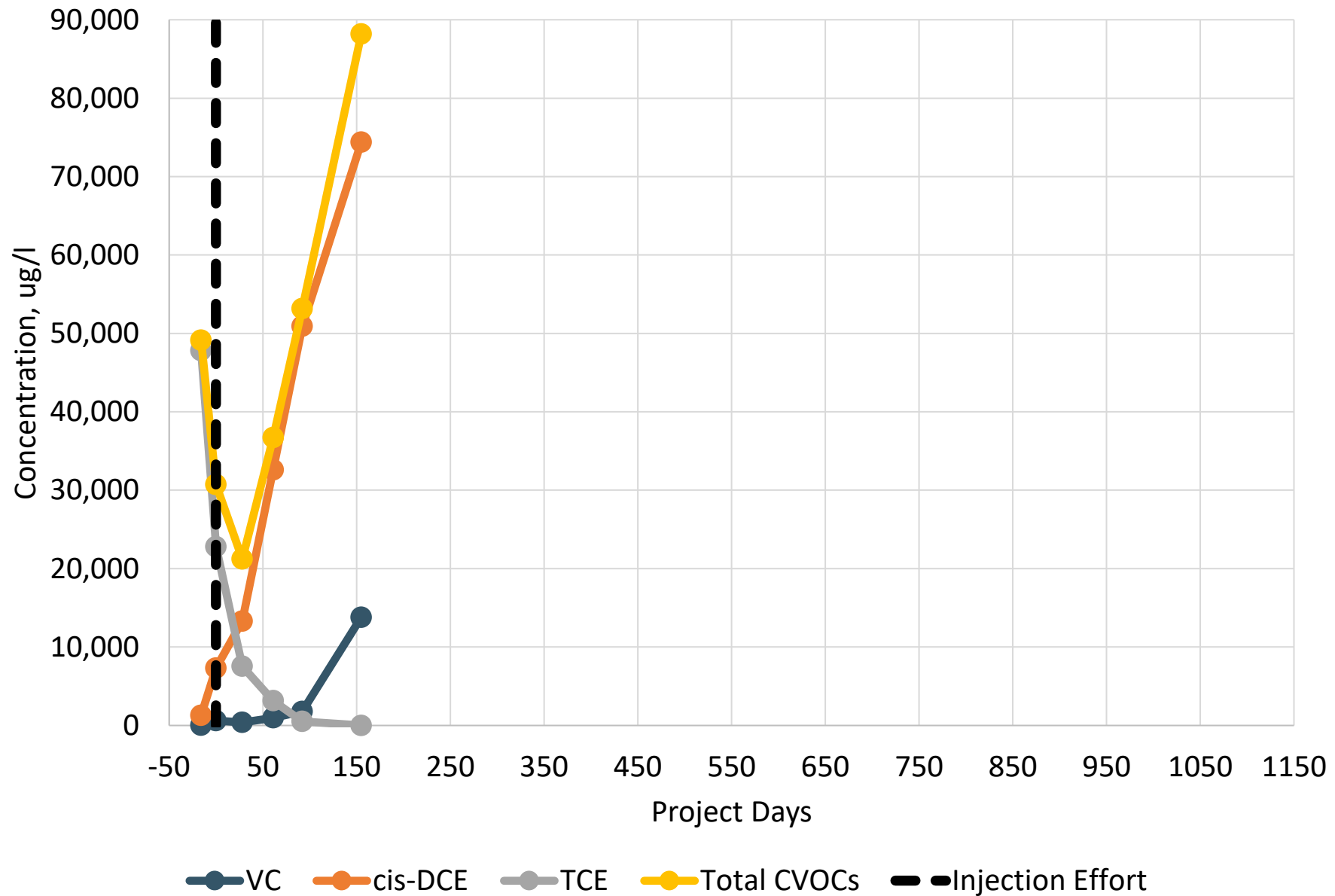
- Example of site with mostly parent compounds at baseline
- April 2020 Installation
- 3,000 kg of product was applied in a 250 m² area from a depth of 2.5 m to 9 m bgs.
- 69 points on 1.8 m centers
- Part of a combined remedy (ISCO and abiotic technology also applied)



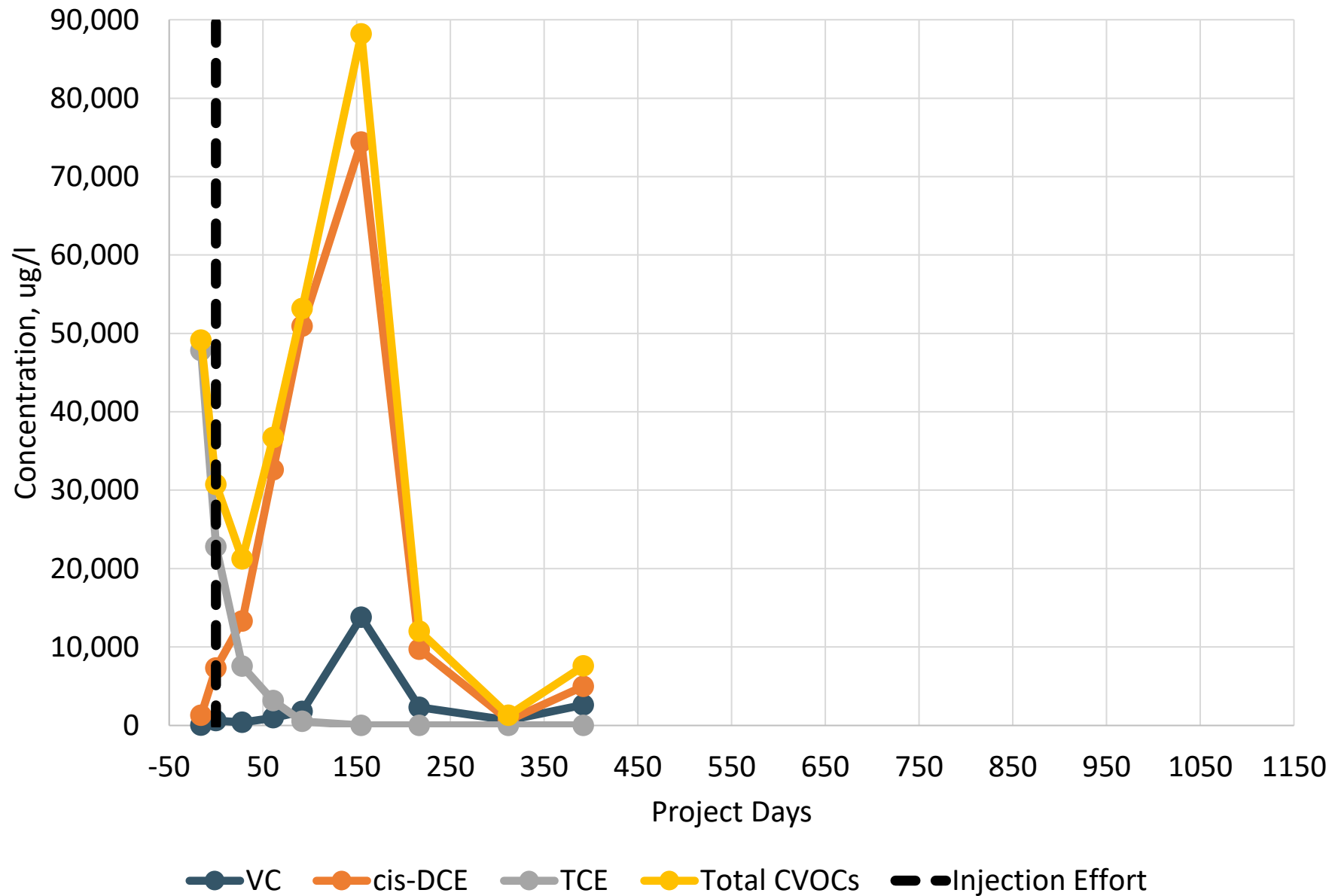
Source Area Concentrations v. Time (Baseline)



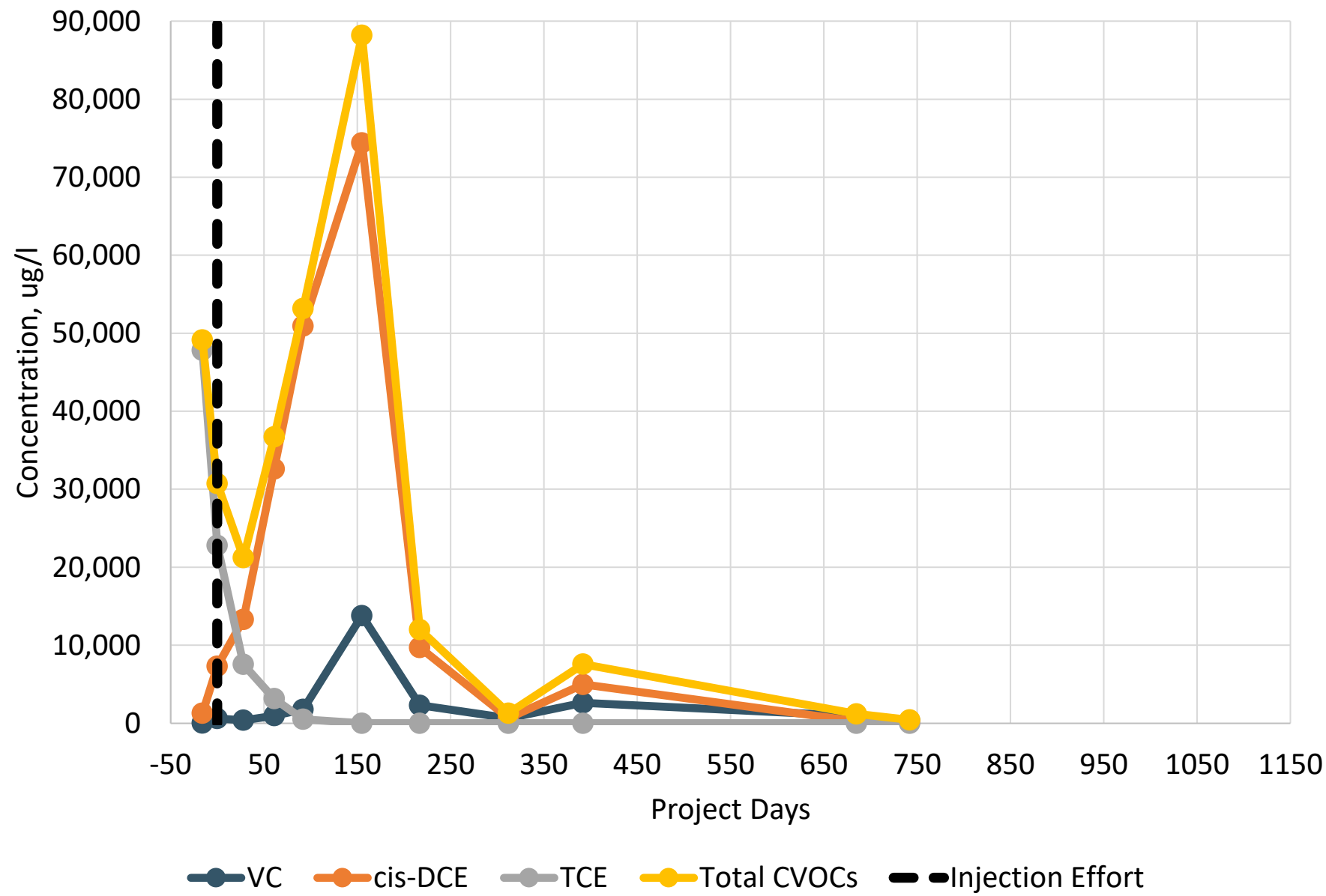
Source Area Concentrations v. Time (~0.5 Yr)



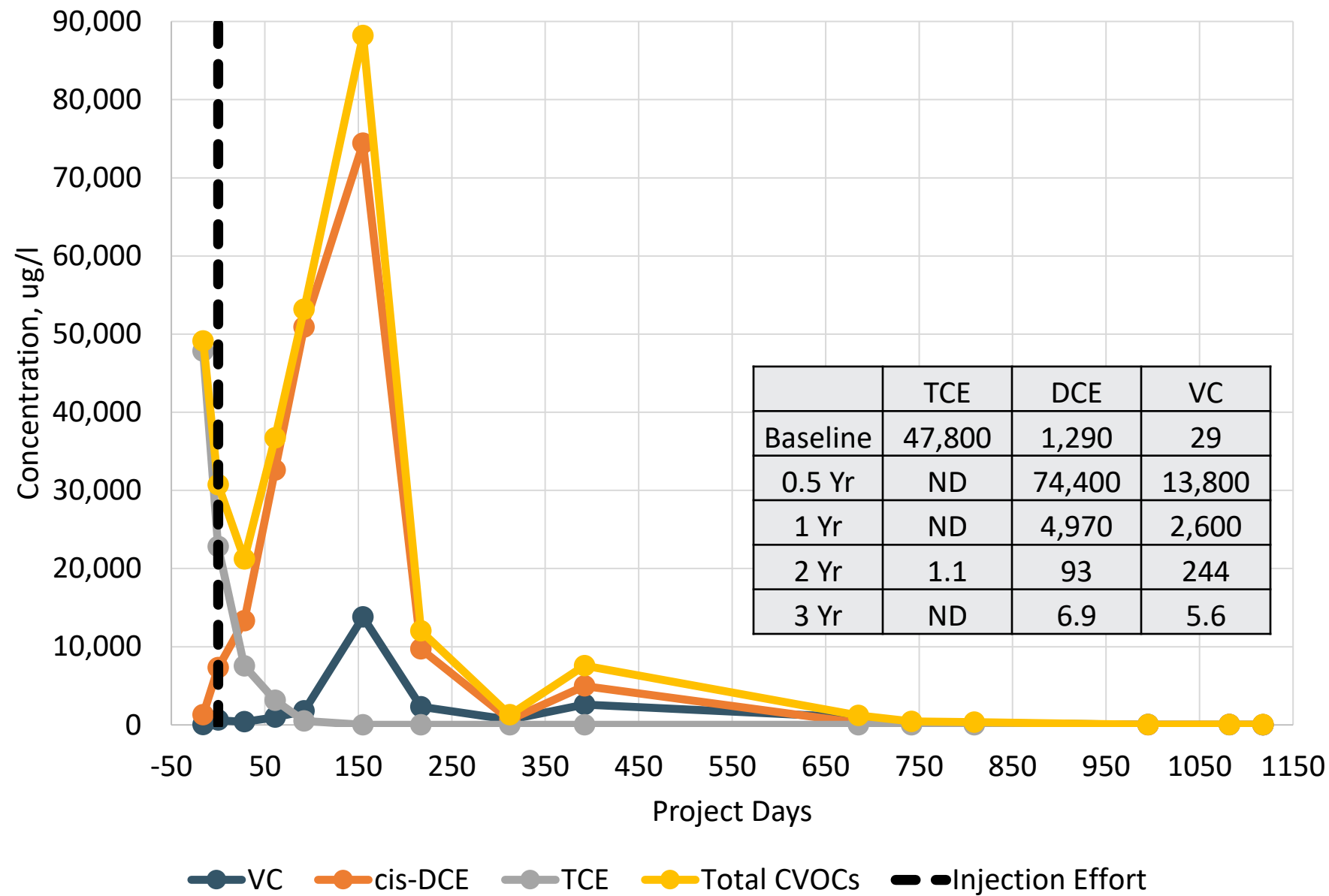
Source Area Concentrations v. Time (~1 Yr)



Source Area Concentrations v. Time (~ 2 Yr)



Source Area Concentrations v. Time (~3 Yr)



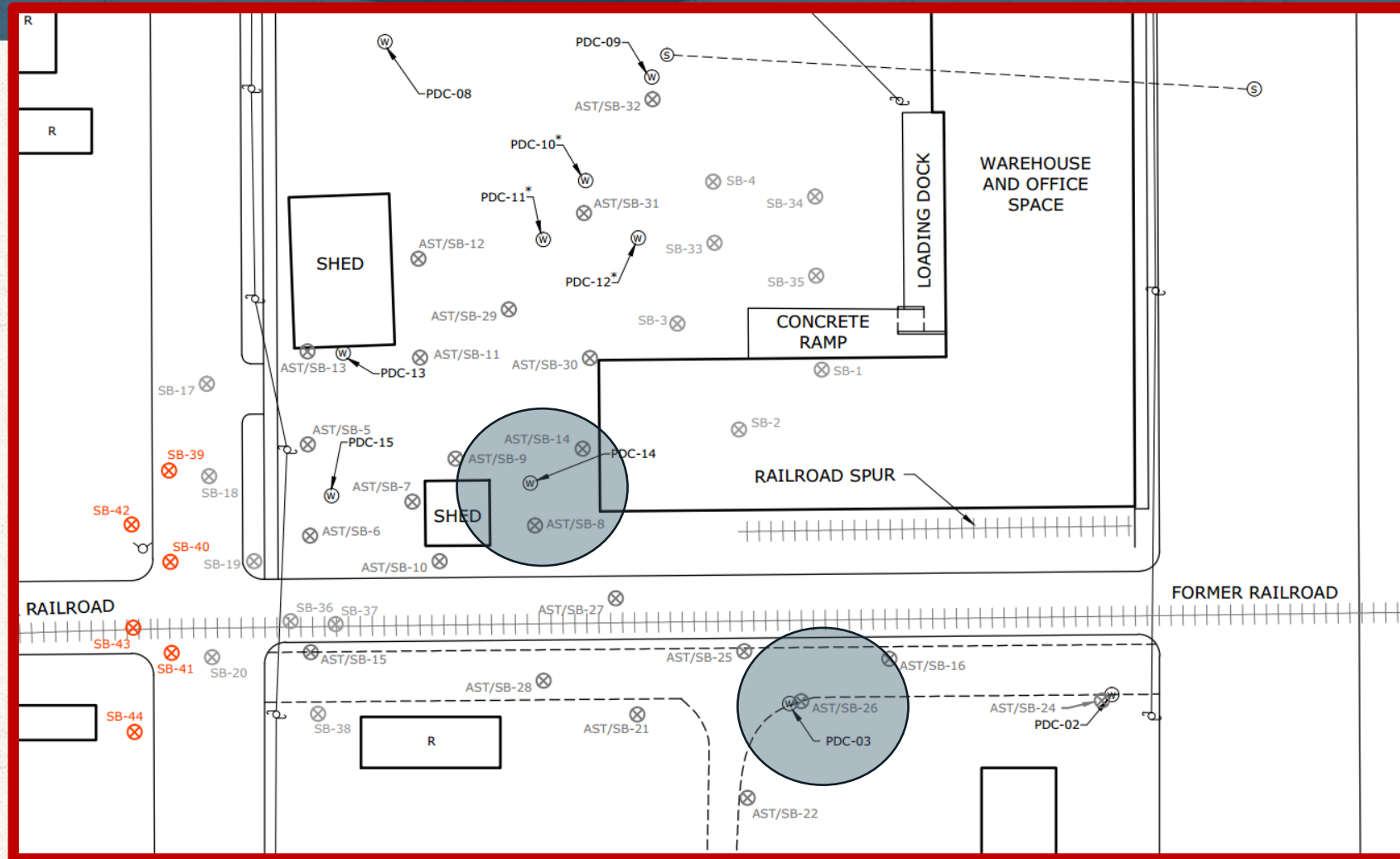


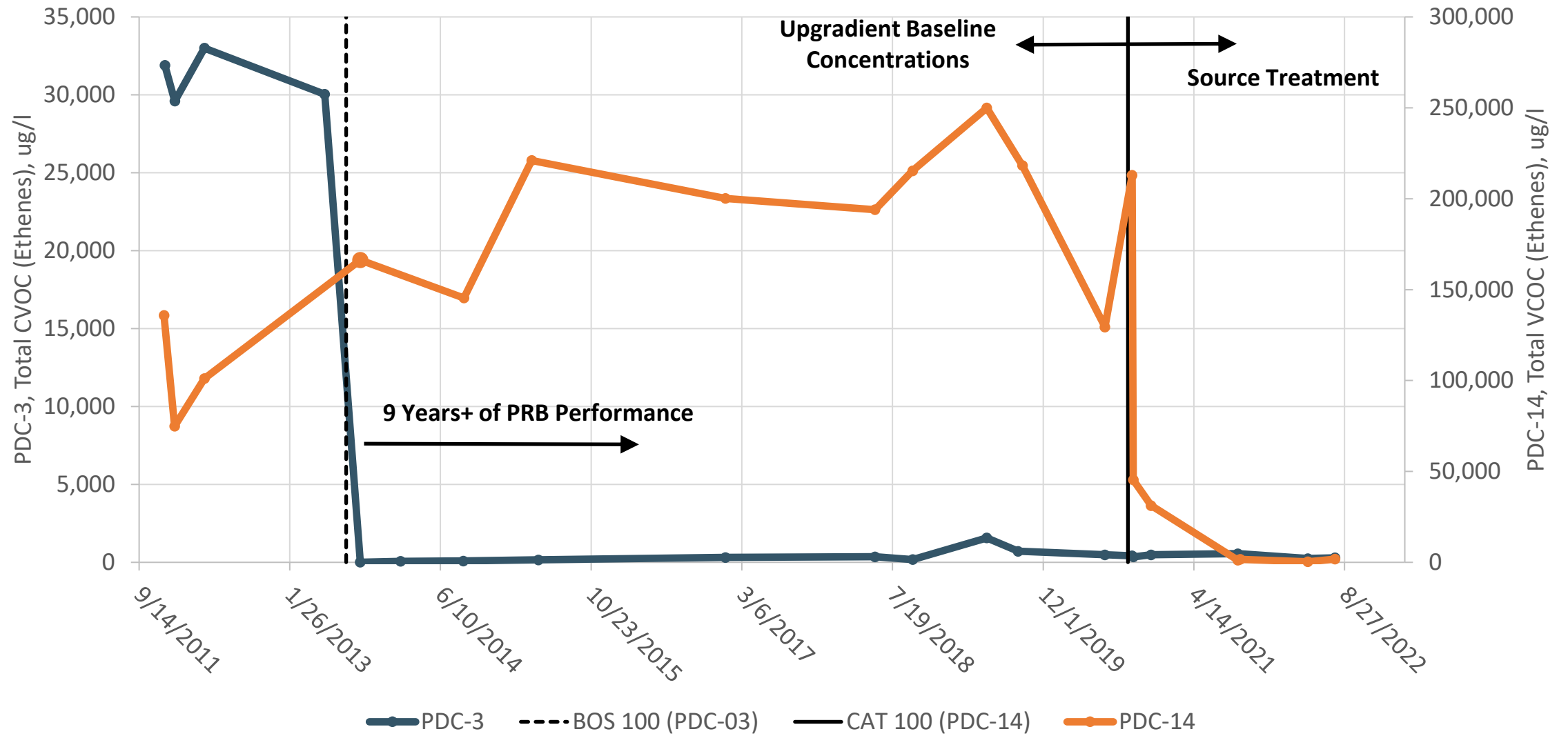
Site #2 – Source Area Application

- Example of site with elevated daughter products at baseline
- Part of multiyear phased approach (ISCO and abiotic technology also applied)
- September 2020 Application

Remedial Design Characterization (RDC), 2011 thru 2013

- Forty-four (44) soil borings
- Nested wells at each soil boring location
 - Shallow and deep groundwater assessment
- Full monitoring network sampling
- Samples run pro bono at our lab in Denver





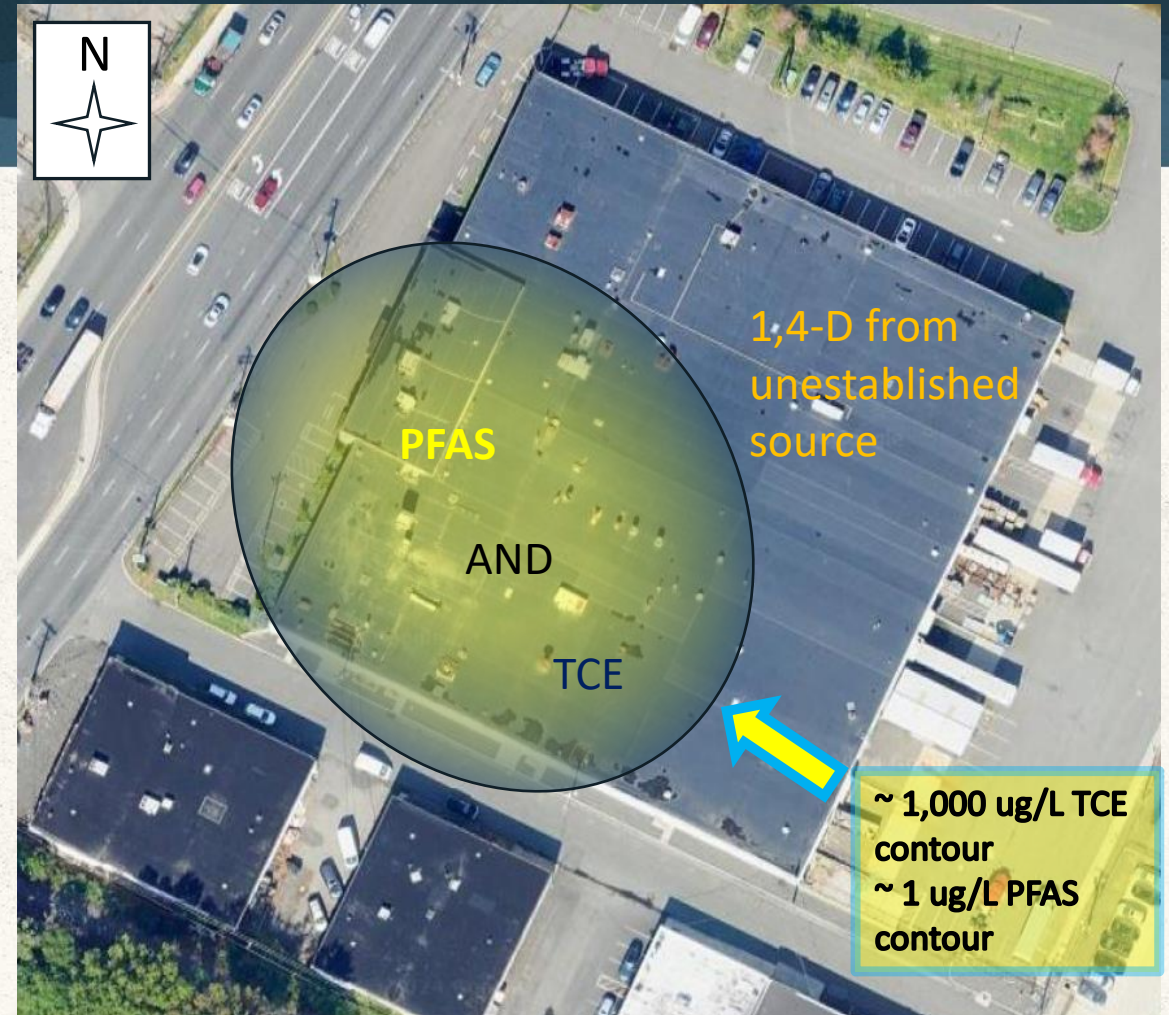
	PCE	TCE	DCE	VC
Baseline	30,800	27,500	144,000	10,700
1 Yr	ND	ND	653	540
2 Yr	ND	ND	123	231

Site #3 – Source Area Application

- Example of large site with elevated parent and daughter products
- RDC and 3-D modeling were critical to CSM development
- Due to DPT refusal (weathered bedrock), modified DPT approach using sonic pre-drilling was used
- Fall 2023 application

Project Site Details

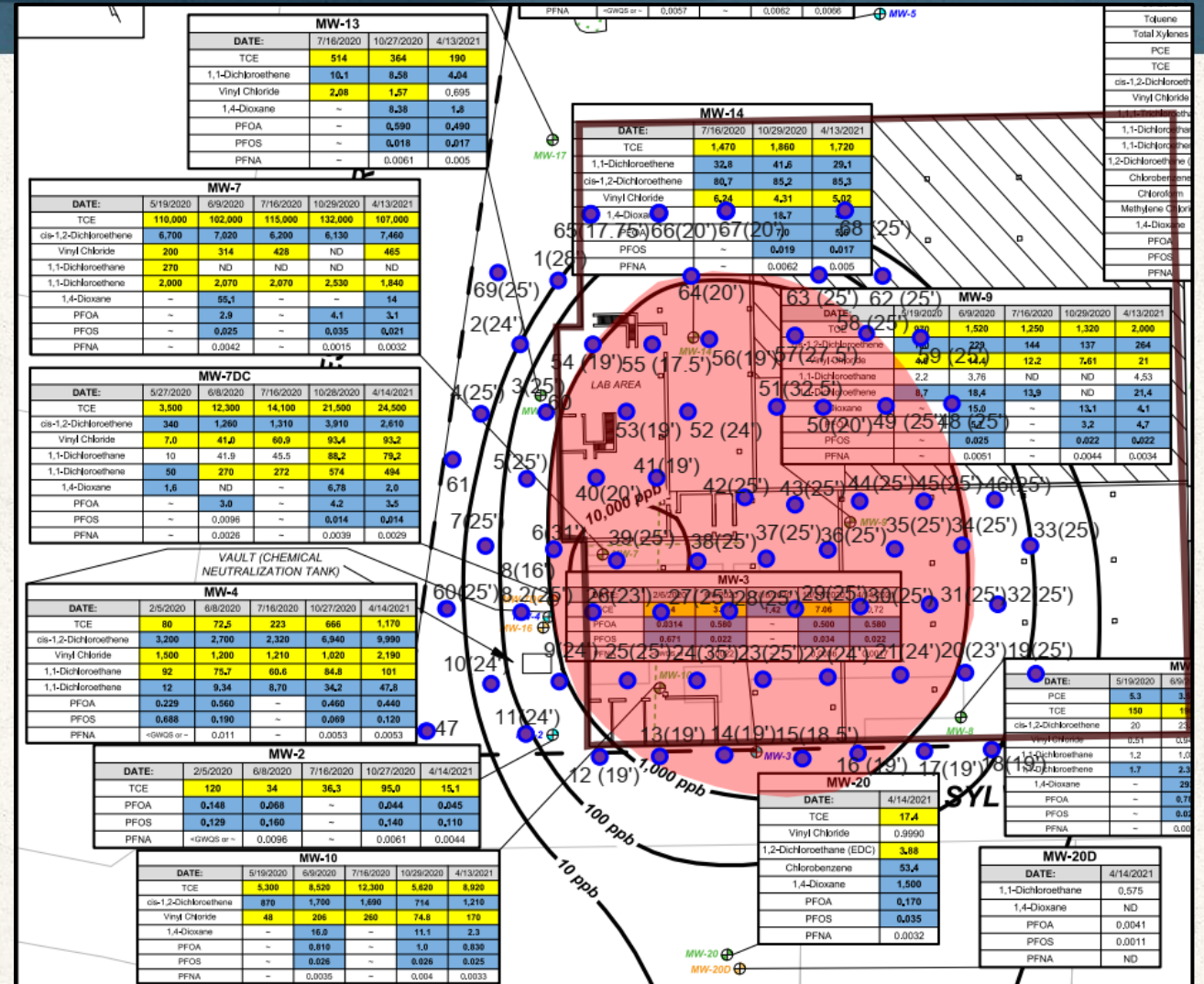
- 7,400 square-meter building
- >4,000 square meters of underlying soil and groundwater contaminated
- Comingled plumes of onsite- and offsite-derived chlorinated VOCs, PFAS, and 1,4-Dioxane
- >100 mg/L TCE in overburden groundwater



Former manufacturing plant, New Jersey

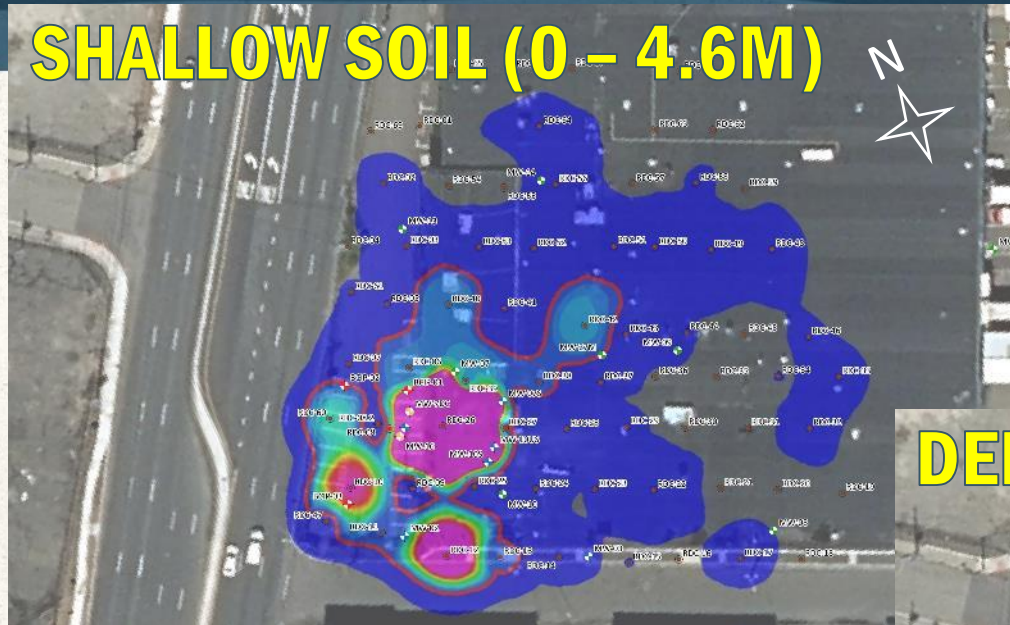
Remedial Design Characterization (RDC)

- Shallow Overburden (0 to ~7.6 m)
 - 69 Soil Borings - 623 samples
 - 124 temporary monitoring wells
 - 13 groundwater permanent monitoring well samples
- Intermediate/Weathered Bedrock (7.6 to ~12 m)
 - Six Sonic Borings
 - 43 soil and rock samples
 - 6 groundwater samples
- Soundings (3230 Geoprobe*)
 - 10 borings (average depth of 10 m bgs)



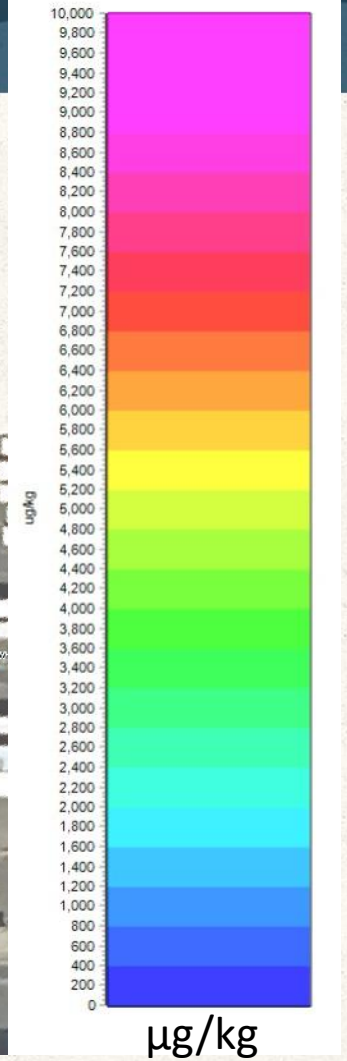
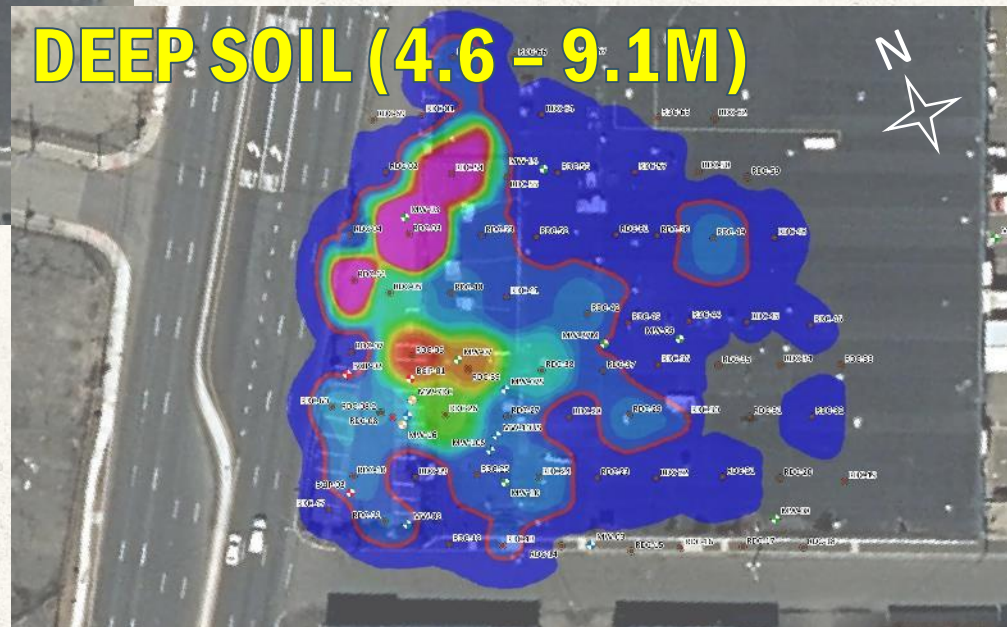
RDC Results

SHALLOW SOIL (0 – 4.6M)



**TCE DETECTED AT
UP TO
179,000 $\mu\text{g}/\text{kg}$**

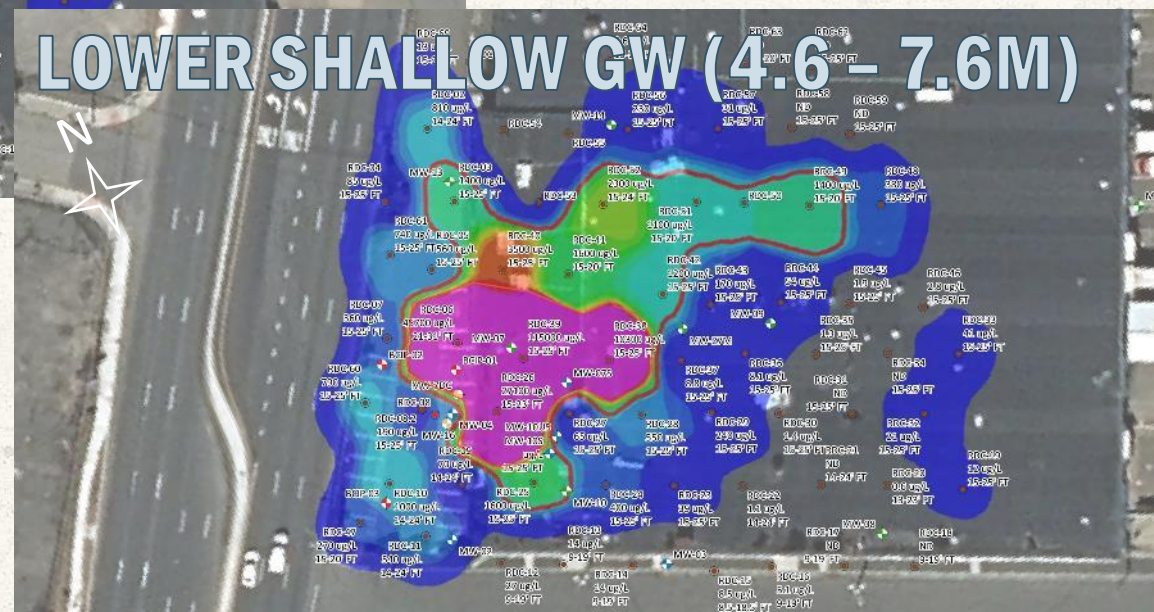
DEEP SOIL (4.6 – 9.1M)



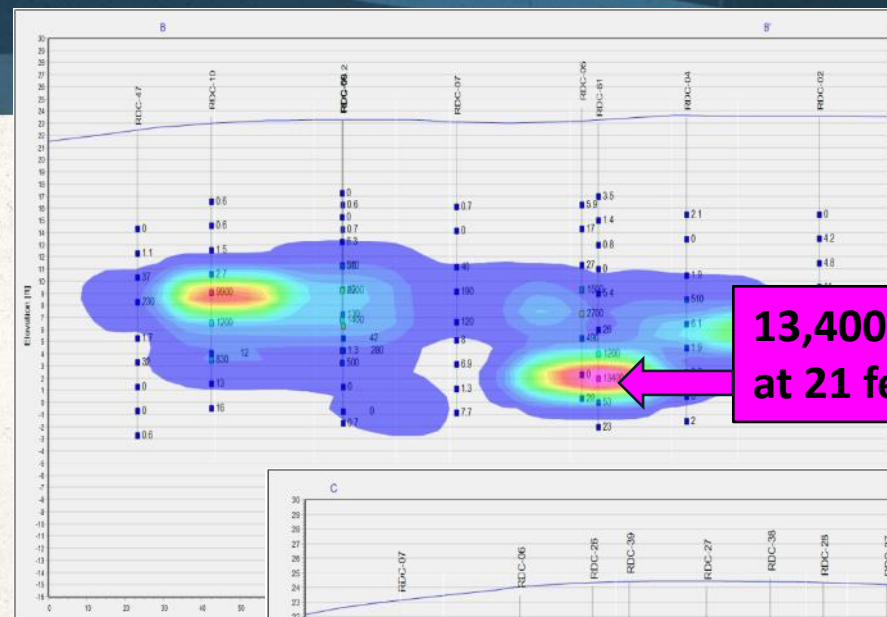
RDC Results



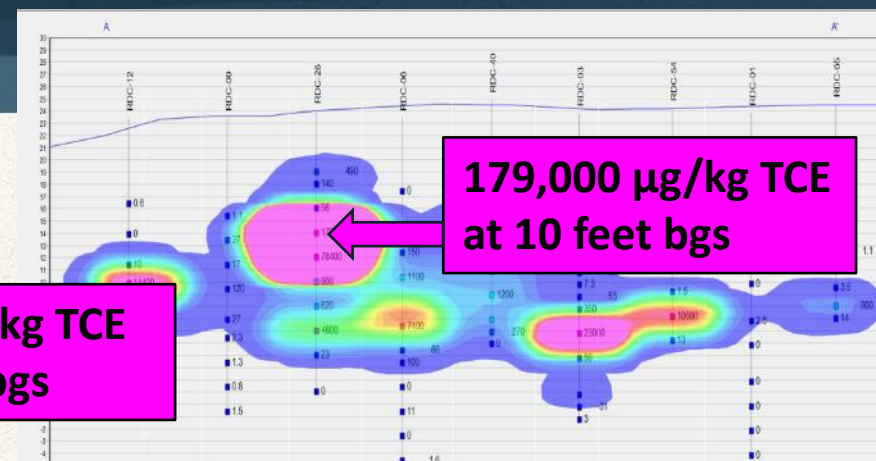
**TCE DETECTED AT
UP TO
136,000 $\mu\text{g/L}$**



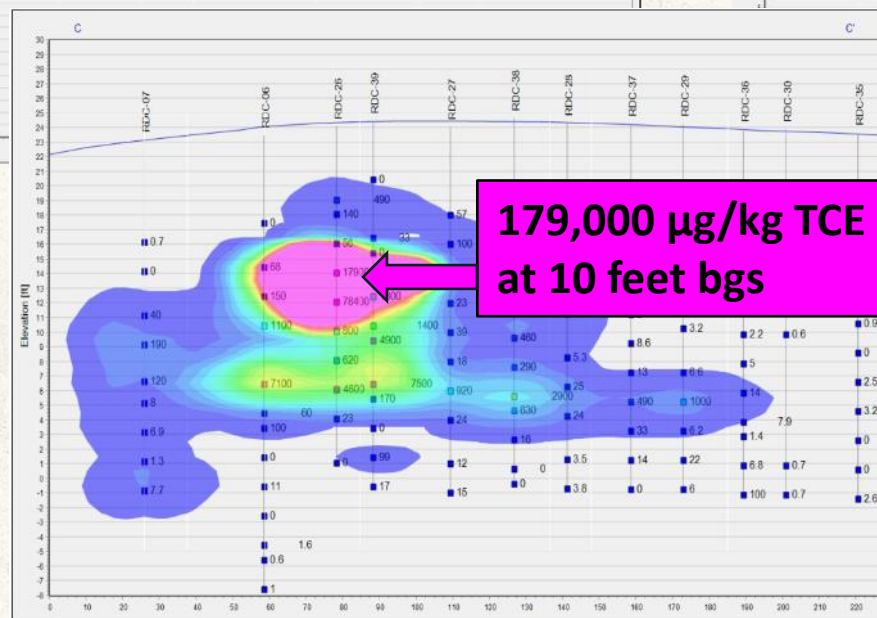
RDC Results



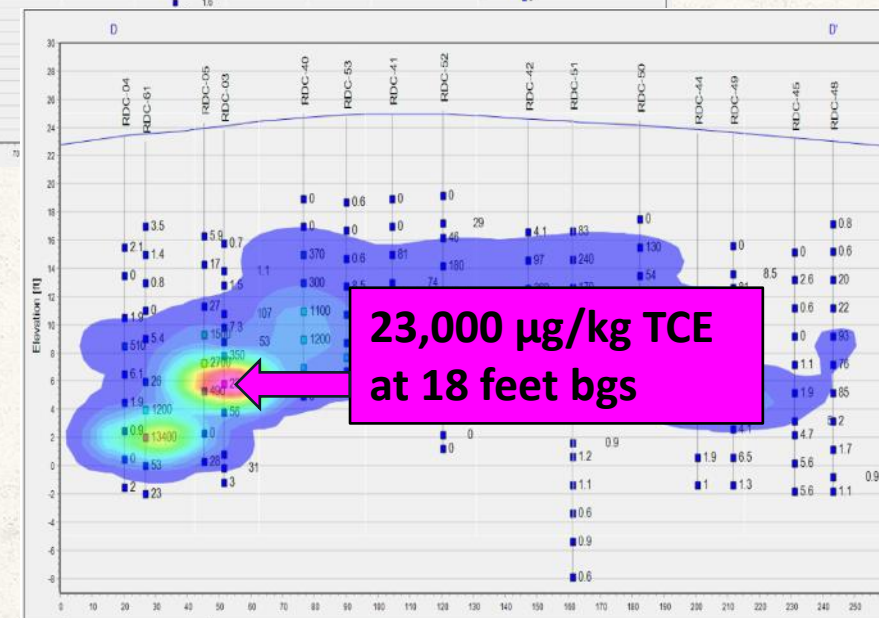
13,400 µg/kg TCE
at 21 feet bgs



179,000 µg/kg TCE
at 10 feet bgs



179,000 µg/kg TCE
at 10 feet bgs



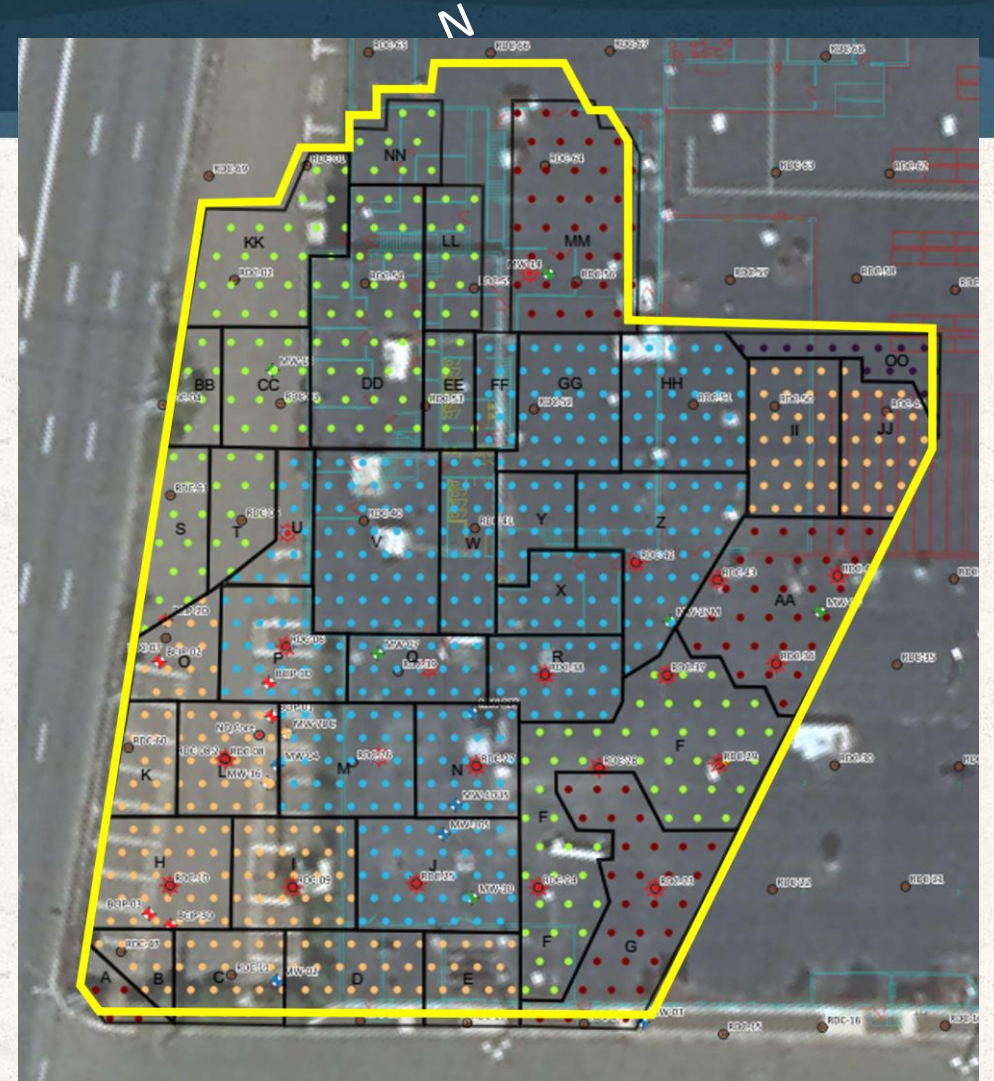
23,000 µg/kg TCE
at 18 feet bgs

SOIL

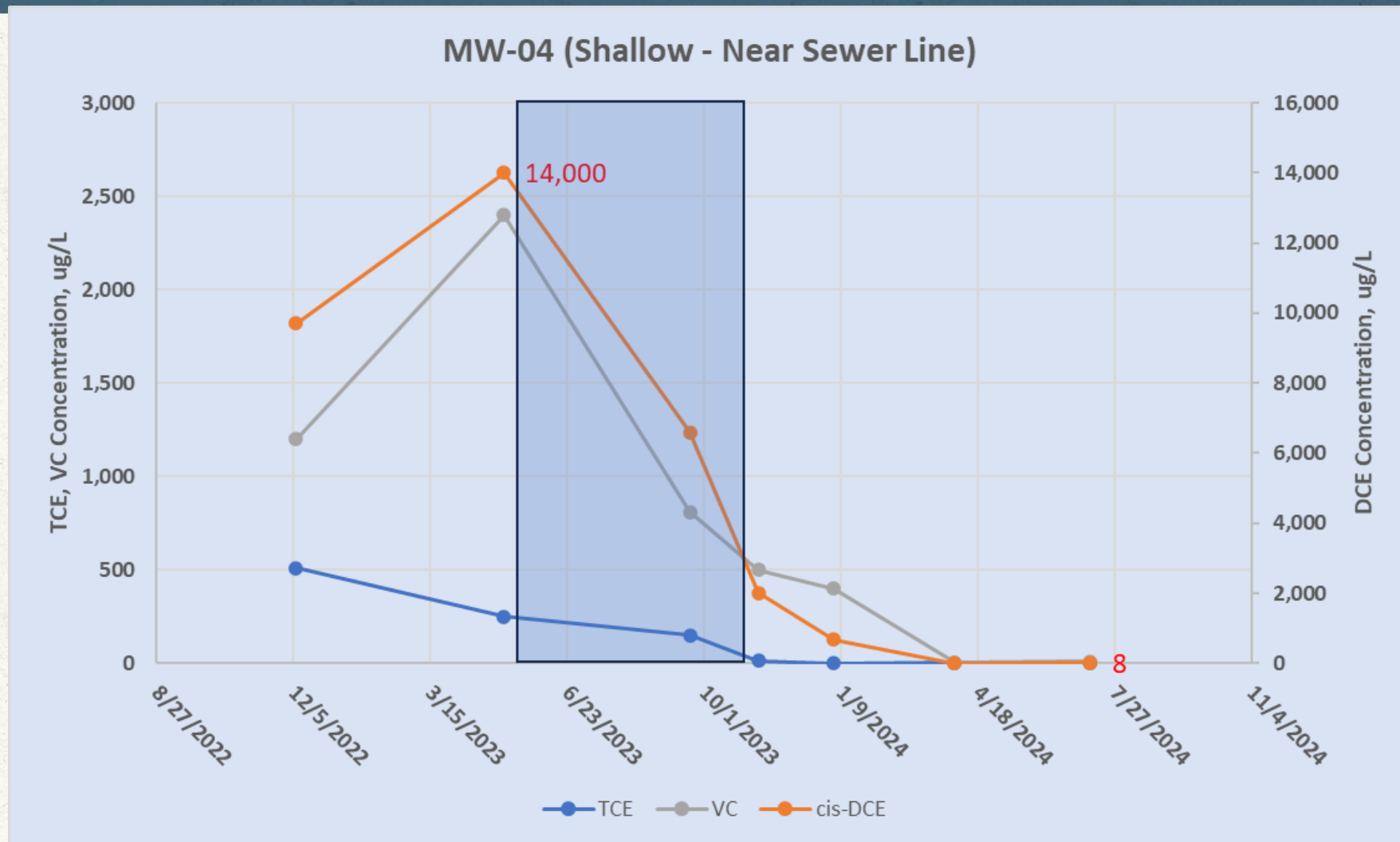
SOIL

Full-scale Implementation

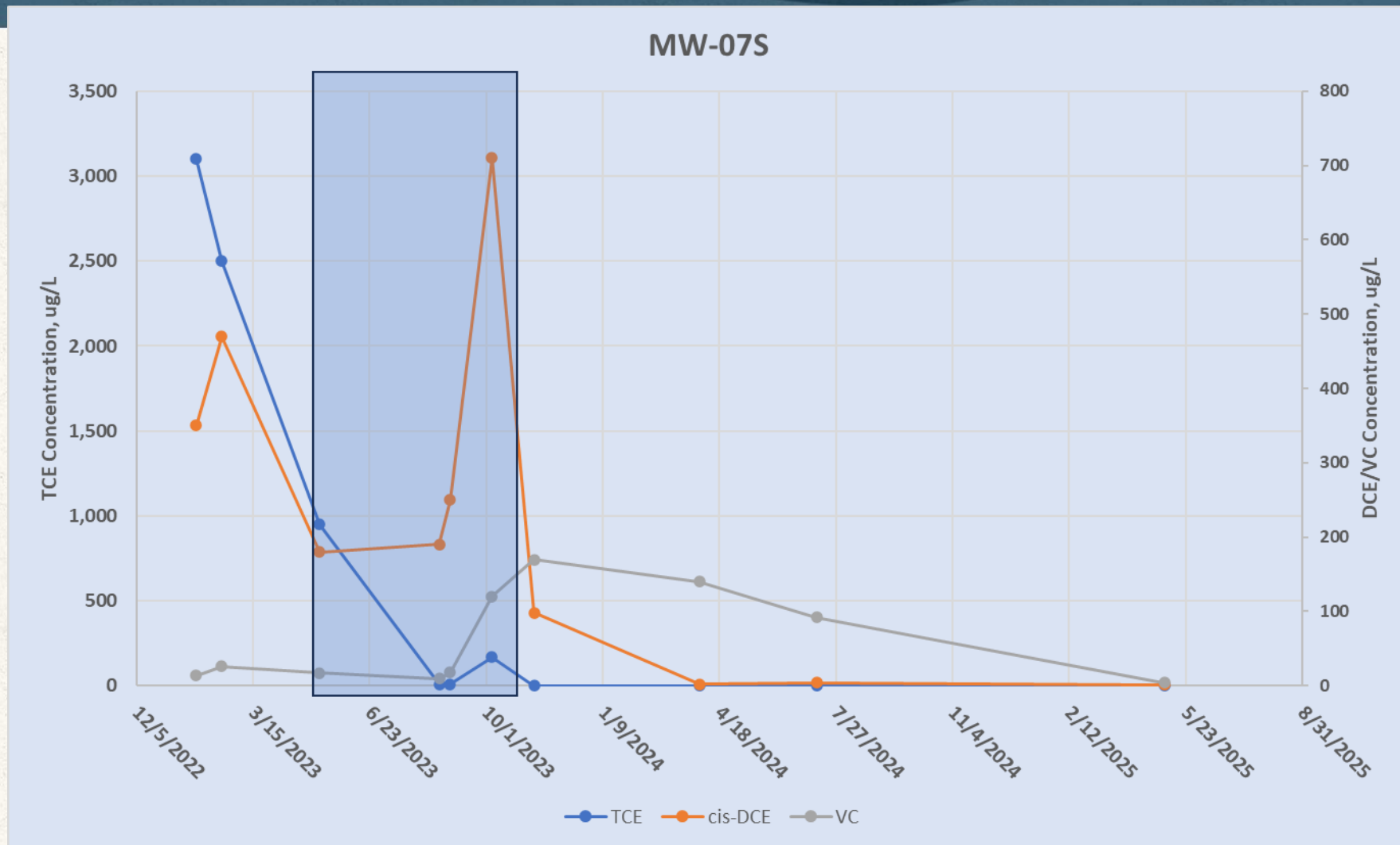
- Direct Push Injections
 - Number of Injection Points: 873
- Pre-drill Injections
 - Number of Injection Points: 20



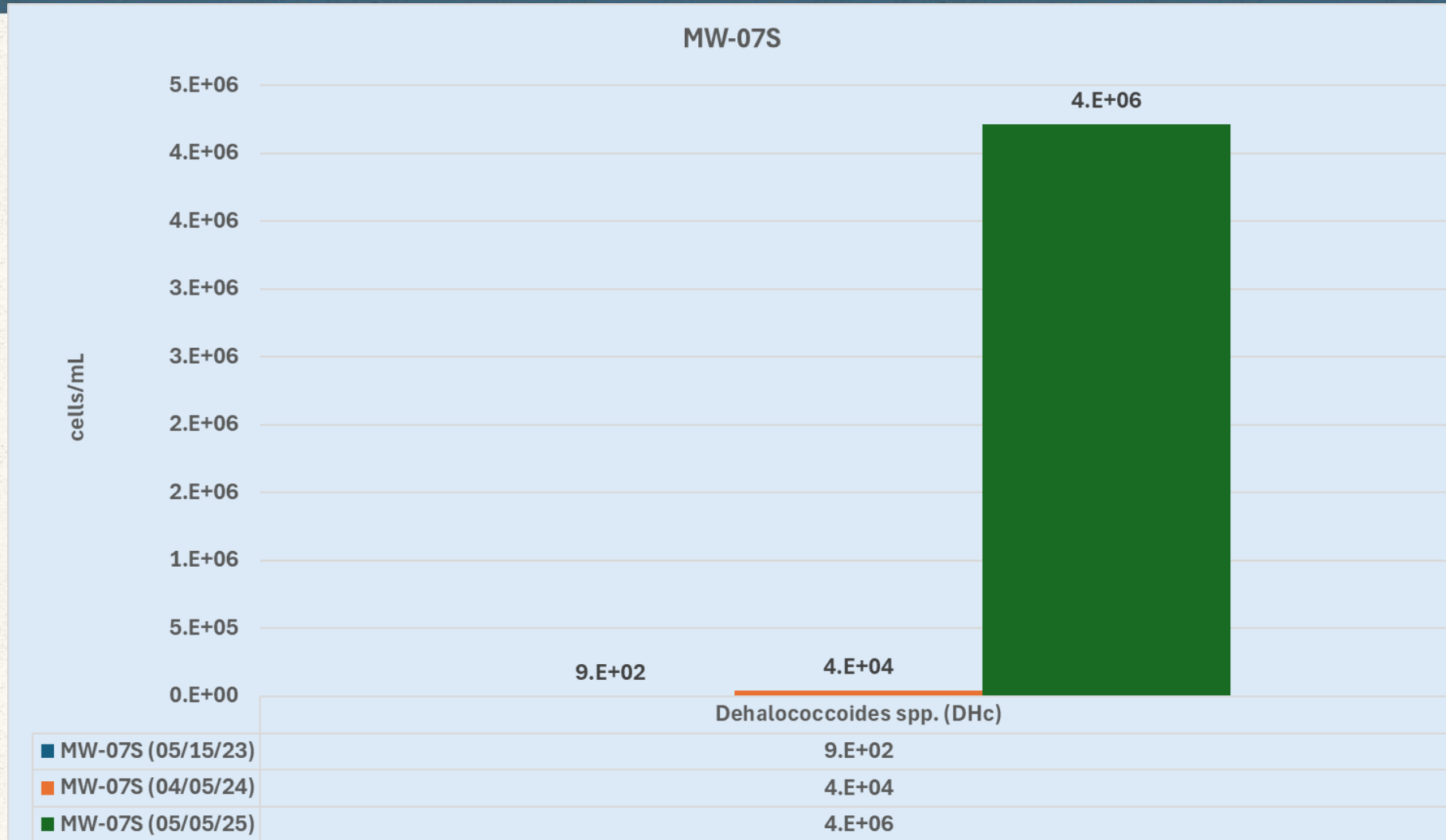
Data Evaluation – Shallow Zone CVOCs

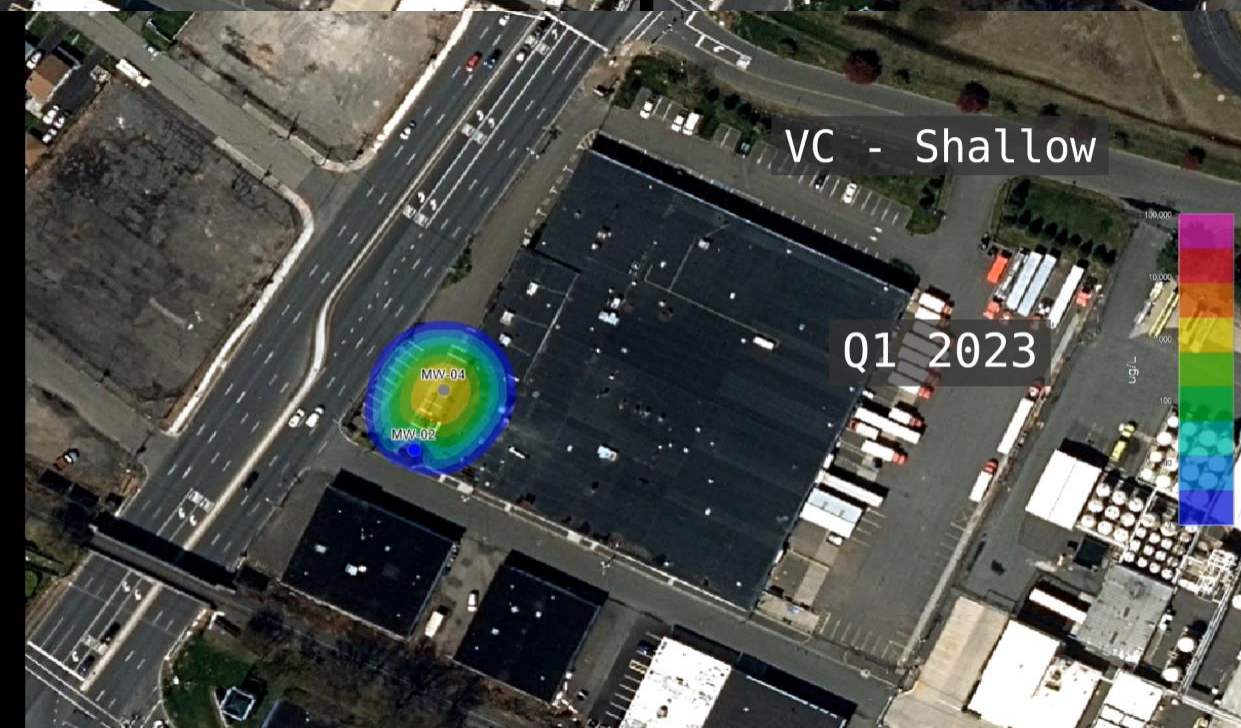
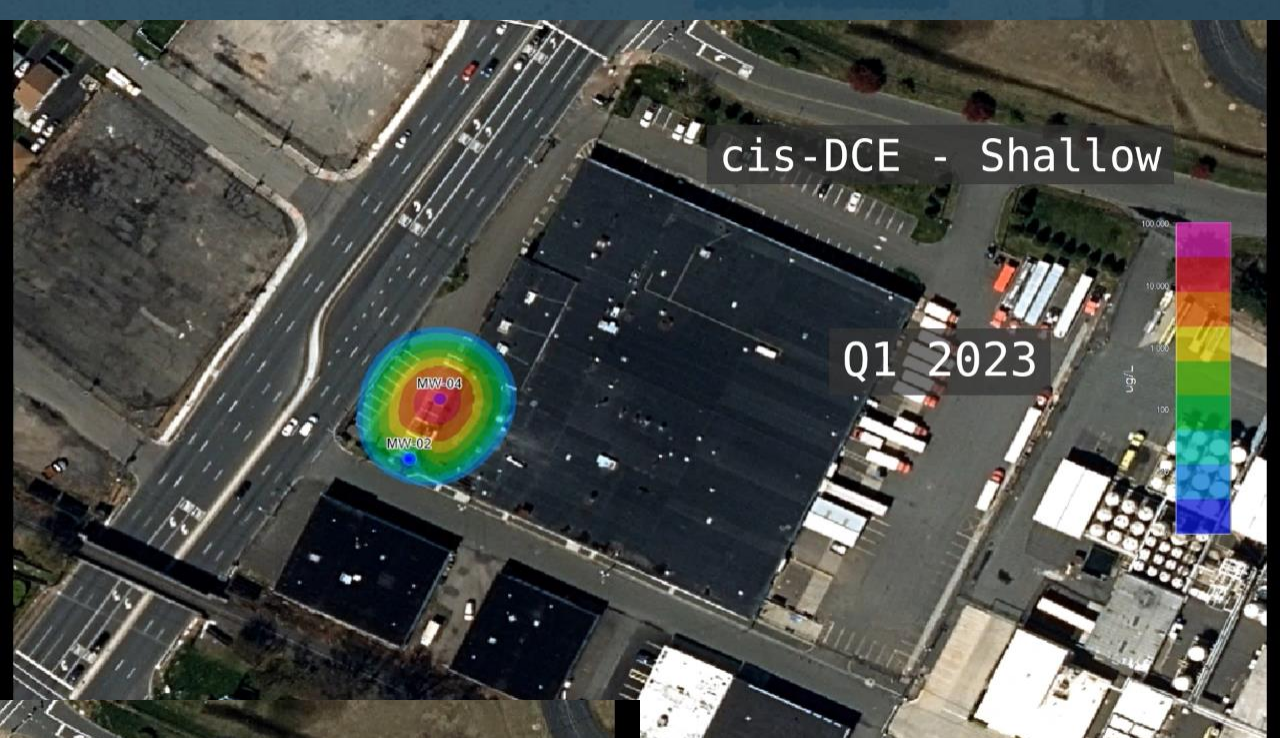
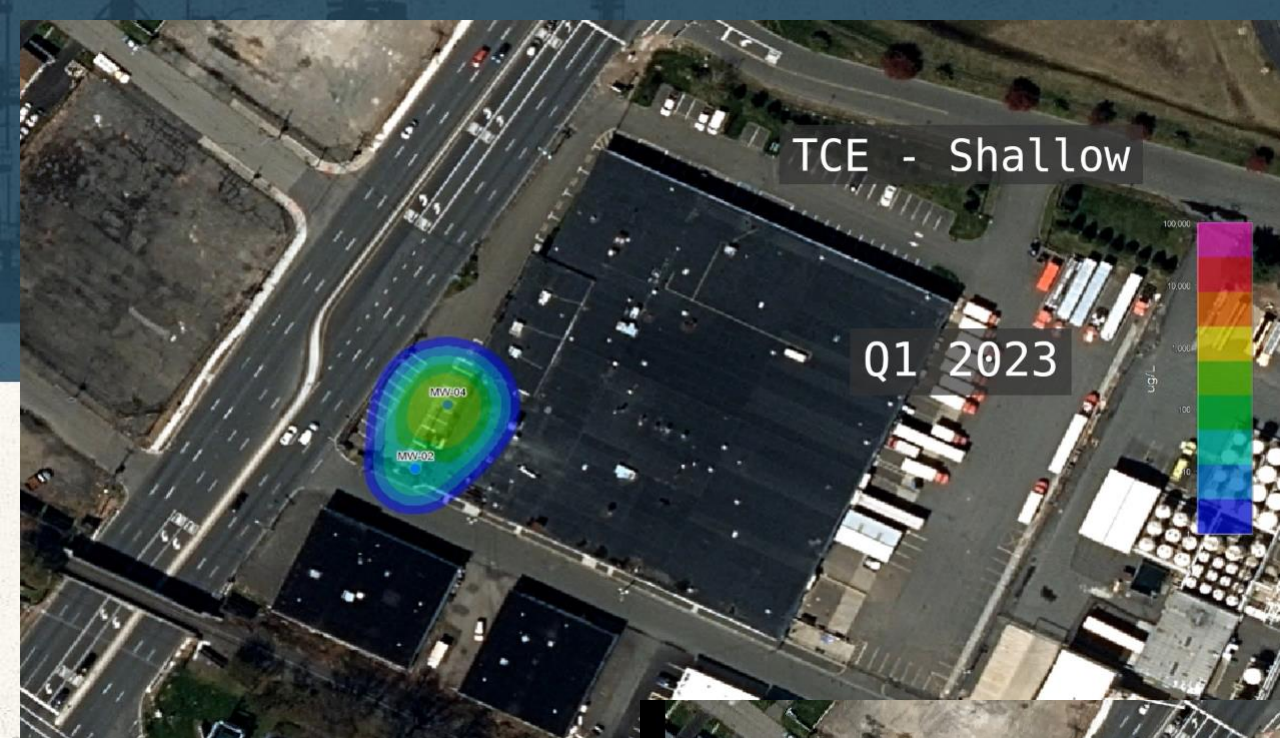


Data Evaluation – Shallow Zone CVOCs



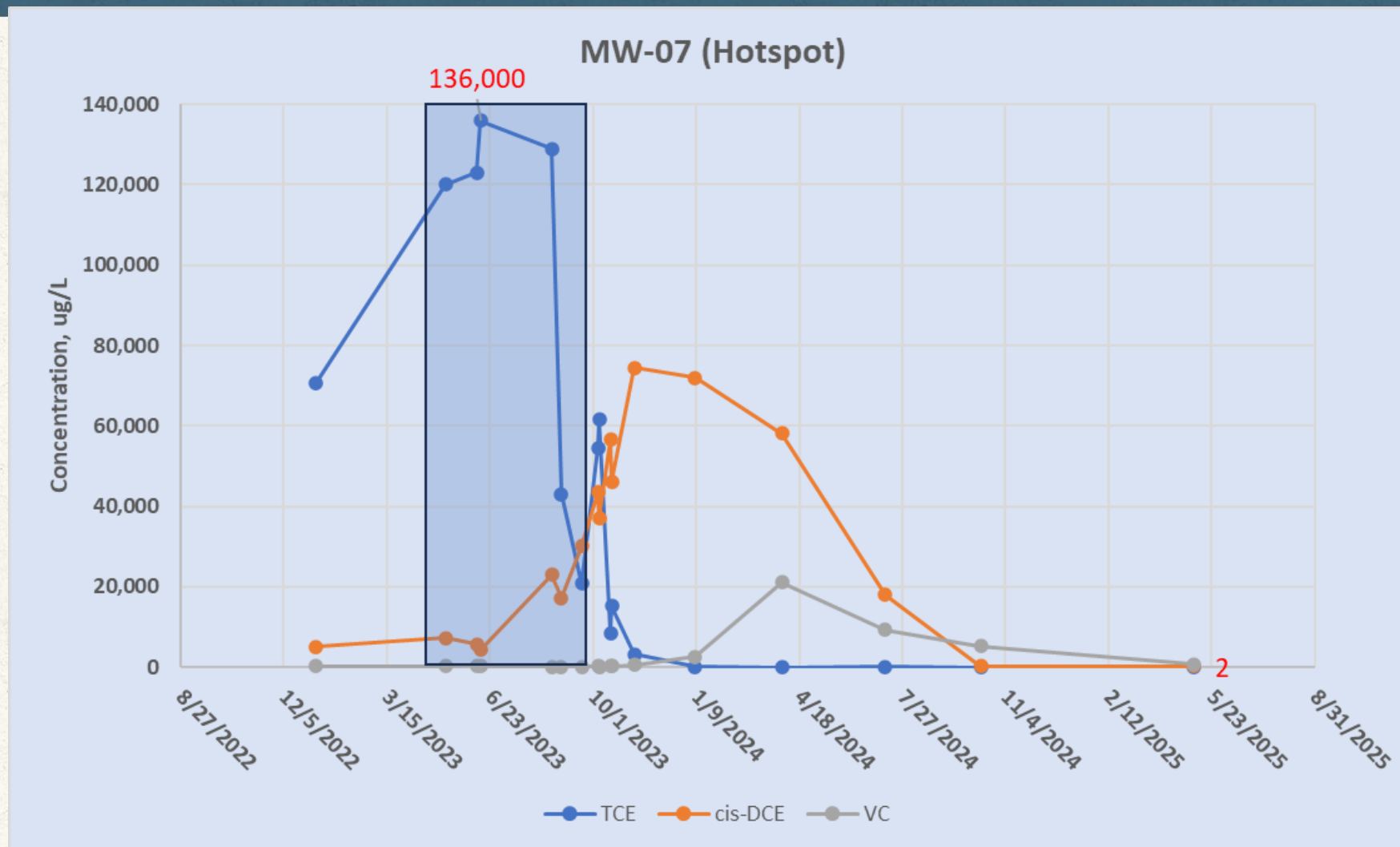
Data Evaluation – DHC Population

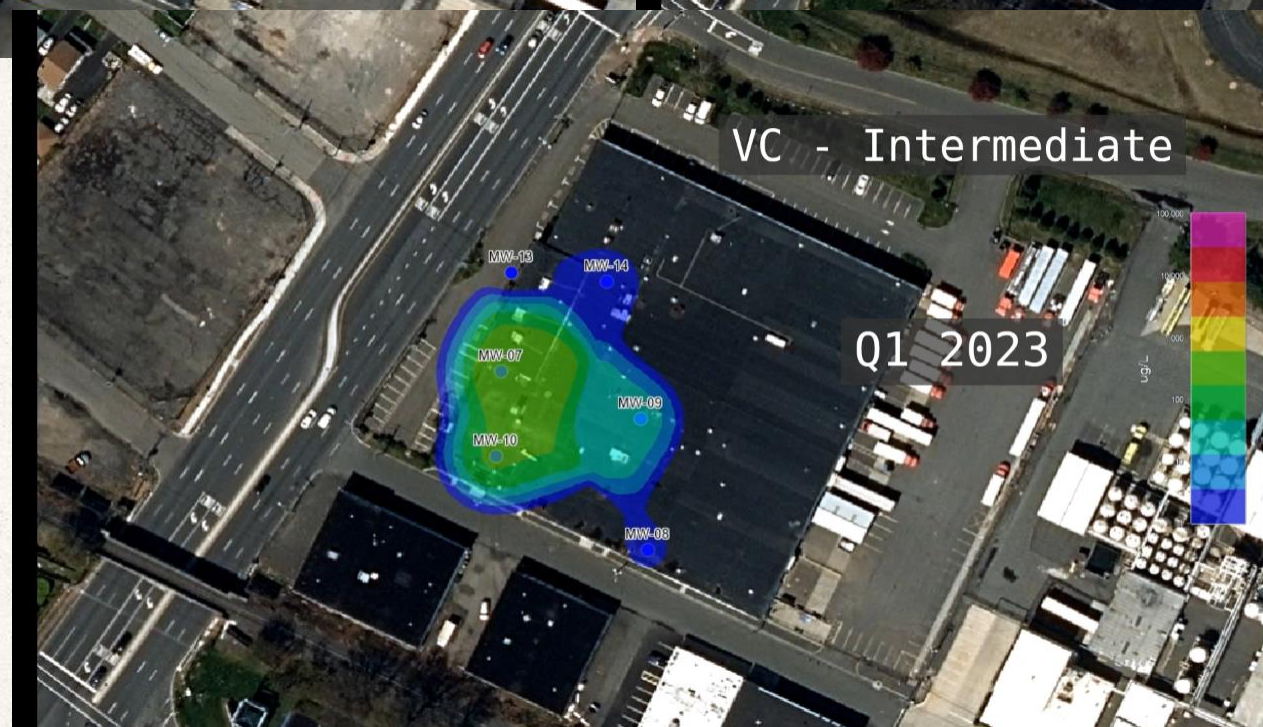
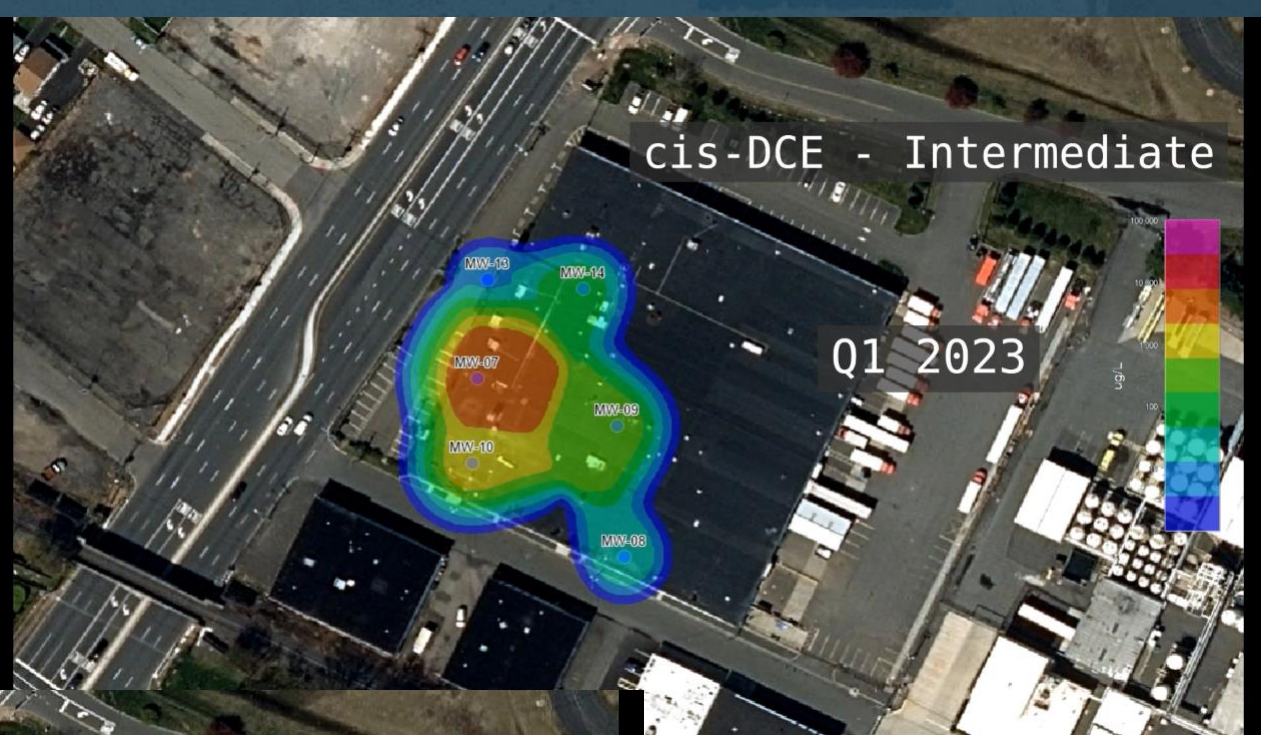
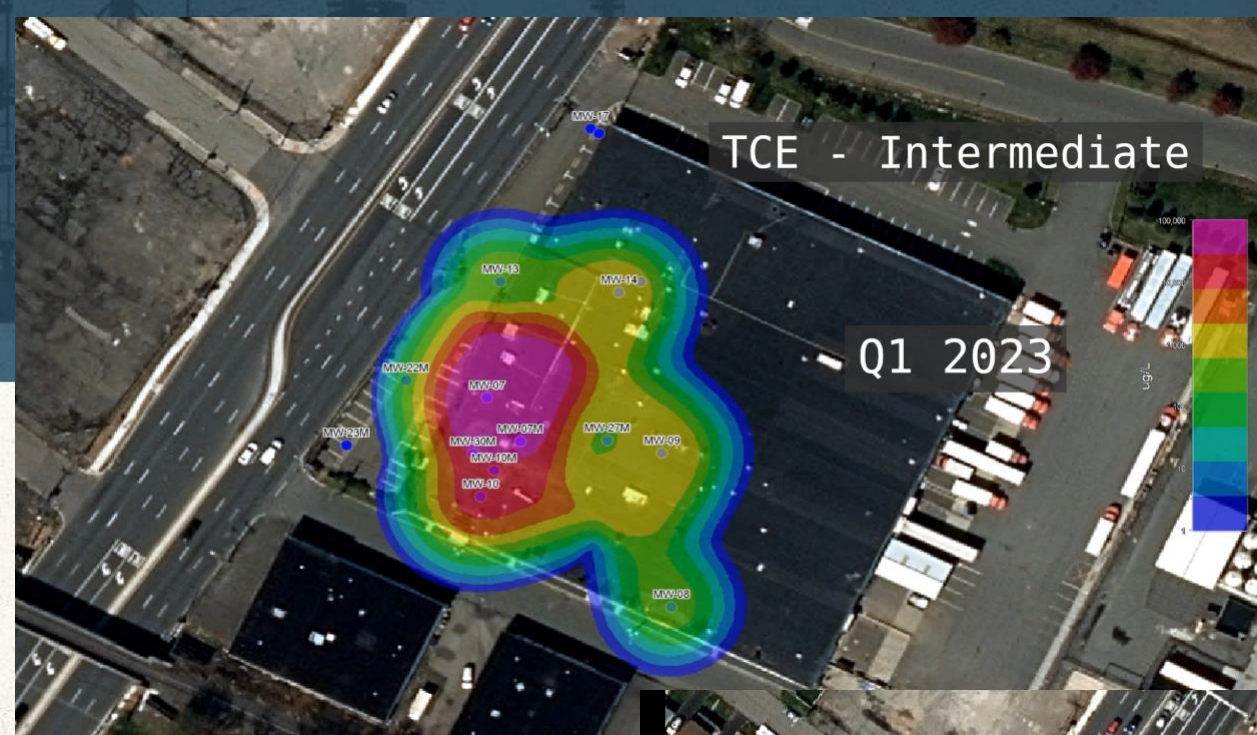




Apr 2
Post

Data Evaluation – Intermediate Zone







Summary

- Success starts with the RDC and accurate CSM
 - Guides dosing and expectations
- Application of synergistic technologies can expeditiously manage daughter products generated naturally or via ERD
- In most instances, an abiotic PRB should be installed for downgradient control of daughter products



Thank you for your time!

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