Source Area Bioremediation in Fractured Bedrock with Karst Features Revisited as Sustainable and Resilient Remediation

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The business of sustainability

ERM

Overview

- Background
- Investigation Summary
- Semi Quantitative Assessment
- Remediation Strategy
- Data
- Adapted Strategy
- Conclusions/Lessons Learned

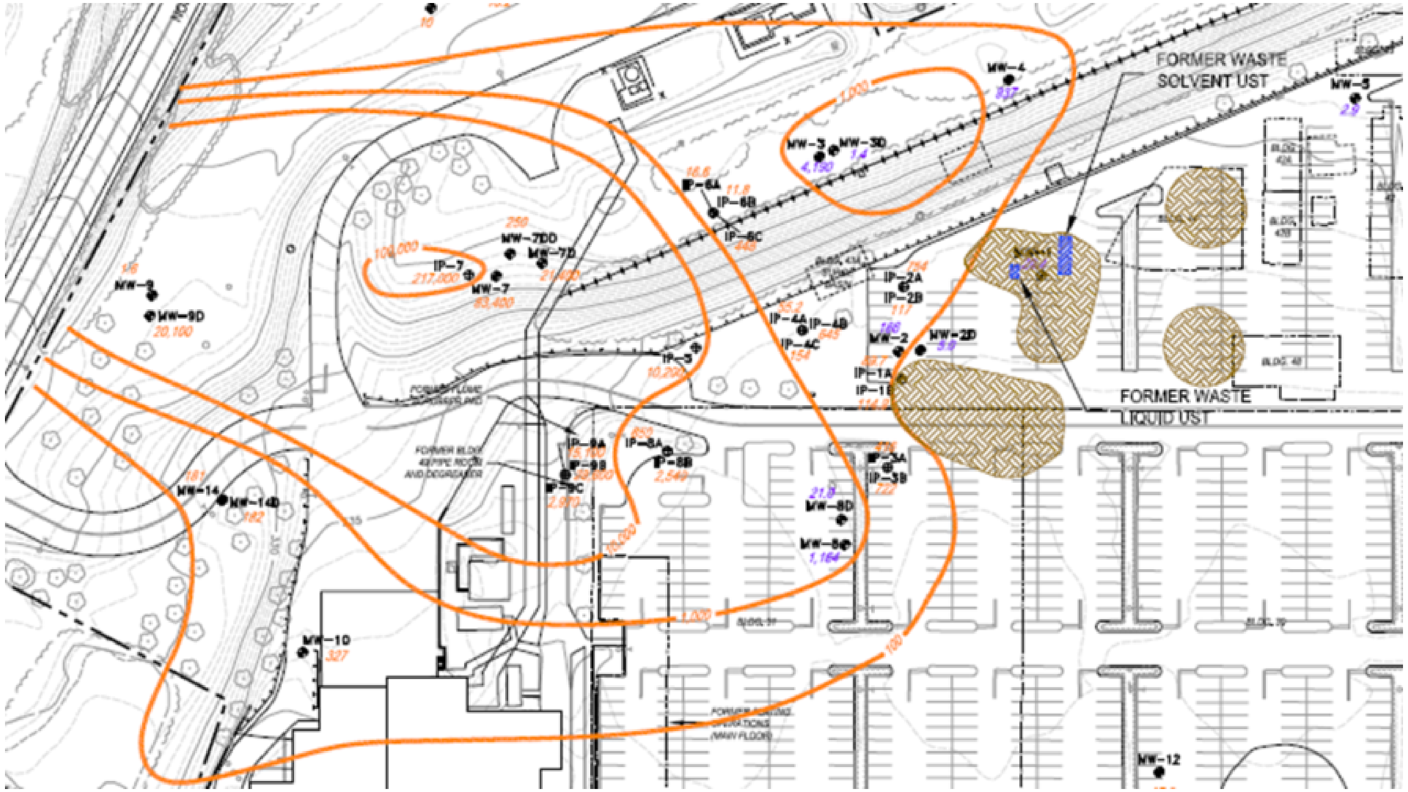
Background

- A manufacturing facility operating since the late 1940's in central Pennsylvania experienced releases of solvents, (primarily tetra and trichloroethene), through leaking underground waste storage tanks (UST) that were installed on top of fractured bedrock.

- The UST's and a small amount of the surrounding soil were removed in the late 1980's. Soil samples collected in the area of the former UST's during Site decommissioning activities in the early 2000's identified PCE and TCE above the state agency medium specific concentrations for soil.

GW Investigations

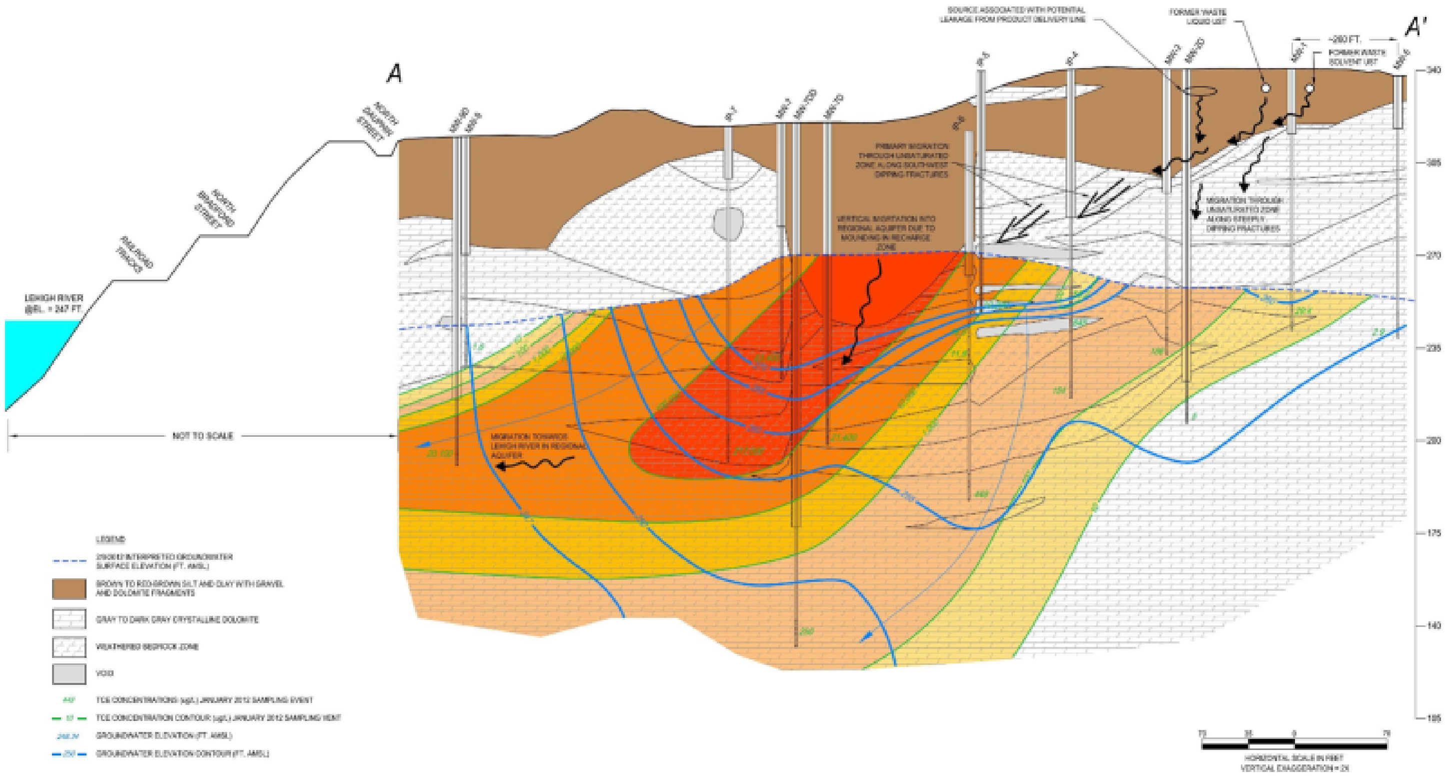
- Approximately 12 wells initially installed in 2005 to identify potential COC impacts to groundwater
- Wells were installed from 90’ to almost 250’ bgs screened in highest producing fractures in the bedrock
- Well clusters were installed in 2010 with shorter screen intervals to better define the vertical extent of the plume and identify higher flow fractures
- GW fate and transport model developed to help define risk based remedial goals to protect the adjacent river



Refining the CSM

- HRSC including sorbers also identified elevated concentrations of TCE and degradation products in the bedrock aquifer at depths of ninety-five to almost two-hundred feet below ground surface (bgs) at concentrations exceeding 300,000 µg/L.

- Concerns regarding off-site migration of the solvent plume in the bedrock aquifer towards the nearby river caused the state agency to request that an aggressive remediation strategy be implemented.

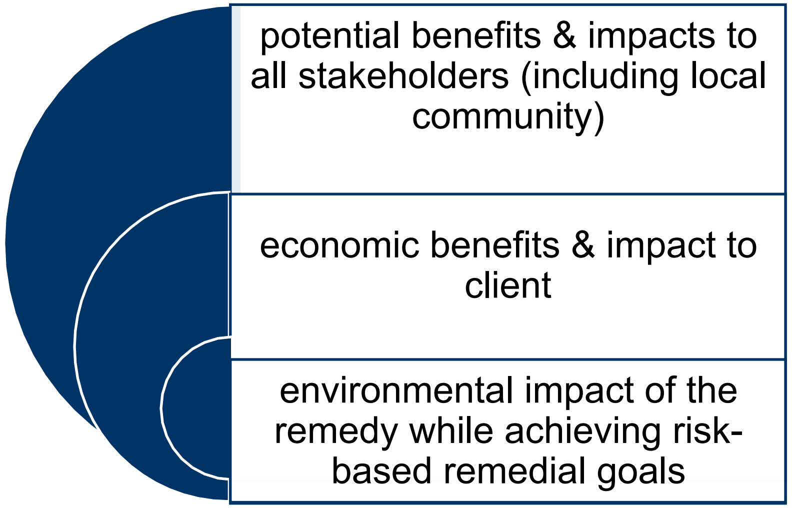


Semi-Quantitative Assessments

- Semi-quantitative sustainability assessment was conducted comparing pump and treat, thermal, in situ chemical oxidation and in situ bioremediation.
- Phased in situ bioremediation (biostimulation and bioaugmentation) was selected as the most sustainable and resilient remedy to achieve risk-based remedial goals.

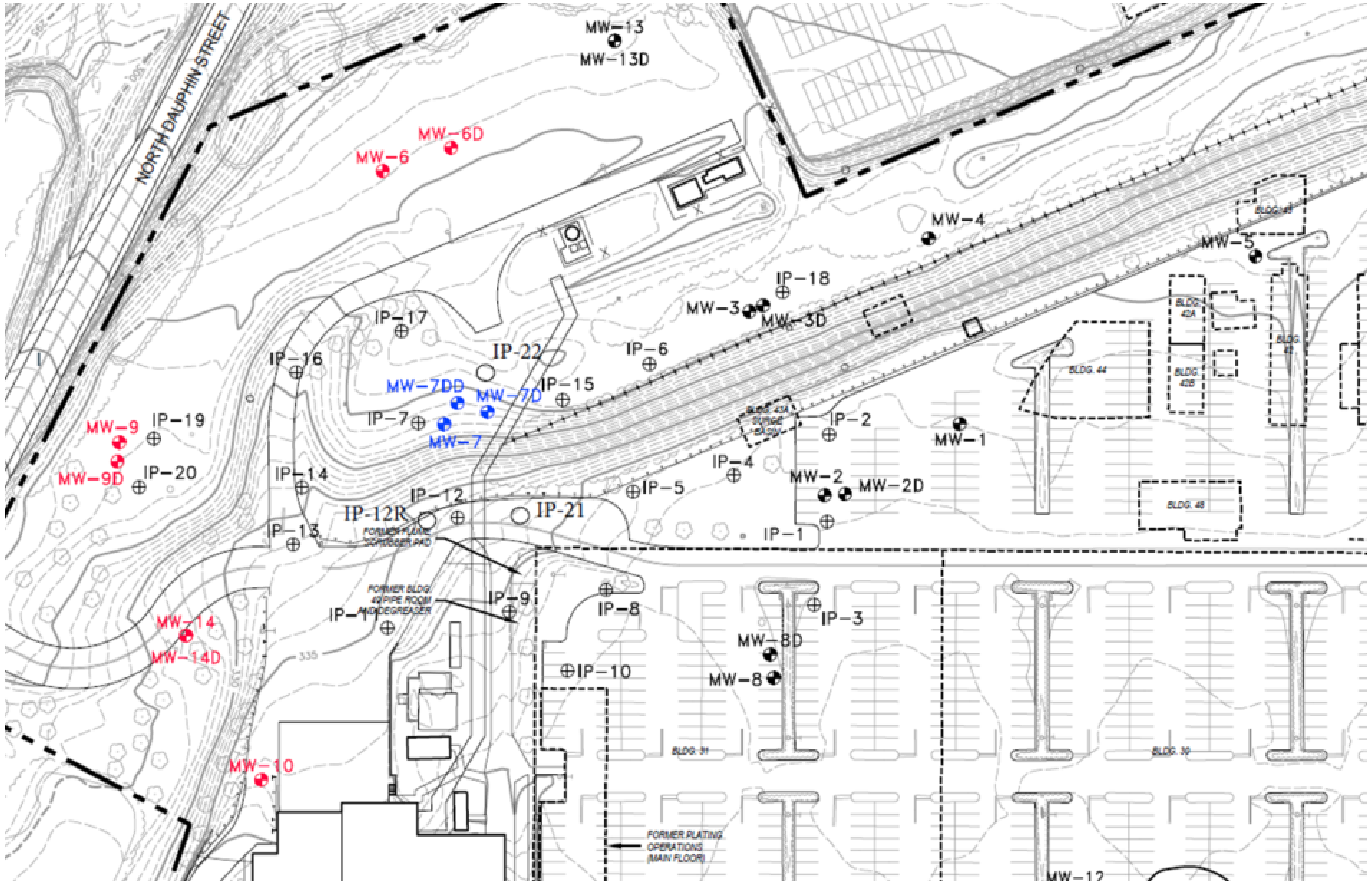
Why Sustainable Remediation?

- We still need to mitigate the risks but also recognize the bigger picture
- Remediation, while mitigating risks can also impact the environment and local communities
- Need to recognise and maximise the overall net environmental, social and economic benefits while minimizing impacts



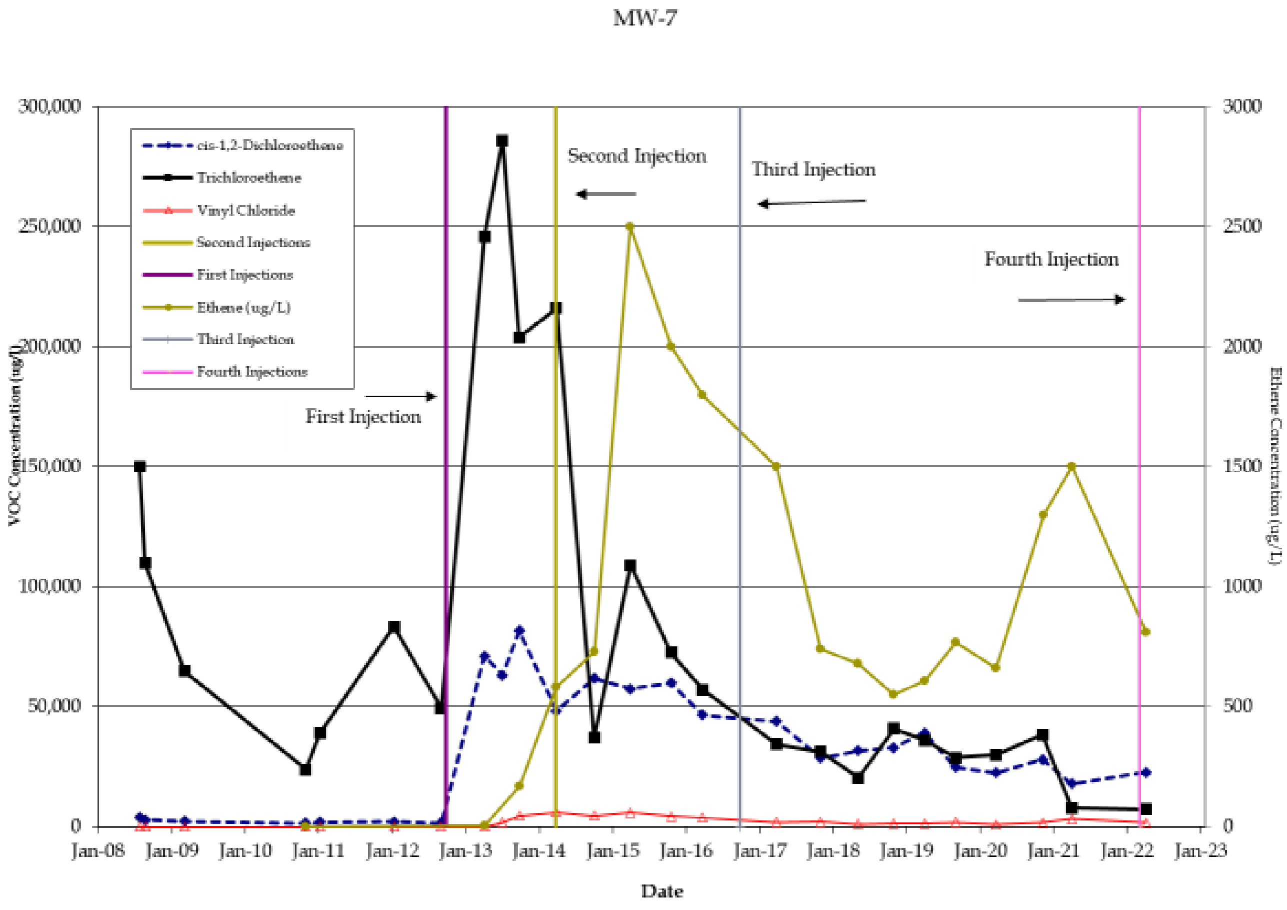
Initial Remediation

- Remedy included installation of 18 injection well clusters focused in the source area and downgradient as a biobarrier
- Injection well clusters installed from 95 to 170' bgs starting in 2014 with injections every 3 years
- Injected an 8% emulsified vegetable oil solution using groundwater from well development
- Also bioaugmented with DHC consortium after reducing conditions were established



Initial Remedy Progress

- Observed DO < 1 mg/L and ORP < -100 within 6 months of first injection event in several monitoring wells
- TOC increased to > 40 mg/L
- Initially observed significant increase in TCE in source area likely due to mobilization during injections
- The elevated TCE and significant increase indicated DNAPL that had not been previously identified



Refining CSM

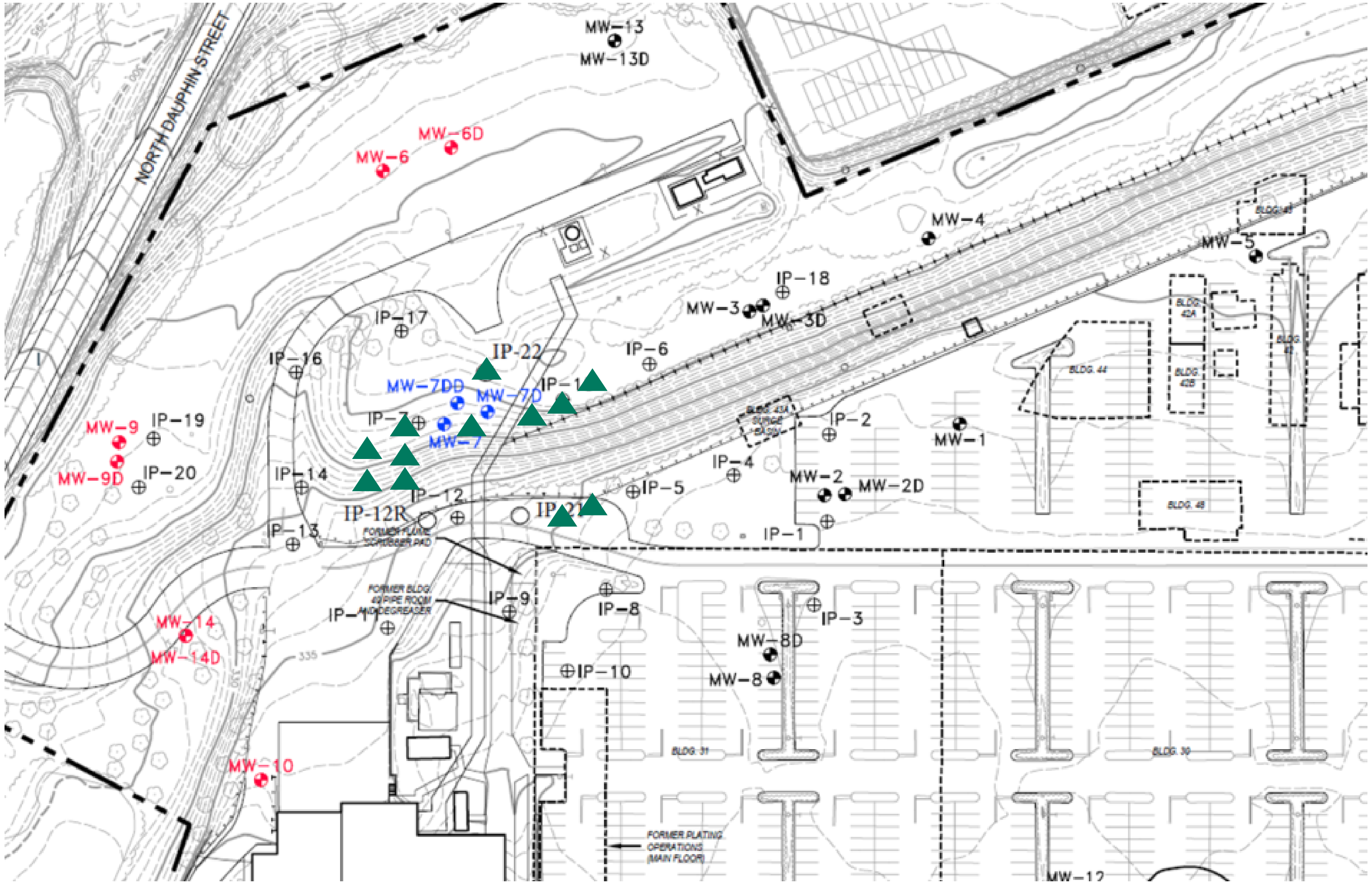
- Additional remediation points were installed, however to better evaluate presence of DNAPL sorbers were placed in the boring and oil red O was used on cuttings
- Sorber confirmed presence of DNAPL at approximately 110’ bgs
- Placed additional sorbers in 3 more borings and additional sorber in initial boring
- To limit potential for mobilizing additional NAPL, remediation point was converted from injection to bioboring

Bioboring Installation

- 12 biorings installed in DNAPL source area and immediately downgradient in 2021

- Bioborings installed from 100’ to a depth of 120’ bgs

- Bioborings backfilled to at least 4’ above the shallow GW table with a locally sourced hardwood mulch/gravel mix and bioaugmented with DHC microbial consortium



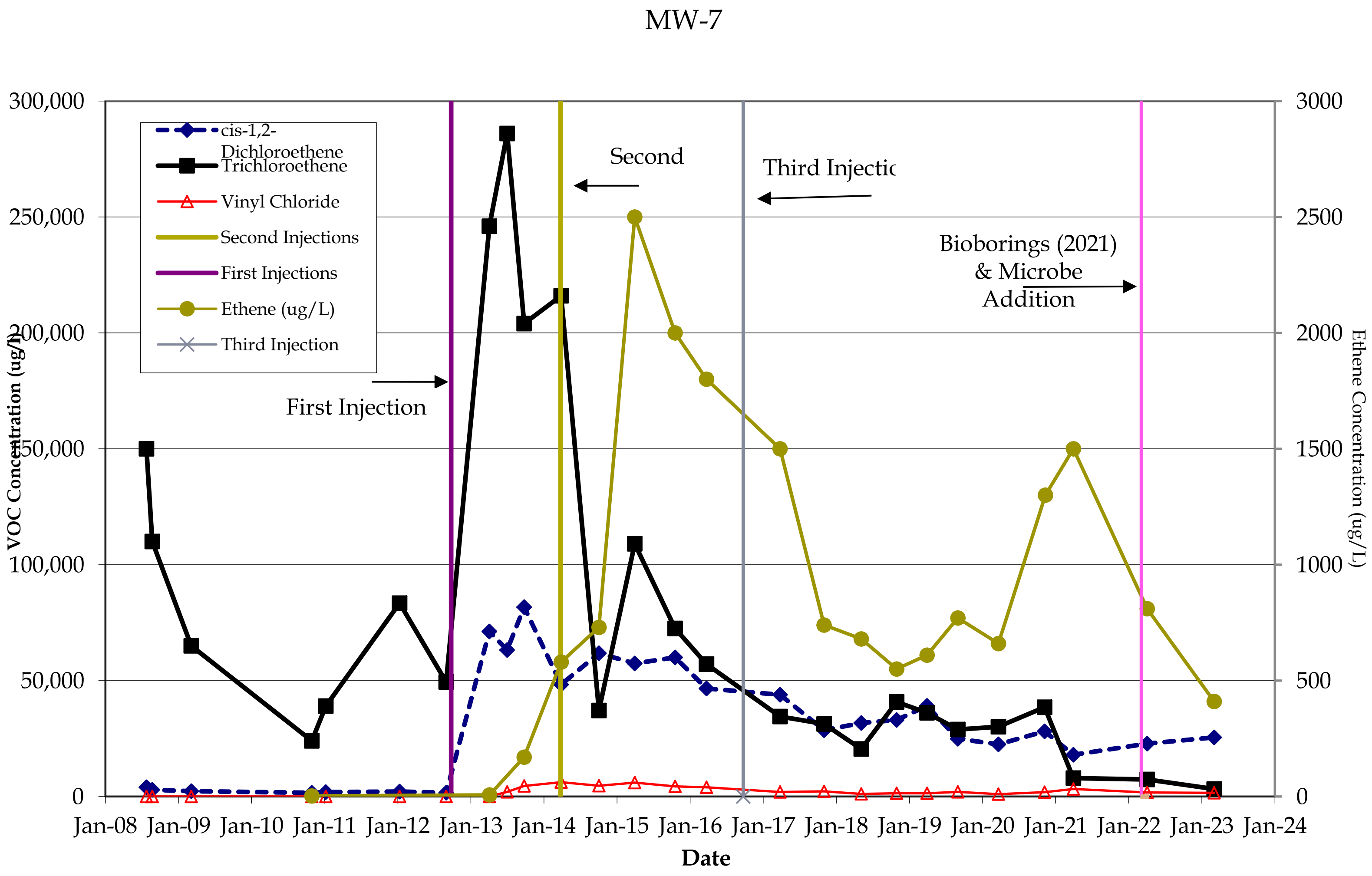
Field Parameters

- Low to no DO and strongly negative ORP observed in treatment zone with mildly aerobic conditions observed outside of treatment zone
- Ferrous iron detected in source area MWs

Well	Date	Temp (°C)	Conductivity (uS/cm)	pH	ORP (mV)	Turbidity (NTU)	DO (mg/L)	Ferrous Iron (mg/L)
MW-7	3/14/2023	10.8	2474	6.99	-63.4	25.5	0.00	3.87
MW-7D	3/14/2023	12.0	2683	7.00	-100.9	5.1	0.00	3.60
MW-7DD	3/14/2023	11.8	1493	7.49	-121.6	0.13	0.00	0.40
MW-9D	3/15/2023	11.5	1931	7.18	-17.9	7.8	0.00	
MW-9	3/15/2023	12.5	1770	6.94	-157.6	1.7	0.24	
MW-10	3/15/2023	12.2	1911	7.04	17.0	20.7	2.53	
MW-6	3/14/2023	9.3	2125	7.16	-150.1	5.2	0.21	
MW-6D	3/14/2023	3.9	1230	7.38	-74.0	4.0	0.31	
MW-14	3/15/2023	12.8	2117	7.26	-48.9	10.0	0.00	
MW-14D	3/15/2023	13.0	2165	7.16	-32.4	1.3	1.98	

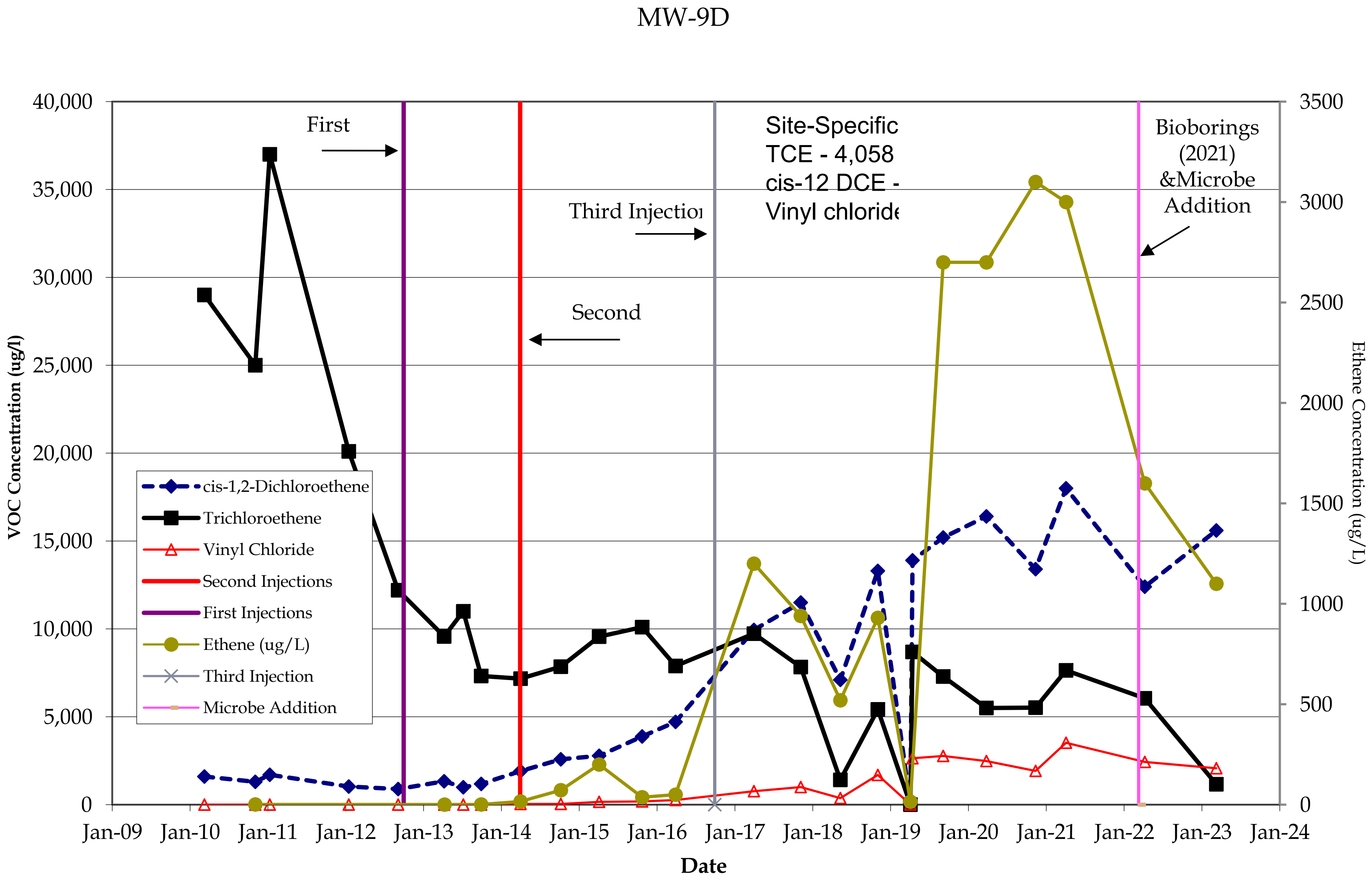
COC Laboratory Data in Source Area MW

- 86% reduction of TCE in source area well previously showing almost 300 mg/L of TCE
- Degradation products observed but not increasing
- Ethene observed at 410 µg/L



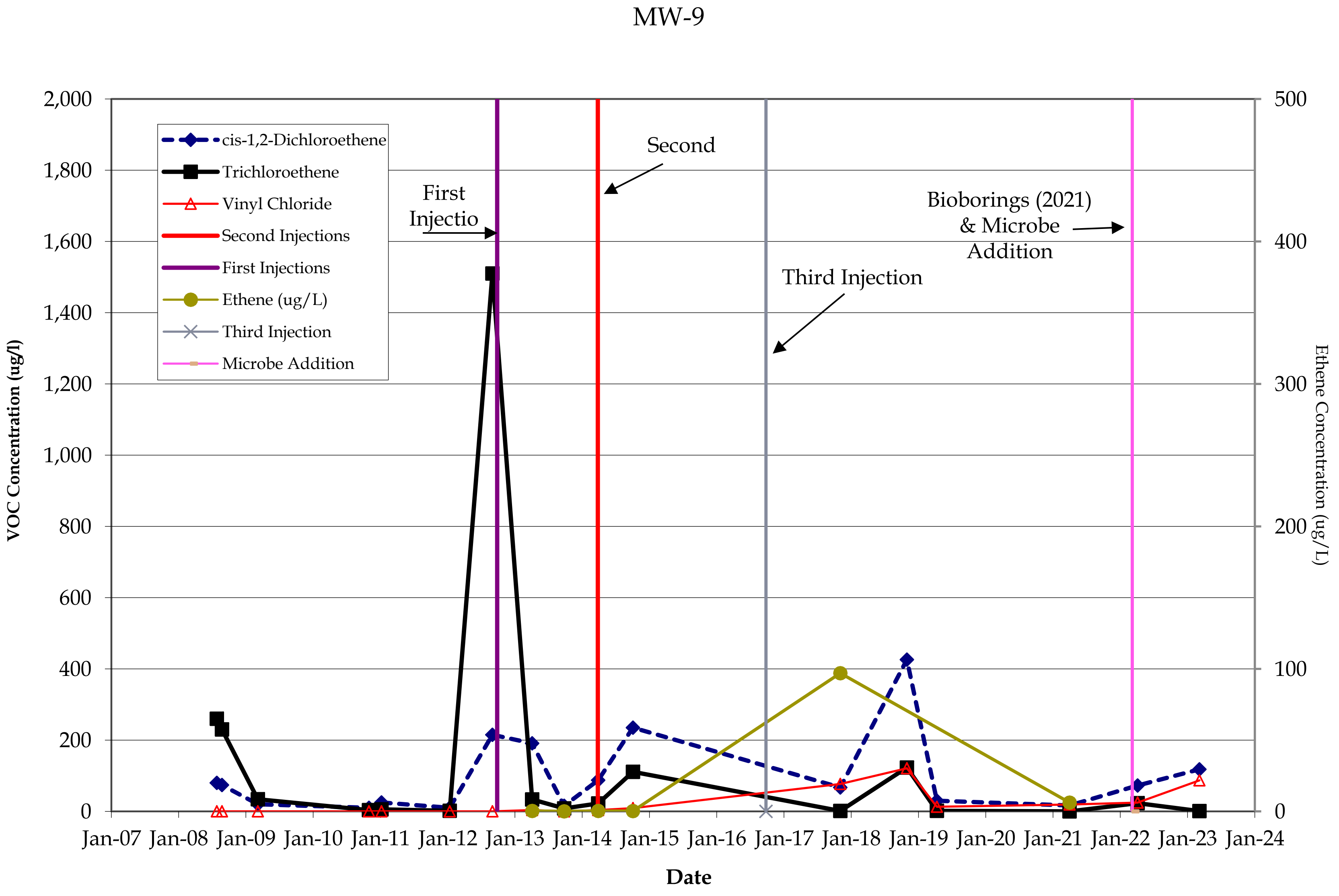
Downgradient MW COC Data

- 99.8% reduction of TCE
- VC reducing in last two years
- Over 1,000 µg/L



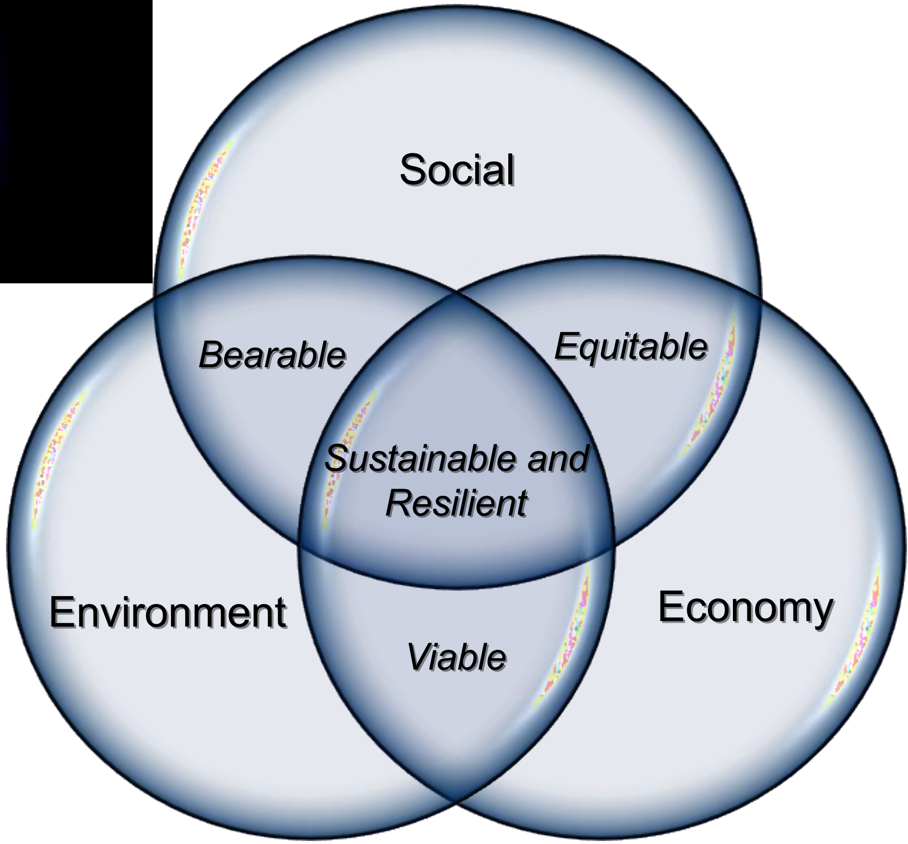
Downgradient MW COC Data, Cont’d

- Very low detections of TCE, well below RBCs
- Low detections of degradation products



Site specific implementation – Lessons Learned

- Establishing reduction treatment zone downgradient of source area critical to mitigate migration of mobilized COCs during source treatment
- Also important to establish healthy reducing conditions prior to introducing laboratory cultured microbes.
- Adaptation of remediation strategy to changing conditions (identification of DNAPL during injection point installation) also key to successfully mitigating additional migration.
- Transitioning to mulch bioboring approach as a longer lasting and more sustainable treatment



Thank you!

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