Former ACCO Brands

Queens County, NY

32-00 Skillman Avenue

Long Island City, New York

Final Engineering Report

NYSDEC Brownfield Cleanup Program

Site No. C241061

Prepared for:

Jim Beam Brands Co.
149 Happy Hollow Road
Clermont, KY 40110

Prepared by:

Fleming Lee Shue

Fleming, Lee Shue Environmental Engineering and Geology D.P.C.
158 West 29th Street
New York, New York 10001

JUNE 2023

CERTIFICATIONS

I, Arnold F. Fleming, P.E., am currently a registered professional engineer licensed by the State of New York, I had primary direct responsibility for implementation of the remedial program activities, and I certify that the Remedial Action Work Plan was implemented and that all construction activities were completed in substantial conformance with the Department-approved Remedial Action Work Plan.

I certify that the data submitted to the Department with this Final Engineering Report demonstrates that the remediation requirements set forth in the Remedial Action Work Plan and in all applicable statutes and regulations have been or will be achieved in accordance with the time frames, if any, established for the remedy.

I certify that all use restrictions, Institutional Controls, Engineering Controls, and/or any operation and maintenance requirements applicable to the Site are contained in an environmental easement created and recorded pursuant ECL 71-3605 and that all affected local governments, as defined in ECL 71-3603, have been notified that such easement has been recorded.

I certify that a Site Management Plan has been submitted for the continual and proper operation, maintenance, and monitoring of all Engineering Controls employed at the Site, including the proper maintenance of all remaining monitoring wells, and that such plan has been approved by the Department.

I certify that all documents generated in support of this report have been submitted in accordance with the DER's electronic submission protocols and have been accepted by the Department.

I certify that all data generated in support of this report have been submitted in accordance with the Department's electronic data deliverable and have been accepted by the Department.

I certify that all information and statements in this certification form are true. I understand that a false statement made herein is punishable as a Class “A” misdemeanor, pursuant to Section 210.45 of the Penal Law. I, Arnold F. Fleming, P.E., of 158 West 29th Street, New York, NY, 10001, am certifying as Owner’s Designated Site Representative for the Site.

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NYS Professional Engineer # 050411 Date Signature

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Appendices

LIST OF ACRONYMS

AWQS	TOGS Ambient Water Quality Standard
BCA	Brownfield Cleanup Agreement
BCP	Brownfield Cleanup Program
CAMP	Community Air Monitoring Program
CPP	Citizen Participation Plan
DNAPL	Dense Non-aqueous Phase Liquid
DOT	United States Department of Transportation
CUSCO	Commercial Use Soil Cleanup Objectives
DUSR	Data Usability Summary Report
EC	Engineering Control
EBR	Enhanced Bioremediation
ERH	Electrical Resistance Heating
FLS	Fleming, Lee Shue Environmental Engineering and Geology D.P.C.
GES	Groundwater and Environmental Services
HASP	Health and Safety Plan
IC	Institutional Control
IRM	Interim Remedial Measures
LGAC	Liquid-Phase Granulated Activated Carbon
LNAPL	Light Non-Aqueous Phase Liquid
NYCDEP	New York City Department of Environmental Protection
NYCDOB	New York City Department of Buildings
NYCT	New York City Transit Authority
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OSHA	Occupational Safety and Health Association
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
QAPP	Quality Assurance Project Plan
RAO	Remedial Action Objective
RAWP	Remedial Action Work Plan
RA	Remedial Action
RE	Remedial Engineer
RRSCO	Restricted Residential Soil Cleanup Objective
SCO	Soil Cleanup Objectives
SEQRA	State Environmental Quality Review Act
SMP	Site Management Plan
SoMP	Soil Management Plan
SOP	Site Operating Plan
SSDS	Sub-Slab Depressurization System
SVE	Soil Vapor Extraction
SVOCs	Semi-Volatile Organic Compounds
TOGS	Class GA Ambient Water Quality Standards and Guidance Values
UUSCO	Unrestricted Use Soil Cleanup Objectives

VGAC	Vapor-Phase Granulated Activated Carbon
VOC	Volatile Organic Compounds

1.0 BACKGROUND AND SITE DESCRIPTION

Jim Beam Brands Co. c/o Beam Suntory is the Participant responsible for remediating the Site under the Brownfield Cleanup Program (BCP) as Site No. C241061 (BCA Index No. C241061-10-17). The Site is located at 32-00 Skillman Avenue, Long Island City, Queens County, New York and is identified as Block 245 and Lot 9 on the New York City Tax Map (hereafter referred to as the Site). The Site is situated on an approximately 0.72-acre area bounded by Skillman Avenue to the north, Queens Boulevard to the south, 32nd Place to the east, and Van Dam Street to the west. The Site Location and Layout are shown in Figures 1 and 2, respectively. The boundaries of the Site are fully described in Appendix A: Environmental Easement and Survey Map, Metes and Bounds.

The Site manufactured staplers and associated metal products as far back as the 1950s. Manufacturing operations included the use of trichloroethylene (TCE), a metal degreaser, which is the principal agent responsible for most of the contamination driving the investigations and cleanup. Participant stopped using TCE in its operations no later than the mid to late 1990s and has been investigating the property since 2000 and has continued investigations and remediation up through the present.

The Site was divided into two operable units in order to address impacts of historic chlorinated solvent use. Operable Unit 1 (OU-1) is located within the property boundary and is defined by the basement footprint of the former ACCO Brands building (the Site). Operable Unit 2 (OU-2) consists of the dissolved groundwater plume and related soil vapor issues in the immediate downstream off-Site areas, outside of the OU-1 boundary. More specifically, the OU-2 BCP Site includes the area outside the OU-1 site boundary within the area bound by the existing well network including the MW-17 wells upgradient of the Site and the downgradient/cross-gradient wells MW-12 series, MW-13I, MW-14I, MW-15I, and MW-9 (Figure 2). The Site OUs are now also referred to as “Onsite” and “Offsite.”

Historically, Participant applied numerous remedial approaches including *in situ* Chemical Oxidation (ISCO) using potassium permanganate, ozone treatment, air sparging, and soil vapor extraction to remediate TCE Onsite. These approaches failed to sustainably reduce TCE levels to achieve the groundwater cleanup goals, and in many instances rebound occurred and TCE levels eventually returned to pre-treatment levels.

Participant then employed Electrical Resistance Heating (ERH) to vaporize the TCE in the subsurface and drive it to extraction points for removal as vapor. ERH works by superheating the subsurface to a point where TCE in water boils off as steam for subsequent collection. Seventytwo electrodes were installed to depths of approximately 35 feet below the basement and energized for 12 months. Subsurface temperatures reached 107° C and an estimated 5,000 pounds of TCE was removed from the subsurface during the treatment period. ERH operated on the Site from September 2017 through August 2018 when ERH operation ended. Ultimately, ERH operation terminated because, despite source removal, TCE levels failed to achieve the ERH 100 µg/L remedial goal or were beginning to rebound. Soon after ERH shut off, TCE concentrations increased dramatically to pre-treatment levels. In some locations, TCE rose to historically high concentrations not previously measured on Site.

In response, Participant applied further active remediation in OU-1 using Enhanced Bioremediation (EBR) to remove the contamination via biological reduction. Participant implemented EBR by injecting a mixture of food source, nutrients, and bacteria into the subsurface to promote bioremediation in June 2020 and November 2020.Subsequent to these EBR events, OU-1 TCE groundwater concentrations have decreased dramatically and as of April 2023, 18 out of 20 performance monitoring wells have reached the TOGS 5 µg/L groundwater cleanup goal and TCE in 14 of these wells was below detection limits. There has been no material rebound in 27 months following the full-scale EBR treatment in November 2020. OU-1 has now met the remedial objectives set forth in the 2015 Decision Document.

An EBR pilot study was conducted in October 2021 to evaluate the effectiveness of EBR in OU-2. The pilot study evaluated EBR in MW-9 where TCE concentrations reduced by more than 99.99 100 percent in the April 2023 sampling event compared with pre-treatment concentrations, thus establishing the effectiveness and efficacy of EBR treatment in OU-2.

Full-scale EBR treatment in OU-2 took place in April 2023 following Department approval in March 2023 (Appendix D). EBR was implemented at OU-2 wells MW-8I, MW-10A, and MWR-10I (no injection into MW-9 during the OU-2 full-scale treatment was necessary).

2.0 SUMMARY OF SITE REMEDY

Remedial activities completed at the Site were conducted in accordance with the NYSDEC-approved Remedial Action Work Plan (RAWP) dated March 2015 (approved June 23, 2015), which allowed for bioremediation. Following application of ERH, which did not adequately achieve the site cleanup goals, Participant filed a modified remedial approach with the Department on January 14, 2020 that provided details for the application of bioremediation to be preceded by a bench-scale and field pilot study. After successful completion of an EBR bench-scale study followed by a successful bioremediation pilot study in June 2020, FLS proceeded with full-scale bioremediation remedy in OU-1 on November 9, 2020, with one follow-up supplemental injection in one well in November 2021. The full-scale treatment took approximately one week to complete.

A second EBR pilot study was completed in OU-2 within well MW-9 in October 2021. This test was similarly highly successful, and the Department approved full-scale EBR treatment in March 2023. The OU-2 EBR treatment was conducted in April 2023 and treatment continued for approximately one week.

2.1 REMEDIAL ACTION OBJECTIVES

Based on the results of the Remedial Investigation, the following Remedial Action Objectives (RAO) were identified for this Site.

Remedial Objectives for OU-1

Groundwater RAOs

RAOs for Public Health Protection

- Prevent ingestion of groundwater containing contaminant levels exceeding drinking water standards.
- Prevent contact with, or inhalation of, volatiles from contaminated groundwater.

RAOs for Environmental Protection

- Restore ground water aquifer, to the extent practicable, to pre-disposal/pre-release conditions.
- Remove the source of groundwater or surface water contamination.

Soil RAOs

RAOs for Public Health Protection

- Prevent ingestion/direct contact with contaminated soil.
- Prevent inhalation of or exposure from contaminants volatilizing from contaminants in soil.

RAOs for Environmental Protection

- Prevent migration of contaminants that would result in groundwater or surface water contamination.

Soil Vapor RAOs

RAOs for Public Health Protection

- Mitigate impacts to public health resulting from existing, or the potential for, soil vapor intrusion into buildings at a site.

Remedial Objectives for OU-2

Groundwater

RAOs for Public Health Protection

- Prevent ingestion of groundwater with contaminant levels exceeding drinking water standards.
- Prevent contact with, or inhalation of, volatiles from contaminated groundwater.

RAOs for Environmental Protection

- Restore ground water aquifer to pre-disposal/pre-release conditions, to the extent practicable.

- Remove the source of ground or surface water contamination.

Soil Vapor

RAOs for Public Health Protection

- Mitigate impacts to public health resulting from existing, or the potential for, soil vapor intrusion into buildings at a site.

2.2 DESCRIPTION OF SELECTED REMEDY

OU-1

OU-1 (Onsite) has achieved near full remediation in accordance with the EBR remedy approved by the NYSDEC on November 4, 2021.. As specified in the June 2015 Decision Document, the groundwater cleanup objectives are to restore groundwater aquifer to pre-disposal/pre-release conditions to the extent practicable and to remove the source of groundwater contamination (see Section 2.1 for the full remediation objectives). The factors considered during the selection of the remedy are those listed in 6NYCRR 375-1.8. The following were the components of the selected remedy:

1. Site mobilization involving site security setup, equipment mobilization, utility mark outs
2. Screening for indications of contamination (by visual means, odor, and monitoring with PID) of all excavated soil during any intrusive Site work
3. EBR treatment within the source area of OU-1
4. All liquids to be removed from the Site, including dewatering fluids, were handled, transported and disposed in accordance with applicable local, State, and Federal regulations. Liquids discharged into the New York City sewer system were addressed through approval by New York City Department of Environmental Protection (NYCDEP).
5. Appropriate off-Site disposal of all material removed from the Site in accordance with all Federal, State and local rules and regulations for handling, transport, and disposal

6. Construction and maintenance of an engineered composite cover to prevent human exposure to soils in OU-1 (Site)

7. Construction and maintenance of a sub-slab depressurization system (SSDS) under the slab of OU-1 to prevent human exposure to potential residual soil vapor contamination

8. Recording of an Environmental Easement, including Institutional Controls, to prevent future exposure to any residual contamination remaining at the Site

9. Restriction on the use of groundwater as a source of potable or process water, without necessary water quality treatment as determined by the NYSDOH

10. Publication of a SMP for long term management of residual contamination as required by the Environmental Easement, including plans for: (1) Institutional and Engineering Controls, (2) monitoring, (3) operation and maintenance and (4) reporting

11. All responsibilities associated with the Remedial Action, including permitting requirements and pretreatment requirements, will be addressed in accordance with all applicable Federal, State and local rules and regulations.

OU-1 EBR Treatment

As ERH did not permanently achieve the cleanup objectives at all on-site wells, Participant sought EBR as the subsequent remedy. As such, Participant injected 2,000 to 3,000 gallons per well of bioremediation amendment to address concentrations of chlorinated solvents, primarily TCE, in OU-1. The amendment was injected into the following wells: MWR-1S, MWR-1I, MWR-2S, MWR-2I, MWR-3S, MWR-3I, MWR-4S, MWR-41, MWR-5S, MWR-5I, MWR-6S, MWR-6I, MWR-7S, MWR-7I, MWR-8S, MWR-8I, MWR-9S, MWR-9I in a one-week full-scale treatment in November 2021 (Figure 3). A Primawave™ Sidewinder(s) injected the material. The EBR treatment amendment consisted of a NYSDEC approved mixture of the following food-grade materials to promote bioremediation:

- Electron donors/Food source
  - EOS_{QR}, fast release carbon substrate
  - EOS_{PRO}, slow-release carbon substrate
- pH buffers:
  - Sodium Bicarbonate (pH buffer)

Diammonium Phosphate (nitrogen and phosphorus nutrients/pH buffer)
Monopotassium Phosphate (phosphorus nutrient/pH buffer)
Dipotassium Phosphate (phosphorus nutrient/pH buffer)
Vitamin B12 and proprietary micronutrients (quantity 7 – 16 fluid ounces [473 mL] bottles)

- Deoxygenation Compounds
  Food grade Ascorbic acid (Vitamin C), 11 pounds/1,400-gallon batch. *Dehalococcoides* bacteria was added to the injection mixture for the purpose of augmenting the existing *in situ* microbial consortium and promoting complete degradation of TCE to ethane and ethene. *Dehalococcoides* requires an oxygen free environment to remain viable and decompose TCE. Therefore, oxygen must be removed from the injection mixture to ensure the bacteria remain alive during injection and to ensure they enter oxygen free groundwater. Sodium sulfide was also used as an oxygen scavenger.

- BAC-9 Microbe Consortium
  Dehalococcoides [Dhc] @ $1x10^{11}$ cells/mL, equivalent of 280 mL per well

Water levels and field parameters were monitored twice per day in the surrounding wells during the injection to assess to radius of influence. The radius of influence was a minimum of 30 feet.

OU-2

In October 2021, Participant conducted a EBR pilot study within OU-2 monitoring well MW-9 to evaluate the efficacy of EBR in treating off Site contamination. The two-day pilot test in MW-9 followed the same procedures as in OU-1 and groundwater sampling results following EBR found the treatment to be extremely effective. The pilot study EBR treatment reduced TCE groundwater concentrations in three successive measurement events and the latest, April 2023, found TCE concentration reduced by more than 99.99 percent compared with pre-treatment TCE concentrations, thus validating EBR as a viable remedy for OU-2.

In April 2023, the Participant then injected approximately 3,000 gallons of bioremediation amendment per well to address remaining off Site concentrations of chlorinated solvents, primarily TCE, in OU-2. The amendment was injected into the following wells: MW-8I, MW-10A, and

MWR-10I in an approximate one-week-long full-scale treatment in April 2023 (injection was not necessary in MW-9). A Primawave™ Sidewinder(s) injected the material. The EBR mixture was the same as used in the OU-1 EBR injection.

The following are the components of the selected OU-2 remedy:

1. Site mobilization involving site security setup and equipment mobilization
2. EBR treatment within the source area of OU-2
3. All liquids to be removed from the Site, including dewatering fluids, were handled, transported and disposed in accordance with applicable local, State, and Federal regulations.
4. Appropriate off-Site disposal of all material removed from the Site in accordance with all Federal, State and local rules and regulations for handling, transport, and disposal
5.
6. Maintenance of the two (2) existing off-Site SSDSs mitigating soil vapor intrusion at off-Site properties including adjacent multi-family residential building west of the Site and the YMCA located east of the Site.
7. Publication of a SMP for long term management of residual contamination as required by the Environmental Easement, including plans for: (1) Institutional and Engineering Controls, (2) monitoring, (3) operation and maintenance and (4) reporting
8. All responsibilities associated with the Remedial Action, including permitting requirements and pretreatment requirements, will be addressed in accordance with all applicable Federal, State and local rules and regulations.

3.0 INTERIM REMEDIAL MEASURES, OPERABLE UNITS AND REMEDIAL CONTRACTS

Participant tried numerous remedial approaches over a period of 23 years to address contamination. These were intended to be final remedies, but were ultimately unable to achieve the cleanup goals. They are presented here as *de facto* interim remedies in order to provide a complete picture of the overall remedial history. Most of these remedies were implemented prior to the June 2015 Decision Document but were approved by the Department. The exception is the Electrical Resistance Heating (2017-2018), which was one of the remedies included in the June 2015 Decision Document.

In situ Chemical Injections, Ozone Treatment, Air Sparging, and Soil Vapor Extraction

In the early portion of the Site's remedial history, previous environmental consultant, GES Engineering, attempted to remediate OU-1 and OU-2 using a combination of *in situ* chemical injections, ozone treatment, air sparging, and soil vapor extraction.[1]

GES advanced 17 soil borings in the basement using a membrane interface probe and electrical conductivity direct push tool to measure volatiles in the soils in addition to classifying soil types and textures. The results confirmed multiple layers of varying permeability and texture. The upper layer is predominantly fine sand and silt, which is underlain by a silt layer and subsequently a second fine sand and silt layer. A deeper clay lens lies beneath this fine sand/silt layer and provides an impermeable barrier above the deepest sand and gravel layer.

The remedy implemented in OU-1 included multiple *in situ* remedial technologies. A combination of soil vapor extraction (SVE) and ambient air sparging/ozone oxidation was used to target the vadose zone soils, air sparging/ozone oxidation was used to target shallow groundwater, and chemical oxidation by potassium permanganate was used to target intermediate and deep groundwater. The remedy was implemented in phases from February 2004 through June 2005. In 2007, supplemental chemical oxidation with potassium permanganate was applied to the shallow groundwater zones in areas outside the original treatment zone. By 2007, a total of nine SVE wells, 30 gas injection wells, and 69 potassium permanganate injection wells were installed in OU-1.

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[1] GES prepared a formal *RAWP* for OU-1 and *RAWP Addendum* submitted to NYSDEC in May 2003 and approved in February 2005.

The potassium permanganate injections were followed by monitoring for reaction of potassium permanganate until it was fully consumed. GES reported that removal of TCE from the vadose zone soils occurred primarily from the start of the SVE system through June 2006, before TCE reduction reached an asymptotic level of 0.01 pounds per day in 2009. The air sparging system, activated in 2004, and ozone injection system, fully activated in 2005, were subject to numerous equipment malfunctions, such as overheating, and were not operating on a consistent basis. GES implemented repairs; however, the system was taken offline in November 2008 due to sparge vapor and ozone preferential pathways identified during injection well installation on Van Dam Street.

GES prepared a Draft Site Management Plan and Draft Final Engineering Report documenting the remedy for the Site in 2011, these reports were never finalized. GES's remedial actions did not attain the cleanup objectives. This led Participant to attempt another remedial approach: Electrical Resistance Heating (ERH).

Electrical Resistance Heating

In February 22, 2016, the ERH contractor, TRS Group, Inc. (TRS), installed 72 electrodes for the purpose of heating the subsurface; electrodes were installed to a depth of approximately 35-45 feet below the basement slab. In September 2017, TRS began applying ERH by energizing the subsurface through the electrodes, which were designed to heat groundwater to the boiling point in order to vaporize TCE and remove it via soil vapor extraction as it moved upward through the soil column. The system was completely energized by November 2017. ERH operated from September 2017 through August 31, 2018. ERH completed operations when vapor removal showed diminishing returns, and TCE groundwater concentrations appeared to rebound. In all, ERH removed an estimated 5,000 pound of TCE. Soon after ERH shut off (and slightly before), TCE groundwater concentrations rebounded and increased, in some cases, to over 200,000 µg/L in discrete locations. The remaining source material led Participant to apply another remedial method, Enhanced Bioremediation (EBR). EBR became the final remedy described in Section 4.4.

4.0 DESCRIPTION OF REMEDIAL ACTIONS PERFORMED

Remedial activities completed at the Site were conducted in accordance with the NYSDEC-approved RAWP by FLS for the Former ACCO Brands Site dated March, 2015, the bioremediation pilot study for OU-1 approved by NYSDEC on January 14, 2020, the full-scale OU-1 treatment work plan approved by the Department on November 4, 2021, the approved OU-2 pilot study work plan of February 20, 2020, and the OU-2 full-scale EBR treatment approval of March 15, 2023.

Enhanced Bioremediation Pilot Study and Treatment

FLS began an EBR pilot study in OU-1 in June 2020 to evaluate whether microbial degradation (Enhanced Biodegradation) could achieve the Site groundwater cleanup goal of 5 µg/L. The pilot test workplan was approved by NYSDEC on February 28, 2020. The successful pilot study was followed by a full-scale treatment in November 2020 of the TCE source contaminant area. The Pilot Study results are documented in the October 2020 Enhanced In-Situ Bioremediation Pilot Study Report along with a workplan to implement full-scale EBR on-Site.

As of April 2023, 27 months after the full-scale OU-1 EBR treatment, 18 out of 20 performance monitoring wells were below the TOGS TCE AWQS of 5 µg/L and 14 wells were non-detect for TCE. TCE breakdown by-products were present at elevated concentrations demonstrating a complete breakdown pathway is in place.

FLS began an EBR pilot study in OU-2 in October 2021 (in MW-9) to evaluate whether microbial degradation (Enhanced Biodegradation) could achieve the Site groundwater cleanup goal of 5 µg/L. The pilot test workplan was approved by NYSDEC on February 28, 2020, and the Pilot Study results are documented in the December 13, 2022, groundwater monitoring report.

The successful pilot study was followed by a full-scale EBR treatment in April 2023 in OU-2 wells MW-8I, MW-10A, and MWR-10I. The results of the full-scale treatment in OU-2 . .

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4.1 GOVERNING DOCUMENTS

4.1.1 Site Specific Health & Safety Plan (HASP)

All remedial work performed under this Remedial Action was in full compliance with governmental requirements, including Site and worker safety requirements mandated by Federal Occupational Safety and Health Administration. The Health and Safety Plan (HASP) was complied with for all remedial and invasive work performed at the Site and is provided in Appendix B.

4.1.2 Quality Assurance Project Plan (QAPP)

The Quality Assurance Project Plan (QAPP) was included as Appendix E of the RAWP approved by the NYSDEC. The QAPP describes the specific policies, objectives, organization, functional activities and quality assurance/ quality control activities designed to achieve the project data quality objectives.

4.1.3 Soil Management Plan (SoMP)

The soil disturbed during remediation (and soil disturbance only occurred during ERH) consisted of the drill cuttings from the soil investigation and the electrode installation. The work area was monitored as part of CAMP and there were no odor complaints. All work performed during remediation was done in accordance with the NYSDEC-approved Soil Management Plan (SoMP) included as Section 5.4 of the RAWP.

Although not anticipated, any future intrusive work that may disturb the residual contamination, and modifications or repairs to the existing composite cover system, will be performed in compliance with the approved SMP included as Appendix C of this FER. No soil waste was generated during bioremediation.

4.1.4 Community Air Monitoring Plan (CAMP)

Potential exposure by work zone personnel was addressed through compliance with the CAMP included in the Site-specific HASP provided as Appendix D of the RAWP. Air monitoring for volatile organic compounds (VOC) was continuously conducted in the work zone and surrounding area during invasive activities such as soil boring or monitoring well installation. When the ERH system was operable, the breathing zone in the basement, staircases, and sidewalks was monitored for VOCs.

Dust monitoring was not required because the majority of the intrusive work (i.e., well installation and electrode installation for ERH) was conducted in the basement. FLS determined that visual monitoring for dust was adequate for the small portion of the intrusive work conducted on the building's west and south sidewalks. While dust suppression was not needed at any part of the project, floor scrubbers were used periodically to clean dust and soil that accumulated on the basement floor.

4.1.5 Contractors Site Operations Plans (SOPs)

The Remediation Engineer reviewed all plans and submittals for this remedy (i.e., those listed above plus contractor and subcontractor submittals) and confirmed that they were in compliance with the RAWP. All remedial documents were submitted to NYSDEC and NYSDOH in a timely manner and prior to the start of work.

4.1.6 Citizen Participation Plan

The approved Citizen Participation Plan (CPP) for this project was included as Appendix C of the RAWP. A certification of mailing was sent to the NYSDEC Project Manager on behalf of the BCP Participant following the distribution of all Fact Sheets and notices that included: (1) certification that the Fact Sheets were mailed, (2) the date they were mailed; (3) a copy of the Fact Sheet; and (4) a list of recipients (contact list). The CPP was submitted with the RAWP to the Court Square Branch of Queens Library on June 26, 2015.

No changes were made to the approved Fact Sheets authorized for release by NYSDEC without written consent of the NYSDEC. No other information (i.e., brochures and flyers) were included with the Fact Sheet mailing.

As per the CPP, a Fact Sheet will be distributed by NYSDEC that announces the completion of remedial activities and the review of the FER. A final Fact Sheet will be distributed to announce that the Certificate of Completion has been issued.

4.2 REMEDIAL PROGRAM ELEMENTS

4.2.1 Contractors and Consultants

The Remedial Engineer (RE) for this project under the RAWP is Arnold F. Fleming, P.E. The RE is a registered professional engineer licensed by the State of New York. The RE coordinated the work of other contractors and subcontractors involved in all aspects of remedial construction, air monitoring, and management of waste transport and disposal. The following table summarizes contractors and consultants involved in remediation:

Table 1 – Contractors and Consultants

Contractor/Consultant	Responsibilities
Fleming, Lee Shue	Under the direct supervision of the RE: • Assisted RE in coordination of contractors and documenting remedial activities performed • Coordinated and observed all on-Site activities in connection with the RAWP and CAMP • Administered adherence with the technical requirements of the RAWP and CAMP • Oversight of vapor point and monitoring well installation • Oversight of waste disposal • Oversight of installation of the EC installation and maintenance • Execution of ICs • Oversight of ERH system and operations • Periodic certification of ICs and ECs • Validated the laboratory reports
XDD (now Loureiro)	• Biological Remediation Contractor
TRS	• Designed, installed, and operated the ERH system
Brookside Environmental	• Loaded and transported the waste for disposal
New Environmental Horizons/In-house chemist	• Validated the laboratory reports. Data also validated by independent in-house chemist, Joel Kane, as approved by NYSDEC.
Lawrence Environmental	• Provided industrial hygiene consulting services
Mueser Rutledge Consulting Engineers	• Conducted structural and vibration monitoring for the building and New York City Transit Authority (NYCT) structure
Ohm Electric	• Connected the ERH system to the building's power supply
Parratt-Wolff Drilling	• Installed the monitoring wells and ERH electrodes and monitoring points
SGS Laboratories	• Analyzed groundwater, soil, soil vapor, and carbon samples
Stantec	• Provided consulting electrical engineering services during remedial equipment installation
Control Point Associates	• Surveyed monitoring wells locations and elevations
Fehringer Surveying	• Surveyed monitoring wells locations and elevations

4.2.2 Site Preparation

FLS coordinated with NYSDEC and the contractors listed in the Table 1 throughout the duration of remediation. The following Site preparation tasks were conducted:

- Mobilization consisted of well abandonment, transporting equipment to the Site, and Site security set up
- Utility mark out
- Acquisition of agency approvals, permits, etc.

Documentation of agency approvals required by the RAWP is included in Appendix D. These include:

- Decision Document
- Supplemental Remedial Investigation Report and RAWP approval
- ERH Pilot Test Work Plan approval
- ERH Design approval
- Bioremediation Pilot Studies
- Full-scale OU-1 Enhanced Bioremediation Work Plan
- Full-scale OU-2 Enhanced Bioremediation Work Plan

Other non-agency permits and approvals relating to the remediation project are provided in Appendix E. These include:

- NYCT approvals for drilling (ERH only)
- New York City Department of Buildings (NYCDOB) approvals for equipment installation and roof dunnage ERH only)
- NYCDOB permit for electricity connection (ERH only)
- NYCDEP approvals and permit for groundwater discharge to the sewer
- SEQRA does not apply as remediation is being implemented under the BCP.

4.2.3 General Site Controls

Access to the entrance of the treatment area was restricted by an interior security fence. During working hours, access to the Site was limited to contractors and other permitted personnel.

Photographs and notes were taken by FLS staff to record Site activities. These notes were used to prepare summaries that were submitted to NYSDEC on a daily and monthly basis. Equipment decontamination and residual waste management were performed as outlined in the RAWP.

4.2.4 Nuisance controls

Several measures were employed to reduce the any odors encountered during invasive work on Site. Large ventilation fans were installed into the windows to facilitate indoor/outdoor air exchange. High-volume portable fans were also use to circulate air throughout the work area. There were no complaints from pedestrians or building tenants.

4.2.5 CAMP Results

Air monitoring for VOCs using instrumentation monitoring was continuous during intrusive work (e.g., soil borings and electrode installation). Site 1st floor, and perimeter air monitoring was conducted on a periodic basis during installation and operation of the ERH system and weekly thereafter during vapor mitigation system operation, maintenance and monitoring. Photoionization detectors (PIDs) were calibrated daily. VOCs were rarely detected in the breathing zone and did not exceed 5 ppm for an extended period of time (i.e., more than five minutes). When VOCs were detected, elevated readings were determined to be caused by vapors from equipment, calibration error, or humidity and not by VOCs from intrusive soil activities or the subsurface. These deviations were noted in the field book. Window and circulation fans were used to vent work areas, as needed. Dust monitoring was not required as noted in Section 4.1.4. Copies of all the NYSDEC daily reports, which includes the CAMP field data, are provided in in Appendix F.

4.2.6 Well Abandonment

A total of 110 wells (109 on-Site, one off-Site) were abandoned in September 2015 and September 2017. This work was conducted to clear the treatment area for the installation of the ERH system and to prevent the vertical migration of impacted groundwater into the basal clay layer. Future well abandoning activities will be conducted under the SMP. Table 2 presents the well abandonment details.

4.2.7 Reporting

Progress Reports were provided to the NYSDEC Case Manager on a monthly basis. The target submittal date for each Monthly Progress Report was the 10th of each month. These reports summarized the following:

- Remedial actions taken during each month

- Other Site activities performed not related to the remediation
- Anticipated actions for the following month; changes in approved activities

Daily progress reports were also provided to the NYSDEC Case Manager during active on-Site work. The daily reports summarized the following:

- An update of progress made during the day
- Locations of work and quantities of material imported and exported from Site
- A summary of any and all complaints with relevant details (names, phone numbers)
- A summary of CAMP findings
- An explanation of notable Site conditions

All daily and monthly reports are included in in Appendices F and G, respectively. The digital photo log required by the RAWP is included in Appendix H.

4.3 CONTAMINATED MATERIALS

Section 4.3 discusses removal of waste materials. Section 4.3 includes waste removal associated with ERH and bioremediation. ERH waste is included because it is close in time with EBR and to document the recent waste generation activity. There was very little waste removal associated with the injection of biotreatment agents. Majority of the waste material generated was associated with ERH installation of electrodes, vaporized groundwater removal, and soil vapor removal. The only waste generated during bioremediation was removal of purge water from wells and a minor amount of silt from the wells.

4.3.1 Soil

Soil cuttings generated during installation of the ERH system (electrodes, temperature monitoring points, trenches) and monitoring wells were collected and staged in 55-gallon DOT-approved drums on Site. Waste characterization sampling was conducted for soils in each drum to determine if soils would be disposed of as non-hazardous or hazardous waste. Determinations were based on analytical results as compared to toxicity characteristic leaching procedure (TCLP) maximum contaminant concentrations and NYSDEC Contained-In Action Levels. The drill cuttings generated during sampling and electrode installation were characterized as hazardous or received a "Contained-In" determination as per NYSDEC approval and were disposed of as non-hazardous waste.

A total of 561 drums (approximately 140 tons) of non-hazardous soil was transported by Brookside Environmental to Cycle Chem, Inc. of Elizabeth, New Jersey for disposal. A total of 39 drums (approximately 9.75 tons) tons of hazardous soil was transported to Cycle Chem by Clean Venture, Inc for disposal. In addition, in 2023 10 drums (2,400 pounds) of Non-RCRA drill cuttings was transported by Brookside Environmental to Dale Transfer Corp. in West Babylon, NY for disposal.

The waste characterization and disposal documentation is included in Appendix I, which includes the analytical results, disposal facility approval letters, disposal logs, manifests and NYSDEC Non-Hazardous Contained-In Determination Letters.

4.3.2 Groundwater

During ERH, vaporized groundwater was extracted via the ERH SVE system and condensed using a vapor-liquid separators, a cooling tower, and heat exchangers. The condensate was treated on-Site with by a treatment system prior to being discharged into the building's sewer. As detailed in the ERH Design Report, the original treatment system consisted of a sediment filter, two 200-lb liquid-phase activated carbon (LGAC) vessels, and a 1,200-gallon holding tank.

In April 2018, the water treatment was modified to account for the increased potential for Phase Liquid LNAPL and PCB extraction. This modification added a 200-lb organoclay/LGAC vessel and two larger 1,100 lb. LGAC vessels (to replace the original two 200-lb LGAC vessels). This modification to the system is detailed in the *ERH System Modification for LNAPL Water Treatment* letter included in Appendix J (the two additional sediment filters were installed but later removed because of excessive back-pressure).

Purge water generated during well development and groundwater sampling events was also treated on-Site via the treatment system. From September 2017 to September 2018, the total ERH condensate discharged into the building's permitted sewer connection was approximately 800,000 gallons. In addition, in 2023 10 drums of Non-RCRA well purge water was transported by Brookside Environmental to Dale Transfer Corp. in West Babylon, NY for disposal.

4.3.3 Soil Vapor

TCE and other VOCs contained in the groundwater and soil vapor were extracted via ERH and pre-remediation SVE systems by the use of vapor-phase granulated activated carbon (VGAC). When the soil vapor is pumped through the VGAC, the VOCs adsorb to the carbon granules. The VGAC vessels were monitored for contaminant breakthrough using a PID and/or vapor sampling throughout system operation.

Prior to breakthrough, the spent VGAC was removed from the vessels and replaced with virgin or regenerated VGAC. The spent VGAC was placed in drums and shipped to a facility for regeneration. A total of 252 drums (approximately 38 tons) of hazardous carbon (as a result of TCE concentrations) was transported by Brookside Environmental to Evoqua Water Technologies of Darlington, Pennsylvania for regeneration.

4.4 REMEDIAL PERFORMANCE/DOCUMENTATION SAMPLING

4.4.1 Soil

Soil sampling was not required to document post-remedial conditions because the Site is beneath a building making this infeasible. Nonetheless, soil sampling was completed during various phases of remediation for the purpose of electrode installation and further site assessment. For these reasons the soil results are documented here.

While conducting oversight of ERH electrode installation north of the bathrooms, FLS observed elevated levels of VOCs measured by the PID. A soil sample collected from soil boring J02 indicated TCE concentrations above the Commercial Use Soil Cleanup Objectives (CUSCO). FLS conducted a soil contaminant delineation investigation stepping out from electrode location J02 to the east and north.

A total of eight (8) soil borings (J00, J01, J02, K00, K02, K03, L00 and L01) were advanced as part of this investigation to delineate the extent of soils impacted by chlorinated solvents at locations J02 and J03. These samples were collected from August 30 to September 14, 2016. Analytical results indicated no TCE concentrations exceeding the CUSCOs in any boring with the exception of J02 from 24-28 feet below grade. Drill cuttings from J02 were separated and disposed of as hazardous materials.

The soil boring locations, full analytical results, and a summary of the delineation are presented in the Soil Investigation letter included as Appendix K. As a result of this soil investigation, the ERH treatment area was expanded. Ten additional electrodes (J01, J02, J02B, L00, L00B, L01, K02, K03, K04, and K05) were installed in the central and north area of the Site.

Additionally, as a result of NYCT requirements, electrode B12, C13, D13, and E13 were installed as two smaller diameter electrodes using the duplex drilling method.

A Supplemental Site Investigation was conducted in February 2019 to evaluate post-ERH subsurface conditions. FLS advanced three soil borings inside the ERH treatment area and three soil borings outside the treatment area in the sidewalk along Van Dam Street. All but one boring extended to the clay later at approximately 55 feet below sidewalk grade. The soil boring locations, full analytical results, and a summary of the delineation are presented in the Supplemental Site Investigation Report included as Appendix L.

4.4.2 Groundwater

Groundwater monitoring results from Site and off-Site wells were used to evaluate remedy effectiveness. Analytical results were compared to the NYSDEC Technical and Operation Guidelines for Ambient Water Quality Standards and Guidance Values (TOGS) and the Site-specific TCE groundwater cleanup goal. The Site and off-Site Monitoring Well Locations are shown on Figure 3. Pre-remediation groundwater contour maps for the shallow and intermediate aquifers are shown in Figures 4A and 4B, respectively.

The groundwater monitoring program will continue as specified in the SMP until approval to reduce scope or discontinue groundwater monitoring is granted by NYSDEC. A summary of the performance and post-remedy groundwater analytical results, as of the date of this FER, are shown in Table 3 and Figures 5A and 5B. All results above TOGS and the Site-specific cleanup goal are highlighted. Figure 5C shows TCE in the deep interval.

All samples were collected in accordance with the QAPP, included as Appendix E of the RAWP. All samples were analyzed by SGS Laboratories of Dayton, New Jersey, a New York ELAP-Certified laboratory.

Laboratory data were validated by New Environmental Horizons, a third-party consultant and an independent in-house data validator as approved by NYSDEC. Data Usability Summary Reports (DUSR) were prepared for all data generated in this remedial performance evaluation program. DUSRs are included in the Quarterly/Semiannual Groundwater Reports as Appendix M.

OU-1 Post-Remedy EBR Results

The EBR remedy achieved and/or made substantial progress in securing the groundwater cleanup goals. EBR became necessary because soon after ERH shut off TCE groundwater concentrations rebounded and increased, in some cases, to over 200,000 μg/L in discrete locations, and up to 568,000 µg/L in one well, indicating that significant quantities of source material remained. The remaining source material and ensuing elevated TCE groundwater concentrations led Participant to apply EBR.

The most recent groundwater sampling results for OU-1 are from the April 2023groundwater sampling event in which 20 performance monitoring wells are regularly monitored to gauge the effectiveness of the EBR remedy. Figures 6, 7, 8, and 9 present TCE groundwater concentrations over time in the on-site performance wells. Figures 5A and Figure 5B depict the areal changes in the TCE groundwater plume in the shallow and intermediate zones, respectively. Table 3 presents the complete analytical data for the performance wells. Appendix M contains the quarterly groundwater monitoring reports and contains additional detail.

Table 4 is a statistical summary comparing TCE groundwater concentrations from before (up through October 2020) and after the full-scale treatment through April 2023. Median (p50) TCE concentrations show a continual and sustained decrease with time. Comparison of the median TCE concentration before full-scale treatment (4,310 µg/L) to the current April 2023 sampling period (0.04 µg/L) shows a more than 99.99 percent decrease in the median TCE groundwater concentrations 27 months following the full-scale EBR treatment. The median decrease in the current sampling period (0.04 µg/L) compared to the median concentration following permanent ERH shutoff (11,900 µg/L) in August 2018 is over 100,000-fold (over five orders-of-magnitude). The median TCE concentration in April 2023 fell by 94 percent compared to the previous sampling period in October 2022.

Overall, TCE in the performance wells decreased relative to the previous sampling event (October 2022) and represents a 10th consecutive overall decrease in 27 months of groundwater monitoring since on-Site EBR treatment (which began November 2020). TCE in 18 of the 20 performance monitoring wells was below the TOGS TCE AWQS of 5 µg/L. Of the two detected concentrations above the AWQS, one measured 8.3 µg/L (MW-1) (below the Site-specific remedial objective) and the highest 315 µg/L (MWR-5S). Fourteen of the performance wells had concentrations of TCE below detection limits.

Additionally, the Interquartile Range (IQR), a measure of variability, decreased by approximately 80 percent from October 2022 to April 2023. This is important as it indicates that

TCE concentrations on-Site are increasingly stable and less subject to sudden spikes or rebound, which is critical in verifying long-term reduction trends and overall assessment that remediation efforts are effective. On-site groundwater conditions have been dramatically improved since the EBR application and have been increasingly stable at levels below the Site-specific remedial objective and the TOGS TCE AWQS, to the extent any concentrations are detected.

Figure 6 shows the data in Table 4 graphically, and, significantly, shows a continual decrease in TCE concentrations and a sustained overall decrease in variability.

Table 4 – Comparison of OU-1 Pre- and Post-Biotreatment TCE Groundwater Concentrations, µg/L TCE Percentiles and Summary Statistics in Performance Monitoring Wells[a]

Sampling Period	No. Obs.	Min	Middle 50% of the Data, IQR: p25	Median, p50	p75	Max	IQR
Before Full-scale EBR Treatment							
After ERH Shut off, before Pilot Study	93	9.4	1,250	11,900	34,700	558,000	33,450
Before Full-scale treatment, Oct. 2020[b]	20	2.6	63	4,310	36,750	160,000	36,687
Post-treatment Results							
First Post-treatment, Jan. 2021	23	nd	22	141	1,030	116,000	1,008
Second Post-treatment, Feb. 2021	20	1.8	5.7	56	592	17,500	586
Q1 2021 (3rd Post-treat.), March 2021	20	nd	6.6	43	368	7,890	361
Fourth Post-treatment, April 2021	20	nd	7.8	20	149	5,040	142
Fifth Post-treatment, June 2021	20	nd	6.2	19	104	1,700	98
Sixth Post-treatment, August 2021	20	nd	4.6	17	162	3,320	158
Seventh Post-treatment, Dec. 2021	20	nd	1	6.2	34	965	33
Q1 2022 8th Post-treat., March 2022	20	nd	0.34	0.79	12	2,830	12
Q4 2022 9th Post-treat., Oct. 2022	20	nd	0.024	0.69	4.35	22,600	4.3
Q1 2023 10th Post-treat, April 2023	20	nd	0.0086	0.04	0.9	315	0.88

[a] nd – non-detect. Min, minimum concentration; p25, 25th percentile; p50, 50th percentile, median; p75, 75th percentile; Max, maximum concentration; IQR, Inter Quartile Range, the middle 50% of the data (p75 – p25). Summary for shallow and intermediate wells only. For nd, 0.1µg/L substituted for calculations prior to the Sixth sampling round. Because of the increasing number of non-detects in the Sixth through Tenth post-treatment sampling rounds, Regression-on-order-statistics (ROS) used to compute percentiles and statistically account for the many results below detection levels.

[b] After Pilot Study.

Figure 6 shows the cumulative TCE results in the performance monitoring wells over time. It clearly shows a steady and continual decrease in TCE concentrations with time. Most notably,

Figure 6 shows the decreases are very large due to the log scale and as of March 2022, the median Site concentration is below the Technical and Operational Guidance series (TOGS) Ambient Water Quality Standard (AWQS, Class GA) for TCE of 5 µg/L.

Figure 7 shows large sustained, order-of-magnitude decreases of TCE in MWR-1S, MWR-2S, MWR-3S, and MWR-4S. The decreases remain many orders-of-magnitude lower than before biotreatment. As of March 2022, the results from three wells in Figure 7 are below the TOGS GA AWQS groundwater criterion for TCE (5 µg/L).

Figure 8 shows large TCE decreases in MWR-1I, MWR-2I, MWR-3I, and MWR-4I. TCE concentrations in these wells have decreased from one to four or more orders-of-magnitude in the time since the pilot test and do not show any material rebound (i.e., there are no concentrations approaching pre-treatment levels). The reductions following treatment remain large and sustained. TCE in three of the four wells in this group is below the TOGS AWQS of 5 µg/L. Three of the four wells in Figure 8 are below TOGS AWQS of 5 µg/L this sampling period.

Figure 9 shows similar large sustained, order-of-magnitude decreases in MWR-5S, MWR-5I, MWR-6S, MWR-6I, MWR-7S, MWR-7I, MWR-8S, MWR-8I, MWR-9S, and MWR-9I. Eight of the 10 performance wells in this group are below the TOGS AWQS of 5 µg/L.

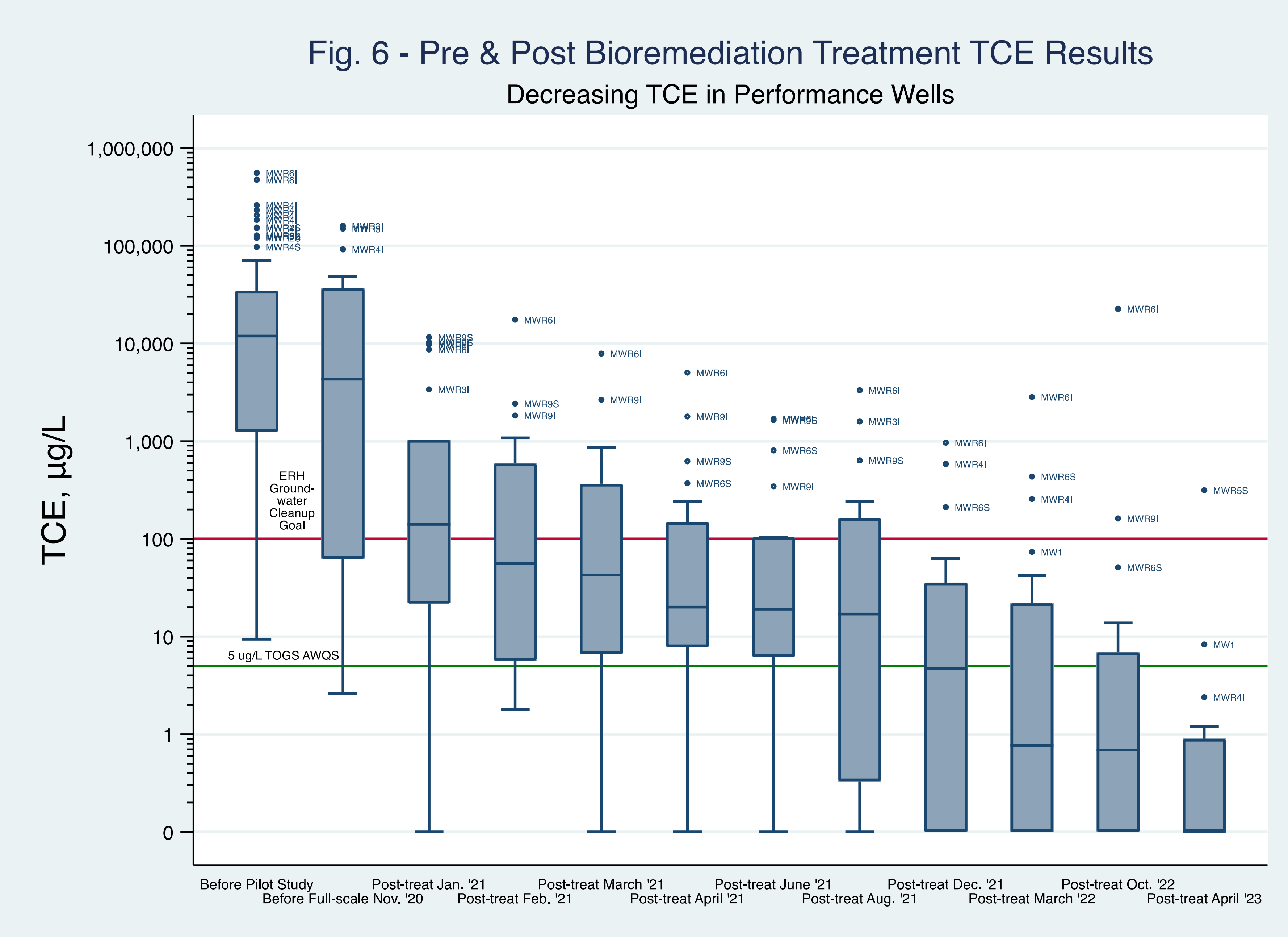
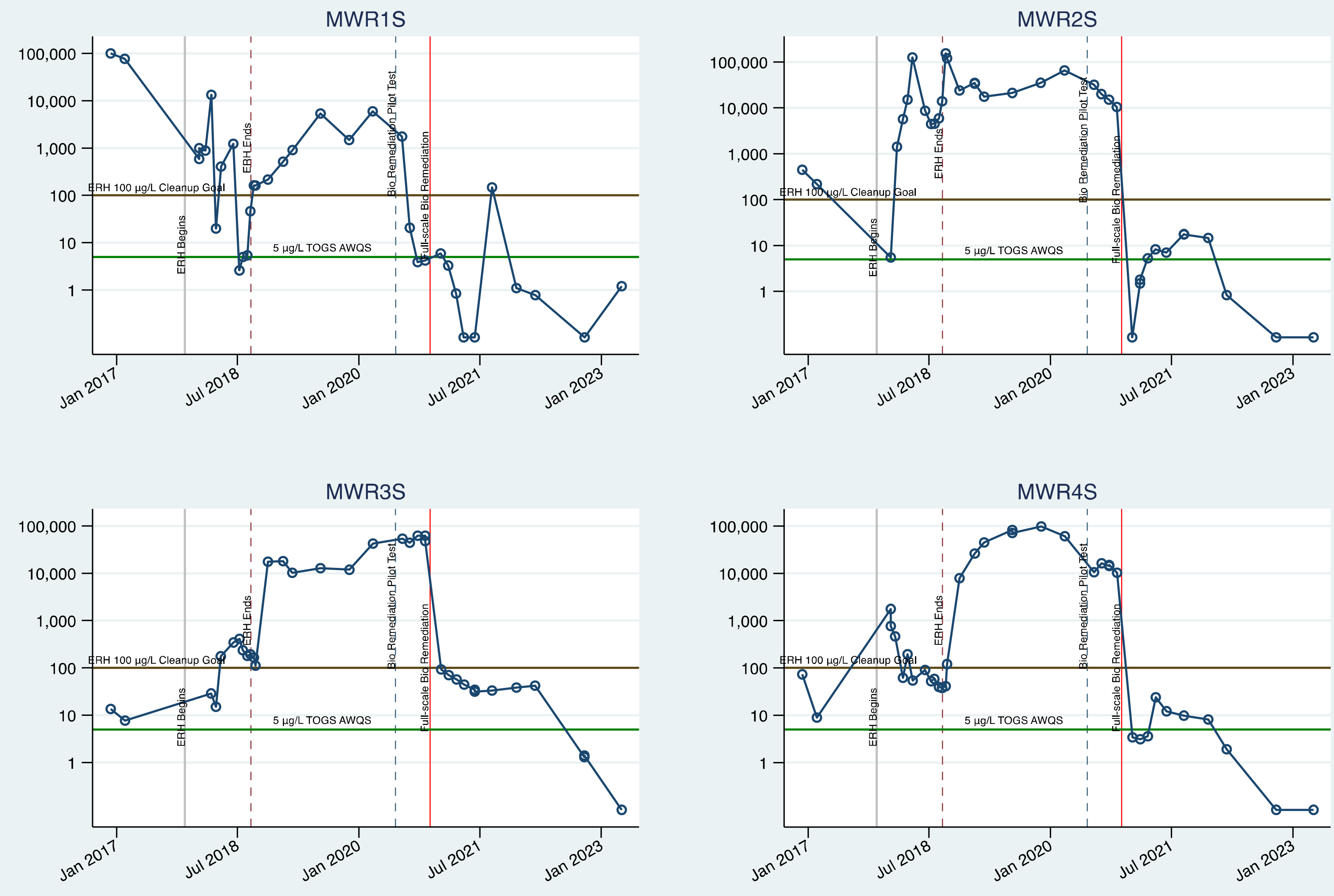


Fig. 6 - Pre & Post Bioremediation Treatment TCE Results
Decreasing TCE in Performance Wells
TCE, µg/L
1,000,000
100,000
10,000
1,000
100
10
1
0
ERH Ground-water Cleanup Goal
5 ug/L TOGS AWQS
MWR6I
MWR4I
MWR3I
MWR9S
MWR9I
MWR6S
MWR4S
MWR5S
MW1
Before Pilot Study
Before Full-scale Nov. '20
Post-treat Jan. '21
Post-treat Feb. '21
Post-treat March '21
Post-treat April '21
Post-treat June '21
Post-treat Aug. '21
Post-treat Dec. '21
Post-treat March '22
Post-treat Oct. '22
Post-treat April '23

Fig. 7 - TCE in Shallow Groundwater, µg/L



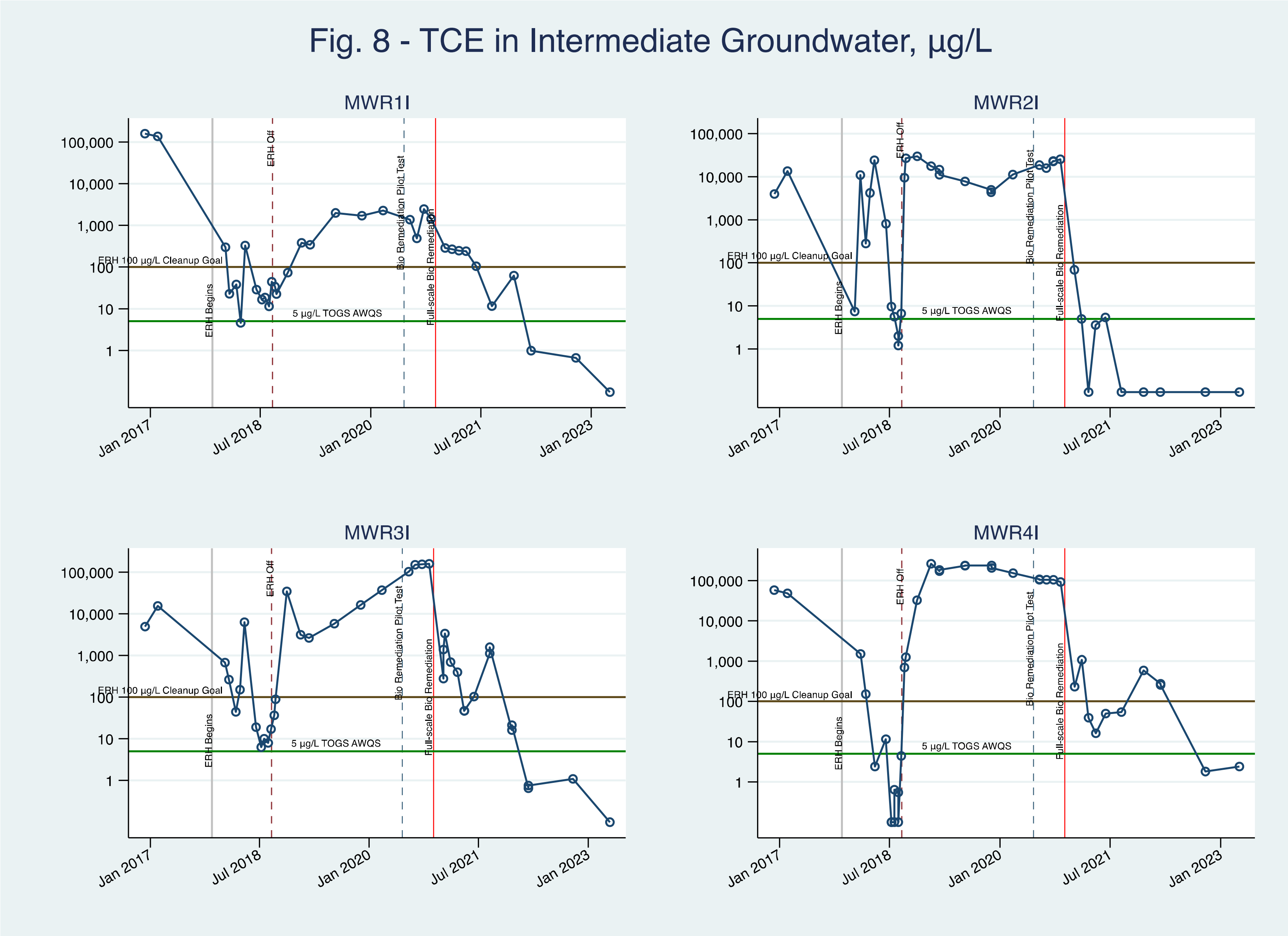


Fig. 8 - TCE in Intermediate Groundwater, µg/L
MWR1I
MWR2I
MWR3I
MWR4I
100,000
10,000
1,000
100
10
1
ERH 100 µg/L Cleanup Goal
5 µg/L TOGS AWQS
ERH Begins
ERH Off
Bio Remediation Pilot Test
Full-scale Bio Remediation
Jan 2017
Jul 2018
Jan 2020
Jul 2021
Jan 2023

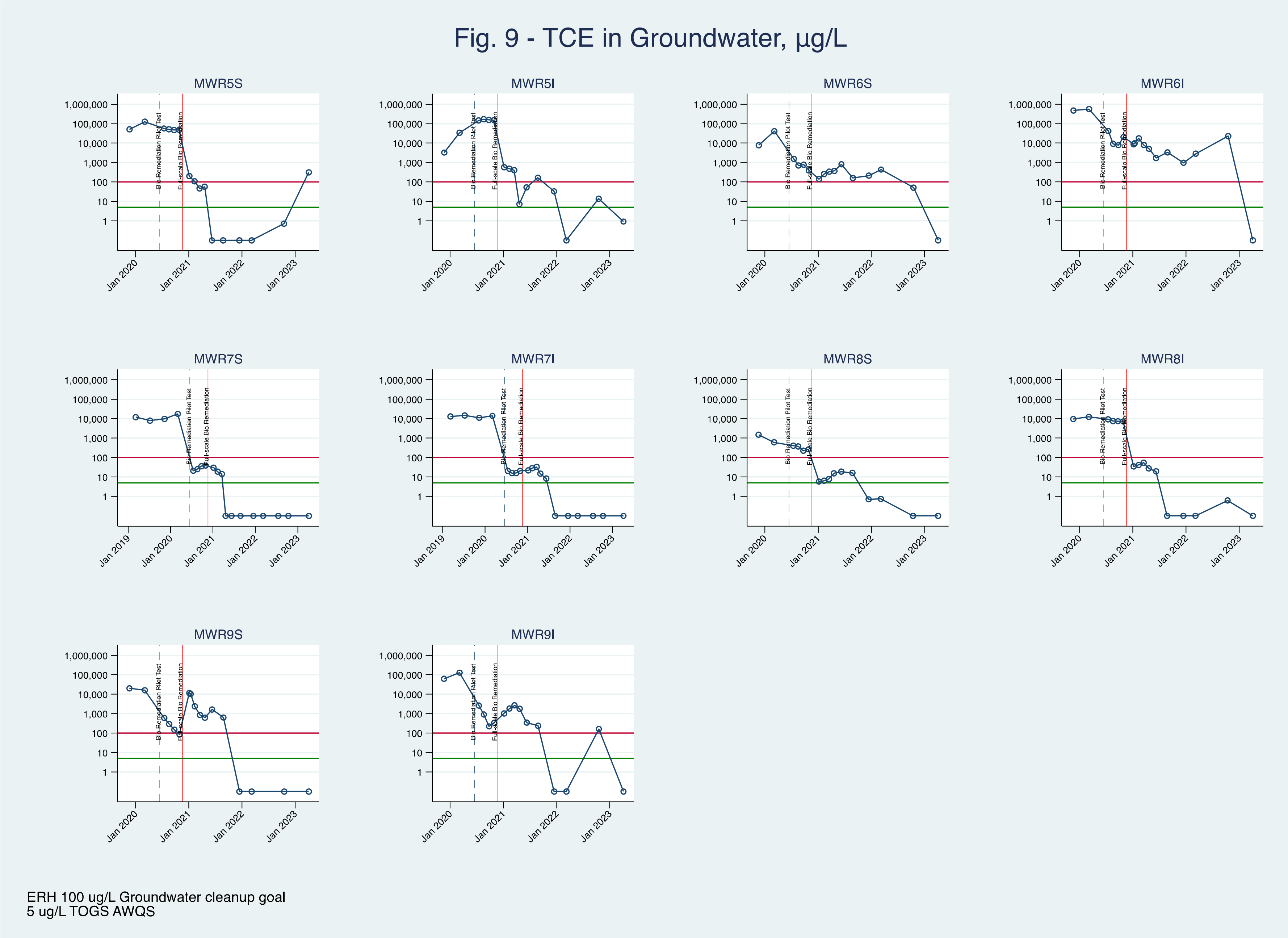


Fig. 9 - TCE in Groundwater, µg/L
MWR5S
MWR5I
MWR6S
MWR6I
MWR7S
MWR7I
MWR8S
MWR8I
MWR9S
MWR9I
1,000,000
100,000
10,000
1,000
100
10
1
Bio Remediation Pilot Test
Full-scale Bio Remediation
Jan 2019
Jan 2020
Jan 2021
Jan 2022
Jan 2023
ERH 100 ug/L Groundwater cleanup goal
5 ug/L TOGS AWQS

Spatial Analysis

Figures 5A and 5B show shallow and intermediate TCE isopleth concentrations over time. Both figures depict very large contractions of the plumes and a continued shrinking of the plumes. Figure 5A shows the OU-1 shallow TCE plume over time. The first thing to notice is the very large reductions in TCE concentrations with time. In particular, the potential DNAPL threshold value of 11,000 µg/L disappears after January 2021, approximately three months after the full-scale EBR, and does not reappear. The second thing to notice is the increasing size of the area with TCE measuring the TOGS AWQS of 5 µg/L or less, which corresponds to the overall increase in the number of wells below the TOGS AWQS with time. Figure 5B shows the OU-1 intermediate TCE plume over time and shows the same pattern as 5A, although the potential DNAPL threshold value disappears after February 2021; the area with TCE measuring 5 µg/L or less continues to increase.

In both instances, as of March 2022, the plumes continue to shrink approximately 16 months after full-scale treatment with no evidence of material rebound. The footprints of both the shallow and intermediate TCE plumes are the smallest they have ever been. TCE concentrations are far below the possible DNAPL threshold indicating that source material has been removed.

Regulatory Comparison

As of April 2023, 27 months after the full-scale EBR, the total number of OU-1 wells below the TOGS TCE AWQS of 5 µg/L is 18 out of 20 (90 percent of all performance monitoring wells). Fourteen sample results were non-detect, and the remaining values are 8.3 µg/L and 315 µg/L (Table 4).

Non-detects

As noted by Hood et al. (2008), the occurrence of multiple non-detects following the application of enhanced bioremediation indicates that the remedy has effectively removed a majority of, if not all of, the remaining TCE mass.[2]

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[2] Hood, E.D., Major, D.W., Quinn, J.W., Yoon, W.-S., Gavaskar, A., and Edwards, E.A. 2008. *Demonstration of Enhanced Bioremediation in a TCE Source Area at Launch Complex 34. Cape Canaveral Air Force Station.* Ground Water Monitoring & Remediation. National Groundwater Association.

The number of non-detects in performance wells following reductions in TCE concentrations has continued to increase beginning the third post-treatment sampling period (March 2021) through April 2023, bringing a total of 14 non-detects (out of 20 performance monitoring wells) in April 2023. This trend of continually *decreasing* TCE concentrations and *increasing* number of non-detects since bioremediation reflects a lack of rebound and demonstrates strong evidence of contaminant source removal (DNAPL source depletion).

Bulk Reduction

FLS compared the maximum TCE concentrations between Electrical Resistivity Heating shutoff and the EBR pilot study. As of March 2022, bulk reduction in the 20 performance monitoring wells ranged from 80 percent to 100 percent. As of April 2023, all 20 performance wells experienced a weighted mean reduction of more than 99.99 percent compared to their maximum pre-EBR treatment concentration.

Fure et al. (2006) found reductions in groundwater flux and DNAPL mass depletion to have an approximate 1:1 relationship.[3] Based on this work, the 100 percent bulk reduction in groundwater concentrations equates to a 100 percent reduction in TCE DNAPL mass.

Carey et al. (2014) describe a method for measuring the Source Strength Reduction (*MdR*) of DNAPL contaminated sites.[4] They state that using a weighted geometric mean based on initial DNAPL concentrations on sites with multiple source wells yields a more accurate representation of the mean *MdR*. *MdR* is calculated using the weighted pre-treatment concentrations and the final concentrations. Using data from the April 2023 sampling period, the pre-treatment geometric mean measured 38,632 µg/L (95% confidence: 24,028 µg/L to 62,114 µg/L; n = 93) and the post-treatment results in April 2023 geometric mean measured 2.24 µg/L (n = 20). Based on this analysis, the overall Site TCE Source Strength Reduction is 99.99 percent with TCE levels continuing to decline.

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[3] Fure, A. D., Jawitz, J. W., Annable, M.D. 2006. *DNAPL source depletion: Linking architecture and flux response.* Journal of Contaminant Hydrology 85 (2006) 118-140.

[4] Carey, G. R., McBean, E. A., and Feenstra, S. *DNAPL Source Depletion:2. Attainable Goals and Cost-Benefit Analyses*. REMEDIATION Autumn 2014.

Degradation and Geochemistry

Site groundwater data show strong evidence of biological degradation in the performance monitoring wells. Generally, TCE breakdown via reductive dechlorination proceeds in the following sequence of TCE and daughter products: TCE → cis-1,2-DCE → Vinyl Chloride → Ethene → Ethane (Wiedemeier 1999, p. 245).[5] The presence or increases in TCE daughter products in conjunction with reduced TCE concentrations provide evidence of reductive dechlorination. Similarly, carbon dioxide is another indicator of biological activity as the final breakdown product of reductive dechlorination. (Wiedemeier 1999, p. 326). Additionally, methane concentrations serve as another indicator of biodegradation since methane is a chemical marker for strong reducing conditions and indicates subsurface conditions are favorable for reductive dechlorination (Wiedemeier 1999, p. 326). Ethene and ethane are final degradation by-products of biodegradation of TCE.

The combined ethane and ethene concentrations in performance wells began to increase appreciably in June 2021 and was among the highest in the December 2021 sampling period both in terms of the highest values, highest median concentration, and highest 75^{th} percentile concentration. The March 2022 median combined ethane and ethene concentration measured approximately 25 µg/L. This is approximately two-and-a-half times greater than the December 2021 median concentration and signifies that complete biodegradation is active and ongoing. The condition continued in the April 2023 results, where the median combined ethane and ethene concentration measured approximately 12 µg/L, which is still among the highest measured to date, again signifying that biodegradation is continuing.

By another measure, if complete degradation is occurring, then the combined total number of moles of TCE+cis-1,2-DCE + vinyl chloride would be expected to decline over time or be much lower than the initial TCE concentrations. The combined moles for OU-1 are much less than the pre-treatment levels indicating that biodegradation is progressing toward completion. Figure 10 shows the decreasing number of overall TCE and daughter compound moles in performance wells over time.

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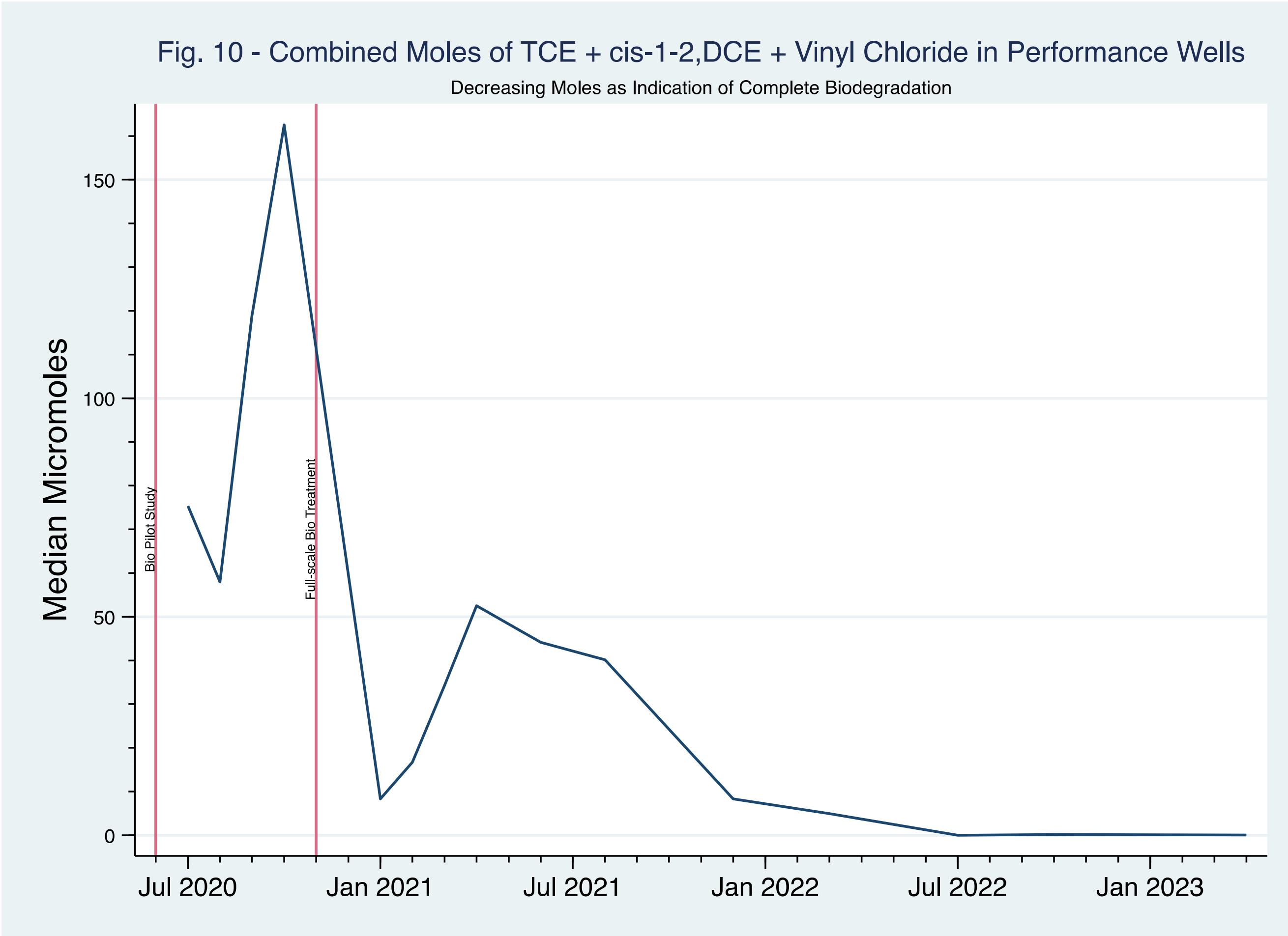
[5] Weidemeier, T. W., Handai, S.R, Newell, C. J., and Wilson, T. W. 1999. *Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface*. John Wiley & Sons, Inc.



Post-EBR OU-2 Sampling Results

The Participant conducted post-treatment sampling in July 2023 following the April 2023 EBR injections. Post-treatment sampling included wells MW-9, MW-8I, MW-10A, MWR-10S/I, MWR-11S/I, and MWR-12S/I. Table 5 compares TCE concentrations in each of these wells from January 2017 through July 2023. Figures 5A and 5B show the offsite TCE groundwater concentrations to the current sampling period (July 2023).

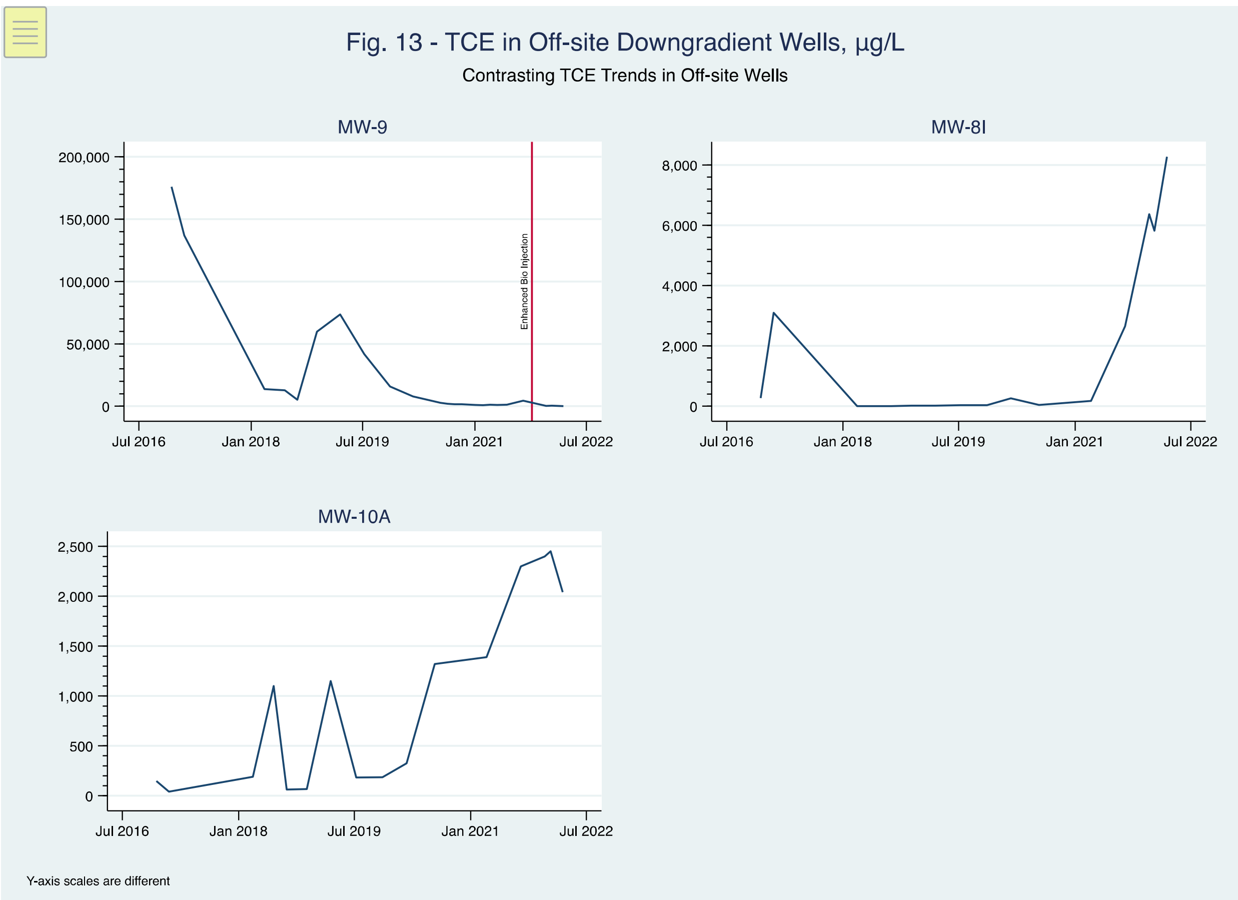
Table 5 – TCE in Off-site Wells, µg/L
Jan. 2017 – July 2023

Sample	No. Obs.	Min	p25	p50	p75	Max	Mean	July 2023
Downgradient								
MW-8I	13	nd	10.8	35	220	3100	529	
MW-10A	13	42	126	259	1,235	2,300	693	
MW-9	20	956	1,330	4,520	15,800	137,000	20,329	
PI-49I	2	ND	--	--	--	ND	ND	
PI-54I	2	497	--	--	--	966	732	
MW13I	2	ND	--	--	--	ND	ND	
MW14I	2	ND	--	--	--	ND	ND	
MW15I	2	ND	--	--	--	2.3	1.2	
PI-59I	2	ND	--	--	--	ND	ND	
PI-55S	2	3	--	--	--	3.6	3.3	
PI-55I	0	--	--	--	--	--	--	
MW-12	4	ND	0.85	2.6	3.7	3.8	2.3	
MW-12I	6	ND	ND	1.9	8.8	17.9	5.1	
MW-17	9	0.32	0.89	1.2	2	3.3	1.5	
MW-17I	9	ND	ND	0.46	0.85	14.7	2	
Crossgradient								
PI46S	2	611	--	--	--	902	757	

Figures 5A and 5B show the results of the recent groundwater sampling results in OU-1 and OU-2. Of the six off-site shallow wells (MW-12, MW-15, MW-17, PI-55S, PI-54S, and PI-46S), four wells have TCE concentrations less than 5 µg/L. Two wells were above 5 µg/L: PI-54S (19.7 µg/L), at the former BP Amoco station, and PI-46S (450 µg/L), just outside the OU-1 boundary. Figure 5A shows the shallow downgradient off-site area to be minimally impacted. Note that MWR-7S, a shallow well between the Site and offsite downgradient wells has been non-detect for five sample rounds.

Figure 5B shows TCE impacts to be confined to the area around MW-9 and in a second area between MW-8I and MW-10A, where the highest TCE concentration is in MW-8I. The orientation of the TCE impacts in MW-8I and MW-10A is north-northwest-south-southeast, which is approximately perpendicular to the groundwater flow direction. The configuration of the impacted areas does not appear consistent with the model of contamination moving with groundwater flow from the Site. Instead, the configuration suggests separate off-site sources. The remaining four downgradient wells show TCE concentrations all less than 5 µg/L and mostly non-detect.

Three off-site intermediate wells have been sampled frequently to monitor TCE concentrations. These include MW-9, MW-8I, and MW-10A. Figure 11 shows TCE concentrations in these wells from 2016 through March 2022.

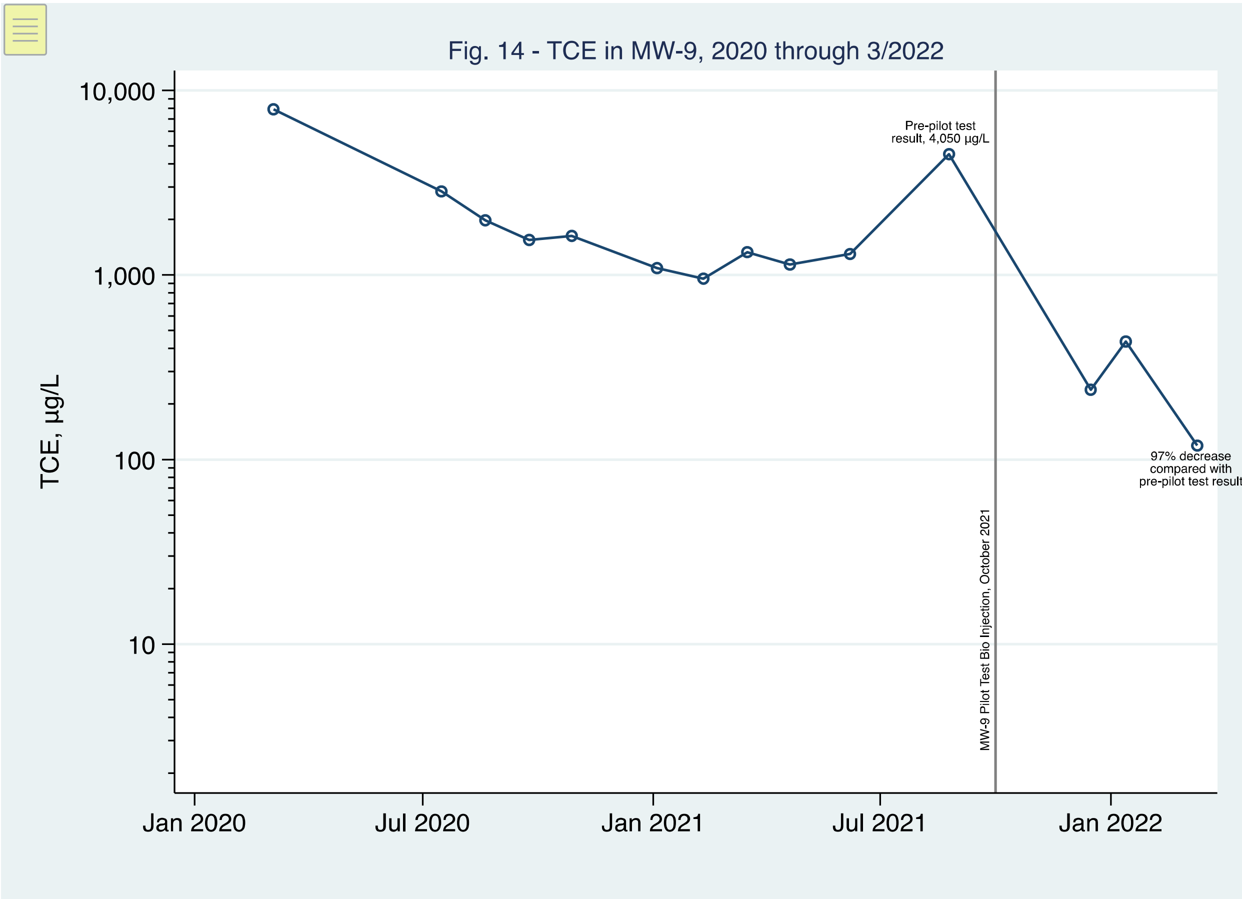


TCE in MW-9 has been *decreasing* overall since December 2016 following concentration spikes in 2016 and 2017. In the current period, March 2022, TCE in MW-9 decreased by over 97 percent [(4,520-119)/4,520] compared to the previous sampling period. This decrease is in direct response to the EBR administered in MW-9 in October 2021.

In contrast, TCE in MW-10A and MW-8I has been *increasing* despite there being no remaining source of TCE at OU-1. TCE in MW-10A has been increasing for the past five years and since 2021 in MW-8I. TCE in these wells has increased to among the highest concentrations observed in these wells: TCE measured 2,040 µg/L in MW-10A and 8,270 µg/L in MW-8I this period (March 2022). These increases also contrast with the non-detects measured in the past few quarters in Site downgradient sentinel wells MWR-7S and MWR-7I. As discussed below, the abrupt increases in the off-site wells appear to be the result of unrelated, off-site sources.

Recall that the facility ceased using TCE by the 1990s and any elevated TCE Site concentrations caused by dispersion of TCE by ERH in 2017-2018 would have already passed these locations.

The TCE concentration trends and location of these off-site wells suggests that TCE in these locations is unrelated to former TCE on the Site. The orientation of the axis of TCE impacts in MW-8I—MW10A (Figure 5B) is approximately perpendicular to the groundwater flow direction, which does not match the direction of groundwater flow. If TCE were related, then the off-site concentration trends would be expected to mirror the decreasing trends in Site wells. That there are abrupt TCE increases in these off-site wells opposite the non-detects in the two most downgradient Site wells, MWR-7S and MWR-7I, points to unrelated, off-site sources.



4.4.3 Soil Vapor

During remedial implementation, FLS calculated the total mass of VOCs removed by ERH based on several factors including blower flow rate, blower operating time, PID readings, and vapor sample results. FLS estimates that a total of 5,000 pounds of VOCs have been removed from the subsurface by ERH.

SSDS Flux

As detailed in the *ERH Soil Vapor Extraction System Air Compliance Letter* to NYSDEC dated September 21, 2017, FLS monitored stack effluent from system operation to confirm that emission rates did not exceed annual or short-term guidance concentrations. The effluent vapor was monitoring using a PID and/or data from vapor samples collected during routine operation, monitoring, and maintenance (OMM) activities.

On December 15, 2016, four soil vapor samples were collected using a one-liter Summa canister with a two-hour flow controller from before carbon treatment (SVE-Inlet), between carbon units (Midstream-2A & Midstream-2B), and post-carbon treatment (SVE-Outlet). Analytical results found the TCE concentration prior to treatment (SVE-Inlet) measured 1,620 $\mu g/m^3$. TCE reduced by 99 percent after passing through the first carbon treatment unit (SVE-Midstream 2A @ 21 $\mu g/m^3$ and 24 $\mu g/m^3$ in SVE-Midstream 2B). TCE concentrations further reduced (>99 percent) after the second carbon unit (SVE-Outlet @ 6.4 $\mu g/m^3$). The flux analysis found emission rates less than 0.1 lb./hr., which were orders of magnitude below the NYS Annual Guidance Concentration (AGC) and the Short-Term Guidance Concentration (SGC). Therefore, FLS concluded that TCE emissions did not have a significant effect on air quality and did not pose an immediate risk to human health or the environment. Ambient air quality impact calculations before and after the SVE treatment are included in Appendix O.

Participant re-evaluated the TCE vapor effluent in the SSDS exhaust in April 2023 using field flow parameters and current SSDS parameters. The analysis showed that TCE concentrations from the SSDS exhaust stack could yield concentrations that would exceed, or even approach, the New York State (NYS) Division of Air Quality (DAR) Annual Guideline Concentrations (AGCs, 0.2 $\mu g/m^3$) and Short-Term Guidance Concentration (SGCs, (20 $\mu g/m^3$).

Soil Vapor

Participant sampled sub-slab vapor and indoor air in October 2018, April 2022, and November 2022. The April and November 2022 results are discussed in Section 4.6.3.

4.5 IMPORTED BACKFILL

Material for backfilling was not required with the selected remedy or interim remedies.

4.6 CONTAMINATION REMAINING AT THE SITE

After completion of the remedial work, some contamination was left in the subsurface at this Site, which is hereafter referred to as "remaining contamination."

4.6.1 Groundwater

Post-remedy groundwater monitoring confirmed there is remaining contamination in groundwater on the Site. Any additional remediation required by NYSDEC (i.e., bioremediation or monitored natural attenuation) will be implemented under the SMP to remediate on-Site shallow and intermediate groundwater concentrations of TCE to the extent such concentrations remain significantly above the cleanup objective.

Table 6 and Figures 5A and 5B summarize the results of performance monitoring wells that currently exceed TOGS after completion of the Remedial Action. The groundwater monitoring program will continue as specified in the SMP until approval to reduce scope or discontinue is granted by NYSDEC.

Table 6 - Post-Remediation TCE Groundwater Results above TOGS Class GA AWQS, July 2023

Wells	TCE 5 µg/L	Vinyl Chloride 2 µg/L
OU-1 Performance Wells		
MW-1	--	--
MWR-5S	--	--
MWR-3S	--	--
MWR-4I	--	--
MWR-6S	--	--
MWR-6I	--	--
MWR-1I	--	--
MWR-1S	--	--
MWR-2S	--	--
MWR-2I	--	--
MWR-3I	--	--
MWR-4S	--	--
MWR-5I	--	--
MWR-7S	--	--
MWR-71	--	--
MWR-8S	--	--
MWR-8I	--	--
MWR-9S	--	--
MWR-9I	--	--
OU-2 Wells	--	--
MW-9	--	--
MW-10A	--	--
MW-8I	--	--
MWR-10S	--	--
MWR-10I	--	--
MWR-11S	--	--
MWR-11I	--	--
MWR-12S	--	--
MWR-12I	--	--

Vinyl chloride is a biodegradation breakdown product of TCE. It further degrades to the final end products of ethane and ethene.

4.6.2 Soil

Soil remediation is outside the scope of the remedy and is not part of the Decision Document. The remediation of the TCE in soil is made by inference from the groundwater sampling results. Low TCE groundwater concentrations and/or TCE concentrations below one percent of solubility (11,000 µg/L is one percent of pure phase TCE solubility) signify that source material (NAPL) has been removed and that soils have been effectively remediated.

Due to the reduction of all OU-1 TCE concentrations below 315 µg/L in groundwater as of April 2023 and 18 out of 20 performance monitoring wells below the TOGS Class GA AWQS for TCE, it is inferred with more weight that the source of contamination at the Site has been addressed through the selected remedy (EBR). There is no anticipated exposure to remaining soil contamination because exposure is effectively prevented by the existing cover system, comprised of the repaired and sealed concrete building slab, which will remain over the entire building footprint.

4.6.3 Soil Vapor

The existing composite cover system and the SSDS are the two engineering controls that will operate pursuant to the SMP terms to mitigate any potential for vapor intrusion. FLS will conduct post-remediation sub-slab soil vapor sampling as part of the SMP. The quality and integrity of these systems will be inspected at defined, regular intervals in perpetuity.

Since contaminated groundwater, soil and soil vapor remain beneath the Site after completion of the Remedial Action, Engineering, and Institutional Controls are required to protect human health and the environment. These Engineering and Institutional Controls (EC/IC) are described in the following sections. Long-term management of these EC/ICs and residual contamination will be performed under the SMP approved by the NYSDEC.

A vapor intrusion investigation in OU-1 was conducted in November 2022 to evaluate post-remediation sub-slab soil vapor concentrations and the potential to vapor intrusion into the basement. This event occurred with the SSDS off for more than one month during the heating season before sampling and included simultaneous sampling of sub-slab soil vapor and indoor air samples to determine if there is any potential for soil vapor intrusion after remediation. As the basement floor does not extend to or below groundwater, there is space for potential soil vapor accumulation.

The results of post-treatment vapor sampling from nine sub-slab vapor points and six indoor air samples in the Site basement are summarized in Table 7.

Table 7 – November 2022 Post-Treatment Soil Vapor Sampling Results, µg/m^3
Sub-slab, n = 9; Indoor Air, n = 6

Compound	Min.	p25	p50	p75	Max	NYSDOH Air Guideline
Sub-Slab Vapor						
TCE	42	170	263	308	623	--
cis-1,2-DCE	1.6	2.6	3.4	5.6	17	--
1,1-DCE	nd	nd	nd	nd	nd	--
Carbon Tetrachloride	nd	nd	nd	nd	nd	--
PCE	nd	1.3	1,7	2.9	8.1	--
1,1,1-TCA	nd	nd	nd	nd	8.7	--
Methylene Chloride	4.5	6.6	9	11	20	--
Vinyl Chloride	nd	nd	nd	nd	nd	--
Indoor Air						
TCE	nd	nd	nd	nd	nd	2
cis-1,2-DCE	nd	nd	nd	nd	nd	--
1,1-DCE	nd	nd	nd	nd	nd	--
Carbon Tetrachloride	nd	nd	nd	nd	nd	--
PCE	nd	nd	nd	nd	nd	30
1,1,1-TCA	nd	nd	nd	nd	nd	--
Methylene Chloride	0.87	0.9	1.04	1.4	5.2	60
Vinyl Chloride	nd	nd	nd	nd	nd	--

Non-detects (nd) coded as -0.0001 in calculation of percentages. This results in the percentiles, p25, p50, p75, being approximate only.

TCE, the principal contaminant of concern, in the indoor air above the slab was non-detect in all six indoor air samples despite TCE concentrations in the sub-slab vapor being many times greater compared with the indoor air levels. The large difference suggests that the potential for vapor intrusion through the slab is low.

Nonetheless, the Soil Vapor/Indoor Air Matrix Table 2 (May 2017) of the NYSDOH document *Guidance for Evaluation Soil Vapor Intrusion in the State of New York,* October 2006, calls for continued operation of the SSDS under conditions where TCE in sub-slab vapor exceeds 60 µg/m^3, regardless of the TCE indoor air concentration. Laboratory results are included in Appendix P.

4.7 COMPOSITE COVER SYSTEM

Exposure to remaining contamination is prevented by a composite cover system that was in place throughout remediation and remains on the Site. This composite cover system is a concrete building slab (with an approximate thickness of six inches).

Figure 13 shows the location of the composite cover at the Site. An Excavation Work Plan, which outlines the procedures required in the event the cover system and/or underlying residual contamination are disturbed, is provided in Appendix D of the SMP.

4.8 OTHER ENGINEERING CONTROLS

Since remaining contaminated groundwater, soil and soil vapor exists beneath the Site, ECs are required to protect human health and the environment. The Site has the following primary Engineering Controls, as described in the following subsections.

4.8.1 Sub-Slab Depressurization System (SSDS)

The SVE system associated with the ERH system operated throughout the duration of the ERH remedy. Upon completion of ERH, the original SVE system was converted to a SSDS that utilized the vapor recovery wells from five electrodes (D11, G11, H04, H06, J08). The temporary SSDS operated until the subsurface cooled to approximate pre-remediation conditions (approximately 18 °C), then a permanent SSDS was installed in May 2020.

The permanent post-remediation SSDS was designed to be unobtrusive and low-maintenance. The pipes were hung from the ceiling or walls. Minimizing the system footprint will also help to protect the system and provide more room in the basement for the next tenant. The permanent post-remediation SSDS was renovated in July 2023 to be more efficient and upgrade the older system and equipment. An as built layout for the upgraded SSDS is shown in Figure 14. A process and instrumentation diagram of the SSDS is shown in Figure 15.

FLS conducted sub-slab vapor sampling in April 2021. Any modifications to the permanent SSDS design will be done under the SMP.

Procedures for monitoring, operating and maintaining the SSDS system are documented in the Operation and Maintenance Plan described in Section 5.0 of the SMP. The monitoring plan also addresses inspection procedures that must occur after any severe weather condition that may affect on-Site ECs.

4.8.2 Off-Site SSDS

In addition to extracting soil vapor and maintaining sub-slab vacuum on-Site, the SSDS is also connected to two laterals (SL-1 and SL-2) that extract sub-slab soil vapor from beneath the building's other concrete slab, which is elevated above the Site's concrete slab and located north of the Site. Soil vapor will continue to be extracted through these laterals by the permanent SSDS.

As part of the remedy, two off-Site SSDSs are maintained. The YMCA directly east of the Site, across 32nd Place, consists of four SSDS fans. The SSDS operating at the multi-family residence west of the Site, across Van Dam Street, has one fan. These two off-Site systems will continue to be inspected on a monthly basis and maintained under the SMP. Layouts of the Van Dam St and YMCA off-site SSDSs are shown in Figures 16 and 17A-D, respectively.

4.9 INSTITUTIONAL CONTROLS

The Site remedy requires that an Environmental Easement be placed on the property to (1) implement, maintain and monitor the Engineering Controls; (2) prevent future exposure to remaining contamination by controlling disturbances of the subsurface contamination; and, (3) limit the use and development of the Site to restricted residential, commercial and industrial use(s) only.

The Environmental Easement was executed by the Department on XXX, 2023, and filed with the Queens County Clerk on XXX, 2023. The County Recording Identifier number for this filing is XX, 2023 A copy of the easement and proof of filing is provided in Appendix A.

4.10 MODIFICATIONS TO THE REMEDIAL ACTION WORK PLAN

There were no deviations from the bioremediation plan; however, several modifications were made to the Remedial Action to address issues that arose during the ERH remedy. The TRS ERH Design Report, included in Appendix N, shows the final ERH design and any modification to the proposed Design Report dated June 2, 2016. The ERH Installation Report includes details of the components, system layout, calculations, operating conditions and support documentation such as manufacturing specifications and as-built drawings and diagrams.

Modifications were made to the original ERH system layout during the installation and operation of the system. These changes were implemented as a result of Site-specific conditions and an increased understanding of the contaminant mass and extent. The system modifications included the following:

- October 2016: Expansion of the treatment area as a result of supplemental soil investigation
- December 2017: Temporary addition of a third VGAC leg to treat elevated VOC concentrations
- April 2018: Additional water treatment equipment/vessels to account for potential LNAPL and PCBs in the extracted soil vapor
- May 2020: The SVE system was converted to the permanent SSDS.

The final as-constructed ERH System Layout is shown on Figure 18.

The well abandonment summary presented in the RAWP detailed which piezometers, monitoring wells, and injection wells would be maintained or abandoned. Table 2 shows which wells were abandoned and which were kept intact over the course of remediation.