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Defense Logistics Agency

Defense Supply Center Richmond

ADMINISTRATIVE RECORD COVER SHEET

AR File Number 1414-1

FINAL

REMEDIAL ACTION WORK PLAN ADDENDUM
OPERABLE UNIT 7
DEFENSE SUPPLY CENTER RICHMOND

Prepared For

Defense Logistics Agency

And

United States Army Corps of Engineers
Baltimore District

Prepared by

AECOM Technical Services, Inc. and Meadows CMPG, Inc.

August 2025

Table of Contents

Figures

Tables

Exhibits

Executive Summary

This Remedial Action Work Plan (RAWP) Addendum describes the proposed follow-up in situ bioremediation (ISB) actions at Operable Unit (OU) 7 at Defense Supply Center Richmond (DSCR). OU 7 consists of impacted groundwater beneath and downgradient of OU 4 (Fire Training Area Source Area) along the central southern boundary of the installation. Contaminants from the OU 13 area (polycyclic aromatic hydrocarbon area) near OU 4 have also potentially impacted OU 7 groundwater. Three dissolved phase plumes of volatile organic compounds (VOC) are associated with former Fire Training Pit Areas 1, 2, and 3. Primary constituents in groundwater are tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), and vinyl chloride (VC) present at concentrations greater than cleanup levels established in the 2012 Record of Decision (ROD) for OU 7. The primary zone of groundwater impacted at OU 7 is the surficial aquifer, which is the target of follow-up ISB actions.

Follow-up ISB actions at OU 7 will target accelerated treatment of remaining hot spot areas in the surficial aquifer. Addressing these hot spot areas will reduce contaminant mass and contaminant flux to downgradient areas. ISB actions proposed in this work plan will target additional treatment of diffuse VOC plumes farther downgradient of source zones with the objective of reducing overall plume areas.

Proposed ISB actions for the Pit 1 plume will target additional treatment of two hot spot areas with the highest concentrations of PCE, TCE, cDCE, and VC in groundwater at OU 7. A third treatment area will target additional treatment of the diffuse VC plume in the farthest downgradient plume area in the Pit 1 monitored area. Proposed ISB actions for the Pit 2 plume will target additional treatment of two hot spot areas for degradation products cDCE and VC in previous 2021 treatment areas. A third area will target additional treatment of a diffuse VC plume in the farthest downgradient plume area in the Pit 2 monitored area. The proposed ISB action for the Pit 3 plume will address a remaining degradation product hot spot in the mid-plume area as a follow-up to 2021 ISB actions.

The process option of the ISB design in this work plan follows the remedial design/remedial action work plan for OU 7 (AECOM 2013) using metabolic anaerobic reductive dechlorination as the targeted degradation process to treat the chlorinated solvents. In this reaction, microorganisms gain energy as one or more chlorine atoms on a chlorinated ethene or ethane compound molecule are replaced with hydrogen atoms in an anaerobic environment. The chlorinated compound serves as the electron acceptor and molecular hydrogen usually serves as the electron donor (source of energy). Hydrogen used in this reaction is supplied by fermentation of organic substrates or a direct electron donor. Biodegradation of an organic substrate depletes the aquifer of dissolved oxygen, and sequentially reduces native electron acceptors nitrate, manganese, iron, sulfate, and carbon dioxide. In general, metabolic anaerobic reductive dechlorination occurs by sequential removal of chlorine atoms with the sequential reaction consisting of PCE → TCE → cDCE → VC → ethene.

For hot spot and source area treatment, emulsified vegetable oil (EVO) is the selected ISB substrate comprised of food-grade soybean oil, emulsifiers, and amendments with demonstrated effectiveness to support enhanced reductive dechlorination (ERD). Evidence of complete ERD pathways to ethene and methane is apparent for previous EVO injections at OU 7 and treatability studies. The low solubility of EVO provides for a long-lasting carbon source due to its slow rate of chemical dissolution into groundwater. EVO can also help sequester chlorinated VOC compounds, which will further reduce their mobility in the aquifer.

The hot spot and source area treatment, the injection process option selected for enhanced ISB for the surficial aquifer at OU 7 is direct push technology (DPT) using a pressure activated injection probe. Previous investigations, pre-design investigations and testing performed at OU 7 indicate that the high density of the mid-to-lower interval of the surficial aquifer will require injection pressures greater than 100 pounds per square inch to distribute reagents in this zone. The high density and variability of the surficial aquifer has limited the effectiveness of previous ISB actions using injection wells in this zone. The optimized reagent mixture will include EVO, sodium bicarbonate for pH buffering, and sodium ascorbate to create anaerobic water for bioaugmentation cultures to enhance and accelerate biodegradation processes. Designs for the treatment areas include 51 DPT injection points and five (5) injection wells. The ISB design period is three (3) years for EVO injections and 1.5 years for sodium lactate.

Sodium lactate is the selected ISB substrate for additional ISB treatment of diffuse vinyl chloride plumes at Pits 1 and 2 in the farthest downgradient areas. This will involve gravity feed injections at one injection well in the Pit 1 plume area and four injection wells in the Pit 2 plume area.

The proposed ISB actions will include remedy verification and performance monitoring. Injection process monitoring will track injection progress relative to the design and include field measurements during the injections to evaluate reagent distribution relative to the treatment design. Performance monitoring will include a baseline monitoring event corresponding to the annual monitoring event scheduled for March 2025. ISB implementation is expected to occur late in the second quarter of 2025 after completion of the annual sampling. The annual monitoring event at OU 7 includes sampling of 88 monitoring wells screened in the surficial aquifer. For ISB performance monitoring, the post-injection monitoring program for 2025-2026 includes two performance monitoring events and one annual event (March 2026). The performance monitoring network includes 14 monitoring wells in the plume areas targeted for treatment. Analytical parameters for each location will include field water quality parameters, volatile organic compounds, total organic carbon, geochemical parameters and select locations for microbial parameters.

ISB performance evaluations will: 1) evaluate reagent distribution and persistence relative to the design, 2) evaluate parameter trends along groundwater flow path across treatment areas and at each performance well, 3) evaluate reduction of contaminant mass using chemical and geochemical data, 4) evaluate changes in contaminant flux across treatment areas using well transects by integrating concentration and flow data, 4) evaluate changes in plume extent (area) by comparing pre-and post-ISB modeled plumes, and 5) evaluate changes in biodegradation rates.

A project technical memorandum will summarize completed remedial action installation activities. Annual reports for OU 7 will report the results of remedy implementation, performance monitoring, monitored natural attenuation, and long-term monitoring components and will include data evaluations and an integrated analysis of remedy performance. Periodic updates of remedy performance and progress will occur during regulatory planning team meetings and for semi-annual restoration advisory board meetings.

Acronyms and Abbreviations

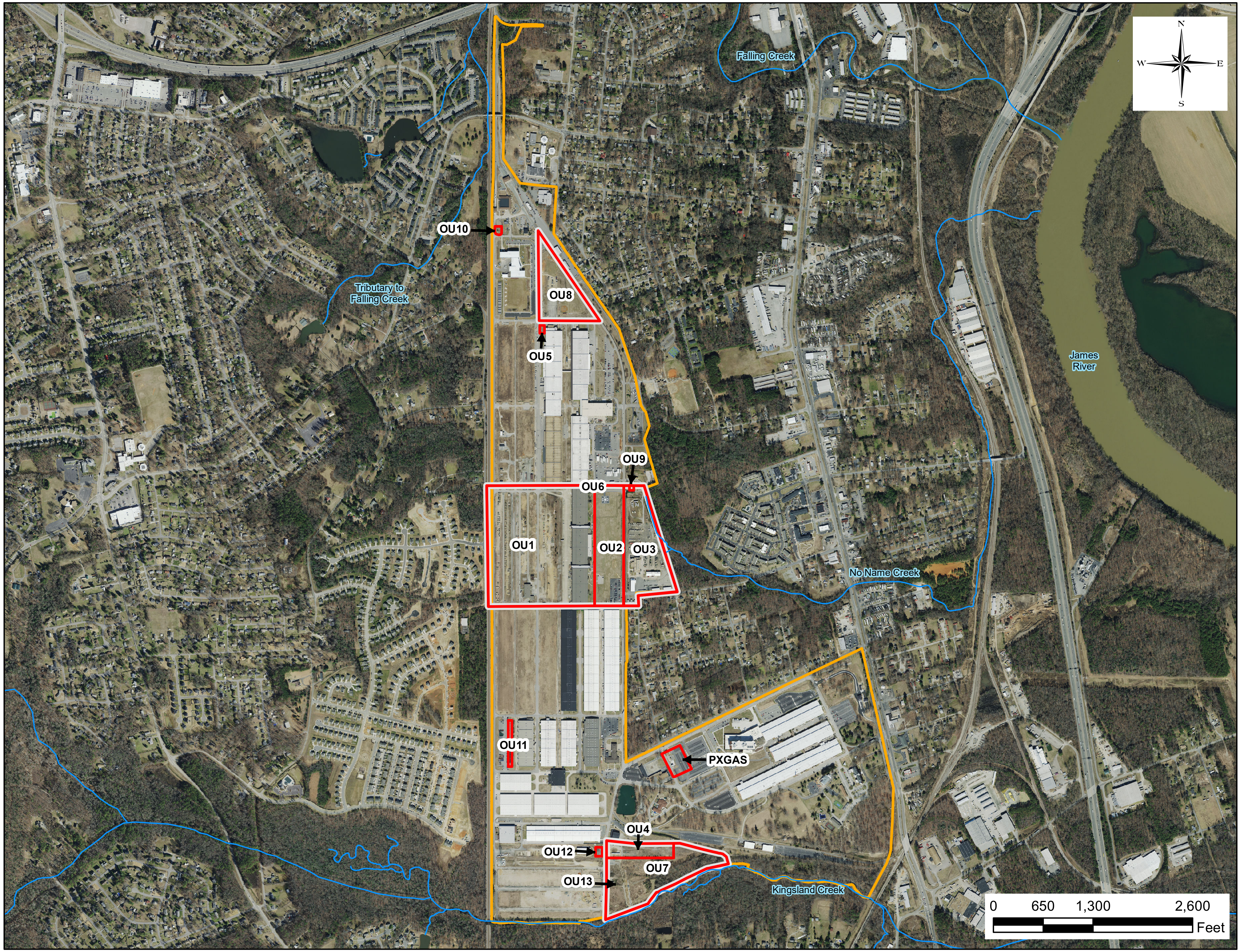
1,4-DCB	1,4-dichlorobenzene
1,1-DCE	1,1-dichloroethene
1,1,1-TCA	1,1,1-trichloroethene
3D	three dimensional
AEHA	United States Army Environmental Health Agency
BGS	below ground surface
BTAG	Biological Technical Assistance Group
BVC	BAV1 Vinyl Chloride
CB	chlorobenzene
cDCE	cis-1,2-dichloroethene
COC	constituent of concern
CSM	conceptual site model
CV	coefficient of variation
DEQ	Virginia Department of Environmental Quality
DHC	*Dehalococcoides*
DLA	Defense Logistics Agency
DO	dissolved oxygen
DPT	direct push technology
DSCR	Defense Supply Center Richmond
EPA	United States Environmental Protection Agency
ERD	enhanced reductive dechlorination
EVO	emulsified vegetable oil
FFS	focused feasibility study
FTA	Fire Training Area
ft.	feet
gal	gallons
gpm	gallons per minute
>	greater than
≥	greater than or equal to
HHRA	human health risk assessment
HPT	hydraulic profile tooling
HRSC	high resolution site characterization
HAS	hollow-stem auger
IC	institutional control
IDM	investigative derived material
ISB	in situ bioremediation
<	less than
≤	less than or equal to
Law	Law Engineering and Environmental Services
lbs	pounds
LOD	limit of detection
LOQ	limit of quantitation
LTM	long term monitoring
Meadows	Meadows CMPG, Inc.
MCL	maximum contaminant level
MIP	membrane interface probe
MNA	monitored natural attenuation
meq	milliequivalents
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter
mg/L	milligrams per Liter
MIP	membrane interface probe
M-K	Mann Kendall
MNA	monitored natural attenuation

mV	millivolt
NAVD88	North American Vertical Datum of 1988
NPL	National Priorities List
ORP	oxidation reduction potential
OU	operable unit
%	percent
PAH	polycyclic aromatic aydrocarbon
PCB	polychlorinated biphenyls
PCE	tetrachloroethene
psi	pounds per square inch
p-value	probability value
qPCR	quantitative polymerase chain reaction
RA	remedial action
RAO	remedial action objective
RAWP	remedial action work plan
RD	remedial design
RI	remedial investigation
ROD	Record of Decision
SC	specific conductance
SOP	standard operating procedure
SPT	standard penetration test
SS	statistically significant
SSA	singular spectrum analysis
SVOC	semi-volatile organic compound
tceA	tceA Reductase
TCE	trichloroethene
tDCE	trans-1,2-dichloroethene
TOC	total organic carbon
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VC	vinyl chloride
VCR	Vinyl Chloride Reductase
VMP	vapor monitoring point
VOC	volatile organic compound
yr.	year

1. Introduction

This document is a Remedial Action Work Plan (RAWP) Addendum for Operable Unit 7 (OU 7) at Defense Supply Center Richmond (DSCR) prepared under Contract W912DR22C0045 awarded by the United States Army Corps of Engineers (USACE) Baltimore District on September 19, 2022, to Meadows CMPG, Inc. (Meadows). Meadows and teaming partner AECOM have prepared this RAWP Addendum following the contract Performance Work Statement and requirements of Contract Line-Item Number 0025. This document describes the proposed follow-up in situ bioremediation (ISB) actions at OU 7 that target the surficial aquifer. Proposed actions will occur in the three plume areas associated with the former Fire Training Area (FTA) (OU 4).

DSCR is the headquarters of the Defense Logistics Agency (DLA) Aviation and is home to various other DLA, Department of Defense, and other federal organizations. The installation is eight miles south of the City of Richmond in Chesterfield County, Virginia. The United States Environmental Protection Agency (EPA) placed DSCR on the National Priorities List (NPL) in 1987. Since 1990, DLA has implemented an environmental restoration program at DSCR under a Federal Facility Agreement with the United States Environmental Protection Agency (EPA) Region 3 and the Virginia Department of Environmental Quality (DEQ). OU 7 designation is the impacted groundwater beneath and downgradient of the former FTA (OU 4) and the polycyclic aromatic hydrocarbon (PAH) Area (OU 13). Figure 1-1 has the layout of DSCR and OU locations.



Legend

- Operable Unit Boundaries
- OU 6; OU 7; OU 8 Boundaries
- Installation Boundary

Notes:
OU6 Includes Groundwater Impacts Beneath OU's 1, 2, & 3
OU7 Includes Groundwater Impacts Beneath OU 4
OU8 Includes Groundwater Impacts Beneath OU 5
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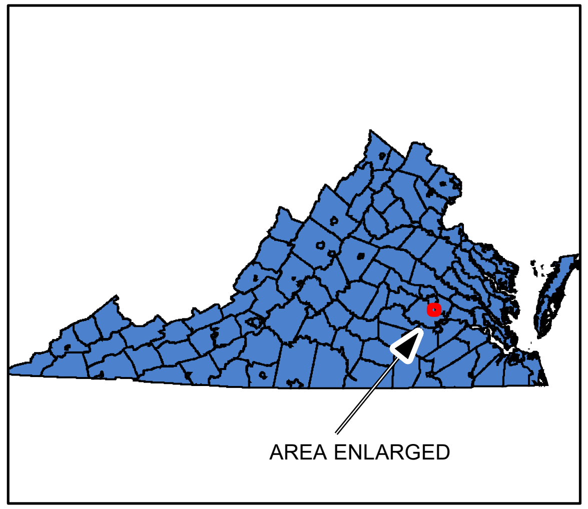

MEADOWS CONSULTING | MANAGEMENT | PLANNING
AECOM

Figure 1-1
DSCR Operable Units

Defense Supply Center Richmond
Richmond, VA

Prepared By: DBC	Reviewed By: KL
Scale: 1" = 1,300'	Date: January 17, 2025

L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 1-1 - DSCR OUs.mxd

2. Background

Section 2 has background information for OU 7 including a site description, site history, and environmental setting.

2.1 OU 7 Description

OU 7 consists of impacted groundwater beneath and downgradient of OU 4 (FTA Source Area) along the central southern boundary of the installation (Figure 1-1). Contaminants from the OU 13 area (PAH Area) near OU 4 have also potentially impacted OU 7 groundwater. Figure 2-1 shows the layout and features of OU 7 area. The northern and western portions of OU 7 consist of open areas with grass and gravel cover with Building 72 located near G Road that borders the OU area to the west. A wooded area in the eastern area of OU 7 slopes down to the floodplain area of Kingsland Creek and the installation boundary road and fence line.

2.2 OU 7 Site History

The FTA had three separate, unlined pits used for firefighting training. Materials dumped into the pits, ignited, and extinguished during firefighting training included flammable liquid chemicals and petroleum products. Potential materials used for fuel included oils, solvents, pesticides, and herbicides (Law 1996a).

FTA Pit 1 in the eastern section of OU 4 consisted of a circular area with a diameter of 50 feet (ft.) and depth of three ft. Pit use occurred from the mid-1970s to 1979 with former uses potentially including drum storage or trash burning. Filling and grading of the pit area with soil occurred in 1983 (Dames & Moore 1989). FTA Pit 2 in the middle portion of OU 4 consisted of a 20 ft. x 40 ft. rectangular area with an unknown depth. Pit 2 use occurred from the late 1960s until the 1970s when Pit 1 replaced Pit 2. Filling and grading of the Pit 2 area with soil reportedly occurred between 1973 and 1975.

FTA Pit 3 in the western portion of OU 4 is a suspect fire training pit identified in 1969 aerial photographs. Construction of a 300,000-gallon aboveground storage tank (fuel oil) occurred over a portion of the Pit 3 area in 1975 (Law 1996a). A No. 4 fuel oil release of approximately 10,000 gallons occurred in 1978 from a cracked valve. Heavy rain at the time of the release caused the oil to overflow the tank containment berm and flow across OUs 4 and 13 before discharging into Kingsland Creek. The area of impacted soil southwest of the former FTA is designated OU 13. Removal of the tank occurred in 1997 and a separate record of decision (ROD) addressed OU 13 soil.

2.2.1 1981 Installation Assessment

The U.S. Army Toxic and Hazardous Materials Agency completed the first environmental assessment at DSCR, and their installation assessment report indicated possible groundwater impacts from the former FTA (OU 4, Army Chemical Systems Laboratory 1981).

2.2.2 1982 Investigations

Remedial investigations began in the OU 7 area before DSCR final listing on the NPL in 1987. Initial investigations completed by the United States Army Environmental Health Agency (AEHA) in March 1982 occurred in the FTA Pit 1 area. At the time of the investigation the pit had a 1-inch layer of petroleum product apparently mixed with fire extinguishing material floating on water, with a bottom 1-4-inch layer of petroleum-based sludge (Army Chemical Systems Laboratory 1981). Initial groundwater sampling of four monitoring wells in the Pit 1 area indicated the presence of volatile organic compounds (VOCs) in shallow groundwater in the parts per million range for chlorinated ethenes and chlorinated benzenes.

AEHA conducted follow-up sampling in October and November 1982 that included sampling surface water of Kingsland Creek at two stations. The results of the sampling did not indicate detection of VOCs in samples at concentrations substantially higher than laboratory quantitation limits (LOQ).

2.2.3 1989 Remedial Investigation

Dames & Moore completed a remedial investigation (RI) of the FTA from 1985 to 1988 that included completion of soil borings, installation of monitoring wells, and sampling of soil, soil gas, groundwater, sediment, and surface water. A 1989 RI Report (Dames & Moore 1989) summarized the results of these investigations along with a benthic macroinvertebrate survey, and human health risk assessment (HHRA). RI findings indicated impacts to groundwater within the FTA and downgradient to the area of Kingsland Creek. Primary constituents detected in groundwater included VOCs. Soils in the area of Pit 1 contained VOCs, semi-volatile organic compounds (SVOCs), pesticides, petroleum hydrocarbons, and cyanides at concentrations higher than Pit 2. The highest contamination levels occurred at a depth of two (2) ft. in Pit 1 and at the surface at Pit 2. The RI indicated a limited extent of soil contamination in the Pit 1 and 2 areas and minimal impacts at Pit 3 and a former drum storage area. Surface water sampling for the RI did not indicate a significant impact to Kingsland Creek.

2.2.4 1992 Field Investigations

In 1992, Law Engineering and Environmental Services (Law) completed additional investigations in 1992 including installation and sampling of monitoring wells throughout OU 7 to further define the extent of VOCs in groundwater. The 1996 RI addendum reports the results of these investigations (Law 1996a).

2.2.5 1994 Field Investigation Report for Fire Training Area

Engineering-Science, Inc. conducted field investigations in August through October 1993 to provide supplemental data for the RI addendum and focused feasibility study (FFS) report for OU 7 (Engineering-Science Inc. 1994). The scope of investigations included shallow soil borings, collection of hydro punch samples, installation of monitoring wells and pumping test wells, performance of pumping tests, geophysical logging of well borings, groundwater sampling, slug tests, and surveys. The investigation report refined determinations of the extent of VOCs in shallower and deeper groundwater downgradient of the pit areas into and beyond (south) of the Kingsland Creek area.

2.2.6 1996 Final Remedial Investigation Report Addendum

Law prepared a RI addendum report that presented results of investigations and sampling conducted after the 1989 RI. Soil samples showed higher concentrations of VOCs in the soils at Pits 1 and 3 with minimal concentrations detected near Kingsland Creek. Groundwater sample result interpretations identified three distinguishable plumes potentially corresponding to the FTA pits with chlorinated VOCs identified as the primary constituents in deeper groundwater. Surface water sampling of Kingsland Creek indicated low levels of VOCs.

The RI addendum also included a human health baseline risk assessment for OU 4 and OU 7. This risk assessment identified cancer risks higher than the EPA range of 1E-06 to 1E-04 for occupational exposure to surface soil in the FTA and a hypothetical scenario involving future use of groundwater as a potable water supply (Law 1996a).

2.2.7 1996 Focused Feasibility Study

An FFS issued in 1996 identified remedial action objectives (RAOs) for shallow groundwater that involved engineered remedies for source control and contaminant reduction and natural attenuation processes for deeper groundwater. Recommended alternatives included groundwater extraction/soil vapor extraction for shallow groundwater and institutional controls (ICs) for deeper groundwater. The FFS recommended performance of a pilot test for design of systems for shallow groundwater (Law 1996b).

2.2.8 1997 Pilot Study Report for Fire Training Area

A pilot test conducted in 1996 evaluated the feasibility of using dual phase extraction as a remedial technology to address contaminated groundwater at OU 7. The pilot test report recommended consideration of dual phase extraction as an element of an overall remediation plan addressing shallow groundwater contamination. This report also recommended preliminary design parameters for design of a full-scale system (Law 1997).

2.2.9 1989 Letter Addendum to OU 7 Feasibility Study

A 1999 letter addendum to the OU 7 FFS evaluated data obtained from a density-driven convection pilot test (completed from December 1998 to January 1999) as an additional alternative to the FFS. The pilot test occurred within the shallow groundwater zone near Kingsland Creek. This letter addendum recommended the inclusion and evaluation of the density-driven convection technology in the revised FFS based on the pilot test results (Law 1999).

2.2.10 Removal Action

A time-critical removal action occurred at OU 4 in 2004. Excavation areas at FTA Pits 1 and 3 extended to a depth of 6 ft. with removal quantities of approximately 484 and 498 cubic yards, respectively. A limited excavation of five (5) cubic yards occurred at FTA Pit 2. Confirmatory sampling results at Pits 1 and 3 indicated that residual chlorinated VOCs remained below the excavation depth (MACTEC 2005).

2.2.11 2006 Supplemental Feasibility Study

MACTEC presented the results of supplemental natural attenuation evaluations (2001-2002) and additional investigations conducted in 2004 in a supplemental feasibility study (MACTEC 2006a) and evaluated the data in the 2006 installation-wide conceptual site model (MACTEC 2006b). The conceptual site model (CSM) presented the nature and extent of contamination of groundwater, described concentration trends, and evaluated natural attenuation processes in groundwater.

2.2.12 Creeks Monitoring Program

MACTEC implemented a three-year creek monitoring program (2001-2004) that included an assessment of Kingsland Creek. This included performance of a HHRA in 2006 that concluded no further action required for Kingsland Creek for human health-based risks. A screening level ecological risk assessment completed in 2001 for Kingsland Creek and subsequent Kingsland Creek monitoring supported the conclusion that detected VOCs did not pose unacceptable risk to potential ecological receptors.

2.2.13 2010 Treatability Study Report for OU 6 and OU 7

AECOM performed treatability studies for VOC plumes at OU 7 in 2007-2009 (AECOM 2010a). These studies performed from April 2007 to February 2009 included completion of direct push technology (DPT) borings and vertical aquifer profiling across the OU 7 study area. Follow-up monitoring well installation included shallow aquifer wells. Six well clusters (CMT) and five monitoring wells installations characterized conditions in the confined aquifer below the surficial aquifer depths characterized by the DPT sampling.

A second phase of treatability studies included construction of two biowalls in the Pit 1 VOC plume area and two biowalls in the Pit 2 VOC plume area. Biowalls had installation depths of 20 ft. in the Pit 1 area, 22 ft. for the northern biowall in the Pit 2 area, and 25 ft. for the southern biowall in the Pit 2 area. Pit 1 biowalls had uncomposted mulch as the substrate amended with dolomite gypsum. Pit 2 biowalls had composted mulch/poultry as the substrate amended with dolomite.

A third phase of treatability study performed at Pit 3 in 2009 injected emulsified vegetable oil (EVO) with amendments (6% emulsion) into the surficial aquifer. The injection emulsion totaling 2,125 gallons into three injection wells included fluorescent dye to evaluate distribution of EVO into the subsurface. Detection of emulsion occurred at monitoring well OU7-MW-94 (20 ft. from injection wells) after injection of 200 gallons of EVO.

Treatability findings for the biowalls at OU 7 showed effective treatment of chlorinated VOCs in groundwater as groundwater passed through the wall areas. Results of the EVO injections at Pit 3 indicated a radius of influence (ROI) greater than 20 ft. and significant reductions of chlorinated VOCs (at residual dense non-aqueous phase liquid levels in groundwater) within five months of injections.

2.2.14 2010 Revised Focused Feasibility Study

A revised HHRA completed as part of the Revised FFS in 2010 evaluated risks for the onsite OU 7 area, Kingsland Creek, and offsite areas (AECOM 2010b). The revised FFS evaluated remedial alternatives in the context of the revised HHRA and in-situ bioremediation treatability tests performed at Pits 1 and 2 in 2007 and at Pit 3 in 2009.

RAOs established based on the HHRA included preventing unacceptable risks to human health and the environment from exposure to constituents of concern (COCs) in groundwater and reduction of COC concentrations to Federal maximum contaminant levels (MCLs). The FFS evaluated various remedial alternatives and recommended enhanced ISB, monitored natural attenuation (MNA), long-term monitoring (LTM), and ICs based on results of pilot testing and natural attenuation evaluations (AECOM 2010b).

2.2.15 Record of Decision

The ROD document for OU 7 finalized in May 2012 identifies OU 7 as groundwater underlying and downgradient from the former FTA (OU 4). Separate remedial actions have addressed OU 4 identified as source material that impacted OU 7 groundwater and also addressed OU 13 that potentially impacted groundwater (DSCR 2012).

The selected remedy in the ROD consists of the following elements:

- ISB to treat COCs in groundwater source areas (Pits 1, 2, and 3) and downgradient portions of the groundwater plumes.
- MNA that involves monitoring of COCs and geochemical conditions in groundwater to document that MNA is reducing chemical mass and concentrations over time.
- Annual LTM of the uppermost groundwater zone for a minimum of five years to monitor for potential leaching of SVOCs, PAHs, polychlorinated biphenyls (PCBs), pesticides, metals, and 2,3,7,8-tetrachlorodibenzo-p-dioxin from OU 4 and OU 13 soils to groundwater, and also includes annual monitoring of surface water of Kingsland Creek until COCs in shallow groundwater have reached cleanup level established in the ROD.
- ICs described in the ROD including groundwater use restrictions, land use restrictions, control exposure to contaminated groundwater and implementation of ICs for future buildings within groundwater plume areas.

Table 2-1 presents the cleanup levels established in the ROD for the COCs in OU 7 groundwater. As described in the ROD, the selected remedy satisfies the statutory requirements of the Comprehensive Environmental Response, Compensation, and Liability Act. Since this remedy will result in hazardous substances, pollutants, or contaminants remaining on site above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within 5 years after initiation of the remedial action (RA), and at a subsequent frequency of at least once every 5 years, to ensure that the remedy is, or will be protective of human health and the environment. Protectiveness reviews will continue until site conditions enable unlimited use and unrestricted exposure.

Table 2-1 OU 7 COCs and Cleanup Levels

Contaminants of Concern	Maximum Contaminant Level (µg/L)
Carbon Tetrachloride	5
Chlorobenzene	100
1,4-Dichlorobenzene	75
1,1-Dichloroethene	7
cis-1,2-Dichloroethene	70
trans-1,2-Dichloroethene	100
Tetrachloroethene	5
Trichloroethene	5
Vinyl Chloride	2

Contaminants of Concern	Maximum Contaminant Level (µg/L)
Chloroform	80

Notes: Maximum Contaminant Level from 40 CFR § 141.61 Maximum contaminant levels for organic contaminants and § 141.64 Maximum contaminant levels for disinfection byproducts including Total trihalomethanes (includes chloroform), µg/L = micrograms per liter.

2.2.16 2013 Remedial Actions

AECOM prepared a Remedial Design (RD)/RAWP in 2013 to implement the remedy components identified in the ROD (AECOM 2013). AECOM implemented remedial actions for the selected remedy at OU 7 in 2013, as generally detailed in in the OU 7 Injection Technical Memorandum that documented completed activities (AECOM 2015).

ISB treatment targeted eight (8) treatment areas in the Pit 1, 2, and 3 plumes at locations and in lithologic units not previously treated by the biowalls (Pits 1 and 2) and previous EVO injections (Pit 3). The ISB process options implemented included EVO as the carbon substrate pressure injected into injection wells designed for the specific treatment areas. In general, injections performed did not achieve design volumes in the treatment areas due to flow rates and pressures. An adaptive approach used increased EVO solution concentrations to achieve design loading rates where possible.

Remedy verification performed as part of the remedial actions included groundwater sampling three months after completion of injection activities followed by annual performance, MNA, and LTM groundwater monitoring. Annual LTM of surface water has occurred at three sampling stations in Kingsland Creek since remedy implementation in accordance with the ROD. Vapor monitoring of exterior vapor monitoring points (VMPs) at Building 72 began in October 2013 and at interior sub-slab VMP 116 in 2016. The EPA and DEQ approved discontinuation of monitoring of exterior VMPs in October 2016 due to persistent infiltration of water into the VMPs. EPA and DEQ approved a change in monitoring frequency at VMP-116 from quarterly to annual in September 2017. The vapor monitoring evaluates for potential accumulation of VOCs and methane beneath Building 72 related to remedy implementation in the OU 7 area. ICs implemented at OU 7 comply with the site-wide, land use control remedial design.

2.2.17 2016 Remedial Action

AECOM developed a RAWP Addendum in December 2015 to perform additional ISB actions as a follow-up to actions completed in 2013 (AECOM 2015). AECOM implemented ISB DPT injections (EVO) in January 2016 at the distal end of the identified Pit 1 plume in the installation fence line area and offsite area south of Kingsland Creek. High injection pressures and dense subsurface conditions required adaptive approaches to achieve targeted injection volumes and EVO loading rates.

2.2.18 2017 Remedial Actions

In 2017, USACE Baltimore District implemented follow-up remedial actions to the ISB injections performed in 2013, which included the installation of 12 additional injection wells (USACE 2017). These efforts involved ISB injections of Lactoil® in high concentration source zone areas at Pits 1, 2, and 3 for long-term treatment and injection of sodium lactate in lower concentration areas (mid plume at Pits 1 and 2). Post injection monitoring occurred three months after the completion of injections followed by annual site-wide groundwater monitoring. ISB injections occurred in December 2017 and January 2018. Figure 2-2 shows the ISB injection wells/areas.

2.2.19 2019 Pre-Design Investigations

Pre-design data collection activities occurred at OU 7 in 2019 to update the CSM and obtain data to support remedy optimization, as detailed in the 2019 Annual Report for OU 7 (AECOM-Meadows, 2021a). The scope of these activities included:

- Expansion of the 2019 annual sampling event from 78 to 168 monitoring well locations.
- Completion of vertical profile sampling at 14 stations in Kingsland Creek to evaluate the groundwater to surface water migration pathway including VOC sampling of surface water, sediment porewater, and groundwater beneath the creek.

- Completion of high-resolution site characterization (HRSC) investigations at OU 4, OU 13, and OU 7 areas including around and within VOC plume areas. HRSC investigations included integrated assessment of contaminant profiling (membrane interface probe [MIP]) and vertical aquifer profiling and hydraulic properties determination (hydraulic profiling tool [HPT]).

The 2019 Annual Report presents a detailed update of the CSM that includes a digital three-dimensional (3D) model of the OU 7 site area.

2.2.20 2021 Remedial Actions

A RAWP Addendum prepared in 2021 described proposed remedy optimizations for OU 7 (AECOM-Meadows, 2021b). The RAWP contained the following proposed actions:

- Targeted ISB injections with in-situ chemical reduction (ISCR) enhancement in 11 grid treatment areas within FTA Pit 1, 2, and 3 plume areas.
- Remedy performance monitoring and MNA actions with an optimized monitoring network.

Figure 2-2 on page 2-8 shows the ISB treatment areas for injections completed in December 2017/January 2018 and November/December 2021.

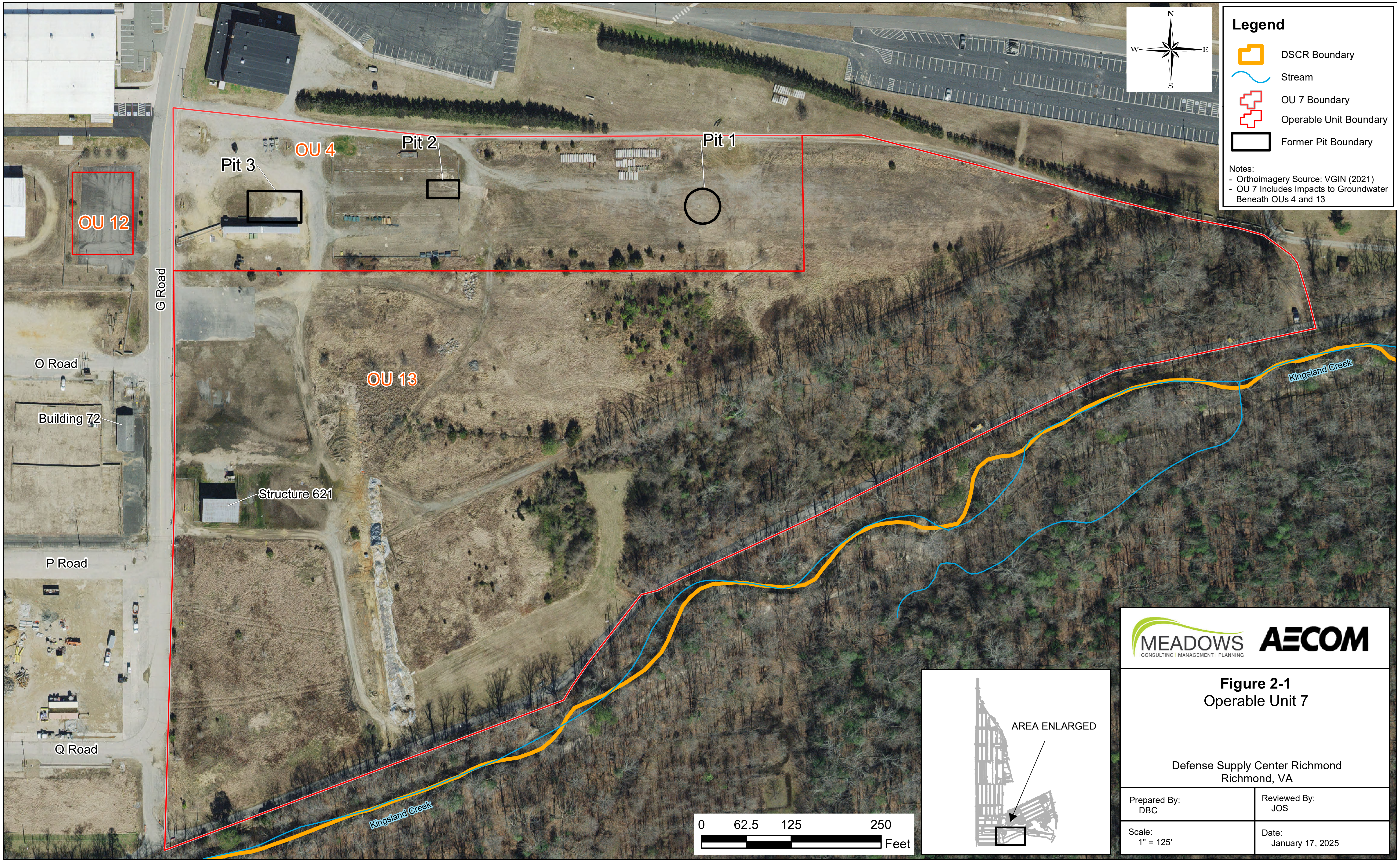

Figure 2-1
Operable Unit 7

Defense Supply Center Richmond
Richmond, VA

Prepared By: DBC	Reviewed By: JOS
Scale: 1" = 125'	Date: January 17, 2025

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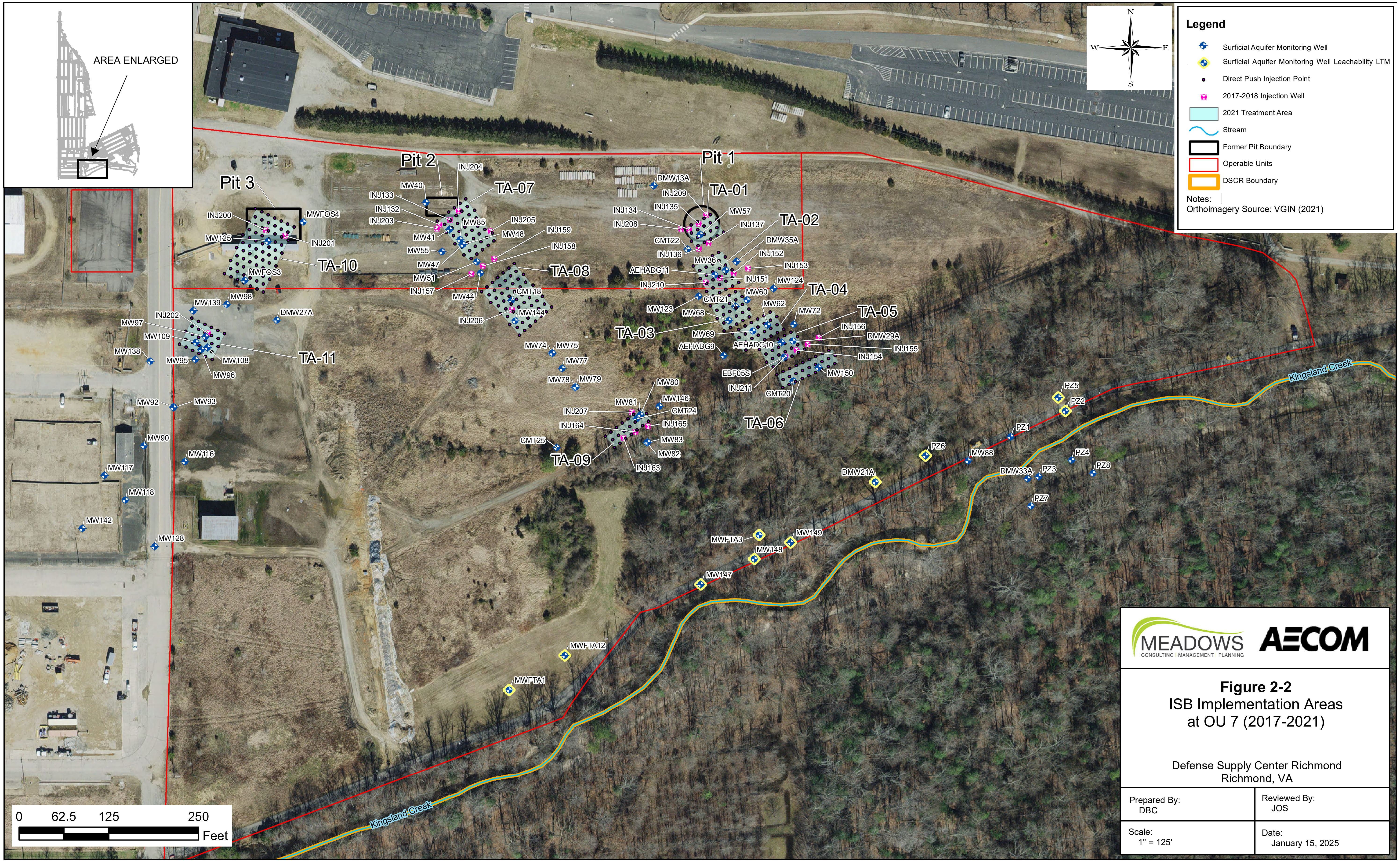


L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 2-2 - ISB Implementation Areas.mxd

2.3 Environmental Setting

Section 2.3 describes the environmental setting for OU 7.

2.3.1 Topography

Historical site activities and development have altered the land surface and topography of the OU 7 area as part of the development of DSCR. Figure 2-3 (page 2-10) has a digital elevation model for OU 7 showing site topography. Overall topographic slope is toward the southeast with elevations ranging from a maximum of approximately 102 ft. North American Vertical Datum of 1988 (NAVD88) in the former Pit 3 area to a minimum of approximately 83 ft. NAVD88 along the fence line area near Kingsland Creek.

A perimeter road encircles the OU 7 area with a gravel road extending east-west across the site within a former railroad spur line area. The area south of this gravel road slopes to a low area in the alluvial flood plain of Kingsland Creek, the eastern portion of this area remains forested.

2.3.2 Surface Water and Wetlands

Kingsland Creek borders OU 7 to the south along the installation boundary with the creek flowing in a northeasterly direction in this area and then flows east approximately 2.2 miles to the James River (Figure 1-1). The creek has a cobbly sediment substrate in the site area. Two storm drains extend north to south across the OU 7 with outfalls into the floodplain area of Kingsland Creek where ditches convey water to the creek. A freshwater forested/shrub wetland area exists in the Kingsland Creek floodplain area near and along the southern border of the installation according to the United States Fish and Wildlife Service's National Wetlands Inventory wetlands mapper accessed at https://www.fws.gov/wetlands/data/mapper.html. A portion of the mapped area extends north across the perimeter road in the eastern portion of OU 7.

2.3.3 Soils

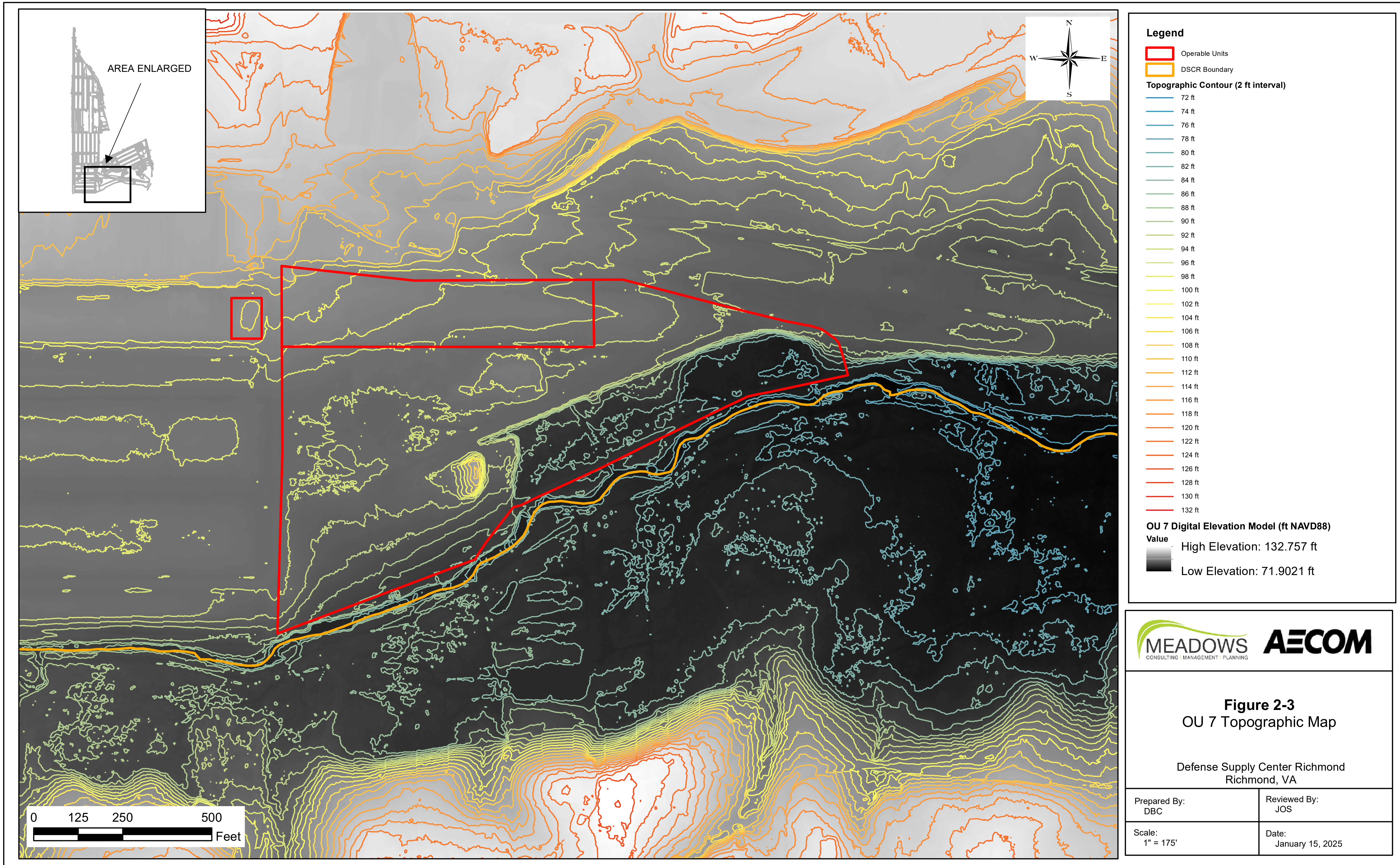
The United States Department of Agriculture web survey accessed at https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx identifies the soil mapping units at OU 7 as made land reflecting disturbance and development of the area and Fluvaquents (map unit 1A) in the flood plain area of Kingsland Creek. The disturbed or reworked soil material varies in consistency, and ranges from loamy sand to clay. Soils in Map Unit 1A consist of the following:

- 0 to 8 inches: silt loam.
- 8 to 40 inches: silty clay loam.
- 40 to 50 inches: sand.

2.3.4 Site Geology

DSCR lies near the western edge of the Virginia Coastal Plain. General stratigraphy found beneath OU 7 from top down is the Eastover Formation, Aquia Formation, and Potomac Formation underlain by Petersburg Granite bedrock. Alluvial sediments overlie the Aquia Formation in the Kingsland Creek flood plain. Surficial fill material associated with site development overlies the majority of the OU 7 area. Table 2-2 (page 2-11) provides general stratigraphy information for the OU 7 area.

The digital 3D CSM developed for the OU 7 area includes a geologic model developed using multiple lines of data and geostatistical methods (kriging). This involved review of original data sources collected for the period 1982 to 2019 and selection of the highest resolution/data quality available for model development. Data types reviewed for model inputs included geological and hydrogeological publications, site and DSCR boring data, lithologic logs, geophysical logs and surveys, physical test data from soil cores, cone penetrometer testing data, and HPT data collected in 2019.



L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 2-3 - OU7 Topographic Map.mxd

Figure 2-4 (page 2-12) has a north-south oriented geologic cross section for the southern half of DSCR from the OU 6 area south across the western OU 7 area and Kingsland Creek. This cross section illustrates changes in topography across the southern DSCR and OU 7 area where the ground surface slopes to the valley of Kingsland Creek. It also illustrates lateral variations in geology where the Calvert Formation pinches out in the OU 7 area and the Aquia Formation thickens and is unconformably overlain by Eastover Formation and underlain by the Potomac Formation. In the Kingsland Creek area, flood plain sediments (alluvium) overlie the Aquia Formation. Figure 2-5 (page 2-13) has an east-west oriented geologic cross section across OU 7 and illustrates a topographic slope toward the east and the Kingsland Creek flood plain. It also illustrates an increase in the thickness of the Aquia toward the east.

2.3.4.1 Alluvium

Alluvium occurs within the flood plain of Kingsland Creek in the southern lowland portion of OU 7. These floodplain deposits have a loose consistency and consist of variable silty sand (SM), clayey sand (SC), poorly sorted sand with gravel (SP), silty gravel with sand (GM), and clayey gravel with sand (GC). The estimated thickness of alluvium is 0 to 8 ft.

2.3.4.2 Eastover Formation

Eastover Formation sediments have variable mottling and color (brown, yellowish red, and reddish brown). Primary lithologies vary from silty sand (SM) to well graded sand (SW) with variable gravel and silty gravel (GM). Reworked surficial material generally consists of Eastover sediments. The thickness of Eastover Formation sediments below the fill material ranges from approximately 6 to 10 ft.

Table 2-2 OU 7 Stratigraphy

Geologic Formation	Age	Origin	Approx. THK (ft)	Primary Lithology Types
Alluvium	Holocene	Alluvial Floodplain Kingsland Creek	0-8	Silty sand (SM), clayey sand (SC), poorly graded sand with gravel (SP), silty gravel with sand (GM), clayey gravel with sand (GC)
Eastover	Pliocene	Alluvial	6-10	Silty sand (SM), well graded sand (SW) with variable gravel, silty gravel (GM), fine grained interbeds of clay and silt
Aquia	Paleocene Early Eocene	Marine	15-22	Silty sand (SM) with basal silty gravel (GM), fine grained interbeds of clay and silt
Potomac	Cretaceous	Alluvial	36-52	Silty sand (SM), poorly graded sand with silt (SP), silty gravel (GM), clay interbeds, clayey sand with gravel (SC)
Petersburg Granite	Mississippian	Bedrock	--	Granite to Granodiorite Bedrock

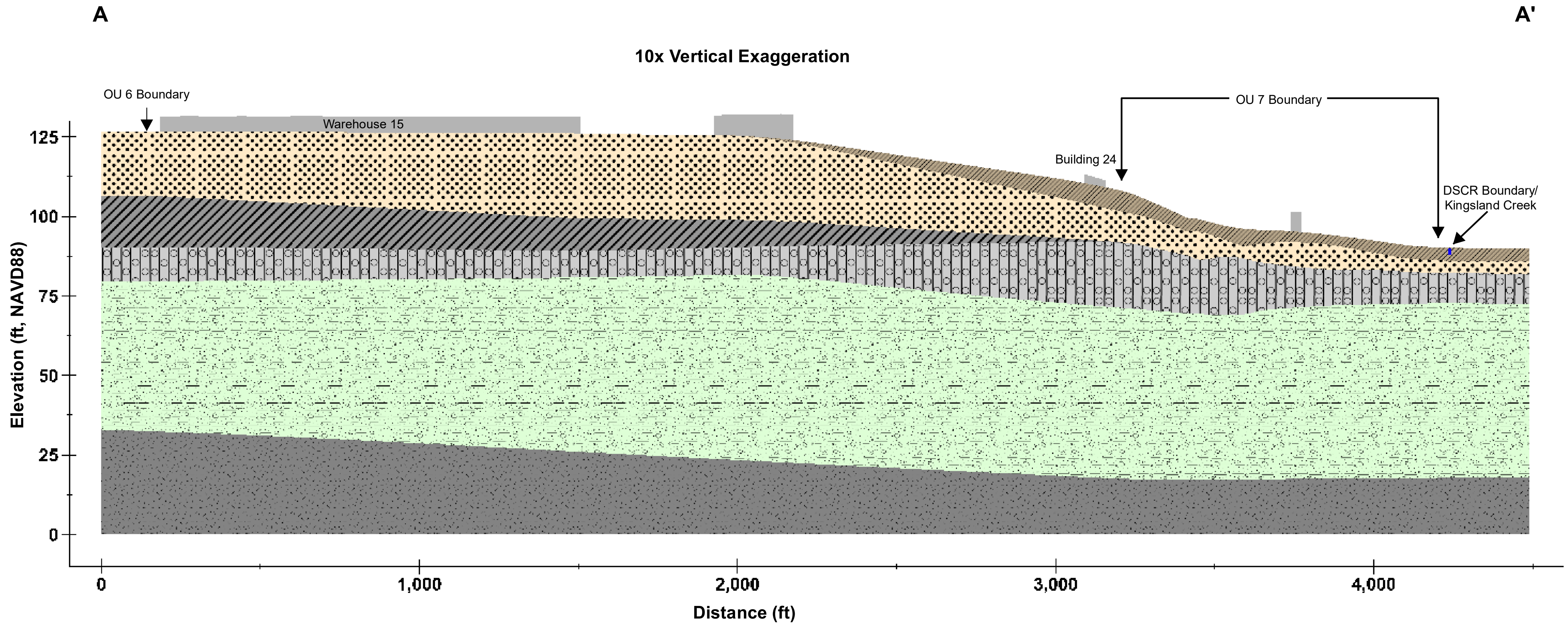
Notes: THK=thickness

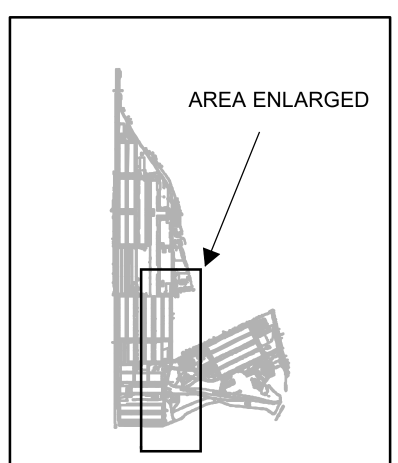
2.3.4.3 Aquia Formation

The Aquia Formation consists of a fining-upward, well graded, gray to dark green, glauconitic silty sand (SM) with a dense basal gravel stratum (GM). The Aquia Formation also contains finer grained clayey strata. Thickness of the Aquia Formation generally ranges from 15 to 22 ft.

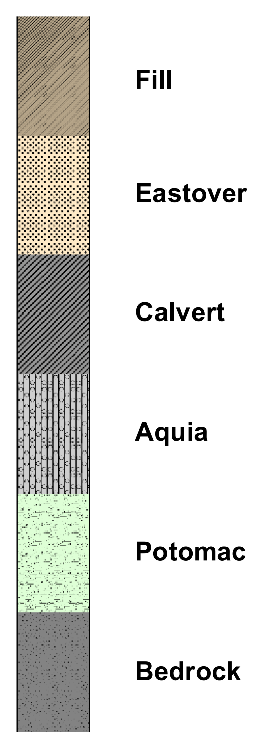
2.3.4.4 Potomac Formation

Potomac Formation sediments consist of interbeds of light gray to greenish gray well graded sand (SW) with silt or clay, silty sand (SM), poorly graded sand (SP) with silt, clayey sand (SC), and clay (CL-CH). Standard penetration test sampling indicates dense to very dense consistency for coarse grained sediments and hard consistency for fine-grained sediments. The approximate thickness of the Potomac Formation ranges from 36 to 52 ft.





Geologic Unit



Legend

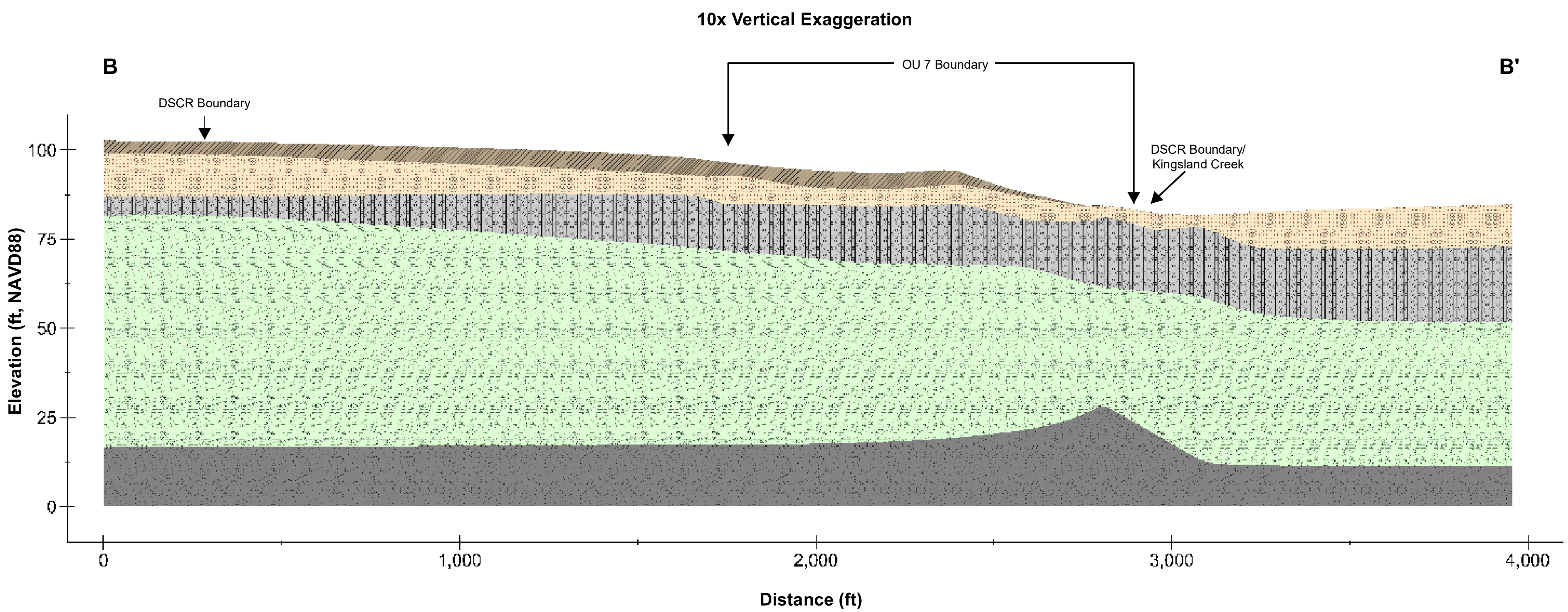
- Cross-Section Transect
- Streams
- Operable Unit Boundaries
- OU 6; OU 7; OU 8 Boundaries
- Installation Boundary

Notes:
OU7 Includes Groundwater Impacts Beneath OU 4
Orthoimagery Source: VGIN (2017)

Figure 2-4
North-South Geologic Cross-Section

Defense Supply Center Richmond
Richmond, VA

Prepared By: RJP	Reviewed By: JOS
Scale: 1" = 1,300'	Date: October 28, 2020



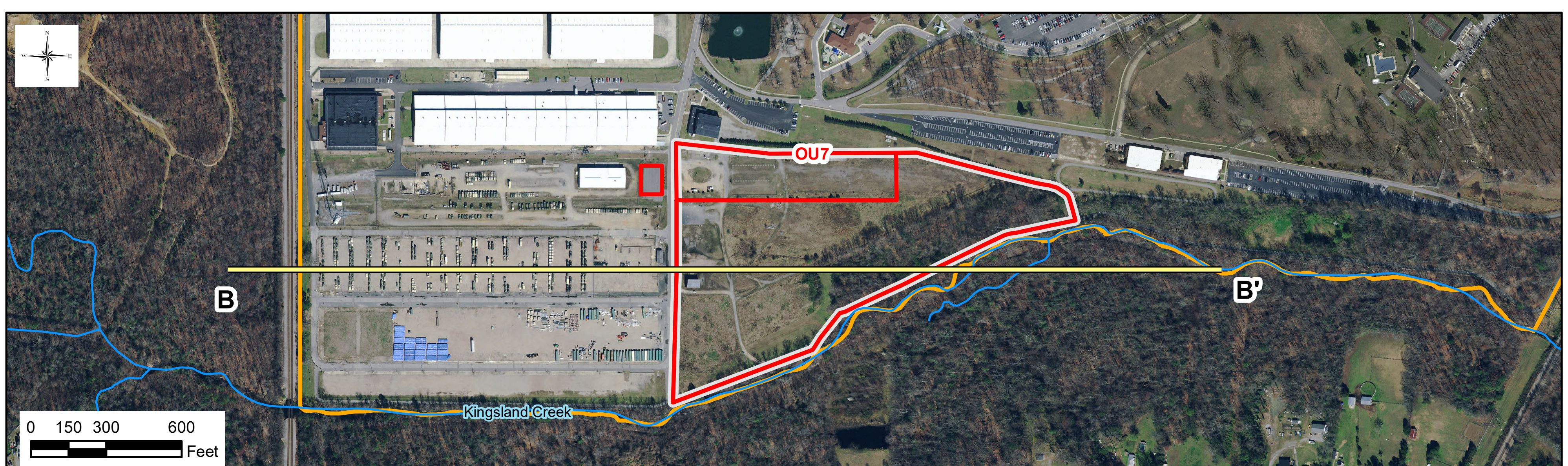
Legend

- Cross-Section Transect
- Streams
- Operable Unit Boundaries
- OU 6; OU 7; OU 8 Boundaries
- Installation Boundary

Notes:
OU7 Includes Groundwater Impacts Beneath OU 4
Orthoimagery Source: VGIN (2017)

Geologic Unit

- Fill
- Eastover
- Calvert
- Aquia
- Potomac
- Bedrock



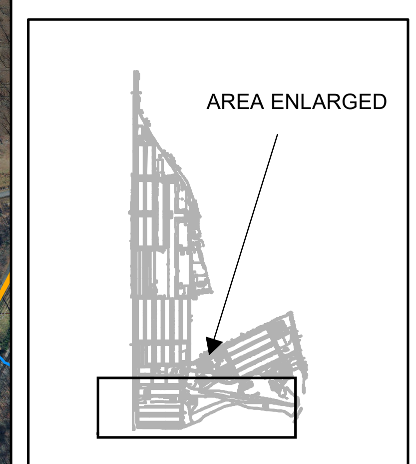


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Figure 2-5
East-West Geologic Cross-Section

Defense Supply Center Richmond
Richmond, VA

Prepared By: RJP	Reviewed By: JOS
Scale: 1" = 1,300'	Date: October 28, 2020

2.3.4.5 Petersburg Granite

Bedrock in the study area is the Petersburg Granite described by the United States Geological Survey (USGS) as chlorite rich granodiorite. Dames & Moore performed rock coring at boring DMW-23A of the uppermost 15 ft. of bedrock (55 to 70 ft. below ground surface, BGS) and described bedrock as a granite with phaneritic, subhedral to euhedral texture primarily consisting of quartz and chlorite, some potassium feldspar, little muscovite and biotite, and trace garnet. Rock coring results indicated a vertical fractured zone at 58-59 ft., a highly fractured zone at 60-65 ft., and highly fractured zone at 68-70 ft. partially filled by green clay. Rock-quality designation values determined included 95 for core run 1, 40 for core run 2, and 90 for core run 3.

2.3.5 Hydrostratigraphy

The digital 3D CSM developed for the OU 7 area includes a refined hydrostratigraphy model developed by integrating the geologic model with existing hydrogeologic data and HRSC data obtained in 2019. A key aspect of the refined hydrostratigraphy is the semi-continuous measurement of hydraulic properties of the four unconsolidated geologic formations and integrated this data with other lines of data such as laboratory testing for physical properties. Table 2-3 summarizes the refined hydrostratigraphy for OU 6 and associated hydraulic properties defined in the 3D model.

Table 2-3 OU 7 Hydrostratigraphy

Hydrostratigraphic Unit	Type	Description	Relative Permeability	Estimated K (cm/sec)
Eastover	Aquifer	Unconfined, discrete zones, highly variable, perched water	Low-High	<1.0E-04 to 3.5E-02[2] 1.52E03 to 9.12E-03[4]
Calvert	Confining Zone	Leaky unit	Very Low	4.8E-08 to 1.8E-06[1]
Aquia	Aquifer	Semi-confined, bulk matrix of formation	Low-High	<1.0E-04 to 3.5E-02[2] 1.76E-06 to 1.55E-05[1]
Potomac	Aquifer	Confined, bulk matrix of formation	Very Low-Moderate	4.9E-03[5] 2.3E-07 to 3.5E-05[3]
Bedrock	Aquifer	Confined in fractures	Not determined	

Notes [1] Laboratory core testing (vertical), [2] Field testing with HPT, [3] Laboratory core testing (horizontal), K= hydraulic conductivity, cm/sec = centimeters per second, [4] Field slug tests at wells at OU 7.,[5] USGS pumping test at OU 8 (USGS 1987)

2.3.5.1 Alluvium

Alluvium in the flood plain potentially contains a seasonally high-water table adjacent to Kingsland Creek. Primary flow and discharge into Kingsland Creek occur from the unconfined surficial aquifer within the uppermost portion of the Potomac.

2.3.5.2 Eastover-Aquia

This hydrostratigraphic unit corresponds to the unconfined surficial aquifer. Depth to groundwater is typically 10 ft. BGS) or less. The saturated thickness of this zone ranges from approximately 20 to 25 ft. The lithology of this zone varies between the upper portion (Eastover Formation) and lower portion (Aquia Formation) of this unit as described in Section 2.3.4.

2.3.5.3 Potomac

This hydrostratigraphic unit corresponds to the confined aquifer with dense strata. The lithology of this zone is heterogeneous as described in Section 2.3.4.

2.3.5.4 Bedrock

This hydrostratigraphic unit corresponds to the Petersburg Granite with an expected confined or semi-confined condition based on the overlying stratigraphy. Groundwater within unweathered bedrock will occur primarily in fractures.

2.3.6 Groundwater Flow

Lateral groundwater flow patterns and direction in the surficial aquifer reflect surface topography and surface water drainage in the Kingsland Creek area. The direction of groundwater flow is generally toward the southeast and Kingsland Creek (see Section 2.4.1). Shallow groundwater from the surficial aquifer discharges into Kingsland Creek with an upward component of flow apparent in the area. Lateral groundwater flow in the confined aquifer is toward the east and at depth beneath Kingsland Creek (see Section 2.4.1).

2.4 Current Conditions for Groundwater in Surficial Aquifer

Section 2.4 describes the current conditions for groundwater in the surficial aquifer from the March 2024 annual sampling event as described in the Fiscal Year 2024 Annual Report for OU 7 (AECOM-Meadows 2024b). The focus of the current conditions summary is the surficial aquifer that is targeted for ISB. Figure 2-6 (page 2-16) shows the current groundwater and surface water monitoring locations at OU 7.

2.4.1 Surficial Aquifer Potentiometric Surface and Groundwater Flow

Figure 2-7 (page 2-17) has a potentiometric surface elevation contour map (March 2024) for the surficial aquifer developed by geostatistical analysis (kriging) in Earth Volumetric Studio using site-wide groundwater elevation data for wells screened in the surficial aquifer. Groundwater flow direction in the Pit 1 and Pit 2 area is toward the southeast and Kingsland Creek with a southwest flow direction in the Pit 3 area. The average hydraulic gradients across the OU 7 ranged from 1.90E-02 ft./ft. (Pit 3 area) to 3.00E-02 ft./ft. (Pit 1 area). Shallow groundwater discharge with an upward component of flow occurs at Kingsland Creek.

Equation 1 calculates the approximate horizontal velocity range of groundwater flow within the surficial aquifer using a form of Darcy's velocity equation:

(1) $$V = {Ki}/{n_e}$$

Where:

V = groundwater flow velocity (ft./yr.)
K = hydraulic conductivity (feet per day [ft/day])
i = hydraulic gradient (ft/ft)
n_e = effective porosity (unitless)

Input values for Equation 1 for the surficial aquifer include:

- Average K of 3.60E+00 ft./day (Table 2-3).
- Estimated effective porosity of 0.27 based on average physical test data for total porosity, air filled porosity, and clay content.
- Average hydraulic gradient ranging from 1.90E-02 ft./ft. to 3.00E-02 ft./ft. for the March 2024 sampling event (Figure 2-7).

The estimated horizontal groundwater flow velocity calculated for the surficial aquifer using the above input values ranges from 2.53E-01 ft./day (91.3 ft./yr.) to 4.0E-01 ft./day (146.0 ft./yr.).

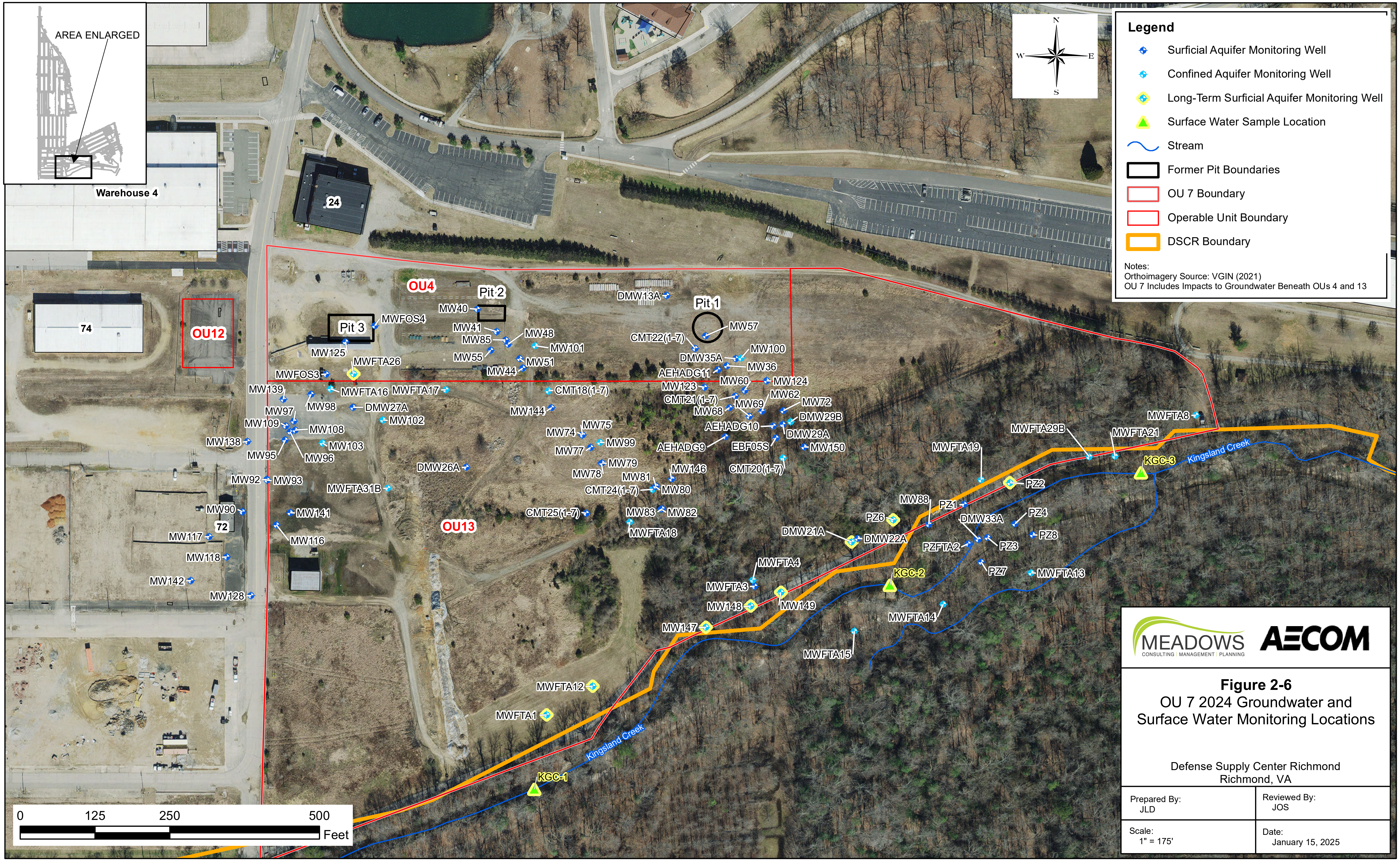
2.4.2 Water Quality Parameters for Surficial Aquifer (2024)

Section 2.4.2 and Exhibit 2-1 (page 2-18) have a summary of data distributions for water quality parameter results for the surficial aquifer for the Pit 1, Pit 2, and Pit 3 monitoring areas. The summaries use the OU 7 annual monitoring data from March 2024.

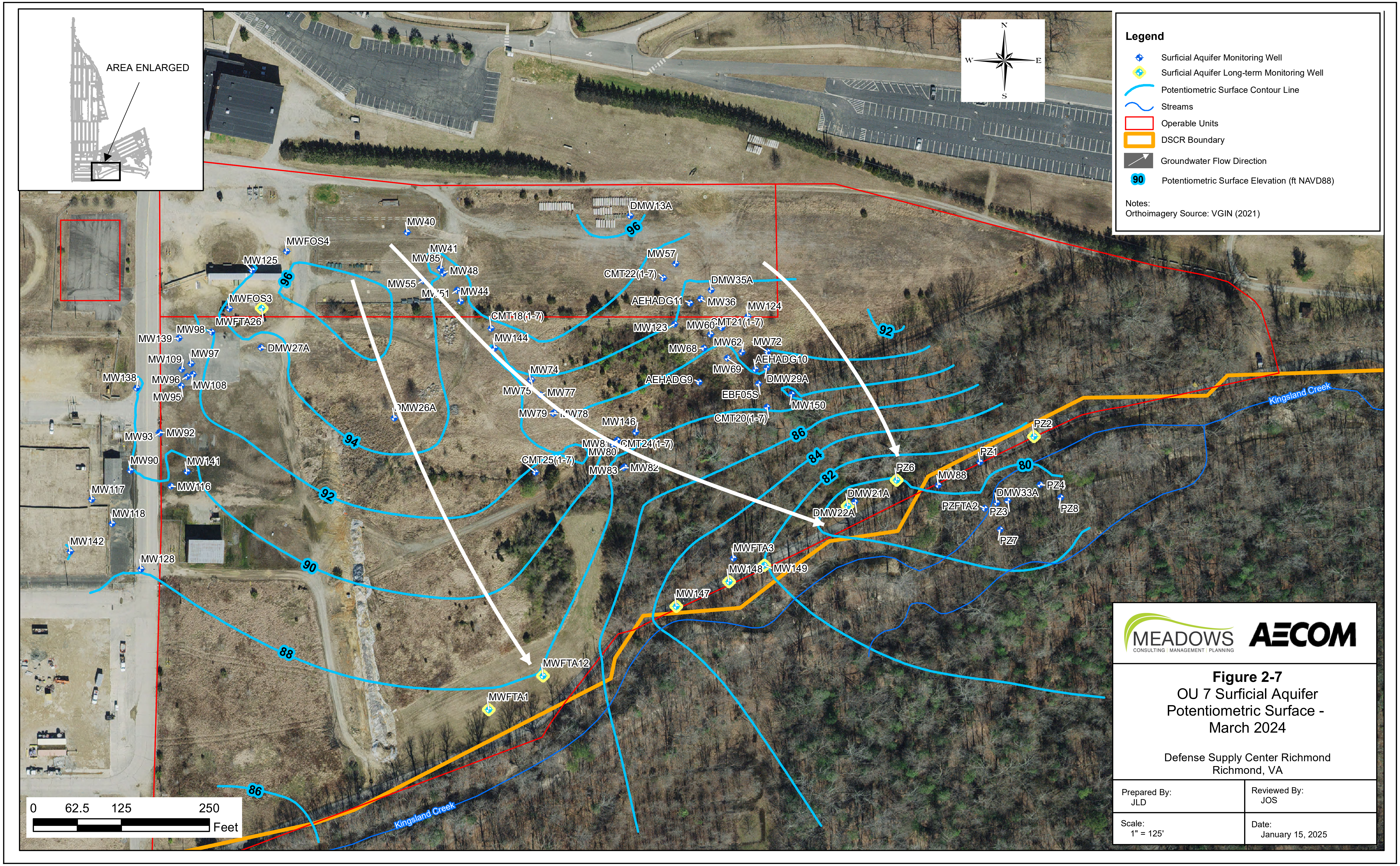
2.4.2.1 pH Results

The data distributions for pH vary by pit area with progressively higher pH levels moving across the site from Pit 1 to Pit 3 (see Exhibit 2-1). For Pit 1, the distribution range for pH is 3.58 with a mean of 5.81 and median of 5.69. The distribution 25th and 75th percentiles are 5.06 and 6.29, respectively. Seven of 36 data observations have a pH less than 5.

For Pit 2, the distribution range is 3.55 with a mean of 5.89 and a median of 5.84. The distribution 25th and 75th percentiles are 5.33 and 6.57, respectively. Four of 33 data observations have a pH less than 5.

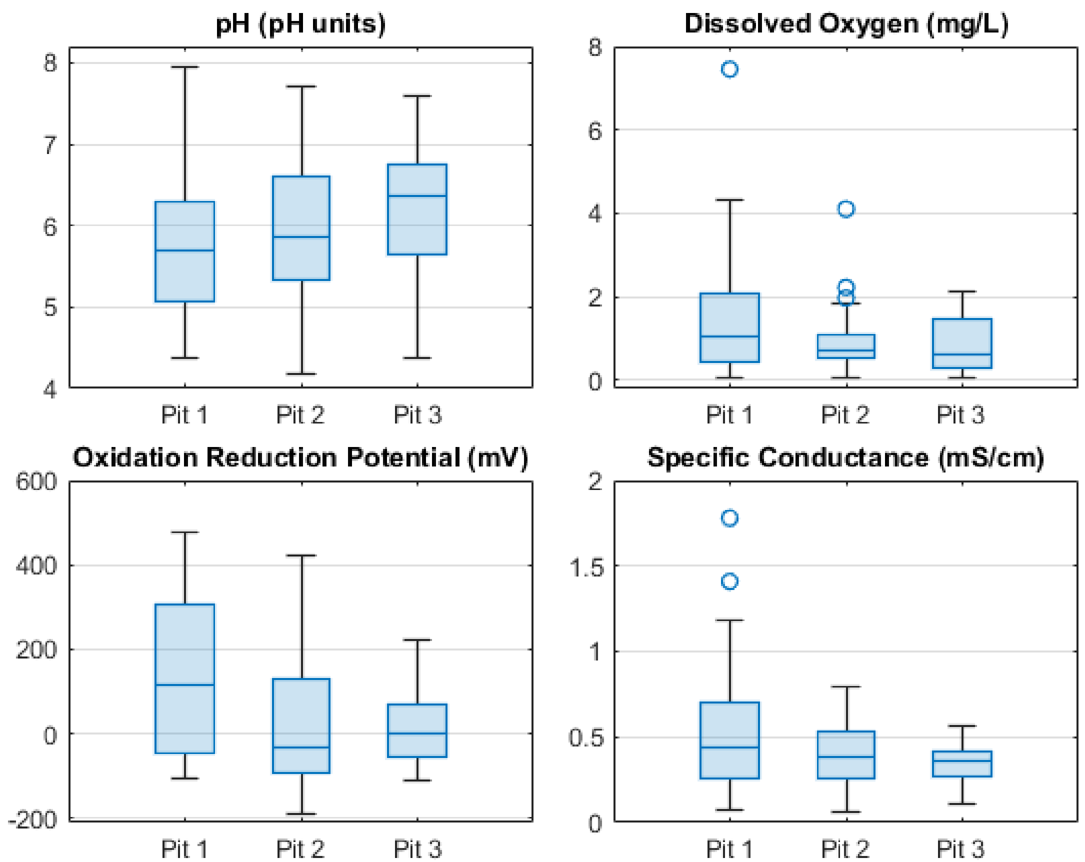


L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 2-6 - 2024 OU7 Monitoring.mxd



L:\Legacy\USGNA2FP002\Data\projects\0_GIS\DLA\OU7\Annual Report\2024\Figure 2-7 - OU 7 Surficial Pot Map

Exhibit 2-1 Water Quality Parameter Data Distribution for Surficial Aquifer: March 2024



pH (pH units)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	pH< 5
Pit 1	36	36	4.38	7.96	3.58	5.81	5.69	0.93	0.87	0.6713	2.7056	0	5.06	6.29	7
Pit 2	31	31	4.17	7.72	3.55	5.92	5.85	0.83	0.69	0.0895	2.6678	0	5.33	6.61	4
Pit 3	20	20	4.36	7.60	3.24	6.18	6.37	0.90	0.81	-0.5816	2.6834	0	5.64	6.75	3

Dissolved Oxygen (milligrams per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	DO<=1
Pit 1	36	36	0.06	7.45	7.39	1.45	1.05	1.46	2.13	2.186	9.162	1	0.41	2.05	18
Pit 2	31	31	0.04	4.10	4.06	0.94	0.70	0.81	0.66	2.082	8.38	3	0.52	1.09	22
Pit 3	20	20	0.06	2.11	2.05	0.83	0.61	0.69	0.47	0.664	1.949	0	0.28	1.45	13

Oxidation Reduction Potential (millivolts)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	ORP<-50
Pit 1	36	36	-106.2	477.9	584.1	146.5	115.4	194.8	37935	0.242	1.600	0	-45.0	307.3	9
Pit 2	31	31	-189	420.6	609.6	21.4	-33.1	149.3	22297	0.838	3.009	0	-94.0	129.5	12
Pit 3	20	20	-111.9	224.6	336.5	16.2	0.1	93.3	8696	0.664	2.589	0	-53.2	70.1	6

Specific Conductance (milliSiemens per centimeter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75
Pit 1	36	36	0.075	1.78	1.705	0.526	0.446	0.390	0.152	1.338	4.614	2	0.261	0.702
Pit 2	31	31	0.067	0.790	0.731	0.397	0.378	0.198	0.039	0.363	2.442	0	0.252	0.526
Pit 3	20	20	0.108	0.564	0.456	0.349	0.364	0.118	0.014	-0.201	2.676	0	0.272	0.415

Notes: N = number of normal samples, D = number of detected results, Min = minimum detected result, max = maximum detected result, Std. Dev. = standard deviation, Var = variance, PCTL25 = 25th percentile, PCTL75. = 75th percentile, pH <5 = number of results with pH less than 5, DO <= 1 = number of results with dissolved oxygen level less than or equal to 1 milligram per liter, ORP<-50 = number of results with oxidation reduction potential less than -50 millivolts.

For Pit 3, the distribution range is 3.24 with a mean of 6.18 and median of 6.37. The distribution 25th and 75th percentiles are 5.64 and 6.75, respectively. Three of 20 data observations have a pH less than 5.

2.4.2.2 Dissolved Oxygen (DO) Results

For Pit 1, the distribution range for dissolved oxygen (DO) is 7.39 milligrams per liter (mg/L) with a mean of 1.45 mg/L and median of 1.05 mg/L. The distribution 25th and 75th percentiles are 0.41 mg/L and 2.05 mg/L, respectively. Eighteen of 36 data observations have a DO level less than or equal to 1 mg/L.

For Pit 2, the distribution range for DO is 6.96 mg/L with a mean of 1.12 mg/L and median of 0.70 mg/L. The distribution 25th and 75th percentiles are 0.53 mg/L and 1.20 mg/L, respectively. Twenty three of 35 data observations have a DO level less than or equal to 1 mg/L.

For Pit 3, the distribution range for DO is 2.05 mg/L with a mean of 0.83 mg/L and median of 0.61 mg/L. The distribution 25th and 75th percentiles are 0.28 mg/L and 1.45 mg/L, respectively. Thirteen of 20 data observations have a DO level less than or equal to 1 mg/L.

2.4.2.3 ORP Results

For Pit 1, the distribution range for oxidation reduction potential (ORP) is 584.1 millivolts (mV) with a mean of 146.5 mV and median of 115.4 mV. The distribution 25th and 75th percentiles are -45.0 mV and 307.3 mV, respectively. Nine of 36 data observations have an ORP level less than -50 mV.

For Pit 2, the distribution range for ORP is 609.6 mV with a mean of 26.5 mV and median of -33.1 mV. The distribution 25th and 75th percentiles are -84.7 mV and 141.2 mV, respectively. Thirteen of 33 data observations have an ORP level less than -50 mV.

For Pit 3, the distribution range for ORP is 336.5 mV with a mean of 16.2 mV and median of 0.1 mV. The distribution 25th and 75th percentiles are -53.2 mV and 70.1 mV, respectively. Six of 20 data observations have an ORP level less than -50 mV.

2.4.2.4 SC Results

For Pit 1, the distribution range for SC is 1.705 mS/cm with a mean of 0.526 mS/cm and median of 0.446 mS/cm. The distribution 25th and 75th percentiles are 0.261 mS/cm and 0.702 mS/cm, respectively.

For Pit 2, the distribution range for SC is 0.963 mS/cm with a mean of 0.424 mS/cm and a median of 0.320 mS/cm. The distribution 25th and 75th percentiles are 0.261 mS/cm and 0.552 mS/cm, respectively.

For Pit 3, the distribution range for SC is 0.456 mS/cm with a mean of 0.349 mS/cm and median of 0.364 mS/cm. The distribution 25th and 75th percentiles are 0.272 mS/cm and 0.415 mS/cm, respectively.

2.4.3 VOC Results for Surficial Aquifer (2024)

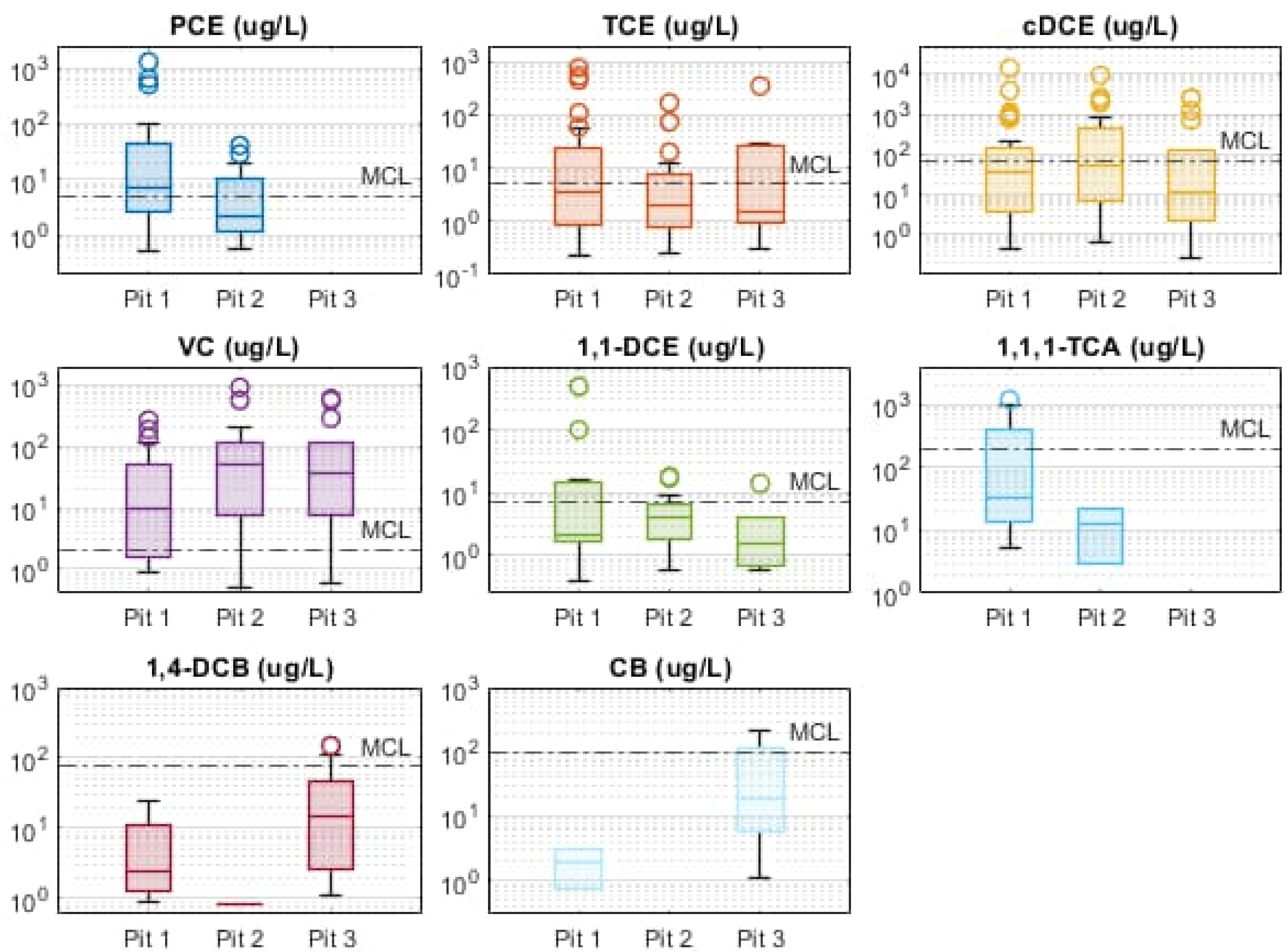
Section 2.4.3 and Exhibit 2-2 (page 2-20) have a summary of data distributions for VOC results (primary COCs) for the surficial aquifer. The summaries use the OU 7 annual monitoring data from March 2024.

2.4.3.1 Constituents of Concern

Table 2-4 on page 2-21 has a statistical summary of VOC constituents detected in one or more samples collected for annual groundwater monitoring. This table has descriptive statistics, identifies the location of the maximum detected concentrations, and presents screening comparisons to remedy cleanup levels (MCLs), EPA regional screening levels (RSLs), and ecological screening benchmarks as defined in the table notes.

VOCs detected in groundwater for this sampling event at levels greater than MCLs include: tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), vinyl chloride (VC), carbon tetrachloride, 1,1-dichloroethene (1,1-DCE), 1,1,1-trichloroethane (1,1,1-TCA), 1,4-dichlorobenzene (1,4-DCB), chlorobenzene (CB), and benzene. For constituents without MCLs, VOCs detected at concentrations greater than RSLs include: 1,1-dichloroethane, 1,2,3-trichlorobenzene, 1,3,5-trichlorobenzene, 2-butanone, 2-hexanone, acetone, hexachlorobutadiene, naphthalene, and o-xylene. Ketone constituents such as 2-butanone, 2-hexanone, and acetone typically form as a temporary by-product of engineered bioremediation actions.

Exhibit 2-2 VOC Data Distribution Surficial Aquifer: Annual Monitoring March 2024



Tetrachloroethene (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>MCL
Pit 1	36	19	0.52	1300	1299.48	143.1	7	331.3	109739	2.640	9.121	3	2.6	45	11
Pit 2	30	13	0.55	41	40.45	8.84	2.2	12.83	164	1.619	4.228	2	1.2	10.2	6
Pit 3	21	0	--	--	--	--	--	--	--	--	--	--	--	--	0

Trichloroethene (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>MCL
Pit 1	36	27	0.22	780	779.78	79.2	3.6	191.6	36706	2.701	9.063	5	0.82	24.2	12
Pit 2	30	20	0.24	170	169.76	15.6	2.0	39.9	1590	3.267	12.71	3	0.80	7.4	7
Pit 3	21	13	0.31	350	349.69	34.3	1.5	95.6	9138	3.090	10.746	1	0.96	27.5	4

Cis-1,2-dichloroethene (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>MCL
Pit 1	36	32	0.43	14000	13999.57	706.6	37	2528	6391301	4.809	25.535	6	3.5	135	12
Pit 2	30	27	0.61	9200	9199.39	710.1	53	1832	3356600	3.936	18.496	4	6.9	445	13
Pit 3	21	19	0.27	2500	2499.73	379.5	12	791	625272	2.042	5.639	4	2.2	128	7

Vinyl Chloride (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>MCL
Pit 1	36	24	0.88	270	269.12	46.3	9.5	70.4	4951	1.861	5.740	3	1.6	52	17
Pit 2	30	24	0.49	920	919.51	118.4	52	208.6	43496	2.907	10.936	2	7.4	120	21
Pit 3	21	15	0.59	600	599.41	126.5	36	198.9	39559	1.684	4.294	3	7.7	118	13

1,1-Dichloroethene (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>MCL
Pit 1	36	17	0.39	490	489.61	66.8	2.1	159.2	25332	2.2843	6.359	3	1.62	14.5	6
Pit 2	30	13	0.58	18	17.42	5.6	4.1	5.74	32.9	1.398	3.525	2	1.78	56.4	3
Pit 3	21	6	0.56	14	13.44	3.7	1.6	5.18	26.9	1.5795	3.781	1	0.7	4.0	1

1,1,1-Trichloroethane (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>MCL
Pit 1	36	9	5.4	1200	1194.6	283.3	33	470	221200	1.312	2.869	1	14	415	3
Pit 2	30	2	3	22	19	12.5	12.5	13.4	180.5	0	1	0	3	22	0
Pit 3	21	0	--	--	--	--	--	--	--	--	--	--	--	--	0

1,4-Dichlorobenzene (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>MCL
Pit 1	36	8	0.88	24	23.12	6.8	2.5	9.2	85	1.196	2.582	0	1.25	11.2	0
Pit 2	30	1	0.85	0.85	0	0.9	0.9	0.0	0	--	--	0	0.85	0.85	0
Pit 3	21	13	1.1	150	148.9	34.2	15	46.6	2169	1.553	4.198	1	2.55	47.2	2

Chlorobenzene (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>MCL
Pit 1	36	2	0.72	3.1	2.38	1.91	1.91	1.68	2.83	-2.6E-16	1.000	0	0.72	3.1	0
Pit 2	32	0	--	--	--	--	--	--	--	--	--	0	--	--	0
Pit 3	21	13	1.1	220	218.9	61.9	19.0	74.4	5529	1.004	2.657	0	5.8	112	4

Notes: N = number of normal samples, D = number of detected results, Min = minimum detected result, max = maximum detected result, Std. Dev. = standard deviation, Var = variance, PCTL25 = 25th percentile, PCTL75. = 75th percentile, >MCL = number of results with concentrations greater than Maximum Contaminant Level. Maximum contaminant level contained in Subpart G—National Primary Drinking Water Regulations: Maximum Contaminant Levels and Maximum Residual Disinfectant Levels, § 141.61 Maximum contaminant levels for organic contaminants

Table 2-4 Statistical Summary for VOCs: March 2024 GW Monitoring Surficial Aquifer (Detects)

Chemical	Matrix	No. of Results	Unit	Min	Max	Mean	Median	95th Percentile	No. > LOD	% > LOD	Location of Max	Federal MCL[1]			EPA RSL[2] (Nov 2024)			BTAG FWSB[3] (2006)		
												No. > MCL	% > MCL	MCL[1]	No. > RSL	No. > RSL	EPA RSL[2]	No. > BTAG	% > BTAG	BTAG FWSB[3]
1,1,1-Trichloroethane	WG	91	ug/L	<0.21	1200	n.d.	n.d.	1100	11	12.1	AEHADG-11	3	3	2.00E+02	2	2	8.01E+02	8	9	1.10E+01
1,1-Dichloroethane	WG	91	ug/L	<0.33	450	14.5	n.d.	127	43	47.3	OU7-MW-68	-	-	-	25	27	2.75E+00	5	5	4.70E+01
1,1-Dichloroethene	WG	91	ug/L	<0.33	490	13.9	n.d.	195	38	41.8	CMT-21-2	11	12	7.00E+00	3	3	2.85E+01	3	3	2.50E+01
1,2,3-Trichlorobenzene	WG	91	ug/L	<0.81	1.5	n.d.	n.d.	n.d.	1	1.1	CMT-18-1	-	-	-	1	1	7.04E-01	0	0	8.00E+00
1,2,4-Trichlorobenzene	WG	91	ug/L	<0.53	3.8	n.d.	n.d.	3	7	7.7	OU7-MW-125	0	0	7.00E+01	7	8	3.99E-01	1	1	2.40E+01
1,2-Dichlorobenzene	WG	91	ug/L	<0.31	220	11.6	n.d.	170	37	40.7	OU7-MW-68	0	0	6.00E+02	6	7	3.04E+01	35	38	7.00E-01
1,2-Dichloroethene, Total	WG	91	ug/L	<0.37	14000	546.1	23	2510	79	86.8	CMT-21-2	-	-	-	-	-	-	15	16	5.90E+02
1,3,5-Trimethylbenzene	WG	91	ug/L	<0.28	7.1	n.d.	n.d.	n.d.	3	3.3	OU7-MW-68	-	-	-	1	1	6.03E+00	0	0	7.10E+01
1,3-Dichlorobenzene	WG	91	ug/L	<0.31	14	1.6	n.d.	11	15	16.5	OU7-MW-125	-	-	-	-	-	-	0	0	1.50E+02
1,4-Dichlorobenzene	WG	91	ug/L	<0.31	150	6.5	n.d.	107	22	24.2	OU7-MW-125	2	2	7.50E+01	22	24	4.82E-01	6	7	2.60E+01
2-Butanone (MEK)	WG	91	ug/L	<6.4	120	n.d.	n.d.	109	13	14.3	DMW-21A	-	-	-	1	1	5.57E+02	0	0	1.40E+04
2-Hexanone	WG	91	ug/L	<3.2	57	n.d.	n.d.	51	5	5.5	OU7-MW-109	-	-	-	1	1	3.80E+00	1	1	9.90E+01
4-Chlorotoluene	WG	91	ug/L	<0.41	0.53	n.d.	n.d.	n.d.	1	1.1	CMT-18-1	-	-	-	0	0	2.50E+01	-	-	-
4-Isopropyltoluene	WG	91	ug/L	<0.44	3.1	n.d.	n.d.	n.d.	3	3.3	OU7-MW-68	-	-	-	-	-	-	0	0	8.50E+01
4-Methyl-2-pentanone (MIBK)	WG	91	ug/L	<2.7	20	n.d.	n.d.	n.d.	2	2.2	OU7-MW-57	-	-	-	0	0	6.26E+02	0	0	1.70E+02
Acetone	WG	91	ug/L	<3.7	19000	403.8	n.d.	2975	36	39.6	CMT-21-2	-	-	-	5	5	1.80E+03	6	7	1.50E+03
Benzene	WG	91	ug/L	<0.27	5.2	n.d.	n.d.	4	11	12.1	OU7-MW-109	1	1	5.00E+00	9	10	4.55E-01	0	0	3.70E+02
Bromobenzene	WG	91	ug/L	<0.24	0.33	n.d.	n.d.	n.d.	1	1.1	CMT-18-1	-	-	-	0	0	6.22E+00	-	-	-
Carbon disulfide	WG	91	ug/L	<0.43	7.9	n.d.	n.d.	6	6	6.6	AEHADG-11	-	-	-	0	0	8.11E+01	3	3	9.20E-01
Carbon tetrachloride	WG	91	ug/L	<0.3	40	n.d.	n.d.	n.d.	1	1.1	AEHADG-11	1	1	5.00E+00	1	1	4.55E-01	1	1	1.33E+01
Chlorobenzene	WG	91	ug/L	<0.15	220	9.4	n.d.	192	15	16.5	OU7-MW-125	4	4	1.00E+02	9	10	7.77E+00	13	14	1.30E+00
Chloroethane	WG	91	ug/L	<4.6	460	n.d.	n.d.	256	13	14.3	CMT-21-1	-	-	-	0	0	8.34E+02	-	-	-
Chloroform	WG	91	ug/L	<0.27	42	n.d.	n.d.	37	7	7.7	CMT-21-2	0	0	8.00E+01	7	8	2.21E-01	6	7	1.80E+00
Chloromethane (Methyl chloride)	WG	91	ug/L	<0.54	1.1	n.d.	n.d.	n.d.	1	1.1	CMT-21-4	-	-	-	0	0	1.88E+01	-	-	-
cis-1,2-Dichloroethene	WG	91	ug/L	<0.25	14000	544.3	23	2500	81	89.0	CMT-21-2	34	37	7.00E+01	65	71	2.52E+00	-	-	-
Ethylbenzene	WG	91	ug/L	<0.2	130	2.5	n.d.	37	19	20.9	CMT-21-2	0	0	7.00E+02	14	15	1.50E+00	1	1	9.00E+01
Hexachlorobutadiene	WG	97	ug/L	<0.22	1.5	n.d.	n.d.	1	5	5.2	CMT-18-1	-	-	-	4	4	1.39E-01	1	1	1.30E+00
Isopropylbenzene (Cumene)	WG	91	ug/L	<0.26	1.5	n.d.	n.d.	n.d.	3	3.3	OU7-MW-68	-	-	-	0	0	4.51E+01	0	0	2.60E+00
m+p-Xylenes	WG	91	ug/L	<0.49	460	9.5	n.d.	235	17	18.7	CMT-21-2	-	-	-	-	-	-	-	-	-
Naphthalene	WG	97	ug/L	<0.021	290	n.d.	n.d.	241	8	8.2	CMT-21-2	-	-	-	6	7	1.17E-01	6	7	1.10E+00
n-Butylbenzene	WG	91	ug/L	<0.52	1.2	n.d.	n.d.	n.d.	2	2.2	CMT-18-1	-	-	-	0	0	1.00E+02	-	-	-
n-Propylbenzene	WG	91	ug/L	<0.41	1.1	n.d.	n.d.	n.d.	2	2.2	OU7-MW-69	-	-	-	0	0	6.56E+01	0	0	1.28E+02
o-Xylene	WG	91	ug/L	<0.26	36	1.6	n.d.	23	17	18.7	CMT-21-2	-	-	-	1	1	1.93E+01	-	-	-
sec-Butylbenzene	WG	91	ug/L	<0.53	0.82	n.d.	n.d.	n.d.	2	2.2	OU7-MW-69	-	-	-	0	0	2.01E+02	-	-	-
Styrene	WG	91	ug/L	<0.27	0.28	n.d.	n.d.	n.d.	1	1.1	CMT-18-1	0	0	1.00E+02	0	0	1.21E+02	0	0	7.20E+01
tert-Butyl methyl ether (MTBE)	WG	91	ug/L	<0.81	1.9	n.d.	n.d.	n.d.	1	1.1	OU7-MW-116	-	-	-	0	5	1.43E+01	0	0	1.11E+04

Chemical	Matrix	No. of Results	Unit	Min	Max	Mean	Median	95th Percentile	No. > LOD	% > LOD	Location of Max	Federal MCL[1]			EPA RSL[2] (Nov 2024)			BTAG FWSB[3] (2006)		
												No. > MCL	% > MCL	MCL[1]	No. > RSL	No. > RSL	EPA RSL[2]	No. > BTAG	% > BTAG	BTAG FWSB[3]
tert-Butylbenzene	WG	91	ug/L	<0.43	0.55	n.d.	n.d.	n.d.	2	2.2	CMT-18-1	-	-	-	0	0	6.91E+01	-	-	-
Tetrachloroethene (PCE)	WG	91	ug/L	<0.35	1300	31.9	n.d.	556	33	36.3	AEHADG-11	20	21	5.00E+00	21	23	4.06E+00	3	3	1.11E+02
Toluene	WG	91	ug/L	<0.25	17	2.0	n.d.	10	34	37.4	OU7-MW-48	0	0	1.00E+03	0	0	1.10E+02	22	24	2.00E+00
trans-1,2-Dichloroethene	WG	91	ug/L	<0.34	34	2.0	n.d.	11	31	34.1	OU7-MW-85	0	0	1.00E+02	7	8	6.78E+00	0	0	9.70E+02
Trichloroethene (TCE)	WG	91	ug/L	<0.2	780	32.3	1.1	341	62	68.1	OU7-MW-36	24	26	5.00E+00	65	71	2.83E-01	15	16	2.10E+01
Trichlorofluoromethane	WG	91	ug/L	<0.33	8.6	n.d.	n.d.	n.d.	1	1.1	AEHADG-11	-	-	-	0	0	5.16E+02	-	-	-
Vinyl chloride	WG	91	ug/L	<0.4	920	67.0	6.9	492	66	72.5	CMT-18-5	54	59	2.00E+00	91	100	1.88E-02	0	0	9.30E+02
Xylene (Total)	WG	91	ug/L	<0.49	500	10.5	n.d.	220	18	19.8	CMT-21-2	0	0	1.00E+04	5	5	1.93E+01	5	5	1.30E+01

Notes: WG = groundwater, ug/L = micrograms per liter, Min = minimum, Max = maximum, No. > = number greater, LOD = limit of detection, % = percent, , [1]Subpart G—National Primary Drinking Water Regulations: Maximum Contaminant Levels and Maximum Residual Disinfectant Levels, § 141.61 Maximum contaminant levels for organic contaminants.> LOD = percent of detected results greater than laboratory limit of detection, [2] EPA Regional Screening Level for Resident Tap Water with a target cancer risk (TR) of 1E-06 and target hazard quotient (THQ) of 0.1, November 2004 at https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables. [3]EPA Region III BTAG Freshwater Screening Benchmarks, 7/2006. https://www.epa.gov/risk/freshwater-screening-benchmarks, Number of results with concentrations greater than the MCL, Number of results with concentration greater than the RSL, Number of results with concentrations greater than the BTAG FWSB

For the ecological screening, groundwater constituents detected in surface water samples in 2024 included cDCE, total dichloroethene, and TCE in one sample (KGC-1) at concentrations less than the laboratory LOQ. Sample KGC-1 is located upstream of the monitoring areas for FTA Pits 1 and 2 (Figure 2-6).

2.4.3.2 Data Distribution for Annual Monitoring

Exhibit 2-2 (2-20) has box plots and tabular information displaying data distributions for primary VOC constituents for annual monitoring for the plume areas associated with FTA Pits 1, 2, and 3. Figure 3-1 shows the locations of monitoring wells referenced in this section.

PCE

PCE occurs in the plume areas associated with FTA Pits 1 and 2 with the data distribution for Pit 1 plotting at a higher concentration range than Pit 2 (see Exhibit 2-2). Samples collected from the Pit 3 area did not have detections of PCE.

Pit 1 has 19 of 36 samples with detections of PCE and a detected concentration range of 0.52 micrograms per liter (µg/L) to 1,300 µg/L. Mean and median concentrations for PCE at Pit 1 are 143.1 µg/L and 7 µg/L, respectively, with 11 samples having concentrations greater than the MCL of 5 µg/L. Distribution 25th and 75th percentiles for PCE at Pit 1 are 2.6 µg/L and 45 µg/L, respectively.

Pit 2 has 13 of 30 samples with detections of PCE and a detected concentration range of 0.55 µg/L to 41 µg/L. Mean and median concentrations for PCE at Pit 2 are 8.84 µg/L and 2.2 µg/L, respectively, with five (5) samples having concentrations greater than the MCL of 5 µg/L. Distribution 25th and 75th percentiles for PCE at Pit 2 are 1.2 µg/L and 10 µg/L, respectively.

TCE

TCE has data distributions in Pit 1, 2, and 3 areas that extend 1 to 2 orders of magnitude higher than the MCL level of 5 µg/L (see Exhibit 2-2).

Pit 1 has 27 of 36 samples with detections of TCE and a detected concentration range of 0.22 µg/L to 780 µg/L. Mean and median concentrations for TCE at Pit 1 are 79.2 µg/L and 3.6 µg/L, respectively, with 12 samples having concentrations greater than the MCL of 5 µg/L. Distribution 25th and 75th percentiles for TCE at Pit 1 are 0.82 µg/L and 24.2 µg/L, respectively.

Pit 2 has 20 of 30 samples with detections of TCE and a detected concentration range of 0.24 µg/L to 170 µg/L. Mean and median concentrations for TCE at Pit 2 are 15.6 µg/L and 2.1 µg/L, respectively, with seven (7) samples having concentrations greater than the MCL of 5 µg/L. Distribution 25th and 75th percentiles for TCE at Pit 2 are 0.80 µg/L and 7.4 µg/L, respectively.

Pit 3 has 13 of 21 samples with detections of TCE and a detected concentration range of 0.31 µg/L to 350 µg/L. Mean and median concentrations for TCE at Pit 3 are 34.3 µg/L and 1.5 µg/L, respectively, with four (4) samples having concentrations greater than the MCL of 5 µg/L. Distribution 25th and 75th percentiles for TCE at Pit 3 are 0.96 µg/L and 27.5 µg/L, respectively.

cDCE

cDCE has data distributions in the Pit 1, 2, and 3 areas that extend 1 to 2 magnitudes higher than the MCL level of 70 µg/L (see Exhibit 2-2).

Pit 1 has 32 of 36 samples with detections of cDCE and a detected concentration range of 0.43 µg/L to 14,000 µg/L. Mean and median concentrations for cDCE at Pit 1 are 706.5 µg/L and 73 µg/L, respectively, with 12 samples having concentrations greater than the MCL of 70 µg/L. Distribution 25th and 75th percentiles for cDCE at Pit 1 are 3.5 µg/L and 135 µg/L, respectively.

Pit 2 has 27 of 30 samples with detections of cDCE and a detected concentration range of 0.61 µg/L to 9,200 µg/L. Mean and median concentrations for cDCE at Pit 2 are 710.1 µg/L and 53 µg/L, respectively, with 13 samples having concentrations greater than the MCL of 70 µg/L. Distribution 25th and 75th percentiles for cDCE at Pit 2 are 6.9 µg/L and 445 µg/L, respectively.

Pit 3 has 19 of 21 samples with detections of cDCE and a detected concentration range of 0.27 µg/L to 2,500 µg/L. Mean and median concentrations for cDCE at Pit 3 are 379.5 µg/L and 12 µg/L, respectively, with seven (7) samples having concentrations greater than the MCL of 70 µg/L. Distribution 25th and 75th percentiles for cDCE at Pit 3 are 2.2 µg/L and 128 µg/L, respectively.

VC

VC has data distributions in the Pit 1, 2, and 3 areas that extend two (2) magnitudes higher than the MCL level of 2 µg/L (see Exhibit 2-2).

Pit 1 has 17 of 36 samples with detections of VC and a detected concentration range of 0.88 µg/L to 270 µg/L. Mean and median concentrations for VC at Pit 1 are 46.3 µg/L and 9.5 µg/L, respectively, with 17 samples having concentrations greater than the MCL of 2 µg/L. Distribution 25th and 75th percentiles for VC at Pit 1 are 1.6 µg/L and 52 µg/L, respectively.

Pit 2 has 24 of 30 samples with detections of VC and a detected concentration range of 0.49 µg/L to 920 µg/L. Mean and median concentrations for VC at Pit 2 are 118.4 µg/L and 52 µg/L, respectively, with 21 samples having concentrations greater than the MCL of 2 µg/L. Distribution 25th and 75th percentiles for VC at Pit 2 are 7.5 µg/L and 120 µg/L, respectively.

Pit 3 has 6 of 21 samples with detections of VC and a detected concentration range of 0.59 µg/L to 600 µg/L. Mean and median concentrations for VC at Pit 3 are 126.5 µg/L and 35 µg/L, respectively, with 13 samples having concentrations greater than the MCL of 2 µg/L. Distribution 25th and 75th percentiles for VC at Pit 3 are 7.7 µg/L and 118 µg/L, respectively.

1,1-DCE

Pit 1 has 17 of 36 samples with detections of 1,1-DCE and a detected concentration range of 0.39 µg/L to 49 µg/L. Mean and median concentrations for 1,1-DCE at Pit 1 are 66.8 µg/L and 2.1 µg/L, respectively, with six (6) samples having concentrations greater than the MCL of 7 µg/L. Distribution 25th and 75th percentiles for 1,1-DCE at Pit 1 are 1.62 µg/L and 14.5 µg/L, respectively.

Pit 2 has 13 of 30 samples with detections of 1,1-DCE and a detected concentration range of 0.58 µg/L to 18 µg/L. Mean and median concentrations for 1,1-DCE at Pit 2 are 5.6 µg/L and 4.1 µg/L, respectively, with three (3) samples having concentrations greater than the MCL of 7 µg/L. Distribution 25th and 75th percentiles for 1,1-DCE at Pit 2 are 1.77 µg/L and 4.0 µg/L, respectively.

Pit 3 has 6 of 21 samples with detections of 1,1-DCE and a detected concentration range of 0.56 µg/L to 14 µg/L. Mean and median concentrations for 1,1-DCE at Pit 3 are 3.7 µg/L and 1.6 µg/L, respectively, with one (1) sample having a concentration greater than the MCL of 7 µg/L. Distribution 25th and 75th percentiles for 1,1-DCE at Pit 3 are 0.7 µg/L and 4.0 µg/L, respectively.

1,1,1-TCA

Pit 1 has 9 of 36 samples with detections of 1,1,1-TCA and a detected concentration range of 5.4 µg/L to 1,200 µg/L. Mean and median concentrations for 1,1,1-TCA at Pit 1 are 283.3 µg/L and 33 µg/L, respectively, with three (3) samples having concentrations greater than the MCL of 200 µg/L. Distribution 25th and 75th percentiles for 1,1,1-TCA at Pit 1 are 14 µg/L and 415 µg/L, respectively.

Pit 2 has 2 of 30 samples with detections of 1,1,1-TCA and a detected concentration range of 3 µg/L to 22 µg/L. Mean and median concentrations for 1,1,1-TCA at Pit 2 are 12.5 µg/L and 12.5 µg/L, respectively, with no samples having concentrations greater than the MCL of 200 µg/L. Distribution 25th and 75th percentiles for 1,1,1-TCA at Pit 2 are 3 µg/L and 22 µg/L, respectively.

Samples collected from the Pit 3 area did not have detections of 1,1,1-TCA.

1,4-DCB

Pit 1 has 8 of 36 samples with detections of 1,4-DCB and a detected concentration range of 0.88 µg/L to 24 µg/L. Mean and median concentrations for 1,4-DCB at Pit 1 are 6.8 µg/L and 2.5 µg/L, respectively, with no samples having concentrations greater than the MCL of 75 µg/L. Distribution 25th and 75th

percentiles for 1,4-DCB at Pit 1 are 1.25 µg/L and 11.2 µg/L, respectively. Pit 2 has 1 of 30 samples with a detection of 1,4-DCB at an estimated concentration of 0.85 µg/L.

Pit 3 has 13 of 21 samples with detections of 1,4-DCB and a detected concentration range of 1.1 µg/L to 150 µg/L. Mean and median concentrations for 1,4-DCB at Pit 3 are 34.2 µg/L and 15 µg/L, respectively, with two (2) samples having a concentration greater than the MCL of 75 µg/L. Distribution 25th and 75th percentiles for 1,4-DCB at Pit 3 are 2.55 µg/L and 47.2 µg/L, respectively.

CB

Pit 1 has 2 of 36 samples with detections of CB at concentrations of 0.72 µg/L to 3.1 µg/L. The detected concentrations of CB did not exceed the MCL of 100 µg/L. Samples collected from the Pit 2 area did not have detections of CB.

Pit 3 has 13 of 21 samples with detections of CB and a detected concentration range of 1.1 µg/L to 220 µg/L. Mean and median concentrations for CB at Pit 3 are 61.9 µg/L and 19.0 µg/L, respectively, with four (4) samples having a concentration greater than the MCL of 100 µg/L. Distribution 25th and 75th percentiles for CB at Pit 3 are 5.8 µg/L and 112 µg/L, respectively.

Carbon Tetrachloride

Carbon tetrachloride had a detection in 1 of 89 samples with reported concentration of 40 µg/L at well AEHADG-11 in the Pit 2 area. The detected concentration is greater than the MCL of 5 µg/L.

Benzene

Benzene had reported detections in 4 of 87 samples with one sample in Pit 3 (well MW-109, 5.2 µg/L) with a reported concentration greater than the MCL of 5 µg/L.

2.4.4 Geochemical Results for Surficial Aquifer (2024)

Section 2.4.4 and Exhibit 2-3 (page 2-26) have a summary of data distributions for geochemical results for the surficial aquifer targeted for ISB actions. The summaries use the OU 7 annual monitoring data from March 2024.

2.4.4.1 Chloride

Pit 1 has chloride concentrations ranging from 0.88 to 160 mg/L with a mean concentration of 54.3 mg/L and median concentration of 29 mg/L. Pit 2 has chloride concentrations ranging from 1.8 mg/L to 260 mg/L with a mean concentration of 96.1 mg/L and median concentration of 85.0 mg/L. Pit 3 has chloride concentrations ranging from 8 mg/L to 130 mg/L with a mean concentration of 58.7 mg/L and median concentration of 53.0 mg/L.

2.4.4.2 Nitrate

Minimal nitrate occurs in groundwater within the monitored areas at Pits 1, 2, and 3 with single detections in each monitoring area at levels less than 1 mg/L.

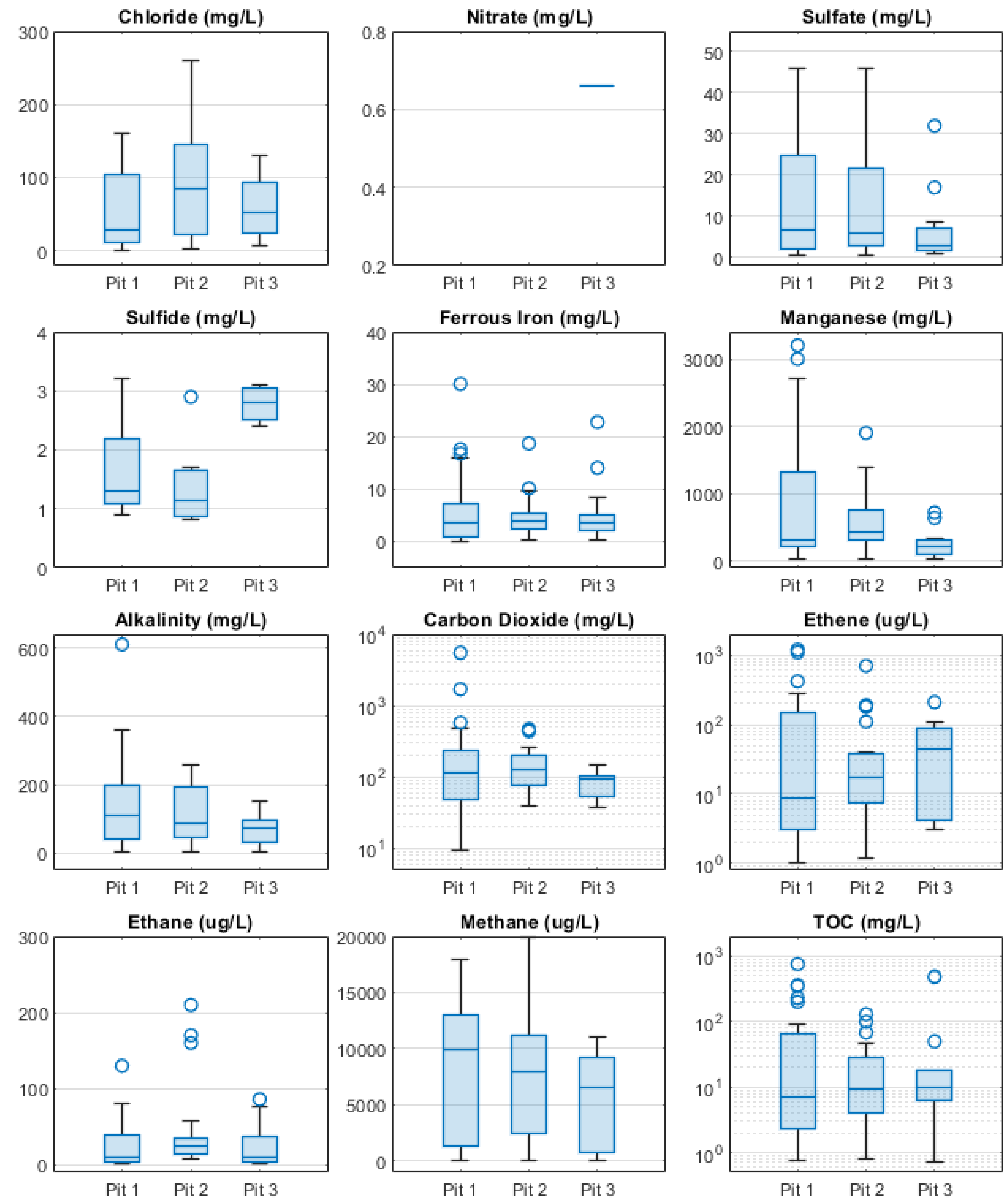
2.4.4.3 Sulfate

At Pit 1, 21 of 31 samples have detectable levels of sulfate ranging from 0.57 mg/L to 46 mg/L with mean and median concentrations of 12.5 mg/L and 6.5 mg/L, respectively. Pit 2 has 20 of 25 samples with detectable levels of sulfate ranging from 0.6 mg/L to 46 mg/L with mean and median concentrations of 13.3 mg/L and 6.0 mg/L, respectively. Pit 3 has 12 of 14 samples with detectable levels of sulfate ranging from 1 mg/L to 32 mg/L with mean and median concentrations of 6.7 mg/L and 2.8 mg/L, respectively.

2.4.4.4 Sulfide

At Pit 1, 7 of 31 samples have detectable levels of sulfide ranging from 0.91 mg/L to 3.2 mg/L. Eight of 25 samples at Pit 2 have detectable levels of sulfide ranging from 0.83 mg/L to 2.9 mg/L. At Pit 3, four of 15 samples have detectable levels of sulfide ranging from 2.4 mg/L to 3.1 mg/L.

Exhibit 2-3 Geochemical Data Distribution for Surficial Aquifer: March 2024



Chloride (milligrams per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75
Pit 1	31	31	0.88	160	159.12	54.3	29	53.7	2886	0.7388	2.0009	0	11.3	105
Pit 2	25	25	1.8	260	258.2	96.2	85.0	74.0	5482	0.4794	2.2672	0	21.8	145
Pit 3	15	15	8	130	122.00	58.7	53.0	39.9	1595	0.2725	1.7346	0	25.3	93.3

Nitrate (milligrams per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	<1
Pit 1	31	1	0.95	0.95	0	0.95	0.95	0	0	--	--	0	0.95	0.95	1
Pit 2	25	1	0.16	0.16	0	0.16	0.16	0	0	--	--	0	0.16	0.16	1
Pit 3	15	1	0.66	0.66	0	0.66	0.66	0	0	--	--	0	0.66	0.66	1

Sulfate (milligrams per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	=<50
Pit 1	31	23	0.57	46	45.4	12.5	6.5	13.6	186	1.072	2.802	0	2.2	24.8	23
Pit 2	25	20	0.6	46	45.4	13.3	6.0	15.5	240	1.102	2.590	0	2.8	21.5	20
Pit 3	14	12	1	32	31.0	6.7	2.8	9.2	84	2.019	5.959	2	1.6	6.9	12

Sulfide (milligrams per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>1
Pit 1	31	7	0.91	3.2	2.29	1.66	1.30	0.84	0.71	0.986	2.518	0	1.10	2.20	6
Pit 2	25	8	0.83	2.9	2.07	1.38	1.14	0.70	0.49	1.338	3.744	1	0.88	1.65	4
Pit 3	15	4	2.4	3.1	0.7	2.78	2.80	0.33	0.11	-0.132	1.284	0	2.50	3.05	4

Ferrous Iron (milligrams per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>1
Pit 1	31	31	0.01	48	47.99	6.9	3.6	10	101	2.724	10.720	4	1.01	7.20	23
Pit 2	27	27	0.26	18.72	18.46	4.5	3.8	3.7	13.5	2.289	9.424	2	2.25	5.28	24
Pit 3	19	19	0.31	22.8	22.49	4.9	3.6	5.4	28.7	2.304	7.949	2	2.05	4.98	16

Manganese (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75
Pit 1	33	33	34	3200	3166	856	310	900	809687	1.292	3.591	2	228	1325
Pit 2	26	26	35	1900	1865	566	435	426	181350	1.493	5.078	1	310	760
Pit 3	15	15	22	720	698	243	210	203	41157	1.256	3.746	1	96	308

Alkalinity (milligrams per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75
Pit 1	31	30	3.8	610	606.2	142	111	131.4	17253	1.546	6.372	1	41	200
Pit 2	25	24	4	260	256.0	111	89	82.8	6864	0.496	1.834	0	44	195
Pit 3	15	13	2.5	150	147.5	67	72	46.8	2188	0.015	2.077	0	29	98

Carbon Dioxide (milligram per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75
Pit 1	31	31	9.7	5500	5490.3	378	115	1018	103550	4.5305	23.012	3	49	230
Pit 2	25	24	40	470	430	151	125	112	12518	1.644	5.2638	2	76	205
Pit 3	15	13	37	150	113	86	92	37	1387	0.249	1.963	0	54	105

Ethene (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>10
Pit 1	31	19	1	1200	1199	182	9	359	129072	2.188	6.328	3	3.1	148	9
Pit 2	25	19	1.2	700	698.8	74	17	162	26209	3.290	13.145	4	7.45	37.8	13
Pit 3	15	9	3	210	207	62	45	67	4486	1.200	3.628	1	4.175	86	6

Ethane (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>10
Pit 1	31	24	0.49	130	129.51	26.4	9.35	33.3	1111	1.604	4.979	1	3.5	39	12
Pit 2	25	20	6.7	210	203.3	45.9	23.5	59.6	3552	1.897	5.023	3	14	36	17
Pit 3	15	11	1.2	86	84.8	26.1	9.00	30.2	912	1.105	2.772	1	4.2	37	5

Methane (micrograms per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>500
Pit 1	31	31	8.2	18000	17991.8	7557	9900	6035	363670	-0.0596	1.5034	0	1325	13000	24
Pit 2	25	25	51	20000	19949	7352	8000	5521	30488000	0.4503	2.2864	0	2675	10750	23
Pit 3	15	15	64	11000	10936	5398	6500	4192	17574101	-0.1898	1.3567	0	802.5	9225	12

Total Organic Carbon (milligram per liter)

Area	N	D	Min	Max	Range	Mean	Median	Std	Var	Skewness	Kurtosis	Outliers	PCTL25	PCTL75	>20
Pit 1	31	31	0.77	760	759.23	74.1	7.2	161	25835	2.981	12.132	5	2.3	63.5	10
Pit 2	25	24	0.8	130	129.2	25.2	9.1	33.9	1154	1.836	5.500	4	4.2	29	9
Pit 3	17	16	0.72	490	489.28	70.8	9.8	162	26274	2.247	6.090	3	6.3	18	3

Notes: N = number of normal samples, D = number of detected results, Min = minimum detected result, max = maximum detected result, Std. Dev. = standard deviation, Var = variance, PCTL25 = 25th percentile, PCTL75. = 75th percentile, > greater than

2.4.4.5 Ferrous Iron

At Pit 1, 31 of 31 samples have detectable levels of ferrous iron ranging from 0.01 mg/L to 48 mg/L with mean and median concentrations of 6.9 mg/L and 3.6 mg/L, respectively. Pit 2 has 27 of 27 samples with detectable levels of ferrous iron ranging from 0.26 mg/L to 18.72 mg/L with mean and median concentrations of 4.52 mg/L and 3.78 mg/L, respectively. Pit 3 has 19 of 19 samples with detectable levels of ferrous iron ranging from 0.31 mg/L to 22.80 mg/L with mean and median concentrations of 4.88 mg/L to 3.60 mg/L, respectively.

2.4.4.6 Manganese

Pit 1 has manganese concentrations ranging from 34 µg/L to 3,200 µg/L with mean and median concentrations of 856 µg/L and 310 µg/L. Pit 2 has manganese concentrations ranging from 35 µg/L to 1,900 µg/L with mean and median concentrations of 566 µg/L and 435 µg/L, respectively. Pit 3 has manganese concentrations ranging from 2 µg/L to 720 µg/L with mean and median concentrations of 242 µg/L and 210 µg/L, respectively.

2.4.4.7 Alkalinity

At Pit 1, 30 of 31 samples have detectable levels of alkalinity ranging from 3.8 mg/L to 610 mg/L with mean and median concentrations of 142 mg/L and 111 mg/L, respectively. Pit 2 has 24 of 25 samples with detectable levels of alkalinity ranging from 4 mg/L to 260 mg/L with mean and median concentrations of 111 mg/L and 88 mg/L, respectively. Pit 3 has 13 of 15 samples with detectable levels of alkalinity ranging from 2.5 mg/L to 150 mg/L with mean and median concentrations of 67 mg/L and 72 mg/L, respectively.

2.4.4.8 Carbon Dioxide

At Pit 1, 30 of 31 samples have detectable levels of carbon dioxide ranging from 9.7 mg/L to 5,500 mg/L with mean and median concentrations of 378 mg/L and 115 mg/L, respectively. Pit 2 has 24 of 25 samples with detectable levels of carbon dioxide ranging from 40 mg/L to 470 mg/L with mean and median concentrations of 151 mg/L and 125 mg/L, respectively. Pit 3 has 13 of 15 samples with detectable levels of carbon dioxide ranging from 37 mg/L to 150 mg/L with mean and median concentrations of 85 mg/L and 92 mg/L, respectively.

2.4.4.9 Ethene

At Pit 1, 19 of 31 samples have detectable levels of ethene ranging from 1 µg/L to 1,200 µg/L with mean and median concentrations of 182 µg/L and 9 µg/L, respectively. Pit 2 has 19 of 25 samples with detectable levels of ethene ranging from 1.2 µg/L to 700 µg/L with mean and median concentrations of 74 µg/L and 17 µg/L, respectively. Pit 3 has 9 of 15 samples with detectable levels of ethene ranging from 3 µg/L to 210 µg/L with mean and median concentrations of 62 µg/L and 45 µg/L, respectively.

2.4.4.10 Ethane

At Pit 1, 24 of 31 samples have detectable levels of ethane ranging from 0.49 µg/L to 130 µg/L with mean and median concentrations of 26.4 µg/L and 9.35 µg/L, respectively. Pit 2 has 20 of 25 samples with detectable levels of ethane ranging from 6.7 µg/L to 210 µg/L with mean and median concentrations of 45.9 µg/L and 23.5 µg/L, respectively. Pit 3 has 11 of 15 samples with detectable levels of ethane ranging from 1.2 µg/L to 86 µg/L with mean and median concentrations of 26.1 µg/L and 9.00 µg/L, respectively.

2.4.4.11 Methane

At Pit 1, 31 of 31 samples have detectable levels of methane ranging from 8.2 µg/L to 18,000 µg/L with mean and median concentrations of 7,557 µg/L and 9,900 µg/L, respectively. Pit 2 has 25 of 25 samples with detectable levels of methane ranging from 51 µg/L to 20,000 µg/ with mean and median concentrations of 7,352 µg/L and 8,000 µg/L, respectively. Pit 3 has 15 of 15 samples with detectable levels of methane ranging from 64 µg/L to 11,000 µg/L with mean and median concentrations of 5,398 µg/L and 6,500 µg/L, respectively.

2.4.4.12 Total Organic Carbon (TOC)

At Pit 1, 31 of 31 samples have detectable levels of total organic carbon (TOC) ranging from 0.77 mg/L to 760 mg/L with mean and median concentrations of 74.1 mg/L and 7.2 mg/L, respectively. Pit 2 has 24 of 25 samples with detectable levels of TOC ranging from 0.8 mg/L to 130 mg/L with mean and median concentrations of 25.2 mg/L and 9.0 mg/L, respectively. Pit 3 has 16 of 17 samples with detectable levels of TOC ranging from 0.72 mg/L to 490 mg/L with mean and median concentrations of 70.8 mg/L and 9.8 mg/L, respectively.

2.4.4.13 Plume Geochemical Environment

Table 2-5 has summary information for geochemical parameters at each monitored plume area used to characterize geochemical environments.

Table 2-5 Plume Geochemical Environments

Area	Median Concentrations (mg/L)					Degradation Products	Geochemical Environment in Plume Area > MCLs
	DO	NO3	Fe2	SO4	CH4		
Pit 1	1.05	0.95	3.6	6.5	9.90	Yes	Anaerobic
Pit 2	0.94	0.16	3.8	6.0	8.00	Yes	Anaerobic
Pit 3	0.61	0.66	3.6	2.8	6.50	Yes	Anaerobic

Notes: DO = dissolved oxygen, SO4 = sulfate, NO3 = nitrate, CH4 = methane, mg/L = milligrams per liter.

2.4.5 Microbial Results

Section 2.4.5 has a summary of microbial sample results for annual monitoring completed in March 2024. Appendix B.4 in the Fiscal Year 2024 OU 7 Annual Report has complete tables with microbial sample results.

2.4.5.1 Pit 1

Microbial sampling in the Pit 1 ISB treatment areas indicated the following results for sampled wells AEHADG-11, MW-36, and MW-124:

- Presence of Dehalococcoides (DHC) at a level of 3.60E+02 cells cells/mL at AEHADG-11, a level of 3.40E+03 cells/mL at MW-36, and a level of 3.20E+01 at MW-124.
- Presence of tceA Reductase (tceA) at an estimated level of 4.50E-01 cells/mL at MW-36, a level of 2.10E-00 at MW-124, with no detection reported for AEHADG-11.
- No detections of BAV1 Vinyl Chloride (BVC).
- Presence of Vinyl Chloride Reductase (VCR) at a level of 2.10E+02 cells/mL at AEHADG-11, a level of 4.80E+03 cells/mL at well MW-36, and a level of 1.40E+00 cells/mL for MW-124.

2.4.5.2 Pit 2

Microbial sampling in the Pit 2 ISB treatment areas indicated the following results for sampled wells CMT-18-3 and MW-48:

- Presence of DHC at a level of 9.50E+03 cell/mL at well CMT-18-4 and a level of 9.40E-04 cells/mL at MW-48.
- Presence of tceA at a level of 4.80E+01 cells/mL at well MW-48 with no detection reported for CMT-18-4.
- Presence of BVC at an estimated level of 7.40E+01 cells/mL at well CMT-18-4 and a level of 1.40E+02 cells/mL at well MW-48.
- Presence of VCR at a level of 2.81E+03 cells/mL at well CMT-18-4 and a level of 1.1E+04 cells/mL.

2.4.5.3 Pit 3

Microbial sampling in the Pit 3 ISB treatment areas indicated the following results for sampled well MWFOS-3:

- Presence of DHC at a level of 2.90E+00 cells/mL.
- tceA, BVC, and VCR not detected.

2.4.6 Primary VOC Plume Areas for Surficial Aquifer (2024)

VOC plumes principally occur in the surficial aquifer at OU 7 with separate plume areas associated with the FTA Pit 1, 2, and 3 areas.

Figure 2-8 (page 2-30) depicts the lateral extent of PCE, TCE, cDCE, and VC plume areas within the surficial aquifer at concentrations equal to and greater than MCLs. VC generally defines the plume extent for Pits 1, 2, and 3. The Pit 1 VOC plume extends from the former pit area more than 600 ft. downgradient to the Kingsland Creek area beyond the installation fence line. At Pit 2, the VOC plume extends from the near the former pit area more than 600 ft. downgradient to the installation fence line at well MW-148. The VOC plume associated with Pit 3 extends approximately 500 ft. downgradient and southeast of the former pit area with the limits more than 300 ft. upgradient of installation fence line and Kingsland Creek.

2.4.6.1 PCE

Figure 2-9 (page 2-31) depicts the PCE plume areas associated with Pits 1 and 2. At Pit 1, a PCE plume area in the upper area has a limited source zone with concentrations greater than or equal to 500 µg/L remaining in the area of AEHADG-11, MW-36, and CMT-21-2. A single detection of PCE at a concentration greater than the MCL (5 µg/L) occurs downgradient of this plume area at well PZ-6 near the installation fence line.

Two isolated and degraded PCE plume areas with concentrations less than 50 µg/L remain in the Pit 2 area. The isolated plumes are in the upper area and around well MW-148 in the fence line area.

2.4.6.2 TCE

Figure 2-10 (page 2-32) depicts the TCE plume areas associated with Pits 1, 2, and 3. At Pit 1, a TCE plume in the upper area has a limited source zone with concentrations greater than 500 µg/L collocated with the TCE plume. A single detection of TCE at a concentration greater than MCL is collocated with PCE at PZ-6 with a second isolated plume area in the flood plain area of Kingsland Creek.

Two isolated TCE plume areas remain in the upper Pit 2 area with another isolated area encompassing wells MWFTA-3 and MW-148 in the lower area near the installation fence line. TCE concentrations are less than 50 µg/L in these plume areas except at well CMT-24-4 (170 µg/L) in the upper area.

At Pit 3, a TCE plume extends 120 ft. downgradient of the former pit with a limited area having concentrations greater than 50 µg/L. A second plume area is located near Building 72 around well MW-117 (29 µg/L).

2.4.6.3 cDCE

Figure 2-11 (page 2-33) depicts the cDCE plume areas associated with Pits 1, 2, and 3. At Pit 1, a cDCE plume extends 250 ft. downgradient of the former pit area with two limited areas within the plume having concentrations greater than 700 µg/L. This plume area does not extend into the lower flood plain area at Kingsland Creek.

At Pit 2, a cDCE plume with an approximate length of 400 ft. is located in the upper area. This plume has limited areas with concentrations greater than 700 µg/L. A isolated cDCE plume area is located around well MWFTA-3 in the lower area upgradient of the fence line.

At Pit 3, a cDCE plume extends approximately 100 ft. downgradient of the former pit area with a limited area at MWFOS-3 having a concentration greater than 700 µg/L. A second isolated cDCE plume area is located between this plume area and Building 72 with a single detection of cDCE at well MW-117 near Building 72.

2.4.6.4 VC

Figure 2-12 (page 2-34) depicts the VC plume areas associated with Pits 1, 2, and 3. Core plume areas generally have VC concentrations less than 20 µg/L with isolated areas greater than 200 µg/L. At Pit 1, a VC plume extends 300 ft. downgradient of the former pit area. A second isolated plume area with VC concentrations less than 20 µg/L is located within the flood plain area of Kingsland Creek. At Pit 2, a VC plume extends more than 600 ft. from the former pit area to well MW-148 in the installation fence line area. In the upper area, the VC plume has two limited areas with concentrations greater than 200 µg/L around wells MW-85 and CMT-18-5.

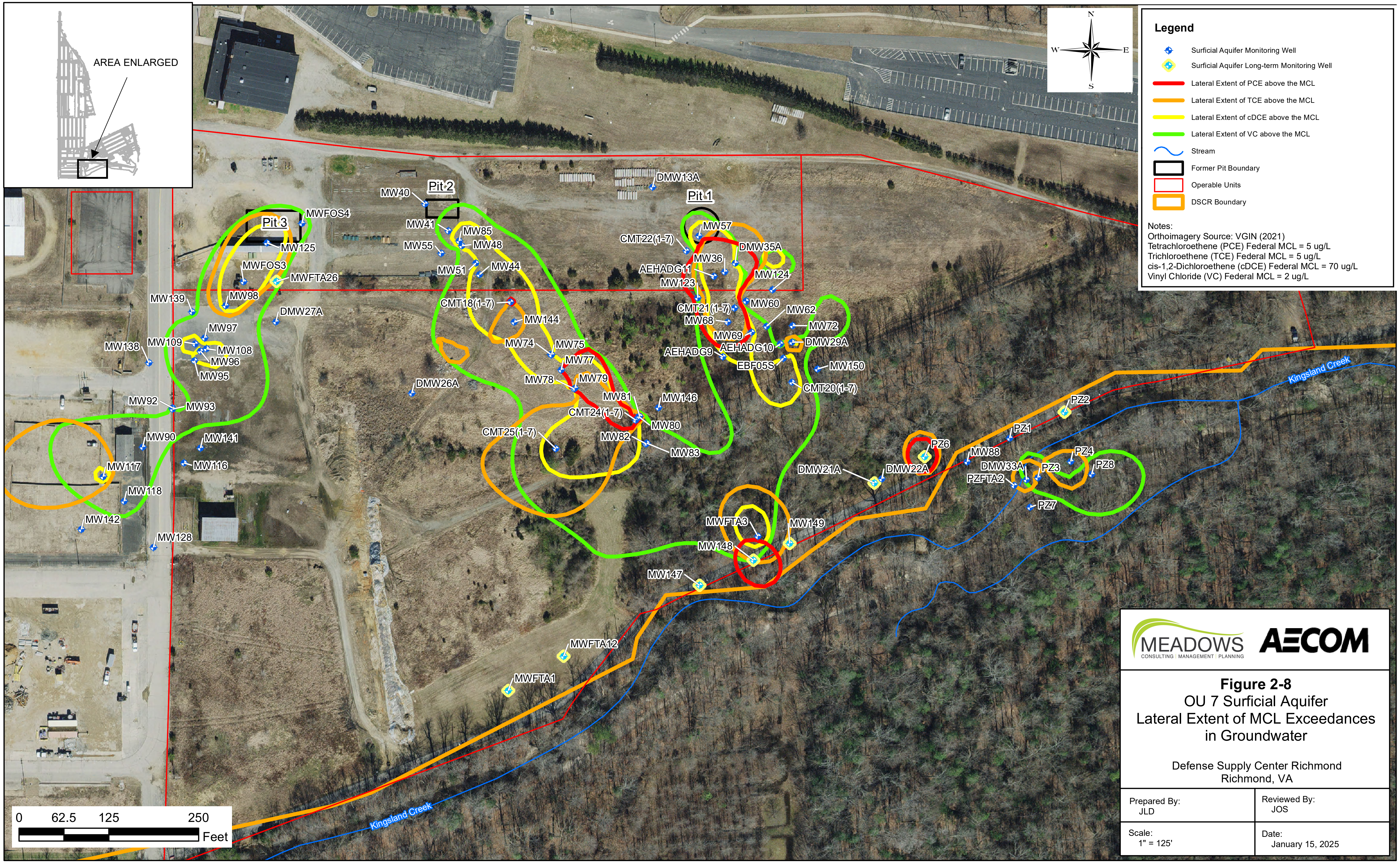


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Figure 2-8
OU 7 Surficial Aquifer
Lateral Extent of MCL Exceedances
in Groundwater

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1" = 125'	Date: January 15, 2025

L:\Legacy\USGNA2FP002\Data\projects\0_GIS\DLA\OU7\Annual Report\2024\Figure 2-8 - Surficial MCL Exceedances

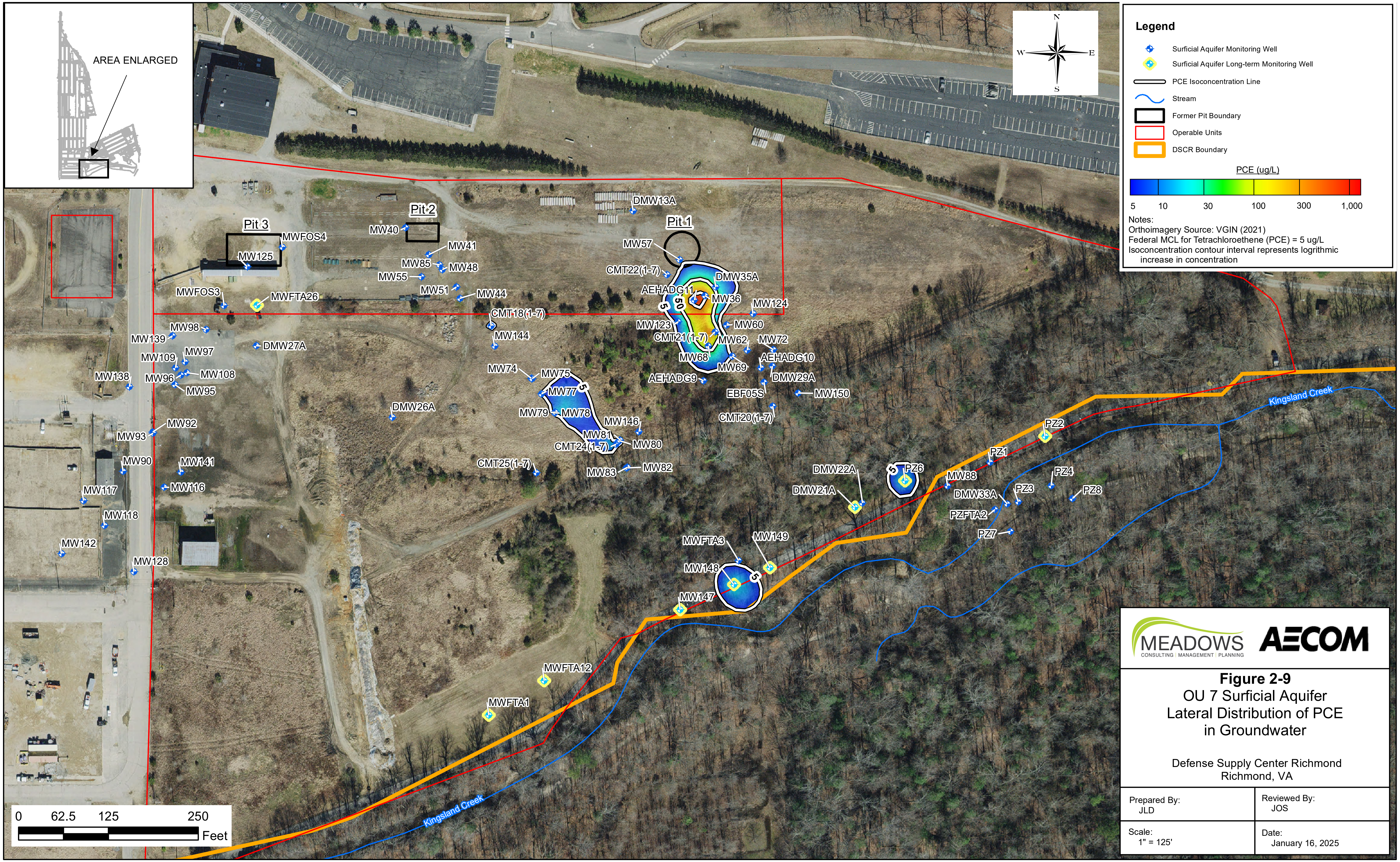
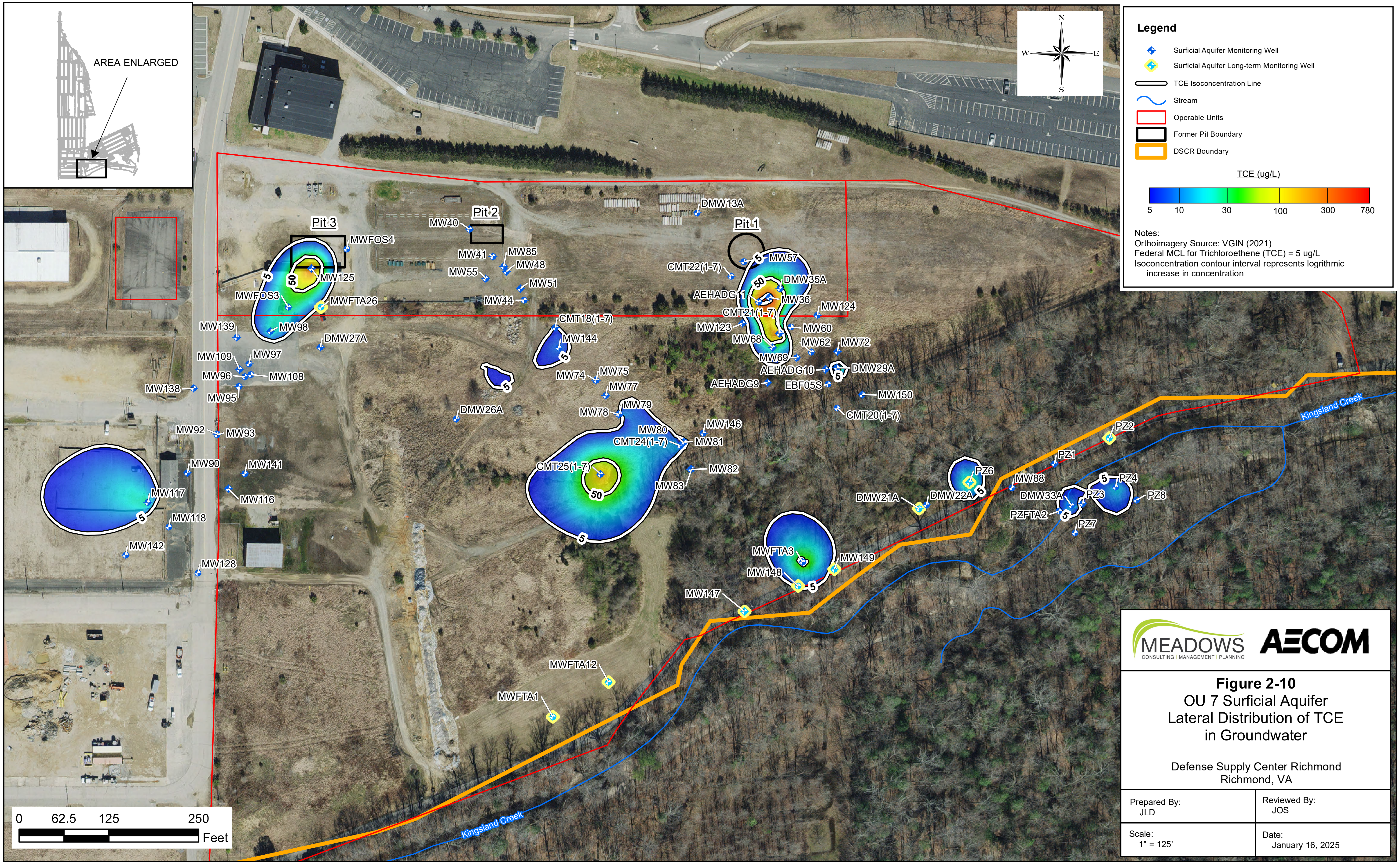


Figure 2-9
OU 7 Surficial Aquifer
Lateral Distribution of PCE
in Groundwater

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1" = 125'	Date: January 16, 2025

L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 2-9 - OU 7 Surficial Lateral Distribution of PCE.mxd



Legend

- Surficial Aquifer Monitoring Well
- Surficial Aquifer Long-term Monitoring Well
- TCE Isoconcentration Line
- Stream
- Operable Units
- Former Pit Boundary
- DSCR Boundary

TCE (ug/L)

5 10 30 100 300 780

Notes:
Orthoimagery Source: VGIN (2021)
Federal MCL for Trichloroethene (TCE) = 5 ug/L
Isoconcentration contour interval represents logrithmic increase in concentration

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Figure 2-10
OU 7 Surficial Aquifer
Lateral Distribution of TCE
in Groundwater

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1" = 125'	Date: January 16, 2025

L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 2-10 - OU 7 Surficial Lateral Distribution of TCE.mxd

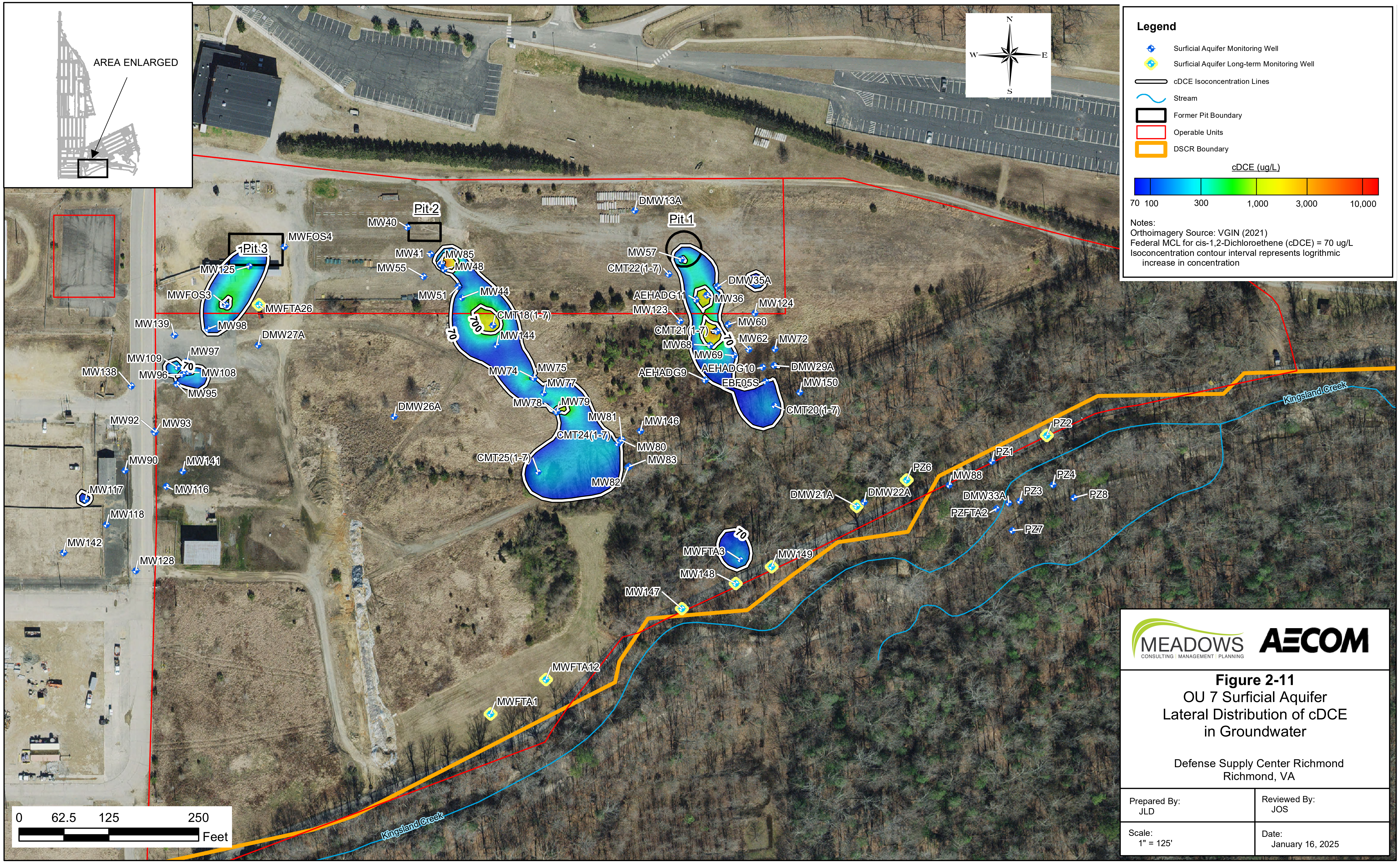

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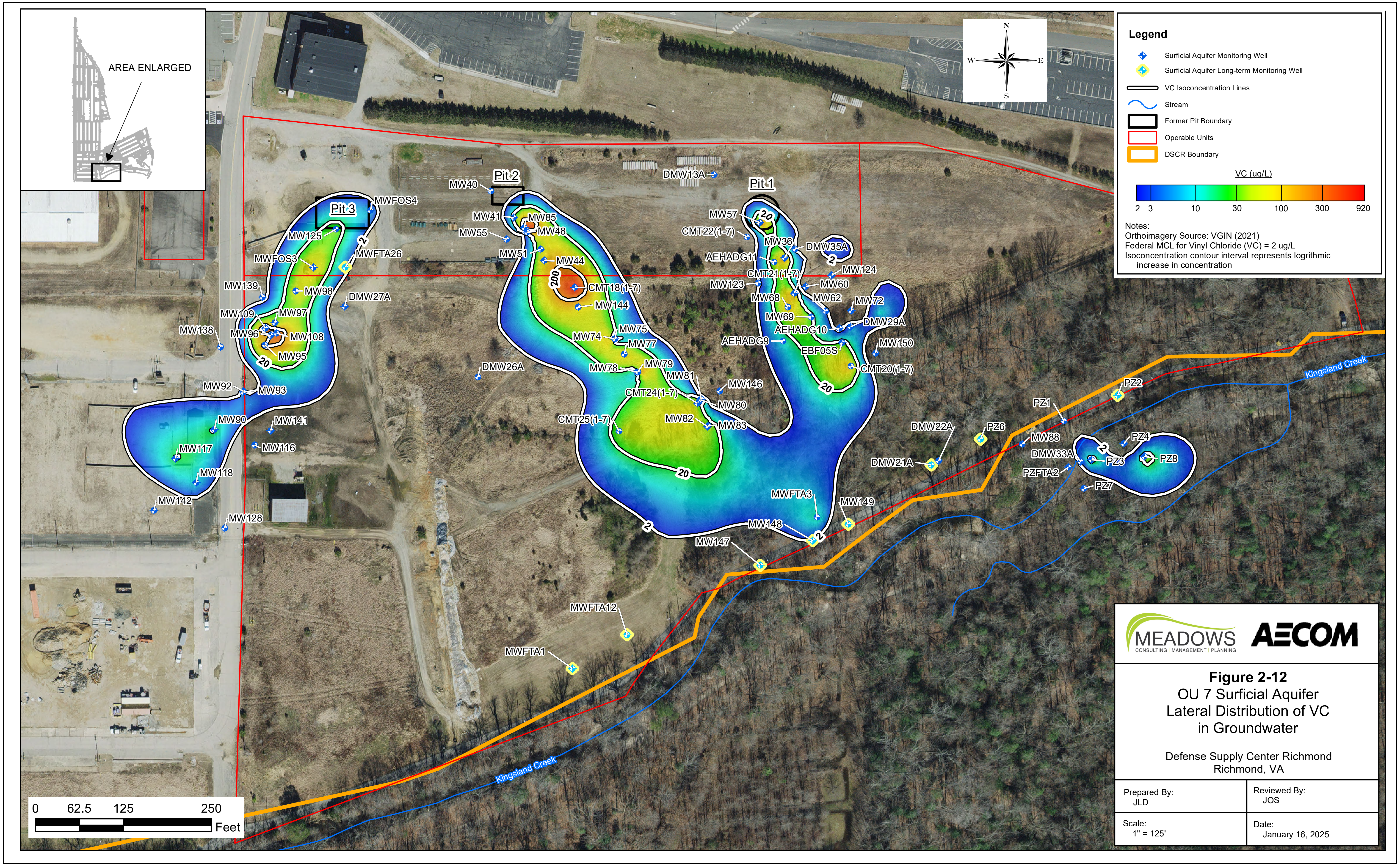
Figure 2-11
OU 7 Surficial Aquifer
Lateral Distribution of cDCE
in Groundwater

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1" = 125'	Date: January 16, 2025

L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 2-11 - OU 7 Surficial Lateral Distribution of cDCE.mxd



L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 2-12 - OU 7 Surficial Lateral Distribution of VC.mxd

2.4.7 Distribution of Dissolved Gases in Surficial Aquifer (2024)

Section 2.4.7 describes the distribution of dissolved gases in the surficial aquifer for site-wide annual sampling performed in March 2024.

2.4.7.1 Carbon Dioxide

For the surficial aquifer at OU 7, background levels of carbon dioxide generally fall in the range of less than or equal to 15 mg/L outside of VOC plume areas and the influence of bioremediation processes. Carbon dioxide levels within the plume areas generally are 2 to 40 times higher than background with the highest concentrations in recent ISB injection areas.

2.4.7.2 Methane

For the 2024 annual sampling event, the number of samples having methane concentrations greater than 500 µg/L is 24 of 31 samples for Pit 1, 25 of 27 samples for Pit 2, and 12 of 15 samples for Pit 3. Samples collected from the most recent bioremediation areas generally have methane concentrations greater than 1,000 µg/L. Methane concentrations < 500 µg/L generally occur at monitoring locations outside of VOC plumes and in the flood plain area of Kingsland Creek where oxidation is frequently a preferred reaction pathway.

2.4.7.3 Ethene

Figure 2-13 (page 2-36) shows contiguous plume areas of dissolved ethene at concentrations greater than or equal to 10 µg/L, which generally occur in the core VOC plume areas in Pits 1, 2, and 3. Maximum ethene concentrations in these pit areas are 1,200 µg/L for Pit 1 (MW-68), 700 µg/L for Pit 2 (CMT-18-5), and 200 µg/L for Pit 3 (MW-108).

2.4.7.4 Ethane

Figure 2-14 (page 2-37) shows contiguous plume areas of dissolved ethane at concentrations greater than or equal to 10 µg/L, which generally occur in the core VOC plume areas in Pits 1, 2, and 3. Maximum ethane concentrations in these pit areas are 130 µg/L for Pit 1 (MW-69), 210 µg/L for Pit 2 (MW-48), and 86 µg/L for Pit 3 (MW-108).

2.4.8 Distribution of Total Organic Carbon

Figure 2-15 (page 2-38) shows areas of TOC in groundwater within the surficial aquifer at concentrations greater than or equal to 20 mg/L. At Pit 1, the area of TOC greater than or equal to 20 mg/L in groundwater extends from the former pit area approximately 300 ft. to the most downgradient ISB treatment area (TA-06). Ten of 31 wells monitored in the Pit 1 area have TOC concentrations greater than or equal to 20 mg/L with these wells having one or more COCs at concentrations greater than or equal to 10 times higher than cleanup levels (MCLs). At Pit 2, the primary area of TOC greater than or equal to 20 mg/L n groundwater extends from the most upgradient ISB treatment area (TA-07) approximately 200 ft. to the mid-plume ISB treatment area (TA-08). Single wells downgradient of this area have TOC concentrations greater than or equal to 20 mg/L including wells MW-75 (mid-plume), CMT-24-2 (downgradient), and well MW-148 (fence line area). Nine of 24 locations sampled including a well cluster with four samples had TOC concentrations greater than or equal to 20 mg/L. Pit 3 had two areas of groundwater with TOC concentrations greater than or equal to 20 mg/L corresponding to treatment areas at the former pit area (TA-10) and in the mid plume area (TA-11). Three of 17 samples had TOC concentrations greater than or equal to 20 mg/L.

2.4.9 Bulk Plume Trends

Section 2.4.9 summarizes bulk plume trends for the surficial aquifer at OU 7. Figures 2-16, 2-17, 2-18, and 2-19 (pages 2-39 through 2-42) have tiled layouts for PCE, TCE, cDCE, and VC plumes characterized for annual sampling events performed in 2021, 2022, 2023, and 2024, respectively. Exhibit 2-4 (page 2-43) has tiled stem plots for plume area data (acres) from 2009, 2012, 2015, and 2018 through 2024. Plots in Exhibit 2-4 use singular spectrum analysis (SSA[1]) to find and plot long-term trends in the time series data. SAA calculates long-term trend as tabular and plotted data allowing for further

[1] Singular spectrum analysis performed using MATLAB 2024a

analysis of rates of change and degree of trend. Each plot has a percent change representing the change from the maximum plume area (pre-2024) to 2024.

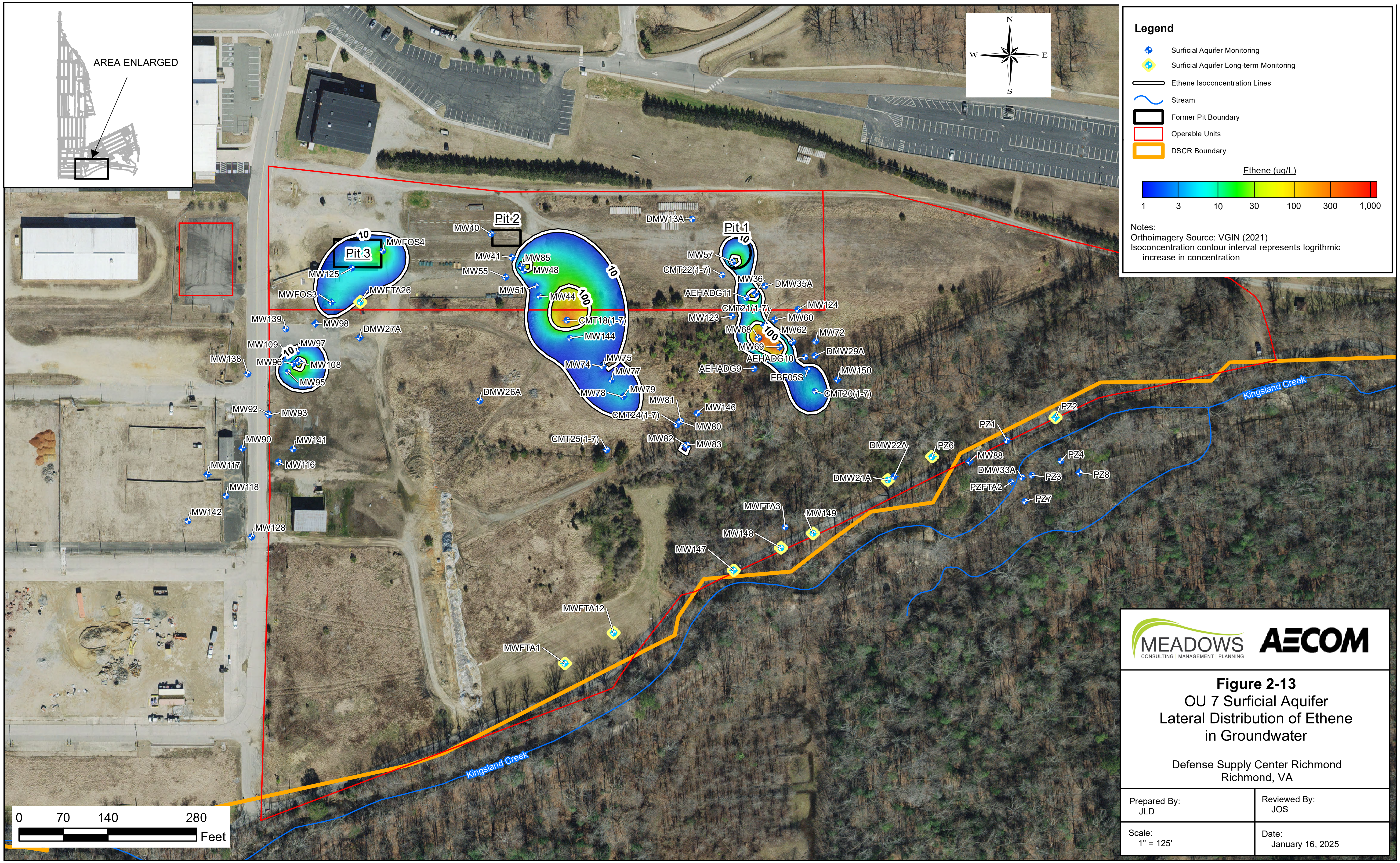


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Figure 2-13
OU 7 Surficial Aquifer
Lateral Distribution of Ethene
in Groundwater

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1" = 125'	Date: January 16, 2025

L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 2-13 - OU 7 Surficial Lateral Distribution of Ethene.mxd

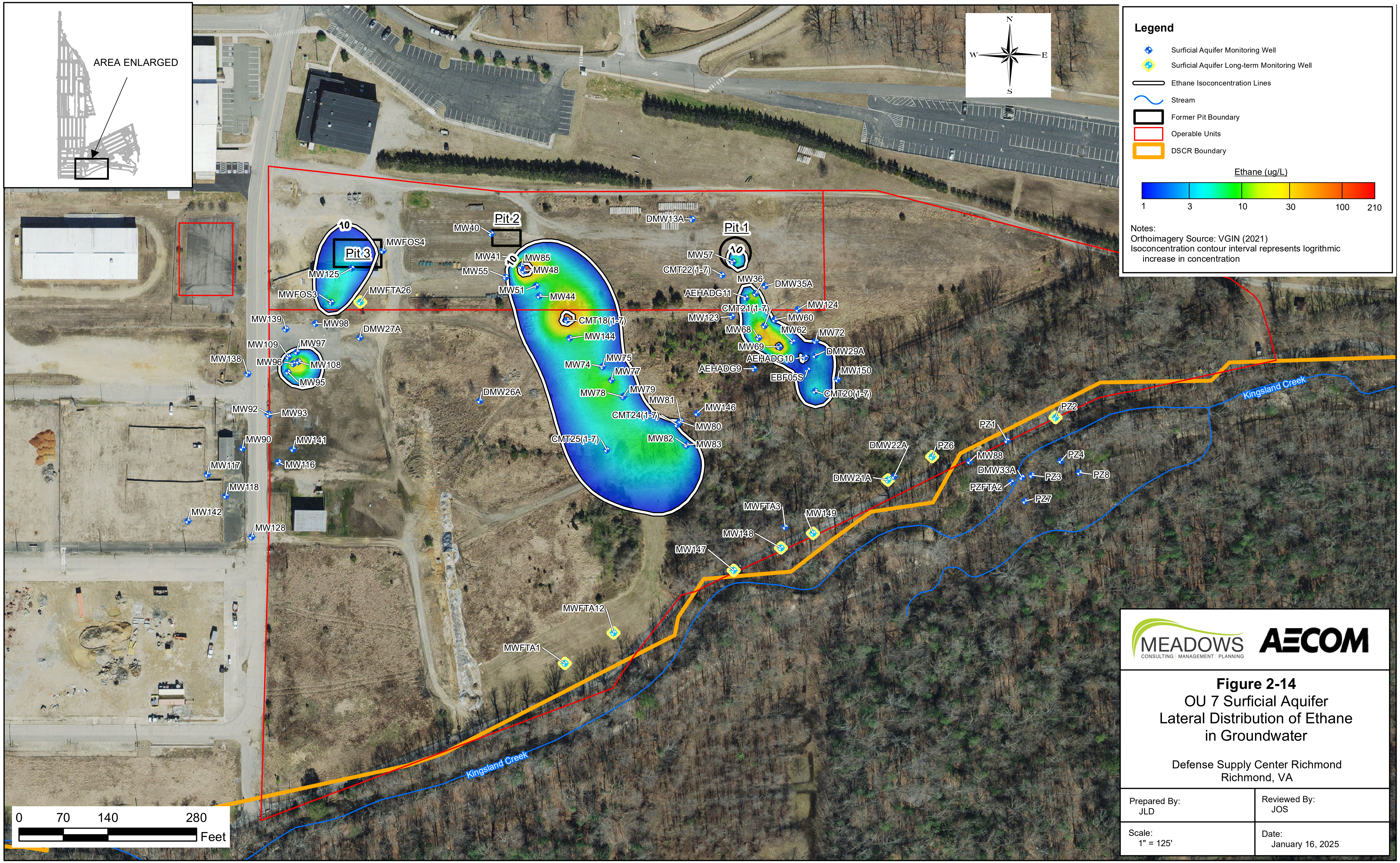


Figure 2-14
OU 7 Surficial Aquifer
Lateral Distribution of Ethane
in Groundwater

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1" = 125'	Date: January 16, 2025

L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 2-14 - OU 7 Surficial Lateral Distribution of Ethane.mxd

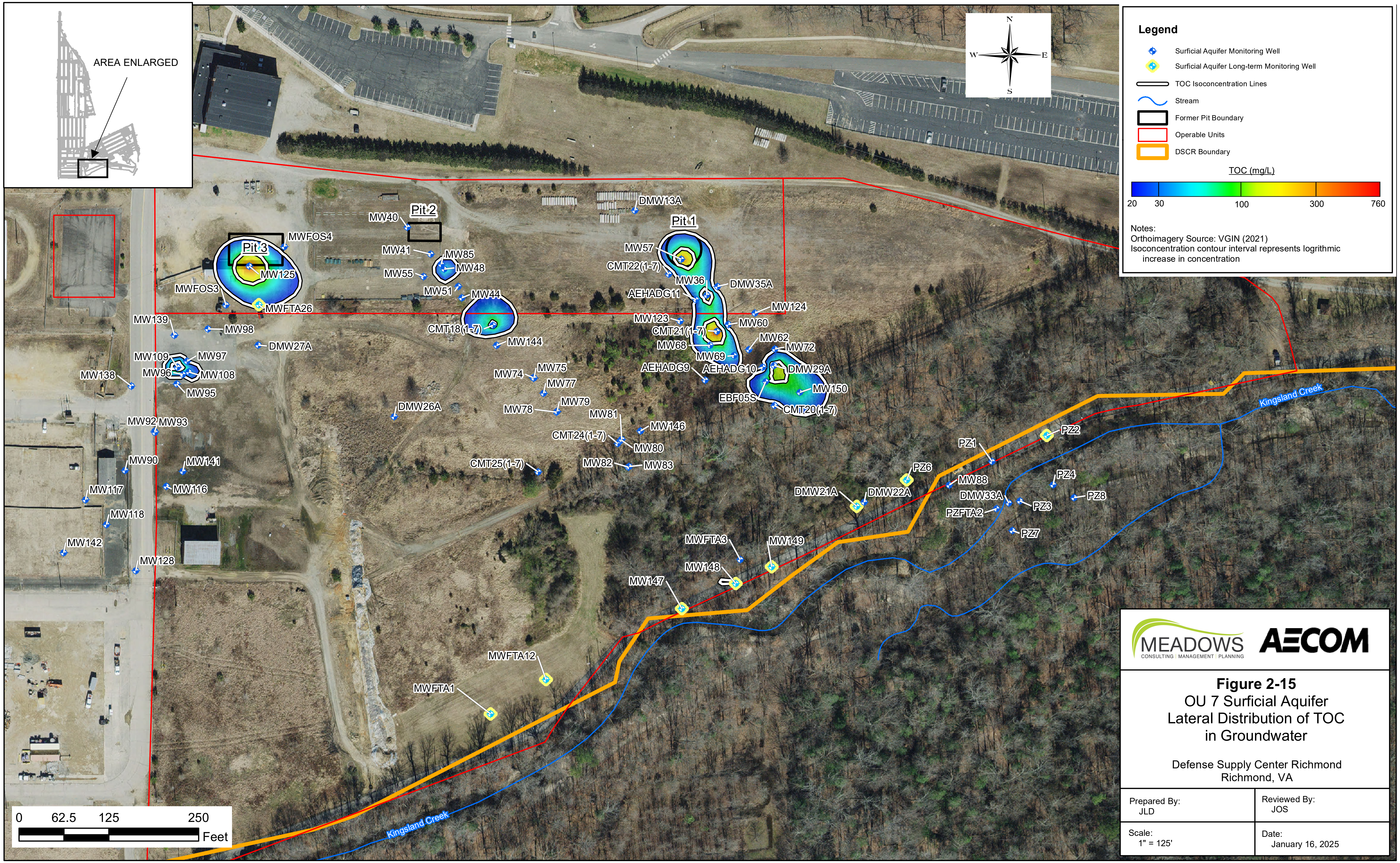
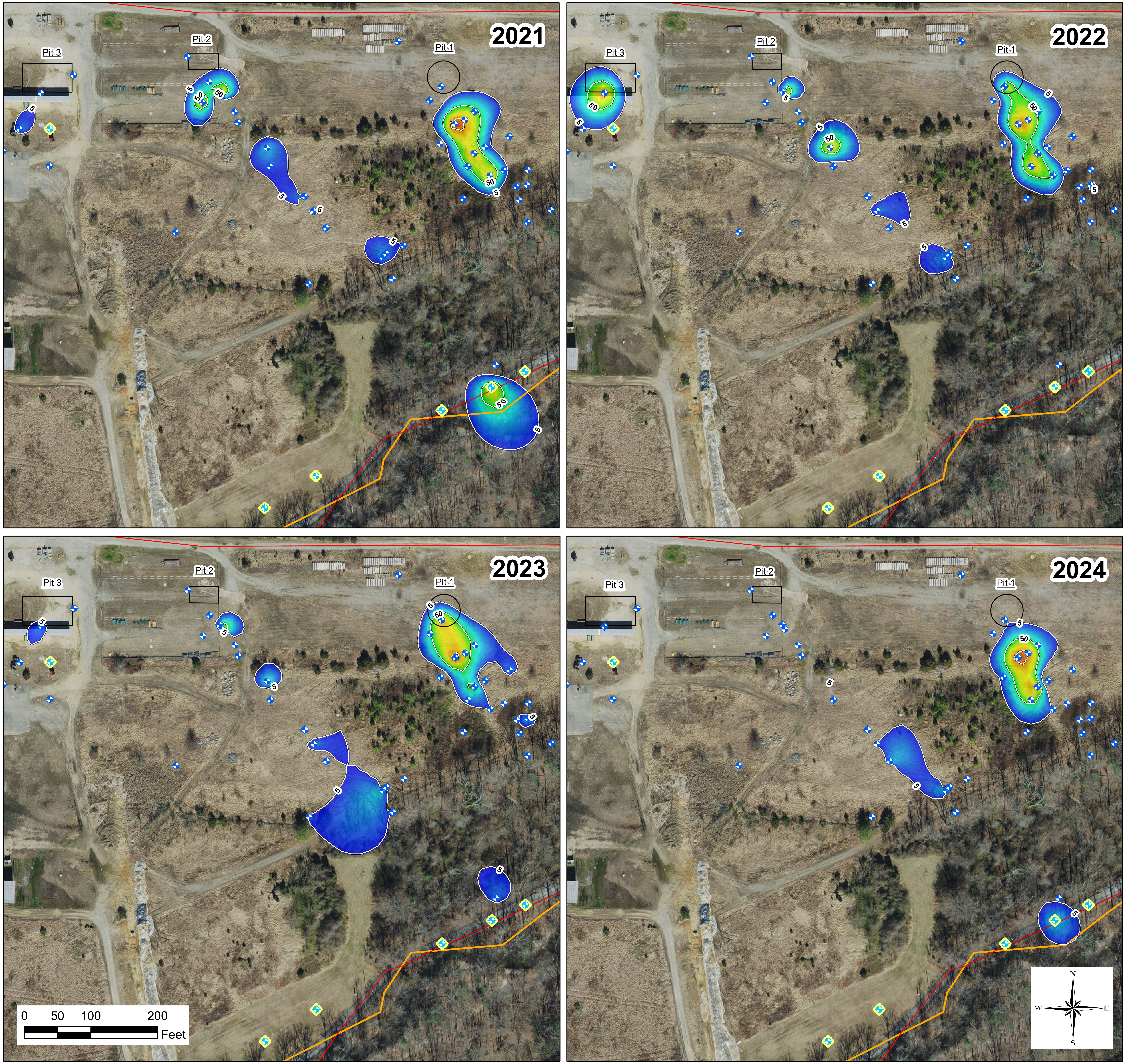


Figure 2-15
OU 7 Surficial Aquifer
Lateral Distribution of TOC
in Groundwater



Legend

- Surficial Aquifer Monitoring Well
- Surficial Aquifer Long-term Monitoring Well
- PCE Isoconcentration Line
- OU7 Boundary
- Installation Boundary

PCE (ug/L)

5 10 30 100 300 1,000 2,400

Notes:
Orthoimagery Source: VGIN (2021)
Federal MCL for Tetrachloroethene (PCE) = 5 ug/L
Isoconcentration contour interval represents logrithmic increase in concentration

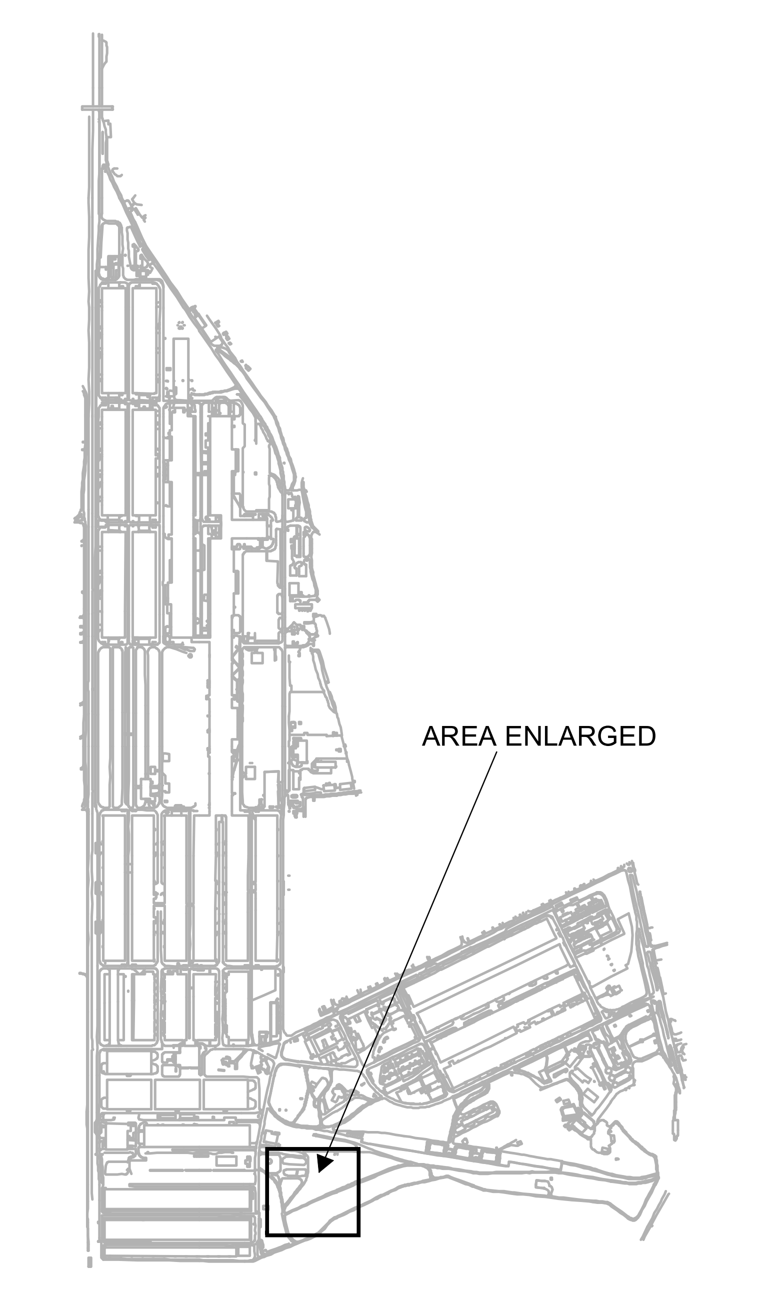


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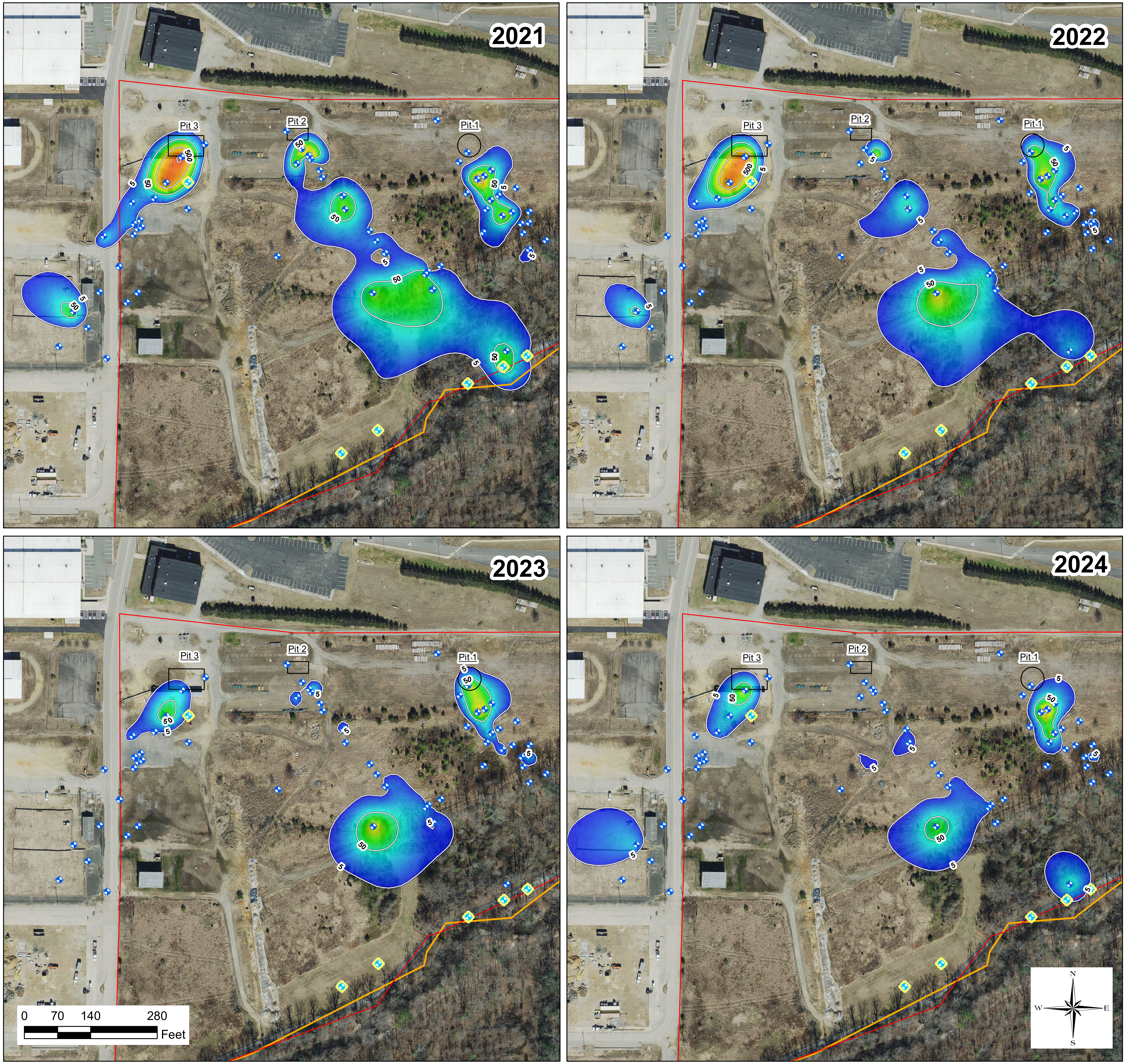
Figure 2-16
Changes in Lateral Distribution of PCE in Surficial Aquifer (2021-2024)

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1 " = 100 '	Date: January 16, 2025



Legend

- Surficial Aquifer Monitoring Well
- Surficial Aquifer Long-term Monitoring Well
- TCE Isoconcentration Line
- OU7 Boundary
- Installation Boundary

TCE (ug/L)

5 10 30 100 300 1,000 3,000 10,000

Notes:
Orthoimagery Source: VGIN (2021)
Federal MCL for Trichloroethene (TCE) = 5 ug/L
Isoconcentration contour interval represents logrithmic increase in concentration

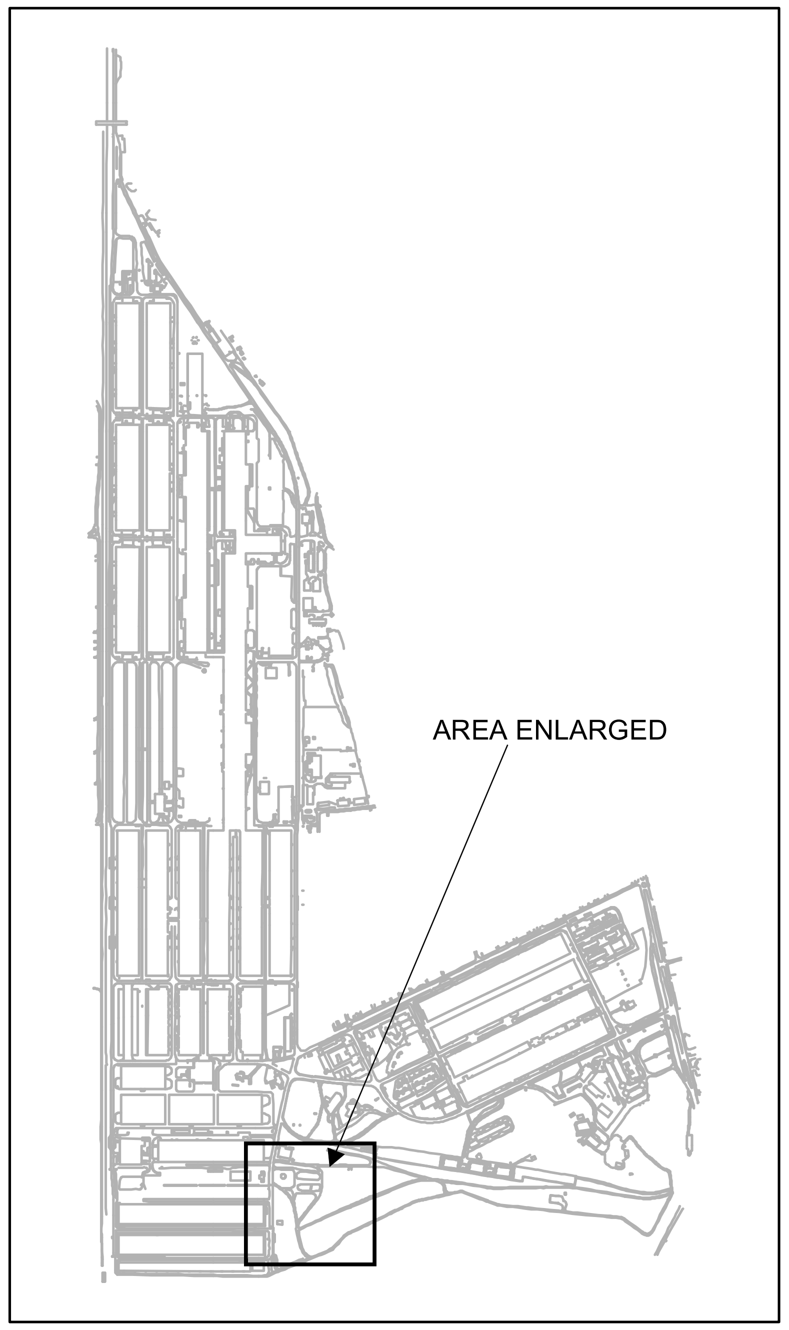


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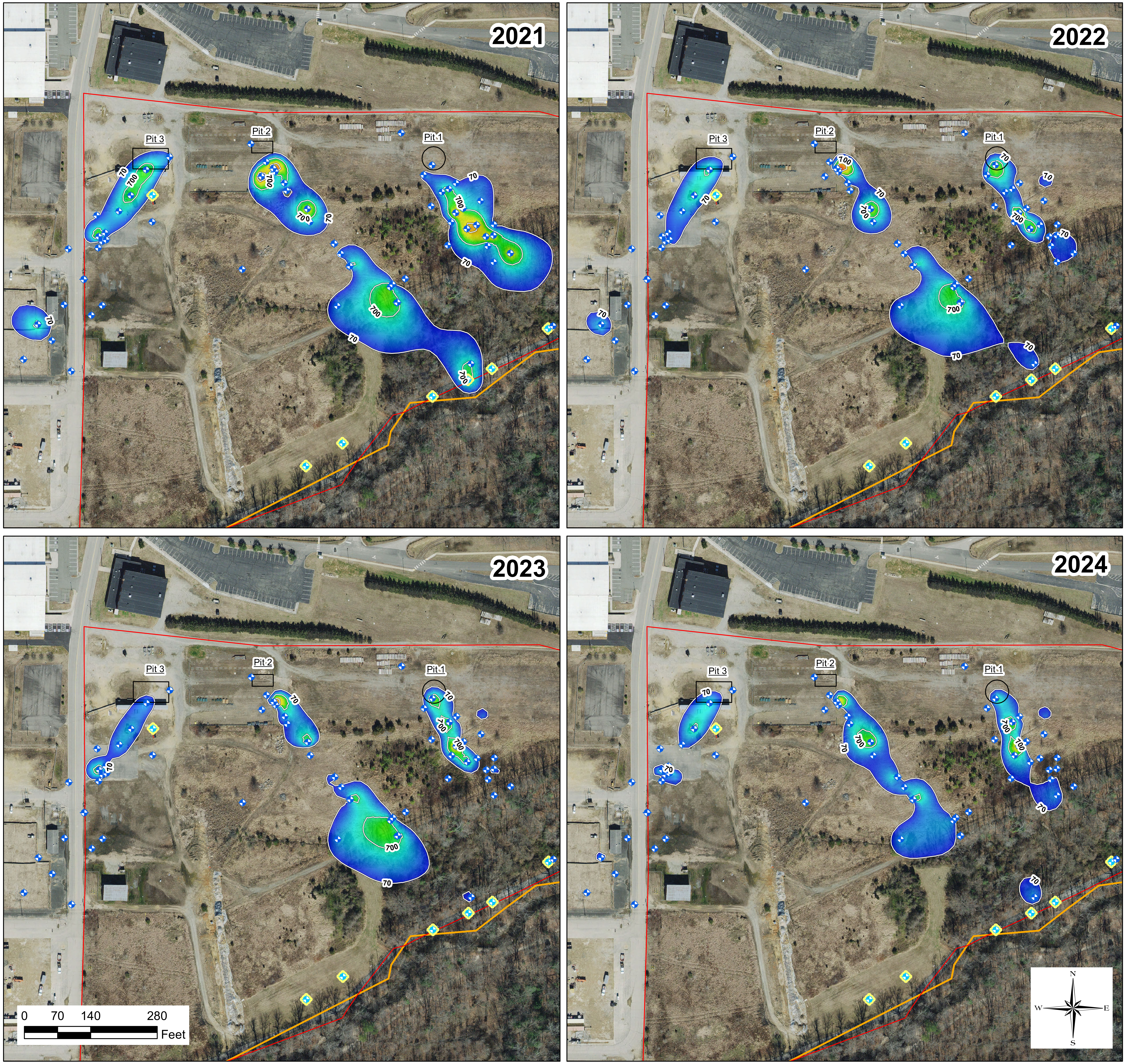
Figure 2-17
Changes in Lateral Distribution of TCE in Surficial Aquifer (2021-2024)

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1 " = 140 '	Date: January 16, 2025



Legend

- Surficial Aquifer Monitoring Well
- Surficial Aquifer Long-term Monitoring Well
- cDCE Isoconcentration Line
- OU7 Boundary
- Installation Boundary

cDCE (ug/L)

70 100 300 1,000 3,000 10,000 30,000 81,000

Notes:
Orthoimagery Source: VGIN (2021)
Federal MCL for cis-1,2-Dichloroethene (cDCE) = 70 ug/L
Isoconcentration contour interval represents logrithmic increase in concentration

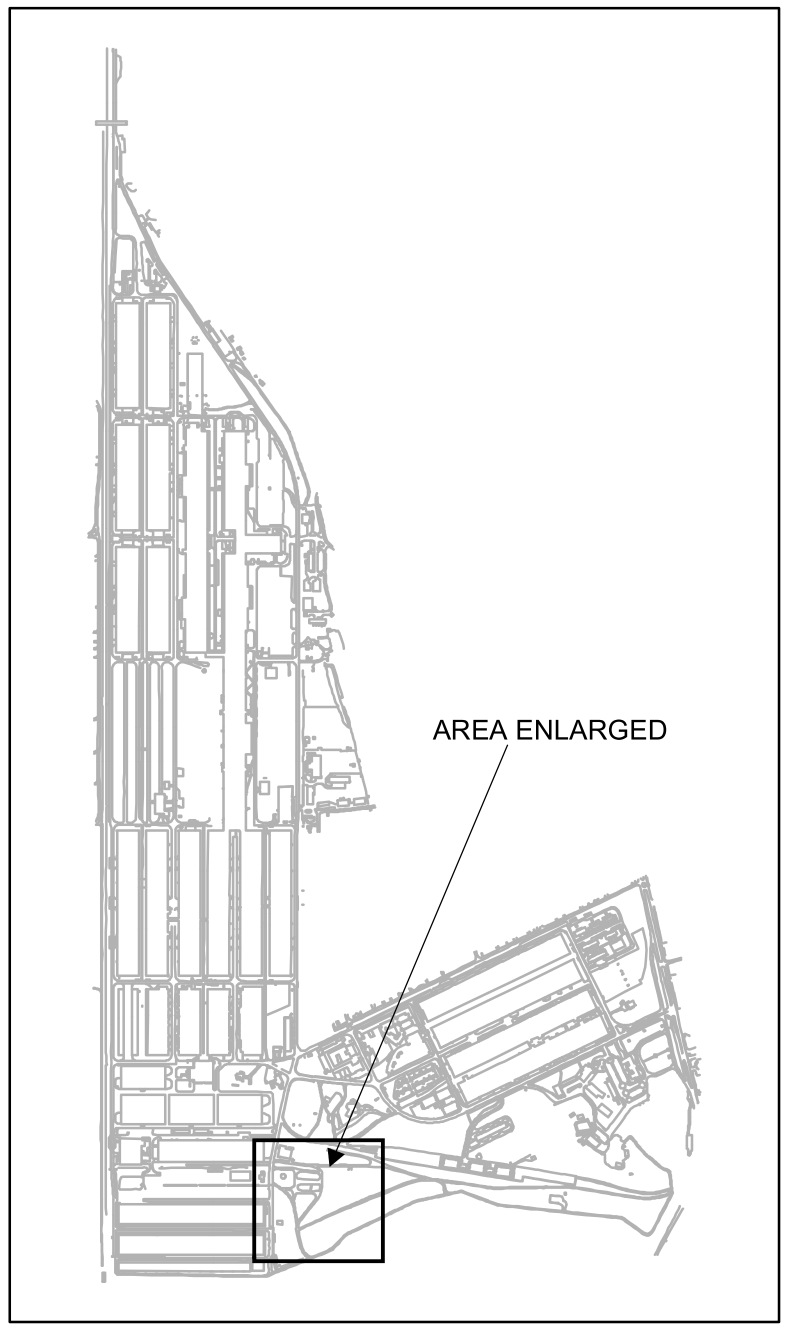


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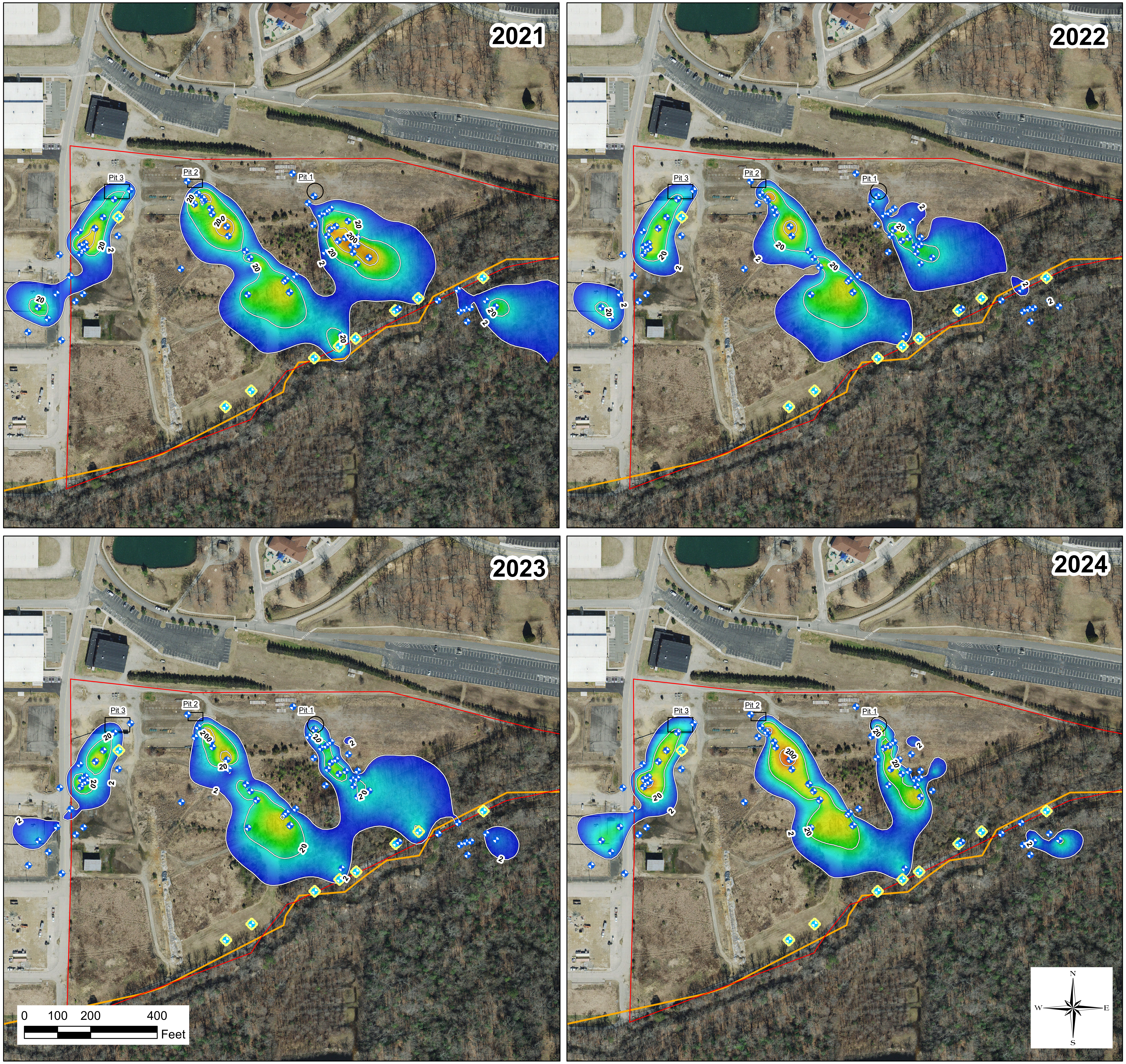
Figure 2-18
Changes in Lateral Distribution of cDCE in Surficial Aquifer (2021-2024)

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1 " = 140 '	Date: January 16, 2025



Legend

- Surficial Aquifer Monitoring Well
- Surficial Aquifer Long-term Monitoring Well
- VC Isoconcentration Line
- OU7 Boundary
- Installation Boundary

VC (ug/L)

2 3 10 30 100 300 1,000 3,000 5,200

Notes:
Orthoimagery Source: VGIN (2021)
Federal MCL for Vinyl Chloride (VC) = 2 ug/L
Isoconcentration contour interval represents logrithmic increase in concentration

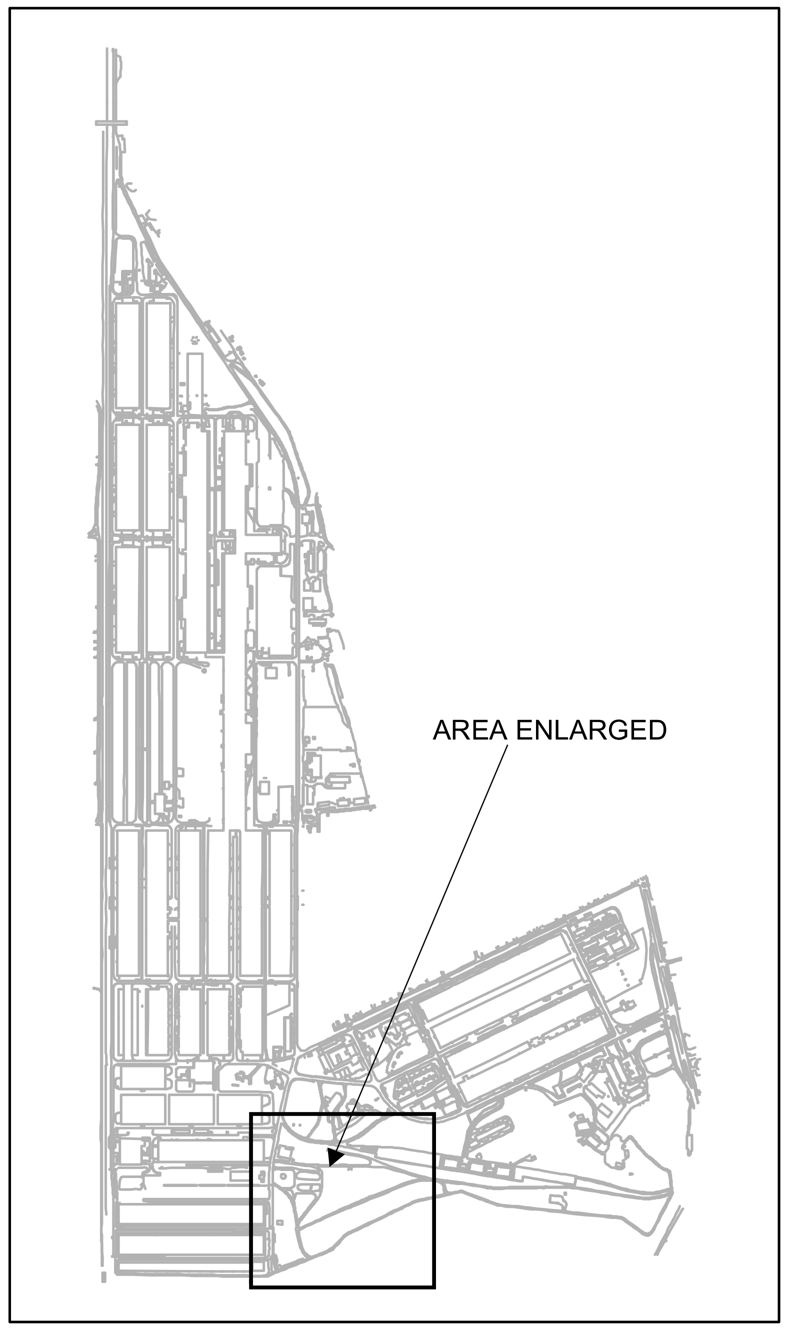


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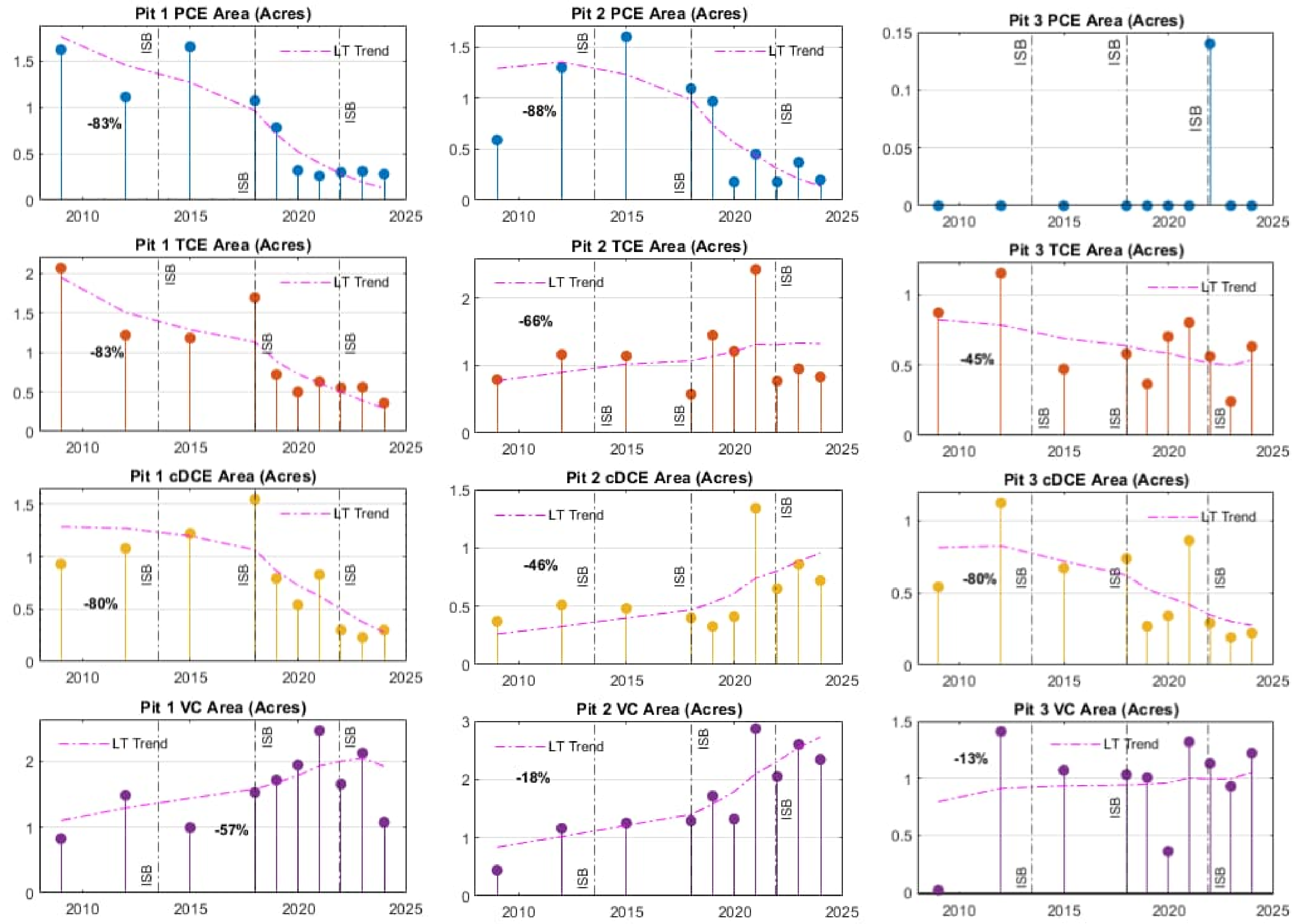
Figure 2-19
Changes in Lateral Distribution of VC in Surficial Aquifer (2021-2024)

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1 " = 200 '	Date: January 17, 2025

L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 2-19 - Changes in Lateral Distribution of VC Surficial.mxd

Exhibit 2-4 Plume Area Changes



Tiled Plume Visualizations (2021-2024)

Figure 2-16 shows a contiguous PCE plume in the Pit 1 area with plume areas ranging from 0.26 acres in 2021 to 0.31 acres in 2023. The PCE plume is disaggregated into separate areas at Pit 2 with a decrease in area from 2.42 acres in 2021 to 0.83 acres in 2024. Figure 2-17 shows reductions and disaggregation of TCE plume areas over time within the three pit areas.

At Pit 1, the TCE plume area decreased from 0.63 acres in 2021 to 0.36 acres in 2024. At Pit 2, the TCE plume area decreased from 2.42 acres in 2021 to 0.83 acres in 2024. Pit 3 had a TCE plume reduction from 0.80 acres in 2021 to 0.63 acres in 2024.

Figure 2-18 shows degradation of cDCE plume areas over time. At Pit 1, the cDCE plume area decreased from 0.83 acres in 2021 to 0.30 acres in 2024. At Pit 2, the cDCE plume area decreased from 1.34 acres in 2021 to 0.72 acres in 2024. At Pit 3, the cDCE plume area decreased from 0.86 acres in 2021 to 0.22 acres in 2024.

VC plumes in the Pit 1, 2, and 3 areas had overall reductions in area over time. At Pit 1, the VC plume area decreased from 2.46 acres in 2021 to 1.07 acres in 2024. At Pit 2, the VC plume area decreased from 2.87 acres in 2021 to 2.34 acres in 2024. At Pit 3, the VC plume area decreased from 1.32 acres in 2021 to 1.22 acres in 2024.

Tiled Stem Plots and Trends

Tiled plots for Pit 1 in Exhibit 2-4 show decreasing trends for PCE, TCE, and cDCE plume areas with percent changes from plume area local maxima of -83 percent (%) for PCE and cDCE, and -75 % for TCE. The slope of the trend line increased for PCE, TCE, and cDCE after completion of ISB actions in late 2017 and early 2018 indicating an increasing rate of plume degradation. VC shows an increasing trend with a local maxima area observed in 2022 with an apparent change to a decreasing trend corresponding to a 57% decrease in plume area from 2022 to 2024.

Tiled plots for Pit 2 show a decreasing trend for the PCE plume area. The slope of the trend line increased for PCE after completion of ISB actions in late 2017 and early 2018 indicating an increasing rate of plume degradation. TCE trend analysis for Pit 2 showed a leveling trend and change to a decreasing trend in 2023 after ISB injections. Plume areas for TCE, cDCE, and VC had reached local maxima in 2021 and by 2024 had decreased by 66% for TCE, 46% for cDCE, and 18 percent for VC. Plume areas for cDCE and VC showed an increasing trend for Pit 2.

Tiled plots for Pit 3 show decreasing trends for TCE and cDCE plume areas with percent changes from plume area local maxima of -45% for TCE and -80% for cDCE. The VC plume reached a local maxima for area in 2012 with a slight upward trend beginning in 2019.

Summary of Plume Areas Changes (2021 to 2024)

Table 2-6 has as summary of plume area changes from 2021 (September) to 2024 (March) illustrating overall decreases in plume areas from baseline sampling performed for the ISB injections in 2021 and the post-ISB sampling event performed in March 2024. The 2024 sampling occurred 27 months after completion of the 2021 ISB injections corresponding to 75% of design treatment period. The post 2021 ISB injection monitoring data indicates a trend change point where post injection monitoring for the first time indicates overall reductions of cDCE and VC plumes at a point more than 2 years after completion of the injections.

Table 2-6 Plume Area Changes (2021 to 2024)

Plume Area (Acres)	PCE			TCE			cDCE			VC		
	2021	2024	%Δ	2021	2024	%Δ	2021	2024	%Δ	2021	2024	%Δ
Pit 1	0.26	0.28	7.7%	0.63	0.36	-42.9	0.83	0.30	-63.9	2.46	1.07	-56.5
Pit 2	0.45	0.20	-56.5	2.42	0.83	-65.7	1.34	0.72	-46.3	2.87	2.34	-18.5
Pit 3	0.00	0.00	--	0.80	0.63	-21.2	0.86	0.22	-74.4	1.32	1.22	-7.8

*Notes: **%Δ** percent change from 2021 to 2024, increase in plume area, decrease in plume area.*

2.4.10 Bulk Plume Distribution Trends

This assessment evaluates changes in data distributions for bulk plume areas associated with Pits 1, 2, and 3. Exhibit 2-5 (page 2-46) has time series, line data plots for PCE, TCE, cDCE, and VC at each pit area for the period 2019-2024 that include number of detections, maximum concentration, mean of detected results, and number of results greater than the MCLs.

2.4.10.1 Number of Detections

Table 2-7 has summary data from the tiled plots in Exhibit 2-5 for each plume area for number of detections of PCE, TCE, cDCE, and VC in 2019 and 2024 with the percent change from 2019 to 2024. Reductions in detection frequency along the reaction pathway in the Pit 1 and 2 areas provides evidence of complete reductive processes. At Pit 3, the detection frequency for TCE increased with the detections decreasing for cDCE and VC. cDCE had the most frequent detections in each monitored area for 2019 and 2024.

Table 2-7 Number of PCE, TCE, cDCE, and VC Detections and Percent Change

	PCE			TCE			cDCE			VC		
Plume Area	2019	2024	%∆	2019	2024	%∆	2019	2024	%∆	2019	2024	%∆
Pit 1	28	18	-35.7	45	27	-40.0	46	32	-30.4	36	24	-33.3
Pit 2	24	14	-42.7	36	22	-38.9	46	29	-37.0	36	24	-33.3
Pit 3	0	0	--	11	23	109	23	19	-17.4	21	15	-28.6

*Notes: **%∆** percent change from 2021 to 2024, increase in frequency of detection, decrease in frequency of detection.*

2.4.10.2 Maximum Concentrations

Local maxima concentrations for PCE, TCE, cDCE, and VC occurred before ISB injections completed in November-December 2021, with the exception of cDCE at Pit 2 where the local maxima occurred in 2022 after ISB injections. Table 2-8 has summary data from the tiled plots in Exhibit 2-5 for each plume area including local maxima concentrations for 2019-2024, the detected maximum concentrations for 2024, and the percent change from the local maxima to the 2024 maximum. Pit 1 had percent changes in concentrations greater than 91% except for cDCE (-47.1%). Pit 2 had percent changes in PCE and TCE greater than -96% with a percent change of -88.6% for cDCE and a percent change of -42.5% for VC. Pit 3 had percent changes in concentrations greater than -90% for TCE, cDCE, and VC.

Table 2-8 Maximum Concentrations and Percent Change

	PCE			TCE			cDCE			VC		
Plume Area	Local Max	2024	%∆	Local Max	2024	%∆	Local Max	2024	%∆	Local Max	2024	%∆
Pit 1	15,000	1,300	-91.3	21,100	780	-96.3	24,000	14,000	-41.7	5,200	270	-94.8
Pit 2	1,300	41	-96.8	20,000	170	-99.1	81,000	9,200	-88.6	1,600	920	-42.5
Pit 3	--	--	--	15,000	350	-97.7	43,000	2,500	-94.1	5,300	600	-90.6

*Notes: local max = local maxima concentration for 2019-2024, **%∆** percent change from 2021 to 2024, decrease in local maxima concentration.*

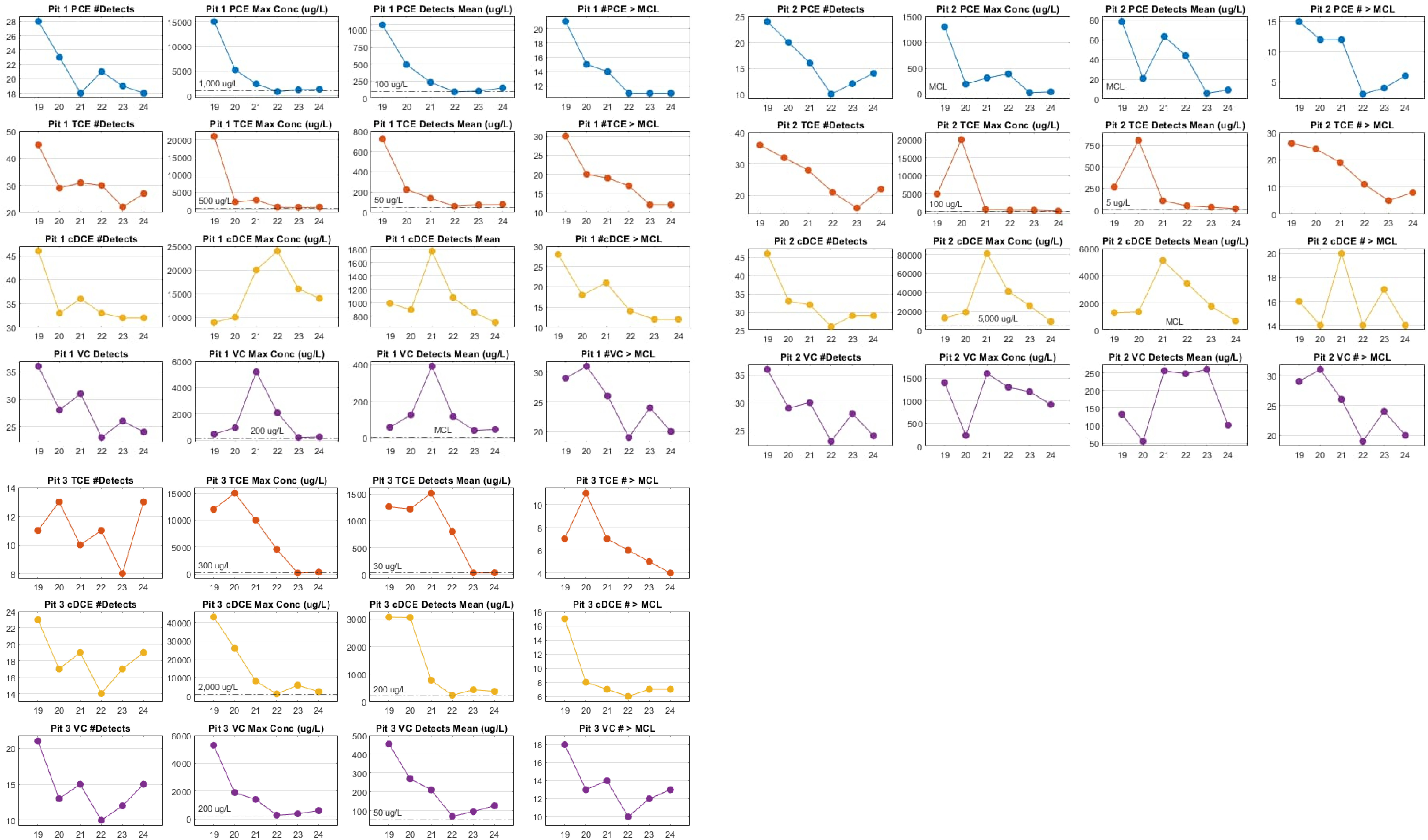
2.4.10.3 Mean of Detected Concentrations

For time series data, mean concentrations of PCE, TCE, cDCE, and VC had similar changes in timeseries data as local maxima concentrations for 2019-2024.

2.4.10.4 Maximum Contaminant Levels (MCLs)

Local maxima for the number of detected results for PCE and TCE greater than MCLs occurred in 2019 except at Pit 3 (2020). For cDCE, the local maxima for the number of detected results greater than MCLs occurred in 2019 at Pits 1 and 2 and in 2022 at Pit 3 (after ISB injections). For VC, the local maxima for the number of detected results greater than MCLs occurred in 2019 in Pit 3 and in 2020 at Pits 1 and 2. Table 2-9 (page 2-47) has summary data from the tiled plots in Exhibit 2-5 for each plume area including the local maxima for number of results greater than MCLs, the number of results greater than MCLs for 2024, and the percent change from the local maxima for results greater than the MCL to the 2024 results.

Exhibit 2-5 Bulk Plume Distribution Trends (2019-2024)



PCE had percent changes in the number of results greater than MCLs from the local maxima to 2024 of -47.6% and -60.0% for Pits 1 and 2, respectively. TCE had the highest percent changes ranging from -63.3% at Pit 1 to -69.2% at Pit 2. cDCE had percent changes ranging from -30.0% at Pit 2 to -58.8% at Pit 3. VC had percent changes in the number of results greater than MCLs from the local maxima to 2024 at levels ranging from -27.8% at Pit 3 to -35.5% at Pit 2.

Table 2-9 Number of Samples with Concentrations > MCLs and Percent Change

	PCE			TCE			cDCE			VC		
Plume Area	**Local Max**	**2024**	**%Δ**	**Local Max**	**2024**	**%Δ**	**Local Max**	**2024**	**%Δ**	**Local Max**	**2024**	**%Δ**
Pit 1	21	11	-47.6	30	11	-63.3	28	12	-57.1	31	21	-32.2
Pit 2	15	6	-60.0	26	8	-69.2	20	14	-30.0	31	20	-35.5
Pit 3	0	0	--	11	4	-63.6	17	7	-58.8	18	13	-27.8

Notes: Max = local maxima for number of results detected at concentrations greater than maximum contaminant levels (MCLs), ***%Δ*** *percent change from 2021 to 2024, decrease in number of results reported at concentrations > MCL.*

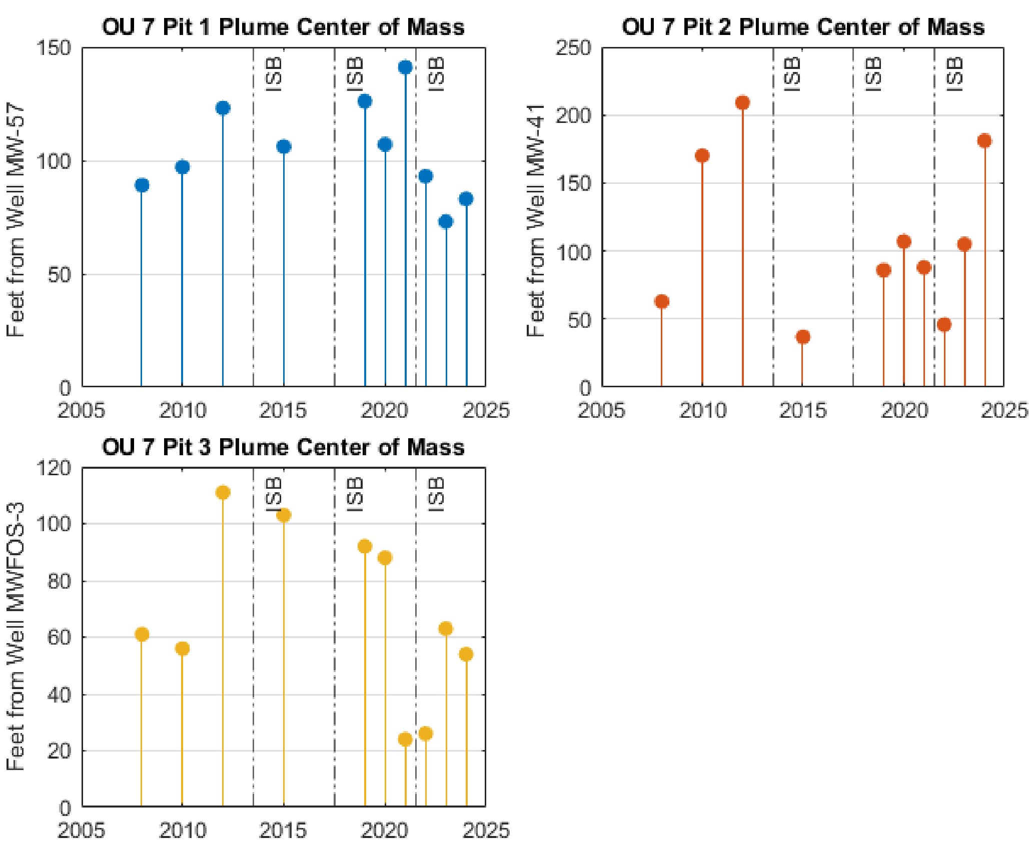
2.4.11 Plume Concentration vs. Distance Plots

This assessment uses monitoring well transects in each pit plume area to evaluate changes in plume molar mass, plume attenuation with distance from former pit areas, and changes in plume center of mass over time.

2.4.11.1 Plume Center of Molar Mass

Exhibit 2-6 plots the calculated plume center of mass for the Pit 1, 2, and 3 areas using well transect data for 2008, 2010, 2012, 2015, and 2019 through 2024. Center of molar mass for this calculation represents the distance along the well transect from the identified well located in or near the former pit areas for each plume. Calculations use micromolar concentrations for PCE, TCE, cDCE, 1,2-trans-dichloroethene (tDCE), and VC at each well along the transect. The stem plots have vertical reference lines for ISB injection events completed at OU 7.

Exhibit 2-6 Plume area Center of Molar Mass for Pits 1, 2, and 3



The Pit 1 well transect covers a distance of 605 ft. from well MW-57 in the former pit area to PZ-4 in the Kingsland Creek flood plain across Kingsland Creek in the off-installation area. Exhibit 2-7 (page 2-49) has the well locations for this flow path above the tiled plots. For Pit 1, the plotted plume center of mass reached its farthest downgradient point in 2021 (pre-ISB injection monitoring event) at a distance of 126 ft. from well MW-57. After injections, the calculated center of mass has moved upgradient to a distance of 83 ft. from well MW-57 as of the 2024 annual monitoring event.

The Pit 2 well transect covers a distance of 588 ft. from well MW-41 near the former pit area to MWFTA-3 in the lower area approximately 30 ft. upgradient of the installation fence line. Exhibit 2-9 (page 2-50) has the well locations for this flow path above the tiled plots. For Pit 2, the plotted plume center of mass reached its farthest downgradient point (209 ft. from well MW-41) in 2012 before the ISB remedial action in 2013. After this remedial action, the calculated plume center of mass has varied between 37 and 181 ft. from well MW-41.

The Pit 3 well transect covers a distance of 348 ft. from well MWFOS-3 near the former pit area to MW-118 south of the Building 72 area. Exhibit 2-11 (page 2-51) has the well locations for this flow path above the tiled pilots. For Pit 3, the plotted plume center of mass reached its farthest downgradient point (111 ft. from well MWFOS-3) in 2012 before the ISB remedial action in 2013. As of 2024, the calculated plume center of mass is 54 ft. downgradient of MWFOS-3.

2.4.11.2 Plume Molar Percentage Plots

Exhibits 2-7, 2-9, and 2-11 (pages 2-49, 50, 51) have relative molar percentage of constituents vs. distance plots that illustrate the relative degree of plume transformation along the groundwater flow path and changes over time. Molar percentages derive from constituent concentrations expressed as micromolar concentrations. Thus, the molar percentages for PCE, TCE, cDCE, tDCE, and VC sum to 100 percent for each stacked stem plot location.

Molar plots for Pit 1 show transformation from predominantly a TCE and cDCE plume in 2008 to predominantly a cDCE and VC plume in the main plume area. For 2024, cDCE predominates in the upper 200 ft. of the transect with VC becoming predominate downgradient to the fence line area. Molar plots for Pit 2 show transformation from predominately a PCE plume in 2008 to predominantly a cDCE and VC plume in 2024. Molar plots for Pit 3 show transformation from predominantly a TCE and cDCE plume in 2008 to predominately a cDCE and VC plume in 2024. For 2024, cDCE predominates over VC closer to the former pit area with the ISB injections in late 2021 reducing TCE in this area. VC is more predominant in downgradient areas.

2.4.11.3 Concentration vs. Distance Plots (2024)

Exhibits 2-8, 2-10, and 2-12 (pages 2-49, 50, 51) have concentration vs. distance plots (2024) that display changes in PCE and degradation by-products along plume centerlines for Pits 1, 2, and 3 (surficial aquifer). Each tile plot has stem plots for PCE, TCE, cDCE, tDCE, and VC with the sixth tile containing a stem plot displaying molar percentages for these constituents along the plume transect.

Pit 1

Concentration peaks for PCE, and TCE occur 60 ft. downgradient of MW-57 with the peak concentrations for cDCE and VC occurring at MW-57. Constituent concentrations in the main plume decrease to levels less than MCLs when reaching the installation fence line at 468 ft. (MW-88). Isolated plume areas with PCE and VC/or TCE concentrations greater than MCL occur in the Kingsland Creek at distances of 579 ft. (PZ-3) and 605 ft. (PZ-4). The molar plot for the Pit 1 plume shows that cDCE predominates on a percentage basis except where location concentrations fall below the LOQ or limit of detection (LOD) at the fence line and at PZ-3.

Exhibit 2-7 Pit 1 Plume Molar Percent vs. Distance Plots vs. Time

Pit 1 MW-57→AEHADG-11→CMT-21-1→MW-69→MW-EBF-05S→MW-86→DMW-33A→PZ-3→PZ-4

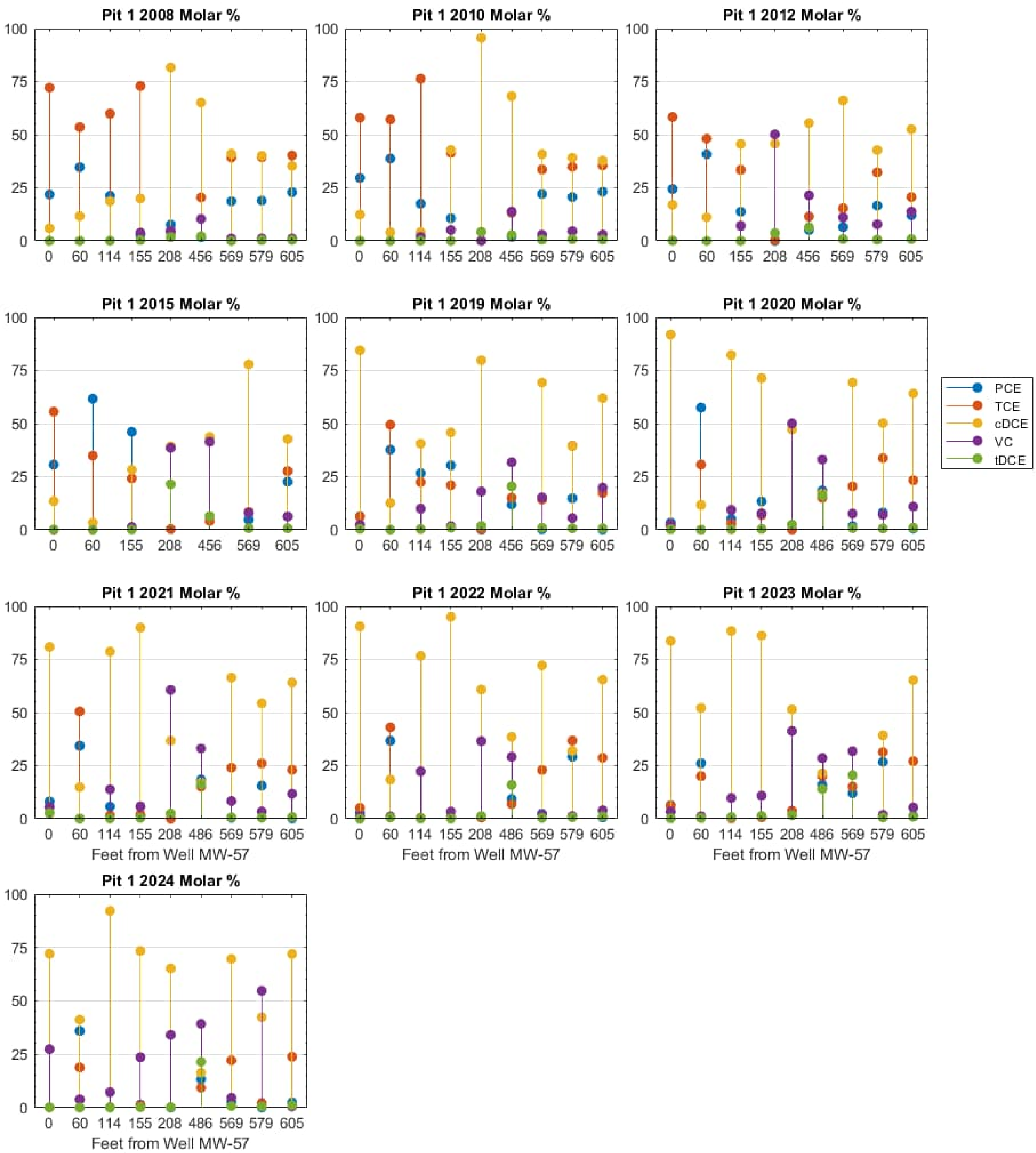


Exhibit 2-8 Pit 1 Concentration vs. Distance (2024)

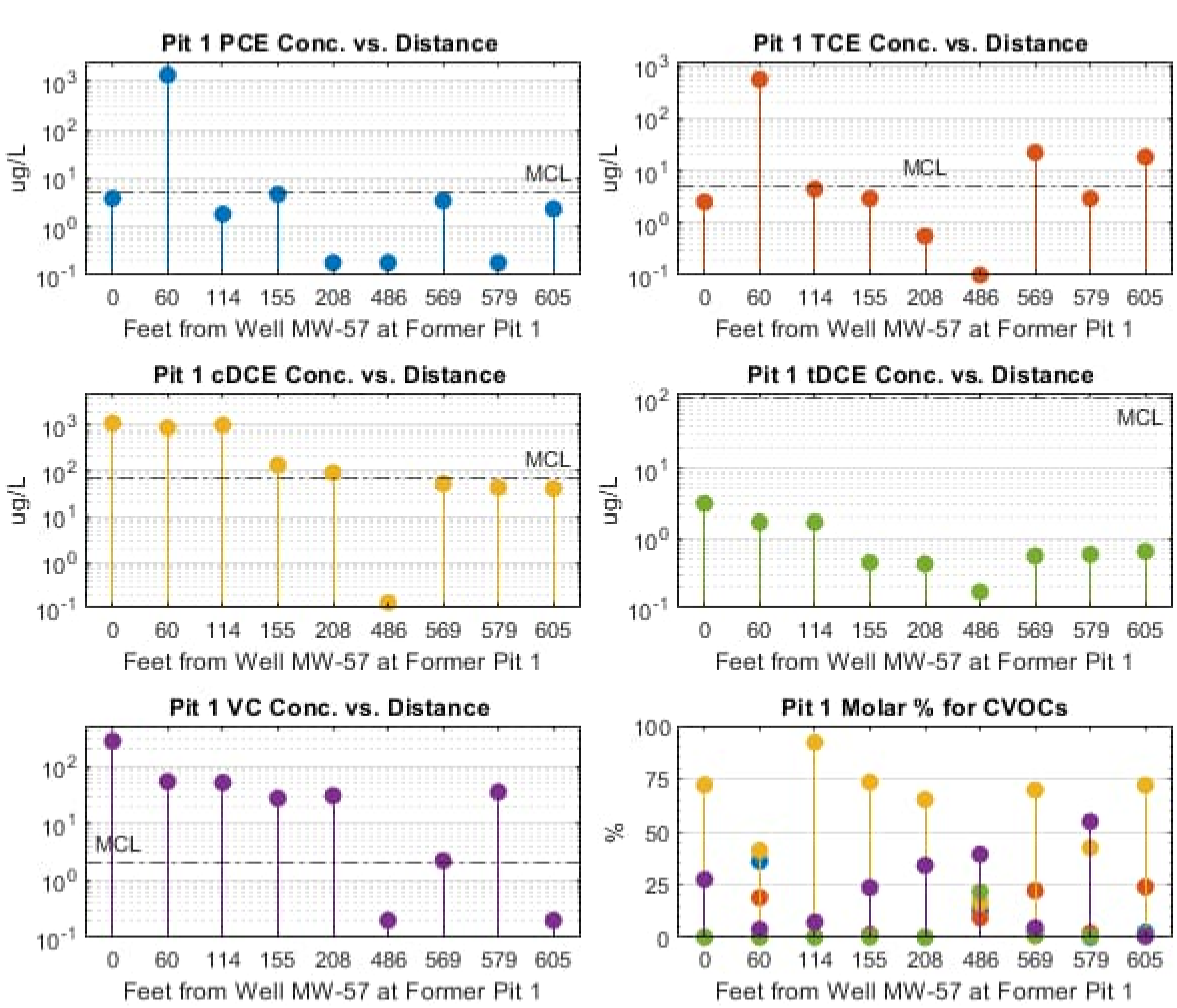


Exhibit 2-9 Pit 2 Plume Molar Percent vs. Distance Plots vs. Time

Pit 2 MW-41→MW-48→MW-51→MW-53→MW-54→CMT-18-6→MW-74→MW-79→MW-83→MWFTA-3

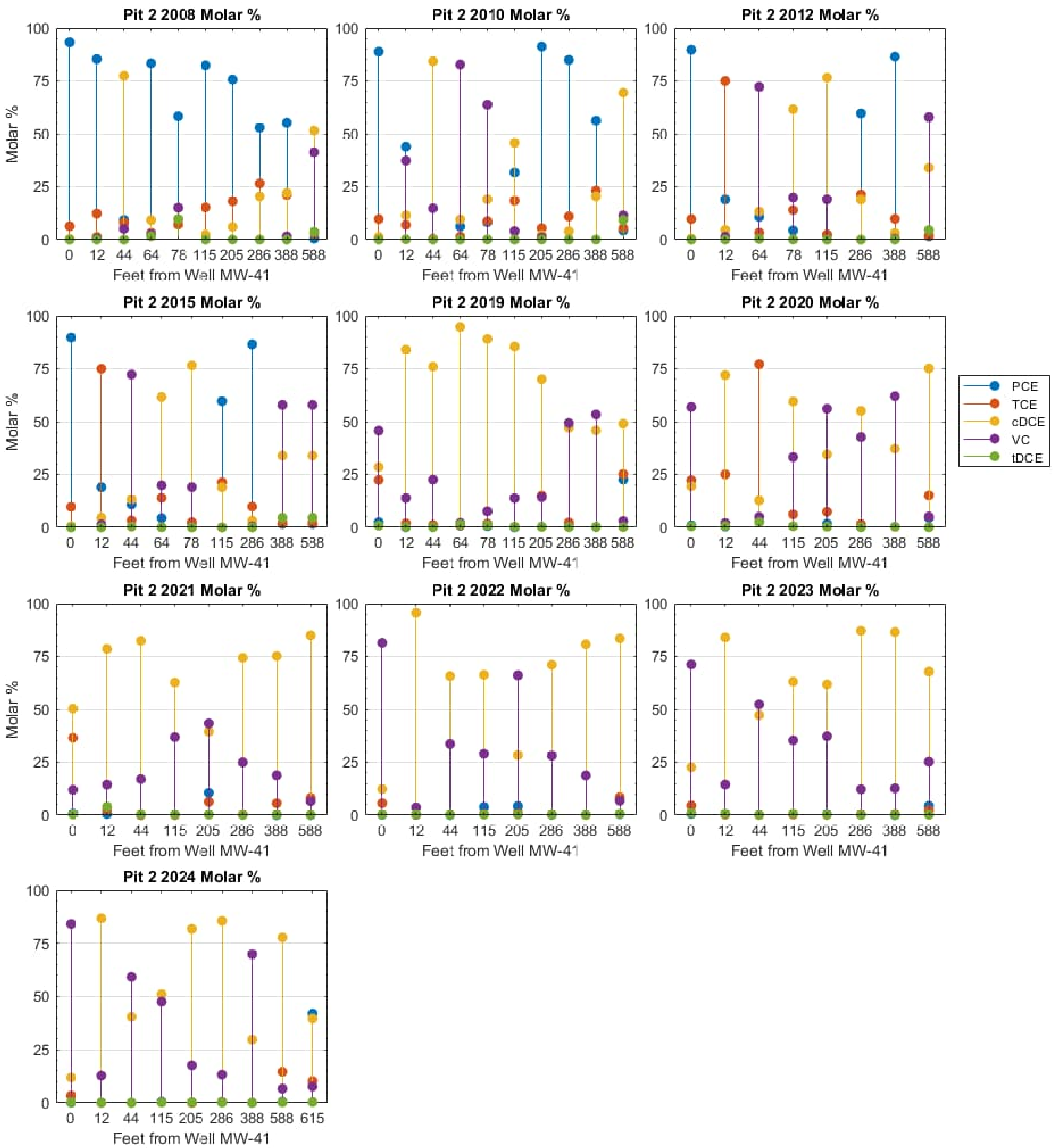


Exhibit 2-10 Pit 2 Concentrations vs. Distance (2024)

Pit 2 MW-41→MW-48→MW-51→MW-53→MW-54→CMT-18-6→MW-74→MW-79→MW-83→MWFTA-3

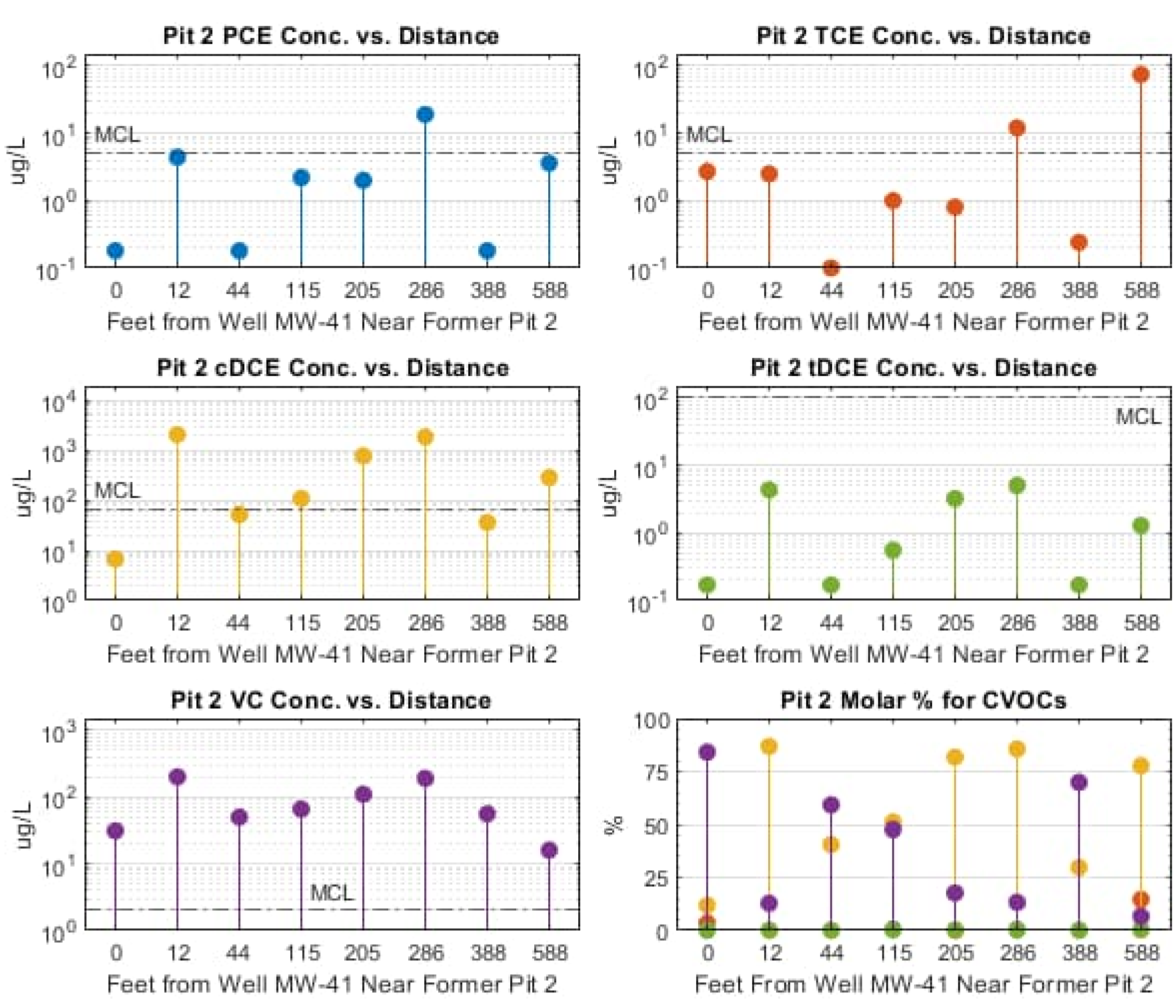


Exhibit 2-11 Pit 3 Plume Molar Percent vs. Distance Plots vs. Time

Pit 3 MWFOS-3→MW97→MW-96→MW95→MW-93→MW90 (2008-2019)→MW-118

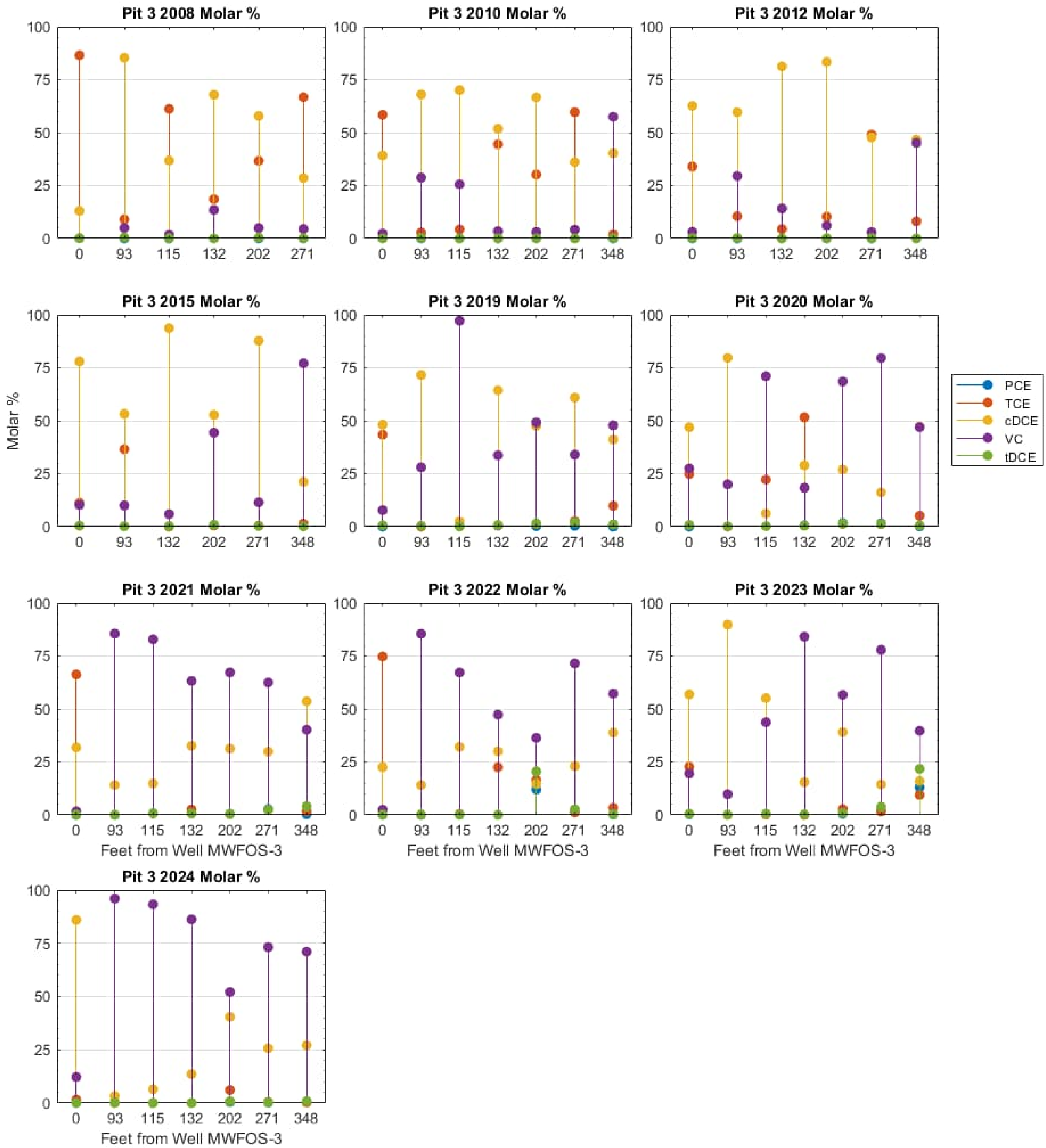
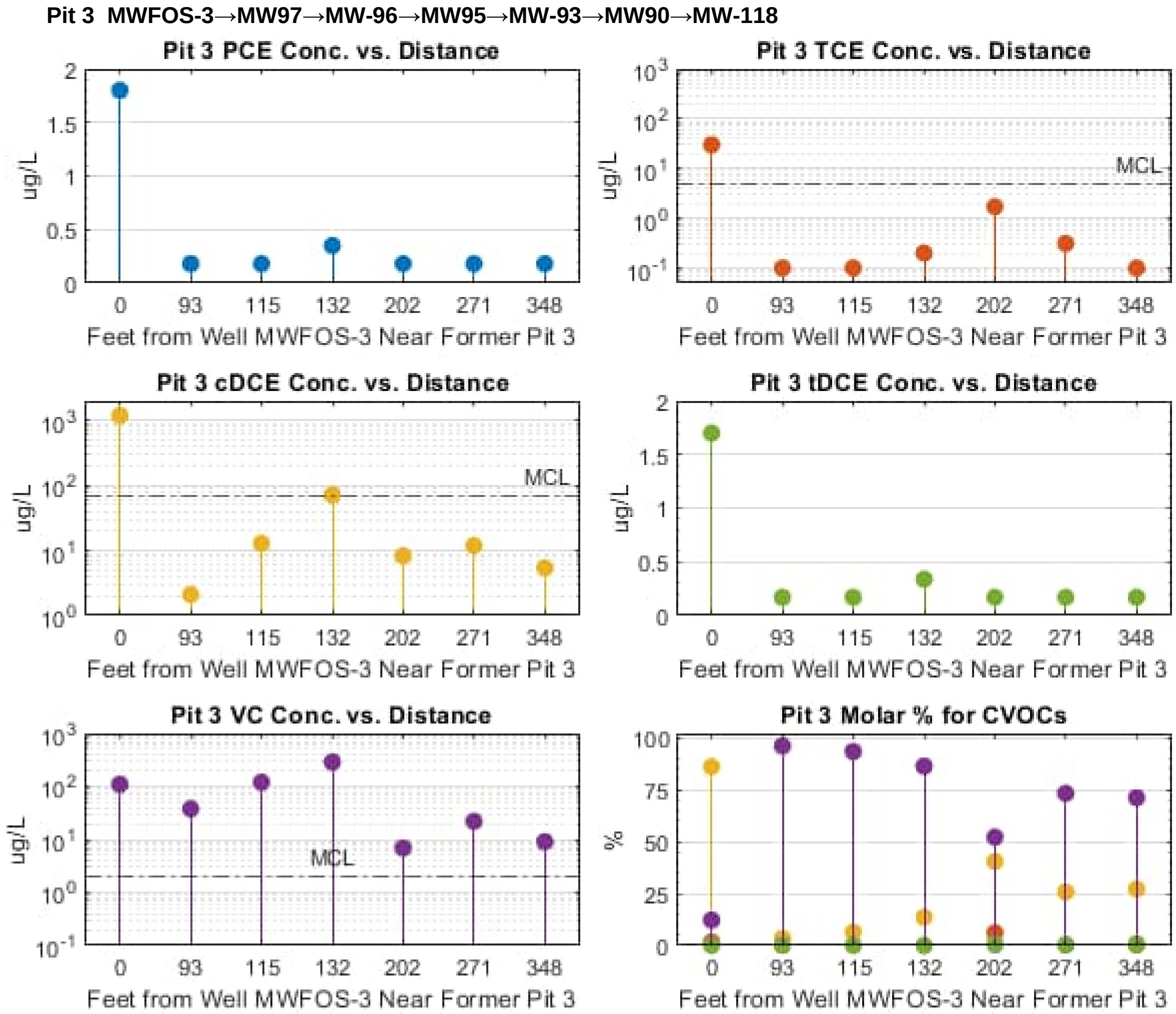


Exhibit 2-12 Pit 3 Concentration vs. Distance (2024)

Pit 3 MWFOS-3→MW97→MW-96→MW95→MW-93→MW90→MW-118



Pit 2

Along the transect, PCE has concentrations less than the MCL except at 278 ft. downgradient of MW-41 at CMT-18-6 with the peak TCE concentration occurring at well MW-FTA-3 near the installation fence line. TCE concentrations are less than the MCL along the transect except at wells CMT-18-6 and MW-FTA-3. cDCE has concentrations greater than MCLs at 5 of 8 well locations along the transect with concentrations less than MCLs at well 41 (0 ft.), 44 ft., and 388 ft. within the upper area. VC concentrations at 8 of 8 locations along the profile exceed the MCL. The molar plot for the Pit 2 plume shows that cDCE or VC predominate on a percentage basis along the transect.

Pit 3

PCE data plotted reflect left-censored data (non-detects). TCE concentrations peak at MWFOS-3 (0 ft.) with concentrations at downgradient profile locations less than the MCL. cDCE concentrations peak at MWFOS-3 (0 ft.) and with only the downgradient profile location at 132 ft. (71 µg/L) greater than MCL. VC concentrations peaked at 132 ft. downgradient of MWFOS-3 with concentrations decreasing to a level below MCLs at 348 ft. The molar plot for the Pit 3 plume shows that VC predominates on a percentage basis along the transect except at 0 ft. (MWFOS-3) closest to the former pit area.

2.4.12 Well Trends

Section 2.4.12 has monitoring well trend analyses for wells in the Pit 1, 2, and 3 areas at select locations from the former pit areas to downgradient monitored areas. Several lines of evaluation used include coefficient of variation (CV), linear correlation (Pearson's linear correlation), Mann-Kendall (M-K) test for trend, sequential M-K test for trend change points, and SAA.

2.4.12.1 Pit 1 Well Trends

Table 2-10 (page 2-53) has a descriptive statistical summary and trend analysis for wells in the Pit 1 plume area at locations from the former pit area downgradient to Kingsland Creek. Exhibit 2-13 (page 2-54) has plots for these wells showing timeseries data and SSA trends as applicable. SSA trend analysis for the Pit 1 monitored area indicated decreasing trends for primary COCs for evaluated locations except for VC at well MW-57 (former pit area) and at well AEHADG-11 located 60 ft. downgradient of MW-57. M-K trend tests indicated statistical evidence of increasing trends for VC at wells MW-57 and AEHAG-11 with no other increasing trends detected. M-K trend tests indicated decreasing trends for one or more COCs at 6 of 8 well locations along the transect.

2.4.12.2 Pit 2 Well Trends

Table 2-11 (page 2-55) has a descriptive statistical summary and trend analysis for wells in the Pit 2 plume area at locations from the former pit area downgradient to the installation fence line at well MW-148. Exhibit 2-14 (page 2-56) has plots for these wells showing timeseries data and SSA trends as applicable. SSA trend tests for the Pit 2 monitored area indicated decreasing trends at 19 of 26 evaluated location/COC combinations with two (2) locations having no trend, and five (5) locations having an increasing trend. M-K trend analysis indicated decreasing concentrations at 8 of 28 evaluated location/COC combinations with 15 locations having no trend, and five (5) locations having an increasing trend. SSA showed decreasing trends at the most downgradient location closest the installation fence line.

2.4.12.3 Pit 3 Well Trends

Table 2-12 (page 2-57) has a descriptive statistical summary and trend analysis for wells in the Pit 3 plume area at locations from the former pit area to well MW-118 downgradient of Building 72. Exhibit 2-15 (page 2-58) has plots for these wells showing timeseries data and SSA trends as applicable. SSA trend analysis for the Pit 3 monitored area indicated decreasing trends at 18 of 20 evaluated location/COC combinations with cDCE and VC at well MW-96 having increasing trends. M-K trend tests indicated decreasing trends at 13 of 20 evaluated location/COC combination with no detected increasing trends. The most downgradient well in the transect (MW-118) had decreasing trends for COCs.

Table 2-10 Statistical Summary and Trend Analysis for Pit 1 Surficial Aquifer Wells (2015-2024)

Well ID	Area	Date Range	Distance from MW-57	Primary COC	Distribution Variance		Linear Correlation[1] (α=0.05)		M-K Trend (One Way) (α=0.05)		2024 Result (µg/L)	MCL (µg/L)	>MCL	SSA Trend	M-K Sequential for Trend Change	M-K Trend – One Way (Increasing or Decreasing)
					CV	Variance	r[1]	p-value	H	p-value						
MW-57	Pit 1	2015-2024	0 ft.	PCE	1.0492	High	-0.9032	5.69E-05	1	-1.60E-03	3.8	5	No	SSA↓,	No trend change	M-K SS Decreasing at α = 0.05
				TCE	1.3115	High	-0.8875	1.17E-04	1	-3.70E-03	2.5	5	No	SSA↓	No trend change	M-K SS Decreasing at α = 0.05
				cDCE	0.9041	Moderate	0.5773	4.93E-02	0	1.08E-01	1100	70	Yes	SSA ↓	No trend change	No M-K SS trend at α = 0.05
				VC	1.4024	High	0.6888	1.32E-02	1	7.84E-04	270	2	Yes	SSA ↑	No trend change	M-K SS Increasing at α = 0.05
AEHADG-11	Source Zone	2015-2024	60 ft.	PCE	0.3464	Low	-0.4448	1.27E-01	0	-2.14E-01	1300	5	Yes	SSA ↓	No trend change	No M-K SS trend at α = 0.05
				TCE	0.9120	Moderate	-0.3971	1.79E-01	0	-7.12E-02	540	5	Yes	SSA ↓	No trend change	No M-K SS trend at α = 0.05
				cDCE	0.8063	Moderate	0.6325	2.03E-02	1	1.39E-01	870	70	Yes	SSA ↓	No trend change	No M-K SS trend at α = 0.05
				VC	1.0770	High	0.7726	2.00E-03	1	4.20E-03	53	2	Yes	SSA ↑	No trend change	M-K SS Increasing at α = 0.05
CMT21-1	Mid-Plume	2019-2024	114 ft.	PCE	NaN	--	NaN	--	1	-3.01E-02	ND	5	No	SSA ↓	No trend change	M-K SS Decreasing at α = 0.05
				TCE	NaN	--	NaN	--	1	-6.30E-03	4.4	5	No	SSA ↓	No trend change	M-K SS Decreasing at α = 0.05
				cDCE	0.1995	Low	0.5162	0.1548	1	5.589E-02	1000	70	Yes	SSA ↑	No trend change	No M-K SS trend at α = 0.05
				VC	0.4601	Low	0.2168	0.5753	0	4.58E-01	51	2	Yes	SSA ↓ Mar. 2024	No trend change	No M-K SS trend at α = 0.05
MW-69	Mid-Plume	2015-2023	155 ft.	PCE	1.2095	High	-0.9112	1.47E-05	1	-6.11E-04	4.6	5	No	SSA ↓	No trend change	M-K SS Decreasing at α = 0.05
				TCE	1.1940	High	-0.8658	1.30E-04	1	-1.40E-03	2.9	5	No	SSA ↓	No trend change	M-K SS Decreasing at α = 0.05
				cDCE	0.7713	Moderate	0.1222	6.91E-01	0	4.76E-01	130	70	Yes	SSA ↓ Mar. 2024	No trend change	No M-K SS trend at α = 0.05
				VC	0.8131	Moderate	0.3933	1.84E-01	0	1.50E-01	27	2	Yes	SSA ↓ Mar. 2024	No trend change	No M-K SS trend at α = 0.05
DMW-29A	Downgradient Upper Area	2015-2024	196 ft.	PCE	2.0641	High	-0.4070	1.68E-01	1	-4.98E-02	6	5	Yes	SSA ↓ Nov 2022	Decreasing trend (Sept 2021)	M-K SS Decreasing at α = 0.05
				TCE	1.4107	High	-0.8486	2.44E-04	0	-8.03E-02	110	5	Yes	SSA ↓ Nov 2022	No trend change	No M-K SS trend at α = 0.05
				cDCE	1.2828	High	-0.2917	3.33E-01	1	-1.40E-03	110	70	Yes	SSA ↓	No trend change	M-K SS trend at α = 0.05
				VC	2.5515	High	0.0928	7.63E-01	0	1.23E-01	6.9	2	Yes	SSA ↓ Mar. 2023	Decreasing trend (Oct 2023)	No M-K SS trend at α = 0.05
EBF-05S	Downgradient Upper Area	2015-2024	206 ft.	PCE	NaN	--	NaN	--	--	--	ND	5	No	Insufficient data	Insufficient data	Insufficient detected observations
				TCE	1.8454	High	-0.4150	0.1798	0	-3.40E-01	0.56	5	No	SSA ↓	No trend change	No M-K SS trend at α = 0.05
				cDCE	1.7754	High	--0.3791	0.2243	0	-1.51E-01	89	70	Yes	SSA ↓	No trend change	No M-K SS trend at α = 0.05
				VC	1.3168	High	-0.4248	0.1686	0	-1.51E-01	30	2	Yes	SSA ↓	No trend change	No M-K SS trend at α = 0.05
MW-150	Downgradient Upper Area	2015-2024	253 ft.	TCE	1.7469	High	NaN	--	1	-9.40E-03	ND	5	No	SSA ↓	No trend change	M-K SS Decreasing at α = 0.05
				cDCE	1.1864	High	-0.7834	1.50E-03	1	-9.90E-05	2.9	5	No	SSA ↓	No trend change	M-K SS Decreasing at α = 0.05
				VC	1.4053	High	-0.3944	1.82E-01	1	-3.96e-04	0.4	70	No	SSA ↓	No trend change	M-K SS Decreasing at α = 0.05
DMW-33A	Off-Installation Kingsland Creek	2015-2024	569 ft.	PCE	1.8057	High	-0.4081	1.66E-01	0	4.27E-01	3.4	5	No	SSA ↓	No trend change	No M-K SS trend at α = 0.05
				TCE	0.7530	Moderate	-0.0362	9.07E-01	0	-2.51E-01	22	5	Yes	SSA↓	No trend change	M-K SS Decreasing at α = 0.05
				VC	1.0476	High	--0.5622	4.59E-02	1	-2.20E-02	2.2	2	Yes	SSA↓	No trend change	No M-K SS trend at α = 0.05

Notes: NaN = not a number, not calculated because of left-censored data, [1]Pearson's linear correlation coefficient, r = correlation coefficient, p-value = probability value, α=0.05 = alpha significance of 0.05 or 5%, SS = statistically significant at a level of 5% (0.05). PCE = tetrachloroethene, cDCE = cis-dichloroethene, TCE = trichloroethene, VC = vinyl chloride, MCL = maximum contaminant level, LOD = laboratory limit of detection, [1]Singular Spectrum Analysis of trend (SSA). SSA ↓ = Singular Spectrum Analysis of trend showed a change to decreasing trend for month shown. SSA ↑ = Singular Spectrum Analysis of trend showed a change to decreasing trend for month shown, SSA → = Singular Spectrum Analysis of trend showed a change to no trend for month shown, [2]Sequential Mann-Kendall Test for detecting potential trend change points. Decreasing trend, Increasing trend, Concentration lower than the MCL.

Exhibit 2-13 Pit 1 Well Trend Plots

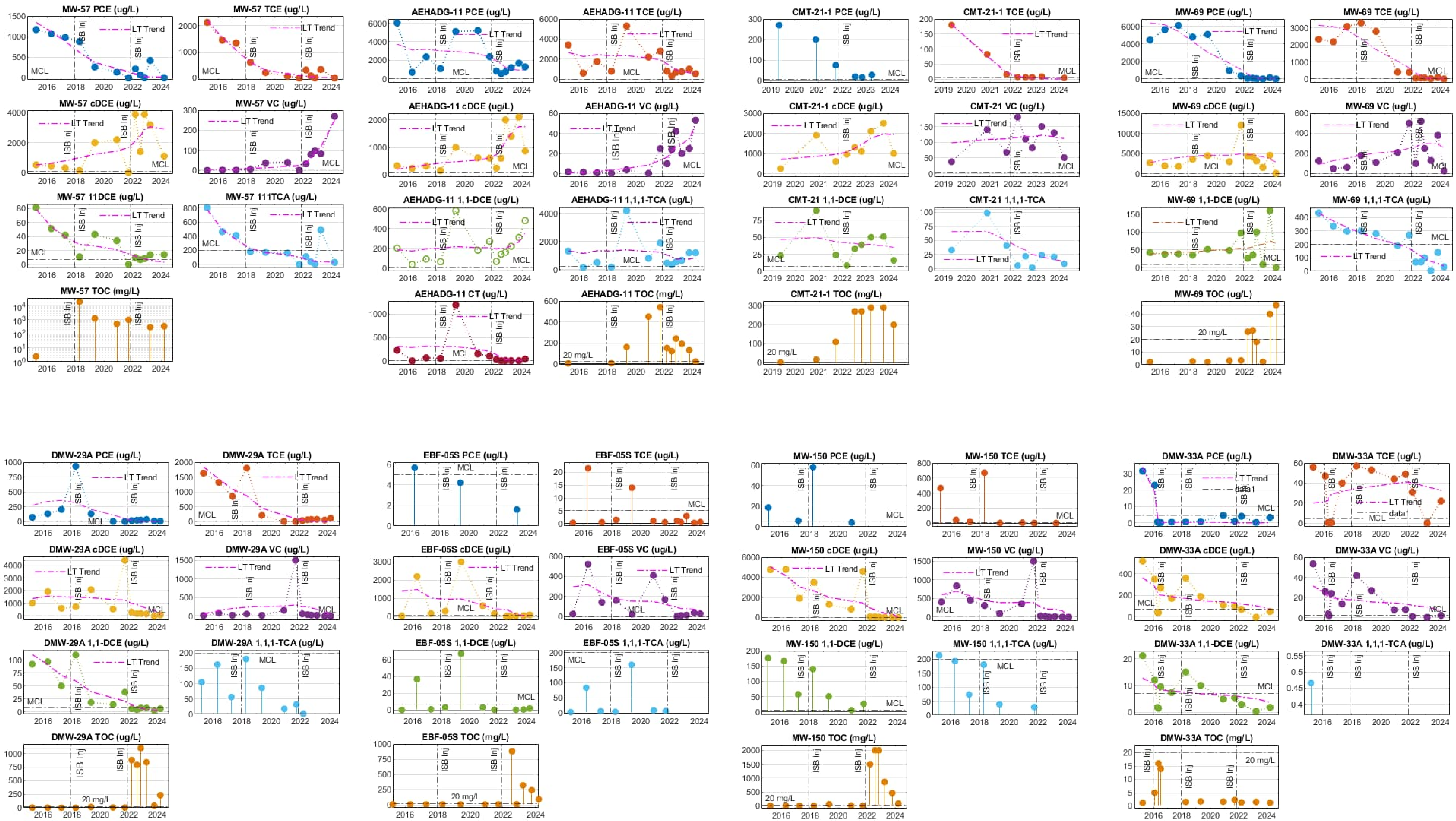


Table 2-11 Statistical Summary and Trend Analysis for Pit 2 Surficial Aquifer Wells

Well ID	Area	Date Range	Distance from MW-57	Primary COC	Distribution Variance		Linear Correlation[1] (α=0.05)		M-K Trend (One Way) (α=0.05)		2024 Result (µg/L)	MCL (µg/L)	>MCL	SSA Trend[1]	Sequential M-K[2]	M-K Trend (One-Way for Increasing or Decreasing Trend)
					CV	Variance	r[1]	p-value	H	p-value						
MW-41	Pit 2 Source Zone	2015-2024	0 ft.	PCE	2.0734	High	-0.7798	1.70E-03	1	-7.81E-04	0.18	5	No	SSA↓,	No trend change detected	M-K SS Decreasing at α = 0.05
				TCE	2.1775	High	-0.5202	6.84E-02	1	-8.70E-03	2.7	5	No	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				cDCE	1.7176	High	-0.1521	6.20E-01	0	-2.24E-01	6.8	70	Yes	SSA↓	No trend change detected	No M-K SS trend at α = 0.05
				VC	1.3056	High	0.2414	4.27E-01	0	2.14E-01	31	2	Yes	SSA↑	No trend change detected	No M-K SS trend at α = 0.05
MW-51	Source Zone	2015-2024	44 ft.	PCE	NaN	--	NaN	--	0	-1.49E-01	ND	5	No	Insufficient data	No trend change detected	No M-K SS trend at α = 0.05
				TCE	2.1685	High	-0.7083	2.19E-02	0	-1.48E-01	0.1	5	No	SSA↓	No trend change detected	No M-K SS trend at α = 0.05
				cDCE	2.0210	High	-0.5709	8.48E-02	1	-2.45E-02	53	70	No	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				VC	1.5490	High	-0.3315	3.49E-01	0	-4.29E-01	50	2	Yes	SSA↓	No trend change detected	No M-K SS trend at α = 0.05
CMT18-5	Downgradient Source Zone	2015-2024	115 ft.	PCE	2.1825	High	-0.4797	9.71E-02	1	-4.35E-02	4.4	5	No	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				TCE	2.5077	High	-0.6200	2.38E-02	1	-3.10E-04	2.5	5	No	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				cDCE	0.6955	Moderate	-0.6434	1.77E-02	1	-3.60E-03	2600	70	Yes	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				VC	0.6790	Moderate	0.7109	6.50E-03	1	2.52E-02	920	2	Yes	SSA→ March 2024	No trend change detected	M-K SS Increasing at α = 0.05
MW-79	Mid-Plume	2015-2024	286 ft.	PCE	1.3422	High	-0.5417	1.65E-01	0	5.00E-01	19	5	Yes	SSA↓	No trend change detected	No M-K SS trend at α = 0.05
				TCE	0.4070	Low	0.4692	2.41E-01	0	1.33E-01	12	5	Yes	SSA↑	No trend change detected	No M-K SS trend at α = 0.05
				cDCE	1.1070	High	0.8386	9.30E-03	1	4.70E-03	1900	70	Yes	SSA↑	No trend change detected	M-K SS Increasing at α = 0.05
				VC	0.8379	Moderate	0.8232	1.21E-02	1	2.30E-02	190	2	Yes	SSA↑	No trend change detected	M-K SS Increasing at α = 0.05
MW-83	Edge Upper Area	2015-2024	388 ft.	PCE	NaN	--	NaN	--	1	-4.47E-02	ND	5	No	Insufficient data	Insufficient data	M-K SS Decreasing at α = 0.05
				TCE	NaN	--	NaN	--	0	-3.94E-01	0.24	5	No	SSA↓ Mar 2024	Insufficient data	No M-K SS trend at α = 0.05
				cDCE	1.3178	Low	0.5673	4.32E-02	1	8.70E-03	37	70	No	SSA↓ Mar 2024	No trend change detected	M-K SS Increasing at α = 0.05
				VC	1.0290	Low	0.6813	1.04E-02	1	6.20E-03	56	2	Yes	SSA↓ Mar 2024	No trend change detected	M-K SS Increasing at α = 0.05
MWFTA-3	Flood Plain Near Perimeter Road	2015-2024	588 ft.	PCE	NaN	--	NaN	--	1	-1.21E-02	3.6	5	No	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				TCE	0.8164	Moderate	-0.0297	0.9234	0	-1.79E-01	74	5	Yes	SSA↓	No trend change detected	No M-K SS trend at α = 0.05
				cDCE	0.7659	Moderate	0.3912	1.86E-01	0	1.50E-01	290	70	Yes	SSA→	No trend change detected	No M-K SS trend at α = 0.05
				VC	0.5862	Moderate	0.5110	7.43E-02	0	5.60E-02	16	2	Yes	SSA↑	No trend change detected	No M-K SS trend at α = 0.05
MW-148	Installation Fence Line	2015-2024	253 ft.	PCE	1.7942	High	-0.3091	2.27E-01	0	-7.28E-02	29	5	Yes	SSA↓	Decreasing trend (Jan 2021)	No M-K SS trend at α = 0.05
				TCE	1.5792	High	-0.2590	3.15E-01	0	-2.42E-01	5.6	5	Yes	SSA↓	Decreasing trend (Jan 2021)	No M-K SS trend at α = 0.05
				cDCE	1.0504	High	0.1996	4.42E-01	0	4.51E-01	16	70	Yes	SSA↓ Mar 2022	Decreasing trend (Oct 2023)	No M-K SS trend at α = 0.05
				VC	1.0822	High	0.3341	1.90E+01	0	1.94E-01	2	2	No	SSA↓ Mar 2024	No trend change detected	No M-K SS trend at α = 0.05

Notes: NaN = not a number, not calculated because of left-censored data, [1]Pearson's linear correlation coefficient, r = correlation coefficient, p-value = probability value, α=0.05 = alpha significance of 0.05 or 5%, SS = statistically significant at a level of 5% (0.05). PCE = tetrachloroethene, cDCE = cis-dichloroethene, TCE = trichloroethene, VC = vinyl chloride, MCL = maximum contaminant level, LOD = laboratory limit of detection, [1]Singular Spectrum Analysis of trend (SSA). SSA ↓ = Singular Spectrum Analysis of trend showed a change to decreasing trend for month shown. SSA ↑ = Singular Spectrum Analysis of trend showed a change to decreasing trend for month shown, SSA → = Singular Spectrum Analysis of trend showed a change to no trend for month shown, [2]Sequential Mann-Kendall Test for detecting potential trend change points. Decreasing trend, Increasing trend, and Concentration lower than the MCL.

Exhibit 2-14 Pit 2 Well Trend Plots

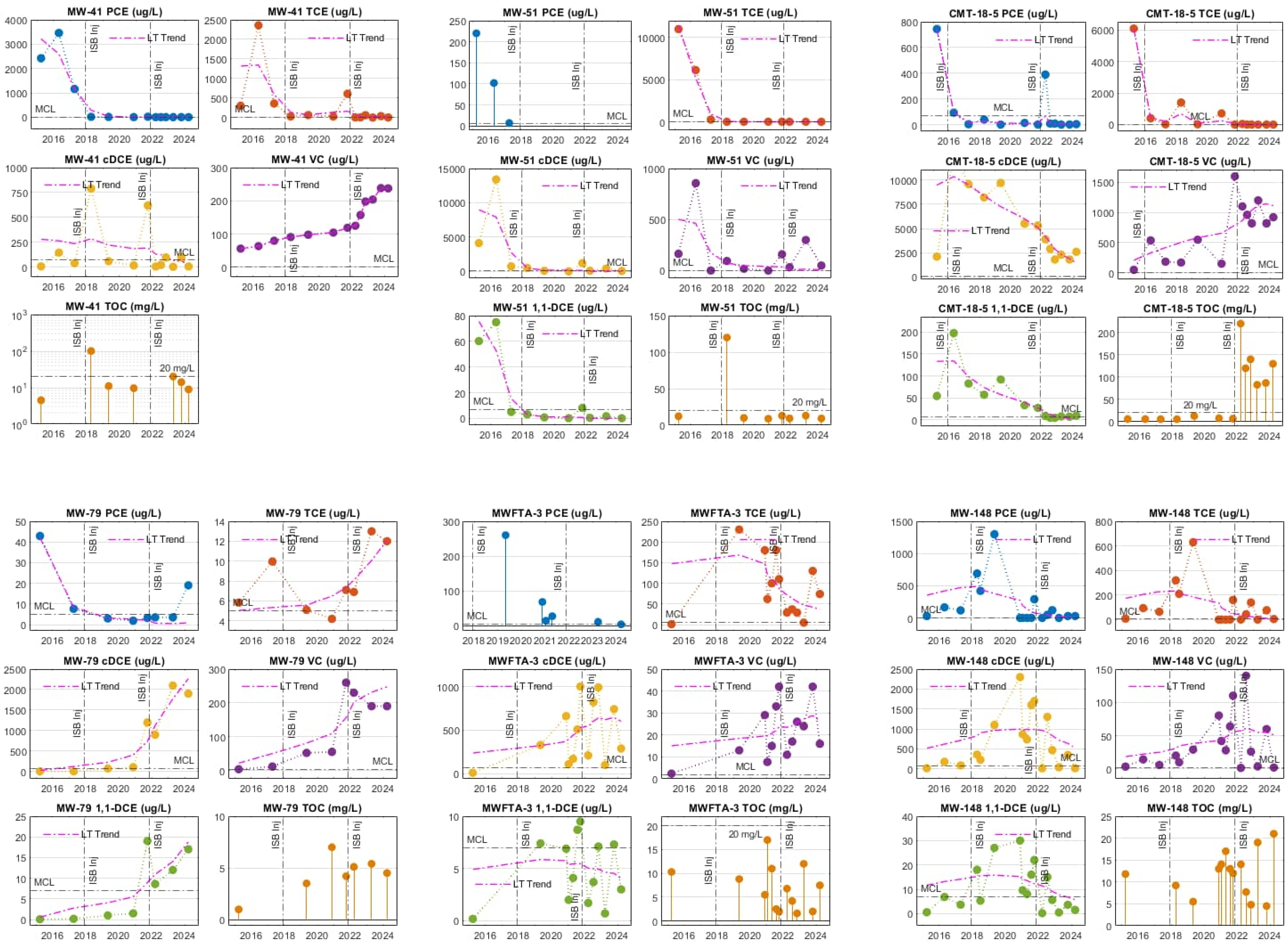
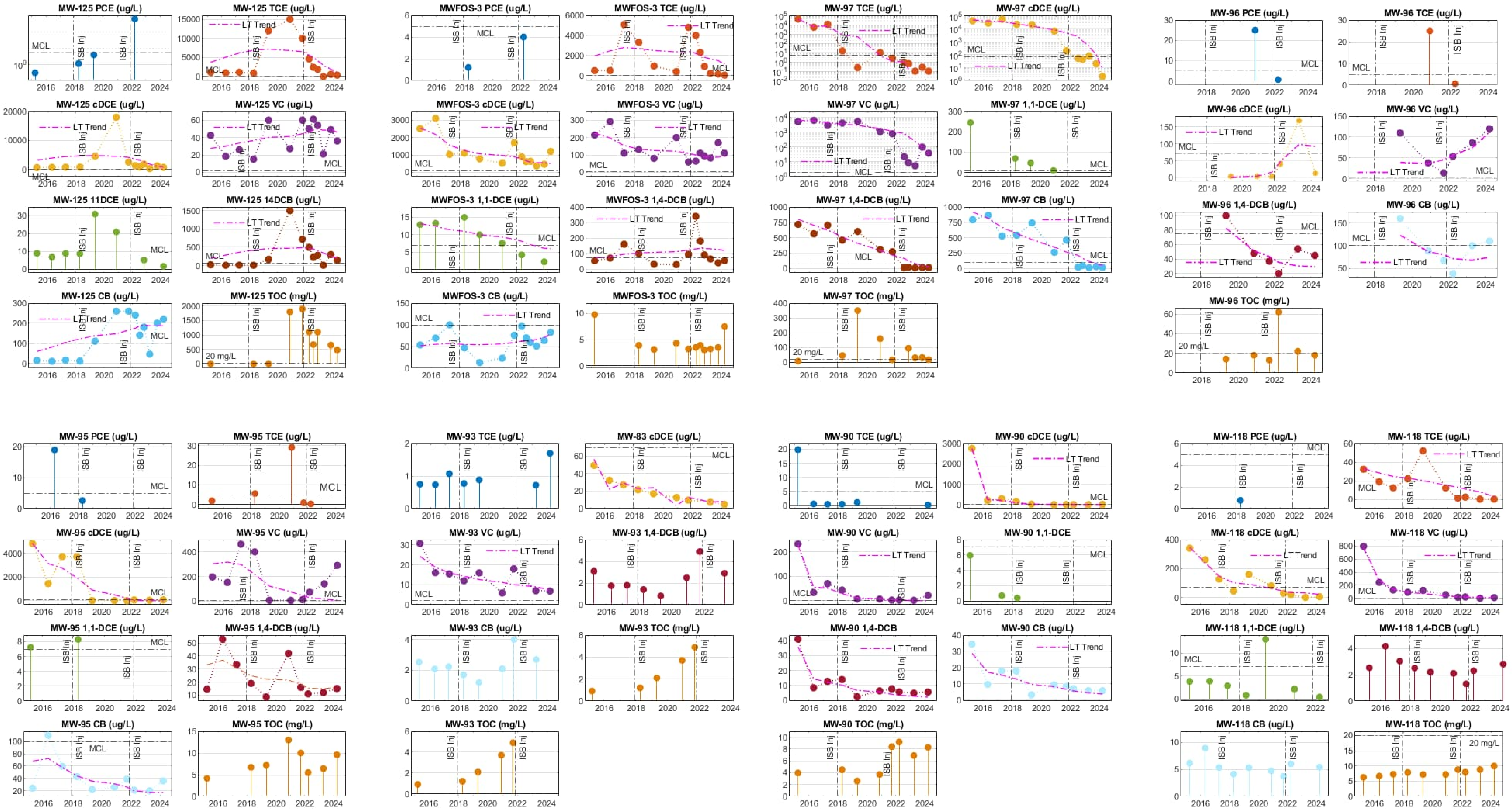


Table 2-12 Statistical Summary and Trend Analysis for Pit 3 Surficial Aquifer Wells

Well ID	Area	Date Range	Distance from MW-41	Primary COC	Distribution Variance		Linear Correlation[1] (α=0.05)		M-K Trend (One Way) (α=0.05)		2024 Result (µg/L)	MCL (µg/L)	>MCL	SSA Trend[1]	Sequential M-K[2]	M-K Trend (One-Way for Increasing or Decreasing Trend)
					CV	Variance	r[1]	p-value	H	p-value						
MW-125	Pit 3 Source Zone	2015-2024	0 ft.	TCE	1.2890	High	0.0220	9.43E-01	0	-1.11E-01	350	5	Yes	SSA↓ Mar 2019	Decreasing Trend (Mar 2023)	No M-K SS trend at α = 0.05
				cDCE	1.8191	High	0.0349	9.10E-01	0	3.80E-01	710	70	Yes	SSA↓ Mar 2019	Decreasing Trend (Oct 2023)	No M-K SS trend at α = 0.05
				VC	0.4254	Low	0.3782	2.03E-01	0	2.32E-01	36	2	Yes	SSA↓ Mar 2024	Decreasing Trend (Oct 2023)	No M-K SS trend at α = 0.05
MWFOS-3	Downgradient of Pit	2015-2024	44 ft.	TCE	1.0616	High	-0.1627	5.94E-01	1	-3.84E-02	30	5	Yes	SSA↓ Apr 2017	No trend change detected	M-K SS Decreasing at α = 0.05
				cDCE	0.7220	Moderate	-0.7021	7.50E-03	1	-1.64E-02	1200	70	Yes	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				VC	0.5194	Moderate	-0.5569	4.80E-02	0	-1.34E-01	110	2	Yes	SSA↓	Decreasing Trend (Oct 2023)	No M-K SS trend at α = 0.05
MW-97	Downgradient TA-11 area	2015-2024	114 ft.	TCE	2.4789	High	-0.6740	1.62E-02	1	-2.94E-04	0.1	5	No	SSA↓	Insufficient data	M-K SS Decreasing at α = 0.05
				cDCE	1.3071	High	-0.8948	8.50E-05	1	-4.69E-05	2.1	70	No	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				VC	1.1369	High	--0.9064	4.82E-05	1	3.20E-03	38	2	Yes	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
MW-96	Downgradient TA-11 area	2019-2024	155 ft.	TCE	NaN	--	NaN	--	--	--	ND	5	No	Insufficient data	Insufficient data	Insufficient detected observations
				cDCE	1.6591	High	0.4415	3.81E-01	0	1.30E-01	13	70	Yes	SSA↑	No trend change detected	No M-K SS trend at α = 0.05
				VC	0.5952	Moderate	0.2046	6.97E-01	0	2.25E-01	120	2	Yes	SSA↑	No trend change detected	No M-K SS trend at α = 0.05
MW-95	Downgradient	2015-2024	196 ft.	TCE	NaN	--	NaN	--	--	--	ND	5	No	Insufficient data	Insufficient data	Insufficient detected observations
				cDCE	0.2110	Low	-0.7697	1.1E-04	1	-4.40E-02	71	70	Yes	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				VC	1.2614	High	-0.7217	4.9E-04	0	-3.60E-01	290	2	Yes	SSA↓	No trend change detected	No M-K SS trend at α = 0.05
MW-93	Downgradient	2015-2024	206 ft.	cDCE	0.7717	Moderate	-0.8213	6.60E-03	1	-2.38E-02	8.3	70	No	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				VC	0.5408	Moderate	--0.7364	2.36E-02	1	-3.82E-02	6.9	2	Yes	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
MW-90	Downgradient near Building 72	2015-2024	253 ft.	cDCE	2.4730	High	-0.6164	5.77E-02	1	-1.50E-03	12	70	No	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				VC	1.6520	High	-0.6885	2.77E-02	1	-6.10E-03	22	2	Yes	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
MW-118	Downgradient	2015-2024	569 ft.	TCE	1.1002	High	-0.6289	5.14E-02	1	-4.60E-03	0.1	5	No	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				cDCE	1.0864	High	0.3961	9.51E-04	1	-6.41E-04	5.4	70	No	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05
				VC	1.6326	High	-0.3487	1.30E-02	1	-3.38E-04	9.1	2	Yes	SSA↓	No trend change detected	M-K SS Decreasing at α = 0.05

Notes: NaN = not a number, not calculated because of left-censored data, [1]Pearson's linear correlation coefficient, r = correlation coefficient, p-value = probability value, α=0.05 = alpha significance of 0.05 or 5%, SS = statistically significant at a level of 5% (0.05). PCE = tetrachloroethene, cDCE = cis-dichloroethene, TCE = trichloroethene, VC = vinyl chloride, MCL = maximum contaminant level, LOD = laboratory limit of detection, [1]Singular Spectrum Analysis of trend (SSA). SSA ↓ = Singular Spectrum Analysis of trend showed a change to decreasing trend for month shown. SSA ↑ = Singular Spectrum Analysis of trend showed a change to decreasing trend for month shown, SSA → = Singular Spectrum Analysis of trend showed a change to no trend for month shown, [2]Sequential Mann-Kendall Test for detecting potential trend change points. Decreasing trend, Increasing trend, and Concentration lower than the MCL.

Exhibit 2-15 Pit 3 Well Trend Plots



2.5 Current Conditions for Surface Water

Table 2-13 on page 2-60 has summary results for detected VOCs in surface water samples collected from Kingsland Creek for the monitoring period 2021-2024. This table compares these results to MCLs, EPA RSLs, and ecological benchmarks. VOCs detected for the four (4) annual LTM events included 1,4-dichlorobenzene, cDCE, chlorobenzene, and TCE. Detected concentrations are less than MCLs and ecological benchmarks. At stations KCG-1, single detections of chlorobenzene and TCE at levels less than the laboratory LOD had reported results greater than their RSL. The RSLs for chlorobenzene and TCE are less than the laboratory LOQ. KGC-1 is located in the stream segment between the monitoring areas of Pit 3 and Pit 2 (see Figure 2-6).

2.6 Building 72 Subsurface Vapor

Annual sampling of sub-slab vapor at Building 72 at VMP-116 began in 2016 after converting over from monitoring external soil gas monitoring points that frequently accumulated perched water. None of the sub-slab sampling results for 2016-2024 at VMP-116 had concentrations greater than the EPA vapor intrusion screening levels (VISLs)[2]. Field monitoring of VMP-116 has not indicated accumulation of methane beneath the building slab.

Sampling for the full list of TO-15 compounds began in 2017. The first full-list sampling had 37 VOC analytes detected, 20 analytes detected in 2018 and 2020-2022, 32 analytes detected in 2019, and six (6) analytes detected in December 2023. The reduced number of VOC detections reflects VOC plume conditions that have degraded over time in the Building 72 area from ISB remedial actions and intrinsic processes. The monitoring has indicated continued remedy protectiveness for workers that occasionally occupy Building 72.

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[2] United States Environmental Protection Agency Vapor Intrusion Screening Level, November 2024 Updated Calculator, target cancer risk (TR) of 1E-06 and target hazard quotient (THQ) of 0.1, commercial exposure scenario, site-specific groundwater temperature of 15.2 Celsius at well OU7-MW-117, adjacent to Building 72, receptor, VISL calculator at Vapor Intrusion Screening Level Home (ornl.gov)

Table 2-13 OU 7 VOC Summary Statistics for Kingsland Creek Surface Water (Detects 2021-2024)

									Federal MCL[1]			EPA RSL[2] (November 2024)					BTAG FWSB[3] (2006)		
Chemical	Matrix	No. of Results	Unit	Min	Max	No. > LOD	% > LOD	Location of Max	No. > MCL	% > MCL	MCL[1]	No. > RSL	% > RSL	EPA RSL[2]	Location >RSL	Yr. >RSL	No. > BTAG	% > BTAG	BTAG FWSB[3]
1,2-Dichloroethene, Total	WS	12	ug/L	<0.25	1.5	7	58.3	KGC-3	--	--	--	--	--	--	--	--	0	0	5.90E+02
cis-1,2-Dichloroethene	WS	12	ug/L	<0.37	1.5	5	41.7	KGC-3	0	0	7.00E+01	0	0	2.52E+00	--	--	0	0	--
Chlorobenzene	WS	12	ug/L	<0.15	1.1	3	25.0	KGC-1	0	0	1.00E+02	0	0	7.77E+00	--	--	0	0	1.30E+00
1,4-Dichlorobenzene	WS	12	ug/L	<0.31	0.87 J	1	8.3	KGC-1	0	0	7.50E+01	1	8	4.82E-01	KGC-1	2021	0	0	2.60E+01
Trichloroethene (TCE)	WS	12	ug/L	<0.2	0.84 J	1	8.3	KGC-1	0	0	5.00E+00	1	8	2.83E-01	KGC-1	2024	0	0	2.10E+01

Notes: WS = surface water ug/L = micrograms per liter, Min = minimum, Max = maximum, No. > = number greater, LOD = limit of detection, % = percent, J = Estimated: the analyte is positively identified; the quantitation is an estimation, [1]Subpart G—National Primary Drinking Water Regulations: Maximum Contaminant Levels and Maximum Residual Disinfectant Levels, § 141.61 Maximum contaminant levels for organic contaminants.> LOD = percent of detected results greater than laboratory limit of detection, 2 EPA Regional Screening Level for Resident Tap Water with a target cancer risk (TR) of 1E-06 and target hazard quotient (THQ) of 0.1, November 2004 at https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables. [3]EPA Region III BTAG Freshwater Screening Benchmarks, 7/2006. https://www.epa.gov/risk/freshwater-screening-benchmarks, Number of results with concentrations greater than the MCL, Number of results with concentration greater than the RSL, Number of results with concentrations greater than the BTAG FWSB

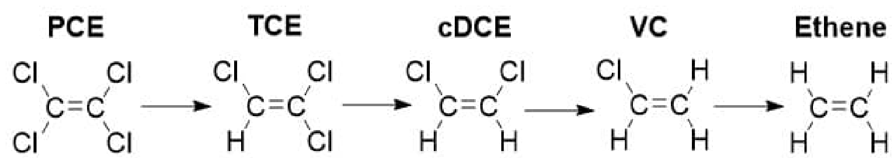
3. Remedial Design

Section 3 presents the remedial design for follow-up enhanced ISB actions at OU 7. Follow-up ISB actions at OU 7 will target accelerated treatment of remaining hot spot areas in the surficial aquifer. Addressing these hot spot areas will reduce contaminant mass and contaminant flux to downgradient areas. ISB actions proposed in this work plan will target additional treatment of diffuse VOC plumes farther downgradient of source zones with the objective of reducing overall plume areas.

3.1 Remedial Design Basis

The process option of the ISB design in this work plan follows the remedial design/remedial action work plan for OU 7 (AECOM 2013) using metabolic anaerobic reductive dechlorination as the targeted degradation process to treat the chlorinated solvents. In this reaction, microorganisms gain energy as one or more chlorine atoms on a chlorinated ethene or ethane compound molecule are replaced with hydrogen atoms in an anaerobic environment. The chlorinated compound serves as the electron acceptor and molecular hydrogen usually serves as the electron donor (source of energy). Hydrogen used in this reaction is supplied by fermentation of organic substrates or a direct electron donor. Biodegradation of an organic substrate depletes the aquifer of DO and sequentially reduces native electron acceptors nitrate, manganese, iron, sulfate, and carbon dioxide. In general, metabolic anaerobic reductive dechlorination occurs by sequential removal of chlorine atoms. Exhibit 3-1 illustrates the reductive dechlorination pathway for PCE the parent compound. Primary COCs for the targeted constituent plume for ISB treatment include TCE, cDCE, and VC.

Exhibit 3-1 Reductive Dechlorination Treatment Pathway



The specific ISB design in this work plan considers the results from previous treatability studies (AECOM, 2010) and remedial implementation for the confined aquifer at OU 7 (AECOM 2013, USACE 2017, AECOM 2021b) and the current conditions presented in Section 2.4.

3.2 Enhanced ISB Treatment Areas

Eight enhanced ISB treatment areas are proposed for the surficial aquifer VOC plumes in the Pit 1, 2, and 3 areas as shown in Figure 3-1 (page 3-2). Figure 3-2 (page 3-3) has a tile layout showing the ISB treatment areas with plume overlays for PCE, TCE, cDCE, and VC. Treatment area nomenclature follows designations established for the 2021 RAWP Addendum (AECOM-Meadows 2021b).

3.2.1 Treatment Area TA-02 (Pit 1)

Treatment area TA-02 targets a hot spot area near the Pit 1 area that includes wells AEHADG-11 and OU7-MW-36, which have the highest PCE concentrations (1,300 µg/L, March 2024) and TCE concentrations (780 µg/L, March 2024) in the Pit 1 plume area. The design dimensions for TA-2 are 45 ft. x 50 ft. The 45 ft. width is oriented perpendicular to the direction of groundwater flow with a 50 ft. length parallel to the direction of groundwater flow. The target depth interval for treatment is 10 to 26 ft. (85 to 69 ft. NAVD88) following the treatment area approach implemented in 2021, which is based on well data and high resolution PDI completed in the area for contaminant profiling by MIP and hydraulic properties profiling by HPT[3].

[3] Design based on PDI location OU7-PDI-10-MHP and well data from AEHADG-11 and MW-36.

Legend

- Performance Monitoring Well
- Surficial Aquifer Monitoring Well
- Proposed Confined Aquifer Monitoring Well
- Proposed Surficial Aquifer Monitoring Well
- Injection Well
- Direct Push Injection Point
- Overall Groundwater Flow Direction
- 2025 Treatment Area (TA)
- Stream
- Former Pit Boundary
- DSCR Boundary
- Operable Units

Notes:
Orthoimagery Source: VGIN (2021)

AREA ENLARGED

MEADOWS CONSULTING | MANAGEMENT | PLANNING

AECOM

0 20 40 80 Feet

N E S W

Figure 3-1
Enhanced ISB Treatment Areas

Defense Supply Center Richmond
Richmond, VA

Prepared By: DBC	Reviewed By: JOS
Scale: 1 " = 40 '	Date: May 30, 2025

L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 3-1 - Enhanced ISB Treatment Areas.mxd

Legend

- 2025 Treatment Area (TA)
- Performance Monitoring Well
- Surficial Aquifer Monitoring Well
- Proposed Surficial Aquifer Monitoring Well
- Injection Well
- Isoconcentration Line
- Overall Groundwater Flow Direction
- Stream
- Former Pit Boundary
- DSCR Boundary
- Operable Units

Notes:
Orthoimagery Source: VGIN (2021)

AREA ENLARGED

MEADOWS
CONSULTING | MANAGEMENT | PLANNING

AECOM

0 30 60 120 Feet

N E S W

Figure 3-2
Enhanced ISB Treatment Areas with Plume Overlay

Defense Supply Center Richmond
Richmond, VA

Prepared By: DBC	Reviewed By: JOS
Scale: 1 " = 60 '	Date: May 30, 2025

L:\DCS\Projects\ENV\60692954 DLA Richmond ERP 23\500-Deliverables\540-CLIN0025 OU7 Inj WP\Figures\Figure 3-2 - Enhanced ISB Treatment Areas-Overlay.mxd

3.2.2 Treatment Area TA-03 (Pit 1)

Treatment area TA-03 targets well cluster CMT-21 a hot spot in the Pit 1 plume and nearby well OU7-MW-68. CMT-21 has the highest cDCE concentration (14,000 µg/L, March 2024) in the Pit 1 plume area. The design dimensions for TA-3 are 45 ft. x 40 ft. The 45 ft. width is oriented perpendicular to the direction of groundwater flow with a 40 ft. length parallel to the direction of groundwater flow. The target depth interval for treatment is 9 to 24 ft. (85 to 70 ft. NAVD88) following the treatment area approach implemented in 2021, which is based on high resolution PDI completed in the area for contaminant profiling by MIP and hydraulic properties profiling by HPT[4].

3.2.3 Treatment Area TA-05 (Pit 1)

Treatment area TA-05 targets well DMW-29A in the Pit 1 plume area, with reported TCE concentrations of 110 µg/L for March 2024. This well is located 180 ft. downgradient of the former FTA Pit 1 area. The design dimensions for TA-3 are 40 ft. x 30 ft. The 50 ft. width is oriented perpendicular to the direction of groundwater flow with a 20 ft. length parallel to the direction of groundwater flow. The target depth interval for treatment is 10 to 28 ft. (85.5 to 66.5 ft. NAVD88) following the treatment area approach implemented in 2021, which is based on high resolution PDI completed in the area for contaminant profiling by MIP and hydraulic properties profiling by HPT[5].

3.2.4 Treatment Area TA-06 (Pit 1)

Treatment area TA-06 targets well cluster CMT-20 in the Pit 1 plume area, with reported cDCE and VC concentrations of 220 µg/L and 120 µg/L, respectively, for March 2024. This well cluster is located 228 ft. downgradient of the former FTA Pit 1 area. The design dimensions for TA-6 are 25 ft. x 50 ft. The 25 ft. width is oriented perpendicular to the direction of groundwater flow with a 50 ft. length parallel to the direction of groundwater flow. The target depth interval for treatment is 10 to 30 ft. (84 to 64 ft. NAVD88) following the treatment area approach implemented in 2021 modified to extend the treatment from 26 ft. to 30 ft., which corresponds to the construction of injection well OU7-INJ-211 proposed for implementing the targeted treatment.

3.2.5 Treatment Area TA-07 (Pit 2)

Treatment area TA-7 targets a hot spot area in the Pit 2 area (near former FTA Pit 2) that includes wells MW-85 and MW-48, which has the highest cDCE concentration (9,200 µg/L, March 2024) in the Pit 2 plume area. The design dimensions for TA-07 are 40 ft. x 34 ft. The 40 ft. width is oriented perpendicular to the direction of groundwater flow with a 34 ft. length parallel to the direction of groundwater flow. The target depth interval for treatment is 20 to 32 ft. (80 to 68 ft. NAVD88) following the treatment area approach implemented in 2021, which is based on well data and high resolution PDI completed in the area for contaminant profiling by MIP and hydraulic properties profiling by HPT[6].

3.2.6 Treatment Area TA-08 (Pit 2)

Treatment area TA-08 targets well cluster CMT-18 in the Pit 2 plume area, with the highest VC concentration (920 µg/L) in the Pit 2 plume area and the second highest cDCE concentration (2,600 µg/L) in the Pit 2 plume area. This well cluster is located 136 ft. downgradient of the former FTA Pit 2 area. The design dimensions for TA-8 are 45 ft. x 34 ft. The 45 ft. width is oriented perpendicular to the direction of groundwater flow with a 34 ft. length parallel to the direction of groundwater flow. The target depth interval for treatment is 17 to 28 ft. (84 to 64 ft. NAVD88) following the treatment area approach implemented in 2021, which is based on well data and high resolution PDI completed in the area for contaminant profiling by MIP and hydraulic properties profiling by HPT[7].

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[4] Design based on PDI location OU7-PDI-11-MHP and well data from CMT-21 and MW-68.
[5] Design based on PDI location OU7-PDI-15-MHP and well data from DMW-29A.
[6] Design based on PDI location OU7-PDI-06-MHP and well data from MW-85 and MW-48.
[7] Design based on PDI location OU7-PDI-07A-MHP and well data from CMT-18.

3.2.7 Treatment Area TA-09 (Pit 2)

Treatment area TA-09 targets the VC plume (greater than cleanup levels) that extends into lower Pit 2 monitored area near the installation fence line. The application area is 365 ft. to 400 ft. downgradient of the former Pit 2 area. The design dimensions for TA-9 are 40 ft. x 30 ft. The 40 ft. width is oriented perpendicular to the direction of groundwater flow with a 30 ft. length parallel to the direction of groundwater flow. The target depth interval for treatment is 16 to 26 ft. (78.5 to 68.5 ft. NAVD88) following the treatment area approach implemented in 2021 slightly modified for the construction of the injection wells proposed for implementation.

3.2.8 Treatment Area TA-11 (Pit 3)

Treatment area TA-11 targets wells OU7-MW-97, OU7-MW-108, and OU7-MW-109 in the Pit 3 plume area, with the highest cDCE concentration (2,500 µg/L) and highest VC concentration (600 µg/L) in the Pit 3 plume area. This group of wells is closely spaced and approximately 170 ft. downgradient of the former FTA Pit 3 area. The design dimensions for TA-11 are 40 ft. x 34 ft. The 40 ft. width is oriented perpendicular to the direction of groundwater flow with a 30 ft. length parallel to the direction of groundwater flow. The target depth interval for treatment is 11 to 25 ft. (88 to 74 ft. NAVD88) following the treatment area approach implemented in 2021, which is based on well data and high resolution PDI completed in the area for contaminant profiling by MIP and hydraulic properties profiling by HPT)[8].

3.3 Substrate Selection

Section 3.3 describes the selection of substrates for enhanced ISB treatment at OU 7.

3.3.1 Source Zone and Hot Spot Treatment

For source zone and hot sport treatment, primary criteria to select a substrate for the ISB design is sustaining treatment for up to three (3) years, compatibility with a DPT treatment approach, and cost effectiveness. The substrate used for the ISB design must support reductive dechlorination; this includes implementable amendments for aquifer buffering and bioaugmentation to support complete reduction of COCs.

EVO is the selected ISB substrate comprised of food-grade soybean oil, emulsifiers, and amendments (e.g., mono and diglycerides, lactate, whey, etc.); it is widely available with demonstrated effectiveness to support enhanced reductive dechlorination (ERD). Evidence of complete ERD pathways to ethene and methane is apparent for previous EVO injections at OU 7 and treatability studies. The low solubility of EVO provides for a long-lasting carbon source due to its slow rate of chemical dissolution into groundwater. EVO can also help sequester chlorinated VOC compounds, which will further reduce their mobility in the aquifer (Borden 2006,5).

Terra Systems, Wilmington Delaware, will provide slow-release, emulsified vegetable oil substrate (small droplet identified as SRS®-SD EVO (60% soybean oil). Table 3-1 provides data on this EVO product. Bioaugmentation of the solution will use Terra Systems TSI DC (dehalococcoides mccartyi) to support consistent dechlorination across the treatment area and address existing cDCE and degradation products in the treatment area. This enriched culture contains greater than1E+11 Dehalococcoides cells per liter. The culture degrades PCE and TCE to ethene. The injection process will include sodium ascorbate (L-ascorbic acid, Vitamin C) as an additive to drive the injection water anaerobic for bioaugmentation injections.

Low alkalinity in groundwater and pH levels less than 6 in soil/groundwater will require buffering to maintain a near-neutral pH for enhanced ISB treatment. Previous buffering studies for treatability studies and injections recommended and have used of sodium bicarbonate for pH buffering. Buffering studies performed in 2021 recommended buffering dosage of 0.16 pounds of sodium bicarbonate per cubic foot of aquifer (Terra Systems 2021).

[8] Design based on PDI location OU7-PDI-03-MHP and well data from MW-97, MW-108, MW-109.

Table 3-1 Terra Systems Inc. 60% Small Droplet Slow Release EVO Substrate (SRS® SD EVO)

Ingredient	Synonyms	CAS No.	Percent
Soybean oil	Soya oil	8001-22-7	60%
Emulsifiers and proprietary Nutri Plus nutrient package containing nitrogen, phosphorus, and vitamin B_{12}		Mixture	5-15%
Sodium lactate	2-hydroxropionnic acid sodium salt	72017-3	<5%
Sodium bicarbonate[1]	Baking soda	144-5-8	0-1%
Calcium carbonate[1]	Lime	471-34-1	0-1%
Sodium carbonate[1]	Soda Ash	497-19-8	0-1%
Magnesium oxide[1]	Magnesia	1309-48-4	0-1%
Water		7732-18-5	20-26%

Notes: Source: Terra Systems, Inc. Safety Data Sheet for SRS®B) in Appendix C.1 [1] Depending on the pH of the aquifer one or more of the above buffers (sodium bicarbonate, calcium carbonate, sodium carbonate or magnesium oxide) will be selected to adjust the pH of acidic aquifers to optimal levels for biodegradation.

Appendix A.1 has technical data sheets and safety data sheets for the selected EVO substrate, bioaugmentation, sodium ascorbate, and pH buffering components.

3.3.2 Diffuse Plume Treatment

For diffuse plume treatment, primary criteria to select a substrate for the ISB design is sustaining treatment for 1 or more years, substrate mobility with advective groundwater flow, compatibility with gravity feed injection in fixed-based injection wells, and cost effectiveness. The substrate used for the ISB design must support reductive dechlorination.

Sodium lactate is the selected ISB substrate comprised of sodium lactate, proprietary nutrients, and Vitamin B12; it is widely available with demonstrated effectiveness to support ERD). Evidence of complete ERD pathways to ethene and methane is apparent for previous sodium lactate injections at OU 7. The low viscosity and high solubility of sodium lactate in water allow for rapid transport with groundwater, which enhances distribution in the aquifer and minimizes the number of injection points.

Terra Systems, Wilmington Delaware, will provide sodium lactate (identified as 60% QRS™-Plus SL). Table 3-2 provides data on this sodium lactate product.

Table 3-2 Terra Systems Inc. 60% Sodium Lactate with Nutrients (60% QRS™-Plus SL)

Ingredient	Percent	Description.	Benefit
Sodium lactate	60%	Rapidly biodegradable soluble substrate; miscible in water	Fast release source of carbon and hydrogen. Rapidly generates reducing conditions. Provides 60% fermentable carbon.
Proprietary Nutrients	<5%	--	--
pH	6.5-7	6.5-7	Optimum microbial activity

Notes: Source: Terra Systems, Inc. Technical Data Sheet for 60%-QRS™ Plus Sodium Lactate in Appendix C.1.

Appendix A.2 has the technical data sheet and safety data sheet for the selected sodium lactate substrate.

3.4 Injection Process Option Selection

Section 3.4 describes the selection of injection process options for source zone/hot spot treatment and diffuse plume treatment.

3.4.1 Source Zone/Hot Spot Treatment

The injection process option selected for enhanced ISB for source zone/hot spot treatment at OU 7 is DPT injection using a pressure activated injection probe. The specified equipment is a Geoprobe® 7822DT Drill Rig with 1.5 inch probe rods. Pre-design investigations and testing performed at OU 7 indicate that the high density of the mid-to-lower intervals of surficial aquifer will require injection pressures greater than 100 pounds per square inch (psi) to distribute reagents in this zone. This 2021 ISB actions effectively used this process option to EVO with ZVI reagents in the surficial aquifer at OU 7.

3.4.2 Diffuse Plume Treatment

The injection process option selected for enhanced ISB for diffuse plume areas downgradient of the source zone/hot spot areas at OU 7 is existing injection wells used most recently for the 2017-2018 injections of sodium lactate.

3.5 Substrate Loading Rates and Injection Volume Estimates

Section 3.5 has design information for substrate loading rates and injection volume estimates.

3.5.1 Substrate Loading Rates

Enhanced ISB substrate mass and loading rates will need to satisfy native and contaminant electron acceptor demand in the reactive treatment zone to stimulate anaerobic reductive dechlorination processes. Too low of a substrate loading rate may result in reducing conditions that are insufficient to support anaerobic dechlorination of COCs. Too high of a substrate loading rate can lead to inefficiencies and uncontrolled reactions that lower pH and result in excessive methanogenesis, degradation of groundwater quality and/or accumulation of methane in the vadose zone. Determining appropriate substrate loading rates is therefore a primary objective of the enhanced ISB design.

Substrate demand for enhanced ISB of chlorinated VOCs is a function of: (1) contaminant electron acceptor supply, (2) native electron receptor supply, and (3) non-specific demands (microbial cell growth, etc.). Following previous pilot tests and remedial designs for OU 7, the theoretical demand for substrate is determined in this work plan through stoichiometric calculations using site data; these calculations quantify the amount of electron donor (hydrogen) required to completely reduce contaminant and native electron receptors based on the substrate used and levels of acceptors present.

The pore water of the aquifer and the solid aquifer matrix contain native electron receptors (such as DO and iron hydroxide materials) that the electron donor may use preferentially over chlorinated VOCs. Substrate loading rates in the enhanced ISB design account for the stoichiometric demand to completely reduce these native electron receptors before complete reductive dechlorination of COCs can occur.

Calculation of Substrate Demand and Loading Rates

The enhanced ISB design for this work plan addendum uses the Substrate Estimating Tool for Enhanced Anaerobic Bioremediation of Chlorinated Solvents Version 1.2 (ESTCP, 2010) to calculate substrate requirements, demand, and loading rates. Each source zone/hot spot treatment area has a design specific to the conditions found in the respective target treatment zones. The DPT injection treatment areas using EVO have a 3 year design period of performance assuming a single application event. The injection well treatment areas using sodium lactate to treat diffuse plume areas have a 1.5 year design period of performance assuming a single application event. Appendices B.1 through B.8 have the treatment design workbooks for TA-02, TA-03, TA-05, TA-06, TA-07, TA-08, TA-09, and TA-11. Table 3-2 (pages 3-7 through 3-10) has a summary of the enhanced ISB design parameter for each treatment area. Table 3-3 (page 3-11) has a summary of design workbook outputs including electron receptor demand and substrate requirements in hydrogen equivalents.

Table 3-3 Enhanced In Situ Bioremediation Design Parameter Summary

Treatment Zone	TA-02	TA-02 Notes	TA-03	TA-03 Notes
Area Description:	--	Hot spot area, wells AEHADG-11, MW-36, 35 ft. downgradient of Former Pit 1	--	CMT-21 Hot spot and MW-68, 100 ft. downgradient of Former Pit 1
Width (ft) ⊥ to GW flow x Length (ft) ∥ to GW flow x TZ Thickness (ft)	45' x 50' x 16'	Vertical treatment interval based on PDI MIP, HPT	45' x 40' x 15'	Vertical treatment interval based on PDI MIP, HPT
Design Period (yrs.)	3	Design period for enhanced in situ bioremediation	3	Design period for enhanced in situ bioremediation
Design Factor (times the electron acceptor hydrogen demand)	10	Electron acceptor (4X), microbial efficiency (4X), loss of substrate leaving reaction zone (2X)	10	Electron acceptor (4X), microbial efficiency (4X), loss of substrate leaving reaction zone (2X)
Aquifer Total Porosity (%) / Aquifer Effective Porosity (%)	0.36 / 0.27	PDI Eastover Formation OU 7/ average based on TP, AP, clay content	0.36 / 0.27	PDI Eastover Formation OU 7/ average based on TP, AP, clay content
Average Hydraulic Conductivity (ft/day)	5	OU7 PDI	5	OU7 PDI
Average Hydraulic Gradient (ft/ft)	1.61E-02	2024 Annual Report	1.61E-02	2024 Annual Report
Soil Bulk Density (gm/cm^3)	1.63	Average OU- PDI for Eastover and Aquia Formations	1.663	Average OU- PDI for Eastover and Aquia
Soil Fraction of Organic Carbon (%)	0.28	PDI-38 Eastover Formation Saturated Zone OU-7 x 2	0.28	PDI-38 Eastover Formation Saturated Zone OU-7 x 2
Substrate	EVO	Terra Systems SRS®-SD EVO (small droplet, 60% soybean oil)	EVO	Terra Systems SRS®-SD EVO (small droplet, 60% soybean oil)
Native Electron Acceptors	**TA-02**		**TA-03**	**Notes**
Dissolved Oxygen (mg/L)	4.3	Data from 11/2020 (Average AEHADG-11, MW-36)	0.2	CMT-21-2, MW-68 (average) 03/2024
Nitrate (mg/L)	0.03	AEHADG-11 03/2024	0.02	CMT-21-2, MW-68 (average) 03/2024
Manganese (IV) (mg/L)	0.22	AEHADG-11 03/2024	1.3	CMT-21-2, MW-68 (average) 03/2024
Iron (III) (mg/L) (estimated as the amount of Fe II produced)	3	AEHADG-11 03/2024	3.43	Average MW-157 and MW-291 (May 2024)
Sulfate (mg/L)	16	AEHADG-11 03/2024	5	MW-68 03/2024
Carbon Dioxide (mg/L)	8	Estimate based on previous EISB injections	10	Estimated based on previous EISB injections
Contaminant Electron Acceptors	**TA-02**		**TA-03**	**Notes**
Tetrachloroethene (mg/L)	1.250	AEHADG-11 03/2024	0.500	Average MW-157 and MW-291 (May 2024)
Trichloroethene (mg/L)	0.520	AEHADG-11 03/2024	0.450	MW-157 (May 2024)
Dichloroethenes (mg/L)	1.300	AEHADG-11 03/2024	14.490	MW-291 (May 2024)
Vinyl Chloride (mg/L)	0.050	AEHADG-11 03/2024	0.140	MW-291 (May 2024)
Carbon Tetrachloride (mg/L)	0.040	AEHADG-11 03/2024	0.000	Not detected (2024)
Chloroform (mg/L)	1.250	AEHADG-11 03/2024	0.042	Not detected (2024)
Methylene chloride (mg/L)	0.000	AEHADG-11 03/2024	0.000	Not detected (2024)
Tetrachloroethanes (mg/L)	0.001	AEHADG-11 03/2024	0.000	Not detected (2024)
Trichloroethanes (mg/L)	1.100	AEHADG-11 03/2024	0.000	Not detected (2024)
Dichloroethanes (mg/L)	0.040	AEHADG-11 03/2024	0.003	MW-291 (May 2024)
Chloroethane (mg/L)	0.120	AEHADG-11 03/2024	0.000	Not detected (2024)
Aquifer Geochemistry	**TA-02**		**TA-03**	**Notes**
Oxidation Reduction Potential (mV)	234	AEHADG-11 03/2024	23	MW-283 (May 2024)
Temperature (°C)	12	AEHADG-11 03/2024	19	MW-283 (May 2024)
pH (standard units)	5.1	AEHADG-11 03/2024	5.4	Average MW-157 and MW-291 (May 2024)
Alkalinity (mg/L)	55	AEHADG-11 03/2024	64	Average MW-157 and MW-291 (May 2024)
Total Dissolved Solids (mg/L)	100	No data	100	No data
Specific Conductance (µs/cm)	158	AEHADG-11 03/2024	441	Average MW-157 and MW-291 (May 2024)
Chloride (mg/L)	6	AEHADG-11 03/2024	104	Average MW-157 and MW-291 (May 2024)
Sulfide – Pre Injection (mg/L)	0.1	Estimate Not Detected	0.1	Estimated
Sulfide – Post Injection (mg/L)	1.7	AEHADG-11 03/2024	2.6	MW-291 (May 2024)
Aquifer Matrix	**TA-02**		**TA-03**	**Notes**
Total Iron (mg/kg)	18000	CSM 2006 Soil Eastover Formation	18000	CSM 2006 Soil Eastover Formation
Cation Exchange Capacity meq/100 g	1	CSM 2006 Soil Eastover Formation	1	CSM 2006 Soil Eastover Formation
Neutralization Potential (percent as CaCO3)	1.0%	CSM 2006 Soil Eastover Formation	1.0%	CSM 2006 Soil Eastover Formation

Notes: yrs. = years, mg/L = milligrams per liter, meq/100 g = milliequivalents per 100 grams, µs/cm = microsiemens per centimeter, CaCO3 = calcium carbonate, ft./ft. = feet per foot, ft./day = feet per day, % = percent, PDI = pre-design investigation, MIP = membrane interface probe, HPT = hydraulic profiling tool. #X = #-times

Table 3-2 (Cont'd)

Treatment Zone	TA-05	TA-05 Notes	TA-06	TA-06 Notes
Area Description:	--	Targets well DMW-29A area, 180 ft. downgradient of Former Pit 1	--	Targets well cluster CMT-20, Uses existing injection well INJ-211, 230 ft. downgradient of Former Pit 1
Width (ft) ⊥ to GW flow x Length (ft) ∥ to GW flow x TZ Thickness (ft)	40' x 30' x 16'	Vertical treatment interval based on PDI MIP, HPT	25' x 50' x 20'	Vertical treatment interval based on PDI MIP, HPT
Design Period (yrs.)	3	Design period for enhanced in situ bioremediation	1.5	Design period for enhanced in situ bioremediation
Design Factor (times the electron acceptor hydrogen demand)	10	Electron acceptor (4X), microbial efficiency (4X), loss of substrate leaving reaction zone (2X)	10	Electron acceptor (4X), microbial efficiency (4X), loss of substrate leaving reaction zone (2X)
Aquifer Total Porosity (%) / Aquifer Effective Porosity (%)	0.36 / 0.27	PDI Eastover Formation OU 7/ average based on TP, AP, clay content	0.36 / 0.27	PDI Eastover Formation OU 7/ average based on TP, AP, clay content
Average Hydraulic Conductivity (ft/day)	5	OU7 PDI	5	OU7 PDI
Average Hydraulic Gradient (ft/ft)	1.61E-02	2024 Annual Report	1.61E-02	2024 Annual Report
Soil Bulk Density (gm/cm^3)	1.63	Average OU- PDI for Eastover and Aquia Formations	1.663	Average OU- PDI for Eastover and Aquia Formations
Soil Fraction of Organic Carbon (%)	0.28	PDI-38 Eastover Formation Saturated Zone OU-7 x 2	0.28	PDI-38 Eastover Saturated Zone OU-7 x 2
Substrate	EVO	Terra Systems SRS®-SD EVO (small droplet, 60% soybean oil)	Sodium Lactate	Terra Systems 60% QRS-SL™ Plus Sodium Lactate
Native Electron Acceptors	**TA-05**		**TA-06**	**Notes**
Dissolved Oxygen (mg/L)	1.1	DMW-29A 03/2024	0.1	CMT-20-3 03/2024
Nitrate (mg/L)	0.05	DMW-29A 03/2024	0.03	CMT-20-3 03/2024
Manganese (IV) (mg/L)	0.46	DMW-29A 03/2024	1.3	CMT-20-3 03/2024
Iron (III) (mg/L) (estimated as the amount of Fe II produced)	9	DMW-29A 03/2024	10	Estimated
Sulfate (mg/L)	1	DMW-29A 03/2024	2	CMT-20-3 03/2024
Carbon Dioxide (mg/L)	10	Estimate based on previous EISB injections	10	Estimated based on previous EISB injections
Contaminant Electron Acceptors	**TA-05**		**TA-06**	**Notes**
Tetrachloroethene (mg/L)	0.006	DMW-29A 03/2024	0.000	CMT-20-3 03/2024
Trichloroethene (mg/L)	0.100	DMW-29A 03/2024	0.001	CMT-20-3 03/2024
Dichloroethenes (mg/L)	0.126	DMW-29A 03/2024	0.221	CMT-20-3 03/2024
Vinyl Chloride (mg/L)	0.007	DMW-29A 03/2024	0.120	CMT-20-3 03/2024
Carbon Tetrachloride (mg/L)	0.000	Not detected	0.000	Not detected (2024)
Chloroform (mg/L)	0.000	Not detected	0.000	Not detected (2024)
Methylene chloride (mg/L)	0.000	Not detected	0.000	Not detected (2024)
Tetrachloroethanes (mg/L)	0.000	Not detected	0.000	Not detected (2024)
Trichloroethanes (mg/L)	0.000	Not detected	0.000	Not detected (2024)
Dichloroethanes (mg/L)	0.000	Not detected	0.024	CMT-20-3 03/2024
Chloroethane (mg/L)	0.010	DMW-29A 03/2024	0.000	Not detected (2024)
Aquifer Geochemistry	**TA-05**		**TA-06**	**Notes**
Oxidation Reduction Potential (mV)	310	DMW-29A 03/2024	-64	CMT-20-3 03/2024
Temperature (°C)	14	DMW-29A 03/2024	16	CMT-20-3 03/2024
pH (standard units)	5.5	DMW-29A 03/2024	6.4	CMT-20 03/2024
Alkalinity (mg/L)	78	DMW-29A 03/2024	153	CMT-20 03/2024
Total Dissolved Solids (mg/L)	100	No data	100	No data
Specific Conductance (µs/cm)	750	DMW-29A 03/2024	479	CMT-20-3 03/2024
Chloride (mg/L)	19	DMW-29A 03/2024	125	CMT-20 03/2024
Sulfide – Pre Injection (mg/L)	0.1	Estimate Not Detected	0.1	Estimate
Sulfide – Post Injection (mg/L)	1.2	DMW-29A 03/2024	0.2	Estimate
Aquifer Matrix	**TA-02**		**TA-06**	**Notes**
Total Iron (mg/kg)	18000	CSM 2006 Soil Eastover Formation	11145	CSM 2006 Soil Eastover Formation
Cation Exchange Capacity meq/100 g	1	CSM 2006 Soil Eastover Formation	1	CSM 2006 Soil Eastover Formation
Neutralization Potential (percent as CaCO3)	1.0%	CSM 2006 Soil Eastover Formation	1.0%	CSM 2006 Soil Eastover Formation

Table 3-2 (Cont'd)

Treatment Zone	TA-07	TA-07 Notes	TA-08	TA-08 Notes
Area Description:	--	Targets hot spot at well MW-85 and MW-48, 35 ft. downgradient of Former Pit 2	--	Targets well cluster CMT-20, Uses existing injection well INJ-211, 145 ft. downgradient of Former Pit 2
Width (ft) ⊥ to GW flow x Length (ft) ∥ to GW flow x TZ Thickness (ft)	40' x 34' x 12'	Vertical treatment interval based on PDI MIP, HPT	55' x 34' x 11'	Vertical treatment interval based on PDI MIP, HPT
Design Period (yrs.)	3	Design period for enhanced in situ bioremediation	1.5	Design period for enhanced in situ bioremediation
Design Factor (times the electron acceptor hydrogen demand)	10	Electron acceptor (4X), microbial efficiency (4X), loss of substrate leaving reaction zone (2X)	10	Electron acceptor (4X), microbial efficiency (4X), loss of substrate leaving reaction zone (2X)
Aquifer Total Porosity (%) / Aquifer Effective Porosity (%)	0.36 / 0.27	PDI Eastover Formation OU 7/ average based on TP, AP, clay content	0.36 / 0.27	PDI Eastover OU 7/ average based on TP, AP, clay content
Average Hydraulic Conductivity (ft/day)	5	OU7 PDI	5	OU7 PDI
Average Hydraulic Gradient (ft/ft)	1.20E-02	2024 Annual Report for Pit 2	1.61E-02	2024 Annual Report
Soil Bulk Density (gm/cm^3)	1.63	Average OU- PDI for Eastover and Aquia Formations	1.663	Average OU- PDI for Eastover and Aquia Formations
Soil Fraction of Organic Carbon (%)	0.28	PDI-38 Eastover Saturated Zone OU-7 x 2	0.28	PDI-38 Eastover Formation Saturated Zone OU-7 x 2
Substrate	EVO	Terra Systems SRS®-SD EVO (small droplet, 60% soybean oil)	Sodium Lactate	Terra Systems 60% QRS-SL™ Plus Sodium Lactate
Native Electron Acceptors	**TA-07**		**TA-08**	**Notes**
Dissolved Oxygen (mg/L)	3.1	MW-85, MW-48 (average), 3/2024	0.1	CMT-18 03/2024
Nitrate (mg/L)	0.05	MW-85, MW-48 (average), 3/2024	0.03	CMT-18 03/2024
Manganese (IV) (mg/L)	0.44	MW-85, MW-48 (average), 3/2024	1.3	CMT-18 03/2024
Iron (III) (mg/L) (estimated as the amount of Fe II produced)	4	MW-85, MW-48 (average), 3/2024	10	CMT-18 03/2024
Sulfate (mg/L)	3.95	MW-85, MW-48 (average), 3/2024	0.5	CMT-18 03/2024
Carbon Dioxide (mg/L)	10	Estimate based on previous EISB injections	10	Estimate based on previous EISB injections
Contaminant Electron Acceptors	**TA-07**		**TA-08**	**Notes**
Tetrachloroethene (mg/L)	0.007	MW-85 3/2024	0.007	CMT-18 03/2024
Trichloroethene (mg/L)	0.007	MW-85 3/2024	0.006	CMT-18 03/2024
Dichloroethenes (mg/L)	9.318	MW-85 3/2024	2.609	CMT-18 03/2024
Vinyl Chloride (mg/L)	0.570	MW-85 3/2024	0.920	CMT-18 03/2024
Carbon Tetrachloride (mg/L)	0.000	Not detected	0.000	Not detected
Chloroform (mg/L)	0.000	Not detected	0.010	CMT-18 03/2024
Methylene chloride (mg/L)	0.000	Not detected	0.000	Not detected
Tetrachloroethanes (mg/L)	0.000	Not detected	0.000	Not detected
Trichloroethanes (mg/L)	0.023	MW-85 3/2024	0.000	Not detected
Dichloroethanes (mg/L)	0.018	MW-85 3/2024	0.027	CMT-18 03/2024
Chloroethane (mg/L)	0.000	Not detected	0.000	Not detected
Aquifer Geochemistry	**TA-07**		**TA-08**	**Notes**
Oxidation Reduction Potential (mV)	49	MW-85, MW-48 (average), 3/2024	249	CMT-18 03/2024
Temperature (°C)	16	MW-85, MW-48 (average), 3/2024	15	CMT-18 03/2024
pH (standard units)	5.8	MW-85, MW-48 (average), 3/2024	5.2	CMT-18 03/2024
Alkalinity (mg/L)	160	MW-85, MW-48 (average), 3/2024	93	CMT-18 03/2024
Total Dissolved Solids (mg/L)	100	No data	100	No data
Specific Conductance (µs/cm)	547	MW-85, MW-48 (average), 3/2024	339	CMT-18 03/2024
Chloride (mg/L)	110	MW-85, MW-48 (average), 3/2024	121	CMT-18 03/2024
Sulfide – Pre Injection (mg/L)	0.1	Estimate Not Detected	0.1	Estimate Not Detected
Sulfide – Post Injection (mg/L)	2.9	Data from MW-85 3/2024	1.6	CMT-18 03/2024
Aquifer Matrix	**TA-07**		**TA-08**	**Notes**
Total Iron (mg/kg)	18000	CSM 2006 Soil Eastover Formation	11145	CSM 2006 Soil Eastover Formation
Cation Exchange Capacity meq/100 g	1	CSM 2006 Soil Eastover Formation	1	CSM 2006 Soil Eastover Formation
Neutralization Potential (percent as CaCO3)	1.0%	CSM 2006 Soil Eastover Formation	1.0%	CSM 2006 Soil Eastover Formation

Table 3-2 (Cont'd)

Treatment Zone	TA-09	TA-09 Notes	TA-11	TA-11 Notes
Area Description:	--	Targets lower diffuse plume area at Pit 2, INJ-163, INJ-164, INJ-165, INJ-207	--	Targets hot spot in well MW-109, MW-108, and MW-97 area, 155 ft. downgradient of Former Pit 3
Width (ft) ⊥ to GW flow x Length (ft) ∥ to GW flow x TZ Thickness (ft)	40' x 30' x 10'	Vertical treatment interval based on injection well construction	40' x 34' x 14'	Vertical treatment interval based on PDI MIP, HPT
Design Period (yrs.)	1.5	Design period for enhanced in situ bioremediation (soluble substrate)	3	Design period for enhanced in situ bioremediation
Design Factor (times the electron acceptor hydrogen demand)	10	Electron acceptor (4X), microbial efficiency (4X), loss of substrate leaving reaction zone (2X)	10	Electron acceptor (4X), microbial efficiency (4X), loss of substrate leaving reaction zone (2X)
Aquifer Total Porosity (%) / Aquifer Effective Porosity (%)	0.36 / 0.27	PDI Eastover Formation OU 7/ average based on TP, AP, clay content	0.36 / 0.27	PDI Eastover Formation OU 7/ average based on TP, AP, clay content
Average Hydraulic Conductivity (ft/day)	5	OU7 PDI	5	OU7 PDI
Average Hydraulic Gradient (ft/ft)	2.23E-02	Between injection transect and MW-149 (03/2024)	1.80E-02	Flow path in injection area 03/2024
Soil Bulk Density (gm/cm^3)	1.63	Average OU- PDI for Eastover and Aquia Formations	1.663	Average OU- PDI for Eastover and Aquia Formations
Soil Fraction of Organic Carbon (%)	0.28	PDI-38 Eastover Saturated Zone OU-7 x 2	0.28	PDI-38 Eastover Saturated Zone OU-7 x 2
Substrate	Sodium Lactate	Terra Systems 60% QRS-SL™ Plus Sodium Lactate	EVO	Terra Systems SRS®-SD EVO (small droplet, 60% soybean oil)
Native Electron Acceptors	**TA-09**		**TA-11**	**Notes**
Dissolved Oxygen (mg/L)	0.5	CMT-18 03/2024	0.4	MW-97 03/2024
Nitrate (mg/L)	0.05	CMT-18 03/2024	0.05	MW-97 03/2024
Manganese (IV) (mg/L)	0.726	CMT-18 03/2024	0.72	MW-95 03/2024
Iron (III) (mg/L) (estimated as the amount of Fe II produced)	3	CMT-18 03/2024	10	Estimated
Sulfate (mg/L)	0.5	CMT-18 03/2024	2	MW-95 03/2024
Carbon Dioxide (mg/L)	10	Estimate based on previous EISB injections	10	Estimated based on previous EISB injections
Contaminant Electron Acceptors	**TA-09**		**TA-11**	**Notes**
Tetrachloroethene (mg/L)	0.041	MW-80 03/2024	0.000	Not detected
Trichloroethene (mg/L)	0.020	MW-80 03/2024	0.001	MW-109 03/2024
Dichloroethenes (mg/L)	0.224	MW-80 03/2024	2.404	MW-109 03/2024
Vinyl Chloride (mg/L)	0.054	MW-80 03/2024	0.560	MW-109 03/2024
Carbon Tetrachloride (mg/L)	0.000	Not detected	0.000	Not detected
Chloroform (mg/L)	0.000	Not detected	0.000	Not detected
Methylene chloride (mg/L)	0.000	Not detected	0.000	Not detected
Tetrachloroethanes (mg/L)	0.000	Not detected	0.000	Not detected
Trichloroethanes (mg/L)	0.003	MW-148 03/2024	0.000	Not detected
Dichloroethanes (mg/L)	0.003	Average for plume area	0.000	Not detected
Chloroethane (mg/L)	0.000	Not detected	0.000	Not detected
Aquifer Geochemistry	**TA-09**		**TA-11**	**Notes**
Oxidation Reduction Potential (mV)	71	MW-80, MW-83, MW-148 (average) 03/2024	-56	MW-98 03/2024
Temperature (°C)	13	MW-80, MW-83, MW-148 (average) 03/2024	19	MW-98 03/2024
pH (standard units)	5.9	MW-80, MW-83, MW-148 (average) 03/2024	6.4	MW-98 03/2024
Alkalinity (mg/L)	54	MW-80, MW-83, MW-148 (average) 03/2024	72	MW-98 03/2024
Total Dissolved Solids (mg/L)	100	Estimate	100	Estimated
Specific Conductance (µs/cm)	533	MW-80, MW-83, MW-148 (average) 03/2024	269	MW-98 03/2024
Chloride (mg/L)	178	MW-80, MW-83, MW-148 (average) 03/2024	24	MW-98 03/2024
Sulfide – Pre Injection (mg/L)	0.1	Estimate	0.1	Estimate
Sulfide – Post Injection (mg/L)	0.2	Estimate	0.2	Estimate
Aquifer Matrix	**TA-09**		**TA-11**	**Notes**
Total Iron (mg/kg)	18000	CSM 2006 Soil Eastover Formation	11145	CSM 2006 Soil Eastover Formation
Cation Exchange Capacity meq/100 g	1	CSM 2006 Soil Eastover Formation	1	CSM 2006 Soil Eastover Formation
Neutralization Potential (percent as CaCO3)	1.0%	CSM 2006 Soil Eastover Formation	1.0%	CSM 2006 Soil Eastover Formation

Table 3-4 Summary of Electron Receptor Requirements in Hydrogen Equivalents

	TA-02		TA-03		TA-05		TA-06		TA-07		TA-08		TA-09		TA-11	
Parameter	% of Total	H Demand (lbs.)	% of Total	H Demand (lbs.)	% of Total	H Demand (lbs.)	% of Total	H Demand (lbs.)	% of Total	H Demand (lbs.)	% of Total	H Demand (lbs.)	% of Total	H Demand (lbs.)	% of Total	H Demand (lbs.)
Aerobic Respiration	7.5%	2.475	0.5%	0.121	2.6%	0.599	0.2%	0.018	6.2%	0.876	1.9%	0.285	0.9%	0.074	0.9%	0.180
Nitrate Reduction	0.0%	0.011	0.0%	0.009	0.1%	0.021	0.0%	0.004	0.1%	0.011	0.3%	0.043	0.1%	0.006	0.1%	0.018
Sulfate Reduction	18.8%	6.234	6.2%	1.646	0.8%	0.182	3.4%	0.332	5.3%	0.744	0.8%	0.119	18.8%	1.504	2.6%	0.538
Manganese Reduction	0.1%	0.037	0.8%	0.199	0.3%	0.073	0.9%	0.087	0.3%	0.036	0.4%	0.064	0.4%	0.032	0.5%	0.100
Iron Reduction	0.9%	0.285	1.0%	0.258	3.0%	0.703	3.3%	0.324	1.1%	0.150	1.1%	0.164	2.8%	0.220	3.3%	0.680
Methanogenesis	69.2%	22.961	79.3%	20.954	93.0%	21.741	91.9%	9.032	80.0%	11.276	92.8%	14.213	76.7%	6.124	90.5%	18.947
Dechlorination	3.6%	1.184	12.3%	3.253	0.2%	0.051	0.3%	0.029	7.1%	0.999	2.8%	0.427	0.3%	0.021	2.2%	0.470
Total	100%	33.19	100%	26.4	100%	23.37	100%	9.83	100%	14.09	100%	15.32	100%	7.98	100%	20.93
Hydrogen Demand (lbs./gal)		6.06E-05		5.29E-05		4.51E-05		4.56E-05		5.24E-05		4.52E-05		5.46E-05		4.63E-05
Hydrogen Demand (g/L)		7.26E-03		6.34E-03		5.40E-03		5.47E-03		6.28E-03		5.41E-03		6.55E-03		5.55E-03
Substrate		EVO		EVO		EVO		Sodium Lactate		EVO		EVO		Sodium Lactate		EVO
Substrate equivalents (10X)		4,810 lbs.		3,832 lbs.		3,387 lbs.		4,554 lbs.		2,043 lbs.		2,220 lbs.		3,699 lbs.		3,034 lbs.
Substrate equivalents (10X)		617 gal		491 gal		434 gal		414 gal		262 gal		285 gal.		336 gal.		389 gal
Effective Concentration[1]		632 mg/L		551 mg/L		470 mg/L		1,221 mg/L		546 mg/L		471 mg/L		1,463 mg/L		483 mg/L

Notes: % = percent, lbs. = pounds, lbs./gal = pounds per gallon, g/L = grams per liter, mg/L = milligrams per liter., EVO = emulsified vegetable oil, 10X = 10 times design factor, [1]effective concentration is for total volume of groundwater treated.

For this work plan addendum, the enhanced ISB designs use data from each treatment area when available. The design for this work plan also applies a design factor of 10 to the calculated total hydrogen demand to account for microbial efficiency (4-times design factor), uncertainties in electron acceptor demand (4-times design factor), and loss of substrate leaving the reaction zone (2-times). The three individual design factors sum to a total design factor of 10. The design or safety factor used for enhanced ISB designs typically ranges from 2 to 10 (AFCEC 2004).

3.5.2 Design Radius of Influence and Injection Volume

Section 3.5.2 describes enhanced ISB design parameters for substrate distribution. In conjunction with sufficient substrate loading, substrate distribution is another critical design parameter. Distribution design parameters ROI, mobile porosity of the targeted formation zone, and injection volume corresponding to the design ROI and mobile porosity.

Design Radius of Influence (ROI)

A design ROI of 12 ft is established for the proposed treatment areas in this work plan addendum. This ROI is based on using the higher-pressure DPT tooling targeting mid-to-deeper intervals of the surficial aquifer that have higher density than shallower intervals and results of previous DPT injections at OU 7. Injection well spacing in proposed treatment areas TA-6 and TA-9 is 18 ft. This well spacing corresponds to a 25 percent overlap for the design radius of influence.

Injected fluids travel principally through the mobile fraction of the surficial aquifer, which is a fraction (or percentage) of the total porosity of the bulk matrix. The mobile fraction or porosity serves as a correction factor to determine the distance injection fluids travel based on the injection volume introduced into the aquifer bulk matrix (Suthersan et al, 2017, 177). Injection tracer testing performed at various locations for porous aquifer media have been used to estimate mobile porosity and established empirical relationships between aquifer mobile fraction, target radial distribution for injection, and injection volume (Suthersan et al. 2017, 177). Equation 3.1 illustrates the mathematical relationship between these parameters (Suthersan et al. 2017, 177).

Equation 3.1: $r_{inj} = \sqrt{\frac{V_{inj}}{\pi \; x \; h \; x \; \theta_m}}$

Where:

h = injection zone thickness
θ_m = mobile fraction (porosity)
V_{inj} = injected volume
π = pi mathematical constant approximately equal to 3.14159

A mobility porosity of 0.02 (2%) is estimated based on the 2007 treatability study performed at OU 7. This falls within the expected range of 0.02 to 0.10 (Payne et al. 2007, 67)[9].

Injection Volume

The estimated mobile porosity (0.02) determined from the 2007 pilot test data is used as a design parameter input along with ROI and target injection interval to determine target injection volumes for the treatment area. Equation 3.2 is a form of Equation 3.1 to solve for injection volume.

Equation 3.2: $V_{inj} = \pi \times h \times r_{inj}^2 \times \theta_m$

Where:

h = injection zone thickness
θ_m = mobile fraction (porosity)
V_{inj} = injected volume
π = pi mathematical constant approximately equal to 3.14159
r_{inj}^2= radius occupied by the injected fluid immediately after injection is completed to the second power.

[9] Payne F.C., J. A. Quinnan, and S. T. Potter 2007. Remediation Hydraulics. CRC Press. Page 67, 432 p.

Appendix B.9 uses Equation 3.2 to calculate injection volumes for each treatment area. Each vertical interval for DPT injection points will receive approximately 68 gallons per linear ft. Table 3-4 has a summary of the injection design and volumes for each injection point and treatment intervals with dosage levels for EVO and sodium lactate.

Table 3-5 Injection Design, Volumes, and Substrate Loading Rates

Treatment Area	Process Option	Dim.	No. of IPs	IP Spacing (ft)	Row Spacing (ft)	Injection Interval (ft BGS)	Vol. per LF (gal)	Vol. per IP (gal)	Total Vol. (gal)	EVO Vol. (gal)	Sodium Lactate Vol. (gal)	Reagent Dosage (%)
TA-02	DPT	45' x 50'	13	20	10	10-26	68	1,088	14,144	617	--	4.6%
TA-03	DPT	45' x 40'	10	20	10	9-24	68	1,020	10,200	491	--	5.1%
TA-05	DPT	40' x 30'	6	20	10	10-28	68	1,224	7,344	434	--	6.3%
TA-06	IW/GF	20' x 50'	1	--	--	10-30	--	--	475	--	425	--
TA-07	DPT	40' x 34'	7	20	10	20-32	68	816	5,712	262	--	4.0%
TA-08	DPT	45' x 34'	8	20	10	17-28	68	748	5,236	233	--	4.1%
TA-09	IW/GF	40' x 30'	4	18	--	16-26	68	--	450	--	400	--
TA-11	DPT	40' x 34'	7	20	10	11-25	68	952	6,664	389	--	6.2%
Total		--	56	--	--	--	--	--	56,372	2,426	825	--

Notes: DPT = direct push technology, IW = injection well, GF = gravity feed, Dim. = dimension of treatment area Width x Length, IP – injection point, ft – feet, BGS. – below ground surface, LF – linear foot, gal – gallon, % - percent, 1 Injection volume is 100% of calculated mobile porosity (0.03) based on injection interval thickness and injection of radius of influence of 12 feet as described in Section 3.5.2 and Appendix B.3.

Reagent Amendments

Amendments to the prepared dilute EVO solution will include sodium bicarbonate for pH buffering and sodium ascorbate to drive the injection water anaerobic for bioaugmentation culture injections. Amendments amounts calculated for sodium bicarbonate and sodium ascorbate are as follows:

-
- 1,555 pounds of sodium bicarbonate for TA-02 corresponding to 0.16 pounds of sodium bicarbonate per cubic foot of aquifer for a treatment zone effective pore volume of 9,720 cubic feet (72,725 gallons[10]). The corresponding load rate is 0.12 pounds per gallon of dilution/chase water.
- 1,166 pounds of sodium bicarbonate for TA-03 corresponding to 0.16 pounds of sodium bicarbonate per cubic foot of aquifer for a treatment zone effective pore volume of 7,290 cubic feet (55,544 gallons[11]). The corresponding load rate is 0.12 pounds per gallon of dilution/chase water.
- 933 pounds of sodium bicarbonate for TA-05 corresponding to 0.16 pounds of sodium bicarbonate per cubic foot of aquifer for a treatment zone effective pore volume of 5,831 cubic feet (43,635 gallons[12]). The corresponding load rate is 0.14 pounds per gallon of dilution/chase water.
- 705 pounds of sodium bicarbonate for TA-07 corresponding to 0.16 pounds of sodium bicarbonate per cubic foot of aquifer for a treatment zone effective pore volume of 4,406 cubic feet (32,969 gallons[13]). The corresponding load rate is 0.13 pounds per gallon of dilution/chase water.
- 722 pounds of sodium bicarbonate for TA-08 corresponding to 0.16 pounds of sodium bicarbonate per cubic foot of aquifer for a treatment zone effective pore volume of 4,544 cubic feet (33,999 gallons[14]). The corresponding load rate is 0.14 pounds per gallon of dilution/chase water.

[10] Treatment zone effective pore volume for Appendix B.1 Part 1
[11] Treatment zone effective pore volume for Appendix B.2 Part 1
[12] Treatment zone effective pore volume for Appendix B.3 Part 1
[13] Treatment zone effective pore volume for Appendix B.5 Part 1
[14] Treatment zone effective pore volume for Appendix B.6 Part 1

- 822 pounds of sodium bicarbonate for TA-011 corresponding to 0.16 pounds of sodium bicarbonate per cubic foot of aquifer for a treatment zone effective pore volume of 5,140 cubic feet (38,463 gallons[15]). The corresponding load rate is 0.13 pounds per gallon of dilution/chase water.
- 135 pounds of sodium ascorbate for TA-02 for making 13,527 gallons of anaerobic water at the rate of 10 pounds per 1,000 gallons of injection water.
- 97 pounds of sodium ascorbate for TA-03 for making 9,709 gallons of anaerobic water at the rate of 10 pounds per 1,000 gallons of injection water.
- 69 pounds of sodium ascorbate for TA-05 for making 6,910 gallons of anaerobic water at the rate of 10 pounds per 1,000 gallons of injection water.
- 54 pounds of sodium ascorbate for TA-07 for making 5,450 gallons of anaerobic water at the rate of 10 pounds per 1,000 gallons of injection water.
- 50 pounds of sodium ascorbate for TA-08 for making 5,003 gallons of anaerobic water at the rate of 10 pounds per 1,000 gallons of injection water.
- 63 pounds of sodium ascorbate for TA-11 for making 6,275 gallons of anaerobic water at the rate of 10 pounds per 1,000 gallons of injection water.

3.6 Treatment Area Configuration and Injection Points

Figure 3-1 shows the layout and configuration of the enhanced ISB treatment areas TA-02, TA-03, TA-05, TA-06, TA-07, TA-08, TA-09, and TA-11. DPT treatment areas have offset rows of injection points with each row having a spacing of 20 ft. between injection points with a row spacing of 10 ft. This provides for a 20% overlap along each row for the design ROI of 12 ft. (perpendicular to groundwater flow) with the row spacing providing a 50% overlap parallel to the direction of groundwater flow. TA-06 uses a single injection well to target well cluster CMT-20 and TA-09 uses four injection wells to target diffuse plume areas in the downgradient area of the VOC plume associated with Pit 2.

[15] Treatment zone effective pore volume for Appendix B.8 Part 1

4. Remedial Action Field Activities

Section 4 describes field activities associated the proposed remedial actions described in the RAWP Addendum. The scope of work for proposed remedial actions will include installation of two monitoring wells for site groundwater monitoring, ISB injections, and remedy performance monitoring.

4.1 Utility Clearance

Utility avoidance will include marking of proposed monitoring well and DPT injection point locations for utility clearance following the DSCR dig permit process including:

- Meadows or their designated contractor will contact the Virginia One Call Center (811) for mark out of utility locations. A minimum of three-day notice is required for 811 notification.
- Meadows will coordinate and provide notification to DSCR Installation Management for utility designation and location in the proposed disturbance areas.
- Meadows will contract with a private utility locating company to survey and mark the proposed disturbance areas (20 ft. scan radius) using ground penetrating radar and magnetic locating equipment.
- The project team will review of available utility maps and other information when proposing subsurface intrusion and disturbance locations (i.e., boring and wells).

The planned locations for utility clearance are in the area of existing well cluster CMT-18 in the Pit 2 monitored area and in the proposed enhanced ISB treatment areas (DPT areas) shown in Figure 3-1.

Per previous regulatory correspondence, an underground injection control permit is not required for the proposed ISB injections (Appendix C).

4.2 Field Survey of Locations and Monitoring Well Survey

The project geodatabase in the geographic information system (GIS) will contain the spatial location information for the proposed monitoring wells and design locations for DPT injection points. For each location, this will include: 1) horizontal coordinates (northing and easting) using the North American Datum of 1983, State Plan – Virginia South, and 2) vertical elevation (North American Vertical Datum of 1988) estimated using the horizontal coordinates in the digital elevation model[16] for OU 7.

The field team will locate the proposed monitoring wells and established DPT injection points in the field using a Trimble handheld global positioning system (GPS) unit with submeter accuracy. The GPS unit has a general design accuracy of 10 millimeters (mm) + 1 part per million for horizontal and 15 mm + 1 ppm for vertical. If boring offsets are required, the project team will use the GPS to determine the revised horizontal coordinates to update the project GIS geodatabase.

Surveying of new monitoring wells by a Commonwealth of Virginia licensed surveyor will occur and include: 1) survey of the horizontal coordinates (northing and easting) of each monitoring well using the North American Datum of 1983, State Plane – Virginia South, and 2) survey of the vertical elevation of each monitoring well using the North American Vertical Datum of 1988 (NAVD88) including the elevation of the top of the inner well casing used for measuring water levels and the ground surface adjacent to the well location.

4.3 Monitoring Well Installation

Proposed actions for this RAWP addendum will include installation of two monitoring wells for remedy monitoring at OU 7 in the area of existing well cluster CMT-18 (see Figure 3-1). Monitoring wells designated OU7-MW-151 and OU7-MW-152 are proposed at adjacent locations to monitor groundwater in the surficial aquifer and confined aquifer, respectively. The proposed spacing of these wells is 7.5 ft. on center east to west perpendicular to groundwater flow. Table 4-1 (page 4-2) has summary information for

[16] Digital Elevation Model, Virginia Geographic Information Network, https://vgin.vdem.virginia.gov/search?tags=dem

the proposed monitoring well construction including boring depth, well completion depth, well type, well screen specifications, and screen interval.

Table 4-1 Monitoring Well Construction

	Depth (ft. BGS)		Well Construction		
Well ID	Boring	Well Completion	Well Type	Well Screen	Screen Interval (ft. BGS)
OU7-MW-151	28.5	28	FM 2-inch Sch 40 PVC	2.0-inch ID, 5 ft. pre-pack 20/40 mesh sand, 0.010-inch slots	23 to 28
OU7-MW-152	50.5	50	FM 2-inch Sch 40 PVC	2.0-inch ID, 5 ft. pre-pack 20/40 mesh sand, 0.010-inch slots	45 to 50

Notes: FM = flush mount, Sch 40 PVC = schedule 40 polyvinyl chloride, ID = inside diameter, ft. BGS = feet below ground surface.

The drilling method for monitoring well installation is hollow-stem auger (HSA) drilling following the procedures outlined in ASTM designation D5784/D5784M-18 Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water Quality Monitoring Devices. The drilling procedure for borings will use 4.25-inch inner diameter HSA (9-inch borehole diameter) to provide for sufficient borehole diameter for installation of single cased monitoring wells (Type II) constructed with 2-inch inner diameter well casing and screen.

HSA operations will involve soil sampling with a 2-ft split barrel sampler following ASTM designation *D1586/D1586M-18 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils* to characterize lithologic conditions and verify well element installation zones. Drilling for OU7-MW-151 will use continuous SPT sampling to 28 ft BGS. Drilling for adjacent OU7-MW-152 will use continuous SPT soil sampling from 20 ft. BGS to 50 ft. bgs.

Monitoring well installation procedures will follow *ASTM designation D5092/D5092M-16 Standard Practice for Design and Installation of Groundwater Monitoring Wells*. A field geologist will oversee drilling operations, sampling, and monitoring well installation and prepare boring logs and construction documentation for each monitoring well location. Boring logs will include the location, geotechnical data, and sample description information for each material identified in the borehole using symbol and word descriptions. Description and identification of soils will follow *ASTM designation D2488-17e1 Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)*. Schematic completion diagrams will document well construction.

Well construction will consist of 2-inch inner diameter, Schedule 40 polyvinyl chloride (PVC) with 10-slot (0.010 inch slotted) PVC screen. Placement of an approximate 3 ft. thick fine-sand filter above the pre-pack screen will create an annular seal, followed by 2-ft. thick bentonite seal, and a bentonite-cement grout within the remaining annulus to the surface. Surface completion with include a flush mouth manhole to match existing grade with affixed well identification labels.

4.4 Well Development

Development of newly installed monitoring wells will commence 24 to 48 hours after emplacement of the final bentonite grout annual seal to allow sufficient time for curing. Well development will remove suspended solids from disturbance of geologic materials during installation and improve the hydraulic characteristics of the filter pack and the hydrologic unit adjacent to the intake. The well development process will include two phases: preliminary development and development. Development will follow procedures identified in ASTM designation D5521/D5521M-18 Standard Guide for Development of Groundwater Monitoring Wells in Granular Aquifers.

Preliminary development will involve mechanical surging, bailing, and potentially other techniques such as air lift pumping to apply sufficient energy in the well to address potential formation damage from the drilling process and remove fine-grained sediment from the screen, filter pack, and geologic formation adjacent to the filter pack. Gradual application of the well development will occur with an increase in intensity, if the well responds to the processes with an increase yield of water and fine-grained sediment.

The final phase of development will involve well pumping with the degree of over pumping, surging, and backwashing determined based on the results of the predevelopment. Development will continue until the discharge water from the well is visibly clear, or until the turbidity of water is reduced to the extent practical. Additional criteria for completion of well development is the stabilization of water quality indicator parameters pH, temperature, specific conductance, oxidation-reduction potential, and dissolved oxygen.

4.5 Enhanced ISB Injection Field Implementation

This section describes field implementation activities and methods for DPT ISB injections. Section 3 describes the proposed injection point locations and specifications for implementation.

4.5.1 Mobilization and Setup

Site mobilization will include delivery of reagents and rental equipment to the site at OU 7. The injection subcontractor will mobilize to the site with personnel, drill rig equipment, injection system equipment, and support materials. Initial activities at the site will include setup of the work area and construction of a secondary containment area to house the injection system. Water tests of all equipment and pumps will verify system integrity. The contractor will use a forklift to stage equipment and reagents within the injection area. EVO is containerized in intermediate bulk container (IBC) totes with a 275-gallon capacity.

Components of the injection system include a high-pressure injection pump equipped with two mix tanks with pneumatic paddle mixers, and a single point manifold equipment with a flow meter and pressure gauge. A single air compressor will power this system. Site control measures will include traffic cones and cone bars to delineate the work area exclusion zone. The injection subcontractor will have spill kits and portable vacuums in the work area for immediate deployment, if needed.

4.5.2 Injection/Reagent Application

Section 4.3.2 describes injection procedures and reagent application for DPT injections and injection wells.

4.5.2.1 DPT Injections

Reagent amendment preparation will include dilution of the vendor provided EVO substrate to the design loading rate (proportions) in Table 3-4. The amount of water needed for the injection will require the use of the installation water system supplied by a hydrant in the OU 7 work area. Following preparation of the injection substrate, the injection subcontractor will thoroughly batch mix in the appropriate mass of sodium bicarbonate for pH buffering and sodium ascorbate to drive the water anaerobic for bioaugmentation culture injections.

DPT drilling (Geoprobe 7822® track unit) will advance temporary injection points and use 1.5-inch diameter, pressure-activated injection probe (nozzles) tooling for reagent application pumped through the drilling rods. Each injection point location will have a 1.5-inch-high pressure, stainless steel threaded injection caps and 1-inch diameter high pressure injection hose connected to the cap. Each cap will have a pressure gauge and pressure relief valve.

Use of the pressure-activated injection probe (activated at a pressure of 100 to 120 psi) will allow for targeted placement of the reagent laterally into the dense strata of the confined aquifer (Potomac Formation). Distribution of the reagent into the confined aquifer will require injection pressures greater than 100 psi because of the higher density of the strata. Once flow is established and the tool is open, pressure may increase or decrease depending on the subsurface conditions. Anticipated injection pressures are in the range of 150 psi to 250 psi. The probe assembly prevents backflow of injection material through the tool string and keep soil out of the tool string during advancement and retraction.

The pressure-activated injection probe can perform top-down or bottom-up injections, with a bottom-up approach planned for the site. Bottom-up injections will start by advancing the tool string to the bottom of the injection interval. Injections will occur at this interval by pumping reagents through the tool string under pressure that in turn activates the injection probe for 360-degree reagent distribution through the probe nozzles. The injection tooling will then work incrementally upward through entire injection interval in each injection point using the same injection process to provide overlapping coverage. A 2-ft. injection interval is anticipated for the site.

If the injectate delivery is not successful to a selected depth interval, injection of the remaining volume will occur at an adjacent depth interval within the same injection point or to the same depth interval at an adjacent injection point. Adjustment of the injection depths and/or volumes will occur in real-time throughout the injections to optimize reagent delivery into the subsurface while limiting the potential for surfacing of the injectate. If daylighting occurs, the injection contractor will discontinue injections at that interval causing daylighting. Site conditions may require adjustment of the conceptual injection layouts and corresponding injection activities if conditions vary significantly from design and implementation assumptions.

The scope of work will include performance of water injection test at the first DPT injection location with approximately 15 gallons of potable water to establish flow rates/pressures and confirm integrity of the injection system and hoses.

DPT injection point abandonment will occur after completion of the injection activities and include removal of the downhole rod string and probe assembly and completely plugging/sealing the boring with bentonite-cement grout. Locations performed in pavement areas will include asphalt or concrete patch to match existing grade. Offsite locations will place native soil on top of the grout to match existing grade.

4.5.2.2 Injection Wells

Preparation for injections at TA-06 and TA-09 will include well inspections to verify integrity. Redevelopment of these wells will occur after inspection to restore any reduced hydraulic connection to the surficial aquifer from previous use in 2018[17]. The field team will containerize the redevelopment water and transfer this water to the Building 40 waste area.

The process option selected for injection of soluble substrate (sodium lactate) is gravity feed following the successful use of this method for the 2017-2018 injections in these injection wells. Gravity feed will include flush water at each well location with the planned quantities of reagent and water identified in Table 3-4.

Setup for gravity feed injections will occur at individual well locations (INJ-211 in TA-06 and INJ-207 in TA-09) and at the well transect in TA-09. The gravity flow setup will include the use of an IBC spill containment pallet when performing gravity feed injections. Appendix A.6 has a manufacturer's technical data sheet for proposed the spill containment pallet. This pallet has a secondary containment capacity of 365 gallons to contain 132% of the full contents of the 275-gallon tote with accommodation for precipitation. The spill pallet has dimensions of 62-inches by 62 inches, a 52-inch by 52-inch deck and has a 28-inch height that when combined with the height of tote drain valve will facilitate gravity flow and adjustment of flow rate. A bucket shelve provides additional containment for connection and dispensing. The spill pallet will also have a drain valve and pullover cover to prevent precipitation from entering the sump when not in use. Forklift slots on the spill pallet facilitate movement and placement of the pallet at the desired locations.

IBC setup for gravity feed operations will include installation of a liquid level gauge in the tote to monitor flow rates, reagent usage, and control application to the design volume (see Appendix A.6). Gravity feed operations setup at each well will include connection of a feed assembly from the IBC tote to the injection well. This assembly will consist of 0.75-inch braided PVC hose that has a 2-inch female National Pipe Straight (NPS) fitting to connect directly to the IBC tote that has a 2-inch drain valve with male-quick disconnect coupler. This PVC hose will extend from the tote and connect to a well head assembly with a coupled fitting configured with a drop tube for gravity feed. The well head assembly will have a fitting to attach a pressure indicator for injection process monitoring.

Setup for gravity injections will include traffic cones and cone bars to delineate the work area exclusion zone. Other actions for setup will include staging and deployment of spill prevention measures in addition to the IBC spill pallet.

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[17] Injection well locations for inspection include INJ-211 in TA-06 and INJ-163, INJ-164, INJ-165, and INJ-207 in TA-09. USACE used these wells for gravity feed injections of sodium lactate followed by flush water to clear well screens.

4.6 Injection Process Monitoring

Table 4-2 describes process monitoring that will occur during the injections performed at OU 7. Injection data will track injection progress relative to the design and identify variations in physical and hydraulic properties of the confined aquifer. Water level measurements (electronic water level indicator) at monitoring well locations in the vicinity of the injection areas will monitor hydraulic influence from injections. Visual checks and water quality measurements at monitoring wells in the vicinity of the injection areas will evaluate distribution of reagents in the targeted areas. Leading indicators at monitoring wells include visual evidence of reagents (cloudy, watercolor change, and odor) and changes in water quality parameters including increased specific conductivity and turbidity levels.

Table 4-2 Remedy Installation Monitoring

Monitoring Element	Parameters	Measures	Locations	Frequency
Injection data	Daily field conditions, injection intervals, measured pressures, injection volumes, and flows at each injection location	Injection performance vs. design, variations in hydrostratigraphy	Equipment system and injection points	Daily and cumulative subcontractor injection logs
Hydraulic data	Water level measurement	Injection effects on aquifer	TA-02: AEHDG-11, MW-36, DMW-35A, MW-123 TA-03: CMT-21, MW-60, MW-68 TA-05: DMW-29A, AEHDG-10, EBF-05S, INJ-154, INJ-155 TA-06: CMT-20, EBF-05S TA-07: MW-85, MW-48, MW-47, MW-55, MW-41, INJ-205 TA-08: CMT-18, INJ-206, MW-144, MW-151 TA-09: CMT-24, MW-80, MW-82, MW-83 TA-11: MW-97, MW-108, MW-109, MW-96, MW-95, INJ-202, MW-139	Baseline before injections Minimum daily during injections
Visual parameters	Bailer checks of monitoring wells in vicinity of injection area	Distribution of injectate in treatment area		
Water quality parameters	pH, SC, DO, ORP, temperature, and turbidity	Injectate lateral and vertical distribution and radius of influence		
Aboveground	Inspection of surface around injection areas	Reagent surfacing	Injection areas and vicinity	During active DPT injection

Notes: gpm = gallons per minute, psi = pounds per square inch, SC = specific conductance, DO = dissolved oxygen, ORP = oxidation reduction potential, temp = temperature.

4.7 Investigative Derived Material Management

Investigative derived material (IDM) generated during implementation of remediation injection related activities will include empty reagent intermediate bulk container (IBC) totes, containerized rinse water from totes, personal protective equipment, packaging materials, etc. Monitoring and sampling activities will include purge and decontamination water, personal protective equipment, and disposable materials used during sampling activities.

Table 4-3 identifies planned IDM containerization and disposal based on previous work conducted at OU 7 and DSCR.

Table 4-3 Investigative Derived Material Containerization and Disposal

IDM Type	Container	Expected Waste Characterization	Anticipated Transportation and Disposal
Soil cuttings from monitoring well drilling	Place in UN certified (Solid) 55-gallon, open head drum	Non-Hazardous Waste (Aqueous), Waste	Shamrock Richmond VA

IDM Type	Container	Expected Waste Characterization	Anticipated Transportation and Disposal
		characterization testing in Table 4-3.	
Personal protection equipment	Place in trash bag and dispose as general solid waste in dumpster at Bldg.40	General solid waste (no testing)	Solid waste for DSCR
Excess packaging materials and disposable items	Place in trash bag and dispose as general solid waste in dumpster at Bldg.40	General solid waste (no testing)	Solid waste for DSCR
IBC rinse water, decontamination water, purge water, new well development water, and injection well redevelopment water	Consolidate into holding containers at Building 40 for Vacuum truck pump out	Non-Hazardous Waste (Aqueous), Waste characterization testing in Table 4-4.	Shamrock Richmond VA
Empty reagent 275 gallon totes	Empty reagent 275 gallon totes, pickup at OU 7	Offsite recycling	Shamrock Richmond VA

Notes: IDM = investigative derived material, OU 7 = operable unit 7, PPE = personal protection equipment, Bldg. = building

Waste characterization will include composite sampling and field subsampling following ASTM Designation *D6051-15 Standard Guide for Composite Sampling and Field Subsampling for Environmental Waste Management Activities*. This sampling will determine if IDM is non-hazardous or hazardous according to the Code of Federal Regulations (CFR) 40 CFR Part 261 – Identification and Listing of Hazardous Waste and also include parameter testing required by the local non-hazardous treatment, storage, and disposal facility (Shamrock Environmental Richmond Virginia).

Table 4-4 Waste Characterization Parameter Analysis

Characteristic	Regulatory	Method	Parameters	Matrix
Ignitability	40 CFR §261.21	SW846 Method 1030 SW846 Method 1010A	Ignitability Ignitability	Solid Aqueous
Corrosivity	40 CFR §261.22	SW846 Method 9045D SW846 Method 9040C	pH pH	Solid Aqueous
Reactivity	40 CFR §261.23	No test	No test	No reactive media identified at site
Toxicity	40 CFR §261.24	SW846 Method 1311 SW846 8260 SW846 8270 SW846 8081 SW846 8051 SW846 6010 SW846 7470/7471	Table 1 - 40 CFR §261.24 Volatile organics Semi-volatile organics Pesticides Chlorinated herbicides Metals/metalloids Mercury	Solid and Aqueous
Other		SM 2320B SM 2540C SW846 8082A	Alkalinity Total dissolved solids Polychlorinated biphenyls (PCBs)	Aqueous Aqueous Solid and Aqueous

Notes: 40 CFR = Title 40 Code of Federal Regulations

4.8 Spill Response Procedures

The injection related work will include implementation of appropriate product handling procedures and spill response procedures, as applicable. Planned measures will include setup of a secondary containment area to house the injection system including mixing equipment and transfer hoses. Planned measures for gravity feed injections will include the use of IBC spill containment pallets.

The injection contractor will have additional containment/berming materials in the case where injected reagents reach the ground surface. If daylighting occurs, the contractor will place containment/berm materials around the affected area until all reagents are properly removed. The injection contractor will have spill kits and portable vacuums in the work area for immediate deployment if a spill or injectate surfacing occurs during site operations. Kingsland Creek is located approximately 360 ft. south (downgradient) of TA-09 and 310 ft. south (downgradient) of TA-06. Injections are not expected to daylight based on the gravity feed methods used and depth. During injection operations, the field team will implement measures to monitor for potential daylighting and have spill containment, sorbent, other materials, and recovery equipment available for deployment. If daylighting occurs, the injection contractor will immediately discontinue injection operations at the location causing daylighting. The field team will maintain spill containment until all reagents are properly removed.

5. Remedy Verification and Performance Monitoring

Remedy performance monitoring will evaluate the enhanced ISB actions for the confined aquifer at OU 7. The technical approach will include baseline monitoring before injections and post-injection performance monitoring at 14 monitoring wells. The proposed network of monitoring wells for performance monitoring is shown in Figure 3-1 (page 3-2) includes:

- Hot spot monitoring wells AEHADG-11 and MW-36 in treatment area TA-02 (Pit 1 monitored area).
- Hot spot monitoring well CMT-21-2 and well MW-68 in treatment area TA-03 (Pit 1 monitored area).
- Monitoring well DMW-29A in treatment area TA-05 (Pit 1 monitored area).
- Monitoring well CMT-20-3 in treatment area TA-06 (Pit 1 monitored area).
- Monitoring wells MW-85 and MW-48 in treatment area TA-07 (Pit 2 monitored area).
- Monitoring well CMT-18-5 in treatment area TA-08 (Pit 2 monitored area).
- Monitoring wells MW-80 and MW-82 in treatment area TA-09 (Pit 2 monitored area).
- Monitoring well MW-148 located near the installation fence line downgradient of treatment area TA-09 (Pit 2 monitored area).
- Monitoring wells MW-109 and MW-95 in treatment area TA-11 (Pit 3 monitored area).

5.1 Baseline Monitoring

Baseline groundwater monitoring for the enhanced ISB injections will occur as part of the 2025 Annual Monitoring Event for OU 7 scheduled for March 2025. This monitoring event includes 87 surficial aquifer monitoring wells including the 14 performance monitoring wells identified in Table 5-1 (page 5-4) identifies the 14 monitoring well locations and scope of baseline monitoring. Proposed new monitoring well OU7-MW-151 will have baseline sampling completed after installation/development and before ISB injections. The baseline data for 2025 will provide comparative data for ISB performance evaluations. The scope of analysis for baseline monitoring will include field water quality parameters, VOCs, ferrous iron, and geochemical parameters including TOC, anions, sulfide, alkalinity, manganese, ethene, ethane, methane, and carbon dioxide.

5.2 Performance Monitoring

ISB performance monitoring will occur after completion of the injections and include sample collection in the fourth quarter 2025 (calendar year), March 2026 as part of annual monitoring, and the fourth quarter 2026 (calendar year). An adaptive approach will determine the frequency and scope of sampling beyond 2026. Table 5-1 (page 5-4) identifies the 15 monitoring well locations and the scope and schedule for performance monitoring.

5.3 Monitoring Procedures

Prior to sampling, the annual sampling events performed in May 2025 and May 2026 will include a synoptic round of water level measurements at all monitoring well locations screened in the surficial aquifer at OU 7. The water level data will input into development of potentiometric surface contour maps to characterize groundwater flow patterns, hydraulic gradient, and to calculate the velocity of groundwater flow. The field team will collect water level measurements at each performance monitoring well prior to sampling.

Exhibit 5-1 (page 5-7) has summary information on groundwater sampling procedures for baseline and performance monitoring that references detailed information contained in the project QAPP (AECOM-Meadows 2024a).

Table 5-1 ISB Baseline and Performance Monitoring Program: OU 7 Surficial Aquifer (2025-2026)

Well ID	Screened Interval		Location	Baseline Q1 Annual 2025	Inj. Event Q3 2025	Q4 2025	Q2 Annual 2026	Q4 2026	Field Water Quality Parameters	VOCs Method SW846 8260D	TOC Method SW846 9060A	Ferrous Iron Method 8146	Anions Method SW846 9065A	Sulfide Method SM4500-S2-F-2011	Mn Method SW846 6020	Alkalinity Method SM2320B-2011	Dissolved Gases Method RSK-175	CO2 Method SM4500-CO2-D	qPCR
	Depth (ft. BGS.)	Elev ft. (NAVD88)																	
AEHADG-11	6.1-16.1	90.2-80.2	TA-02	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	X
OU7-MW-36	9.0-19.0	87.3-77.3	TA-02	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
CMT-21-2	18.5-20.0	76.0-74.5	TA-03	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	X
OU7-MW-68	5.0-15.0	89.9-79.9	TA-03	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
DMW-29A	23.0-28.0	71.7-66.7	TA-05	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
CMT-20-3	18.5-20.0	77.7-75.70	TA-06	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
OU7-MW-85	22.5-25.0	76.5-74.0	TA-07	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
OU7-MW-48	15.0-25.0	83.9-73.9	TA-07	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
CMT-18-5	26.5-28.0	70.1-68.8	TA-08	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
OU7-MW-151	23.0-28.0	73.8-68.8	TA-08	X[1]	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
OU7-MW-80	16.0-21.0	78.9-73.9	TA-09	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
OU7-MW-82	8.0-13.0	86.6-81.6	TA-09	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
OU7-MW-148	8.0-18.0	76.8-66.8	TA-09	X	None	X		X	X	X	X	X	X	X	X	X	X	X	
OU7-MW-109	9.0-14.0	89.6-84.6	TA-11	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	
OU7-MW-95	9.0-14.0	88.1-83.1	TA-11	X	Process Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X	

Notes: [1] new monitoring well location with planned installation before injections, baseline sampling will occur after well development and before injections, ft. = feet, ft. BGS. = feet below ground surface, Elev NAVD88 = elevation North American Vertical Datum of 1988, UG = upgradient, DG = downgradient, TAC-1 = treatment area confined aquifer in OU 3 upgradient of installation fence line, TAC-2 = treatment area confined aquifer in offsite OU 7 area. Q1 = quarter 1 of calendar year, Q2 = quarter 2 of calendar year, Q4 = quarter 4 of calendar year, field water quality parameters = water quality parameters including pH, dissolved oxygen, specific conductivity, oxidation reduction potential, and turbidity, VOC = volatile organic compound, TOC = total organic compound, Anions incudes chloride, nitrite as nitrogen, nitrate nitrite as nitrogen, nitrite as nitrogen, and sulfate, Mn = manganese, alkalinity includes total alkalinity, bicarbonate alkalinity as CaCO3, carbonate alkalinity as CaCO3, CO2 = carbon dioxide, qPCR = quantitative polymerase chain reaction with analysis parameters including Dehalococcoides, tceA Reductase, BAV1 Vinyl Chloride Reductase, and Vinyl Chloride Reductase.

Exhibit 5-1 Summary of Monitoring Procedures

Procedure Element	Description	Reference
Logs and record keeping	Sampling documentation in logbooks, recordkeeping, sample labeling, and chain of custody	QAPP Worksheets #26 and #27 QAPP Worksheet #21 SOPs P-01, P-02
Sample handling, storage, and shipping	Methods for sample handling, storage, and shipping	QAPP Worksheets #26 and #27, #29 QAPP Worksheet #21 SOP P-03
Planning, preparing, and documenting groundwater sampling events	Methods for planning, preparing, and documenting groundwat3er sampling events	QAPP Worksheets #21 SOPs P-04, P-05, QAPP Worksheet #29 QAPP Appendix B.1 Groundwater sampling form
Groundwater purging and sampling method	Low-flow purging and sampling using a peristaltic pump, and new disposable tubing for each location	QAPP Worksheet #21, SOPs P-07, P-08, P-12, P-13, P-14, P-15, P-16
Field preservation of samples	Methods for preserving samples	QAPP Worksheets #19 and #20 QAPP Worksheet #21, SOP P-09
Field analysis for Ferrous Iron	Field analysis of ferrous iron by Method 8146	QAPP Worksheet #21, SOPs P-11, P-12
Field measurement of water quality parameters and use of flow-through cell	Field measurement of pH, temp, DO, SC, and ORP	QAPP Worksheet #21, SOPs P-19, P-20
Field measurement of turbidity	Field measurement of turbidity	QAPP Worksheet #21, SOPs P-21, P-22
Equipment decontamination	Decontamination of field equipment	QAPP Worksheet #21, SOP P-25
Field measurements with photoionization detector	Use of photoionization detector for field screening of VOCs	QAPP Worksheet #21, SOP P-30

Notes: temp = temperature, DO = dissolved oxygen, SC = specific conductivity, ORP = oxidation reduction potential, SOP = standard operating procedure, QAPP = quality assurance project plan.

Exhibit 5-2 identifies the quality assurance and quality control samples established in the project QAPP (Worksheet #20) for annual monitoring at OU 7. The baseline and annual sampling will follow the established locations in the QAPP. Quarterly performance monitoring events will use the same matrix spike/matrix spike duplicate and field equipment blank locations for annual sampling (Work Sheet #18) and reduce the number of field duplicates to one at location AEHADG-11.

Exhibit 5-2 Quality Assurance/Quality Control Samples: Baseline/Performance Monitoring

Sample Event	Field Duplicate[1]	MS/MSD[2]	Field EB[3]	Trip Blank[4]
Annual Events	AEHADG-11	OU7-MW-148	NA	1 per cooler of VOCs
Performance Monitoring	AEHADG-11	OU7-MW-148	NA	1 per cooler of VOCs

Notes: MS/MSD = matrix spike/matrix spike duplicate., EB = equipment blank, [1]duplicate samples analyzed for the same parameters as associated normal sample, [2]matrix spike/matrix spike duplicate analyzed for the same parameters as normal samples except for microbial analysis, [3]equipment blank samples analyzed for the same parameters as normal samples except for alkalinity and microbial analysis, [4]trip blank sample analysis for volatile organic compounds, NA = equipment not applicable based on sampling method used (peristaltic pump with new disposable tubing at each location).

5.4 ISB Performance Evaluation

Performance evaluations for the proposed ISB actions in this work plan will use multiple lines of evaluation as generally described in the 2013 RD/RAWP for OU 7 (AECOM 2013). Table 5-2 has a summary of planned ISB performance evaluations relative to ISB objectives.

Table 5-2 Enhanced ISB Performance Evaluation

Evaluation Element	Description
Reagent distribution	Evaluate reagent distribution and persistence relative to treatment design Perform injection process monitoring to evaluate reagent distribution Perform post-injection WQP measurements and sampling (TOC, geochemical) ISB objectives: distribute reagents across design treatment areas, enhance downgradient treatment zones for diffuse VC plumes in downgradient areas of Pit 1 and Pit 2 monitored plume areas.
Post-injection concentration trends	Evaluate parameter trends along groundwater flow path across barrier areas and at each performance well (WQP, VOCs, TOC, geochemical) Compare parameter concentrations to baseline + historical results Time series analysis: visualizations, exploratory data analysis, statistics, trend analysis ISB objectives: accelerate reduction of PCE, TCE, cDCE, and VC concentrations, reduce accumulation of cDCE/VC in plume areas.
Contaminant mass	Evaluate reduction of contaminant mass using chemical and geochemical data Time series analysis: evaluate changes in molar concentrations and ratios along flow paths across treatment areas, at individual wells, plume area analysis Evaluate depletion of electron acceptors and donors Evaluate increases in metabolic by-product concentrations Favorable succession of redox conditions ISB objective: reduce contaminant mass (molar) in target treatment/plume areas.
Contaminant flux	Evaluate changes in contaminant flux across treatment areas using well transects by integrating concentration and flow data Time series evaluation: individual monitoring events, changes over time ISB objective: reduce overall contaminant flux from remaining source areas and to downgradient areas near the fence line.
Plume stability and extent	Evaluate changes in plume extent (area) by comparing pre-and post-ISB modeled plumes Perform time series statistical evaluations for plume stability ISB objective: mitigate plume instability and reduce plume extent in the offsite area.
Biodegradation rates	Use data modeling to calculate rate of change of contaminant mass over time Compare estimates of pre-ISB biodegradation rates with update estimates after ISB actions Microbiological laboratory or field data that support the occurrence of biodegradation and provide estimated rates of biodegradation ISB objective: increase biodegradation rates for PCE, TCE, cDCE, and VC.

Notes: WQP = water quality parameters including pH, dissolved oxygen, specific conductivity, oxidation reduction potential, and turbidity, VOCs = volatile organic compounds, TCE = trichloroethene, cDCE = cis-1,2-dichloroethene, VC = vinyl chloride, ISB = in situ bioremediation.

6. Permitting

Section 6 discusses permitting requirements and activities for implementing ISB actions at OU 7.

6.1 Drilling and Subsurface Installations

Monitoring well drilling, DPT drilling, and subsurface disturbance are subject to the DSCR permitting system requirements for underground facilities protection. Meadows will clear drilling and subsurface injection activities through the DSCR excavation permitting system and obtain an excavation permit prior to commencing work. Subsurface utility mark outs and clearing will occur prior to commencing any intrusive activities as described in Section 4.1.

Monitoring well installation will not require permitting with local or Commonwealth of Virginia regulatory agencies.

6.2 Site Security and Communications

Meadows will coordinate all remedial activities with DSCR operations personnel to ensure compliance with DSCR physical and operational security requirements. This will include developing transit corridors for vehicles and transport of equipment and materials, participating in training, and participating in security briefings, as appropriate.

Oversight personnel and the project management (PM) Team will coordinate with DSCR personnel to establish specific lines of communication during remedial activities. These will include providing specific contacts for each phase of work.

6.3 Health and Safety

Remediation work at OU 7 will occur under the project health and safety plan and accident prevention plan, which complies with the applicable requirements of the Occupational Safety and Health Agency General Industry Standards (29 Code of Federal Regulations 1910), Construction Safety Standards (29 Code of Federal Regulations 1926), and Hazardous Waste Operations and Emergency Response Standards (29 Code of Federal Regulations 1910.120) and applicable requirements of USACE Engineer Manual 385-1-1. In addition, the safety program for all work activities will coordinate with applicable DSCR operational and emergency response policies and programs.

The PM Team will designate a task Site Safety Officer (SSO). The SSO will oversee health and safety requirements for task related field activities. The SSO will confer and coordinate with DSCR and/or USACE Safety Officer to identify hazards associated with the planned remedial activities and will ensure any concurrent activities and field work do not interfere with installation activities (in cooperation with the PM Team).

7. Reporting

A project technical memorandum will summarize completed remedial action installation activities. Annual reports for OU 7 will report the results of remedy implementation, performance monitoring, MNA and LTM and include data evaluations described in Table 5-2 and integrated analysis of remedy performance. Periodic updates of remedy performance and progress will occur during regulatory planning team meetings and for semi-annual restoration advisory board meetings.

8. References

AECOM. 2010a. Final Treatability Study Results for Operable Units 6 and 7, Defense Supply Center Richmond, Prepared for Defense Logistics Agency and Defense Supply Center, July 2010.

AECOM. 2010b. Final Revised Focused Feasibility Study for Operable Unit 7, Defense Supply Center Richmond, Prepared for Defense Supply Center Richmond, Defense Logistics Agency, and Air Force Center for Engineering and the Environment, July 2010.

AECOM. 2013. Final Remedial Design/Remedial Action Work Plan for Operable Unit 7, Defense Supply Center Richmond, Prepared for Defense Logistics Agency and Defense Supply Center, May 2013.

AECOM. 2015. Final Technical Memorandum, Remedial Design/Remedial Action Work Plan Addendum, Operable Unit 7, Defense Supply Center Richmond. December 2015.

AECOM-Meadows. 2021a. 2019 Annual Monitoring Report for Operable Unit 7, Prepared for Defense Logistics Agency and U.S. Army Corps of Engineers, Baltimore, March 2021.

AECOM-Meadows. 2021b. Final Operable Unit 7 – 2021 Remedial Design/Remedial Action Work Plan Addendum, Prepared for Defense Logistics Agency and U.S. Army Corps of Engineers, Baltimore, August 27, 2021.

AECOM-Meadows. 2024a. Draft Quality Assurance Project Plan, Prepared for Defense Logistics Agency and United States Army Corps of Engineers, Baltimore District, November 2024.

AECOM-Meadows. 2024b. Final Fiscal Year 2024 Annual Report, Operable Unit 7 Defense Supply Center Richmond, Prepared for Defense Logistics Agency and United States Army Corps of Engineers, Baltimore District, December 2024.

Army Chemical Systems Laboratory. 1981. Installation Assessment of Defense General Supply Center, Virginia, Prepared by Army Chemical Systems Laboratory, Environmental Technology Branch Prepared for Defense General Supply Center and U.S. Army Toxic and Hazardous Materials Agency. August 1981.

Borden, Robert. 2006. Protocol for Enhanced In Situ Bioremediation Using Emulsified Edible Oil, Prepared for Environmental Security Technology Certification Program (ESTCP) by Solutions-IES, May 2005.

Dames & Moore. 1989. Remedial Investigation Fire Training Area, Defense General Supply Center, Richmond, Virginia. May 31, 1989.

DSCR. 2012. Final Record of Decision – Operable Unit 7, Fire Training Area Groundwater, Defense Supply Center Richmond. May 2012, Revision 5.

Engineering-Science, Inc. 1994. Final Field Investigation Report for Fire Training Area. Defense Supply Center Richmond, Richmond, Virginia. February 1994.

Law. 1996a Final Remedial investigation Report Addendum for Fire Training Area. Defense Supply Center Richmond, Richmond, Virginia. Law Engineering and Environmental Services. January 1996.

Law. 1996b. Final Focused Feasibility Study for OU 7- Fire Training Area Groundwater. Defense Supply Center Richmond, Richmond, Virginia. Law Engineering and Environmental Services. April 1996.

Law. 1997. Final Pilot Test Report for Fire Training Area Groundwater. Defense Supply Center Richmond, Richmond, Virginia. Law Engineering and Environmental Services. January 1997.

Law 1999. Letter Addendum to Operable Unit 7 Feasibility Study, Defense Supply Center Richmond, Law Engineering and Environmental Services. September 8, 1999.

MACTEC. 2005. Final Principal Threat Source Material Removal Action Completion Report. Operable Unit 4 - Former Fire Training Area, Defense Supply Center Richmond. Richmond. Virginia. Revision I. July 2005.

MACTEC. 2006a. Final Supplemental Feasibility Study Investigation Report (includes Operable Unit 7), Defense Supply Center Richmond, Richmond, Virginia. February 2006.

MACTEC. 2006b. Conceptual Site Model Report, Defense Supply Center Richmond, Richmond, Virginia. August 2006.

Terra Systems. 2021. Buffer Studies for Soil and Groundwater at Operable Unit 6, September 10, 2021.

USACE. 2017. Final OU 7 Remedial Design/Remedial Action Work Plan Addendum, Defense Supply Center Richmond, Virginia, November 17, 2017.

Appendix A Remedy Design Support Information

A.1 EVO Technical Data Sheet and Safety Data Sheet

Patented *Injection Ready* 60% SRS®-SD Small Droplet Emulsified Vegetable Oil (EVO) Substrate for Maximum Radius of Influence

United States Patent #RE40,448

Terra Systems patented "*injection ready*" **60% SRS®-SD** Small Droplet Emulsified Vegetable Oil Substrate is added to the groundwater to rapidly generate reducing conditions and provide the necessary carbon and hydrogen to support native or introduced microorganisms (*Dehalococcoides*) for the biodegradation of chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) to innocuous end products including ethene and ethane.

Key Communication Points

- The 0.6 um droplet size results in better substrate distribution for the client, easier substrate injectability for the driller and fewer injection points for the consultant thereby lowering costs
- Provides 73% fermentable carbon
- Has >98% biobased content
- Includes sodium or potassium lactate to kick-start the anaerobic degradation process, nutrients and Vitamin B_{12} a micronutrient, which *He et al. 2007* demonstrated is an important micronutrient to enhance dechlorination activity.
- The nonionic emulsifier (does not have a charge) results in better distribution and bacteria contact for the client because the substrate does not readily stick to the positively charged soil particles.
- It arrives as a homogenous ***injection ready substrate***, which results in lower field labor costs from inefficient field mixing.
- Proven effective with PCE, TCE, TECA, DNAPL (Sabre Project), Perchlorate, TCA, Cr^{6+}, TNT, Uranium and Nitrate.
- Proven effective at military installations (Andrews AFB, Dover AFB, Beale AFB, Ft. Gillem, Fort Dix, Camp Bullis, Aberdeen Proving Ground, etc.), dry cleaners, semiconductor manufacturers, fabricators and manufacturing firms that use and clean metal parts (air conditioners, dishwashers, etc.).

Table I: SRS®-SD Small Droplet Emulsified Vegetable Oil Substrate Specifications

Ingredient	Percent	Description	Benefit
Food Grade U.S. Grown Soybean Oil	60%	Locally sourced soybean oil.	Long lasting slow release source of carbon and hydrogen.
Food Grade Soluble Substrate	5.5%	Rapidly biodegradable soluble substrate	Fast release source of carbon and hydrogen to rapidly generate anaerobic conditions
Proprietary Food Grade Nutrients	<1%	Proprietary organic and inorganic nutrients such as yeast extract, nitrogen and phosphorus.	Nutrients have been demonstrated to support the growth of the anaerobic microbial population.

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Proprietary Food Grade Emulsifiers, Preservatives and other Organics	7.5%	Proprietary nonionic emulsifier and other organics	Maximum radius of influence due to small droplet size and nonionic emulsifier in moderate to fine sand, silt and clay aquifers
Vitamin B_{12}	<1%	250 µg/L of Vitamin B_{12}	He et al. 2007 demonstrated Vitamin B_{12} to be an important micronutrient to enhance dechlorination activity with 25 µg/L providing maximum stimulation
Median Oil Droplet Size (microns)	NA	0.6 µm	Maximum radius of influence due to small droplet size and nonionic emulsifier in moderate to fine sand, silt and clay aquifers
pH	6.5 - 7	6.5 - 7	Optimum microbial activity
Organic Carbon (wt%)	73%		60% soy bean oil and 13% from lactate, nutrients, emulsifiers and VB_{12}
Zero Carbon Footprint	0%		Certified by The CarbonNeutral Co., SRS® has a carbon neutral footprint when it arrives at the job site.
Biobased Content	98%		Certified under USDA Biopreferred Program

Injection Ready Manufactured Emulsion

Terra Systems ***Family*** of patented SRS® emulsified vegetable oil substrates

- Arrives injection ready
- Nutrients are premixed into the SRS® during the manufacturing process - ensuring a homogenous substrate and avoiding the additional labor cost of mixing in the field
- Vitamin B_{12} is premixed into the SRS® during the manufacturing process - ensuring a homogenous substrate and avoiding the additional labor cost of mixing in the field
- Sodium lactate, which kick starts the anaerobic process is premixed into the SRS® during the manufacturing process - ensuring a homogenous substrate and avoiding the additional labor cost of mixing in the field
- Arrives at the site with a zero carbon footprint
- Certified under the USDA Biopreferred Program with >98% biobased content

Result: A consistent emulsified vegetable oil substrate, which arrives *ready to inject* for maximum distribution in the aquifer.

It Avoids Field Mixing and Their Hidden Costs Such As:

- The cost of inadequate distribution due to variable droplet size and emulsion inconsistency
- The inability to accurately determine if you have 100% emulsification.

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- The lack of QA/QC in the field

<u>Terra Systems QA/QC</u>

Terra Systems owns and operates a state-of-the-art US based "*just-in-time*" manufacturing plant with an in-house quality control laboratory for strict quality assurance of the emulsion, droplet size and pH. A Microscope with "***Droplet Size Calculation Software***" calculates the "***mean***" droplet size for each batch of SRS® before we transfer to a bucket, drum, tote or tanker for shipment to the customer. With every shipment, we include a QA/QC sheet for the actual batch that the customer receives. Included are:

- **Date Manufactured**: Freshly manufactured products have a longer shelf life in the field. Avoid buying substrates that have been stored for >1 month as fermentation can start and the pH will be negatively impacted.
- **pH**: We provide the pH of the product the day it is shipped
- **Droplet Size**: is a key measure of how effective the client can distribute the substrate in the sub-surface. The smaller the droplet, the more effective the distribution and ease of injection.
- **Lot#'s for all the ingredients**: This is especially useful if the driller accidentally hits a discharge pipe and the consultant needs to provide documentary evidence of what exactly was injected to the regulatory agency. All of our ingredients are GRAF (generally recognized as safe).

Terra Systems Manufacturing Quality Control Checklist

I. Product Information

Parameter	Value
Customer or Site	Young-Rainey STAR Center, Largo, Florida
Product manufactured	60% SRS®-SD
Date manufactured	November 4th, 2019
Lot#	A2701
Customer packaging	275 Gallon IBC Totes
Date shipped	November 8th, 2019

II. Ingredients Information

Ingredient	Lot#	Manufacturing Engineer
Soy Bean Oil	11182014	Erich H.
60% Sodium Lactate	M-1406-018	Erich H.
Emulsifiers	G270059 885648	Erich H.
Nutrients	CYE06060960	Erich H.
Vitamin B_{12}	11765655	Erich H.
Water	-	Erich H.

III.Physical Parameters

Parameter	Value
Mean Droplet Size (µm)	0.61
pH	7.2

Manufacturing Engineer

11/7/2019
Date

Production Supervisor

11/8/2019
Date

Packaging: Terra Systems patented SRS® Family of EVO substrates can be shipped in 5-gallon buckets, 55-gallon drums, 275-gallon IBC totes, 275-gallon cardboard totes or bulk tankers.

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For More Information Call Michael Free at 302-798-9553 or Email: mfree@terrasystems.net

Patented *Injection Ready* 60% SRS®-SD Small Droplet Emulsified Vegetable Oil (EVO) Substrate for Maximum Radius of Influence

United States Patent #RE40,448

SAFETY DATA SHEET

1. Product Identification

Synonyms:	60% Small Droplet Slow Release Substrate (SRS®-SD) Emulsified Vegetable Oil Substrate (EVO)
Recommended Use:	Treatment of groundwater contaminated with chlorinated solvents and other anaerobically degradable compounds.
Supplier:	Terra Systems, Inc. 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Telephone (302) 798-9553 Fax (302) 798-9554 www.terrasystems.net

2. Hazards Identification

Emergency Overview	
Caution:	May cause eye irritation.
Health Rating:	1 - Slight
Flammability Rating:	1 - Slight
Reactivity Rating:	1 - Slight
Contact Rating:	1 - Slight
Protective Equipment:	Goggles; Proper Gloves
Storage Color Code:	Green (General Storage)
Potential Health Effects	
Inhalation:	Not expected to be a health hazard. If heated, may produce vapors or mists that irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air.
Ingestion:	Not expected to be a health hazard via ingestion. Large doses may produce abdominal spasms or diarrhea.
Skin Contact:	No adverse effects expected. May cause irritation or sensitization in sensitive individuals.
Eye Contact:	May cause mild irritation, possible reddening.
Chronic Exposure:	No information found.
Aggravation of Pre-existing Conditions:	No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Soy bean oil	Soya oil	8001-22-7	60%	No
Emulsifiers and proprietary nutrient package containing nitrogen, phosphorus and vitamin B_{12}		Mixture	7.5 - 10%	No
Sodium lactate	2-hydroxpropionic acid sodium salt	72-17-3	5.5%	Yes
Water		7732-18-5	Difference	No

The emulsifiers and nutrient package mixture is a trade secret and consists of ingredients of unknown acute toxicity.

4. First Aid Measures

Inhalation: Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty.

Ingestion: If large amounts were swallowed, give water to drink and get medical advice.

Skin Contact: Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact: Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.

5. Fire Fighting Measures

Fire: Flash point: >200 C (>392 F). Not considered to be a fire hazard. Isolate from heat and open flame.

Explosion: Not considered to be an explosion hazard. Closed containers may explode if exposed to extreme heat.

Fire Extinguishing Media: Dry chemical, foam, or carbon dioxide. Water spray may be ineffective on fire but can protect fire-fighters and cool closed containers. Use fog nozzles if water is used.

Special Information: In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Clean-up personnel may require protective clothing. Absorb in sand, paper towels, “Oil Dry”, or other inert material. Scoop up and containerize for disposal. Flush trace residues to sewer with soap and water. Containerized waste may be sent to an approved waste disposal facility.

7. Handling and Storage

Store in a cool, dry, ventilated area. Do not store in sunlight or above 32 C (90 F). Keep container tightly closed and upright when not in use to prevent leakage. Observe all warnings and precautions listed for the product. Protect against physical damage.

If container begins to bulge, open cap slowly to release carbon dioxide from biological activity on the SRS-SD and call TSI.

Containers of this material are not hazardous when empty since they do not contain vapors or harmful substances; if drum or tote is observed to bulge, keep cap off as pressurization can occur on empty container with caps in place unless container is thoroughly rinsed.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:	None established.
Ventilation System:	Not expected to require any special ventilation.
Personal Respirators (NIOSH Approved):	Not expected to require personal respirator usage.
Skin Protection:	Wear protective gloves and clean body-covering clothing.
Eye Protection:	Use chemical safety goggles and/or a full-face shield where splashing is possible. Provide readily accessible eye wash stations and safety showers.
Slips, Trips, and Falls:	Material is slippery when spilled. Clean up with sand, paper towels, "Oil Dry", or other inert material.

9. Physical and Chemical Properties

Appearance:	White liquid.
Odor:	Vegetable oil.
Solubility:	Miscible in water.
Specific Gravity (water=1):	0.95-0.98. 8.09 pounds per gallon.
pH:	6-7 (40% aqueous solution)
% Volatiles by volume @ 21C (70F):	Negligible.
Boiling Point:	$\geq$ 100C ($\geq$ 212F)
Melting Point:	No information found.
Flash Point (F):	No information found.
Autoignition Temperature:	No information found.
Decomposition Temperature:	No information found.
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	< 1.0 @ 20C (68F).
Evaporation Rate (BuAc=1):	No information found.
Viscosity @23 C (73 F):	213 centipoises (1.2 centipoises diluted 1:10)
Partition Coefficient (octanol/water):	No information found.

10. Stability and Reactivity

Stability:	Stable under ordinary conditions of use and storage.
Reactivity:	Not reactive under ordinary conditions.
Hazardous Decomposition Products:	Carbon dioxide and carbon monoxide may form when heated to decomposition.
Hazardous Polymerization:	Will not occur.
Incompatibilities:	Strong oxidizers, acids.
Conditions to Avoid:	Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Soybean Oil:	No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or ACGIH.
Emulsifier/Nutrient Mixture:	No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or ACGIH.
Sodium Lactate:	Oral rat LD50: 2,000 mg/kg. 100 mg caused mild irritation to rabbit eye in Draize test. This compound is not listed as a carcinogen by IARC, NRP, NIOSH, OSHA, or ACGIM.
SRS-SD:	The toxicity of the mixture has not been measured.

12. Ecological Information

Environmental Fate:	No information found.
Environmental Toxicity:	No information found.
Degradability:	This product is completely biodegradable under both aerobic and anaerobic conditions.
Soil Mobility:	This compound will move with groundwater until the adsorbed onto the soil. Degradation products may be mobile.
Bioaccumulation Potential:	No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Section 10.

TSCA STATUS: No component of this product is listed on the TSCA inventory.

CERCLA (Comprehensive Response Compensation, and Liability Act): Not reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act)
Section 312 Extremely Hazardous Substances: None
Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312
Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer.

16. Other Information

NFPA Ratings:	Health: **1** Flammability: **1** Reactivity: **1**
Date Prepared:	September 11, 2019
Revision Information:	SDS Section(s) changed since last revision of document include: Updated Section 3 Composition/Information on Ingredients.
Disclaimer:	Terra Systems, Inc. provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. TERRA SYSTEMS, INC. MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, TERRA SYSTEMS, INC. WILL NOT BE RESPONSIBLE FOR

	DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION.
Prepared by:	Terra Systems, Inc.
Phone Number:	(302) 798-9553 (U.S.A.)

A.2 Bioaugmentation Technical Data Sheet and Safety Data Sheet

TSI DC *Dehalococcoides mccartyi* Bioaugmentation Culture®

Containing >1 x 10^{11} Dehalococcoides cells/L

Terra Systems TSI DC *Dehalococcoides mccartyi* Bioaugmentation Culture® is added to the groundwater at sites where the native microorganisms of Dehalococcoides are not present, are not in sufficient quantity, where the native population does not express all of the required functional genes for TCE and vinyl chloride reduction, or when the client wants to decrease the remediation time frame for the biodegradation of chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) to innocuous end products including ethene and ethane.

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Key Communication Points

- TSI DC *Dehalococcoides mccartyi* Bioaugmentation Culture® is an enriched natural bacteria culture that contains *Dehalococcoides* species for bioaugmentation.
- TSI DC® contains >1 x 10^{11} *Dehalococcoides* cells/L
- This culture dechlorinates tetrachloroethene (PCE) and trichloroethene (TCE) to the non-toxic product ethene.
- The culture also biodegrades 1,1,1-trichloroethane to 1,1-dichloroethene, 1,1-dichloroethane, and chloroethane.
- It also can biodegrade carbon tetrachloride and chloroform to methylene chloride and innocuous products.
- It can be used at sites where bacteria capable of complete reductive dechlorination are not present or there is a need to decrease the remediation time frame. It is estimated that *Dehalococcoides* are not present in 10 to 40 percent of chlorinated solvent contaminated sites.

- **Key Benefits of TSI DC *Dehalococcoides mccartyi* Bioaugmentation Culture®**

- The TSI-DC® Bioaugmentation Culture has been proven to be effective with a growing body of laboratory and field data demonstrating that the *Dehalococcoides* group of microorganisms is primarily responsible for the complete dechlorination of PCE and TCE to ethene. Some *Dehalogenimonas* species can also biodegrade PCE and TCE.
- At sites where *Dehalococcoides* microorganisms are not present or are found at low numbers, the process will often "**stall**" at cis-1,2-dichloroethene (cDCE). Low pH or insufficient substrate can also contribute to the cDCE stall.

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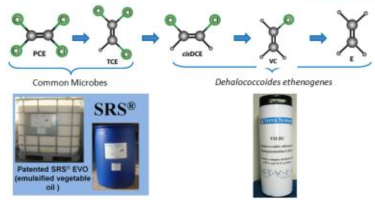

- The TSI-DC® Bioaugmentation Culture will promote the complete dechlorination of PCE or TCE.
- The TSI-DC® Bioaugmentation Culture contains greater than **1×10^{11}** *Dehalococcoides*/L.

Terra Systems QA/QC

Terra Systems owns and operates a state-of-the-art US based "*just-in-time*" manufacturing plant with an in-house quality control laboratory for strict quality assurance of our products. With every shipment, we include a QA/QC sheet for the actual batch that the customer receives. Included are the date manufactured, batch#, DHC concentration (cells/L), PCE dechlorination activity and cDCE dechlorination activity.

Manufacturing Quality Control Checklist for TSI DC
***Dehalococcoides mccartyi* Bioaugmentation Culture®**

I. Product Information

Parameter	Value
Product manufactured	TSI DC *Dehalococcoides mccartyii* Bioaugmentation Culture®
Date manufactured	07/16/2019
Batch#	805-19
Customer packaging	Two (2) 19 L Kegs
Customer	Navarro Research and Engineering, Inc.
Volume of Culture	76 L concentrated 2X to fit into (2) 19 L Kegs
Date shipped	8/19/2019
Date delivered	8/21/2019
Site location	Largo, FL.

II. Ingredients Information

Test	Results	Acceptable Range	Date	Method
DHC content of Pre-concentrated culture (copies/L)	>1E11	1E11	07/25/2019	qPCR
PCE dechlorination activity, mg/h per gram of dry weight	98	50	08/13/2019	Bottle Assay
cDCE declorination activity, mg/h per gram of dry weight	61	50	08/13/2019	Bottle Assay

Michael D Lee, PhD.

August 19th, 2019

Date

Michael D. Lee, Ph.D.
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The TSI-DC® Bioaugmentation Culture is cost effective and is typically a minor component of the total remediation project cost. At sites where the *Dehalococcoides* is present, but at low numbers or poorly distributed, bioaugmentation can be used to reduce the treatment time. Bioaugmentation can also reduce the time required to grow the *Dehalococcoides* population to effective cell densities. Therefore, future costs can be reduced.

- The TSI-DC® Bioaugmentation Culture works with all commonly used electron donors.
- The TSI-DC® Bioaugmentation Culture is not genetically modified or engineered.
- The TSI-DC® Bioaugmentation Culture is certified to be free of known human pathogens.
- Each purchase comes with free technical phone support from an experienced Terra Systems microbiologist.
- The TSI-DC® Bioaugmentation Culture has rigorous quality control procedures in place to ensure that each shipment is of the highest quality, stable, safe, effective and free of chlorinated volatile organic compounds.
- The TSI-DC® Bioaugmentation Culture is shipped overnight in specially designed stainless-steel containers that prevent exposure to air and are safe & easy to handle.
- A senior level microbiologist is also available to be on-site to support the successful application at $1,200 per day plus travel expenses

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TERRA SYSTEMS, INC DECHLORINATING BIOAUGMENTATION CULTURE (TSI-DC) SAFETY DATA SHEET

1. Product Identification

Synonyms:	*Dehalococcoides* or DHC Microbial Consortium (TSI-DC)
Recommended Use:	Bioremediation of groundwater contaminated with chlorinated solvents such as tetrachloroethene and trichloroethene.
Supplier:	Terra Systems, Inc. 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Telephone (302) 798-9553 Fax (302) 798-9554 www.terrasystems.net

2. Hazards Identification

The available data indicates no known hazards associated with exposure to this product. Nevertheless, individuals who are allergic to enzymes or other related proteins should avoid exposure and handling. Health effects associated with exposure to similar organisms are listed below.

Emergency Overview

Caution:	May cause eye irritation or discomfort if ingested or inhaled or allergic reaction to sensitive individuals.
Health Rating:	1 - Slight
Flammability Rating:	0 - None
Reactivity Rating:	0 - None
Contact Rating:	1 - Slight
Protective Equipment:	Goggles; Proper Gloves
Storage Color Code:	Green (General Storage)

Potential Health Effects

Inhalation:	Not expected to be a health hazard. Hypersensitive individuals may experience breathing difficulties after inhalation of aerosols.
Ingestion:	Not expected to be a health hazard via ingestion. Ingestion of large quantities may result in abdominal discomfort including nausea, vomiting, cramps, diarrhea, and fever.
Skin Contact:	No adverse effects expected. May cause irritation or sensitization in sensitive individuals upon prolonged contact.
Eye Contact:	May cause mild irritation, possible reddening unless immediately rinsed.

Chronic Exposure: No information found.

Aggravation of Pre-existing Conditions: No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Non-hazardous ingredients	DHC	Not applicable	100%	No

4. First Aid Measures

Inhalation: Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty or if allergic symptoms develop.

Ingestion: Thoroughly rinse mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Get immediate medical attention. Never give anything by mouth to an unconscious or convulsing person.

Skin Contact: Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact: Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.

Note to Physicians: All treatments should be based on observed signs and symptoms of distress in the patient. Consideration should be given to the possibility that overexposure to materials other than this material may have occurred.

5. Fire Fighting Measures

Fire: Non-flammable. Flash point and flammable limits are not available.

Explosion: Not considered to be an explosion hazard.

Fire Extinguishing Media: Dry chemical, foam, carbon dioxide, or water.

Special Information: In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Clean-up personnel may require protective clothing and avoid skin contact. Absorb in sand, paper towels, or other inert material. Scoop up and containerize for disposal. Flush trace residues to sewer with soap and water. Containerized waste may be sent to an approved waste disposal facility. After clean-up, disinfect all cleaning materials and storage containers that come in contact with the spilled liquid.

7. Handling and Storage

Avoid breathing breathe aerosol. Avoid contact with skin. Use personal protective equipment recommended in Section 8. Keep containers tightly closed in a cool, well-ventilated area. The DHC microbial consortium (TSI-DC) can be supplied in stainless steel kegs designed for maximum working pressure of 130 psi and equipped with pressure relief valves. The kegs are pressurized with nitrogen gas up to the pressure of 15 psi. Do not exceed pressure of 15 psi during transfer of DHC microbial consortium (TSI-DC) from kegs. Don't open keg if content of the keg is under pressure. DHC microbial consortium (TSI-DC) may be stored for up to 3 weeks at temperature 2-4°C without aeration. Avoid freezing.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:	None established.
Ventilation System:	Not expected to require any special ventilation. Provide adequate ventilation to remove odors.
Personal Respirators (NIOSH Approved):	Not expected to require personal respirator usage. If aerosols might be generated, use N95 respirator.
Skin Protection:	Wear protective rubber, nitrile, or vinyl gloves and clean body-covering clothing.
Eye Protection:	Use chemical safety goggles and/or a full face shield where splashing is possible. Provide readily accessible eye wash stations and safety showers.

9. Physical and Chemical Properties

Appearance:	Light greenish, murky liquid.
Odor:	Musty.
Solubility:	Soluble in water.
Specific Gravity (water=1):	1.0. 8.34 pounds per gallon.
pH:	6-8
% Volatiles by volume @ 21C (70F):	Negligible.
Boiling Point:	100C (212F)
Melting Point:	0C (32F)
Flash Point (F):	No information found.
Autoignition Temperature:	No information found.
Decomposition Temperature:	No information found.
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	24 mm @ 25C (77F).
Evaporation Rate (BuAc=1):	No information found.
Viscosity @23 C (73 F):	1 centipoises

Partition Coefficient (octanol/water): No information found.

10. Stability and Reactivity

Stability:	Stable under ordinary conditions of use and storage.
Reactivity:	Not reactive under ordinary conditions.
Hazardous Decomposition Products:	None.
Hazardous Polymerization:	Will not occur.
Incompatibilities:	Strong oxidizers, acids, water reactive materials.
Conditions to Avoid:	Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

TSI-DC No information found on toxicology. It is not a carcinogen listed by IARC, NTP, NIOSH, OSHA, or ACGIH. It has tested negative for pathogenic microorganisms such as *Bacillus cereus*, *Listeria monocytogens*, *Salmonella* sp., *Pseudomonas* sp., fecal coliform, total coliform, yeast, and mold.

12. Ecological Information

Environmental Fate:	No information found.
Environmental Toxicity:	No information found.
Degradability:	This product is completely biodegradable under both aerobic and anaerobic conditions.
Soil Mobility:	This compound will move with groundwater until the adsorbed onto the soil.
Bioaccumulation Potential:	No information found.

13. Disposal Considerations

Waste Disposal Method: No special disposal methods are required. The material is compatible with all known biological treatment methods. To reduce odors and permanently inactivate microorganisms, mix 100 parts (by volume) of TSI-DC consortium with 1 part (by volume) of bleach. Dispose of in accordance with local, state and federal regulations.

14. Transport Information

DOT Classification:	N/A
Labeling:	NA
Shipping Name:	Not regulated

15. Regulatory Information

OSHA STATUS: This product is not hazardous under the criteria of the Federal OSHA hazard Communication Standard 29 CFR 1910.1200.

TSCA STATUS: No component of this product is listed on the TSCA inventory.
CERCLA (Comprehensive Response Compensation, and Liability Act): Not reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act)
Section 312 Extremely Hazardous Substances: None
Section 311/312 Hazard Categories: Non-hazardous Under Section 311/312
Section 313 Toxic Chemicals: None

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste. (40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65: The following statement is made in order to comply with the California safe Drinking Water and Toxic Enforcement Act of 1986. The product contains no chemicals known to the State of California to cause cancer.

16. Other Information

NFPA Ratings:	Health: **1** Flammability: **0** Reactivity: **0**
Date Prepared:	March 26, 2014
Revision Information:	SDS Section(s) changed since last revision of document include: None.
Disclaimer:	Terra Systems, Inc. provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. TERRA SYSTEMS, INC. MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, TERRA SYSTEMS, INC. WILL NOT BE RESPONSIBLE FOR DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION.
Prepared by:	Terra Systems, Inc.
Phone Number:	(302) 798-9553 (U.S.A.)

A.3 pH Buffer Technical Data Sheet and Safety Data Sheet

Terra Systems pH Buffers and Buffer Capacity Test

Emulsified Vegetable Oil Substrates, lactate and other carbon substrates are added to the groundwater to rapidly generate reducing conditions and provide the necessary carbon and hydrogen to support native or introduced microorganisms (*Dehalococcoides*) for the biodegradation of chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) to innocuous end products including ethene and ethane. Often pH at a site is below optimal levels of 6.5 to 8.5 and a buffer needs to be added to the aquifer for complete dechlorination to occur.

Key Communication Points

1. A combination of laboratory and field studies has indicated that the optimal pH range for anaerobic bioremediation of chlorinated solvents is between 6.5 and 8.5.
2. Based upon laboratory studies at Terra Systems, between 76.4 to 99.1% of the buffer demands (average 93.3%) are associated with the soil phase rather than the groundwater phase.
3. Since the pH of just the groundwater is an unreliable determinant of the buffer demand, if possible, we strongly recommend that a saturated soil sample be collected and sent to Terra Systems Treatability Lab for a pH Buffer Capacity Test.
4. Terra Systems will recommend a buffer to counter the natural drop in pH due to the acids produced during the reductive dechlorination process and to optimize pH conditions at the site

Table I: pH Buffer Options

Buffer	Effective in pH Range	Benefit
pH Buff-Up	3.0-5.5	Liquid slurry, easy to mix, long-lasting
Sodium Bicarbonate Powder	5.0-6.0	Can't take the pH to high, maximum pH is 8.3. Inexpensive.
Calcium Carbonate Powder	4.0-6.0	Low solubility contributes to enhanced longevity. Inexpensive.
Sodium Carbonate Powder	4.0-6.0	Higher solubility but can take pH to high if overdosed. Inexpensive.
Magnesium Oxide or Magnesium Hydroxide Powder	3.0-5.0	Higher solubility but can take pH to high if overdosed. Moderately expensive.

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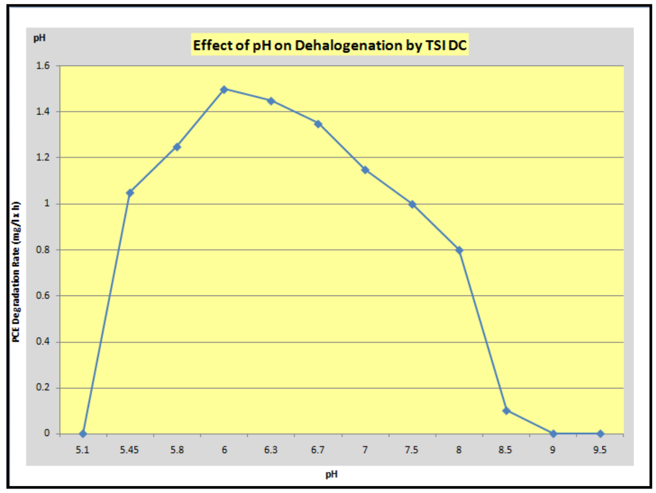
Terra Systems, Inc. (TSI) will conduct a test to determine the quantity of several potential amendments to neutralize the acidity of the groundwater at a potential bioremediation site. The objective of the evaluation is to select a buffering agent that can be added to increase the groundwater and soil pH and maintain neutral conditions needed for biological reductive dechlorination. The criteria for selecting the pH buffering agent are the following:

1. Increases the pH to between 7 and 9
2. Does not exceed pH 10
3. The lowest price (either the lowest cost per unit or lower price for a larger quantity)
4. Is relatively soluble or has fine particles that can be suspended in the chase water



The quantities of the following buffering agents necessary to increase and maintain a neutral pH at the site will be determined:

1. Sodium bicarbonate or baking soda
2. Calcium carbonate or crushed limestone
3. Sodium carbonate or soda ash
4. **Magnesium oxide**

Technical References for the benefits of optimizing pH for in-situ bioremediation.

Alexander, M. L., R. Cronce, and T. Battenhouse. 2011. Differential Adjustment of pH for Optimal Reductive Dechlorination Conditions. *A-65*, in: H.V. Rectanus and R. Sirabian (Chairs), *Bioremediation and Sustainable Environmental Technologies—2011*. International Symposium on Bioremediation and Sustainable Environmental Technologies (Reno, NV; June 27–30, 2011). ISBN 978-0-9819730-4-3, Battelle Memorial Institute, Columbus, OH.

Lee, M. D., E. Hauptmann, R. L. Raymond, D. Ochs, R. Lake, and M. Selover. 2010. Buffering Acidic Aquifers with Soluble Buffer to Promote Reductive Dechlorination. *F-031*, in K.A. Fields and G.B. Wickramanayake (Chairs), *Remediation of Chlorinated and Recalcitrant Compounds—2010*. Seventh International Conference on Remediation of Chlorinated and Recalcitrant Compounds (Monterey, CA; May 2010). ISBN 978-0-9819730-2-9, Battelle Memorial Institute, Columbus, OH, **www.battelle.org/chlorcon**.

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SODIUM BICARBONATE
Safety Data Sheet

1. Product Identification

Synonyms:	Sodium Hydrogen Carbonate, Baking Soda
CAS No:	144-55-8
Chemical Formula:	$NaHCO_3$
Recommended Use:	Food ingredient, pharmaceutical, water treatment
Supplier:	Terra Systems, Inc. 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Telephone (302) 798-9553 Fax (302) 798-9554 www.terrasystems.net

2. Hazards Identification

Emergency Overview	
Caution:	None
Health Rating:	0 - None
Flammability Rating:	0 - None
Reactivity Rating:	0 - None
Contact Rating:	0 - None
Protective Equipment:	Goggles; Proper Gloves
Storage Color Code:	Green (General Storage)
Potential Health Effects	
Inhalation:	Not expected to be a health hazard. If heated, may produce vapors or mists that irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air. Possible irritant.
Ingestion:	Not expected to be a health hazard via ingestion. Material is practically non-toxic. Small amounts (1-2 tablespoonfuls) swallowed during normal handling operations are not likely to cause injury as long as the stomach is not overly full; swallowing larger amounts may cause injury.
Skin Contact:	Not a skin irritant.
Eye Contact:	Not an eye irritant.

Chronic Exposure: Based on published studies on its effects in animals and humans, sodium bicarbonate is not teratogenic or genotoxic. Only known subchronic effect is that of a marked systemic alkalosis. Not classified as carcinogenic by NTP, IARC, OSHA, ACGIH or NIOSH.

Aggravation of Pre-existing Conditions: No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Sodium Bicarbonate	Baking soda	144-5-8	100	No

White crystalline powder; no odor.

4. First Aid Measures

Inhalation: Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty.

Ingestion: If large amounts were swallowed, do not induce vomiting. Give water to drink if person is conscious and get medical advice.

Skin Contact: Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact: Check for and remove contacts. Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.

Note to Physician: Large doses may produce systemic alkalosis and expansion in extracellular fluid volume with edema.

5. Fire Fighting Measures

Fire: Not combustible. Not considered to be a fire hazard. Isolate from heat and open flame.

Explosion: Not considered to be an explosion hazard.

Fire Extinguishing Media: Use extinguishing media suitable against surrounding fire or the cause of the fire.

Special Information: Carbon Dioxide may be generated making necessary the use of a self-contained breathing apparatus (SCBA) and full protective equipment (Bunker Gear). Carbon dioxide is an asphyxiant at levels over 5% w/w. Sodium oxide, another thermal decomposition product existing at temperatures above

1564°F is a respiratory, eye, and skin irritant. Avoid inhalation, eye and skin contact with sodium oxide dusts

6. Accidental Release Measures

Scoop up into dry, clean containers. Wash away small uncontaminated amounts of residue with water.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Containers of this material are not hazardous when empty since they do vapors or harmful substances; observe all warnings and precautions listed for the product. Do not store above 49 C (120 F). Keep container tightly closed and upright when not in use to prevent leakage.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits: None established.
Ventilation System: Not expected to require any special ventilation.
Personal Respirators (NIOSH Approved): Dust mask required if total dust level exceeds 10 mg/m3.
Skin Protection: Wear protective gloves and clean body-covering clothing.
Eye Protection: Use chemical safety glasses when handling bulk material or when dusts can be generated. Provide readily accessible eye wash stations and safety showers.

9. Physical and Chemical Properties

Appearance: White crystalline.
Molecular Weight: 84.02
Odor: None.
Solubility: 86 g/L at 20 C.
Bulk Density: 9.94 g/cm^3 or 62 pounds/ft^3
pH: 8.2 (1% aqueous solution)
% Volatiles by volume @ 21C (70F): Negligible.
Boiling Point: Not applicable.
Melting Point: Not applicable.
Flash Point (F): Not applicable.
Autoignition Temperature: Not flammable, will not support combustion.
Decomposition Temperature: 50 C.
Vapor Density (Air=1): No information found.

Vapor Pressure (mm Hg): Not applicable.
Evaporation Rate (BuAc=1): No information found.
Partition Coefficient (octanol/water): No information found.

10. Stability and Reactivity

Stability: Stable under ordinary conditions of use and storage.
Reactivity: Not reactive under ordinary conditions. Reacts with acids to yield carbon dioxide.
Hazardous Decomposition Products: Carbon dioxide may form when heated to decomposition at >100 C. If heated to >850 C, yields sodium oxide which should inhalation, eye and skin contact should be avoided.
Hazardous Polymerization: Will not occur.
Incompatibilities: Strong acids.
Conditions to Avoid: Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Toxic Dose: 4,220 mg/kg (oral rat).
Inhalation: High concentrations of dust may cause transient irritation to upper respiratory tract.
Ingestion: Ingestion of small amounts is unlikely to cause any adverse effects. Ingestion of (excessive amounts) may cause vomiting, nausea, convulsions
Skin: Repeated or prolonged contact may cause mild irritation and/or drying (defatting) of skin.
Eyes: The material was minimally irritating to unwashed eyes and practically non-irritating to washed eyes (rabbits).

12. Ecological Information

Environmental Fate: No information found.
Environmental Toxicity: 4,100 mg/L EC50 Daphnids. 7.100 mg/L LC50 Bluegills. 7,700 mg/L: LCt0 Rainbow trout.
Persistence: This product is expected to persist in the environment. It is inorganic and not subject to biodegradation.
Soil Mobility: This compound will move with groundwater until it reacts with acid.
Bioaccumulation Potential: This product is not expected to bioaccumulate

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13. Disposal Considerations

Bury in a secured landfill in accordance with all local, state and federal environmental regulations. Empty containers may be incinerated or discarded as general trash.

14. Transport Information

Not regulated.

15. Regulatory Information

CLEAN AIR ACT SECTION 611: Material neither contains nor is it manufactured with ozone depleting substances (ODS).
FEDERAL WATER POLLUTION CONTROL ACT (40 CFR 401.15): Material contains no intentionally added or detectable (contaminant) levels of EPA priority toxic pollutants.
FOOD AND DRUG ADMINISTRATION: Generally Recognized As Safe (GRAS) direct food additive (21 CFR 184.1736).
US DEPARTMENT OF AGRICULTURE: List of Proprietary Substances - Permitted Use Codes 3A, J1, A1, G1, and L1.
CERCLA REPORTABLE QUANTITY: None
OSHA: Not hazardous under 29 CFR 1910.1200
RCRA: Not a hazardous material or a hazardous waste by listing or characteristic.
SARA TITLE III:
Section 302, Extremely Hazardous Substances: None
Section 311/312, Hazardous Categories: Non-hazardous
Section 313, Toxic Chemicals: None
Sodium Bicarbonate is reported in the EPA TSCA Inventory List.
Contains no VOCs.
NSF STANDARD 60: Corrosion and Scale Control in Potable Water. Max use 200 mg/l.

16. Other Information

NFPA Ratings:	Health: **0** Flammability: **0** Reactivity: **0**
Date Prepared:	July 18, 2014
Revision Information:	SDS Section(s) changed since last revision of document include: None.
Disclaimer:	Terra Systems, Inc. provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their

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Prepared by: Terra Systems, Inc.

Phone Number: (302) 798-9553 (U.S.A.)

A.4 Sodium Absorbate Technical Data Sheet and Safety Data Sheet

ChemicalBook

Chemical Safety Data Sheet MSDS / SDS

Sodium ascorbate

Revision Date:2024-12-21 Revision Number:1

SECTION 1: Identification of the substance/mixture and of the company/undertaking

Product identifier

Product name	: Sodium ascorbate
CBnumber	: CB8155737
CAS	: 134-03-2
EINECS Number	: 205-126-1
Synonyms	: sodium ascorbate,sodium L-ascorbate

Relevant identified uses of the substance or mixture and uses advised against

Relevant identified uses	: For R&D use only. Not for medicinal, household or other use.
Uses advised against	: none

Company Identification

Company	: Chemicalbook
Address	: Building 1, Huihuang International, Shangdi 10th Street, Haidian District, Beijing
Telephone	: 400-158-6606

SECTION 2: Hazards identification

GHS Label elements, including precautionary statements

Signal word	No signal word

Hazard statement(s)

none

Prevention

none

Response

none

Storage

none

Disposal

none

SECTION 3: Composition/information on ingredients

Substance

Product name	: Sodium ascorbate
Synonyms	: sodium ascorbate,sodium L-ascorbate
CAS	: 134-03-2
EC number	: 205-126-1
MF	: $C_6H_7NaO_6$
MW	: 198.11

SECTION 4: First aid measures

Description of first aid measures

If inhaled

After inhalation: fresh air.

In case of skin contact

In case of skin contact: Take off immediately all contaminated clothing. Rinse skin with water/ shower.

In case of eye contact

After eye contact: rinse out with plenty of water. Remove contact lenses.

If swallowed

After swallowing: make victim drink water (two glasses at most). Consult doctor if feeling unwell.

Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

Indication of any immediate medical attention and special treatment needed

No data available

SECTION 5: Firefighting measures

Extinguishing media

Suitable extinguishing media

Water Foam Carbon dioxide (CO_2) Dry powder

Unsuitable extinguishing media

For this substance/mixture no limitations of extinguishing agents are given.

Special hazards arising from the substance or mixture

Carbon oxides Sodium oxides Combustible.

Development of hazardous combustion gases or vapours possible in the event of fire. Risk of dust explosion.

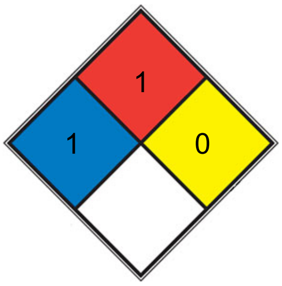
Advice for firefighters

In the event of fire, wear self-contained breathing apparatus.

Further information

Suppress (knock down) gases/vapors/mists with a water spray jet. Prevent fire extinguishing water from contaminating surface water or the ground water system.

NFPA 704



■	HEALTH	1	Exposure would cause irritation with only minor residual injury (e.g. acetone, sodium bromate, potassium chloride)
■	FIRE	1	Materials that require considerable preheating, under all ambient temperature conditions, before ignition and combustion can occur. Includes some finely divided suspended solids that do not require heating before ignition can occur. Flash point at or above 93.3 °C (200 °F). (e.g. mineral oil, ammonia)
■	REACT	0	Normally stable, even under fire exposure conditions, and is not reactive with water (e.g. helium,N_2)
□	SPEC. HAZ.		

SECTION 6: Accidental release measures

Personal precautions, protective equipment and emergency procedures

Advice for non-emergency personnel: Avoid inhalation of dusts. Evacuate the danger area, observe emergency procedures, consult an expert.

For personal protection see section 8.

Environmental precautions

Do not let product enter drains.

Methods and materials for containment and cleaning up

Cover drains. Collect, bind, and pump off spills. Observe possible material restrictions (see sections 7 and 10). Take up dry. Dispose of properly. Clean up affected area. Avoid generation of dusts.

Reference to other sections

For disposal see section 13.

SECTION 7: Handling and storage

Precautions for safe handling

For precautions see section 2.2.

Conditions for safe storage, including any incompatibilities

Storage conditions

Tightly closed. Dry.

Light sensitive.

Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

SECTION 8: Exposure controls/personal protection

control parameter

Hazard composition and occupational exposure limits

Does not contain substances with occupational exposure limits.

Exposure controls

Personal protective equipment

Eye/face protection

Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU). Safety glasses

Respiratory protection

required when dusts are generated.

Our recommendations on filtering respiratory protection are based on the following standards: DIN EN 143, DIN 14387 and other accompanying standards relating to the used respiratory protection system.

Recommended Filter type: Filter type P1

The entrepeneur has to ensure that maintenance, cleaning and testing of respiratory protective devices are carried out according to the instructions of the producer.

These measures have to be properly documented.

Control of environmental exposure

Do not let product enter drains.

SECTION 9: Physical and chemical properties

Information on basic physicochemical properties

Appearance	light yellow crystalline
Odour	odorless
Odour Threshold	Not applicable
pH	7 - 8 at 100 g/l at 20 °C
Melting point/freezing point	Melting point/range: 220 °C
Initial boiling point and boiling range	235 °C
Flash point	No data available
Evaporation rate	No data available
Flammability (solid, gas)	May form combustible dust concentrations in air.

Upper/lower flammability or explosive limits	No data available
Vapour pressure	No data available
Vapour density	No data available
Relative density	1,88 at 19,7 °C - OECD Test Guideline 109
Water solubility	642,6 g/l at 20 °C - OECD Test Guideline 105- completely soluble
Partition coefficient: n-octanol/water	log Pow:< -4,2 at 22 °C - Bioaccumulation is not expected.
Autoignition temperature	No data available
Decomposition temperature	232 °C -
Viscosity	Viscosity, kinematic: No data available Viscosity, dynamic: No data available
Explosive properties	No data available
Oxidizing properties	No data available

Other safety information

Surface tension 74 mN/m at 20,3 °C

- OECD Test Guideline 115

SECTION 10: Stability and reactivity

Reactivity

The following applies in general to flammable organic substances and mixtures: in correspondingly fine distribution, when whirled up a dust explosion potential may generally be assumed.

Chemical stability

The product is chemically stable under standard ambient conditions (room temperature) .

Possibility of hazardous reactions

Violent reactions possible with:

Oxidizing agents

Conditions to avoid

Light.

no information available

Incompatible materials

No data available

Hazardous decomposition products

In the event of fire: see section 5

SECTION 11: Toxicological information

Information on toxicological effects

Acute toxicity

LD50 Oral - Rat - 11.900 mg/kg

Remarks: (calculated on the free acid)(RTECS)

Skin corrosion/irritation

Skin - Rabbit

Result: No skin irritation - 4 h (OECD Test Guideline 404)

Remarks: (in analogy to similar products)

The value is given in analogy to the following substances: ascorbic acid

Serious eye damage/eye irritation

Eyes - Rabbit

Result: No eye irritation (OECD Test Guideline 405)

Remarks: (in analogy to similar products)

The value is given in analogy to the following substances: ascorbic acid

Respiratory or skin sensitization

Local lymph node assay (LLNA) - Mouse

Result: negative

(OECD Test Guideline 429)

Germ cell mutagenicity

No data available

Carcinogenicity

No data available

Reproductive toxicity

No data available

Specific target organ toxicity - single exposure

No data available

Specific target organ toxicity - repeated exposure

No data available

Aspiration hazard

Toxicity

sce-hmn:lym 100 mmol/L MUREAV 60,321,79

SECTION 12: Ecological information

Toxicity

Toxicity to fish

static test LC50 - Oncorhynchus mykiss (rainbow trout) - > 1.020 mg/l - 96 h

(OECD Test Guideline 203)

Toxicity to daphnia and other aquatic invertebrates

semi-static test EC50 - Daphnia magna (Water flea) - 74 mg/l - 48 h (OECD Test Guideline 202)

Toxicity to algae

static test ErC50 - Pseudokirchneriella subcapitata - > 74 mg/l - 72 h

(OECD Test Guideline 201)

Persistence and degradability

Biodegradability aerobic - Exposure time 28 d

Result: > 99 % - Readily biodegradable. (OECD Test Guideline 301A)

Bioaccumulative potential

No data available

Mobility in soil

No data available

Results of PBT and vPvB assessment

This substance/mixture contains no components considered to be either persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) at levels of 0.1% or higher.

Other adverse effects

No data available

SECTION 13: Disposal considerations

Waste treatment methods

Product

See www.retrologistik.com for processes regarding the return of chemicals and containers, or contact us there if you have further questions.

Incompatibilities

Incompatible with oxidizing agents, heavy metal ions, especially copper and iron, methenamine, sodium nitrite, sodium salicylate, and theobromine salicylate. The aqueous solution is reported to be incompatible with stainless steel filters.

SECTION 14: Transport information

UN number

ADR/RID: - IMDG: - IATA: -

UN proper shipping name

ADR/RID: Not dangerous goods IMDG: Not dangerous goods IATA: Not dangerous goods

Transport hazard class(es)

ADR/RID: - IMDG: - IATA: -

Packaging group

ADR/RID: - IMDG: - IATA: -

Environmental hazards

ADR/RID: no IMDG Marine pollutant: no IATA: no

Special precautions for user

Further information

Not classified as dangerous in the meaning of transport regulations.

SECTION 15: Regulatory information

Safety, health and environmental regulations/legislation specific for the substance or mixture

Regulations on the Safety Management of Hazardous Chemicals

China Catalog of Hazardous chemicals 2015:Not Listed. website: https://www.mem.gov.cn/

Measures for Environmental Management of New Chemical Substances

Philippines Inventory of Chemicals and Chemical Substances (PICCS):Listed. website: https://emb.gov.ph/

United States Toxic Substances Control Act (TSCA) Inventory:Listed. website: https://www.epa.gov/

Korea Existing Chemicals List (KECL):Listed. website: http://ncis.nier.go.kr

New Zealand Inventory of Chemicals (NZIoC):Listed. website: https://www.epa.govt.nz/

European Inventory of Existing Commercial Chemical Substances (EINECS):Listed. website: https://echa.europa.eu/

EC Inventory:Listed.

Vietnam National Chemical Inventory:Listed. website: https://chemicaldata.gov.vn/

Chinese Chemical Inventory of Existing Chemical Substances (China IECSC):Listed. website: https://www.mee.gov.cn/

SECTION 16: Other information

Abbreviations and acronyms

CAS: Chemical Abstracts Service

ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road

RID: Regulation concerning the International Carriage of Dangerous Goods by Rail

IMDG: International Maritime Dangerous Goods

IATA: International Air Transportation Association

TWA: Time Weighted Average

STEL: Short term exposure limit

LC50: Lethal Concentration 50%

LD50: Lethal Dose 50%

EC50: Effective Concentration 50%

References

【1】CAMEO Chemicals, website: http://cameochemicals.noaa.gov/search/simple

【2】ChemIDplus, website: http://chem.sis.nlm.nih.gov/chemidplus/chemidlite.jsp

【3】ECHA - European Chemicals Agency, website: https://echa.europa.eu/

【4】eChemPortal - The Global Portal to Information on Chemical Substances by OECD, website:

http://www.echemportal.org/echemportal/index?pageID=0&request_locale=en

【5】ERG - Emergency Response Guidebook by U.S. Department of Transportation, website: http://www.phmsa.dot.gov/hazmat/library/erg

【6】Germany GESTIS-database on hazard substance, website: http://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp

【7】HSDB - Hazardous Substances Data Bank, website: https://toxnet.nlm.nih.gov/newtoxnet/hsdb.htm

【8】IARC - International Agency for Research on Cancer, website: http://www.iarc.fr/

【9】IPCS - The International Chemical Safety Cards (ICSC), website: http://www.ilo.org/dyn/icsc/showcard.home

【10】Sigma-Aldrich, website: https://www.sigmaaldrich.com/

A.5 Sodium Lactate Technical Data Sheet and Safety Data Sheet

Injection Ready 60% QRS-SL™ Sodium Lactate
Quick Release Substrate
For Aquifer Remediation and Conditioning

Terra Systems "*injection ready*" **<u>60% QRS™-SL</u>** Sodium Lactate Quick Release Substrate is added to the groundwater to rapidly generate reducing conditions and provide the necessary carbon and hydrogen to support native or introduced microorganisms (*Dehalococcoides*) for the biodegradation of chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) to innocuous end products including ethene and ethane.

<u>Key Communication Points</u>

- 60% QRS™-SL sodium lactate is an inexpensive, soluble, food grade substrate
- It rapidly establishes reducing conditions to support the biodegradation of PCE, TCE, TECA, DNAPL (Sabre Project), Perchlorate, TCA, Cr^{6+}, TNT, Uranium and Nitrate
- It is one of the most efficient electron donors available
- Provides 60% fermentable carbon
- 100% biobased content
- Its miscibility in water and low viscosity allow for effective transport with groundwater, enhancing subsurface radius of influence and minimizing the number of injection points.
- It arrives as a homogenous ***injection ready substrate***, which results in lower field labor costs
- Proven effective at dry cleaners, semiconductor manufacturers, fabricators, manufacturing firms and military installations, that use and clean metal parts (air conditioners, dishwashers, etc.).

<u>Table I</u>: 60% QRS™-SL Sodium Lactate Specifications

Ingredient	Percent	Description	Benefit
Sodium lactate	60%	Rapidly biodegradable soluble substrate; miscible in water	Fast release source of carbon and hydrogen Rapidly generates reducing conditions High radius of influence Provides 60% fermentable carbon
pH	6.5 - 7	6.5 - 7	Optimum microbial activity
Organic Carbon (wt%)	60%		Provides 60% fermentable carbon
Biobased Content	100%		

<u>Packaging</u>: 5-gallon buckets, 55-gallon drums, 275-gallon IBC totes or bulk tankers.

130 Hickman Road – Suite 1 – Claymont – Delaware – 19703
For More Information Call Michael Free at 302-798-9553 or Email: mfree@terrasystems.net

Since 1992

Terra Systems INCORPORATED

USDA CERTIFIED BIOBASED PRODUCT PRODUCT 100%

CERTIFIED CARBON NEUTRAL® product

"*Injection Ready"* 60% QRS-SL™ Plus Sodium Lactate

Quick Release Substrate with NutriPlus™ a Proprietary Nutrient Package For Aquifer Remediation and Conditioning

SAFETY DATA SHEET

Effective Date: 1/1/2020

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1. Product Identification

Synonyms:	Quick Release Substrate Plus (QRS™-SL Plus); Sodium Lactate; Propanoic acid, 2-Hydroxy Monosodium salt; L-Lactic Acid, Sodium Salt
Recommended Use:	Treatment of groundwater contaminated with chlorinated solvents and other anaerobically degradable compounds.
Supplier:	Terra Systems, Inc. 130 Hickman Road, Suite 1 Claymont, Delaware 19703 Telephone (302) 798-9553 Fax (302) 798-9554 www.terrasystems.net

---

2. Hazards Identification

Emergency Overview	
Caution:	May cause eye irritation.
Health Rating:	1 - Slight
Flammability Rating:	0 - None
Reactivity Rating:	0 - None
Contact Rating:	1 - Slight
Protective Equipment:	Goggles; Proper Gloves
Storage Color Code:	Orange (General Storage)
Potential Health Effects	
Inhalation:	Not expected to be a health hazard
Ingestion:	Not expected to be a health hazard via ingestion
Skin Contact:	No adverse effects expected
Eye Contact:	May cause irritation, possible reddening
Chronic Exposure:	No information found

Aggravation of Pre-existing Conditions: No information found

3. Composition/Information on Ingredients

Ingredient	CAS#	Percent	Hazardous
Sodium Lactate	72-17-3	60	Yes
Organic Nutrients, Inorganic Nutrients and Surfactants	Mixture	1-5	No
Water	7732-18-5	35-39	No

Molecular Weight: No available
Chemical Formula: Not available

The organic, inorganic nutrients and surfactant mixture is a trade secret and consists of ingredients of unknown acute toxicity.

4. First Aid Measures

Inhalation: Not expected to require first aid measures. Remove to fresh air. Get medical attention for any breathing difficulty.

Ingestion: If large amounts were swallowed, give water to drink and get medical advice.

Skin Contact: Not expected to require first aid measures. Wash exposed area with soap and water. Get medical advice if irritation develops.

Eye Contact: Immediately flush eyes with plenty of water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get medical attention if irritation persists.

5. Fire Fighting Measures

Fire: Flash point: 110 C (230 F). Not considered to be a fire hazard.

Explosion: Not considered to be an explosion hazard.

Fire Extinguishing Media: Use any means suitable for extinguishing surrounding fire.

Special Information: In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

Clean-up personnel may require protective clothing. Absorb in sand, paper towels, “Oil Dry”, or other inert material. Scoop up and containerize for disposal. Flush trace residues to sewer with soap and water. Containerized waste may be sent to an approved waste disposal facility.

7. Handling and Storage

Keep in a tightly closed container, stored in a cool, dry, ventilated area. Protect against physical damage. Avoid long storage times. Containers of this material may be hazardous when empty since they do retain product residues (vapors, liquid). Observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:	None established.
Ventilation System:	Not expected to require any special ventilation.
Personal Respirators (NIOSH Approved):	Not expected to require personal respirator usage.
Skin Protection:	Wear protective gloves and clean body-covering clothing.
Eye Protection:	Use chemical safety goggles and/or a full face shield where splashing is possible. Provide readily accessible eye wash stations and safety showers.
Slips, Trips, and Falls:	Material is slippery when spilled. Clean up with sand, paper towels, or other inert material.

9. Physical and Chemical Properties

Appearance:	Colorless to yellow liquid.
Odor:	Odorless
Solubility:	100% soluble in water.
Specific Gravity (water=1):	1.32. (11.01 pounds per gallon)
pH:	6.5-8.5
% Volatiles by volume @ 21C (70F):	No information found.
Boiling Point:	110 C (230 F)
Melting Point:	17 C (63 F)
Flash Point (F):	No information found
Autoignition Temperature:	No information found
Decomposition Temperature:	No information found.
Vapor Density (Air=1):	0.7
Vapor Pressure (mm Hg):	14 @ 20 C (68 F)
Evaporation Rate (BuAc=1):	No information found
Viscosity @23 C (73 F):	100 centipoises

Partition Coefficient (octanol/water): No information found

10. Stability and Reactivity

Stability:	Stable under ordinary conditions of use and storage.
Reactivity:	Not reactive under ordinary conditions.
Hazardous Decomposition Products:	Carbon dioxide and carbon monoxide may form when heated to decomposition.
Hazardous Polymerization:	Will not occur.
Incompatibilities:	Strong oxidizers, acids.
Conditions to Avoid:	Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Oral rat LD50: 2000 mg/Kg. Irritation Data for Sodium Lactate: (Std Draize, rabbit, eye): 100 mg - mild.

--------\Cancer Lists\--

	---NTP Carcinogen---		
Ingredient	Known	Anticipated	IARC Category
Sodium Lactate (72-17-3)	No	No	None
Water (7732-18-5)	No	No	None

12. Ecological Information

Environmental Fate:	Mobile with water and readily biodegradable
Environmental Toxicity:	Ecological injuries are not known or expected under normal use; (No effect on Daphnia @ 10g/L)
Degradability:	This product is completely biodegradable under both aerobic and anaerobic conditions.
Soil Mobility:	This compound will move with groundwater until the adsorbed onto the soil. Degradation products may be mobile.
Bioaccumulation Potential:	No information found.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be managed in an appropriate and approved waste disposal facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Not regulated.

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\---------------------------------

Ingredient	TSCA	EC	Japan	Australia
Sodium Lactate (72-17-3)	Yes	Yes	Yes	Yes
Water (7732-18-5)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\---------------------------------

		--Canada--		
Ingredient	Korea	DSL	NDSL	Phil.
Sodium Lactate (72-17-3)	Yes	Yes	No	Yes
Water (7732-18-5)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\----------------

	-SARA 302-		------SARA 313------	
Ingredient	RQ	TPQ	List	Chemical Catg.
Sodium Lactate (72-17-3)	No	No	No	No
Water (7732-18-5)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\----------------

		-RCRA-	-TSCA-
Ingredient	CERCLA	261.33	8(d)
Sodium Lactate (72-17-3)	No	No	No
Water (7732-18-5)	No	No	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: No
SARA 311/312: Acute: Yes Chronic: No Fire: No Pressure: No
Reactivity: No (Mixture / Liquid)

Terra Systems, Inc.
130 Hickman Road, Suite 1, Claymont, Delaware 19703
Contact: Michael Free, VP, Sales and Marketing
Office: 302-798-9553; Cell: 484-889-2214 Email: mfree@terrasystems.net

16. Other Information

NFPA Ratings:	Health: **1** Flammability: **0** Reactivity: **0**
Date Prepared:	March 28, 2014
Revision Information:	SDS Section(s) changed since last revision of document include: None.
Disclaimer:	Terra Systems, Inc. provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. TERRA SYSTEMS, INC. MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, TERRA SYSTEMS, INC. WILL NOT BE RESPONSIBLE FOR DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION.
Prepared by:	Terra Systems, Inc.
Phone Number:	(302) 798-9553 (U.S.A.)

A.6 Technical Data Sheets for Gravity Feed Injection

Ultratech IBC Spill Pallet Plus With Drain 1158

Ultratech IBC Spill Pallet 1158 Specifications:
Dimensions: 62" x 62" x 28"
Uniformly Distributed Load: 8,500 lbs
Containment Capacity: 365 Gallons
Weight: 324 lbs
Options: Ultra Bucket Shelf (Part#1160)
Contact us anytime for IPI customer service on all UltraTech IBC Spill Pallet & Spill Containment Products

Key Features:
- Low profile, 28" overall height - allows safe and convenient IBC tank handling and dispensing.
- All polyethylene construction - offers excellent chemical resistance and will not rust or corrode.
- Forkliftable - allows convenient positioning to desired locations.
- Low-cost design with value-added features and benefits.
- Large 52" x 52" deck allows safe and convenient placement of IBC tanks.
- Small footprint - 62" x 62" unit requires minimal floor space.
- 365-gallon sump capacity meets SPCC and EPA Container Storage and Spill Containment Regulations.
- Optional Pull Over Cover keeps rainwater out of the sump and helps comply with Stormwater Management Regulations.
- Five inner polyethylene columns support uniformly distributed loads of up to 8,500 lbs. All components are easily removed for cleaning.
- Optional Bucket Shelf captures spills from dispensing. Spills that exceed 3 gallons are channeled into the 365-gallon sump through a bulkhead fitting.

The Therma Gauge—Type H

Calibration: Consists of 3 pieces. Outer plastic piece, inner plastic piece, and a piece of paper in between. Optional glass inner piece is available.

Red Lock Nut: HDPE Plastic. Also available in aluminum or PVC.

Bushing: Aluminum bushing, can be 2", 1.5". Special package allows for a Stain-less Steel Bushing also.

HDPE Float: Also available in Stainless Steel or Nitrophyll.

Internal Rods: Standard construction is galvanized steel rods with brass rivets. Optional stainless steel rods are available. Stainless steel rod construction eliminates the rivets.

Part Number—
H-(size opening)-(tank depth)+(ext)-(list options) Sample—H-2-48+12

What it is:

Top mounted liquid level gauge that can measure from 6 inches to 144 inches in depth. Bushing size can be 2" or 1.5". Gauges are custom made in house to fit your tank. Can also accommodate for double walls and pipe risers. The Type H Gauge has a 2 piece bushing construction that allows you to aim your swing arm away from walls, corners, and other obstructions.

Additional Options:

Audible Alarm Accessory: This add on feature can turn your mechanical gauge into an audible Hi or Lo level alarm.

LED At-A-Glance Accessory: Another add on feature. This can give your mechanical gauge remote reading capability.

Gauge Guard: A cover that protects the exposed plastic components on top of the gauge.

Material Packages / Gauge Packages:

- **Standard Therma Gauge**-Type H-Rods are galvanized steel, floats are HDPE plastic, bushing is aluminum, calibration top is plastic.
- **Stainless Level One**-Type H-S1- Rods become stainless.
- **Stainless Level Two**-Type -H-S2- Rods and floats become stainless.
- **Stainless Level Three**-Type H-S3- This model comes standard with Glass Calibration, Aluminum Locking Nut, Stainless Steel Bushing, Stainless Steel Rods, and Stainless Steel Floats.
- **All Plastic Model**—Type PH—This model comes standard with Glass Calibration, PVC Gauge Guard, PVC Bushing, PEEK Plastic Rods, HDPE Plastic Float.

The Cary Company
1195 W. Fullerton Ave.
Addison, IL 60101

thecarycompany.com

Contact us for more info :
Ph: 630-629-6600

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Therma Gauge Accessories and Replacement Parts

Accessories

Glass Calibration

LED At A Glance Remote Display-Turns the direct reading Therma gauge into a wired remote reading gauge. (part # add -Ledaag)
Direct Mount Alarms- Audible alarm that mounts directly to the gauge and provides your choice of overfill or low level warnings. (part # add -Dalarm)
Remote Mount Alarms- Audible alarm that can be remotely wired and provides your choice of overfill or low level warnings. (part # add -Ralarm)
Aluminum Lock Nut- Replace the red lock nut for added durability. (part # add -ALN)
Gauge Guard- Protective Cover that replaces the red locking nut providing protection from physical damage and weathering damage. Also helps with passing fire inspections. (part # add -ALG)
Glass Calibration- The internal piece of the calibration becomes glass. Provides protection from heat, fumes, weathering, and also helps with passing fire inspections. (part # add -GLC)

Direct Mount Alarm

Gauge Guard

Aluminum Lock Nut

Led At A Glance

Remote Alarm

Replacement Parts

- **H-Kit-** Replaces all the top components with standard materials.
- **HG-Kit** Replaces all the top components with standard materials and a glass calibration.
- **HALN-Kit-** Replaces all the top components with standard materials and an aluminum lock nut.
- **HGALN-Kit-** Replaces the top components with a glass calibration and aluminum lock nut.

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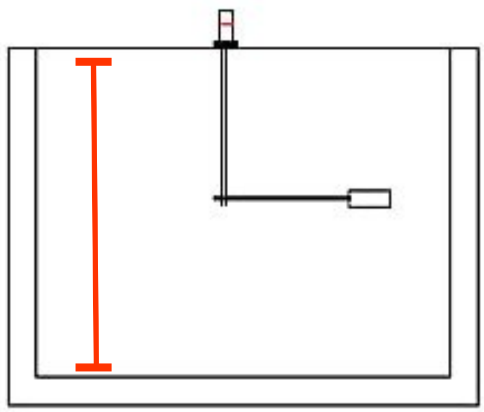
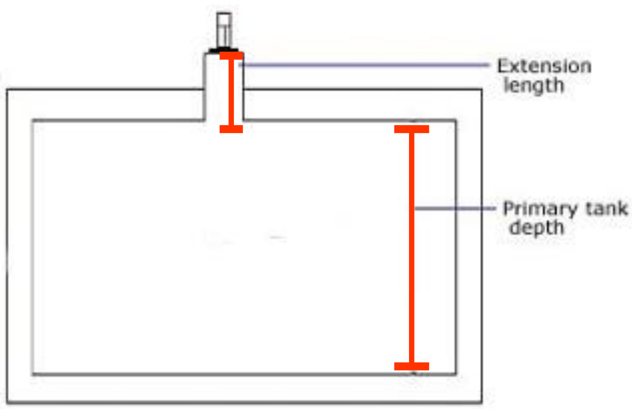
Ordering, Installation, Maintenance and Operation





Ordering Instructions:

Part Number Layout-
H-(Opening Size)-(tank depth)-(ext. length)-(material package)-(options)

1. State the gauge type (Type H for metal or Type PH for all plastic)
2. State the opening size your are using. (1.5"---2")
3. State the tank depth (pictured left). Tank depth is the distance from empty to full.
4. When necessary, provide the extension length (pictured left). Extension length is the distance from full to gauge threads. (sometimes zero)
5. List the material package you prefer for best compatibility with your liquid. Material packages are explained on page 1 of this document. Skip this if you want standard materials
6. List other material options and accessories that you prefer. These options and accessories can be located on page 2 of this document. Skip this if you want standard materials.

Example Part numbers

- H-2-48-12-S3
- H-2-24-GLC

Installation Instructions:
When installing, unthread the red nut and remove the calibration and bushing. Thread in the bushing first. Drop the gauge through the center hole, make sure your swing arm is facing in the direction you want. Replace the calibration and tighten down your red locking nut.

Instructions for Operation:
The top of the red indicator is an indication of your approximate fuel level in your tank. Once installed, you simply view the calibration to monitor your tank level. Indicator is calibrated in eighths of a tank on one side, and quarters of a tank on the other as well as Gallons and Liters.

Maintenance:

The Therma Gauge can fail in one of three ways.

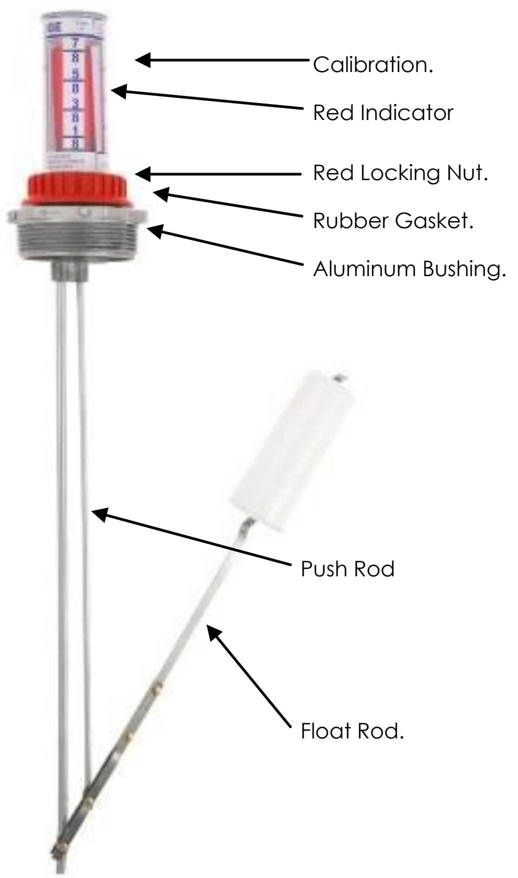
- The calibration assembly on the outside of the tank can become weathered, unreadable, or broken.
- The connecting rods that extend into the tank can come apart or become damaged.
- The float that sits at the bottom of the gauge can come off or become saturated with product (leak).

Recommended Maintenance Procedures:

- Once per month: Inspect the top of the unit once per month to ensure that the calibration is visible, readable, and unbroken. (these top pieces can be easily replaced without having to replace the whole gauge)
- Once every 6 months: Unthread the unit and carefully remove it from the tank. Be sure all rods are connected as one piece from the red indicator all the way down to the float. Also inspect the float for damage or leakage. To ensure proper working order, manually raise the float arm from empty to full to be sure that the red indicator freely moves up and down with the motion of the float rod.
- When performing maintenance, be sure to follow the installation instructions above to prevent damaging the gauge

The CARY COMPANY Est. 1895

The Therma Gauge—FAQ, Troubleshooting



Frequently Asked Questions:

Q: What is the difference between the Therma Gauge and the standard Direct Reading Gauge.
A: The two gauges are nearly identical, but the Therma gauge has a two piece bushing. This allows you to remove the bushing, thread it in, then drop the gauge in and point the swing arm in the direction of your choice. This makes installation easier when you fitting is near a wall/corner or if you have baffles/obstructions in your tank that you need to avoid.

Q: The top plastic portion of my gauge has become damaged or weathered, what can I do?
A: The top of the gauge is easily replaced, just order a H-Repair Kit which replaces all of the top components of the gauge.

Q: How can I prevent the top of my gauge from becoming weathered or warped in the future?
A: Several upgrades exist that improve the life and performance of the gauge. The glass calibration, which makes the internal part of the calibration into glass, increases the gauges resistance to heat, fumes, and sun.

Q: My gauge top keeps getting broken by hoses/weather/people, do you have a more durable option?
A: We offer something called a Gauge Guard. This is an aluminum cage that replaces the red lock nut and protects the top of your gauge from physical damage and weathering.

Q: The fire inspector says my gauge is not up to code? How can I satisfy their requirements.
A: If you get the glass calibration and the gauge guard, you are creating a glass and metal barrier between the inside of the tank and the external environment. Explain this to your inspector and see if it satisfies their requirements.

Q: I have aggressive chemicals that I need to gauge, will this work?
A: Our gauge has many material options, including all stainless components or all plastic components. We can help with determining what material option you need, but compatibility is ultimately the end users decision.

The Cary Company
1195 W. Fullerton Ave.
Addison, IL 60101

thecarycompany.com

Contact us for more info:
Ph: 630-629-6600

PRECISION IBC CALIBRATION CHART
for Supertainer IBC Tanks

FILL HEIGHT (inches)	42” x 48” (GALLONS)	42” x 42” (GALLONS)
3″	22.3	18
4″	31	25.5
5″	39.7	33.1
6″	48.4	40.6
7″	57.2	48.1
8″	65.9	55.6
9″	74.6	63.2
10″	83.4	70.7
11″	92.1	78.2
12″	100.8	85.7
13″	109.6	93.3
14″	118.3	100.8
15″	127	108.3
16″	135.7	115.8
17″	144.5	123.4
18″	152.2	130.9
19″	160.9	138.4
20″	169.6	145.9
21″	177.6	153.5
22″	186.4	161
23″	195.1	168.5
24″	203.8	176
25″	212.5	183.6
26″	221.3	191.1
27″	230	198.6
28″	238.7	206.1
29″	247.5	213.7
30″	263	221.2
31″	271.7	228.7
32″	280.4	236.2
33″	289.2	243.8
34″	297.9	251.3

FILL HEIGHT (inches)	42” x 48” (GALLONS)	42” x 42” (GALLONS)
35″	306.6	258.8
36″	316.9	266.3
37″	325.6	273.9
38″	334.3	281.4
39″	343.1	288.9
40″	351.8	296.4
41″	360.5	304
42″	370.2	311.5
43″	379	319
44″	387.7	326.5
45″	396.4	334.1
46″	405.2	341.6
47″	413.9	349.1
48″	422.6	356.7
49″	431.3	364.2
50″	440.1	371.7
51″	448.8	379.2
52″	457.5	386.8
53″	466.3	394.3
54″	477.6	401.8
55″	486.3	409.3
56″	495.1	416.9
57″	503.8	424.4
58″	512.5	431.9
59″	521.2	439.4
60″	530	447
61″	538.7	454.5
62″	547.4	462
63″	556.2	469.5
64″	564.9	477.1
65″	573.6	484.6
66″	582.4	492.1

PRECISION iBC INCORPORATED

**NOTE: All capacity values are approximate and are not to be used for dispensing. Values may vary from IBC to IBC.*

BROUSSARD, LA
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MAY 2018

Appendix B Remedial Design

B.1 TA-02 Treatment Area Design

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: **OU7 Pit 1 TA-02 AEHADG-11 Hotspot**

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet	Hotspot in AEHADG-1 and MW-36 Area, 14 DPT Points
Length (Parallel to predominant groundwater flow)	50	1-1,000	feet	
Saturated Thickness	16	1-100	feet	10-26
Treatment Zone Cross Sectional Area	720	--	ft^2	
Treatment Zone Volume	36,000	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	96,967	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	72,725	--	gallons	
Design Period of Performance	3.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	10.0	2 to 20	unitless	
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	36%	.05-50	percent	PDI Eastover OU 7
Effective Porosity	27%	.05-50	percent	PDI Eastover OU 7, average based on TP, AP, clay content
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day	OU7 PDI
Average Hydraulic Gradient	1.61E-02	0.0001-0.1	ft/ft	2024 Annual Report
Average Groundwater Seepage Velocity through the Treatment Zone	0.30	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	108.8	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	158,285	--	gallons/year	
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3	Average OU- PDI for Eastover and Aquia
Soil Fraction Organic Carbon (foc)	0.28%	0.01-10	percent	PDI-38 Eastover Saturated Zone OU-7 x 2
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	4.3	0.01 to 10	mg/L	Data from 11/2020 (Average AEHADG-11, MW-36)
Nitrate	0.03	0.1 to- 20	mg/L	AEHADG-11 03/2024
Sulfate	16	10 to 5,000	mg/L	AEHADG-11 03/2024
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	Estimate based on previous EISB injections
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	0	0.1 to 20	mg/L	AEHADG-11 03/2024
Iron (III) (estimated as the amount of Fe (II) produced)	3	0.1 to 20	mg/L	AEHADG-11 03/2024
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	1.250	--	mg/L	AEHADG-11 03/2024
Trichloroethene (TCE)	0.520	--	mg/L	AEHADG-11 03/2024
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	1.300	--	mg/L	AEHADG-11 03/2024
Vinyl Chloride (VC)	0.050	--	mg/L	AEHADG-11 03/2024
Carbon Tetrachloride (CT)	0.040	--	mg/L	AEHADG-11 03/2024
Trichloromethane (or chloroform) (CF)	0.024	--	mg/L	AEHADG-11 03/2024
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	AEHADG-11 03/2024
Chloromethane	0.000	--	mg/L	AEHADG-11 03/2024
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.001	--	mg/L	AEHADG-11 03/2024
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	1.100	--	mg/L	AEHADG-11 03/2024
Dichloroethane (1,1-DCA and 1,2-DCA)	0.040	--	mg/L	AEHADG-11 03/2024
Chloroethane	0.120	--	mg/L	AEHADG-11 03/2024
Perchlorate	0.000	--	mg/L	No data
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	234	-400 to +500	mV	AEHADG-11 03/2024
Temperature	12	5.0 to 30	ºC	AEHADG-11 03/2024
pH	5.1	4.0 to 10.0	su	AEHADG-11 03/2024
Alkalinity	55	10 to 1,000	mg/L	AEHADG-11 03/2024
Total Dissolved Solids (TDS, or salinity)	100	10 to 1,000	mg/L	No data
Specific Conductivity	158	100 to 10,000	µs/cm	AEHADG-11 03/2024
Chloride	6	10 to 10,000	mg/L	AEHADG-11 03/2024
Sulfide - Pre injection	0.1	0.1 to 100	mg/L	Estimate Not Detected
Sulfide - Post injection	1.7	0.1 to 100	mg/L	AEHADG-11 03/2024
B. Aquifer Matrix				
Total Iron	18000	200 to 20,000	mg/kg	CSM 2006 Soil Eastover
Cation Exchange Capacity	1	1.0 to 10	meq/100 g	CSM 2006 Soil Eastover
Neutralization Potential	1.0%	1.0 to 100	Percent as $CaCO_3$	CSM 2006 Soil Eastover

NOTES:

Design ROI = 12 ft., Injection Point Spacing = 20 ft., Row Spacing -= 10 ft.

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: **OU7 Pit 1 TA-02 AEHADG-11 Hotspot**

RETURN TO COVER PAGE

NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet
Length (Parallel to predominant groundwater flow)	50	1-1,000	feet
Saturated Thickness	16	1-100	feet
Treatment Zone Cross Sectional Area	720	--	ft^2
Treatment Zone Volume	36,000	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	72,725	--	gallons
Design Period of Performance	3.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

		Values	Range	Units
Total Porosity		0.36	.05-50	
Effective Porosity		0.27	.05-50	
Average Aquifer Hydraulic Conductivity		5	.01-1000	ft/day
Average Hydraulic Gradient		0.0161	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone		0.30	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone		108.8	--	ft/yr
Average Groundwater Flux through the Treatment Zor	0	158,285	--	gallons/year
Soil Bulk Density		1.63	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)		0.0028	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	4.3	2.61	7.94	0.33	4
Nitrate (denitrification)	0.0	0.02	12.30	0.00	5
Sulfate	16.25	9.86	11.91	0.83	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	6.07	1.99	3.05	8
Soluble Competing Electron Acceptor Demand (lb.)				**4.21**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	0.2	1.01	27.25	0.04	2
Iron (III) (estimated as the amount of Fe (II) produced)	3.5	15.81	55.41	0.29	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**0.32**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	1.250	0.76	20.57	0.04	8
Trichloroethene (TCE)	0.520	0.32	21.73	0.01	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	1.300	0.79	24.05	0.03	4
Vinyl Chloride (VC)	0.050	0.03	31.00	0.00	2
Carbon Tetrachloride (CT)	0.040	0.02	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.024	0.01	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.001	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	1.100	0.67	22.06	0.03	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.040	0.02	24.55	0.00	4
Chloroethane	0.120	0.07	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.12**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.92	3.37	20.57	0.16	8
Trichloroethene (TCE)	107	0.16	0.57	21.73	0.03	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.16	0.60	24.05	0.02	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.03	0.09	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.02	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	0.32	1.18	22.06	0.05	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.00	0.01	24.55	0.00	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.28**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	4.3	5.68	7.94	0.72	4
Nitrate (denitrification)	0.0	0.03	10.25	0.00	5
Sulfate	16.25	21.46	11.91	1.80	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	13.21	1.99	6.64	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**9.2**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	1.250	1.65	20.57	0.08	8
Trichloroethene (TCE)	0.520	0.69	21.73	0.03	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	1.300	1.72	24.05	0.07	4
Vinyl Chloride (VC)	0.050	0.07	31.00	0.00	2
Carbon Tetrachloride (CT)	0.040	0.05	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.024	0.03	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.001	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	1.100	1.45	22.06	0.07	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.040	0.05	24.55	0.00	4
Chloroethane	0.120	0.16	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.26**	

Initial Hydrogen Requirement First Year (lb)	**14.3**
Total Life-Cycle Hydrogen Requirement (lb)	**33.2**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**10.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**331.9**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^{2} = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^{3} = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

RETURN TO COVER PAGE

Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4
Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 3

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	10.0	7,415	7,415	3.36E+09	1,623
Sodium Lactate Product (60 percent solution)	10.0	7,415	15,383	3.36E+09	1,623
Molasses (assuming 6 0	10.0	7,044	11,740	3.20E+09	1,541
HFCS (assuming 40% fructose and 40% glucose by weight)	10.0	7,416	9,270	3.36E+09	1,623
Ethanol Product (assuming 80% ethanol by weight)	10.0	3,792	4,740	1.72E+09	830
Whey (assuming 100% lactose)	10.0	5,118	7,312	2.32E+09	1,120
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	10.0	5,621	5,621	2.55E+09	984
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	10.0	2,886	2,886	1.31E+09	632
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	10.0	2,886	4,810	1.31E+09	632

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: **OU7 Pit 1 TA-02 AEHADG-11 Hotspot**

RETURN TO COVER PAGE

1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	45	feet	14	meters
Length (parallel to groundwater flow)	50	feet	15.2	meters
Saturated Thickness	16	feet	4.9	meters
Design Period of Performance	3	years	3	years

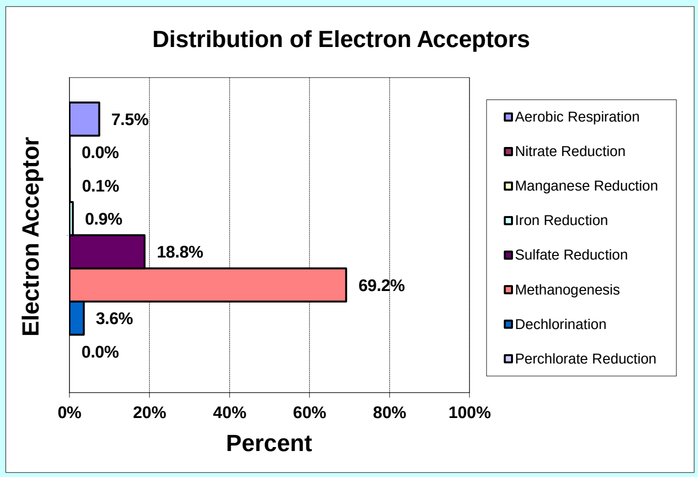
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.36	percent	0.36	percent
Effective Porosity	0.27	percent	0.27	percent
Average Aquifer Hydraulic Conductivity	5	ft/day	1.8E-03	cm/sec
Average Hydraulic Gradient	0.0161	ft/ft	0.0161	m/m
Average Groundwater Seepage Velocity	0.30	ft/day	9.1E+00	cm/day
Average Groundwater Seepage Velocity	109	ft/yr	33.2	m/yr
Effective Treatment Zone Pore Volume	72,725	gallons	275,287	liters
Groundwater Flux (per year)	158,285	gallons/year	599,156	liters/year
Total Groundwater Volume Treated (over entire design period)	547,579	gallons total	2,072,755	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	7.5%	2.475
Nitrate Reduction	0.0%	0.011
Sulfate Reduction	18.8%	6.234
Manganese Reduction	0.1%	0.037
Iron Reduction	0.9%	0.285
Methanogenesis	69.2%	22.961
Dechlorination	3.6%	1.184
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**33.19**

Hydrogen demand in pounds/gallon:	6.06E-05
Hydrogen demand in grams per liter:	7.26E-03



4. Substrate Equivalents: Design Factor = 10.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	15,383	1,398	1,623	as lactic acid
2. Molasses Product	11,740	978	1,541	as sucrose
3. Fructose Product	9,270	828	1,623	as fructose
4. Ethanol Product	4,740	687	830	as ethanol
5. Sweet Dry Whey (lactose)	7,312	sold by pound	1,120	as lactose
6. HRC®	5,621	sold by pound	984	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	2,886	370	632	as soybean oil
8. Emulsified Vegetable Oil	4,810	617	632	as soybean oil

Notes:
1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

B.2 TA-03 Treatment Area Design

Substrate Estimating Tool (Version 1.2)

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: **OU7 Pit 1 TA-03 CMT-21 Hot Spot and MW-68**

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	**Values**	**Range**	**Units**	**User Notes**
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet	Hotspot CMT-21 area and MW-68, 10 DPT Points
Length (Parallel to predominant groundwater flow)	40	1-1,000	feet	
Saturated Thickness	15	1-100	feet	9-24
Treatment Zone Cross Sectional Area	675	--	ft^2	
Treatment Zone Volume	27,000	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	72,725	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	54,544	--	gallons	
Design Period of Performance	3.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	10.0	2 to 20	unitless	
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	36%	.05-50	percent	PDI Eastover OU 7
Effective Porosity	27%	.05-50	percent	PDI Eastover OU 7, average based on TP, AP, clay content
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day	OU7 PDI
Average Hydraulic Gradient	1.61E-02	0.0001-0.1	ft/ft	2024 Annual Report
Average Groundwater Seepage Velocity through the Treatment Zone	0.30	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	108.8	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	148,392	--	gallons/year	
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3	Average OU- PDI for Eastover and Aquia
Soil Fraction Organic Carbon (foc)	0.28%	0.01-10	percent	PDI-38 Eastover Saturated Zone OU-7 x 2
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.2	0.01 to 10	mg/L	CMT-21-2, MW-68 (average) 03/2024
Nitrate	0.02	0.1 to- 20	mg/L	CMT-21-2, MW-68 (average) 03/2024
Sulfate	5	10 to 5,000	mg/L	MW-68 03/2024
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	Estimate based on previous EISB injections
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	1	0.1 to 20	mg/L	CMT-21-2, MW-68 (average) 03/2024
Iron (III) (estimated as the amount of Fe (II) produced)	3	0.1 to 20	mg/L	CMT-21-2, MW-68 (average) 03/2024
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.500	--	mg/L	CMT-21-2 03/2024
Trichloroethene (TCE)	0.450	--	mg/L	CMT-21-2 03/2024
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	14.490	--	mg/L	CMT-21-2 03/2024
Vinyl Chloride (VC)	0.140	--	mg/L	CMT-21-2 03/2024
Carbon Tetrachloride (CT)	0.000	--	mg/L	Not detected
Trichloromethane (or chloroform) (CF)	0.042	--	mg/L	CMT-21-2 03/2024
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	Not detected
Chloromethane	0.000	--	mg/L	Not detected
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	Not detected
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	1.000	--	mg/L	CMT-21-2 03/2024
Dichloroethane (1,1-DCA and 1,2-DCA)	0.130	--	mg/L	CMT-21-2 03/2024
Chloroethane	0.000	--	mg/L	Not detected
Perchlorate	0.000	--	mg/L	No data
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-45	-400 to +500	mV	CMT-21-2, MW-68 (average) 03/2024
Temperature	13	5.0 to 30	ºC	CMT-21-2, MW-68 (average) 03/2024
pH	6.0	4.0 to 10.0	su	CMT-21-2, MW-68 (average) 03/2024
Alkalinity	225	10 to 1,000	mg/L	CMT-21-2, MW-68 (average) 03/2024
Total Dissolved Solids (TDS, or salinity)	100	10 to 1,000	mg/L	No data
Specific Conductivity	918	100 to 10,000	µs/cm	CMT-21-2, MW-68 (average) 03/2024
Chloride	46	10 to 10,000	mg/L	CMT-21-2, MW-68 (average) 03/2024
Sulfide - Pre injection	0.1	0.1 to 100	mg/L	Estimated
Sulfide - Post injection	2.5	0.1 to 100	mg/L	Estimated
B. Aquifer Matrix				
Total Iron	18000	200 to 20,000	mg/kg	CSM 2006 Soil Eastover
Cation Exchange Capacity	1	1.0 to 10	meq/100 g	CSM 2006 Soil Eastover
Neutralization Potential	1.0%	1.0 to 100	Percent as $CaCO_3$	CSM 2006 Soil Eastover

NOTES:

Design ROI = 12 ft., Injection Point Spacing = 20 ft., Row Spacing -= 10 ft.

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: **OU7 Pit 1 TA-03 CMT-21 Hot Spot and MW-68**

RETURN TO COVER PAGE

NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet
Length (Parallel to predominant groundwater flow)	40	1-1,000	feet
Saturated Thickness	15	1-100	feet
Treatment Zone Cross Sectional Area	675	--	ft^2
Treatment Zone Volume	27,000	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	54,544	--	gallons
Design Period of Performance	3.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

	Values	Range	Units
Total Porosity	0.36	.05-50	
Effective Porosity	0.27	.05-50	
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day
Average Hydraulic Gradient	0.0161	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.30	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	108.8	--	ft/yr
Average Groundwater Flux through the Treatment Zor 0	148,392	--	gallons/year
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.0028	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.2	0.10	7.94	0.01	4
Nitrate (denitrification)	0.0	0.01	12.30	0.00	5
Sulfate	4.7	2.14	11.91	0.18	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	4.55	1.99	2.29	8
	Soluble Competing Electron Acceptor Demand (lb.)			**2.48**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	1.3	5.42	27.25	0.20	2
Iron (III) (estimated as the amount of Fe (II) produced)	3.4	14.30	55.41	0.26	1
	Solid-Phase Competing Electron Acceptor Demand (lb.)			**0.46**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.500	0.23	20.57	0.01	8
Trichloroethene (TCE)	0.450	0.20	21.73	0.01	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	14.490	6.60	24.05	0.27	4
Vinyl Chloride (VC)	0.140	0.06	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.042	0.02	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	1.000	0.46	22.06	0.02	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.130	0.06	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
	Total Soluble Contaminant Electron Acceptor Demand (lb.)			**0.32**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.37	1.01	20.57	0.05	8
Trichloroethene (TCE)	107	0.13	0.37	21.73	0.02	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	1.83	5.02	24.05	0.21	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.01	0.02	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	0.29	0.81	22.06	0.04	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.01	0.03	24.55	0.00	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
	Total Sorbed Contaminant Electron Acceptor Demand (lb.)				**0.31**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.2	0.28	7.94	0.04	4
Nitrate (denitrification)	0.0	0.03	10.25	0.00	5
Sulfate	4.7	5.82	11.91	0.49	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	12.38	1.99	6.22	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**6.7**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.500	0.62	20.57	0.03	8
Trichloroethene (TCE)	0.450	0.56	21.73	0.03	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	14.490	17.94	24.05	0.75	4
Vinyl Chloride (VC)	0.140	0.17	31.00	0.01	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.042	0.05	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	1.000	1.24	22.06	0.06	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.130	0.16	24.55	0.01	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.87**	

Initial Hydrogen Requirement First Year (lb)	**11.2**
Total Life-Cycle Hydrogen Requirement (lb)	**26.4**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**10.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**264.4**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
μs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

RETURN TO COVER PAGE

Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4

Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 3

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	10.0	5,907	5,907	2.68E+09	1,416
Sodium Lactate Product (60 percent solution)	10.0	5,907	12,255	2.68E+09	1,416
Molasses (assuming 6 0	10.0	5,612	9,353	2.55E+09	1,346
HFCS (assuming 40% fructose and 40% glucose by weight)	10.0	5,908	7,385	2.68E+09	1,417
Ethanol Product (assuming 80% ethanol by weight)	10.0	3,021	3,776	1.37E+09	724
Whey (assuming 100% lactose)	10.0	4,078	5,825	1.85E+09	978
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	10.0	4,478	4,478	2.03E+09	859
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	10.0	2,299	2,299	1.04E+09	551
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	10.0	2,299	3,832	1.04E+09	551

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: **OU7 Pit 1 TA-03 CMT-21 Hot Spot and MW-68**

RETURN TO COVER PAGE

1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	45	feet	14	meters
Length (parallel to groundwater flow)	40	feet	12.2	meters
Saturated Thickness	15	feet	4.6	meters
Design Period of Performance	3	years	3	years

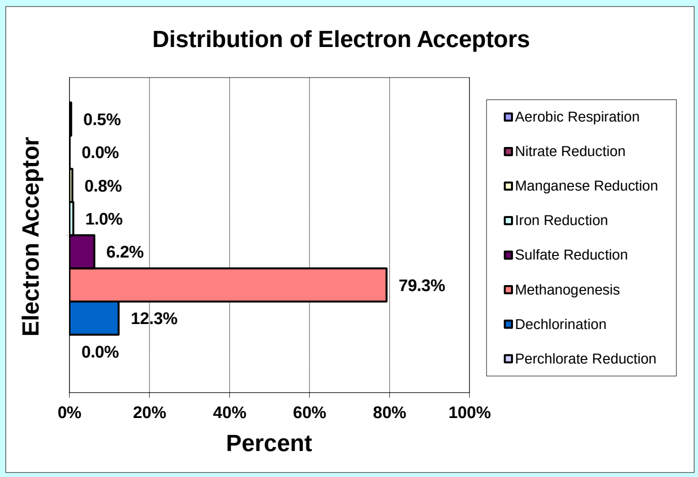
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.36	percent	0.36	percent
Effective Porosity	0.27	percent	0.27	percent
Average Aquifer Hydraulic Conductivity	5	ft/day	1.8E-03	cm/sec
Average Hydraulic Gradient	0.0161	ft/ft	0.0161	m/m
Average Groundwater Seepage Velocity	0.30	ft/day	9.1E+00	cm/day
Average Groundwater Seepage Velocity	109	ft/yr	33.2	m/yr
Effective Treatment Zone Pore Volume	54,544	gallons	206,465	liters
Groundwater Flux (per year)	148,392	gallons/year	561,709	liters/year
Total Groundwater Volume Treated (over entire design period)	499,720	gallons total	1,891,591	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.5%	0.121
Nitrate Reduction	0.0%	0.009
Sulfate Reduction	6.2%	1.646
Manganese Reduction	0.8%	0.199
Iron Reduction	1.0%	0.258
Methanogenesis	79.3%	20.954
Dechlorination	12.3%	3.253
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**26.44**

Hydrogen demand in pounds/gallon:	5.29E-05
Hydrogen demand in grams per liter:	6.34E-03



4. Substrate Equivalents: Design Factor = 10.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	12,255	1,114	1,416	as lactic acid
2. Molasses Product	9,353	779	1,346	as sucrose
3. Fructose Product	7,385	659	1,417	as fructose
4. Ethanol Product	3,776	547	724	as ethanol
5. Sweet Dry Whey (lactose)	5,825	sold by pound	978	as lactose
6. HRC®	4,478	sold by pound	859	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	2,299	295	551	as soybean oil
8. Emulsified Vegetable Oil	3,832	491	551	as soybean oil

Notes:
1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

B.3 TA-05 Treatment Area Design

Substrate Estimating Tool (Version 1.2)

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: OU7 Pit 1 TA-05 DMW-29A

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet	Pit 1 Area, Target DMW-29A Area 6 DPT Points
Length (Parallel to predominant groundwater flow)	30	1-1,000	feet	
Saturated Thickness	18	1-100	feet	10-28
Treatment Zone Cross Sectional Area	720	--	ft^2	
Treatment Zone Volume	21,600	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	58,180	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	43,635	--	gallons	
Design Period of Performance	3.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	10.0	2 to 20	unitless	
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	36%	.05-50	percent	PDI Eastover OU 7
Effective Porosity	27%	.05-50	percent	PDI Eastover OU 7, average based on TP, AP, clay content
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day	OU7 PDI
Average Hydraulic Gradient	1.61E-02	0.0001-0.1	ft/ft	2024 Annual Report
Average Groundwater Seepage Velocity through the Treatment Zone	0.30	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	108.8	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	158,285	--	gallons/year	
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3	Average OU- PDI for Eastover and Aquia
Soil Fraction Organic Carbon (foc)	0.28%	0.01-10	percent	PDI-38 Eastover Saturated Zone OU-7 x 2
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	1.1	0.01 to 10	mg/L	DMW-29A 03/2024
Nitrate	0.05	0.1 to- 20	mg/L	DMW-29A 03/2024
Sulfate	1	10 to 5,000	mg/L	DMW-29A 03/2024
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	Estimate based on previous EISB injections
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	0	0.1 to 20	mg/L	DMW-29A 03/2024
Iron (III) (estimated as the amount of Fe (II) produced)	9	0.1 to 20	mg/L	DMW-29A 03/2024
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.006	--	mg/L	DMW-29A 03/2024
Trichloroethene (TCE)	0.100	--	mg/L	DMW-29A 03/2024
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.126	--	mg/L	DMW-29A 03/2024
Vinyl Chloride (VC)	0.007	--	mg/L	DMW-29A 03/2024
Carbon Tetrachloride (CT)	0.000	--	mg/L	Not detected
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	Not detected
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	Not detected
Chloromethane	0.000	--	mg/L	Not detected
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	Not detected
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	--	mg/L	Not detected
Dichloroethane (1,1-DCA and 1,2-DCA)	0.000	--	mg/L	Not detected
Chloroethane	0.010	--	mg/L	DMW-29A 03/2024
Perchlorate	0.000	--	mg/L	No data
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	310	-400 to +500	mV	DMW-29A 03/2024
Temperature	14	5.0 to 30	ºC	DMW-29A 03/2024
pH	5.5	4.0 to 10.0	su	DMW-29A 03/2024
Alkalinity	78	10 to 1,000	mg/L	DMW-29A 03/2024
Total Dissolved Solids (TDS, or salinity)	100	10 to 1,000	mg/L	No data
Specific Conductivity	750	100 to 10,000	µs/cm	DMW-29A 03/2024
Chloride	19	10 to 10,000	mg/L	DMW-29A 03/2024
Sulfide - Pre injection	0.1	0.1 to 100	mg/L	Estimate Not Detected
Sulfide - Post injection	1.2	0.1 to 100	mg/L	DMW-29A 03/2024
B. Aquifer Matrix				
Total Iron	18000	200 to 20,000	mg/kg	CSM 2006 Soil Eastover
Cation Exchange Capacity	1	1.0 to 10	meq/100 g	CSM 2006 Soil Eastover
Neutralization Potential	1.0%	1.0 to 100	Percent as $CaCO_3$	CSM 2006 Soil Eastover

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: **OU7 Pit 1 TA-05 DMW-29A**

RETURN TO COVER PAGE

NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet
Length (Parallel to predominant groundwater flow)	30	1-1,000	feet
Saturated Thickness	18	1-100	feet
Treatment Zone Cross Sectional Area	720	--	ft^2
Treatment Zone Volume	21,600	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	43,635	--	gallons
Design Period of Performance	3.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

	Values	Range	Units
Total Porosity	0.36	.05-50	
Effective Porosity	0.27	.05-50	
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day
Average Hydraulic Gradient	0.0161	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.30	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	108.8	--	ft/yr
Average Groundwater Flux through the Treatment Zor 0	158,285	--	gallons/year
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.0028	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	1.1	0.40	7.94	0.05	4
Nitrate (denitrification)	0.1	0.02	12.30	0.00	5
Sulfate	0.5	0.18	11.91	0.02	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	3.64	1.99	1.83	8
Soluble Competing Electron Acceptor Demand (lb.)				**1.90**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	0.5	1.99	27.25	0.07	2
Iron (III) (estimated as the amount of Fe (II) produced)	9.0	38.94	55.41	0.70	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**0.78**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.006	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.100	0.04	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.126	0.05	24.05	0.00	4
Vinyl Chloride (VC)	0.007	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.000	0.00	24.55	0.00	4
Chloroethane	0.010	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.00**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.00	0.01	20.57	0.00	8
Trichloroethene (TCE)	107	0.03	0.07	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.02	0.03	24.05	0.00	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	0.00	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.00	0.00	24.55	0.00	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.00**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	1.1	1.45	7.94	0.18	4
Nitrate (denitrification)	0.1	0.07	10.25	0.01	5
Sulfate	0.5	0.66	11.91	0.06	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	13.21	1.99	6.64	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**6.9**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.006	0.01	20.57	0.00	8
Trichloroethene (TCE)	0.100	0.13	21.73	0.01	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.126	0.17	24.05	0.01	4
Vinyl Chloride (VC)	0.007	0.01	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.000	0.00	24.55	0.00	4
Chloroethane	0.010	0.01	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.01**	

Initial Hydrogen Requirement First Year (lb)	**9.6**
Total Life-Cycle Hydrogen Requirement (lb)	**23.4**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**10.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**233.7**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
μs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

RETURN TO COVER PAGE

Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4
Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 3

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	10.0	5,221	5,221	2.37E+09	1,207
Sodium Lactate Product (60 percent solution)	10.0	5,221	10,832	2.37E+09	1,207
Molasses (assuming 6 0	10.0	4,960	8,267	2.25E+09	1,146
HFCS (assuming 40% fructose and 40% glucose by weight)	10.0	5,222	6,528	2.37E+09	1,207
Ethanol Product (assuming 80% ethanol by weight)	10.0	2,670	3,338	1.21E+09	617
Whey (assuming 100% lactose)	10.0	3,604	5,149	1.63E+09	833
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	10.0	3,958	3,958	1.80E+09	732
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	10.0	2,032	2,032	9.22E+08	470
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	10.0	2,032	3,387	9.22E+08	470

NOTES: Sodium Lactate Product
1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product
1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product
1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: **OU7 Pit 1 TA-05 DMW-29A**

RETURN TO COVER PAGE

1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	40	feet	12	meters
Length (parallel to groundwater flow)	30	feet	9.1	meters
Saturated Thickness	18	feet	5.5	meters
Design Period of Performance	3	years	3	years

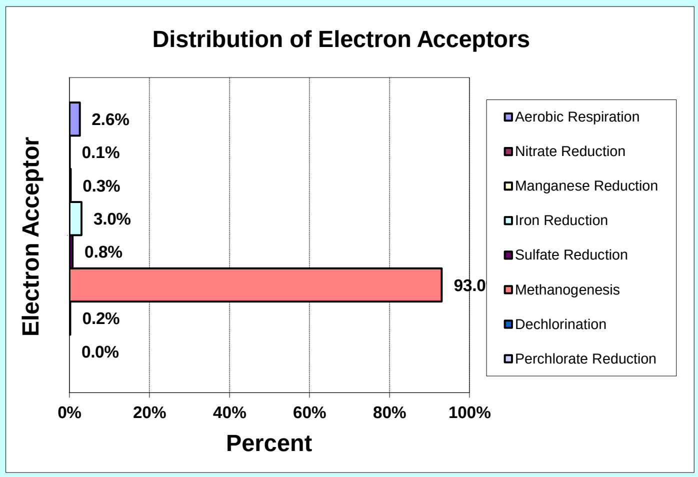
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.36	percent	0.36	percent
Effective Porosity	0.27	percent	0.27	percent
Average Aquifer Hydraulic Conductivity	5	ft/day	1.8E-03	cm/sec
Average Hydraulic Gradient	0.0161	ft/ft	0.0161	m/m
Average Groundwater Seepage Velocity	0.30	ft/day	9.1E+00	cm/day
Average Groundwater Seepage Velocity	109	ft/yr	33.2	m/yr
Effective Treatment Zone Pore Volume	43,635	gallons	165,172	liters
Groundwater Flux (per year)	158,285	gallons/year	599,156	liters/year
Total Groundwater Volume Treated (over entire design period)	518,489	gallons total	1,962,640	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	2.6%	0.599
Nitrate Reduction	0.1%	0.021
Sulfate Reduction	0.8%	0.182
Manganese Reduction	0.3%	0.073
Iron Reduction	3.0%	0.703
Methanogenesis	93.0%	21.741
Dechlorination	0.2%	0.051
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**23.37**

Hydrogen demand in pounds/gallon:	4.51E-05
Hydrogen demand in grams per liter:	5.40E-03



4. Substrate Equivalents: Design Factor = 10.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	10,832	985	1,207	as lactic acid
2. Molasses Product	8,267	689	1,146	as sucrose
3. Fructose Product	6,528	583	1,207	as fructose
4. Ethanol Product	3,338	484	617	as ethanol
5. Sweet Dry Whey (lactose)	5,149	sold by pound	833	as lactose
6. HRC®	3,958	sold by pound	732	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	2,032	261	470	as soybean oil
8. Emulsified Vegetable Oil	3,387	434	470	as soybean oil

Notes:
1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

B.4 TA-06 Treatment Area Design

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: OU7 Pit 1 TA-06 CMT-20 (INJ-211) | RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	25	1-10,000	feet	Pit 1 Area, INJ-211
Length (Parallel to predominant groundwater flow)	50	1-1,000	feet	
Saturated Thickness	20	1-100	feet	10-30 ft
Treatment Zone Cross Sectional Area	500	--	ft^2	
Treatment Zone Volume	25,000	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	67,338	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	50,504	--	gallons	
Design Period of Performance	1.5	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	10.0	2 to 20	unitless	
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	36%	.05-50	percent	PDI Eastover OU 7
Effective Porosity	27%	.05-50	percent	PDI Eastover OU 7, average based on TP, AP, clay content
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day	OU7 PDI
Average Hydraulic Gradient	1.61E-02	0.0001-0.1	ft/ft	2024 Annual Report
Average Groundwater Seepage Velocity through the Treatment Zone	0.30	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	108.8	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	109,920	--	gallons/year	
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3	Average OU- PDI for Eastover and Aquia
Soil Fraction Organic Carbon (foc)	0.28%	0.01-10	percent	PDI-38 Eastover Saturated Zone OU-7 x 2
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.1	0.01 to 10	mg/L	CMT-20-3 (03/2024)
Nitrate	0.03	0.1 to- 20	mg/L	CMT-20-3 (03/2024)
Sulfate	2	10 to 5,000	mg/L	CMT-20-3 (03/2024)
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	Estimate based on previous EISB injections
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	1	0.1 to 20	mg/L	Data from 11/2020 (CMT20)
Iron (III) (estimated as the amount of Fe (II) produced)	10	0.1 to 20	mg/L	Estimated
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.000	--	mg/L	CMT-20-3 03/2024
Trichloroethene (TCE)	0.001	--	mg/L	CMT-20-3 03/2024
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.221	--	mg/L	CMT-20-3 03/2024
Vinyl Chloride (VC)	0.120	--	mg/L	CMT-20-3 03/2024
Carbon Tetrachloride (CT)	0.000	--	mg/L	Not detected
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	Not detected
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	Not detected
Chloromethane	0.000	--	mg/L	Not detected
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	Not detected
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	--	mg/L	Not detected
Dichloroethane (1,1-DCA and 1,2-DCA)	0.024	--	mg/L	CMT-20-3 03/2024
Chloroethane	0.000	--	mg/L	Not detected
Perchlorate	0.000	--	mg/L	No data
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-64	-400 to +500	mV	CMT-20-3 03/2024
Temperature	16	5.0 to 30	ºC	CMT-20-3 03/2024
pH	6.4	4.0 to 10.0	su	CMT-20 03/2024
Alkalinity	153	10 to 1,000	mg/L	CMT-20 03/2024
Total Dissolved Solids (TDS, or salinity)	100	10 to 1,000	mg/L	No data
Specific Conductivity	479	100 to 10,000	µs/cm	CMT-20-3 03/2024
Chloride	125	10 to 10,000	mg/L	CMT-20 03/2024
Sulfide - Pre injection	0.1	0.1 to 100	mg/L	Estimate
Sulfide - Post injection	0.2	0.1 to 100	mg/L	Estimate
B. Aquifer Matrix				
Total Iron	18000	200 to 20,000	mg/kg	CSM 2006 Soil Eastover
Cation Exchange Capacity	1	1.0 to 10	meq/100 g	CSM 2006 Soil Eastover
Neutralization Potential	1.0%	1.0 to 100	Percent as $CaCO_3$	CSM 2006 Soil Eastover

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: **OU7 Pit 1 TA-06 CMT-20 (INJ-211)**

RETURN TO COVER PAGE

NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions	**Values**	**Range**	**Units**
Width (Perpendicular to predominant groundwater flow direction)	25	1-10,000	feet
Length (Parallel to predominant groundwater flow)	50	1-1,000	feet
Saturated Thickness	20	1-100	feet
Treatment Zone Cross Sectional Area	500	--	ft^2
Treatment Zone Volume	25,000	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	50,504	--	gallons
Design Period of Performance	1.5	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties			
Total Porosity	0.36	.05-50	
Effective Porosity	0.27	.05-50	
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day
Average Hydraulic Gradient	0.0161	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.30	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	108.8	--	ft/yr
Average Groundwater Flux through the Treatment Zor 0	109,920	--	gallons/year
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.0028	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.1	0.03	7.94	0.00	4
Nitrate (denitrification)	0.0	0.01	12.30	0.00	5
Sulfate	2.2	0.93	11.91	0.08	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	4.21	1.99	2.12	8
Soluble Competing Electron Acceptor Demand (lb.)				**2.20**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	1.3	2.36	27.25	0.09	2
Iron (III) (estimated as the amount of Fe (II) produced)	10.0	17.97	55.41	0.32	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**0.41**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.000	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.001	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.221	0.09	24.05	0.00	4
Vinyl Chloride (VC)	0.120	0.05	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.024	0.01	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.01**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.00	0.00	20.57	0.00	8
Trichloroethene (TCE)	107	0.00	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.03	0.07	24.05	0.00	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	0.00	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.00	0.01	24.55	0.00	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.00**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.1	0.07	7.94	0.01	4
Nitrate (denitrification)	0.0	0.02	10.25	0.00	5
Sulfate	2.2	2.02	11.91	0.17	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	9.17	1.99	4.61	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**4.8**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.000	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.001	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.221	0.20	24.05	0.01	4
Vinyl Chloride (VC)	0.120	0.11	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.024	0.02	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.01**	

Initial Hydrogen Requirement First Year (lb)	**7.4**
Total Life-Cycle Hydrogen Requirement (lb)	**9.8**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**10.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**98.3**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
μs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

RETURN TO COVER PAGE

Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4
Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 1.5

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	10.0	2,195	2,195	9.96E+08	1,221
Sodium Lactate Product (60 percent solution)	10.0	2,195	4,554	9.96E+08	1,221
Molasses (assuming 6 0	10.0	2,085	3,476	9.46E+08	1,160
HFCS (assuming 40% fructose and 40% glucose by weight)	10.0	2,196	2,745	9.96E+08	1,222
Ethanol Product (assuming 80% ethanol by weight)	10.0	1,123	1,403	5.09E+08	625
Whey (assuming 100% lactose)	10.0	1,515	2,165	6.87E+08	843
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	10.0	1,664	1,664	7.55E+08	741
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	10.0	854	854	3.88E+08	475
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	10.0	854	1,424	3.88E+08	475

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: **OU7 Pit 1 TA-06 CMT-20 (INJ-211)**

RETURN TO COVER PAGE

1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	25	feet	8	meters
Length (parallel to groundwater flow)	50	feet	15.2	meters
Saturated Thickness	20	feet	6.1	meters
Design Period of Performance	1.5	years	1.5	years

2. Treatment Zone Hydrogeologic Properties

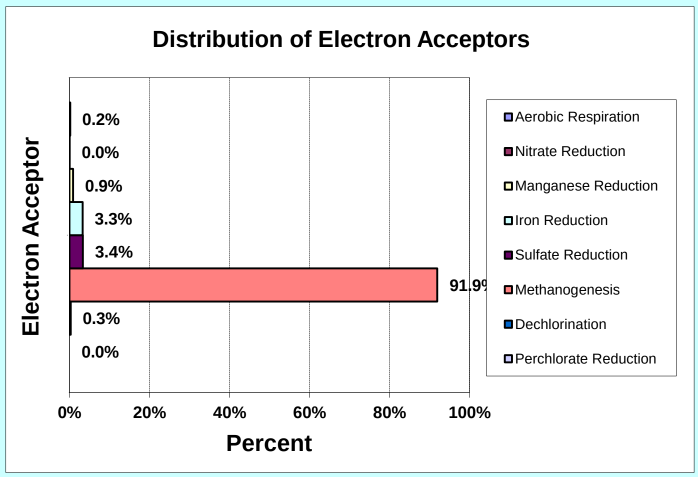
	Values	Units	Values	Units
Total Porosity	0.36	percent	0.36	percent
Effective Porosity	0.27	percent	0.27	percent
Average Aquifer Hydraulic Conductivity	5	ft/day	1.8E-03	cm/sec
Average Hydraulic Gradient	0.0161	ft/ft	0.0161	m/m
Average Groundwater Seepage Velocity	0.30	ft/day	9.1E+00	cm/day
Average Groundwater Seepage Velocity	109	ft/yr	33.2	m/yr
Effective Treatment Zone Pore Volume	50,504	gallons	191,171	liters
Groundwater Flux (per year)	109,920	gallons/year	416,081	liters/year
Total Groundwater Volume Treated (over entire design period)	215,383	gallons total	815,292	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.2%	0.018
Nitrate Reduction	0.0%	0.004
Sulfate Reduction	3.4%	0.332
Manganese Reduction	0.9%	0.087
Iron Reduction	3.3%	0.324
Methanogenesis	91.9%	9.032
Dechlorination	0.3%	0.029
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**9.83**

Hydrogen demand in pounds/gallon: 4.56E-05

Hydrogen demand in grams per liter: 5.47E-03



4. Substrate Equivalents: Design Factor = 10.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	4,554	414	1,221	as lactic acid
2. Molasses Product	3,476	290	1,160	as sucrose
3. Fructose Product	2,745	245	1,222	as fructose
4. Ethanol Product	1,403	203	625	as ethanol
5. Sweet Dry Whey (lactose)	2,165	sold by pound	843	as lactose
6. HRC®	1,664	sold by pound	741	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	854	110	475	as soybean oil
8. Emulsified Vegetable Oil	1,424	183	475	as soybean oil

Notes:
1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

B.5 TA-07 Treatment Area Design

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: OU7 Pit 2 TA-07 MW-85, and MW-48

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet	Pit 2 Area, 7 DPT Points
Length (Parallel to predominant groundwater flow)	34	1-1,000	feet	
Saturated Thickness	12	1-100	feet	20-32
Treatment Zone Cross Sectional Area	480	--	ft^2	
Treatment Zone Volume	16,320	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	43,958	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	32,969	--	gallons	
Design Period of Performance	3.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	10.0	2 to 20	unitless	
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	36%	.05-50	percent	PDI Eastover OU 7
Effective Porosity	27%	.05-50	percent	PDI Eastover OU 7, average based on TP, AP, clay content
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day	OU7 PDI
Average Hydraulic Gradient	1.20E-02	0.0001-0.1	ft/ft	2024 Annual, Pit 2 Upper Area
Average Groundwater Seepage Velocity through the Treatment Zone	0.22	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	81.1	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	78,651	--	gallons/year	
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3	Average OU- PDI for Eastover and Aquia
Soil Fraction Organic Carbon (foc)	0.28%	0.01-10	percent	PDI-38 Eastover Saturated Zone OU-7 x 2
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	3.1	0.01 to 10	mg/L	MW-85, MW-48 (average), 3/2024
Nitrate	0.05	0.1 to- 20	mg/L	MW-85, MW-48 (average), 3/2024
Sulfate	4	10 to 5,000	mg/L	MW-85, MW-48 (average), 3/2024
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	Estimate based on previous EISB injections
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	0	0.1 to 20	mg/L	MW-85, MW-48 (average), 3/2024
Iron (III) (estimated as the amount of Fe (II) produced)	4	0.1 to 20	mg/L	MW-85, MW-48 (average), 3/2024
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.007	--	mg/L	MW-85 3/2024
Trichloroethene (TCE)	0.007	--	mg/L	MW-85 3/2024
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	9.318	--	mg/L	MW-85 3/2024
Vinyl Chloride (VC)	0.570	--	mg/L	MW-85 3/2024
Carbon Tetrachloride (CT)	0.000	--	mg/L	Not detected
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	Not detected
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	Not detected
Chloromethane	0.000	--	mg/L	Not detected
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	Not detected
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.023	--	mg/L	MW-85 3/2024
Dichloroethane (1,1-DCA and 1,2-DCA)	0.018	--	mg/L	MW-85 3/2024
Chloroethane	0.000	--	mg/L	Not detected
Perchlorate	0.000	--	mg/L	No data
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	49	-400 to +500	mV	MW-85, MW-48 (average), 3/2024
Temperature	16	5.0 to 30	ºC	MW-85, MW-48 (average), 3/2024
pH	5.8	4.0 to 10.0	su	MW-85, MW-48 (average), 3/2024
Alkalinity	160	10 to 1,000	mg/L	MW-85, MW-48 (average), 3/2024
Total Dissolved Solids (TDS, or salinity)	100	10 to 1,000	mg/L	No data
Specific Conductivity	547	100 to 10,000	μs/cm	MW-85, MW-48 (average), 3/2024
Chloride	110	10 to 10,000	mg/L	MW-85, MW-48 (average), 3/2024
Sulfide - Pre injection	0.1	0.1 to 100	mg/L	Estimate Not Detected
Sulfide - Post injection	2.9	0.1 to 100	mg/L	Data from MW-85 3/2024
B. Aquifer Matrix				
Total Iron	18000	200 to 20,000	mg/kg	CSM 2006 Soil Eastover
Cation Exchange Capacity	1	1.0 to 10	meq/100 g	CSM 2006 Soil Eastover
Neutralization Potential	1.0%	1.0 to 100	Percent as $CaCO_3$	CSM 2006 Soil Eastover

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: **OU7 Pit 2 TA-07 MW-85, and MW-48**

RETURN TO COVER PAGE

NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet
Length (Parallel to predominant groundwater flow)	34	1-1,000	feet
Saturated Thickness	12	1-100	feet
Treatment Zone Cross Sectional Area	480	--	ft^2
Treatment Zone Volume	16,320	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	32,969	--	gallons
Design Period of Performance	3.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

		Values	Range	Units
Total Porosity		0.36	.05-50	
Effective Porosity		0.27	.05-50	
Average Aquifer Hydraulic Conductivity		5	.01-1000	ft/day
Average Hydraulic Gradient		0.012	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone		0.22	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone		81.1	--	ft/yr
Average Groundwater Flux through the Treatment Zor	0	78,651	--	gallons/year
Soil Bulk Density		1.63	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)		0.0028	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	3.1	0.85	7.94	0.11	4
Nitrate (denitrification)	0.1	0.01	12.30	0.00	5
Sulfate	3.95	1.09	11.91	0.09	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	2.75	1.99	1.38	8
Soluble Competing Electron Acceptor Demand (lb.)				**1.58**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	0.4	0.99	27.25	0.04	2
Iron (III) (estimated as the amount of Fe (II) produced)	3.7	8.33	55.41	0.15	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**0.19**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.007	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.007	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	9.318	2.56	24.05	0.11	4
Vinyl Chloride (VC)	0.570	0.16	31.00	0.01	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.023	0.01	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.018	0.00	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.11**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.00	0.01	20.57	0.00	8
Trichloroethene (TCE)	107	0.00	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	1.17	1.95	24.05	0.08	4
Vinyl Chloride (VC)	3.0	0.00	0.01	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	0.01	0.01	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.00	0.00	24.55	0.00	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.08**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	3.1	2.03	7.94	0.26	4
Nitrate (denitrification)	0.1	0.03	10.25	0.00	5
Sulfate	3.95	2.59	11.91	0.22	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	6.56	1.99	3.30	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**3.8**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.007	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.007	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	9.318	6.12	24.05	0.25	4
Vinyl Chloride (VC)	0.570	0.37	31.00	0.01	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.023	0.02	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.018	0.01	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.27**	

Initial Hydrogen Requirement First Year (lb)	**6.0**
Total Life-Cycle Hydrogen Requirement (lb)	**14.1**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**10.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**140.9**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
μs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

RETURN TO COVER PAGE

Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4
Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 3

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	10.0	3,148	3,148	1.43E+09	1,403
Sodium Lactate Product (60 percent solution)	10.0	3,148	6,532	1.43E+09	1,403
Molasses (assuming 6 0	10.0	2,991	4,985	1.36E+09	1,333
HFCS (assuming 40% fructose and 40% glucose by weight)	10.0	3,149	3,936	1.43E+09	1,403
Ethanol Product (assuming 80% ethanol by weight)	10.0	1,610	2,013	7.30E+08	718
Whey (assuming 100% lactose)	10.0	2,173	3,105	9.86E+08	968
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	10.0	2,387	2,387	1.08E+09	851
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	10.0	1,226	1,226	5.56E+08	546
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	10.0	1,226	2,043	5.56E+08	546

NOTES: Sodium Lactate Product
1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product
1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product
1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: **OU7 Pit 2 TA-07 MW-85, and MW-48**

RETURN TO COVER PAGE

1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	40	feet	12	meters
Length (parallel to groundwater flow)	34	feet	10.4	meters
Saturated Thickness	12	feet	3.7	meters
Design Period of Performance	3	years	3	years

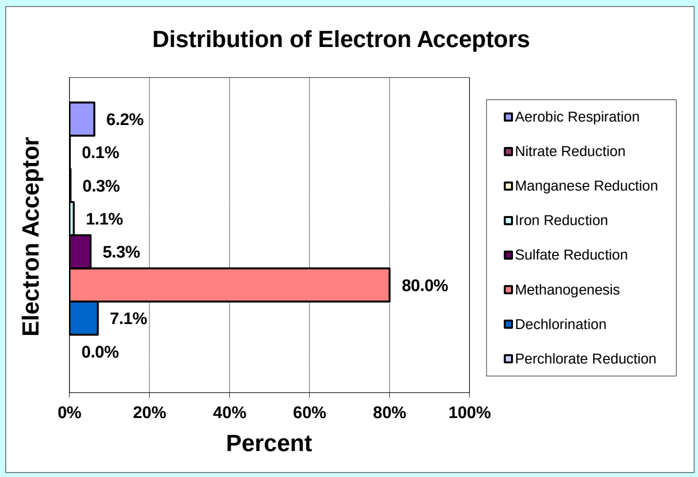
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.36	percent	0.36	percent
Effective Porosity	0.27	percent	0.27	percent
Average Aquifer Hydraulic Conductivity	5	ft/day	1.8E-03	cm/sec
Average Hydraulic Gradient	0.012	ft/ft	0.012	m/m
Average Groundwater Seepage Velocity	0.22	ft/day	6.8E+00	cm/day
Average Groundwater Seepage Velocity	81	ft/yr	24.7	m/yr
Effective Treatment Zone Pore Volume	32,969	gallons	124,797	liters
Groundwater Flux (per year)	78,651	gallons/year	297,717	liters/year
Total Groundwater Volume Treated (over entire design period)	268,921	gallons total	1,017,948	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	6.2%	0.876
Nitrate Reduction	0.1%	0.011
Sulfate Reduction	5.3%	0.744
Manganese Reduction	0.3%	0.036
Iron Reduction	1.1%	0.150
Methanogenesis	80.0%	11.276
Dechlorination	7.1%	0.999
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**14.09**

Hydrogen demand in pounds/gallon:	5.24E-05
Hydrogen demand in grams per liter:	6.28E-03



4. Substrate Equivalents: Design Factor = **10.0**

Effective concentration is for total volume of groundwater treated.

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	
1. Sodium Lactate Product	6,532	594	1,403	as lactic acid
2. Molasses Product	4,985	415	1,333	as sucrose
3. Fructose Product	3,936	351	1,403	as fructose
4. Ethanol Product	2,013	292	718	as ethanol
5. Sweet Dry Whey (lactose)	3,105	sold by pound	968	as lactose
6. HRC®	2,387	sold by pound	851	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	1,226	157	546	as soybean oil
8. Emulsified Vegetable Oil	2,043	262	546	as soybean oil

Notes:
1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

B.6 TA-08 Treatment Area Design

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: OU7 Pit 2 TA-08 CMT-18, MW-144

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet	Pit 2 Area, 7 DPT points
Length (Parallel to predominant groundwater flow)	34	1-1,000	feet	
Saturated Thickness	11	1-100	feet	17-28
Treatment Zone Cross Sectional Area	495	--	ft^2	
Treatment Zone Volume	16,830	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	45,332	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	33,999	--	gallons	
Design Period of Performance	3.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	10.0	2 to 20	unitless	

2. Treatment Zone Hydrogeologic Properties				
Total Porosity	36%	.05-50	percent	PDI Eastover OU 7
Effective Porosity	27%	.05-50	percent	PDI Eastover OU 7, average based on TP, AP, clay content
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day	OU7 PDI
Average Hydraulic Gradient	1.20E-02	0.0001-0.1	ft/ft	2024 Annual, Pit 2 Upper Area
Average Groundwater Seepage Velocity through the Treatment Zone	0.22	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	81.1	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	81,109	--	gallons/year	
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3	Average OU- PDI for Eastover and Aquia
Soil Fraction Organic Carbon (foc)	0.28%	0.01-10	percent	PDI-38 Eastover Saturated Zone OU-7 x 2

3. Native Electron Acceptors

A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.8	0.01 to 10	mg/L	CMT-18 03/2024
Nitrate	0.16	0.1 to- 20	mg/L	CMT-18 03/2024
Sulfate	1	10 to 5,000	mg/L	CMT-18 03/2024
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	Estimate based on previous EISB injections

B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	1	0.1 to 20	mg/L	CMT-18 03/2024
Iron (III) (estimated as the amount of Fe (II) produced)	3	0.1 to 20	mg/L	CMT-18 03/2024

4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.007	--	mg/L	CMT-18 03/2024
Trichloroethene (TCE)	0.006	--	mg/L	CMT-18 03/2024
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.609	--	mg/L	CMT-18 03/2024
Vinyl Chloride (VC)	0.920	--	mg/L	CMT-18 03/2024
Carbon Tetrachloride (CT)	0.000	--	mg/L	Not detected
Trichloromethane (or chloroform) (CF)	0.010	--	mg/L	CMT-18 03/2024
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	Not detected
Chloromethane	0.000	--	mg/L	Not detected
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	Not detected
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	--	mg/L	Not detected
Dichloroethane (1,1-DCA and 1,2-DCA)	0.027	--	mg/L	CMT-18 03/2024
Chloroethane	0.000	--	mg/L	Not detected
Perchlorate	0.000	--	mg/L	No data

5. Aquifer Geochemistry (Optional Screening Parameters)

A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	249	-400 to +500	mV	CMT-18 03/2024
Temperature	15	5.0 to 30	ºC	CMT-18 03/2024
pH	5.2	4.0 to 10.0	su	CMT-18 03/2024
Alkalinity	93	10 to 1,000	mg/L	CMT-18 03/2024
Total Dissolved Solids (TDS, or salinity)	100	10 to 1,000	mg/L	No data
Specific Conductivity	339	100 to 10,000	µs/cm	CMT-18 03/2024
Chloride	121	10 to 10,000	mg/L	CMT-18 03/2024
Sulfide - Pre injection	0.1	0.1 to 100	mg/L	Estimate Not Detected
Sulfide - Post injection	1.6	0.1 to 100	mg/L	CMT-18 03/2024

B. Aquifer Matrix				
Total Iron	18000	200 to 20,000	mg/kg	CSM 2006 Soil Eastover
Cation Exchange Capacity	1	1.0 to 10	meq/100 g	CSM 2006 Soil Eastover
Neutralization Potential	1.0%	1.0 to 100	Percent as $CaCO_3$	CSM 2006 Soil Eastover

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: **OU7 Pit 2 TA-08 CMT-18, MW-144**

RETURN TO COVER PAGE

NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	45	1-10,000	feet
Length (Parallel to predominant groundwater flow)	34	1-1,000	feet
Saturated Thickness	11	1-100	feet
Treatment Zone Cross Sectional Area	495	--	ft^2
Treatment Zone Volume	16,830	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	33,999	--	gallons
Design Period of Performance	3.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

	Values	Range	Units
Total Porosity	0.36	.05-50	
Effective Porosity	0.27	.05-50	
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day
Average Hydraulic Gradient	0.012	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.22	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	81.1	--	ft/yr
Average Groundwater Flux through the Treatment Zor 0	81,109	--	gallons/year
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.0028	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.8	0.23	7.94	0.03	4
Nitrate (denitrification)	0.2	0.05	12.30	0.00	5
Sulfate	0.5	0.14	11.91	0.01	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	2.84	1.99	1.43	8
Soluble Competing Electron Acceptor Demand (lb.)				**1.47**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	0.6	1.43	27.25	0.05	2
Iron (III) (estimated as the amount of Fe (II) produced)	3.2	7.43	55.41	0.13	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**0.19**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.007	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.006	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.609	0.74	24.05	0.03	4
Vinyl Chloride (VC)	0.920	0.26	31.00	0.01	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.010	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.027	0.01	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.04**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.01	0.01	20.57	0.00	8
Trichloroethene (TCE)	107	0.00	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.33	0.56	24.05	0.02	4
Vinyl Chloride (VC)	3.0	0.01	0.01	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	0.00	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.00	0.00	24.55	0.00	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.02**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.8	0.54	7.94	0.07	4
Nitrate (denitrification)	0.2	0.11	10.25	0.01	5
Sulfate	0.5	0.34	11.91	0.03	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	6.77	1.99	3.40	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**3.5**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.007	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.006	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.609	1.77	24.05	0.07	4
Vinyl Chloride (VC)	0.920	0.62	31.00	0.02	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.010	0.01	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.027	0.02	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.10**	

Initial Hydrogen Requirement First Year (lb)	**5.3**
Total Life-Cycle Hydrogen Requirement (lb)	**12.5**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**10.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**125.3**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
µs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

RETURN TO COVER PAGE

Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4
Estimated Substrate Requirements for Hydrogen Demand in Table S.3

Design Life (years): 3

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	10.0	2,800	2,800	1.27E+09	1,210
Sodium Lactate Product (60 percent solution)	10.0	2,800	5,808	1.27E+09	1,210
Molasses (assuming 6 0	10.0	2,660	4,433	1.21E+09	1,149
HFCS (assuming 40% fructose and 40% glucose by weight)	10.0	2,800	3,500	1.27E+09	1,210
Ethanol Product (assuming 80% ethanol by weight)	10.0	1,432	1,790	6.49E+08	619
Whey (assuming 100% lactose)	10.0	1,933	2,761	8.77E+08	835
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	10.0	2,122	2,122	9.63E+08	734
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	10.0	1,090	1,090	4.94E+08	471
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	10.0	1,090	1,816	4.94E+08	471

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: **OU7 Pit 2 TA-08 CMT-18, MW-144**

RETURN TO COVER PAGE

1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	45	feet	14	meters
Length (parallel to groundwater flow)	34	feet	10.4	meters
Saturated Thickness	11	feet	3.4	meters
Design Period of Performance	3	years	3	years

2. Treatment Zone Hydrogeologic Properties

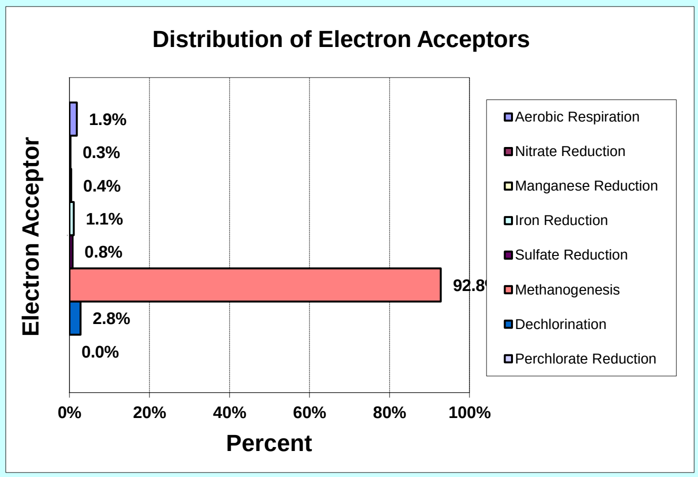
	Values	Units	Values	Units
Total Porosity	0.36	percent	0.36	percent
Effective Porosity	0.27	percent	0.27	percent
Average Aquifer Hydraulic Conductivity	5	ft/day	1.8E-03	cm/sec
Average Hydraulic Gradient	0.012	ft/ft	0.012	m/m
Average Groundwater Seepage Velocity	0.22	ft/day	6.8E+00	cm/day
Average Groundwater Seepage Velocity	81	ft/yr	24.7	m/yr
Effective Treatment Zone Pore Volume	33,999	gallons	128,696	liters
Groundwater Flux (per year)	81,109	gallons/year	307,021	liters/year
Total Groundwater Volume Treated (over entire design period)	277,325	gallons total	1,049,759	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	1.9%	0.233
Nitrate Reduction	0.3%	0.035
Sulfate Reduction	0.8%	0.097
Manganese Reduction	0.4%	0.053
Iron Reduction	1.1%	0.134
Methanogenesis	92.8%	11.629
Dechlorination	2.8%	0.350
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**12.53**

Hydrogen demand in pounds/gallon: 4.52E-05

Hydrogen demand in grams per liter: 5.41E-03



4. Substrate Equivalents: Design Factor = 10.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	5,808	528	1,210	as lactic acid
2. Molasses Product	4,433	369	1,149	as sucrose
3. Fructose Product	3,500	313	1,210	as fructose
4. Ethanol Product	1,790	259	619	as ethanol
5. Sweet Dry Whey (lactose)	2,761	sold by pound	835	as lactose
6. HRC®	2,122	sold by pound	734	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	1,090	140	471	as soybean oil
8. Emulsified Vegetable Oil	1,816	233	471	as soybean oil

Notes:
1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

B.7 TA-09 Treatment Area Design

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: OU7 Pit 2 TA-09 INJ-163, INJ-164, INJ-165, INJ-207

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	**Values**	**Range**	**Units**	**User Notes**
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet	Pit 2 Area
Length (Parallel to predominant groundwater flow)	30	1-1,000	feet	
Saturated Thickness	10	1-100	feet	16-26
Treatment Zone Cross Sectional Area	400	--	ft^2	
Treatment Zone Volume	12,000	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	32,322	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	24,242	--	gallons	
Design Period of Performance	1.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	10.0	2 to 20	unitless	
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	36%	.05-50	percent	PDI Eastover OU 7
Effective Porosity	27%	.05-50	percent	PDI Eastover OU 7, average based on TP, AP, clay content
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day	OU7 PDI
Average Hydraulic Gradient	2.23E-02	0.0001-0.1	ft/ft	Between injection transect and MW-149 03/2024
Average Groundwater Seepage Velocity through the Treatment Zone	0.41	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	150.7	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	121,799	--	gallons/year	
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3	Average OU- PDI for Eastover and Aquia
Soil Fraction Organic Carbon (foc)	0.28%	0.01-10	percent	PDI-38 Eastover Saturated Zone OU-7 x 2
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.5	0.01 to 10	mg/L	MW-80, MW-83, MW-148 (average) 03/2024
Nitrate	0.05	0.1 to- 20	mg/L	MW-80, MW-83, MW-148 (average) 03/2024
Sulfate	15	10 to 5,000	mg/L	MW-80, MW-83, MW-148 (average) 03/2024
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	Estimate based on previous EISB injections
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	1	0.1 to 20	mg/L	MW-80, MW-83, MW-148 (average) 03/2024
Iron (III) (estimated as the amount of Fe (II) produced)	10	0.1 to 20	mg/L	Estimated
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.041	--	mg/L	MW-80 03/2024
Trichloroethene (TCE)	0.020	--	mg/L	MW-80 03/2024
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.224	--	mg/L	MW-80 03/2024
Vinyl Chloride (VC)	0.054	--	mg/L	MW-80 03/2024
Carbon Tetrachloride (CT)	0.000	--	mg/L	Not detected
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	Not detected
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	Not detected
Chloromethane	0.000	--	mg/L	Not detected
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	Not detected
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.003	--	mg/L	MW-148 03/2024
Dichloroethane (1,1-DCA and 1,2-DCA)	0.003	--	mg/L	Average for plume area
Chloroethane	0.000	--	mg/L	Not detected
Perchlorate	0.000	--	mg/L	No data
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	71	-400 to +500	mV	MW-80, MW-83, MW-148 (average) 03/2024
Temperature	13	5.0 to 30	ºC	MW-80, MW-83, MW-148 (average) 03/2024
pH	5.9	4.0 to 10.0	su	MW-80, MW-83, MW-148 (average) 03/2024
Alkalinity	54	10 to 1,000	mg/L	MW-80, MW-83, MW-148 (average) 03/2024
Total Dissolved Solids (TDS, or salinity)	100	10 to 1,000	mg/L	Estimate
Specific Conductivity	533	100 to 10,000	µs/cm	MW-80, MW-83, MW-148 (average) 03/2024
Chloride	178	10 to 10,000	mg/L	MW-80, MW-83, MW-148 (average) 03/2024
Sulfide - Pre injection	0.1	0.1 to 100	mg/L	Estimate
Sulfide - Post injection	0.2	0.1 to 100	mg/L	Estimate
B. Aquifer Matrix				
Total Iron	18000	200 to 20,000	mg/kg	CSM 2006 Soil Eastover
Cation Exchange Capacity	1	1.0 to 10	meq/100 g	CSM 2006 Soil Eastover
Neutralization Potential	1.0%	1.0 to 100	Percent as $CaCO_3$	CSM 2006 Soil Eastover

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: **OU7 Pit 2 TA-09 INJ-163, INJ-164, INJ-165, INJ-207**

RETURN TO COVER PAGE

NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet
Length (Parallel to predominant groundwater flow)	30	1-1,000	feet
Saturated Thickness	10	1-100	feet
Treatment Zone Cross Sectional Area	400	--	ft^2
Treatment Zone Volume	12,000	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	24,242	--	gallons
Design Period of Performance	1.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

	Values	Range	Units
Total Porosity	0.36	.05-50	
Effective Porosity	0.27	.05-50	
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day
Average Hydraulic Gradient	0.0223	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.41	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	150.7	--	ft/yr
Average Groundwater Flux through the Treatment Zor 0	121,799	--	gallons/year
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.0028	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.5	0.10	7.94	0.01	4
Nitrate (denitrification)	0.1	0.01	12.30	0.00	5
Sulfate	14.7	2.97	11.91	0.25	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	2.02	1.99	1.02	8
Soluble Competing Electron Acceptor Demand (lb.)				**1.28**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	0.7	0.89	27.25	0.03	2
Iron (III) (estimated as the amount of Fe (II) produced)	10.0	12.19	55.41	0.22	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**0.25**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.041	0.01	20.57	0.00	8
Trichloroethene (TCE)	0.020	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.224	0.05	24.05	0.00	4
Vinyl Chloride (VC)	0.054	0.01	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.003	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.003	0.00	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.00**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.03	0.04	20.57	0.00	8
Trichloroethene (TCE)	107	0.01	0.01	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.03	0.03	24.05	0.00	4
Vinyl Chloride (VC)	3.0	0.00	0.00	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	0.00	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.00	0.00	24.55	0.00	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.00**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.5	0.49	7.94	0.06	4
Nitrate (denitrification)	0.1	0.05	10.25	0.00	5
Sulfate	14.7	14.94	11.91	1.25	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	10.16	1.99	5.11	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**6.4**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.041	0.04	20.57	0.00	8
Trichloroethene (TCE)	0.020	0.02	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.224	0.23	24.05	0.01	4
Vinyl Chloride (VC)	0.054	0.05	31.00	0.00	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.003	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.003	0.00	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.01**	

Initial Hydrogen Requirement First Year (lb)	**8.0**
Total Life-Cycle Hydrogen Requirement (lb)	**8.0**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**10.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**79.8**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
μs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

RETURN TO COVER PAGE

Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4
Estimated Substrate Requirements for
Hydrogen Demand in Table S.3

Design Life (years): 1

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	10.0	1,783	1,783	8.09E+08	1,463
Sodium Lactate Product (60 percent solution)	10.0	1,783	3,699	8.09E+08	1,463
Molasses (assuming 6 0	10.0	1,694	2,823	7.68E+08	1,390
HFCS (assuming 40% fructose and 40% glucose by weight)	10.0	1,783	2,229	8.09E+08	1,463
Ethanol Product (assuming 80% ethanol by weight)	10.0	912	1,140	4.14E+08	748
Whey (assuming 100% lactose)	10.0	1,231	1,758	5.58E+08	1,010
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	10.0	1,352	1,352	6.13E+08	887
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	10.0	694	694	3.15E+08	569
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	10.0	694	1,157	3.15E+08	569

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product

1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product

1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: **OU7 Pit 2 TA-09 INJ-163, INJ-164, INJ-165, INJ-207**

RETURN TO COVER PAGE

1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	40	feet	12	meters
Length (parallel to groundwater flow)	30	feet	9.1	meters
Saturated Thickness	10	feet	3.0	meters
Design Period of Performance	1	years	1	years

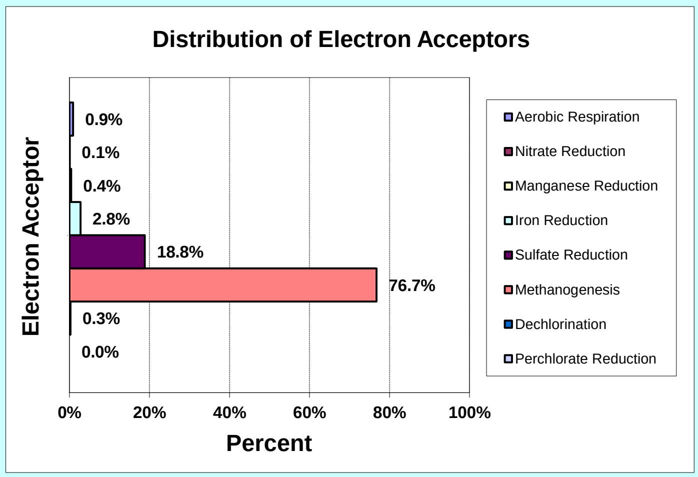
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.36	percent	0.36	percent
Effective Porosity	0.27	percent	0.27	percent
Average Aquifer Hydraulic Conductivity	5	ft/day	1.8E-03	cm/sec
Average Hydraulic Gradient	0.0223	ft/ft	0.0223	m/m
Average Groundwater Seepage Velocity	0.41	ft/day	1.3E+01	cm/day
Average Groundwater Seepage Velocity	151	ft/yr	45.9	m/yr
Effective Treatment Zone Pore Volume	24,242	gallons	91,762	liters
Groundwater Flux (per year)	121,799	gallons/year	461,048	liters/year
Total Groundwater Volume Treated (over entire design period)	146,041	gallons total	552,810	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.9%	0.074
Nitrate Reduction	0.1%	0.006
Sulfate Reduction	18.8%	1.504
Manganese Reduction	0.4%	0.032
Iron Reduction	2.8%	0.220
Methanogenesis	76.7%	6.124
Dechlorination	0.3%	0.021
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**7.98**

Hydrogen demand in pounds/gallon:	5.46E-05
Hydrogen demand in grams per liter:	6.55E-03



4. Substrate Equivalents: Design Factor = 10.0

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	Effective concentration is for total volume of groundwater treated.
1. Sodium Lactate Product	3,699	336	1,463	as lactic acid
2. Molasses Product	2,823	235	1,390	as sucrose
3. Fructose Product	2,229	199	1,463	as fructose
4. Ethanol Product	1,140	165	748	as ethanol
5. Sweet Dry Whey (lactose)	1,758	sold by pound	1,010	as lactose
6. HRC®	1,352	sold by pound	887	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	694	89	569	as soybean oil
8. Emulsified Vegetable Oil	1,157	148	569	as soybean oil

Notes:
1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

B.8 TA-11 Treatment Area Design

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: OU7 Pit 3 TA-11 MW-109, MW-108, MW-97

RETURN TO COVER PAGE

NOTE: Unshaded boxes are user input.

1. Treatment Zone Physical Dimensions	Values	Range	Units	User Notes
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet	Pit 3, 9 DPT Points
Length (Parallel to predominant groundwater flow)	34	1-1,000	feet	
Saturated Thickness	14	1-100	feet	11-25
Treatment Zone Cross Sectional Area	560	--	ft^2	
Treatment Zone Volume	19,040	--	ft^3	
Treatment Zone Total Pore Volume (total volume x total porosity)	51,285	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	38,463	--	gallons	
Design Period of Performance	3.0	.5 to 5	year	
Design Factor (times the electron acceptor hydrogen demand)	10.0	2 to 20	unitless	
2. Treatment Zone Hydrogeologic Properties				
Total Porosity	36%	.05-50	percent	PDI Eastover OU 7
Effective Porosity	27%	.05-50	percent	PDI Eastover OU 7, average based on TP, AP, clay content
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day	OU7 PDI
Average Hydraulic Gradient	1.80E-02	0.0001-0.1	ft/ft	Flow path in injection area 03/2024
Average Groundwater Seepage Velocity through the Treatment Zone	0.33	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	121.8	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	137,792	--	gallons/year	
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3	Average OU- PDI for Eastover and Aquia
Soil Fraction Organic Carbon (foc)	0.28%	0.01-10	percent	PDI-38 Eastover Saturated Zone OU-7 x 2
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.4	0.01 to 10	mg/L	MW-97 03/2024
Nitrate	0.05	0.1 to- 20	mg/L	MW-97 03/2024
Sulfate	2	10 to 5,000	mg/L	MW-95 03/2024
Carbon Dioxide (estimated as the amount of Methane produced)	10.0	0.1 to 20	mg/L	Estimate based on previous EISB injections
B. Solid-Phase Native Electron Acceptors				
Manganese (IV) (estimated as the amount of Mn (II) produced)	1	0.1 to 20	mg/L	MW-95 03/2024
Iron (III) (estimated as the amount of Fe (II) produced)	10	0.1 to 20	mg/L	Estimated
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.000	--	mg/L	Not detected
Trichloroethene (TCE)	0.001	--	mg/L	MW-109 03/2024
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.404	--	mg/L	MW-109 03/2024
Vinyl Chloride (VC)	0.560	--	mg/L	MW-109 03/2024
Carbon Tetrachloride (CT)	0.000	--	mg/L	Not detected
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	Not detected
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	Not detected
Chloromethane	0.000	--	mg/L	Not detected
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	Not detected
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	--	mg/L	Not detected
Dichloroethane (1,1-DCA and 1,2-DCA)	0.000	--	mg/L	Not detected
Chloroethane	0.000	--	mg/L	Not detected
Perchlorate	0.000	--	mg/L	No data
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	-56	-400 to +500	mV	MW-98 03/2024
Temperature	19	5.0 to 30	ºC	MW-98 03/2024
pH	6.4	4.0 to 10.0	su	MW-98 03/2024
Alkalinity	72	10 to 1,000	mg/L	MW-98 03/2024
Total Dissolved Solids (TDS, or salinity)	100	10 to 1,000	mg/L	Estimated
Specific Conductivity	269	100 to 10,000	µs/cm	MW-98 03/2024
Chloride	24	10 to 10,000	mg/L	MW-98 03/2024
Sulfide - Pre injection	0.1	0.1 to 100	mg/L	Estimate
Sulfide - Post injection	0.2	0.1 to 100	mg/L	Estimate
B. Aquifer Matrix				
Total Iron	18000	200 to 20,000	mg/kg	CSM 2006 Soil Eastover
Cation Exchange Capacity	1	1.0 to 10	meq/100 g	CSM 2006 Soil Eastover
Neutralization Potential	1.0%	1.0 to 100	Percent as $CaCO_3$	CSM 2006 Soil Eastover

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents

Site Name: **OU7 Pit 3 TA-11 MW-109, MW-108, MW-97**

RETURN TO COVER PAGE

NOTE: Open cells are user input.

1. Treatment Zone Physical Dimensions

	Values	Range	Units
Width (Perpendicular to predominant groundwater flow direction)	40	1-10,000	feet
Length (Parallel to predominant groundwater flow)	34	1-1,000	feet
Saturated Thickness	14	1-100	feet
Treatment Zone Cross Sectional Area	560	--	ft^2
Treatment Zone Volume	19,040	--	ft^3
Treatment Zone Effective Pore Volume (total volume x effective porosity)	38,463	--	gallons
Design Period of Performance	3.0	.5 to 5	year

2. Treatment Zone Hydrogeologic Properties

	Values	Range	Units
Total Porosity	0.36	.05-50	
Effective Porosity	0.27	.05-50	
Average Aquifer Hydraulic Conductivity	5	.01-1000	ft/day
Average Hydraulic Gradient	0.01802	0.1-0.0001	ft/ft
Average Groundwater Seepage Velocity through the Treatment Zone	0.33	--	ft/day
Average Groundwater Seepage Velocity through the Treatment Zone	121.8	--	ft/yr
Average Groundwater Flux through the Treatment Zor 0	137,792	--	gallons/year
Soil Bulk Density	1.63	1.4-2.0	gm/cm^3
Soil Fraction Organic Carbon (foc)	0.0028	0.0001-0.1	

3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)

A. Aqueous-Phase Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.4	0.12	7.94	0.02	4
Nitrate (denitrification)	0.1	0.02	12.30	0.00	5
Sulfate	1.7	0.55	11.91	0.05	8
Carbon Dioxide (estimated as the amount of methane produced)	10.0	3.21	1.99	1.61	8
Soluble Competing Electron Acceptor Demand (lb.)				**1.68**	

B. Solid-Phase Native Electron Acceptors (Based on manganese and iron produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Manganese (IV) (estimated as the amount of Mn (II) produced)	0.7	2.71	27.25	0.10	2
Iron (III) (estimated as the amount of Fe (II) produced)	10.0	37.70	55.41	0.68	1
Solid-Phase Competing Electron Acceptor Demand (lb.)				**0.78**	

C. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.000	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.001	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.404	0.77	24.05	0.03	4
Vinyl Chloride (VC)	0.560	0.18	31.00	0.01	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.000	0.00	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand (lb.)				**0.04**	

D. Sorbed Contaminant Electron Acceptors (Soil Concentration = Koc x foc x Cgw)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	263	0.00	0.00	20.57	0.00	8
Trichloroethene (TCE)	107	0.00	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	45	0.30	0.59	24.05	0.02	4
Vinyl Chloride (VC)	3.0	0.00	0.01	31.00	0.00	2
Carbon Tetrachloride (CT)	224	0.00	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	63	0.00	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	28	0.00	0.00	21.06	0.00	4
Chloromethane	25	0.00	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	117	0.00	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	105	0.00	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	30	0.00	0.00	24.55	0.00	4
Chloroethane	3	0.00	0.00	32.00	0.00	2
Perchlorate	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)					**0.02**	

(continued)

Table S.2 Substrate Calculations in Hydrogen Equivalents

4. Treatment Cell Electron-Acceptor Flux (per year)

A. Soluble Native Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Oxygen	0.4	0.44	7.94	0.06	4
Nitrate (denitrification)	0.1	0.06	10.25	0.01	5
Sulfate	1.7	1.95	11.91	0.16	8
Carbon Dioxide (estimated as the amount of Methane produced)	10	11.50	1.99	5.78	8
Total Competing Electron Acceptor Demand Flux (lb/yr)				**6.0**	

B. Soluble Contaminant Electron Acceptors	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h_2)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Tetrachloroethene (PCE)	0.000	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.001	0.00	21.73	0.00	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	2.404	2.76	24.05	0.11	4
Vinyl Chloride (VC)	0.560	0.64	31.00	0.02	2
Carbon Tetrachloride (CT)	0.000	0.00	19.08	0.00	8
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.74	0.00	6
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	21.06	0.00	4
Chloromethane	0.000	0.00	25.04	0.00	2
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	20.82	0.00	8
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	0.00	22.06	0.00	6
Dichloroethane (1,1-DCA and 1,2-DCA)	0.000	0.00	24.55	0.00	4
Chloroethane	0.000	0.00	32.00	0.00	2
Perchlorate	0.000	0.00	12.33	0.00	6
Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)				**0.14**	

Initial Hydrogen Requirement First Year (lb)	**8.7**
Total Life-Cycle Hydrogen Requirement (lb)	**20.9**

5. Design Factors

Microbial Efficiency Uncertainty Factor	2X - 4X
Methane and Solid-Phase Electron Acceptor Uncertainty	2X - 4X
Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)	1X - 3X
Design Factor	**10.0**
Total Life-Cycle Hydrogen Requirement with Design Factor (lb)	**209.3**

6. Acronyns and Abbreviations

^{o}C =degrees celsius
μs/cm = microsiemens per centimeter
cm/day = centimeters per day
cm/sec = centimeters per second
ft^2 = square feet
ft/day = feet per day
ft/ft = foot per foot
ft/yr = feet per year
gm/cm^3 = grams per cubic centimeter
kg of CaCO3 per mg = kilograms of calcium carbonate per milligram
lb = pounds
meq/100 g = milliequivalents per 100 grams
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
m/m = meters per meters
mV = millivolts
m/yr = meters per year
su = standard pH units
wt/wt H2 = concetration molecular hydrogen, weight per weight

Table S.3

Hydrogen Produced by Fermentation Reactions of Common Substrates

RETURN TO COVER PAGE

Substrate	Molecular Formula	Substrate Molecular Weight (gm/mole)	Moles of Hydrogen Produced per Mole of Substrate	Ratio of Hydrogen Produced to Substrate (gm/gm)	Range of Moles H_2/Mole Substrate
Lactic Acid	$C_3H_6O_3$	90.1	2	0.0448	**2 to 3**
Molasses (assuming 100% sucrose)	$C_{12}H_{22}O_{11}$	342	8	0.0471	**8 to 11**
High Fructose Corn Syrup (assuming 50% fructose and 50% glucose)	$C_6H_{12}O_6$	180	4	0.0448	**4 to 6**
Ethanol	C_2H_6O	46.1	2	0.0875	**2 to 6**
Whey (assuming 100% lactose)	$C_{12}H_{22}O_{11}$	342	11	0.0648	**11**
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	$C_{39}H_{56}O_{39}$	956	28	0.0590	**28**
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	$C_{18}H_{32}O_2$	281	16	0.1150	**16**

Table S.4
Estimated Substrate Requirements for
Hydrogen Demand in Table S.3

Design Life (years): 3

Substrate	Design Factor	Pure Substrate Mass Required to Fulfill Hydrogen Demand (pounds)	Substrate Product Required to Fulfill Hydrogen Demand (pounds)	Substrate Mass Required to Fulfill Hydrogen Demand (milligrams)	Effective Substrate Concentration (mg/L)
Lactic Acid	10.0	4,677	4,677	2.12E+09	1,240
Sodium Lactate Product (60 percent solution)	10.0	4,677	9,703	2.12E+09	1,240
Molasses (assuming 6 0	10.0	4,443	7,405	2.02E+09	1,178
HFCS (assuming 40% fructose and 40% glucose by weight)	10.0	4,678	5,847	2.12E+09	1,241
Ethanol Product (assuming 80% ethanol by weight)	10.0	2,392	2,990	1.08E+09	634
Whey (assuming 100% lactose)	10.0	3,228	4,612	1.46E+09	856
HRC® (assumes 40% lactic acid and 40% glycerol by weight)	10.0	3,545	3,545	1.61E+09	752
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	10.0	1,820	1,820	8.26E+08	483
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	10.0	1,820	3,034	8.26E+08	483

NOTES: Sodium Lactate Product
1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH_3-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid ($C_6H_6O_3$) = 90.08 .
4. Therefore, sodium lactate product yields 48.4 (0.60 x (90.08/112.06)) percent by weight lactic acid.
5. Weight of sodium lactate product = 11.0 pounds per gallon.
6. Pounds per gallon of lactic acid in product = 1.323 x 8.33 lb/gal H2O x 0.60 x (90.08/112.06) = 5.31 lb/gal.

NOTES: Standard HRC Product
1. Assumes HRC product is 40 percent lactic acid and 40 percent glycerol by weight.
2. HRC® weighs approximately 9.18 pounds per gallon.

NOTES: Vegetable Oil Emulsion Product
1. Assumes emulsion product is 60 percent soybean oil by weight.
2. Soybean oil is 7.8 pounds per gallon.
3. Assumes specific gravity of emulsion product is 0.96.

Table S.5 Output for Substrate Requirements in Hydrogen Equivalents

Site Name: **OU7 Pit 3 TA-11 MW-109, MW-108, MW-97**

RETURN TO COVER PAGE

1. Treatment Zone Physical Dimensions

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	40	feet	12	meters
Length (parallel to groundwater flow)	34	feet	10.4	meters
Saturated Thickness	14	feet	4.3	meters
Design Period of Performance	3	years	3	years

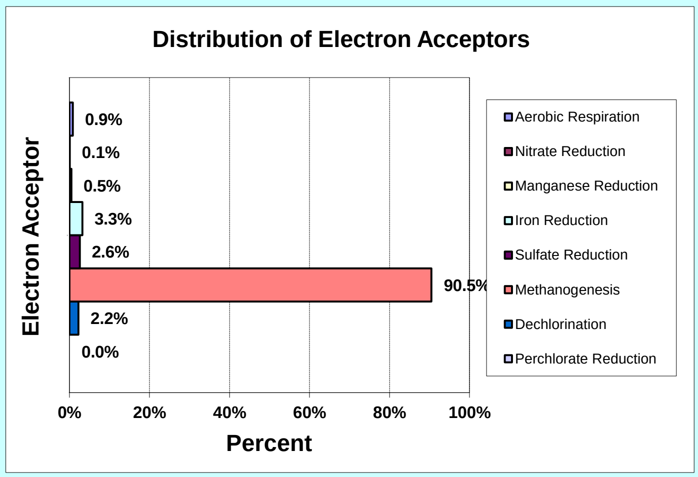
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.36	percent	0.36	percent
Effective Porosity	0.27	percent	0.27	percent
Average Aquifer Hydraulic Conductivity	5	ft/day	1.8E-03	cm/sec
Average Hydraulic Gradient	0.01802	ft/ft	0.01802	m/m
Average Groundwater Seepage Velocity	0.33	ft/day	1.0E+01	cm/day
Average Groundwater Seepage Velocity	122	ft/yr	37.1	m/yr
Effective Treatment Zone Pore Volume	38,463	gallons	145,596	liters
Groundwater Flux (per year)	137,792	gallons/year	521,584	liters/year
Total Groundwater Volume Treated (over entire design period)	451,839	gallons total	1,710,348	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.9%	0.180
Nitrate Reduction	0.1%	0.018
Sulfate Reduction	2.6%	0.538
Manganese Reduction	0.5%	0.100
Iron Reduction	3.3%	0.680
Methanogenesis	90.5%	18.947
Dechlorination	2.2%	0.470
Perchlorate Reduction	0.0%	0.000
Totals:	**100.00%**	**20.93**

Hydrogen demand in pounds/gallon:	4.63E-05
Hydrogen demand in grams per liter:	5.55E-03



4. Substrate Equivalents: Design Factor = 10.0

Effective concentration is for total volume of groundwater treated.

Product	Quantity (lb)	Quantity (gallons)	Effective Concentration (mg/L)	
1. Sodium Lactate Product	9,703	882	1,240	as lactic acid
2. Molasses Product	7,405	617	1,178	as sucrose
3. Fructose Product	5,847	522	1,241	as fructose
4. Ethanol Product	2,990	433	634	as ethanol
5. Sweet Dry Whey (lactose)	4,612	sold by pound	856	as lactose
6. HRC®	3,545	sold by pound	752	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	1,820	233	483	as soybean oil
8. Emulsified Vegetable Oil	3,034	389	483	as soybean oil

Notes:
1. Quantity assumes product is 60% sodium lactate by weight.
2. Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
3. Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
4. Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
5. Quantity assumes product is 70% lactose by weight.
6. Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
7. Quantity of neat soybean oil, corn oil, or canola oil.
8. Quantity assumes commercial product is 60% soybean oil by weight.

B.9 Injection Point Volume Calculations

SITE NAME:	**DSCR Operable Unit 7, TA-02**	

INJECTION POINT CALCULATIONS

Where, h is thickness, r is planned radius, Θ_M is mobile porosity,
and V_{inj} is injection volume.

POROSITY 0.35

$$V_{inj} = \pi \cdot h \cdot r_{inj}^2 \cdot \theta_M$$

Θ_M	0.02		per Remediation Engr Design Concepts, 2nd Edition, pp 177
h	16	feet	injection interval thickness
r_{inj}	12	feet	desired radius of influence
V_{inj}	144.7645895	ft^3	
	1082.9	**gallons**	Delivery volume over the treated interval
	67.7	**gallons/ft**	Injection volume per foot

SITE NAME:	**DSCR Operable Unit 7, TA-03**	

INJECTION POINT CALCULATIONS

Where, h is thickness, r is planned radius, Θ_M *is mobile porosity,*
and V_{inj} *is injection volume.*

POROSITY 0.35

$$V_{inj} = \pi \cdot h \cdot r_{inj}^2 \cdot \theta_M$$

Θ_M	0.02		per Remediation Engr Design Concepts, 2nd Edition, pp 177
h	15	feet	injection interval thickness
r_{inj}	12	feet	desired radius of influence
V_{inj}	135.7168026	ft^3	
	1015.2	**gallons**	Delivery volume over the treated interval
	67.7	**gallons/ft**	Injection volume per foot

SITE NAME:	**DSCR Operable Unit 7, TA-05**	

INJECTION POINT CALCULATIONS

Where, h is thickness, r is planned radius, Θ_M *is mobile porosity,*
and V_{inj} *is injection volume.*

POROSITY 0.35

$$V_{inj} = \pi \cdot h \cdot r_{inj}^2 \cdot \theta_M$$

Θ_M	0.02		per Remediation Engr Design Concepts, 2nd Edition, pp 177
h	18	feet	injection interval thickness
r_{inj}	12	feet	desired radius of influence
V_{inj}	162.8601632	ft^3	
	1218.3	**gallons**	Delivery volume over the treated interval
	67.7	**gallons/ft**	Injection volume per foot

SITE NAME:	**DSCR Operable Unit 7, TA-06**

INJECTION POINT CALCULATIONS

Where, h is thickness, r is planned radius, Θ_M is mobile porosity,
and V_{inj} is injection volume.

POROSITY 0.35

$$V_{inj} = \pi \cdot h \cdot r_{inj}^2 \cdot \theta_M$$

Θ_M	0.02		per Remediation Engr Design Concepts, 2nd Edition, pp 177
h	20	feet	injection interval thickness
r_{inj}	12	feet	desired radius of influence
V_{inj}	180.9557368	ft^3	
	1353.6	**gallons**	Delivery volume over the treated interval
	67.7	**gallons/ft**	Injection volume per foot

SITE NAME:	**DSCR Operable Unit 7, TA-07**		
	INJECTION POINT CALCULATIONS		

Where, h is thickness, r is planned radius, Θ_M is mobile porosity,
and V_{inj} is injection volume.

POROSITY 0.35

$$V_{inj} = \pi \cdot h \cdot r_{inj}^2 \cdot \theta_M$$

Θ_M	0.02		per Remediation Engr Design Concepts, 2nd Edition, pp 177
h	12	feet	injection interval thickness
r_{inj}	12	feet	desired radius of influence
V_{inj}	108.5734421	ft^3	
	812.2	**gallons**	Delivery volume over the treated interval
	67.7	**gallons/ft**	Injection volume per foot

SITE NAME: **DSCR Operable Unit 7, TA-08**

INJECTION POINT CALCULATIONS

Where, h is thickness, r is planned radius, Θ_M is mobile porosity,
and V_{inj} is injection volume.

POROSITY 0.35

$$V_{inj} = \pi \cdot h \cdot r_{inj}^2 \cdot \theta_M$$

Θ_M	0.02		per Remediation Engr Design Concepts, 2nd Edition, pp 177
h	11	feet	injection interval thickness
r_{inj}	12	feet	desired radius of influence
V_{inj}	99.52565527	ft^3	
	744.5	**gallons**	Delivery volume over the treated interval
	67.7	**gallons/ft**	Injection volume per foot

SITE NAME:	**DSCR Operable Unit 7, TA-09**		
	INJECTION POINT CALCULATIONS		

Where, h is thickness, r is planned radius, Θ_M *is mobile porosity,*
and V_{inj} *is injection volume.*

POROSITY 0.35

$$V_{inj} = \pi \cdot h \cdot r_{inj}^2 \cdot \theta_M$$

Θ_M	0.02		per Remediation Engr Design Concepts, 2nd Edition, pp 177
h	10	feet	injection interval thickness
r_{inj}	12	feet	desired radius of influence
V_{inj}	90.47786842	ft^3	
	676.8	**gallons**	Delivery volume over the treated interval
	67.7	**gallons/ft**	Injection volume per foot

SITE NAME:	**DSCR Operable Unit 7, TA-11**		
	INJECTION POINT CALCULATIONS		
Where, h is thickness, r is planned radius, Θ_M is mobile porosity,			
and V_{inj} is injection volume.		POROSITY	0.35

$$V_{inj} = \pi \cdot h \cdot r_{inj}^2 \cdot \theta_M$$

Θ_M	0.02		per Remediation Engr Design Concepts, 2nd Edition, pp 177
h	14	feet	injection interval thickness
r_{inj}	12	feet	desired radius of influence
V_{inj}	126.6690158	ft^3	
	947.5	**gallons**	Delivery volume over the treated interval
	67.7	**gallons/ft**	Injection volume per foot

Appendix C Regulatory Correspondence

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Wheeling Field Office
1060 Chapline Street
Wheeling, West Virginia 26003

March 7, 2013

Ms. Susan Trussell
U.S. Army Corps of Engineers, Tulsa District
CESWT-EC-EE
1645 S. 101st E. Avenue
Tulsa, Oklahoma 74128-4609

Re: Defense Supply Center Richmond
Operable Unit 7
Richmond, Chesterfield County, VA

Dear Ms. Trussell:

We have received correspondence from your consultant, AECOM Technical Services, dated February 28, 2013 describing ground water remediation efforts at the above referenced facility. We understand that you intend to utilize enhanced in-situ bioremediation processes, involving shallow injection wells, to reduce volatile organic compound (VOC) contamination. **The subsurface emplacement of fluids through injection wells as part of an aquifer cleanup project is subject to the ground water protection requirements of the Underground Injection Control (UIC) program.** The UIC program is administered by the Environmental Protection Agency (EPA) in the Commonwealth of Virginia.

Based upon our understanding of aquifer remediation of contaminated soil and ground water in general, and the proposed subsurface emplacement of nutrients to facilitate biodegradation specifically, we believe that the injection wells pose minimal potential to adversely impact ground water. For these reasons you may proceed with plans to construct and operate aquifer remediation related injection wells and you will not be required to obtain an Underground Injection Control (UIC) program permit.

The above referenced facility has been added to our inventory of shallow injection wells. The UIC program prohibits the subsurface emplacement of fluids which have the potential to adversely impact underground sources of drinking water.

EPA approval or "rule authorization" of the injection wells is contingent upon operator compliance with all applicable requirements. We appreciate your cooperation in these matters and the opportunity to address these issues with you. Please contact me at (304) 234-0286 if you have any questions.

Sincerely,

Mark Nelson

Mark A. Nelson, Hydrologist
Water Protection Division

Cc: Manish M. Joshi, AECOM