



Defense Logistics Agency

Defense Supply Center Richmond

ADMINISTRATIVE RECORD COVER SHEET

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FINAL

REMEDIAL ACTION WORK PLAN ADDENDUM
OPERABLE UNIT 6
DEFENSE SUPPLY CENTER RICHMOND

Prepared For



Defense Logistics Agency

And



United States Army Corps of Engineers
Baltimore District

Prepared by

August 2025

Table of Contents

1.	Introduction	1-1
2.	Background.....	2-1
2.1	OU 6 Description	2-1
2.2	OU 6 Site History	2-1
2.3	Environmental Setting	2-8
2.4	Current Conditions for Groundwater in Confined Aquifer	2-15
2.5	Current Conditions for Surface Water	2-51
3.	Remedial Design.....	3-1
3.1	Remedial Design Basis	3-1
3.2	Enhanced ISB Treatment Areas	3-1
3.3	Substrate Selection	3-3
3.4	Injection Process Option Selection	3-3
3.5	Substrate Loading Rates and Injection Volume Estimates	3-4
3.6	Treatment Area Configuration and Injection Points	3-8
4.	Remedial Action Field Activities	4-1
4.1	Utility Clearance.....	4-1
4.2	Field Survey of Locations	4-1
4.3	Enhanced ISB Injection Field Implementation.....	4-1
4.4	Injection Process Monitoring	4-3
4.5	Investigative Derived Material Management	4-4
4.6	Spill Response Procedures	4-5
5.	Remedy Verification and Performance Monitoring	5-1
5.1	Baseline Monitoring	5-1
5.2	Performance Monitoring	5-1
5.3	Monitoring Procedures	5-1
5.4	ISB Performance Evaluation	5-4
6.	Permitting	6-1
6.1	Drilling and Subsurface Installations	6-1
6.2	Site Security and Communications.....	6-1
6.3	Health and Safety	6-1
7.	Reporting	7-1
8.	References.....	8-1
Appendix A Remedy Design Support Information		
A.1	EVO Technical Data Sheet and Safety Data Sheet	
A.2	Bioaugmentation Technical Data Sheet and Safety Data Sheet	
A.3	pH Buffer Technical Data Sheet and Safety Data Sheet	
A.4	Sodium Absorbate Technical Data Sheet and Safety Data Sheet	
Appendix B Remedial Design		
B.1	TAC-1 Treatment Area Design	
B.2	TAC-2 Treatment Area Design	
B.3	Injection Point Volume Calculations	
Appendix C Regulatory Correspondence		
Appendix D IPaC Report for Offsite Work Area (July 21, 2025)		

Figures

Figure 1-1	DSCR Operable Units	1-2
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Figure 2-1 Operable Unit 6.....	2-2
Figure 2-2 OU 6 Topographic Map.....	2-9
Figure 2-3 Wetlands Mapper in OU 6 Area.....	2-10
Figure 2-4 OU 6 Geologic Cross-Section A-A'	2-12
Figure 2-5 OU 6 Fence Line Geologic Cross-Section B-B'	2-13
Figure 2-6 OU 6 2024 Groundwater and Surface Water Monitoring Locations	2-17
Figure 2-7 OU 6 Confined Aquifer Potentiometric Surface (May 2024).....	2-18
Figure 2-8 OU 6 Confined Aquifer 2024 Lateral Extent of MCL Exceedances in Groundwater	2-26
Figure 2-9 2024 Lateral Distribution of PCE in the Confined Aquifer	2-27
Figure 2-10 2024 Lateral Distribution of TCE in the Confined Aquifer.....	2-28
Figure 2-11 2024 Lateral Distribution of cDCE in the Confined Aquifer.....	2-29
Figure 2-12 2024 Lateral Distribution of VC in the Confined Aquifer	2-30
Figure 2-13 2024 Lateral Distribution of Ethene in the Confined Aquifer	2-32
Figure 2-14 2024 Lateral Distribution of Ethane in Confined Aquifer	2-33
Figure 2-15 Changes in Lateral Distribution of PCE in Confined Aquifer (2021 and 2024).....	2-36
Figure 2-16 Changes in Lateral Distribution of TCE in Confined Aquifer (2021 and 2024).....	2-37
Figure 2-17 Changes in Lateral Distribution of cDCE in Confined Aquifer (2021 and 2024).....	2-38
Figure 2-18 Changes in Lateral Distribution of VC in Confined Aquifer (2021 and 2024)	2-39
Figure 3-1 Enhanced ISB Treatment Areas and Performance Monitoring Locations.....	3-2

Tables

Table 2-1 OU 6 COCs and Cleanup Levels	2-5
Table 2-2 OU 6 Stratigraphy.....	2-11
Table 2-3 OU 6 Hydrostratigraphy	2-15
Table 2-4 Bulk Plume Area Metrics: Southern Area Confined Aquifer	2-35
Table 2-5 OU 2 Confined Aquifer Wells for Southern Area: Summary of Statistical and Trend Analysis.....	2-42
Table 2-6 OU 3 Confined Aquifer Wells for Southern Area: Summary of Statistical and Trend Analysis.....	2-47
Table 2-7 OU 6 Confined Aquifer Wells for Offsite Area: Summary of Statistical and Trend Analysis.....	2-48
Table 2-8 Summary of Statistical and Trend Analysis for Confined Aquifer: Offsite Area	2-50
Table 2-9 OU 6 VOC Summary Statistics for No Name Creek Surface Water (2020-2024)	2-52
Table 2-10 OU 6 Trend Analysis for PCE and TCE for No Name Creek Surface Water (2007-2023).....	2-52
Table 3-1 Terra Systems Inc. 60% Small Droplet Slow Release EVO Substrate (SRS® SD EVO)	3-3
Table 3-2 Enhanced In Situ Bioremediation Design Parameter Summary	3-5
Table 3-3 Summary of Electron Receptor Requirements in Hydrogen Equivalents	3-6
Table 3-4 Injection Design, Volumes, and Substrate Loading Rates.....	3-7
Table 4-1 Remedy Installation Monitoring.....	4-4
Table 4-2 Investigative Derived Material Containerization and Disposal.....	4-4
Table 4-3 Waste Characterization Parameter Analysis.....	4-5
Table 5-1 ISB Baseline and Performance Monitoring Program: OU 6 Confined Aquifer (2025-2026)	5-3
Table 5-2 Quality Assurance/Quality Control Samples: Baseline/Performance Monitoring.....	5-4
Table 5-3 Enhanced ISB Performance Evaluation.....	5-4

Exhibits

Exhibit 2-1 Water Quality Parameter Distribution: Southern Area Confined Aquifer (May 2024)	2-19
Exhibit 2-2 VOC Parameter Distribution: Southern Area Confined Aquifer (May 2024)	2-20
Exhibit 2-3 Geochemical Parameter Distribution: Southern Area Confined Aquifer (May 2024).....	2-22
Exhibit 2-4 Dissolved Gas Distribution: Southern Area Confined Aquifer (May 2024).....	2-24
Exhibit 2-5 VOC Distribution Trends Confined Aquifer: Southern Area (2018-2024).....	2-34
Exhibit 2-6 VOC Plume Area Changes in Confined Aquifer: Southern Area	2-40
Exhibit 2-7 Plume Center of Mass	2-40
Exhibit 2-8 Plume Distance vs. Concentration: Southern Area Confined Aquifer (May 2024)	2-41
Exhibit 2-9 Data Plots for OU 2 Area: Confined Aquifer Southern Area	2-43
Exhibit 2-10 Data Plots for OU 3 Area: Confined Aquifer Southern Area	2-46

Exhibit 2-11 Data Plots for Offsite OU 6 Area: Confined Aquifer Southern Area	2-49
Exhibit 2-12 OU 6 Time Series Data Plots for PCE and TCE for No Name Creek	2-52
Exhibit 5-1 Water Level Measurement Locations for Quarterly Monitoring	5-2
Exhibit 5-2 Summary of Monitoring Procedures	5-2

EXECUTIVE SUMMARY

This Remedial Action Work Plan (RAWP) Addendum describes the proposed follow-up in situ bioremediation (ISB) actions at Operable Unit (OU) 6 at Defense Supply Center Richmond (DSCR). OU 6 is impacted groundwater associated with OU 1 (Open Storage Area), OU 2 (Area 50 Landfill), and OU 3 (National Guard Area, NGA). Follow-up ISB actions will target the confined aquifer in OU 3 near the installation fence line and in the adjacent offsite area (OU 6). A new monitoring network implemented at OU 6 in 2021 has detected apparent expansion and movement of dissolved phase plumes in groundwater into the offsite area. The dissolved phase plumes of trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), and vinyl chloride (VC) have concentrations greater than cleanup levels established in the Record of Decision (ROD) for OU 6 (DSCR 2013).

Objectives of the follow-up ISB actions at OU 6 are to: 1) mitigate plume instability and reduce plume extent in the offsite area, 2) accelerate reduction of TCE, cDCE, and VC concentrations and eliminate cDCE/VC accumulation in offsite area, 3) reduce contaminant mass (molar) in target plume area, and 4) reduce contaminant flux across the installation fence line and in the offsite area.

The proposed ISB actions will consist of the installation of two treatment areas in barrier configuration, one located approximately 60 feet upgradient of the installation fence line and the second located in the offsite area where plume concentrations are highest. Design dimensions of the treatment barrier in the NGA are 250 feet (width) x 34 feet (length) with a vertical treatment depth interval of 27 feet to 55 feet below ground surface. Design dimensions of the treatment barrier in the lower elevation offsite area are 175 feet (width) x 34 feet (length) with a vertical treatment depth interval of 25 feet to 50 feet below ground surface. The treatment intervals will address the permeable interval of the confined aquifer containing the volatile organic compound plume.

The process option of the ISB design in this work plan follows the remedial design/remedial action work plan for OU 6 (AECOM 2015) 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 molecules 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 tetrachloroethene (PCE) → TCE → cDCE → VC → ethene.

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 6 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 injection process option selected for enhanced ISB for the confined aquifer at OU 6 is direct push technology (DPT) using a pressure activated injection probe. Pre-design investigations and testing performed at OU 6 indicate that the high density of the confined aquifer (Potomac Formation) will require injection pressures > 100 pounds per square inch to distribute reagents in this zone. The high density of the confined aquifer limited the effectiveness 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 barriers include 28 injection points and 19 injection points for the NGA and offsite areas, respectively. The ISB design period is three (3) years.

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 the treatment design. Performance monitoring will include a baseline monitoring event corresponding to the annual monitoring event scheduled for May

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 6 includes sampling of 46 monitoring wells screened in the confined aquifer including 31 monitoring wells in OU 3 and offsite area. For ISB performance monitoring, the post-injection monitoring program for 2025-2026 includes four quarterly events and one annual event (May 2025). The performance monitoring network for quarterly monitoring includes 11 monitoring wells with two (2) upgradient wells and nine (9) wells in the plume area 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 barrier areas and at each performance well, 3) evaluate reduction of contaminant mass using chemical and geochemical data, 4) evaluate changes in contaminant flux across barrier 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 6 will report the results of remedy implementation, performance monitoring, monitored natural attenuation, and long-term monitoring. components and 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

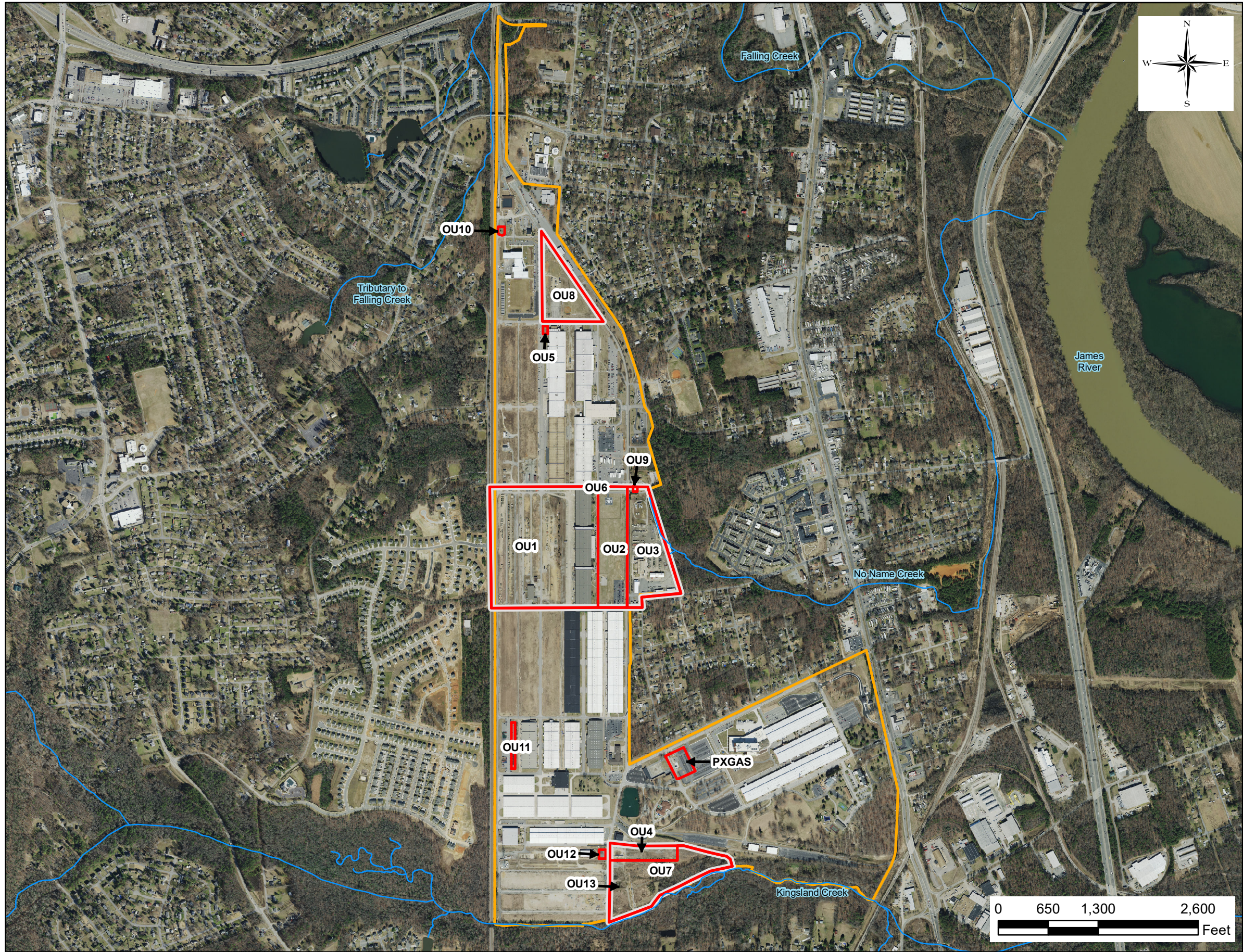
1,1-DCE	1,1-Dichloroethene
3D	three dimensional
AEHA	United States Army Environmental Health Agency
BGS	below ground surface
BTAG	Biological Technical Assistance Group
cDCE	cis-1,2-dichloroethene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	constituent of concern
CPT	cone penetrometer test
CSM	conceptual site model
CV	coefficient of variation
DCE	dichloroethene
DEM	digital elevation model
DEQ	Virginia Department of Environmental Quality
DLA	Defense Logistics Agency
DO	dissolved oxygen
DPE	dual phase extraction
DPT	direct push technology
DSCR	Defense Supply Center Richmond
≥	greater than or equal to
EPA	United States Environmental Protection Agency
ERD	enhanced reductive dechlorination
EVO	emulsified vegetable oil
EVS	Earth Volumetric Studio
FFA	Federal Facility Agreement
FFS	focused feasibility study
ft.	feet
gpm	gallons per minute
>	greater than
HHRA	human health risk assessment
HRSC	high resolution site characterization
IC	institutional control
IDM	investigative derived material
ISB	in situ bioremediation
<	less than
≤	less than or equal to
Law	Law Engineering and Environmental Services
LOD	limit of detection
LOQ	limit of quantitation
LTM	long term monitoring
Meadows	Meadows CMPG, Inc.
MCL	maximum contaminant level
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
NGA	National Guard Area
NPL	National Priorities List
ORP	oxidation reduction potential
OSA	Open Storage Area

OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyls
PCE	tetrachloroethene
psi	pounds per square inch
p-value	probability value
qPCR	quantitative polymerase chain reaction
RA	remedial action
RAWP	remedial action work plan
RD	remedial design
RI	remedial investigation
ROD	Record of Decision
SC	specific conductance
SOP	standard operating procedure
SS	statistically significant
SSA	singular spectrum analysis
SSDS	sub-slab depressurization system
SSO	site safety officer
SVOC	semi-volatile organic compound
TCE	trichloroethene
TOC	total organic carbon
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VC	vinyl chloride
VOC	volatile organic compound
WBU	water bearing unit
yr.	year

1. Introduction

This document is a Remedial Action Work Plan (RAWP) Addendum for Operable Unit 6 (OU 6) 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 0024. This document describes the proposed follow-up in situ bioremediation (ISB) actions at OU 6 that target the confined aquifer. Proposed actions will occur in the fence line area in the National Guard Area and the adjacent offsite environmental easement area.

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 (FFA) with the United States Environmental Protection Agency (EPA) Region 3 and the Virginia Department of Environmental Quality (DEQ). OU 6 designation is the impacted groundwater beneath and downgradient of OU 1 (Open Storage Area, OSA), OU 2 (Area 50 Landfill), and OU 3 (National Guard Area, NGA) in the central portion of the Installation. 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
Orthoimagery Source: VGIN (2021)

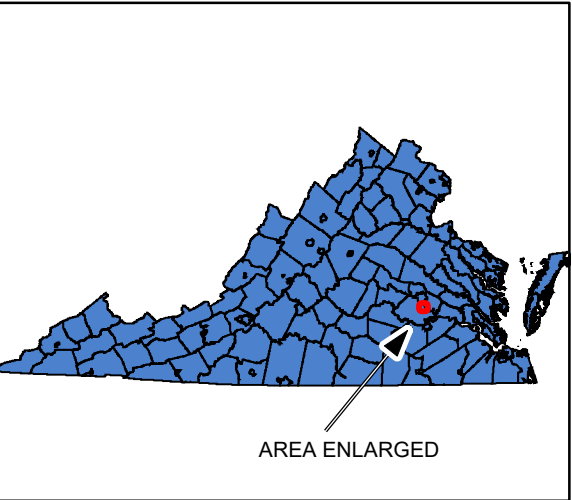


Figure 1-1
DSCR Operable Units

Defense Supply Center Richmond
Richmond, VA

Prepared By: DBC	Reviewed By: KL
Scale: 1" = 1,300'	Date: January 03, 2025

2. Background

Section 2 has background information for OU 6 including a site description, site history, and environmental setting.

2.1 OU 6 Description

OU 6 consists of impacted groundwater beneath and downgradient of OU 1, OU 2, and OU 3 in the central portion of the Installation. Figure 2-1 (page 2-2) shows the location and the layout and features of the OU 6 area, which has large open areas bisected by Building 54 with several buildings in the developed NGA. OU 6 extends offsite to the east into an undeveloped woodland area where a volatile organic compound (VOC) plume mostly occurs in the confined aquifer. No Name Creek begins at the northeast corner of OU 6 and flows south parallel to the Installation boundary and then southeast into the offsite area.

2.2 OU 6 Site History

OU 1 is a 43-acre fenced area and formerly consisted of an unpaved storage area for bulk drummed chemicals (primarily petroleum, oil, and lubricants), the recouping of liquids from leaking drums, and the repair/replacement of damaged containers. Storage activities in the OSA began in 1942 and drum recoupage activities occurred between the early 1960s and late 1970s (Dames & Moore 1989).

OU 2 consisted of a disposal site for waste, contaminated and outdated chemicals, and construction debris from the late 1950s until the early 1970s. The landfill area originally consisted of a ravine approximately 200 feet x 300 feet x 10 feet that contained wet soils and vegetative cover. Dumping occurred in various areas of the ravine and by 1975 previously used areas had been graded to current elevations and revegetated (Dames & Moore 1989). A fence surrounds OU 2 separating it from the OU 1 and OU 3.

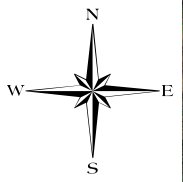
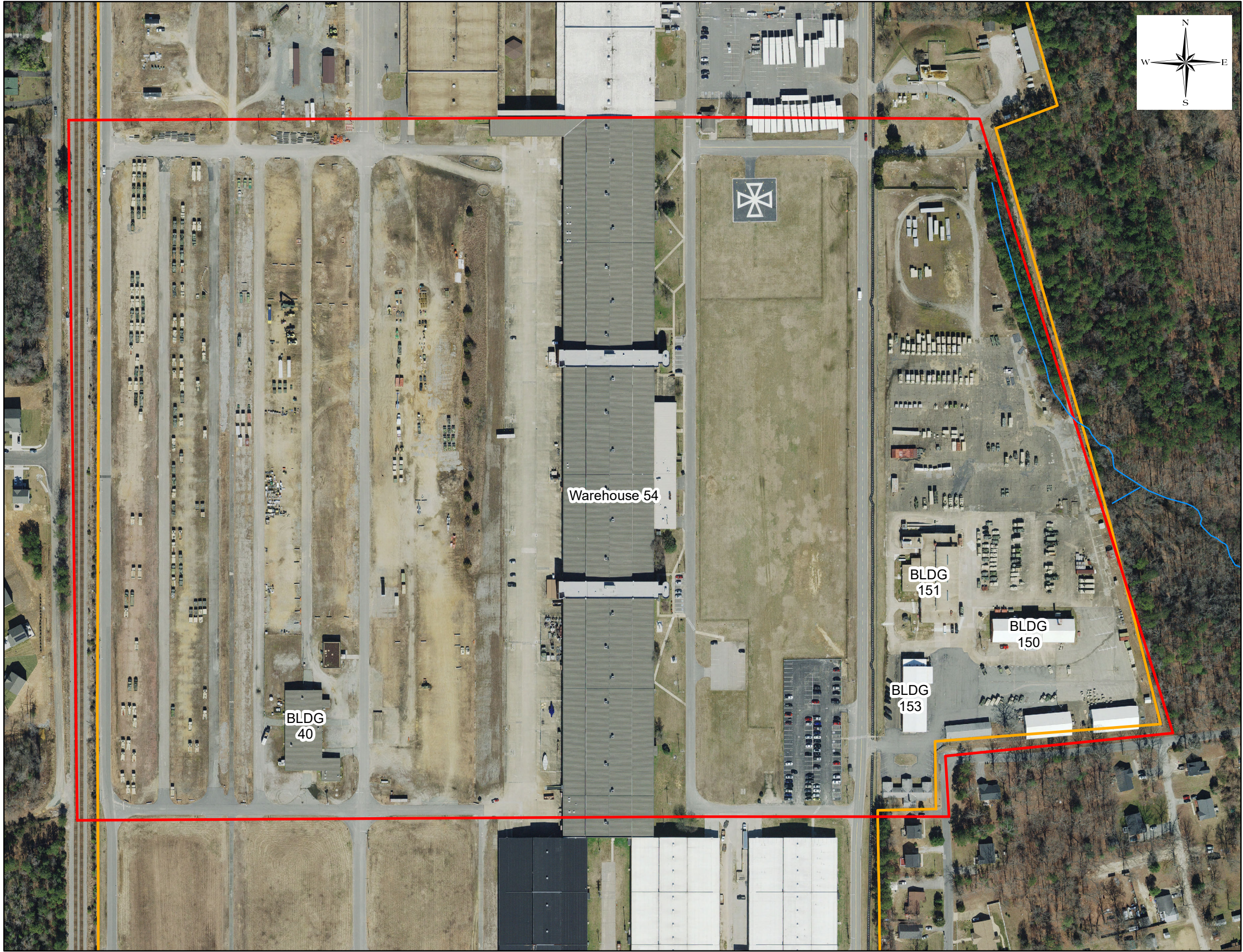
OU 3 is located on a 15-acre area leased by the Army National Guard from DSCR and contains a number of maintenance shops and administrative buildings. Since the late 1940s, the primary function at the NGA is vehicle maintenance operations. In the past, underground and aboveground tanks contained fuels, oil, and solvents, and reportedly disposal of some waste solvents occurred in the site's storm sewer system or on an unpaved area.

2.2.1 1981 Installation Assessment

The United States Army Toxic and Hazardous Materials Agency completed the first environmental assessment at DSCR, and their installation assessment report indicated possible groundwater impacts from OU 2 and OU 3 (Army Chemical Systems Laboratory 1981).

2.2.2 U.S. Army and USGS Investigations

Remedial investigations began in the OU 6 area before the DSCR final listing on the NPL in 1987. Initial investigations completed by the United States Army Environmental Health Agency (AEHA) occurred in and around OU 2 and OU 3 in 1982 and 1983 (AEHA 1982, 1983). These investigations detected VOCs in the upper and lower aquifers beneath the site. The United States Geological Survey (USGS) completed investigations east of OU 3 in 1984 to delineate the extent of offsite migration of VOCs in the upper and lower aquifers. USGS found that No Name Creek acted as groundwater flow boundary for the upper aquifer preventing further VOC migration beyond the creek. Groundwater monitoring conducted by USGS indicated VOC impacts throughout the bulk matrix of the lower aquifer (Potomac Formation) with detected trichloroethene (TCE) concentrations as high as 1,700 micrograms per liter (µg/L) (USGS 1987, 1990).



Legend

-  Streams
-  Operable Unit 6 Boundary
-  Installation Boundary

Note: Orthoimagery Source: VGIN (2021)

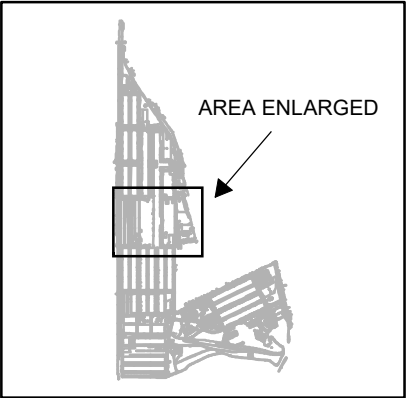


Figure 2-1
Operable Unit 6

Defense Supply Center Richmond
Richmond, VA

Prepared By:
DBC

Reviewed By:
JOS

Scale:
1" = 225'

Date:
January 03, 2025

2.2.3 1989 Remedial Investigation

Dames & Moore completed a remedial investigation (RI) for OUs 1, 2, and 3 from 1985 to 1988 that included completion of soil borings, installation of monitoring wells, and sampling of soil, 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 OUs 1, 2, and 3 source areas and downgradient of the installation east of OU 3. Primary constituents included VOCs with semi-volatile organic compounds (SVOCs) also detected in OU 2 soil. RI sampling of No Name Creek indicated low levels of VOCs present in surface water potentially from contaminated surface water runoff and/or contaminated groundwater discharge. HHRA results identified off-installation groundwater users, recreational users of No Name Creek, and onsite workers conducting excavation in OU 2 as potential receptors. The RI recommended remediation of impacted groundwater in the upper and lower water bearing units (WBUs) and remediation of contaminated soil within OU 2 (Dames & Moore 1989).

2.2.4 1993 Focused Feasibility Study

A Draft Focused Feasibility Study (FFS) issued in 1993 incorporated the results of a revised baseline HHRA and established remedial action objectives to prevent potential exposure to impacted groundwater and surface water of No Name Creek, and to prevent migration of groundwater to surface water of No Name Creek at concentrations exceeding ambient water quality criteria. The FFS identified in situ bioremediation as the preferred remedial alternative for OU 6 groundwater (Law 1993).

2.2.5 OU 9 Interim Remedial Action

Implementation of an interim remedial action occurred in 1996 (identified as OU 9) with the installation of a groundwater extraction and treatment system at the installation boundary in OU 3. Stated objectives of this remedial measure included reducing the migration of contaminated groundwater, reduction of toxicity, mobility, and volume of contaminants in groundwater, and collection of data related to aquifer and contaminant responses to remedial measures to support design of a final remedy for OU 6.

This system included 17 extraction wells in the surficial aquifer and 5 extraction wells in the confined aquifer with a treatment system designed for 100 gallon per minute flow. Performance evaluations of the system after startup indicated that the system did not achieve the stated objectives because of low well yields and mass removal rates, limited lateral influence of the system, operational issues, and cost (Earth Tech 2007). Operations of the system ceased in January 2006 and decommissioning occurred by December 31, 2008. Decommissioning included conversion of system extraction wells to monitoring wells (Earth Tech 2009).

2.2.6 1999 Pilot Tests at OU 3

Law Engineering and Environmental Services (Law) performed pilot tests in 1999 in OU 3 to determine the feasibility and effectiveness of using dual phase extraction (DPE) as a groundwater remedy for OU 6. Separate test locations in OU 3 evaluated areas of elevated VOCs in the surficial aquifer and confined aquifer. The results indicated low well yields, low air flows, and minimal mass removal with the pilot test report recommending no further consideration of the DPE technology for groundwater at OU 6 (Law 2000b).

2.2.7 2000 MNA Evaluation Report

Law issued a Final Natural Attenuation Studies Report for OU 6 in June 2000. This report included an analysis of natural attenuation processes for the "lower aquifer" using data collected in 1997 from onsite and offsite monitoring wells. The analysis followed the 1998 EPA technical protocol for evaluating natural attenuation of chlorinated solvents in groundwater and used the EPA BIOCHLOR attenuation modeling tool to evaluate USGS data from 1985 to 1992. The study used six onsite AEHA wells screened across the Aquia and Potomac Formations, three 'lower aquifer' extraction wells screened across the entire thickness of the Potomac Formation, and seven offsite USGS wells screened at various discrete depth intervals within the Potomac Formation. The report also included a performance evaluation of the OU 9 interim action groundwater extraction and treatment system (Law 2000a).

The report indicated that analysis of the USGS data from 1985 to 1992 combined with BIOCHLOR modeling demonstrated destruction of contaminant mass by biodegradation prior to operation of the OU 9 system. Another conclusion reached by the report indicated a favorable geochemical environment with the 'lower aquifer' for biodegradation and also cited the presence of degradation products such as cis-1,2-dichloroethene (cDCE), chloride, and carbon dioxide as evidence of biodegradation. The report recommended further consideration of monitored natural attenuation (MNA) as a viable remedy for the 'lower aquifer' at OU 6 and also recommended implementation of a monitoring program to collect additional data (Law 2000a).

2.2.8 Creeks Monitoring Program

MACTEC implemented a three-year creek monitoring program that included an assessment of No Name Creek. This included performance of a HHRA in 2006 that concluded no further action required for No Name Creek for human health-based risks (MACTEC 2006c). A screening level ecological risk assessment completed in 2001 for No Name Creek indicated risks low in magnitude and limited in spatial scale.

2.2.9 2006 Supplemental Feasibility Study

MACTEC issued a Final Supplemental Feasibility Study in 2006 that presented results for geophysical surveys, membrane interface probe (MIP) screening with cone penetrometer testing (CPT), soil and groundwater sampling, piezometer installation, meteorological and soil moisture monitoring, No Name Creek discharge evaluations, and slug testing (MACTEC 2006a,b). The installation-wide, conceptual site model (CSM) completed by MACTEC in 2006 incorporated the FFS data (MACTEC 2006d).

2.2.10 2011 Revised HHRA and Focused Feasibility Study

A HHRA completed as part of the Revised FFS in 2011 evaluated risks from potential exposures to contaminated groundwater at OU 6. The FFS evaluated remedial alternatives based on the results of the revised HHRA supported by an in-situ bioremediation treatability test conducted in September 2007. This treatability study evaluated the effectiveness of enhanced in situ bioremediation (ISB) using organic substrates for degradation of chlorinated VOCs in OU 6 groundwater (AECOM 2011).

The bioremediation treatability tests involved injection of 1,000 gallons of six percent edible oil emulsions in each injection location including two injection wells in the surficial aquifer and monitoring well AEHA-30B screened across the Aquia Formation and uppermost interval of the Potomac Formation. Injections occurred into monitoring well AEHA-30B after determining that the injection well installed in the Potomac Formation would not accept injectate.

Treatability results indicated favorable conditions for ISB targeting reductive dechlorination of chlorinated solvents in the upper aquifer and lower aquifer. Pre-injection and post-injection samples analyzed for microbes indicated an increase in microbial populations following injections. An identified constraint included optimizing substrate distribution in the surficial aquifer to address variable subsurface conditions including increasing injection pressures and appropriate screening of wells (AECOM 2011).

2.2.11 ROD

The Record of Decision (ROD) document for OU 6 finalized in September 2013 identifies OU 6 as groundwater underlying and downgradient from the OU 1, OU 2, and OU 3. It also identifies discharge of surficial aquifer groundwater to No Name Creek as a component of OU 6. Separate remedial actions have addressed OUs 1, 2, and 3 identified as the source materials that impacted OU 6 groundwater (DSCR 2013).

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

- ISB to treat constituents of concern (COC) in the upper aquifer and lower aquifer source areas and downgradient portions of the groundwater plumes.
- MNA that involves monitoring of COCs and geochemical conditions in the upper aquifer and lower aquifer to document that MNA is reducing chemical mass and concentrations over time.

- Annual long-term monitoring (LTM) of the upper aquifer for a minimum of five years to monitor for potential leaching of SVOCs, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and metals from OUs 1, 2, and 3 soils to groundwater and also includes annual monitoring of surface water of No Name Creek until COCs in the surficial aquifer have reached cleanup levels established in the ROD.
- Institutional controls (ICs) described in the ROD included groundwater use restrictions, land use restrictions, control exposure to contaminated groundwater and implementation of institutional controls for future buildings within groundwater plume areas.
- Air sampling (indoor air and subsurface vapor monitoring) every three and five years for Building 151 and every five years for other buildings over the OU 6 surficial aquifer plume.

Table 2-1 presents the cleanup levels established in the ROD for the COCs in OU 6 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 occur within 5 years after initiation of the remedial action, 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 6 COCs and Cleanup Levels

Contaminants of Concern	Maximum Contaminant Level (MCL) (micrograms per liter, µg/L)
Upper Aquifer	
Bromochloromethane	(1)
Carbon Tetrachloride	5
Chlorobenzene	100
Dibromomethane	(1)
1,2-Dichloroethane	5
Dichlorodifluoromethane	(1)
1,4-Dichlorobenzene	75
1,1-Dichloroethene	7
cis-1,2-Dichloroethene	70
Methylene chloride	5
Naphthalene	(1)
Tetrachloroethene	5
Toluene	100
1,2,4-Trichlorobenzene	70
1,1,2-Trichloroethane	5
Trichloroethene	5
1,2,4-Trimethylbenzene	(1)
Vinyl Chloride	2
Chloroform (2)	80
Lower Aquifer	
1,2-Dichloroethane	5
cis-1,2-Dichloroethene	70
1,4-Dioxane	(1)
bis(2-Ethylhexyl)phthalate	6
3- & 4-Methylphenol	(1)
Tetrachloroethene	5
Trichloroethene	5
Vinyl Chloride	2

Notes: (1) There is no Federal MCL for drinking water for this constituent. For groundwater COCs that do not have MCLs, the remedy will continue until the concentrations have reached acceptable risk levels (non-carcinogenic hazard index of 1 and carcinogenic risk of 1E-04 for on-installation and 1E-06 for off-installation receptors). The risk levels will be confirmed via a future risk assessment, which shall assume that people, both on- and off-site, will use the Upper and Lower WBUs for potable water. The goal is to restore both WBUs to their potential beneficial use as potable water sources. This risk assessment is recommended to be performed after groundwater COCs (that have MCLs) have reached their cleanup levels. (2) Chloroform was identified as a risk driver in the OU 6 HHRA. Based on communication with EPA Region III, the trihalomethane MCL was applied to chloroform and chloroform was added as a COC for OU 6.

2.2.12 2015 Remedial Action

AECOM implemented remedial actions for the selected remedy at OU 6 in 2015, as generally detailed in the OU 6 Injection Technical Memorandum that documented completed activities (AECOM 2016). A Final Revised Remedial Design/Remedial Action Work Plan (RD/RAWP) for OU 6 detailed the proposed remedial actions (AECOM 2015).

ISB treatment areas targeted higher concentration areas and mid plume areas at OUs 1, 2, and 3. ISB actions focused on the surficial aquifer at OU 1 and both the surficial aquifer and confined aquifer at OUs 2 and 3. The ISB process options implemented included emulsified vegetable oil (EVO) as the carbon substrate pressure injected into injection wells designed for the specific treatment areas. Adaptation of the injection processes occurred in the field based on observed injection rates relative to design, where some wells received greater injection volumes to compensate for other wells in the treatment area that did not accept design injection volumes. Injection wells in area No. 6 located in OU 3 across the fence line (targeting surficial aquifer) and near the fence line (targeting confined aquifer) accepted approximately 50 percent of the design volumes. Additional injection occurred at monitoring wells AEHA-27B and AEHA-31B screened across the upper confined aquifer and the upper-middle portion of the confined aquifer to reach 50 percent of the design volume. Gravity feed injections occurred in monitoring wells in the surficial aquifer and confined aquifer in the OU 3 and offsite area to use available EVO for treatment of targeted zones (AECOM 2016).

Remedy verification performed as part of the remedial actions included quarterly remedy verification monitoring of groundwater for two years beginning three months after initial injections followed by semi-annual monitoring of treatment areas for ISB effectiveness. Since 2015, annual MNA monitoring of the surficial aquifer and confined aquifer has occurred with annual LTM for leachability at select wells in the surficial aquifer and annual LTM surface water monitoring of No Name Creek in accordance with the ROD. Post-injection monitoring of soil vapor occurred around Buildings 54 and 151 and indoor air sampling occurred at site buildings at the frequency specified by the ROD. ICs implemented at OU 6 are in accordance with the site-wide land use control remedial design.

2.2.13 2018 Building 151 Sub Slab Depressurization System

Arcadis implemented engineered measures at Building 151 located within OU 3 in OU 6 in 2018 as detailed in the Operation, Maintenance, and Monitoring Plan, Building 151 Sub Slab Depressurization System (Arcadis 2018). This building houses vehicle maintenance bays, sub-grade service pits, offices, a breakroom, tool room, and other facilities.

Installation and startup of a sub slab depressurization system (SSDS) occurred in 2018 with the objective of addressing the presence or potential presence of VOCs beneath the building floor slab. The SSDS has two vapor extraction points including one in the tool room and the other in the break room. Quarterly field monitoring of the SSDS is performed to verify effectiveness of the engineered control measure.

2.2.14 2019 Pre-Design Investigations

Pre-design data collection activities occurred at OU 6 in 2019 to update the CSM and obtain data to support remedy optimization, as detailed in the 2019 Annual Report for OU 6 (AECOM-Meadows 2021a). The scope of these activities included:

- Expansion of the 2019 annual sampling event from 91 to 162 monitoring well locations.
- Completion of vertical profile sampling at six stations in No Name 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 1, OU 2, OU 3, and the offsite area east of OU 3 (OU 6).

The 2019 Annual Report presents a detailed update of the CSM that includes a digital three-dimensional (3D) model of the OU 6 site area.

2.2.15 Remedial Action Work Plan Addendum

A RAWP Addendum prepared in 2021 described proposed remedy optimizations for OU 6 (AECOM-Meadows 2021b). The RAWP contained the following proposed actions:

- Targeted ISB injections in the residual source zone beneath OU 1.
- Implementation of an optimized monitoring well network at OU 6 including the installation of 61 new monitoring wells.
- Remedy performance monitoring and MNA actions.
- Planned future abandonment of wells no longer used or needed for monitoring.

2.2.16 Monitoring Well Installation and Optimized Monitoring Network

Implementation of the RAWP Addendum included the installation of 61 new monitoring wells in August and September 2021. Implementation of a new optimized network for remedy performance monitoring, MNA, and LTM occurred in December 2021 and included 66 monitoring wells screened in the surficial aquifer, 44 monitoring wells screened in the confined aquifer, and 3 surface water stations at No Name Creek. The optimized monitoring network excluded wells used for gravity feed EVO injections in 2015 and 2016.

The annual monitoring network for OU 6 in 2022 added existing well DMW-8A to refine plume delineations in the surficial aquifer in the OU 1 area. In December 2022, EPA and DEQ approved the installation of four additional monitoring wells (MW-298, MW-299, MW-300, and MW-301) for incorporation into the 2023 annual monitoring network for remedy performance and MNA evaluations. These well installations occurred in the first quarter of 2023.

2.2.17 ISB actions and Performance Monitoring

Implementation of the RAWP Addendum included optimized ISB injections targeting the residual source zone beneath OU 1. Field implementation of the injections occurred from October 25 through November 17, 2021. ISB injections used direct push technology (DPT) with EVO as the carbon amendment with bioaugmentation and included three treatment areas with 80 injection points injecting more than 5,160 gallons of EVO.

A pre-injection baseline monitoring event for groundwater occurred at 15 monitoring wells in OU 1 in October 2021. One year of quarterly ISB performance monitoring of groundwater occurred at 15 monitoring wells in OU 1 followed by semi-annual monitoring to evaluate injection performance and treatment progress. The analytical parameters for performance monitoring included VOCs, geochemical parameters, field water quality parameters, and select samples for microbial analysis.

2.2.18 Monitoring Well Decommissioning

A technical memorandum finalized on October 24, 2022 detailed proposed abandonment of 14 monitoring wells in OU 3 prior to asphalt resurfacing for LUC maintenance (AECOM-Meadows, 2022b). Well plugging and abandonment of these wells occurred on December 5 and 6, 2022. Wells abandoned had a status of not used or needed for LTM.

A technical memorandum finalized on October 6, 2022 details proposed abandonment of 39 monitoring wells in OU 3 and off-installation areas (AECOM-Meadows, 2022a). Well plugging and abandonment of these wells occurred in January 2023. Wells abandoned had a status of not used or needed for LTM.

A technical memorandum finalized in May 2023 details proposed abandonment of 243 monitoring wells in the OU 1, OU 2, OU 3, and off-installation areas (AECOM-Meadows, 2023). Well plugging and abandonment of these wells occurred in May-June 2023. Wells abandoned had a status of not used or needed for LTM.

2.3 Environmental Setting

Section 2.3 describes the environmental setting for OU 6.

2.3.1 Site Topography

Historical site activities and development have altered the land surface and topography of the OU 6 area. A former ravine existed in the OU 2 area before landfilling and realignment of No Name Creek to the eastern installation boundary occurred as part of the initial development of DSCR. Figure 2-2 (page 2-9) has a digital elevation model (DEM) for OU 6 showing site topography. Overall topographic slope is toward the northeast with elevations ranging from a maximum of approximately 134 feet (ft.) North American Vertical Datum of 1988 (NAVD88) in OU 1 to a minimum of approximately 106 ft. NAVD88 in the OU 3.

The open area of OU 1 has gravel and soil ground cover with Building 85 located between OUs 1 and 2. Grass covers most of the former landfill area at OU 2 except for two parking areas and a heliport located at the southern and northern ends of OU 2, respectively. Tarmac (concrete and asphalt) covers the southern two thirds of OU 3 with the remaining area covered by gravel and grassland vegetation. Building development in the southern portion of OU 3 includes eight buildings associated with NGA operations (Figure 2-1).

2.3.2 Surface Water and Wetlands

No Name Creek originates near the northeast corner of OU 3 and flows south along the eastern boundary of the installation turning southeast into off installation area and flowing in a southeasterly direction away from the installation. The former creek alignment passed through the northern end of OU 2, north of the helipad and landfill area. Creek realignment of up to 450 ft. east occurred in the northern portion of OU 3 as part of DSCR development. This involved placement of up to 15 ft. of fill in the creek valley to attain current surface grades at OU 3 (MACTEC 2006d).

Surface water in the OU 6 area drains through a storm sewer drainage system with outfalls into No Name Creek. The southern portion of OU 3 including the areas of Buildings 150 and 151 drains through a storm sewer that extends to an undesignated outfall at a ditch that flows east to No Name Creek outside of the installation boundary.

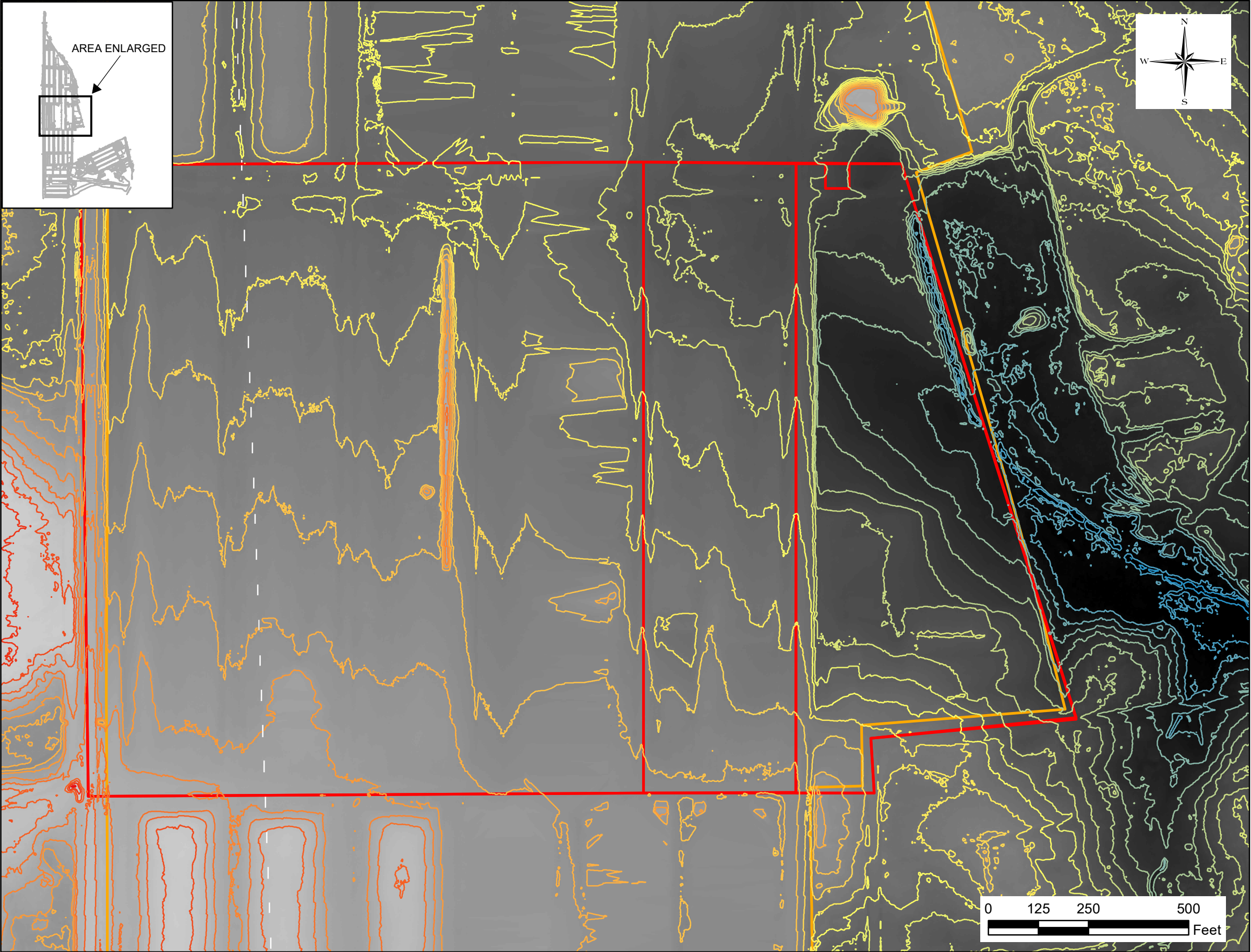
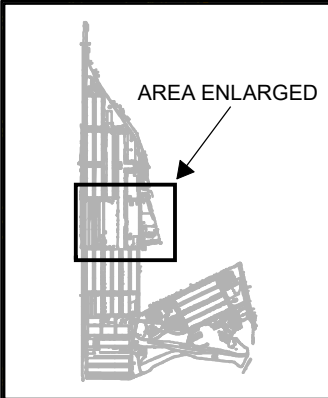
There are no wetlands located within the installation area comprising OU 6. A freshwater forested/shrub wetland area (6.07 acre) is mapped in the undeveloped No Name Creek area located east of the installation according to the United States Fish and Wildlife Service's National Wetlands Inventory wetlands mapper included as Figure 2-3 (page 2-10).

2.3.3 Soils

The United States Department of Agriculture (USDA) web survey accessed at <https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx> identifies the soil mapping unit at OU 6 as made land reflecting disturbance and development of the area. USDA defines made land as areas where soil material has been removed or reworked by machinery, varies in consistency, and ranges from loamy sand to clay. East of the installation at OU 6 the USDA survey identifies sandy loam, loam, and loamy sands derived from marine terraces and flood plain soils in the No Name Creek area.

2.3.4 Site Geology

DSCR lies near the western edge of the Virginia Coastal Plain. General stratigraphy found beneath OU 6 includes four coastal plain formations present above bedrock from top down: the Eastover Formation, Calvert Formation, Aquia Formation, and Potomac Formation. A weathered saprolite zone is typically present above competent bedrock. Table 2-2 (page 2-11) provides general stratigraphy information for the OU 6 area.



Legend

- Operable Units
- DSCR Boundary

Topographic Contour (2 ft interval)

- 98 ft
- 100 ft
- 102 ft
- 104 ft
- 106 ft
- 108 ft
- 110 ft
- 112 ft
- 114 ft
- 116 ft
- 118 ft
- 120 ft
- 122 ft
- 124 ft
- 126 ft
- 128 ft
- 130 ft
- 132 ft
- 134 ft
- 136 ft
- 138 ft
- 140 ft
- 142 ft

OU 6 Digital Elevation Model (ft NAVD88)

Value

High Elevation: 142.468 ft

Low Elevation: 96.1081 ft



Figure 2-2
OU 6 Topographic Map

Defense Supply Center Richmond
Richmond, VA

Prepared By:
DBC

Reviewed By:
JOS

Scale:
1" = 250'

Date:
January 03, 2025

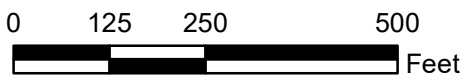


Figure 2-3 Wetlands Mapper in OU 6 Area

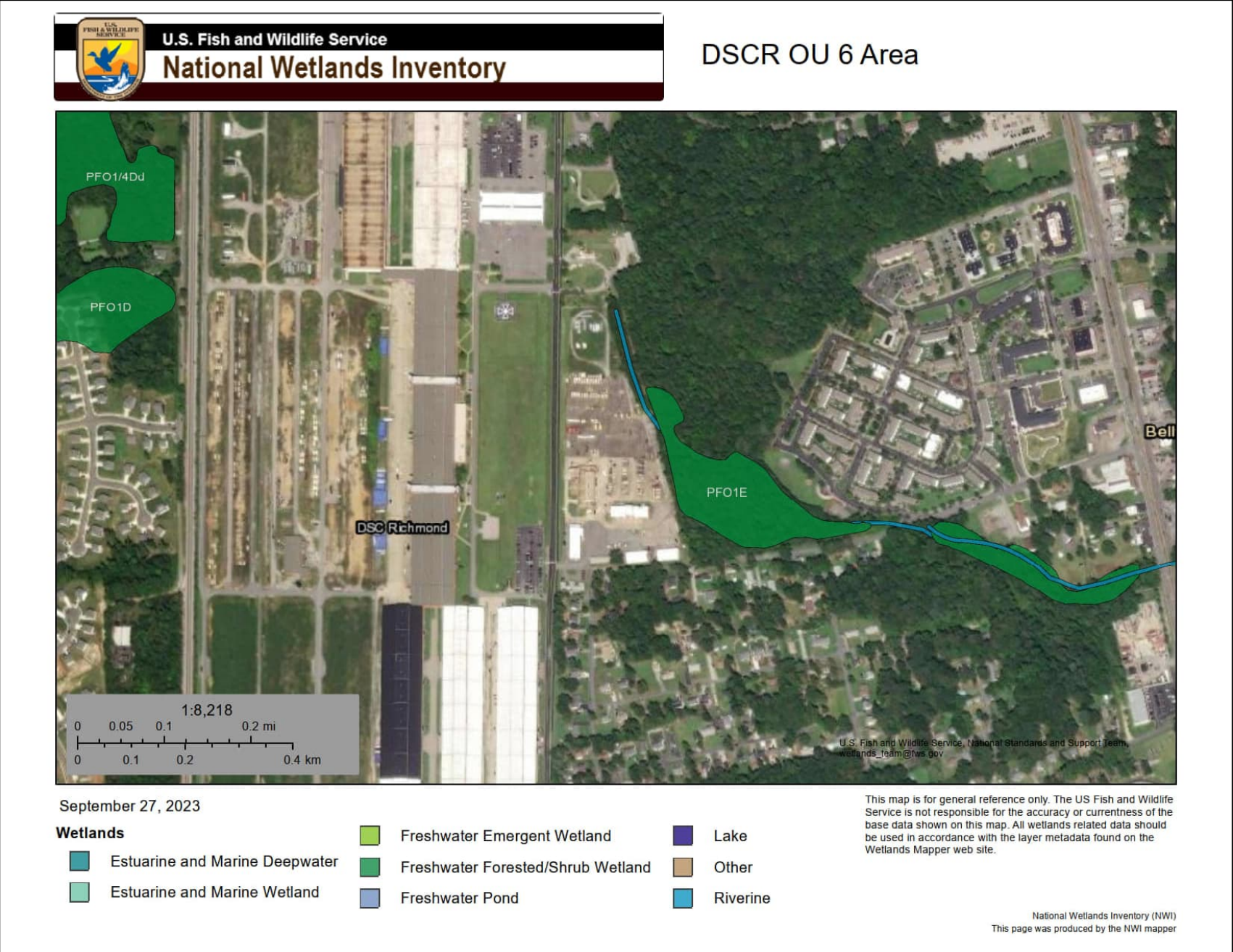


Table 2-2 OU 6 Stratigraphy

Geologic Formation	Age	Origin	Approx. THK (ft.)	Primary Lithology Types
Eastover	Pliocene	Alluvial	6-32	(a) Clay (CL), clayey sand, and silty sand (SM) (b) Poorly graded sand with gravel (SP) (c) Clay (CL)
Calvert	Miocene	Marine	6-10	Clay (CH) and organic sand silt (OL)
Aquia	Paleocene Early Eocene	Marine	6-12	Silty sand (SM)
Potomac	Cretaceous	Alluvial	20-30	(a) Clayey sand with gravel (SC) (b) Clayey sand with gravel, elastic silt with sand (MH), clayey sand with gravel (SC)
Petersburg Granite	Mississippian	Bedrock	--	(a) Saprolite (b) Granite to Granodiorite Bedrock

Notes: ft. = feet.

The digital 3D CSM developed for the OU 6 area has a geologic model developed using multiple lines of data and geostatistical methods (kriging) in Earth Volumetric Studio (EVS). This involved review of original data sources collected for the period 1982-2019 and selection of the highest resolution/data quality available for model development. Data types reviewed for model inputs included geological and hydrogeological publications, site boring data, lithologic logs, geophysical logs and surveys, physical test data from soil cores, CPT data, and HRSC hydraulic profile tool (HPT) and sonic coring data collected in 2019.

Figure 2-4 (page 2-12) has a site-wide geologic cross-section (A-A') from west to east across the OU 6 area extending east of the installation area at OU 3. Figure 2-5 (page 2-13) has a geologic cross-section (B-B') across the fence-line area at OU 3.

Eastover Formation

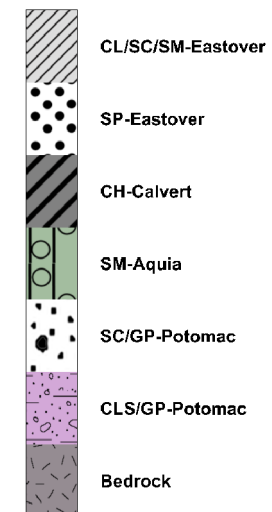
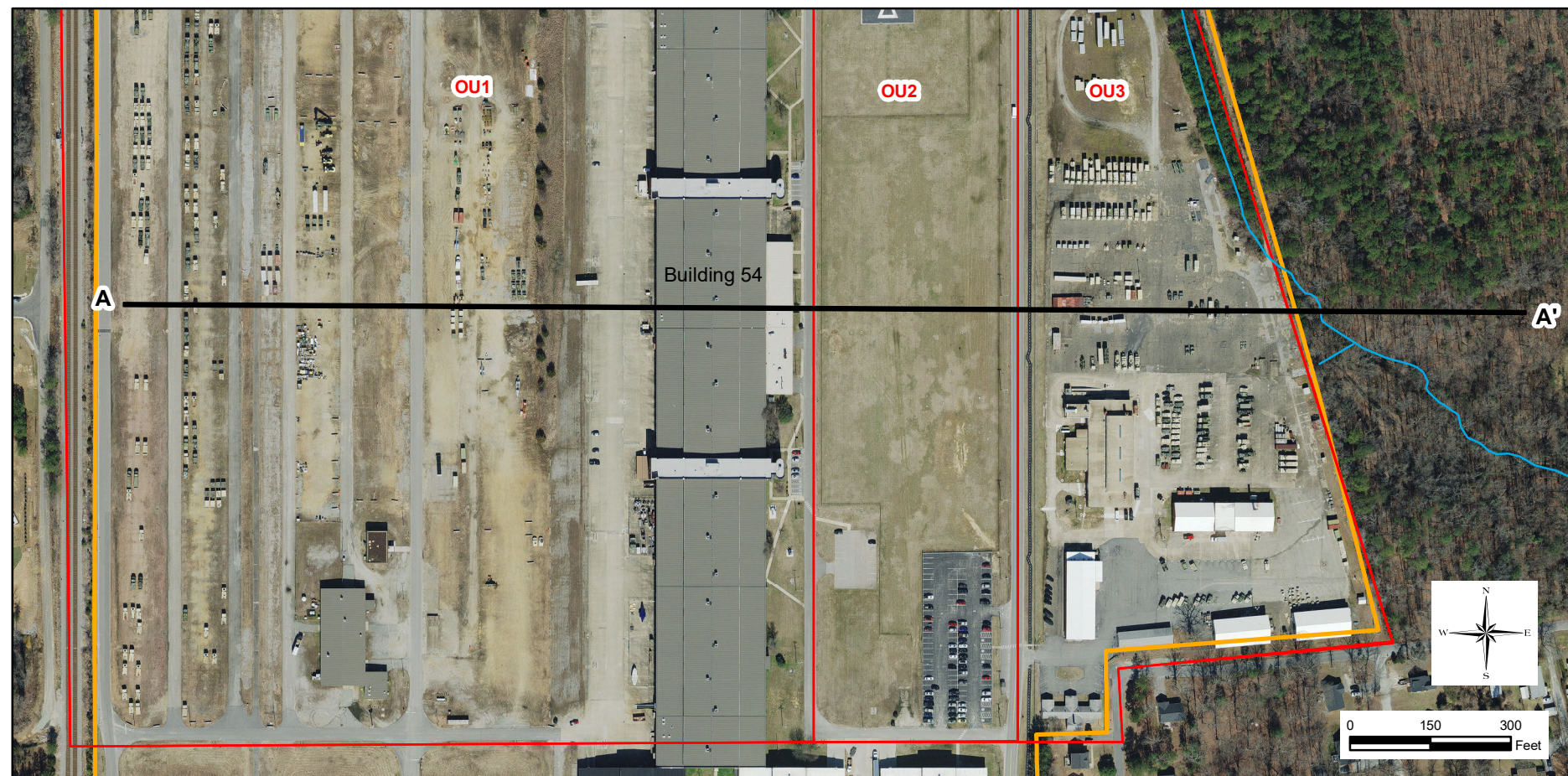
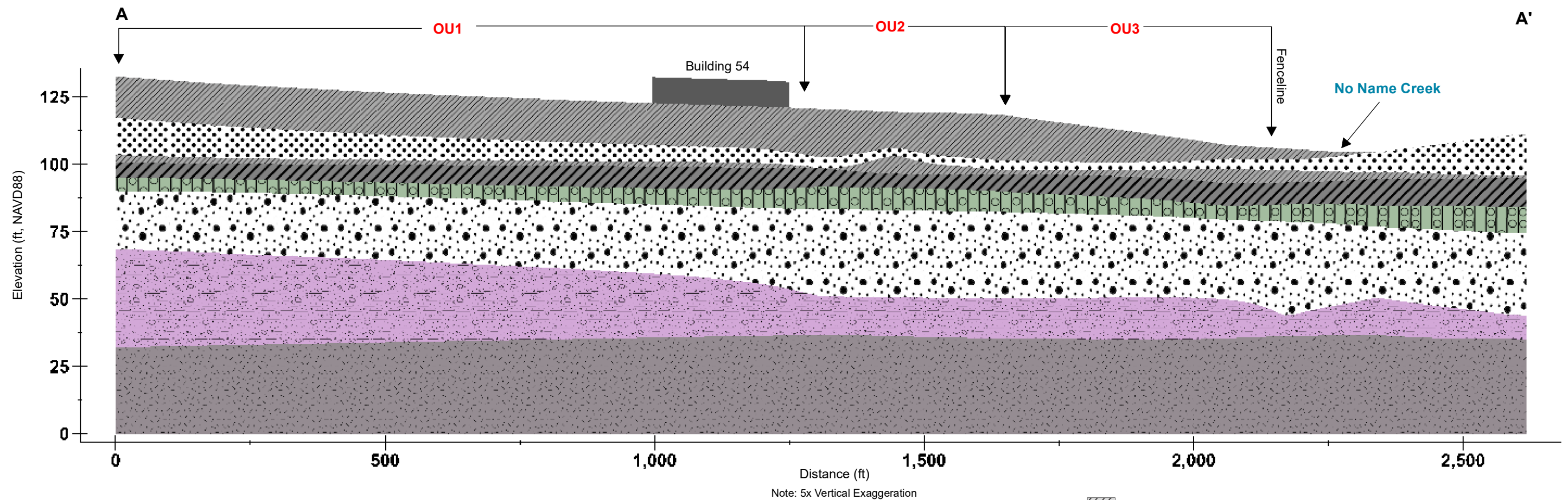
The lithology and thickness of the Eastover Formation varies across the OU 6 area (approximately 6 to 32 ft.) as illustrated in Figures 2-4 and 2-5. In general, the Eastover has three distinct lithologic zones from top down:

- Clay with variable mottling and interbeds, clayey sand, and silty sand
- Poorly graded sand with variable gravel
- Soft clay with laminations

At OU 1, HRSC boring data indicates 3D variability in the thickness of the poorly graded sand with gravel zone (0 to 10 ft.) within the OU 1 groundwater source zone. Substantial fill overlies the Eastover in OU 2 in the former ravine area containing in the OU 2 area. The clay zone beneath the fill material includes an organic rich clay layer and mottled clay and silt. The poorly graded sand with gravel zone is thinner and discontinuous across the OU 2 area where the lithologic zone consists of a variable clay and sand with some gravel. The thickness of the Eastover decreases toward the east and No Name Creek where elevations are lower than in the western portion of OU 6. A soft clay with laminations occurs at the base of the Eastover Formation and generally ranges from 1 to 4 ft. thick.

Calvert Formation

The Calvert Formation is a dark gray highly plastic clay and organic sandy silt with a dry consistency. The Calvert Formation generally ranges from 5 to 10 ft. thick with the top of the formation elevation generally sloping toward the northeast and east (Figures 2-4 and 2-5). A core sample tested by the USGS indicated a total organic carbon content of 32,700 milligrams per kilogram (mg/kg) with a sieve analysis indicating 57 percent finer by weight for the No. 200 sieve (USGS 1987). Physical testing analysis contained in the RI Report for two core samples of the Calvert Formation indicated a fat clay (CH) classification with No. 200 sieve analysis showing 69 and 86 percent finer by weight (Dames & Moore 1989).



- Legend**
- Cross-Section Transect
 - Streams
 - Operable Units
 - DSCR Boundary

Notes:
Orthoimagery Source: VGIN (2021)



Figure 2-4
OU 6 Geologic Cross-Section A-A'

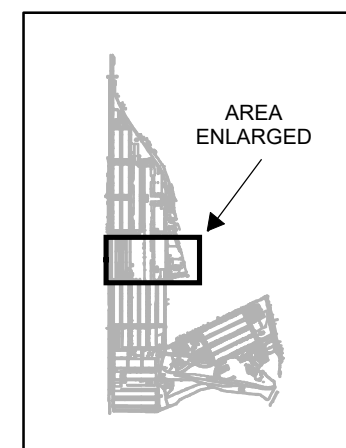
Defense Supply Center Richmond
Richmond, VA

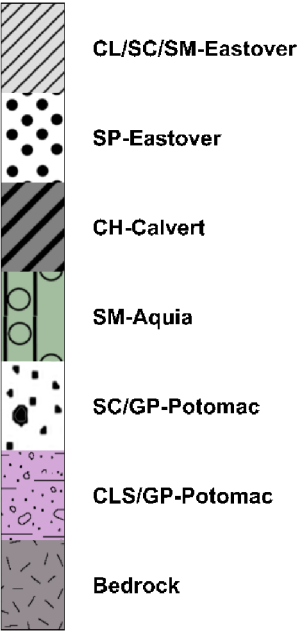
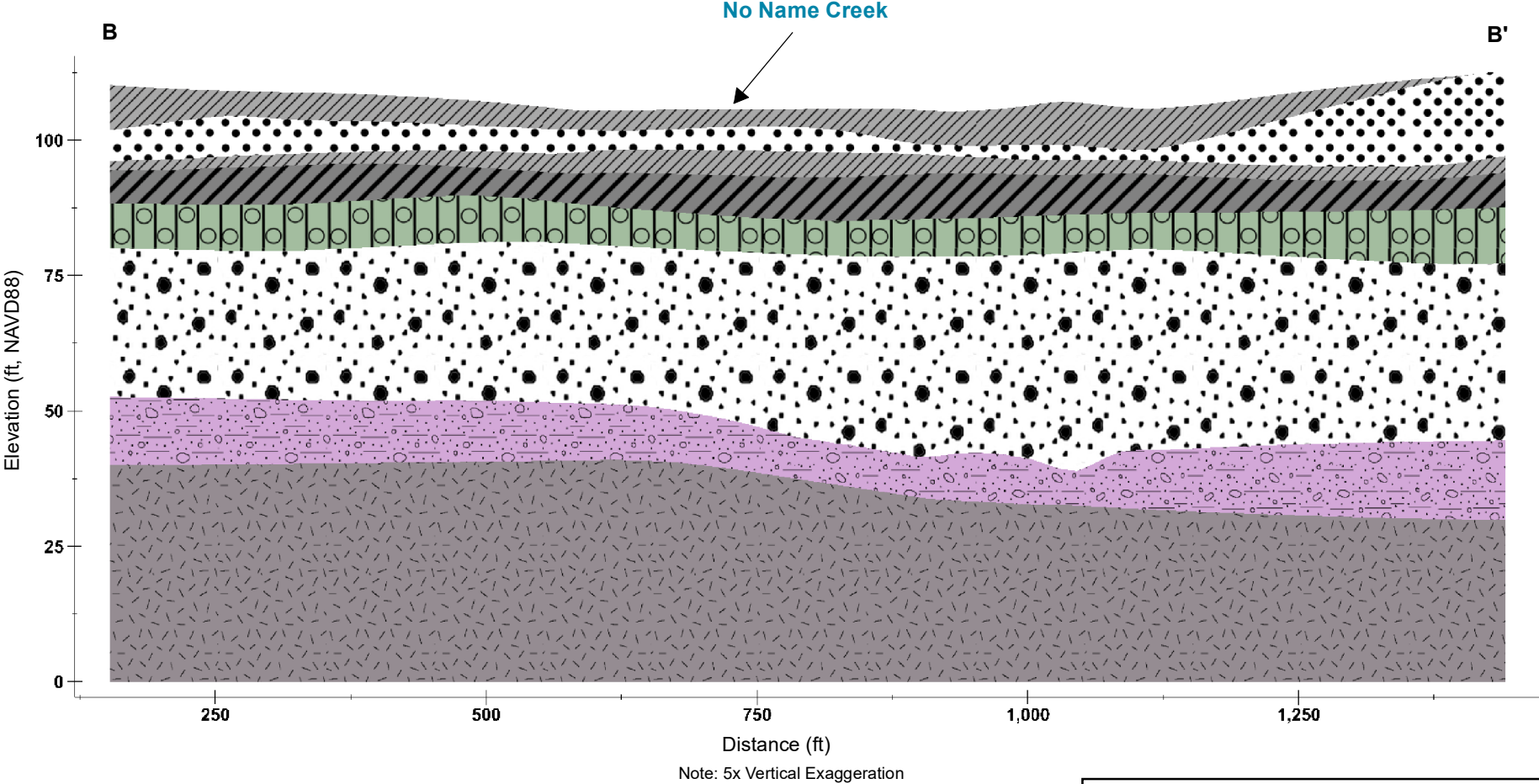
Prepared By:
DBC

Reviewed By:
JOS

Scale:
As Shown

Date:
January 03, 2025





- Legend**
- Cross-Section Transect
 - Streams
 - Operable Units
 - DSCR Boundary

Notes:
Orthoimagery Source: VGIN (2021)

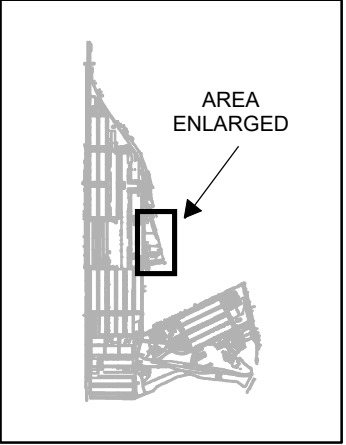


Figure 2-5
OU 6 Fenceline Geologic
Cross-Section B-B'

Defense Supply Center Richmond
Richmond, VA

Prepared By: DBC	Reviewed By: JOS
Scale: As Shown	Date: January 03, 2025

Aquia Formation

The Aquia Formation is a fining-upward, well sorted, dark green, glauconitic silty sand with a basal gravel stratum. This formation thickness generally ranges from 6 to 12 ft. with an average thickness of 10 ft. in the study area. A core sample tested by the USGS indicated a classification of silty sand (SM) with sieve analysis results indicating 16.42 percent fines by weight for the No. 200 sieve (USGS 1987). Physical testing analysis contained in the RI Report for a core sample of the Aquia Formation indicated the same classification with No. 200 sieve analysis showing 19 percent fines by weight (Dames & Moore 1989).

Potomac Formation

Potomac Formation sediments generally consist of an upper lithologic zone of greyish-green clayey sand with gravel (SC) ranging in thickness from approximately 20 to 35 ft. and a lower lithologic zone of grayish-green, clayey sand with gravel (SC) with a texturally finer basal layer varying from elastic silt with sand (MH) to clayey sand (SC). The thickness of the lower lithologic zone ranges from approximately 25 ft. in the western portion of OU 6 to 12 ft. or less at the installation fence line at OU 3. The top of the Potomac Formation elevation generally slopes toward the east (Figure 2-4).

The above lithologic descriptions and associated Unified Soil Classification System classifications are based on physical testing of core samples collected from discrete intervals of the Potomac Formation at PDI-14 and PDI-18 boring locations at the OU 3 fence line.

Petersburg Granite

Bedrock in the study area is the Petersburg Granite described by the USGS as chlorite rich granodiorite that has a weathered saprolite of variable thickness that grades into unweathered rock (USGS 1987). A boring BR-1 completed by the USGS near No Name Creek encountered saprolite, decomposed rock at a depth of 67 to 71 ft. and penetrated hard bedrock from 71 to 96 ft. below ground surface (BGS).

2.3.5 Hydrostratigraphy

The digital 3D CSM developed for the OU 6 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 (page 2-15) summarizes the refined hydrostratigraphy for OU 6 and associated hydraulic properties defined in the 3D model.

The HRSC HPT used to characterize hydrostratigraphy at OU 6 is a logging tool that measures the pressure required to inject a flow of water into the soil as the probe is advanced into the subsurface. This injection pressure log is an indicator of formation permeability. HPT generally has an inverse relationship to permeability with HPT maximum pressure data that scales up to 110 pounds per square inch (psi). The HPT can measure hydrostatic pressure under the zero-flow condition, which allows for the development of an absolute piezometric pressure profile for the log and prediction of the position of the water table. The piezometric profile can be used to calculate the corrected HPT pressure. This data along with the flow rate can then be used to calculate an estimate of the horizontal hydraulic conductivity (K_h) in the saturated formation. Estimates can be provided in the 1 to 100 feet per day (ft./day) range.

Eastover

This hydrostratigraphic unit corresponds to the Eastover Formation and groundwater within this unit is an unconfined water table. Some localized discontinuous perched water zones exist within the Eastover including the OU 2 area. Depth to groundwater is greater than (>) 10 ft. in the western portion of OU 6 and less than (<) 5 ft. at the OU 3 fence line. The thickness of the Eastover saturated zone decreases toward the east corresponding to the lower surface elevations and reduced thickness of the Eastover Formation. Because of the textural variation of the Eastover saturated zone, the hydraulic conductivity can vary by more than two orders of magnitude as illustrated in Table 2-3 and is highest in the poorly graded sand containing variable gravel. HPT data within this lithologic zone at OUs 1 and 2 indicated estimated K_h values in the 1.0E-02 to 3.5E-02 cm/sec range.

Table 2-3 OU 6 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	Semi-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 6., ⁵ USGS pumping test at OU 8 (USGS 1987)

Calvert

This hydrostratigraphic unit corresponds to the Calvert Formation and is a leaky confining zone that ranges from approximately 5 to 10 ft. thick. It has a low vertical hydraulic conductivity (K_v) based on laboratory testing (Table 2-3) and high HPT pressures (100-110 psi). The Calvert separates the overlying Eastover hydrostratigraphic unit from the underlying Aquia and Potomac hydrostratigraphic units. Some vertical groundwater flow through the Calvert is implied by the apparent vertical migration of site COCs from source zones present in the Eastover to the underlying Aquia and Potomac hydrostratigraphic units that exist under semi-confining conditions.

Aquia

This hydrostratigraphic unit corresponds to the Aquia Formation and is a semi-confined zone of groundwater that averages 10 ft. thick. HPT profiling indicates that the K_h of the Aquia varies by more than two magnitudes (Table 2-3) with discrete zones having K_h values > 1.0E-02 cm/sec. K_v determined for the USGS and RI are 3 to 4 orders of magnitude lower. Horizontal groundwater flow patterns and hydraulic gradient within the Aquia are likely similar to the underlying Potomac. Some vertical groundwater flow from the Aquia into the Potomac is implied by the apparent vertical migration of site COCs from the source zones in the Eastover to the Potomac.

Potomac

This hydrostratigraphic unit corresponds to the Potomac Formation and is a semi-confined zone of groundwater with moderate to very low permeability and high density. The thickness of this unit varies as described in Section 2.3.4. HPT profiling and testing indicates consistent maximum pressure responses of 110 psi. Clean water injection testing in the northern and southern areas of the OU 3 fence line confirmed these pressure profiles and indicated zero flow into the bulk matrix. Table 2-3 shows the range of laboratory tested K_h results for a series of vertical profile cores completed at two locations along the OU 3 fence line that provides an additional confirming line of evidence on bulk matrix characteristics.

USGS in their 1986 study investigated temporal changes in water levels in the USGS B well cluster (Eastover and Potomac wells) in response to precipitation (USGS 1987). The data collected demonstrated response of each hydrostratigraphic unit to recharge by precipitation and provided evidence of hydraulic interconnection of these units. Responses of water levels to precipitation differed between the Eastover (immediate) and Potomac (more subdued).

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.

2.4 Current Conditions for Groundwater in Confined Aquifer

Section 2.4 describes the current conditions for groundwater in the confined aquifer from the May 2024 annual sampling event. The focus of the current conditions summary is the confined aquifer in the

southern area of OU 6 that is targeted for ISB. Figure 2-6 (page 2-17) shows the current groundwater and surface water monitoring locations at OU 6.

2.4.1 Potentiometric Surface for Confined Aquifer

Figure 2-7 (page 2-18) has a potentiometric surface contour map (May 15, 2024) for the Potomac that occurs under confined conditions. Groundwater flow direction is generally toward the east-southeast. Equation 1 calculates the approximate horizontal velocity range of groundwater flow within the confined aquifer using a form of Darcy's velocity equation:

$$(1) \quad V = \frac{Ki}{n_e}$$

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 the confined aquifer include:

- K of 14.0 ft./day (average for pumping test from USGS 1987).
- Estimated effective porosity of 0.22 (estimated from OU 6 physical data from the Potomac).
- Average hydraulic gradient of 0.01 for the May 2024 sampling event across OU 1 (Figure 2-7).
- Average hydraulic gradient of 0.0079 for the May 2024 sampling event across OU 2/OU 3 (Figure 2-7).

The estimated horizontal groundwater flow velocity calculated for the confined aquifer using the above input values is 6.4E-01 ft./day (232 ft./yr.) for OU 1 flow path and 5.0E-01 ft./day (184 ft./yr.) for OU 2/OU 3 flow path.

2.4.2 Water Quality Parameters for Confined Aquifer: Southern Area (2024)

Section 2.4.2 and Exhibit 2-1 (page 2-19) have a summary of data distributions for water quality parameter results for the confined aquifer within the southern OU 6 area targeted for ISB actions. The summaries use the OU 6 annual monitoring data from May 2024.

2.4.2.1 pH

The distribution range for pH is 6.80 with a mean of 6.24 and median of 5.80. The distribution 25th and 75th percentiles are 5.65 and 6.06, respectively. The distribution is positively skewed with three outliers. No data observations have a pH < 5 with 23 of 34 data observations having a pH < 6.

2.4.2.2 Dissolved Oxygen

The distribution range for dissolved oxygen (DO) is 9.94 milligrams per liter (mg/L) with a mean of 1.73 mg/L and median of 1.03 mg/L. The distribution 25th and 75th percentiles are 0.49 mg/L and 1.63 mg/L, respectively. The distribution is positively skewed with four data outliers. Seventeen of 34 data observations have a DO level less than or equal to (≤) 1 mg/L.

2.4.2.3 Oxidation-Reduction Potential

The distribution range for oxidation-reduction potential (ORP) is 434.8 millivolts (mV) with a mean of 97.3 mV and median of 77.3 mV. The distribution 25th and 75th percentiles are 23.0 mV and 178.1 mV, respectively. The distribution has slight positive skewness with no data outliers. One data observation has an ORP level < 50 mV.

2.4.2.4 Specific Conductivity

The distribution range for specific conductivity (SC) is 1.268 millisiemens per centimeter (mS) with a mean of 0.234 mS and median of 0.168 mS. The distribution 25th and 75th percentiles are 0.104 mS and 0.276 mS, respectively. The distribution has positive skewness with one data outlier.



Legend

- Confined Aquifer Monitoring Well
- Upper Aquifer Monitoring Well
- Long-term Monitoring Well
- NNC Surface Water Sample Location
- EISB Performance Monitoring Well
- Stream
- Operable Units
- DSCR Boundary

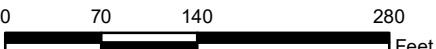
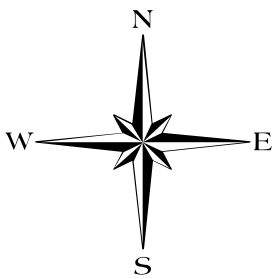


Figure 2-6
OU 6 2024 Groundwater and
Surface Water Monitoring Locations

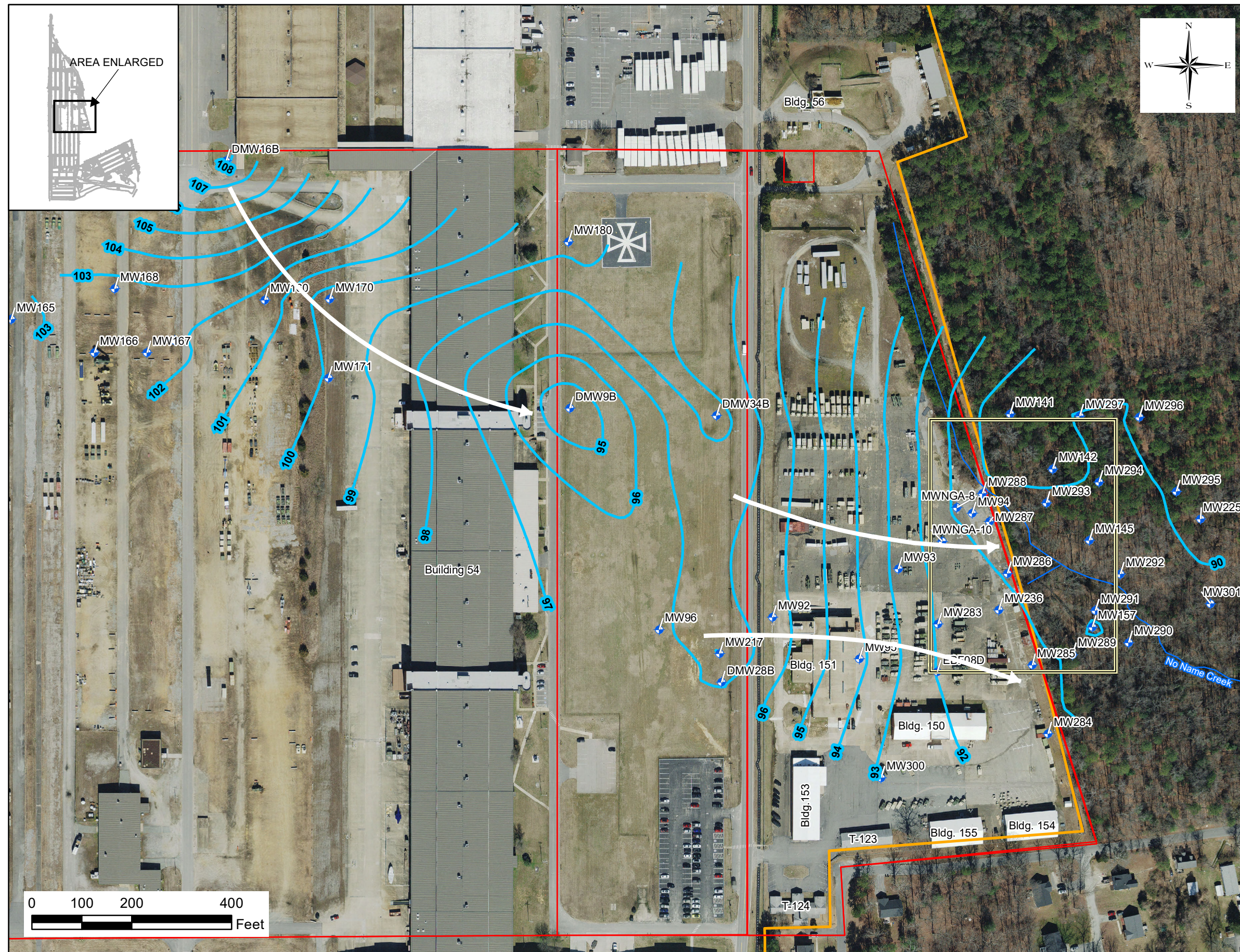
Defense Supply Center Richmond
Richmond, VA

Prepared By:
DBC

Reviewed By:
JOS

Scale:
1 in = 140 ft

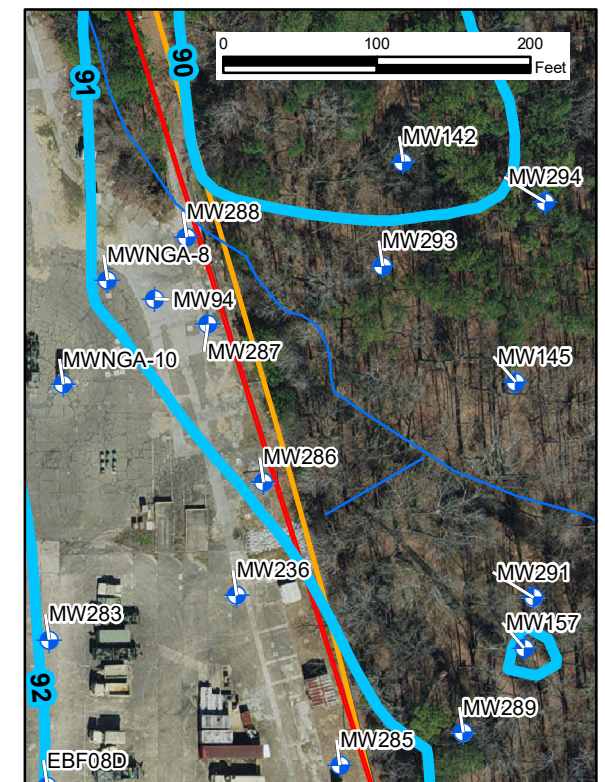
Date:
January 03, 2025



Legend

- Confined Aquifer Monitoring Well
- Confined Aquifer Potentiometric Surface Contour Line
- Stream
- Operable Units
- DSCR Boundary
- Groundwater Flow Direction
- Potentiometric Surface Elevation (ft NAVD88)

Notes:
Orthoimagery Source: VGIN (2021)

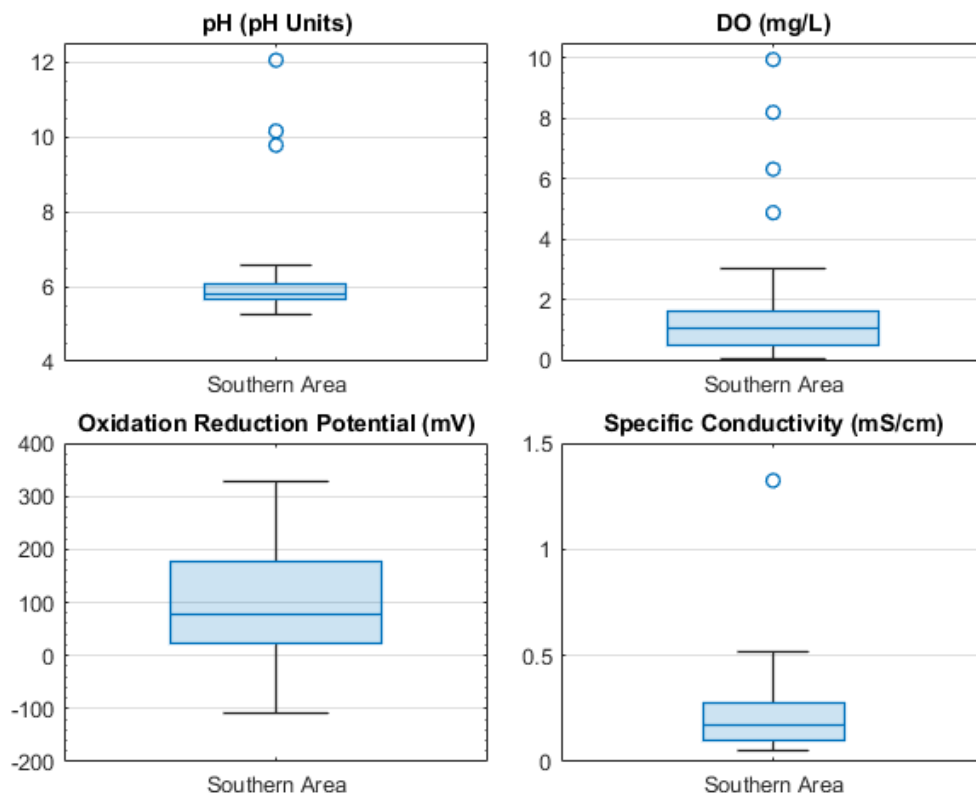


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Figure 2-7
OU 6 Confined Aquifer Potentiometric Surface (May 2024)

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1" = 200'	Date: January 03, 2025

Exhibit 2-1 Water Quality Parameter Distribution: Southern Area Confined Aquifer (May 2024)**pH (pH units)**

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	pH< 5
34	34	5.24	12.04	6.80	6.24	5.80	2.9398	3	5.65	6.06	0

Dissolved Oxygen (milligrams per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	DO<=1
34	34	0.01	9.95	9.94	1.73	1.03	2.3874	4	0.49	1.63	17

Oxidation-Reduction Potential (millivolts)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	ORP<-50
34	34	-107.3	327.5	434.8	97.3	77.3	0.4956	0	23.0	178.1	1

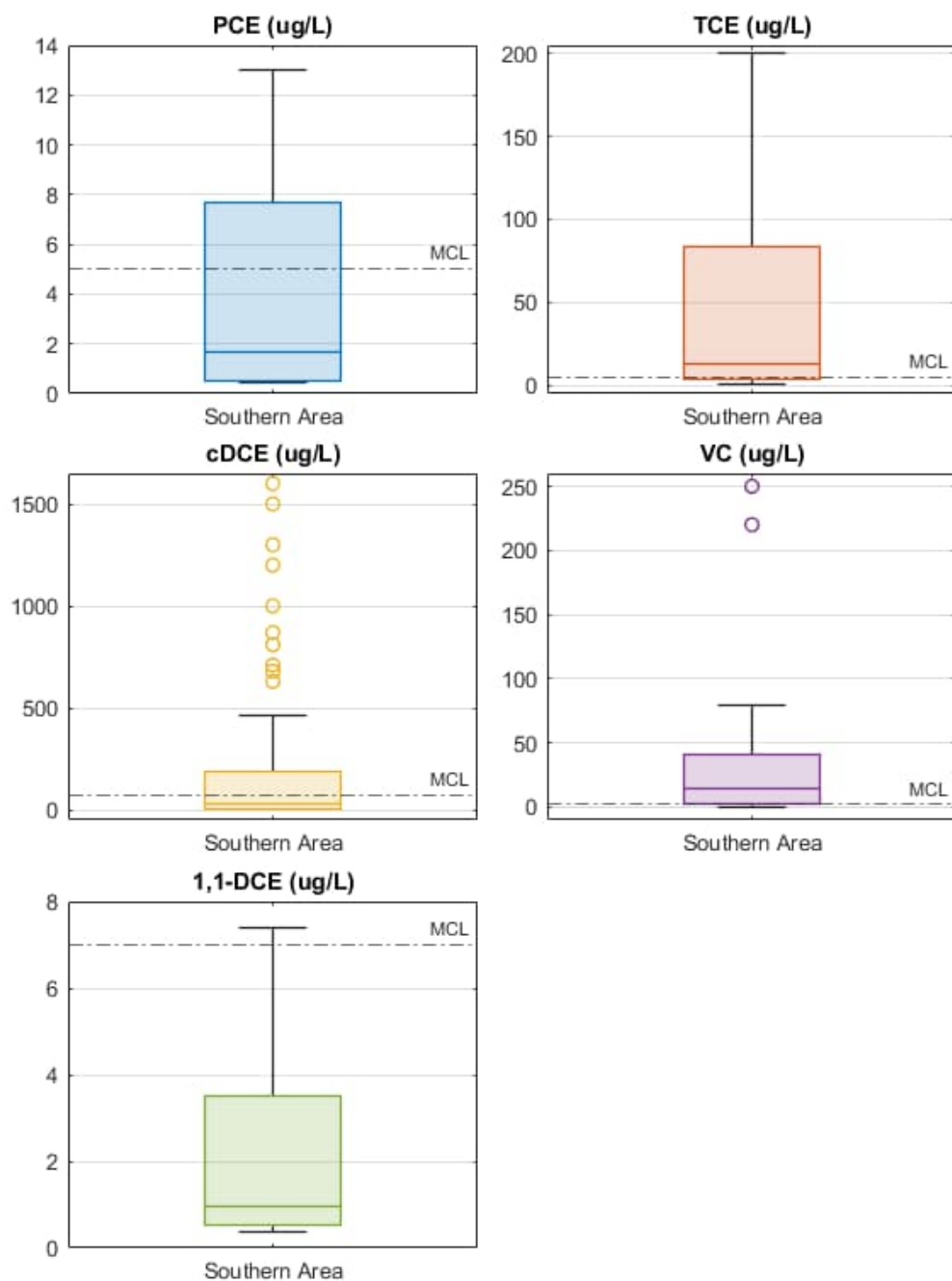
Specific Conductance (millisiemens per ohm)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75
34	34	0.056	1.324	1.268	0.234	0.168	3.2869	1	0.104	0.276

Notes: D = number of detected results, Min = minimum detected result, max = maximum detected result, 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.

2.4.3 VOC Results for Confined 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 confined aquifer within the southern OU 6 area targeted for ISB actions. The summaries use the OU 6 annual monitoring data from May 2024.

Exhibit 2-2 VOC Parameter Distribution: Southern Area Confined Aquifer (May 2024)**Tetrachloroethene (micrograms per liter)**

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	PCE>5
34	8	0.42	13	12.58	4.2	1.7	0.8632	0	0.54	7.7	3

Trichloroethene (micrograms per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	TCE>5
34	26	0.41	200	199.59	46.6	13.0	1.1556	0	3.4	84	17

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

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	cDCE>70
34	27	0.31	1300	1299.70	248.9	68	1.5966	14	5.13	267.5	13

Vinyl chloride (micrograms per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	VC>2
34	22	0.41	250	249.59	38.1	14.5	2.4301	2	2.1	41	17

1,1-Dichloroethene (micrograms per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	11DCE>7
34	14	0.37	7.4	7.03	2.2	0.98	1.1968	0	0.53	3.5	1

Notes: N = number of normal samples, D = number of detected results, Min = minimum detected result, max = maximum detected result, PCTL25 = 25th percentile, PCTL75 = 75th percentile

2.4.3.1 Tetrachloroethene (PCE)

Eight of 34 samples had detections of tetrachloroethene (PCE) with detected concentrations ranging from 0.42 µg/L to 13 µg/L. Three samples have concentrations > the maximum contaminant level (MCL) of 5 µg/L. The maximum detected concentration is at well MW-285 in the fence line area.

2.4.3.2 Trichloroethene (TCE)

Twenty-six of 34 samples had detections of TCE with detected concentrations ranging from 0.41 µg/L to 200 µg/L. Mean and median concentrations for TCE are 46.6 µg/L and 13 µg/L, respectively. Distribution 25th and 75th percentiles for TCE are 3.4 µg/L and 84 µg/L, respectively, with 17 samples having TCE concentrations > MCL of 5 µg/L. The distribution has positive skewness with the maximum detected concentration of TCE reported at well MW-157 in the offsite area.

2.4.3.3 cis-1,2-Dichloroethene (cDCE)

Twenty seven of 34 samples had detections of cis-1,2-dichloroethene (cDCE) with detected concentrations ranging from 0.31 µg/L to 1,300 µg/L. Mean and median concentrations for cDCE are 248.9 µg/L and 68 µg/L, respectively. Distribution 25th and 75th percentiles for cDCE are 5.13 µg/L and 267.5 µg/L, respectively, with 13 samples having cDCE concentrations > MCL of 70 µg/L. The distribution has positive skewness with 14 outliers with the maximum detected concentration of cDCE reported at well MW-291 in the offsite area.

2.4.3.4 Vinyl Chloride (VC)

Twenty two of 34 samples had detections of vinyl chloride (VC) with detected concentrations ranging from 0.41 µg/L to 250 µg/L. Mean and median concentrations for VC are 81.1 µg/L and 14.5 µg/L, respectively. Distribution 25th and 75th percentiles for VC are 2.1 µg/L and 41 µg/L, respectively. The distribution is positively skewed with two outliers and 17 samples having VC concentrations > MCL of 2 µg/L. The maximum detected concentration of VC occurred at well MW-291 in the offsite area.

2.4.3.5 1,1-Dichloroethene (1,1-DCE)

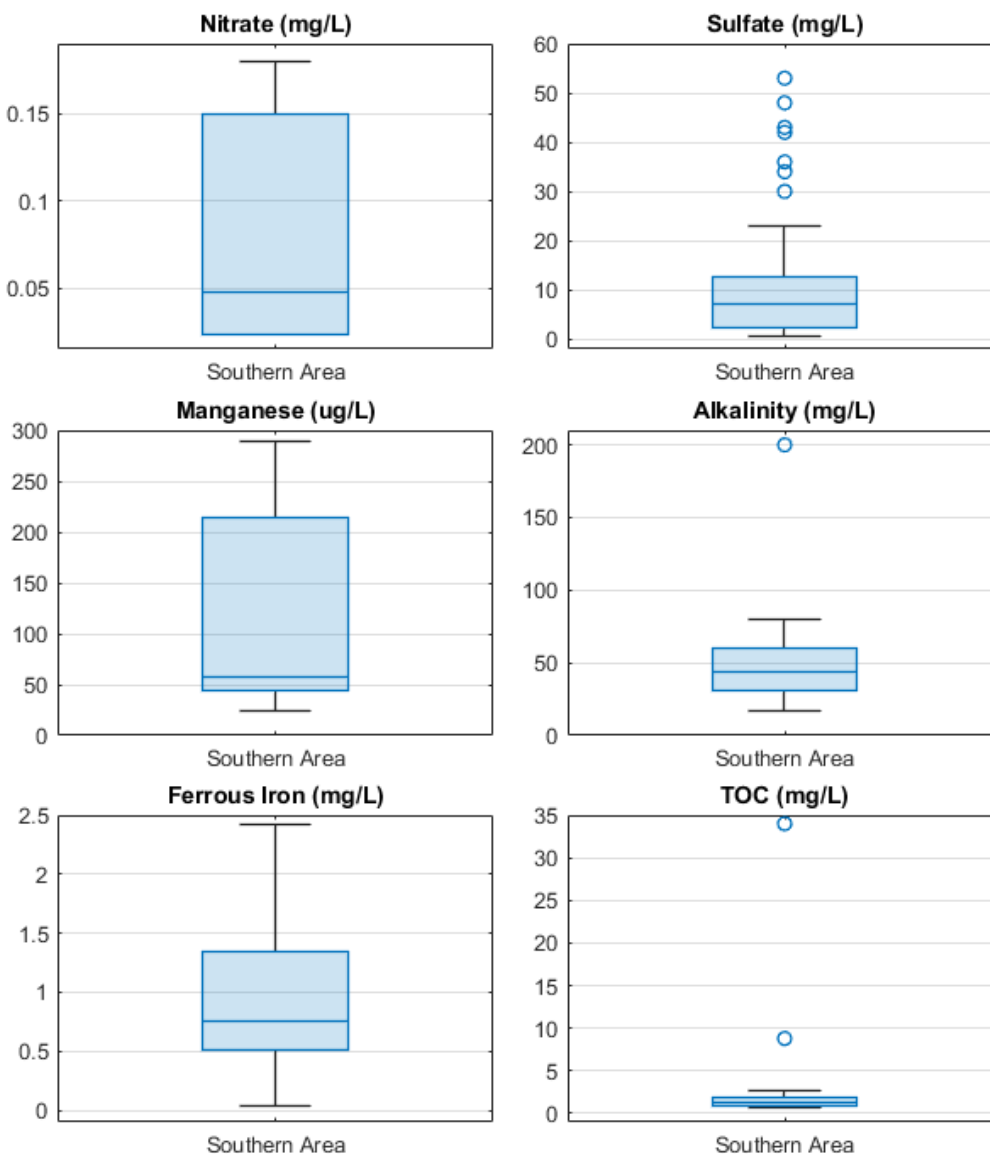
Fourteen of 34 samples had detections of 1,1-dichloroethene (1,1-DCE) with detected concentrations ranging from 0.37 µg/L to 7.4 µg/L. Mean and median concentrations for 1,1-DCE are 2.2 µg/L and 0.98 µg/L, respectively. Distribution 25th and 75th percentiles for 1,1-DCE are 0.53 µg/L and 3.5 µg/L, respectively, with no distribution outliers. One sample (MWNGA-8) had a concentration > MCL of 7 µg/L.

2.4.4 Geochemical Results for Confined Aquifer: Southern Area (2024)

Section 2.4.4 and Exhibit 2-3 (page 2-22) have a summary of data distributions for geochemical results for confined aquifer within the southern OU 6 area targeted for ISB actions. The summaries use the OU 6 annual monitoring data from May 2024.

2.4.4.1 Nitrate

Five of 20 samples had detections of nitrate with detected concentrations ranged from 0.023 mg/L to 0.18 mg/L. Mean and median concentrations for nitrate are 0.1 mg/L and 0.05 mg/L, respectively. Distribution 25th and 75th percentiles for nitrate are 0.02 mg/L and 0.15 mg/L, respectively, with no data outliers.

Exhibit 2-3 Geochemical Parameter Distribution: Southern Area Confined Aquifer (May 2024)**Nitrate (milligrams per liter)**

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	NO3<1
20	5	0.023	0.18	0.157	0.1	0.05	0.4668	0	0.02	0.15	5

Sulfate (milligrams per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	SO4=<50
20	20	0.48	43	42.52	13.1	9.8	1.4865	3	5.35	14.5	20

Manganese (micrograms per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75
20	20	25	290	2.65E+02	114	57	0.7325	0	44	215

Alkalinity (milligrams per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75
20	19	17	200	1.83E+02	53	44	2.7475	1	31	60

Ferrous Iron (milligrams per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	Fe2>1
21	21	0.04	2.42	2.38	1.0	0.76	0.6809	0	0.44	1.3	10

Total Organic Carbon (milligram per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	TOC>20
20	15	0.64	34	3.34E+01	4.0	1.3	3.1863	2	0.82	1.8	1

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, NaN = not a number.

2.4.4.2 Sulfate

Sulfate concentrations range from 0.48 mg/L to 43 mg/L. Mean and median concentrations for sulfate are 13.1 mg/L and 9.8 mg/L, respectively. Distribution 25th and 75th percentiles for sulfate are 6.425 mg/L and 14.75 mg/L, respectively, with three data outliers in the southern area.

2.4.4.3 Sulfide

Two of 20 samples had detections of sulfide (2.5 mg/L and 2.6 mg/L).

2.4.4.4 Sulfide as Hydrogen Sulfide

Two of 20 samples had detections of sulfide as hydrogen sulfide (2.6 mg/L and 2.7 mg/L).

2.4.4.5 Manganese

Manganese concentrations range from 25 mg/L to 290 mg/L. Mean and median concentrations for manganese are 114 mg/L and 57 mg/L, respectively. Distribution 25th and 75th percentiles for manganese are 44 mg/L and 215 mg/L, respectively, with no data outliers.

2.4.4.6 Alkalinity

Alkalinity levels ranged from 17 mg/L to 200 mg/L. Mean and median concentrations for alkalinity are 53 mg/L and 44 mg/L, respectively. Distribution 25th and 75th percentiles for alkalinity are 31 mg/L and 60 mg/L, respectively, with one data outlier.

2.4.4.7 Ferrous Iron

Ferrous iron concentrations ranged from 0.04 mg/L to 2.42 mg/L. Mean and median concentrations for ferrous iron are 1.0 mg/L and 0.76 mg/L, respectively. Distribution 25th and 75th percentiles for ferrous iron are 0.44 mg/L and 1.3 mg/L, respectively, with no data outliers. Ten of the samples have ferrous iron concentrations > 1 mg/L.

2.4.4.8 Total Organic Carbon (TOC)

Fifteen of 20 samples had detections of total organic carbon (TOC) at concentrations ranging from 0.64 mg/L to 34 mg/L. Mean and median concentrations for TOC are 4.0 mg/L and 1.3 mg/L, respectively. Distribution 25th and 75th percentiles for TOC are 0.82 mg/L and 1.8 mg/L, respectively, with two data outliers. The sample collected from well MW-217 (OU 2 area) has a TOC concentration > 20 mg/L.

2.4.5 Dissolved Gas Results for Confined Aquifer: Southern Area (2024)

Section 2.4.5 and Exhibit 2-4 (page 2-24) have a summary of data distributions for dissolved gas results for the confined aquifer within the southern OU 6 area targeted for ISB actions. The summaries use the OU 6 annual monitoring data from May 2024.

2.4.5.1 Carbon Dioxide

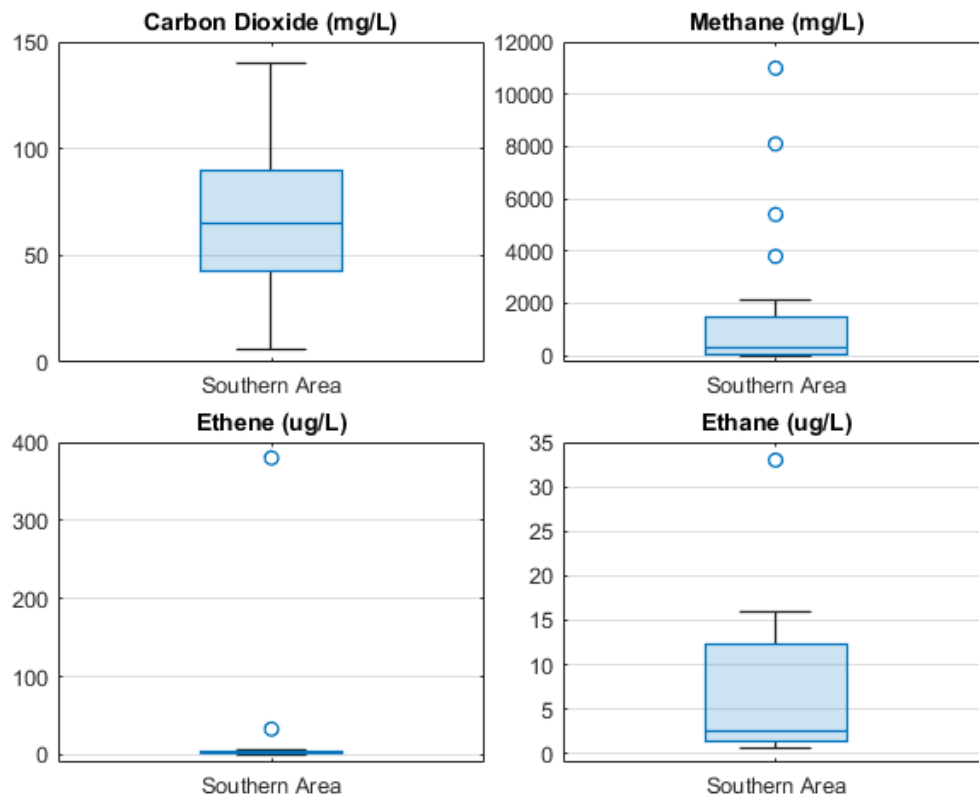
Carbon dioxide concentrations ranged from 6 mg/L to 100 mg/L. Mean and median concentrations for carbon dioxide are 66 mg/L and 65 mg/L, respectively. Distribution 25th and 75th percentiles for carbon dioxide are 31 mg/L and 60 mg/L, respectively, with no data outliers.

2.4.5.2 Methane

Methane concentrations ranged from 3.2 µg/L to 11,000 µg/L. Mean and median concentrations for methane are 1,705 µg/L and 300 µg/L, respectively. Distribution 25th and 75th percentiles for methane are

29 µg/L and 1,780 µg/L, respectively, with four data outliers. Nine of the samples had methane concentrations > 500 µg/L.

Exhibit 2-4 Dissolved Gas Distribution: Southern Area Confined Aquifer (May 2024)



Carbon Dioxide (milligram per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75
20	18	6	140	1.34E+02	66	65	0.3147	0	43	100

Methane (micrograms per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	CH4>500
20	20	3.2	11000	1.10E+04	1705	300	2.0076	4	29	1455	9

Ethene (micrograms per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	C2H4>10
20	13	0.34	380	379.66	34	1.8	3.1381	2	0.93	5.0	2

Ethane (micrograms per liter)

N	D	Min	Max	Range	Mean	Median	Skewness	Outliers	PCTL25	PCTL75	C2H6>10
20	13	0.65	33	32.35	7.78	2.6	1.6168	1	1.4	12.25	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, > greater than, NaN = not a number.

2.4.5.3 Ethene

Thirteen of 23 samples had detections of ethene ranging from 0.34 µg/L to 380 µg/L. Mean and median concentrations for ethene are 34 µg/L and 1.8 µg/L, respectively. Distribution 25th and 75th percentiles for ethene in the southern area are 0.93 µg/L and 5.0 µg/L, respectively, with two data outliers. One of the samples had ethene concentrations > 10 µg/L.

2.4.5.4 Ethane

Thirteen of 23 samples had detections of ethane ranging from 0.65 µg/L to 33 µg/L. Mean and median concentrations for ethane are 7.8 µg/L and 2.6 µg/L, respectively. Distribution 25th and 75th percentiles for ethane are 1.4 µg/L and 12 µg/L, respectively, with one data outlier. Four of the samples had ethane concentrations > 10 µg/L.

2.4.6 Primary VOC Plume Areas for Confined Aquifer: Southern Area (2024)

In the southern area of OU 6, a VOC plume consisting of PCE, TCE, cDCE, and VC extends from the central OU 3 area 380 ft. into the undeveloped offsite area east of the installation where DLA has an environmental easement. Figure 2-8 (page 2-26) shows the lateral extent of these VOCs with concentrations > MCLs. VC defines the lateral extent of the VOC plume in the southern area of OU 6. Figures 2-9 through Figure 2-12 (pages 2-27 through 2-30) show the distribution of PCE, TCE, cDCE, and VC within the confined aquifer.

2.4.6.1 PCE

For the confined aquifer, plume renderings in Figure 2-9 (page 2-27) show the extent of PCE at concentrations greater than or equal to ($\geq$) the MCL (5 µg/L). In the southern area, limited PCE plume areas are located along the fence line in OU 3 extending into the offsite area between the installation fence line and No Name Creek. The maximum PCE concentration detected in the southern area is 13 µg/L at well MW-285 at the fence line.

2.4.6.2 TCE

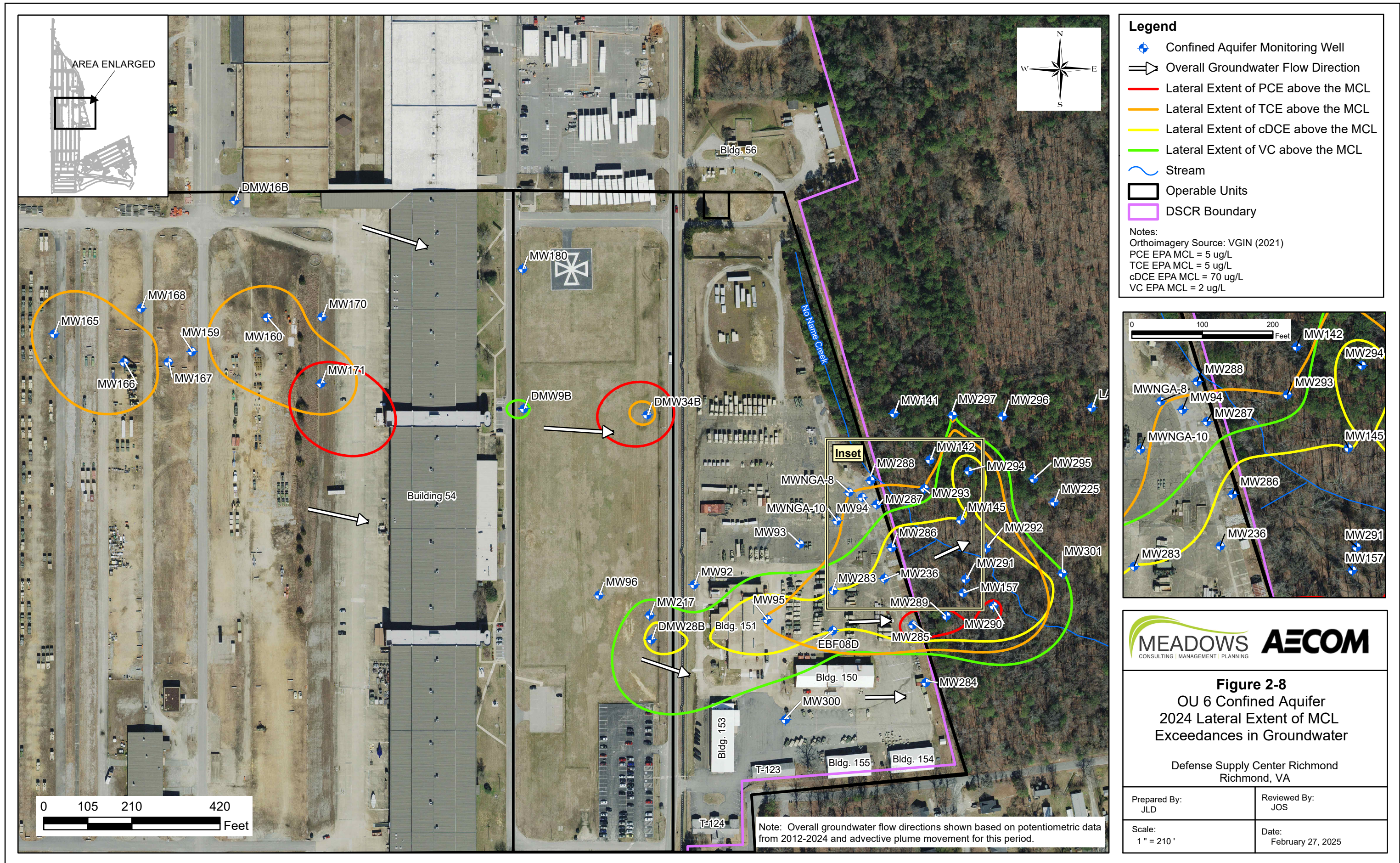
For the confined aquifer, plume renderings in Figure 2-10 (page 2-28) show the extent of TCE at concentrations $\geq$ the MCL (5 µg/L). Isoconcentration lines for TCE in Figure 2-10 are based a logarithmic scale from 5 µg/L to 50 µg/L. A TCE plume in the southern area extends from the Building 151 area across the OU 3 area into the offsite site approximately 320 ft. beyond the installation fence line. The maximum concentration of TCE in the southern area is 200 µg/L at well MW-157 in the offsite area between the installation fence line and No Name Creek. The approximate area of this TCE plume is 4.88 acres.

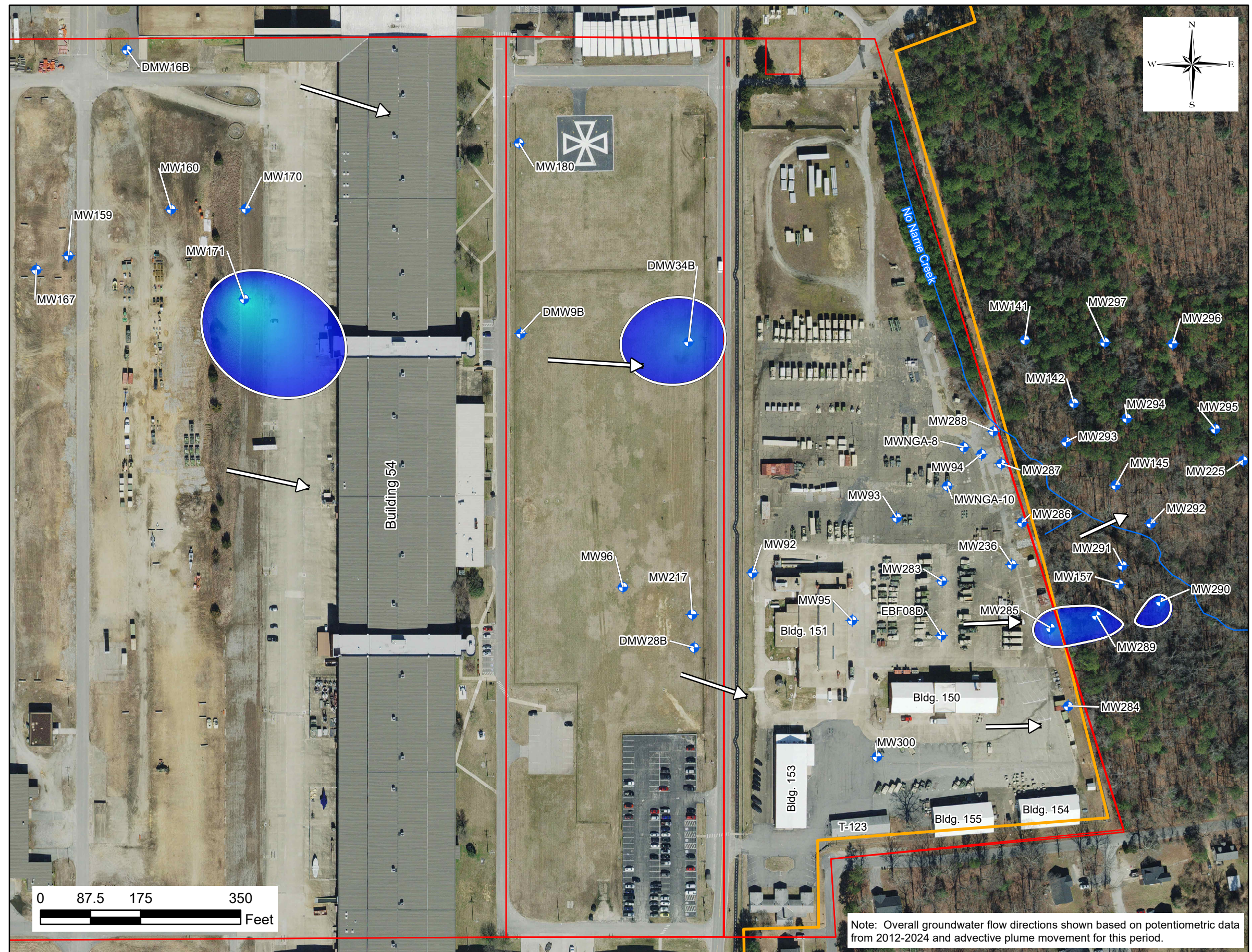
2.4.6.3 cDCE

For the confined aquifer, plume renderings in Figure 2-11 (page 2-29) show the extent of cDCE at concentrations $\geq$ MCL (70 µg/L). Isoconcentration lines for cDCE in Figure 2-11 are based a logarithmic scale from 70 µg/L to 700 µg/L. In the southern area is 1,300 µg/L at well MW-291 in the offsite area between the installation fence line and No Name Creek. The approximate area of this cDCE plume is 3.68 acres.

2.4.6.4 VC

For the confined aquifer, plume renderings in Figure 2-12 (page 2-30) show the extent of VC at concentrations equal to and greater than the MCL of 2 µg/L. Isoconcentration lines for VC in Figure 2-12 are based a logarithmic scale from 2 µg/L to 200 µg/L. A VC plume in the southern area extends from the OU 2 area across the OU 3 area into the offsite site approximately 370 ft. beyond the installation fence line. The maximum concentration of VC in the southern area is 250 µg/L at well MW-291 in the offsite area between the installation fence line and No Name Creek. The approximate area of this VC plume is 7.74 acres.





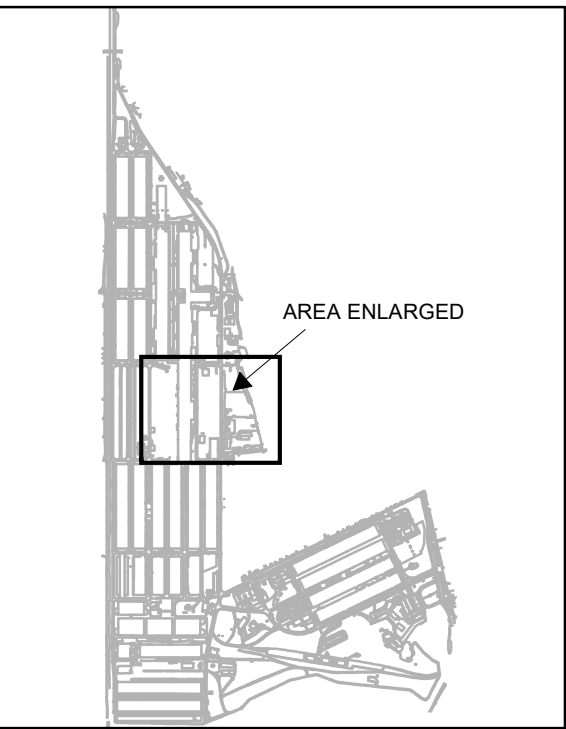
Legend

- Confined Aquifer Monitoring
- Overall Groundwater Flow Direction
- Isoconcentration Contours
- Stream
- Operable Units
- Installation Boundary

PCE Concentration (ug/L)

5 10 30 100 300 1,000 3,000

Notes:
Orthoimagery Source: VGIN (2021)



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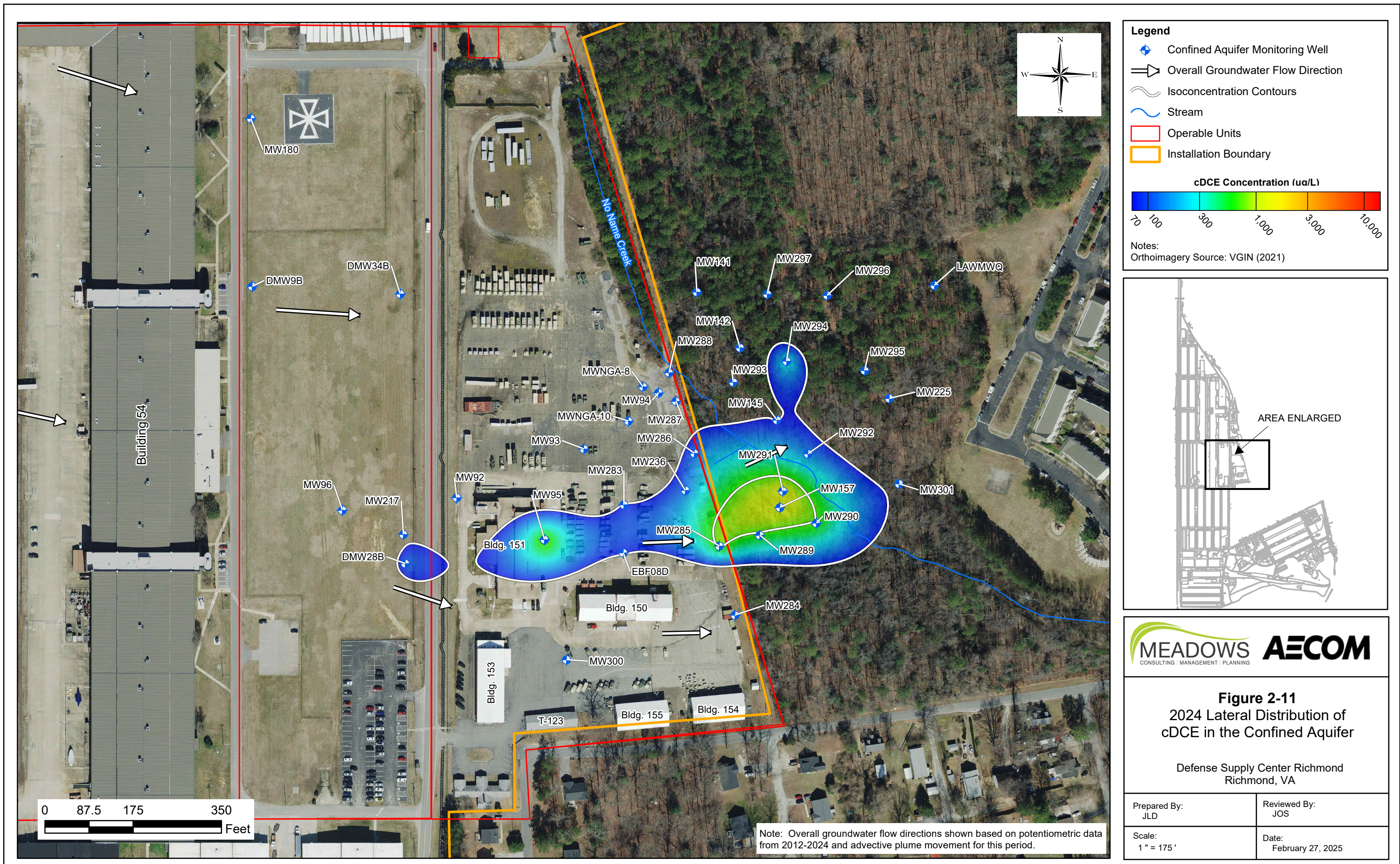
AECOM

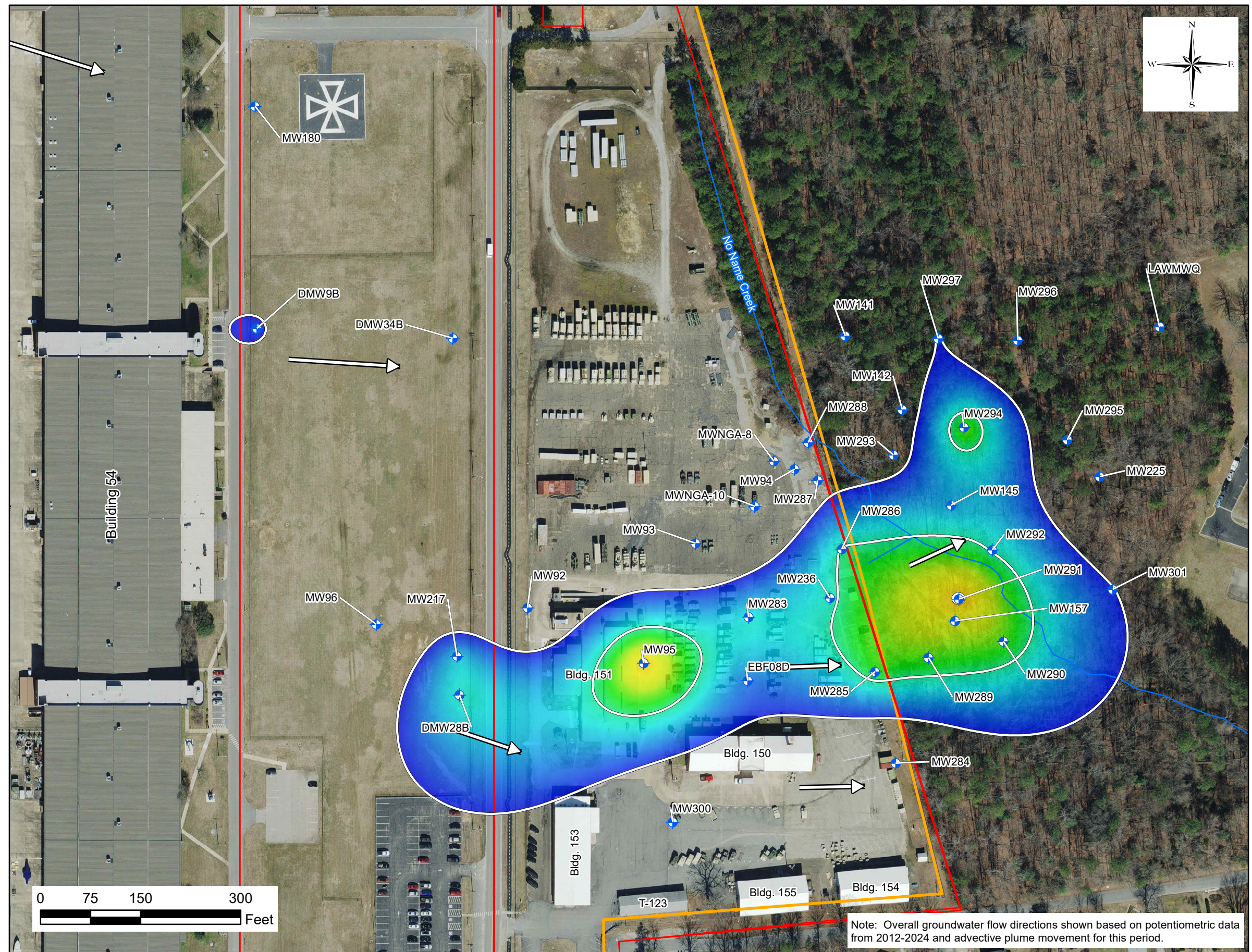
Figure 2-9
2024 Lateral Distribution of
PCE in the Confined Aquifer

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1" = 175'	Date: February 27, 2025

Note: Overall groundwater flow directions shown based on potentiometric data from 2012-2024 and advective plume movement for this period.





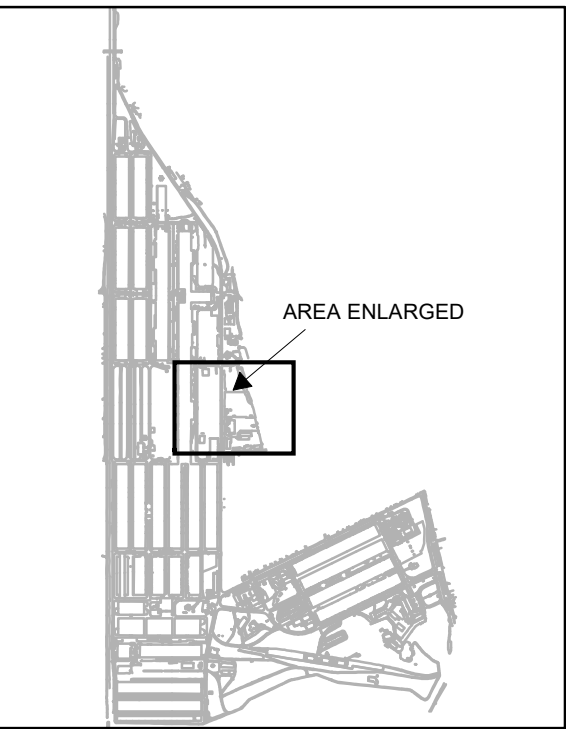
Legend

- Confined Aquifer Monitoring Well
- Overall Groundwater Flow Direction
- Isoconcentration Contours
- Stream
- Operable Units
- Installation Boundary

VC Concentration (ug/L)

0 75 150 300 1,000

Notes:
Orthoimagery Source: VGIN (2021)



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Figure 2-12
2024 Lateral Distribution of
VC in the Confined Aquifer

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1" = 150'	Date: February 27, 2025

2.4.7 Distribution of Ethene and Ethane in Confined Aquifer: Southern Area (2024)

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

2.4.7.1 Ethene

Figure 2-13 (page 2-32) shows the distribution of ethene in groundwater within the confined aquifer. Plume renderings show the extent of ethene at concentrations ≥ 1 $\mu\text{g/L}$. Isoconcentration lines for ethene in Figure 2-13 are based a logarithmic scale from 1 $\mu\text{g/L}$ to 100 $\mu\text{g/L}$. In the southern area, an ethene plume extends from OU 2 across OU 3 and approximately 180 ft. beyond the installation fence line. Well MW-95 near the eastern edge of Building 151 has the highest ethene concentration (380 $\mu\text{g/L}$) in the southern area.

2.4.7.2 Ethane

Figure 2-14 (page 2-33) shows the distribution of ethane in groundwater within the confined aquifer. Plume renderings show the extent of ethane ≥ 1 $\mu\text{g/L}$. Isoconcentration lines for ethane in Figure 2-14 are based a logarithmic scale from 1 $\mu\text{g/L}$ to 100 $\mu\text{g/L}$. In the southern area, an ethane plume extends from OU 2 across OU 3 and approximately 300 ft. beyond the installation fence line. Well MW-95 near the eastern edge of Building 151 has the highest ethane concentration (33 $\mu\text{g/L}$) in the southern area.

2.4.8 VOC Plume Distribution Trends for Confined Aquifer (Southern Area)

Section 2.4.8 uses time-series plots (box plots and line plots) in Exhibit 2-5 (page 2-34) to evaluate plume distribution for PCE, TCE, cDCE, VC, and 1,1-DCE in the confined aquifer (southern area). Box plots have y-axis reference lines for cleanup levels (MCLs).

Number of Detections

cDCE and TCE had the most detections for the confined aquifer in the southern area followed by VC and PCE. Parent and immediate daughter products through the sequential degradation pathway for PCE have moderate correlation (positive) for number of detections.

Concentrations

For 2018-2024, PCE had a Mann-Kendall¹ (M-K) increasing trend for maximum concentrations with an overall increase in the distribution mean. 1,1-DCE had increasing trends for maximum, mean, and median concentrations with no overall trends for TCE, cDCE, and VC concentrations.

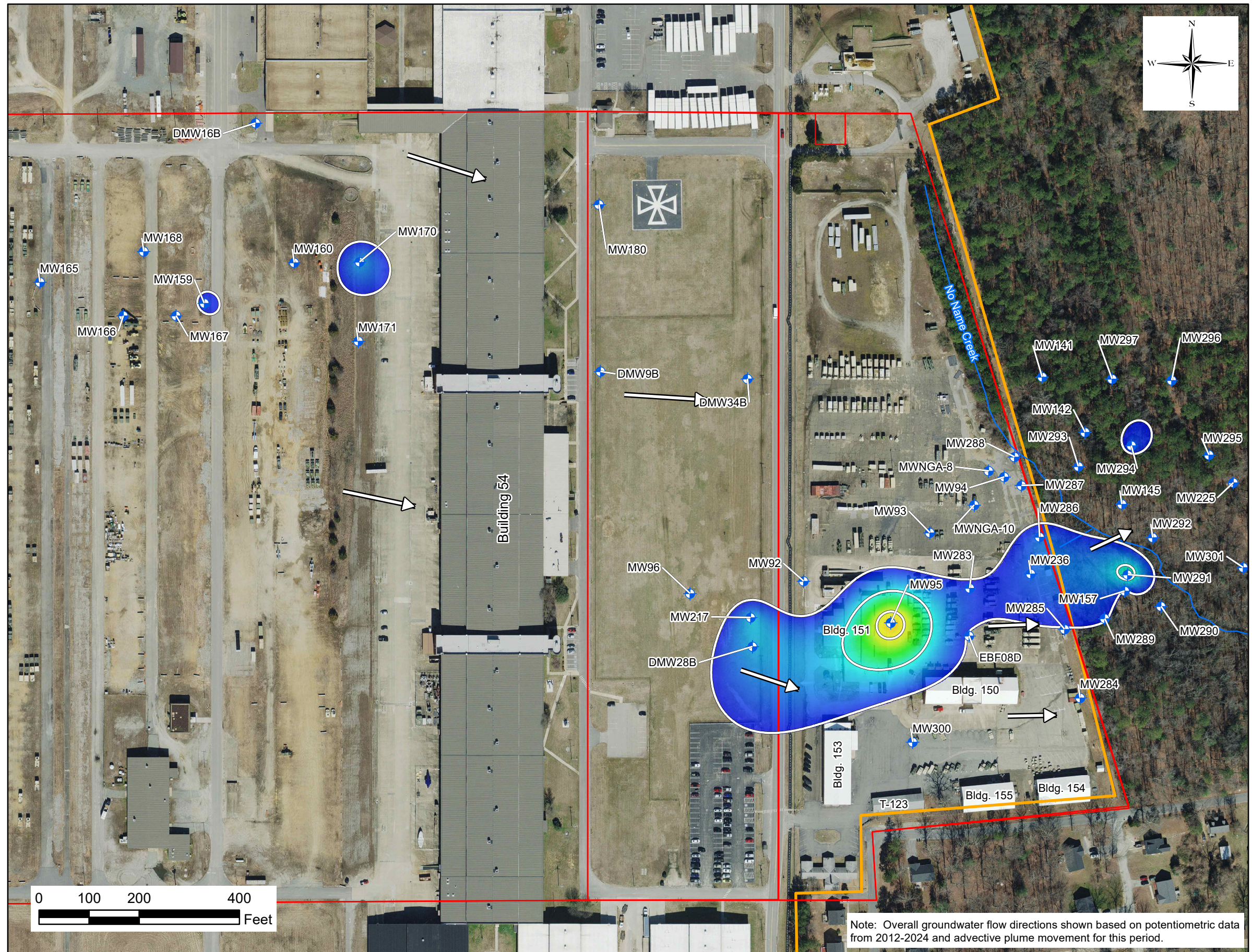
Distribution Outliers

For 2018-2024, the number of distribution outliers for PCE (1) and TCE (5) peaked in 2023 with an increasing trend for cDCE with no outliers reported for 2018 and five outliers reported for 2022 and 2024. VC had one distribution outlier reported for 2023 and two distribution outliers reported for 2024.

No. of Detections > MCLs

For 2018-2024, a peak for the number samples with concentrations > MCLs occurred in 2022 with the most exceedances for TCE (26) followed by VC (24), cDCE (23), and PCE (5). As of 2024, TCE and VC each 17 samples with concentrations > MCLs with 13 for cDCE and three (3) for PCE. Parent and daughter products have positive correlation (moderate) for the number of detections > MCLs.

¹ Mann-Trend test for monotonic trend with a one-way test that evaluate an alternative hypothesis of trend greater than zero or less than zero.



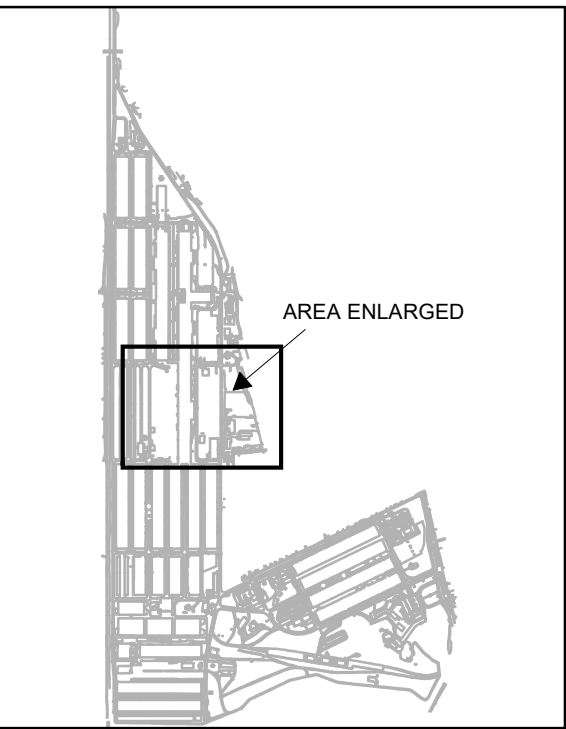
Legend

- Confined Aquifer Monitoring Well
- Overall Groundwater Flow Direction
- Isoconcentration Contours
- Stream
- Operable Units
- Installation Boundary

Ethene Concentration (ug/L)

7 3 70 30 100 300 1,000 3,000

Notes:
Orthoimagery Source: VGIN (2021)



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Figure 2-13
2024 Lateral Distribution of
Ethene in the Confined Aquifer

Defense Supply Center Richmond
Richmond, VA

Prepared By: JLD	Reviewed By: JOS
Scale: 1" = 200'	Date: February 27, 2025

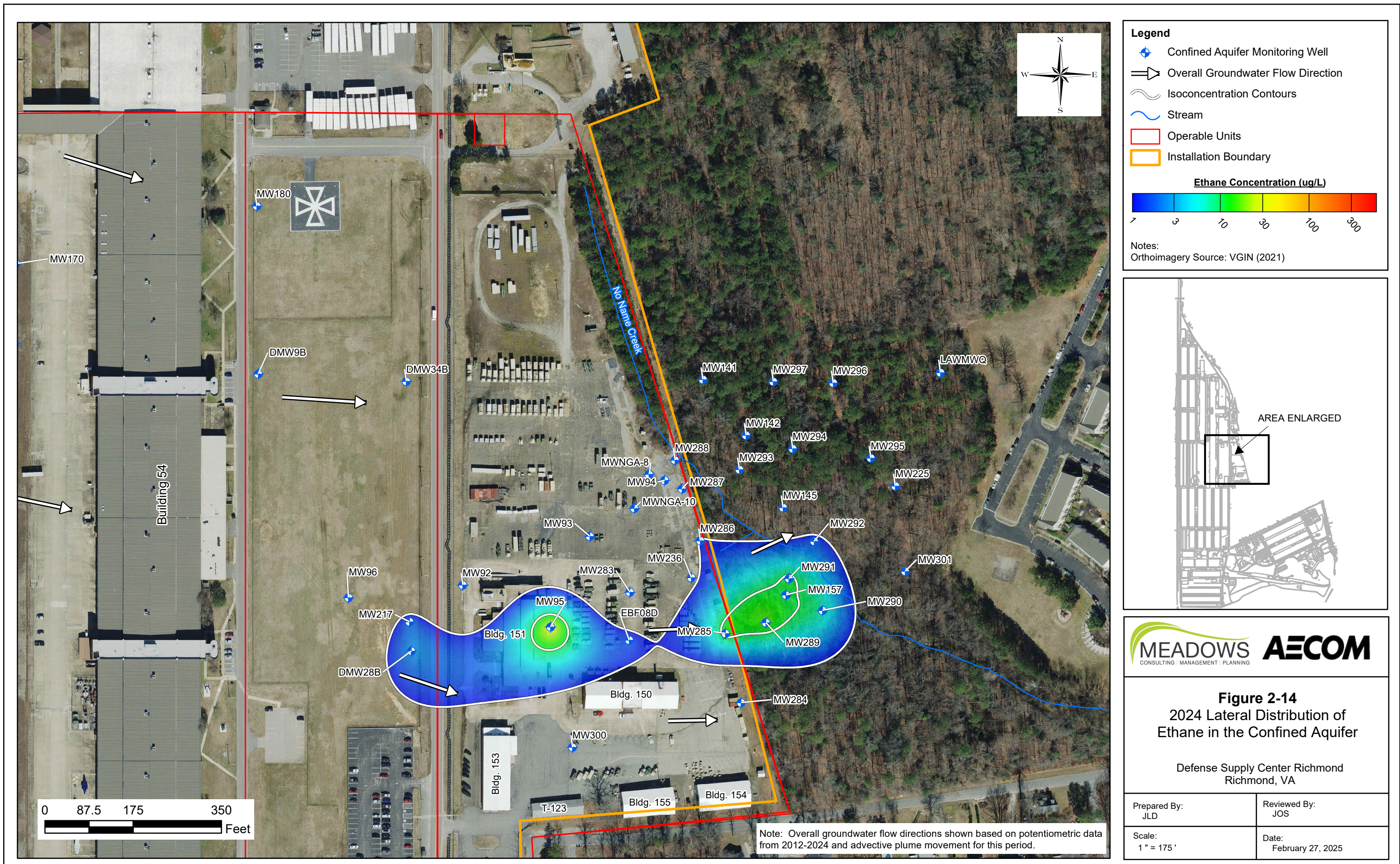
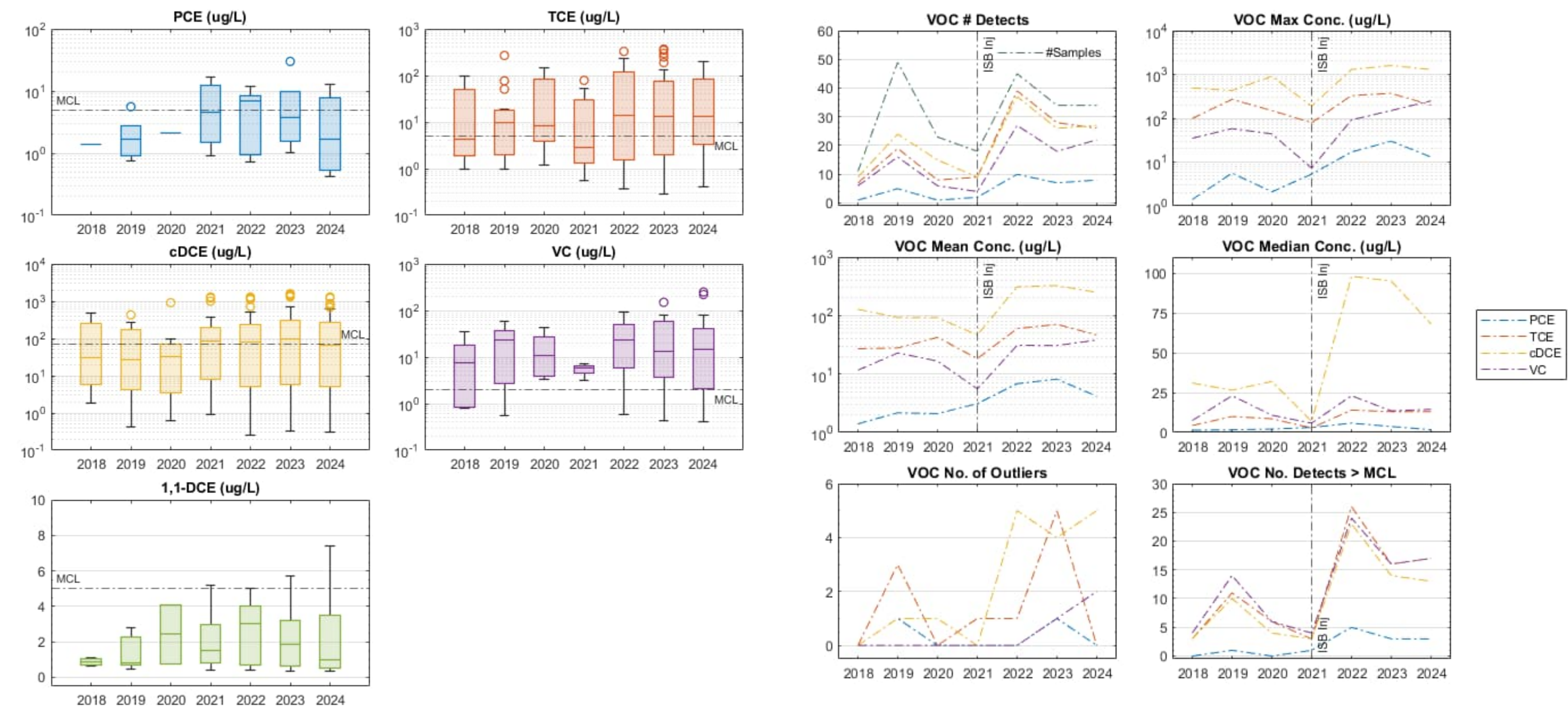


Exhibit 2-5 VOC Distribution Trends Confined Aquifer: Southern Area (2018-2024)



2.4.9 Bulk Plume Area Trends for Confined Aquifer (Southern Area)

For the southern area, bulk plume area trends for the confined aquifer at OU 6 are evaluated using data from the new monitoring network for 2021-2024. Descriptive statistics used to evaluate changes in bulk plume areas include percent change², linear correlation (correlation)³ for plume area vs. times and between parent and daughter plume areas over time, and M-K trend tests for plume area vs. time. Appendix E.4 of the 2024 Annual Report for OU 6 has statistical evaluations for bulk plume trends for OU 6 (AECOM-Meadows 2024b).

Figures 2-15 through 2-18 (pages 2-36 through 2-39) display the differences in PCE, TCE, cDCE, and VC plumes for 2021 and 2024. Table 2-4 has summary statistics for bulk plume areas for the confined aquifer in the southern monitoring area. Exhibit 2-6 (page 2-40) has stem plots that visualize the timeseries data for the plume areas. PCE, TCE, cDCE, and VC plume areas did not have statistically significant correlation or M-K trends for plume areas vs. time. PCE had a 38.5% decrease in plume area from 0.39 acres in 2021 to 0.24 acres in 2024 with moderate correlation (negative). Figure 2-15 (page 2-36) shows limited PCE plume areas in the fence line area (OU 3) extending into the offsite area.

TCE had a 19.6% increase in plume area from 4.08 acres in 2021 to 4.88 acres in 2024. PCE and TCE plume areas had no correlation for 2021-2024. Figure 2-16 (page 2-37) shows a contiguous TCE plume area extending from the Building 151 area into the offsite area with the 2024 plume extending farther into the offsite area.

cDCE had a 46% percent increase in plume area from 2.52 acres in 2021 to 3.68 acres in 2024. Figure 2-17 (page 2-38) shows a cDCE plume area extending from OU 2 across OU 3 into the offsite area with the 2024 plume extending farther into the offsite area. TCE and cDCE had statistically significant correlation (positive) for 2021-2024. VC had a 41% increase in plume area from 5.49 acres in 2021 to 7.74 acres in 2024. Figure 2-18 (page 2-39) shows a VC plume area extending from OU 2 across OU 3 into the offsite area with the 2024 plume extending farther into the offsite site area. cDCE and VC had statistically significant correlation (positive) for 2021-2024.

Table 2-4 Bulk Plume Area Metrics: Southern Area Confined Aquifer

Plume	Plume Area (Acres)				$\Delta\%$	Linear Correlation			M-K One Way Trend		
	2021	2022	2023	2024		r	p-value ($\alpha=0.05$)	Corr	H	p-value ($\alpha=0.05$)	SS Trend
PCE	0.39	0.32	0.45	0.24	-38.5	-4.56E-01	5.44E-01	Mod (-)	0	-3.67E-01	No
TCE	4.08	3.63	4.74	4.88	19.6	7.76E-01	2.24E-01	Mod (+)	0	1.54E-01	No
cDCE	2.52	1.91	2.61	3.68	46.0	7.34E-01	2.66E-01	Mod (+)	0	1.54E-01	No
VC	5.49	4.50	5.35	7.74	41.0	7.09E-01	2.91E-01	Mod (+)	0	3.67E-01	No
PCE vs TCE						-5.36E-02	9.46E-01	No			
TCE vs cDCE						8.54E-01	1.46E-01	High (+)			
cDCE vs VC						9.89E-01	1.07E-02	SS (+)			

Notes: PCE = tetrachloroethene, TCE = trichloroethene, cDCE = cis-1,2-dichloroethene, VC = vinyl chloride, $\Delta\%$ = percent change in bulk plume area from 2021 to 2024, % reduction in plume area from 2021 to 2024, r = Pearson's linear correlation coefficient, p-value = probability value, Corr. = correlation: negative (-), positive correlation (+), M-K = Mann-Kendall, SS Trend = statistically significant trend at a significance level of 0.05 (5 percent).

² Percent change of bulk plume area from 2021 to 2024.

³ Pearson's linear correlation coefficient at a significance level (alpha) of 0.05 or 5 percent.

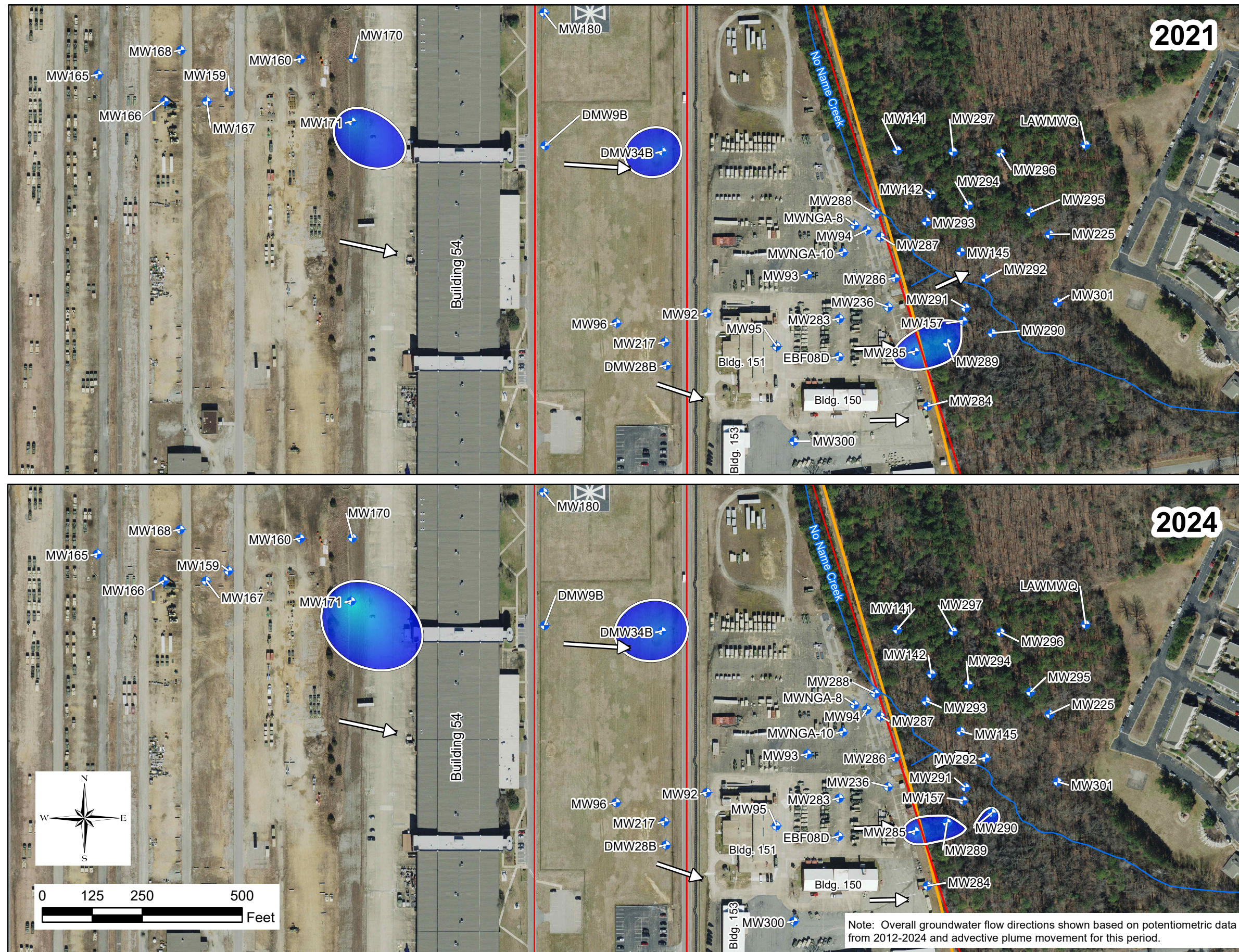


Figure 2-15
Changes in Lateral Distribution of
PCE in Confined Aquifer (2021-2024)

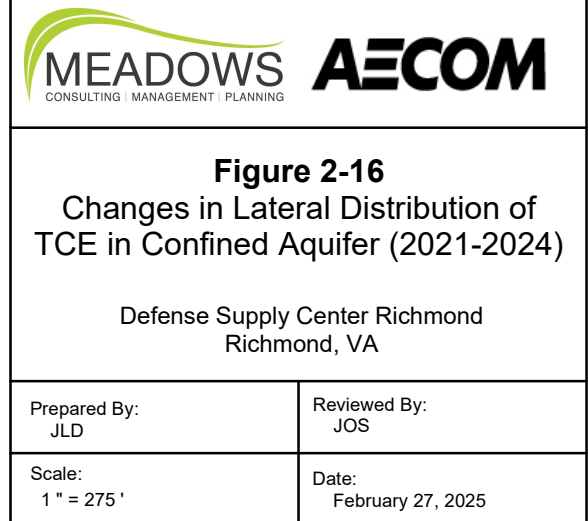
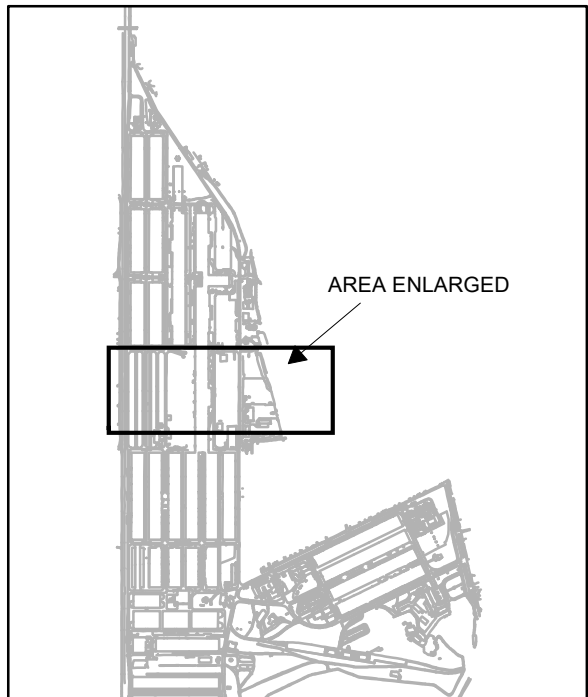
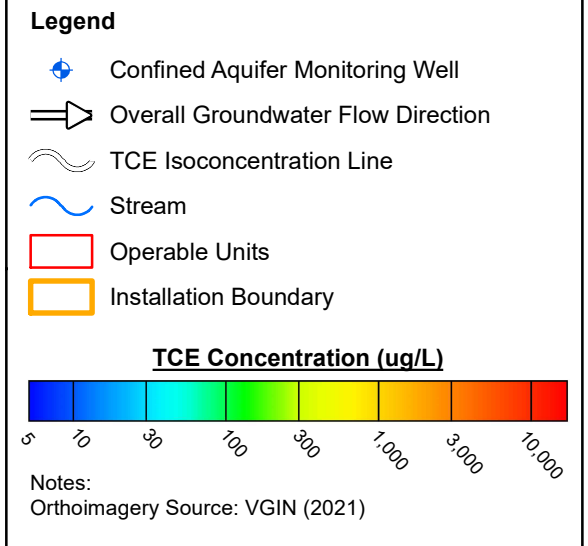
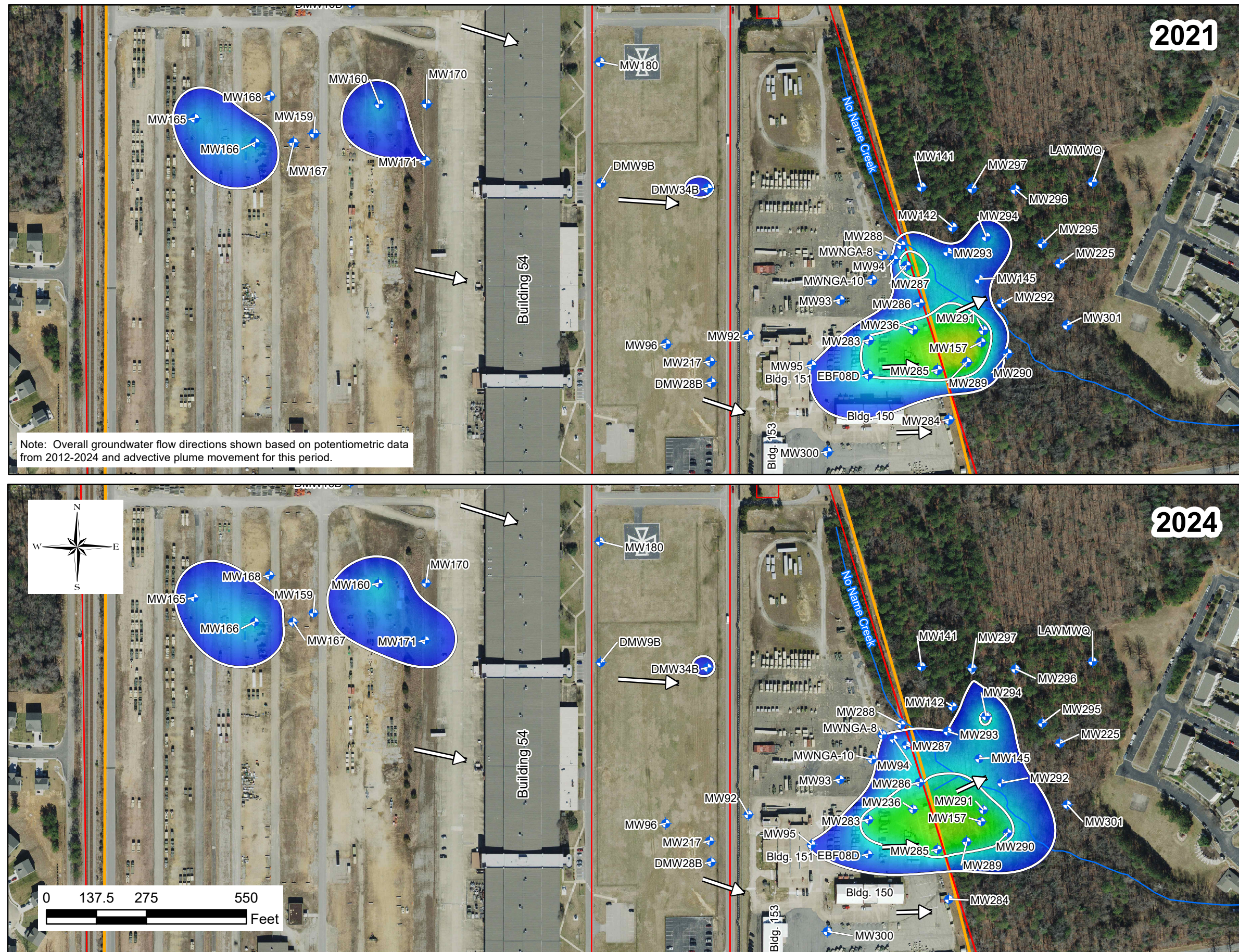
Defense Supply Center Richmond
Richmond, VA

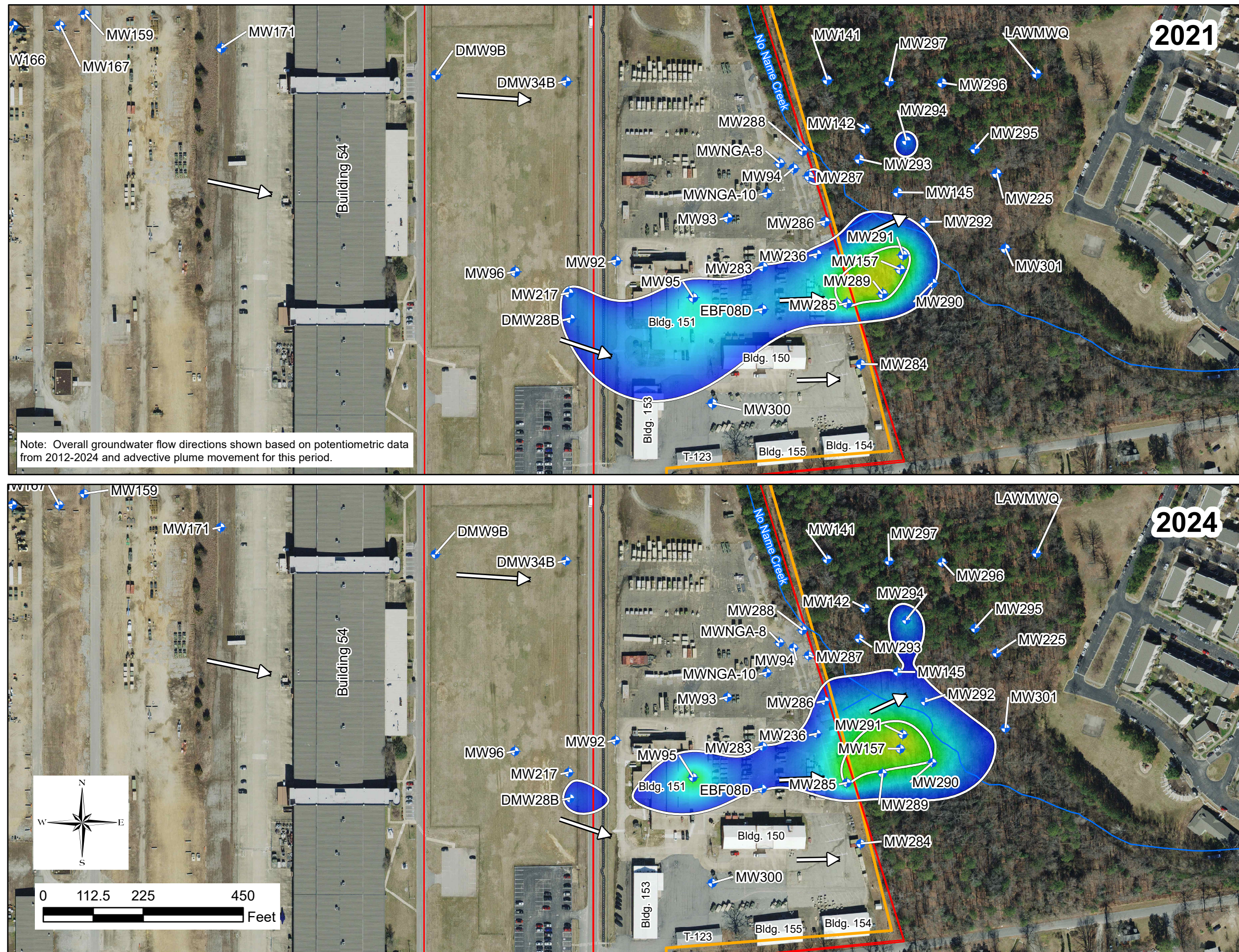
Prepared By:
JLD

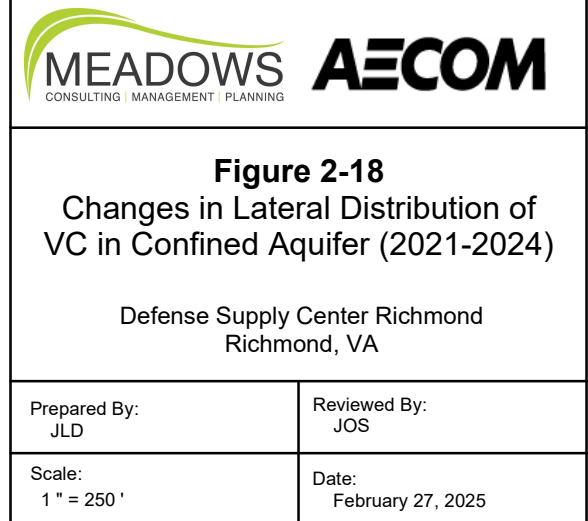
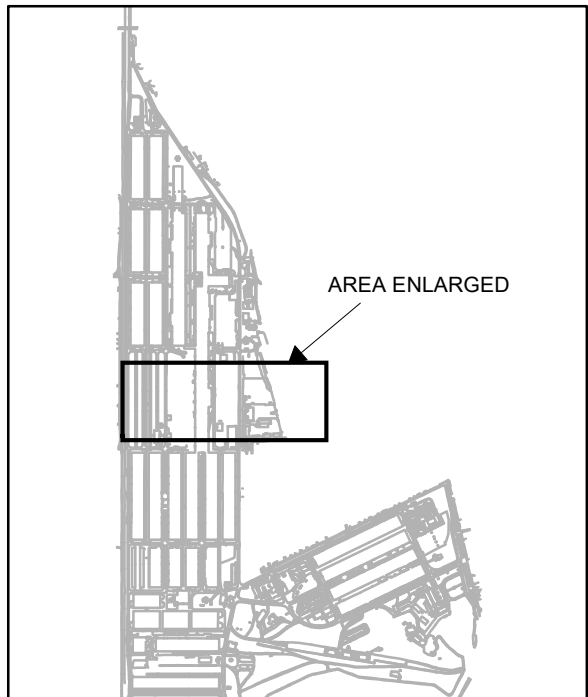
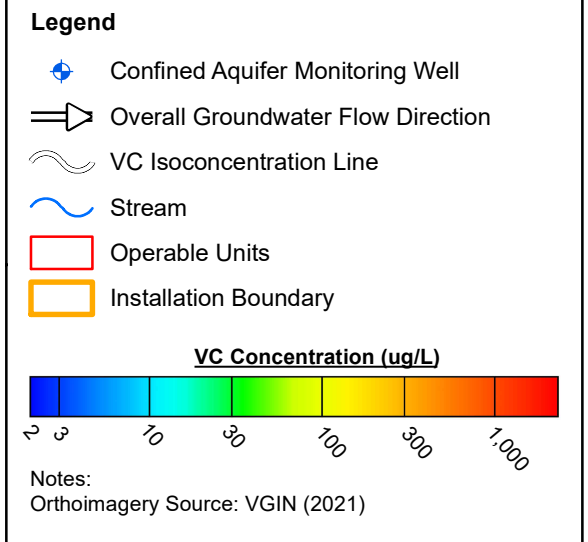
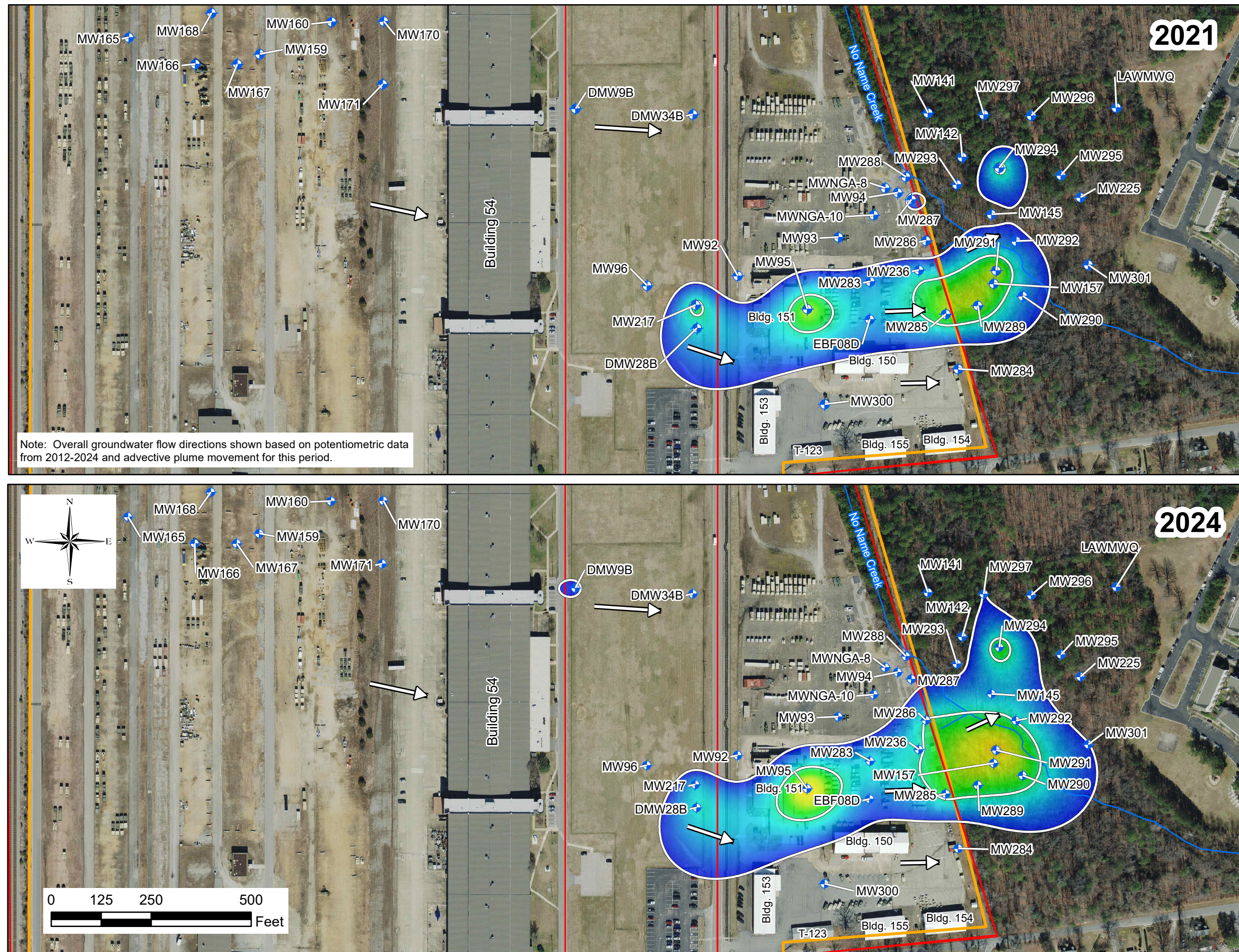
Reviewed By:
JOS

Scale:
1" = 250'

Date:
February 27, 2025



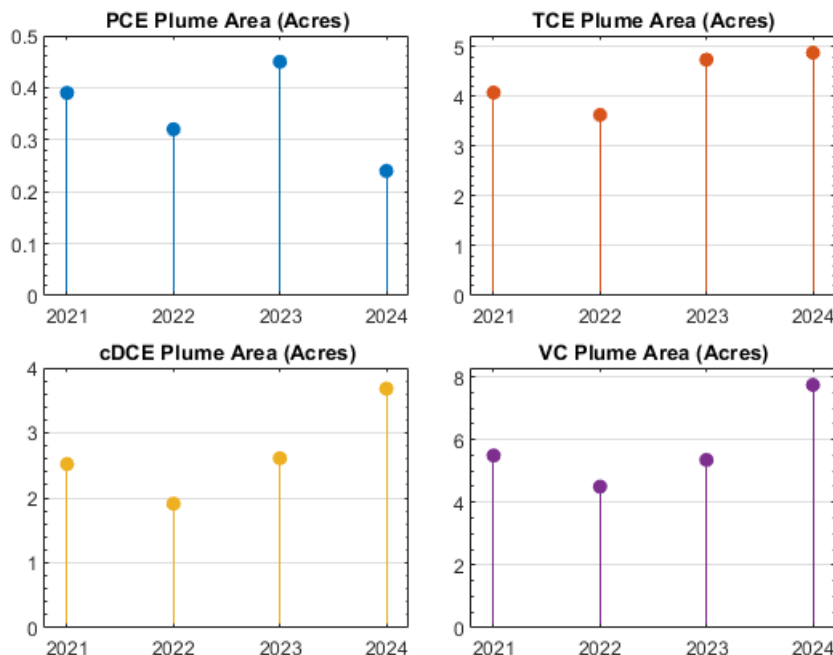




2.4.10 Plume Area Concentration vs. Distance Plots

For the confined aquifer, this assessment uses a monitoring well transect for the southern monitored area to evaluate plume changes and attenuation with distance. Exhibit 2-7 has a time series plot of the plume center of mass (molar) along the transect shown in Exhibit 2-8. Exhibit 2-8 (page 2-41) has concentration vs. distance plots (2024) for the confined aquifer in the southern area. The transect plots are along plume centerlines with the left plot using concentrations reported in micrograms per liter and the right plot exhibit using molar concentrations expressed as micromoles.

Exhibit 2-6 VOC Plume Area Changes in Confined Aquifer: Southern Area



The transect in Exhibit 2-8 extends from well DMW-28B in OU 2 across OU 3 to offsite well MW-295 over a distance of 1,054 ft. TCE, cDCE, and VC along the plume transect have the highest concentrations in the offsite area at well MW-289 (TCE and cDCE) and well MW-291 (VC). The peak concentration from PCE (17 µg/L) occurred at fence line well MW-285. PCE, TCE, and cDCE concentrations decrease to levels < MCL at well MW-292 located 215 ft. downgradient of the installation fence line. VC concentrations decreased to a level < MCL at well MW-295 located 350 ft. downgradient of the installation fence line.

As a molar percentage of chlorinated VOCs, cDCE predominates (78% to 87%) along the plume transect (confined aquifer in southern area) where constituents have concentrations > MCLs. TCE has the next highest molar percentage in the transect segment from the center of OU 3 extending into the offsite area 120 ft. to well MW-157. VC had the second highest molar percentage at well DMW-28B in OU 2 and in the offsite area downgradient of MW-157 at wells MW-291 and MW-292.

Exhibit 2-7 shows the plume center of mass (molar) in the range of 688 ft (2024) and 705 ft. (2023) near well MW-289 in the offsite area approximately 70 ft downgradient of the installation fence line.

2.4.11 Well Trends for Confined Aquifer

This section evaluates COC concentration trends at monitoring well locations for the confined aquifer at OU 6 (southern area). The trend assessment for the confined aquifer in the southern area evaluates two (2) wells monitored in OU 2, seven (7) wells monitored in the OU3 area, and eight (8) wells monitored in the offsite OU 6 area. These wells are located in the plume area in the confined aquifer where COCs for the monitoring period 2021-2024 had concentrations > cleanup levels (MCLs) for one or more samples. For 2021-2024, PCE, TCE, cDCE, and VC had detected concentrations > MCLs. Each monitoring well has a minimum of four (4) data observations. Appendix E.8 of the 2024 OU 6 Annual Report has statistical and trend analysis documentation for the confined aquifer in the southern area (AECOM Meadows 2024).

Exhibit 2-7 Plume Center of Mass

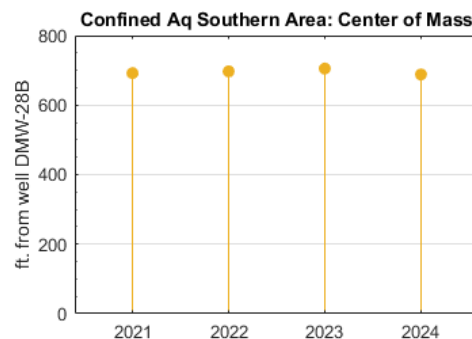
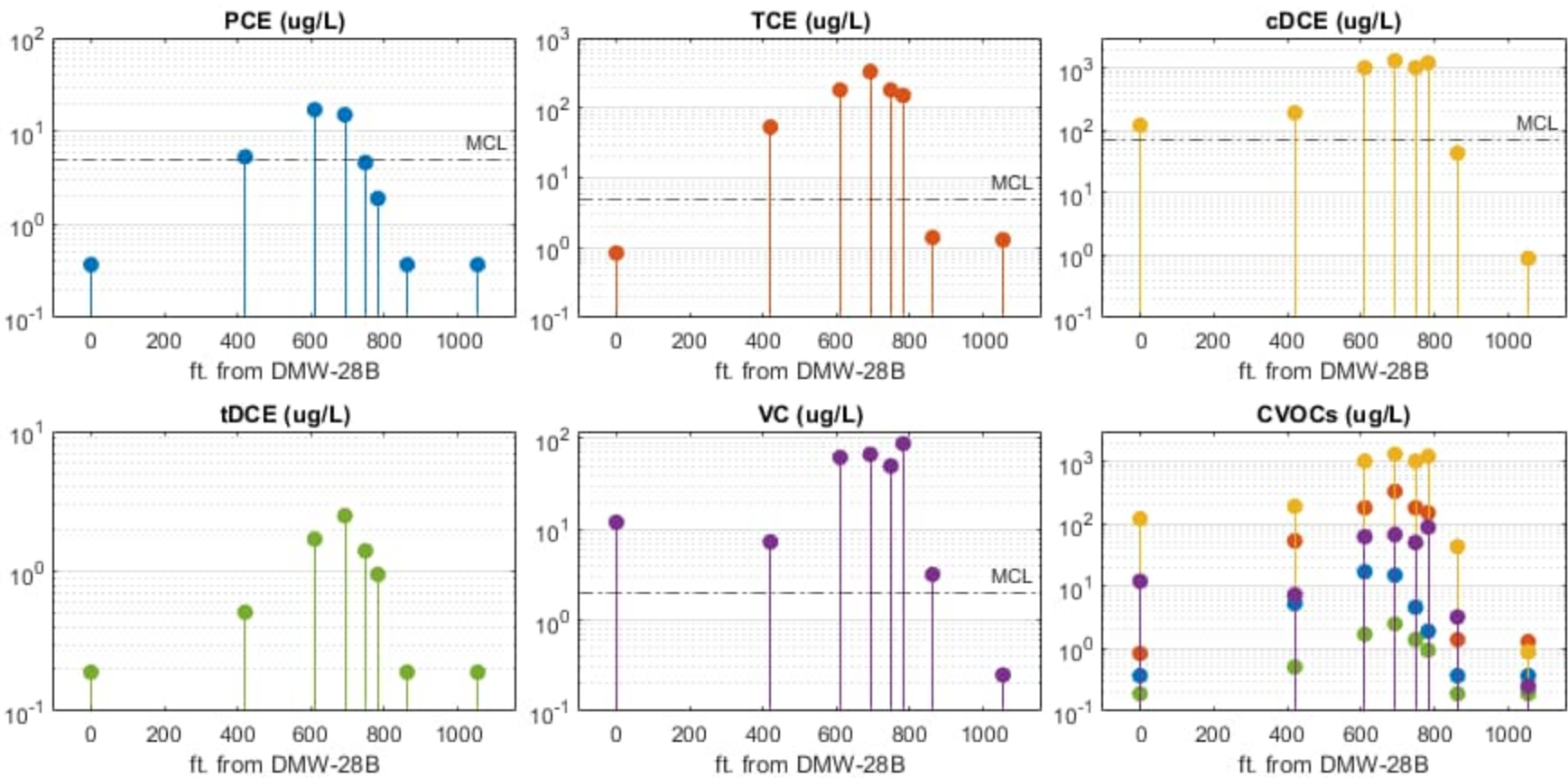
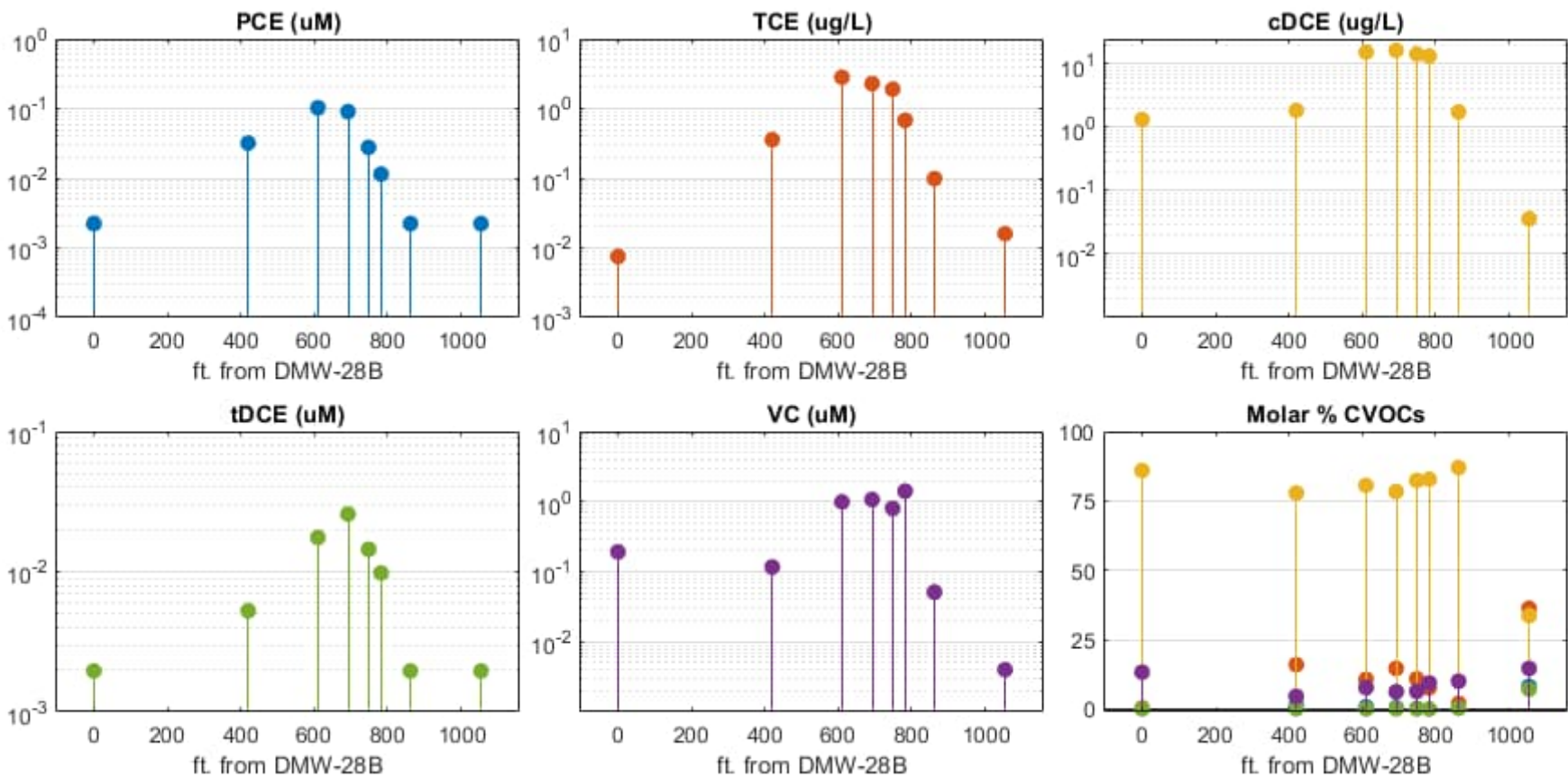


Exhibit 2-8 Plume Distance vs. Concentration: Southern Area Confined Aquifer (May 2024)

DMW-28B→EBF-08D→MW-285→MW-289→MW-157→MW-291→MW-292→MW-295



DMW-28B→EBF-08D→MW-285→MW-289→MW-157→MW-291→MW-292→MW-295



2.4.11.1 OU 2 Area

Wells evaluated for the OU 2 area include DMW-28B and MW-217 with a former higher concentration source zone in the confined aquifer (Figure 2-8). Table 2-5 has a summary of the statistical and trend analysis performed for wells DMW-28B and MW-217. Exhibit 2-9 (page 2-43) has time series plots with x-axis reference lines for injections performed in 2015 and y-axis reference lines for cleanup levels (MCLs).

The coefficients of variation for DMW-28B and MW-217 indicate high and moderate variation, respectively. COCs have negative linear correlation for concentrations vs. time, except for cDCE at MW-217 with no correlation. M-K trend tests indicated decreasing trends for TCE, cDCE, and VC at DMW-28B with no trends for MW-217. Singular spectrum analysis (SSA)⁴ indicated decreasing trends for TCE, cDCE, and VC at DMW-28B and VC at MW-217. SSA detected a trend change for cDCE at MW-217 from increasing to decreasing in 2022.

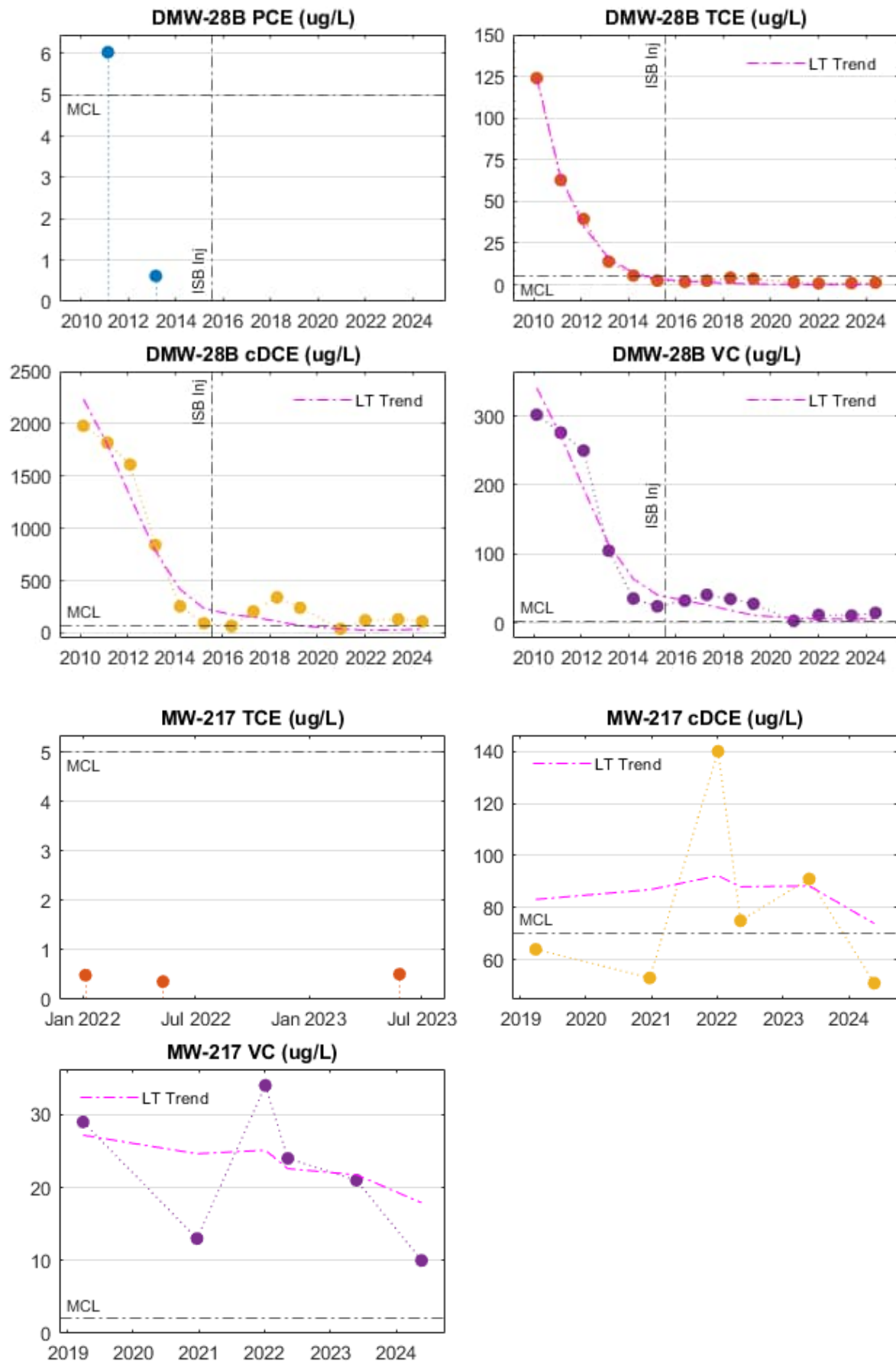
Table 2-5 OU 2 Confined Aquifer Wells for Southern Area: Summary of Statistical and Trend Analysis

Location	Analyte	Monitoring Period	No. of Samples	Concentration (µg/L)		Variance		Pearson's Linear Correlation			Mann-Kendall Trend One Way			Singular Spectrum Analysis (SSA)	
				Start	2024	CV	Variance	R	p-value (α=0.05)	Corr	H	p-value (α=0.05)	Trend	Trend	Change Point
DMW-34B	TCE	2012-2024	14	124	1.3	1.8611	High	-0.6865	6.70E-03	(-)	1	-6.35E-05	SS↓	↓	--
	cDCE			1980	110	1.2590	High	0.4162	1.10E-03	(-)	1	-2.20E-03	SS↓	↓	--
	VC			302	15	1.2848	High	-0.0538	6.93E-04	(-)	1	-1.51E-04	SS↓	↓	--
MW-217	cDCE	2019-2024	6	64	51	0.4223	Moderate	0.0573	9.14E-01	None	0	-5.00E-01	None	2022	↓
	VC			29	10	0.4212	Moderate	-0.4706	3.45E-01	(-)	0	-1.30E-01	None	↓	↑

Notes: PCE = tetrachloroethene, TCE = trichloroethene, cDCE = cis-1,2-dichloroethene, VC = vinyl chloride, CV = coefficient variation, r = correlation coefficient, p -value = probability value, Corr. = correlation: negative (-) and positive (+), SS = statistically significant at an alpha significance level of 0.05 (5 percent), ¹decreasing trend at alpha significance level of 0.10 (10 percent), **Constituent concentration is less than the MCL**, *decreasing trend*, ↓decreasing trend, ↑ increasing trend, → SSA no trend

⁴ SSA is a spectrum estimation method (non-parametric) to analyze time series data for trend and forecasting. SSA assumes the additive decomposition of the data into long-term trend, oscillatory or seasonal trend or trends, and remainder or random. The SSA function used for OU 6 evaluations solves for long-term trend without decomposition of seasonal or remainder components given the variable or annual frequency of sampling.

Exhibit 2-9 Data Plots for OU 2 Area: Confined Aquifer Southern Area



2.4.11.2 OU 3 Area

Wells evaluated for the OU 3 area include: MW-95 (Building 151 area), EBF-08D, MW-283, fence line wells MW-285, MW-286, MW-287, and MW-288, and well MW-236 located 50 ft. upgradient of the fence line (Figure 2-6). Exhibit 2-10 (page 2-46) has time series plots with x-axis reference lines for injections performed in 2015 (as applicable) and y-axis reference lines for cleanup levels (MCLs). Table 2-6 (page 2-47) has a summary of the statistical and trend analysis performed for the wells in the central area of OU 3.

The central OU 3 area includes wells MW-95, EBF-8D, and MW-283 downgradient of Building 151 (Figure 2-6). Closest to Building 151 at MW-95, M-K tests indicate increasing trends for cDCE and VC with an overall decrease in TCE concentrations for the period 2019-2024. M-K tests at EBF-08D indicate a decreasing trend for TCE with no other COC trends detected for this well. At well MW-283, M-K tests did not indicate trends for PCE, TCE, cDCE, and VC.

Northern Fence Line Area

The northern fence line area at OU 3 includes wells MW-287, MW-288, and MW-94 (Figure 2-6). Each of these wells had overall decreasing concentrations for COCs for the monitoring periods evaluated. M-K tests at MW-287 indicated decreasing trends for PCE and VC with no trends identified for TCE and cDCE.

At MW-288, M-K tests indicated a decreasing trend for TCE and no trend for cDCE detected at levels less than the MCL. M-K and SSA tests for MW-94 indicated decreasing trends for PCE, TCE, cDCE, and VC.

Central Fence Line Area

The central fence line area of OU 3 includes wells MW-285 and MW-286 with well MW-236 located 50 ft upgradient of the fence line. M-K tests did not identify COC trends for these wells. SSA tests for MW-236 did not show a consistent trend over the 2019-2024 monitoring period.

Southern Fence Line Area

Well MW-284 is located in the southern fence line area. Monitoring results for 2021-2024 did not report detections of VOCs.

2.4.11.3 Offsite Area

Wells evaluated for the offsite area at OU 6 include: MW-145, MW-157, MW-289, MW-290, MW-291, MW-292, MW-294, MW-297, and LAWMW-Q (Figure 2-6). Table 2-7 (page 2-48) has a summary of the statistical and trend analysis performed for the wells. Exhibit 2-11 (page 2-49) has time series plots with x-axis reference lines for injections performed in 2015 (as applicable) and y-axis reference lines for cleanup levels (MCLs).

MW-289

Well MW-289 installed in 2021 is located 65 ft. into the offsite area between the fence line and No Name Creek (Figure 2-6). This well is in the southern portion of the offsite area monitoring the confined aquifer. Overall, concentrations for PCE, TCE, cDCE, and VC decreased from 2021 to 2024. M-K tests did not indicate trends for these COCs.

MW-157

Well MW-157 installed in 2010 is located 120 ft. into the offsite area between the installation fence line and No Name Creek (Figure 2-6). This well did not have COC detections for 2010-2014. Trend evaluations use monitoring data from 2015-2024. Coefficient of variation tests indicate moderate variance for TCE, cDCE, and VC. M-K and SSA tests indicate increasing trends for TCE, cDCE, and VC at well MW-157.

MW-290

Well MW-290 installed in 2021 is located 180 ft. into the offsite area between the fence line and No Name Creek (Figure 2-6). This well is in the southern portion of the offsite area monitoring the confined aquifer. Overall, concentrations for PCE, TCE, cDCE, and VC have increased from 2021 to 2024. M-K tests indicate increasing trends for TCE, cDCE, and VC.

MW-291

Well MW-291 installed in 2021 is located 130 ft. into the offsite area between the fence line and No Name Creek (Figure 2-6). This well is 36 ft. north of well MW-157. Overall, concentrations for PCE and TCE decreased from 2021 and 2024 with cDCE and VC having overall concentration increases from 2021 to 2024. M-K tests did not indicate trends for TCE, cDCE, and VC with insufficient data to evaluate PCE trends.

Exhibit 2-10 Data Plots for OU 3 Area: Confined Aquifer Southern Area

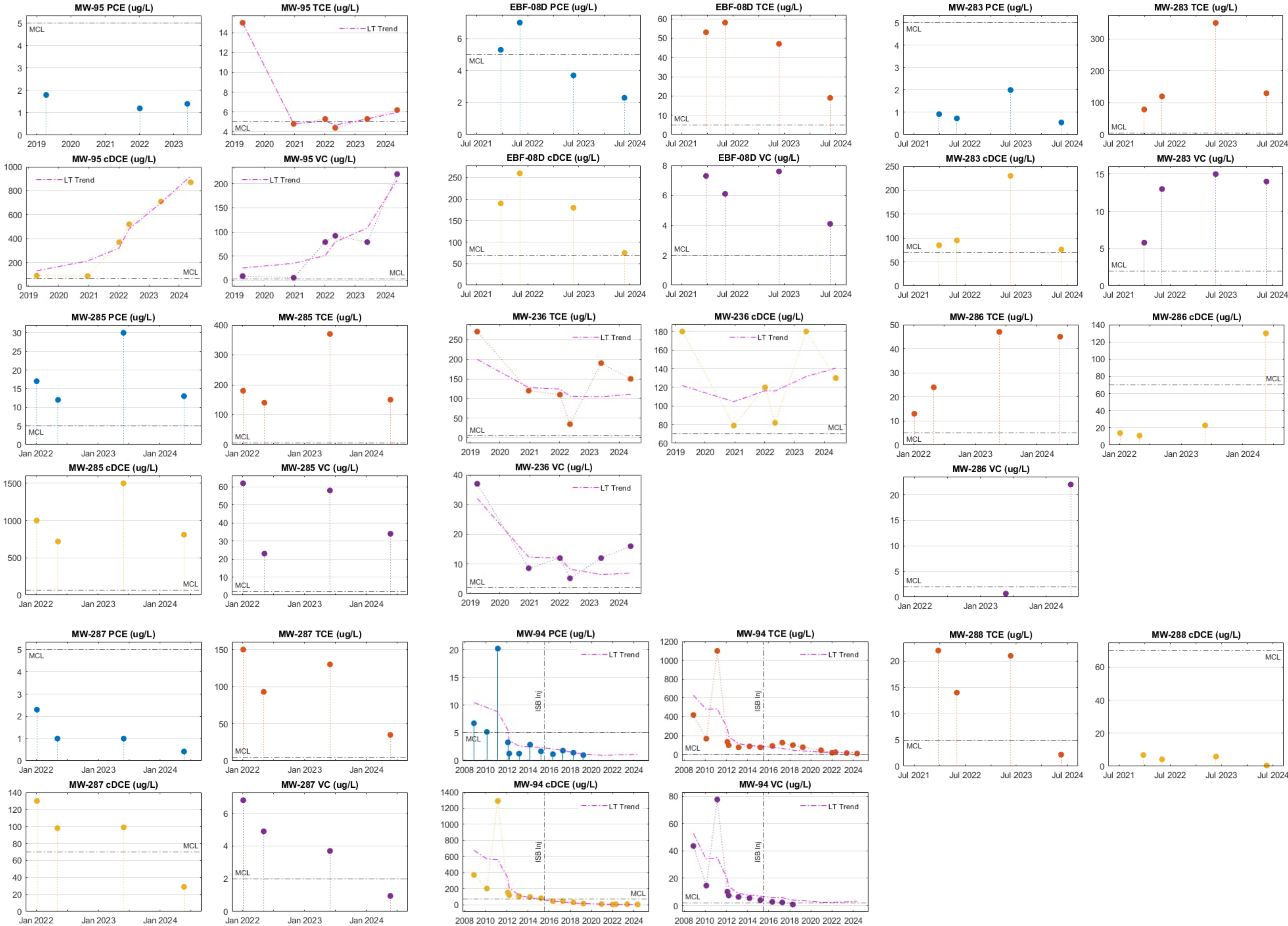


Table 2-6 OU 3 Confined Aquifer Wells for Southern Area: Summary of Statistical and Trend Analysis

Location	Analyte	Monitoring Period	No of Samples	Concentration (µg/L)		Variance		Pearson's Linear Correlation			Mann-Kendall Trend One Way			Singular Spectrum Analysis (SSA)	
				Start	2024	CV	Variance	R	p-value (α=0.05)	Corr	H	p-value (α=0.05)	Trend	Trend	Change Point
MW-95	TCE	2019-2024	6	15	16.2	0.5921	Moderate	0.0092	9.83E-01	(-)	0	0	None	2024	→
	cDCE			91	870	0.7275	Moderate	0.9491	3.80E-02	(+)	1	1.21E-02	SS↑	↑	
	VC			8.4	220	0.9693	Moderate	0.8659	2.58E-02	(-)	1	4.26E-02	SS↑	↑	
EBF-08D	PCE	2021-2024	4	5.3	2.3	--	--	-0.8798	1.20E-01	(-)	0	1.01E-01	None	--	--
	TCE			53	19	--	--	-0.9122	8.78E-02	(-)	0	-6.73E-02	↓ ¹	--	--
	cDCE			190	75	--	--	-0.8340	1.67E-01	(-)	0	-1.54E-01	None	--	--
	VC			7.3	4.1	--	--	-0.6618	3.38E-01	(-)	0	-3.67E-01	None	--	--
MW-283	PCE	2021-2024	4	0.92	0.55	--	--	0.0099	9.90E-01	None	0	-3.67E-01	None	--	--
	TCE			79	130	--	--	0.3510	6.48E-01	(+)	0	1.54E-01	None	--	--
	cDCE			85	76	--	--	0.1424	8.58E-01	(+)	0	0	None	--	--
	VC			5.8	14	--	--	0.7021	2.98E-01	(+)	0	1.54E-01	None	--	--
MW-285	PCE	2021-2024	4	17	12	--	--	0.1068	8.93E-01	(+)	1	9.40E-013	SS↑	--	--
	TCE			180	150	--	--	0.1645	8.36E-01	(+)	1	1.77E-02	SS↑	--	--
	cDCE			1000	810	--	--	0.1079	8.92E-01	(+)	0	0	None	--	--
	VC			62	34	--	--	-0.2043	7.96E_01	(-)	0	3.67E-01	None	--	--
MW-236	TCE	2019-2024	6	270	150	0.5453	Moderate	-0.3940	4.40E-01	(-)	0	-3.54E-01	None	↓	
	cDCE			180	130	0.3479	Low	-0.0750	8.82E-01	None	0	4.24E-01	None	→	
	VC			37	16	0.7475	Moderate	-0.5798	2.28E-01	(-)	0	0	None	↓	
MW-286	TCE	2021-2024	4	13	45	--	--	0.8979	1.02E-01	(+)	0	1.54E-01	None	--	--
	cDCE			14	130	--	--	0.8768	1.23E-01	(+)	0	1.54E-01	None	--	--
	VC			ND	22	--	--	--	--	--	--	--	--	--	--
MW-287	PCE	2021-2024	4	2.3	0.42	--	--	-0.8220	1.78E-01	(-)	0	-7.43E-02	↓ ¹	--	--
	TCE			150	35	--	--	-0.7508	2.49E-01	(-)	0	-1.54E-01	None	--	--
	cDCE			130	29	--	--	-0.9082	9.18E_02	(-)	0	-1.54E-01	None	--	--
	VC			6.8	0.95	--	--	-0.9735	2.65E-02	(-)	1	4.47E-02	SS↓	--	--
MW-94	PCE	2008-2024	17	6.7	ND	1.3636	High	-0.5081	9.17E-02	(-)	1	-3.70E-03	SS↓	↓	
	TCE			419	10	1.6685	High	-0.5228	3.13E-02	(-)	1	-3.22E-05	SS↓	↓	
	cDCE			372	4.7	2.0094	High	-0.5236	3.10E-02	(-)	1	-2.02E-07	SS↓	↓	
	VC			43.6	ND	1.4883	High	-0.6100	4.63E-01	(-)	1	-4.96E-05	SS↓	↓	
MW-288	TCE	2021-2024	4	22	2.2	--	--	-0.7333	2.67E-01	(-)	1	-2.30E-02	SS↓	--	--
	cDCE			6.8	0.43	--	--	-0.7856	2.14E-01	(-)	0	-1.54E-01	None	--	--

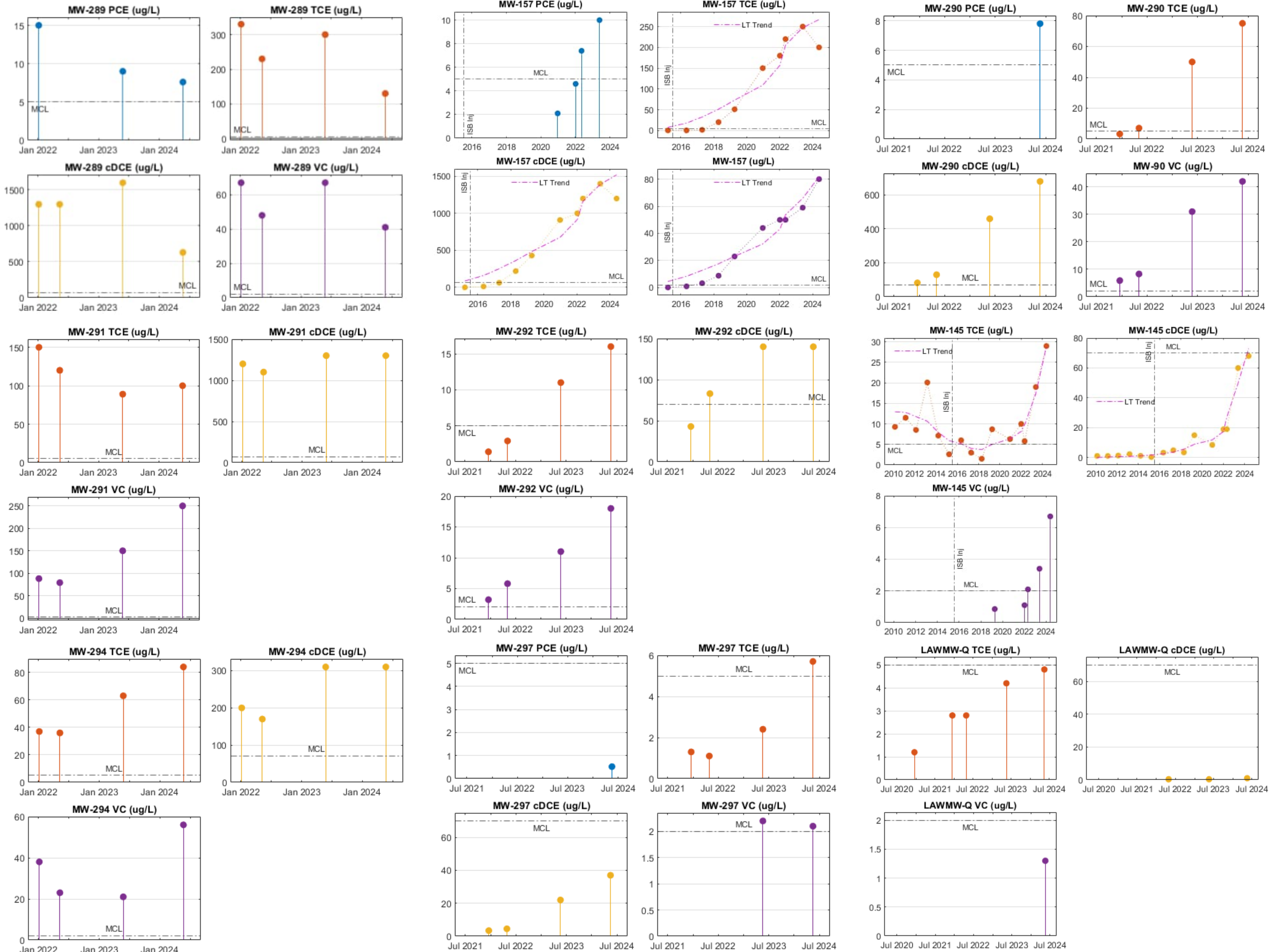
Notes: PCE = tetrachloroethene, TCE = trichloroethene, cDCE = cis-1,2-dichloroethene, VC = vinyl chloride, CV = coefficient variation, r = correlation coefficient, p-value = probability value, Corr. = correlation: negative (-) and positive (+), SS = statistically significant at an alpha significance level of 0.05 (5 percent), ¹decreasing trend at alpha significance level of 0.10 (10 percent), **Constituent concentration is less than the MCL**, **decreasing trend** , ↓decreasing trend, ↑ increasing trend, → SSA no trend

Table 2-7 OU 6 Confined Aquifer Wells for Offsite Area: Summary of Statistical and Trend Analysis

Location	Analyte	Monitoring Period	No of Samples	Concentration (µg/L)		Variance		Pearson's Linear Correlation			Mann-Kendall Trend One Way			Singular Spectrum Analysis (SSA)		Sequential Mann-Kendall Trend Changes	
				Start	2024	CV	Variance	R	p-value (α=0.05)	Corr	H	p-value (α=0.05)	Trend	Trend	Change Point	Trend Change	Change Point
MW-289	PCE	2021-2024	4	15	7.6	--	--	--	--	--	--	--	--	--	--	--	--
	TCE			330	130	--	--	-0.7415	2.58E-01	(-)	0	1.54E-01	None	--	--		
	cDCE			1300	630	--	--	-0.6021	3.98E-01	(-)	0	-5.00E-01	None	--	--		
	VC			67	41	--	--	-0.5139	4.84E-01	(-)	0	-2.35E-01	None	--	--		
MW-157	PCE	2015-2024	10	ND	ND	--	--	--	--	--	--	--	--	--	--		
	TCE			0.19	200	0.9506	Moderate	0.9474	3.15E-05	(+)	1	1.73E-04	SS↑	↑	--		
	cDCE			0.15	1200	0.8615	Moderate	0.9686	4.11E-06	(+)	1	1.16E-04	SS↑	↑	--		
	VC			0.1	80	0.8894	Moderate	0.9780	1.00E-06	(+)	1	5.63E-05	SS↑	↑	--		
MW-290	PCE	2021-2024	4	ND	7.8	--	--	--	--	--	--	--	--	--	--		
	TCE			3.3	75	--	--	0.9917	8.30E-03	(+)	1	4.47E-02	SS↑	--	--		
	cDCE			82	680	--	--	0.9955	4.50E-03	(+)	1	4.47E-02	SS↑	--	--		
	VC			5.9	42	--	--	0.9885	1.15E-02	(+)	1	4.47E-02	SS↑	--	--		
MW-291	TCE	2021-2024	4	150	100	--	--	-0.7979	2.02E-01	(-)	0	-1.54E-01	None	--	--		
	cDCE			1200	1300	--	--	0.7739	2.26E-01	(+)	0	2.35E-01	None	--	--		
	VC			88	250	--	--	0.9721	2,79E-02	(+)	0	1.54E-01	None	--	--		
MW-292	TCE	2021-2024	4	1.4	16	--	--	0.9954	4.6E-03	(+)	1	4.47E-02	SS↑	--	--		
	cDCE			43	140	--	--	0.9105	8.95E-01	(+)	0	7.43E-02	↑ ¹	--	--		
	VC			3.2	18	--	--	0.9969	3.1E-03	(+)	0	4.47E-02	SS↑	--	--		
MW-145	TCE	2019-2024	6	9.27	29	0.7551	Moderate	0.2754	3.20E-01	(+)	0	4.60E-01	None	↑	2022	↑	2022
	cDCE			1.13	68	1.5344	High	0.7536	1.20E-03	(+)	1	1.54E-05	SS↑	↑			
	VC			ND	6.7	0.8413	Moderate	0.8258	8.49E-02	(+)	1	1.37E-02	SS↑	↑			
MW-294	TCE	382021-2024	4	37	84	--	--	0.9892	1.08E-02	(+)	0	1.54E-01	None	--	--		
	cDCE			200	310	--	--	0.8831	1.17E-01	(+)	0	2.35E-01	None	--	--		
	VC			38	56	--	--	0.5441	4.56E-01	(+)	0	0	None	--	--		
MW-297	PCE	2008-2024	4	ND	0.52	--	--	--	--	--	--	--	--	--	--		
	TCE			1.3	5.7	--	--	0.9402	5.98E-02	(+)	0	1.54E-01	None	--	--		
	cDCE			3.4	37	--	--	0.9943	5.70E-03	(+)	1	4.47E-02	SS↑	--	--		
	VC			ND	2.1	--	--	--	--	--	--	--	--	--	--		
LAWMW-Q	TCE	2020-2024	5	1.2	4.8	0.7810	Moderate	0.9833	2.60E-03	(+)	1	2.16E-02	SS↑	--	--		
	cDCE			ND	0.99	--	--	--	--	--	--	--	--	--	--	--	--
	VC			ND	1.3	--	--	--	--	--	--	--	--	--	--	--	--

Notes: PCE = tetrachloroethene, TCE = trichloroethene, cDCE = cis-1,2-dichloroethene, VC = vinyl chloride, CV = coefficient variation, r = correlation coefficient, p-value = probability value, Corr. = correlation: negative (-) and positive (+), SS = statistically significant at an alpha significance level of 0.05 (5 percent), ¹decreasing trend at alpha significance level of 0.10 (10 percent), **Constituent concentration is less than the MCL**, *decreasing trend* , ↓decreasing trend, ↑ increasing trend, → SSA no trend

Exhibit 2-11 Data Plots for Offsite OU 6 Area: Confined Aquifer Southern Area



MW-292

Well MW-290 installed in 2021 is located 200 ft. into the offsite area and east of No Name Creek (Figure 2-6). This well is in the central portion of the offsite area monitoring the confined aquifer. Overall, concentrations for TCE, cDCE, and VC have increased from 2021 to 2024. No samples collected from well MW-292 had PCE detections. M-K tests indicate increasing trends for TCE, cDCE, and VC.

MW-145

Well MW-145 installed in 2010 is located 160 ft. into the offsite area and east of No Name Creek (Figure 2-6). MW-145 is 175 ft. north of MW-157. Trend evaluations use monitoring data from 2010-2024. Coefficient of variation tests indicate high variance for cDCE and moderate variance for TCE and VC. M-K tests indicate increasing trends for cDCE and VC with the sequential M-K and SSA tests indicating a change to an increasing trend for TCE in 2022. SSA tests indicate an increasing trend for TCE with insufficient data to evaluate trends for VC.

MW-294

Well MW-294 installed in 2021 is located 210 ft. into the offsite area and east of No Name Creek (Figure 2-6). This well is in the northern portion of the offsite area monitoring the confined aquifer. Overall, concentrations for TCE, cDCE, and VC have increased from 2021 to 2024. No samples collected from well MW-292 had PCE detections. M-K tests did not indicate trends for TCE, cDCE, and VC.

MW-297

Well MW-294 installed in 2021 is located 210 ft. into the offsite area and east of No Name Creek (Figure 2-6). This well is 135 ft. north of MW-294 within the northern portion of the offsite area monitoring the confined aquifer. Overall, concentrations for PCE, TCE, cDCE, and VC have increased from 2021 to 2024. No samples collected from well MW-292 had PCE detections. M-K tests indicate an increasing trend for cDCE with no trend detected for TCE. PCE and VC had insufficient detected results to evaluate trend.

LAWMW-Q

Well LAWMW-Q installed in 1996 is located 535 ft. into the offsite area and east of No Name Creek (Figure 2-6). LAWMW-Q is the farthest downgradient monitoring well in the offsite area. Monitoring at this well initially occurred in 1997 to support completion of a natural attenuation study for OU 6 (Law 2000a). Samples collected from this well in 1997 and 1999 had detections of TCE at levels less than the laboratory limit of quantitation (LOQ) with a sample collected in 2012 having a TCE concentration of 1.2 µg/L. No VOC sampling for this well occurred from 2013-2019. The trend assessment uses data from 2020-2024. The tiled plot in Exhibit 2-11 (page 2-49) shows one three detections for cDCE at levels less than the laboratory LOQ with one detection of VC in 2024. M-K testing for TCE indicate an increasing trend for 2020-2024.

2.4.11.4 Summary of Trend Analysis for Confined Aquifer: Offsite OU 6 Area

Table 2-8 has a summary of the statistical and trend analysis for the confined aquifer in the southern area of OU 6. M-K trend trends indicated 13 of 24 tests had an increasing trend with no tests having a decreasing trend. Because of the limited observations (4) at 6 of 9 wells, M-K tests at these wells generally will indicate a trend only if there is a monotonic increase or decrease for the four observations at each location with no left censored results for the well evaluated (non-detect).

Table 2-8 Summary of Statistical and Trend Analysis for Confined Aquifer: Offsite Area

Parameter	No of Well Locations	Samples for Mann-Kendall Trend Evaluation	Mann-Kendall Trend (M-K, One Way)			Seq Mann-Kendall Trend	Singular Spectrum Analysis (SSA) of Trend	
			No Trend	Increasing ($\alpha - 0.05$)	Increasing ($\alpha - 0.10$)		Samples for Trend Evaluation	Increasing as of 2024
Total	9	24	11	12	1	--	--	--
PCE	0	--	--	--	--	--	--	--

Parameter	No of Well Locations	Samples for Mann-Kendall Trend Evaluation	Mann-Kendall Trend (M-K, One Way)			Seq Mann-Kendall Trend	Singular Spectrum Analysis (SSA) of Trend	
			No Trend	Increasing ($\alpha - 0.05$)	Increasing ($\alpha - 0.10$)	Change to Increasing	Samples for Trend Evaluation	Increasing as of 2024
TCE	9	9	5	4	--	1	2	2
cDCE	9	8	3	4	1	--	2	2
VC	11	7	3	4	--	--	1	1

Notes: PCE = tetrachloroethene, TCE = trichloroethene, cDCE = cis-1,2-dichloroethene, VC = vinyl chloride, $\alpha - 0.05$ = alpha significance level of 0.05 (5 percent), $\alpha - 0.10$ = alpha significance level of 0.10 (10 percent).

2.5 Current Conditions for Surface Water

Table 2-9 (page 2-52) has summary statistics for detected VOC results for surface water in No Name Creek for the monitoring period 2020-2024 and compares the results to MCLs and Biological Technical Assistance Group (BTAG) screening benchmarks⁵ for surface water. VOCs detected in surface water samples collected for this five-year period include cDCE, chloroform, chloromethane, ethylbenzene, PCE, and TCE. No samples had detected concentrations > MCLs or BTAG screening benchmarks.

Table 2-10 (page 2-52) has a summary of trend analysis performed for PCE and TCE for surface water monitoring at No Name Creek. M-K and SSA tests indicate decreasing trends for TCE at NNC-2 (off installation mid-point) and NNC-3 (on-installation location).

Exhibit 2-12 (page 2-52) has data plots (line) for PCE and TCE for 2007-2024 with SSA trend lines as applicable. The plots show synchronous variation for PCE between the locations with maximum concentrations for PCE occurring in 2020 followed by minimum concentrations less than the laboratory limit of detection (LOD) in 2024. TCE also had minimum concentrations near or less than the LOQ in 2024. At NNC-2 in the off-installation area where the VOC plume previously had reached No Name Creek at concentrations > MCLs, TCE concentrations peaked in 2008 with local maxima in 2015 and 2020. The maxima for TCE in 2008 and 2015 had concentrations slightly greater than the MCL of 5 µg/L. At NNC-3 in the on-installation area, TCE concentrations peaked in 2013 with the most prominent local maxima occurring in 2018. SSA plots showed decreasing trends for TCE at NNC-2 and NNC-3.

⁵ United States Environmental Protection Agency (EPA) Region III Biological Technical Assistance Group (BTAG) Freshwater Screening Benchmarks, 7/2006. <https://www.epa.gov/risk/freshwater-screening-benchmarks>

Table 2-9 OU 6 VOC Summary Statistics for No Name Creek Surface Water (2020-2024)

Volatile Organic Compound	Matrix	No. of Results	Unit	Min	Max	Max Date	# > LOD	% > LOD	Location of Max	Federal MCL Screening ¹			BTAG SW Screening ²		
										No. Exceeding	% Exceeding	MCL	No. Exceeding	% Exceeding	EPA BTAG R3 SW
1,2-Dichloroethene, Total	WS	15	µg/L	<0.37	1.8	Dec 2020	11	73.3	NNC-3	-	-	-	0	0	5.90E+02
Chloroform	WS	15	µg/L	<0.27	0.39 J	May 2023	1	6.7	NNC-3	0	0	8.00E+01	0	0	1.80E+00
Chloromethane (Methyl chloride)	WS	15	µg/L	<0.54	0.64 J	May 2024	1	6.7	NNC-2	-	-	-	-	-	-
cis-1,2-Dichloroethene	WS	15	µg/L	<0.25	1.8	Dec 2020	13	86.7	NNC-3	0	0	7.00E+01	-	-	-
Ethylbenzene	WS	15	µg/L	<0.2	0.38 J	Dec 2020	3	20.0	NNC-2	0	0	7.00E+02	0	0	9.00E+01
Tetrachloroethene (PCE)	WS	15	µg/L	<0.35	3.8	Dec 2020	5	33.3	NNC-3	0	0	5.00E+00	0	0	1.11E+02
Trichloroethene (TCE)	WS	15	µg/L	<0.48	4.6	Dec 2020	14	93.3	NNC-1	0	0	5.00E+00	0	0	2.10E+01

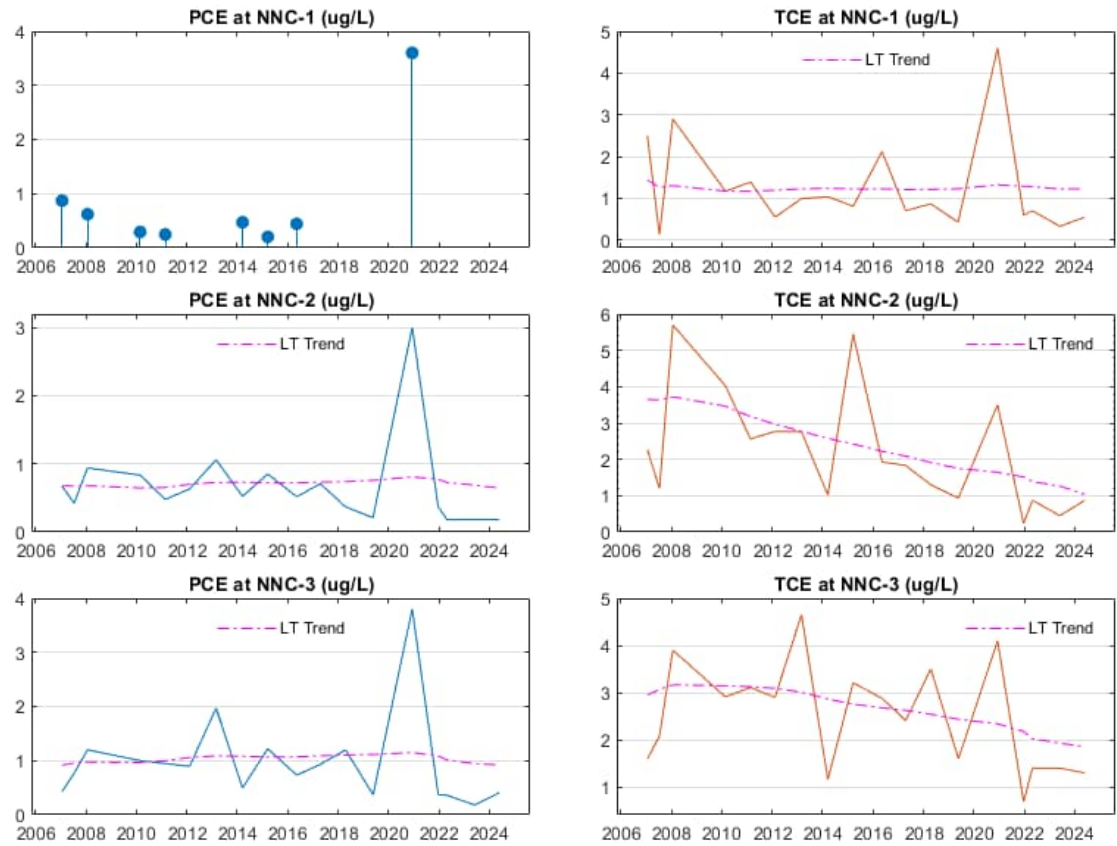
Notes: WS = surface water matrix, µg/L = micrograms per liter, Min = minimum, Max = maximum, LOD = limit of detection, No. = number, J = the reported result is an estimated value with an unknown bias at a level less than the laboratory limit of quantitation, MCL = maximum contaminant level, BTAG = EPA Region 3 Biological Technical Assistance Group (BTAG) Freshwater Screening Benchmarks for surface water (July 2006), MCL = Maximum Contaminant Level contained in the National Primary Drinking Water Regulations in 40 CFR Part 141.

Table 2-10 OU 6 Trend Analysis for PCE and TCE for No Name Creek Surface Water (2007-2023)

Volatile Organic Compound	NNC-1 (Off-Installation, Downstream)						NNC-2 (Off-Installation, Midpoint)						NNC-3 (Onsite)					
	N	CV	M-K Trend (One Way)			SSA Trend	N	CV	M-K Trend (One Way)			SSA Trend	N	CV	M-K Trend (One Way)			SSA Trend
			H ₀	p-value (α=0.05)	Result	Result			H ₀	p-value (α=0.05)	Result	Result			H ₀	p-value (α=0.05)	Result	Result
Tetrachloroethene (PCE)	8 of 18	1.3472	0	-3.55E-01	No Trend	No Trend	12 of 18	0.9505	1	-9.20E-03	No Trend	No Trend	15 of 18	0.8693	0	-6.46E02	Decreasing ¹	No Trend
Trichloroethene (TCE)	16 of 18	0.9044	0	-2.91E-02	Decreasing	No Trend	17 of 18	0.7304	1	-2.80E-03	Decreasing	Decreasing	18 of 18	0.4597	0	-8.04E-02	Decreasing ¹	Decreasing

Notes: N = number of detected observations of total observations, H₀ = null hypothesis of no trend at significance level of 5%, α=0.05 = alpha significance of 0.05 or 5%. H₀ = 0 indicates no statistical evidence of trend, H₀ = 1 indicates statistical evidence of trend at significance level of 0.05 (5%), ¹decreasing trend at a significance level of 0.10 (10%), CV = coefficient of variation., SSA = Singular spectrum analysis, LT = long-term trend line from singular spectrum analysis.

Exhibit 2-12 OU 6 Time Series Data Plots for PCE and TCE for No Name Creek



3. Remedial Design

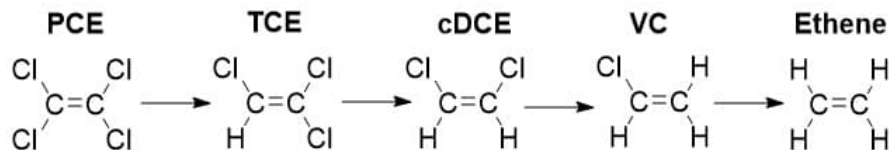
Section 3 presents the remedial design for follow-up enhanced ISB actions at OU 6.

3.1 Remedial Design Basis

For the confined aquifer in the southern area of OU 6, the new monitoring network implemented at OU 6 in 2021 has detected apparent TCE, cDCE, and VC plume expansion/movement for the period 2021-2024 with an increase in concentrations and plume area in the offsite area. Additional optimization of the OU 6 remedy is proposed to address VOC plume instability in the confined aquifer within the southern area extending into the offsite area.

The designed ISB measures will reduce contaminant mass, create treatment barriers in the VOC plume area to reduce contaminant flux into the offsite area, and reduce the potential for further migration of the VOC plume in the offsite area. The process option of the ISB design in this work plan follows the remedial design/remedial action work plan for OU 6 (AECOM 2015) 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

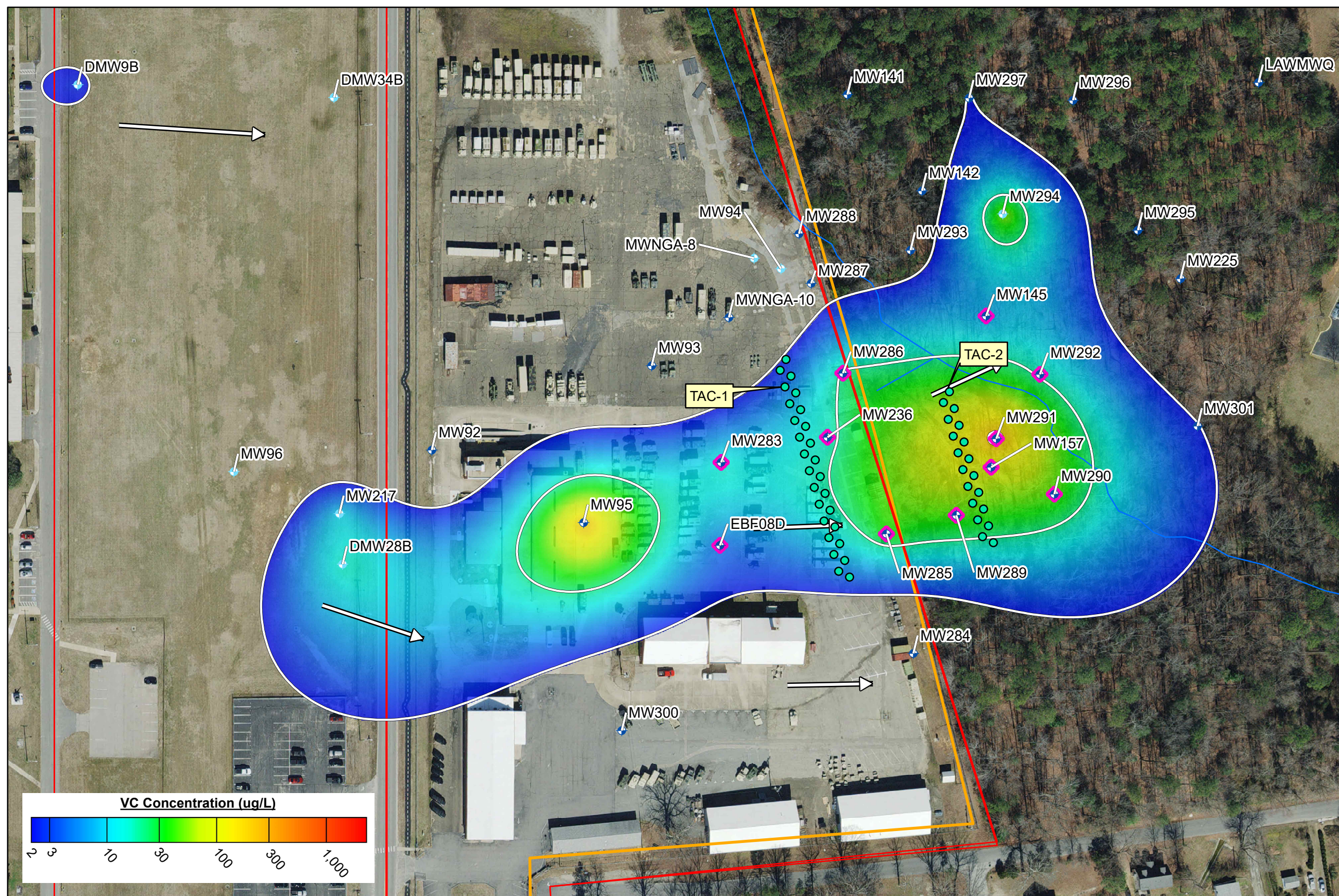
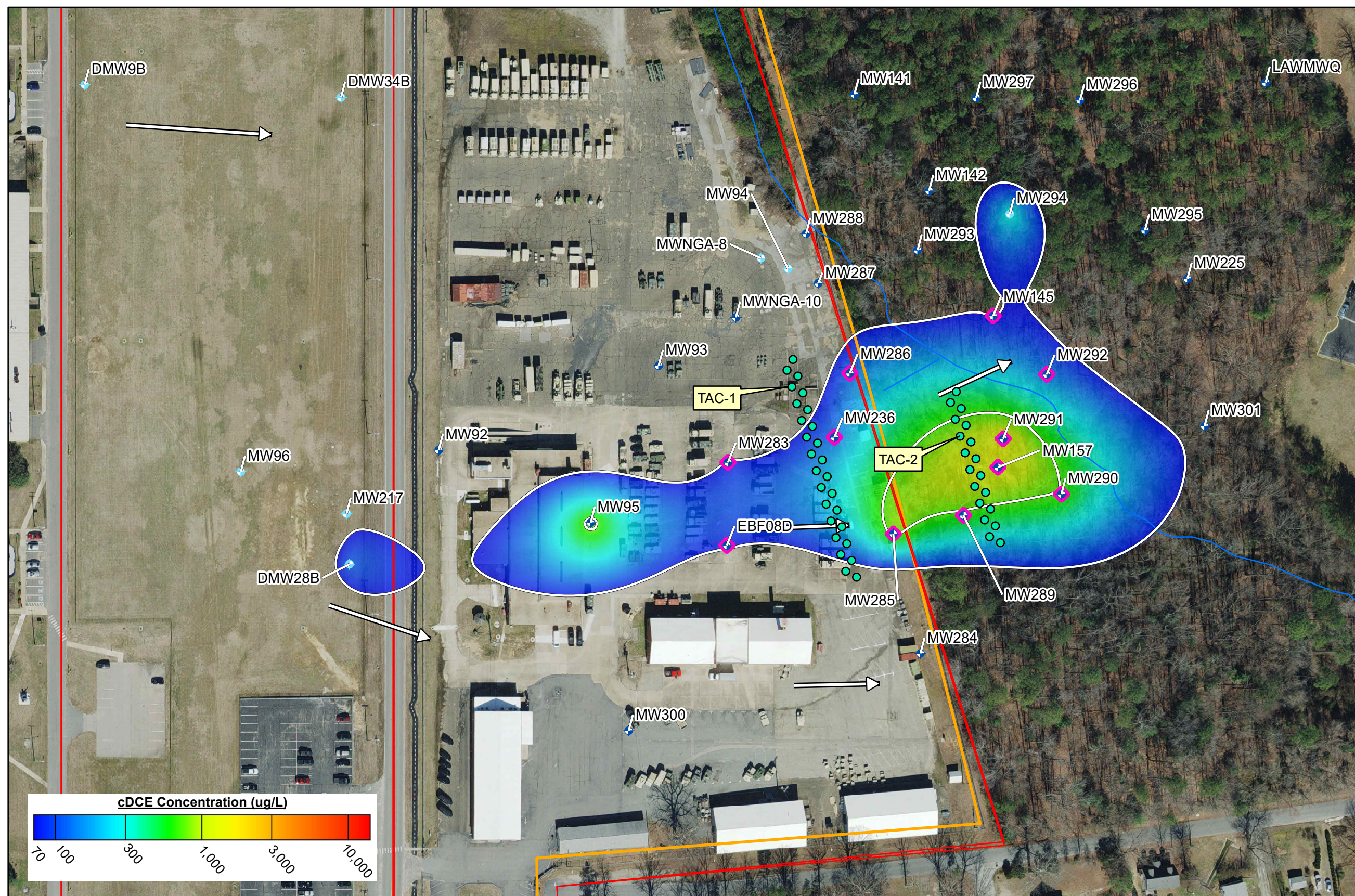
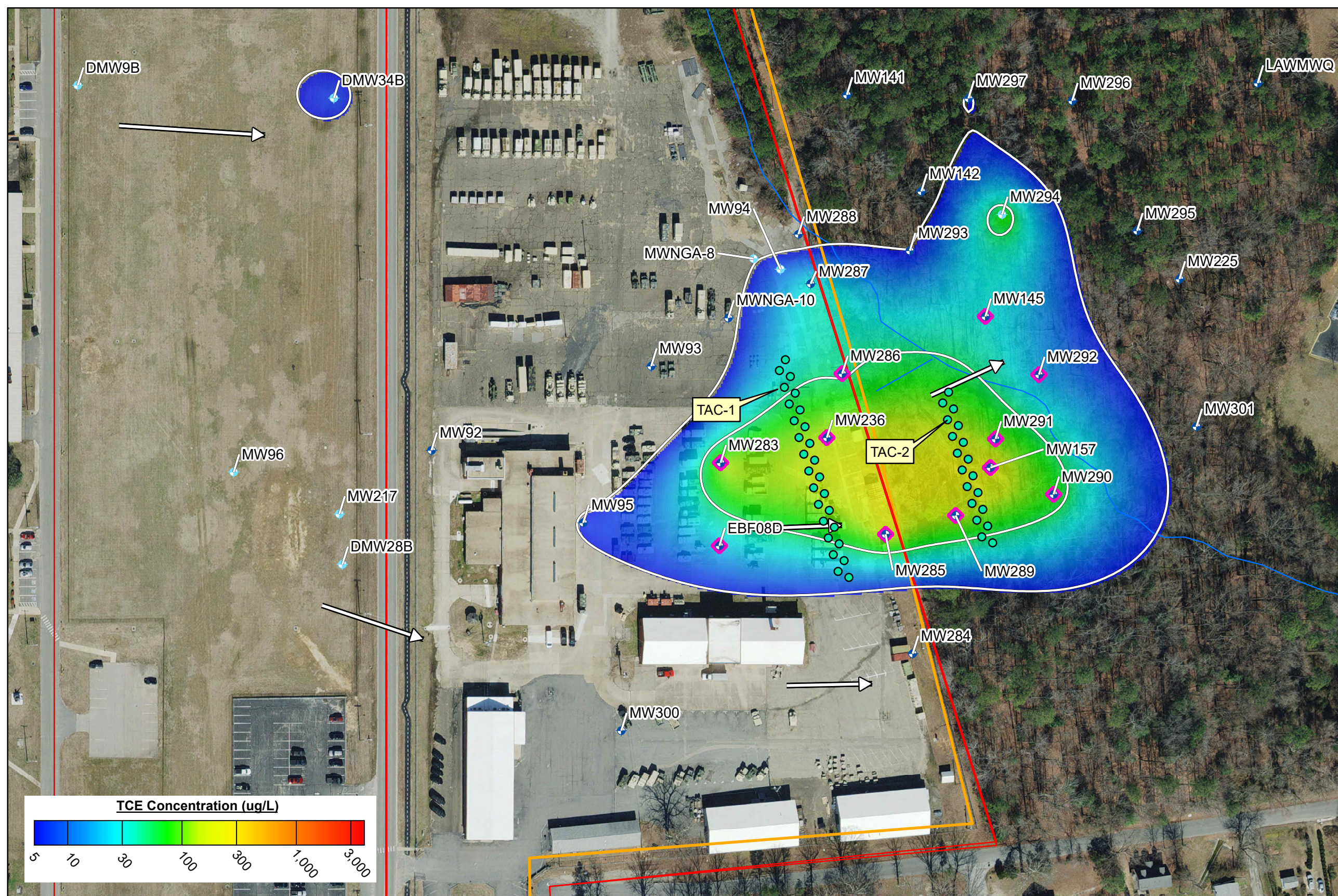
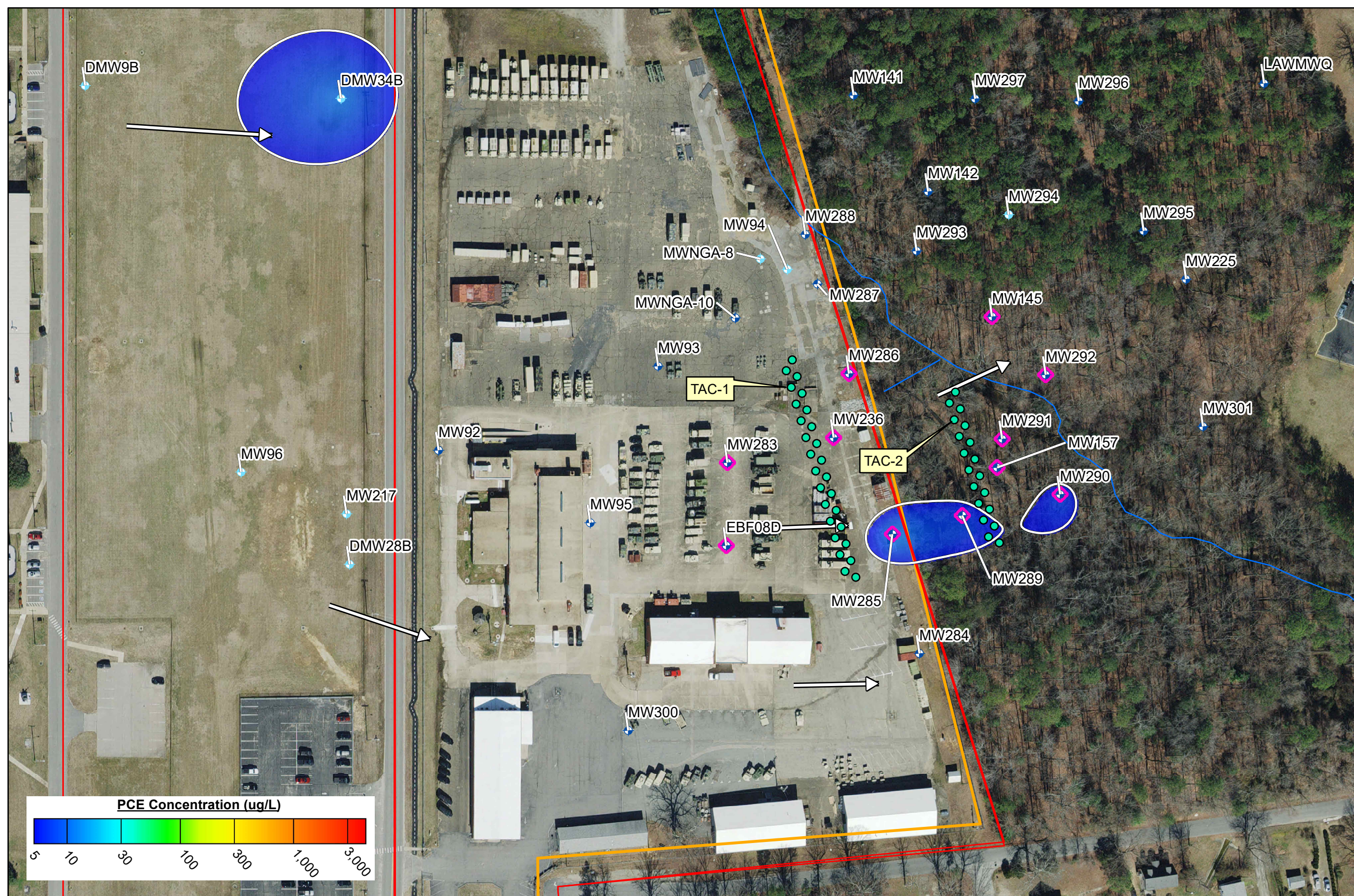


The specific ISB design in this work plan considers the results from previous treatability studies (AECOM, 2010) and remedial implementation for the confined aquifer at OU 6 (AECOM 2016) and the current conditions presented in Section 2.4.

3.2 Enhanced ISB Treatment Areas

Two enhanced ISB treatment areas (barriers) are proposed for the VOC plume in the confined aquifer as shown in Figure 3-1 (page 3-2). TAC-1 is located approximately 55 ft. to 60 ft. upgradient of the installation fence line in OU 3 with design dimensions of 250 ft. x 34 ft. The 250 ft. width is oriented perpendicular to the direction of groundwater flow with a 34 ft. length parallel to the direction of groundwater flow. TAC-1 extends across the TCE plume area with concentrations ≥ 50 $\mu\text{g/L}$ and VC concentrations ≥ 20 $\mu\text{g/L}$, and nearly across the cDCE plume with concentrations ≥ 70 $\mu\text{g/L}$. TAC-2 is located in the offsite area 90 ft. to 100 ft. beyond the installation fence line and slightly upgradient of MW-157. TAC-2 has design dimensions of 175 ft. x 34 ft. The 175 ft. width is oriented perpendicular to the direction of groundwater flow with a 34 ft. length parallel to the direction of groundwater flow. TAC-2 addresses the plume area with the highest TCE, cDCE, and VC concentrations in the area of wells MW-157 and MW-291.

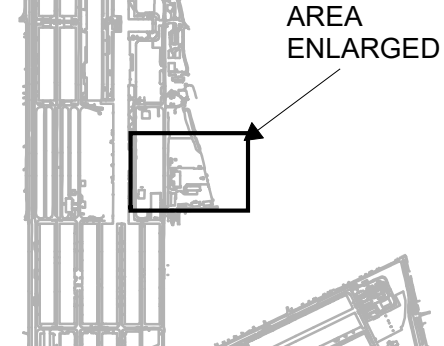
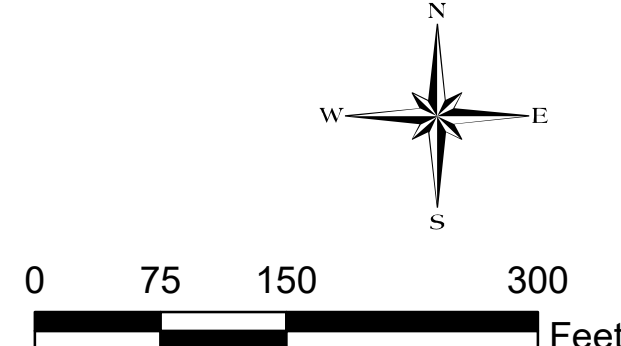
The design treatment interval is the confined aquifer beneath the confining unit. For TAC-1, the proposed treatment interval is from a depth of 27 ft. to 55 ft. BGS. This corresponds to elevations of approximately 79.5 ft. to 51.5 ft. NAVD88. For TAC-2, the proposed treatment interval is from a depth of 22 ft. to 50 ft. BGS, which corresponds to elevations of approximately 74 ft to 52 ft. NAVD88.



Orthoimagery Source: VGIN (2021)

Legend

- ◆ Confined Aquifer Monitoring Well
- ◆ Performance Monitoring Well - Water Level Only
- ◆ Performance Monitoring Well
- ISB Injection Point
- Overall Groundwater Flow Direction
- ~ Stream
- Operable Units
- Installation Boundary
- TAC-1 ISB Treatment Area



Prepared By: DBC	Reviewed By: JOS
Scale: 1" = 115'	Date: February 27, 2025

Figure 3-1
Enhanced In Situ Bioremediation
Treatment Areas and Performance
Monitoring Wells - Confined Aquifer

Defense Supply Center Richmond
Richmond, VA

3.3 Substrate Selection

Primary criteria to select a substrate for the ISB design is sustaining treatment for up to three (3) years, compatibility with a direct push barrier 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 6 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 >1E+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 < 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 at OU 6 recommended and have used sodium bicarbonate for pH buffering. Buffering studies performed for OU 6 in 2021 recommended buffering dosage of 0.16 pounds of sodium bicarbonate per cubic foot of aquifer (Terra Systems 2021).

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-hydroxypropionic 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 has technical data sheets and safety data sheets for the selected EVO substrate, bioaugmentation, sodium ascorbate, and pH buffering components.

3.4 Injection Process Option Selection

The injection process option selected for enhanced ISB for the confined aquifer at OU 6 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 6 indicate that the high density of the confined aquifer (Potomac Formation) will require injection pressures > 100 pounds per square inch (psi) to distribute reagents in this zone.

EVO injections performed in 2015 for the confined aquifer (Area 6) in the southern area of OU 6 used six (6) injection wells as the delivery process option for barrier treatment. These injection wells addressed the lower portion of the confined aquifer ≥ 40 ft. depths and had minimal to low injection rates and limited distribution because of the high density and properties of the confined aquifer. Injection wells had low flow rates of 0.1 gallons per minute (gpm), for two wells, and 0.2 gpm, 0.4 gpm, 0.5 gpm, and 0.9 gpm at the remaining injection wells.

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 6, 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 treatment area has a design specific to the conditions found in the respective target treatment zones and uses a 3 year design period of performance assuming a single application event. Appendix B.1 and B.2 contain the design work books for the treatment areas TAC-1 and TAC-2, respectively. Table 3-2 (page 3-5) contains a summary of enhanced ISB design parameters for these treatment areas. Table 3-3 (page 3-6) has a summary of design outputs including electron receptor demand and substrate requirements in hydrogen equivalents.

For this work plan, the enhanced ISB design uses 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 (4X design factor), uncertainties in electron acceptor demand (4X design factor), and loss of substrate leaving the reaction zone (2X). 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).

Table 3-2 Enhanced In Situ Bioremediation Design Parameter Summary

Treatment Zone	Treatment Area TAC-1	TAC-1 Notes	Treatment Area TAC-2	TAC-2 Notes
Area Description: Treat barrier in OU 3 (wells MW-236, MW-285, MW-286	--	Located 50 ft. to 60 ft upgradient of installation fence line		Located offsite 90 ft. to 100 ft. beyond the installation fence line and slightly upgradient of MW-157.
Width (ft) perpendicular to GW flow x Length (ft) parallel to GW flow x Treatment Zone Thickness (ft)	250' x 34' x 28'	Treatment interval, permeable zones of confined aquifer below confining unit	175' x 34' x 25'	Treatment interval, permeable zones of confined aquifer below confining unit
Design Period (yrs.)	3	Design period for enhance in situ bioremediation	3	Design period for enhance 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 / 0.22	Physical Test Data Potomac Formation OU 6 (2019)	0.36 / 0.22	Physical Test Data Potomac Formation OU 6 (2019)
Average Hydraulic Conductivity (ft/day)	14	USGS Pumping Test Confined Aquifer (1987)	14	USGS Pumping Test Confined Aquifer (1987)
Average Hydraulic Gradient (ft/ft)	4.46E-03	MW-283 to MW-236 (May 2024)	4.81E-03	MW-285 to MW-291 (May 2024)
Soil Bulk Density (gm/cm³)	1.745	Physical Test Data Potomac Formation OU 6 (2019)	1.745	Physical Test Data Potomac Formation OU 6 (2019)
Soil Fraction of Organic Carbon (%)	0.06	Physical Test Data Potomac Formation OU 6 (2019)	0.06	Physical Test Data Potomac Formation OU 6 (2019)
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	Treatment Area TAC-1		Treatment Area TAC-2	Notes
Dissolved Oxygen (mg/L)	0.3	Average MW-236 (May 2024), MW-285 (May 2023), MW-286 (May 2024)	0.9	Average MW-157 and MW-291 (May 2024)
Nitrate (mg/L)	0.023	MW-285 (May 2024)	0.27	Average MW-157 and MW-291 (May 2024)
Manganese (IV) (mg/L)	0.115	Average MW-236, MW-285, MW-286 (May 2024)	5	Average MW-157 and MW-291 (May 2024)
Iron (III) (mg/L) (estimated as the amount of Fe II produced)	20	Average MW-236 and MW-285 (May 2024)	20	Average MW-157 and MW-291 (May 2024)
Sulfate (mg/L)	0.535	Average MW-236 and MW-285 (May 2024)	2	Average MW-157 and MW-291 (May 2024)
Carbon Dioxide (mg/L)	8	Estimated based on amount of methane produced from previous ISB injections	16	Estimated based on previous ISB injections
Contaminant Electron Acceptors	Treatment Area TAC-1		Treatment Area TAC-2	Notes
Tetrachloroethene (mg/L)	0.013	Well MW-285 (May 2024)	0.0005	Average MW-157 and MW-291 (May 2024)
Trichloroethene (mg/L)	0.150	Well MW-236, MW-285 (May 2024)	0.200	MW-157 (May 2024)
Dichloroethenes (mg/L)	0.811	Well MW-285 (May 2024)	1.300	MW-291 (May 2024)
Vinyl Chloride (mg/L)	0.034	Well MW-285 (May 2024)	0.250	MW-291 (May 2024)
Carbon Tetrachloride (mg/L)	0.000	Not detected (2024)	0.000	Not detected (2024)
Chloroform (mg/L)	0.000	Not detected (2024)	0.000	Not detected (2024)
Methylene chloride (mg/L)	0.000	Not detected (2024)	0.000	Not detected (2024)
Tetrachloroethanes (mg/L)	0.000	Not detected (2024)	0.000	Not detected (2024)
Trichloroethanes (mg/L)	0.000	Not detected (2024)	0.000	Not detected (2024)
Dichloroethanes (mg/L)	0.006	Well MW-285 (May 2024)	0.003	MW-291 (May 2024)
Chloroethane (mg/L)	0.000	Not detected (2024)	0.000	Not detected (2024)
Aquifer Geochemistry	TAC-1		TAC-2	Notes
Oxidation-Reduction Potential (mV)	71	Average MW-236, MW-285, MW-286 (May 2024)	23	MW-283 (May 2024)
Temperature (°C)	21	Average MW-236, MW-285, MW-286 (May 2024)	19	MW-283 (May 2024)
pH (standard units)	5.8	Average MW-236, MW-285, MW-286 (May 2024)	5.4	Average MW-157 and MW-291 (May 2024)
Alkalinity (mg/L)	56	Average MW-236, MW-285, MW-286 (May 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)	239	Average MW-236, MW-285, MW-286 (May 2024)	441	Average MW-157 and MW-291 (May 2024)
Chloride (mg/L)	39	Average MW-236, MW-285, MW-286 (May 2024)	104	Average MW-157 and MW-291 (May 2024)
Sulfide – Pre Injection (mg/L)	0.1	Estimated	0.1	Estimated
Sulfide – Post Injection (mg/L)	1	Estimated	2.6	MW-291 (May 2024)
Aquifer Matrix	TAC-1		TAC-2	Notes
Total Iron (mg/kg)	11145	CSM 2006 mean of subsurface soil	11145	CSM 2006 mean of subsurface soil
Cation Exchange Capacity meq/100 g	1	Estimated based on soil data from Potomac Formation	1	Estimated based on soil data from Potomac Formation
Neutralization Potential (percent as CaCO3)	1.0%	Estimated based on soil data from Potomac Formation	1.0%	Estimated based on soil data from Potomac 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

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

Parameter	TAC-1 (OU 3)		TAC-2 (OU 6 Offsite Area)	
	% of Total	Hydrogen Demand (lbs.)	% of Total	Hydrogen Demand (lbs.)
Aerobic Respiration	0.6%	1.211	2.6%	2.570
Nitrate Reduction	0.0%	0.073	0.0%	0.049
Sulfate Reduction	32.6%	65.966	6.5%	6.519
Manganese Reduction	0.1%	0.140	0.1%	0.151
Iron Reduction	0.2%	0.326	0.5%	0.460
Methanogenesis	65.8%	133.266	88.7%	89.183
Dechlorination	0.7%	1.447	1.6%	1.616
Total	100%	202.43	100%	100.55
Hydrogen Demand (lbs./gal)	5.10E-05		3.78E-05	
Hydrogen Demand (g/L)	6.11E-03		4.53E-03	
EVO substrate equivalents (10X)	29,339 lbs. 3,761 gal		14,573 lbs. 1,868 gal	
Effective Concentration ¹	531 mg/L		394 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, 1effective concentration is for total volume of groundwater treated.

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 based on using the higher-pressure DPT tooling to distribute the reagents and the results of previous pilot tracer studies and injections in the confined aquifer.

Injected fluids travel principally through the mobile fraction of the 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).

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

Where:

h = injection zone thickness

θ_m = mobile fraction (porosity)

V_{inj} = injected volume

π = pi mathematical constant approximately equal to 3.14159

The 2007 pilot study data performed at OU 6 for the confined aquifer estimated a mobile porosity of 0.03 (3%). This falls within the expected range of 0.02 to 0.10 (Payne et al. 2007, 67)⁶.

Injection Volume

The estimated mobile porosity (0.03) 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.

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

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.

Appendix B.3 uses Equation 4.2 to calculate injection volumes for each treatment area. Each vertical interval will receive approximately 102 gallons per linear ft. with a total delivery volume of approximately 2,843 gallons for 28 ft. vertical treatment interval for TAC-1 and a total delivery volume of approximately 2,538 gallons for 25 ft. vertical treatment interval for TAC-2. Table 3-4 has a summary of the injection design and volumes for each injection point and treatment intervals.

Table 3-4 Injection Design, Volumes, and Substrate Loading Rates

Treatment Area	Dimensions	No. of IPs	IP Spacing (ft)	Row Spacing (ft)	Injection Interval (ft)	Vol. per LF (gal)	Vol. per IP (gal)	Total Vol. (gal)	EVO Vol. (gal)	EVO 60 Dosage (%)
TAC-1	250' x 34'	27	20	10	27-55	102	2843	76,734	3761	5.1%
TAC-2	175 x 34'	19	20	10	25-50	102	2538	30,000	1,838	4.0%

Notes: 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. Amendment amounts calculated for sodium bicarbonate and sodium ascorbate are as follows:

- 8,379 pounds of sodium bicarbonate for TAC-1 corresponding to 0.16 pounds of sodium bicarbonate per cubic foot of aquifer for a treatment zone effective pore volume of 52,370 cubic feet (391,758 gallons⁷). The corresponding load rate is 0.11 pounds per gallon of dilution/chase water.
- 5,237 pounds of sodium bicarbonate for TAC-2 corresponding to 0.16 pounds of sodium bicarbonate per cubic foot of aquifer for a treatment zone effective pore volume of 32,731 cubic feet (244,848 gallons⁸). The corresponding load rate is 0.18 pounds per gallon of dilution/chase water.
- 767 pounds of sodium ascorbate for TAC-1 for making 72,973 gallons of anaerobic water at the rate of 10 pounds per 1,000 gallons of injection water.
- 297 pounds of sodium ascorbate for TAC-1 for making 29,742 gallons of anaerobic water at the rate of 10 pounds per 1,000 gallons of injection water.

⁶ Payne F.C., J. A. Quinnan, and S. T. Potter 2007. Remediation Hydraulics. CRC Press. Page 67, 432 p.

⁷ Treatment zone effective pore volume for Appendix B.1 Part 1

⁸ Treatment zone effective pore volume for Appendix B.2 Part 1

3.6 Treatment Area Configuration and Injection Points

Figure 3-1 shows the layout and configuration of the enhanced ISB treatment areas TAC-1 and TAC-2. Both treatment areas have two 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. For TAC-1, the barrier configuration has design treatment area dimensions of 250 ft x 34 ft with a treatment interval thickness of 28 ft. For TAC-2, the barrier configuration 1 has design treatment area dimensions of 250 ft x 34 ft with a treatment interval thickness of 28 ft.

4. Remedial Action Field Activities

Section 4 describes field activities associated the proposed remedial actions described in the RAWP Addendum.

4.1 Utility Clearance

Utility avoidance will include marking of proposed 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 proposed enhanced ISB treatment 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

The project geodatabase in the geographic information system (GIS) will contain the spatial location information for 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 model⁹ for OU 6.

The field team will locate the 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.

4.3 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.

4.3.1 Offsite Area Access

The offsite work area for proposed injections is within a woodland area where previous well installations, work, and land disturbance have occurred as part of remedial implementation and monitoring. This area is part of a governmental easement within the OU 6 area (groundwater). Proposed work will occur in previously cleared areas with localized, low understory management expected to access some proposed locations, where offsetting is not possible. No tree removal or land clearing is proposed for the work.

Given the localized vegetation management (understory) subject to field conditions, disturbance areas are not identifiable or quantifiable in the work plan. Restoration would occur within any areas where

⁹ Digital Elevation Model, Virginia Geographic Information Network, <https://vgin.vdem.virginia.gov/search?tags=dem>

activities expose soil previously under ground cover. This would include restoring ground cover to the original grade.

Appendix D contains a United States Fish and Wildlife Service, Information and Planning Consultation (IPaC) Report run on July 21, 2025. The report identified “the following species are potentially affected by activities at this location”:

- Mammals: Tricolored Bat *Perimyotis subflavus* (wherever found), no critical habitat designed for this species.
- Insects: Monarch Butterfly *Danaus plexippus* (wherever found), there is proposed critical habitat for this species. The proposed project location does not overlap the critical habitat.
- Bald and Golden Eagles. The report notes Bald Eagles and/or Golden Eagles in the project area.
- Migratory Birds: Bald Eagle, Chimney Swift *Chaetura pelagica*, Prairie Warbler *Setophaga discolor*, Prothonotary Warbler *Protonotaria citrea*, Red-headed Woodpecker *Melanerpes erythrocephalus*, Wood Thrush *Hylocichla mustelina*.

The IPaC report did not identify critical habitats at the proposed project location or National Wildlife Refuge Lands or fish hatcheries. The report identified that the project location overlaps Freshwater Forested/Shrub Wetland (PFO1E). This wetlands area is photo interpreted using one meter (or less) digital, true color imagery from 2012. No site-specific study in the offsite area has occurred to determine the presence or absence of wetlands.

The proposed work in the government easement area will not include land clearing or tree removal. This easement area is part of OU 6 undergoing Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) response actions for groundwater. CERCLA response actions at site operable units do not require federal, state, or local permits for implementation of response actions. Previous response actions performed in this area of OU 6 since the ROD (2013) have followed this approach.

4.3.2 Mobilization and Setup

Site mobilization will include delivery of reagents and rental equipment to the site at OU 6. 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. The planned central staging area for equipment and reagents contained in 275-gallon totes is in the central open area between Pits 1 and 2. The planned number of totes for ISB actions is eight totes of EVO and three totes of sodium lactate. A forklift will move totes and other materials to the planned injection and treatment areas.

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.

4.3.3 Injection/Reagent Application

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 6 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 psi 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.

Part of the Injection work will occur in the undeveloped offsite area adjacent to installation within the environmental easement area. It is anticipated that injection work will occur over successive days outside of the secured installation area. If overnight storage of ISB containers is required in this area for the injections, security provisions will include locking totes to prevent unauthorized access to the materials.

4.4 Injection Process Monitoring

Table 4-1 (page 4-3) describes process monitoring that will occur during the injections performed at OU 6. 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, water color change, and odor) and changes in water quality parameters including increased specific conductivity and turbidity levels.

Table 4-1 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	OU 3: MW-283, MW-236, MW-285, MW-286 Offsite: MW-289, MW-157, MW-291, MW-290	Baseline before injections Min. daily during injections
Visual parameters	Bailer checks of monitoring wells in vicinity of injection area	Distribution of injectate in treatment area	OU 3: MW-283, MW-236, MW-285, MW-286 Offsite: MW-289, MW-157, MW-291, MW-290	Baseline before injections Min. daily during injections
Water quality parameters	pH, SC, DO, ORP, temperature, and turbidity	Injectate lateral and vertical distribution and radius of influence	OU 3: MW-283, MW-236, MW-285, MW-286 Offsite: MW-289, MW-157, MW-291, MW-290	Baseline before injections Min. daily during injections
Aboveground	Inspection of surface around injection areas	Reagent surfacing	Injection areas and vicinity	

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

4.5 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 4-2 identifies planned IDM containerization and disposal based on previous work conducted at OU 6 and DSCR.

Table 4-2 Investigative Derived Material Containerization and Disposal

IDM Type	Container	Expected Waste Characterization	Anticipated Transportation and Disposal
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, and purge Water	Consolidate into holding containers at Building 40 for Vacuum truck pump out	Non-Hazardous Waste (Aqueous), Waste characterization testing in Table 4-3.	Shamrock Richmond VA
Empty reagent 275 gallon totes	Empty reagent 275 gallon totes, pickup at NGA	Offsite recycling	Shamrock Richmond VA

Notes: IDM = investigative derived material, NGA = National Guard Area, 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 4-3 has a summary of the parameter analysis for characterization of waste (IDM).

Table 4-3 Waste Characterization Parameter Analysis

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

4.6 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.

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.

A stormwater outfall ditch is located approximately 95 ft south (downgradient) of the TAC-1 injection area with this ditch located 50 ff. northwest of TAC-2. No Name Creek is located 125 ft. south (downgradient) of TAC-1 with at 25 ft. to 140 ft south (downgradient) of TAC-2. Injections in the confined aquifer are not expected to daylight based on the methods used and depth. During injection operations, the field team will implement measures to monitor for potential daylighting in the outfall ditch and No Name Creek 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 6. The technical approach will include baseline monitoring before injections and post-injection performance monitoring at 11 monitoring wells. The proposed network of monitoring wells for performance monitoring is shown in Figure 3-1 (page 3-2) includes:

- Monitoring wells OU8-MW-283 and EBF-08D located 70 ft. and 100 ft, respectively, upgradient of barrier TAC-1 in OU 3.
- Monitoring well OU8-MW-236 located immediately downgradient of barrier TAC-1.
- Monitoring wells OU8-MW-285 and OU6-MW-286 located downgradient of barrier TAC-1 along the installation fence line in OU 3.
- Monitoring well OU8-MW-289 located in the offsite area between barriers TAC-1 and TAC-2.
- Monitoring well OU8-MW-157 located immediately downgradient of barrier TAC-2 in the offsite area.
- Monitoring wells OU8-MW-290, OU8-MW-291, and OU8-MW-292 located downgradient of barrier TAC-2 in the offsite area.
- Monitoring well OU8-MW-145 located in the offsite area more than 200 ft. downgradient of barrier TAC-1.

5.1 Baseline Monitoring

Baseline groundwater monitoring for the enhanced ISB injections will occur as part of the 2025 Annual Monitoring Event for OU 6 scheduled for May 2025. Table 5-1 (page 5-3) identifies the 11 monitoring well locations and scope of baseline monitoring. The baseline data for 2025 combined with data collected from the new monitoring network from 2021-2024 will provide comparative data for ISB performance evaluations. Baseline monitoring will include two (2) upgradient locations and nine (9) locations to monitor plume response to ISB injections in the confined aquifer. 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 annual sampling at the two upgradient wells and one year of quarterly sampling of nine (9) wells that monitor plume areas targeted for treatment (see Figure 3-1, page 3-2). The quarterly sampling combines three quarterly events for 2025-2026 with the annual sampling event scheduled for May 2026. An adaptive approach will determine the frequency and scope of sampling beyond 2026. Table 5-1 (page 5-3) identifies the 11 monitoring well locations and scope of 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 confined aquifer at OU 6. 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. Prior to each quarterly monitoring event, a synoptic round of water levels will include measurements at the 28 well locations identified in Figure 3-1 and listed in Exhibit 5-1 (page 5-2). This number of wells will allow development of potentiometric contour maps and analysis of groundwater flow, hydraulic gradient, and groundwater flow velocity in the plume area targeted for enhanced ISB treatment.

Exhibit 5-1 Water Level Measurement Locations for Quarterly Monitoring

OU6-MW-92	OU6-MW-284	OU6-MW-288	OU6-MW-145	OU6-MW-295
OU6-MW-95	OU6-MW-285	OU6-MW-289	OU6-MW-293	OU6-MW-297
OU6-MW-300	OU6-MW-236	OU6-MW-157	OU6-MW-142	OU6-MW-296
EBF-08D	OU6-MW-286	OU6-MW-290	OU6-MW-141	LAWMW-Q
OU8-MW-283	MWNGA-10	OU6-MW-291	OU6-MW-301	
OU6-MW-93	OU6-MW-287	OU6-MW-292	OU6-MW-225	

Exhibit 5-2 has summary information on groundwater sampling procedures for baseline and performance monitoring that references detailed information contained in the project QAPP (AECOM-Meadows 2024a).

Exhibit 5-2 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 groundwater 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 bladder pump, new disposable bladders, and 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

Table 5-1 ISB Baseline and Performance Monitoring Program: OU 6 Confined Aquifer (2025-2026)

Well ID	Screened Interval		Location	Baseline Q2 Annual 2025	Inj. Event Q3 2025	Q4 2025	Q1 2026	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)																		
OU6-MW-283	36.0-41.0	73.45-68.45	UG of TAC-1	X	Process Monitoring	X		X		A	A	A	A	A	A	A	A	A	A	
EBF-08D	29.0-49.0	81.88-61.88	UG of TAC-1	X	Process Monitoring	X		X		A	A	A	A	A	A	A	A	A	A	
OU8-MW-236	46.0-56.0	60.23-50.23	TAC-1 Area	X	Process Monitoring	X	X	X	X	X	X	X	X	X	A	X	X	X	X	
OU8-MW-285	36.0-41.0	72.23-67.23	DG of TAC-1	X	Process Monitoring	X	X	X	X	X	X	X	X	X	A	X	X	X	X	X
OU8-MW-286	36.0-41.0	69.50-64.50	DG of TAC-1	X	Process Monitoring	X	X	X	X	X	X	X	X	X	A	X	X	X	X	
OU8-MW-289	36.0-41.0	65.15-60.15	DG of TAC-1 TAC-2 Area	X	Process Monitoring	X	X	X	X	X	X	X	X	X	A	X	X	X	X	
OU8-MW-157	30.0-40.0	71.10-61.10	TAC-2 Area	X	Process Monitoring	X	X	X	X	X	X	X	X	X	A	X	X	X	X	X
OU8-MW-290	36.0-41.0	65.23-60.23	DG of TAC-2	X	Process Monitoring	X	X	X	X	X	X	X	X	X	A	X	X	X	X	
OU8-MW-291	36.0-41.0	65.02-60.02	DG of TAC-2	X	Process Monitoring	X	X	X	X	X	X	X	X	X	A	X	X	X	X	
OU8-MW-292	36.0-41.0	66.86-61.86	DG of TAC-1 DG of TAC-2	X	Process Monitoring	X	X	X	X	X	X	X	X	X	A	X	X	X	X	
OU8-MW-145	40.0-50.0	64.2-54.2	DG of TAC-1	X	Process Monitoring	X	X	X	X	X	X	X	X	X	A	X	X	X	X	

Notes: ft. = feet, ft. BGS.= feet below ground surface, Elev NAVD88 = elevation National 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 6 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.

Table 5-2 identifies the quality assurance and quality control samples established in the project QAPP (Worksheet #20) for annual monitoring at OU 6. 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 OU6-MW-157.

Table 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 ⁵	MW-145, MW-157, MW-292	MW-236	MW-290	1 per cooler of VOCs
Quarterly Performance Monitoring	MW-157	MW-236	MW-290	1 per cooler of VOCs

Notes: MS/MSD = matrix spike/matrix spike duplicate., EB = equipment blank, ¹duplicate samples analyzed for the same parameters as associated normal sample, ²matrix spike/matrix spike duplicate analyzed for the same parameters as normal samples except for microbial analysis, ³equipment blank samples analyzed for the same parameters as normal samples except for alkalinity and microbial analysis, ⁴trip blank sample analysis for volatile organic compounds, ⁵baseline monitoring locations will be covered under the 2025 annual sampling.

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 2015 RD/RAWP for OU 6 (AECOM 2015). Table 5-3 has a summary of planned ISB performance evaluations relative to ISB objectives.

Table 5-3 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 barriers, create expanded downgradient reactive zone across the fence line area and in the offsite area.
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 TCE, cDCE, and VC concentrations, eliminate cDCE/VC accumulation in offsite area.
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 barrier 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 plume area.
Contaminant flux	Evaluate changes in contaminant flux across barrier treatment areas using well transects by integrating concentration and flow data Time series evaluation: individual monitoring events, changes over time ISB objective: reduce contaminant flux across the fence line and in the offsite area.
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

**Evaluation
Element****Description**

Microbiological laboratory or field data that support the occurrence of biodegradation and provide estimated rates of biodegradation

ISB objective: increase biodegradation rates for 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.

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6. Permitting

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

6.1 Drilling and Subsurface Installations

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.

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 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 6 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 6 will report the results of remedy implementation, performance monitoring, MNA and LTM and include data evaluations described in Table 5-3 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.

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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 B₁₂ 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, Cr⁶⁺, 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.



Terra Systems

INCORPORATED



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 B₁₂ 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.

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

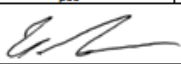


- The lack of QA/QC in the field

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 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 B12	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-hydroxypropionic 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:	≥ 100C (≥ 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, NTP, NIOSH, OSHA, or ACGIH.
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:
Phone Number:

Terra Systems, Inc.
(302) 798-9553 (U.S.A.)

A.2 Bioaugmentation Technical Data Sheet and Safety Data Sheet



TSI DC *Dehalococcoides mccartyi* Bioaugmentation Culture®

Containing $>1 \times 10^{11}$ *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.

Key Communication Points

- TSI DC *Dehalococcoides mccartyi* Bioaugmentation Culture® is an enriched natural bacteria culture that contains *Dehalococcoides* species for bioaugmentation.
- TSI DC® contains $>1 \times 10^{11}$ *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.



- 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 <i>Dehalococcoides mccartyi</i> 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 dechlorination activity, mg/h per gram of dry weight	61	50	08/13/2019	Bottle Assay

Michael D Lee, Ph.D.

August 19th, 2019 |

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Date

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On the Web: www.terrasystems.net



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





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

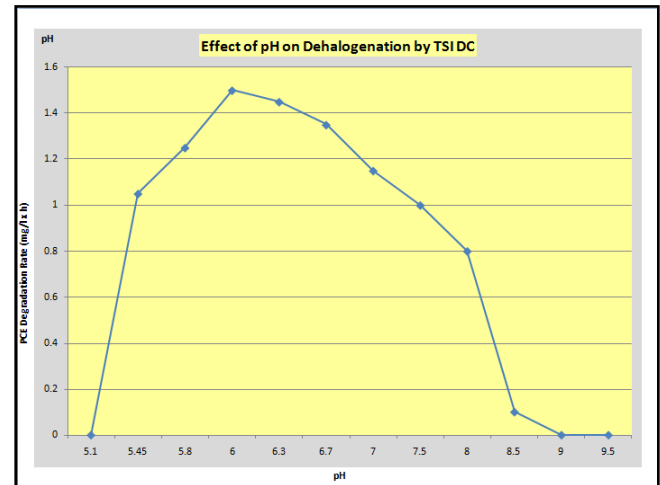
Table I: pH Buffer Options

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.



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. Cronic, 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.



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.

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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

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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/m ³ .
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.

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





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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.
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Hazardous Polymerization:	Will not occur.
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Incompatibilities:	Strong acids.
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Conditions to Avoid:	Incompatibles. Isolate from heat and open flame.
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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:

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



SODIUM ASCORBATE SAFETY DATA SHEET

1. Product Identification

Synonyms: Sodium Salt of Vitamin C
Recommended Use: Additive for treatment of water to remove dissolved oxygen.
CAS#: 134-03-2
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 or skin irritation.
Health Rating: 2 - Moderate
Flammability Rating: 1 - Slight
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.
Ingestion: Hazard via ingestion.
Skin Contact: May cause irritation or sensitization in sensitive individuals.
Eye Contact: May cause mild irritation.
Chronic Exposure: No information found.
Aggravation of Pre-existing Conditions: No information found.

3. Composition/Information on Ingredients

Ingredient	Synonyms	CAS #	Percent	Hazardous
Sodium Ascorbate	Sodium Salt of Vitamin C	134-03-2	100	No

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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 and auto ignition: not available. May be combustible at high temperature. Isolate from heat and open flame.
Explosion:	Slightly explosive in presence of open flames and sparks. Non-flammable in presence of shocks.
Fire Extinguishing Media:	Dry chemical powder for small fires. Water spray, fog, or foam may be effective for large fires. Do not use water jet. .
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. Fine dust dispersed in air at sufficient concentrations with an ignition source is a potential dust explosion hazard.

6. Accidental Release Measures

Clean-up personnel may require protective clothing. 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 away from sources of heat or ignition. Protect against physical damage. Containers of this material may pose a fire risk due to dusts. Keep container tightly closed and upright when not in use to prevent leakage. Sensitive to light. Store in light-resistant containers.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:	None established.
Ventilation System:	Use ventilation to keep exposure below exposure limits.
Personal Respirators (NIOSH)	

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Approved):
Skin Protection:
Eye Protection:

Use dust respirator usage.
Wear protective gloves and clean body-covering clothing.
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:	White to yellowish granular or crystalline solid
Molecular Weight:	198.11 g/mole
Odor:	Odorless.
Solubility:	620 g/L solubility in water at 25 C.
Specific Gravity (water=1):	1.66 (water = 1).
pH:	Not available
% Volatiles by volume	
@ 21C (70F):	Negligible.
Boiling Point:	No information found.
Melting Point:	No information found.
Flash Point (F):	No information found.
Autoignition Temperature:	No information found.
Decomposition Temperature:	Decomposition temperature 200 C (392 F)
Vapor Density (Air=1):	No information found.
Vapor Pressure (mm Hg):	Not applicable.
Evaporation Rate (BuAc=1):	Not applicable.
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, reducing agents, acids, alkalis.
Conditions to Avoid:	Incompatibles. Isolate from heat and open flame.

11. Toxicological Information

Routes of Entry	Inhalation and ingestion.
Toxicity to Animals:	Acute oral toxicity (LD50): 16300 mg/kg Rat.
Chronic Effects on Humans:	Carcinogenic effects – classified 4 (no evidence) by NTP and none by OSHA. Mutagenic effects – mutagenic to mammalian somatic cells. May cause damage to kidneys, gastrointestinal tract, and upper respiratory tract. May affect genetic material (mutagenic) based on animal test data. No human data found

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Other Toxic Effects:

(Registry of Toxic Effects of Chemicals). May cause cancer based on animal test data. No human data found (Registry of Toxic Effects of Chemicals).

Hazardous in case of ingestion. Slightly hazardous in case of skin contact (irritant) or inhalation.

12. Ecological Information

Environmental Fate: No information found.

Environmental Toxicity: No information found.

Degradability: This product is inherently biodegradable under both aerobic and anaerobic conditions.

Soil Mobility: No information found.

Bioaccumulation Potential: Does not bioaccumulate.

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)

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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: **2** Flammability: **1** Reactivity: **0**

Date Prepared:

February 3, 2015

Revision Information:

SDS Section(s) changed since last revision of document include: None.

Disclaimer:

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Appendix B Remedial Design

B.1 TAC-1 Treatment Area Design

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: OU 3 TAC-1 Barrier MW-236, MW-285, MW-286

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)	250	1-10,000	feet	Barrier transect immediately downgradient of MW-283
Length (Parallel to predominant groundwater flow)	34	1-1,000	feet	Barrier thickness
Saturated Thickness	28	1-100	feet	27 ft to 55 ft
Treatment Zone Cross Sectional Area	7000	--	ft ²	
Treatment Zone Volume	238,000	--	ft ³	
Treatment Zone Total Pore Volume (total volume x total porosity)	641,058	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	391,758	--	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	Physical Test Data Potomac Fm. OU 6 (2019)
Effective Porosity	22%	.05-50	percent	Physical Test Data Potomac Fm. OU 6 (2019)
Average Aquifer Hydraulic Conductivity	14	.01-1000	ft/day	USGS Pumping Test Confined Aq (1987)
Average Hydraulic Gradient	4.46E-03	0.0001-0.1	ft/ft	MW-283 to MW-236 (May 2024)
Average Groundwater Seepage Velocity through the Treatment Zone	0.28	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	103.6	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	1,193,635	--	gallons/year	Physical Test Data Potomac Fm OU 6 (2019)
Soil Bulk Density	1.745	1.4-2.0	gm/cm ³	Physical Test Data Potomac Fm OU 6 (2019)
Soil Fraction Organic Carbon (foc)	0.06%	0.01-10	percent	Physical Test Data Potomac Fm OU 6 (2019)
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.3	0.01 to 10	mg/L	Average MW-236, MW-285 (May 2023), MW-286
Nitrate	0.02	0.1 to- 20	mg/L	MW-285 (May 2024)
Sulfate	24	10 to 5,000	mg/L	Average MW-236, MW-285, MW-286 (May 2024)
Carbon Dioxide (estimated as the amount of Methane produced)	8.0	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	Average MW-236, MW-285, MW-286 (May 2024)
Iron (III) (estimated as the amount of Fe (II) produced)	1	0.1 to 20	mg/L	Average MW-236 and MW-285 (May 2024)
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.013	--	mg/L	Well MW-285 (May 2024)
Trichloroethene (TCE)	0.150	--	mg/L	Well MW-236, MW-285 (May 2024)
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.811	--	mg/L	Well MW-285 (May 2024)
Vinyl Chloride (VC)	0.034	--	mg/L	Well MW-285 (May 2024)
Carbon Tetrachloride (CT)	0.000	--	mg/L	Not detected (2024)
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	Not detected (2024)
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	Not detected (2024)
Chloromethane	0.000	--	mg/L	Not detected (2024)
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	Not detected (2024)
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	--	mg/L	Not detected (2024)
Dichloroethane (1,1-DCA and 1,2-DCA)	0.006	--	mg/L	Well MW-285 (May 2024)
Chloroethane	0.000	--	mg/L	Not detected (2024)
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	Average MW-236, MW-285, MW-286 (May 2024)
Temperature	21	5.0 to 30	°C	Average MW-236, MW-285, MW-286 (May 2024)
pH	5.8	4.0 to 10.0	su	Average MW-236, MW-285, MW-286 (May 2024)
Alkalinity	56	10 to 1,000	mg/L	Average MW-236, MW-285, MW-286 (May 2024)
Total Dissolved Solids (TDS, or salinity)	100	10 to 1,000	mg/L	No data
Specific Conductivity	239	100 to 10,000	µs/cm	Average MW-236, MW-285, MW-286 (May 2024)
Chloride	39	10 to 10,000	mg/L	Average MW-236, MW-285, MW-286 (May 2024)
Sulfide - Pre injection	0.1	0.1 to 100	mg/L	Estimated
Sulfide - Post injection	2.0	0.1 to 100	mg/L	Estimated
B. Aquifer Matrix				
Total Iron	11145	200 to 20,000	mg/kg	CSM 2006 Mean of Subsurface Soil
Cation Exchange Capacity	1	1.0 to 10	meq/100 g	Estimated based on soil data
Neutralization Potential	1.0%	1.0 to 100	Percent as CaCO ₃	Estimated based on soil data

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents						
Site Name: OU 3 TAC-1 Barrier MW-236, MW-285, MW-286		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)		250	1-10,000	feet		
Length (Parallel to predominant groundwater flow)		34	1-1,000	feet		
Saturated Thickness		28	1-100	feet		
Treatment Zone Cross Sectional Area		7000	--	ft ²		
Treatment Zone Volume		238,000	--	ft ³		
Treatment Zone Effective Pore Volume (total volume x effective porosity)		391,758	--	gallons		
Design Period of Performance		3.0	.5 to 5	year		
2. Treatment Zone Hydrogeologic Properties						
Total Porosity		0.36	.05-50			
Effective Porosity		0.22	.05-50			
Average Aquifer Hydraulic Conductivity		14	.01-1000	ft/day		
Average Hydraulic Gradient		0.00446	0.1-0.0001	ft/ft		
Average Groundwater Seepage Velocity through the Treatment Zone		0.28	--	ft/day		
Average Groundwater Seepage Velocity through the Treatment Zone		103.6	--	ft/yr		
Average Groundwater Flux through the Treatment Zor		1,193,635	--	gallons/year		
Soil Bulk Density		1.745	1.4-2.0	gm/cm ³		
Soil Fraction Organic Carbon (foc)		0.00055	0.0001-0.1			
3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)						
A. Aqueous-Phase Native Electron Acceptors						
Oxygen	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h ₂)	Hydrogen Demand (lb)	Electron Equivalents per Mole	
Nitrate (denitrification)	0.3	0.95	7.94	0.12	4	
Sulfate	0.0	0.08	12.30	0.01	5	
Carbon Dioxide (estimated as the amount of methane produced)	23.7	77.48	11.91	6.51	8	
	8.0	26.15	1.99	13.14	8	
Soluble Competing Electron Acceptor Demand (lb.)				19.77		
B. Solid-Phase Native Electron Acceptors						
(Based on manganese and iron produced)						
Manganese (IV) (estimated as the amount of Mn (II) produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h ₂)	Hydrogen Demand (lb)	Electron Equivalents per Mole	
Iron (III) (estimated as the amount of Fe (II) produced)	0.1	3.81	27.25	0.14	2	
	0.5	18.07	55.41	0.33	1	
Solid-Phase Competing Electron Acceptor Demand (lb.)				0.47		
C. Soluble Contaminant Electron Acceptors						
Tetrachloroethene (PCE)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h ₂)	Hydrogen Demand (lb)	Electron Equivalents per Mole	
Trichloroethene (TCE)	0.013	0.04	20.57	0.00	8	
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.150	0.49	21.73	0.02	6	
Vinyl Chloride (VC)	0.811	2.65	24.05	0.11	4	
Carbon Tetrachloride (CT)	0.034	0.11	31.00	0.00	2	
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.08	0.00	8	
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	19.74	0.00	6	
Chloromethane	0.000	0.00	21.06	0.00	4	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	25.04	0.00	2	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	0.00	20.82	0.00	8	
Dichloroethane (1,1-DCA and 1,2-DCA)	0.000	0.00	22.06	0.00	6	
Chloroethane	0.006	0.02	24.55	0.00	4	
Perchlorate	0.000	0.00	32.00	0.00	2	
	0.000	0.00	12.33	0.00	6	
Total Soluble Contaminant Electron Acceptor Demand (lb.)				0.14		
D. Sorbed Contaminant Electron Acceptors						
(Soil Concentration = Koc x foc x Cgw)						
Tetrachloroethene (PCE)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h ₂)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Trichloroethene (TCE)	263	0.00	0.05	20.57	0.00	8
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	107	0.01	0.23	21.73	0.01	6
Vinyl Chloride (VC)	45	0.02	0.52	24.05	0.02	4
Carbon Tetrachloride (CT)	3.0	0.00	0.00	31.00	0.00	2
Trichloromethane (or chloroform) (CF)	224	0.00	0.00	19.08	0.00	8
Dichloromethane (or methylene chloride) (MC)	63	0.00	0.00	19.74	0.00	6
Chloromethane	28	0.00	0.00	21.06	0.00	4
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	25	0.00	0.00	25.04	0.00	2
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	117	0.00	0.00	20.82	0.00	8
Dichloroethane (1,1-DCA and 1,2-DCA)	105	0.00	0.00	22.06	0.00	6
Chloroethane	30	0.00	0.00	24.55	0.00	4
Perchlorate	3	0.00	0.00	32.00	0.00	2
	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)				0.03		
(continued)						

Table S.2 Substrate Calculations in Hydrogen Equivalents**4. Treatment Cell Electron-Acceptor Flux (per year)****A. Soluble Native Electron Acceptors**

Oxygen
 Nitrate (denitrification)
 Sulfate
 Carbon Dioxide (estimated as the amount of Methane produced)

Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h ₂)	Hydrogen Demand (lb)	Electron Equivalents per Mole
0.3	2.89	7.94	0.36	4
0.0	0.23	10.25	0.02	5
23.7	236.06	11.91	19.82	8
8	79.68	1.99	40.04	8

Total Competing Electron Acceptor Demand Flux (lb/yr)**60.2****B. Soluble Contaminant Electron Acceptors**

Tetrachloroethene (PCE)
 Trichloroethene (TCE)
 Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)
 Vinyl Chloride (VC)
 Carbon Tetrachloride (CT)
 Trichloromethane (or chloroform) (CF)
 Dichloromethane (or methylene chloride) (MC)
 Chloromethane
 Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)
 Trichloroethane (1,1,1-TCA and 1,1,2-TCA)
 Dichloroethane (1,1-DCA and 1,2-DCA)
 Chloroethane
 Perchlorate

Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h ₂)	Hydrogen Demand (lb)	Electron Equivalents per Mole
0.013	0.13	20.57	0.01	8
0.150	1.49	21.73	0.07	6
0.811	8.08	24.05	0.34	4
0.034	0.34	31.00	0.01	2
0.000	0.00	19.08	0.00	8
0.000	0.00	19.74	0.00	6
0.000	0.00	21.06	0.00	4
0.000	0.00	25.04	0.00	2
0.000	0.00	20.82	0.00	8
0.000	0.00	22.06	0.00	6
0.006	0.06	24.55	0.00	4
0.000	0.00	32.00	0.00	2
0.000	0.00	12.33	0.00	6

Total Soluble Contaminant Electron Acceptor Demand Flux (lb/yr)**0.42****Initial Hydrogen Requirement First Year (lb)****81.1****Total Life-Cycle Hydrogen Requirement (lb)****202.4****5. Design Factors**

Microbial Efficiency Uncertainty Factor
 Methane and Solid-Phase Electron Acceptor Uncertainty
 Remedial Design Factor (e.g., Substrate Leaving Reaction Zone)

2X - 4X

2X - 4X

1X - 3X

Design Factor**10.0****Total Life-Cycle Hydrogen Requirement with Design Factor (lb)****2,024.3****6. Acronyms and Abbreviations**

°C =degrees celsius

µs/cm = microsiemens per centimeter

cm/day = centimeters per day

cm/sec = centimeters per second

ft² = square feet

ft/day = feet per day

ft/ft = foot per foot

ft/yr = feet per year

gm/cm³ = grams per cubic centimeterkg 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 = concentration 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 ₃ H ₆ O 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 ₆ H ₁₂ O ₆	180	4	0.0448	4 to 6
Ethanol	C ₂ H ₆ O	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	45,225	45,225	2.05E+10	1,364
Sodium Lactate Product (60 percent solution)	10.0	45,225	93,829	2.05E+10	1,364
Molasses (assuming 60% sucrose)	10.0	42,964	71,606	1.95E+10	1,296
HFCS (assuming 40% fructose and 40% glucose by weight)	10.0	45,235	56,544	2.05E+10	1,364
Ethanol Product (assuming 80% ethanol by weight)	10.0	23,130	28,912	1.05E+10	698
Whey (assuming 100% lactose)	10.0	31,219	44,598	1.42E+10	942
HRC [®] (assumes 40% lactic acid and 40% glycerol by weight)	10.0	34,283	34,283	1.56E+10	827
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	10.0	17,603	17,603	7.98E+09	531
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	10.0	17,603	29,339	7.98E+09	531

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH₃-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid (C₃H₆O₃) = 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:****OU 3 TAC-1 Barrier MW-236, MW-285, MW-286**[RETURN TO COVER PAGE](#)**1. Treatment Zone Physical Dimensions**

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	250	feet	76	meters
Length (parallel to groundwater flow)	34	feet	10.4	meters
Saturated Thickness	28	feet	8.5	meters
Design Period of Performance	3	years	3	years

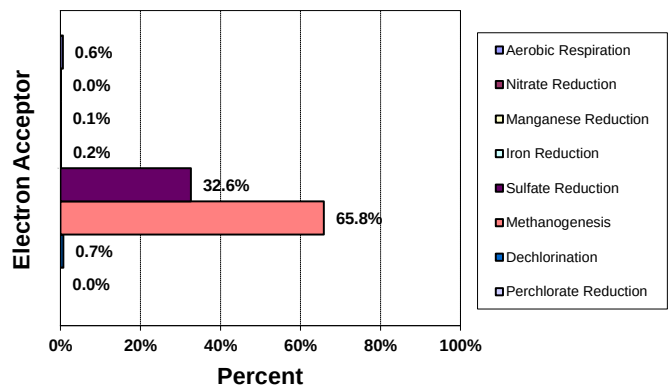
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.36	percent	0.36	percent
Effective Porosity	0.22	percent	0.22	percent
Average Aquifer Hydraulic Conductivity	14	ft/day	4.9E-03	cm/sec
Average Hydraulic Gradient	0.00446	ft/ft	0.00446	m/m
Average Groundwater Seepage Velocity	0.28	ft/day	8.7E+00	cm/day
Average Groundwater Seepage Velocity	104	ft/yr	31.6	m/yr
Effective Treatment Zone Pore Volume	391,758	gallons	1,482,922	liters
Groundwater Flux (per year)	1,193,635	gallons/year	4,518,273	liters/year
Total Groundwater Volume Treated (over entire design period)	3,972,662	gallons total	15,037,742	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	0.6%	1.211
Nitrate Reduction	0.0%	0.073
Sulfate Reduction	32.6%	65.966
Manganese Reduction	0.1%	0.140
Iron Reduction	0.2%	0.326
Methanogenesis	65.8%	133.266
Dechlorination	0.7%	1.447
Perchlorate Reduction	0.0%	0.000
Totals:	100.00%	202.43

Hydrogen demand in pounds/gallon:	5.10E-05
Hydrogen demand in grams per liter:	6.11E-03

Distribution of Electron Acceptors**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	93,829	8,530	1,364	as lactic acid
2. Molasses Product	71,606	5,967	1,296	as sucrose
3. Fructose Product	56,544	5,049	1,364	as fructose
4. Ethanol Product	28,912	4,190	698	as ethanol
5. Sweet Dry Whey (lactose)	44,598	sold by pound	942	as lactose
6. HRC®	34,283	sold by pound	827	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	17,603	2,257	531	as soybean oil
8. Emulsified Vegetable Oil	29,339	3,761	531	as soybean oil

Notes:

- Quantity assumes product is 60% sodium lactate by weight.
- Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
- Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
- Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
- Quantity assumes product is 70% lactose by weight.
- Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
- Quantity of neat soybean oil, corn oil, or canola oil.
- Quantity assumes commercial product is 60% soybean oil by weight.

B.2 TAC-2 Treatment Area Design

Table S.1 Input for Substrate Requirements in Hydrogen Equivalents

Site Name: TAC-2 MW-157,MW-291 Offsite Barrier

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)	175	1-10,000	feet	Barrier transect immediately downgradient of MW-283
Length (Parallel to predominant groundwater flow)	34	1-1,000	feet	Barrier thickness
Saturated Thickness	25	1-100	feet	25 ft to 50 ft
Treatment Zone Cross Sectional Area	4375	--	ft ²	
Treatment Zone Volume	148,750	--	ft ³	
Treatment Zone Total Pore Volume (total volume x total porosity)	400,661	--	gallons	
Treatment Zone Effective Pore Volume (total volume x effective porosity)	244,848	--	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	Physical Test Data Potomac Fm. OU 6 (2019)
Effective Porosity	22%	.05-50	percent	Physical Test Data Potomac Fm. OU 6 (2019)
Average Aquifer Hydraulic Conductivity	14	.01-1000	ft/day	USGS Pumping Test Confined Aq (1987)
Average Hydraulic Gradient	4.81E-03	0.0001-0.1	ft/ft	MW-285 to MW-291 (May 2024)
Average Groundwater Seepage Velocity through the Treatment Zone	0.31	--	ft/day	
Average Groundwater Seepage Velocity through the Treatment Zone	111.7	--	ft/yr	
Average Groundwater Discharge through the Treatment Zone	804,566	--	gallons/year	Physical Test Data Potomac Fm OU 6 (2019)
Soil Bulk Density	1.745	1.4-2.0	gm/cm ³	Physical Test Data Potomac Fm OU 6 (2019)
Soil Fraction Organic Carbon (foc)	0.06%	0.01-10	percent	Physical Test Data Potomac Fm OU 6 (2019)
3. Native Electron Acceptors				
A. Aqueous-Phase Native Electron Acceptors				
Oxygen	0.9	0.01 to 10	mg/L	Average MW-157 and MW-291 (May 2024)
Nitrate	0.02	0.1 to- 20	mg/L	Average MW-157 and MW-291 (May 2024)
Sulfate	4	10 to 5,000	mg/L	Average MW-157 and MW-291 (May 2024)
Carbon Dioxide (estimated as the amount of Methane produced)	8.0	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	Average MW-157 and MW-291 (May 2024)
Iron (III) (estimated as the amount of Fe (II) produced)	1	0.1 to 20	mg/L	Average MW-157 and MW-291 (May 2024)
4. Contaminant Electron Acceptors				
Tetrachloroethene (PCE)	0.001	--	mg/L	Average MW-157 and MW-291 (May 2024)
Trichloroethene (TCE)	0.200	--	mg/L	MW-157 (May 2024)
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	1.300	--	mg/L	MW-291 (May 2024)
Vinyl Chloride (VC)	0.250	--	mg/L	MW-291 (May 2024)
Carbon Tetrachloride (CT)	0.000	--	mg/L	Not detected (2024)
Trichloromethane (or chloroform) (CF)	0.000	--	mg/L	Not detected (2024)
Dichloromethane (or methylene chloride) (MC)	0.000	--	mg/L	Not detected (2024)
Chloromethane	0.000	--	mg/L	Not detected (2024)
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	--	mg/L	Not detected (2024)
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	--	mg/L	Not detected (2024)
Dichloroethane (1,1-DCA and 1,2-DCA)	0.003	--	mg/L	MW-291 (May 2024)
Chloroethane	0.000	--	mg/L	Not detected (2024)
Perchlorate	0.000	--	mg/L	No data
5. Aquifer Geochemistry (Optional Screening Parameters)				
A. Aqueous Geochemistry				
Oxidation-Reduction Potential (ORP)	23	-400 to +500	mV	MW-283 (May 2024)
Temperature	19	5.0 to 30	°C	MW-283 (May 2024)
pH	5.4	4.0 to 10.0	su	Average MW-157 and MW-291 (May 2024)
Alkalinity	64	10 to 1,000	mg/L	Average MW-157 and MW-291 (May 2024)
Total Dissolved Solids (TDS, or salinity)	100	10 to 1,000	mg/L	No data
Specific Conductivity	441	100 to 10,000	µs/cm	Average MW-157 and MW-291 (May 2024)
Chloride	104	10 to 10,000	mg/L	Average MW-157 and MW-291 (May 2024)
Sulfide - Pre injection	0.1	0.1 to 100	mg/L	Estimated
Sulfide - Post injection	2.6	0.1 to 100	mg/L	MW-291 (May 2024)
B. Aquifer Matrix				
Total Iron	11145	200 to 20,000	mg/kg	CSM 2006 Mean of Subsurface Soil
Cation Exchange Capacity	1	1.0 to 10	meq/100 g	Estimated based on soil data
Neutralization Potential	1.0%	1.0 to 100	Percent as CaCO ₃	Estimated based on soil data

NOTES:

Table S.2 Substrate Calculations in Hydrogen Equivalents						
Site Name:		TAC-2 MW-157,MW-291 Offsite Barrier		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)		175	1-10,000	feet		
Length (Parallel to predominant groundwater flow)		34	1-1,000	feet		
Saturated Thickness		25	1-100	feet		
Treatment Zone Cross Sectional Area		4375	--	ft ²		
Treatment Zone Volume		148,750	--	ft ³		
Treatment Zone Effective Pore Volume (total volume x effective porosity)		244,848	--	gallons		
Design Period of Performance		3.0	.5 to 5	year		
2. Treatment Zone Hydrogeologic Properties						
Total Porosity		0.36	.05-50			
Effective Porosity		0.22	.05-50			
Average Aquifer Hydraulic Conductivity		14	.01-1000	ft/day		
Average Hydraulic Gradient		0.00481	0.1-0.0001	ft/ft		
Average Groundwater Seepage Velocity through the Treatment Zone		0.31	--	ft/day		
Average Groundwater Seepage Velocity through the Treatment Zone		111.7	--	ft/yr		
Average Groundwater Flux through the Treatment Zor		804,566	--	gallons/year		
Soil Bulk Density		1.745	1.4-2.0	gm/cm ³		
Soil Fraction Organic Carbon (foc)		0.00055	0.0001-0.1			
3. Initial Treatment Cell Electron-Acceptor Demand (one total pore volume)						
A. Aqueous-Phase Native Electron Acceptors						
Oxygen	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h ₂)	Hydrogen Demand (lb)	Electron Equivalents per Mole	
Nitrate (denitrification)	0.9	1.88	7.94	0.24	4	
Sulfate	0.0	0.05	12.30	0.00	5	
Carbon Dioxide (estimated as the amount of methane produced)	3.5	7.15	11.91	0.60	8	
	8.0	16.35	1.99	8.21	8	
Soluble Competing Electron Acceptor Demand (lb.)				9.05		
B. Solid-Phase Native Electron Acceptors						
(Based on manganese and iron produced)						
Manganese (IV) (estimated as the amount of Mn (II) produced)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h ₂)	Hydrogen Demand (lb)	Electron Equivalents per Mole	
Iron (III) (estimated as the amount of Fe (II) produced)	0.2	4.10	27.25	0.15	2	
	1.2	25.51	55.41	0.46	1	
Solid-Phase Competing Electron Acceptor Demand (lb.)				0.61		
C. Soluble Contaminant Electron Acceptors						
Tetrachloroethene (PCE)	Concentration (mg/L)	Mass (lb)	Stoichiometric demand (wt/wt h ₂)	Hydrogen Demand (lb)	Electron Equivalents per Mole	
Trichloroethene (TCE)	0.001	0.00	20.57	0.00	8	
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	0.200	0.41	21.73	0.02	6	
Vinyl Chloride (VC)	1.300	2.66	24.05	0.11	4	
Carbon Tetrachloride (CT)	0.250	0.51	31.00	0.02	2	
Trichloromethane (or chloroform) (CF)	0.000	0.00	19.08	0.00	8	
Dichloromethane (or methylene chloride) (MC)	0.000	0.00	19.74	0.00	6	
Chloromethane	0.000	0.00	21.06	0.00	4	
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	0.000	0.00	25.04	0.00	2	
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	0.000	0.00	20.82	0.00	8	
Dichloroethane (1,1-DCA and 1,2-DCA)	0.000	0.00	22.06	0.00	6	
Chloroethane	0.003	0.01	24.55	0.00	4	
Perchlorate	0.000	0.00	32.00	0.00	2	
	0.000	0.00	12.33	0.00	6	
Total Soluble Contaminant Electron Acceptor Demand (lb.)				0.15		
D. Sorbed Contaminant Electron Acceptors						
(Soil Concentration = Koc x foc x C _{gw})						
Tetrachloroethene (PCE)	Koc (mL/g)	Soil Conc. (mg/kg)	Mass (lb)	Stoichiometric demand (wt/wt h ₂)	Hydrogen Demand (lb)	Electron Equivalents per Mole
Trichloroethene (TCE)	263	0.00	0.00	20.57	0.00	8
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	107	0.01	0.19	21.73	0.01	6
Vinyl Chloride (VC)	45	0.03	0.52	24.05	0.02	4
Carbon Tetrachloride (CT)	3.0	0.00	0.01	31.00	0.00	2
Trichloromethane (or chloroform) (CF)	224	0.00	0.00	19.08	0.00	8
Dichloromethane (or methylene chloride) (MC)	63	0.00	0.00	19.74	0.00	6
Chloromethane	28	0.00	0.00	21.06	0.00	4
Tetrachloroethane (1,1,1,2-PCA and 1,1,2,2-PCA)	25	0.00	0.00	25.04	0.00	2
Trichloroethane (1,1,1-TCA and 1,1,2-TCA)	117	0.00	0.00	20.82	0.00	8
Dichloroethane (1,1-DCA and 1,2-DCA)	105	0.00	0.00	22.06	0.00	6
Chloroethane	30	0.00	0.00	24.55	0.00	4
Perchlorate	3	0.00	0.00	32.00	0.00	2
	0.0	0.00	0.00	12.33	0.00	6
Total Sorbed Contaminant Electron Acceptor Demand (lb.)				0.03		

(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	0.9	6.18	7.94	0.78	4
Nitrate (denitrification)	0.0	0.15	10.25	0.02	5
Sulfate	3.5	23.50	11.91	1.97	8
Carbon Dioxide (estimated as the amount of Methane produced)	8	53.71	1.99	26.99	8
Total Competing Electron Acceptor Demand Flux (lb/yr)			29.8		
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)	0.001	0.00	20.57	0.00	8
Trichloroethene (TCE)	0.200	1.34	21.73	0.06	6
Dichloroethene (cis-DCE, trans-DCE, and 1,1-DCE)	1.300	8.73	24.05	0.36	4
Vinyl Chloride (VC)	0.250	1.68	31.00	0.05	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)	0.003	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)			0.48		
Initial Hydrogen Requirement First Year (lb)			40.1		
Total Life-Cycle Hydrogen Requirement (lb)			100.5		
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)			1,005.5		
6. Acronyms and Abbreviations					
°C =degrees celsius		meq/100 g = milliequivalents per 100 grams			
µs/cm = microsiemens per centimeter		mg/kg = milligrams per kilogram			
cm/day = centimeters per day		mg/L = milligrams per liter			
cm/sec = centimeters per second		m/m = meters per meters			
ft ² = square feet		mV = millivolts			
ft/day = feet per day		m/yr = meters per year			
ft/ft = foot per foot		su = standard pH units			
ft/yr = feet per year		wt/wt H ₂ = concentration molecular hydrogen, weight per weight			
gm/cm ³ = grams per cubic centimeter					
kg of CaCO ₃ per mg = kilograms of calcium carbonate per milligram					
lb = pounds					

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 ₃ H ₆ O 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 ₆ H ₁₂ O ₆	180	4	0.0448	4 to 6
Ethanol	C ₂ H ₆ O	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	22,464	22,464	1.02E+10	1,013
Sodium Lactate Product (60 percent solution)	10.0	22,464	46,606	1.02E+10	1,013
Molasses (assuming 60% sucrose)	10.0	21,341	35,568	9.68E+09	962
HFCS (assuming 40% fructose and 40% glucose by weight)	10.0	22,469	28,086	1.02E+10	1,013
Ethanol Product (assuming 80% ethanol by weight)	10.0	11,489	14,361	5.21E+09	518
Whey (assuming 100% lactose)	10.0	15,507	22,153	7.03E+09	699
HRC [®] (assumes 40% lactic acid and 40% glycerol by weight)	10.0	17,029	17,029	7.72E+09	614
Linoleic Acid (Soybean Oil, Corn Oil, Cotton Oil)	10.0	8,744	8,744	3.97E+09	394
Commercial Vegetable Oil Emulsion Product (60% oil by weight)	10.0	8,744	14,573	3.97E+09	394

NOTES: Sodium Lactate Product

1. Assumes sodium lactate product is 60 percent sodium lactate by weight.
2. Molecular weight of sodium lactate (CH₃-CHOH-COONa) = 112.06.
3. Molecular weight of lactic Acid (C₃H₆O₃) = 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:****TAC-2 MW-157,MW-291 Offsite Barrier**[RETURN TO COVER PAGE](#)**1. Treatment Zone Physical Dimensions**

	Values	Units	Values	Units
Width (perpendicular to groundwater flow)	175	feet	53	meters
Length (parallel to groundwater flow)	34	feet	10.4	meters
Saturated Thickness	25	feet	7.6	meters
Design Period of Performance	3	years	3	years

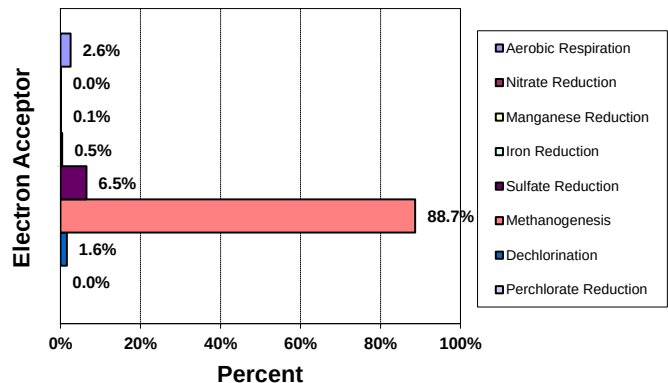
2. Treatment Zone Hydrogeologic Properties

	Values	Units	Values	Units
Total Porosity	0.36	percent	0.36	percent
Effective Porosity	0.22	percent	0.22	percent
Average Aquifer Hydraulic Conductivity	14	ft/day	4.9E-03	cm/sec
Average Hydraulic Gradient	0.00481	ft/ft	0.00481	m/m
Average Groundwater Seepage Velocity	0.31	ft/day	9.3E+00	cm/day
Average Groundwater Seepage Velocity	112	ft/yr	34.1	m/yr
Effective Treatment Zone Pore Volume	244,848	gallons	926,826	liters
Groundwater Flux (per year)	804,566	gallons/year	3,045,529	liters/year
Total Groundwater Volume Treated (over entire design period)	2,658,547	gallons total	10,063,413	liters total

3. Distribution of Electron Acceptor Demand

	Percent of Total	Hydrogen Demand (lb)
Aerobic Respiration	2.6%	2.570
Nitrate Reduction	0.0%	0.049
Sulfate Reduction	6.5%	6.519
Manganese Reduction	0.1%	0.151
Iron Reduction	0.5%	0.460
Methanogenesis	88.7%	89.183
Dechlorination	1.6%	1.616
Perchlorate Reduction	0.0%	0.000
Totals:	100.00%	100.55

Hydrogen demand in pounds/gallon:	3.78E-05
Hydrogen demand in grams per liter:	4.53E-03

Distribution of Electron Acceptors**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	46,606	4,237	1,013	as lactic acid
2. Molasses Product	35,568	2,964	962	as sucrose
3. Fructose Product	28,086	2,508	1,013	as fructose
4. Ethanol Product	14,361	2,081	518	as ethanol
5. Sweet Dry Whey (lactose)	22,153	sold by pound	699	as lactose
6. HRC®	17,029	sold by pound	614	as 40% lactic acid/40% glycerol
7. Linoleic Acid (Soybean Oil)	8,744	1,121	394	as soybean oil
8. Emulsified Vegetable Oil	14,573	1,868	394	as soybean oil

Notes:

- Quantity assumes product is 60% sodium lactate by weight.
- Quantity assumes product is 60% sucrose by weight and weighs 12 pounds per gallon.
- Quantity assumes product is 80% fructose by weight and weighs 11.2 pounds per gallon.
- Quantity assumes product is 80% ethanol by weight and weighs 6.9 pounds per gallon.
- Quantity assumes product is 70% lactose by weight.
- Quantity assumes HRC® is 40% lactic acid and 40% glycerol by weight.
- Quantity of neat soybean oil, corn oil, or canola oil.
- Quantity assumes commercial product is 60% soybean oil by weight.

B.3 Injection Point Volume Calculations

SITE NAME: DSCR OU 6 TAC-1	
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	0.03 per Remediation Engr Design Concepts, 2nd Edition, pp 177
h	28 feet injection interval thickness
r_{inj}	12 feet desired radius of influence
V_{inj}	380.0070474 ft ³
	2842.6 gallons Delivery volume over the treated interval
	101.5 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:

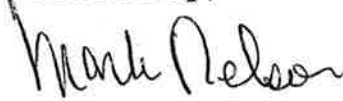
We have received correspondence from your consultant, AECOM Technical Services, dated February 28, 2013 describing ground water remediation efforts at the above referenced facility. We understand that you intend to utilize enhanced in-situ bioremediation processes, involving shallow injection wells, 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,

A handwritten signature in dark ink, appearing to read "Mark Nelson", with a stylized, cursive script.

Mark A. Nelson, Hydrologist
Water Protection Division

/ Cc: Manish M. Joshi, AECOM



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
Four Penn Center
1600 John F. Kennedy Boulevard
Philadelphia, Pennsylvania 19103-2852

EPA Comments on *Draft Remedial Action Work Plan Addendum – Building 65 Injections Technical Memorandum*, dated December 1, 2022

January 17, 2023

Comment from USEPA Hydrogeologist, Ryan Bower

Overall, the planned injection approach appears sufficient and the performance monitoring adequate. My only suggestion would be to collect a Microbial Assay at a downgradient location from either the Quarterly or Semi-Annual Monitoring Well Network(s) depicted on **Figure 7**. While the VOC data will ultimately demonstrate the effectiveness of the injection, it would be beneficial to assess whether any downgradient DHC communities are present.

Project name:
DLA – DSCR

Project ref:
60598154

From:
AECOM

Date:
January 18, 2023

To:
Defense Logistics Agency
United States Army Corps of Engineers,
Baltimore District

CC:

Response to Comments

Subject: Draft Remedial Action Work Plan Addendum - Building 65 Injections, Defense Supply Center
Richmond, December 1, 2022

The following comments were received on 17 January 2023 from Ryan Bower, United States Environmental Protection Agency, Region 3, transmitted by email from Andrea Barbieri, the EPA Remedial Project Manager.

Comment from USEPA Hydrogeologist, Ryan Bower

Overall, the planned injection approach appears sufficient and the performance monitoring adequate. My only suggestion would be to collect a Microbial Assay at a downgradient location from either the Quarterly or Semi-Annual Monitoring Well Network(s) depicted on Figure 7. While the VOC data will ultimately demonstrate the effectiveness of the injection, it would be beneficial to assess whether any downgradient DHC communities are present.

Response

The project team proposes to add Microbial qPCR analysis at quarterly monitoring location OU8-MW-72. This location is downgradient of the in situ bioremediation area shown in Figure 7 of the Remedial Action Work Plan Addendum. Sample results from October 2022 below show that well OU8-MW-72 has the highest overall constituent concentrations for downgradient wells near the injection area.

Sample Results Downgradient of Building 65 In Situ Bioremediation Injection Area: October 2022

Location Sample Date				DMW-24A 10/20/2022	DMW-30A 10/26/2022	DP-11 10/24/2022	DP-12 10/26/2022	OU8-MW-115 10/24/2022	OU8-MW-50 10/27/2022
Constituent	Cas Number	Unit	MCL						
Tetrachloroethene	127-18-4	ug/L	5	13	22	9.3	3.7	18	0.38
Trichloroethene	79-01-6	ug/L	5	5.1	9.0	17	7.5	17	< 0.20
cis-1,2-Dichloroethene	156-59-2	ug/L	70	9.9	8.1	8.6	6.3	12	< 0.25
trans-1,2-Dichloroethene	156-60-5	ug/L	100	< 0.34	0.43	0.90	< 0.34	< 0.34	< 0.34
Vinyl chloride	75-01-4	ug/L	2	< 0.40	11	0.46	0.40	2.1	< 0.40

Location Sample Date				OU8-MW-51 10/26/2022	OU8-MW-67 10/25/2022	OU8-MW-68 10/27/2022	OU8-MW-70 10/24/2022	OU8-MW-72 10/26/2022	OU8-MW-75 10/20/2022
Constituent	Cas Number	Unit	MCL						
Tetrachloroethene	127-18-4	ug/L	5	< 0.35	< 0.35	< 0.35	< 0.35	9.8	29
Trichloroethene	79-01-6	ug/L	5	0.26	0.33	1.4	< 0.20	47	0.61
cis-1,2-Dichloroethene	156-59-2	ug/L	70	2.9	11	9.7	0.67	95	< 0.25
trans-1,2-Dichloroethene	156-60-5	ug/L	100	< 0.34	< 0.34	< 0.34	< 0.34	6.8	< 0.34
Vinyl chloride	75-01-4	ug/L	2	0.45	3.8	9.4	< 0.40	25	< 0.40

Notes: µg/L = micrograms per liter, MCL = maximum contaminant level 47 = Concentration greater than the MCL

Appendix D IPaC Report for Offsite Work Area (July 21, 2025)

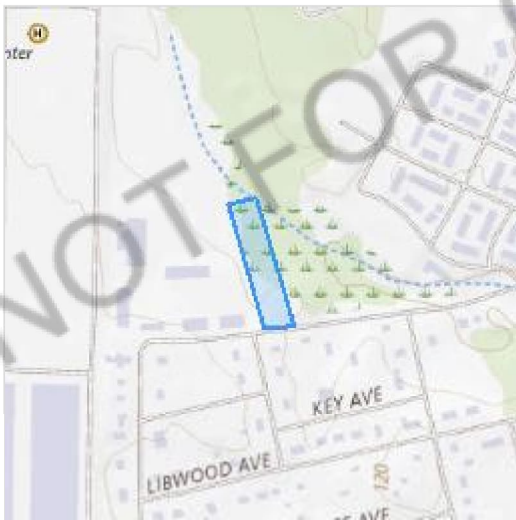
IPaC resource list

This report is an automatically generated list of species and other resources such as critical habitat (collectively referred to as *trust resources*) under the U.S. Fish and Wildlife Service's (USFWS) jurisdiction that are known or expected to be on or near the project area referenced below. The list may also include trust resources that occur outside of the project area, but that could potentially be directly or indirectly affected by activities in the project area. However, determining the likelihood and extent of effects a project may have on trust resources typically requires gathering additional site-specific (e.g., vegetation/species surveys) and project-specific (e.g., magnitude and timing of proposed activities) information.

Below is a summary of the project information you provided and contact information for the USFWS office(s) with jurisdiction in the defined project area. Please read the introduction to each section that follows (Endangered Species, Migratory Birds, USFWS Facilities, and NWI Wetlands) for additional information applicable to the trust resources addressed in that section.

Location

Chesterfield County, Virginia



Local office

Virginia Ecological Services Field Office

☎ (804) 693-6694

6669 Short Lane

Gloucester, VA 23061-4410

Endangered species

This resource list is for informational purposes only and does not constitute an analysis of project level impacts.

The primary information used to generate this list is the known or expected range of each species. Additional areas of influence (AOI) for species are also considered. An AOI includes areas outside of the species range if the species could be indirectly affected by activities in that area (e.g., placing a dam upstream of a fish population even if that fish does not occur at the dam site, may indirectly impact the species by reducing or eliminating water flow downstream). Because species can move, and site conditions can change, the species on this list are not guaranteed to be found on or near the project area. To fully determine any potential effects to species, additional site-specific and project-specific information is often required.

Section 7 of the Endangered Species Act **requires** Federal agencies to "request of the Secretary information whether any species which is listed or proposed to be listed may be present in the area of such proposed action" for any project that is conducted, permitted, funded, or licensed by any Federal agency. A letter from the local office and a species list which fulfills this requirement can **only** be obtained by requesting an official species list from either the Regulatory Review section in IPaC (see directions below) or from the local field office directly.

For project evaluations that require USFWS concurrence/review, please return to the IPaC website and request an official species list by doing the following:

1. Draw the project location and click CONTINUE.
2. Click DEFINE PROJECT.
3. Log in (if directed to do so).
4. Provide a name and description for your project.
5. Click REQUEST SPECIES LIST.

Listed species¹ and their critical habitats are managed by the [Ecological Services Program](#) of the U.S. Fish and Wildlife Service (USFWS) and the fisheries division of the National Oceanic and Atmospheric Administration (NOAA Fisheries²).

Species and critical habitats under the sole responsibility of NOAA Fisheries are **not** shown on this list. Please contact [NOAA Fisheries](#) for [species under their jurisdiction](#).

-
1. Species listed under the [Endangered Species Act](#) are threatened or endangered; IPaC also shows species that are candidates, or proposed, for listing. See the [listing status page](#) for more information. IPaC only shows species that are regulated by USFWS (see FAQ).
 2. [NOAA Fisheries](#), also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

The following species are potentially affected by activities in this location:

Mammals

NAME	STATUS
Tricolored Bat <i>Perimyotis subflavus</i> Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/10515	Proposed Endangered

Insects

NAME	STATUS
Monarch Butterfly <i>Danaus plexippus</i> Wherever found There is proposed critical habitat for this species. Your location does not overlap the critical habitat. https://ecos.fws.gov/ecp/species/9743	Proposed Threatened

Critical habitats

Potential effects to critical habitat(s) in this location must be analyzed along with the endangered species themselves.

There are no critical habitats at this location.

You are still required to determine if your project(s) may have effects on all above listed species.

Bald & Golden Eagles

Bald and Golden Eagles are protected under the Bald and Golden Eagle Protection Act ² and the Migratory Bird Treaty Act (MBTA) ¹. Any person or organization who plans or conducts activities that may result in impacts to Bald or Golden Eagles, or their habitats, should follow appropriate regulations and consider implementing appropriate avoidance and minimization measures, as described in the various links on this page.

Additional information can be found using the following links:

- Eagle Management <https://www.fws.gov/program/eagle-management>
- Measures for avoiding and minimizing impacts to birds
<https://www.fws.gov/library/collections/avoiding-and-minimizing-incident-take-migratory-birds>
- Nationwide avoidance and minimization measures for birds
<https://www.fws.gov/sites/default/files/documents/nationwide-standard-conservation-measures.pdf>
- Supplemental Information for Migratory Birds and Eagles in IPaC
<https://www.fws.gov/media/supplemental-information-migratory-birds-and-bald-and-golden-eagles-may-occur-project-action>

There are Bald Eagles and/or Golden Eagles in your [project](#) area.

Measures for Proactively Minimizing Eagle Impacts

For information on how to best avoid and minimize disturbance to nesting bald eagles, please review the [National Bald Eagle Management Guidelines](#). You may employ the timing and activity-specific distance recommendations in this document when designing your project/activity to avoid and minimize eagle impacts. For bald eagle information specific to Alaska, please refer to [Bald Eagle Nesting and Sensitivity to Human Activity](#).

The FWS does not currently have guidelines for avoiding and minimizing disturbance to nesting Golden Eagles. For site-specific recommendations regarding nesting Golden Eagles, please consult with the appropriate Regional [Migratory Bird Office](#) or [Ecological Services Field Office](#).

If disturbance or take of eagles cannot be avoided, an [incidental take permit](#) may be available to authorize any take that results from, but is not the purpose of, an otherwise lawful activity. For assistance making this determination for Bald Eagles, visit the [Do I Need A Permit Tool](#). For assistance making this determination for golden eagles, please consult with the appropriate Regional [Migratory Bird Office](#) or [Ecological Services Field Office](#).

Ensure Your Eagle List is Accurate and Complete

If your project area is in a poorly surveyed area in IPaC, your list may not be complete and you may need to rely on other resources to determine what species may be present (e.g. your local FWS field office, state surveys, your own surveys). Please review the [Supplemental Information on Migratory Birds and Eagles](#), to help you properly interpret the report for your specified location, including determining if there is sufficient data to ensure your list is accurate.

For guidance on when to schedule activities or implement avoidance and minimization measures to reduce impacts to bald or golden eagles on your list, see the "Probability of Presence Summary" below to see when these bald or golden eagles are most likely to be present and breeding in your project area.

Review the FAQs

The FAQs below provide important additional information and resources.

NAME

BREEDING SEASON

This is not a Bird of Conservation Concern (BCC) in this area, but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities.

<https://ecos.fws.gov/ecp/species/1626>

Probability of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds. Please make sure you read "[Supplemental Information on Migratory Birds and Eagles](#)", specifically the FAQ section titled "Proper Interpretation and Use of Your Migratory Bird Report" before using or attempting to interpret this report.

Probability of Presence (■)

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.
2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is $0.25/0.25 = 1$; at week 20 it is $0.05/0.25 = 0.2$.
3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

To see a bar's probability of presence score, simply hover your mouse cursor over the bar.

Breeding Season (■)

Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

Survey Effort (I)

Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

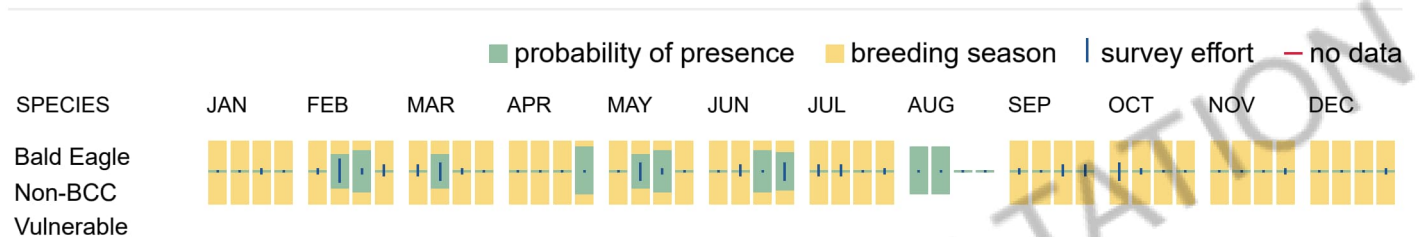
To see a bar's survey effort range, simply hover your mouse cursor over the bar.

No Data (—)

A week is marked as having no data if there were no survey events for that week.

Survey Timeframe

Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.



Bald & Golden Eagles FAQs

What does IPaC use to generate the potential presence of bald and golden eagles in my specified location?

The potential for eagle presence is derived from data provided by the [Avian Knowledge Network \(AKN\)](#). The AKN data is based on a growing collection of [survey, banding, and citizen science datasets](#) and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) which your project intersects, and that have been identified as warranting special attention because they are an eagle ([Bald and Golden Eagle Protection Act](#) requirements may apply).

Proper interpretation and use of your eagle report

On the graphs provided, please look carefully at the survey effort (indicated by the black vertical line) and for the existence of the "no data" indicator (a red horizontal line). A high survey effort is the key component. If the survey effort is high, then the probability of presence score can be viewed as more dependable. In contrast, a low survey effort line or no data line (red horizontal) means a lack of data and, therefore, a lack of certainty about presence of the species. This list is not perfect; it is simply a starting point for identifying what birds have the potential to be in your project area, when they might be there, and if they might be breeding (which means nests might be present). The list and associated information help you know what to look for to confirm presence and helps guide you in knowing when to implement avoidance and minimization measures to eliminate or reduce potential impacts from your project activities or get the appropriate permits should presence be confirmed.

How do I know if eagles are breeding, wintering, or migrating in my area?

To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating, or resident), you may query your location using the [RAIL Tool](#) and view the range maps provided for birds in your area at the bottom of the profiles provided for each bird in your results. If an eagle on your IPaC migratory bird species list has a breeding season associated with it (indicated by yellow vertical bars on the phenology graph in

your "IPaC PROBABILITY OF PRESENCE SUMMARY" at the top of your results list), there may be nests present at some point within the timeframe specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

Interpreting the Probability of Presence Graphs

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. A taller bar indicates a higher probability of species presence. The survey effort can be used to establish a level of confidence in the presence score.

How is the probability of presence score calculated? The calculation is done in three steps:

The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.

To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is $0.25/0.25 = 1$; at week 20 it is $0.05/0.25 = 0.2$.

The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

Breeding Season ()

Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

Survey Effort ()

Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps.

No Data ()

A week is marked as having no data if there were no survey events for that week.

Survey Timeframe

Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.

Migratory birds

The Migratory Bird Treaty Act (MBTA) ¹ prohibits the take (including killing, capturing, selling, trading, and transport) of protected migratory bird species without prior authorization by the Department of Interior U.S. Fish and Wildlife Service (Service).

-
1. The [Migratory Birds Treaty Act](#) of 1918.
 2. The [Bald and Golden Eagle Protection Act](#) of 1940.

Additional information can be found using the following links:

- Eagle Management <https://www.fws.gov/program/eagle-management>
- Measures for avoiding and minimizing impacts to birds
<https://www.fws.gov/library/collections/avoiding-and-minimizing-incidental-take-migratory-birds>
- Nationwide avoidance and minimization measures for birds
- Supplemental Information for Migratory Birds and Eagles in IPaC
<https://www.fws.gov/media/supplemental-information-migratory-birds-and-bald-and-golden-eagles-may-occur-project-action>

Measures for Proactively Minimizing Migratory Bird Impacts

Your IPaC Migratory Bird list showcases [birds of concern](#), including [Birds of Conservation Concern \(BCC\)](#), in your project location. This is not a comprehensive list of all birds found in your project area. However, you can help proactively minimize significant impacts to all birds at your project location by implementing the measures in the [Nationwide avoidance and minimization measures for birds](#) document, and any other project-specific avoidance and minimization measures suggested at the link [Measures for avoiding and minimizing impacts to birds](#) for the birds of concern on your list below.

Ensure Your Migratory Bird List is Accurate and Complete

If your project area is in a poorly surveyed area, your list may not be complete and you may need to rely on other resources to determine what species may be present (e.g. your local FWS field office, state surveys, your own surveys). Please review the [Supplemental Information on Migratory Birds and Eagles document](#), to help you properly interpret the report for your specified location, including determining if there is sufficient data to ensure your list is accurate.

For guidance on when to schedule activities or implement avoidance and minimization measures to reduce impacts to migratory birds on your list, see the "Probability of Presence Summary" below to see when these birds are most likely to be present and breeding in your project area.

Review the FAQs

The FAQs below provide important additional information and resources.

NAME	BREEDING SEASON
Bald Eagle <i>Haliaeetus leucocephalus</i> This is not a Bird of Conservation Concern (BCC) in this area, but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities. https://ecos.fws.gov/ecp/species/1626	Breeds Sep 1 to Jul 31
Chimney Swift <i>Chaetura pelagica</i> This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds Mar 15 to Aug 25

Prairie Warbler *Setophaga discolor*

Breeds May 1 to Jul 31

This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.

Prothonotary Warbler *Protonotaria citrea*

Breeds Apr 1 to Jul 31

This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.

Red-headed Woodpecker *Melanerpes erythrocephalus*

Breeds May 10 to Sep 10

This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.

Wood Thrush *Hylocichla mustelina*

Breeds May 10 to Aug 31

This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.

Probability of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds. Please make sure you read ["Supplemental Information on Migratory Birds and Eagles"](#), specifically the FAQ section titled "Proper Interpretation and Use of Your Migratory Bird Report" before using or attempting to interpret this report.

Probability of Presence (■)

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.
2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is $0.25/0.25 = 1$; at week 20 it is $0.05/0.25 = 0.2$.

3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

To see a bar's probability of presence score, simply hover your mouse cursor over the bar.

Breeding Season (🟡)

Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

Survey Effort (I)

Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

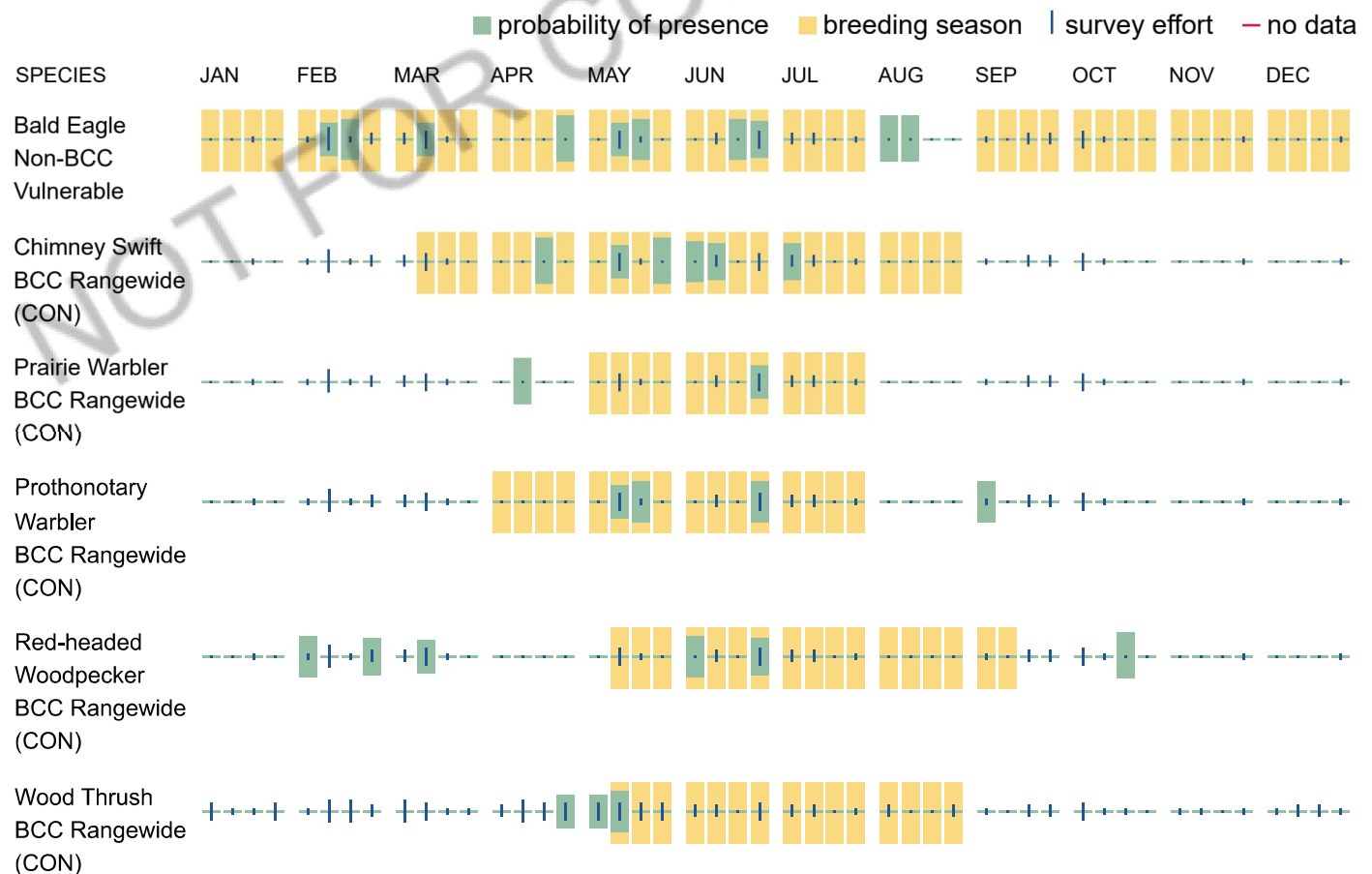
To see a bar's survey effort range, simply hover your mouse cursor over the bar.

No Data (—)

A week is marked as having no data if there were no survey events for that week.

Survey Timeframe

Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.



Migratory Bird FAQs

Tell me more about avoidance and minimization measures I can implement to avoid or minimize impacts to migratory birds.

[Nationwide Avoidance & Minimization Measures for Birds](#) describes measures that can help avoid and minimize impacts to all birds at any location year-round. When birds may be breeding in the area, identifying the locations of any active nests and avoiding their destruction is one of the most effective ways to minimize impacts. To see when birds are most likely to occur and breed in your project area, view the Probability of Presence Summary. [Additional measures](#) or [permits](#) may be advisable depending on the type of activity you are conducting and the type of infrastructure or bird species present on your project site.

What does IPaC use to generate the list of migratory birds that potentially occur in my specified location?

The Migratory Bird Resource List is comprised of [Birds of Conservation Concern \(BCC\)](#) and other species that may warrant special attention in your project location, such as those listed under the Endangered Species Act or the [Bald and Golden Eagle Protection Act](#) and those species marked as "Vulnerable". See the FAQ "What are the levels of concern for migratory birds?" for more information on the levels of concern covered in the IPaC migratory bird species list.

The migratory bird list generated for your project is derived from data provided by the [Avian Knowledge Network \(AKN\)](#). The AKN data is based on a growing collection of [survey, banding, and citizen science datasets](#) and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) with which your project intersects. These species have been identified as warranting special attention because they are BCC species in that area, an eagle ([Bald and Golden Eagle Protection Act](#) requirements may apply), or a species that has a particular vulnerability to offshore activities or development.

Again, the Migratory Bird Resource list includes only a subset of birds that may occur in your project area. It is not representative of all birds that may occur in your project area. To get a list of all birds potentially present in your project area, and to verify survey effort when no results present, please visit the [Rapid Avian Information Locator \(RAIL\) Tool](#).

Why are subspecies showing up on my list?

Subspecies profiles are included on the list of species present in your project area because observations in the AKN for **the species** are being detected. If the species are present, that means that the subspecies may also be present. If a subspecies shows up on your list, you may need to rely on other resources to determine if that subspecies may be present (e.g. your local FWS field office, state surveys, your own surveys).

What does IPaC use to generate the probability of presence graphs for the migratory birds potentially occurring in my specified location?

The probability of presence graphs associated with your migratory bird list are based on data provided by the [Avian Knowledge Network \(AKN\)](#). This data is derived from a growing collection of [survey, banding, and citizen science datasets](#).

Probability of presence data is continuously being updated as new and better information becomes available. To learn more about how the probability of presence graphs are produced and how to interpret them, go to the Probability of Presence Summary and then click on the "Tell me about these graphs" link.

How do I know if a bird is breeding, wintering, or migrating in my area?

To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating, or resident), you may query your location using the [RAIL Tool](#) and view the range maps provided for birds in your area at the bottom of the profiles provided for each bird in your results. If a bird on your IPaC migratory bird species list has a breeding season associated with it (indicated by yellow vertical bars on the phenology graph in your "IPaC PROBABILITY OF PRESENCE SUMMARY" at the top of your results list), there may be nests present at some point within the timeframe specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

What are the levels of concern for migratory birds?

Migratory birds delivered through IPaC fall into the following distinct categories of concern:

1. "BCC Rangewide" birds are [Birds of Conservation Concern](#) (BCC) that are of concern throughout their range anywhere within the USA (including Hawaii, the Pacific Islands, Puerto Rico, and the Virgin Islands);
2. "BCC - BCR" birds are BCCs that are of concern only in particular Bird Conservation Regions (BCRs) in the continental USA; and
3. "Non-BCC - Vulnerable" birds are not BCC species in your project area, but appear on your list either because of the [Bald and Golden Eagle Protection Act](#) requirements (for eagles) or (for non-eagles) potential susceptibilities in offshore areas from certain types of development or activities (e.g. offshore energy development or longline fishing).

Although it is important to avoid and minimize impacts to all birds, efforts should be made, in particular, to avoid and minimize impacts to the birds on this list, especially BCC species. For more information on avoidance and minimization measures you can implement to help avoid and minimize migratory bird impacts, please see the FAQ "Tell me more about avoidance and minimization measures I can implement to avoid or minimize impacts to migratory birds".

Details about birds that are potentially affected by offshore projects

For additional details about the relative occurrence and abundance of both individual bird species and groups of bird species within your project area off the Atlantic Coast, please visit the [Northeast Ocean Data Portal](#). The Portal also offers data and information about other taxa besides birds that may be helpful to you in your project review. Alternately, you may download the bird model results files underlying the portal maps through the [NOAA NCCOS Integrative Statistical Modeling and Predictive Mapping of Marine Bird Distributions and Abundance on the Atlantic Outer Continental Shelf](#) project webpage.

Proper interpretation and use of your migratory bird report

The migratory bird list generated is not a list of all birds in your project area, only a subset of birds of priority concern. To learn more about how your list is generated and see options for identifying what other birds may be in your project area, please see the FAQ "What does IPaC use to generate the migratory birds potentially occurring in my specified location". Please be aware this report provides the "probability of presence" of birds within the 10 km grid cell(s) that overlap your project; not your exact project footprint. On the graphs provided, please look carefully at the survey effort (indicated by the black vertical line) and for the existence of the "no data" indicator (a red horizontal line). A high survey effort is the key component. If the survey effort is high, then the probability of presence score can be viewed as more dependable. In contrast, a low survey effort bar or no data bar means a lack of data and, therefore, a lack of certainty about presence of the species. This list does not represent all birds present in your project area. It is simply a starting point for identifying what birds of concern

have the potential to be in your project area, when they might be there, and if they might be breeding (which means nests might be present). The list and associated information help you know what to look for to confirm presence and helps guide implementation of avoidance and minimization measures to eliminate or reduce potential impacts from your project activities, should presence be confirmed. To learn more about avoidance and minimization measures, visit the FAQ "Tell me about avoidance and minimization measures I can implement to avoid or minimize impacts to migratory birds".

Interpreting the Probability of Presence Graphs

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. A taller bar indicates a higher probability of species presence. The survey effort can be used to establish a level of confidence in the presence score.

How is the probability of presence score calculated? The calculation is done in three steps:

The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.

To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is $0.25/0.25 = 1$; at week 20 it is $0.05/0.25 = 0.2$.

The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

Breeding Season ()

Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

Survey Effort ()

Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps.

No Data ()

A week is marked as having no data if there were no survey events for that week.

Survey Timeframe

Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.

Facilities

National Wildlife Refuge lands

Any activity proposed on lands managed by the [National Wildlife Refuge](#) system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

There are no refuge lands at this location.

Fish hatcheries

There are no fish hatcheries at this location.

Wetlands in the National Wetlands Inventory (NWI)

Impacts to [NWI wetlands](#) and other aquatic habitats may be subject to regulation under Section 404 of the Clean Water Act, or other State/Federal statutes.

For more information please contact the Regulatory Program of the local [U.S. Army Corps of Engineers District](#).

Please note that the NWI data being shown may be out of date. We are currently working to update our NWI data set. We recommend you verify these results with a site visit to determine the actual extent of wetlands on site.

This location overlaps the following wetlands:

FRESHWATER FORESTED/SHRUB WETLAND

[PFO1E](#)

A full description for each wetland code can be found at the [National Wetlands Inventory website](#)

NOTE: This initial screening does **not** replace an on-site delineation to determine whether wetlands occur. Additional information on the NWI data is provided below.

Data limitations

The Service's objective of mapping wetlands and deepwater habitats is to produce reconnaissance level information on the location, type and size of these resources. The maps are prepared from the analysis of high altitude imagery. Wetlands are identified based on vegetation, visible hydrology and geography. A margin of error is inherent in the use of imagery; thus, detailed on-the-ground inspection of any particular site may result in revision of the wetland boundaries or classification established through image analysis.

The accuracy of image interpretation depends on the quality of the imagery, the experience of the image analysts, the amount and quality of the collateral data and the amount of ground truth verification work conducted. Metadata should be consulted to determine the date of the source imagery used and any mapping problems.

Wetlands or other mapped features may have changed since the date of the imagery or field work. There may be occasional differences in polygon boundaries or classifications between the information depicted on the map and the actual conditions on site.

Data exclusions

Certain wetland habitats are excluded from the National mapping program because of the limitations of aerial imagery as the primary data source used to detect wetlands. These habitats include seagrasses or submerged aquatic vegetation that are found in the intertidal and subtidal zones of estuaries and nearshore coastal waters. Some deepwater reef communities (coral or tubercid worm reefs) have also been excluded from the inventory. These habitats, because of their depth, go undetected by aerial imagery.

Data precautions

Federal, state, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of this inventory, to define the limits of proprietary jurisdiction of any Federal, state, or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate Federal, state, or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities.