FINAL
REMEDIAL DESIGN WORK PLAN
Chlorinated Solvents in Groundwater
Former Waldorf Nike Missile Battery W-44
Waldorf, Maryland

Prepared for:

United States Army Corps of Engineers
Baltimore District

Contract No.: W912DR-13-D-0002
Task Order 0005

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LIST OF ACRONYMS

%	percent
µg/L	micrograms per liter
ATEC	ATEC & Associates, Inc.
bgs	below ground surface
CENAB	United States Army Corps of Engineers, Baltimore District
COC	contaminant of concern
CPT	Cone Penetrometer Testing
CT	carbon tetrachloride
CVOC	chlorinated volatile organic compound
DCE	dichloroethylene
DD	Decision Document
DHC	Dehalococcoides
DNA	deoxyribonucleic acid
DNAPL	dense non-aqueous phase liquid
DO	dissolved oxygen
DoD	Department of Defense
DPT	direct-push technology
EHC® Plus	PeroxyChem EHC® Plus ISCR reagent
ERT	ERT, Inc.
Fe+2	ferrous iron
FFS	Focused Feasibility Study
ft/d	feet per day
FUDS	Formerly Used Defense site
H&S	health and safety
Halliburton NUS	Halliburton NUS Environmental Corporation
ISCR	in-situ chemical reduction
LUCs	land use controls
MCL	Maximum Contaminant Level
MDE	Maryland Department of the Environment
MIHS	Maryland Indian Heritage Society
MIP	membrane interface probe
NTUs	nephelometric turbidity units
ORP	oxidation-reduction potential
PAC	powdered activated carbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene
PeroxyChem	PeroxyChem, LLC
PRDI	pre-remedial design investigation

psi	pounds per square inch
RAOs	Remedial Action Objectives
RD	Remedial Design
RFP	request for proposal
RI	Remedial Investigation
ROI	radius of injection
SMPE	Site Monitoring and Performance Evaluation
SOP	Standard Operating Procedure
SOW	Statement of Work
Stell	Stell Environmental, Inc.
SVOC	semi-volatile organic compound
TCE	trichloroethylene
TMV	toxicity, mobility, and volume
TOC	total organic carbon
TPH	total petroleum hydrocarbons
U.S.	United States
USACE	Unites States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
VCR	Vinyl Chloride Reductase
VOC	volatile organic compound
WESTON®	Weston Solutions, Inc.
ZVI	zero-valent iron

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1.0 INTRODUCTION

1.1 PURPOSE OF WORK PLAN

Stell Environmental, Inc. (Stell) prepared this Remedial Design (RD) Work Plan to describe the methods and activities that will be used for implementation of the selected remedy per the Final Decision Document (DD) dated February 2015 for the former Waldorf Nike Missile Battery W-44 site in Waldorf, Maryland (the site) (ERT, Inc. [ERT] 2015). The selected remedy will remediate chlorinated volatile organic compounds (CVOCs) impacts in groundwater at the site.

Stell developed this Work Plan in accordance with the 23 June 2015 revised request for proposal (RFP) and statement of work (SOW) issued by the United States (U.S.) Army Corps of Engineers (USACE) Baltimore District (CENAB) (CENAB 2015) and Stell's 13 July 2015 Technical Approach and Cost Proposal. Stell teamed with Weston Solutions, Inc. (WESTON®) to execute this task order and prepare this Work Plan under a Prime/Subcontractor relationship.

This RD Work Plan is intended to provide sufficient detail for CENAB to proceed with implementation of the remedial action (RA) at the site.

The Maryland Department of the Environment (MDE) is the lead regulatory agency for this project. Documents are not required to be provided to the U.S. Environmental Protection Agency (USEPA) for review and concurrence.

1.2 WORK PLAN OBJECTIVES

The goals of the Work Plan, per the Stell 13 July 2015 Technical and Cost Proposal, are as follows:

- A comprehensive description of the preferred remedy of in-situ chemical reduction (ISCR) and enhanced bioremediation of CVOCs as presented in the 2015 Final DD.
- A description of the studies that have been performed to support the development and implementation of the preferred remedy.
- Design specifications for ISCR applications, ISCR injection array, calculated application rates, required injection and monitoring equipment, and performance monitoring metrics.
- Descriptions of the necessary institutional controls, permits, and public and private easements that need to be obtained for implementation and long-term monitoring of the remedy.
- Descriptions and specifications for site preparation, remediation and environmental media materials management, and environmental controls that will be used during implementation.
- Environmental health and safety (H&S) management and controls during implementation.
- Site restoration requirements and institutional controls for long-term protectiveness during the remediation period.
- Preparation of a Site Monitoring and Performance Evaluation (SMPE) Plan summarizing the methods that will be used to evaluate if the effectiveness of the remedy in attaining Remedial Action Objectives (RAOs) within the projected remediation period and the metrics used to determine efficacy and progress.

If properly implemented, this Work Plan will meet the project objectives and RAOs stated in the Final DD.

1.3 SITE BACKGROUND

1.3.1 SITE DESCRIPTION

The site is located in Waldorf, Charles County, Maryland (Figure 1-1). The site is defined as all federal, private, and municipal properties that require investigation or remedial activities relative to addressing the release of carbon tetrachloride (CT) and trichloroethylene (TCE) to groundwater, as described in the 2015 DD (ERT 2015). The site boundary and features are shown on Figure 1-2.

The site is a Formerly Used Defense site (FUDS) that was transferred by the Department of Defense (DoD) to Charles County, Maryland, and is leased by Charles County to the Maryland Indian Heritage Society (MIHS) for use as a cultural center.

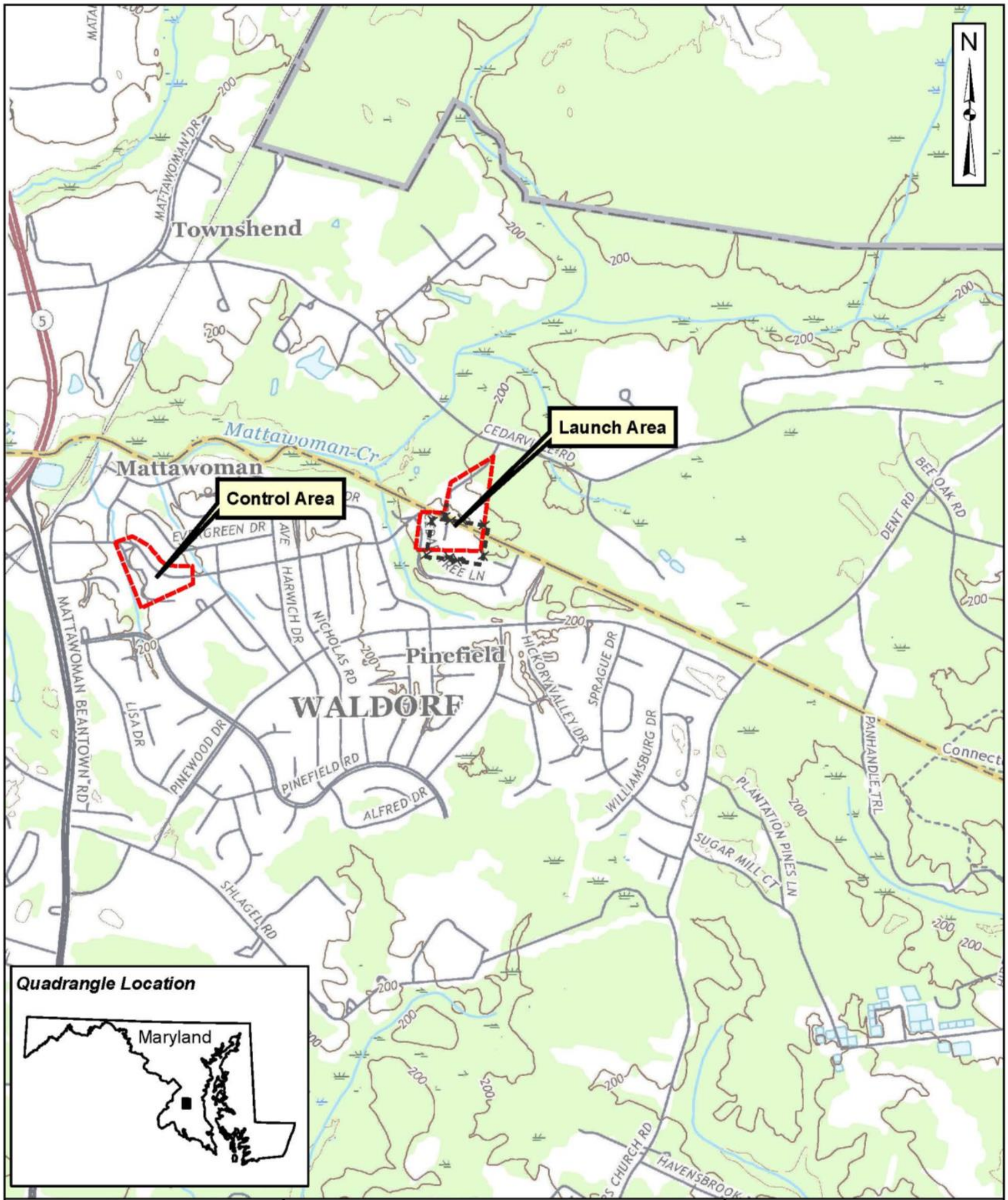
1.3.2 SITE HISTORY

The government acquired two separate properties between 1955 and 1960 to develop Nike Missile Battery W-44, which included a missile Control Area, a missile Launch Area, and easements for access roads. The Launch Area was located in the southern portion of Prince George’s County and the northern portion of Charles County. The Control Area was located approximately 1 mile west of the Launch Area, along Country Lane.

Operations and maintenance at the site included the use of chlorinated solvents such as CT and TCE as cleaning agents for bare metals parts, missile bodies, steering fins, stabilizer fins, ailerons, rocket motor fins, and system components including filters for the launching control group, power simulator group, flight simulator group, and launcher interconnection box. Additionally, CT and TCE were used as degreasing agents and to remove corrosion-prevention compounds from unpainted surfaces of missile stabilizer fins (USACE 2003).

Between June 1965 and February 1986, the 15.1 acres that compose the property for the Launch Area were declared as excess by DoD, and the site was formally transferred to Charles County, Maryland. The county currently leases the land and some buildings to MIHS for use as a cultural center. According to CENAB, all structures, underground storage tanks, and electrical distribution system equipment constructed by DoD remained on the property at the time of conveyance. The boundaries of the property coincide with the FUDS boundary shown in .

The Launch Area became eligible for funding under the FUDS program in 1987. Since then, USACE has conducted several investigations at the site, including groundwater, surface water, surface and subsurface soil, silo sampling, and soil gas. Samples were analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), pesticides, metals, perchlorate, total petroleum hydrocarbons (TPHs), indicators for natural attenuation of VOCs, and radioactivity, and microbial indicators (biological oxygen demand, CENSUS deoxyribonucleic acid [DNA] bioassay for *Dehalococcoides sp.* [DHC]). Additional analyses include cone penetrometer testing (CPT), risk assessment, and a pilot ISCR injection test. Sampling locations from these previous investigations are summarized on Figure 1-3.



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Feet: 0 1,000 2,000

Meters: 0 200 400

Source:
Adapted from USGS 7.5 Min. Topographic Quadrangle for Brandywine, MD (2016), Weston Site Map
Projection:
NAD WGS 1984 UTM Zone 18 North

FIGURE 1-1

SITE LOCATION MAP

Waldorf Nike Site (W-44)

Launch Area Location

Waldorf, Charles County, MD

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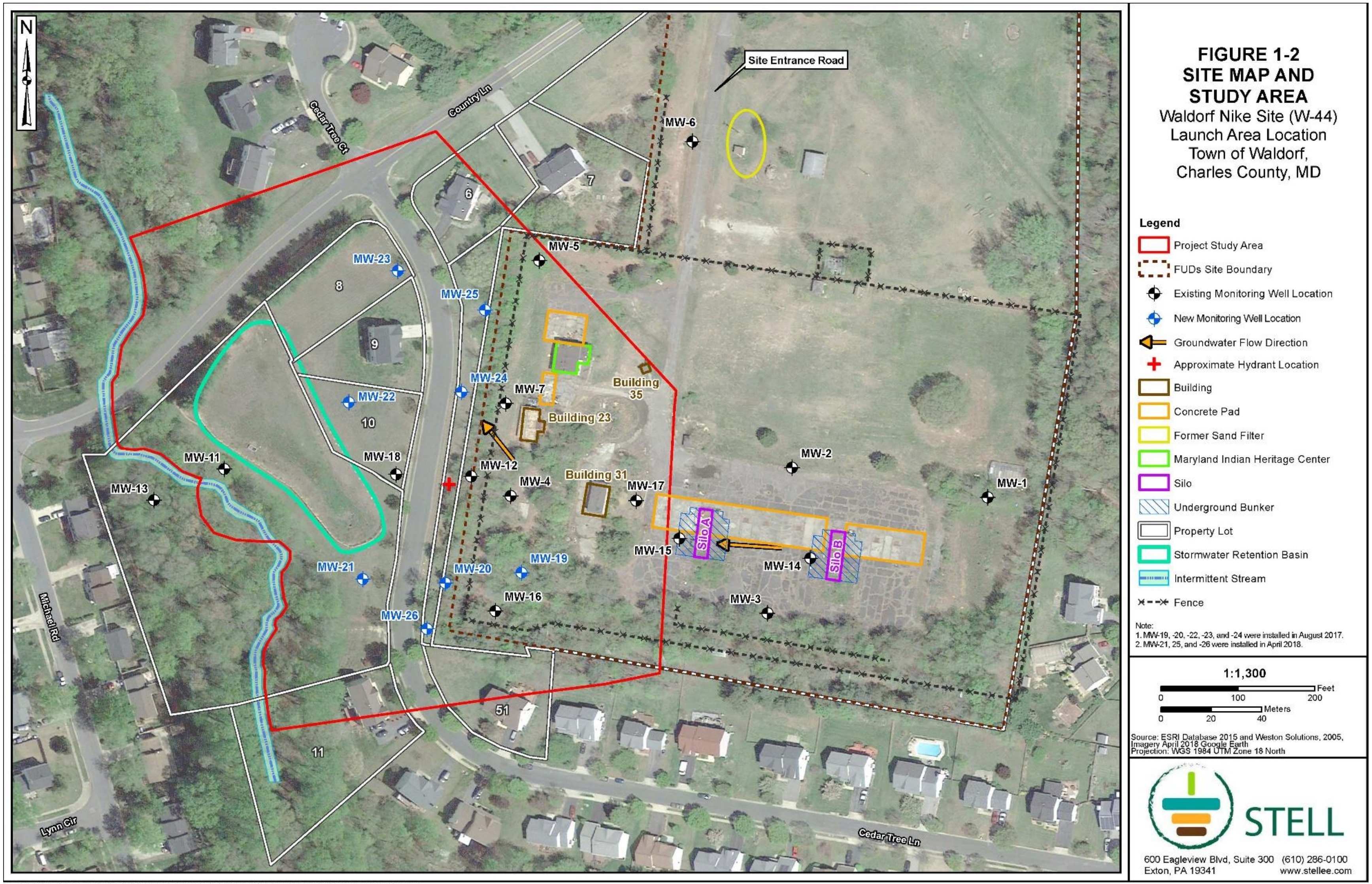

FIGURE 1-2
SITE MAP AND STUDY AREA
Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf,
Charles County, MD

Note:
1. MW-19, -20, -22, -23, and -24 were installed in August 2017.
2. MW-21, 25, and -26 were installed in April 2018.

Source: ESRI Database 2015 and Weston Solutions, 2005,
Imagery April 2018 Google Earth
Projection: WGS 1984 UTM Zone 18 North

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Completed by Brittany McCabe on 2/3/2020 C:\Users\Brittany McCabe\stellee.com\Projects - 1474\MXDs\Remedial Design Work Plan\Figure 1_2_Site_Map.mxd

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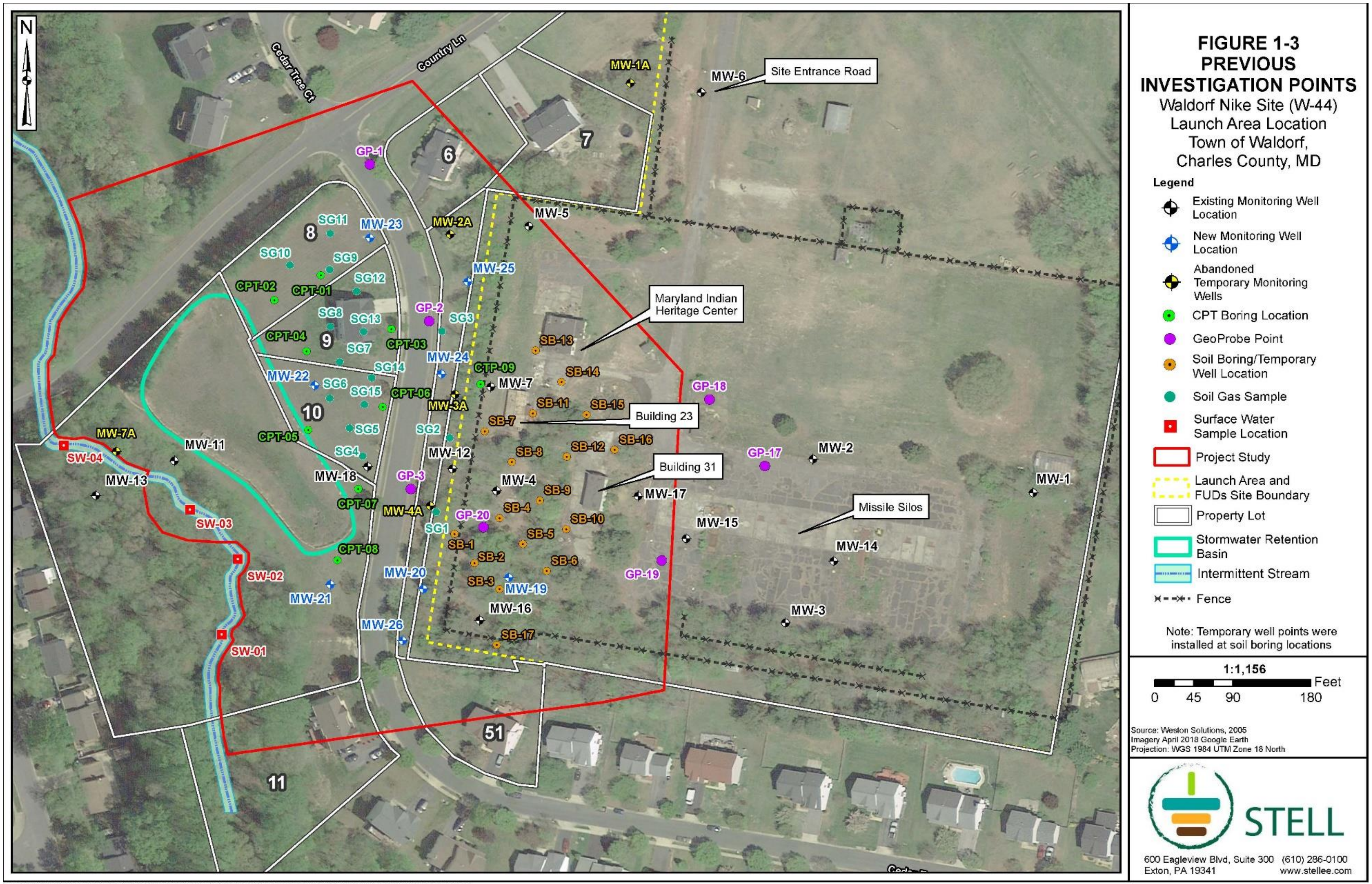

FIGURE 1-3
PREVIOUS INVESTIGATION POINTS
Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf,
Charles County, MD

Note: Temporary well points were installed at soil boring locations

Source: Weston Solutions, 2005
Imagery April 2018 Google Earth
Projection: WGS 1984 UTM Zone 18 North

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Completed by Brittany McCabe on 2/5/2020 C:\Users\Brittany McCabe\stellee.com\Projects - 1474\MXDs\Remedial Design Work Plan\Figure 1_3_Previous Investigation Points.mxd

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During the environmental investigations, groundwater samples collected from monitoring wells immediately adjacent to and downgradient of the Missile Assembly Building (Building 31,) exhibited CT and TCE at concentrations exceeding their respective Maximum Contaminant Levels (MCLs). Other CVOCs were detected at concentrations less than their respective MCLs. Samples collected from monitoring wells MW-4 and MW-12 historically have exhibited the highest concentrations of CT and TCE. This indicates that the source of the contaminants was likely superficial spill(s) of solvents used to clean missile parts on the western side of Building 31 (Stell Environmental, Inc. [Stell] 2017).

1.3.3 PREVIOUS INVESTIGATIONS

Previous investigations, including the summaries of CT and TCE results necessary for the Work Plan development, are summarized below. A complete listing and description of historical data collected is available in the referenced documents and the project administrative record.

1.3.3.1 1986 Donohue Confirmation Study

During the Confirmation Study conducted by Donohue & Associates, five monitoring wells were installed, groundwater samples collected, and additional water samples were collected from missile silos and a water supply well. The groundwater samples were analyzed for metals, TPH, and VOCs. Additionally, soil samples were collected. The soil samples were analyzed for metals, TPH, and VOCs.

CVOCs were detected in groundwater, CT and TCE, were detected in groundwater samples from monitoring wells MW-4 and MW-5 at concentrations exceeding MCLs (Donohue & Associates, Inc. 1987). The locations of MW-4 and MW-5 are shown on and Figure 1-3.

1.3.3.2 1991 Haliburton NUS Site Screening Inspection

During the Site Screening Inspection conducted by Haliburton NUS in 1991, soil, surface water, groundwater, and sediment samples from monitoring wells at the site (Figure 1-3) were analyzed for VOCs, petroleum hydrocarbons, metals, SVOCs, PCBs, and pesticides. Analytical data identified CT and TCE in groundwater at concentrations above MCLs (Halliburton NUS Environmental Corporation [Halliburton NUS] 1992).

1.3.3.3 1993 to 2000 Various Limited Investigations

Between 1993 and 2000, various limited investigations were performed by ATEC Associates, Inc. (ATEC) (1994a, 1994b) and WESTON® (1995, 1996, 2000). The investigations included monitoring well installation and sampling, soil sampling, a soil gas survey along the western extent of the FUDS boundary and downgradient of the boundary, and risk assessment. Data and results of these investigations and risk assessment were summarized and can be reviewed in the WESTON® 2005 Remedial Investigation (RI) Report. Locations are shown on Figure 1-3.

The findings of the investigations relative to the objectives of the response action described in the 2015 DD are:

- CT and TCE concentrations in groundwater samples from monitoring wells MW-4 and MW-7, and in temporary monitoring wells MW-3A and MW-4A, exceeded federal MCLs (groundwater monitoring well locations are shown on). CT was also detected at a concentration exceeding the MCL in direct-push technology (DPT) groundwater sample point GP-3, located immediately downgradient of MW-4. All other CT and TCE concentrations detected were either less than MCLs or non-detect below the MCL (WESTON® 2005).

- Soil gas surveys indicated maximum CT and TCE vapor concentrations of 16 and 23 µg/L in samples collected from SG-1, SG-2, and SG-3 located along the western FUDS boundary (Figure 1-3). Off-site and downgradient soil gas points indicated a maximum CT vapor concentration of 6 µg/L at SG-4 located near the present location of monitoring well MW-18 on unoccupied Lot 10, and a maximum TCE vapor concentration of 0.08 µg/L at SG-11 located on unoccupied Lot 8 (Figure 1-3).
- The risk assessment performed by WESTON® identified the potential exposure pathways for vapor entrance and accumulation in basements and ingestion of groundwater obtained from shallow private wells if installed in the future. Presently, the sole residence downgradient of the FUDS boundary and the adjoining residences obtain drinking water from municipal supply.

1.3.3.4 2001 Cone Penetrometer Testing

CPT was performed at nine locations (CPT-01 to CPT-09) during July 2001 using a truck-mounted cone penetrometer rig and an integrated electrical resistivity cone under the supervision of WESTON® on-site personnel. At each CPT location, groundwater samples were collected (WESTON® 2005). CPT sample locations are shown on Figure 1-3.

1.3.3.5 2003 Silo Investigation

In 2003, samples of standing water were collected from defunct on-site missile silos, Silo A and Silo B, and analyzed for VOCs, perchlorate, and total metals. Perchlorate and VOCs were not detected in samples collected from either silo (WESTON® 2005). The locations of the silos are shown on Figures 1-2 and 1-3.

Three downgradient monitoring wells (MW-14, MW-15, and MW-17) were installed to assess potential leaching of constituents from the silos. Groundwater samples collected from the wells downgradient of the silos did not exhibit detectable levels of any chemicals of potential concern. A dye tracer test was performed to determine if standing water in the silos was potentially leaching from the silos to groundwater. The dye tracer test confirmed that the silos were not leaking and, therefore, not considered to be a hazard to human health or the environment and not a source area contributing to the groundwater contaminant plume at the site (WESTON® 2005).

1.3.3.6 2005 RI Report

The following conclusions were presented in the 2005 RI report:

(1) The two former missile silos at the site are not leaking standing water;

(2) CT and TCE concentrations in groundwater were detected above their respective MCLs;

(3) The unnamed intermittent stream west of the site was not contaminated and could be considered as unthreatened by contamination from the site; and

(4) Potential future groundwater use and the inhalation of vapors associated with contaminant of concern (COC) concentrations are potential exposure pathways (WESTON® 2005).

1.3.3.7 2009 RI Addendum

In 2009, an RI Addendum was conducted by ERT to evaluate the potential risk of COC soil gas intrusion into future on-site and off-site buildings. The RI Addendum concluded that:

(1) Concentrations of CT and TCE in shallow soil gas were below USEPA risk-based screening levels for residential air (USEPA 2002);

(2) Concentrations of CT and TCE in groundwater decreased radially and downgradient of the potential source area at Building 31; and

(3) Concentrations of CT and TCE in groundwater continued to exceed the USEPA MCL (ERT 2009).

The passive soil gas survey reported in the 2009 RI Addendum included 15 soil gas points, 5 of which were located along the western FUDS boundary. CT and TCE were detected at maximum concentrations of 0.17 micrograms per liter (µg/L) and 0.04 µg/L, respectively, at soil gas points SG-1 and SG-2. The concentrations detected were below the site-specific Remedial Goal of 0.33 µg/L calculated in the 2005 WESTON® RI Report.

1.3.3.8 2011 Focused Feasibility Study

The 2011 Focused Feasibility Study (FFS) established RAOs for the site-related COCs and evaluated potential remedial alternatives. The FFS evaluated remedies to address two potential exposure pathways for the COCs: (1) vapors present in the unsaturated zone entering basements on adjacent residential Cedar Tree Properties, and (2) potential future groundwater use (WESTON® 2011). Results of the FFS were used to develop the proposed remedial response action identified in the Proposed Remedial Action Plan that was eventually chosen as the selected remedy in the DD.

1.3.3.9 2012 RI Addendum

In 2011, a second RI Addendum was completed to address data gaps related to the location of a potential source area and to refine the extent of the groundwater plume (ERT 2012). A groundwater sample collocated with boring SB-3 (Figure 1-3) reported a CT concentration of 29.7 µg/L and a TCE concentration of 32.4 µg/L. This sample was located approximately 15 feet north-northwest of an empty, deteriorating steel 55-gallon drum southwest of Building 31. The 55-gallon drum was corroded, broken, and tipped on its side in a ditch. Because of the drum's apparent age and condition, its location upgradient of the groundwater plume, and the presence of TCE in soil samples adjacent to the drum, the deteriorated drum was determined to be a potential source of the groundwater plume (ERT 2012).

In addition, indoor air samples were collected in 2010 from the basement and first floor of the residential structure situated on Lot 9 (Figure 1-3), west of Cedar Tree Lane, to address the potential for a vapor intrusion pathway in residential structures west of Cedar Tree Lane (ERT 2012). In accordance with USEPA and MDE guidance, indoor air sampling is the most definitive approach for determining if a potential vapor intrusion pathway exists. Based on the results of the indoor air sampling, no COC concentrations were detected. Therefore, the RI Addendum determined that no vapor intrusion pathway exists for residential structures west of Cedar Tree Lane (ERT 2012).

1.3.3.10 2015 Decision Document

The Final DD presents and describes the selected remedy for the site as ISCR with the implementation of land use controls (LUCs) (ERT 2015). LUCs will be implemented to prevent the use of groundwater for drinking purposes at the site and the impacted area downgradient of the site and prevent indoor activities at Buildings 23 and 31 (Figure 1-3), unless the area is ventilated until groundwater COCs achieve the RAOs for the site. The RAOs for the site stated in the DD are as follows:

- Prevent human exposure via inhalation of CT and TCE concentrations above risk-based concentrations; and
- Prevent the use of groundwater until the CT and TCE concentrations in groundwater are below the USEPA MCLs of 5 μg/L.

1.3.3.11 February 2019 Pre-Remedial Design Investigation Final Technical Memorandum

Stell and Weston conducted a pre-remedial design investigation (PRDI) during 2017 and 2018 to determine the current site conditions with respect to groundwater contamination and collect additional information necessary to support this Work Plan. PRDI activities consisted of baseline groundwater sampling, the installation and sampling of eight new monitoring wells (shown on Figure 1-2 and 1-3), assessment of the site's hydraulic conductivity, a bench scale buffer test, and an injection pilot test to assess site injectability, radius of injection (ROI), and optimal site-specific injection protocol. The PRDI also included post-injection groundwater monitoring at MW-4 and MW-19 at 2, 4, and 6-month intervals. Features of the PRDI are shown in Figure 1-4: MW-4/MW-19 Injection Wells and Soil Borings December 2017/April 2018 CT Plume and 1-5.

Current site conditions were determined during the PRDI. The CT and TCE groundwater plumes were delineated (Figure 1-4: MW-4/MW-19 Injection Wells and Soil Borings December 2017/April 2018 CT Plume and 1-5). Aquifer tests were performed to determine hydraulic conductivity. A dense gravel layer above the water-bearing zone prevented the implementation of membrane interface probe (MIP) technology during the PRDI to evaluate EHC® distribution in the subsurface. The PRDI recommended the use of magnetic susceptibility field screening methods and visual color contrast are recommended for future ROI investigations at the site (Stell 2019).

The PRDI produced results indicating the site would be amenable to a large-scale EHC® injection. Using a top-down injection method coupled with water pre-fracturing, EHC® was detected in multiple directions from the injection point at distances of between 3 feet and 6 feet from the injection point. An injection boring spacing interval of 8 feet was recommended for full-scale implementation based on a 4-foot ROI. Additionally, the aquifer geochemistry responded favorably to amendment injections during the PRDI. Oxidation-reduction potential (ORP) was substantially reduced as a result of the injections. Full scale implementation would likely further reduce ORP to desirable levels, further promoting the degradation of TCE. The groundwater pH increased to ranges within or nearly within a range ideal for ISCR following the addition of a buffer solution.

CT concentrations were significantly reduced at MW-4. ISCR appears to be the mechanism behind observed CT reductions. TCE concentrations were not significantly reduced at either monitoring well sampled (MW-4 and -19). Some microbial activity appears to be occurring at the site as indicated by the slight increases in TCE daughter products and slight increases in SVOC degrading microbial populations. Although TCE concentration reduction was limited during the relatively

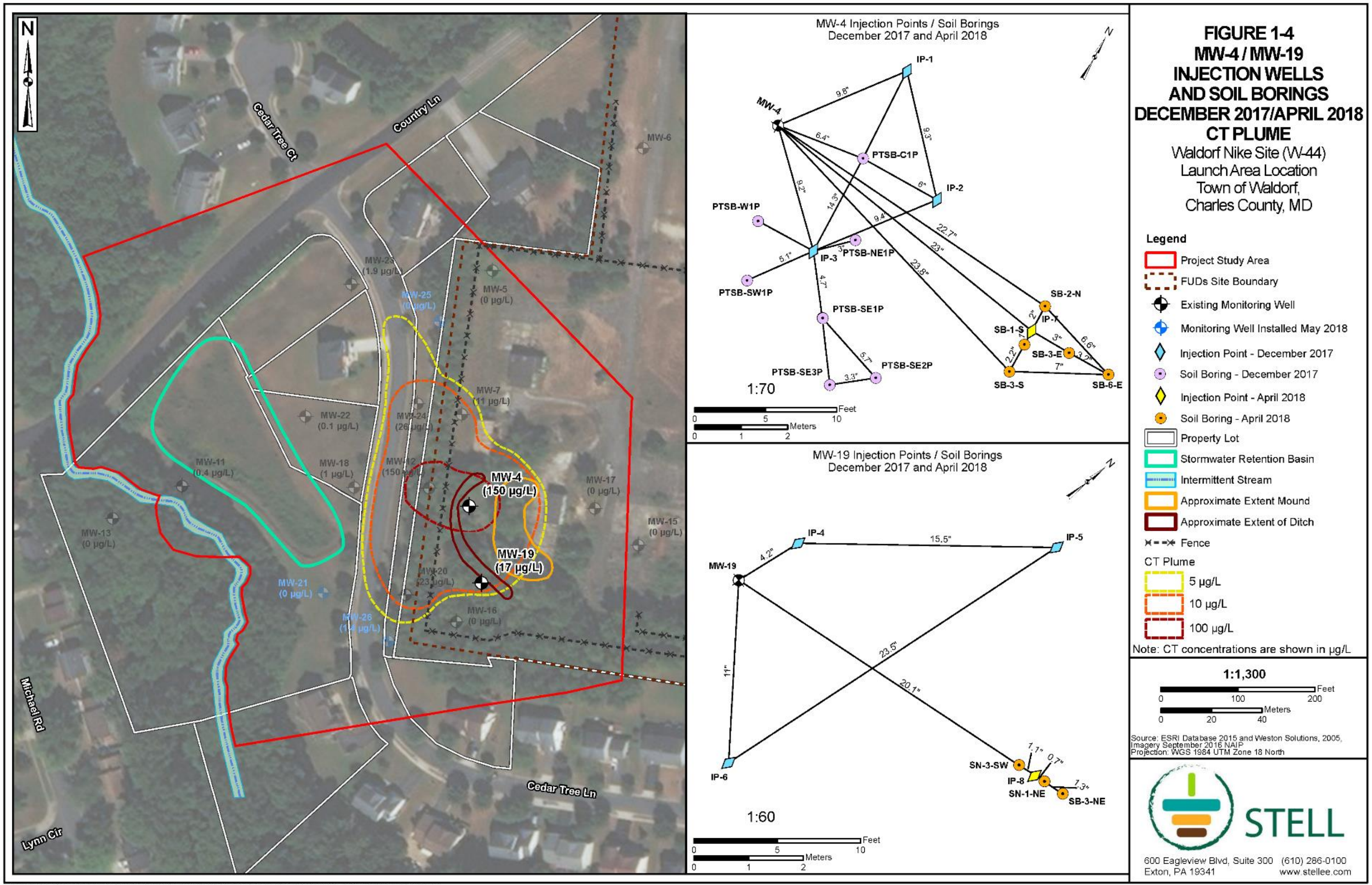

FIGURE 1-4
MW-4 / MW-19
INJECTION WELLS
AND SOIL BORINGS
DECEMBER 2017/APRIL 2018
CT PLUME
Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf,
Charles County, MD

Source: ESRI Database 2015 and Weston Solutions, 2005, Imagery September 2016 NAIP
Projection: WGS 1984 UTM Zone 18 North

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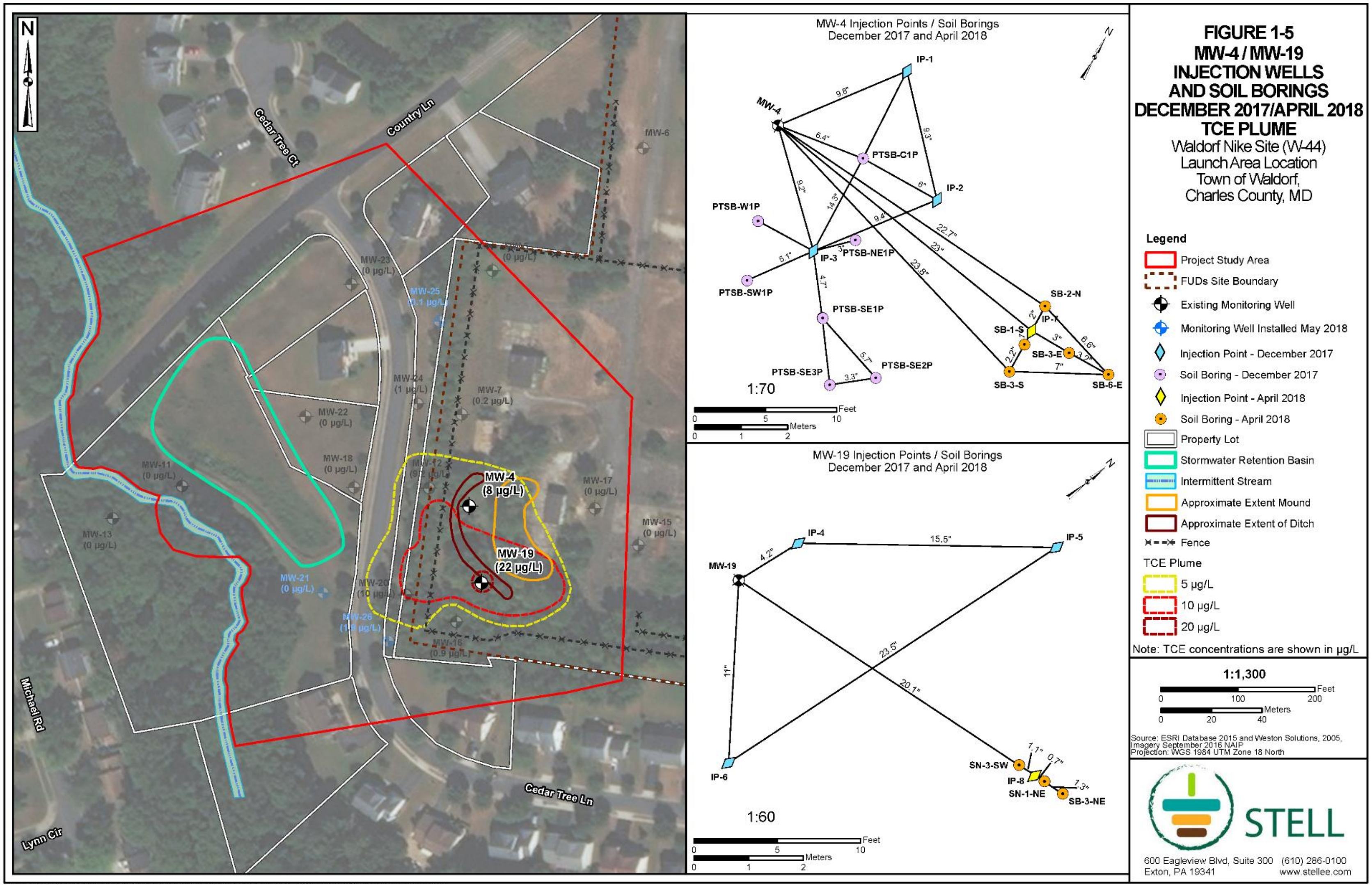

FIGURE 1-5
MW-4 / MW-19 INJECTION WELLS AND SOIL BORINGS DECEMBER 2017/APRIL 2018 TCE PLUME

Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf,
Charles County, MD

Source: ESRI Database 2015 and Weston Solutions, 2005,
Imagery September 2016 NAIP
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small-scale pilot test implementation, the pilot test demonstrated effective reagent distribution and geochemical influence. As previously stated, ORP and pH were not in the ideal ranges for full scale ISCR effectiveness. During full scale implementation, reductions of ORP and increases of pH are expected which are expected to increase TCE degradation (Stell 2019).

1.4 **REMEDIAL ACTION OBJECTIVES**

The 2015 Final DD is the current and guiding document for the selected remedy. This document identifies the selected remedy as ISCR using zero-valent iron (ZVI), combined with LUCs, to prevent exposure to CVOCs until concentrations in groundwater have declined to below USEPA groundwater standards that meet the RAOs (ERT 2015). The DD describes the ISCR amendments as “typically consisting of fibrous organic carbon and microscale ZVI”. The DD further states: “Toxicity, mobility and volume of contaminants will be reduced quickly through abiotic chemical reduction reactions that occur between the VOCs and the reactive iron amendments” and “Additional reductions in TMV of contaminants will occur more gradually via biological transformation processes stimulated by the carbon portion of the in-situ amendments”. Specifically, the selected remedy will address concentrations of CT and TCE in groundwater. The RAOs for the site stated in the DD are as follows:

- Prevent human exposure via inhalation of CT and TCE concentrations above risk-based concentrations.
- Prevent the use of groundwater until the CT and TCE concentrations in groundwater are below the MCL for CT and TCE of 5 μg/L.

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2.0 SITE CHARACTERISTICS

The location of the site is shown in Figure 1-1. The boundaries of the study area at the site are shown in Figure 1-2. The site is located on the boundary of the southern portion of Prince George's County and the northern portion of Charles County, Maryland, approximately 15 miles southeast of the center of Washington, D.C. (Figure 1-1).

2.1 **CLIMATE**

The site is located within the humid subtropical climate zone and exhibits four distinct seasons. The site is in a temperate climate with a warm spring and fall. Annual snowfall in the area averages 15.5 inches. Winter temperatures average around 38 degrees Fahrenheit from mid-December to mid-February. Summers are hot and humid with a July daily average of 79.8 degrees Fahrenheit and average daily relative humidity around 66 percent (%). The combination of heat and high humidity in the summer results in frequent thunderstorms, some of which occasionally produce tornadoes in the area.

Blizzards affect the site on average once every 4 to 6 years. Hurricanes occasionally track through the area in late summer and early fall but are often weakened by the time they reach the site area, partly due to its inland location.

2.2 **TOPOGRAPHY**

The elevation of study area ranges from approximately 210 to 186 feet above mean sea level. The site is very similar to the physical geography of much of Maryland and is typically flat and forested. The topography at the site is mostly level, having a relief of less than 5 feet relative to Cedar Tree Lane, which parallels the site on the west (Figure 1-2). The surface gradient at the site dips to the west/southwest toward the stormwater detention basin and an unnamed intermittent tributary to Mattawoman Creek on the other side of Cedar Tree Lane. The surrounding area is bounded by low-density residential neighborhoods and forest. There is one unnamed intermittent tributary that borders the study area on the west (Stell 2017)

2.3 **GEOLOGY/HYDROGEOLOGY**

2.3.1 GEOLOGY

The site is located in the Atlantic Coastal Plain physiographic province, and the area is underlain by sedimentary and metamorphic rocks. The sedimentary deposits consist of gravels, sands, silts, and clays up to 2,000 feet thick. The metamorphic rock formations consist of granite, gabbro, quartz diorite, schist, rhyolite, greenstone, and quartzite (Stell 2017).

The shallow deposits in the area surrounding the site consist of Quaternary-age Upland and Lowland Deposits made up of sand and gravel with some silt and clay. In the region, these two units have a maximum combined total thickness of 200 feet. Underlying these deposits are the Calvert, Nanjemoy, and Marlboro Clay Formations, and the upper portion of the Aquia Formation. All of these formations are confining units with a total thickness of 150 to 300 feet. Underlying these deposits are the Monmouth, Magothy, and Patapsco Formations. These formations are all productive aquifers in the region (WESTON® 2005).

The subsurface of the site is summarized in Figures 2-1 through 2-3.

2.3.2 HYDROGEOLOGY

The primary water-bearing geologic unit at the site consists of interbedded sands and gravels from the Monmouth, Magothy, and Patapsco Formations. The average vertical hydraulic conductivity of these formations is 1.0 X 10^{-5} feet per day (ft/d) (WESTON® 2011). Water storage and movement in these unconsolidated deposits occur within the interstices or voids of the unconsolidated overburden. Based on aquifer test results, the 2005 RI determined a representative hydraulic conductivity of 9.3 ft/d and effective porosity of 0.35 (WESTON® 2005). Additional aquifer tests were performed by Stell in 2017. After removing falling head tests from wells with partially-submerged screens the hydraulic conductivity results (averaged for each well if more than one valid test was available) ranged from 1.8 feet per day ft/d at MW-19 to 30.3 ft/d at MW-16. If only slug tests with at least three valid tests are considered, the range of average hydraulic conductivity values at each well ranged from 2.8 ft/d at MW-22 to 19.0 ft/d at MW-4. This range is consistent with the 2005 aquifer test results and expectations for a silty sand aquifer.

Based on soil borings performed during the 2017 and 2018 PRDI, aquifer materials impacted by CVOCs consist of silty, poorly sorted fine to coarse sands with some gravel content (Figure 2-2 and 2-3). A contiguous clayey silt unit, believed to be a confining unit, was encountered below the sand and gravel groundwater-bearing zone. This clayey silt unit is greater than 16 feet thick at some locations and, based on the cone penetrometer dynamic pore pressure data, the hydraulic conductivity of the clayey silt unit is low (approximately 1.4 X 10^{-3} ft/d), making the unit a potential lower confining aquitard or aquiclude for the shallow aquifer (WESTON® 2005).

The depth to groundwater (shallow aquifer) at the site is on the order of 5 to 15 feet below ground surface (bgs). Groundwater flow at the site is generally west and northwest at an average gradient of approximately 0.012 (WESTON® 2005). Figure 2-4 is a representative map of the groundwater potentiometric surface of the shallow aquifer at the site from August 2018.

Based on 2017 hydraulic conductivity results of 1.8 to 30.3 ft/d, typical groundwater gradient of 0.012, and assumed effective porosities of 0.25 to 0.35 for a silty gravel and sand mixture (Fetter 2001), the linear groundwater flow velocity across the site ranges from 0.09 to 1.04 ft/d, with an average groundwater flow velocity of 0.75 ft/d. This is equivalent to approximately 274 feet per year.

The shallow aquifer is unconfined and recharged locally by direct precipitation and infiltration. The deeper aquifers are recharged through slow percolation of local precipitation and infiltration of precipitation through outcrops located west of the Potomac River in Virginia (WESTON® 2005).

2.3.3 SURFACE HYDROLOGY

The site is generally flat terrain. There appears to be little potential for significant runoff to leave the site. Surface drainage on the western side of the site flows approximately 300 feet overland southwest to Mattawoman Creek. Surface water runoff east of Cedar Tree Lane is collected in storm drains and discharged into an unlined stormwater detention basin west of the site, between Lots 8, 9, and 10 and the intermittent stream (Figure 1-2). Stormwater drains from the detention basin through a flow-control culvert on the western side of the basin to the intermittent stream.

Residual stormwater not drained from the basin infiltrates to the shallow groundwater table. The intermittent stream flows northward approximately 600 feet to its confluence with Mattawoman Creek. Mattawoman Creek flows west and southwest and eventually discharges into the Potomac

FIGURE 2-1
SITE MAP AND
CROSS SECTION
Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf,
Charles County, MD

Source: ESRI Database 2015 and Weston Solutions, 2005,
Imagery April 2018 Google Earth
Projection: WGS 1984 UTM Zone 18 North

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Completed by ATuleya on 4/18/2019 C:\Users\atuleya\stellee.com\Projects - 1474\MXDs\Remedial Design Work Plan\Figure 2-1 Cross Section Site Map.mxd

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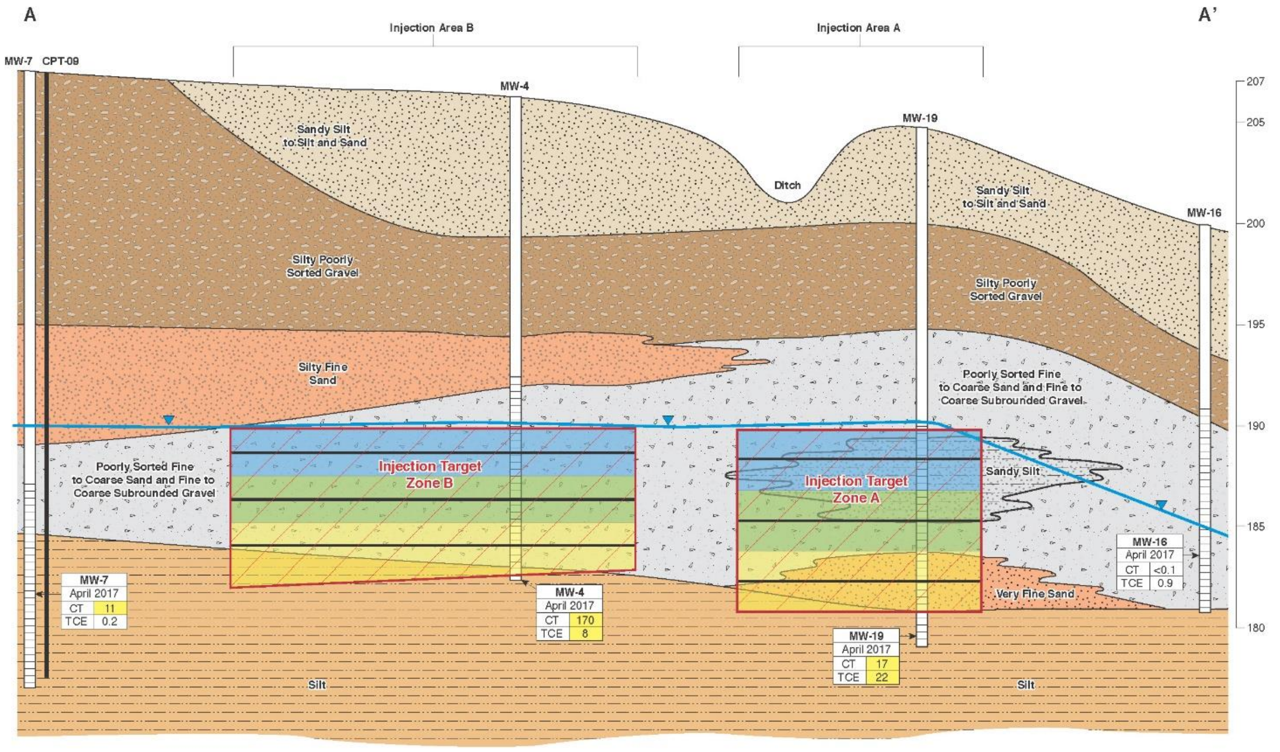

19P-0061-1

FIGURE 2-2
CROSS SECTION A-A'

Remedial Action Work Plan
Town of Waldorf,
Charles County, MD

LEGEND

- Water Table
- Soil Boring
- Well Riser
- Well Screen
- EHC® Pressure Fracture and Injection

Notes:
CT = Carbon Tetrachloride
TCE = Trichloroethene
Concentrations are in micrograms per Liter.
Elevations are in feet above mean sea level.
Boring CPT-09 collected during Remedial Investigation, FINAL Remedial Investigation, NIKE Battery Launch Area (W-44), Waldorf, Maryland, Weston Solutions, February 2005.

Horizontal Scale in Feet
0 50 100 150 200

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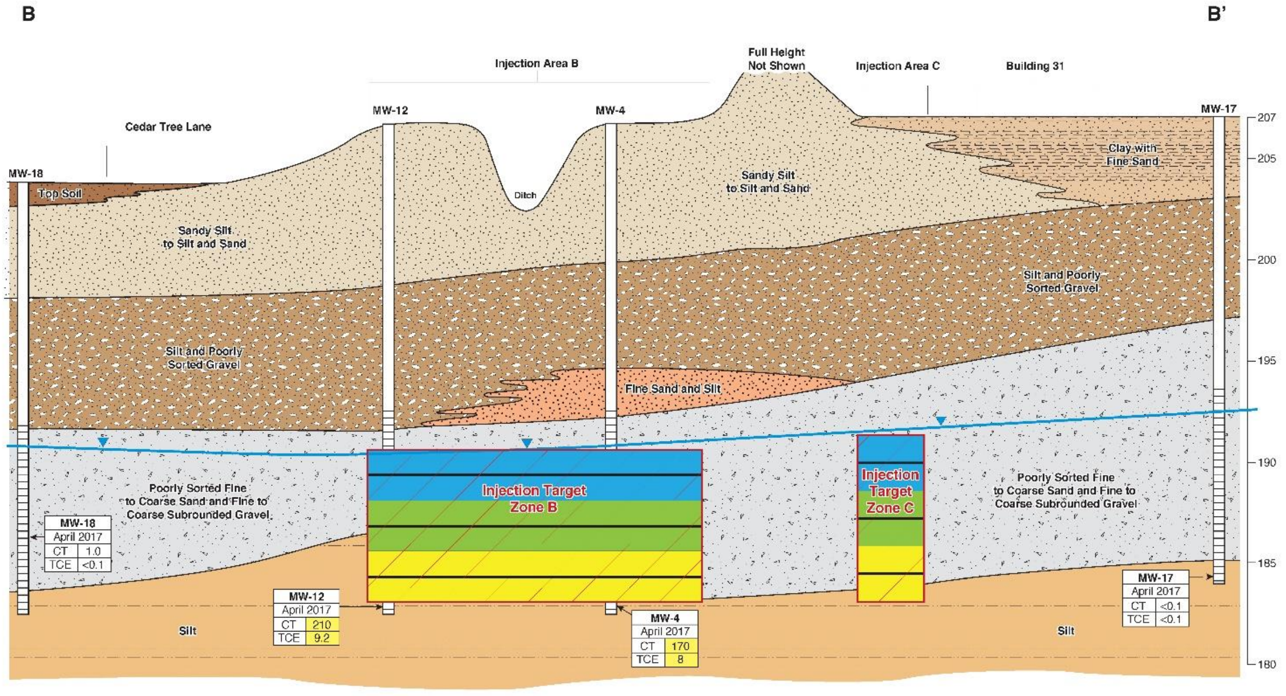

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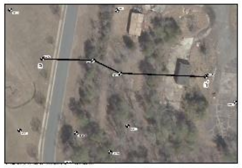
FIGURE 2-3
CROSS SECTION B-B'

Remedial Action Work Plan
Town of Waldorf,
Charles County, MD



LEGEND

- Water Table
- Well Riser
- Well Screen
- EHC® Pressure Fracture and Injection

Notes:
CT = Carbon Tetrachloride
TCE = Trichloroethene
Concentrations are in micrograms per Liter.
Elevations are in feet above mean sea level.

Horizontal Scale in Feet
0 50 100 150 200

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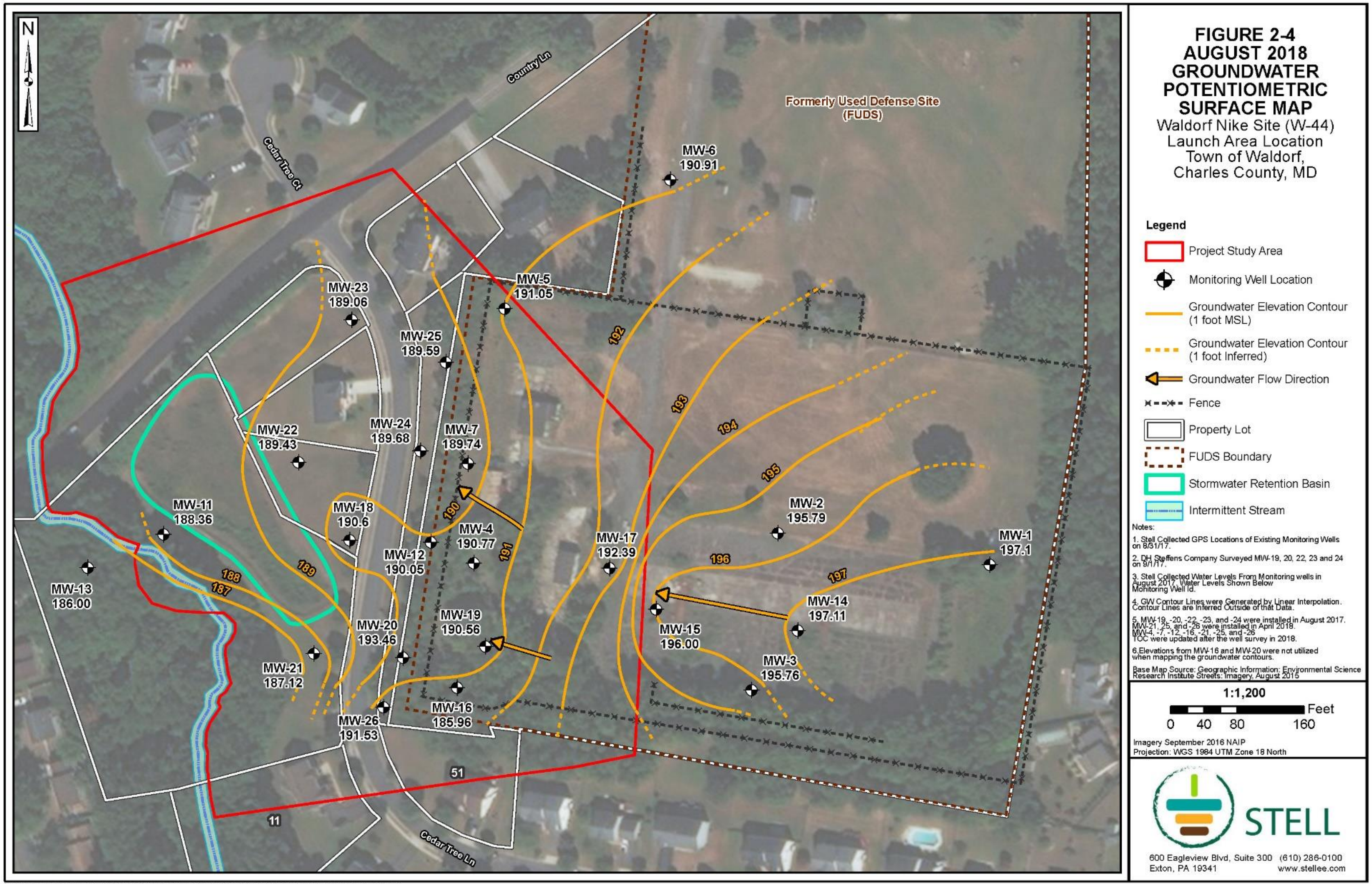

FIGURE 2-4
AUGUST 2018
GROUNDWATER POTENTIOMETRIC SURFACE MAP
Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf,
Charles County, MD

Notes:

1. Stell Collected GPS Locations of Existing Monitoring Wells on 8/31/17.
2. DH Steffens Company Surveyed MW-19, 20, 22, 23 and 24 on 9/1/17.
3. Stell Collected Water Levels From Monitoring wells in August 2017. Water Levels Shown Below Monitoring Well Id.
4. GW Contour Lines were Generated by Linear Interpolation. Contour Lines are Inferred Outside of that Data.
5. MW-19, -20, -22, -23, and -24 were installed in August 2017. MW-21, 25, and -26 were installed in April 2018. MW-4, -7, -12, -16, -21, -25, and -26 TOC were updated after the well survey in 2018.
6. Elevations from MW-16 and MW-20 were not utilized when mapping the groundwater contours.

Base Map Source: Geographic Information: Environmental Science Research Institute Streets: Imagery, August 2015

Imagery September 2016 NAIP
Projection: WGS 1984 UTM Zone 18 North

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River. Another unnamed perennial stream passes approximately 700 feet northeast of the site, flowing northward into Mattawoman Creek about 1,500 feet north of the site. Mattawoman Creek and the unnamed tributary are designated as Class 1 water bodies by the State of Maryland and are protected for the basic uses of water contact recreation; the growth and propagation of fish, other aquatic life, and wildlife; and water supply (WESTON® 2005).

2.3.4 WATER SUPPLY

Shallow unconfined groundwater at the site is not currently used as a potable source of water and will likely not be used in the future. However, the selected remedy will prevent the use of shallow unconfined groundwater until the groundwater concentrations for CT and TCE achieve the RAOs.

The main supply aquifer in the site vicinity is the Magothy Formation, which is roughly 500 feet bgs. Four wells that supply residents in the area are drawing from the Magothy Formation. These wells are located within a 4-mile radius of the site (WESTON® 2005). The Magothy aquifer's recharge area is located in Virginia and is overlain by three main confining units. These aquitards consist of the Calvert, Nanjemoy, and Marlboro Formations, and together are roughly 300 feet thick. Based on site and regional stratigraphy, there is no reasonable potential for contaminants present in the shallow aquifer to migrate laterally or vertically into a drinking water aquifer.

2.4 CURRENT AND POTENTIAL FUTURE LAND USE

After the DoD declared the Waldorf Nike Battery excess between 1965 and 1986, the property was conveyed to other owners. The site is currently owned by Charles County and is leased to the MIHS for use as a cultural center.

The property remains in use by the MIHS, which uses the former personnel barracks, vehicle maintenance building, warhead maintenance building, and generator building remaining at the site (future use is expected to be the same).

Land use adjacent to the site is primarily low-density residential. The Cedar Tree Development residential properties are immediately adjacent to the site and will continue to be so for the foreseeable future.

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3.0 NATURE AND EXTENT OF CONTAMINATION

This section presents the details for the nature and extent of contamination at the site.

3.1 SOURCE AREA

The source of the CT and TCE detected in groundwater is likely a surficial spill or spills of solvents used to clean missile parts west of the Missile Assembly Building (Building 31, Figure 1-2). Based on the results of historical site investigations, a source area in soil for CVOCs has not been clearly identified. CVOCs in soil have not been detected at concentrations exceeding screening levels or at concentrations and distributions indicative of a residual source area in soil. Based on past investigations at the site, USACE believes that any remaining unknown sources are unlikely. Source areas and vadose zone contamination are discussed in the Final Remedial Investigation Report Addendum No.2, Dec 2012 (ERT 2012).

Historical groundwater monitoring since 1987 has consistently detected CVOCs, specifically CT and TCE. These compounds are detected in concentrations exceeding MDE and USPEA screening levels in groundwater. The groundwater contaminant plume was fully delineated during the PRDI, as demonstrated in Figure 1-4: MW-4/MW-19 Injection Wells and Soil Borings December 2017/April 2018 CT Plume and 1-5. The center of mass of the groundwater plume appears to be approximately 100 feet west of the former rocket booster maintenance building (Building 31).

3.2 CARBON TETRACHLORIDE AND TRICHLOROETHYLENE CONCENTRATIONS

CT and TCE maximum concentrations have ranged up to 14 and 450 µg/L, respectively, in groundwater sampled from monitoring well MW-4 located west of Building 31. The solubility of CT and TCE in water is approximately 0.8E+05 and 1.0E+06 µg/L, respectively. Therefore, the presence of a reservoir of dense non-aqueous phase liquid (DNAPL) as a source of CT or TCE at this site is highly unlikely based on the historically low groundwater sampling results and the USEPA guidance, which indicates that concentrations of at least approximately one percent of the contaminant’s solubility limit needs to be present to suggest the presence of DNAPL (USEPA 2004).

PRDI performance monitoring was performed in monitoring wells MW-4 and MW-19 at 2, 4, and 6 months following injection of ISCR reagent. CT concentrations decreased at both monitoring wells in comparison to pre-injection concentrations. The concentrations of TCE did not change; however, there were increases of its breakdown products (cis-1,2-dichloroethylene [DCE], ethene, and ethane) at MW-19. During the PRDI, ORP and pH were not in the ideal ranges for full effectiveness; however, ideal ORP and pH ranges are expected during full scale implementation (Stell 2019).

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4.0 SITE PREPARATION

The site will require some vegetation removal and earth moving site preparation for the ISCR application in the area of the soil mound to provide access for the DPT injection equipment. This area is shown on Figure 5-1 in Section 5.0. The potential area of disturbance is approximately 1,800 square feet.

According to Charles County regulations, the area of disturbance that triggers an Erosion and Sediment Control Plan is 5,000 square feet or 100 cubic yards of soil. Although an Erosion and Sediment Control Plan would not be required, the site clearing and earth moving work will be conducted in accordance with Maryland best management practices for erosion and sediment control. No other environmental controls are anticipated during implementation of the RD.

4.1 SITE CONTROLS

The site is fenced, and the gate is locked. No additional security is planned for the injection equipment. Access to the site will be coordinated through staff at the American Indian Cultural Center located on-site.

LUCs will be implemented to prevent the use of groundwater for drinking purposes at the site and the downgradient impacted area, if necessary, until the CT and TCE concentrations achieved the RAOs.

4.1.1 STAGING AREA PREPARATION

The staging area will serve as the equipment and remedial amendment storage area for the implementation of the RD. The proposed staging area is secure inside locked gate and a chain-link fence surrounding the perimeter of the site. The proposed staging area will be located near defunct Building 31 and missile silos (Figure 1-2). Paved surfaces are also present on-site and will facilitate heavy vehicle traffic (i.e., frac tank mobilization or equipment and amendment deliveries). The injection DPT rig and support trucks may be stored at the staging area overnight, if necessary.

Before beginning the injection program, the following equipment will be staged at the site's staging area and discussed in further detail below:

- Two frac tanks with a volume capacity of approximately 20,000 gallons
- Hose of sufficient length and capacity to connect the frac tanks with the fire hydrant located west of the site
- ISCR application material
- Portable toilet
- Conex box
    - Inoculum (described below) must remain chilled to maintain efficacy. Coolers will be staged in the Conex box, so inoculum can be maintained on ice.
    - Can also be used to store equipment and supplies.

4.1.2 MAKEUP WATER SUPPLY

The makeup water needed to act as the dilution water for the injection will come from a potable water source. This Work Plan proposes to use the fire hydrant located outside the site's perimeter fence (Figure 1-2). This hydrant is located west of the site beyond the site's perimeter fence along Cedar Tree Lane.

As a result of the location of the proposed water source, two frac tanks with a volume capacity of approximately 20,000 gallons will be brought on-site. These frac tanks will be positioned near the injection area and will mix water from the hydrant and ISCR amendment. Water will be added to the frac tanks by running hose from the fire hydrant to the frac tanks. The perimeter fence may have to be temporarily opened to facilitate placement of the hose.

4.1.3 INJECTION CONDITIONING

Prior to mixing, the initial water quality of the potable water from the hydrant will need to be assessed (i.e., pH, ORP, and dissolved oxygen [DO]). This will determine the proper treatment dosage to generate makeup water with anaerobic, reducing conditions. ORP, pH, and DO will be measured using a calibrated multi-parameter water quality meter (YSI Pro Plus, or equivalent).

The makeup water must be anaerobic before injection to prevent conditions that would be detrimental or lethal to dehalogenating bacteria that would support biotic COC degradation. Potable water quality data will also be obtained from the Charles County Public Works Utilities Division to confirm that the water is usable with or without pretreatment.

In order to allow sufficient time to create the necessary anaerobic conditions in the frac tanks, the process of filling these tanks will begin several days before the injections begin. Sodium ascorbate will be added to the makeup water to turn the water anaerobic and neutralize chlorine that could inhibit or kill microbial communities at an initial rate of 2.5 pounds per 1,000 gallons of water. Additional sodium ascorbate will be added if DO is detected at 1 mg/L or greater in the makeup water.

4.1.4 DISCHARGE TO SURFACE WATER BODIES

Based on the depth of injection and dense nature of subsurface materials, surface discharge of injected materials to surface water bodies is unlikely. However, if surface discharge were to occur, the most likely location would be the on-site ditch adjacent to the injection area. The ditch will be visually monitored for surface discharge. If injection amendment discharge is detected visually in the ditch, the injection boring experiencing active injection at the time of the detection will be terminated and abandoned.

4.2 PERMITTING AND ACCESS REQUIREMENTS

The following permits and waivers must be completed and approved before the ISCR injections can take place.

4.2.1 UTILITIES CLEARANCE

Maryland Miss Utility will be notified before intrusive work begins. A private utility locator will also be contracted to screen the planned injection area for utilities and subsurface anomalies.

4.2.2 FIRE HYDRANT PERMIT

If used, a fire hydrant permit would be obtained before withdrawing water from the hydrant. A fire hydrant permit, if issued by Charles County, would require the following:

- Reduced pressure principal backflow preventer assembly, tested annually.
- County-issued water volume meter.
- Compliance with meter reading schedule set forth by Charles County.

4.2.3 INJECTION PERMIT

The Code of Maryland Regulation 26.08.07.01 establishes Maryland’s primacy of the Underground Injection Control Program, which is managed by the MDE, and prohibits any underground injection except as authorized by rule or permit. No permits are required for RAs performed at CERCLA sites. An injection permit would not likely be required from MDE because the injection work would be conducted in accordance with an approved Work Plan. However, MDE would be notified prior to beginning injections and an injection permit would be obtained if required.

4.2.4 MATERIALS MANAGEMENT

Portions of the ISCR applications require additional management. The microbial inoculum must stay cold. Inoculum can be stored for up to three weeks if temperature is maintained between 2 to 4 degrees Celsius. It is the recommendation of this Work Plan to store the inoculum within a Conex box on ice to ensure the material is kept at the correct temperature before application. Additionally, the ISCR application material must be kept dry prior to use.

4.3 SURVEY LOCATIONS AND UTILITY CLEARANCE

Before the start of the injection program, the injection locations will be marked in the field based on existing permanent landmarks (i.e., permanent groundwater monitoring wells). As discussed in Section 4.2.1, a Miss Utility public utility locate request will be submitted and verified for completion before intrusive work begins. The locate request will also be renewed as needed for the duration of intrusive work. Additionally, a private utility locator will be subcontracted to screen the proposed injection area using radiofrequency and ground-penetrating radar utility-locating techniques. Markings emplaced by the private utility locator will be maintained by injection implementation personnel for the duration of intrusive work.

4.4 FIRE HYDRANT WATER SUPPLY

Water for injectate preparation can be obtained from a fire hydrant located west of the injection area along Cedar Tree Lane. Details of permitting and compliance for use of the fire hydrant are described above in Section 4.2.2.

4.5 PRE-INJECTION DEPTH TO GROUNDWATER MONITORING

Prior to the commencement of injections, one round of baseline groundwater monitoring will be conducted. This effort will include the measuring of the static water level and groundwater monitoring.

4.5.1 DEPTH-TO-WATER AND NAPL MEASUREMENT

The static water level of eight groundwater monitoring wells will be determined prior to groundwater sampling. Groundwater elevation measurements will be taken using an interface probe designed to differentiate between two liquid phases, if present. Groundwater elevations will be measured to the nearest 0.01 feet.

The interface probe will be lowered gently into the well casing until it signals contact with the fluid surface in the well, and a level reading will be recorded. The probe will then be lowered to verify the total depth of the monitoring well. The differences between the measured total well depths and constructed well depths will be compared to determine if significant siltation of the well screen has occurred.

Although NAPL has never been detected at the site, if the presence of NAPL is indicated using the interface probe, the probe will be lowered until the NAPL/water interface is detected. This procedure will be continued during total depth measurement to determine if dense NAPL is present in the bottom of the well. Measurements will be referenced to the top of the well casing at a point based on a visual examination of the high-point of the cut casing surface, previously marked reference point, or to magnetic north if the previous points are not discernable. All depth measurements will be interpolated and recorded to one hundredth of a foot.

Depth-to-water and NAPL measurements will be collected for the following wells, which are shown on Figure 1-2:

- MW-4
- MW-7
- MW-12
- MW-17
- MW-18
- MW-19
- MW-20
- MW-24

These measurements will be used to adjust injection depth intervals, which are provided in Tables 5-1 through 5-4, located at the end of Section 5.0.

Of note, during pre-design gauging activities, static water levels observed at wells MW-20 and MW-22 were noted to be above the well screen following installation. Existing well caps at MW-20 and MW-22 should be replaced with vented well caps should the screened intervals at these wells remain fully saturated during subsequent gauging and/or sampling events.

4.5.2 GROUNDWATER MONITORING

The eight groundwater monitoring wells will be purged and sampled for VOCs using a submersible pump with dedicated tubing using low stress (low flow) protocols in accordance with USEPA Standard Operating Procedure (SOP) EQASOP-GW4 (2017). Care must be taken to ensure the sample pump intake is installed within the screened interval at each monitoring well location. Field measurement equipment used during groundwater sampling will consist of a Horiba U-52 water quality meter, or similar instrument, with a flow-through cell and a water level indicator. The Horiba water quality meter will be calibrated each morning prior to usage in the field. Purge water will pass through the Horiba flow-through cell where pH, conductivity, turbidity, DO, temperature, and ORP values will be monitored and recorded on each well's groundwater purge log every 3 to 5 minutes; dependent upon the flow rate to ensure that a minimum of one flow-through cell volume is purged between each consecutive reading. Each well will be purged until the groundwater quality parameters have stabilized, as indicated below, to ensure that formation water is being sampled. Wells will be considered stabilized when the following criteria are observed over three consecutive measurements obtained approximately 3 to 5 minutes apart:

- pH: +/- 0.1 standard pH unit
- Specific conductance: +/- 3%
- Turbidity: +/- 10% nephelometric turbidity units (NTUs)
- DO: within 10%
- Temperature: +/- 3%

- ORP: +/- 10%

Field parameters including pH, DO, and ORP will be monitored to assess geochemical conditions are appropriate for COC degradation.

Ideal field parameter ranges for reductive dechlorination are as follows:

- pH between 5 and 9 standard pH units
- DO less than 0.5 mg/L
- ORP less than -100 mV

Dedicated tubing will be disconnected from the flow-through cell once the water quality has stabilized. Using the same pump and dedicated tubing from the well purging, the groundwater will be transferred directly into laboratory-supplied sample containers. The samples will be shipped to a certified laboratory and analyzed for the following constituents:

- VOCs by USEPA SW-846 Method 8260B
    - VOCs will be monitored to track concentrations of COCs and their degradation products.
- Total iron by USEPA SW-846 Method 6010C
    - Total iron will be monitored to track the presence of iron-based ZVI amendment. Total iron concentrations elevated above background concentrations indicate the likely presence of EHC®.
- Performance monitoring parameters:
    - Performance monitoring parameters will be monitored to track geochemical conditions and their appropriateness for reductive COC degradation. These parameters supplement information provided by measuring field parameters such as pH, DO, and ORP.
    - Total organic carbon (TOC) by USEPA SW-846 Method 9060A
        - TOC at concentrations above approximately 20 mg/L are generally needed to support biotic dechlorination.
    - Alkalinity by Standard Method 2320B
        - Alkalinity can be an indicator of carbon dioxide generated by microbial activity. Generally, an alkalinity twice that of background is interpreted as evidence of microbial activity.
    - Chloride, nitrate, and sulfate anions by USEPA SW-846 Method 9056A
        - Chloride can be a daughter product of organic chlorine. A chlorine concentration of twice background concentration is generally indicative of chlorinated organic compound degradation. Nitrate and sulfate can complete with CVOC degradation and indicate that geochemical conditions are not adequately reducing. Concentrations are ideally less than 1 mg/L and 20 mg/L, respectively.
    - Dissolved gases (methane, ethene, ethane) by Method AM20GAx
        - Methane, ethene, and ethane are CVOC breakdown chain end products and can indicate that complete CVOC breakdown has occurred.
    - Total sulfide by USEPA SW-846 Method 9034

        - Sulfide is an indicator of sulfide-reducing conditions. Sulfide concentrations greater than 1 mg/L are ideal, but this depends on pre-existing sulfur in the system.
    - Total manganese by USEPA SW-846 Method 6020A
        - Manganese can act as a competing electron acceptor to the reductive dehalogenation process.
- Microbial analyses (MW-4, MW-12, and MW-19 only):
    - Census-DNA (DHC). The cell count of the only bacterial group isolated to date that is capable of complete reductive dechlorination of tetrachloroethylene (PCE) and TCE to ethene.
    - Census-DNA (bvcA Reductase – BVC). The bvcA gene encodes the vinyl chloride reductase (VCR) enzyme responsible for reductive dechlorination of vinyl chloride to ethene by DHC.
    - Census-DNA (tceA Reductase – TCE). The tceA gene encodes the enzyme responsible for reductive dechlorination of TCE to DCE in some strains of DHC.
    - Census-DNA (VCR). The vcrA gene encodes the VCR enzyme responsible for reductive dechlorination of DCE and vinyl chloride by DHC.

Groundwater samples will be collected in laboratory-provided containers that hold an appropriate preservative for the proposed test method. The samples will be labeled, placed in an ice-cooled chest, and transported by an overnight courier service to a predetermined laboratory for analysis.

5.0 IN-SITU CHEMICAL REDUCTION APPLICATION METHODOLOGY

The amendments and microbes will be injected into the ground during two separate events. Initially, EHC® Plus (or equivalent) and a potassium bicarbonate buffer will be injected followed by injections of SDC-9 (or equivalent), an inoculum containing a consortium of naturally occurring microbes capable of degrading CT and TCE. ISCR reagent demand and decay rate calculations performed by PeroxyChem, LLC (PeroxyChem), to support development of the RD are provided in Appendix A.

5.1 EHC® PLUS INJECTION COMPOSITION

EHC® Plus is a proprietary amendment used for stimulating ISCR of organic compounds in groundwater and is composed of ZVI nano-particles, controlled release substrate, and nutrients. EHC® Plus is an amendment based on EHC® which was used during the Pre-Remedial Design (Stell 2019). When properly injected, EHC® Plus will rapidly create strong reducing conditions via abiotic and biotic mechanisms. Nano-size (i.e., less than 100 micron) ZVI particles provide substantial reactive surface area that stimulates direct chemical dechlorination of CVOCs upon contact. Additionally, ferrous iron (Fe+2) is generated in the groundwater by the introduction of the ZVI component of EHC® Plus. Following injection, dissolved Fe+2 will migrate into areas with higher redox potential and will precipitate out as various ferrous and ferric compounds, including, but not limited to, iron oxide or sulfide. The iron can act as an oxygen scavenger to help create reducing conditions.

As the bacteria ferment the organic portion of EHC® Plus, they release volatile fatty acids (e.g., lactic, propionic, butyric acids), which diffuse into the groundwater plume and serve as electron donors to stimulate the metabolic processes of other bacteria, including dehalogenators.

In addition to the ZVI and carbon substrate in EHC®, EHC® Plus also contains 15% powdered activated carbon (PAC). PAC is useful in biotic CVOC degradation. Contaminant mass and electron donors supplied by the organic portion of the EHC® Plus are concentrated on PAC particles, allowing dehalogenating bacteria to more effectively metabolize contaminant mass. PAC also sequesters contaminant mass from the dissolved phase, potentially aiding in slowing COC migration via groundwater flow.

EHC® Plus is sold as a solid powder and is prepared as a slurry on-site by mixing with anaerobic water. A product fact sheet for EHC® Plus is included in Appendix B. A potassium bicarbonate buffer will also be added to the slurry to adjust aquifer pH to the ideal pH range for biotic CVOC degradation (6 to 8). The buffer dosing rate was established by a buffer titration bench test conducted by PeroxyChem before implementing the injection pilot test; PeroxyChem's summary report is provided in Appendix C for reference. The PRDI demonstrated that the site's groundwater ranged between 4.5 and 5.5 (Stell 2019).

For each injection point, the slurry will be prepared consisting of 350 pounds of EHC® Plus, 350 pounds of potassium bicarbonate, and 120 gallons of anaerobic water. As discussed previously, sodium ascorbate will be added to the makeup water to turn the water anaerobic and neutralize chlorine that could inhibit or kill the SDC-9 microbes. SDC-9 is discussed in further detail in Section 5.3.

The approximate total quantities of amendments and makeup water are as follows, assuming 194 EHC® Plus injection points and 64 SDC-9 injection points, which is discussed in further detail in the subsequent sections:

- 68,250 pounds of EHC® Plus
- 68,250 pounds of potassium bicarbonate
- 23,400 gallons of anaerobic water
- 59 pounds of sodium ascorbate

The prepared slurry will be injected at three discrete depth intervals and will be preceded by pre-fracturing using anaerobic water, as described below.

5.2 pH BUFFER

Acceptable pH for microbial contaminant degradation is between 5 to 9, with an optimal pH range from 6 to 8. Existing pH values typical of the contaminated aquifer are generally below the ideal range. Additionally, the contaminant degradation process can further lower the pH of the aquifer by generating volatile fatty acids and liberating chloride ions from chlorinated contaminant molecules. Therefore, the pH of the aquifer will be adjusted to the appropriate pH range by injecting potassium bicarbonate buffer concurrently with the EHC® Plus amendment. A bench scale buffer test was performed prior to implementation of the pilot scale injection test and buffer dosing results from the buffer tests were establish buffer dosing rates for the pilot test and full-scale implementation.

5.3 SDC-9 INJECTION COMPOSITION

After the EHC® Plus injection program is complete, the site will be inoculated with SDC-9 (or equivalent) at areas with higher contaminant concentrations. SDC-9 is a consortium of microorganisms used to completely biodegrade TCE to ethene. It contains multiple strains of *Dehalococcoides maccatri* (*DHC*) as well as other bacteria that support the growth of *DHC* populations. SDC-9 is effective where *DHC* is absent and can increase the dechlorination rates. As demonstrated in the 2019 Technical Memorandum, *DHC* populations are not found at this site (Stell 2019). The addition of an inoculum, such as SDC-9, will help ensure that the organic component of the injected EHC® Plus is used for biotic contaminant degradation. A product fact sheet for SDC-9 is included in Appendix B.

SDC-9 is sold in 19-liter stainless steel kegs as a greenish liquid. The SDC-9 inoculum must be maintained on ice until injected. As previously discussed, coolers containing ice will be staged in the Conex box for the purpose of maintaining the ideal temperature of the SDC-9 inoculum. Although SDC-9 has a shelf life of approximately 3 weeks if properly stored, weekly shipments of SDC-9 will be arranged to ensure microbe viability.

The buffer solution used to adjust the groundwater pH for the application of EHC® Plus will also be beneficial for the application of SDC-9; SDC-9 is also most effective in the pH range of 6 to 8.

Care must be taken not to introduce air or aerobic water during the application of the SDC-9 inoculation. Pressurized nitrogen should be used to deliver the SDC-9 to the injection points. If water is used during the inoculation process, anaerobic water should be used.

One liter per inoculum boring of SDC-9 will be applied to the 64 borings shown in Figures 5-1 through 5-4 and summarized in Section 5.7. The total amount of SDC-9 necessary will be calculated determining the total inner volume of hoses and DPT rods that will be used to deliver the SDC-9 inoculum. This will be determined by the injection application subcontractor.

5.4 INJECTION SPACING

Injection amendments will be applied to the most heavily impacted portions of the contaminant plume in four injection areas (Injection Areas A, B, C, and D, as shown on Figures 5-1 through 5-4).

A treatment area of approximately 14,100 square feet is proposed based on the most recent treatment area-wide groundwater sampling results (Figures 1-4 and 1-5). This area was selected to eliminate contaminant source mass identified near Building 31 and along the ditch near monitoring well MW-4. Injection points will be horizontally spaced at 8-foot intervals. This interval assumes an injection ROI of 4 feet. This ROI was determined to be ideal for the site as a result of the PRDI injection test observations (Stell 2019). The DD calls for an injection area approximately 100 feet long by 100 feet wide. However, the approximate 14,100 square foot injection area has been selected based on recent groundwater monitoring results to address apparent contaminant mass source areas. Assuming an injection spacing of 8 feet, approximately 194 injection points of EHC® Plus would be required to apply amendment to the proposed treatment area.

Injection locations will be placed in an offset grid pattern to maximize the distribution effectiveness. Some injection points may have to be omitted or relocated due to site conditions (i.e., topography inaccessible to the injection equipment, subsurface utilities, buried debris, etc.).

5.5 INJECTION AREAS

Injections will be applied sequentially in Injection Areas A, B, C and D, as shown on Figures 5-1 through 5-4.

Injection areas are as follows:

- Injection Area A – selected to degrade CT and TCE mass in the area surrounding MW-19. See Figure 5-2.
- Injection Area B – selected to degrade CT and TCE mass in the area surrounding MW-4 and MW-12 plus the mound area extending east to Injection Area C. See Figure 5-3.
- Injection Area C – selected to degrade suspected CT and TCE mass near Building 31 (suspected source of TCE impacts). See Figure 5-4.
- Injection Area D – selected to degrade CT and TCE mass in the area between MW-4 and MW-19. See Figure 5-2.

The area between Building 31 and MW-4 is characterized by a large topographic mound. It is anticipated that brush clearing and limited earth moving will be required for the DPT equipment to access the mound area to conduct injection operations.

Additionally, there is a ditch shown on Figures 5-1 through 5-3 to indicate that this area may be problematic to access with DPT equipment when injecting the amendments.

5.6 EHC® PLUS INJECTION METHODOLOGY

Injections of the EHC® Plus will be implemented using a pressure-activated injection tooling tip and hollow drive rods. These rods will be advanced into the subsurface by a DPT machine. Injections will be completed using a top-down approach with pre-water fracturing based on favorable results during the injection pilot test using this method. Other injection methods were evaluated during the injection pilot test, including bottom-up and top-down without pre-water fracturing; those methods did not result in the vertical and lateral distribution observed using the top-down with pre-water fracturing method. The amendment slurry will be injected at the shallowest target interval first, subsequently followed by injections into deeper target intervals.

Three injection target intervals have been selected for the application of EHC® Plus. These intervals were established in order to distribute amendments across the CVOC-impacted stratum in the aquifer. The intervals are shown in Tables 5-1 through 5-4.

It is critical that injection depths not exceed 25 feet bgs under any circumstance, so as to prevent penetration of the base of the silt layer, which could result in contaminant migration to the clean units below the silt layer. This is noted here, as well as in Tables 5-1 through 5-4. Injection borings should not penetrate the base of the silt layer encountered at the bottom of the proposed injection intervals. Introducing some remedial amendment within or immediately above the silt layer may help facilitate remediation as some contaminant mass may have infiltrated the silt layer over time, despite its relatively low hydraulic conductivity. Further, emplacing PAC in close proximity to the silt layer may help control back-diffusion that may occur as the more permeable lithologic units are remediated and the more difficult to access silts contribute contaminant mass to the remediated units above it. However, the base of the silt layer should not be penetrated, as to prevent contaminant migration to the clean units below the silt layer.

At each injection location, the DPT machine will advance injection tooling to the shallowest target interval and apply approximately 15 gallons of anaerobic water at approximately 100 to 150 pounds per square inch (psi) of pressure to pre-fracture the aquifer formation. The preparation of the anaerobic water is discussed in Section 4.1.3. During injection, ORP, pH, and DO of the amendment will need to be monitored.

Following pre-fracturing, one-third of the prepared slurry will be injected into the shallowest target interval at an approximate pressure of 200 to 300 psi. The DPT tooling will then be advanced to the next deepest tip opening depth. The pre-fracturing and injection process will be repeated. Once the intermediate depth has been injected, the deepest target interval will be injected.

After completing injections at a given injection point, DPT tooling will be retracted and the borehole will be filled with bentonite chips and hydrated to seal the borehole.

5.7 SDC-9 INJECTION METHODOLOGY

The SDC-9 inoculum will be injected at select injection borings shown on Figures 5-1 through 5-4. Pressure-activated injection tooling tip and hollow drive rods, advanced by a DPT machine, will be used to inject the SDC-9 inoculum.

Care must be taken not to introduce air or aerobic water during the SDC-9 inoculation process. Prior to injecting the SDC-9 inoculum, one system volume of anaerobic water will be pumped through the hoses and DPT rods to ensure that air and anaerobic water have been purged. Pressurized nitrogen should be used to deliver the SDC-9. If water is used during the inoculation process, anaerobic water should be used.

SDC-9 borings will be as close as possible to corresponding EHC® Plus injection borings without causing daylighting of either material. One Liter per boring of SDC-9 will be introduced in accordance with user instructions provided in Appendix B. SDC-9 injections will occur at one depth per boring, at the intermediate tip opening depths summarized in Tables 5-1 through 5-4.

The injection tool tip will be vertically centered within the EHC® Plus injection depth intervals surrounding the SDC-9 injection points.

After applying the SDC-9 inoculum, two system volumes of anaerobic water will be pumped through the hoses and DPT rods to ensure that the inoculum is delivered into the subsurface. DPT rods will then be retracted and the borehole will be filled with bentonite chips and hydrated.

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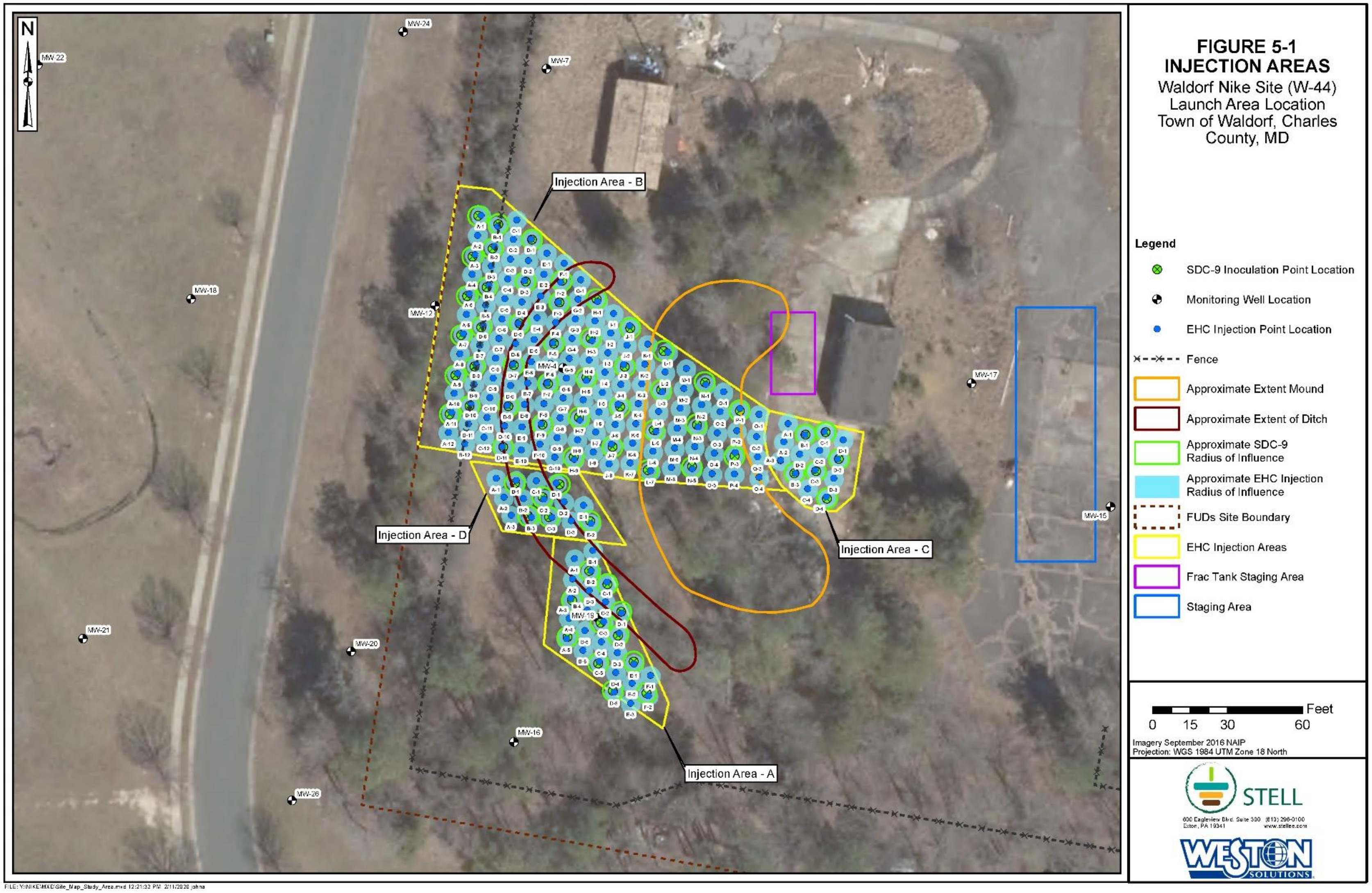

FIGURE 5-1
INJECTION AREAS
Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf, Charles
County, MD

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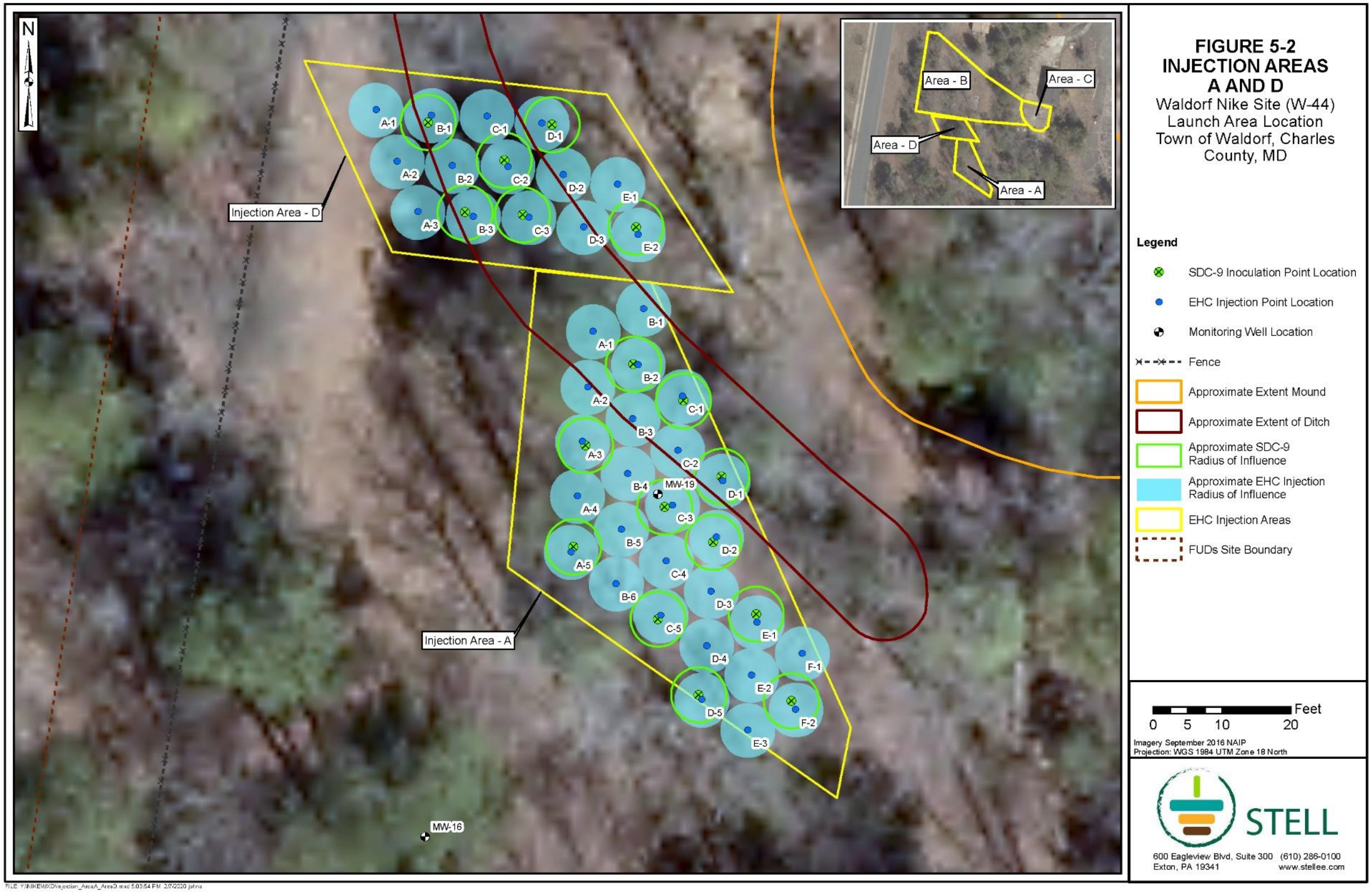

FIGURE 5-2
INJECTION AREAS A AND D
Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf, Charles County, MD

Imagery September 2016 NAIP
Projection: WGS 1984 UTM Zone 18 North

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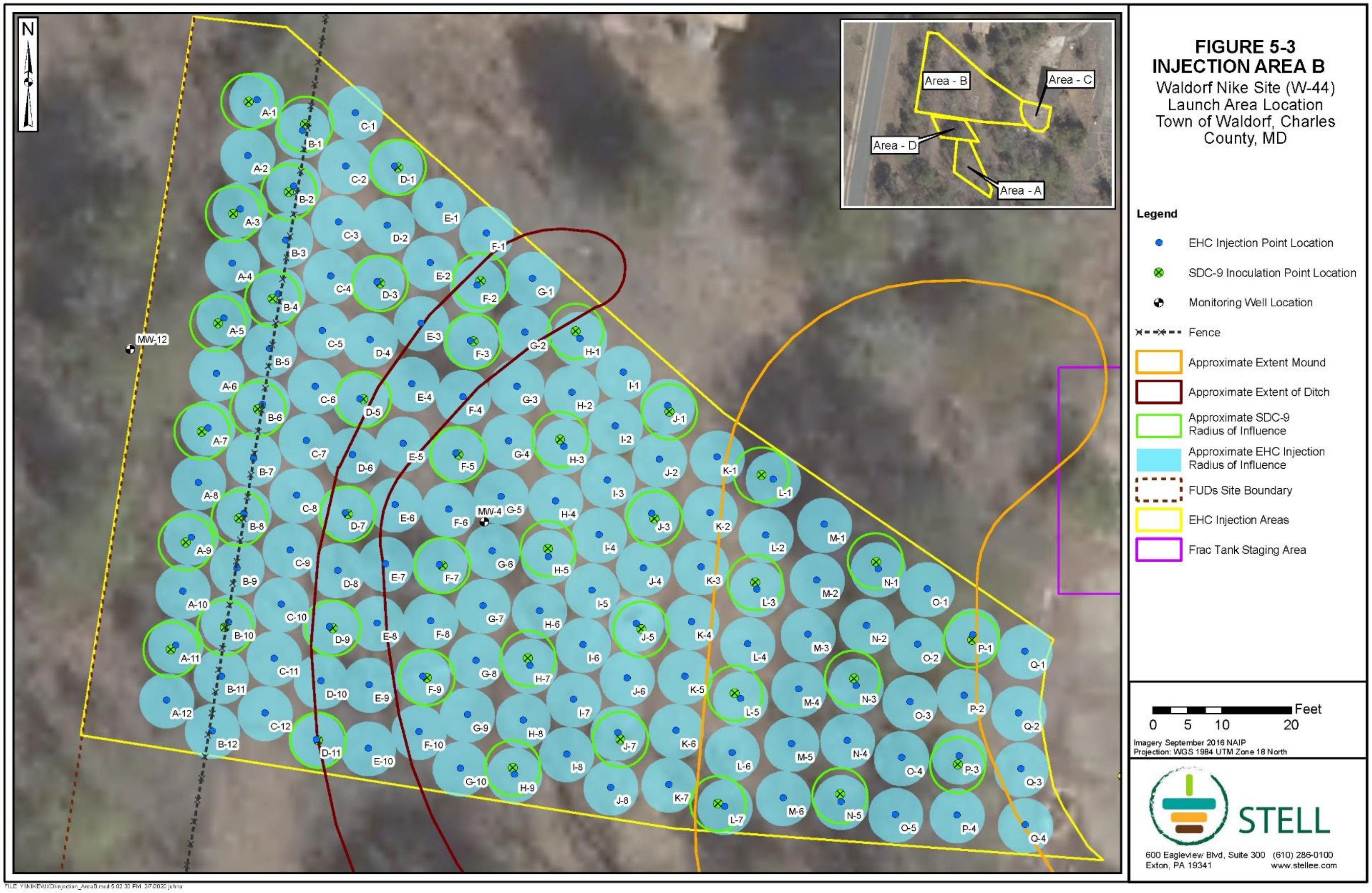

FIGURE 5-3
INJECTION AREA B
Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf, Charles County, MD

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FIGURE 5-4
INJECTION AREA C
Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf,
Charles County, MD

Imagery September 2016 NAIP
Projection: WGS 1984 UTM Zone 18 North

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Table 5-1: Injection Area A Depths and Amendment Amounts

Injection ID	Upper Tip Opening Depths (Feet bgs)	Intermediate Tip Opening Depths (Feet bgs)	Lower Tip Opening Depths (Feet bgs) *	EHC® Plus (Pounds)	Potassium Bicarbonate (Pounds)	Anaerobic Water (Gallons)	SDC-9 (Liters)
A-A1	18	21.5	25	350	350	120	N/A
A-A2	18	21.5	25	350	350	120	N/A
A-A3	18	21.5	25	350	350	120	N/A
A-A3 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
A-A4	18	21.5	25	350	350	120	N/A
A-A5	18	21.5	25	350	350	120	N/A
A-A5 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
A-B1	18	21.5	25	350	350	120	N/A
A-B2	18	21.5	25	350	350	120	N/A
A-B2 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
A-B3	18	21.5	25	350	350	120	N/A
A-B4	18	21.5	25	350	350	120	N/A
A-B5	18	21.5	25	350	350	120	N/A
A-B6	18	21.5	25	350	350	120	N/A
A-C1	18	21.5	25	350	350	120	N/A
A-C1 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
A-C2	18	21.5	25	350	350	120	N/A
A-C3	18	21.5	25	350	350	120	N/A
A-C3 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
A-C4	18	21.5	25	350	350	120	N/A
A-C5	18	21.5	25	350	350	120	N/A
A-C5 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
A-D1	18	21.5	25	350	350	120	N/A
A-D1 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
A-D2	18	21.5	25	350	350	120	N/A

Injection ID	**Upper Tip Opening Depths (Feet bgs)**	**Intermediate Tip Opening Depths (Feet bgs)**	**Lower Tip Opening Depths (Feet bgs) ***	**EHC® Plus (Pounds)**	**Potassium Bicarbonate (Pounds)**	**Anaerobic Water (Gallons)**	**SDC-9 (Liters)**
A-D2 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
A-D3	18	21.5	25	350	350	120	N/A
A-D4	18	21.5	25	350	350	120	N/A
A-D5	18	21.5	25	350	350	120	N/A
A-D5 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
A-E1	18	21.5	25	350	350	120	N/A
A-E1 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
A-E2	18	21.5	25	350	350	120	N/A
A-E3	18	21.5	25	350	350	120	N/A
A-F1	18	21.5	25	350	350	120	N/A
A-F2	18	21.5	25	350	350	120	N/A
A-F2 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1

Notes:

**** Injection depths shall not exceed 25 feet bgs under any circumstance, so as to prevent penetration of the base of the silt layer, which could result in contaminant migration to the clean units below the silt layer.***

bgs = below ground surface

Anaerobic water to be prepared using sodium ascorbate prior to injection.

Field adjustment of locations will be necessary due to topography and/or subsurface obstructions.

Table 5-2: Injection Area B Depths and Amendment Amounts

Injection ID	Upper Tip Opening Depths (Feet bgs)	Intermediate Tip Opening Depths (Feet bgs)	Lower Tip Opening Depths (Feet bgs) *	EHC® Plus (Pounds)	Potassium Bicarbonate (Pounds)	Anaerobic Water (Gallons)	SDC-9 (Liters)
B-A1	18	20.5	23	350	350	120	N/A
B-A1 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-A2	18	20.5	23	350	350	120	N/A
B-A3	18	20.5	23	350	350	120	N/A
B-A3 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-A4	18	20.5	23	350	350	120	N/A
B-A5	18	20.5	23	350	350	120	N/A
B-A5 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-A6	18	20.5	23	350	350	120	N/A
B-A7	18	20.5	23	350	350	120	N/A
B-A7 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-A8	18	20.5	23	350	350	120	N/A
B-A9	18	20.5	23	350	350	120	N/A
B-A9 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-A10	18	20.5	23	350	350	120	N/A
B-A11	18	20.5	23	350	350	120	N/A
B-A11 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-A12	18	20.5	23	350	350	120	N/A
B-B1	18	20.5	23	350	350	120	N/A
B-B1 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-B2	18	20.5	23	350	350	120	N/A
B-B2 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-B3	18	20.5	23	350	350	120	N/A
B-B4	18	20.5	23	350	350	120	N/A
B-B4 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-B5	18	20.5	23	350	350	120	N/A

Injection ID	Upper Tip Opening Depths (Feet bgs)	Intermediate Tip Opening Depths (Feet bgs)	Lower Tip Opening Depths (Feet bgs) *	EHC® Plus (Pounds)	Potassium Bicarbonate (Pounds)	Anaerobic Water (Gallons)	SDC-9 (Liters)
B-B6	18	20.5	23	350	350	120	N/A
B-B6 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-B7	18	20.5	23	350	350	120	N/A
B-B8	18	20.5	23	350	350	120	N/A
B-B8 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-B9	18	20.5	23	350	350	120	N/A
B-B10	18	20.5	23	350	350	120	N/A
B-B10 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-B11	18	20.5	23	350	350	120	N/A
B-B12	18	20.5	23	350	350	120	N/A
B-C1	18	20.5	23	350	350	120	N/A
B-C2	18	20.5	23	350	350	120	N/A
B-C3	18	20.5	23	350	350	120	N/A
B-C4	18	20.5	23	350	350	120	N/A
B-C5	18	20.5	23	350	350	120	N/A
B-C6	18	20.5	23	350	350	120	N/A
B-C7	18	20.5	23	350	350	120	N/A
B-C8	18	20.5	23	350	350	120	N/A
B-C9	18	20.5	23	350	350	120	N/A
B-C10	18	20.5	23	350	350	120	N/A
B-C11	18	20.5	23	350	350	120	N/A
B-C12	18	20.5	23	350	350	120	N/A
B-D1	18	20.5	23	350	350	120	N/A
B-D1 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-D2	18	20.5	23	350	350	120	N/A
B-D3	18	20.5	23	350	350	120	N/A
B-D3 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1

Injection ID	Upper Tip Opening Depths (Feet bgs)	Intermediate Tip Opening Depths (Feet bgs)	Lower Tip Opening Depths (Feet bgs) *	EHC® Plus (Pounds)	Potassium Bicarbonate (Pounds)	Anaerobic Water (Gallons)	SDC-9 (Liters)
B-D4	18	20.5	23	350	350	120	N/A
B-D5	18	20.5	23	350	350	120	N/A
B-D5 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-D6	18	20.5	23	350	350	120	N/A
B-D7	14	16.5	19	350	350	120	N/A
B-D7 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-D8	14	16.5	19	350	350	120	N/A
B-D9	14	16.5	19	350	350	120	N/A
B-D9 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-D10	14	16.5	19	350	350	120	N/A
B-D11	14	16.5	19	350	350	120	N/A
B-D11 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-E1	18	20.5	23	350	350	120	N/A
B-E2	18	20.5	23	350	350	120	N/A
B-E3	18	20.5	23	350	350	120	N/A
B-E4	14	16.5	19	350	350	120	N/A
B-E5	14	16.5	19	350	350	120	N/A
B-E6	14	16.5	19	350	350	120	N/A
B-E7	18	20.5	23	350	350	120	N/A
B-E8	18	20.5	23	350	350	120	N/A
B-E9	14	16.5	19	350	350	120	N/A
B-E10	14	16.5	19	350	350	120	N/A
B-F1	18	20.5	23	350	350	120	N/A
B-F2	14	16.5	19	350	350	120	N/A
B-F2 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-F3	14	16.5	19	350	350	120	N/A
B-F3 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1

Injection ID	Upper Tip Opening Depths (Feet bgs)	Intermediate Tip Opening Depths (Feet bgs)	Lower Tip Opening Depths (Feet bgs) *	EHC® Plus (Pounds)	Potassium Bicarbonate (Pounds)	Anaerobic Water (Gallons)	SDC-9 (Liters)
B-F4	14	16.5	19	350	350	120	N/A
B-F5	18	20.5	23	350	350	120	N/A
B-F5 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-F6	18	20.5	23	350	350	120	N/A
B-F7	18	20.5	23	350	350	120	N/A
B-F7 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-F8	18	20.5	23	350	350	120	N/A
B-F9	18	20.5	23	350	350	120	N/A
B-F9 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-F10	18	20.5	23	350	350	120	N/A
B-G1	14	16.5	19	350	350	120	N/A
B-G2	14	16.5	19	350	350	120	N/A
B-G3	18	20.5	23	350	350	120	N/A
B-G4	18	20.5	23	350	350	120	N/A
B-G5	18	20.5	23	350	350	120	N/A
B-G6	18	20.5	23	350	350	120	N/A
B-G7	18	20.5	23	350	350	120	N/A
B-G8	18	20.5	23	350	350	120	N/A
B-G9	18	20.5	23	350	350	120	N/A
B-G10	18	20.5	23	350	350	120	N/A
B-H1	18	20.5	23	350	350	120	N/A
B-H1 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-H2	18	20.5	23	350	350	120	N/A
B-H3	18	20.5	23	350	350	120	N/A
B-H3 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-H4	18	20.5	23	350	350	120	N/A
B-H5	18	20.5	23	350	350	120	N/A

Injection ID	Upper Tip Opening Depths (Feet bgs)	Intermediate Tip Opening Depths (Feet bgs)	Lower Tip Opening Depths (Feet bgs) *	EHC® Plus (Pounds)	Potassium Bicarbonate (Pounds)	Anaerobic Water (Gallons)	SDC-9 (Liters)
B-H5 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-H6	18	20.5	23	350	350	120	N/A
B-H7	18	20.5	23	350	350	120	N/A
B-H7 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-H8	18	20.5	23	350	350	120	N/A
B-H9	18	20.5	23	350	350	120	N/A
B-H9 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-I1	18	20.5	23	350	350	120	N/A
B-I2	18	20.5	23	350	350	120	N/A
B-I3	18	20.5	23	350	350	120	N/A
B-I4	18	20.5	23	350	350	120	N/A
B-I5	18	20.5	23	350	350	120	N/A
B-I6	18	20.5	23	350	350	120	N/A
B-I7	18	20.5	23	350	350	120	N/A
B-I8	18	20.5	23	350	350	120	N/A
B-J1	18	20.5	23	350	350	120	N/A
B-J1 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-J2	18	20.5	23	350	350	120	N/A
B-J3	18	20.5	23	350	350	120	N/A
B-J3 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-J4	18	20.5	23	350	350	120	N/A
B-J5	18	20.5	23	350	350	120	N/A
B-J5 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-J6	18	20.5	23	350	350	120	N/A
B-J7	18	20.5	23	350	350	120	N/A
B-J7 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-J8	18	20.5	23	350	350	120	N/A

Injection ID	Upper Tip Opening Depths (Feet bgs)	Intermediate Tip Opening Depths (Feet bgs)	Lower Tip Opening Depths (Feet bgs) *	EHC® Plus (Pounds)	Potassium Bicarbonate (Pounds)	Anaerobic Water (Gallons)	SDC-9 (Liters)
B-K1	18	20.5	23	350	350	120	N/A
B-K2	18	20.5	23	350	350	120	N/A
B-K3	18	20.5	23	350	350	120	N/A
B-K4	18	20.5	23	350	350	120	N/A
B-K5	18	20.5	23	350	350	120	N/A
B-K6	18	20.5	23	350	350	120	N/A
B-K7	18	20.5	23	350	350	120	N/A
B-L1	18	20.5	23	350	350	120	N/A
B-L1 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-L2	18	20.5	23	350	350	120	N/A
B-L3	18	20.5	23	350	350	120	N/A
B-L3(SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-L4	18	20.5	23	350	350	120	N/A
B-L5	18	20.5	23	350	350	120	N/A
B-L5 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-L6	18	20.5	23	350	350	120	N/A
B-L7	18	20.5	23	350	350	120	N/A
B-L7 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-M1	18	20.5	23	350	350	120	N/A
B-M2	18	20.5	23	350	350	120	N/A
B-M3	18	20.5	23	350	350	120	N/A
B-M4	18	20.5	23	350	350	120	N/A
B-M5	18	20.5	23	350	350	120	N/A
B-M6	18	20.5	23	350	350	120	N/A
B-N1	18	20.5	23	350	350	120	N/A
B-N1 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-N2	18	20.5	23	350	350	120	N/A

Injection ID	Upper Tip Opening Depths (Feet bgs)	Intermediate Tip Opening Depths (Feet bgs)	Lower Tip Opening Depths (Feet bgs) *	EHC® Plus (Pounds)	Potassium Bicarbonate (Pounds)	Anaerobic Water (Gallons)	SDC-9 (Liters)
B-N3	18	20.5	23	350	350	120	N/A
B-N3 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-N4	18	20.5	23	350	350	120	N/A
B-N5	18	20.5	23	350	350	120	N/A
B-N5 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-O1	18	20.5	23	350	350	120	N/A
B-O2	18	20.5	23	350	350	120	N/A
B-O3	18	20.5	23	350	350	120	N/A
B-O4	18	20.5	23	350	350	120	N/A
B-O5	18	20.5	23	350	350	120	N/A
B-P1	18	20.5	23	350	350	120	N/A
B-P1 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-P2	18	20.5	23	350	350	120	N/A
B-P3	18	20.5	23	350	350	120	N/A
B-P3 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
B-P4	18	20.5	23	350	350	120	N/A
B-Q1	18	20.5	23	350	350	120	N/A
B-Q2	18	20.5	23	350	350	120	N/A
B-Q3	18	20.5	23	350	350	120	N/A
B-Q4	18	20.5	23	350	350	120	N/A

Notes:

**** Injection depths shall not exceed 25 feet bgs under any circumstance, so as to prevent penetration of the base of the silt layer, which could result in contaminant migration to the clean units below the silt layer.***

bgs = below ground surface

Anaerobic water to be prepared using sodium ascorbate prior to injection.

Shallower depths are indicated to compensate for lower surface elevations in the ditch west of monitoring well MW-4.

Field adjustment of locations will be necessary due to topography and/or subsurface obstructions.

Table 5-3: Injection Area C Depths and Amendment Amounts

Injection ID	Upper Tip Opening Depths (Feet bgs)	Intermediate Tip Opening Depths (Feet bgs)	Lower Tip Opening Depths (Feet bgs) *	EHC® Plus (Pounds)	Potassium Bicarbonate (Pounds)	Anaerobic Water (Gallons)	SDC-9 (Liters)
C-A1	18	20.5	23	350	350	120	N/A
C-A2	18	20.5	23	350	350	120	N/A
C-A3	18	20.5	23	350	350	120	N/A
C-A3 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
C-B1	18	20.5	23	350	350	120	N/A
C-B1 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
C-B2	18	20.5	23	350	350	120	N/A
C-B3	18	20.5	23	350	350	120	N/A
C-C1	18	20.5	23	350	350	120	N/A
C-C2	18	20.5	23	350	350	120	N/A
C-C3	18	20.5	23	350	350	120	N/A
C-C3 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1
C-C4	18	20.5	23	350	350	120	N/A
C-D1	18	20.5	23	350	350	120	N/A
C-D2	18	20.5	23	350	350	120	N/A
C-D3	18	20.5	23	350	350	120	N/A
C-D3 (SDC-9)	N/A	20.5	N/A	N/A	N/A	Varies	1

Notes:

**** Injection depths shall not exceed 25 feet bgs under any circumstance, so as to prevent penetration of the base of the silt layer, which could result in contaminant migration to the clean units below the silt layer.***

bgs = below ground surface

Anaerobic water to be prepared using sodium ascorbate prior to injection.

Field adjustment of locations will be necessary due to topography and/or subsurface obstructions.

Table 5-4: Injection Area D Depths and Amendment Amounts

Injection ID	Upper Tip Opening Depths (Feet bgs)	Intermediate Tip Opening Depths (Feet bgs)	Lower Tip Opening Depths (Feet bgs) *	EHC® Plus (Pounds)	Potassium Bicarbonate (Pounds)	Anaerobic Water (Gallons)	SDC-9 (Liters)
D-A1	18	21.5	25	350	350	120	N/A
D-A2	18	21.5	25	350	350	120	N/A
D-A3	18	21.5	25	350	350	120	N/A
D-B1	18	21.5	25	350	350	120	N/A
D-B1 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
D-B2	18	21.5	25	350	350	120	N/A
D-B3	18	21.5	25	350	350	120	N/A
D-B3 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
D-C1	18	21.5	25	350	350	120	N/A
D-C2	18	21.5	25	350	350	120	N/A
D-C2 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
D-C3	18	21.5	25	350	350	120	N/A
D-C3 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1
D-D1	18	21.5	25	350	350	120	N/A
D-D1 (SDC-9)	18	21.5	25	350	350	120	N/A
D-D2	18	21.5	25	350	350	120	N/A
D-D3	18	21.5	25	350	350	120	N/A
D-E1	18	21.5	25	350	350	120	N/A
D-E2	18	21.5	25	350	350	120	N/A
D-E2 (SDC-9)	N/A	21.5	N/A	N/A	N/A	Varies	1

Notes:

**** Injection depths shall not exceed 25 feet bgs under any circumstance, so as to prevent penetration of the base of the silt layer, which could result in contaminant migration to the clean units below the silt layer.***

bgs = below ground surface

Anaerobic water to be prepared using sodium ascorbate prior to injection.

Field adjustment of locations will be necessary due to topography and/or subsurface obstructions.

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6.0 SITE MONITORING AND PERFORMANCE EVALUATION

Following the injections of the ISCR amendment, the SMPE plan will be implemented. The SMPE will consist of groundwater sampling the existing groundwater monitoring wells at regular intervals and evaluating analytical data to evaluate the effectiveness of the RA.

6.1 GROUNDWATER SAMPLING

Once the RA is complete, groundwater sampling will be conducted to determine the effectiveness of the RA and to ensure that the injection program has not resulted in the mobilization of COCs and expansion of the contaminant plumes toward the adjacent private residences. Groundwater samples are scheduled to be collected from eight groundwater monitoring wells at 3, 6, 9, 12, 18, 24, 30, and 36 months following injection completion. However, quarterly sampling may be continued after the first year based on the results of technical reviews and discussions with MDE. Per the DD, it is anticipated that the RAOs will be achieved upon the completion of three years of monitoring and four total years following the implementation of the RA (ERT 2015).

The following eight wells selected for post-injection site monitoring are shown on Figure 6-1 and are located within the outline of the CT and TCE plumes, as well as up, cross, and downgradient of the plume:

- MW-17 (upgradient of the CT and TCE plumes, unimpacted background well)
- MW-4 (within CT and TCE plumes; location of the highest CT concentration)
- MW-7 (within CT and TCE plumes)
- MW-12 (within CT and TCE plumes; location of the highest CT concentration)
- MW-18 (within the CT plume; downgradient sentinel well)
- MW-19 (within the CT and TCE plumes; location of the highest TCE concentration)
- MW-20 (within the CT and TCE plumes)
- MW-24 (within the CT and TCE plumes)

Groundwater sampling at these monitoring wells is expected to provide adequate information to evaluate potential increases in COC concentrations near the downgradient residences that may occur if COCs mobilize. Of particular concern near the downgradient residences is the vinyl chloride byproduct generated from the ISCR process, which may present an inhalation hazard if present in sufficient concentrations.

It is noted that groundwater sampling at MW-24 is critical to verifying CVOC concentrations in groundwater upgradient of the private residence located immediately northwest of MW-24.

6.1.1 GROUNDWATER LEVEL MEASUREMENTS

Prior to purging or sampling, the static water level of each groundwater monitoring well will be determined. Groundwater level measurements will be taken using an interface probe designed to differentiate between two liquid phases, if present. Groundwater elevations will be measured to the nearest 0.01 feet.

The probe will be lowered gently into the well casing until it signals contact with the fluid surface in the well, and a level reading will be recorded. The probe will then be lowered to verify the total depth of the monitoring well. The differences between the measured total well depths and constructed well depths will be compared to determine if significant siltation of the well screen has occurred.

Although NAPL has never been detected at the site, if NAPL is indicated, the probe will be lowered until the NAPL/water interface is detected. This procedure will be continued during total depth measurement to determine if dense NAPL is present in the bottom of the well. Measurements will be referenced to the top of the well casing at a point based on a visual examination of the high-point of the cut casing surface, previously marked reference point, or to magnetic north if the previous points are not discernable. All depth measurements will be interpolated and recorded to one hundredth of a foot.

6.1.2 GROUNDWATER SAMPLE COLLECTION

Eight existing groundwater monitoring wells will be purged and sampled for VOCs using a submersible pump with dedicated tubing using low stress (low flow) protocols in accordance with USEPA SOP EQASOP-GW4 (2017). Care must be taken to ensure the sample pump intake is installed within the screened interval at each monitoring well location. Field measurement equipment used during groundwater sampling will consist of a Horiba U-52 water quality meter, or similar instrument, with a flow-through cell and a water level indicator. The Horiba water quality meter will be calibrated each morning prior to usage in the field. Purge water will pass through the Horiba flow-through cell where pH, conductivity, turbidity, DO, temperature, and ORP values will be monitored and recorded on each well’s groundwater purge log every 3 to 5 minutes; dependent upon the flow rate to ensure that a minimum of one flow-through cell volume is purged between each consecutive reading. Each well will be purged until the groundwater quality parameters have stabilized, as indicated below, to ensure that formation water is being sampled. Wells will be considered stabilized when the following criteria are observed over three consecutive measurements obtained approximately 3 to 5 minutes apart:

- pH: +/- 0.1 standard pH unit
- Specific conductance: +/- 3%
- Turbidity: +/- 10% NTUs
- DO within 10%
- Temperature: +/- 3%
- ORP: +/- 10%

Dedicated tubing will be disconnected from the flow-through cell once the water quality has stabilized. Using the same pump and dedicated tubing from the well purging, the groundwater will be transferred directly into laboratory-supplied sample containers. The samples will be shipped to a certified laboratory and analyzed for the following parameters:

- VOCs by USEPA SW-846 Method 8260B
- Total iron by USEPA SW-846 Method 6010C
- Performance monitoring parameters:
  - TOC by USEPA SW-846 Method 9060A
  - Alkalinity by Standard Method 2320B
  - Chloride, nitrate, and sulfate anions by USEPA SW-846 Method 9056A

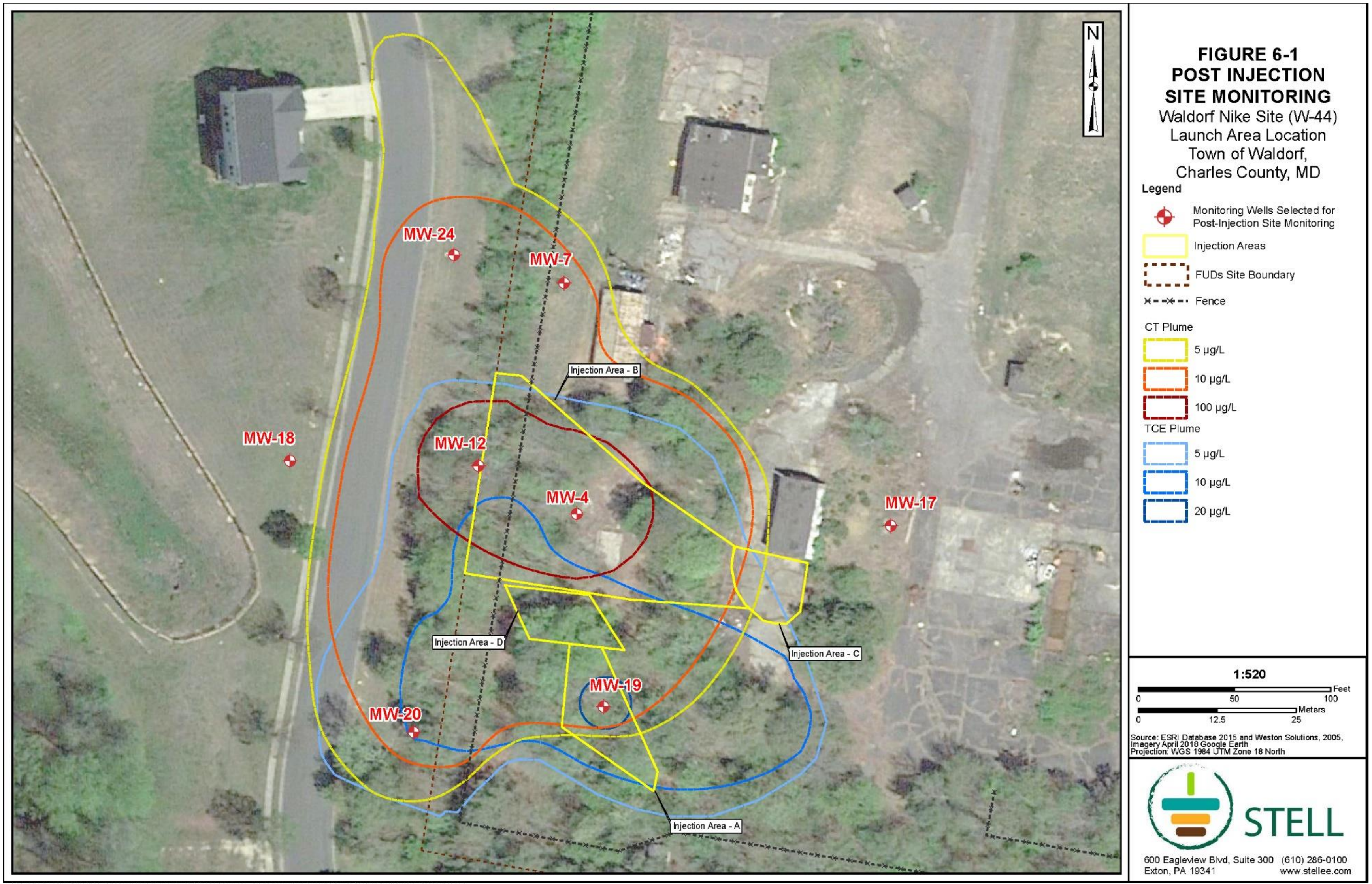

FIGURE 6-1
POST INJECTION SITE MONITORING
Waldorf Nike Site (W-44)
Launch Area Location
Town of Waldorf,
Charles County, MD

Source: ESRI Database 2015 and Weston Solutions, 2005,
Imagery April 2018 Google Earth
Projection: WGS 1984 UTM Zone 18 North

600 Eagleview Blvd, Suite 300 (610) 286-0100
Exton, PA 19341 www.stellee.com

Completed by Brittany McCabe on 2/21/2020 C:\Users\Brittany McCabe\stellee.com\Projects - 1474\MXDs\Remedial Design Work Plan\Figure 6-1 Post_Injection_Monitoring.mxd

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  - Dissolved gases (methane, ethene, ethane) by Method AM20GAx
  - Total sulfide by USEPA SW-846 Method 9034
  - Total manganese by USEPA SW-846 Method 6020A
- Microbial analyses (MW-4, MW-12, and MW-19 only):
  - Census-DNA (DHC). The cell count of the only bacterial group isolated to date that is capable of complete reductive dechlorination of PCE and TCE to ethene.
  - Census-DNA (bvcA Reductase – BVC). The bvcA gene encodes the VCR enzyme responsible for reductive dechlorination of vinyl chloride to ethene by DHC.
  - Census-DNA (tceA Reductase – TCE). The tceA gene encodes the enzyme responsible for reductive dechlorination of TCE to DCE in some strains of DHC.
  - Census-DNA (VCR). The vcrA gene encodes the VCR enzyme responsible for reductive dechlorination of DCE and vinyl chloride by DHC.

Groundwater samples will be collected in laboratory-provided containers that hold an appropriate preservative for the proposed test method. The samples will be labeled, placed in an ice-cooled chest, and transported by an overnight courier service to a predetermined laboratory for analysis.

6.1.3 GROUNDWATER DATA EVALUATION

Following the receipt of the groundwater analytical results, the data will be evaluated using a Mann-Kendall trend analysis to determine if the concentrations of CT and TCE are declining. These results will be tabulated and compared to the USEPA MCL of 5 μg/L for both CT and TCE.

6.2 POST INJECTION CONFIRMATION SOIL GAS SAMPLING

Following the first round of groundwater sampling, soil gas sampling will be performed to determine if the CT and TCE plumes are migrating and to monitor for inhalation exposure and vapor intrusion potential at the adjacent residential properties. Pursuant to the DD, soil gas sampling will be performed in Lots 8, 9, and 10 of the Cedar Tree Properties (Figure 1-3). These properties are located immediately downgradient of the site and will be used to verify that there is no remaining vapor intrusion risk. In addition to the DD-specified lots, soil gas sampling will also be performed in Lots 11 and 51 located southwest of the site. All soil gas samples will be collected in accordance with the USEPA Region 4 Operating Procedure for Soil Gas Sampling (USEPA 2014).

6.2.1 SOIL GAS SAMPLE LOCATIONS

Ten (10) total soil gas samples will be collected from Lots 8, 9, 10, 11, and 51. Two soil gas samples will be collected at the property boundary of each of the residential properties from shallow depths (surface to 1 foot below ground surface). Sampling at the property boundary will aid in developing a line of evidence that the CT and TCE plumes have not expanded post-injection. In addition, one control sample will be collected, as well as a field blank, an equipment rinsate blank, and a field split sample.

6.2.2 SOIL GAS SAMPLE COLLECTION

Soil gas samples will be collected through the use of a Post-Run Tubing (PRT) system following the below steps:

1. Place O-ring on PRT expendable point holder and attach to initial section of probe rod.
2. Place O-ring on expendable point and press into expendable point holder.
3. Add drive cap to probe rod and push PRT system into ground the distance of the intended open-interval. Take special care to assure that the rods are in line with the push axis of the probe machine. Dig a small depression around the rod string. Fill the depression with bentonite crumbles (not pellets) and hydrate with tap water.
4. At the desired sampling depth, attach a point popper to an extension rod and insert extension rod string into rods so that the point popper rests on the expendable point. Using the rod puller and taking special care to maintain probe alignment with the rods, begin pulling the rods while maintaining pressure on the extension rods. The extension rods should drop when the pull is started, indicating that the expendable point has been ejected. The rods can then be pulled to expose the desired open sampling interval.
5. Using a properly decontaminated water level sounder, check, if conditions warrant, to make sure groundwater is not present prior to proceeding with Step 6.
6. Secure the PRT adapter to a length of tubing sufficient to reach from the sampling interval to the surface, with several feet of excess tubing extending beyond the top of the probe rod to facilitate sampling. The adapter is secured tightly to the tubing using electrical tape. This will not compromise the integrity of the sample to be collected, as the sample is pulled directly through the adapter and is never exposed to the tape.
7. Run the tubing and adapter into the probe rod and, using steady downward pressure, turn the tubing counter-clockwise to dock the adapter into the top of the expendable point holder. Tug gently on the tubing to ensure that the adapter engaged with the expendable point holder. Continue rotating tubing until the adapter is firmly seated. Failure to dock could indicate that soil intruded during the push or that the expendable point was lost during the push.
8. At this point, the PRT system has been installed and is ready for sampling. If the sample cannot be collected immediately, the end of the tubing should be capped with a stainless-steel Swagelok® cap.
9. Soil gas samples will be collected by directly filling laboratory prepared stainless steel canisters and delivering the samples to a qualified laboratory.

To ensure high-quality soil gas samples are collected, the PRT system will be checked for ambient air leakage using a helium housing and detector to confirm that the collected samples have not been exposed to ambient air.

6.2.3 SOIL GAS SAMPLE LOCATION DECOMMISSIONING

The 10 soil gas sampling locations will be decommissioned following sampling through filling the points with bentonite chips and hydrating.

6.2.4 SOIL GAS SAMPLE DATA EVALUATION

Following the receipt of the soil gas analytical results, the data will be evaluated to determine if the plumes of CT and TCE are migrating. These results will be tabulated and compared to the USEPA and MDE Residential Ambient Air Standards for CT and TCE which are 4.1 μg per meter cubed (μg/m^3) and 420 μg/m^3 respectively.

7.0 DATA EVALUATION AND REPORTING

A technical memorandum will be prepared once the RA activities are complete. The technical memorandum will summarize the work completed to date, including any deviations from this Work Plan. The technical memorandum will be submitted approximately 1 month after completing the injections.

During the 36-month post-injection performance monitoring period, RA progress reports will be prepared every 6 months for the first year, followed by annual reporting thereafter. However, 6-month progress reporting may be continued after the first year based on the results of technical reviews and discussions with MDE. Initial evidence of post-injection geochemical changes are expected to occur within the first 6 months.

Following the 36-month post-injection performance monitoring sampling event, a RA outcome report will be prepared. That report will discuss remedial effectiveness and recommendations for further RA, if warranted.

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8.0 SITE RESTORATION AND INSTITUTIONAL CONTROLS

Once three consecutive groundwater sampling results confirm contaminant concentrations consistently achieve the RAOs for CT and TCE, groundwater monitoring will be halted. Following the halting of the groundwater monitoring, the subcontractor implementing this Work Plan will submit an application to enter the site into MDE’s Voluntary Cleanup Program on behalf of USACE (if requested by USACE). Following successful application and approval from MDE, either a No Further Requirements Determination or a Certificate of Completion will be issued and LUCs will be lifted from the site.

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9.0 HEALTH AND SAFETY AND WASTE MANAGEMENT

9.1 HEALTH AND SAFETY

The contractor selected for implementation of the Work Plan will be responsible for managing the H&S program and establishing all necessary H&S controls in accordance with EM 385-1-1 (USACE 2014).

9.2 WASTE MANAGEMENT

Investigation derived waste (IDW) is expected to be limited to decontamination water, disposable personal protection equipment, and purge water produced during groundwater sampling. The contractor implementing this Work Plan will be responsible for IDW containerization, characterization, and disposal. USACE will provide signature authority for disposal.

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10.0 PROJECT AND QUALITY MANAGEMENT

10.1 PROJECT ORGANIZATION AND RESPONSIBILITIES

10.1.1 LEAD CONSULTANT

The lead consultant (to be determined) will be responsible for:

- H&S oversight.
- Technical oversight.
- Coordinating schedules with subcontractors and suppliers (DPT and injection contractor, amendment vendor, frac tank vendor, etc.).
- Arranging for water supply (securing permits and monitoring water use volumes).
- Providing field documentation and quality control.

10.1.2 SUBCONTRACTORS

The primary subcontractors required to implement substrate injection at the site will include the following:

- A driller to conduct the DPT drilling, substrate mixing, and injection tasks.
- A vendor to supply injection amendments, including EHC® Plus, potassium bicarbonate, SDC-9 inoculum, and sodium ascorbate.

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APPENDIX A

ISCR REAGENT DEMAND AND DECAY RATE CALCULATIONS

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EHC® Plus Original ISCR Reagent Demand Calculations

PeroxyChem

Customer:	**Weston Solutions**		4-Mar-2019
Contact:	**Josh Frizzell**		**Prepared by:**
Site Location:	**Waldorf, MD**		**Fayaz Lakhwala PhD**
Proposal Number:	**OPP18294**		**1-908-230-9567**
Application Type:	**Source Zone Treatment**		**Fayaz.Lakhwala@peroxychem.com**

EHC® ISCR Reagent Demand Calculations and Cost Estimate

Please find a reagent cost quotation below for the site and application referenced above. A product description, design assumptions, demand calculations and application guidelines are included as an appendix to this cost proposal.

Item	**Quantity**	**Unit**	**Price**	**Cost**
EHC Plus Reagent	72,900	lbs	TBD	**#VALUE!**
Optional items:				
DHC Inoculum	104	L	TBD	#VALUE!
KHCO3 Buffer	33,280	lbs	TBD	#VALUE!

1) Price valid for 90 days from date at top of document. Terms: net 30 days.

2) Any applicable taxes not included. Please provide a copy of your tax exempt certificate or resale tax number when placing your order. In accordance with the law, applicable state and local taxes will be applied at the time of invoicing if PeroxyChem has not been presented with your fully executed tax exemption documentation.

3) Price excludes shipping. Freight estimates available upon request. Volumes were rounded up based on container size.

4) Return Policy: Unless otherwise stated, within 90 days after sale, following written approval by PeroxyChem, products in their unopened containers in good condition, may be accepted for return at invoiced price, less 25% handling charge and return freight, excluding original freight paid by buyer. Products made to order, custom blended, or buffers are non-returnable.

5) All sales are per PeroxyChem's Terms and Conditions.

Disclaimer:

The estimated dosage and recommended application methodology described in this document are based on the site information provided to us, but are not meant to constitute a guaranty of performance or a predictor of the speed at which a given site is remediated. The calculations in the Cost Estimate regarding the amount of product to be used in your project are based on stoichiometry or default minimum guideline values, and do not take into account the kinetics, or speed of the reaction. Note that the Stoichiometric mass represents the minimum anticipated amount needed to address the constituents of concern (COCs). As a result, these calculations should be used as a general approximation for purposes of an initial economic assessment. PeroxyChem recommends that you or your consultants complete a comprehensive remedial design that takes into consideration the precise nature of the COC impact and actual site conditions.

PROPOSAL ATTACHMENTS

PRODUCT OVERVIEW

EHC® Plus Reagent is composed of controlled-release fermentable organic carbon, zero valent iron (ZVI), powdered activated carbon (PAC) particles and nutrients used for stimulating *in situ* chemical reduction (ISCR) of otherwise persistent organic compounds in groundwater. Following placement of EHC Plus into the subsurface environment, a number of physical, chemical and microbiological processes combine to create very strong reducing conditions that stimulate rapid and complete dechlorination of organic solvents and other recalcitrant compounds (e.g., explosives and organochlorine pesticides).

EHC Plus is delivered as a dry powder in 50-lb / 25-kg bags or super-sacs. It can be placed into the saturated zones in a variety of ways including direct push injections, hydraulic and pneumatic fracturing, and direct soil mixing. It is completely non-hazardous and safe to handle. EHC Plus is manufactured in the USA, EU and Brazil.

SITE INFORMATION / ASSUMPTIONS

	Value	**Unit**	**Comment**
Treatment Area Dimensions:			
Width of targeted zone (perpendicular to gw flow)	133	ft	customer supplied
Length of targeted zone (parallel to gw flow)	100	ft	customer supplied
Depth to top of treatment zone	20	ft bgs	customer supplied
Treatment zone thickness	6	ft	customer supplied
Treatment volume	79,800	ft3	calculated value
Total Porosity	35	%	default value
Groundwater volume	27,930	ft3	calculated value
Soil bulk density	110	lbs/ft3	default value
Soil mass	4,389	ton	calculated value
Transport characteristics:			
Treatment time / design life for one application	5	years	default value
Linear groundwater flow velocity	110	ft/year	calculated value
Distance of inflowing gw over design life	548	ft	calculated value
Effective porosity for groundwater flow	20	%	default value
Volume of water passing region over design life	87381	ft3	calculated value
Soil type	low permeability		customer supplied
Fraction organic carbon in soil, foc	0.100		estimated value

CONTAMINANTS OF CONCERN (COCs)

Constituent	GW (mg/L)	Soil* (mg/kg)	Total Mass** (lb)
CT	0.3	3.3	31.1
TCE	0.05	0.535	5.1

*Unless provided, sorbed concentrations were roughly estimated based on expected groundwater concentrations, foc and Koc values. For a more refined estimate, it is recommended that actual values be verified via direct sampling of the targeted treatment interval.

**The total COC mass was estimated based on concentrations in soil and groundwater within the targeted area plus expected contributions from inflowing groundwater over the projected design life.

GEOCHEMICAL DATA

Competing Electron Acceptors	GW (mg/L)	
Dissolved oxygen	3	customer provided
Nitrate (as N)	10	customer provided
Manganese (dissolved)*	10	default value
Iron (III)*	15	default value
Sulfate	25	customer provided

*An estimated projection of dissolved concentrations of Mn and Fe following ERD/ISCR were used to estimate H demand from the reduction of oxidized Fe and Mn minerals (typically only a portion of actual soil concentrations will be reduced).

ORP (mV)	50	
pH	4.5	Note: It is recommended to inject a pH buffer together with the EHC to adjust the pH to around 7.

STOICHIOMETRIC DEMAND CALCULATIONS

	GW (mg/L)	Soil (mg/kg)
H2 Demand from COIs	0.0	0.2
H2 Demand from Competing Electron Acceptors	3.9	0.0
Total H2 Demand	3.9	0.2
H2 Demand from Soil within Targeted Area	1.7	lb
H2 Demand from GW within Targeted Area	6.9	lb
H2 Demand from Influx over Design Life	21.5	lb
Total Estimated H2 Demand	30.1	lb

EHC Plus DEMAND CALCULATIONS

The stoichiometric demand for the targeted area was calculated using available data presented above, noting that the stoichiometric demand represents minimum requirements and require a complete geochemical data set to be calculated accurately. Therefore, the resulting EHC dosing required to meet the estimated stoichiometric demand was compared to our minimum guidelines for the selected type of application, selecting the higher number.

Application type: Source Zone Treatment

	Value	Unit
Minimum EHC Plus application rate to meet H2 demar	0.02	% by soil mass
Minimum recommended dosing for application type*	0.83	% by soil mass
Recommended EHC Plus application rate	0.83	% by soil mass
Mass of EHC Plus required	72,857	lbs
Mass of EHC Plus per bag	50	lbs
Number of bags required	1,458	bags
Mass EHC Plus (rounded up based on bag size)	72,900	lbs

*Our general recommended minimum guideline for the proposed application exceeds the dose rate required based on hydrogen demand calculations and was therefore used for the purpose of this dosing calculation.

OPTIONAL DHC INOCULANT

Although not typically required for ISCR, DHC inoculants have shown to improve removal kinetics, in particular for potential daughter products such as cis-DCE and VC. The DHC can be added with or after EHC Plus application, once favorable redox conditions (ORP < -75 mV, DO <0.2 mg/L, pH between 6 and 8.5) have been attained. The DHC inoculant will contain at least 5 x10E10 cfu/L of live bacteria including high numbers of dehalococcoides species with known abilities to biodegrade DCE. The target density of DHC cells in the treated aquifer is 1x10E6 cfu/L.

	Value	Unit
Dechlorinating consortium concentration in inoculant	7.65E+09	DHC/L
Design final concentration after dilution in aquifer	1.00E+06	DHC/L
Volume of Inoculant Required	104	L

INSTALLATION

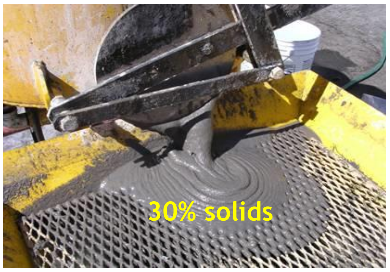
EHC Plus Reagent is supplied as a dry powder which can be mixed with soil or slurried in water. Installation techniques vary widely depending on the application. For example, the powder can be directly mixed into the soil using deep soil mixing equipment or placed into an open excavation where prior soil removal has been conducted. A slurry can be made and the mixture can be injected into the subsurface using techniques such as injection through direct push rods or hydraulic fracturing. Injection through fixed wells is not recommended given that the product does not dissolve in water. If application via wells or injection networks were to be the preferred installation method at your site, we instead recommend our soluble ISCR substrate EHC Liquid. **Review and follow guidance in the appropriate Safety Data Sheet (SDS) with all workers prior to use.**

EHC Plus Slurry Preparation:

The EHC Plus slurry can been prepared in a variety of ways, including using paddle mixers. However, particularly for larger projects, PeroxyChem recommends having a mechanical mixing system available on site. In general we recommend continuous mixing in smaller batches (<100 USG / 400 L) to avoid settling of solids at the bottom. For example Chem Grout's high pressure mixing and injection units are ideal for continuous preparation and injection of EHC Plus.

The amount of water to prepare the EHC Plus slurry could be varied depending on the desired injection volume and slurry properties. When applied via direct injection, normally a concentration of between 25 and 35% is targeted. The below table shows the amount of water needed per 50-lb / 25-kg bag depending on the targeted concentration and the resulting total injection volumes and percent pore fill (injection volume to total pore volume). Note that a thinner slurry will promote permeation into more permeable formations, whereas a more concentrated/more viscous slurry will promote fracturing and horizontal propagation into more fine-grained formations.

Target concentration (% solids):	**25%**	**30%**	**35%**
Mass EHC Plus per bag (lbs)	50	50	50
Volume water per bag (USG)	18.0	14.0	11.1
Volume slurry per bag (lbs)	22.0	18.0	15.2
Total mass EHC Plus (lbs)	72,900	72,900	72,900
Total volume water (USG)	26,209	20,385	16,225
Total injection volume (USG)	32,005	26,231	22,118
Injection volume to total pore volume	15.3%	12.5%	10.6%



INSTALLATION (continued)

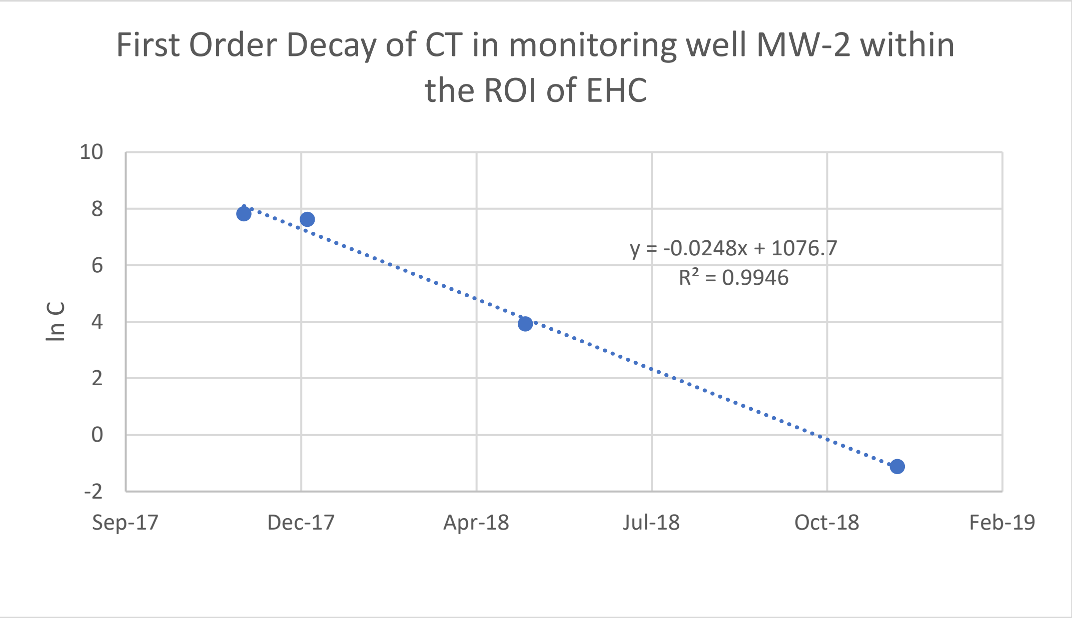
Injection recommendations (can be altered):

The EHC Plus slurry can be injected into the ground in a variety of ways including direct injection and hydraulic/pneumatic fracturing. The injection spacing will be determined based on the radius of influence and soil acceptance for the given application method, lithology and depth. Assuming installation via direct push injections and a radius of influence (ROI) of 5 to 8 ft (1.7 to 2.5 m), an injection spacing of 10 to 15 ft (3 to 5 m) is normally applied. For injection PRB applications, a closer spacing is normally recommended to create some overlap or the PRB may be made up of multiple off-set injection lines to improve contact.

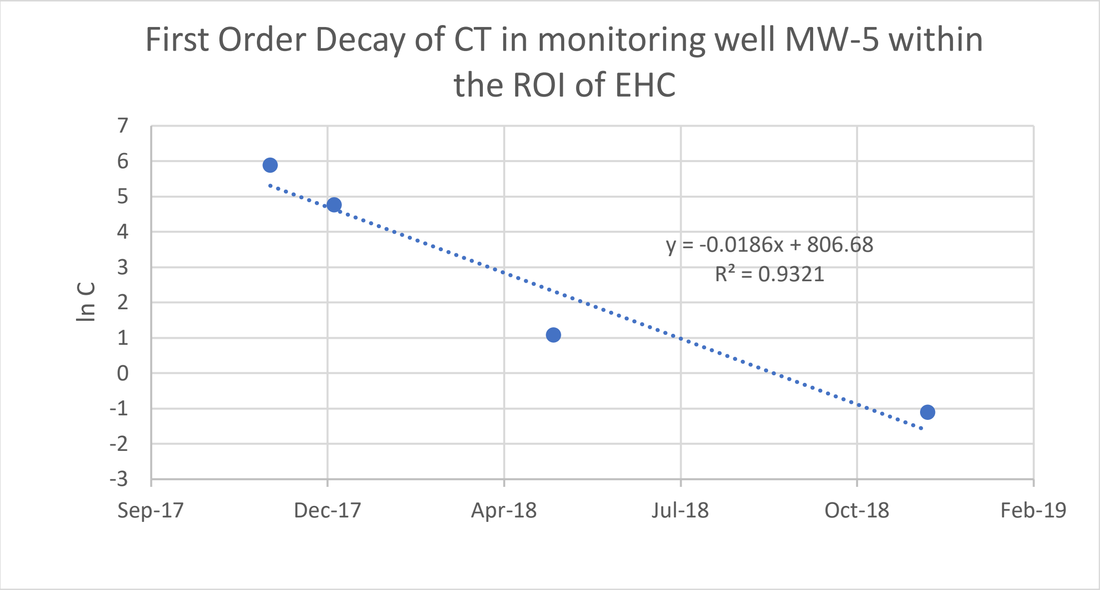
Unless specified by the consultant, the below recommendations was based on our experience from other similar lithologies and considers both the estimated ROI and the estimated soil acceptance (maximum injection volume per vertical foot for lithology and depth) using direct injection. However, please note that actual ROI and soil acceptance can vary widely and are also highly influenced by the injection method employed (slurry viscosity, injection pressures and flow rates). **Therefore, PLEASE NOTE that the construction estimates presented below can be readily modified in the field as required (for example, the density of the slurry can be changed to modify the total injection volume or the injections spacing could be altered based in installation technology).**

	Value	Unit	Comment
Total EHC Plus mass	72,900	lbs	calculated value
Concentration of EHC Plus slurry to inject	30%	by weight	can be altered
Total volume of water required	20,381	U.S. gallons	calculated value
Approximate volume of slurry to inject	26,231	U.S. gallons	calculated value
Injection spacing (grid)	8	ft	customer provided
Number of injection points	208	locations	calculated value
Mass EHC Plus per injection point	350	lbs	calculated value
Mass EHC Plus per vertical foot	58	lbs	calculated value
Injection volume to total pore space volume	12.6%	by volume	calculated value

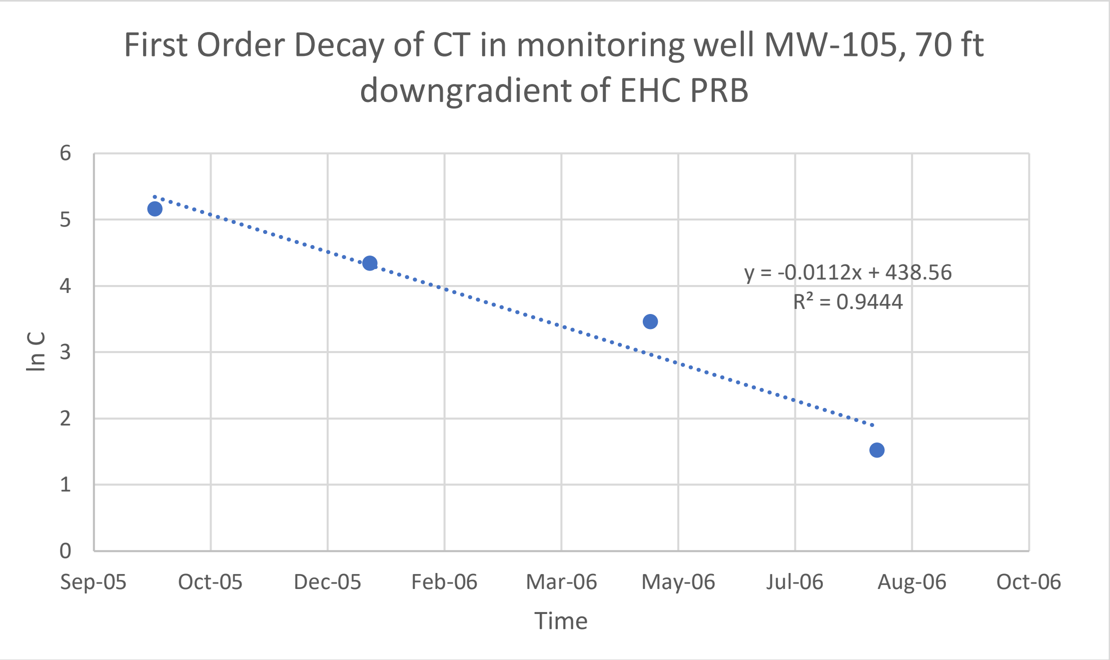
		days		ln C
MW-2	Nov-17	1	**2500**	7.824046
Consultech	Jan-18	36	**2030**	7.615791
Albany, MO Site	May-18	161	**50.3**	3.918005
	Dec-18	373	0.33	-1.10866



				ln C
MW-5	Nov-17	1	**359**	5.883322
Consultech	Jan-18	36	**118**	4.770685
Albany, MO Site	May-18	161	2.96	1.085189
	Dec-18	373	0.33	-1.10866



MW-105	175	Oct-05	5.164786
Kansas Grain Sil	77	Jan-06	4.343805
	32	May-06	3.465736
	4.6	Aug-06	1.526056



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APPENDIX B

REMEDIAL AMENDMENT PRODUCT SHEETS AND SDC-9 USER MANUAL

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EHC® Plus

Proven Power of EHC Reagent Plus Activated Carbon

EHC® Plus is a combination of EHC Reagent plus powdered activated carbon (PAC). This combined remedy approach can be used for the treatment of groundwater and saturated soil impacted by persistent halogenated compounds, including chlorinated solvents, pesticides, and organic explosives. EHC Plus is a synergistic mixture comprised of 35% (wt) micro-scale zero valent iron (ZVI), 50% (wt) controlled-release organic carbon, and 15% (wt) PAC. The product stimulates both abiotic and biotic de-chlorination mechanisms and provides an adsorption pathway to help to achieve low remedial goals for difficult to treat contaminants.

Key Benefits

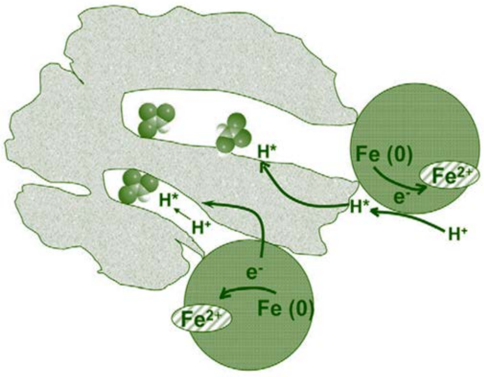
- Multiple and dynamic reaction pathways → abiotic, biotic, and adsorption
- Abiotic and biotic pathways destroy contaminants including those with lower adsorption affinity for activated carbon, such as vinyl chloride, chloroethanes, and dichloroethanes
- Synergistic organic carbon and ZVI mixture creates a reactive halo in the Downgradient Zone by the volatile fatty acids and soluble iron corrosion products
- Solid PAC stays in the Injection Zone and does not migrate with groundwater flow cutting off contaminant plumes and helping to achieve low remedial goals.

The sound science of EHC Plus

Following an application of EHC Plus, the PAC results in an immediate reduction in aqueous concentrations of contaminants via adsorption and allows time for EHC Plus to create strong reducing conditions via biotic and abiotic mechanisms. This creates a powerful two-step treatment process and allows time for reductive treatment to be established.

As the bacteria ferment the organic component of EHC Plus, a variety of volatile fatty acids (VFAs) diffuse into the groundwater to serve as electron donors while corroding iron is released into the groundwater forming ferric and ferrous precipitates,

In addition, the PAC can serve as media to support both abiotic and biotic reactions on its surface with CVOCs (Nath and Bhakhar, 2011, Gamal et al., 2018, Aktas, Tang et al. 2011 and Cecen, 2007)



Mechanisms of reductive dechlorination of trichloroethylene adsorbed in the micropores of activated carbon. Activated carbon serves as the conductor for electrons and/or atomic hydrogen. H* represents adsorbed atomic hydrogen. Tang et al. (2011)

EHC Plus Applications

- Permeable Reactive Barriers (PRBs) for Plume Control: EHC Plus has an estimated lifetime of 5 to 10 years in the subsurface which makes it ideal for placement into PRBs to promote CVOC removal under flow-through conditions.
- Source Areas: EHC Plus can also be used for hot-spot treatment and the product's adsorptive capability and longevity allows for continued treatment of contaminants as they slowly back diffuse from the solid matrix to groundwater at sites with high concentrations of sorbed mass / NAPL.
- Plume Treatment: A remedial design with multiple injection areas or reactive zone provides cost effective treatment approach for large dilute plumes.

Installation Methods

- Injection of slurry via direct push technology (DPT)
- Hydraulic or Pneumatic Fracturing (applied to fine-grain formations including weathered and fractured bedrock)
- Direct placement into open excavations or trench PRBs
- Deep soil mixing

References

Maisa El Gamal, Hussein A.Mousa, Muftah H.El-Naas, Renju Zacharia, and Simon Judd. (2018). Bio-regeneration of activated carbon: A comprehensive review. *Separation and Purification Technology, Volume 197, 31 May 2018, Pages 345-359*

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Tang, Hao, Zhu, Dongqiang, Li, Tielong, Kong, Haonan and Chen, Wei. (2011). Reductive Dechlorination of Activated Carbon-Adsorbed Trichloroethylene by Zero-Valent Iron: Carbon as Electron Shuttle. *Journal of environmental quality. 40. 1878-85.*

Product Information

Product Data Sheet

Sodium Ascorbate Crystalline

Description

Sodium Ascorbate Crystalline is a practically odourless powder. It decomposes at about 220 °C without melting sharply.

Product identification

Product code: 04 0817 4

Chemical names: 2,3-didehydro-L-*threo*-hexono-1,4-lactone sodium enolate; 3-oxo-L-gulofuranolactone sodium enolate

Synonyms: sodium L-ascorbate; L-ascorbic acid monosodium salt; vitamin C (sodium salt)

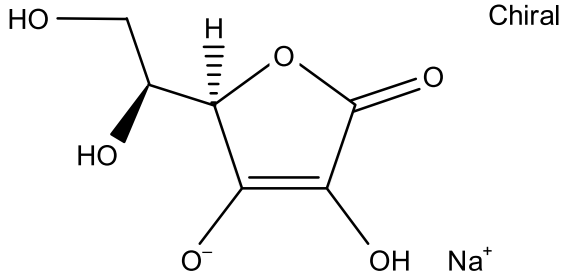
CAS No.: 134-03-2

EINECS No.: 205-126-1

E No.: E 301

Empirical formula: $C_6H_7NaO_6$

Molecular mass: 198.11 g/mol



Specifications

Appearance:	powder
Colour:	white to yellowish
Fineness (US standard sieves):	
• through sieve No. 80	min. 98%
• through sieve No. 100	min. 95%
pH of a solution 10% in water:	7.0–8.0
Identity:	corresponds
Specific rotation: (589 nm, 20°C, c = 10 in water)	+103.0° to +108.0° (on dry material)
Loss on drying:	max. 0.25%
Related substances:	
• D-sorbosonic acid (impurity C)	max. 0.15%
• Methyl D-sorbosonate (impurity D)	max. 0.15%
• Unspecified impurities (each)	max. 0.10%
• Total*	max.0.2%
*Disregard limit	0.05%

Sodium Ascorbate Crystalline

Heavy metals:	max. 10 ppm
Lead:	max. 2 ppm
Mercury:	max. 1 ppm
Zinc:	max. 25 ppm
Copper:	max. 5.0 ppm
Arsenic:	max. 3 ppm
Oxalic acid (impurity E):	max. 0.3%
Sulphates:	max. 150 ppm
Iron:	max. 2.0 ppm
Nickel:	max. 1.0 ppm
Solution 10% in water:	clear and not more intensely coloured than Ph. Eur. reference solution Y6
Residual solvents:	
• Ethanol	max. 1000 mg/kg
• Methanol	max. 3000 mg/kg
Assay:	99.0–101.0% (on dry material)

Solubility

Sodium Ascorbate Crystalline is freely soluble in water (approx. 90 g per 100 mL), very slightly soluble in ethanol and practically insoluble in ether and chloroform.

Stability and storage

Sodium Ascorbate Crystalline is somewhat sensitive to air, heat and humidity. The product may be stored for 18 months from the date of manufacture in the unopened original container and at a temperature below 25 °C. The ‘best use before’ date is printed on the label. On prolonged storage, a yellow discoloration may occur which, however, does not affect the biological activity. In aqueous solutions, sodium ascorbate is very susceptible to oxidative decomposition.

Uses

For the enrichment and stabilization of dry food preparations, and as a curing agent in the meat industry.

For solid and liquid multivitamin and monovitamin preparations.

For solid and liquid pharmaceutical preparations.

This product is not intended for use in the manufacture of sterile drug products. The purchaser assumes all responsibility for additional processing, testing, labelling and registration required for such use.

Compendial compliance

Sodium Ascorbate Crystalline meets all requirements of the current version of the USP, FCC and Ph. Eur. when tested according to these compendia.

Safety

This product is safe for the intended use. Avoid ingestion, inhalation of dust or direct contact by applying suitable protective measures and personal hygiene.

For full safety information and necessary precautions, please refer to the respective DSM Material Safety Data Sheet.

Legal notice

The information given in this publication is based on our current knowledge and experience, and may be used at your discretion and risk. It does not relieve you from carrying out your own precautions and tests. We do not assume any liability in connection with your product or its use. You must comply with all applicable laws and regulations, and observe all third party rights.

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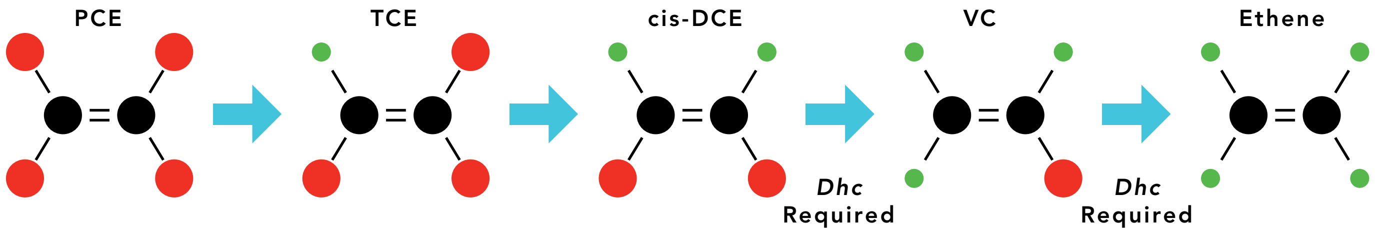
www.rnasinc.com

SDC-9

Bioaugmentation Culture for Groundwater Remediation

SDC-9™ is a field proven, highly effective consortium of microorganisms for in situ bioremediation of chlorinated solvents. SDC-9 contains multiple strains of *Dehalococcoides mccartyi* (*Dhc*), the only species known to completely biodegrade PCE and TCE to non-toxic ethene. For sites where *Dhc* are absent or present at low concentrations bioaugmentation provides the necessary bacteria for complete dechlorination. Even when *Dhc* is present bioaugmentation can provide substantial benefits by increasing dechlorination rates, using electron donor more efficiently and reaching site closure sooner.



Benefits - Higher Dechlorination Rates

SDC-9 contains a natural consortium of bacteria that includes not only dechlorinating microbes but other beneficial bacteria that support *Dhc* growth by supplying required substrates and growth factors. "*Dhc* in mixed cultures exhibit shorter lag times following transfers, grow faster and exhibit higher dechlorination rates than pure *Dhc* cultures" (Bioaugmentation for Groundwater Remediation, 2013).

Benefits - Low pH Tolerant

SDC-9 continues to perform at pH levels as low as 5.5 (Vainberg and Steffan, 2014), although pH levels above 6.0 are recommended for more effective dechlorination.

Application

SDC-9 is commonly injected between rounds of anaerobic water and electron donor, which minimizes exposure to oxygen while mixing SDC-9 throughout the treatment area. Recommended dosing for SDC-9 is $1x10^7$ *Dhc* cells per liter in target zones (Lu et al., 2006).

Contaminants Treated by SDC-9:

Tetrachloroethene (PCE)
Trichloroethene (TCE)
cis-Dichloroethene (cDCE)
trans-Dichloroethene (tDCE)
1,1-Dichloroethene (DCE)
Vinyl Chloride (VC)
Freon 11
Freon 113

1,1,2,2-Tetrachloroethane (TeCA)
1,1,1-Trichloroethane (TCA)
1,1-Dichloroethane (DCA)
Carbon Tetrachloride (CT)
Chloroform (CF)
Dichloromethane (DCM)
Hydrochlorofluorocarbon (HCFC)
Tetrafluoroethene (TFE)

SDC-9 Contains:

Dehalococcoides mccartyi
Dehalogenimonas spp.
Desulfovibrio spp.
Desulfitobacterium spp.
Methanogenic bacteria
Sulfate Reducing bacteria

EHC® Plus

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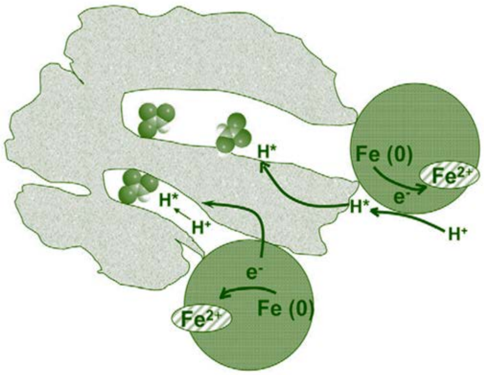

Mechanisms of reductive dechlorination of trichloroethylene adsorbed in the micropores of activated carbon. Activated carbon serves as the conductor for electrons and/or atomic hydrogen. H* represents adsorbed atomic hydrogen. Tang et al. (2011)

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SDC-9

Bioaugmentation Culture for Groundwater Remediation

Product Characteristics

Parameter	Unit	Specification
Cell Count	*Dhc* Cells/Liter	>1 x 10^{11}
Density	g/cm^3	0.9 - 1.1
pH	Standard Units	6.0 - 8.0
Appearance		Light Greenish, Murky Liquid
Odor		Musty

Packaging

SDC-9 is shipped in 19L stainless steel kegs. Kegs are pressurized with Nitrogen and stored in chilled coolers. Calibrated delivery system (1, 2 or 3.5 L) and fittings are provided. Users will need to provide an inert gas cylinder (Nitrogen or Argon) and regulator.

Storage

Keep containers tightly closed in a cool, well-ventilated area. SDC-9 may be stored for up to 3 weeks at temperature 2-4° C. Avoid freezing conditions. Avoid exposure to oxygen.

Safety

SDC-9 is a non-toxic, non-pathogenic, non-genetically modified, naturally occurring consortium of microbes. No known hazards are associated with exposure to this product. Nevertheless, appropriate Personal Protective Equipment is recommended when handling this product.

User Manual for Calibrated Culture Delivery System

USER INSTRUCTION

WARNINGS

1. **Keg is pressurized to 10 to 15 psi with Nitrogen before shipping.**
2. **Wear suitable eye and face protection, gloves and protective clothing.**
3. **Gas cylinders used to dispense culture MUST be equipped with a proper pressure regulator.**
4. **During operation DO NOT exceed the keg's maximum working pressure of 15 psi.**

UNPACKING

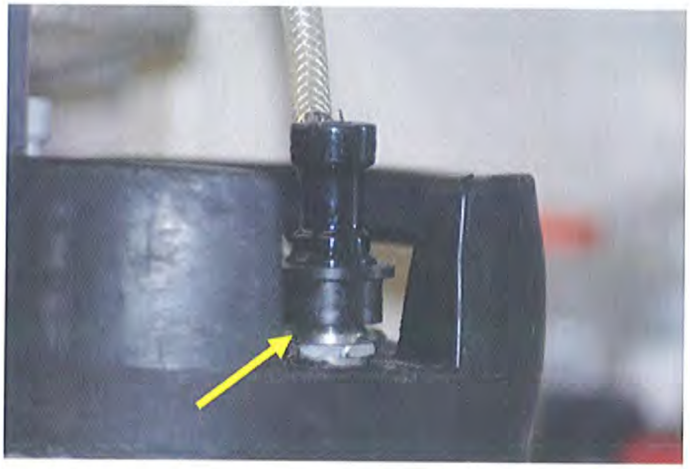
1. **Carefully remove keg and measuring cylinder from shipping container and stand keg upright.**
2. **Attach measuring cylinder to the keg by using the black Velcro straps.**
3. **Carefully check the keg, measuring cylinder, connectors, valves and tubing for any damage or defects. If any defects or damage is observed, do not use. Report any damage to Shaw Environmental, Inc. immediately at 609-895-5376. A back-up set of quick connects is provided in the packaging material.**
4. **Check and ensure that black, white and green valves are in the CLOSED position and brass three-way valve is in position "1" (handle of the valve should be directed to position perpendicular to the body of the valve).**

SET-UP

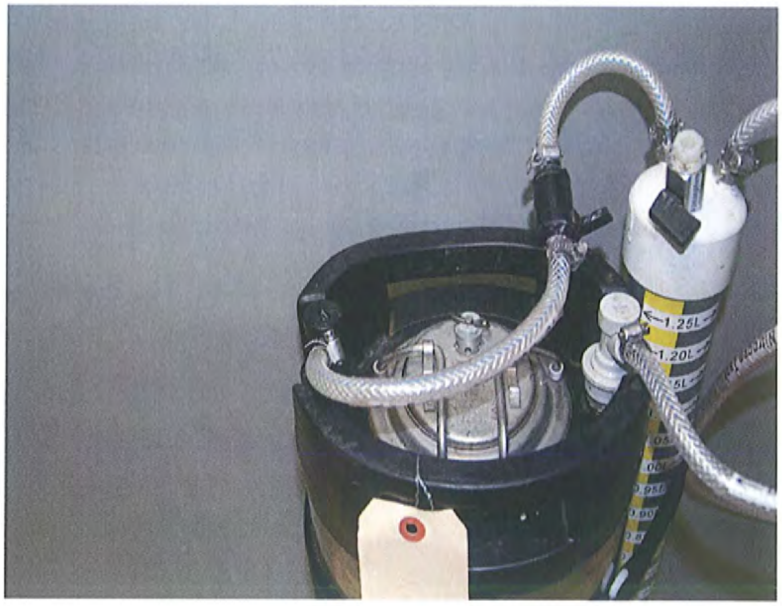
1. **Using an appropriate length of reinforced ¼" ID tubing, connect the tubing marked "Nitrogen tank →" to the gas tank regulator. Another end of the tubing is connected to position "1" of three way brass valve.**

2. **Connect the GREY connector to Gas "In" fitting of the keg. Be sure that the GREY connector is designed to be connected only to Gas "In" keg's fitting. Lubricate fitting with water before attachment.**

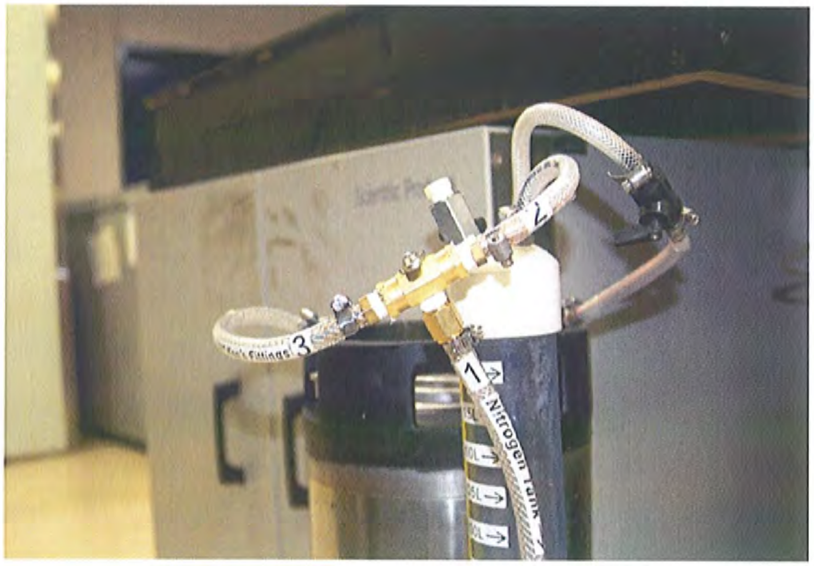
3. **Connect the Black connector to Liquid "Out" fitting of the keg. Be sure that the Black connector is designed to be connected only to Liquid "Out" keg's fitting. Lubricate fitting with water before attachment. Ensure that the black valve attached to the BLACK quick connect is tightly closed.**



4. **Connect an appropriate length of reinforced ¼" ID tubing marked "Bacteria→" by the barbed fitting to the site tubing to distribute bacterial culture to the desired injection point. Be sure that the green valve is closed. Do not connect this line to the injection line yet.**



Keg and measuring cylinder attached to the keg's fittings black and grey connectors.



Measuring cylinder with attached three-way brass valve.

Keg and measuring cylinder connected to delivery gas tank.

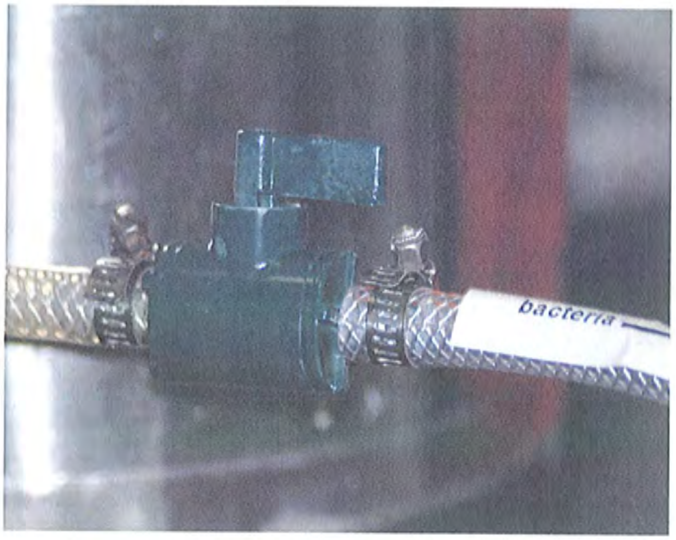
OPERATION

1. Set up the gas pressure on the delivery gas (Nitrogen or Argon) tank regulator at 10 to 15 psi.

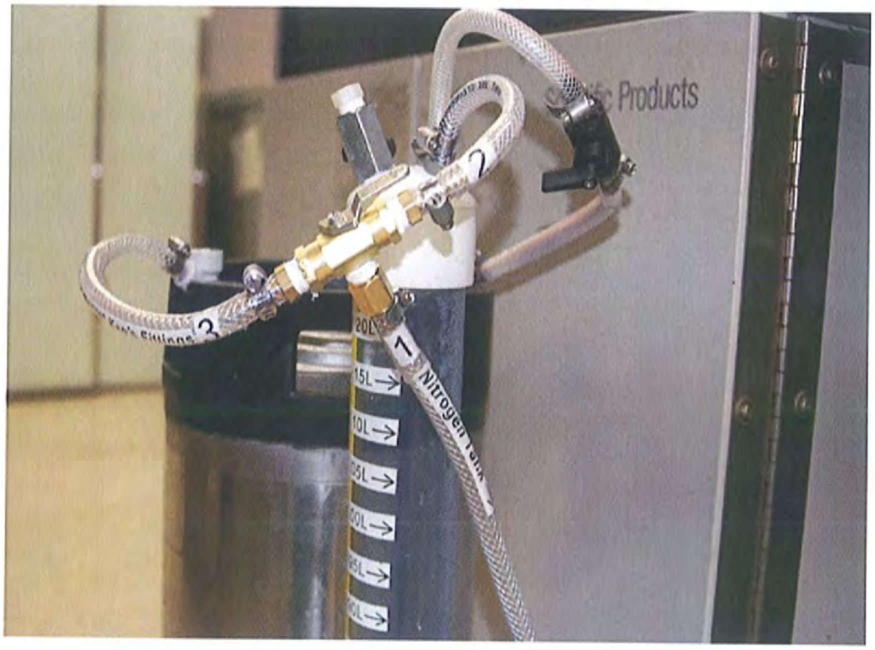
2. Remove air from injection line by the following procedure:

    A. Be sure that at this point that the injection line is not connected to the injection point.

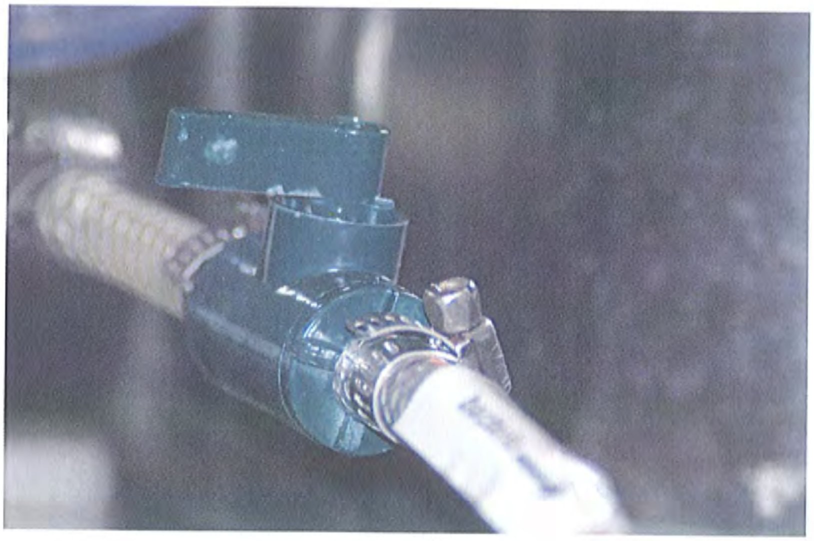
B. **Open the green valve located on the bottom of measuring cylinder.**



C. **Slowly turn the three way brass valve to position "2" to start supplying the delivery gas (nitrogen, argon) to the measuring cylinder and injection tubing. Flush the cylinder and injection tubing with gas for 2-3 min.**

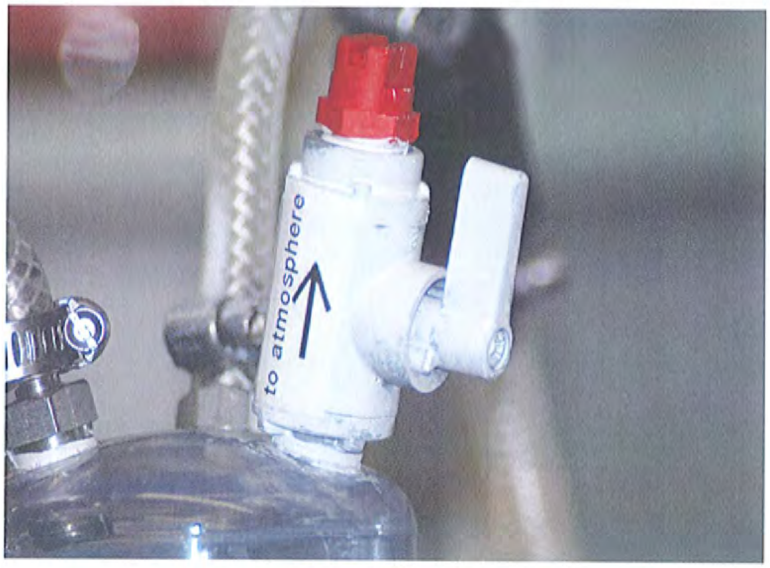


D. **Close the green valve.**



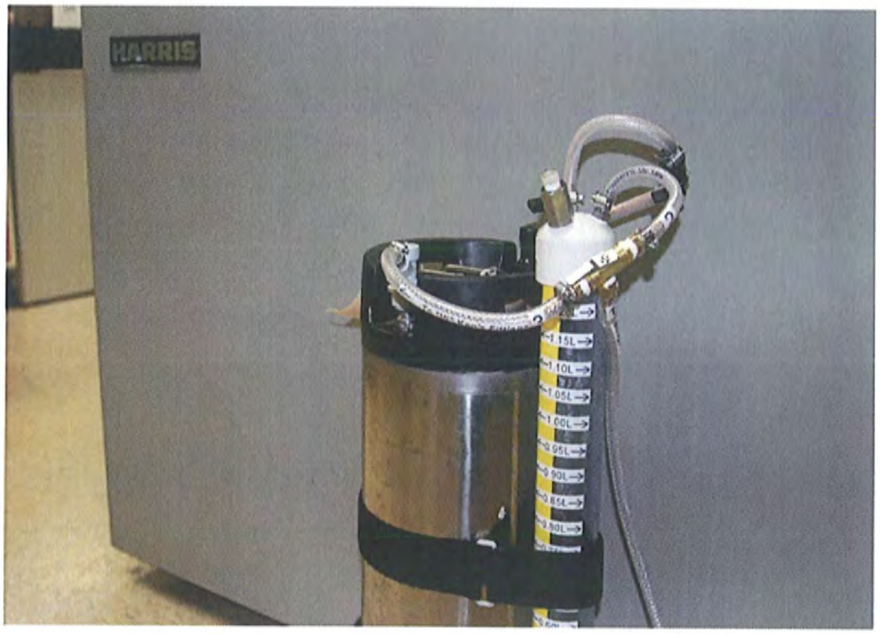
E. **Turn the three way brass valve to position “1”.**

F. **Open the white valve “to atmosphere “position to release any gas pressure in the measuring cylinder. The white valve is equipped with a check valve that prevents the air from being added into the measuring cylinder.**



3. **Add the required amount of bacteria to the measuring cylinder:**

   A. **Turn the brass three way valve to position "3" to pressurize the keg with delivery gas.**



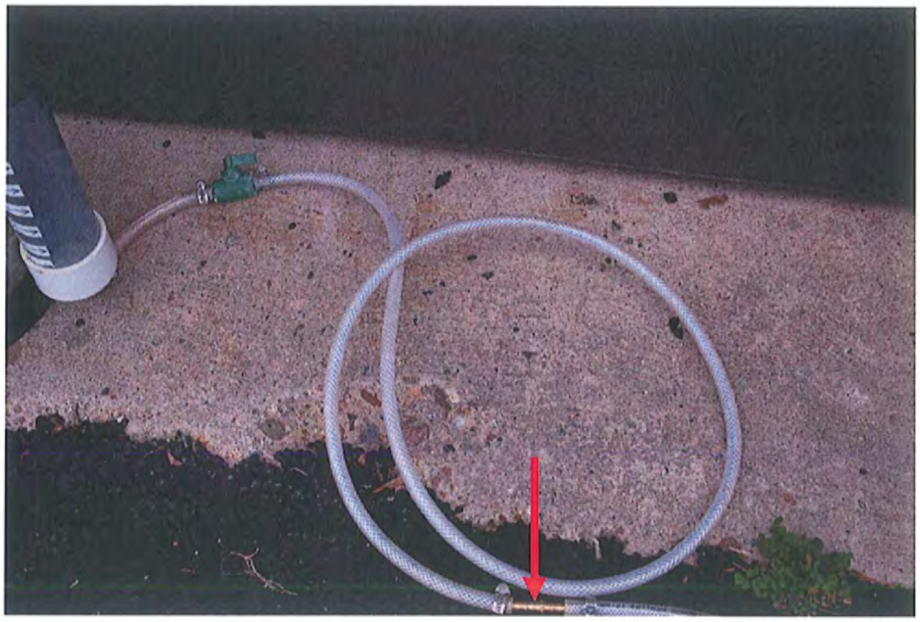
   B. **Slowly open the black valve to add bacteria from the keg to the cylinder.**

C. Add the required amount of bacteria and close the black valve.

D. Close the white valve.

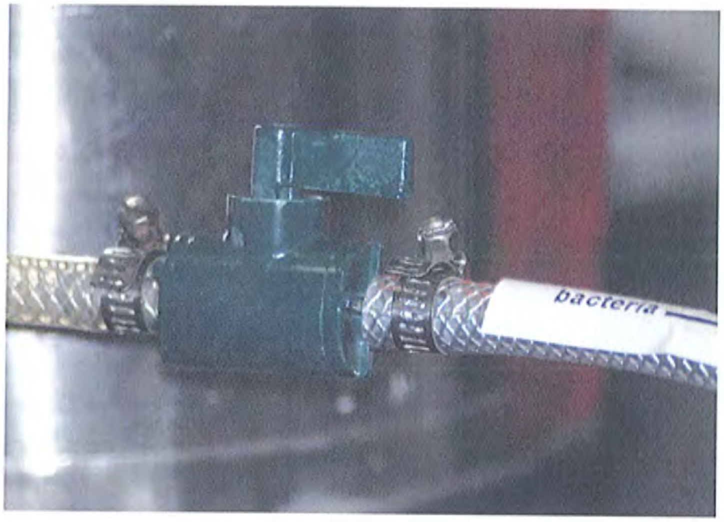
4. Transferring the measured amount of bacteria from the measuring cylinder to the injection point:

A. Be sure that at this point that the injection line is connected to the injection point.

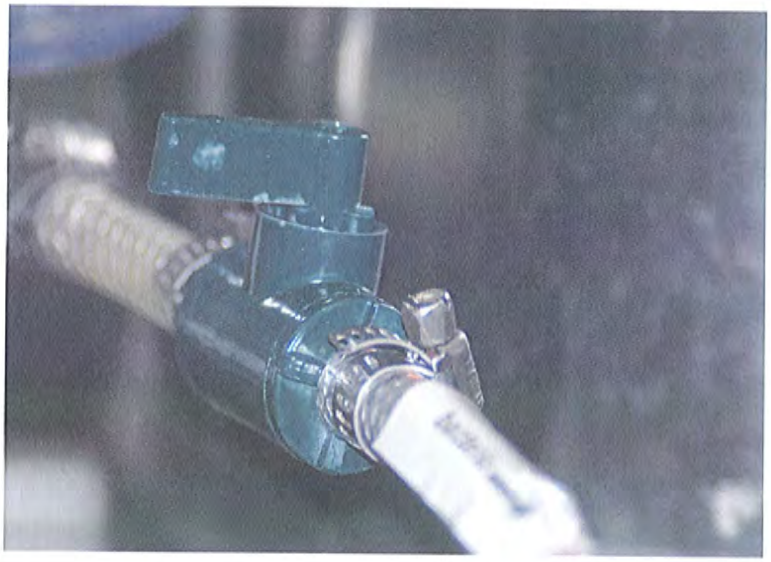


B. Turn **the brass three way valve to position"2" to pressurize the measuring cylinder with delivery gas.**

C. Slowly open the green valve on the "bacteria →" line to provide the desired flow of bacterial suspension. Delivery of the culture can be monitored by watching the liquid level in the measuring cylinder.



5. **After delivery of the desired volume of bacterial suspension, close the green valve.**



A. **Turn the brass three way valve to position "1".**

6. **To add more bacteria, follow the instructions according to steps 3 and 4 above.**
7. **After finishing distributing the bacteria, disconnect the black and grey connectors from the keg by pulling up on the barrel of the quick connects.**

STORAGE

If the schedule of bacteria application requires adding the bacteria over a period of more than one day, the keg(s) should be stored at a temperature 2-4 °C, but do not freeze. This can normally be achieved by storing the kegs under ice in the provided coolers. The keg should be pressurized with Nitrogen to pressure 10- 15 psi before storing to ensure a tight seal on the keg cap.

SHIPPING

Cooler and Keg Packed for Return Shipment

After completion of operation, please ship the cooler with keg, delivery system and all spare fittings back to the following address:

Simon Vainberg
CB&I
17 Princess Road, Lawrenceville, NJ 08648

APPENDIX C

BENCH SCALE BUFFER TEST SUMMARY REPORT

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pH Titration Test

Client:

Weston Solutions Inc.
1400 Weston Way
West Chester, PA 19380
Christopher Moran
Phone: 610.701.3907
Email: chris.moran@westonsolutions.com

Performing Lab:

PeroxyChem Environmental Solutions USA
Tonawanda, New York, 14150

Date August 31, 2017

I. Sample Handling

Client Sample Identification

Site Identification: NIKE Waldorf, MD.
Soil ID: 0268-SS-01
GW ID: 0268-MW02

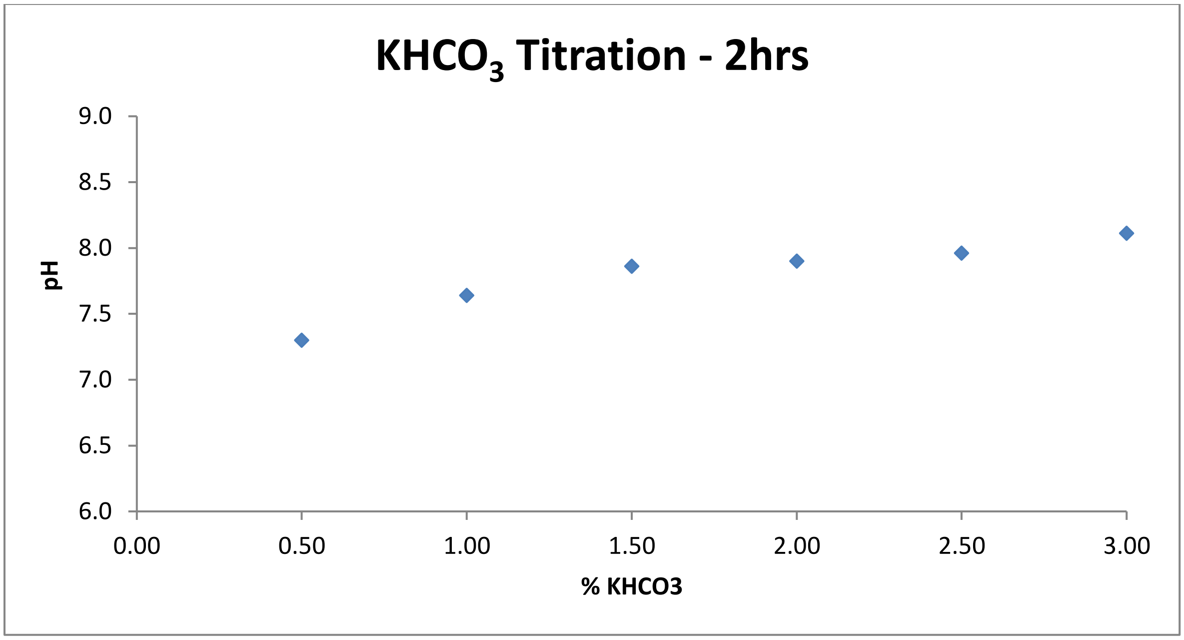
Handling Procedures

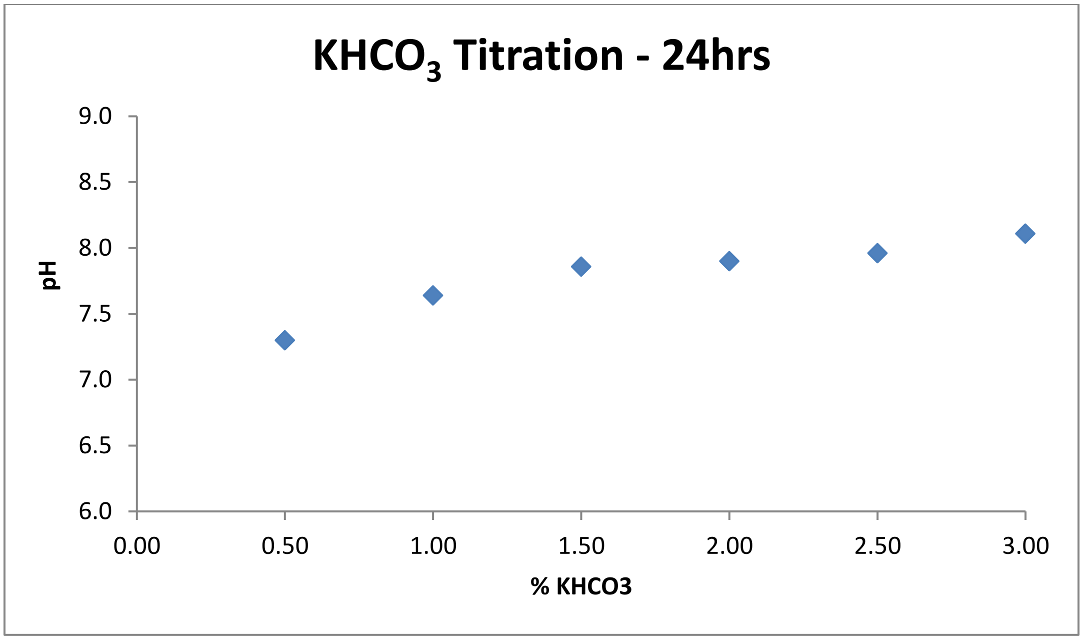
- Soil was transferred into a stainless steel bowl and mixed well.
- The remaining soil was put into its original container and stored at ambient lab temperature.
- A pH titration test was performed to determine the mass of $KHCO_3$ required to raise the site soil and groundwater to pH 7.0.
- A 2:1 ratio of groundwater to soil was set up in centrifuge tubes with the required mass of the pH adjuster.
- Tubes were then placed on a shaker platform for 2 hours.
- Samples were allowed to settle for 15 min and the first reading was taken.
- Tubes were then allowed to sit undisturbed.
- At 24 and 48 hours the tubes were inverted, the soil was allowed to settle and the pH readings were taken.
- The unused soil will be disposed of responsibly after about one month.

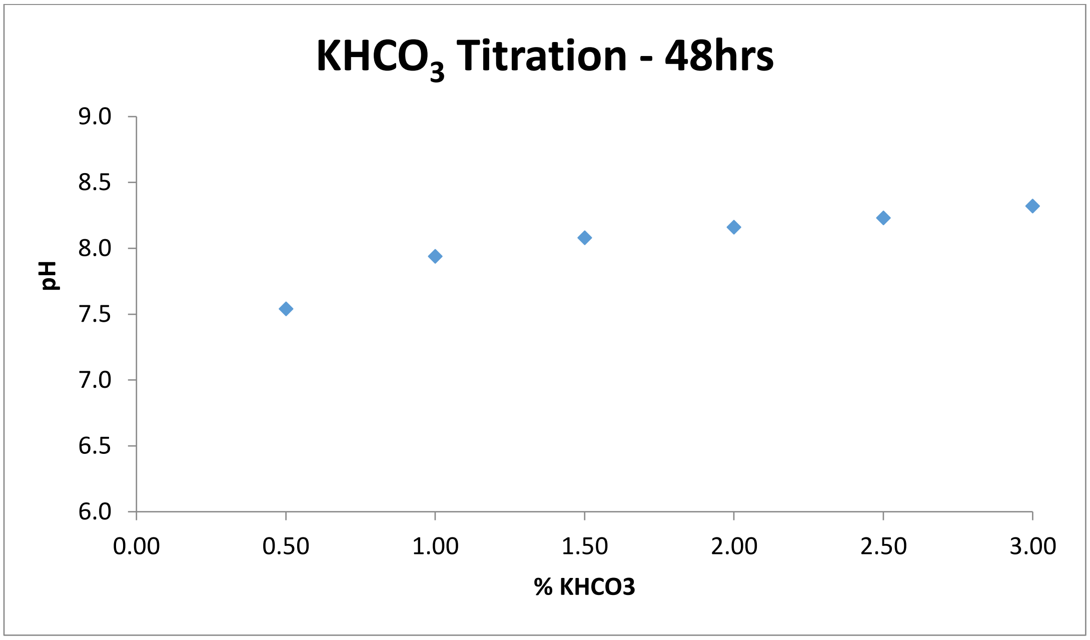
II. Results

KHCO$_3$ Titration details

% KHCO3 by soil mass	pH		
	2 hours	24 hours	48 hours
0.00	5.09	5.12	5.30
0.50	7.16	7.30	7.54
1.00	7.56	7.64	7.94
1.50	7.73	7.86	8.08
2.00	7.76	7.90	8.16
2.50	7.87	7.96	8.23
3.00	7.96	8.11	8.32


KHCO$_3$ Titration - 2hrs





III. Conclusions

A dosage of 0.50% $KHCO_3$ was sufficient to raise the pH of the soil slurry to 7.0 after 2 hours, though it is noted that the pH continued to rise over the period of observation.

IV. Authorizing Signatures

This report contains the results as determined by PeroxyChem laboratory protocol and are accurately represented herein.

Note: PeroxyChem recommends performing suitable treatability testing and field pilot demonstration to determine the soil pH buffer demand. The pH titration results do not imply a guarantee of demand in actual field situations. 2. ANY SUCH QUANTITY OR WARRANTY IS EXPRESSLY DISCLAIMED.