ANALYSIS OF BROWNFIELDS CLEANUP ALTERNATIVES (ABCA)

Former CG Conn Property
1101 East Beardsley Avenue
Elkhart, Indiana
Brownfield #4140202
IFA/EPA RLF No. 4B-00E03232-0

Prepared For:

The City of Elkhart

&

Prepared By:

Roberts Environmental Services, LLC
2112 Carmen Court
Goshen, IN 46526

ROBERTS Project No. 24-10938-10
August 12, 2024 (Revised August 29, 2024)

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Prepared For:

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August 12, 2024 (Revised August 29, 2024)

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ACRONYMS

AAI	All Appropriate Inquiry
AOC	Area of Concern
AR	Administrative Record
AS/SVE	Air Sparge/Soil Vapor Extraction
AST	Aboveground Storage Tank
BG	Background
COCs	Contaminants of Concern
CMT	Continuous Multi-channel Tubing
C-O-C	Chain-of-Custody
DC	Direct Contact
DCE	Dichloroethylene
DO	Dissolved Oxygen
DQA	Data Quality Assessment
DQO	Data Quality Objectives
EPA	Environmental Protection Agency
ERC	Environmental Restrictive Covenant
FB	Field Blank
FD	Field Duplicate
Foc	Fraction of Organic Carbon
FSI	Further Site Investigation
GIS	Geographic Information System
HASP	Health and Safety Plan
HCL	Hydrochloric Acid
HNO3	Nitric Acid
IA	Indoor Air
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
IFA	Indiana Finance Authority
IR	Information Repository
ISI	Initial Site Investigation
JHA	Job Hazard Analysis
L.P.G.	Licensed Professional Geologist (Indiana)
MACOG	Michiana Area Council of Governments
MCL	Maximum Contaminant Level
mg/kg	Milligrams per kilogram (ppm)
mg/l	Milligrams per liter
MSDS	Material Safety Data Sheet
MS/MSD	Matrix Spike / Matrix Spike Duplicate
MW	Monitoring Well
NELAP	National Environmental Lab Accreditation Program
NPD	Non-Rule Policy Document
OLQ	Office of Land Quality
ORP	Oxidation Reduction Potential
OSHA	Occupational Safety & Health Administration
PAHs	Polynuclear Aromatic Hydrocarbons
PERC	Tetrachloroethylene
PID	Photo Ionization Detector
PL	Published Level (IDEM)
PPE	Personal Protective Equipment
PPB	Parts per billion (ug/kg or ug/l)
PPM	Parts per million (mg/kg or mg/l)
PRB	Permeable Reactive Barrier
QA/QC	Quality Assurance / Quality Control
QAPP	Quality Assurance Project Plan
R2	IDEM Risk-Based Closure Guide (2022)
REC	Recognized Environmental Condition
RCG	Remediation Closure Guide
RLF	Revolving Loan Fund
RWP	Remediation Work Plan
SAP	Sampling & Analysis Plan
SGe	Exterior Soil Gas
SLs	Screening Levels
SOP	Standard Operating Procedures
SOW	Statement of Work
SRF	State Revolving Loan Fund
SVOC	Semivolatile Organic Compounds
TB	Trip Blank
TCE	Trichloroethylene
TW	Temporary Well
UFP	Uniform Federal Policy
ug/kg	Micrograms per kilogram (ppb)
ug/l	Micrograms per liter (ppb)
ug/m^3	Micrograms per cubic meter
USGS	United States Geological Survey
USP	Uncontaminated Soil Policy
UST	Underground Storage Tank
VAS	Vertical Aquifer Screening
VC	Vinyl Chloride
VEC	Vapor Exposure Condition
VI	Vapor Intrusion
VMS	Vapor Mitigation System
VOC	Volatile Organic Compound
VRP	Voluntary Remediation Program
XSPL	Excavation Worker Published Level

1.0 INTRODUCTION

This Analysis of Brownfields Cleanup Alternatives (ABCA) report has been prepared by Roberts Environmental Services, LLC ("ROBERTS") for planned remedial activities at the Former CG Conn Property ("Former Conn") located at 1101 East Beardsley Avenue, in Elkhart County, within the City of Elkhart, Indiana (hereinafter referred to as the "Site"). The location of the Site is depicted in Figure 1 and a Site overview map is provided as Figure 2. The ABCA report, required by the United States Environmental Protection Agency (U.S. EPA), was prepared in support of ongoing Indiana Brownfields Program (IBP) activities to identify and evaluate cleanup alternatives to mitigate potential risks to human health and the environment from identified subsurface environmental impacts at the Site.

Previous assessment activities were completed at the Site and funded under the IBP under the MACOG Brownfields Coalition Grant (Grant No. BF-00E02717-0 and 4B-00E03206-0). Additional assessment and monitoring activities were funded by the City of Elkhart.

This ABCA report has been prepared in support of the Site's Community Involvement Plan (CIP), submitted to the IBP for review and approval. As part of the CIP, the existing Administrative Records (AR) file and the Information Repository (IR) for the Site will be updated to be made available for public review and comment. The AR/IR will be available at the City of Elkhart's offices and through a website hosted by the City of Elkhart. Reasonable public notice will be provided that the required documents are being prepared and will be available for public review and comment. The City of Elkhart will also conduct public meetings to gather community input regarding the cleanup process.

The City of Elkhart and its environmental consultant, ROBERTS, shall consider all comments received and provide responses to those comments at the end of the public comment period. Comments that may change or supplement the Remediation Work Plan will be provided to the IBP Project Manager for review. All public comments will be summarized and documented and included in the AR, as well as any responses to public comments.

After the designated, required public review/comment period and issuance of the Decision Memorandum (summarizing the selected cleanup alternatives and serving as a notice to proceed with federally funded cleanup actions), ROBERTS and the City of Elkhart will obtain Request for Proposals/Qualifications and Bids from multiple contractors, including local minority business enterprises, women's business enterprises, and disadvantaged business enterprises (MBE/WBE/DBE) qualified companies. Pending community input and IBP approval, ROBERTS and the City of Elkhart plan on implementation of the remedial program in fall 2024.

2.0 BACKGROUND

2.1 Property Description

The Site is identified as one (1) parcel of land (Parcel No. 20-02-33-381-001.000-027) totaling approximately 10-acres. The Site is situated south of East Beardsley Avenue and north of Greenleaf Boulevard and is part of the southwest ¼ of Section 33, Township 38 North, Range 5 East, Osolo Township, Elkhart County, Indiana. The southern-most portion of the Site along Greenleaf Boulevard is part of the northwest ¼ of Section 4, Township 37 North, Range 5 East, Concord Township, Elkhart County, Indiana. The approximate geographic coordinates of the middle of the Site are 41.6955° North and -85.9596° West (NAD83). The Site is currently owned by the City of Elkhart Department of Redevelopment. The location of the Site is depicted in Figure 1 and a Site overview map is provided as Figure 2. The Site is currently vacant. The City maintains the Site (grass cutting, etc.).

2.2 Property History

The property was developed in circa 1910 by C.G. Conn Limited for the manufacturing of musical instruments. Prior to that time, the Site was apparently undeveloped/vacant and/or agricultural land. The entire central and eastern portion of the Site consisted of manufacturing buildings/areas, while the far western portion of the Site was believed to always have been a parking lot area. After Conn vacated the Site in circa 1977/1978, most of the Site buildings were demolished and Coachmen Industries utilized the Site, reportedly as office space from 1978 to 2011. Various other entities owned the Site after 2011, but may have left the building vacant. The Site remained in a similar state with a vacant dilapidated building on the far northeastern portion of the property until the City demolished the building in October/November 2023.

2.3 Proposed Redevelopment

The Site is currently vacant. Indications are that future land uses will be residential (single family homes, townhomes, etc.) with some areas of the Site possibly devoted to a park or open green space and limited commercial developemnt.

It is anticipated that the proposed remedial activities will allow for residential property reuse with soil and ground water concentrations below Indiana Department of Environmental Management (IDEM) R2 Published Levels (PLs) after remediation is complete. Following soil and ground water remediation, Site closure soil gas samples will be collected prior to redevelopment to determine if certain areas of the Site may require vapor mitigation as an engineering control.

3.0 SUMMARY OF PROPERTY CHARACTERIZATION

3.1 Prior Investigations & Reports

All of the previous investigation results have been incorporated when evaluating remedial options for the Site. The following previous and recent investigations have occurred:

- *ISI activities (ROBERTS - July 2020)*: See ISI Report. Thirteen (13) borings with nineteen (19) soil samples and thirteen (13) ground water samples;
- *FSI activities (ROBERTS – April 2021)*: See FSI Report. Fifteen (15) borings with thirteen (13) soil samples and eighteen (18) ground water samples. Included a geologic boring to 35-feet below surface grade (bsg), two (2) deeper (below the water table) vertical aquifer screening (VAS) ground water samples, and the installation of five (5) monitoring wells with sampling of six (6) monitoring wells (off-Site Bergerson Screw monitoring well to the north also sampled);
- *Off-Site TCE in Ground Water Investigation (Roberts – November 2021)*: See Off-Site Report. Six (6) soil borings at off-Site locations. Soil gas sampling was also performed at two (2) off-Site locations. A total of six (6) ground water samples and two (2) soil gas samples.
- *Ground Water Sampling Report (SES – August 2022)*: Two (2) rounds of monitoring well sampling (May and July 2022) six (6) monitoring wells each event.
- *Additional Soil Investigation Report (SES – August 2022)*: Ten (10) soil borings with two (2) soil samples per boring (20 total soil samples).
- *Additional MACOG Brownfields Sampling (ROBERTS – October & November 2022)*: TCLP soil sampling at four (4) locations with previous elevated lead and silver. Eight (8) soil borings with sixteen (16) soil samples. Twelve (12) soil gas sampling locations with two (2) variable depth vapor samples at each location (24 total soil gas samples).
- *Additional Investigation (ROBERTS/METRIC – December 2022)*: Fifty-four (54) soil borings with one-hundred fifty-three (153) soil samples, eight (8) ground water samples, and thirty-seven (37) shallow soil gas samples.
- *Additional Lead & Arsenic Step-Out Sampling (ROBERTS – March 2023)*: Four (4) shallow step-out samples each around grid nodes G-6 and G-43.
- *Demolition Oversight* Report (ROBERTS – Oct./Nov. 2023) – Soil screening at seventy-seven (77) locations with eight (8) soil samples collected for analysis.

To date, a total of two-hundred and forty-two (242) soil samples, forty-five (45) ground water samples, and sixty-three (63) soil gas samples have been collected and analyzed at the Site.

Relevant Previous Reports

Several previous environmental reports have been prepared for the Site, including:

- Phase I ESA (2016), ROBERTS, included in RWP;
- An Initial Site Investigation (ISI) (ROBERTS - report dated July 23, 2020 – IDEM VFC ID 83013661) for the City of Elkhart under the MACOG Brownfields Coalition Grant (Grant No. BF-00E02717-0);
- A Further Site Investigation (FSI) (ROBERTS - report dated April 12, 2021 – IDEM VFC ID 83275289) for the City of Elkhart under the MACOG Brownfields Coalition Grant (Grant No. BF-00E02717-0);
- An Off-Site TCE in ground water investigation (ROBERTS - report dated November 15, 2021 – IDEM VFC ID 83251606) for the City of Elkhart under the MACOG Brownfields Coalition Grant (Grant No. BF-00E02717-0);
- An Additional Soil Investigation Report (SES – report dated August 16, 2022 – IDEM VFC ID 83357476) for Indiana Brownfields Program and the City of Elkhart;
- A Ground Water Sampling Report (SES – report dated August 16, 2022 – IDEM VFC ID 83357477) for Indiana Brownfields Program and the City of Elkhart;
- Addendum to April 12, 2021 FSI Report – TCLP Soil Sampling (ROBERTS – report dated January 27, 2023 – IDEM VFC 83432938) for City of Elkhart under the MACOG Brownfields Coalition Grant (Grant No. BF-00E02717-0).
- An Additional Site Investigation Report (ROBERTS – report dated February 1, 2023 – IDEM VFC ID 83427832) for City of Elkhart under the MACOG Brownfields Coalition Grant (Grant No. 4B-00E03206-0).
- Additional Lead & Arsenic Step-Out Sampling at G-6 & G-43 (ROBERTS – report dated June 6, 2023 – IDEM VFC ID 83487428) for City of Elkhart under the MACOG Brownfields Coalition Grant (Grant No. 4B-00E03206-0).
- A Demolition Oversight Report (ROBERTS – report dated December 18, 2023 – IDEM VFC ID 83572739) for City of Elkhart under the MACOG Brownfields Coalition Grant (Grant No. 4B-00E03206-0).

3.2 Identification of Impacts

Historical investigations completed by other consultants and previous investigations conducted at the Site by ROBERTS have revealed areas of soil and ground water impacts. Soil impacts include metals (primarily lead and silver) and polynuclear aromatic hydrocarbons (PAHs) at concentrations greater than IDEM RCG (R2) residential soil published levels (RSPLs), some at concentrations that exceed excavation worker published levels (XSPLs). Chlorinated solvents (primarily trichloroethylene - TCE) have also been identified in soils on the eastern and central portion of the Site. Ground water impacts identified through prior investigations include relatively low-level concentrations (all less than 15 ug/l) of TCE. No elevated concentrations of PAHs or metals have been identified in the ground water to date. Recent soil gas investigations have also identified chlorinated solvent vapor concentrations that exceed IDEM RCG (R2) residential soil gas published levels (RSGPLs - shallow and deep). The precise source of the soil, ground water, and soil gas impacts is unknown, but is believed to be related to residual contamination from past musical instrument manufacturing activities that previously occurred at the Site. Historical fill encountered on some portions of the Site, including under the former building footprint, appears to coincide with some of the elevated metals and PAHs soil impacts.

Soil. The primary chemicals of concern (COCs) in soils at the Site are metals ((primarily lead and silver), PAHs, and the chlorinated solvent TCE) along with some detections of tetrachloroethylene (PERC - see Figures 3 and 4). However, although the TCE detections in soils are below the XSPL, it appears that the various TCE detections in soils are contributing to vapor RSGPL exceedances in soil gas at the Site.

Ground Water. The primary COCs in ground water at the Site are the chlorinated solvent TCE along with some detections of PERC (see Figure 5). No metals or PAHs have been identified in ground water at concentrations greater than ground water published levels (GWPLs).

Vapor. The primary COCs in vapor at the Site are the chlorinated solvent TCE along with some detections of PERC. Shallow soil gas impacts are shown on Figure 6.

Fire and explosion hazards can be associated with chlorinated solvents and PAHs. However, the nature and degraded state of the contaminants at the Site would minimize fire and/or explosion hazards. Potential exposure pathways are ingestion from ground water, contact with contaminated soil, or inhalation of vapors. At this time, the identified soil contamination is primarily confined to locations underneath grass-covered areas and/or pavement thus limiting most potential exposure scenarios. Ground water ingestion pathways are mitigated by the use of municipal water in the entire area. As such, potential exposure associated with residual contamination after remediation activities take place will be minimal.

3.2.1 Metals & PAHs Soil Contamination

As shown in Figure 3, the horizontal extent of metals and PAHs soil contamination is limited to five (5) main areas (shaded in red on Figure 3). Unsaturated soil samples exhibit metals and PAH concentrations greater than RSPLs. Some concentrations of lead also exceed XSPLs, at boring locations B-5 (2,000 mg/kg), B-8 (1,100 mg/kg), G-6 (1,500 mg/kg), G-20 (19,000 mg/kg), and G-21 (6,800 mg/kg).

3.2.2 Chlorinated Solvent Soil Contamination

As shown in Figure 4, the horizontal extent of non-saturated chlorinated solvent soil impacts are primarily limited to areas located south of the former on-Site building on the eastern portion of the Site. Chlorinated solvent VOC concentrations in soil do not exceed the July 2022 PLs at any location. However, the elevated concentration of TCE and PERC in soil appear to be the primary contributing source to the identified vapor concentrations in soil gas. No other VOCs were identified at elevated concentrations.

3.2.3 Chlorinated Solvent Ground Water Impacts

Chlorinated solvent COCs in ground water identified at the Site are shown on Figure 5. The impacted area of historical chlorinated solvent ground water contamination is defined as areas that previously exceeded GWPLs (primarily TCE). As shown in Figure 5, the horizontal extent of historical chlorinated solvent ground water impacts (TCE) extends from south of the former on-Site building westerly towards the intersection of Greenleaf Boulevard and East Beardsley Avenue. As shown in the *Off-Site TCE in Ground Water Investigation (Roberts – November 2021),* the plume migrates off-Site approximately one (1) block west of that same intersection. A smaller area of TCE in ground water impacts appears to be centered around a catch basin/drywell structure on the far northern portion of the Site (concentrations less than GWPLs at 1.2 to 1.3 ug/l TCE).

No light non-aqueous phase liquids (LNAPLs) or dense non-aqueous phase liquids (DNAPL) have been identified in any of the borings or monitoring wells at the Site. The vast majority of ground water contamination is limited to on-Site areas (i.e., the actual Former CG Conn property). As discussed below, the relatively low-level concentrations of TCE in ground water appear to be contributing to vapor phase soil gas impacts.

3.2.4 Chlorinated Solvent Vapor Impacts

As previously mentioned, the chlorinated solvent impacts (primarily TCE and to a lesser extent PERC) in soil and ground water are contributing to vapor phase soil gas impacts at the Site. Figure 6 depicts shallow (+/-5.0-feet bsg) TCE impacts in soil gas. Previous deeper (+/-10-feet bsg) TCE vapor concentrations are generally greater than shallow concentrations, particularly in areas outside of the known TCE in soil impacts, which suggests that the historical TCE ground water impacts are contributing to vapor phase impacts. In areas of TCE in soil impacts (Figure 4), soil gas concentrations are highly elevated, orders of magnitude greater than RSGPLs. As shown on Figure 6, the greatest concentrations of TCE vapors in soil gas are centered around/near the SG-7 area south of the former building with TCE concentrations in shallow soil gas at 35,000 micrograms per cubic meter (ug/m^3) and TCE in deeper soil gas at 50,000 ug/m^3. The vapor phase impacts extend westerly across the Site towards the intersection of Greenleaf and Beardsley (similar to the historical ground water impacts).

At this time, no significant concentration trends in soil, ground water, or vapors have been identified at the Site. The areas of identified contamination appear to be at steady-state with concentrations of COCs remaining fairly constant over the past several years. Of note, as part of the *Ground Water Sampling Report (SES – August 2022)*, TCE was identified over the GWPL (5.0 ug/l) in ground water during the first sampling event in May 2022, but all concentrations were below GWPLs during the July 2022 monitoring well sampling event.

3.2.5 PFAS Impacts in Soil and Ground Water

Per and polyfluoroalkyl substances (PFAS) were analyzed as part of SES's 2022 soil and ground water investigations. PFAS were not detected in most soil samples with the exception of relatively low concentrations of n-Methylperfluorooctanesulfonamidoethanol (no PLs exist) in four (4) soil samples collected on the southeastern portion of the Site. Detected PFAS in ground water included various concentrations of Perfluorooctanoic Acid (PFOA), Perfluorooctanesulfonic Acid (PFOS), Perfluorohexanoic Acid (PFHxA), and Perfluoropentanoic Acid (PFPeA). Concentrations of PFOA in ground water at MW-1 (8.1 nanograms per liter – ng/l) and MW-5 (4.5 ng/l) exceed the current (April 2024) EPA drinking water maximum contaminant level (MCL) of 4.0 ng/l. No other PFAS concentrations exceed MCLs or PLs. However, PFOA was not identified above detection limits in ground water samples at monitoring wells MW-2, MW-3, or MW-4 located hydrogeologically downgradient of MW-1 and upgradient of MW-5. Additionally, no PFOA was identified in the soil samples. Therefore, the anomalous low-level concentrations of PFOA in ground water may not be related to historical Site activities and may be coming onto the Site from some unknown off-Site source. Nonetheless, these detections should be verified via additional sampling to establish the need for a possible ground water use restriction or additional PFAS remedy evaluations.

3.3 Property Geology and Hydrogeology

Site Soils and Geology. According to the *Soil Survey of Elkhart County, Indiana* (U.S. Department of Agriculture (USDA), 2021 – via Web Soil Survey), surficial soils on the Site primarily consist of the Urban land-Bristol complex (UdpA). The Urban land-Bristol soils are described as a loamy sand that formed from glacial outwash plain deposits and outwash terraces. These soils are nearly level and occupy swells. Surficial layers consist of loamy sands that become loamy coarse sands at approximately 21-inches. The soils have a low available water capacity and are excessively drained.

Surficial geology in the general vicinity of the Site is represented by outwash deposits of gravel, sand, and silt (IndianaMap (http://maps.indiana.edu/)). These sediments are associated with the outwash facies of the Atherton Formation in Indiana. Bedrock subcrops at an approximate depth of 150 feet beneath the surficial unconsolidated deposits and consists of the Sunbury and Ellsworth Shales.

Site-wide stratigraphy tends to match the soil survey descriptions and generally consists of loamy sands and sandy loams near the surface and sands with some gravels at depth. In general, loamy topsoils with silty sands are encountered at the surface to depths of 5.0 to 8.0-feet bsg, followed by fine/mediums sands in some areas to depths of 8.0 to 12-feet bsg. Coarser sands and gravels are generally encountered across the Site at depths greater than 10-feet bsg. Historical fill is also encountered generally at depths of 1.0 to 3.0-feet bsg on the central and eastern portions of the Site. A deeper geologic boring (35-feet deep) advanced near the center of the Site identified a clay layer at a depth of 33-feet bsg. The depth to ground water across the Study Area varies between 7.5 to 12.5-feet bsg.

Site Hydrogeology. According to *Water Resources Availability in the St. Joseph River Basin, Indiana* (Indiana Department of Natural Resources - IDNR, 1987, and the IndianaMap (http://maps.indiana.edu/), the Site is located within the St. Joseph Aquifer System. Water wells in the area (IDNR) and installed at the Site indicate the depth to ground water at the Site is approximately 6.0 to 12.0-feet below surface grade (bsg). Investigations at the Site indicate depth to water (water table) varies from 7.5 feet bsg (south) to 12.5-feet bsg (north). The regional ground water flow direction is likely southwesterly towards the St. Joseph River, which is located approximately 200-feet south of the southern-most portion of the Site. However, the ground water flow direction at the Site has been documented as westerly (ROBERTS FSI Report, 2021), which is likely influenced by the nearby AEP hydroelectric dam southwest of the Site on the St. Joseph River. The St. Joseph Aquifer System consists of thick sand and gravel deposits that have excellent ground water availability (100 to 1,500 gallons per minute (gpm)). According to IDNR, the St. Joseph Aquifer is highly susceptible to contamination and is a designated sole-source aquifer.

The ground water table is generally encountered at depths of 10 to 12.5-feet bsg on the central and northern portions of the Site and 7.5 to 9.0-feet bsg on the southern portions of the Site. Typical seasonal water table fluctuations range from 1.0 to 4.0-feet within the unconfined sand and gravel aquifers in Elkhart County. The unconfined aquifer at the Site consists of poorly sorted sands with some gravel down to the depths investigated. The primary impacted aquifer zone at the Site consists of the shallow water table aquifer zone. Deeper VAS ground water sampling, (two zones: 25.5 to 29-feet and 30.5 to 34-feet below surface grade), below the water table, did not identify any GWPL exceedances.

Porosity calculations would likely fall within the typical range of porosities for sand and gravel soils (i.e., 20% to 40%), with an average porosity across the Study Area on the order of 30% for the shallow water table aquifer. Hydraulic conductivity values likely range from 100 to over 300 feet/day within coarser zones. A westerly ground water flow direction has been documented at the Site, which likely reflects influences from the nearby hydroelectric dam on the St. Joseph River southwest of the Site. A hydraulic gradient of approximately 0.002 feet/feet was calculated as part of the FSI monitoring well sampling activities.

4.0 CLEANUP ALTERNATIVES ANALYSIS

Based on the investigation results, active on-Site remediation will be necessary in order to meet the residential end-use scenario in a timely fashion. Some metals concentrations exceed XSPLs and PAHs exceed RSPLs, while vapors in soil gas are highly elevated at certain locations where chlorinated solvent impacts have been identified in soils. TCE soil gas vapor concentrations are also greater than RSGPLs at areas outside of the chlorinated solvent soil impacts, near/above the relatively low-concentration historical TCE in ground water impacts.

4.1 Cleanup Goals

Cleanup goals include eliminating or reducing impacts to soil and ground water for successful residential redevelopment. Current Risk-Based Closure Guide (RCG-R2) published levels (PLs) will be used to guide the remedial activities (most recent March 2024). Since redevelopment plans include a residential end use, residential soil published levels (RSPLs) will be utilized for on-Site direct contact soil cleanup objectives (note that no RSPLs exist for TCE, only XSPLs). This includes the new EPA soil screening guidance of 200 mg/kg for lead, which IDEM has indicated will be adopted as the new RSPL for lead. Residential soil gas published levels (RSGPLs) will be utilized for on-Site vapor media cleanup objectives. Ground water published levels (GWPLs) will also be referenced. Institutional controls may also be used to control risk/exposure, if necessary.

4.2 Soil, Ground Water, & Vapor Cleanup Alternatives Analysis

The intent of the cleanup is to reduce chlorinated VOCs (cVOCs), particularly TCE, in ground water and cVOCs, PAHs, and metals in shallow unsaturated soils, and mitigate exposure to human health and the environment. Reducing or eliminating cVOCs in soil and ground water should also reduce or eliminate vapor concerns.

The cleanup alternatives considered for mitigating the risks associated with the impacted ground water and soil are discussed below. Cleanup alternatives were evaluated based on the following criteria:

1) Effectiveness
    a) The degree in which toxicity, mobility, and contaminant volume is expected to be reduced.
    b) The degree in which a corrective action will protect human health and the environment over time.
    c) Consideration for any adverse impact to human health and the environmental during corrective action implementation.

2) Implementation
    a) Technical feasibility of corrective action at the site.
    b) Availability of materials, equipment, and services needed to carry out corrective action.
    c) Administrative feasibility of corrective action (access agreements, permits, approvals from municipal, state, and/or federal agencies).

3) Cost
    a) Initial costs – planning and implementation (contractors, laboratory, etc.)
    b) Annual operation and maintenance costs

4.2.1 Ground Water Cleanup Alternatives Analysis

4.2.1.1 Alternative 1a – No Action

A no action alternative was considered for ground water. Under this scenario, the surface conditions would remain as-is. A no action alternative would require ongoing monitoring (which would incur costs) to assess/confirm the extent of the ground water plume. Additionally, as demonstrated via soil gas sampling, installation of vapor mitigation systems (VMSs) would be required to protect human health at on-Site areas with ground water impacts.

Alternative 1a – No Action/Ground Water Monitoring	**Low Cost**	**High Cost**
Quarterly Ground Water Monitoring/Sampling & Reporting (2 Years)	$120,000	$180,000
Vapor Mitigation Systems (20 to 70 Properties)	$180,000	$630,000
Probable Cost	**$300,000**	**$810,000**

Although no action is one of the least costly, it does not achieve the City of Elkhart's goal for residential redevelopment, creating jobs, and returning the Site to productive use. On-Site impacts must be remediated to protect human health and the environment, increasing the marketability of the Site. Therefore, the no-action alternative was eliminated from further consideration.

4.2.1.1 Alternative 2a – Pump & Treat

Only treats ground water impacts. Pump and treat systems tend to be effective only to a certain point resulting in average to good initial contaminant mass removal then greatly reduced contaminant mass removal thereafter. This limited long-term effectiveness can lead to extended clean up times and accrued costs.

Alternative 2a – Pump & Treat	Low Cost	High Cost
Quarterly Ground Water Monitoring/Sampling & Reporting (10 Years)	$600,000	$800,000
System Construction & Operation (10 Years)	$1,900,000	$2,700,000
Probable Cost	**$2,500,000**	**$3,500,000**

Given the moderately high transmissivity of the aquifer, a pump and treat system at the Site would likely require high volume pumping rates to be adequately effective at this Site. Combined with the high iron content and hardness of the water in this area, which would tend to clog air stripping units and would require more intense maintenance and/or the addition of acid before stripping, along with no soil treatment, this option was rejected.

4.2.1.1 Alternative 3a – AS/SVE

Soil vapor extraction (SVE) systems have been used at a wide variety of chlorinated solvent and petroleum hydrocarbon impacted sites across the country. Air sparging (AS) is often combined with SVE in order to volatilize shallow areas of ground water contamination. Due to the coarse-grained soils at the Site, AS/SVE systems would likely be an effective remedial technology (Appendix A). The relatively shallow water table across the Site may be best suited for horizontally installed extraction wells, rather than vertical extraction wells. However, AS/SVE systems often require pilot testing and upfront construction timeframes that can take months depending on the size of the overall system. Additionally, AS/SVE systems are typically utilized to remediate elevated impacts in ground water, which are not present on-Site (i.e., only relatively low-level concentrations exist). AS/SVE systems typically require 24 to 36 months of operation to effectively reduce mass, but may not always reduce concentrations to below PLs.

Alternative 3a – AS/SVE	Low Cost	High Cost
Quarterly Ground Water Monitoring/Sampling & Reporting (4 to 5 Years)	$240,000	$400,000
System Construction & Operation (24 to 36 Months)	$675,000	$885,000
Probable Cost	**$915,000**	**$1,285,000**

Due to the physical nature of the remediation system (i.e., not all areas are contacted by the air movement) some residual mass can remain, which could create future vapor concerns. Additionally, the longer operation times of 24 to 36-months would not be conducive to the City’s planned timing for redevelopment. As such, this remediation technology was rejected. However, note that some type of SVE/vapor capture system may be ultimately required to control migrating vapors from off-Site areas to the east.

4.2.1.1 Alternative 4a – Permeable Reactive Barrier & EBM Injections

Enhanced biodegradation materials (EBMs) help stimulate bacteriological breakdown of the contaminants. They "enhance" the activity of the natural microbes already found in the subsurface. EBMs can be aerobic-based or anaerobic-based, both of which can be utilized for chlorinated solvent remediation (vinyl chloride tends to degrade more readily under aerobic conditions). Anaerobic EBMs provide a controlled release of hydrogen through a lactic acid carbon source. The natural bacteria are then stimulated or "enhanced" by the release of these electron donors and, as a result, degrade the contaminants more rapidly. In some cases, it is necessary to bioaugment the aquifer with manufactured microbes to populate the impacted ground water zones for quicker, more complete, biodegradation. Micro zero-valent iron (ZVI) can also be added to create a highly reducing aquifer environment, which is beneficial to achieving complete reductive dichlorination to ethene.

Chlorinated degradation products of PERC/TCE have been detected in the study area (primarily cis-1,2-dichloroethylene). As such, it appears aquifer conditions are already somewhat conducive to reductive dechlorination, but may be limited by too much oxygen and/or limited carbon sources. Pre-injection sampling and analysis for enhanced reductive dechlorination (ERD) indicator parameters would be required to properly design any remedial injections at the Site. EBMs are typically injected using a direct-push rig directly into subsurface zones of contamination. Access limitations and disruptions are only limited by normal operations of the direct-push rig. Another benefit with this technology is that both the horizontal extent and vertical extent of the contaminated zones can be contacted considering the EBMs move with ground water and contact the same surfaces as the ground water. EBMs typically have excellent treatment rates in sandy soils similar to those observed at the Site. A sorption and biodegradation in-situ permeable reactive barrier (PRB) material (i.e., Regenesis PlumeStop®) could also be incorporated into the injection program with the EBMs to minimize or eliminate the TCE (and/or degradation products) in ground water migration off-Site along the western/northwestern Subject Property boundary. EBMs would reduce the TCE in ground water levels and help reduce the soil gas concentrations across the plume, which would likely reduce or eliminate the number of vapor mitigation systems (VMSs) and environmental restrictive covenants (ERCs) required for future home-sites/lots. Therefore, utilization of a PRB and EBM injections are a viable remedial alternative at the Site (Appendix B).

Alternative 4a – PRB & EBM Injections	**Low Cost**	**High Cost**
Monitoring Well Installs & Initial Performance Monitoring	$50,000	$60,000
PRB & EBM Injections	$1,650,000	$2,440,000

Alternative 4a – PRB & EBM Injections	Low Cost	High Cost
Monitoring Well Installs & Initial Performance Monitoring	$50,000	$60,000
Probable Cost	**$1,700,000**	**$2,500,000**

*High cost includes $800,000 added to line item for variabilities in performance, which may require some type of re-injections or higher volumes after final injection designs are determined.

Potential disadvantages include diffusion of cVOCs from saturated soils back into the ground water following consumption of the EBMs and the return to natural oxidation state. However, due to the low concentrations of cVOCs, significant diffusion is not expected. Build-up of vinyl chloride (VC) is possible in some instances, but the use of ZVI can help with complete dechlorination to ethene. Methane gas can be produced with EBM injections and methane monitoring will likely be required at distal property boundary areas.

4.2.2 Soil Cleanup Alternatives Analysis

4.2.2.1 Alternative 1b – No Action

A no action alternative was considered for soils as part of the ABCA process, which would be the least expensive alternative. Under this scenario, soil conditions would remain as-is. A no-action alternative does not include a cost that would be incurred.

Although no action is the least costly, it does not achieve the City of Elkhart's goal for residential redevelopment in the near future. On-Site soil impacts must be remediated to protect human health and the environment. Therefore, the no-action alternative was eliminated from further consideration.

4.2.2.2 Alternative 2b – Thermal Desorption

Thermal desorption remediation utilizes heat to volatilize contaminants in the subsurface. Hot air is pumped into the subsurface and/or a network of pipes that transmit heat are typically buried in the source zone (i.e., conductive heating). The vaporized contaminants are then usually collected and treated in one of a variety of secondary extraction systems (SVE also needed).

Alternative 2b – Thermal Desorption	Low Cost	High Cost
SVE System Construction & Operation (10 Years)	$440,000	$680,000
Thermal Desorption System Construction & Operation (10 Years)	$2,700,000	$3,420,000
Probable Cost	**$3,140,000**	**$4,100,000**

Thermal desorption was dismissed due to its high initial costs, difficult construction conditions at the Site (electrical requirements), and primarily since this technology would not remediate metals in soils.

4.2.2.3 *Alternative 3b – AS/SVE*

SVE systems can also effectively remediate VOCs in soils. Due to the coarse-grained soils at the Site, AS/SVE systems would likely be an effective remedial technology. AS/SVE systems (Appendix A) typically require 24 to 36 months of operation to effectively reduce mass, but may not always reduce concentrations to below PLs.

Alternative 3b – SVE Portion of AS/SVE	Low Cost	High Cost
Quarterly Ground Water Monitoring/Sampling & Reporting (4 to 5 Years)	$240,000	$400,000
System Construction & Operation (24 to 36 Months)	$675,000	$885,000
Probable Cost	**$915,000**	**$1,285,000**

Due to the physical nature of the remediation system (i.e., not all areas are contacted by the air movement) some residual mass can remain, which could create future vapor concerns. As such, this remediation technology was rejected. However, note that some type of SVE/vapor control system may be ultimately required to control migrating vapors from off-Site areas to the east.

4.2.2.4 *Alternative 4b – Excavation & Disposal*

Excavation and disposal activities were explored for both the chlorinated solvent and metals/PAHs COCs in unsaturated soils. Excavation and off-Site disposal typically removes the most contaminant mass in the shortest period of time and is often the most cost-effective when considering mass removal rates. Several thousand cubic yards of impacted soils can be remediated in a matter of weeks. Removal of chlorinated solvent impacted soils would also help mitigate on-Site vapor issues. Elevated chlorinated solvent impacts in soils also likely act as a continuing source contributing to the low-level TCE in ground water impacts observed at the Site. Therefore, excavation and disposal is a viable remedial alternative at the Site.

Alternative 4b – Excavation & Disposal	Low Cost	High Cost
Excavation, Transportation, Disposal, & Backfill (38,000 to 55,000-tons)	$3,000,000	$4,500,000
Excavation Oversight & Confirmation Soil Sampling (assumes up to 260 soil samples)	$235,000	$315,000
Probable Cost	**$3,235,000**	**$4,815,000**

Potential disadvantages include disruption to neighboring properties from dust, which can be alleviated with proper dust control and soil management. After excavation activities, backfill would be required along with grass planting in order to properly restore the Site.

4.2.2.5 Alternative 5b – Soil Capping

Caps must be engineered (installed in lifts with compaction testing) and certified. Caps can be engineered as direct contact and/or infiltration barriers. Chlorinated solvent areas may also require a clay "base layer" with engineered drainage, etc. The cap must be maintained on a perpetual basis (long-term operations, maintenance, and monitoring required). Since a cap is an engineering control, an ERC for each area would be required with reporting to the Institutional Controls Group. This alternative may not adequately control vapors, but can be combined with vapor mitigation systems within chlorinated solvent areas.

Alternative 5b – Soil Capping	**Low Cost**	**High Cost**
Soil Capping (+/-125,000-square feet)	$1,500,000	$2,500,000
Ongoing Maintenance and/or Repairs	$500,000	$750,000
Probable Cost	**$2,000,000**	**$3,250,000**

Caps are not permanent and may require periodic reinstallations, repairs, and long term monitoring/maintenance. As such, this remediation technology was rejected. However, if residual impacts remain after remedial activities are implemented, caps may be used as direct contact barriers on certain portions of the Site (i.e., designated building slab areas, parking lots, green space areas, etc.).

4.2.3 Vapor Cleanup Alternatives Analysis

4.2.3.1 Alternative 1c – No Action

A no-action alternative was considered for vapor as part of the ABCA process, which would be the least expensive alternative. Under this scenario, vapor conditions would remain as-is. A no-action alternative does not include a cost that would be incurred. No option for vapor cleanup or mitigation would require successful implementation of the soil and ground water remedial activities with no residual or off-Site vapor impacts remaining. Confirmation of vapor exposure conditions after soil and ground water remedial activities will be necessary.

4.2.3.2 *Alternative 2c – Vapor Mitigation Systems (VMSs)*

If necessary, vapor mitigation systems (VMSs) can be installed during construction with minimal to no disruptions. VMSs are proven technologies to reduce/eliminate vapor intrusion concerns. Geomembrane or synthetic vapor barriers can be installed with passive sub-slab depressurization system (SSDS) piping that can be retro-fitted to active systems, if necessary (i.e., install electrified fan unit).

Alternative 2c – Vapor Mitigation	Low Cost	High Cost
VMS System Construction (20 to 70 homesites)	$180,000	$630,000
Long-Term Operation and Maintenance* (per year)	$10,000	$35,000
Probable Cost	**$190,000**	**$665,000**

*These costs may not be incurred by the City of Elkhart.

Disadvantages include, VMSs require some-type of long-term operation, maintenance, and monitoring (OMM, including periodic monitoring of vacuums and/or indoor air concentrations). Since a VMS is an engineering control, an ERC for each home-site with a VMS would be required with reporting to the Institutional Controls Group. Vapor mitigation system information is presented in Appendix A.

4.3 Proposed Remedial Actions

In order to meet the City's goal of cleanup to a residential land use scenario, proposed remedial actions chosen for the Site will include the following three (3) activities: **Alternative 4a – PlumeStop® permeable reactive barrier, Alternative 4b – Excavation and Disposal of impacted soils, and Alternative 4a – Enhanced Biodegradation Material (EBM)** injections within the primary area of impacted ground water. **Alternative 2c – Vapor Mitigation Systems (VMSs)** may also be utilized to control vapor migration at the Site, if ultimately deemed necessary**.** These planned remediation activities are discussed in detail throughout this ABCA. Cleanup objectives for the VRP Site will be concentrations below IDEM R2 residential published levels in soil, ground water, and vapor. Total implementation costs have been estimated at $5,923,500 to $8,816,500.

4.4 Cleanup Schedule

In situ permeable reactive barrier (PRB) injection final designs using Regenesis' PlumeStop® can start as soon as aquifer indicator parameter analysis is performed and evaluated. Actual injections could begin shortly after programmatic documents (RWP, CIP, ABCA, and QAPP) are approved and would take approximately two (2) to three (3) weeks to apply. The installation of the PRB is scheduled for fall 2024. Excavation activities will require formal landfill approvals, which can take several weeks if additional waste characterization analysis is requested. As such, excavation and disposal activities are scheduled to begin in early 2025. Given the projected volume of impacted soils (over 30,000 tons), excavation and disposal activities could take several weeks (estimated at 8 to 10-weeks). Subsequent EBM injections would take approximately eight (8) weeks to apply followed by performance monitoring. The need for VMSs will be evaluated after remedial activities have been completed and post-remedial soil gas sampling is performed.

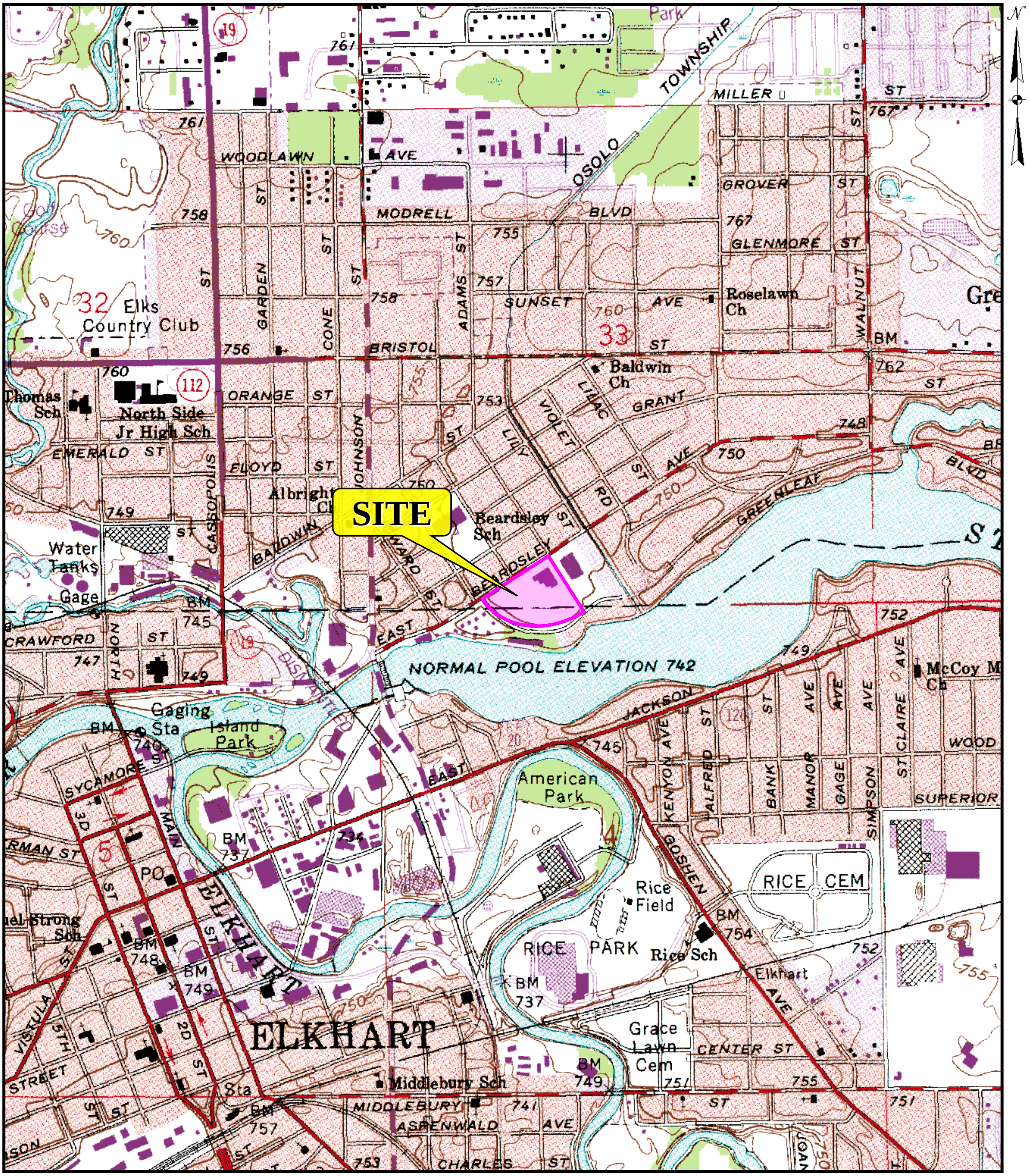
4.5 Resiliency & Best Management Practices

The resilience of the chosen remedial alternatives should not be affected by extreme weather events such as potential sea level rise or potential increased frequency and intensity of flooding. The Site is not located near a sea or ocean and, while the St, Joseph River is located approximately 250-feet south of the Site, the Site property is not located within a designated floodplain area. Best management practices (BMPs), including green remediation strategies, will be utilized throughout the implementation of remedial activities. BMPs and green remediation strategies to be utilized given the remedial alternatives, include (when feasible):

- Disposing of soils at a local landfill (Elkhart County Landfill is less than 10-miles from the Site) and excavated soils will be covered during transportation to the landfill,
- Reducing unnecessary idling of vehicles, trucks, and equipment,
- Reduce energy and water usage whenever possible,
- Using local contractors/subcontractors when feasible,
- Recycling of Site waste when feasible,
- Minimize/eliminate excavation and disposal of non-impacted soils during excavation by the use of experienced field crews and monitoring equipment,
- Purchasing/rental of equipment from local sources,
- Using 1.5-inch diameter monitoring wells vs. 2.0-inch diameter wells to reduce IDW, and
- Teleconferences will be held as opposed to commuting for face-to-face meetings as practicable

U.S.EPA, 2022. Green Remediation Best Management Practices: An Overview

FIGURES



Site Boundary (Approximate Only)

SCALE

0 *1,500* *3,000*

1-Inch = 1,500-Feet

Prepared By:	Date Prepared:
DDJ	*Dec. 2022*

USGS 7.5-Minute Topographic Map
Elkhart, Indiana, 1981

ROBERTS
ENVIRONMENTAL SERVICES, LLC
2112 Carmen Court • Goshen, Indiana
www.robertsenvironmental.net

FIGURE 1
SITE VICINITY MAP
FORMER C.G. CONN PROPERTY
1101 EAST BEARDSLEY AVENUE
ELKHART, INDIANA

FIGURE 2 - SITE OVERVIEW MAP
FORMER CONN PROPERTY
1101 EAST BEARDSLEY AVENUE
ELKHART, INDIANA

ROBERTS
ENVIRONMENTAL SERVICES, LLC
2112 Carmen Court • Goshen, Indiana
www.robertsenvironmental.net

Date:
Dec. 2022

2019 Aerial
(Elkhart
Co. GIS)

FIGURE 3 - METALS & PAHs EXCEEDANCES in SOILS FORMER CONN PROPERTY 1101 EAST BEARDSLEY AVENUE ELKHART, INDIANA

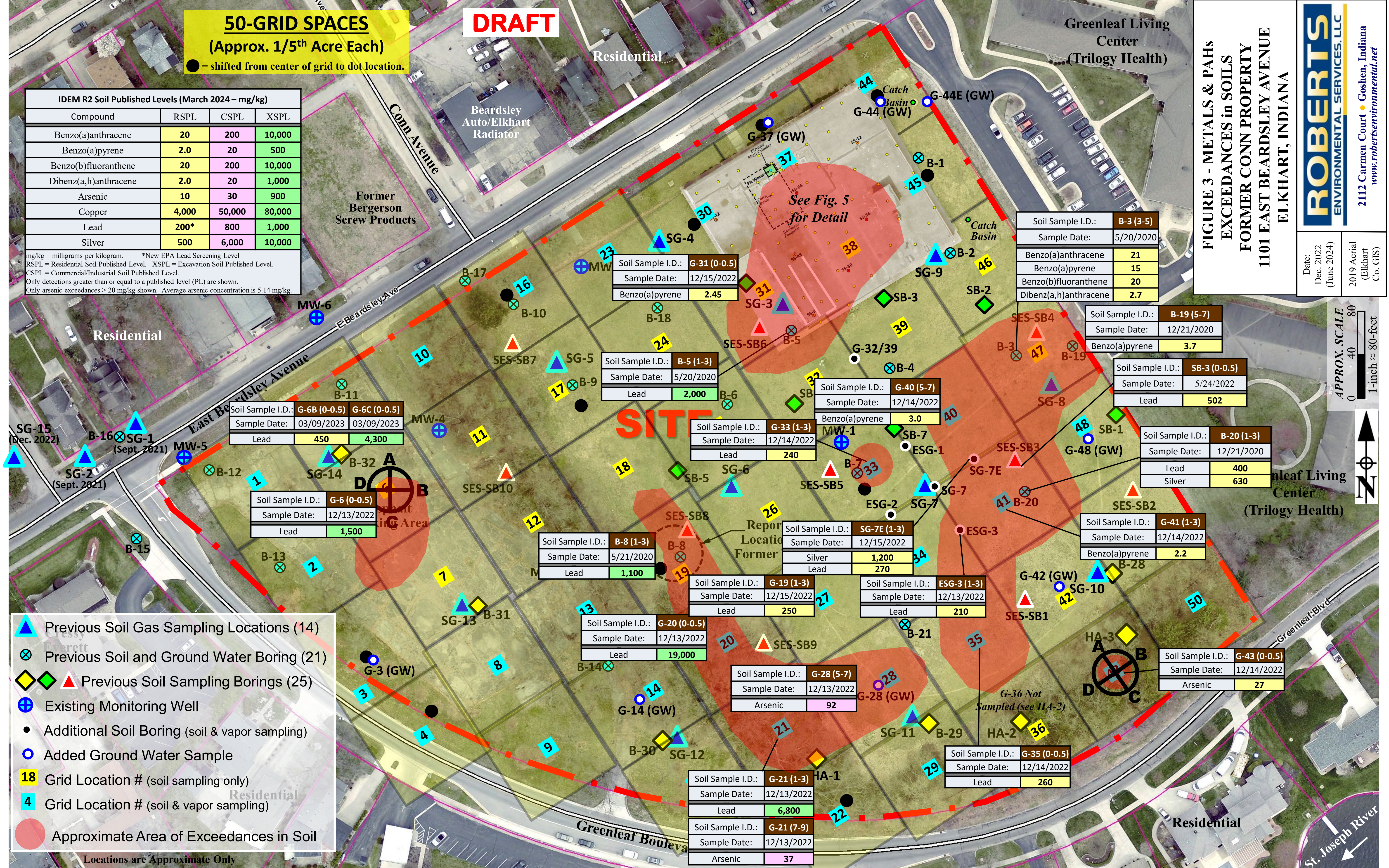
ROBERTS ENVIRONMENTAL SERVICES, LLC
2112 Carmen Court • Goshen, Indiana
www.robertsenvironmental.net

Date: Dec. 2022 (June 2024)

2019 Aerial (Elkhart Co. GIS)

DRAFT

50-GRID SPACES
(Approx. 1/5th Acre Each)
● = shifted from center of grid to dot location.



IDEM R2 Soil Published Levels (March 2024 – mg/kg)			
Compound	RSPL	CSPL	XSPL
Benzo(a)anthracene	20	200	10,000
Benzo(a)pyrene	2.0	20	500
Benzo(b)fluoranthene	20	200	10,000
Dibenz(a,h)anthracene	2.0	20	1,000
Arsenic	10	30	900
Copper	4,000	50,000	80,000
Lead	200*	800	1,000
Silver	500	6,000	10,000

mg/kg = milligrams per kilogram. *New EPA Lead Screening Level
RSPL = Residential Soil Published Level. XSPL = Excavation Soil Published Level.
CSPL = Commercial/Industrial Soil Published Level.
Only detections greater than or equal to a published level (PL) are shown.
Only arsenic exceedances > 20 mg/kg shown. Average arsenic concentration is 5.14 mg/kg.

Soil Sample I.D.:	G-31 (0-0.5)
Sample Date:	12/15/2022
Benzo(a)pyrene	2.45

Soil Sample I.D.:	B-3 (3-5)
Sample Date:	5/20/2020
Benzo(a)anthracene	21
Benzo(a)pyrene	15
Benzo(b)fluoranthene	20
Dibenz(a,h)anthracene	2.7

Soil Sample I.D.:	B-19 (5-7)
Sample Date:	12/21/2020
Benzo(a)pyrene	3.7

Soil Sample I.D.:	SB-3 (0-0.5)
Sample Date:	5/24/2022
Lead	502

Soil Sample I.D.:	B-5 (1-3)
Sample Date:	5/20/2020
Lead	2,000

Soil Sample I.D.:	G-40 (5-7)
Sample Date:	12/14/2022
Benzo(a)pyrene	3.0

Soil Sample I.D.:	G-6B (0-0.5)	G-6C (0-0.5)
Sample Date:	03/09/2023	03/09/2023
Lead	450	4,300

Soil Sample I.D.:	G-33 (1-3)
Sample Date:	12/14/2022
Lead	240

Soil Sample I.D.:	B-20 (1-3)
Sample Date:	12/21/2020
Lead	400
Silver	630

Soil Sample I.D.:	G-6 (0-0.5)
Sample Date:	12/13/2022
Lead	1,500

Soil Sample I.D.:	G-41 (1-3)
Sample Date:	12/14/2022
Benzo(a)pyrene	2.2

Soil Sample I.D.:	SG-7E (1-3)
Sample Date:	12/15/2022
Silver	1,200
Lead	270

Soil Sample I.D.:	B-8 (1-3)
Sample Date:	5/21/2020
Lead	1,100

Soil Sample I.D.:	G-19 (1-3)
Sample Date:	12/15/2022
Lead	250

Soil Sample I.D.:	ESG-3 (1-3)
Sample Date:	12/13/2022
Lead	210

Soil Sample I.D.:	G-20 (0-0.5)
Sample Date:	12/13/2022
Lead	19,000

Soil Sample I.D.:	G-43 (0-0.5)
Sample Date:	12/14/2022
Arsenic	27

Soil Sample I.D.:	G-28 (5-7)
Sample Date:	12/13/2022
Arsenic	92

Soil Sample I.D.:	G-35 (0-0.5)
Sample Date:	12/14/2022
Lead	260

Soil Sample I.D.:	G-21 (1-3)
Sample Date:	12/13/2022
Lead	6,800

Soil Sample I.D.:	G-21 (7-9)
Sample Date:	12/13/2022
Arsenic	37

- ▲ Previous Soil Gas Sampling Locations (14)
- ⊗ Previous Soil and Ground Water Boring (21)
- ◆ ◆ ▲ Previous Soil Sampling Borings (25)
- ⊕ Existing Monitoring Well
- ● Additional Soil Boring (soil & vapor sampling)
- ○ Added Ground Water Sample
- 18 Grid Location # (soil sampling only)
- 4 Grid Location # (soil & vapor sampling)
- ● Approximate Area of Exceedances in Soil

Locations are Approximate Only

FIGURE 4 - TCE & PERC in SOIL
FORMER CONN PROPERTY
1101 EAST BEARDSLEY AVENUE
ELKHART, INDIANA

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www.robertsenvironmental.net

Date: Dec. 2022 (June 2024)

2019 Aerial (Elkhart Co. GIS)

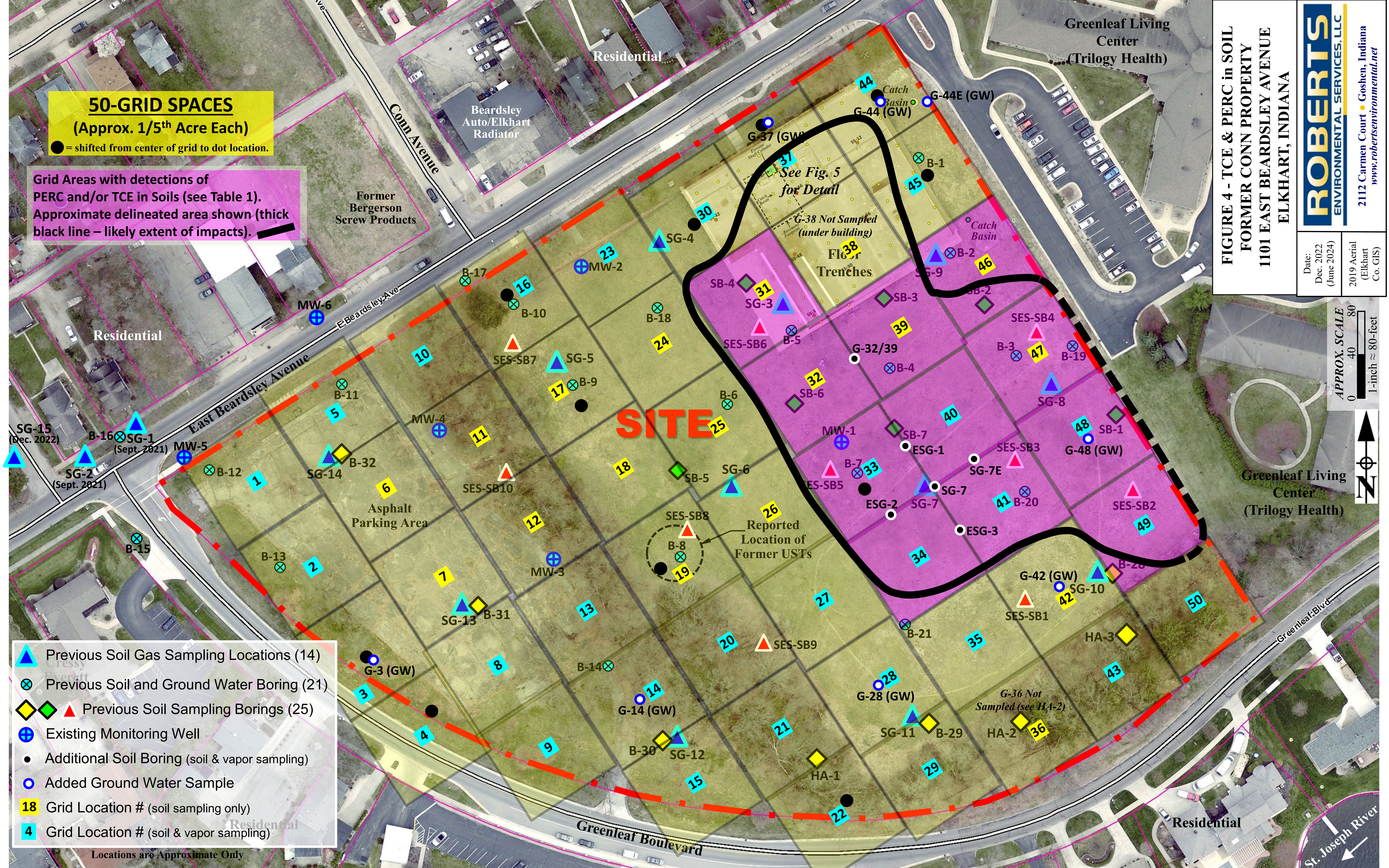

FIGURE 5
ON-SITE TCE in GROUND WATER
FORMER CONN PROPERTY
1101 EAST BEARDSLEY AVENUE
ELKHART, INDIANA

ROBERTS ENVIRONMENTAL SERVICES, LLC
2112 Carmen Court • Goshen, Indiana
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Date: Dec. 2022
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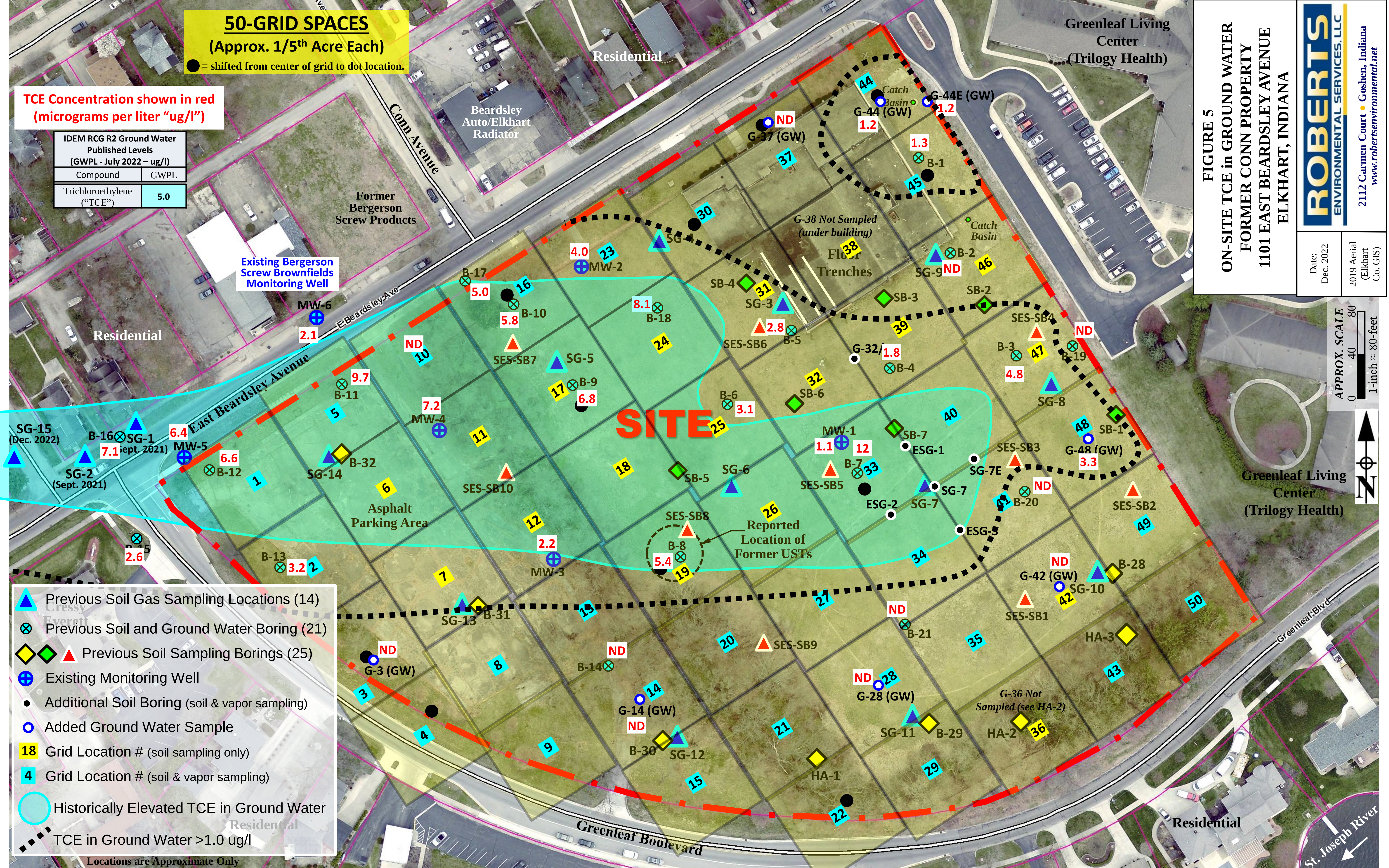


IDEM RCG R2 Ground Water Published Levels (GWPL - July 2022 – ug/l)

Compound	GWPL
Trichloroethylene ("TCE")	5.0

- ▲ Previous Soil Gas Sampling Locations (14)
- ⊗ Previous Soil and Ground Water Boring (21)
- ◆ ◆ ▲ Previous Soil Sampling Borings (25)
- ⊕ Existing Monitoring Well
- ● Additional Soil Boring (soil & vapor sampling)
- ○ Added Ground Water Sample
- 18 Grid Location # (soil sampling only)
- 4 Grid Location # (soil & vapor sampling)
- ◯ Historically Elevated TCE in Ground Water
- ···· TCE in Ground Water >1.0 ug/l

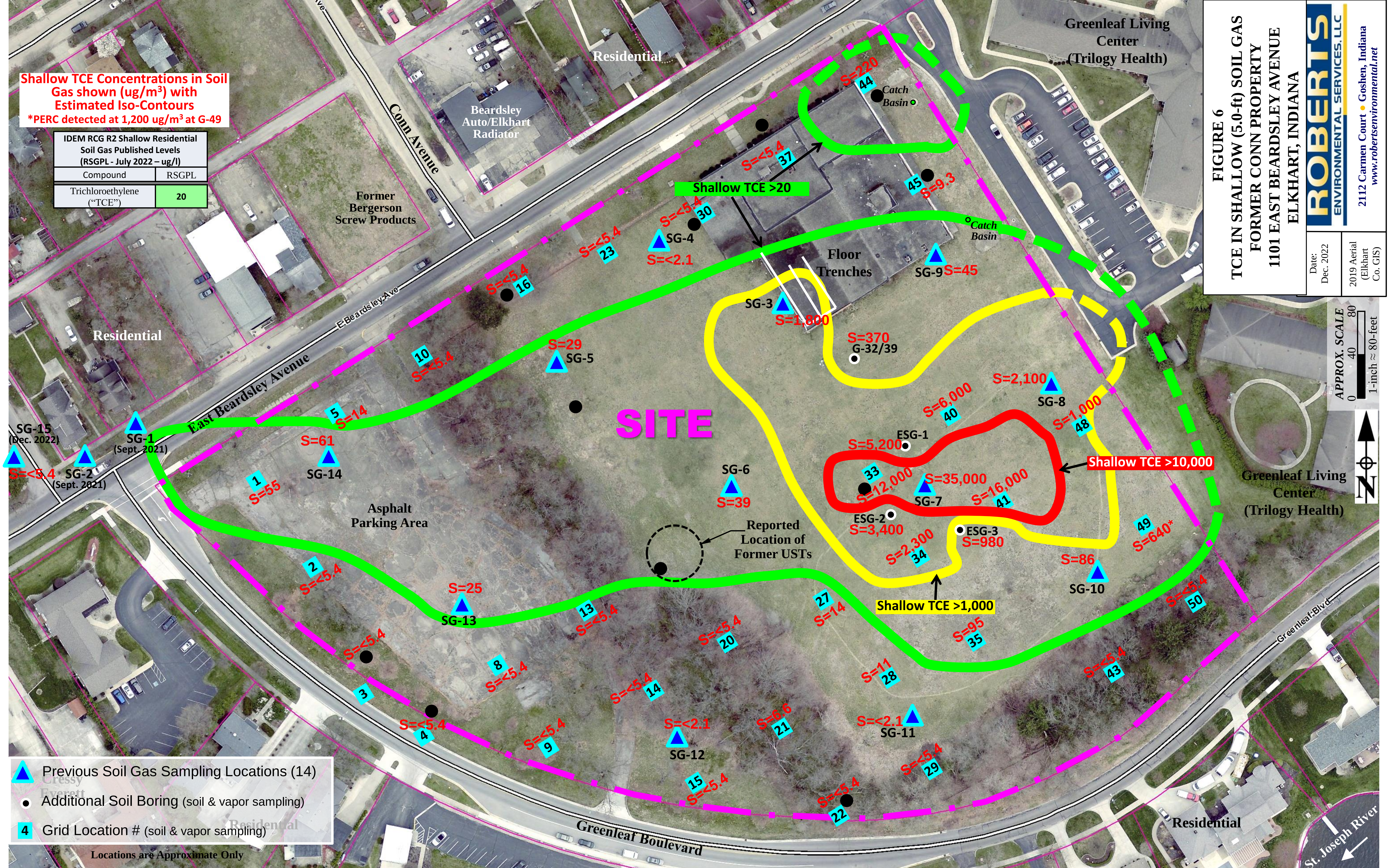
Locations are Approximate Only

FIGURE 6
TCE IN SHALLOW (5.0-ft) SOIL GAS
FORMER CONN PROPERTY
1101 EAST BEARDSLEY AVENUE
ELKHART, INDIANA

ROBERTS ENVIRONMENTAL SERVICES, LLC
2112 Carmen Court • Goshen, Indiana
www.robertsenvironmental.net

Date:
Dec. 2022

2019 Aerial
(Elkhart
Co. GIS)



IDEM RCG R2 Shallow Residential Soil Gas Published Levels (RSGPL - July 2022 – ug/l)	
Compound	RSGPL
Trichloroethylene ("TCE")	20

- ▲ Previous Soil Gas Sampling Locations (14)
- ● Additional Soil Boring (soil & vapor sampling)
- 4 Grid Location # (soil & vapor sampling)

Locations are Approximate Only

APPENDIX A

AS/SVE & VMS Information

A Citizen's Guide to Soil Vapor Extraction and Air Sparging

What Are Soil Vapor Extraction And Air Sparging?

Both soil vapor extraction, or "SVE," and air sparging extract (remove) contaminant vapors from below ground for treatment above ground. Vapors are the gases that form when chemicals evaporate. SVE extracts vapors from the soil *above* the water table by applying a vacuum to pull the vapors out. Air sparging, on the other hand, pumps air underground to help extract vapors from groundwater and wet soil found *beneath* the water table. The addition of air makes the chemicals evaporate faster, which makes them easier to extract with another technology, such as SVE.

Both methods are used for chemicals that evaporate easily—like those found in solvents and gasoline. These chemicals are known as "volatile organic compounds," or "VOCs."

How Do They Work?

Extraction:

SVE involves drilling one or more *extraction* wells into the contaminated soil to a depth above the water table, which must be deeper than 3 feet below the ground surface. Attached to the wells is equipment (such as a blower or vacuum pump) that creates a vacuum. The vacuum pulls air and vapors through the soil and up the well to the ground surface for treatment. Sometimes the ground must be paved or covered with a tarp to make sure that the vacuum does not pull air from above into the system. Pulling in clean air would reduce the efficiency of the cleanup. The cover also prevents any vapors from escaping from the ground to the air above.

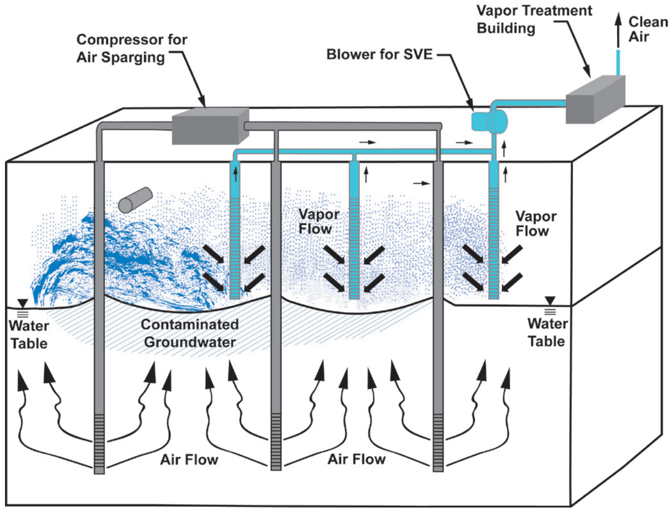


Illustration of a combined air sparging and SVE system.

Air sparging involves drilling one or more *injection* wells into the groundwater-soaked soil below the water table. An air compressor at the surface pumps air underground through the wells. As air bubbles through the groundwater, it carries contaminant vapors upward into the soil above the water table. The mixture of air and vapors is then pulled out of the ground for treatment using SVE.

Treatment:

Extracted air and contaminant vapors, sometimes referred to as "off-gases," are treated to remove any harmful levels of contaminants. The off-gases are first piped from the extraction wells to an air-water separator to remove moisture, which interferes with treatment. The vapors are then separated from the air, usually by pumping them through containers of activated carbon. The chemicals are captured by the carbon while clean air exits to the atmosphere. (See *A Citizen's Guide to Activated Carbon Treatment* [EPA 542-12-001.]).

Filter materials other than activated carbon may be used. In a process called "biofiltration," tiny microbes (bacteria) are added to break down the vapors into gases, such as carbon dioxide and water vapor. Another option is to destroy vapors by heating them to high temperatures.

How Long Will They Take?

Cleaning up a site using SVE or air sparging may take several years. The actual cleanup time depends on several factors. For example, cleanup may take longer where:

- Contaminant concentrations are high.
- The contaminated area is large or deep.
- The soil is dense or moist, which slows the movement of vapors.

These factors vary from site to site.

Are SVE And Air Sparging Safe?

When properly designed and operated, SVE and air sparging pose little risk to site workers or the community. Treatment of the vapors involves no harmful chemicals that must be transported to the site. Chemical vapors are contained from extraction to treatment so they cannot be accidentally inhaled by anyone nearby. Only clean air that meets air quality standards is released. The air released to the atmosphere following treatment may be sampled to make sure all harmful vapors have been removed or destroyed.

How Might It Affect Me?

Area neighborhoods may experience some increased truck traffic as the equipment for SVE or air sparging is delivered and later removed. Installation of the systems involves the use of drilling rigs and sometimes other heavy machinery to install wells, blowers, and treatment equipment. Sheds or larger buildings may be built to house the treatment systems, keeping any noise to a minimum. Workers will visit these systems regularly to ensure they are working.

Why Use Soil Vapor Extraction And Air Sparging?

SVE and air sparging are efficient ways to remove VOCs above and below the water table. Both methods can help clean up contamination under buildings, and cause little disruption to nearby activities when in full operation. SVE and air sparging are often used together. SVE and air sparging are being used or have been selected for use at approximately 285 and 80 Superfund sites, respectively.

Pipes transport vapors from the underground SVE extraction well to treatment.

Above-ground treatment system includes two tanks of activated carbon.

Example

Both SVE and air sparging are being used to clean up several acres of contaminated soil and groundwater at the Vienna PCE Superfund site in West Virginia. Two dry cleaning facilities contaminated the area with PCE (also known as perchloroethene or "perc"), a solvent used to clean clothing, forcing the shutdown of the town's drinking water wells.

In 2005, construction of the cleanup systems was completed and included 74 air sparging wells, 34 extraction wells, and four treatment buildings. The off-gases are piped to an air-water separator, followed by containers of activated carbon for treatment. By 2010, 1,618 pounds of PCE had been removed and PCE concentrations had decreased by as much as 99% in some wells. EPA will continue to operate the systems and monitor PCE levels until cleanup objectives have been reached throughout the site.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

U.S. EPA
Technology Innovation &
Field Services Division
Technology Assessment Branch
(703) 603-9910

Or visit:
www.cluin.org/sve
www.cluin.org/airsparging

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United States
Environmental Protection
Agency

Office of Solid Waste and
Emergency Response
(5102G)

EPA 542-F-12-018
September 2012
www.epa.gov/superfund/sites
www.cluin.org

Naval Facilities Engineering Command

ENVIRONMENTAL RESTORATION

Vapor Intrusion Mitigation in Construction of New Buildings Fact Sheet

Introduction

Vapor intrusion (VI) is the migration of volatile chemicals from subsurface soil and/or groundwater into the indoor air of overlying buildings. Most VI events occur when volatile organic compounds (VOCs) are released into the subsurface from sources such as underground storage tanks, dry cleaners, gasoline stations, or industrial processes such as degreasing metals. VOCs typically associated with VI are chlorinated solvents, including carbon tetrachloride, tetrachloroethene (PCE), trichloroethene (TCE), and methylene chloride, and gasoline derivatives such as benzene. Hazards presented by these chemicals are typically chronic human health effects such as cancer, organ toxicity, or reproductive toxicity. Gases, such as methane migrating from landfills, may also present potential explosive hazards.

If the contaminants present in the subsurface are predicted to result in indoor air concentrations above acceptable risk levels, VI mitigation measures should be incorporated into the design of any new buildings. This fact sheet provides an overview of VI mitigation methods used in new buildings along with important factors to consider when selecting and designing these mitigation systems. In new construction, VI mitigation can include passive methods such as vapor barriers and natural venting systems; active systems such as sub-slab depressurization (SSD) systems; or a combination of passive and active methods. VI mitigation systems integrated during construction of new buildings are more cost effective, function better and are less obtrusive than mitigation systems retrofitted into existing buildings.

This fact sheet was prepared by the Navy Alternative Restoration Technology Team (ARTT) workgroup for use by Navy personnel such as remedial project managers (RPMs) and planners. RPMs may want to consider it for inclusion in Land Use Controls (LUCs) or provide it to base personnel or the public for informational purposes. Typically, Environmental Restoration, Navy (ER,N) funds shall not be used to install VI mitigation systems for new construction; however, RPMs and other Navy personnel should consult the Navy Environmental Restoration Program (NERP)/Defense Environmental Restoration Program (DERP) manuals for the latest guidance.

Key Factors When Considering VI Mitigation

Once the vapor sources have been assessed and it has been determined that there is potential for VI to pose an unacceptable risk in buildings constructed on the site, the next step is to select which preconstruction mitigation strategies should be implemented to prevent VI. Three primary factors drive the occurrence of VI in buildings:

- contaminant properties, concentrations and locations,
- potential entry routes (e.g., floor drains, French drains, sumps, seams or cracks in the floor slab, utility penetrations, and open top blocks in the foundation walls) and
- pressure differentials between the building and the subsurface that could draw contaminants from the soil into the building.

Understanding these components and the effects that they have on the transfer of subsurface VOCs to indoor air will help to determine which VI mitigation strategies should be integrated into the construction of a new building.

Prevention of VI in New Construction

New construction provides many opportunities to prevent VI that are not available for existing buildings. For example, at some sites, the area most likely to produce unacceptable VI can be avoided and set aside for another purpose such as green space. Also, new buildings can sometimes be designed to include a highly ventilated, low occupancy area at ground level, such as an open parking garage. It should be noted, however, that if contaminated areas of the site are to be covered with pavement, the resultant effects on migration of vapors should be considered in order to avoid effects on adjacent structures.

Methods for VI mitigation in new construction can be passive (such as vapor barriers and natural venting systems) or active (using blowers to depressurize the sub-slab area). Frequently in new construction, elements of both passive and active methods are combined (e.g., a vapor barrier may be installed along with active SSD) or a passive ventilation system may be designed to allow for conversion to an active system (e.g., by adding blowers) at a later time if the passive system fails to prevent VI.

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For construction of new buildings, there are five basic components to effective VI resistant construction:

- permeable sub-slab support material (e.g., gravel),
- venting all sub-slab areas below occupied spaces,
- properly-sized sub-slab and riser piping,
- a sealed vapor barrier, and
- if an active system is specified, a properly-sized blower to maintain sufficient negative pressure beneath the slab.

Passive venting systems typically have the first four components above, but do not have a blower to mechanically draw soil gases from sub-slab collection piping to above the roof. Rather, they rely on thermal and atmospheric effects to draw the soil gases into the piping and vent it outside. Active SSD systems are powered by blowers that create a vacuum beneath the slab and actively vent sub-slab gases through solid conveyance piping to above the roof line. A typical active mitigation system is illustrated in Figure 1. A passive system would be similar but would not include a blower.

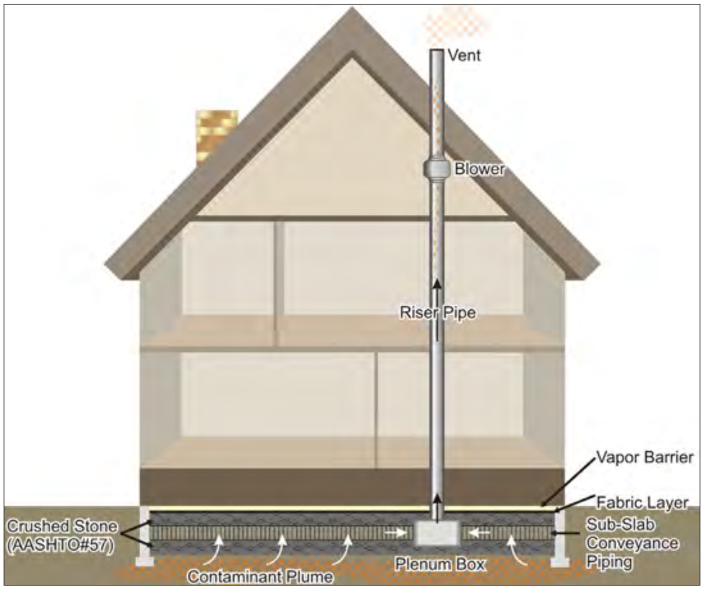

Figure 1. VI mitigation system with a vapor barrier and active SSD.

Permeable Sub-slab Support Material

After the ground has been proof-rolled by removing undesirable items, drying, leveling and compacting the soil, a permeable layer of crushed stone should be installed (Figure 2).

Figure 2. Proof-rolled ground covered with 8 inches AASHTO #57 stone.

Eight inches or more of a highly permeable, coarse aggregate such as American Association of State Highway and Transportation Officials (AASHTO) #57 stone is preferred. There should be a minimum of 2 inches of crushed stone above and below any sub-slab conveyance pipe to prevent slab cracking. If 6-inch pipe is used, the ground beneath the pipe may need to be trenched to ensure sufficient crushed stone for slab support (Figure 3).

Figure 3. Gravel placed over proof-rolled site with trenching for vent piping.

Venting

The most efficient way to vent sub-slab soil gas is using perforated ventilation pipes that run beneath the slab and direct the vapors to a centrally located plenum box. The plenum box is constructed of hollow concrete blocks turned on their sides with an empty space in the center (Figure 4).

Figure 4. Connecting isolated slab areas with a central plenum box.

The box is connected to vertical riser piping that transports soil gases to vents above the roof line. There should be a minimum of 8 inches of crushed stone beneath and beside the plenum box. All slab areas within the occupied portions of the building need to be included in the sub-slab vapor collection system and connected to the plenum. Footings at grade changes and thickened slabs beneath concrete masonry walls often create isolated sub-slab areas (Figure 5). These isolated areas need to be addressed by placing adequate gravel below them or adding ventilation pipe to connect them to the system. Commercial venting products such as those consisting of a thick rectangular-shaped roll-out plastic and fabric-covered conveyance plenum, or perforated collection pipe can provide a conduit to connect isolated slab areas to a central sub-slab plenum box (Figure 6).

Figure 5. Isolated gravel beds.

Figure 6. Commercial venting product has properties similar to 4-inch PVC pipe with lower installation costs.

Sizing the conveyance pipe is based on the square feet of the area to be vented and the number of pipe fittings used between the sub-slab plenum box and the vent termination point. Drag coefficient tables exist for different pipe diameters and assorted fittings. Since coordinated drawings are usually not part of the design phase, the person designing the system should plan for twice the number of pipe fittings when calculating the pressure drop associated with a riser pipe system. The most commonly used riser pipe material is polyvinyl chloride (PVC) because of its availability, low cost, and low airflow drag coefficients. No-hub cast iron pipe is used when there is concern of exceeding the flame spread or smoke index. This is a concern when conveyance piping passes through a return air plenum. Protective pipe enclosures or steel pipe is used in areas of vehicle or fork lift traffic.

Conveyance piping can be joined together beneath the slab to minimize vertical risers (Figure 7). A 3-inch riser pipe can service up to 1,500 ft^2, a 4-inch riser can service up to 4,000 ft^2 and 6-inch riser pipe can service up to 15,000 ft^2. Sub-slab conveyance pipe should have 5/8-inch condensate drain holes that face down at 4-inch intervals. If factory perforated pipe is used, one set of holes should face down.

Figure 7. Risers grouped for future pairing and efficient construction.

Vapor Barriers

Selecting the right vapor barrier is a critical part of the VI mitigation system and the vapor barrier can be the most expensive part of the system. The type of vapor barrier and the quality of the seal will determine the efficiency and effectiveness of the protective measure. After the contaminants of concern (COCs) have been identified, the protective qualities of the vapor barrier material should be matched to the identified compounds to minimize potential for chemical breakthrough. The types of vapor barriers available and their advantages and disadvantages are summarized in Table 1.

The most important part of the effectiveness of any vapor barrier system is achieving a tight seal to foundation walls and around utility penetrations through the membrane. A filter fabric layer is recommended to protect all vapor barriers from punctures associated with construction debris and the underlying stone. The concrete slab installer must not be allowed to puncture the vapor barrier to drain off extra water that may be associated with the concrete finishing process.

Table 1. Types of vapor barriers used in VI mitigation.

Vapor Barrier Material	Advantages	Disadvantages
6-mil polyethylene or polyolefin (Figure 8).	• Inexpensive • Often made from post-consumer recycled materials.	• Permeance water vapor transmission rate (WVTR) is between 0.1 to 0.3 perms; considered a vapor retarder not a true vapor barrier - slows down vapor transmission but does not completely block vapors • May not be chemically resistant • Difficult to seal at walls and utility penetrations • Low puncture and tear resistance compared to reinforced materials • Standard applications with unsealed seams are only partially effective for preventing VI • Not recommended for most VI applications.
>10-mil polyethylene or polyolefin (Figure 9).	• Relatively inexpensive • Permeance WVTR is <0.1 perms (considered a true vapor barrier; almost completely blocks vapors) • Often made from post-consumer recycled materials.	• May not be chemically resistant • Difficult to seal at perimeter walls and utility penetrations • Low puncture and tear resistance compared to reinforced materials of similar thickness.

Table 1. Types of vapor barriers used in VI mitigation. (continued)

Vapor Barrier Material	Advantages	Disadvantages
Cross laminate polyethylene or polyolefin; generally 3-ply materials with woven scrim between two polyethylene sheets.	• Permeance WVTR is <0.1 perms (considered a true vapor barrier; almost completely blocks vapors) • Puncture/tear resistance up to 50 times greater than 6-mil polyethylene/polyolefin vapor retarder. • Improved sealing at perimeter walls and utility penetrations because manufacturer-supplied tapes and cloth binders are generally used.	• Moderately expensive • May not be chemically resistant.
Spray-applied vapor barrier: Non-woven geotextile fabric base over stone layer followed by a spray-applied coating. The coating material binds to the support fabric, column pads, side foundation walls; minimum thickness of 60 mil; total thickness including support fabric is 73 mil (see Figures 10, 11, and 12).	• Permeance WVTR is <0.1 perms (considered a true vapor barrier; almost completely blocks vapors) • Provides a nearly gas-tight seal since coating material binds to column pads and side foundation walls. • Leak test is performed following installation and any leaks are repaired. • Installers must be licensed by manufacturer. • Coating selected for chemical resistance to specific contaminants.	• Generally more expensive than other types of barriers.

Note: Information on the chemical resistance and ability of a particular vapor barrier material to block a particular contaminant should be obtained from the manufacturer of the specific product being considered. Some information may be available on the Web sites for specific vapor barrier products.

Figure 8. Standard vapor barrier with unsealed seams.

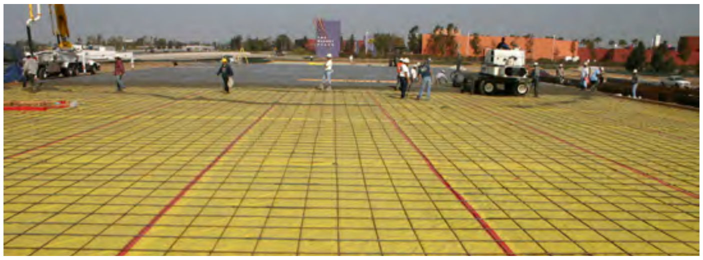

Figure 9. Polyolefin vapor barrier with sealed seams shown with rebar and concrete slab being installed over top.

Figure 10. Geotextile fabric is placed over stone followed by spray application of the sealant.

Figure 11. Spraying an emulsified asphalt latex barrier.

Figure 12. Installation of a spray-applied barrier at a large site.

Active VI Mitigation Systems

Active VI mitigation systems in new construction generally consist of a sub-slab depressurization system with ventilation piping connected to a blower that depressurizes the sub-slab and vents the vapor above the roof level. Depending on the leakage associated with the vapor barrier, the configuration of the sub-slab conveyance piping and the design of the plenum box, a single properly-sized collection system can service up to 15,000 ft^2 of floor space. The design goal is to create a minimum sub-slab negative pressure of -0.02 inches of water column (in. w.c.) at the area that is most distant from the plenum box using a blower that consumes no more than 140 watts and can move 200 cubic feet per minute (CFM) at 1.0 in. w.c. static pressure. Even though lower pressure differentials may be able to successfully arrest the soil gases, a pressure of -0.02 in. w.c. is recommended as a design goal to provide a safety factor for construction conditions that could potentially reduce the efficiency of vacuum distribution (e.g., sand particles mixed in with the crushed stone, elevated sub-slab utility conduits, presence of overburden from trenching, and conveyance piping that has been crushed or distorted by unscheduled vehicle traffic).

When designing a depressurization system and specifying blowers, it is important to include the projected piping pressure losses. Speculating the final active system airflow is one of the most difficult parts of the design process. Airflow is a function of blower capacity, piping size, fittings and layout, sub-slab aggregate resistance, soil permeability and slab and foundation leakage. The performance required from the blower to achieve the specified vacuum field is largely determined by the slab leakage and quality of the vapor barrier seal. If there is clean crushed stone and 4-inch conveyance piping, a blower that can move 200 CFM at -1.0 in. w.c. can create a vacuum field of -0.02 in. w.c. or greater over a 4,000 ft^2 area. Reducing the slab leakage can significantly increase the coverage area. The primary design goal should always be highly permeable sub-slab material and minimal slab leakage.

During the construction phase, soil probes should be embedded in the crushed stone to allow testing of system effectiveness after the slab has been poured (Figure 13). Probes are embedded because drilling through the concrete creates an unnecessary risk of damaging sub-slab utilities and will void most vapor barrier warranties. Probes should be located distant from the plenum box near the projected end of the negative pressure field. These probes are typically made of heavily perforated PVC pipe that is 2 inches in diameter or less and connected to rigid, smaller diameter pipe that extends to a sampling port above the slab. Typically, this is 0.5-inch gas pipe that is embedded into a column pocket to protect it from damage during the concrete pour and power trowel process. Depending on the potential for soil vapor entry, these probes could be as numerous as one per isolated foundation area. At least one probe should be installed per 5,000 ft^2 of slab area and for each different slab elevation. Each blower system should have at least one soil probe.

Figure 13. Forms for vertical column support pad with embedded soil probes.

The effectiveness of any soil depressurization system should be quantified after the slab is poured and allowed to cure for at least 14 days. The test is performed by temporarily installing the specified blower and measuring the extension of the negative pressure field. The efficiency of the system is measured by temporarily activating the system after hooking up the blower that has been specified for permanent installation. The pressure field extensions should be measured at the sample ports that are at the end of the embedded probes. A micromanometer that can measure to a sensitivity of -0.001 in. w.c. should be used. If vacuum field measurements at the probe most distant from the blower exceed 0.036 in. w.c. (9 pascals), the top of the acceptable vacuum range specified by ASTM, the procedure can be repeated with a blower that uses less electricity. If favorable test results are obtained, the blower can be downgraded to a lower wattage blower that will save energy and reduce operating expenses. The minimum induced sub-slab vacuum field in an unfinished, unheated building should be -0.02 in. w.c. The selected blower model, vacuum field and exhaust airflow values should be recorded and included in the construction documents that are presented at the end of the project. Sampling for indoor air contaminant concentrations should occur once the building is weather tight and the air handling systems are operational.

Passive Mitigation Systems

As noted above, passive VI mitigation methods do not require an electrical power source to operate. These include physical vapor barriers and piping systems that rely on natural ventilation to move air from the subsurface to prevent the buildup of contaminated vapors. The integrity of the vapor barrier and efficiency of a passive vent system are two main variables in determining the effectiveness of a passive system. Punctures or tears in the vapor barrier that can occur during the construction process will diminish the effectiveness of a passive system. Efficiency of passive venting can be affected by weather, functioning better in some conditions than others. However, the benefit of a well-designed passive system is that it can be converted to an active system if indoor air concentrations are determined to exceed acceptable risk levels.

It should be noted that passive mitigation methods alone may not be acceptable to state regulators when human health risk is above acceptable limits. For example, in California, the installation of a vapor barrier alone is not an acceptable VI mitigation method where indoor air risk is greater than or equal to 1 x 10^{-6} or the hazard index is greater than or equal to 1.0. In these situations, a vapor barrier can only be used in combination with an active VI mitigation system such as SSD.

Energy and Sustainability Considerations

When designing a system to prevent VI, long-term energy considerations need to be factored into the design. Greater design efficiency reduces operational costs and extends the time that an active venting system can be sustained for a fixed capital expenditure. A streamlined sub-slab collection plenum system with minimal conveyance piping fittings will increase the efficiency of sub-slab vacuum distribution and reduce the energy required by the blower. Three components need to be considered when attempting to lower the operational energy costs of a VI mitigation system. They are: the cost of operating the blower(s) that will maintain the negative pressure beneath the slab, the cost of the heat that is being drawn out of the building and the cost of the cooled conditioned air that is being drawn out of the building. An additional cost that must be considered is the cost of replacing the blowers themselves. Additional blowers will result in higher operations and maintenance costs. Selecting a sealed vapor barrier system that minimizes leakage is the largest variable in reducing ongoing energy costs. The cost to heat or cool the conditioned air that is drawn into the collection system can be a greater operational expense than the electrical cost to operate the blowers. Installing a tightly-sealed vapor barrier system and optimizing the blower size can save up to $1,000 annually in heating, cooling and electric costs per 10,000 ft^2 of floor space. Also, a new type of mitigation control system is currently being piloted that will optimize the blower speed on active mitigation systems. This new control system has pressure sensors in the soil and in the building and uses software to adjust the blower speed to attain the targeted pressure differential between building and soil. This allows the blower to run at reduced speeds while still achieving the desired mitigation results. Optimizing the blower speed in this way is expected to reduce energy costs of active mitigation systems by as much as 50 percent. These systems are expected to be commercially available soon.

Cost for VI Mitigation Systems in New Construction

Designing and implementing a VI mitigation system as part of planning and construction is far more cost effective than a retrofit installation midway through construction or after construction is complete. The cost of installing a VI mitigation system during construction can vary significantly based on the COCs, the soil properties, and construction style of the building. The design and installation costs can range from $2.50/ft^2 to $6.75/ft^2; however, for most buildings, the cost of a combination vapor barrier/venting system is in the $3.00/ft^2 to $4.00/ft^2 range. For comparison, installation costs to retrofit mitigation systems into existing buildings typically range from $5/ft^2 to $8/ft^2.

Several variables affect these costs and every building will be different. The type of vapor barrier required and construction style of the building are the variables that have the greatest impacts on cost. For example, spray-applied asphalt latex vapor barriers, which are extremely effective, can be eight times the per square foot cost of 10 mil polyethylene. However, polyethylene may not be an effective option for some COCs. The soil variables to consider are the concentrations of the COCs, the permeability of the soil and the potential for the contaminant plume to move toward the building after construction. The primary construction variable is the area of the open foundation, since smaller segmented foundation areas and frequent utility penetrations will drive up the labor cost of sealing the vapor barrier. Also, the type of riser pipe used on the interior of the building affects cost. PVC riser pipes are more economical; however, metal riser pipes may be required to meet smoke index and flame spread requirements. There are greater costs associated with piping through a multistory building when compared to a single story building. Whether the system will be active or passive is another cost variable. The more gas tight a vapor barrier is, the greater the energy savings and the lower the long-term operational cost. It is best to plan out each component with a mitigation expert, select the materials and venting options, then calculate the costs.

Case Study for Joint Expeditionary Base Little Creek

This case study describes a VI mitigation system installed at Joint Expeditionary Base (JEB) Little Creek, Virginia during construction of its new Commissary (Building 3445). The Commissary is a supermarket-style building with approximately 150,000 to 200,000 ft^2 of floor space. The VI mitigation system includes both a passive soil venting system and a spray-applied elastomeric urethane vapor barrier.

Background

Site 12 is the location of the former Navy Exchange laundry/dry cleaning facility (Building 3323), which was demolished in 1987. The site is situated in the eastern portion of JEB Little Creek just south of the new Commissary (Figure 14). In the 1970s, dry cleaning wastes, including PCE sludges, were discharged from Building 3323 to the storm sewer. Environmental investigations of Site 12 indicated that the groundwater contained VOCs including PCE and its breakdown products; TCE, cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride. The highest concentrations of VOCs were present beneath the planned parking lot next to the location of the new Commissary, although the plume did not extend beneath the Commissary itself (Figure 15). Because of this close proximity to the plume, it was decided that a VI mitigation system should be installed during construction of the new Commissary as a precautionary measure.

Figure 14. Location of Site 12 on JEB Little Creek.

Figure 15. Arial photo of Building 3445 adjacent to Site 12 groundwater plume.

Mitigation System

The VI mitigation system included a passive subsurface venting system installed under the floor of the new Commissary to depressurize the subsurface and prevent the intrusion of VOC vapors into the building. The venting system installed beneath the Commissary consists of five rows of 4-inch perforated PVC piping running north-south at 60-ft intervals. The piping was placed in a layer of gravel (#57 stone) and surrounded by filter fabric. The piping connects to three riser pipes, which extend through the roof and are topped with wind-driven turbines to create a slight negative pressure in the vent system (Figure 16). A spray-on elastomeric urethane vapor barrier was applied above the soil gas venting layer before the building's concrete slab was poured. The slab is approximately 8 inches thick. Additionally, all new sewer manholes were sealed with waterproofing, and any existing sanitary sewer lines that were to be abandoned were grouted in place.

In addition to the mitigation system in the Commissary, groundwater remediation has been implemented to treat the source and reduce the extent of the groundwater plume beneath the adjacent parking lot. The selected remedial action was enhanced reductive dechlorination using injection of a trademarked emulsified oil substrate along with land use controls and groundwater monitoring.

Figure 16. Roof vents fitted with wind turbines provide slight depressurization of the sub-slab area and prevent the buildup of contaminants beneath the building.

In the Commissary's VI mitigation system, the vapor barrier is the principal component for preventing VI. Its purpose is to prevent the diffusion of soil gas and associated contaminants into the building. The passive venting system serves as augmentation for the vapor barrier, rather than as the primary mitigation measure. This passive system is suitable for a site such as Site 12 where the plume is not immediately beneath the building and is not causing a significant threat to the building occupants and where remedial action is underway to further reduce the potential risk to occupants in the future. In situations where there are high VOC concentrations below the building and human health risks are predicted to be significant, an active system such as an SSD with blowers would most likely be required.

Post-Mitigation Inspection

A site inspection of the VI mitigation system at the Commissary was conducted several years after installation. This inspection found that the concrete slab was competent with no apparent penetrations that could be conduits for intrusion of subsurface vapor. The rooftop wind turbines exhibited some corrosion and would spin intermittently in a wind of about 10 mph, rather than spinning freely. Maintenance such as lubricating the shaft and bearings of the turbines or, if necessary, replacement with aluminum turbines would improve the functionality of the venting system. However, in the future, if groundwater sampling indicates that the remedial action is effective in reducing the VOC contaminants, these inspections and maintenance may no longer be necessary for protection of human health.

Resources

Additional information on VI mitigation for new construction can be found in the following sources:

California Department of Toxic Substances Control. 2009. Vapor Intrusion Mitigation Advisory. http://www.dtsc.ca.gov/sitecleanup/upload/VI_Mitigation_Advisory_Apr09.pdf

Interstate Technology and Regulatory Council (ITRC). 2007. Vapor Intrusion Pathway: A Practical Guideline. http://www.itrcweb.org/Documents/VI-1.pdf

U.S. Environmental Protection Agency. 2008. Engineering Issue: Indoor Air Vapor Intrusion Mitigation Approaches. EPA/600/R-08-115. http://www.clu-in.org/download/char/600r08115.pdf

Photos and drawings throughout provided courtesy of Clean Vapor, LLC, CETCO, and CH2M Hill.

For the most current information, please contact the NAVFAC Alternative Restoration Technology Team or e-mail the NAVFAC Engineering Service Center at **PRTH_NFESCT2@navy.mil**.

APPENDIX B

PlumeStop & Anaerobic EBM Injection Materials

(PlumeStop, 3DMe®, S-MicroZVI, BDI)

PLUME STOP®
Liquid Activated Carbon

PlumeStop® Liquid Activated Carbon™ Technical Description

PlumeStop Liquid Activated Carbon is an innovative groundwater remediation technology designed to rapidly remove and permanently degrade groundwater contaminants. PlumeStop is composed of very fine particles of activated carbon (1-2µm) suspended in water through the use of unique organic polymer dispersion chemistry. Once in the subsurface, the material behaves as a colloidal biomatrix, binding to the aquifer matrix, rapidly removing contaminants from groundwater, and expediting permanent contaminant biodegradation.

This unique remediation technology accomplishes treatment with the use of highly dispersible, fast-acting, sorption-based technology, capturing and concentrating dissolved-phase contaminants within its matrix-like structure. Once contaminants are sorbed onto the regenerative matrix, biodegradation processes achieve complete remediation at an accelerated rate.

Distribution of PlumeStop in water

To see a list of treatable contaminants with the use of PlumeStop, view the Range of Treatable Contaminants Guide.

Chemical Composition

- Water - CAS# 7732-18-5
- Colloidal Activated Carbon ≤2.5 - CAS# µm 7440-44-0
- Proprietary Additives

Properties

- Physical state: Liquid
- Form: Aqueous suspension
- Color: Black
- Odor: Odorless
- pH: 8 - 10

Storage and Handling Guidelines

Storage
Store in original tightly closed container
Store away from incompatible materials
Protect from freezing

Handling
Avoid contact with skin and eyes
Avoid prolonged exposure
Observe good industrial hygiene practices
Wash thoroughly after handling
Wear appropriate personal protective equipment

PLUME STOP®
Liquid Activated Carbon

PlumeStop® Liquid Activated Carbon™ Technical Description

Applications

PlumeStop is easily applied into the subsurface through gravity-feed or low-pressure injection.

Health and Safety

Wash hands after handling. Dispose of waste and residues in accordance with local authority requirements. Please review the Material Safety Data Sheet for additional storage, usage, and handling requirements here: PlumeStop SDS.

S-MicroZVI Specification Sheet

S-MicroZVI Technical Description

S-MicroZVI® is an *In Situ* Chemical Reduction (ISCR) reagent that promotes the destruction of many organic pollutants and is most commonly used with chlorinated hydrocarbons. It is engineered to provide an optimal source of micro-scale zero valent iron (ZVI) that is both easy to use and delivers enhanced reactivity with the target contaminants via multiple pathways. S-MicroZVI can destroy many chlorinated contaminants through a direct chemical reaction (**see Figure 1**). S-MicroZVI will also stimulate anaerobic biological degradation by rapidly creating a reducing environment that is favorable for reductive dechlorination.

Sulfidated ZVI

S-MicroZVI is composed of colloidal, sulfidated zero-valent iron particles suspended in glycerol using proprietary environmentally acceptable dispersants. The passivation technique of sulfidation, completed using proprietary processing methods, provides unparalleled reactivity with chlorinated hydrocarbons like PCE and TCE and increases its stability and longevity by minimizing undesirable side reactions.

S-MicroZVI is Best in Class For

☑ Longevity
☑ Reactivity
☑ Transport

In addition to superior reactivity, S-MicroZVI is designed for easy handling that is unmatched by any ZVI product on the market. Shipped as a liquid suspension, S-MicroZVI requires no powder feeders, no thickening with guar, and pneumatic or hydraulic fracturing is not mandatory. When diluted with water prior to application, the resulting suspension is easy to inject using either direct push or permanent injection wells.

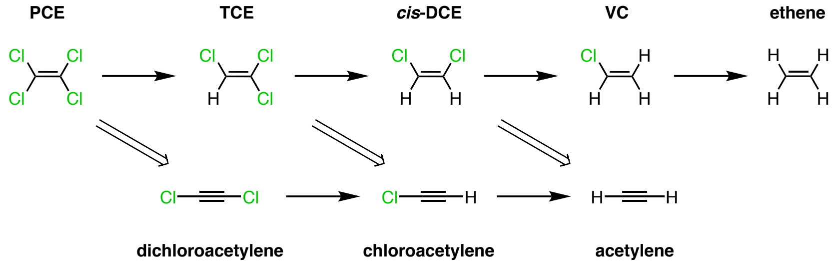

Figure 1: *Chlorinated ethene degradation pathways and products. The top pathway with single line arrows represent the reductive dechlorination (hydrogenolysis) pathway. The lower pathway with downward facing double line arrows represent the beta-elimination pathway.*

To see a list of treatable contaminants, view the S-MicroZVI treatable contaminants guide.

S-MicroZVI®
Sulfidated Zero-Valent Iron

S-MicroZVI Specification Sheet

Chemical Composition

Iron, powders CAS 7439-89-6
Iron (II) sulfide CAS 1317-37-9
Glycerol CAS 56-81-8

Properties

Physical State: Liquid
Form: Viscous metallic suspension
Color: Dark gray
Odor: Slight
pH: Typically 7-9 as applied
Density: 15 lb/gal

Storage and Handling Guidelines

Storage:
- Use within four weeks of delivery
- Store in original containers
- Store at temperatures below 95F°
- Store away from incompatible materials

Handling:
- Never mix with oxidants or acids
- Wear appropriate personal protective equipment
- Do not taste or swallow
- Observe good industrial hygiene practices

Applications

S-MicroZVI is diluted with water on site and easily applied into the subsurface through low-pressure injections. S-MicroZVI can also be mixed with products like 3-D Microemulsion® or PlumeStop® prior to injection.

Health and Safety

The material is relatively safe to handle; however, avoid contact with eyes, skin and clothing. OSHA Level D personal protection equipment including: vinyl or rubber gloves and eye protection are recommended when handling this product. Please review the Safety Data Sheet for additional storage, and handling requirements here: S-MicroZVI SDS.

REGENESIS®

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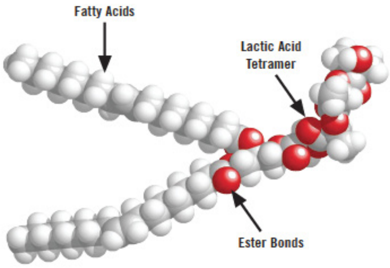
3-D Microemulsion® Factory Emulsified Technical Description

3-D Microemulsion (3DME®) is comprised of a patented molecular structure containing oleic acids (i.e., oil component) and lactates/polylactates, which are molecularly bound to one another (figure 1). The 3DME molecule contains both a soluble (hydrophilic) and insoluble (lipophilic) region. These two regions of the molecule are designed to be balanced in size and relative strength. The balanced hydrophilic/lipophilic regions of 3DME result in an electron donor with physical properties allowing it to initially adsorb to the aquifer material in the area of application, then slowly redistribute via very small 3DME "bundles" called micelles. These 3DME micelles spontaneously form within sections of the aquifer where concentrations of 3DME reach several hundred parts per million. The micelles' small size and mobility allow it to move with groundwater flow through the aquifer matrix, passing easily through the pore throats in between soil grains resulting in the further redistribution of 3DME within the aquifer. This allows for advective distribution of the oleic acids which are otherwise insoluble and unable to distribute in this manner, allowing for increased persistence of the lactate/polylactates component due to their initial attachment to the oleic acids.

Example of 3-D Microemulsion

Due to its patented molecular structure, 3DME offers far greater transport when compared to blended emulsified vegetable oil (EVO) products, which fail to distribute beyond the limits of pumping. 3DME also provides greater persistence when compared to soluble substrates such as lactates or simple sugars. The 3DME molecular structures capitalize on the best features of the two electron-donor types while at the same time, minimize their limitations. 3DME is delivered to the site as a ready-to-apply emulsion that is simply diluted with water to generate a large volume of a 3DME colloidal suspension.

FIGURE 1: THE 3-D MICROEMULSION MOLECULAR STRUCTURE



Suspension of 3DME generated by this mixing range from micelles on the order of .02 microns to .05 microns in diameter, to "swollen" micelles, (termed "microemulsions") which are on the order of .05 to 5 microns in diameter. Once injected into the subsurface in high volumes, the colloidal suspension mixes and dilutes in existing pore waters. The micelles/microemulsions on the injection front will then begin to sorb onto the surfaces of soils as a result of zeta potential attraction and organic matter within the soils themselves. As the sorption continues, the 3DME will "coat" pore surfaces developing a layer of molecules and in some cases a bilayer. This sorption process continues as the micelles/microemulsion moves outward and disassociates into their hydrophilic/hydrophobic components. The specialized chemistry of 3DME results in a staged release of electron donors: free lactate (immediate); polylactate esters (mid-range) and free fatty acids & fatty acid esters (long-term). Material longevity of three years or greater has been seen at most sites as determined from biogeochemical analyses.

For a list of treatable contaminants with the use of 3DME, view the Range of Treatable Contaminants Guide.

3-D MICROEMULSION
Factory Emulsified

3-D Microemulsion® Factory Emulsified Technical Description

Chemical Composition

- Fatty acid esters
- Water
- Lactate oligomers
- Sodium lactate
- Proprietary surfactants

Properties

- Density – Approximately 1.0 grams per cubic centimeter (relative to water)
- pH – Neutral (approximately 6.5 to 7.5 standard units)
- Solubility – Soluble in Water
- Appearance – White emulsion
- Odor – Not detectable
- Vapor Pressure – None
- Non-hazardous

Storage and Handling Guidelines

Storage
Store in original tightly closed container
Store in a cool, dry, well-ventilated place
Store away from incompatible materials
Recommended storage containers: plastic-lined steel, plastic, glass, aluminum, stainless steel, or reinforced fiberglass

Handling
Avoid contact with eyes, skin, and clothing
Provide adequate ventilation
Wear appropriate personal protective equipment
Observe good industrial hygiene practices

Applications

- 3DME is diluted with water prior to application. Resulting emulsion has viscosity similar to water.
- Easily injects into formation through direct push injection points, injection wells or other injection delivery systems.

Application instructions for this product are contained in the 3DME FE Application Instructions.

Health and Safety

Material is food grade and relatively safe to handle. We recommend avoiding contact with eyes and prolonged contact with skin. OSHA Level D personal protection equipment including vinyl or rubber gloves, and eye protection are recommended when handling this product. Please review the 3DME FE Material Safety Data Sheet for additional storage, usage, and handling requirements.

REGENESIS®

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BIO-DECHLOR
INOCULUM

BDI PLUS® Technical Description

Bio-Dechlor INOCULUM Plus (BDI PLUS®) is an enriched natural consortium containing species of Dehalococcoides sp. (DHC). BDI PLUS has been shown to simulate the rapid and complete dechlorination of chlorinated solvents such as tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE) and vinyl chloride (VC) to non-toxic end products, ethene, carbon dioxide and water.

The culture also contains microbes capable of dehalogenating halomethanes (e.g., carbon tetrachloride and chloroform) and haloethanes (e.g., 1,1,1-TCA and 1,1-DCA) as well as mixtures of these contaminants.


Species of Dehalococcoides sp. (DHC)

For a list of treatable contaminants with the use of BDI PLUS, view the Range of Treatable Contaminants Guide

Chemical Composition

- Non-hazardous, naturally-occurring, non-altered anaerobic microbes and enzymes in a water-based medium.

Properties

- Appearance – Murky, yellow to grey water
- Odor – Musty
- pH 6.0 to 8.0
- Density – Approximately 1.0 grams per cubic centimeter (0.9 to 1.1 g/cc)
- Solubility – Soluble in Water
- Vapor Pressure – None
- Non-hazardous

Storage and Handling Guidelines

Storage
Store in original tightly closed container
Store away from incompatible materials
Recommended storage containers: plastic lined steel, plastic, glass, aluminum, stainless steel, or reinforced fiberglass
Store in a cool, dry area at 4-5°C (39 - 41°F)
Material may be stored for up to 3 weeks at 2-4°C without aeration

Handling
Avoid prolonged exposure
Observe good industrial hygiene practices
Wear appropriate personal protective equipment

BIO-DECHLOR
INOCULUM

BDI PLUS® Technical Description

Applications

- BDI PLUS is delivered to the site in liquid form and is designed to be injected directly into the saturated zone requiring treatment.
- Most often diluted with de-oxygenated water prior to injection into either hydraulic push injection points or properly constructed injection wells.
- The typical dilution rate of the injected culture is 10 gallons of deoxygenated water to 1 liter of standard BDI PLUS culture.

Application instructions for this product are contained here BDI PLUS Application Instructions.

Health and Safety

Material is non-hazardous and relatively safe to handle; however avoid contact with eyes and prolonged contact with skin. OSHA Level D personal protection equipment including: vinyl or rubber gloves and safety goggles or a splash shield are recommended when handling this product. An eyewash station is recommended. Please review the Material Safety Data Sheet for additional storage, usage, and handling requirements here: BDI PLUS SDS.

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