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RECEIVED
By Terri.Drake at 7:07 am, Feb 14, 2022

February 10, 2022

Mr. Brian Begley
Federal Facility Agreement Manager
Division of Waste Management
Kentucky Department for Environmental Protection
300 Sower Boulevard, 2nd Floor
Frankfort, Kentucky 40601

PPPO-02-10018973-22B

Mr. Victor Weeks
Federal Facility Agreement Manager
U.S. Environmental Protection Agency, Region 4
61 Forsyth Street
Atlanta, Georgia 30303

Dear Mr. Begley and Mr. Weeks:

TRANSMITTAL OF THE PLANT INDUSTRIAL AREA VAPOR INTRUSION PRELIMINARY RISK ASSESSMENT REPORT, PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY (DOE/LX/07-2471&D2)

Please find enclosed the *Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-2471&D2. This document reflects changes made in response to comments received from the U.S. Environmental Protection Agency (EPA) and the Kentucky Department for Environmental Protection (KDEP) on December 21, 2021, and December 28, 2021, respectively. Comments received via e-mail from EPA and KDEP following these meetings and comments received from discussions held on January 10, 2022; January 20, 2022; and February 3, 2022, are also incorporated.

DOE appreciates EPA's and KDEP's assistance with the finalization of this D2 report. A redline version of the D2 report and comment response summaries are also provided to assist with your review. DOE looks forward to EPA's and KDEP's approval of the D2 Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report.

If you have any questions or require additional information, please contact Rich Bonczek at (859) 219-4051.

Sincerely,

Tracey L. Duncan

Digitally signed by Tracey L. Duncan
Date: 2022.02.10 14:36:16 -06'00'

Tracey Duncan
Federal Facility Agreement Manager
Portsmouth/Paducah Project Office

Enclosures:

1. *Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-2471&D2—Clean
2. *Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-2471&D2—Redline
3. EPA Comment Response Summary
4. KDEP Comment Response Summary
5. Other Changes

Administrative Record File—ARF ARR and GWARC

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DOE/LX/07-2471&D2
Secondary Document

Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report, Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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Secondary Document

Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report, Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—February 2022

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Contract DE-EM0004895

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FIGURES

TABLES

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ACRONYMS

bgs	below ground surface
CSM	conceptual site model
DOE	U.S. Department of Energy
EMP	environmental monitoring plan
EPA	U.S. Environmental Protection Agency
HPFW	high-pressure fire water
KDEP	Kentucky Department for Environmental Protection
MCL	maximum contaminant level
MOA	memorandum of agreement
PGDP	Paducah Gaseous Diffusion Plant
PI	preliminary investigation
PVC	polyvinyl chloride
RGA	Regional Gravel Aquifer
UCRS	Upper Continental Recharge System
VI	vapor intrusion
VISL	vapor intrusion screening level
VOC	volatile organic compound

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EXECUTIVE SUMMARY

This report presents the results of the vapor intrusion (VI) study performed in accordance with the *Paducah Gaseous Diffusion Plant Industrial Area Vapor Intrusion Investigation Work Plan for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2447&D2/R1 (VI Work Plan) (DOE 2020a). The VI Work Plan was developed in response to the March 2019 *Memorandum of Agreement for Resolution of Formal Dispute Concerning Kentucky Department for Environmental Protection Nonconcurrence and U.S. Environmental Protection Agency Conditions Submitted on the Site Management Plan, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision—Fiscal Year 2018*, *DOE/LX/07-2418&D2* (MOA) (DOE 2019).

Based on the MOA, the following text was added to Appendix 3 of the Site Management Plan in the Dissolved-Phase Groundwater Operable Unit section (DOE 2020b):

> DOE will develop a Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Work Plan and Report to focus on PGDP buildings located over the groundwater plumes, consistent with EPA vapor intrusion guidance, with input from EPA and Kentucky Department for Environmental Protection (KDEP)…. The work plan identifies the information to be obtained and decision criteria for responding to the question of whether vapor intrusion from volatile organic compounds in soils and groundwater poses a potential threat to human health in buildings located over these areas at the Paducah Site and if human exposure to vapor intrusion is under control. Upon completion of the assessment, a Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report will be issued by DOE (scheduled in FY 2021).…The report will specify whether any additional actions are necessary to satisfy the question of potential threat to human health from vapor intrusion and/or to bring human exposure to vapor intrusion under control….

The U.S. Department of Energy (DOE) Paducah Site is located in a generally rural area of McCracken County, Kentucky, 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River. References in this report pertaining to the Paducah Site generally mean the property, programs, and facilities at or near the Paducah Gaseous Diffusion Plant [U.S. Environmental Protection Agency (EPA) site identification number KY8890008982)]. The VI Work Plan presented the preliminary VI conceptual site model (CSM) for facilities within the Paducah Gaseous Diffusion Plant Industrial Area; documented the VI/CSM-based selection process for facilities to be included in the preliminary investigation (PI); and described the investigation strategy, selection of analytes, and sample collection methods to be used during the PI. Facilities with the highest likelihood of a complete VI pathway were selected for inclusion in the PI. As described in the VI Work Plan, some of the PI buildings were selected to represent groups of buildings with similar CSMs. In those cases, results from the PI buildings serve as proxy results for the rest of the buildings within the group. The purpose of the PI is to evaluate whether measured volatile organic compound concentrations in indoor air [primarily trichloroethene (TCE)] present an unacceptable risk to human health due to VI in 61 buildings (23 PI buildings and the 38 by-proxy buildings they represent). This report presents the results of the PI, the outcome of the project decision rules based on the PI results, and recommendations based on the decision rules.

To meet project objectives, a combination of indoor air samples (coupled with outdoor air samples for background[1] comparison), subslab vapor samples, and/or crawlspace air samples were collected from 23 PI buildings, which represent the 38 by-proxy buildings. These samples were analyzed for the PI analytes TCE, *cis*-1,2-dichloroethene (*cis*-1,2-DCE), *trans*-1,2-dichloroethene (*trans*-1,2-DCE), vinyl chloride (VC), 1,1,1-trichloroethane (1,1,1-TCA), and chloroform using the EPA Method TO-15. Screening-level mercury concentrations were collected from indoor air sampling locations using a Jerome® field meter. Additionally, weather data were collected during sampling and cross-slab differential pressure was recorded at one subslab location per building where paired indoor air samples were collected and subslab sample ports were installed.

Chloroform was the most commonly detected compound, with 61 out of 113 samples in 19 out of 23 PI buildings, and it was detected in all four media (i.e., subslab vapor, indoor air, crawlspace air, outdoor air). TCE was detected in 27 out of 113 samples and 7 out of 10 PI buildings where both subslab vapor and indoor air samples were collected. 1,1,1-TCA was detected in three subslab samples within two PI buildings; *trans*-1,2-DCE was detected in four indoor air samples within two PI buildings; and VC was detected in two crawlspace air samples within two PI buildings. *cis*-1,2-DCE was not detected in any sample. Mercury was detected at 12 out of 53 locations where screening was conducted.

Field screening results for mercury and analytical results for all other PI analytes were compared to their respective target concentrations, or vapor intrusion screening levels (VISLs), and the decision rules defined in the VI Work Plan. Chloroform and TCE were the only PI analytes detected at concentrations above their VISLs and are contaminants of potential concern. Chloroform was detected above its indoor air VISL in indoor air or crawlspace air samples in 15 of the 18 PI buildings where indoor air or crawlspace air samples were collected; it was also detected in two outdoor air samples. Concentrations of chloroform and TCE in subslab vapor exceeded their VISLs in five PI buildings and two PI buildings, respectively.

The EPA *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air* (2015 VI Technical Guide) (EPA 2015) states that a potential VI pathway should be considered complete when the following five key conditions are all present (EPA 2015):

1. A subsurface source of vapor-forming chemicals exists.
2. There is a route for the vapors to migrate.
3. The building is susceptible to VI.
4. Vapors are present in the indoor environment.
5. People are in the indoor environment.

Based on an evaluation of multiple lines of evidence, the subsurface to indoor air VI pathway is incomplete in all 23 PI buildings. None of the indoor air exceedances from this sampling event are attributable to subsurface environmental sources from site-related contamination; therefore, there is no unacceptable risk to workers from the VI pathways under current conditions. Because no PI buildings have complete VI pathways, the 38 by-proxy buildings are also considered to have incomplete VI pathways. This conclusion was reached in one of the following three ways for each building, depending on the circumstances present at the time of the PI.

- In PI buildings where chloroform exceeded its VISLs in subslab or indoor air, there are no known chloroform sources in groundwater or soil near the PI buildings; therefore, there is no known source of subsurface contamination to the VI pathway—fails key condition 1. Chloroform was included as a

[1] The term background, as used in this report, refers to anthropogenic background as defined in the EPA 2015 VI Technical Guide: "… natural and human-made substances present in the environment as a result of human activities and not specifically related to the site-related release in question…" (EPA 2015).

PI analyte based on only a few VISL exceedances in groundwater across the site. Chloroform was detected in subslab vapor samples that were collected near the C-409 building; however, there are no chloroform detections in the soil or VISL exceedances in the groundwater samples.

- In most PI buildings, no PI analyte other than chloroform exceeded VISLs in either subslab or indoor air—fails key conditions 1 and 4.

- In PI buildings where TCE in subslab vapor exceeded its VISL, there were no exceedances in indoor air, therefore, there is no VI pathway under current conditions at these locations—fails key condition 4.

The only PI analyte with VISL exceedances in indoor air was chloroform, which is a common background contaminant associated with chlorinated drinking water. The following additional lines of evidence were used to conclude that chloroform is a background contaminant at the PI buildings as described in the 2015 EPA VI Technical Guide.

- In locations where chloroform exceeded its VISL in subslab vapor, there were no known environmental sources of chloroform from site-related contamination nearby.

- Of the 26 locations where chloroform exceeded VISLs in indoor air, chloroform exceeded its VISL in the co-located subslab sample in only three locations. Detecting a PI analyte in indoor air, but not in its paired subslab vapor sample, is consistent with the spatial pattern of a background contaminant that is present indoors and is inconsistent with a subsurface environmental source of chloroform from site-related contamination.

- According to the EPA, "Chloroform may be released to the air as a result of its formation in the chlorination of drinking water, wastewater and swimming pools" (EPA 2000). In the EPA study, *Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990–2005)*, chloroform was detected in 69% of collected indoor air samples across 15 case studies (EPA 2011).

Based on multiple lines of evidence, the interpretation of VI investigation results, and in consideration of the decision rules, the VI pathway is incomplete within the PI buildings; therefore, there is no unacceptable risk to workers from the VI pathway under current conditions for all PI buildings and by-proxy buildings— because there is no unacceptable risk to workers, worker exposure to VI is under control. No indoor air exceedances from this sampling event are attributable to subsurface environmental sources from site-related contamination. For chloroform, exceedances are attributed to background sources, however, the VI CSM derived from on-site datasets that were evaluated for this investigation does not preclude the possibility of chloroform being released to the environment from other sources, including materials used at PGDP or PGDP operations. TCE exceeded its VISL in subslab vapor in two PI buildings—C-310 and C-720; however, it did not exceed the VISL for indoor air in any PI building. In all other PI buildings, no subsurface source of PI analytes was identified.

Based on the results of the PI investigation, an evaluation of the decision rules, and the conclusion that chloroform is derived from background sources (i.e., not an environmental source from site-related contamination), no additional actions are recommended at most PI buildings, under current conditions and building uses; however, EPA acknowledges in its 2015 VI Technical Guide that contaminant concentrations in indoor air from VI are often temporally variable, and it is industry standard to conduct at least two seasonal indoor air sampling events (i.e., one warm weather, one cold weather) when a significant subslab vapor source is present. Thus, a second sampling event is recommended for PI buildings where TCE concentrations in subslab vapor exceeded VISLs to reduce this temporal uncertainty. The following

additional actions are recommended as the VI pathway evaluation is continued to satisfy the question of potential threat to human health from VI.

- Conduct an additional round of paired subslab vapor/indoor air sampling at paired locations 2, 3, and 4 in C-310. During the PI, TCE exceeded its VISL in subslab sample locations 2 and 3; however, it did not exceed its VISL in the paired indoor air samples. During the PI, chloroform exceeded its VISL in both subslab and indoor air samples at paired location 4.

- Conduct an additional round of paired subslab vapor/indoor air sampling at paired locations 1 and 3 in C-409. During the PI, chloroform exceeded its VISL in both subslab and indoor air samples at these two paired locations.

- Conduct an additional round of paired subslab vapor/indoor air sampling at paired location 4 in C-720. During the PI, TCE exceeded its VISL in this subslab sample; however, it did not exceed its VISL in the paired indoor air sample.

No further evaluation is recommended at this time for the remaining 20 PI buildings or for the 38 by-proxy buildings represented by the selected PI buildings. Furthermore, consistent with the requirements in the risk methods document (DOE 2021), if or when the use of an occupiable building on the DOE Paducah Site changes, a new building is constructed, or a parcel of land is transferred for a different use, DOE will evaluate the VI pathway to the building or proposed building at that time.

1. INTRODUCTION

This report presents the results of the vapor intrusion (VI) study performed in accordance with the *Paducah Gaseous Diffusion Plant Industrial Area Vapor Intrusion Investigation Work Plan for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (VI Work Plan) (DOE 2020a). The VI Work Plan was developed in response to the March 2019 *Memorandum of Agreement for Resolution of Formal Dispute Concerning Kentucky Department for Environmental Protection Nonconcurrence and U.S. Environmental Protection Agency Conditions Submitted on the Site Management Plan, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision-Fiscal Year 2018*, *DOE/LX/07-2418&D2* (MOA) (DOE 2019).

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The VI Work Plan was written to (1) document the U.S. Department of Energy (DOE) Paducah Gaseous Diffusion Plant (PGDP) Industrial Area preliminary VI conceptual site model (CSM) for facilities within the PGDP Industrial Area; (2) document the CSM-based selection process for facilities that will be included in the preliminary investigation (PI); and (3) provide assessment methods to guide the collection of vapor samples during the PI to evaluate if VI pathways present an unacceptable risk to human health under current conditions.

To fulfill the preliminary VI evaluation required per the MOA, and consistent with the U.S. Environmental Protection Agency (EPA) *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air* (2015 VI Technical Guide) (EPA 2015), the VI Work Plan included the following information, which is summarized in Sections 1.5 through 1.7 of this report:

1. A compilation and summary of existing information and data relevant to the PGDP Industrial Area VI CSM;

2. The PGDP Industrial Area VI CSM and rationale for prioritizing certain facilities with the highest likelihood of a complete VI pathway for further VI evaluation during the PI;

3. The rationale for VI sampling at PI buildings (those facilities that met the definition of building and were retained for sampling);

4. Recommended screening levels based on current toxicity values and risk assessment methods;

5. Sampling and analysis steps to evaluate whether volatile organic compound (VOC) [primarily trichloroethene (TCE)] concentrations in indoor air from VI present an unacceptable risk to human health in selected PI buildings; and

6. Decision rules for evaluating the data collected as part of this study and recommending further VI investigation, as necessary.

The information and data collected during the field effort (via the methods presented in Section 2) are intended to fill the data gaps identified in the work plan to complete the preliminary VI evaluation and demonstrate whether human exposure to VI is under control.

1.1 PROJECT OBJECTIVE

The objective of the VI study is to evaluate whether the subsurface-to-indoor air VI pathways are complete and whether they present an unacceptable risk to workers in the buildings within the PGDP Industrial Area under current conditions. The results of the PI investigation sampling were evaluated to develop conclusions about the impact of VI on the indoor air of PI buildings at PGDP. PI results and evaluations are presented in Sections 3 and 4 of this report, respectively, and subsequent recommendations are proposed in Section 5.

1.2 AREA DESCRIPTION

The DOE Paducah Site is located in a generally rural area of McCracken County, Kentucky, 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River. References in this report to the Paducah Site generally mean the property, programs, and facilities at or near PGDP (EPA site identification number KY8890008982) for which DOE has ultimate responsibility. The DOE-owned Paducah Site is 3,556 acres. The PGDP and buffer zone were approximately 750 acres in size when the plant was operational.

PGDP is an inactive gaseous diffusion plant that was used to produce enriched uranium beginning in 1952. The facility first was owned and managed by the Atomic Energy Commission and the Energy Research and Development Administration, DOE's predecessors. DOE managed the PGDP until 1993. On July 1, 1993, the United States Enrichment Corporation assumed management and operation of the PGDP enrichment facility under a lease agreement with DOE that continued until October 2014, when the facility was returned to DOE. DOE currently retains ownership of the PGDP.

1.3 GEOLOGY AND SOIL

The Paducah Site is underlain by a sequence of clay, silt, sand, and gravel layers that unconformably overly limestone bedrock. The sediments above the limestone bedrock are grouped into three major stratigraphic units in the northern portion of the site (loess, Continental Deposits, and McNairy Formation), as shown in Figure 1. The silt to clayey silt loess deposits overly the Continental Deposits, which are divided into upper and lower facies. The Upper Continental Deposits consist of an upper silt and sand interval; an intermediate interval of common sand and gravel lenses; and a lower silt, sand, and clay interval. The Lower Continental Deposits is a gravel facies that ranges from pebbles to cobbles in a matrix of poorly sorted sand and silt. The McNairy Formation is a carbonaceous unit that consists of micaceous clay and fine sand. The sediments are also grouped into three major hydrogeologic units [i.e., Upper Continental Recharge System (UCRS), Regional Gravel Aquifer (RGA), McNairy Flow System], as shown in Figure 2. Additional information on Paducah Site geology can be found in numerous documents, including the *Remedial Investigation/Feasibility Study Work Plan for the C-400 Complex Operable Unit at the Paducah Gaseous*

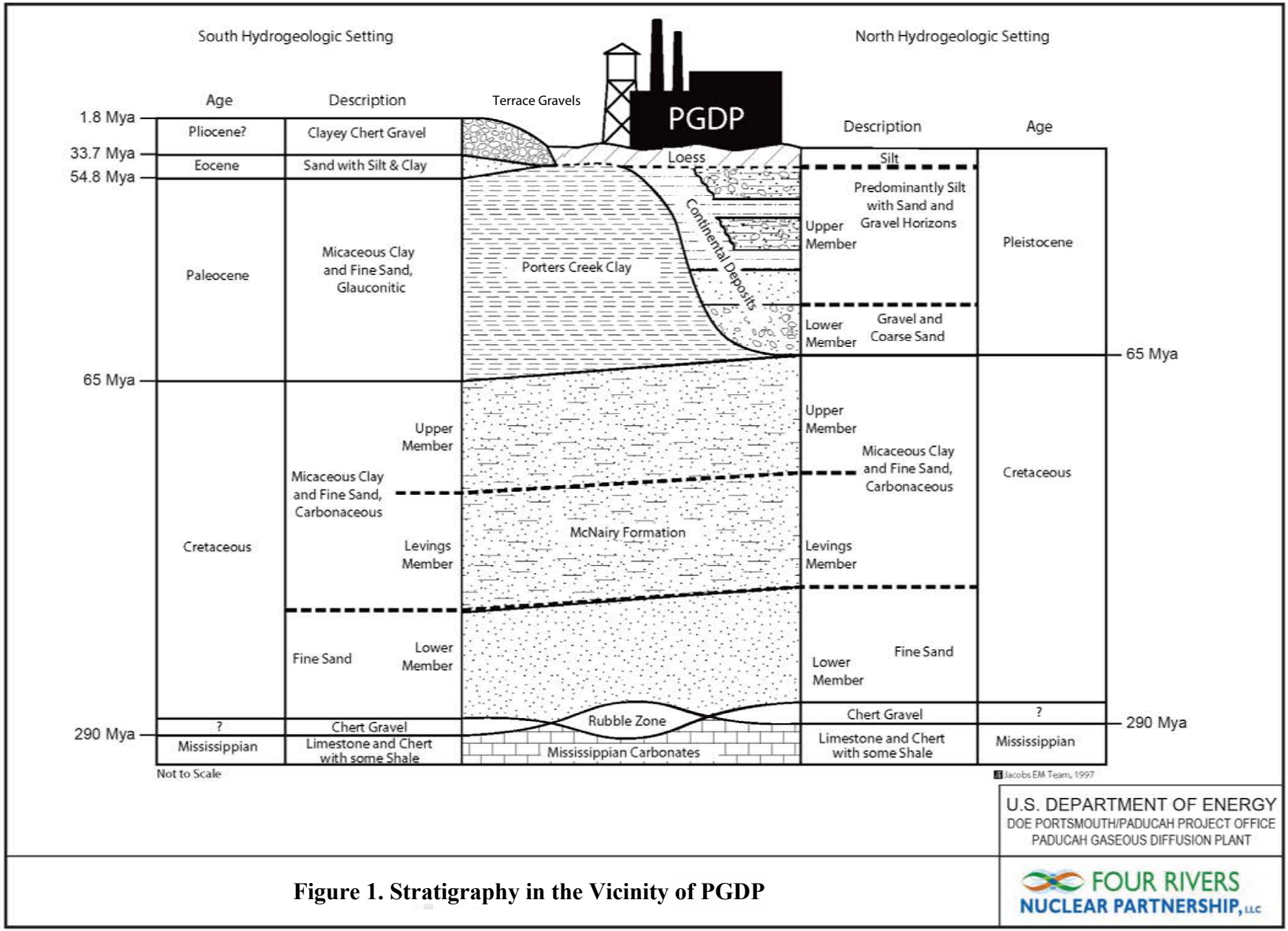
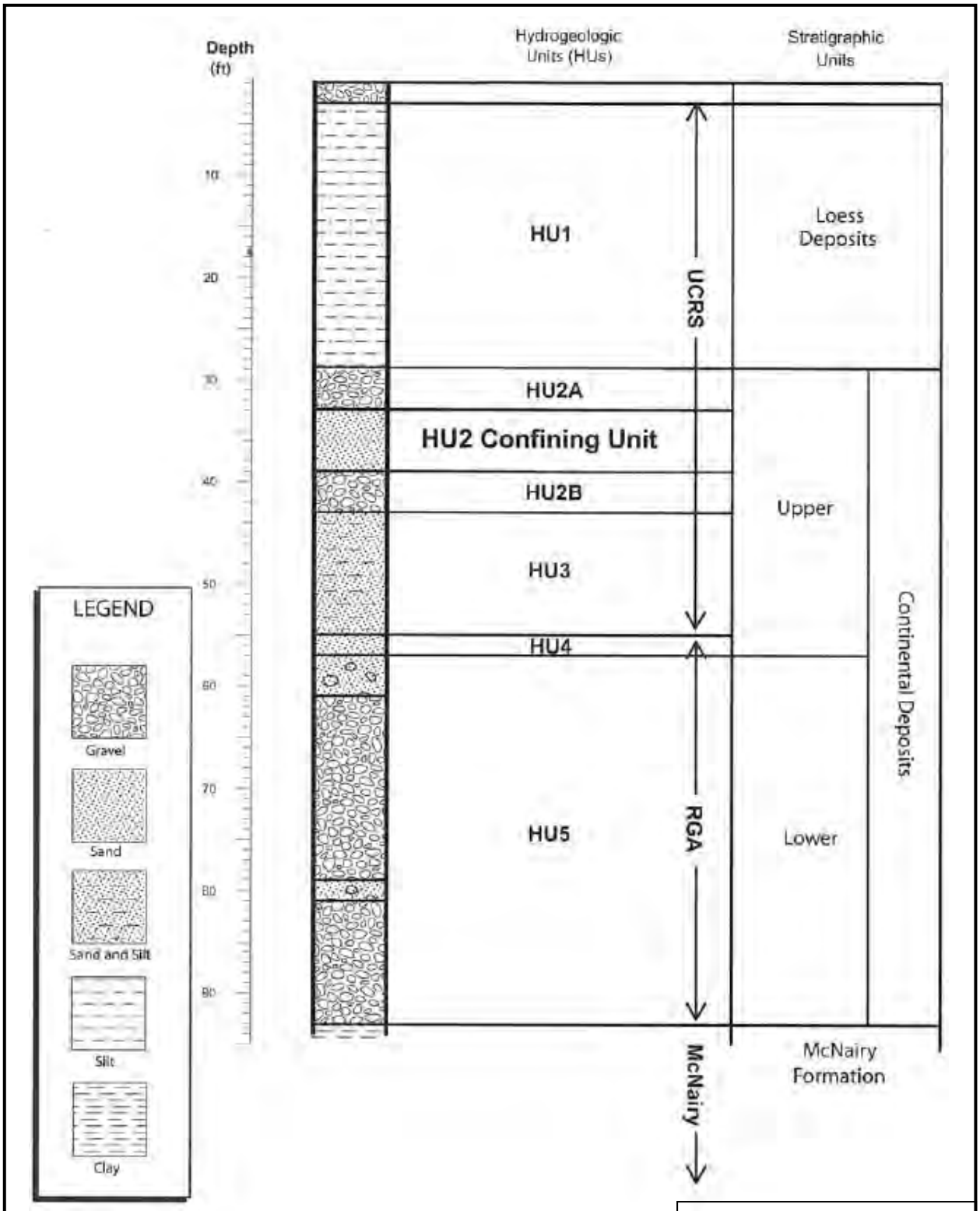


Figure 1. Stratigraphy in the Vicinity of PGDP

Adapted from DOE 2020b



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

FOUR RIVERS
NUCLEAR PARTNERSHIP, LLC

Figure 2. Major Hydrogeologic Units beneath the Paducah Site

Source: DOE 2020b

Diffusion Plant, Paducah, Kentucky, DOE/LX-07-2433&D2R1 (DOE 2020c) and the VI Work Plan (DOE 2020a).

1.4 HYDROGEOLOGY

The geologic units that control shallow groundwater flow at the Paducah Site include the Terrace Gravel and Porters Creek Clay (Figure 1), which underlie the south sector of the Paducah Site, and the Pleistocene Continental Deposits and McNairy Formation, which underlie the Paducah Site and adjacent areas to the north. The Porters Creek Clay acts as a confining unit to downward groundwater flow south of the Paducah Site. This aquitard creates a shallow water table flow system in the Terrace Gravel where it overlies the Porters Creek Clay south of the Paducah Site. The UCRS is the upper strata where the infiltration of surface water occurs north of the Porters Creek Clay Terrace slope. Beneath the Paducah Site, the water table is found within the UCRS, terrace gravels, and surface loess. Groundwater flow is primarily downward in the Upper Continental Deposits; however, lateral flow may occur over short distances. The RGA is the lateral flow system that underlies the UCRS. Additional information on Paducah Site hydrogeology can be found in numerous documents, including the *Remedial Investigation/Feasibility Study Work Plan for the C-400 Complex Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2433&D2/R1 (DOE 2020c) and the VI Work Plan (DOE 2020a).

1.5 PI PROJECT SCOPE

Scoping meetings related to the PI were held among DOE, the Kentucky Department for Environmental Protection (KDEP), and EPA on September 27, 2019; October 17, 2019; October 30, 2019; November 22, 2019; December 18, 2019; and January 14, 2020. The VI Work plan includes a full description of the project scope, which is summarized below. Note that much of the material developed in the work plan is incorporated into the preliminary VI risk assessment completed as part of this project.

In the VI Work Plan, preliminary CSMs were developed using existing information and data for PGDP facilities, ranging from the VI pathway being incomplete (i.e., the facility does not meet the definition of a building, there is no known source near the facility) to the VI pathway needing further evaluation to determine completeness. Facilities with the highest likelihood of a complete VI pathway, based on preliminary CSMs, were selected for inclusion in the PI. Facilities that did not meet the definition of a building or were not near a known environmental source of volatile contaminants from site-related contamination were excluded from the PI investigation. Seven chemicals (shown in Table 1) were chosen for evaluation in this PI. These chemicals, referred to as PI analytes, are chemicals that (1) are present in groundwater above their respective target concentrations, or vapor intrusion screening levels (VISLs); and/or (2) have been used in operations or processes at PGDP, and/or (3) provide information about contaminant degradation, with their selection process described in Section 5 of the VI Work Plan.

Table 1. VISLs for PI Analytes of Interest for PGDP Area—Commercial

Chemical	Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk via VI from Soil Source?	Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk via VI from Groundwater Sources?	Indoor Air VISL (µg/m³) at TCR = 1E-06 or THQ = 1[a]	Toxicity Basis	Soil Gas VISL (µg/m³) at TCR = 1E-06 or THQ = 1[a]	Target Groundwater Concentration (µg/L) at TCR = 1E-06 or THQ = 1[a]
	Cvp > Cia, target?	Chc > Cia, target?	Min (Cia, c; Cia, nc)	C or NC	Csg	Chc
Chloroform	Yes	Yes	0.533	C	17.8	3.55
Dichloroethene, 1,2-*cis*- (*cis*-1,2-DCE)	No Inhalation Toxicological Information	No Inhalation Toxicological Information	NVA*, 3,500	--, NC	--	--
Dichloroethene, 1,2-*trans*- (*trans*-1,2-DCE)[b]	No Inhalation Toxicological Information	No Inhalation Toxicological Information	NVA*, 3,500	--, NC	--	--
Mercury (elemental)[c]	Yes	Yes	1.31	NC	43.8	3.73
Trichloroethane, 1,1,1- (1,1,1-TCA)[d]	Yes	Yes	21,900	NC	730,000	31,100
TCE	Yes	Yes	2.99	C	99.7	7.43
Vinyl Chloride (VC)	Yes	Yes	2.79	C	92.9	2.45

C = carcinogenic
Cia = concentration, indoor air
Chc = concentration, groundwater vapor
Csg = concentration, subslab and exterior soil gas concentration
Cvp = concentration, pure phase vapor
NVA* = no VISL value available; provisional value provided by EPA, as documented in Appendix E (E.9) of the risk methods document (DOE 2021). Value for *cis*-1,2-DCE uses *trans*-1,2-DCE value as surrogate.
NC = noncarcinogenic
TCR = target risk for carcinogens
THQ = target hazard quotient for noncarcinogens

[a] The agreed upon VISLs laid out in the VI Work Plan were calculated at a hazard quotient of 1 because this was a preliminary assessment and was not intended to be used for human health risk assessment at this time. Reporting limits were targeted to meet the hazard quotient of 0.1 so that the data could still be used for future risk assessment.

[b] At the time of the VI Work Plan issuance, EPA did not have a VISL for *trans*-1,2-DCE. Using the most recent version of the EPA VISL calculator, accessed on June 9, 2021, the VISL for *trans*-1,2-DCE is 175 µg/m³ and 5,840 µg/m³ for indoor air and subslab vapor, respectively (EPA 2019). These VISLs are based on the EPA May 2021 Regional Screening Levels. The results of this study were evaluated against the new VISL for *trans*-1,2-DCE. Because the maximum concentrations of *trans*-1,2-DCE in this study were 0.77 µg/m³ and 2 µg/m³ (nondetect) for indoor air and subslab vapor, respectively, the new VISL does not change the interpretation of the results.

[c] For an analyte to be considered a contaminant of potential concern for VI, the analyte must be toxic and sufficiently volatile to migrate from a subsurface source into a building at a concentration greater than its indoor air screening level. Elemental mercury is toxic and can be sufficiently volatile to exist in vapors at levels potentially harmful to human receptors; therefore, mercury must be present in subsurface media in elemental form to pose a VI risk. The majority of mercury, which is a common industrial contaminant and by-product of coal combustion, detected in groundwater or soils at the Paducah Site is expected to be in the form of salts—not elemental mercury. Mercury has not been detected in site monitoring wells at concentrations greater than its groundwater VISL; therefore, mercury is not expected to be present in vapor form above trace concentrations. Indoor air in each building identified for PI sampling, however, was screened for mercury using a field meter as a protective measure based on its widespread detection in site soil.

[d] 1,1,1-TCA was included to be considered only when there is documented use within a facility. It was not considered in ranking PI facilities; however, it was sampled in each building identified for PI sampling.

The following criteria presented in the VI Work Plan were devised to prioritize sampling PI facilities during this VI investigation.

1. The facility is considered to be a building—Each facility in the PGDP facility database was classified as a building or non-building based on the following definition of "building" in the 2015 EPA VI Technical Guide:

   > "For purposes of this Technical Guide and its recommendations for evaluating human health risk posed by vapor forming chemicals, 'building' refers to a structure that is

intended for occupancy and use by humans. This would include, for instance, homes, offices, stores, commercial and industrial buildings, etc., but would not normally include sheds, carports, pump houses, or other structures that are not intended for human occupancy."

AND

2. The building is considered to be occupiable—Occupiable buildings are those that could be occupied by workers without major renovations to the building structure.

AND ANY OF

3. The TCE in RGA groundwater exists beneath the building and is ≥ 100 µg/L.

OR

4. There has been a VISL exceedance of the sum of VISL-normalized PI analyte concentrations in UCRS groundwater within 100 ft of the building.

The sum of [(analyte 1/VISL 1) + (analyte 2/VISL 2) + (analyte 3/VISL 3) + …] ≥ 1

OR

5. There has been a PI analyte detection in soil within 100 ft of the building.

Buildings were grouped based on similarities in construction and proximity to sources of PI analytes. One to two buildings were selected from each group and were investigated by building walkdowns and sampling; the selected buildings from each group were used in this study to represent other members of the group (Table 2). The 23 buildings that were selected for PI sampling are referred to as "PI buildings" and the 38 by-proxy buildings they represent are referred to as "by-proxy buildings." This grouping allowed for greater spatial coverage by allowing a small number of facilities to represent others with the same VI CSM.

Table 2. PI Building Groups

PI Building	By-Proxy Building
C-100	-
C-103	-
C-200	-
C-304	-
C-310	-
C-337	-
C-337-A	-
C-360-A	-
C-409	-
C-410-K	C-410-D
C-412-T11A	C-412-T01
	C-412-T02
	C-412-T03
	C-412-T04

PI Building	By-Proxy Building
C-615	-
C-720	-
C-720-G	-
C-724	C-200-A
	C-720-A
	C-720-B
	C-720-E
	C-720-H
	C-720-J
	C-720-R
	C-720-M
	C-720-M-T01
	C-724-C
C-725	-
C-746-U1	-

PI Building	By-Proxy Building
C-755-T16 and C-755-T27	C-755-A
	C-755-B
	C-755-S
	C-755-T01
	C-755-T02
	C-755-T03
	C-755-T04
	C-755-T05
	C-755-T06
	C-755-T07
	C-755-T09
	C-755-T18
	C-755-T19
	C-755-T20
	C-755-T21

Table 2. PI Building Groups (Continued)

PI Building	By-Proxy Building
C-412-T11A (Continued)	C-412-T06
	C-412-T07
	C-412-T12

PI Building	By-Proxy Building
C-752-A-T10	-
C-752-B-T01	-
C-754-B	-

PI Building	By-Proxy Building
C-755-T16 and C-755-T27 (Continued)	C-755-T22A
	C-755-T23
	C-755-T26
	C-755-T28
	C-755-W
C-764-T3	-

Before buildings and sampling locations within buildings were selected, PI facility walkdowns were conducted from February 11, 2020, through February 13, 2020, to confirm building construction characteristics; heating, ventilation, and air conditioning and ventilation characteristics; building occupancy; and to identify potential indoor PI analyte sources and preferential pathways. Notable changes to the PI scope that occurred as a result of walkdowns included the consensus by the walkdown parties to replace two facilities that did not meet the objectives of the study. C-410-L was replaced with C-410-D and C-410-K; C-360 was replaced with C-361-A. Planned sampling locations based on this information are presented in Table 3 and are shown on Figure 3.

1.6 PROJECT APPROACH

To meet the project objectives of this VI study, a combination of indoor air samples (coupled with outdoor air samples for background[2] comparison), subslab vapor samples, and/or crawlspace air samples were planned in areas believed to be susceptible to VI based on the building-specific CSMs. Additionally, weather data was collected during sampling and cross-slab differential pressure was recorded at one subslab location per PI building where paired indoor air samples were collected and subslab sample ports were installed. Table 3 and Figure 3 present the PI buildings sampled. Table 3 also presents the type and number of planned samples to be collected in each PI building. The projected location for each planned sample to be collected in each PI building is presented in the VI Work Plan.

The following CSM-based concepts were applied to sample planning for PI buildings.

- In skirted trailers with crawlspaces, crawlspace air samples were planned because crawlspaces underlie the entire PI building and, therefore, intercept soil vapor that may migrate to indoor air. Analytical results from crawlspace air samples have been evaluated the same as indoor air samples because the 2015 EPA VI Technical Guide states the assumption that vapors do not attenuate between crawlspace and indoor air.

[2] The term background, as used in this report, refers to anthropogenic background as defined in the EPA 2015 VI Technical Guide: "… natural and human-made substances present in the environment as a result of human activities and not specifically related to the site-related release in question…" (EPA 2015).

Table 3. Planned Sampling Locations and Types of Samples

Facility Number	Facility Description	Facility Walkdown Description	PI Inclusion Rationale	Building Type	Number of Indoor Air Samples	Number of Subslab Samples	Number of Crawlspace Samples	Number of Outdoor Air Samples
C-100	ADMINISTRATION BUILDING	Offices with Basement	Soil	Building with Basement	4 (2 first floor; 2 basement)	4 (2 first floor; 2 basement)	0	1
C-103	DOE SITE OFFICE & ANNEX	Site Offices	Soil	Slab on Grade Structure	3	3	0	1
C-200	GUARD & FIRE HEADQUARTERS	Police/Fire	UCRS GW and Soil	Building with Basement	4 (3 first floor; 1 basement)	4 (3 first floor; 1 basement)	0	1
C-304	TRAINING & CASCADE OFFICE BUILDING	Offices	Soil	Slab on Grade Structure	3	3	0	1
C-310	PURGE & PRODUCT BUILDING	Former Process Building	Soil	Building with Basement	4 (3 first floor; 1 basement)	4 (3 first floor; 1 basement)	0	1
C-337	PROCESS BUILDING	Former Process Building	RGA GW	Building with Basement	1 (tunnel)	4 (3 first floor; 1 basement)	0	1
C-337-A	FEED VAPORIZATION FACILITY	Office/Bath	RGA GW	Slab on Grade Structure	0	2	0	0
C-360-A	TOLL TRANSFER & SAMPLING BUILDING ANNEX	Vehicle/Heavy Equipment Maintenance	RGA GW	Slab on Grade Structure	0	3	0	0
C-409	STABILIZATION BUILDING	Big Ovens/Lab	RGA/UCRS GW and Soil	Slab on Grade Structure	3	3	0	1
C-410-K	FLUORINE FACILITY BUILDING	F2 Process	RGA GW and Soil	Slab on Grade Structure	0	1	0	0
C-412-T11A	SHOWER & CHANGE TRAILER	Female and Male Change Trailer	UCRS GW	Trailer (Skirted)	0	0	1	0
C-615	SEWAGE DISPOSAL PLANT	Sewage Plant	Soil	Building with Basement	2 (basement)	2 (basement)	0	1
C-720 & C-720-C	MAINTENANCE & STORES BUILDING; CONVERTOR SHOP ADDITION	Stores; Maintenance Shops. C-720 and C-720-C are connected; will be assessed together.	UCRS GW and Soil	Slab on Grade Structure	7	7	0	1
C-720-G	WAREHOUSE	Warehouse; intended for future occupancy.	Soil	Slab on Grade Structure	4	4	0	1
C-724-A & C-724-B	CARPENTER SHOP; CARPENTER SHOP ANNEX	Carpenter Shop. C-724-A and C-724-B are connected; will be assessed together	RGA GW and Soil	Slab on Grade Structure	4	4	0	1
C-725	PAINT SHOP	Paint Shop/Storage	RGA GW	Slab on Grade Structure	0	2	0	0
C-746-U1	LANDFILL OFFICE BUILDING	Landfill Office	Unique CSM*	Sealand Container	1	0	0	1
C-752-A-T10	WASTE OPERATIONS OFFICE TRAILERS	Breakroom	RGA GW and Soil	Trailer (Skirted)	0	0	1	0
C-752-B-T01	FUELING STATION TRAILER	AST Trailer	Soil	Trailer (Skirted)	0	0	1	0
C-754-B	LOW LEVEL WASTE STORAGE	Police Training; No Floor Slab	RGA GW	Quonset Hut (No Slab)	1	0	0	1
C-755-T16	RADCON TRAILER	Change/Shower Trailer	RGA GW	Trailer (Skirted)	0	0	1	0
C-755-T27	OFFICE TRAILER	Operations & Maintenance Office	RGA GW and Soil	Trailer (Skirted)	0	0	1	0
C-764-T03	OFFICE TRAILER	Offices	Soil	Trailer (Skirted)	0	0	1	0

Information checked and revised 2/14/2020.

*Facility included for sampling because it is located near a landfill.

AST = aboveground storage tank

GW = groundwater

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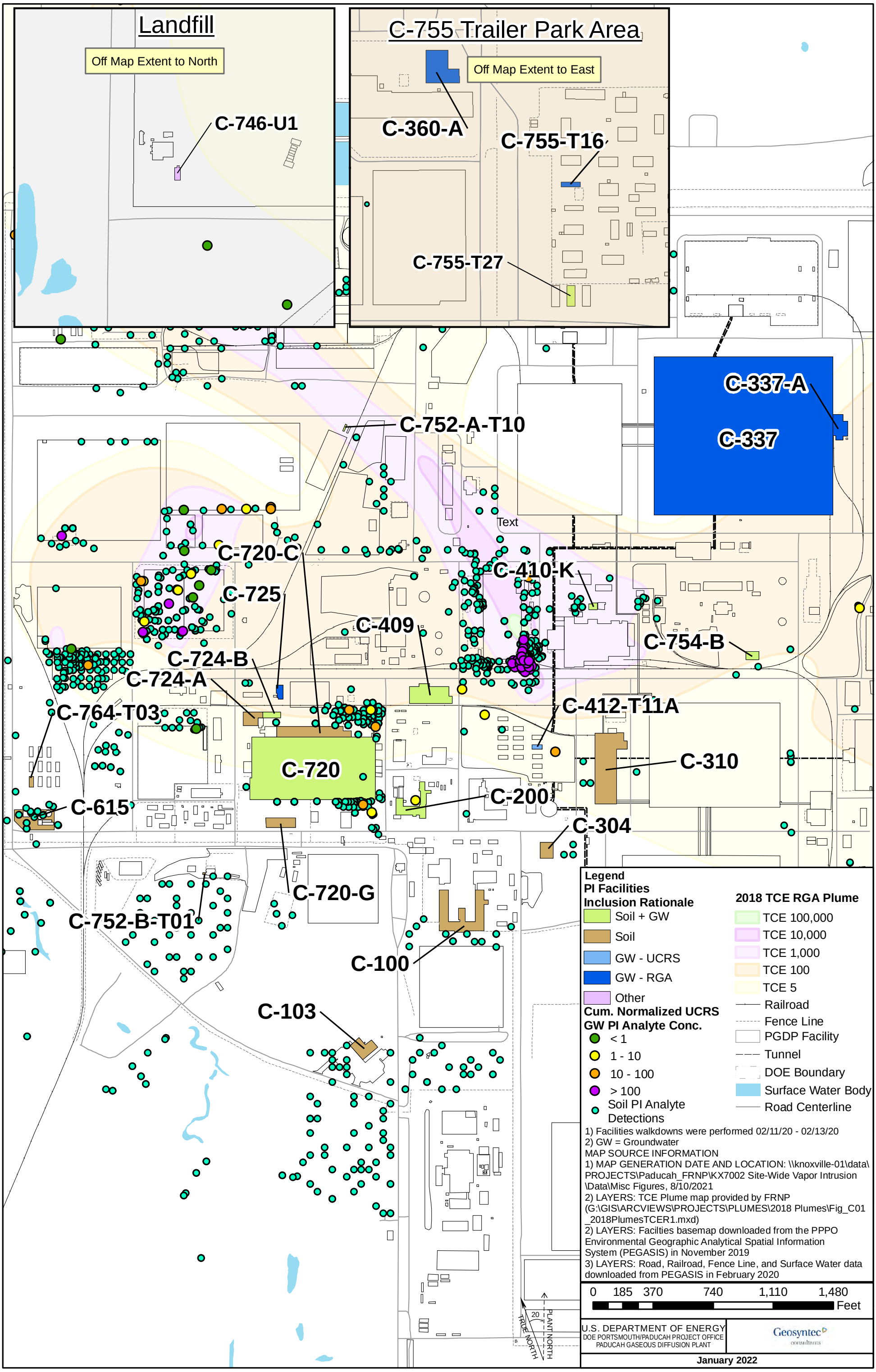

Figure 3. Preliminary Investigation Buildings Selected for Sampling

Source: DOE 2020a

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- In PI buildings with slabs that overlie a source of TCE in RGA groundwater only, subslab vapor samples were planned because the dissolved TCE plume in the RGA[3] is delineated.

- In PI buildings with slabs that overlie or are adjacent to detections of PI analytes in soil and/or UCRS groundwater, which can serve as sources of subslab vapor, subslab vapor samples were paired with indoor air samples because the extent of PI analytes in soil and/or UCRS groundwater have more spatial uncertainty than the TCE plume in the RGA.

- In PI buildings with no slab or crawlspace (e.g., C-746-U1, C-754-B), indoor air sampling was planned because samples in indoor breathing space provide direct exposure point concentrations.

- An outdoor air sample was planned for each PI building where crawlspace air or indoor air sampling was planned because outdoor air samples provide concentrations of analytes in ambient air that may impact analyte concentrations in indoor air and crawlspace air.

1.7 PRELIMINARY VAPOR INTRUSION CONCEPTUAL SITE MODELS

Section 6 of the VI Work Plan presents building-specific VI CSMs for the PI buildings in this study to outline possible pathways for VI and to understand whether vapors from VOCs are potentially migrating into occupied buildings.

The VI CSMs detailed in the VI Work Plan used site-specific information collected during characterization studies and interim remedial actions to describe the nature, location, and spatial extent of the vapor sources in the subsurface and to determine the uses, occupancy, and construction of PI buildings. In addition to the subsurface sources, these CSMs consider building uses that might source vapors to indoor air. The VI CSMs portray the hydrology, hydrogeology, and geology of the building and immediate area and consider how these factors influence vapor migration and attenuation in the vadose zone.

Figure 4 presents a schematic sitewide VI CSM based on the 2015 EPA VI Technical Guide which has been adapted to PGDP. This figure illustrates the subsurface sources of contamination being evaluated at PGDP. As described in the VI Work Plan, large volumes of TCE were used as an industrial cleaning solvent in historical operations at PGDP between the 1960s and 1993. During this time, TCE migrated into soil and groundwater, with dissolved-phase TCE contamination in groundwater and dense nonaqueous-phase liquid in soil and groundwater in various locations in the UCRS and RGA, which possibly extended into the McNairy Formation. The VOCs of interest are TCE and its breakdown products, *cis*-1,2-DCE, *trans*-1,2-DCE, and VC. There is evidence that 1,1,1-TCA was used in some site buildings; therefore, 1,1,1-TCA was included as a PI analyte.

Within the PGDP Industrial Area, groundwater is encountered at approximately 30–35 ft below ground surface (bgs) in the UCRS. The highly permeable sands and gravels of the RGA are encountered at approximately 50 ft bgs, where groundwater velocity is estimated to be on the order of 0.1–0.3 ft/day. Groundwater in the RGA flows generally to the north. The UCRS is the surficial or near-surface soil facies at the Paducah Site and directly underlies many buildings.

[3] The VI Work Plan (DOE 2020a) was issued in 2020 and the screening and ranking of buildings was performed in the work plan with respect to TCE in groundwater, based on the 2018 RGA TCE plume (FRNP 2019). The 2018 RGA TCE plume is used in this report for consistency in the evaluation of the PI results in comparison to the screening and ranking performed in the VI Work Plan; all discussion of the TCE plume herein refers to the 2018 RGA TCE plume (FRNP 2019).

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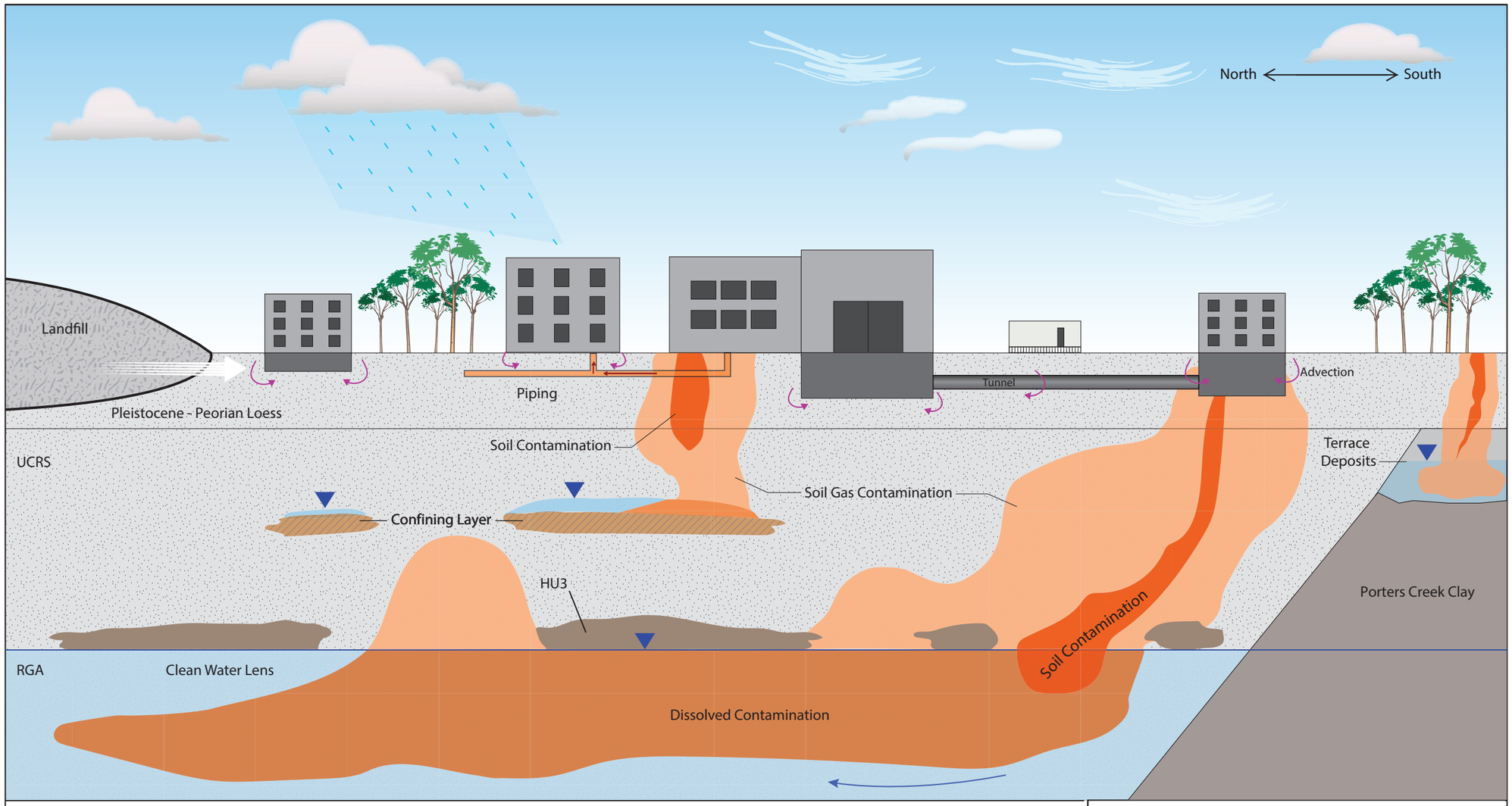

Adapted from DOE 2020a

Figure 4. Conceptual Site Model Schematic

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TCE is the most widespread PI analyte in the UCRS groundwater and is the PI analyte most frequently detected above its groundwater VISL. The second most commonly detected PI analyte is *cis*-1,2-DCE. Both TCE and *cis*-1,2-DCE are primarily present on the western side of the Paducah Site. VC is present in the high-concentration contours (i.e., 100+ µg/L) of the TCE plume near the C-400 and C-747/C-748-B buildings. The presence of *cis*-1,2-DCE and VC indicate reducing conditions and active TCE destruction through anaerobic dechlorination in these areas. Mercury and TCE also are found in and around the landfills (C-746-S&T and C-746-U) in the northern portion of the site.

Detections of the other PI analytes are not widespread or numerous enough to display obvious spatial distributions; however, chloroform has been detected in groundwater across a wide portion of the Paducah Site at low concentrations, which is consistent with widespread potable water leaks. As documented in the sitewide groundwater flow model (DOE 2017a), various sources of anthropogenic recharge (i.e., recharge that is caused or produced by human activity) are present in the plant area (Figure 5), including leaking underground water supply and fire protection lines, and leakage from cooling towers. The high-pressure fire water (HPFW) system and the cooling towers were chlorinated using chlorine gas through 2014 and were chlorinated using sodium hypochlorite tablets after 2014. The site water tower experienced overflow conditions during the winter months and as part of site maintenance events. The HPFW system was taken offline in November 2021. Both water systems are expected to leak water containing chloroform at concentrations greater than the groundwater VISL, 3.55 µg/L, making the water supply and wastewater piping leaks important and creating widespread sources of chloroform to soil gas and indoor air at the Paducah Site. Although there is variability and uncertainty in recharge rates across the site, anthropogenic recharge rates tended to be higher in 2014 than in 1995, which is consistent with the notion that more leaks would occur as the infrastructure ages. Quantifying historical leakage rates is imprecise; however, in 2016, leakage from the HPFW system was estimated to be 40 gal per minute based on the refill rate required to maintain a constant water level in the HPFW supply tower. Moreover, the locations of historical leaks are not well characterized, but it is likely that leaks in the piping system spread horizontally within the piping subbase gravel before migrating vertically to recharge the UCRS.

At the Paducah Site, fine-grained sediment (mostly silt and fine sand) of the UCRS comprises much of the vadose zone, which overlies the RGA. Although they are less common, sand and gravel layers are present in the UCRS. Typically, the UCRS is unsaturated for the first 35 ft bgs. Soil data have been collected during many projects at the Paducah Site since 1989. In historical data, most VOCs were detected near the C-748-B, C-400, C-720, and C-747 buildings, with a small cluster of detections in the northwest portion of the Paducah Site near the C-746-U Landfill. TCE was also detected south of the C-333 building.

As described above, TCE-contaminated groundwater and soil near and under PI buildings are potential sources of vapors for the VI pathway. Subsurface conditions near the PI buildings have been assessed to understand the potential vapor transport toward them. PI analyte concentrations in groundwater exceed EPA groundwater VISLs. Similarly, PI analytes were detected in post-remediation soil samples. Vapor concentrations associated with post-remediation TCE in groundwater and soil still have the potential to pose an unacceptable health risk to workers in PI buildings.

Vapor migration from subsurface groundwater and soil through the vadose zone is driven first by diffusion in response to PI analyte concentration gradients in the UCRS. Where PI analyte vapors have migrated into proximity of a building's foundation, the building may induce a pressure gradient (i.e., advection) that can draw soil vapor, including VOCs, into the building. Pressure gradients can be affected by a number of building systems such as heating, ventilation, and air conditioning systems, fume hoods, and exhaust fans. Once indoors, VOC vapors are mixed and diluted into indoor air. Utilities or tunnels that intercept contaminated groundwater or contaminated soil could also serve as atypical preferential pathways for VI. Deteriorated concrete in some building slabs, expansion joints, etc., could also provide pathways for vapor to migrate into the buildings.

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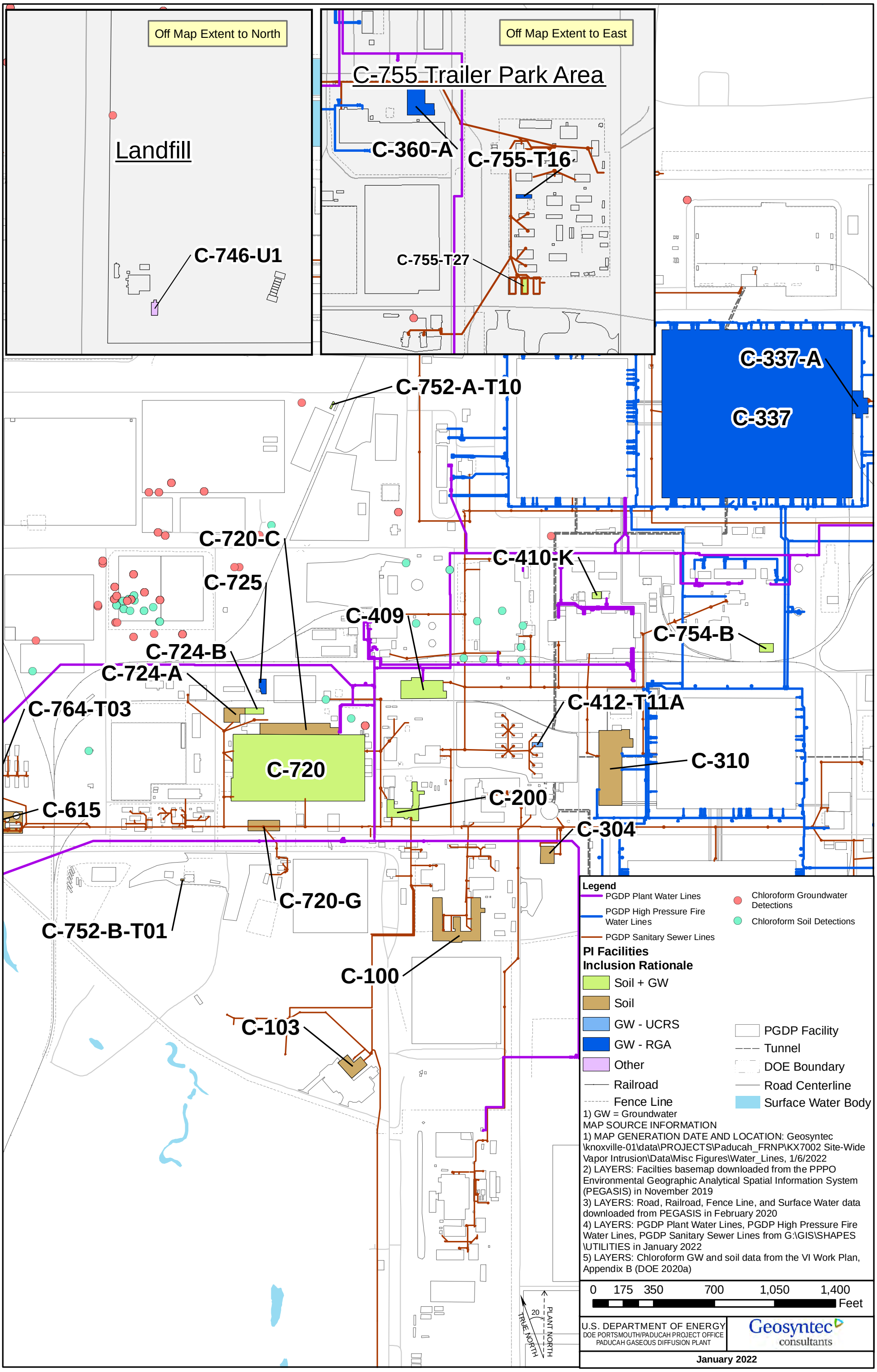

Figure 5. Plant Water, High Pressure Fire Water, and Sanitary Water Lines

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Current and reasonably foreseeable future land uses at and adjacent to the Paducah Site are industrial and waste management for areas located primarily inside the security fence; industrial and waste management or recreational for areas located outside the security fence; and residential, recreational, and industrial (e.g., Tennessee Valley Authority) for areas beyond the DOE property (DOE 2020b). TCE and other VOCs in soil and groundwater originate in an area where current and expected future land use is industrial. There are no current exposures to on-site groundwater by nonremediation workers or the general public because of existing on-site restrictions and controls [e.g., excavation/penetration permit program, Land Use Control Implementation Plan (DOE 2008)] (DOE 2020a). There is a potential for TCE vapors from subsurface sources and indoor sources to impact indoor air in the study area; therefore, both the remediation workers currently deactivating buildings in anticipation of eventual demolition and nonremediation workers working in the building may come in contact with these vapors.

VI pathways in the C-400 Cleaning Building, the location at the Paducah Site with the highest concentrations of TCE in soil and groundwater, were previously investigated with the results presented in Appendix D of the *Five-Year Review for Remedial Actions at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1289&D2/R1/A3/R1 (DOE 2018) and summarized in Section 4.5.6 of the VI Work Plan. The C-400 Cleaning Building VI study results show that the VI pathway for TCE is complete, and TCE concentrations exceeded the project action limit in indoor air at three locations. TCE concentrations measured in subslab vapor were above EPA's commercial subslab soil gas VISL at several locations, indicating that TCE concentrations in indoor air greater than the project action limit continue to be possible, particularly when building fans are off and doors are closed (i.e., fan off, closed door conditions); however, cumulative excess lifetime cancer risk, assuming chronic exposure by industrial workers, was less than 6.0E-06 at all individual locations and less than 2.0E-06 across all three scenarios, and cumulative hazards, assuming chronic exposure by industrial workers, was less than a hazard index of 1.0 at all individual locations, except at one location (hazard quotient = 1.4 to 1.6 under fan off, closed door conditions), and less than 1.0 across all three scenarios. Based on the presence of TCE in subslab vapor above the EPA subslab soil gas VISL, the study recommended that periodic air monitoring, worker access restriction (or both), and/or increased ventilation may be the appropriate steps to take if it is anticipated workers will spend substantial time in the building in the vicinity of the three locations where TCE concentrations exceeded the project action limit in indoor air, until the building is decommissioned or the source is remediated. The groundwater under the C-400 Cleaning Building contains the highest concentrations of TCE at the Paducah Site. The VOC concentrations in the C-400 Cleaning Building were shown throughout the study not to pose an unacceptable risk to workers. The C-400 Cleaning Building was undergoing deactivation at the time of the study and was occupied by workers who were engaged in deactivation activities and protected under DOE health and safety requirements.

EPA's VI Technical Guide states that a potential VI pathway should be considered complete when the following five key conditions are all present.

1. A subsurface source of vapor-forming chemicals exists.
2. There is a route for the vapors to migrate.
3. The building is susceptible to VI.
4. Vapors are present in the indoor environment.
5. People are in the indoor environment.

The building-specific VI CSMs describe the presence or absence of TCE sources immediately under and adjacent to PI buildings and the routes and mechanisms by which they may migrate to indoor air. Information collected to date indicate that key conditions 1, 2, 3, and 5 are present at PGDP facilities, regarding completeness of the VI pathway.

Indoor air sampling has been performed to evaluate key condition 4, and those results are discussed in this report.

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2. VAPOR INTRUSION STUDY APPROACH

This section describes the methods used to collect indoor air samples, crawlspace air samples, subslab vapor samples, and outdoor air samples and to gather other relevant information, such as differential pressure readings, to support the PI. Field activities were performed in accordance with the VI Work Plan and deviations from the work plan are described in Sections 2.1.2 and 2.2.2 of this report. Representative photographs taken during sample collection are included in Appendix A, and field forms are included in Appendix B.

2.1 SUBSLAB VAPOR SAMPLING FIELD METHODS

The following subsections describe subslab vapor sampling and deviations from the VI Work Plan.

2.1.1 Subslab Vapor Sampling

Mini Vapor Pin® subslab vapor monitoring probes were installed using a hammer drill with a ⅝-inch bit to drill through concrete to the top of the substrate underlying the slab from February 23, 2021, through February 26, 2021. After each hole was drilled, a Mini Vapor Pin® was installed by inserting the Mini Vapor Pin® into the drilled hole, placing the Mini Vapor Pin® installation tool over the barbed fitting at the top of the Mini Vapor Pin®, tapping the top of the installation tool with a hammer until the Mini Vapor Pin® was flush with the slab. The probes were performed by removing the barbed fitting and screwing a Mini Vapor Pin® secure cover onto the surface port.

Leak checks were performed prior to subslab sample collection at each location. After removing the Mini Vapor Pin® secure cover, screwing in the barbed fitting, and placing a piece of silicone tubing over the barbed fitting, each probe was subjected to a water dam check to ensure that the annular seal for the probe was not leaking. A circle of putty approximately 1 inch in diameter was pressed to the bottom edge of a 2-inch polyvinyl chloride (PVC) pipe coupling and the PVC coupling was placed around the probe, putty side down, then pushed against the concrete to form a seal between the putty and the slab. Water was then poured into the PVC coupling and observed for bubbling or dropping of water level that might indicate a leaky probe, and thus, not a secure seal. The water dam method is described in the *Standard Operating Procedure Leak Testing the VAPOR PIN® Sampling Device Via Water Dam* (Vapor Pin® 2021). All locations passed the water dam test.

After each probe passed a leak test, a 1-liter, individually certified SUMMA® canister was connected to a tee-fitting, with a ball valve on each side to facilitate the transition from purging to sampling. The sampling tee was connected to the probe using ¼-inch Nylaflow® tubing with a compression fitting. A lung box equipped with a Tedlar® bag was attached to the other end of the sampling tee using ¼-inch Nylaflow® tubing and compression fitting. Prior to sample collection at each location, a shut-in vacuum test was performed and then a vacuum box equipped with a 1-liter Tedlar® bag was used to purge three volumes of air, which were screened for total VOCs, oxygen, carbon dioxide, and methane using a photoionization detector and landfill gas meter.

Subslab vapor sampling was conducted from March 4, 2021, through March 9, 2021. For each grab sample, the 1-liter SUMMA® canister was opened and the canister vacuum was recorded at the start of sample collection. The vacuum gauge was observed during sample collection and the SUMMA® canister was closed when the vacuum gauge reached approximately -5 inches of mercury (inHg), except at locations C103VI-SS-3, C200-VI-SS-1, and C360AVI-SS-3 where low conductivity soil below the slab restricted

soil vapor flow. At these three locations, the final vacuum measurements were -9 inHg, -10 inHg, and -17 inHg, respectively.

2.1.2 Deviations from the VI Work Plan

Changed conditions for subslab sampling are shown in Table 4. Each of the conditions described was communicated to EPA and KDEP via e-mail at the time of sampling; the correspondence is included in Appendix C.

Table 4. Summary of Subslab Sampling Changed Conditions

Expected Condition	Changed Condition	Response
Three subslab locations were identified in the VI Work Plan in C-103.	During drilling at the planned subslab sample location at C-103 (the northwest location in Room 36), it was discovered to overlay a crawlspace rather than a foundation slab.	This location was sampled as a crawlspace air sample.
Subslab samples are intended to be "grab" or of a relatively short duration and should take typically between 10–20 minutes at most locations.	At locations where tight (i.e., low conductivity) soils were present under the slab, more time was needed to collect each sample. One subslab canister at C-360-A was terminated at over 4 hours even though it was not quite half full (-17 inHg indicated on the gauge).	This subslab sample was sent to the laboratory for analysis; however, it was noted during sampling that the sample may not be able to be analyzed due to the low volume collected. This deviation was communicated to the laboratory. The sample was analyzed without issue.
Mini Vapor Pins® would be installed in bare or tiled flooring.	Several Mini Vapor Pins® were installed in carpeted areas. Although the VI Work Plan stated the following, it is not possible to employ a water dam in carpeted areas. "A water dam will be placed around the probe to prevent air from entering the subslab environment along the annular space between the tubing and the slab, and a shut-in test of the sampling train will be performed prior to purging to verify that there are no leaks in the tubing or connections."	A non-VOC, nonporous putty was used in lieu of the water dam at carpeted locations and the shut-in test was performed as planned prior to purging to verify that there were no leaks in the tubing or connections.
Collection of subslab vapor from two locations in C-615.	While setting up the differential pressure meter in both Mini Vapor Pins® in C-615, water was observed in the tubing attached to the Mini Vapor Pins®.	Subslab sampling was not performed at the C-615 subslab locations because water should not be introduced to the interior of the Summa® canisters. Differential pressure was also not able to be collected from these locations due to the presence of water.
Two subslab samples were to be collected and analyzed from C-337-A.	One subslab sample from C-337-A (kitchen location) was received at the laboratory at 0 inHg differential, despite being shipped at a final vacuum of approximately -5 inHg. This suggests that the valve leaked in transit and air not associated with the sample may have been introduced into the canister after sampling was performed.	The data for this subslab sample was rejected during the data assessment process. Because there was another subslab sample collected from C-337-A, the data quality objectives for the VI project can be met. This location was not resampled.

2.2 INDOOR, CRAWLSPACE, AND OUTDOOR AIR FIELD METHODS

The following subsections describe indoor air sampling, crawlspace air sampling, outdoor air sampling, and deviations from the VI Work Plan.

2.2.1 Indoor, Crawlspace, and Outdoor Air Sampling

Crawlspace air samples were collected using 6-liter, individually certified SUMMA® canisters. The canisters were transported to their respective PI buildings and set up in the morning for sampling, in accordance with the VI Work Plan. Nylaflow® tubing (¼-inch) was connected to each canister using a compression fitting, with the other end of the tubing placed within the crawlspace. Crawlspace air sampling was conducted on February 27, 2021, March 4, 2021, and March 6, 2021. SUMMA® canisters were opened and the canister vacuums were recorded. For duplicate samples, two SUMMA® canisters were connected to a laboratory-supplied duplicate tee using compression fittings, and both canisters were opened simultaneously. During sample collection, the canister vacuum was observed to determine whether the flow regulator was functioning as expected and if it would last for the full 10-hour sampling period. After 10 hours, the SUMMA® canisters were closed and final canister vacuums were recorded.

The indoor and outdoor air samples were collected using 6-liter, individually certified SUMMA® canisters. The morning of sample collection, indoor and outdoor canisters were positioned so that the intake was in the breathing zone 3–5 ft above the ground. This was achieved by placing the canister on a surface in the breathing zone, attaching the canister with zip ties to a tripod set to breathing zone height, or setting the canister on the ground and connecting a piece of ¼-inch Nylaflow® tubing to the canister using a compression fitting on one end and affixing the other end to a tripod set to breathing zone height. In addition to being placed within the breathing zone, outdoor air canisters were placed on the upwind side of the PI building based on wind direction at the time of setup.

Indoor and outdoor air samples were collected on February 24, 2021, and from March 2, 2021, through March 8, 2021. At the start of each sampling event, SUMMA® canisters were placed and opened at indoor and outdoor air sampling locations, and the canister vacuums were recorded. For duplicate samples, two SUMMA® canisters were connected to a laboratory-supplied duplicate tee using compression fittings, and both canisters were opened simultaneously. During sample collection, the canister vacuum was observed for all samples to determine whether the flow regulator was functioning as expected and if it would last for the full 10-hour sampling period. After 10 hours, the SUMMA® canisters were closed and final canister vacuums were recorded.

For all indoor air sample locations, mercury screening was also conducted at breathing zone height using a Jerome® J505 Mercury Vapor Analyzer.

2.2.2 Deviations from the VI Work Plan

The submitted changed condition for indoor air sampling, crawlspace air sampling, and outdoor air sampling is shown in Table 5. The condition described was also communicated to EPA and KDEP via e-mail at the time of sampling; the correspondence is included in Appendix C.

Table 5. Summary of Indoor, Crawlspace, and Outdoor Air Sampling Changed Conditions

Expected Condition	Changed Condition	Response
Original sampling location indicated as approximately the center of C-754-B.	Original sampling location was not accessible for placement of sampling equipment.	The sampling location was moved to the southeast quadrant of C-754-B.

2.3 POST-SAMPLING EVENT ACTIVITIES

After being closed and collected, SUMMA® canister labels were performed and the canisters were then released for radiological scanning and subsequent shipment to the laboratory under chain-of-custody control for analysis by EPA Method TO-15. At subslab sample locations, tubing was removed, the barbed fitting was removed, and a Mini Vapor Pin® secure cover was screwed onto the Mini Vapor Pin® surface port. For indoor and outdoor air locations where a tripod stand was used, the stand was disassembled and removed at the time of SUMMA® canister collection. All nonreusable materials (e.g., tubing, compression fittings) were appropriately disposed.

3. RESULTS

This section presents laboratory analytical results from samples collected during PI fieldwork, field measurements, and relevant weather data.

3.1 ANALYTICAL RESULTS

Analytical results are presented in Table 6, and mercury screening results are presented in Table 7. Results for chloroform and TCE are shown on the PI building maps in Appendix D. Sumps, drains, and other features relevant to the study and identified during the walkdowns are also noted on the building maps included in Appendix D. Laboratory analytical results are included in Appendix E. The results by medium are summarized in the following subsections. Chloroform was the most commonly detected compound at 61 out of 113 samples and 19 out of 23 PI buildings, and it was detected in all four media (subslab vapor, indoor air, crawlspace air, and outdoor air). TCE was detected in 27 out of 113 samples and 7 out of 10 PI buildings where both subslab vapor and indoor air samples were collected. Chloroform and TCE were the only PI analytes detected at concentrations above their respective VISLs and are chemicals of potential concern. 1,1,1-TCA was detected in three subslab samples within two PI buildings; *trans*-1,2-DCE was detected in four indoor air samples within two PI buildings; and VC was detected in two crawlspace air samples within two PI buildings—all at concentrations below their respective VISLs. *cis*-1,2-DCE was not detected in any sample. Mercury was detected at 12 out of 53 locations where screening was conducted and all detections were below the indoor air VISL.

3.1.1 Indoor Air and Crawlspace Air Analytical Results

Forty-three indoor air samples were collected from 13 PI buildings, and 8 crawlspace air samples were collected from 7 PI buildings, as shown in Table 6. TCE, *trans*-1,2-DCE, VC, and chloroform were detected in indoor air and/or crawlspace air samples.

- TCE was detected in nine indoor air samples from four PI buildings—C-100, C-200, C-310, and C-720. Detected concentrations of TCE in indoor air ranged from 0.23 micrograms per cubic meter ($\mu g/m^3$) in C-720 to 0.96 $\mu g/m^3$ in C-200. TCE was not detected in any crawlspace air sample.

- *trans*-1,2-DCE was detected in four indoor air samples from two PI buildings. Detected concentrations of *trans*-1,2-DCE in indoor air ranged from 0.2 $\mu g/m^3$ in C-720 to 0.77 $\mu g/m^3$ in C-720-G. *trans*-1,2-DCE was not detected in any crawlspace air samples.

- VC was detected in two crawlspace air samples from two PI buildings. Detected concentrations of VC in crawlspace air ranged from 0.21 $\mu g/m^3$ in C-764-T03 to 0.9 $\mu g/m^3$ in C-752-B-T01. VC was not detected in any indoor air samples.

- Chloroform was detected in 38 indoor air samples from 12 PI buildings—C-100, C-103, C-200, C-304, C-310, C-337, C-409, C-615, C-720-G, C-720, C-724, C-746-UI—and eight crawlspace air samples from seven PI buildings—C-103, C-412-T11A, C-752-A-T01, C-752-B-T01, C-755-T16, C-755-T27, and C-764-T03. Detected concentrations of chloroform in indoor air ranged from 0.19 $\mu g/m^3$ in C-720 to 25 $\mu g/m^3$ in C-200. Detected concentrations of chloroform in crawlspace air ranged from 1.3 $\mu g/m^3$ in C-412-T11A to 3 $\mu g/m^3$ in C-764-T03.

Table 6. Analytical Results

				1,1,1-TCA	Chloroform	*cis*-1,2-DCE	*trans*-1,2-DCE	TCE	VC
VISL [a]		*Target Indoor Air Concentration*		21,900 µg/m^3	0.533 µg/m^3	3,500 µg/m^3[b]	3,500 µg/m^3[b]	2.99 µg/m^3	2.79 µg/m^3
		Target Subslab Soil Gas Concentration		730,000 µg/m^3	17.8 µg/m^3	--	--	99.7 µg/m^3	92.9 µg/m^3
Building	**Medium**	**Sample ID**[c]	**Date**	**Results**[d] **(µg/m^3)**					
C-100	Outdoor Air	C100VI-OA-1	3/2/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 U
	Indoor Air	C100VI-IA-1	3/2/2021	0.16 U	0.72 J	0.24 U	0.2 U	0.19 U	0.18 U
		C100VI-IA-2	3/2/2021	0.16 U	0.76 J	0.24 U	0.2 U	0.19 U	0.18 U
		C100VI-IA-3	3/2/2021	0.16 U	1.2	0.24 U	0.2 U	0.27 J	0.18 U
		C100VI-IA-4	3/2/2021	0.16 U	0.69 J	0.24 U	0.2 U	0.19 U	0.18 U
	Subslab	C-100VI-SS-1	3/4/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C-100VI-SS-2	3/4/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C100VI-SS-3	3/4/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C100VI-SS-4	3/4/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
C-103	Crawlspace	C103VI-CS-2	3/9/2021	0.16 U	2	0.24 U	0.2 U	0.17 U	0.18 U
	Outdoor Air	C103VI-OA-1	3/2/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 U
	Indoor Air	C103VI-IA-1	3/2/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 U
		C103VI-IA-2	3/2/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 U
		C103VI-IA-3	3/2/2021	0.16 U	0.23 J	0.24 U	0.2 U	0.19 U	0.18 U
	Subslab	C103VI-SS-1	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C103VI-SS-3	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
C-200	Outdoor Air	C200VI-OA-1	3/4/2021	0.16 U	0.2 J	0.24 U	0.2 U	0.17 U	0.18 U
	Indoor Air	C200VI-IA-1	3/4/2021	0.16 U	25	0.24 U	0.2 U	0.17 U	0.18 U
		C200VI-IA-2	3/4/2021	0.16 U	3	0.24 U	0.2 U	0.17 U	0.18 U
		C200VI-IA-3	3/4/2021	0.16 U	8.1	0.24 U	0.2 U	0.17 U	0.18 U
		C200VI-IA-3D	3/4/2021	0.16 U	7.5	0.24 U	0.2 U	0.96 J	0.18 U
		C200VI-IA-4	3/4/2021	0.16 U	12	0.24 U	0.2 U	0.17 U	0.18 U
	Subslab	C200VI-SS-1	3/6/2021	1.6 U	4.5 J	2.4 U	2 U	2.7 J	1.8 U
		C200VI-SS-2	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C200VI-SS-2D	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C200VI-SS-3	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.9 J	1.8 U
		C200VI-SS-4	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
C-304	Outdoor Air	C304VI-OA-1	3/2/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 U
	Indoor Air	C304VI-IA-1	3/2/2021	0.16 U	1.2	0.24 U	0.2 U	0.19 U	0.18 U
		C304VI-IA-2	3/2/2021	0.16 U	0.97 J	0.24 U	0.2 U	0.19 U	0.18 U
		C304VI-IA-3	3/2/2021	0.16 U	0.76 J	0.24 U	0.2 U	0.19 U	0.18 U
	Subslab	C304VI-SS-1	3/5/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C304VI-SS-2	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C304VI-SS-3	3/5/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
C-310	Outdoor Air	C310VI-OA-1	3/3/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 UX
	Indoor Air	C310VI-IA-1	3/3/2021	0.16 U	0.33 J	0.24 U	0.2 U	0.19 U	0.18 UX
		C310VI-IA-2	3/3/2021	0.16 U	1.3	0.24 U	0.2 U	0.19 U	0.18 UX
		C310VI-IA-3	3/3/2021	0.16 U	1.4	0.24 U	0.2 U	0.19 U	0.18 UX
		C310VI-IA-4	3/4/2021	0.16 U	1.6	0.24 U	0.2 U	0.28 J	0.18 U
	Subslab	C310VI-SS-1	3/5/2021	1.6 U	1.9 U	2.4 U	2 U	46	1.8 U
		C310VI-SS-2	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	130	1.8 U
		C310VI-SS-3	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	750	1.8 U
		C310VI-SS-4	3/8/2021	1.6 U	44	2.4 U	2 U	97	1.8 U
C-337-A	Subslab	C337AVI-SS-2	3/5/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
C-337	Outdoor Air	C337VI-OA-1	3/3/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 UX
	Indoor Air	C337VI-IA-1	3/3/2021	0.16 U	0.42 J	0.24 U	0.2 U	0.19 U	0.18 UX
	Subslab	C337VI-SS-1	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C337VI-SS-2	3/6/2021	1.6 U	850	2.4 U	2 U	2.2 J	1.8 U
		C337VI-SS-3	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C337VI-SS-4	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
C-360-A	Subslab	C360AVI-SS-1	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C360AVI-SS-2	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C360AVI-SS-3	3/5/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
C-409	Outdoor Air	C409VI-OA-1R	3/8/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.17 U	0.18 U
	Indoor Air	C409VI-IA-1	3/3/2021	0.16 U	0.59 J	0.24 U	0.2 U	0.19 U	0.18 UX
		C409VI-IA-2	3/3/2021	0.16 U	0.55 J	0.24 U	0.2 U	0.19 U	0.18 UX
		C409VI-IA-3	3/3/2021	0.16 U	1.2	0.24 U	0.2 U	0.19 U	0.18 UX
	Subslab	C409VI-SS-1	3/5/2021	1.6 U	56	2.4 U	2 U	2.3 J	1.8 U
		C409VI-SS-2	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C409VI-SS-3	3/8/2021	1.6 U	620	2.4 U	2 U	1.7 U	1.8 U
C-410-K	Subslab	C410KVI-SS-1	3/6/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
C-412-T11A	Crawlspace	C412T11AVI-CS-1	3/4/2021	0.16 U	1.3	0.24 U	0.2 U	0.17 U	0.18 U
		C412T11AVI-CS-1D	3/4/2021	0.16 U	1.4	0.24 U	0.2 U	0.17 U	0.18 U
C-615	Outdoor Air	C615VI-OA-1	3/5/2021	0.16 U	0.8 J	0.24 U	0.2 U	0.17 U	0.18 U
	Indoor Air	C615VI-IA-1	3/5/2021	0.16 U	0.36 J	0.24 U	0.2 U	0.17 U	0.18 U
		C615VI-IA-2	3/5/2021	0.16 U	0.37 J	0.24 U	0.2 U	0.17 U	0.18 U
		C615VI-IA-2D	3/5/2021	0.16 U	0.35 J	0.24 U	0.2 U	0.17 U	0.18 U

Table 6. Analytical Results (Continued)

				1,1,1-TCA	Chloroform	*cis* -1,2-DCE	*trans* -1,2-DCE	TCE	VC
VISL [a]		*Target Indoor Air Concentration*		21,900 µg/m^3	0.533 µg/m^3	3,500 µg/m^3 [b]	3,500 µg/m^3 [b]	2.99 µg/m^3	2.79 µg/m^3
		Target Sub Slab Soil Gas Concentration		730,000 µg/m^3	17.8 µg/m^3	--	--	99.7 µg/m^3	92.9 µg/m^3
Building	**Medium**	**Sample ID** [c]	**Date**	**Results** [d] **(µg/m^3)**					
C-720-G	Outdoor Air	C720GVI-OA-1	3/2/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 U
	Indoor Air	C720GVI-IA-1	3/2/2021	0.16 U	0.24 J	0.24 U	0.3 J	0.19 U	0.18 U
		C720GVI-IA-2	3/2/2021	0.16 U	0.23 J	0.24 U	0.2 U	0.19 U	0.18 U
		C720GVI-IA-3	3/2/2021	0.16 U	1.1	0.24 U	0.51 J	0.19 U	0.18 U
		C720GVI-IA-4	3/2/2021	0.16 U	0.36 J	0.24 U	0.77 J	0.19 U	0.18 U
	Subslab	C720GVI-SS-1	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C720GVI-SS-2	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C720GVI-SS-2D	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C720GVI-SS-3	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C720GVI-SS-4	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
C-720	Outdoor Air	C720VI-OA-1	3/4/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.17 U	0.18 U
	Indoor Air	C720VI-IA-1	3/6/2021	0.16 U	1.4	0.24 U	0.2 U	0.42 J	0.18 U
		C720VI-IA-2	3/4/2021	0.16 U	0.87 J	0.24 U	0.2 J	0.59 J	0.18 U
		C720VI-IA-3	3/4/2021	0.16 U	1.5	0.24 U	0.2 U	0.33 J	0.18 U
		C720VI-IA-4	3/4/2021	0.16 U	0.57 J	0.24 U	0.2 U	0.32 J	0.18 U
		C720VI-IA-5	3/4/2021	0.16 U	2.5	0.24 U	0.2 U	0.23 J	0.18 U
		C720VI-IA-6	3/4/2021	0.16 U	0.64 J	0.24 U	0.2 U	0.47 J	0.18 U
		C720VI-IA-7	3/4/2021	0.16 U	0.19 J	0.24 U	0.2 U	0.17 U	0.18 U
	Subslab	C720VI-SS-1	3/8/2021	1.6 U	12	2.4 U	2 U	2.2 J	1.8 U
		C720VI-SS-2	3/5/2021	2 J	1.9 U	2.4 U	2 U	21	1.8 U
		C720VI-SS-3	3/8/2021	1.6 U	9.1 J	2.4 U	2 U	63	1.8 U
		C720VI-SS-4	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	270	1.8 U
		C720VI-SS-5	3/5/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C720VI-SS-6	3/8/2021	1.6 U	1.9 J	2.4 U	2 U	16	1.8 U
		C720VI-SS-7	3/8/2021	2.6 J	1.9 U	2.4 U	2 U	6.8 J	1.8 U
C-724	Outdoor Air	C724VI-OA-1	3/3/2021	0.16 U	0.61 J	0.24 U	0.2 U	0.19 U	0.18 UX
		C724VI-OA-1D	3/3/2021	0.16 U	0.63 J	0.24 U	0.2 U	0.19 U	0.18 UX
	Indoor Air	C724VI-IA-1	3/3/2021	0.16 U	0.2 J	0.24 U	0.2 U	0.19 U	0.18 UX
		C724VI-IA-2	3/3/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 UX
		C724VI-IA-3	3/3/2021	0.16 U	0.4 J	0.24 U	0.2 U	0.19 U	0.18 UX
		C724VI-IA-4	3/3/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 UX
	Subslab	C724VI-SS-1	3/8/2021	1.6 U	6.1 J	2.4 U	2 U	7.6 J	1.8 U
		C724VI-SS-2	3/8/2021	2.1 J	23	2.4 U	2 U	1.7 U	1.8 U
		C724VI-SS-3	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	4.6 J	1.8 U
		C724VI-SS-4	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	38	1.8 U
C-725	Subslab	C725VI-SS-1	3/8/2021	1.6 U	1.9 U	2.4 U	2 U	1.7 U	1.8 U
		C725VI-SS-2	3/8/2021	1.6 U	38	2.4 U	2 U	3.4 J	1.8 U
C-746-U1	Outdoor Air	C746U1VI-OA-1	2/24/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 U
	Indoor Air	C746U1VI-IA-1	2/24/2021	0.16 U	0.71 J	0.24 U	0.2 U	0.19 U	0.18 U
C-752-A-T01	Crawlspace	C752AT10VI-CS-1	2/27/2021	0.16 U	1.9	0.24 U	0.2 U	0.19 U	0.18 U
C-752-B-T01	Crawlspace	C752BT01VI-CS-1	3/6/2021	0.16 U	1.9	0.24 U	0.2 U	0.17 U	0.9 J
C-754-B	Outdoor Air	C754BVI-OA-1	3/3/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 UX
	Indoor Air	C754BVI-IA-1	3/3/2021	0.16 U	0.19 U	0.24 U	0.2 U	0.19 U	0.18 UX
C-755-T16	Crawlspace	C755T16VI-CS-1	2/27/2021	0.16 U	2.2	0.24 U	0.2 U	0.19 U	0.18 U
C-755-T27	Crawlspace	C755T27VI-CS-1	2/27/2021	0.16 U	2.3	0.24 U	0.2 U	0.19 U	0.18 U
C-764-T03	Crawlspace	C764T03VI-CS-1	2/27/2021	0.16 U	3	0.24 U	0.2 U	0.19 U	0.21 J

Yellow shaded values exceed indoor air target concentrations.

Orange shaded values exceed sub slab soil gas target concentrations.

[a] The EPA VISLs are the default commercial values for CR = 1E-06 or HQ = 1 for all chemicals except *cis* - and *trans* -1,2-DCE. The VISLs for *cis* - and *trans* -1,2-DCE are provided by EPA, and were derived based on the Agency for Toxic Substances and Disease Registry Inhalation Minimal Risk Level of 0.2 ppm (0.8 mg/m^3).

[b] For all indoor air, outdoor air, and crawlspace chloroform results, the reporting limit is greater than the project action limit.

[c] "D" as the last character in the Sample ID indicates the sample is a field duplicate of the corresponding Sample ID.

[d] No VISL value available; provisional value provided by EPA as documented in Appendix E (E.9) of the risk methods document (DOE 2021). Value for *cis* -1,2-DCE uses *trans* -1,2-DCE value as surrogate.

Qualifiers:

U = compound analyzed for but not detected at or below the lowest concentration reported (method detection limit)

J = estimated value

X = see comments for explanation (see Appendix E)

Table 7. Mercury Vapor Field Screening Results

PI Building	Sample ID/Location	Date	Mercury Field Screening Result (µg/m^3)
Target Mercury Indoor Air Concentration = 1.31 µg/m^3*			
C-100	C100VI-IA-1	3/2/2021	0.04
	C100VI-IA-2	3/2/2021	0.01
	C100VI-IA-3	3/2/2021	0.00
	C100VI-IA-4	3/2/2021	0.00
C-103	C103VI-IA-1	3/2/2021	0.02
	C103VI-IA-2	3/2/2021	0.00
	C103VI-IA-3	3/2/2021	0.01
C-200	C200VI-IA-1	3/4/2021	0.00
	C200VI-IA-2	3/4/2021	0.00
	C200VI-IA-3	3/4/2021	0.00
	C200VI-IA-4	3/4/2021	0.00
C-304	C304VI-IA-1	3/2/2021	0.00
	C304VI-IA-2	3/2/2021	0.00
	C304VI-IA-3	3/2/2021	0.00
C-310	C310VI-IA-1	3/3/2021	0.00
	C310VI-IA-2	3/3/2021	0.00
	C310VI-IA-3	3/3/2021	0.00
	C310VI-IA-4	3/4/2021	0.00
C-337	C337VI-IA-1	3/3/2021	0.00
	C337VI-SS-4	3/9/2021	0.00
C-337-A	C337AVI-SS-1	3/9/2021	0.00
C-360-A	C360AVI-SS-2	3/9/2021	0.00
	C360AVI-SS-3	3/9/2021	0.00
C-409	C409VI-IA-1	3/3/2021	0.00
	C409VI-IA-2	3/3/2021	0.00
	C409VI-IA-3	3/3/2021	0.01
C-410-K	C410KVI-SS-1	3/9/2021	0.00
C-412-T11A	C412T11AVI-CS-1	3/9/2021	0.00
C-615	C615VI-IA-1	3/5/2021	0.07
	C615VI-IA-2	3/5/2021	0.00
C-720	C720VI-IA-1	3/6/2021	0.00
	C720VI-IA-2	3/4/2021	0.00
	C720VI-IA-3	3/4/2021	0.04
	C720VI-IA-4	3/4/2021	0.00
	C720VI-IA-5	3/4/2021	0.00
	C720VI-IA-6	3/4/2021	0.01
	C720VI-IA-7	3/4/2021	0.00
C-720-G	C720GVI-IA-1	3/2/2021	0.05
	C720GVI-IA-2	3/2/2021	0.02
	C720GVI-IA-3	3/2/2021	0.00
	C720GVI-IA-4	3/2/2021	0.01

Table 7. Mercury Vapor Field Screening Results (Continued)

PI Building	Sample ID/Location	Date	Mercury Field Screening Result
C-724	C724VI-IA-1	3/3/2021	0.00
	C724VI-IA-2	3/3/2021	0.02
	C724VI-IA-3	3/3/2021	0.00
	C724VI-IA-4	3/3/2021	0.00
C-725	C725VI-SS-2	3/9/2021	0.00
C-746-U1	C746U1VI-IA-1	2/24/2021	0.00
C-752-A-T10	C752AT10VI-CS-1	3/9/2021	0.00
C-752-B-T01	C752BT01VI-CS-1	3/9/2021	0.00
C-754-B	C754BVI-IA-1	3/3/2021	0.00
C-755-T16	C755T16VI-CS-1	3/9/2021	0.00
C-755-T27	C755T27VI-CS-1	3/9/2021	0.00
C-764-T3	C764T03VI-CS-1	3/9/2021	0.00

*EPA VISL default commercial value for cancer risk = 1E-06 and hazard quotient = 1.

- Mercury screening was conducted at 53 locations in 23 PI buildings and was detected in indoor air at 12 locations in 7 PI buildings—C-100, C-103, C-409, C-615, C-720, C-720-G, and C-724. Concentrations ranged from 0 $\mu g/m^3$ to 0.07 $\mu g/m^3$.

3.1.2 Subslab Vapor Analytical Results

Forty-eight subslab vapor samples were collected from 14 PI buildings, as shown in Table 6. TCE, 1,1,1-TCA, and chloroform were detected in subslab vapor samples.

- TCE was detected in 18 subslab vapor samples from 7 PI buildings—C-200, C-310, C-337, C-409, C-720, C-724, and C-725—at concentrations ranging from 2.2 $\mu g/m^3$ in C-337 and C-720 to 750 $\mu g/m^3$ in C-310.

- Chloroform was detected in 11 subslab vapor samples from 7 PI buildings—C-200, C-310, C-337, C-409, C-720, C-724, and C-725—at concentrations ranging from 1.9 $\mu g/m^3$ in C-720 to 850 $\mu g/m^3$ in C-337.

- 1,1,1-TCA was detected in three subslab vapor samples from two PI buildings—C-720 and C-724—at concentrations ranging from 2 $\mu g/m^3$ to 2.6 $\mu g/m^3$.

3.1.3 Outdoor Air Analytical Results

Fourteen outdoor air samples were collected outside of 13 PI buildings, as shown in Table 6. PI analytes were not detected in any outdoor air samples, with the exception of chloroform which was detected at concentrations of 0.2 $\mu g/m^3$, 0.8 $\mu g/m^3$, and 0.63 $\mu g/m^3$ outside of C-200, C-615, and C-724, respectively.

3.2 OTHER DATA

Field crews measured and recorded the differential pressure between subslab vapor and indoor air in each PI building where indoor air samples were collected and a subslab pin was installed.

3.2.1 Pressure Monitoring Data

Differential pressure was recorded at 5-second intervals during the 10-hour indoor air sampling events using data-logging field micromanometers.[4] These data were collected to assist with interpreting subslab vapor and indoor air analytical data. The results for each PI building where differential pressure was recorded are presented in Table 8.

Table 8. Pressure Monitoring Summary

PI Building	Date	Sample ID/ Location	Location Description	Average Differential Pressure (Pa)	Indoor Air with Respect to Subslab Vapor
C-100	3/5/2021	C100VI-SS-3	Room 104	8.32	Overpressurized
C-103	3/6/2021	C103VI-SS-3	Mechanical Room	-1.18	Underpressurized
C-200	3/4/2021	C200VI-SS-2	East Hallway by Break Room	-0.19	Slightly Underpressurized
C-304	3/5/2021	C304VI-SS-2	Room 108	-0.61	Slightly Underpressurized
C-310	3/3/2021	C310VI-SS-1	Computer Room	-2.58	Underpressurized
C-337	3/3/2021	C337VI-SS-2	Basement	-0.07	Slightly Underpressurized
C-409	3/3/2021	C409VI-SS-1	Control Room	-0.02	Slightly Underpressurized
C-720	3/4/2021	C720VI-SS-3	Training Area/Breaker Room	-0.20	Slightly Underpressurized
C-720-G	3/8/2021	C720GVI-SS-2	South Bay Door	-0.82	Underpressurized
C-724	3/3/2021	C724VI-SS-3	NE corner by door	-1.70	Underpressurized

Temporal trends in differential pressure data varied across the PI buildings. Pressure monitoring time series graphs that represent data during the time of sampling are presented in Appendix F.

- At C-720-G, C-409, C-337, and C-200, fluctuation in differential pressure between the subslab and indoor air throughout the day was centered around 0 Pa.
- At C-304 and C-103, indoor air was measured at a slightly lower pressure than subslab vapor (indoor air was slightly underpressurized) throughout the day.
- At C-100, indoor air was overpressurized throughout the day, with a slightly lower positive pressure between the hours of 0900 and 1500.
- At C-310, indoor air was overpressurized at the start of the day and transitioned to being underpressurized around mid-morning.

[4] Differential pressure for C-100, C-103, C-304, and C-720-G were collected on a different day from the collection of the indoor air samples, when weather conditions were similar. While it is preferable to collect differential pressure data while indoor air samples are being collected, the pressure results for these PI buildings are immaterial to the pathway analysis because the PI analytes were not detected in subslab soil gas in these PI buildings; therefore, there is not a subsurface source for potential VI and no additional field actions are recommended. Additionally, the weather conditions for the dates of the recollection of differential pressure were similar to the date of the indoor air sample collection. Because each building has a unique pressure signature based on its main operating system, it would be expected that the pressure data collected at the later date would inform typical building conditions relevant to indoor air data evaluation.

- At C-724, differential pressure between subslab and indoor air was net neutral (fluctuation in pressure centered around 0 Pa) at the start of the day and transitioned to being underpressurized around 0900 hours.

- At C-720, indoor air was neutral to slightly overpressurized in the morning and transitioned to being underpressurized around mid-day; the indoor air transitioned back to neutral pressure in the evening.

3.2.2 Weather Data

Throughout the sample collection period, weather data (e.g., temperature, barometric pressure, wind direction, wind speed) were recorded at an on-site weather station. Weather summary data are presented in Appendix G. Outdoor temperature at the weather station ranged from 28–79°F throughout the sampling event, with an average temperature of 50°F. Barometric pressure ranged from approximately 28–31 inHg. Conditions were generally calm, with sustained wind speeds from 0–4 miles per hour (mph) and some gusts to 11 mph. Prevailing wind is generally from the southwest; however, there was some variability noted during sample collection (DOE 2017b).

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4. DISCUSSION

This section includes an evaluation of VI pathway completeness for each PI building. The evaluation includes the comparison of measured concentrations to regulatory screening levels, comparison of PI analyte concentrations between sampled media, a review of study decision rules, and a risk evaluation.

4.1 PROJECT ACTION LEVEL COMPARISON

In this section, laboratory analytical results are compared to project action levels (i.e., VISLs; see Table 1). For each PI analyte there is an indoor air VISL that is used to compare sample results from indoor air samples, crawlspace air samples, and outdoor air samples. Each PI analyte also has a soil gas VISL used to compare results from subslab vapor samples.

4.1.1 Indoor, Crawlspace, and Outdoor Air Samples

PI analytes TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, 1,1,1-TCA, and VC were not detected above screening levels in any indoor air sample or crawlspace air sample. Chloroform was detected above its indoor air screening level of 0.533 µg/m^3 in either indoor air samples or crawlspace air samples in 15 of the 19 PI buildings where indoor air samples or crawlspace air samples were collected, as shown in Table 6. Mercury was not detected above the screening level of 1.31 µg/m^3 at any location where field screening of indoor air was conducted, as shown in Table 7. Chloroform concentrations exceeded the indoor air VISL of 0.533 µg/m^3 in the outdoor air samples associated with C-615 and C-724.

4.1.2 Subslab Samples

PI analytes *cis*-1,2-DCE, *trans*-1,2-DCE, 1,1,1-TCA, and VC were not detected above screening levels in any subslab vapor sample.

TCE exceeded its soil gas VISL of 99.7 µg/m^3 at the following locations:

- Two locations in C-310—130 µg/m^3 at C310VI-SS-2 near the traps in the southeast corner of the building and 750 µg/m^3 at C310VI-SS-3 near the traps and emergency diesel generator in the southwest corner of the building—as shown on Figure 6; and

- One location in C-720—270 µg/m^3 at C720VI-SS-4 in the old machine shop on the eastern side of the building—as shown on Figure 7.

Chloroform exceeded its soil gas VISL of 17.8 µg/m^3 at the following locations:

- One location in C-310—44 µg/m^3 at C310VI-SS-4 near the center of the basement;

- One location in C-337—850 µg/m^3 at C337VI-SS-2 near the sump in the southeast corner of the basement;

- Two locations in C-409—56 µg/m^3 at C409VI-SS-1 in the control room on the north end of the building and 620 µg/m^3 at C409VI-SS-3 located to the east of the ovens;

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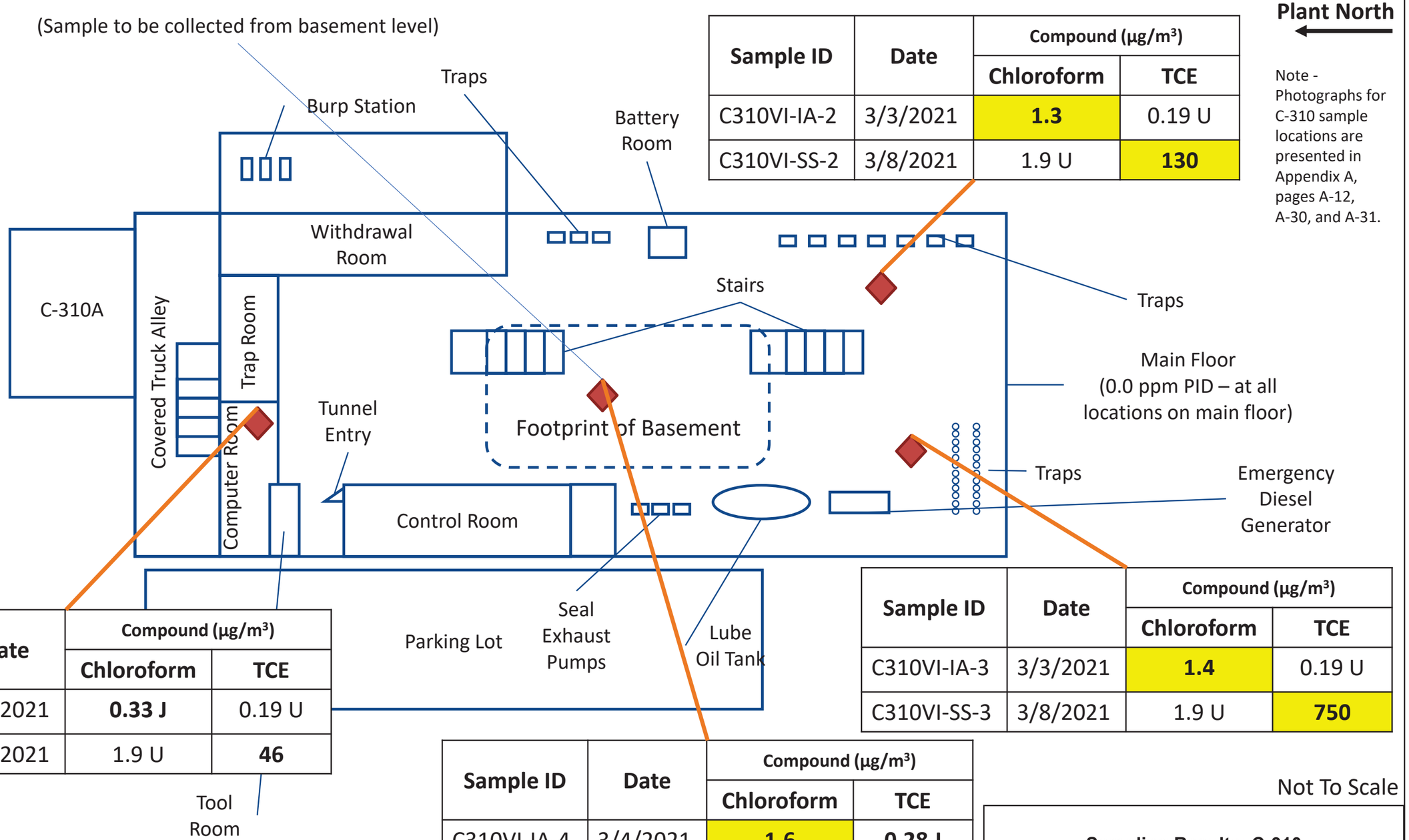
Source: Soil



Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C310VI-IA-2	3/3/2021	**1.3**	0.19 U
C310VI-SS-2	3/8/2021	1.9 U	**130**

Plant North

Note - Photographs for C-310 sample locations are presented in Appendix A, pages A-12, A-30, and A-31.

Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C310VI-IA-1	3/3/2021	**0.33 J**	0.19 U
C310VI-SS-1	3/5/2021	1.9 U	**46**

Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C310VI-IA-3	3/3/2021	**1.4**	0.19 U
C310VI-SS-3	3/8/2021	1.9 U	**750**

Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C310VI-IA-4	3/4/2021	**1.6**	**0.28 J**
C310VI-SS-4	3/8/2021	**44**	**97**

Not To Scale

Legend

◆ Paired Sub-slab/Indoor Air Sampling Location (approximate)

Notes

Facility Size: 62,863 ft²

Basement Size: 2,100 ft²

*All dimensions and locations are approximate unless otherwise noted.
*Detections are bolded and results greater than their VISLs are highlighted in yellow.
*Only chloroform and TCE results shown. There were no exceedances of VISLs for the other PI Analytes.

Sampling Results: C-310
Paducah Gaseous Diffusion Plant
McCracken County, Kentucky

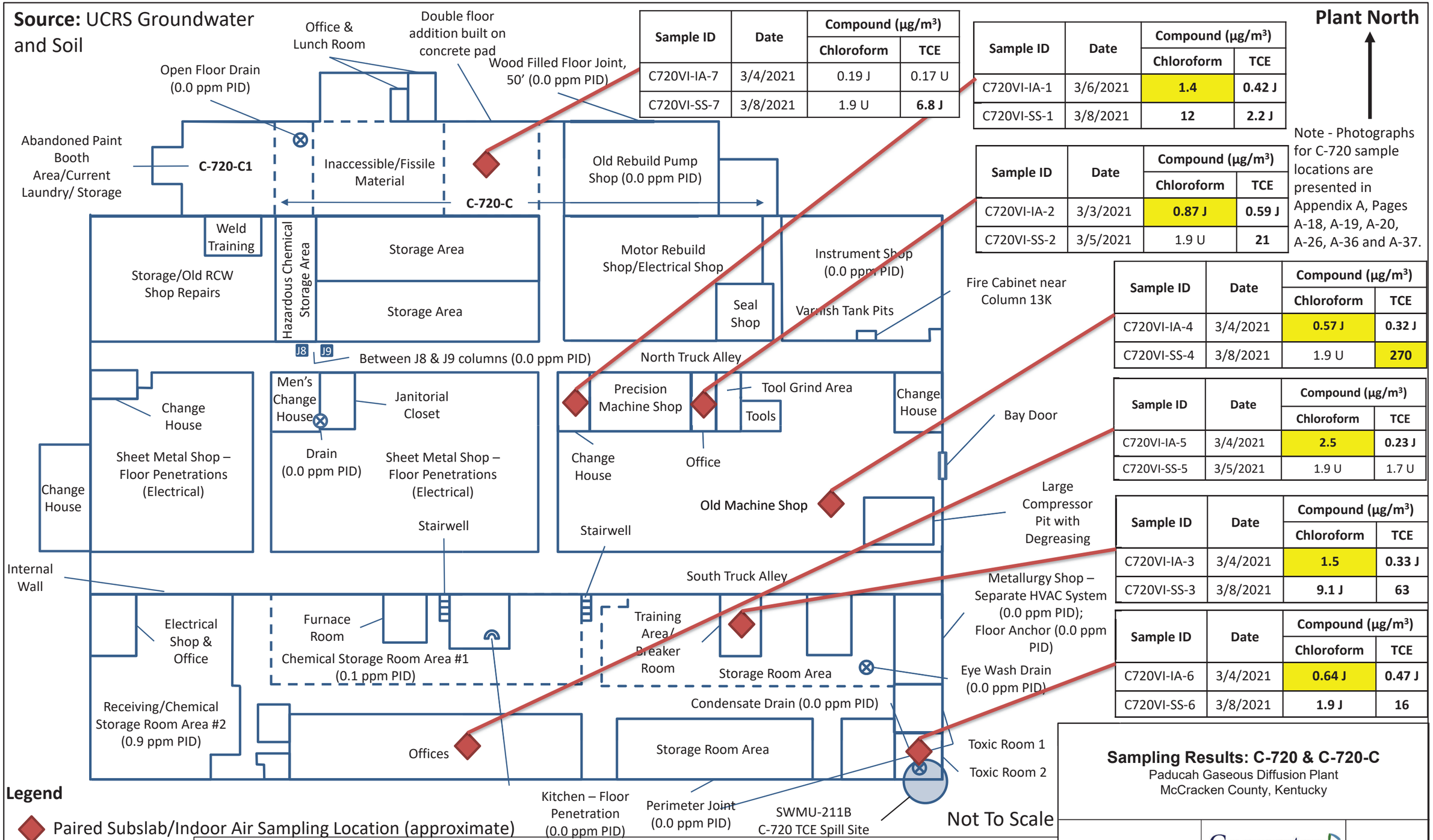
U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Geosyntec consultants

August 2021

Figure 6. Sampling Results in Building C-310

Source: UCRS Groundwater and Soil



Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C720VI-IA-7	3/4/2021	0.19 J	0.17 U
C720VI-SS-7	3/8/2021	1.9 U	**6.8 J**

Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C720VI-IA-1	3/6/2021	**1.4**	**0.42 J**
C720VI-SS-1	3/8/2021	**12**	**2.2 J**

Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C720VI-IA-2	3/3/2021	**0.87 J**	**0.59 J**
C720VI-SS-2	3/5/2021	1.9 U	**21**

Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C720VI-IA-4	3/4/2021	**0.57 J**	**0.32 J**
C720VI-SS-4	3/8/2021	1.9 U	**270**

Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C720VI-IA-5	3/4/2021	**2.5**	**0.23 J**
C720VI-SS-5	3/5/2021	1.9 U	1.7 U

Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C720VI-IA-3	3/4/2021	**1.5**	**0.33 J**
C720VI-SS-3	3/8/2021	**9.1 J**	**63**

Sample ID	Date	Compound (µg/m³)	
		Chloroform	TCE
C720VI-IA-6	3/4/2021	**0.64 J**	**0.47 J**
C720VI-SS-6	3/8/2021	**1.9 J**	**16**

Plant North

Note - Photographs for C-720 sample locations are presented in Appendix A, Pages A-18, A-19, A-20, A-26, A-36 and A-37.

Legend

Paired Subslab/Indoor Air Sampling Location (approximate)

Notes

Facility Size: 322,698 ft²

*All dimensions and locations are approximate unless otherwise noted. Only representative floor drains shown.
*Detections are bolded and results greater than their VISLs are highlighted in yellow.
*Only chloroform and TCE results shown. There were no exceedances of VISLs for the other PI Analytes.

Sampling Results: C-720 & C-720-C
Paducah Gaseous Diffusion Plant
McCracken County, Kentucky

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Geosyntec consultants

August 2021

Figure 7. Sampling Results in Building C-720

- One location in C-724—23 µg/m^3 at C724VI-SS-2 in the office along the southern edge of the building; and

- One location in C-725—38 µg/m^3 at C725VI-SS-2 in the center of the southern portion of the building, near asbestos-containing material storage and pesticide/fertilizer storage.

4.2 COMPARISON OF INDOOR AIR AND CRAWLSPACE AIR/SUBSLAB VAPOR RESULTS

As discussed in Section 1.7, a complete VI pathway results from a concentration gradient that decreases from source to receptor, which includes a much lower concentration of an analyte in indoor air than in the medium sampled below the floor—either subslab vapor or crawlspace air. While this comparison is conducted for the whole investigation dataset using the project decision rules in Section 4.3, the samples reviewed for this assessment include only PI analytes that exceed their VISLs—TCE in subslab vapor and chloroform in indoor air. Both chemical and physical results for these samples are discussed in this section, followed by a discussion section on uncertainty (Section 4.4).

4.2.1 Chemical Results

Of the three locations where TCE exceeded its subslab soil gas VISL—C310VI-SS-2, C310VI-SS-3, and C720VI-SS-4—none of the paired indoor air samples collected from these locations had TCE concentrations greater than its VISL. As discussed in Section 4.3, in the context of decision rules, this result is consistent with an incomplete VI pathway.

The only PI analyte with VISL exceedances in indoor air was chloroform, which is a common background contaminant associated with the disinfection of water using chlorine. The following lines of evidence were used to conclude that chloroform is a background contaminant at the PI buildings.

- Of the 26 locations where chloroform exceeded VISLs in indoor air,[5] chloroform exceeded the VISL in the co-located subslab sample in only three locations: C-310, paired location 4; and C-409, paired locations 1 and 3. Detecting a PI analyte in indoor air, but not in its paired subslab vapor sample, is consistent with the spatial pattern of a background contaminant present indoors and is inconsistent with an environmental source of chloroform from site-related contamination in the subsurface. Chloroform was also detected above the subslab VISL in C337VI-SS-2, C724VI-SS-2, and C725VI-SS-2; however, there was no corresponding indoor air sample or the indoor air sample was below the VISL.

- Chloroform is common in chlorinated water supplies, and in indoor air. According to the EPA, "Chloroform may be released to the air as a result of its formation in the chlorination of drinking water, wastewater and swimming pools" (EPA 2000). In the EPA study, *Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990–2005)*, chloroform was detected in 69% of collected indoor air samples across 15 case studies (EPA 2011). Though using chlorinated water in a building may comprise a set of conditions that are efficient at releasing chloroform to indoor air directly (e.g., showering, laundry, etc.), continuing and episodic releases of chlorinated water to the subsurface near buildings is another highly plausible mechanism to

[5] 25 of the 26 samples had paired subslab samples. The twenty-sixth indoor air sample, from C-746, did not have a paired subslab sample due to this building having a metal floor.

deliver a low concentration supply of chloroform to soil gas, subslab soil gas, and indoor air via the VI pathway.

- The low concentrations of chloroform measured in subslab soil gas and crawlspace samples are consistent with known, widespread leaks and releases of potable water at the Paducah Site, as discussed below and in the CSM included in Section 1.

A subset of the site monitoring wells is sampled periodically and analyzed for chloroform as detailed in each fiscal year Environmental Monitoring Plan (EMP)[6]. Of the 1,990 chloroform samples in groundwater included in Appendix B of the VI Work Plan, 1,940 (or 97%) have reporting limits or detected concentrations less than 80 µg/L [the maximum contaminant level (MCL) for total trihalomethanes in drinking water]. Of the 50 samples with detections or reporting limits above 80 µg/L, only 30 (or 1.5%) of the samples had chloroform detections between 80 and 1,200 µg/L, all of which are located near C-747 and C-748-B. These two buildings and the adjacent facilities include inactive burial areas, an inactive uranium scrap burial yard, and UF_6 cylinder storage. Of the 20 non-detect samples with reporting limits greater than 80 µg/L, the majority of the samples were taken from locations near C-400 and C-747 and C-748-B as noted above. While some higher reporting limits from laboratory-diluted aqueous samples do not preclude the presence of chloroform at higher concentrations, the range of observed chloroform detections is more consistent with potable water leaks than with environmental releases of chloroform-containing contaminants. For example, the range of measured concentrations of TCE in groundwater is several orders of magnitude larger than the range for chloroform. This range of TCE concentrations is consistent with its known history of process use and environmental release. Leaks from the water supply and wastewater piping are believed to be the most important source of chloroform to soil gas and indoor air at the Paducah Site.

Figure 8 shows the location of chloroform sample information in soil and groundwater based on previously collected data, with respect to the buildings included in the PI. As stated in Section 1.5, PI analytes, including chloroform, are chemicals that (1) are present in groundwater above their respective VISLs and/or; (2) have been used in operations or processes at PGDP, and/or (3) provide information about contaminant degradation.

Chloroform was included as a PI analyte based on only a few VISL exceedances in groundwater across the Paducah Site. As shown on Figure 8, there are no chloroform soil detections or groundwater VISL exceedances in the many samples collected near the C-409 building, where chloroform was detected in subslab vapor; however, some of the groundwater samples from this geography had reporting limits that were elevated above the VISL, adding uncertainty to the presence or absence of chloroform in this area. TCE exceeded the VISL for subslab vapor at two locations in C-310 and one location in C-720. Both PI buildings are located within the 5–100 µg/L contour of the RGA TCE plume (Figure 3) and were included in the investigation due to TCE exceedances in soil.

Subslab soil gas analytical data provide independent lines of evidence that supports the conclusion that water system leaks are the most important source of chloroform to soil gas and indoor air at the Paducah Site. It is useful context to consider the observed range of chloroform concentrations in air-phase samples from this study against the air-phase concentrations that can be predicted from sources of chloroform.

[6] Although there were 1,990 results available, uncertainty exists in the distribution of chloroform presence and concentration in groundwater across the Paducah Site. This uncertainty is due to having data from only the subset of wells collected under the EMP and an analytical suite that varies among samples. Specifically, some samples collected under the EMP may not have been analyzed for chloroform.

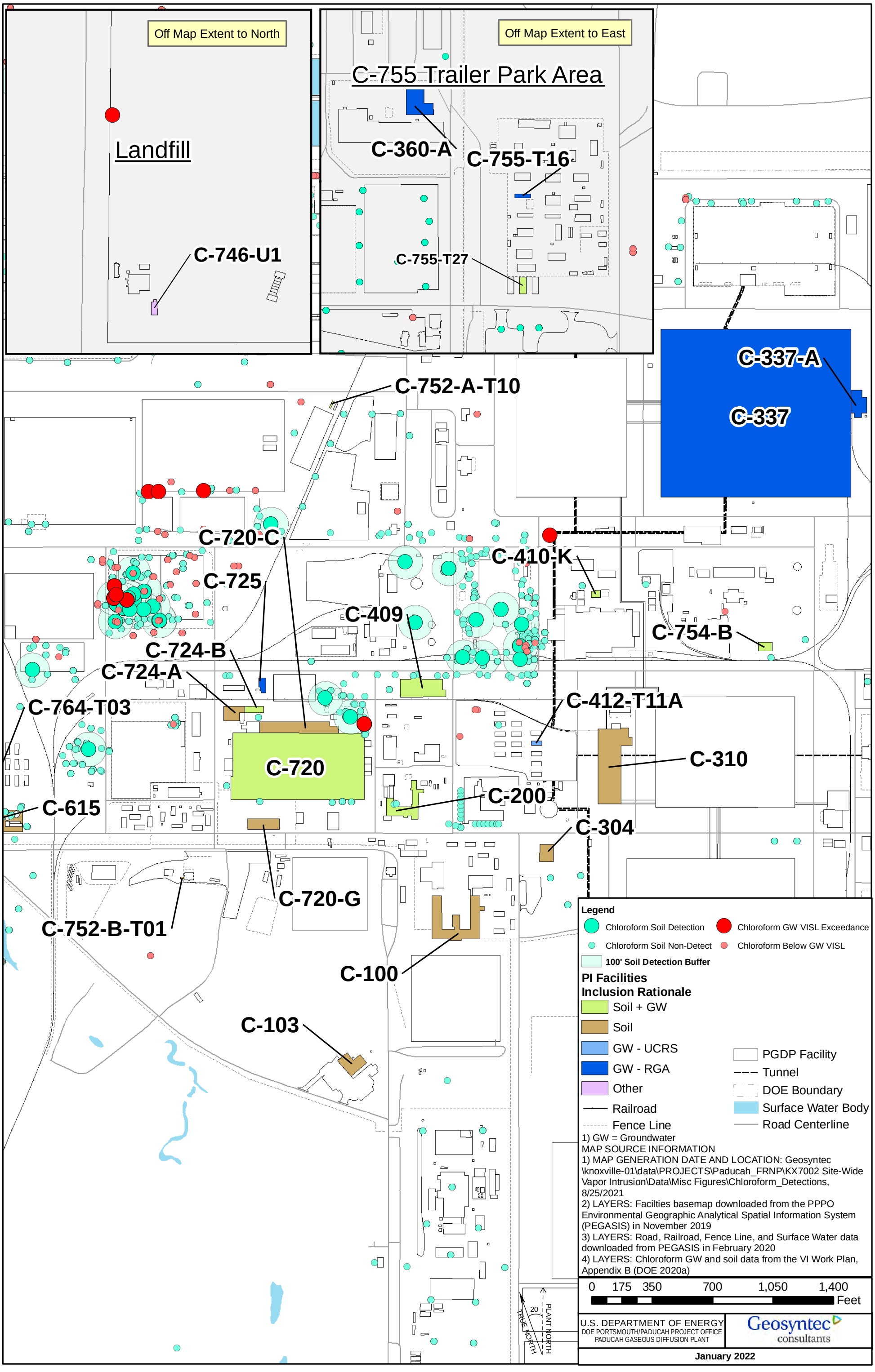


Figure 8. Subsurface Chloroform Results in Relation to PI Facilities

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Three Henry's Law calculations are presented to compare the measured concentrations in subslab soil gas to theoretical equilibrium concentrations in soil gas adjacent to groundwater with detections or with elevated reporting limits. Henry's Law dimensionless constant is 0.12 at 20° centigrade using the EPA calculator (https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/esthenry.html).

$$C_w = (C_a/H')/(1000\ L/m^3)$$

$$C_a = (C_w * H') * (1000\ L/m^3)$$

where

C_w is the concentration of chloroform in water (µg/L)
C_a is the concentration of chloroform in air (µg/m^3)
H' is the Henry's Law Constant (unitless)

- The highest measured chloroform concentration in subslab soil gas (850 µg/m^3) would correspond to an aqueous chloroform concentration of approximately 7.1 µg/L in adjacent water or soil moisture.

- The highest detected chloroform concentration in groundwater (1,200 µg/L in SWMU 4 Phase III sample 004-015P3) would correspond to a gas-phase equilibrium concentration of 144,000 µg/m^3 in adjacent soil gas.

- If chloroform were present in groundwater where the highest non-detected chloroform reporting limit in groundwater was reported by the lab (13,000 µg/L in well MW157[7]), this concentration would correspond to a gas-phase equilibrium concentration of up to 1,560,000 µg/m^3 in adjacent soil gas.

Henry's Law predicts a maximum concentration in air adjacent to water with a known dissolved concentration, meaning that somewhat higher aqueous concentrations would be needed in practice to produce each air-phase result described above; however, even if 10 times the aqueous concentration were needed to produce the maximum observed chloroform concentration 850 µg/m^3, that would be 71 µg/L. If a significant source or sources of chloroform were present as the result of a release to the environment from an industrial use or process, a subslab soil gas sample collected near such a release would be expected to have a much higher concentration because of chloroform's volatility and because the aqueous concentration from such a release would be expected to be much greater. Consistent with this concept are the 2019–2021 quarterly total trihalomethanes (of which chloroform is a key member) testing data from potable water in buildings C-755 and C-212 which ranged from 23 to 87 µg/L (KDOW 2021), and the 2020 annual testing summary from the West McCracken Water District which noted that total trihalomethanes (of which chloroform is one component) detections in treated water ranged from 19 to 110 µg/L (West McCracken Water District, 2020). West McCracken water is not used at the Paducah Site; both systems are subject to regulation as municipal water supplies.

Taken together, the leaking chlorinated water systems that cover a wide area, the typical total trihalomethanes concentrations in treated potable water that range up to approximately 100 µg/L, the soil gas data set with chloroform detections that are all consistent with this range of aqueous concentrations, and the measured chloroform concentrations in site groundwater that are also consistent with this range over the vast majority of the dataset, all these lines of evidence point toward a potable water source of the

[7] The 13,000 µg/L non-detect value is an overestimation of any actual chloroform concentration, if present, because the groundwater sample was diluted by the laboratory during analysis.

chloroform observed in soil gas and indoor air. These data limit the likelihood, but do not preclude the possibility, of a source of chloroform from historical environmental release; however, the best evidence for such a source is limited to a small fraction of one line of evidence (i.e., several groundwater samples) all of which were collected near C-747 and C-748-B. These two buildings and the adjacent facilities include inactive burial areas, an inactive uranium scrap burial yard, and UF_6 cylinder storage.

4.2.2 Physical Results

In the PI buildings where chloroform concentrations in indoor air were below VISLs, indoor air was measured at a lower pressure than subslab vapor (the building was underpressurized), and a condition favorable for VI existed at the time of sampling. In both C-337 and C-724, chloroform exceeded its VISL in subslab vapor at one subslab sampling location (C337-VI-SS-2 and C724VI-SS-2); however, chloroform did not exceed its VISL for indoor air in the corresponding indoor air samples. During indoor air sample collection, C-337 was slightly underpressurized and C-724 was underpressurized, indicating that there was some driving force for VI. Because there were no indoor air exceedances from this sampling event under these conditions, exceedances would not be expected under other weather conditions.

In the PI buildings where TCE concentrations exceeded the VISL for subslab vapor (C-310 and C-720), the buildings were underpressurized (C-310) or slightly underpressurized (C-720)—a condition favorable for VI. In both C-310 and C-720, TCE exceeded its VISL in subslab vapor for at least one sampling location; however, it did not exceed its VISL for indoor air in corresponding indoor air samples. Because there were no indoor air exceedances from this sampling event under these conditions, exceedances would not be expected under most weather conditions.

4.3 DECISION RULES

The following decision rules were defined in Section 10 of the VI Work Plan and have been applied to the sampling results. The statements that PI buildings are excluded from further VI consideration that are listed below apply to current conditions. Consistent with the requirements in the risk methods document (DOE 2021), if or when the use of an occupiable building on the DOE Paducah Site changes, a new building is constructed, or a parcel of land is transferred for a different use, DOE will evaluate the VI pathway to the building or proposed building at that time.

1. **IF** the building ranking process (based on the CSM) indicates a facility does not have a potentially complete VI pathway (no source, pathway, and/or potential receptors), **THEN** that facility will be excluded from further VI consideration, **ELSE** recommendations for further assessment will be included in the Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report.

   Buildings were eliminated from consideration in the PI based on the ranking process discussed in the VI Work Plan as part of the preliminary VI analysis.

2. **IF** the facility walkdown indicates a facility does not have a potentially complete VI pathway (no source, pathway, and/or potential receptors), **THEN** that facility will be excluded from further VI consideration, **ELSE** recommendations for further assessment will be included in the Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report.

   Buildings eliminated from consideration based on facility walkdowns are discussed in the VI Work Plan as part of the preliminary VI analysis.

3. **IF** subslab vapor [or crawlspace air] concentrations for selected analytes [PI analytes] in a facility are less than their respective VISL values, **THEN** the VI pathway is considered to be incomplete, **AND** the facility will be excluded from further VI consideration, **ELSE** recommendations for further assessment will be included in the Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report.

   The following six PI buildings are excluded from further VI consideration based on this decision rule. All PI analytes were detected at concentrations in subslab vapor below VISLs or were not detected with reporting limits below VISLs.

   - *C-100*
   - *C-200*
   - *C-304*
   - *C-360-A*
   - *C-410-K*
   - *C-720-G*

4. **IF** the subslab [or crawlspace air] concentrations for selected analytes in a facility are greater than their respective VISL values and the indoor air concentrations for same selected analytes are less than their respective VISL values, **THEN** the pathway is considered to be incomplete and/or not to result in unacceptable concentrations under current conditions, **AND** recommendations for further assessment to confirm these findings will be included in the Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report.

   The VI pathways for the following PI buildings are considered incomplete under current conditions based on this decision rule.

   - *C-103: the chloroform concentration exceeded its VISL in crawlspace air in one location; however, it did not exceed its VISL in the paired indoor air sample.*

   - *C-310, paired locations 2 and 3: the TCE concentration exceeded its VISL in two subslab sample locations; however, it did not exceed its VISL in the paired indoor air samples.*

   - *C-720: the TCE concentration exceeded its VISL in one subslab sample location; however, it did not exceed its VISL in the paired indoor air sample.*

   - *C-724: the chloroform concentration exceeded its VISL in one subslab sample location; however, it did not exceed its VISL in the paired indoor air sample.*

   For the indoor air samples collected in the following PI buildings, PI analyte concentrations were below their respective VISLs; however, they did not have paired subslab or crawlspace air samples because building construction prohibited sample collection. The VI pathway is considered incomplete under current conditions.

   - *C-615: All PI analyte concentrations in indoor air were below VISLs.*
   - *C-754-B: All PI analyte concentrations in indoor air were below VISLs.*

   The following PI buildings had VISL exceedances for chloroform in crawlspace air or subslab vapor, as noted, but do not have paired indoor air samples for comparison.

   - *C-337: one subslab vapor sample*

- *C-412-T11A: the crawlspace air samples*
- *C-725: one subslab vapor sample*
- *C-752-A-T01: the crawlspace air sample*
- *C-752-B-T01: the crawlspace air sample*
- *C-755-T16: the crawlspace air sample*
- *C-755-T27: the crawlspace air sample*
- *C-764-T03: the crawlspace air sample*

5. **IF** subslab vapor concentrations for selected analytes in a facility are greater than their respective VISL values **AND** the indoor air samples for the same selected analytes are greater than their respective VISL values, **THEN** the pathway is considered potentially complete **AND** recommendations for further assessment will be included in the Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report.

   The VI pathway for the following PI buildings is considered potentially complete under current conditions based on this decision rule. Recommendations for further assessment are presented in Section 5.

   - *C-310, paired location 4: the chloroform concentration exceeded its VISL in both subslab vapor and indoor air at one location.*

   - *C-409: the chloroform concentration exceeded its VISL in both subslab vapor and indoor air at two locations.*

   - *C-746-U1: the chloroform concentration exceeded its VISL in indoor air; however, neither a crawlspace air nor a subslab vapor sample could be collected because the building is a prefabricated metal structure with a metal floor, which could not be drilled through.*

6. **IF** outdoor air concentrations are comparable to those in indoor air samples in a facility, **THEN** the above conclusions will be reevaluated to determine the degree of certainty of the relative contributions of subslab, indoor, and outdoor sources.

   Chloroform was detected in outdoor air near C-200, C-615, and C-724. At C-200, chloroform concentrations in indoor air were much greater than in outdoor air, which is consistent with a source of chloroform indoors. At C-615 and C-724, chloroform concentrations in indoor air were less than concentrations in outdoor air. This observation is consistent with outdoor air being the source of chloroform in indoor air. No PI buildings were considered for reevaluation based on this decision rule.

7. **IF** the above evaluation indicates that background sources are the cause of indoor air exceedances, **THEN** the VI pathway is considered to be incomplete, **AND** the facility will be excluded from further VI consideration.

   Based on decision rule 6, outdoor air does not appear to be a background source for indoor air exceedances; however, as discussed in Section 4.2, the prevalence of chloroform exceedances in indoor air, when paired subslab vapor samples do not have exceedances—four of the PI buildings, C-100, C-200, C-304, and C-720-G, listed in decision rule 3—is consistent with chloroform being derived from a background source at PGDP. Recommendations for PI buildings retained for further investigation based only on chloroform exceedances are discussed in Section 5.

8. **IF** a facility is retained following the previous steps, **THEN** recommendations for further desktop or field VI investigation will be included in the Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report.

   Two facilities—C-310 and C-720—are retained from the previous steps and are therefore recommended for further investigation; specific recommendations for these facilities are presented in Section 5.

A summary of the decision rules and outcomes are presented in Table 9.

Table 9. Decision Rule Summary

PI Building	Decision Rule for Outcome Basis	Summary of VI Conditions	Decision Rule Outcome
C-100	Rule 3	PI analytes in SS below VISLs	Excluded from further consideration
C-103	Rule 4	Chloroform exceeded VISL at one CS location but not in the paired IA sample	Excluded from further consideration
C-200	Rule 3	PI analytes in SS below VISLs	Excluded from further consideration
C-304	Rule 3	PI analytes in SS below VISLs	Excluded from further consideration
C-310	Rule 4 (paired locations 2 and 3) Rule 5 (paired location 4)	TCE concentration exceeded its VISL in two SS locations (paired locations 2 and 3), but did not exceed its VISL in the paired IA samples; chloroform concentration exceeded its VISL SS and IA at one location (paired location 4)	See Section 5
C-337-A	Rule 3	PI analytes in SS below VISLs	Excluded from further consideration
C-337	Rule 4*	Chloroform concentration exceeded its VISL in one SS sample, but does not have a paired IA sample for comparison	Excluded from further consideration
C-360-A	Rule 3	PI analytes in SS below VISLs	Excluded from further consideration
C-409	Rule 5	Chloroform concentration exceeded its VISL in both SS and IA at two locations	See Section 5
C-410-K	Rule 3	PI analytes in SS below VISLs	Excluded from further consideration
C-412-T11A	Rule 4*	Chloroform concentration exceeded its VISL in CS, but does not have a paired IA sample for comparison	Excluded from further consideration
C-615	Rule 4	PI analytes in IA below VISLs, but did not a have paired SS or CS samples	Excluded from further consideration
C-720-G	Rule 3	PI analytes in SS below VISLs	Excluded from further consideration
C-720	Rule 4	TCE concentration exceeded its VISL in one SS location, but did not exceed its VISL in its paired IA sample	See Section 5

Table 9. Decision Rule Summary (Continued)

PI Building	Decision Rule for Outcome Basis	Summary of VI Conditions	Decision Rule Outcome
C-724	Rule 4*	Chloroform concentration exceeded VISL at one SS location but not in the paired IA sample	Excluded from further consideration
C-725	Rule 4*	Chloroform concentration exceeded its VISL in one SS sample, but does not have a paired IA sample for comparison	Excluded from further consideration
C-746-U1	Rule 5	Chloroform concentration exceeded its VISL in IA, but does not have a CS or SS sample for comparison	Excluded from further consideration
C-752-A-T01	Rule 4*	Chloroform concentration exceeded its VISL in CS, but does not have a paired IA sample for comparison	Excluded from further consideration
C-752-B-T01	Rule 4*	Chloroform concentration exceeded its VISL in CS, but does not have a paired IA sample for comparison	Excluded from further consideration
C-754-B	Rule 4	PI analytes in IA below VISLs, but did not have a paired SS or CS samples	Excluded from further consideration
C-755-T16	Rule 4*	Chloroform concentration exceeded its VISL in CS, but does not have a paired IA sample for comparison	Excluded from further consideration
C-755-T27	Rule 4*	Chloroform concentration exceeded its VISL in CS, but does not have a paired IA sample for comparison	Excluded from further consideration
C-764-T03	Rule 4*	Chloroform concentration exceeded its VISL in CS, but does not have a paired IA sample for comparison	Excluded from further consideration

SS = subslab
CS = crawlspace
IA = indoor air
*Chloroform concentrations were evaluated based on the multiple lines of evidence presented in Section 4.2.1.

4.4 UNCERTAINTY

On-site chlorination of Ohio River water and the subsequent leaks from potable water and fire-suppression systems are believed to be primary sources of chloroform observed in groundwater, subslab soil gas, crawlspace air, and indoor air at the Paducah Site. “Chloroform may be released to the air as a result of its formation in the chlorination of drinking water, wastewater and swimming pools” (EPA 2000); however, the VI CSM derived from on-site datasets evaluated for this investigation does not preclude the possibility of chloroform having been released to the environment from other sources, including materials used at PGDP or PGDP operations. For example, in the United States, common industrial and institutional uses of

chloroform include use as an extraction solvent for oils, greases, waxes, lacquers, floor polishes, resins, rubber, gums, and adhesives (ATSDR 1997). Chloroform is also used in the production of materials that may have been acquired for use at PGDP such as refrigerants [e.g., chlorofluorocarbon (CFC)-22, fluorocarbon-22], fumigants, plastics (including VC) and in fire extinguishers to help lower the freezing temperature of carbon tetrachloride (NIH 2021; Holbrook 2018).

A review of historical groundwater sampling and analysis at PGDP gives some context to the uncertainty of the chloroform's origins. Of the 1,990 chloroform samples in groundwater included in Appendix B of the VI Work Plan, 1,940 (or 97%) have reporting limits or detected concentrations less than 80 µg/L (i.e., the MCL for total trihalomethanes in drinking water). As discussed in Section 4.2, this range of concentrations is consistent with sourcing from treated potable water. Of the 50 samples with detections or reporting limits above 80 µg/L, only 30 (or 1.5%) samples had chloroform detections between 80 and 1,200 µg/L, all of which are located near C-747 and C-748-B. These two facilities as well as adjacent facilities include inactive burial areas, an inactive uranium scrap burial yard, and UF_6 cylinder storage. Of the 20 non-detect samples with reporting limits greater than 80 µg/L, the majority are located near C-400, C-747, and C-748-B, as noted above. The 50 out of 1,990 samples with detections or reporting limits greater than 80 µg/L allow for the possibility of chloroform having been released to the environment from sources other than potable water, including PGDP operations, but significantly limit the scope of those potential releases.

Although there were 1,990 results available, uncertainty exists in the distribution of chloroform presence and concentration in groundwater across the Paducah Site. This uncertainty is due to having data from only the subset of wells collected under the EMP and an analytical suite that varies among samples. Specifically, some samples collected under the EMP may not have been analyzed for chloroform.

In recognition of the uncertainty involved in the sources of the chloroform, a point risk evaluation for chloroform for the current industrial worker inhalation scenario has been performed and demonstrates that the risk associated with the inhalation of chloroform in indoor air is within the acceptable EPA risk range of 1E-06 to 1E-04 (Table 10 and Figure 9). For all detections of chloroform in indoor air and crawlspace samples, the calculated excess lifetime cancer risk for an industrial setting was below 1E-04, with the bulk of results below 1E-05; and the calculated Hazard Index for non-cancer effects for an industrial setting was below 0.1, with the bulk of results below 0.01.

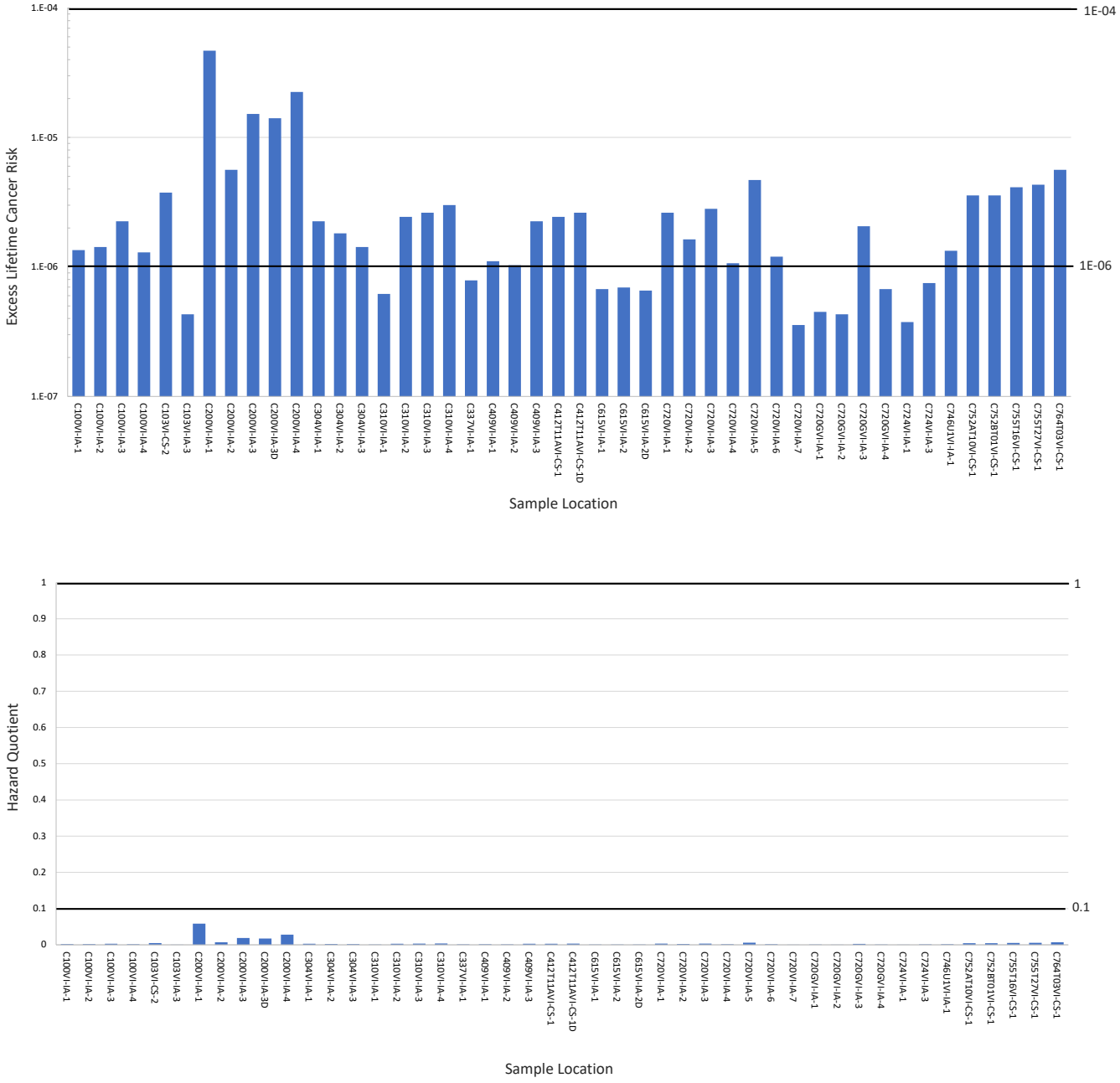
Table 10. Chloroform Point Risk Calculations for the Current Industrial Worker Inhalation Exposure Scenario

Building	Medium[a]	Sample ID[b]	Chloroform Concentration (µg/m^3)	Cancer Risk	Noncancer Hazard Quotient
Chloroform Industrial Air PRGcancer[c] = 0.533 µg/m^3 ***Chloroform Industrial Air PRGnoncancer[c,d] = 428 µg/m^3***					
C-100	Indoor Air	C100VI-IA-1	0.72 J	1E-06	0.002
		C100VI-IA-2	0.76 J	1E-06	0.002
		C100VI-IA-3	1.2	2E-06	0.003
		C100VI-IA-4	0.69 J	1E-06	0.002
C-103	Crawlspace[e]	C103VI-CS-2	2	4E-06	0.005
	Indoor Air	C103VI-IA-3	0.23 J	4E-07	0.0005
C-200	Indoor Air	C200VI-IA-1	25	5E-05	0.06
		C200VI-IA-2	3	6E-06	0.007
		C200VI-IA-3	8.1	2E-05	0.02
		C200VI-IA-3D	7.5	1E-05	0.02
		C200VI-IA-4	12	2E-05	0.03

Table 10. Chloroform Point Risk Calculations for the Current Industrial Worker Inhalation Exposure Scenario (Continued)

Building	Medium[a]	Sample ID[b]	Chloroform Concentration (µg/m^3)		Cancer Risk	Noncancer Hazard Quotient
C-304	Indoor Air	C304VI-IA-1	1.2		2E-06	0.003
		C304VI-IA-2	0.97	J	2E-06	0.002
		C304VI-IA-3	0.76	J	1E-06	0.002
C-310	Indoor Air	C310VI-IA-1	0.33	J	6E-07	0.0008
		C310VI-IA-2	1.3		2E-06	0.003
		C310VI-IA-3	1.4		3E-06	0.003
		C310VI-IA-4	1.6		3E-06	0.004
C-337	Indoor Air	C337VI-IA-1	0.42	J	8E-07	0.001
C-409	Indoor Air	C409VI-IA-1	0.59	J	1E-06	0.001
		C409VI-IA-2	0.55	J	1E-06	0.001
		C409VI-IA-3	1.2		2E-06	0.003
C-412-T11A	Crawlspace[e]	C412T11AVI-CS-1	1.3		2E-06	0.003
		C412T11AVI-CS-1D	1.4		3E-06	0.003
C-615	Indoor Air	C615VI-IA-1	0.36	J	7E-07	0.0008
		C615VI-IA-2	0.37	J	7E-07	0.0009
		C615VI-IA-2D	0.35	J	7E-07	0.0008
C-720-G	Indoor Air	C720GVI-IA-1	0.24	J	5E-07	0.001
		C720GVI-IA-2	0.23	J	4E-07	0.0005
		C720GVI-IA-3	1.1		2E-06	0.003
		C720GVI-IA-4	0.36	J	7E-07	0.0008
C-720	Indoor Air	C720VI-IA-1	1.4		3E-06	0.003
		C720VI-IA-2	0.87	J	2E-06	0.002
		C720VI-IA-3	1.5		3E-06	0.004
		C720VI-IA-4	0.57	J	1E-06	0.001
		C720VI-IA-5	2.5		5E-06	0.006
		C720VI-IA-6	0.64	J	1E-06	0.001
		C720VI-IA-7	0.19	J	4E-07	0.0004
C-724	Indoor Air	C724VI-IA-1	0.2	J	4E-07	0.0005
		C724VI-IA-3	0.4	J	8E-07	0.0009
C-746-U1	Indoor Air	C746U1VI-IA-1	0.71	J	1E-06	0.002
C-752-A-T01	Crawlspace[e]	C752AT10VI-CS-1	1.9		4E-06	0.004
C-752-B-T01	Crawlspace[e]	C752BT01VI-CS-1	1.9		4E-06	0.004
C-755-T16	Crawlspace[e]	C755T16VI-CS-1	2.2		4E-06	0.005
C-755-T27	Crawlspace[e]	C755T27VI-CS-1	2.3		4E-06	0.005
C-764-T03	Crawlspace[e]	C764T03VI-CS-1	3		6E-06	0.007

[a] Only detected indoor air/crawlspace results are presented and evaluated for risk.
[b] "D" as the last character in the Sample ID indicates the sample is a field duplicate of the corresponding sample ID.
[c] PRGs were calculated with the EPA VISL calculator, using the following exposure parameters for the current industrial worker scenario: ET = 10 hr/d; EF = 200 d/yr; ED = 25 yrs; AT(nc) = 25 yrs × 365 d/yr; and AT(c) = 70 yrs × 365 d/yr. For future VI evaluations, these exposure parameters should be modified to reflect conditions at the time of the evaluation.
[d] Chloroform Industrial Air $VISL_{noncancer}$ is the noncarcinogenic EPA VISL default commercial value for CR = 1E-06 or HQ = 1.
[e] Without the inclusion of an attenuation factor between crawlspace air and indoor air, the conservative assumption is workers have direct exposure to the crawlspace air.



Note: Only samples with detected values presented.

Figure 9. Chloroform Point Risk for the Current Industrial Worker Inhalation Exposure Scenario (Indoor Air and Crawlspace Sample Detections)

4.5 RISK EVALUATION

No PI analytes except for chloroform were present in indoor air at concentrations equal to or greater than VISLs. Chloroform exceedances are consistent with background sources, such as off gassing from chlorinated water. As of this evaluation of the VI pathways, there is no unacceptable risk to workers from the VI pathway under current conditions for all PI buildings. Further context for the observed concentrations of PI analytes in the context of occupational thresholds is provided in Appendix H. No indoor air exceedances from this sampling event are attributable to subsurface environmental sources from site-related contamination. As presented in the VI Work Plan, some PI buildings also represent groups of buildings with similar spatial proximity, analyte source(s), and building size (DOE 2020a). The buildings included in this investigation are representative of their groups and their results are intended to be used as a proxy to evaluate whether VI may be occurring at the by-proxy buildings within each group (DOE 2020a). Because there were no indoor air exceedances attributable to environmental sources from site-related contamination and, therefore, there are no complete VI pathways under current conditions in the PI buildings, this conclusion can be extrapolated to all grouped buildings. This conclusion applies to conditions encountered at the time of sampling. The investigation was conducted to evaluate whether there are complete VI pathways in a selection of facilities with the greatest potential to have a completed VI pathway, based on the VI CSM. Consistent with the requirements in the risk methods document (DOE 2021), if or when the use of an occupiable building on the DOE Paducah Site changes, a new building is constructed, or a parcel of land is transferred for a different use, DOE will evaluate the VI pathway to the building or proposed building at that time.

5. SUMMARY AND CONCLUSIONS

This section summarizes the VI pathway evaluations and provides conclusions and recommendations for future sampling.

5.1 SUMMARY

As described in Section 1.7, the EPA 2015 VI Technical Guide states that a potential VI pathway should be considered complete when the following five key conditions are all present.

1. A subsurface source of vapor-forming chemicals exists.
2. There is a route for the vapors to migrate.
3. The building is susceptible to VI.
4. Vapors are present in the indoor environment.
5. People are in the indoor environment.

Based on an evaluation of multiple lines of evidence, the subsurface to indoor air VI pathway is incomplete in all 23 PI buildings. None of the indoor air exceedances from this sampling event are attributable to subsurface environmental sources from site-related contamination; therefore, there is no unacceptable risk to workers from the VI pathway under current conditions. Because no PI buildings have complete VI pathways, the 38 by-proxy buildings are also considered to have incomplete VI pathways. For each PI building, this conclusion was reached in one of the following three ways, depending on the circumstances present.

- In PI buildings where chloroform exceeded its VISLs in subslab vapor or indoor air, there are no known chloroform sources in groundwater or soil near the PI buildings; therefore, there is no known source of subsurface contamination to the VI pathway—fails key condition 1. Chloroform was included as a PI analyte based on a few VISL exceedances in groundwater across the Paducah Site. As shown on Figure 8, there are no chloroform detections in soil or groundwater VISL exceedances in the many samples collected near the C-409 building, where chloroform was detected in subslab vapor.

- In most PI buildings, no PI analyte other than chloroform exceeded VISLs in either subslab or indoor air—fails key conditions 1 and 4.

- In PI buildings where TCE in subslab vapor exceeded its VISL, there is no VI pathway under current conditions because there were no exceedances in indoor air at these locations—fails key condition 4.

Chloroform was detected in locations that do not overlie a source in groundwater or soil and, as stated in Section 4, detections of chloroform, including exceedances, are consistent with background sources; however, the VI CSM derived from on-site datasets evaluated for this investigation does not preclude the possibility of chloroform being released to the environment from other sources including materials used at PGDP or PGDP operations. Both PI buildings where TCE exceeded its VISL are consistent with proximity to known sources in groundwater or soil. C-310 is located within the 5-100 µg/L TCE RGA plume and C-720 is located on the edge of the 5–100 µg/L TCE RGA plume and is proximal to soil PI analyte detections (Figure 3); however, there were no TCE exceedances in any of the other PI buildings located above the mapped TCE plume or near soil exceedances.

A screening-level mercury evaluation was conducted in all locations where indoor air samples were collected; and it was not detected above its screening level in any location.

5.2 CONCLUSIONS

Based on multiple lines of evidence, interpretation of VI investigation results, and in consideration of the decision rules, the VI pathway is incomplete within the PI buildings; therefore, there is no unacceptable risk to workers from the VI pathway under current conditions for all PI buildings and by-proxy buildings—because there is no unacceptable risk to workers, worker exposure to VI is under control. No indoor air exceedances from this sampling event are attributable to subsurface environmental sources from site-related contamination. For chloroform, detections and exceedances are consistent with and attributed to background sources, though the possibility remains that some chloroform on site may be derived from other sources, including materials used at PGDP or PGDP operations. TCE exceeded its VISL in subslab vapor in two PI buildings—C-310 and C-720; however, it did not exceed the VISL for indoor air in any PI building. In all other PI buildings, no subsurface source of PI analytes was identified.

As discussed in the VI Work Plan, mercury was not expected to be present in vapor form above trace concentrations; however, a screening-level evaluation was included as a protective measure. Because mercury was not detected in indoor air at concentrations exceeding its VISL, the VI pathway is considered incomplete, with respect to mercury.

5.2.1 Recommendations

Based on the results of the PI investigation, evaluation of the decision rules, and the conclusion that chloroform is derived from background sources (i.e., not an environmental source from site-related contamination), no additional actions are recommended at most PI buildings; however, EPA acknowledges in its 2015 VI Technical Guide that contaminant analyte concentrations in indoor air from VI are often temporally variable, and it is industry standard to conduct at least two seasonal indoor air sampling events (i.e., one warm weather, one cold weather) when a significant subslab vapor source is present. Thus, a second sampling event is recommended for PI buildings where TCE concentrations in subslab vapor exceeded VISLs or chloroform concentrations exceeded VISLs in both subslab vapor and indoor air to reduce this temporal uncertainty. The following additional actions are recommended as the VI pathway evaluation is continued to satisfy the question of potential threat to human health from VI.

- Conduct an additional round of paired subslab vapor/indoor air sampling at paired locations 2, 3, and 4 in C-310. During the PI, TCE exceeded its VISL in subslab sample locations 2 and 3; however, it did not exceed its VISL in the paired indoor air samples. During the PI, chloroform exceeded its VISL in both subslab and indoor air samples at paired location 4.

- Conduct an additional round of paired subslab vapor/indoor air sampling at paired locations 1 and 3 in C-409. During the PI, chloroform exceeded its VISL in both subslab and indoor air samples at these two paired locations.

- Conduct an additional round of paired subslab vapor/indoor air sampling at paired location 4 in C-720. During the PI, TCE exceeded its VISL in this subslab sample; however, it did not exceed its VISL in the paired indoor air sample.

- No further evaluation is recommended for the remaining 20 PI buildings or for the 38 by-proxy buildings represented by selected PI buildings.

These conclusions and recommendations do not supersede the requirements in the risk methods document (DOE 2021), if or when the use of an occupiable building on the DOE Paducah Site changes, a new building is constructed, or a parcel of land is transferred for a different use, DOE will evaluate the VI pathway to the building or proposed building at that time (DOE 2021). Based on the results of this study, the analyte suite

from this study [i.e., chloroform; *cis*-1,2-DCE; *trans*-1,2-DCE; mercury (elemental); 1,1,1-TCA; TCE; and VC] is recommended as a minimum analyte list for evaluation in future VI evaluations.

5.2.2 Lessons Learned

Because chloroform is a common background contaminant, limiting the inclusion of chloroform as a PI analyte to locations where previous soil and groundwater data indicate that there is an environmental source from site-related contamination should be considered in future studies. This would target locations where VISL exceedances may indicate a complete VI pathway and limit exceedances due to backgrounds sources.

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6. REFERENCES

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APPENDIX A

PHOTOGRAPHIC LOG (CD)

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APPENDIX A

PHOTOGRAPHIC LOG (CD)

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APPENDIX B

FIELD FORMS (CD)

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APPENDIX B

FIELD FORMS (CD)

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APPENDIX C

FIELD CHANGE CORRESPONDENCE (CD)

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APPENDIX C

FIELD CHANGE CORRESPONDENCE (CD)

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APPENDIX D

BUILDING MAPS WITH TCE AND CHLOROFORM RESULTS (CD)

(Note: PI building sample location photographs are presented in Appendix A.)

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APPENDIX D

BUILDING MAPS WITH TCE AND CHLOROFORM RESULTS (CD)

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APPENDIX E

ANALYTICAL RESULTS (CD)

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APPENDIX E

ANALYTICAL RESULTS (CD)

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APPENDIX F

PRESSURE MONITORING DATA (CD)

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APPENDIX F

PRESSURE MONITORING DATA (CD)

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APPENDIX G

WEATHER DATA (CD)

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APPENDIX G

WEATHER DATA (CD)

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APPENDIX H

REVIEW OF OCCUPATIONAL THRESHOLDS FOR PI ANALYTES (CD)

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APPENDIX H

REVIEW OF OCCUPATIONAL THRESHOLDS FOR PI ANALYTES (CD)

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