ATSDR
Public Health Assessment

Perchloroethylene (PCE) Southeast Contamination Site

York, York County, Nebraska

August 26, 2025

Final

EPA/CERCLA ID: NEN000706200

Cost Recovery: 7AX700

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

The ATSDR Public Health Assessment: A Note of Explanation

This Public Health Assessment-Final Release was prepared by the Agency for Toxic Substances and Disease Registry (ATSDR) pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them. This revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Use of trade names is for identification only and does not constitute endorsement by the U.S. Department of Health and Human Services.

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Agency for Toxic Substances and Disease Registry (ATSDR)
Office of Community Health Hazard Assessment
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About ATSDR

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency of the U.S. Department of Health and Human Services (HHS). ATSDR works with other agencies and tribal, state, and local governments to study possible health risks in communities where people could come in contact with dangerous chemicals. For more information about ATSDR, visit the ATSDR website at www.atsdr.cdc.gov/.

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1. Summary

In October 2010, the Environmental Protection Agency (EPA) detected volatile organic compounds (VOCs) in five private drinking water wells in southeastern York, Nebraska. Four of the contaminated wells contained perchloroethylene (also known as PCE or PERC) at levels above the maximum contaminant level (MCL, an enforceable drinking water standard set by the EPA). In May 2014, the EPA placed the PCE Southeast Contamination Site on its National Priority List (NPL). The NPL is a list of sites that are of national priority among the known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States and its territories.

The EPA and its contractor, Tetra Tech, sampled soil, groundwater, and air in areas surrounding the contaminated wells to determine the source(s) and extent of the contamination. Investigations centered on a downtown area near the York County Courthouse, located between North Lincoln and Grant Avenues and East 5th and 6th Streets. In the past, several dry cleaners operated in this area that used PCE as a cleaning agent. The EPA and Tetra Tech divided the site into three operable units (OUs) to make it easier to manage remediation in each area. The background section of this document contains descriptions of each OU.

ATSDR evaluated 2010–2019 environmental sampling data associated with the PCE Southeast Contamination site to determine the contaminant levels and potential health effects resulting from any potential exposures. Currently, there are no public health concerns because no site exposure is occurring at a level that can harm human health. ATSDR released a draft of this report for public comment on December 6, 2024, and accepted comments through January 6, 2025. No comments were received.

In April 2025, ATSDR posted a Targeted Systematic Evidence Map (SEM) and Rapid Systematic Review for Trichloroethylene and Developmental Cardiotoxicity that screened new literature published since the release of the ATSDR Toxicological Profile: https://www.atsdr.cdc.gov/ToxProfiles/SEM-for-Trichloroethylene-508.pdf. The document reported that the studies available are not of sufficient quality to provide an exposure dose or air concentration at which developmental cardiotoxicity, if any, may or may not occur. The York PHA was revised to incorporate this new information into the document.

2. Conclusions and Recommendations of ATSDR's Evaluation

ATSDR reached the following conclusions for the site:

Conclusion 1

ATSDR does not expect vapor intrusion (VI) of PCE or other site-related VOCs to harm the health of children or adults at properties that have been sampled and where vapor mitigation systems (VMSs) are installed, operated, and maintained as recommended. If the soil vapor plume migrates or building changes occur, susceptibility to VI could change.

Basis for Conclusion

- The extent of the current soil vapor plume has been determined. Properties within the investigation area have been sampled and, if needed, mitigated. To date, 27 VMSs have been installed.
- The VMSs prevent contaminated vapor from entering structures by drawing vapors from beneath the structure and venting the vapors outside. The systems contain a motorized fan that draws subsurface vapors into the system. A vent pipe routes the air outside of the building. Figure 9 in Appendix A is a picture of a VMS vent pipe. Once outside, the vapors quickly separate and break down.
- The EPA completed diagnostic testing after the installation of each VMS by collecting additional samples from indoor air. EPA used the additional samples, also referred to as confirmation samples, to confirm the systems are operating per the manufacturer's standards. The additional samples did show that after the systems were installed, a couple of the locations continued to have elevated vapor concentrations. It is unclear what caused the elevated readings. Potential causes include inadvertent VMS shutdown, preferential pathways, background sources, and changes in air pressure or temperature. The most recent sampling in 2018 didn't show detectable contaminant concentrations above ATSDR comparison values (CVs).

Recommendations

- ATSDR recommends EPA provide and install lockboxes on the outdoor power switches of VMSs to prevent the units from being inadvertently turned off.
- ATSDR recommends VMSs remain operational until the groundwater contamination no longer presents a VI hazard.
- ATSDR recommends that EPA monitor indoor air in homes[1] with VMSs to ensure the effectiveness of the systems until remediation is complete.

[1] It is preferable to monitor for vapor intrusion during closed-building conditions when heating and air conditioning systems are operating, and windows and doors remain mostly closed.

- ATSDR recommends that EPA continue to monitor and test for VI as the plumes migrate over time and install additional VMSs as needed. Sewer gas can migrate up to 500 feet [Beckley 2020]. Indicators, tracers, and surrogates can maximize the effectiveness of indoor sampling.
- ATSDR recommends owners and occupants allow EPA to perform indoor air and sub-slab gas sampling inside their properties.
- Property owners who have questions about the integrity of their VMS or are concerned about exposures may contact[2] EPA at this link: https://cumulis.epa.gov/supercpad/CurSites/csitinfo.cfm?id=0706200&msspp=med. They can also call the Nebraska Department of Environment and Energy (NDEE) at 402-471-2186 to discuss follow-up actions.

Conclusion 2

ATSDR does not expect the use of water from the York public water supply or water where EPA installed whole-house filtration (WHF) units to harm people's health.

Basis for Conclusion

- EPA approved an action memorandum in 2011 that allowed residents affected by the contaminant plumes to have their homes connected to the York public water supply. WHF units were installed at residences that were too far away to be connected to the public water supply or where residents refused connection to the public water supply.
- The City of York Water Division is required to test for contaminants in the water supply, including PCE, trichloroethylene (TCE), *cis*-1,2 dichloroethylene (DCE), vinyl chloride, and many other metals and VOCs. Site-related contaminants are not currently impacting the public water supply.
- The two most recent sampling events in the homes with WHF units indicated VOCs were not at levels of concern in the filtered water.

Recommendations

- ATSDR recommends residents that have WHF units check their filters regularly and replace filters according to the manufacturer's recommendations. They own the filtration units and need to properly maintain them to ensure their water is not contaminated.
- ATSDR recommends residents using WHF units, but with access to the public water supply, consider establishing a connection to the supply to eliminate the operation and maintenance requirements of WHF units.
- ATSDR recommends that EPA continue to sample potentially impacted privately owned wells as the plume migrates over time and install WHF units as needed or offer connection to the public water supply.

[2] If you are unable to access the link, call EPA region 7 at 913-551-7003 or 800-223-0425

Conclusion 3

At designated Property J, exposure prior to April 2014 to TCE in water used for drinking, showering, and other water-related activities could have harmed the occupants' health.

Basis for Conclusion

- ATSDR estimated exposure doses and risks from the maximum TCE concentration of 21 ppb measured at Property J. Increased cancer risks are a concern only if high levels of exposure consistently occurred to the maximum TCE level. TCE was detected at 21 ppb only once during the sampling events. High levels of exposure include assumptions that adults at the residence drank three liters of unfiltered tap water every day and four people showered sequentially every day.
- All other past and current VOC estimated doses were below the levels where adverse health effects have been seen in scientific studies.
- TCE was not detected in the two sampling events that followed the initial detection. The residence (Property J) was connected to the public water supply in 2015.

Conclusion 4

ATSDR does not expect contact with soil contamination from the PCE Southeast Contamination site to harm health.

Basis for Conclusion

- Contaminated soils are located under buildings and paved surfaces, with the highest concentrations between 17 and 18 feet below ground surface.
- Community members will likely not experience direct exposure to contaminated soils.
- Utility, construction, or remediation workers that dig in the soil could be exposed to contaminated soils. Remediation personnel are the only workers likely to be exposed to contaminated soils. Wearing personal protective equipment and following a site health and safety plan may reduce direct exposure to contaminated soil.
- Remediation of the contaminated soils is ongoing, which is likely to eliminate the potential for future exposures.

Recommendations

- Utility, construction, or remediation workers who may be exposed to contaminated soils should take precautions to prevent direct contact with soils.
- ATSDR recommends monitoring the indoor air of nearby occupied buildings during the remediation process to ensure soil vapors do not affect surrounding structures.
- ATSDR recommends groundwater monitoring near the remediation areas to detect potential changes to contaminant levels or migration of contaminants.

3. Statement of Issues

ATSDR is the principal federal public health agency responsible for evaluating human health effects associated with exposure to hazardous substances in the environment.

ATSDR's purpose is to protect public health from harmful toxic substances by using the best science, taking responsive public health actions, and providing trusted health information. ATSDR is required under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) to conduct public health assessments of sites selected by EPA for addition to the NPL.

This public health assessment is an evaluation of the potential for adverse health effects from exposures to VOCs found at the site. The evaluation assessed residents' potential VOC exposure through indoor air inhalation, drinking and showering with contaminated groundwater, and contacting contaminated soils. ATSDR scientists assessed the potential for exposure and the potential health implications from such exposures to children, adults, and workers. ATSDR scientists assessed the initial environmental sampling data (well water and limited soil samples) from 2010–2011, from 2014–2018 for VI, 2010–2016 for water, and 2014–2018 for soils.

EPA determined the remedial actions needed for soils in OU 1 in 2018 and for OU 2 soils and OU 3 site-wide groundwater in 2021. The EPA awarded a remedial action contract on September 19, 2022, to conduct in-situ thermal remediation (ISTR) at OU 1 and OU 2. The remedial action work began at OU 2 in March 2023. From March 2023 into fall 2023, the ISTR wells, vapor cap, and vapor treatment plumbing were fully installed at OU 2 [EPA 2023].

4. Background

In October 2010, the EPA found several VOCs in private drinking water wells in southeastern York, Nebraska. Several of the contaminated wells contained PCE/PERC at levels above the MCL of 5 micrograms per liter (µg/L) or 5 parts per billion (ppb). These wells are located within 0.25 miles of East Nobes Road, between South Iowa Avenue in southeastern York, and Road N, which is about 0.75 miles east of the York city limits. EPA identified the contaminated wells when it was investigating a separate groundwater contaminant plume in the northeastern part of York.

PCE is a chlorinated solvent that has been used for years in dry-cleaning operations and as a degreaser for metal parts [ATSDR 2019a]. PCE has been used as a dry-cleaning agent since the 1930s. By the 1960s, dry cleaning operations accounted for 90 percent of the PCE used in the United States [SCRD 2007]. Several dry-cleaning facilities in York used PCE. Figure 4 shows the dry-cleaning facilities of interest.

In the United States, the majority of PCE and another chlorinated solvent, TCE, were released between the 1950s and 1970s. The disposal of environmental contaminants during this timeframe was not as regulated as it is today, and they may have been disposed of down a drain, discharged to a septic system, or dumped onto or buried in the soil. These chlorinated solvents have a low (PCE) to moderate (TCE) water solubility and can persist below ground surfaces for long periods of time. The solubility of a substance is how susceptible it is to be dissolved in a fluid. PCE and TCE continue to degrade slowly in

the subsurface and will move in the direction of groundwater flow [ATSDR 2019a, 2019b]. Past improper disposal practices may have led to the contamination of soil and groundwater in the York area.

EPA and Tetra Tech sampled the groundwater in the York area through a series of monitoring wells and identified two PCE plumes that have comingled or come together [Tetra Tech 2012]. The two groundwater plumes are thought to have originated from contaminated soils at businesses in the downtown commercial district near 5th Street, 7th Street, and North Platte Avenue. PCE and TCE were detected in monitoring and private drinking water wells at concentrations above the EPA MCLs.

The site was divided into three OUs in 2017. Dividing the site into OUs helps separate the remedial action(s) needed for each OU.

- OU 1 (7th Street source area soil) is the area of soil contamination near the former York Laundry and Dry Cleaning (YLDC) building. YLDC is at the intersection of West 7th Street and North Platte Avenue.
- OU 2 (5th Street source area soil) is the area of soil contamination near the former Econowash/Norge Self Service Dry Cleaning (Econowash/Norge) business located at the intersection of 5th Street and North Platte Avenue.
- OU 3 (groundwater site wide) contains the contaminated groundwater plumes beneath and downgradient of the former dry cleaners.

The northern plume, associated with OU 1 soil contamination, originates at the YLDC facility at the corner of West 7th Street and North Platte Avenue. The northern plume contains mainly PCE and extends southeastward for approximately 2.8 miles to the intersection of Road O and East Nobes Road. The southern plume, associated with OU 2 soil contamination, originates at the former Econowash/Norge facility at the corner of West 5th Street and North Platte Avenue and extends southeastward for 1.9 miles to East Nobes Road about 0.4 miles west of Road N [Tetra Tech 2018b]. The southern plume is primarily composed of PCE but also includes PCE degradation (breakdown) products such as TCE and cis-1,2-dichloroethene (DCE).

PCE degrades over time into TCE, which degrades to DCE, and these eventually degrade to vinyl chloride. Fuel-related VOCs in the soil from former gasoline stations near the former Econowash/Norge facility helped degrade the PCE to its breakdown products [USEPA 2016]. Figure 1 shows the boundaries of the northern/southern plumes in blue. OU 1 and OU 2 are also shown in Figure 1. The two plumes have comingled as they migrated away from their sources.

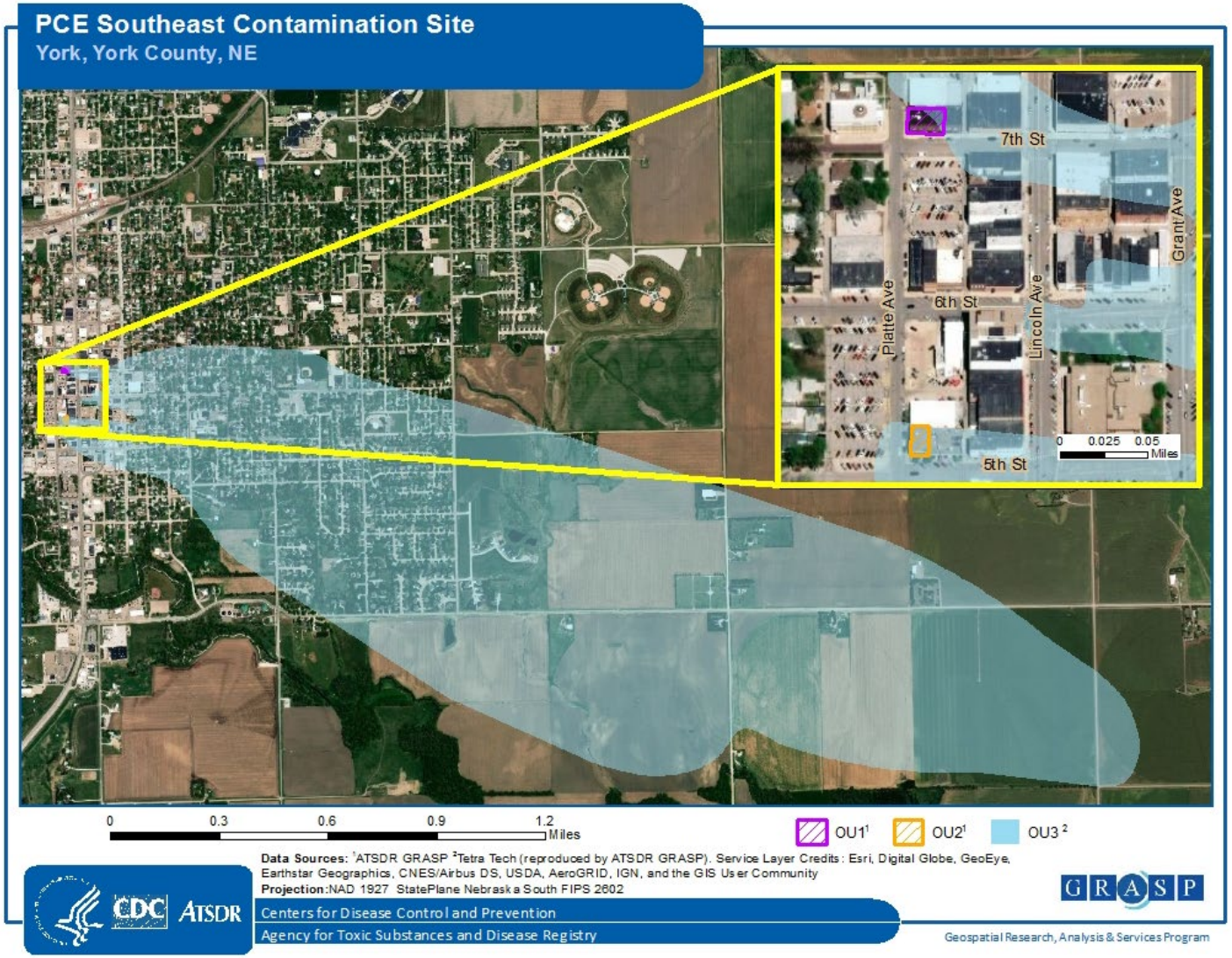

Figure 1. Groundwater Plumes in York, NE.

4.1. Site Description

The city of York, located in the west-central area of York County in southeast Nebraska, is about 47 miles west of Lincoln and approximately three miles north of Interstate 80. In 2022, York had an estimated population of 8,174 [US Census 2022]. The contaminant plumes extend from the sources in downtown York to the southeast of York, near the intersection of Road N and East Nobes Road. The commercial and industrial areas of downtown York are about one mile northwest (upgradient) of the intersection of East Nobes Road and South Delaware Avenue, or about two miles northwest of the intersection of East Nobes Road and Road N [Tetra Tech 2015].

The site is largely residential inside the city limits, with farmland south of East Nobes Road and east of the city limits, and commercial areas around Lincoln Avenue. Most of the contaminated private wells are either on South Delaware Avenue or Road N just north and south of East Nobes Road, or on East Nobes Road between South Iowa Avenue and Road O. The southern plume extends southeastward for approximately 1.5 miles to East Nobes Road about 0.4 miles west of Road N.

4.2. Groundwater Characteristics

The High Plains aquifer is the source of groundwater in York. The aquifer is an underground layer of permeable rock, sediment, or soil that yields water. Figure 2 shows the different layers of groundwater in the High Plains aquifer. From 2010 to 2019, EPA and Tetra Tech performed extensive groundwater sampling in York. They used a group of monitoring wells and private wells to help identify the source and extent of contamination. Knowing the depth of the contamination helped determine which wells were or could be impacted by the contaminants.

In 2003 and 2004, the United States Geological Survey (USGS) installed 36 monitoring wells to investigate groundwater flow. USGS determined that wells screened at depths less than 100 feet below ground surface (bgs) are in the unconfined aquifer. Wells screened between 100 and 200 feet bgs are in the upper part of the confined aquifer, and those screened between 200 and 300 feet bgs are in the lower part [USEPA 2016]. The York public water supply consists of 15 active municipal wells, with the majority screened in the upper and lower confined aquifer [USEPA 2018b].

Nearly all York public water supply wells and many irrigation wells are fully screened across sand in the upper confined aquifer [USGS 2008]. According to the USGS, most private wells in the York area are likely in the unconfined aquifer. USGS concluded that groundwater withdrawals from private wells could form paths for contaminants to migrate downward from the unconfined aquifer into the upper and lower confined aquifers [USGS 2008]. Groundwater flow in the York area is predominately from northwest to southeast, but USGS studies show groundwater flows eastward in the southern York area [USGS 2008].

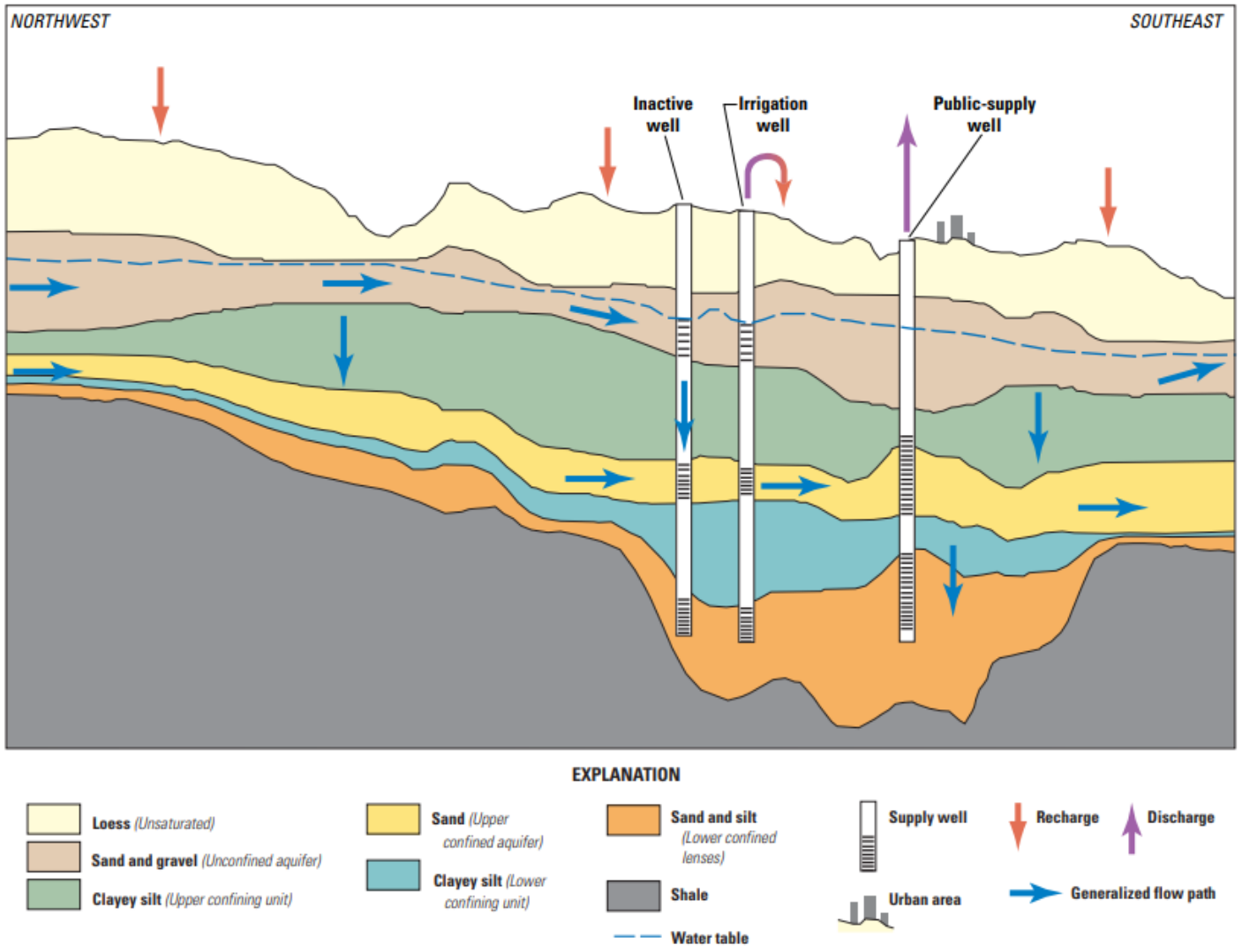

Figure 2. High Plains aquifer near York, NE.

Source - USGS April 2008

5. ATSDR's Evaluation Process

ATSDR evaluates contaminants in the environment (air, groundwater, soil, etc.) by comparing contaminant concentrations to ATSDR's comparison values (CVs). CVs represent known or anticipated safe concentrations of contaminants in the environment. They are used to identify the contaminants at a site that could be present at levels of public health concern and require further evaluation. When a contaminant level exceeds a CV, it does not necessarily indicate that the contaminant will cause adverse health effects. Rather, it indicates that further evaluation is needed [ATSDR 2022].

Comparison helps ATSDR narrow down the contaminants of concern at a site. ATSDR does not consider a contaminant to be of concern if all the detected levels of the contaminant are below its CV. In this document, ATSDR uses parts per million (ppm) or parts per billion (ppb) to refer to a contaminant's concentration in soil or water. Micrograms per cubic meter ($\mu g/m^3$) are used to discuss air concentrations. ATSDR CVs are used in many of the tables within this assessment.

The following are definitions of ATSDR-derived CVs:

Minimal Risk Levels (MRLs)

An MRL is an estimate of daily human exposure to a substance that is not likely to result in noncarcinogenic health effects during a specified duration of exposure. MRLs are based on noncancerous health effects only and do not consider carcinogenic effects. For oral exposures, MRLs are reported as milligrams per kilogram per day [mg/kg/day]. For inhalation exposures, MRLs are reported in units of either ppb or $\mu g/m^3$.

Environmental Media Evaluation Guides (EMEGs)

EMEGs are estimated contaminant concentrations that are not expected to cause adverse noncancerous health effects. EMEGs are based on ATSDR MRLs. They are derived from conservative assumptions about exposure (e.g., intake rate, exposure frequency, duration) and body weight.

Cancer Risk Evaluation Guides (CREGs)

CREGs are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in one million persons exposed during their lifetime (70 years). CREGs are calculated from EPA's cancer slope factors (CSFs) for oral exposures or unit risk values for inhalation exposures. CSFs and unit risk values are based on EPA evaluations and assumptions about hypothetical cancer risks at low levels of exposure.

6. Environmental Sampling Results

6.1. Residential Wells

In the fall of 2010, the EPA found VOC contamination in private wells in the Nobes Road area. They were conducting downgradient sampling for the PCE/TCE Northeast Contamination Site, another Superfund

site, in the area when they found the contamination. Most of the wells with concentrations exceeding the MCL were within about a half-mile north or south of East Nobes Road (Road 12) in the area extending from North Lincoln Avenue east to Road O. The EPA sampled 20 residential drinking water wells in the area and found that eight had PCE concentrations above the MCL (5 ppb). Concentrations ranged from 9.6 ppb to 32 ppb [Tetra Tech 2012]. One of these wells also contained TCE at 5.9 ppb, which is slightly above TCE's MCL of 5 ppb. However, this was not a concern because this well was specifically used for irrigation. In addition, the residents who use this well for irrigation also use city water as their source of drinking water.

EPA offered affected residents a connection to the York public water supply. EPA installed WHF units where connection to the York public water supply was not feasible or if the residents refused the connection. Figure 11 in Appendix A shows the locations with PCE above the MCL in 2010. In 2015, the York public water supply extended water lines to Road N and East Nobes Road. EPA continued sampling the private residential wells in 2011, 2012, 2014, and 2016. In 2018, they sampled the two wells with WHF units. Table 1 shows the 2010–2018 residential results for well samples that exceeded the MCL or ATSDR's CVs.

EPA collected multiple samples from the residences with filtration systems. Before (pre-) and after (post-) filtration samples helped EPA determine the effectiveness of the WHF units. Post-filtration sample results showed that the filtration units were removing the contaminants and lowering concentrations to nondetectable (ND) levels. Overall, the filtration systems were working as designed except for one location (location J). In that location, the post filtration sample results exceeded both the PCE and TCE CVs and MCLs. It is uncertain whether the filter at this location was changed and if the filtration system was maintained according to the manufacturer's recommendations. In two subsequent sampling rounds at this location, PCE and TCE were not detected.

Table 1. Private well sample results.

Property	*Sample Date*	*PCE (ppb)*	*TCE (ppb)*
A	8/9/2011	**11**	1.5
A	1/16/2014	ND	ND
B	1/16/2014	ND	ND
C	10/13/2010	**22**	2.1
C	2/10/2014*	**14**	0.79
C	2/10/2014†	ND	ND
D	8/9/2011	**8.2**	0.89
D	1/16/2014	**13**	ND
E	8/10/2011	**12**	**3.8**
E	1/16/2014	**9.8**	ND
F	2/10/2014*	**10**	1.6
F	2/10/2014†	ND	ND
G	8/9/2011	**21**	**8**
G	1/16/2014	**14**	2.3
H	10/8/2014	**19**	**3.9**
I	8/9/2011	**6.1**	2
I	1/16/2014	**35**	**8**
J	4/26/2011	**46**	**4.9**
J	9/4/2012†	**37**	**14**
J	1/16/2014†	**64**	**21**
J	4/30/2014	ND	ND
J	7/10/2014	ND	ND
K	10/13/2010	**22**	1.4
K	9/4/2012	ND	ND
K	2/11/2014	ND	ND

Property	***Sample Date***	***PCE (ppb)***	***TCE (ppb)***
K	5/3/2016*	**87**	**15**
K	5/3/2016†	ND	ND
K	7/9/2018*	**49**	6.7
K	7/9/2018†	ND	ND
L	9/8/2010	**19**	ND
L	2/12/2014	**32**	ND
M	9/8/2010	**9.6**	ND
M	2/11/2014*	**44**	ND
M	2/11/2014†	ND	ND
N	2/11/2014	**29**	ND
O	9/8/2010	**32**	ND
O	2/13/2014	**18**	ND
P	9/8/2010	**22**	ND
P	9/4/2012	ND	ND
P	2/11/2014	1.3	ND
Q	8/9/2014	**22**	ND
Q	5/3/2016*	**31**	ND
Q	5/3/2016†	ND	ND
Q	7/9/2018*	**19**	ND
Q	7/9/2018†	ND	ND

ppb – parts per billion
MCL – Maximum contaminant level for PCE and TCE in water (5 ppb)
CV – ATSDR EMEG for TCE in water (3.5 ppb)
PCE – Perchloroethylene TCE - Trichloroethene
Bolded and underlined numbers indicate a concentration above MCL or ATSDR CV
ND – non-detection
* Sample collected before filtration (raw untreated water)
† Sample collected post reverse osmosis (filtered water)
Reference – USEPA 2018c

6.2. Actions Taken to Reduce/Eliminate Exposure

EPA has completed removal actions at 17 residences (properties A– Q) and one business where PCE or TCE levels exceeded their respective MCLs. All residential locations, except two, were connected to public water supply in 2015 and the one business was connected in 2017. The two residential locations were connected to WHF units. Before the homes were connected to the public water supply or received WHF units, the EPA sampled properties C, F, and M. They had filters on the tap, and two samples were collected from each property. One of the samples was collected before (pre-) filtration and one after (post-) filtration.

Source Investigation Sampling 2011–2018

EPA and Tetra Tech have been investigating the York site for many years and have collected numerous groundwater, soil, and soil-gas samples to determine the source(s) and extent of the contamination. At the time of writing this report, over 700 groundwater, 350 soil, and 90 soil-gas samples have been collected [USEPA 2018a].

6.3. Groundwater

OU 3 (site-wide groundwater) contains the contaminated groundwater plumes beneath and downgradient of the former dry cleaners. The northern plume contains mainly PCE, which originates at the former YLDC facility (OU 1) and extends southeastward for about 2.8 miles to the area near the intersection of East Nobes Road and Road O. The southern plume is predominately PCE associated with the contamination at OU 2 but includes common PCE degradation products such as TCE and cis-1,2-dichloroethene (DCE). The southern plume extends southeastward for about 1.9 miles to East Nobes Road and about 0.4 miles west of Road N. PCE and TCE concentrations above their respective MCLs are primarily found in the unconfined aquifer; however, concentrations below the MCLs have been found in the lower confined aquifer.

In 2011, EPA installed temporary wells in the downtown area and initially sampled them at multiple intervals to a depth of 80 feet bgs. Sampling results indicated the contaminants were undetectable below about 50 feet bgs. More recent sampling was concentrated in the 31–35 feet bgs (top of the groundwater) to 46–50 feet bgs interval.

In July 2014, EPA began conducting the remedial investigation/feasibility study (RI/FS) at the site to select a remedy that eliminates or reduces the risk to human health. The RI/FS involves the investigation and sampling of contaminated soil and groundwater at the source area(s).

In May 2015, EPA collected groundwater samples at multiple depths from 17 temporary wells. Individuals were not drinking from these wells. EPA used the data results from this sampling to determine the extent of the plumes. EPA determined from their sampling that several former dry-cleaning businesses are contributing to the groundwater contamination. Several areas were sampled upgradient of the former dry cleaners to use as background (naturally occurring or unaffected by man) samples. These samples were thought to be unaffected by the plumes and would provide background water quality parameters. The background samples provided what the naturally occurring constituents of the water were without the presence of contamination. They can be compared to samples taken from

areas of known contamination. Within the immediate area of OU 1, there are no known active, private drinking water wells [Tetra Tech 2018b].

Figure 3, shown next, identifies the PCE plumes and their boundaries. Colored bands show the different PCE concentrations. The highest PCE concentrations (>5,000 ppb) are near the source and are shown in red. Farther from the source, the concentrations drop to greater than or equal to 500 ppb and are shown in dark orange. As the plume branches out, the concentrations are between 50 ppb (light orange) to 5 ppb (MCL level) in the green shaded area. The blue area shows PCE levels below 5 ppb and the boundaries of the PCE plume. The expanded view in Figure 3 shows the source areas OU 1 (7th Street) to the north and OU 2 (5th Street) to the south.

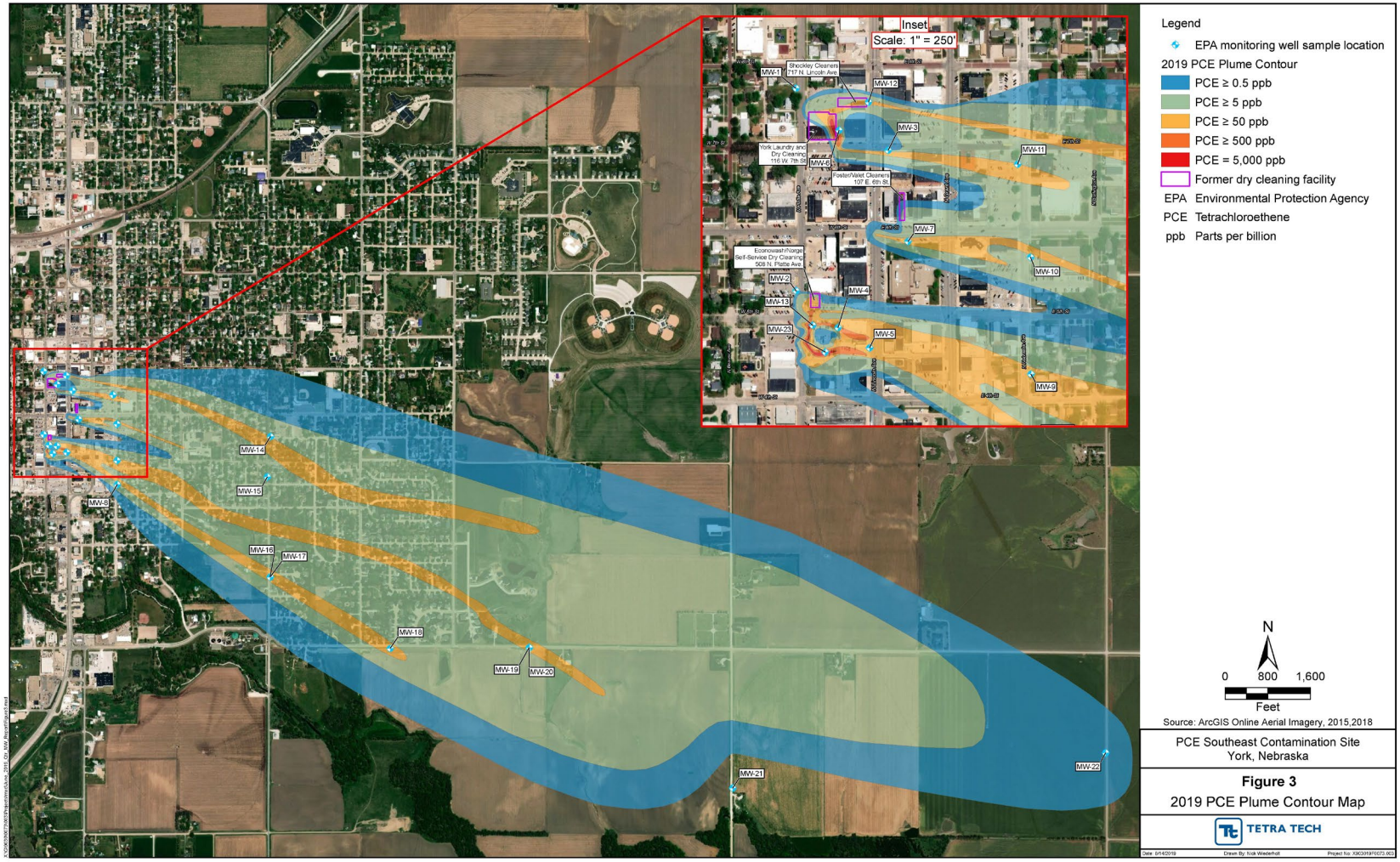

Figure 3. PCE contour plumes.

Source – Tetra Tech 2019 Soil

6.4. Soil

The EPA and Tetra Tech conducted limited soil sampling in York beginning in November 2011. They sampled locations at several potential source areas (old dry-cleaning facilities and gas stations) in the commercial area of downtown York and the industrial area to the southwest. Soil samples were limited in 2011 at or near OU 1 because buildings covered the properties and little to no surface soils were present [Tetra Tech 2019].

In November 2011, PCE was found in the soil immediately north of the former Foster/Valet Cleaner building at 107 East 6th Street. PCE was found at a concentration of 56 ppb 1–3 feet bgs in soil and 180 ppb 30 feet bgs in groundwater approximately 100 feet southeast of the facility. No TCE or related degradation products were detected in either soil or groundwater.

EPA collected soil borings (below surface) due to there being little to no surface soil in OU 1. A boring is a core or section of soil taken from beneath the surface at a specific depth. EPA analyzed the different sections of soil in the boring. EPA continued subsurface soil sampling in November 2014, and March, November, and December of 2015 to determine the source.

Operable Unit 1

The OU 1 property consists of two separately owned parcels with adjoining buildings covering most of the ground surface. The southern parcel is covered by a two-story brick building. It contains four commercial spaces with the addresses 106 West 7th Street (formerly Jazzercise), 110 West 7th Street (Washing Well — laundromat), 116 West 7th Street (formerly Captain Red Beard's Café), and 706 North Platte Avenue (formerly Global Tech computer repair shop) [USEPA 2018c]. The four commercial spaces are currently vacant. Figure 4 shows the dry-cleaning facilities in the area and the inset pictures show OU 1 and OU 2 boundaries. Figure 12 in Appendix A shows a recent photo of the OU 1 location.

The YLDC facility or its predecessors operated at the northeast corner of West 7th Street and North Platte Avenue from about 1915 to 1972 [Tetra Tech 2018b]. Review of Nebraska's online deed records indicates the two parcels at OU 1 were under single ownership until 1984, when the property was subdivided. The current owner of the southern building purchased the property in 2012 and uses it for commercial space. The current owner of the northern building purchased the property in 2010 and uses it to store equipment and materials for their business (USEPA 2018b).

EPA and Tetra Tech collected over 150 soil samples from multiple depths and analyzed soil samples in OU 1 from March 2015 through November 2018. In March 2015, soil samples were collected from multiple depths ranging from 0.5 feet to 28 feet bgs in 16 soil boring samples. Soil sample results from the March 2015 sampling period identified elevated PCE concentrations in the soil near the former YLDC building. However, only low concentrations were detected in groundwater samples immediately downgradient of this facility. PCE concentrations ranged from 22 to 4,100 ppb, with the highest concentrations detected between 2 and 3 feet bgs near the former YLDC facility. The maximum PCE

concentration detected in March 2015 was 4,100 ppb, which is equal to 4.1 ppm and is below ATSDR's soil pica PCE comparison value of 43 ppm. No TCE or any other PCE degradation products were detected in the soil samples. Table 2 and Table 3 give a historical perspective of the dry cleaners and businesses that operated in the OU 1 source area.

EPA and Tetra Tech conducted more extensive soil sampling in June and July 2016 to find the source of the PCE. The maximum concentration detected during this timeframe was 8,300 ppb, which is equal to 8.3 ppm. The elevated concentration was found 1 to 2 feet bgs at 708 North Platte Avenue. This was the highest PCE concentration ATSDR found in their review of the environmental soil sampling data for OU 1 when producing this document. However, 8.3 ppm is still below ATSDR's soil pica PCE comparison value of 43 ppm.

Table 2. Dry cleaners/businesses north of the former York Laundry that potentially used volatile chemicals at or near Operable Unit (OU) 1.

Facility Address	Business Name	Approximate Dates	Current Occupant
827 Lincoln Ave.	Service Station	1939–1981	Valentino's Pizza
	H & H Cleaners	1981–1991	
717 Lincoln Ave. (715 N. Lincoln Ave.)	Shockley Cleaners	1928–1936	Vacant (formerly Isaiah's Toy Box) or a parking lot
609 N. Lincoln Ave.	Deluxe Cleaners	1948–present	Deluxe Cleaners
116 W. 7th St. (Southern Building – 106, 110, 116 W. 7th St. and 706 N. Platte Ave. Northern Building – 708 N. Platte Ave.)	116 – York Steam Laundry or York Laundry	1928–1946	116 – Vacant (formerly Captain Red Beard's Café) 110 – Washing Well 106 – Vacant (formerly Jazzercise) 706 – Vacant (formerly Global Tech computer store) 708 – T & D Construction storage garage
	116 – York Laundry and Dry Cleaning	1960–1972	
	116 – Dale Electronics	1977–1984	
	116 – Midland Manufacturing Inc.	1987	
	110 Nebraskaland Video 114 – Kirby Sales & Service	1988–1991	
	116 York Vacuum Center	1991	

Table 3. Dry cleaners/businesses south of the former York Laundry that potentially used volatile chemicals at or near Operable Unit (OU) 1

Facility Address	Business Name	Approximate Dates	Current Occupant
107 E. 6th St.	Foster Cleaners	1948	Crossroads Awards & Gifts
107 E. 6th St.	Valet Cleaners	1961	Crossroads Awards & Gifts
107 E. 6th St.	Redman Shoes	1977–1984	Crossroads Awards & Gifts
508 Platte Ave. (124 W. 5th St.)	Econowash Laundromat; Norge Self Service Dry Cleaning (OU 2)	1963–1981	Chances R – Hob-Nob Lounge (1983 – present)

Source – Tetra Tech 2018a.

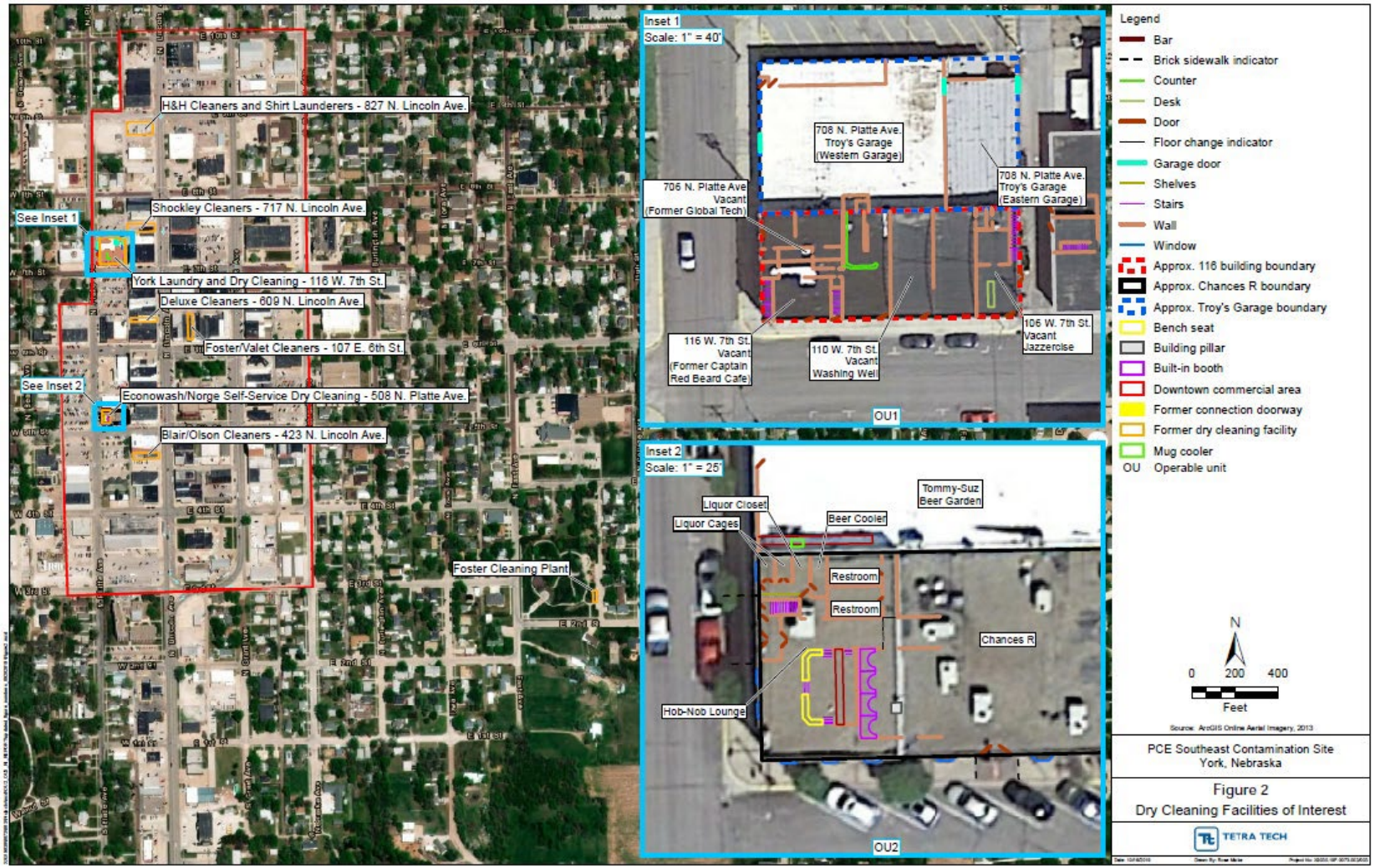

Figure 4. Dry Cleaning Facilities of Interest.

Source - USEPA 2021

Operable Unit 2

OU 2, the 5th Street source area soil, contains contamination associated with the former Econowash/Norge Self-Service Dry-Cleaning facility. The former Econowash/Norge facility was located at 508 North Platte Avenue and occupied the southwestern building at the northeast corner of West 5th Street and North Platte Avenue.

ATSDR reviewed soil sample results from March 2015; February, May, July, August, and October 2017; and June and July 2018 for OU 2. The highest PCE level found was in June 2018 at 74,000 ppm in soil 17–18 feet bgs on the Northbound side of North Platte Avenue about 75 feet south of West 5th Street [Tetra Tech 2019]. The highest levels of PCE degradation products were also found in the same sample. TCE was detected at 710 ppm, cis-1,2-DCE at 460 ppm, and vinyl chloride at 0.370 ppm. Very low to undetectable concentrations of the same compounds were found in the 1–2 feet bgs and 5–6 feet bgs samples at the same location. Figure 5 shows the extent of contamination in soil at the depth where the maximum concentrations were detected (15–20 feet bgs). The PCE concentrations are shown with contour lines and the associated levels of PCE within them. The use of contour lines to show the different concentrations is referred to as an iso-concentration depiction.

Table 4 shows the PCE and TCE soil concentrations in OU 2 that exceeded ATSDR CVs. The soil samples collected in March 2015, February 2017, and July 2017 did not contain any of the contaminants above ATSDR CVs. It is important to note that the contamination wasn't evenly distributed throughout the sampling areas. Only a few locations had concentrations above ATSDR CVs.

Table 4. Operable Unit (OU) 2 maximum soil sample concentrations exceeding ATSDR CVs.

Sampling date	PCE (CV=180)	TCE (CV=5.6)	Number of samples exceeding CV/total samples
May 2017	90	5.8	2/7
August 2017	NE	650	3/7
October 2017	NE	6.9	1/13
June 2018	74,000	710	1/13
July 2018	130	2.7	3/13

Concentrations are in parts per million (ppm)
CV – Comparison value
NE- No exceedances
PCE – perchloroethylene
TCE - trichloroethylene

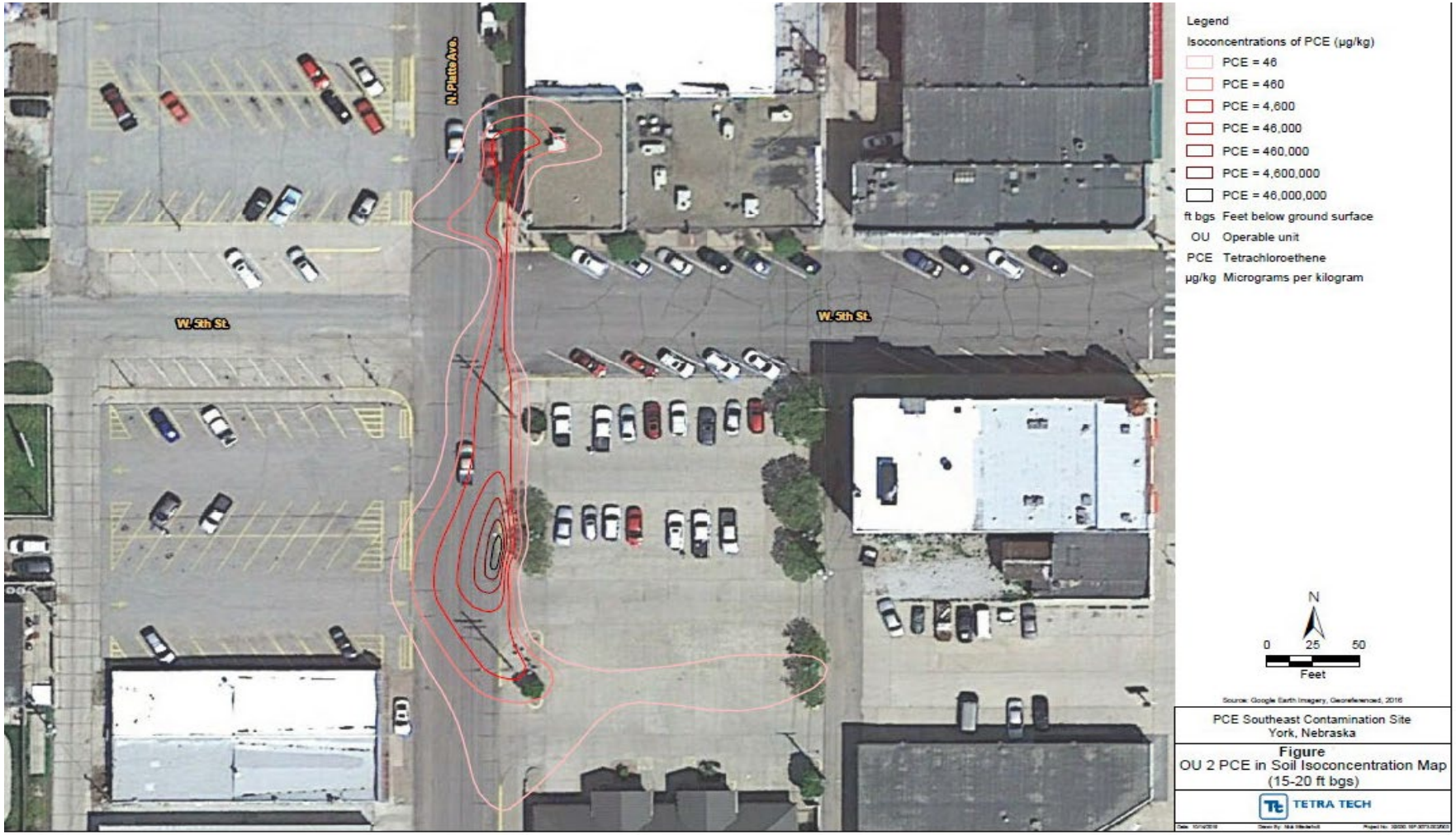

Figure 5. PCE Iso-concentration Map (15–20 feet below ground surface) for OU 2 soils.

OU 2 – Operable Unit 2 PCE- Perchloroethylene

Source - Tetra Tech 2020

The contaminated soils from OU 1 and OU 2 are a continuing source of groundwater contamination because the contaminants in the soil move towards the groundwater and impact the groundwater. EPA has a remediation goal for PCE in soils equal to 46 ppb or 0.046 ppm and 36 ppb or 0.036 ppm for TCE [EPA 2021]. Keeping PCE and TCE soil concentrations below these levels will protect the groundwater from exceeding the MCL and will allow residents to use the water in the future.

6.5. Vapor Intrusion

Several of the chemicals detected in the groundwater at the PCE Southeast Contamination Site are classified as volatile. Volatile chemicals are a class of chemicals that evaporate (volatilize) easily and form a vapor in the air. Sources of volatile chemicals include gas stations, dry cleaners, and other industries that use or used them in their day-to-day operations. Volatile contaminants in groundwater can form a vapor from the soil gas and move into nearby buildings, contaminating the indoor air. This process is referred to as vapor intrusion (VI) shown in Figure 6.

PCE is a manufactured volatile chemical that has been widely used for dry cleaning of fabrics. PCE evaporates easily, and most people can smell it at a concentration as low as 1 ppm (7,000 µg/m^3). PCE has relatively low solubility in water and medium to high mobility in soil. Because PCE can travel through soils quite easily, it can get into underground drinking water supplies or volatilize into the air. It has a higher density than water and can persist in the water because of its low solubility. Soil vapor (the air between soil particles) can become contaminated and move up through the soil into buildings through cracks in the foundation of the building. In some cases, it can move into basement floors or walls.

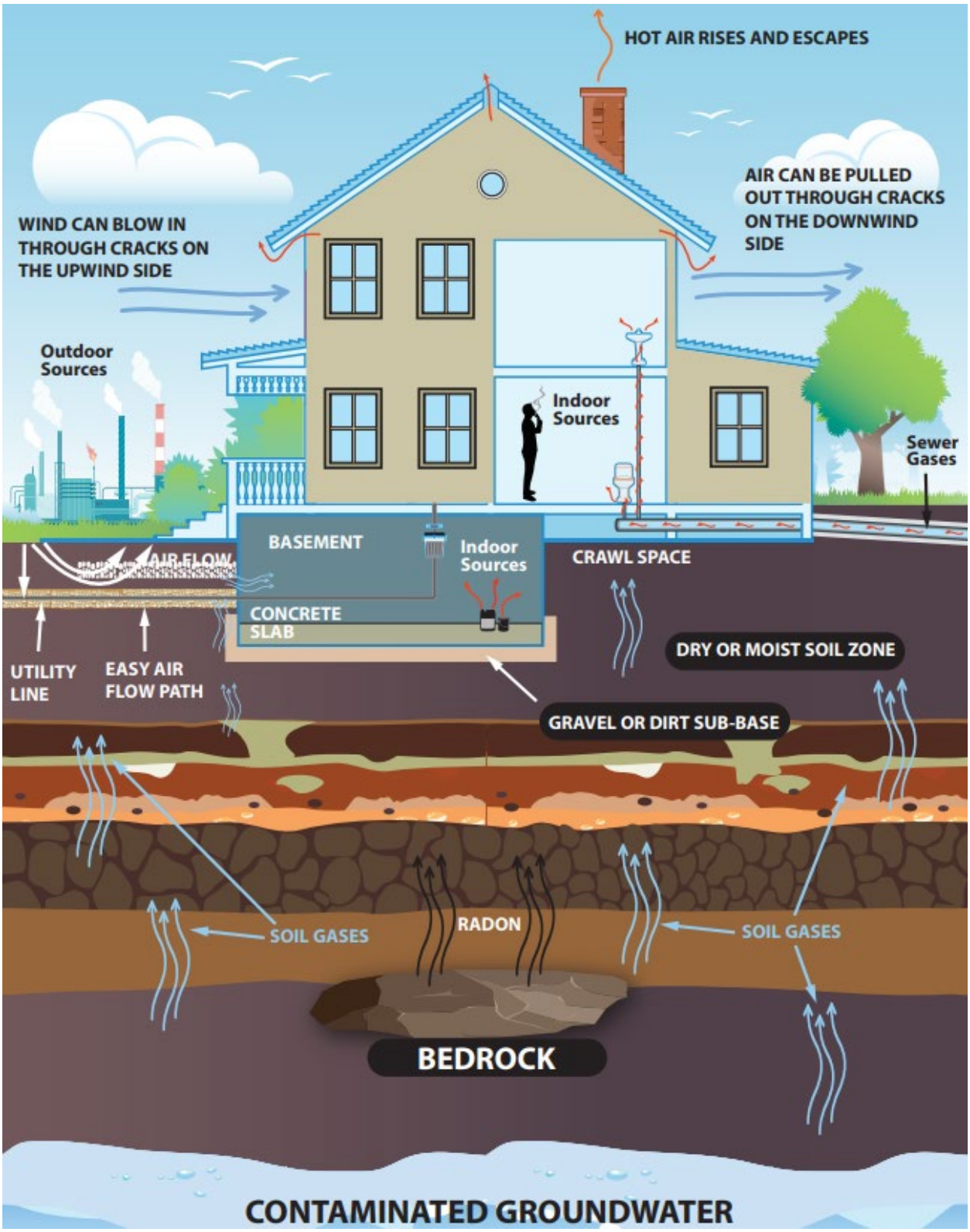

Figure 6. Vapor Intrusion (VI) Process.

Source - ATSDR

The potential for contaminants in groundwater to volatilize into the surrounding air spaces above the groundwater plume created concern for VI. The EPA sampled homes and businesses above the groundwater plumes and utilized multiple lines of evidence including groundwater, soil, soil gas, indoor air, sub-slab, and ambient air sampling to determine the extent of VI at the site. It is important to note that the potential for VI can be highly variable. VI changes depending on utility corridors, soil contamination, groundwater concentrations, depth to groundwater, geology, building construction, and temporal or weather changes. The variability of concentrations for the same location over time can be seen in Table 5. Variability was seen at most of the properties.

EPA began VI sampling at the site in November 2014 when they installed sub-slab sampling ports at 11 businesses in the downtown area, near the suspected sources. Many downtown buildings have commercial businesses at street level and residential apartments on upper levels. EPA collected sub-slab samples from residences and businesses above the groundwater plumes. Indoor air samples were also collected when sub-slab samples indicated elevated readings or if the sub-slab areas (crawlspace) were not accessible. In March 2015, EPA personnel installed an additional 80 sub-slab sampling ports at businesses, residential properties, and schools in downtown York [Tetra Tech 2018a]. Quarterly VI sampling began in 2015 and continued through February 2018. Figure 7 shows the indoor air sampling locations that were sampled between 2014 and 2018 and are color-coded based on the year they were initially sampled.

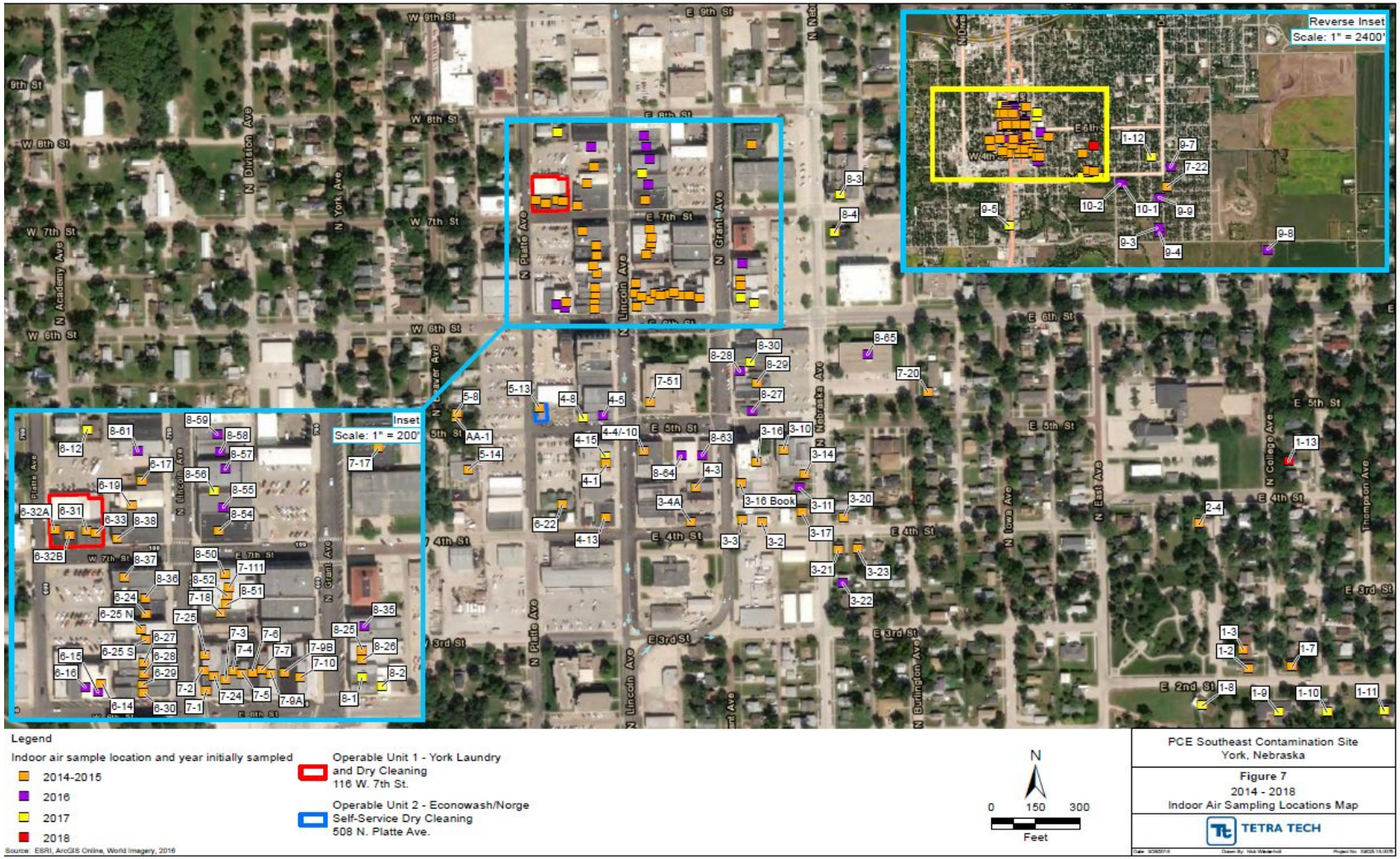

Figure 7. Indoor air sampling locations.

Source – Tetra Tech 2018b

ATSDR analyzed the 2014 to 2018 samples to determine the PCE and TCE levels in the sub-slab or crawlspace, indoor air, and ambient air. Samples were collected in residences and commercial properties in the York area.

ATSDR identified 16 properties that had PCE and TCE concentrations above ATSDR's CVs, as shown in Table 5. Ten of the properties are identified as business (B) or industrial settings, and the remaining six are residential settings. Only one location, property 16B, had both PCE and TCE concentrations above their respective CVs. However, this location is a business and did not exceed EPA's action levels for industrial (business) settings. Table 5 also shows the variation of sampling results within short periods of time at these locations.

EPA has specific action levels for both PCE and TCE. If the concentrations exceed these levels, a removal or remedial action is initiated. EPA's action levels are greater for business and industrial locations because individuals are not in these locations for as long (typically 8 to 10 hours per day) compared to someone in a residential setting (as much as 24 hours per day). EPA's action levels for PCE are 42 µg/m³ (residential), which is very similar to ATSDR's chronic-duration inhalation MRL of 41 µg/m³, and 180 µg/m³ (business/industrial). EPA's action levels for TCE are 2 µg/m³ (residential) and 6 µg/m³ (business/industrial). The ATSDR chronic-duration inhalation MRL for TCE is equal to 0.4 ppb (2 µg/m^3). ATSDR does not have separate CVs for business/industry and residential locations.

In September 2015, VI properties 4B and 5B had concentrations exceeding EPA's action level. Both properties had VMSs installed in July 2015, yet concentrations remained elevated after the systems were installed. ATSDR does not know if the systems were running at the time or why they were elevated shortly after being installed. VMSs that vent gas from beneath a building may not be effective against preferential pathways that bypass the sub-slab soil gas area, such as sewer lines or lateral drains. In EPA's subsequent sampling events at these properties, elevated concentrations were not detected.

Property 6 from Table 5 had concentrations exceeding the PCE CV from January through October 2017. A VMS was installed in December 2017. The maximum PCE concentration throughout 2017 was equal to 97.2 µg/m³, more than 25 times the recommended CV based on cancer effects and more than double the noncancer CV.

Some of the locations in Table 5 either had multiple businesses within the same larger building or adjoining buildings were previously connected but they had interconnected basements or upper-level apartments [EPA 2018]. Also, some of the properties are vacant and are labeled as such. Properties 7 and 9 are two locations that contained a business and apartments that were attached or adjacent to each other. Property 7 had an initial PCE level above the action level in March 2015, yet in June 2015 and September 2015 they were below the action level. The business associated with this property uses VOCs in their daily operations. The elevated reading may have been from some of the chemicals used at the business. Also, the sub-slab sample results for this location were below EPA's site-specific residential screening levels.

Property 9 contained a TCE concentration in March 2016 right at the action level, but the concentrations were below it in September 2015 and June 2016. ATSDR only had indoor air sampling data available to review for this property. Three properties (8, 15B, and 16B) had higher PCE or TCE concentrations in the

indoor air when compared to the sub-slab. This is an indication that there may be a separate source of PCE or TCE inside the building or residence not related to the underground source. Sub-slab samples are closer to the source and normally have higher concentrations than indoor air samples.

TCE is widely used as a general-purpose solvent in adhesives, lubricants, paints, varnishes, paint strippers, pesticides, and cold metal cleaners. It is possible that a solvent may have been used at the business or one of the individual apartments prior to the sample being collected. Neither of these locations had a VMS installed. At some locations, VMSs were installed to help remove vapors in adjoining residential properties or a sensitive population (young children or women of childbearing age) may have resided there.

Five of the residential locations initially had PCE or TCE concentrations above their CVs. By the next sampling round, the concentrations were either below the CV or were non-detectable.

In February 2018, EPA completed a round of VI confirmation sampling to ensure the VMSs were operating as intended. The sampling results show that the systems are keeping the concentrations below ATSDR CVs.

Figure 12 in Appendix A shows the sub-slab vapor concentration map for properties during July 2017. Sub-slab vapor sample results showed high PCE concentrations (>10,000 µg/m^3) at or near the former dry cleaner buildings of Foster/Valet Cleaners, Econowash/Norge, and York Laundry and Dry Cleaner (YLDC). Similar PCE concentrations were also found in sub-slab vapor samples collected at Culligan Water [Tetra Tech 2015, 2016].

The parking lot south of the YLDC was formerly a steam-heat generating plant, and a network of steam tunnels connected this facility to many older buildings in downtown York [Tetra Tech 2018a]. These steam tunnels may have been a route for contaminants to move. Figure 13, in Appendix A, shows the locations of the steam tunnels. ATSDR cannot determine the extent to which the steam tunnels may have served, or may still serve, as a conduit for vapors because samples were not collected from them.

Table 5. Sampled properties with indoor air results exceeding ATSDR CVs.

VI property number	Sample date	Contaminant concentration µg/m³	ATSDR comparison value µg/m³ (EPA action level for business)	Contaminant
1(VMS 7/9/15) Vacant	3/5/15	47	3.8	PCE
1 Vacant	9/1/15	14	3.8	PCE
1 Vacant	02/18	0.34U	3.8	PCE
2B/R (VMS 7/17/15)	6/3/15	3.1	0.21	TCE
2B/R	02/18	0.27U	0.21	TCE
3B (VMS 7/18/15)	3/4/15	11	3.8 (180)	PCE
3B	9/1/15	40.9	3.8 (180)	PCE
3B	11/5/15	3.05	3.8 (180)	PCE
3B	02/18	0.88	3.8 (180)	PCE
4B (VMS 7/13/15)	3/4/15	3.1	0.21 (6)	TCE
4B	9/1/15	23.4	0.21 (6)	TCE
4B	11/5/15	1.07	0.21 (6)	TCE
4B	7/11/16	0.62 J	0.21 (6)	TCE
4B	02/18	0.27U	0.21 (6)	TCE
5B (VMS 7/10/15)	3/6/15	1.4U	3.8 (180)	PCE
5B	9/1/15	310	3.8 (180)	PCE
5B	11/5/15	0.475	3.8 (180)	PCE
5B	02/18	0.34U	3.8 (180)	PCE
6R (VMS 12/15/17)	1/19/17	57	3.8	PCE

VI property number	Sample date	Contaminant concentration µg/m³	ATSDR comparison value µg/m³ (EPA action level for business)	Contaminant
6R	4/12/17	45	3.8	PCE
6R	7/11/17	97.2	3.8	PCE
6R	8/30/17	96	3.8	PCE
6R	10/18/17	60	3.8	PCE
6R	02/18	3.2	3.8	PCE
7B/R	3/5/15	63	3.8	PCE
7B/R	6/3/15	11	3.8	PCE
7B/R	9/1/15	14	3.8	PCE
8R*	7/12/16	130 (sub-slab is 59.9)	3.8	PCE
9B/R	9/2/15	0.752	0.21	TCE
9B/R	3/23/16	2.15	0.21	TCE
9B/R	6/20/16	0.44J	0.21	TCE
9B/R	1/19/17	0.27U	0.21	TCE
10B Vacant	3/6/15	17	3.8 (180)	PCE
10 B Vacant	6/2/15	39	3.8 (180)	PCE
10B Vacant	9/2/15	139	3.8 (180)	PCE
10B Vacant	11/5/15	14.9	3.8 (180)	PCE
11B Vacant	3/4/15	51	3.8 (180)	PCE
11B Vacant	1/19/17	0.34U	3.8 (180)	PCE

VI property number	Sample date	Contaminant concentration µg/m³	ATSDR comparison value µg/m³ (EPA action level for business)	Contaminant
11B Vacant	4/11/17	0.63	3.8 (180)	PCE
12B	3/6/15	1.1U	0.21 (6)	TCE
12B	9/2/15	19.9	0.21 (6)	TCE
12B	11/5/15	1.13	0.21 (6)	TCE
12B	3/22/16	0.43U	0.21 (6)	TCE
13B	1/19/17	58	3.8 (180)	PCE
13B	4/12/17	2.3	3.8 (180)	PCE
14B*	1/18/17	51	3.8 (180)	PCE
14B*	4/12/17	45	3.8 (180)	PCE
14B*	7/11/17	46.8 (sub-slab conc. Is 28.1)	3.8 (180)	PCE
14B*	8/30/17	42.46	3.8 (180)	PCE
14B*	10/18/17	50 (sub-slab conc. Is 36.23)	3.8 (180)	PCE
15B*	7/11/17	20 (sub-slab conc. Is undetectable)	0.21 (6)	TCE
15B*	8/30/17	0.27U	0.21 (6)	TCE
15B*	10/18/17	0.27U (sub-slab conc. Is undetectable)	0.21 (6)	TCE
16B	9/2/15	50.2	3.8 (180)	PCE
16B	11/5/15	35.5	3.8 (180)	PCE

VI property number	Sample date	Contaminant concentration µg/m³	ATSDR comparison value µg/m³ (EPA action level for business)	Contaminant
16B	3/23/16	29.2	3.8 (180)	PCE
16B	6/20/16	80	3.8 (180)	PCE
16B	9/2/15	1.61	0.21 (6)	TCE
16B	11/5/15	1.34	0.21 (6)	TCE
16B	3/23/16	0.43U	0.21 (6)	TCE
16B	6/20/16	2.6	0.21 (6)	TCE

Legend:
µg/m³ - micrograms per cubic meter of air PCE - Perchloroethylene TCE - Trichloroethylene
B - business property CV – Comparison Value
J – estimated concentration
R - residential
U – contaminant was not detected at or above the detection level
VMS – Vapor mitigation system

* - sub-slab concentration lower than indoor air concentration

6.6. Reducing and Eliminating Exposure

VMSs have been installed at several properties in the downtown area where VI presents a potential health threat. Since 2011, 27 VMSs have been installed in the residences and businesses that had PCE or TCE concentrations in the air above EPA action levels [EPA 2018]. Nine of the systems installed are in the 100 block of E. 6th Street or the adjoining 600 block of N. Lincoln Avenue [Tetra Tech 2018a].

The VMSs installed to reduce chemical vapors inside homes and businesses are very similar to radon mitigation systems that reduce radon levels in homes and other buildings. VMSs work by drawing contaminated air out from beneath a structure and venting the contaminated air into the atmosphere, where it quickly dissipates. Such a system prevents soil vapors from entering a building by using a fan to create a slight vacuum beneath the slab, relative to the interior air pressure, to draw the vapors from below the slab. A pipe then vents the soil vapors to the air above the home. Figure 9, in Appendix A, shows a VMS vent pipe on the exterior of the home. Figure 8 shows the sub-slab vapor plume and the locations of the VMS [USEPA 2021].

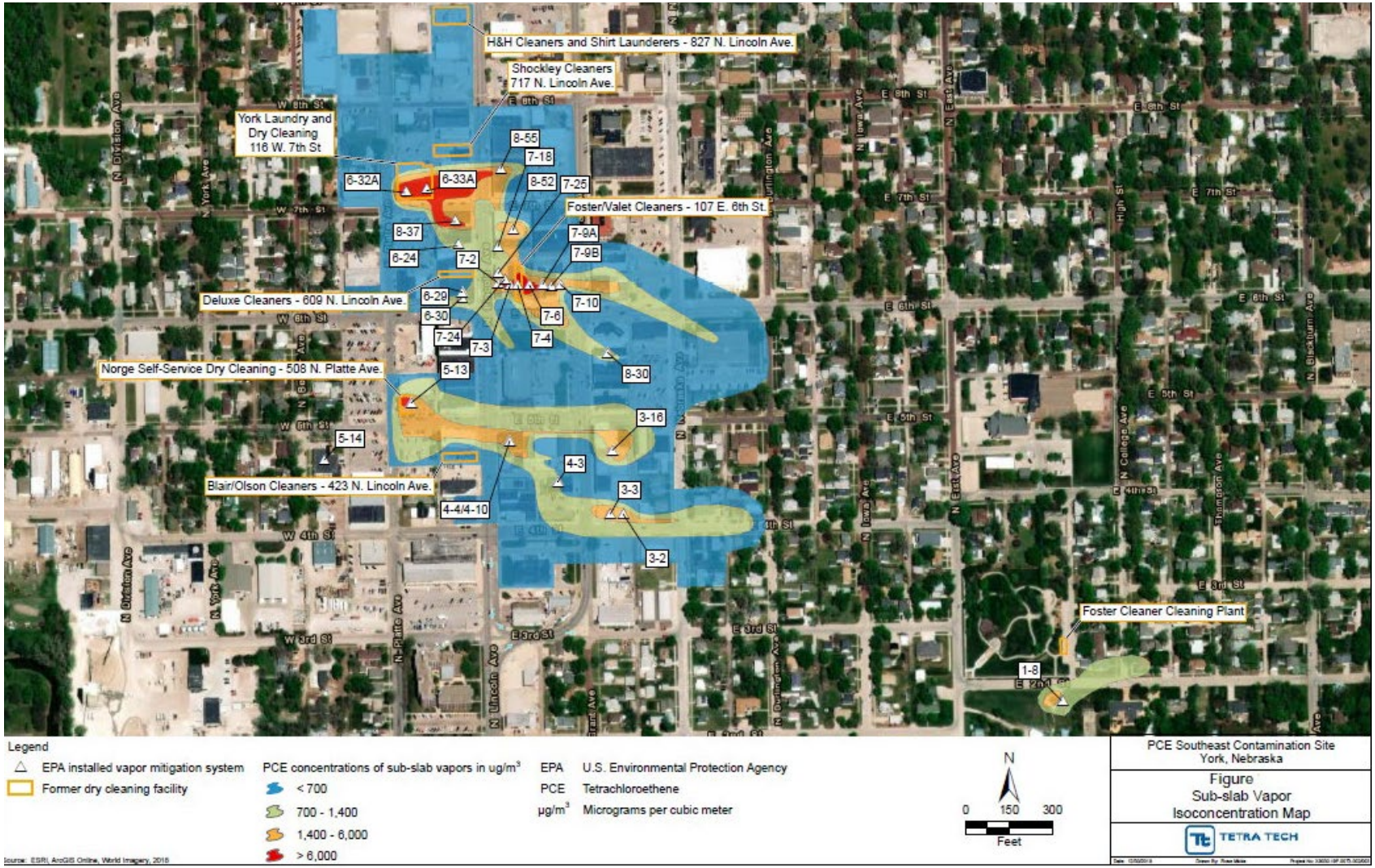

Figure 8. Sub-slab vapor plume with VMS locations.

VMS – Vapor mitigation system
Source -Tetra Tech 2019

Figure 8 identifies the locations where VMSs have been installed and indicates the type of receptor population associated with each. As previously stated, many buildings in downtown York have commercial businesses at the street level and residential apartments above them. These locations are considered residential. The locations that have sensitive populations present for more than a few hours are also listed and are considered residential. Not all locations in Table 6 had concentrations above ATSDR CVs. At the time of this report, the following properties were listed as they are in Table 6. Due to remedial actions, some of these property designations could change.

Table 6. Property numbers with vapor mitigation systems (VMSs) installed.

Property number	Receptor population
3B	Business
17B	Business
18	Sensitive
19/20	Residential
21B	Business
22	Sensitive
1	Sensitive
23	Sensitive
24	Residential
25	Residential
4B	Business
5B	Business
26B	Business
27	Residential
28	Residential
29	Residential
30	Residential
31	Residential
32	Residential
33	Residential
34	Sensitive
2	Residential
35B	Business
36B	Business
37	Residential
38	Sensitive
6	Residential

Source - EPA 2018

Table 7. PCE Southeast Contamination Site completed and potential* exposure pathways.

Source	Medium	Exposure Point	Route of Exposure	Exposed Population
Contaminated groundwater	Groundwater	Private well water	Ingestion Inhalation Skin (Dermal)	Past residents using contaminated well water
Contaminated soil at the site*	Soil	Subsurface	Ingestion Skin (Dermal)	Past, present, and future workers who contact contaminated subsurface soil
Contaminated air inside homes or business	Air	Indoor air	Inhalation	Persons who reside(d) in residences or work(ed) at a business where elevated VOCs were detected in indoor air

PCE – Perchloroethylene

*ATSDR is considering exposure to subsurface soils for workers as potential due to the uncertainty that workers were exposed to contaminated soils at depth.

Exposure Pathway and Health Effects Analysis

ATSDR evaluates exposure pathways to determine how a person could contact, or be exposed to, contaminants in the environment. An exposure pathway is the link between environmental contaminants and people. People can be exposed to contaminated media such as air, soil, or water through different exposure routes. The extent to which exposure can harm people depends upon specific conditions, including the route of exposure, the level of contamination, and frequency and duration of exposure. Sensitive populations, such as children, pregnant women, elderly, sick, or immunocompromised persons, require special considerations. People can be exposed to contaminants in environmental media in one or more of the following ways:

- Ingestion of contaminants in groundwater, surface water, food, and soil
- Inhalation of contaminants in air (dust, gases, or vapors), including those that have volatilized or been emitted from groundwater, surface water, and soil
- Skin (dermal) contact with contaminants in air, soil, and water

ATSDR identifies an exposure pathway as "complete, " " potential," or "eliminated." An exposure pathway is considered completed if all five of these elements are present:

- Source of contamination (an abandoned business)
- Environmental media and transport mechanism (air, groundwater, or soil)
- Point of exposure (private well, inside a residence)
- Route of exposure (breathing, drinking, eating, or touching)
- Receptor population (people that are actually or potentially exposed)

A pathway is considered potential if one of the five elements is missing, but there isn't enough information to eliminate or exclude it. An exposure pathway is eliminated if one or more of the five elements is missing and will never be present [ATSDR 2005]. Exposure pathways can also be "past," "current," or "future." Table 7 summarizes ATSDR's exposure pathway analysis for the PCE Southeast Contamination Site.

7. Children's Health Considerations

In communities faced with environmental contamination, children could be at a greater risk than adults from exposure to hazardous substances. The physical differences between children and adults demand special emphasis. This public health assessment uses child-specific exposure factors, such as body weights and intake rates, as the basis for calculating exposures to contaminants in drinking water, soil, and air. Children's lower body weight and relatively higher water ingestion rates result in a greater dose of hazardous substance per kilogram (kg) body weight.

An infant who drinks formula prepared with contaminated drinking water is likely to have a higher exposure dose because of the large volume of water they consume relative to their body size. PCE and TCE intake from the ambient air is expected to be greater in infants and children than adults because infants and children have increased ventilation rates and cardiac output per kg of body weight. The resulting exposure doses for children are higher than for adults. ATSDR also considers children at greater risk than adults from PCE and TCE exposure because young children and unborn children of pregnant women are more sensitive to the effects of PCE and TCE. Two of the locations that had VMSs installed were a daycare and a preschool.

Limitations/Data Gaps

ATSDR used the available monitoring data to assess the potential impact of site contaminants on the community's health. However, several limitations can affect ATSDR's ability to know the full extent of contamination and impact.

Other limitations include the following:

- Domestic water well registration was not required in Nebraska before September 30, 1993, so there is limited information in the Nebraska Department of Natural Resources (NDNR) registered well database [NDNR 2010]. There are no records for many of the older domestic wells in the area, and many homeowners are uncertain about the depth of their wells.
- The level of exposure a person receives depends on the concentration of PCE and TCE in the well at a given time. However, sampling data is either unavailable or very limited, which makes it difficult to determine past contamination. Past exposure to contaminants that entered any individual building through VI is largely unknown because there was very limited or no indoor air monitoring before 2014. Some locations were first sampled in 2017. Recent indoor air data shows variability in contaminant concentrations at different times in the same building. Some buildings might be more susceptible than others to soil gas intrusion. A few locations had higher concentrations indoors compared to the sub-slab, indicating that there might have been other sources unrelated to the groundwater and soil vapor plume.
- Steam tunnels were not sampled, so no data exist to characterize VOC concentrations within the tunnels or the potential for the tunnels to serve as a conduit for vapors.

8. Exposures to PCE and TCE in private well water

In 2010, EPA initially found PCE contamination in eight residential water wells, ranging from 9.6 ppb to 32 ppb. The maximum PCE concentration of 32 ppb was below ATSDR's EMEG of 56 ppb for children, but greater than the CREG of 12 ppb. One of these wells also contained TCE at a concentration of 5.9 ppb, but this well was specifically used for irrigation. It was not the main source of water for the residence.

EPA conducted additional private well sampling in 2011, 2012, and 2014, and higher levels of PCE and TCE were detected. The maximum PCE and TCE concentrations detected in household water between 2011 and 2014 occurred in January 2014 from a private well on property J (Table 1). A WHF unit was installed at this residence sometime after April 2011 and was sampled in September 2012. The post-filtration samples identified PCE levels as high as 64 ppb and TCE as high as 21 ppb. Despite the unit being in operation, the sampled water concentrations were above ATSDR's chronic EMEG for children (56ppb), CREG and MCL for PCE; and above ATSDR's chronic EMEG (3.5 ppb for children and 13 ppb for adults) and CREG for TCE from April 2011 through January 2014. Samples collected in April and July 2014 had no detections of PCE or TCE. This was the only well that had post-filtration PCE concentrations above the chronic EMEG. The residence was connected to the public water supply in 2015.

Drinking (private) well water

In this section, ATSDR calculated estimated exposure doses for individuals who used this well water solely for drinking. ATSDR calculated combined estimated doses from multiple uses of water in the next section of this assessment. ATSDR used the maximum PCE (64 ppb) and TCE (21 ppb) concentrations detected in the wells for the dose calculations. Table 8 and Table 9 below show the central tendency exposure (CTE) and reasonable maximum exposure (RME) doses for each age group. The CTE and RME scenarios approximate the 50th and 95th percentile exposures, respectively, for each age group.

We can evaluate the likelihood of noncancer health hazards by calculating hazard quotients (HQ) for individual contaminants. The HQ is the ratio of a single substance exposure dose over a specified time to a health guideline dose (such as an MRL or reference dose) for that substance derived from a similar exposure time frame. If the HQ calculated is equal to or less than 1, noncancer adverse health effects are not expected to result from exposure to the contaminant. If the HQ is greater than 1, further toxicological evaluation is warranted by reviewing the critical and supporting studies used to develop the health guideline.

Using the chronic RME exposure scenario at property J, ATSDR determined the HQ of 1 was exceeded in the past for TCE in water for all age groups. The highest concentration was found post (after) filtration. In the CTE scenario, only children younger than 1 year exposed to the maximum TCE concentration exceeded the HQ of 1. For PCE, only children younger than 1 year in the RME scenario exceeded the HQ of 1 for PCE. No age group had a HQ above 1 in the CTE scenario for PCE.

Table 8. Default exposure doses for chronic exposure to perchloroethylene (PCE) in drinking water at 0.064 mg/L, along with noncancer hazard quotients and cancer risk estimates[*]

Exposure Group	CTE Dose (mg/kg/day)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Dose (mg/kg/day)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	0.0049	0.61	-	1	0.0091	1.1 [†]	-	1
1 to < 2 years	0.0014	0.17	-	1	0.0037	0.46	-	1
2 to < 6 years	0.0012	0.15	-	4	0.0031	0.39	-	4
6 to < 11 years	0.00092	0.11	-	5	0.0025	0.32	-	5
11 to < 16 years	0.00063	0.079	-	1	0.0020	0.25	-	5
16 to < 21 years	0.00065	0.081	-	0	0.0020	0.25	-	5
Total Child	-	-	4.4E-7	12	-	-	1.6E-6 [‡]	21
Adult	0.0011	0.13	3.4E-7	12	0.0026	0.32	2.3E-6 [‡]	33
Pregnant Women	0.0010	0.13	-	-	0.0026	0.32	-	-
Breastfeeding Women	0.0013	0.16	-	-	0.0027	0.34	-	-
Birth to < 21 years plus 12 years during adulthood[§]	-	-	-	-	-	-	2.4E-6 [‡]	33

"-" = Not applicable

Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher); yrs = years

[*] ATSDR's PHAST v2.4.1.0 generated these calculations. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.008 mg/kg/day. The cancer risks were calculated using the cancer slope factor (CSF) of 0.0021 $(mg/kg/day)^{-1}$.

[†] Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

‡ Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
§ This cancer risk represents a scenario where children are likely to continue to live in their childhood home as adults.

Table 9. Default exposure doses for chronic exposure to trichloroethylene (TCE) in drinking water at 0.021 mg/L along with noncancer hazard quotients*

Exposure Group	CTE Dose (mg/kg/day)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Dose (mg/kg/day)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	0.0016	3.2 †	-	1	0.0030	6.0 †	-	1
1 to < 2 years	0.00045	0.90	-	1	0.0012	2.4 †	-	1
2 to < 6 years	0.00041	0.81	-	4	0.0010	2.1 †	-	4
6 to < 11 years	0.00030	0.60	-	5	0.00083	1.7 †	-	5
11 to < 16 years	0.00021	0.42	-	1	0.00065	1.3 †	-	5
16 to < 21 years	0.00021	0.42	-	0	0.00065	1.3 †	-	5
Total Child	-	-	6.2E-6 ‡	12	-	-	1.9E-5 ‡	21
Adult	0.00034	0.69	2.5E-6 ‡	12	0.00085	1.7 †	1.7E-5 ‡	33
Pregnant Women	0.00033	0.67	-	-	0.00084	1.7 †	-	-
Breastfeeding Women	0.00043	0.86	-	-	0.00088	1.8 †	-	-
Birth to < 21 years plus 12 years during adulthood §	-	-	-	-	-	-	2.5E-5 ‡	33

"-" = Not applicable
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher); yrs = years

* ATSDR's PHAST v2.4.1.0 generated these calculations. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0005 mg/kg/day. The cancer risks were calculated using the cancer slope factors (CSFs) of 0.022 [NHL], 0.016 [liver], 0.0093 [kidney] $(mg/kg/day)^{-1}$ and age-dependent adjustment factors.

† Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

‡ Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

ATSDR used the exposure doses from Table 8 and Table 9 to compare with results from scientific studies to determine the likelihood for adverse health effects in individuals.

PCE

The only age group that had a HQ greater than 1 in Table 8 was younger than age 1 year. ATSDR's chronic oral MRL for PCE is equal to 0.008 mg/kg/day. The default exposure dose for the birth to 1 year age group in Table 8 is equal to 0.0091 mg/kg/day, which is slightly above the MRL. ATSDR reviewed the studies that the MRL was derived from and found the level at which adverse health effects were noted in the study was equal to 2.3 mg/kg/day [Cavalleri 1994; Gobba 1998]. The exposure doses from drinking PCE-contaminated water at 64 ppb are well below the adverse health effect level observed in the studies. ATSDR does not expect adverse health effects at this level of exposure.

ATSDR also calculated default exposure doses for the next highest concentration of PCE (32 ppb) and found that none of the age groups had a HQ above 1 for either the CTE or RME scenario. The table containing the doses for PCE at 32 ppb is listed as Table 24 in Appendix B.

TCE

All age groups exceeded the HQ of 1 in Table 9 for the RME scenario and those younger than age 1 year in the CTE scenario. ATSDR's chronic oral MRL for TCE is 0.0005 mg/kg/day. The oral TCE MRL is based on the results of two critical oral exposure studies that reported immunotoxicity (decreased plaque-forming cell response and increased delayed-type hypersensitivity) in mice [Peden-Adams 2006] and decreased thymus weight in female mice [Keil 2009]. Low to very low levels of evidence indicate the potential for developmental cardiotoxicity in children of mothers exposed during pregnancy, but the studies available are not of sufficient quality to provide an exposure dose or air concentration at which developmental cardiotoxicity, if any, may occur [ATSDR 2025]. ATSDR reviewed the studies the MRL was derived from to determine at what level adverse health effects occurred.

In mice pups exposed via drinking water from gestation day 0 until 3 or 8 weeks of age, the Peden-Adams study showed decreased plaque forming cell response at 3 and 8 weeks as well as increased delayed-type sensitivity at 8 weeks at the LOAEL dose of 0.37 mg/kg/day. Exposure occurred from placental and lactational transfer and from pup ingestion of drinking water [Peden-Adams 2006].

Based on a 30-week drinking water, mouse study, Keil et al. showed immunological effects in female mice resulting in decreased thymus weight and increased serum levels of immunoglobulin G (IgG) and selected autoantibodies at an administered oral dose of 0.35 mg/kg/day (the study LOAEL). Using physiologically based pharmacokinetic (PBPK) modeling, this mouse LOAEL was converted to a 99th percentile human equivalent dose $HED_{99,LOAEL}$ of 0.048 mg/kg/day.

The estimated exposure doses for all age groups evaluated in York shown in Table 9 are below the LOAEL of 0.37 mg/kg/day effect level and the $HED_{99,LOAEL}$ of 0.048 mg/kg/day. Individuals drinking water at this level of contamination would not be expected to experience adverse health effects from it.

Combined Exposures from Well Water Use

In the previous section, ATSDR discussed the potential hazards of only drinking the contaminated water. In this section, ATSDR considered the potential risks of using the water in addition to being the source of drinking water. Individuals that live outside the downtown area and had PCE or TCE concentrations in their well water were potentially exposed to the contaminants when they used the water for laundering, cooking, or showering. The contaminants may have volatilized from the water into the air within the residence and individuals may have been breathing (inhaling) in the PCE or TCE while they were in their residence.

ATSDR used their Shower and Household Water-use Exposure (SHOWER) model to estimate the indoor PCE and TCE air concentrations based upon the concentrations detected in private wells [ATSDR 2021]. ATSDR used the maximum concentrations and the second highest TCE concentrations found in wells when using the SHOWER model, because there were varying concentrations in the different wells. ATSDR used the SHOWER model's default which assumes four persons resided in the home, and they all took sequential showers, with no fan on, and the residents being in the home all day. According to the 2011 American Community Survey conducted by the U.S. Census Bureau, the typical household (50th percentile) has two persons and the 90th, 95th, and 98th percentile households have four, five, and six persons, respectively [ACS 2011].

The target person in ATSDR's SHOWER model is the fourth person to take a shower in the home each day. The RME scenario for the four-person household assumes three people take 10-minute consecutive showers and the fourth person takes a 15-minute shower, each followed by 5-minute bathroom stays. Infants younger than age 1 year old don't shower, but they could be exposed when taking a bath. Their inhalation and dermal exposures from a 20-minute bath scenario are comparable to the RME inhalation and dermal exposures from the default shower scenario.

ATSDR calculated estimated average daily exposure from breathing air that contained the volatilized PCE and TCE during and after showering and calculated the combined exposures of drinking the water and dermal exposures from showering in it. The average daily exposure concentration in the different age groups for each contaminant is provided in the results. The results of ATSDR's modeling of PCE and TCE while showering and residing in the home are listed in several tables below.

PCE

ATSDR determined from the SHOWER model that residents' inhalation exposures to PCE in water containing 64 ppb would be exposed to 46 $\mu g/m^3$ in air in the RME scenario, which is above the ATSDR inhalation health guideline (41 $\mu g/m^3$). The HQ of 1 in Table 10 was slightly exceeded for all age groups in the RME scenario. In the CTE scenario, no age groups exceeded the HQ of 1.

Table 10. Default inhalation only exposure concentrations for chronic exposure to perchloroethylene (PCE) in household water at 64 µg/L, along with noncancer hazard quotients and cancer risk estimates.[*]

Exposure Group	CTE Adjusted EPC (µg/m³)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Adjusted EPC (µg/m³)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	21	0.50	-	1	46	1.1 [†]	-	1
1 to < 2 years	21	0.50	-	1	46	1.1 [†]	-	1
2 to < 6 years	21	0.50	-	4	46	1.1 [†]	-	4
6 to < 11 years	21	0.50	-	5	46	1.1 [†]	-	5
11 to < 16 years	21	0.50	-	1	46	1.1 [†]	-	5
16 to < 21 years	21	0.50	-	0	46	1.1 [†]	-	5
Total Child	-	-	8.2E-7	12	-	-	3.2E-6 [‡]	21
Adult	21	0.50	8.2E-7	12	46	1.1 [†]	5.1E-6 [‡]	33
Pregnant Women	21	0.50	-	-	46	1.1 [†]	-	-
Breastfeeding Women	21	0.50	-	-	46	1.1 [†]	-	-
Birth to < 21 years plus 12 years during adulthood [§]	-	-	-	-	-	-	5.1E-6 [‡]	33

"-" = Not applicable

Abbreviations: adjusted EPC = the exposure point concentration (EPC) times the appropriate exposure factors; µg/m³ = micrograms per meter cubed; CTE = central tendency exposure (typical); RME = reasonable maximum exposure (higher); yrs = years

[*] ATSDR's PHAST v2.4.1.0 generated these calculations. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 41 µg/m³ and the cancer risks were calculated using the inhalation unit risk of 2.6E-07 $(\mu g/m^3)^{-1}$.

[†] Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

[‡] Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

The combined dermal and ingestion doses for each age group are listed below. The HQ of 1 was only exceeded for the birth to age 1 year group. The oral MRL for PCE is equal to 0.008 mg/kg/day and the combined dose for children younger than age 1 year in Table 11 is slightly higher at 0.011 mg/kg/day in the RME scenario. ATSDR reviewed the studies the MRL was based upon and found the dose used to derive the MRL that identified the lowest observed adverse effect level (LOAEL) at 2.3 mg/kg/day [Cavalleri 1994; Gobba 1998]. This concentration is greater than the 0.011 mg/kg/day exposure level estimated for those younger than age 1 year.

Table 11. Default combined ingestion and dermal exposure doses for chronic exposure to perchloroethylene (PCE) in household water at 64 µg/L, along with noncancer hazard quotients and cancer risk estimates.*

Exposure Group	CTE Dose (mg/kg/day)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Dose (mg/kg/day)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	0.0059	0.74	-	1	0.011	1.3 †	-	1
1 to < 2 years	0.0024	0.29	-	1	0.0052	0.64	-	1
2 to < 6 years	0.0021	0.26	-	4	0.0044	0.55	-	4
6 to < 11 years	0.0016	0.20	-	5	0.0035	0.44	-	5
11 to < 16 years	0.0012	0.15	-	1	0.0028	0.35	-	5
16 to < 21 years	0.0012	0.14	-	0	0.0027	0.34	-	5
Total Child	-	-	6.9E-7	12	-	-	2.1E-6 ‡	21
Adult	0.0015	0.19	5.0E-7	12	0.0033	0.42	3.0E-6 ‡	33
Pregnant Women	0.0015	0.19	-	-	0.0033	0.42	-	-
Breastfeeding Women	0.0018	0.23	-	-	0.0034	0.43	-	-
Birth to < 21 years plus 12 years during adulthood §	-	-	-	-	-	-	3.2E-6 ‡	33

"-" = Not applicable

Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; RME = reasonable maximum exposure (higher); yrs = years

* ATSDR's PHAST v2.4.1.0 generated these calculations. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.008 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 0.0021 $(mg/kg/day)^{-1}$.

† Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

‡ Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table 12 provides the total cancer risk for each age group using PCE-contaminated water at 64 ppb. It shows the total cancer risk for individuals who could be exposed from birth to age 21 years, from birth to age 33 years, and an adult potentially exposed for 33 years. The total cancer risk for individuals drinking and using PCE-contaminated water for multiple purposes at 64 ppb would be in the 5.3 E-6 to 8.3 E-6 range. ATSDR does not consider this a concern for increased cancer risk.

Table 12. Total cancer risk from using water with PCE at 64 ppb.

Age	*Systemic (Ingestion and Dermal)*	*Inhalation*	*Total Cancer Risk*
Total child (Birth to <21 Years)	2.1E-6	3.2E-6	5.3E-6
Birth to 33 Years	3.2E-6	5.1E-6	8.3E-6
Adult 33 Years	3.0E-6	5.1E-6	8.1E-6

PCE - Perchloroethylene

TCE at 21ppb

The adjusted exposure point concentration in Table 13 for the RME scenario is equal to 21 µg/m³ or 3.9 ppb, which is above the effect level of the Keil (2009) study. The TCE inhalation MRL for intermediate and chronic exposures is equal to 2 µg/m^3 (0.4 ppb) with an uncertainty factor of 100 for immunological effects. In the CTE scenario, the exposure point concentration was equal to 9.2 µg/m^3 or 1.7 ppb. This level is also above the MRL.

Table 13. Default inhalation only exposure concentrations for chronic exposure to trichloroethylene (TCE) in household water at 21 µg/L, along with noncancer hazard quotients.[*]

Exposure Group	CTE Adjusted EPC (µg/m³)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Adjusted EPC (µg/m³)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	9.2	4.4 [†]	-	1	21	10 [†]	-	1
1 to < 2 years	9.2	4.4 [†]	-	1	21	10 [†]	-	1
2 to < 6 years	9.2	4.4 [†]	-	4	21	10 [†]	-	4
6 to < 11 years	9.2	4.4 [†]	-	5	21	10 [†]	-	5
11 to < 16 years	9.2	4.4 [†]	-	1	21	10 [†]	-	5
16 to < 21 years	9.2	4.4 [†]	-	0	21	10 [†]	-	5
Total Child	-	-	1.0E-5 [‡]	12	-	-	3.6E-5 [‡]	21
Adult	9.2	4.4 [†]	5.8E-6 [‡]	12	21	10 [†]	3.6E-5 [‡]	33
Pregnant Women	9.2	4.4 [†]	-	-	21	10 [†]	-	-
Breastfeeding Women	9.2	4.4 [†]	-	-	21	10 [†]	-	-
Birth to < 21 years plus 12 years during adulthood [§]	-	-	-	-	-	-	4.9E-5 [‡]	33

"-" = Not applicable

Abbreviations: adjusted EPC = the exposure point concentration (EPC) times the appropriate exposure factors; µg/m³ = micrograms per meter cubed; CTE = central tendency exposure (typical); RME = reasonable maximum exposure (higher); yrs = years

[*] ATSDR's PHAST v2.4.1.0 generated these calculations. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 2.1 µg/m³ and the cancer risks were calculated using the inhalation unit risks of 2.1E-06 [NHL], 1.0E-06 [liver], 1.0E-06 [kidney] $(\mu g/m^3)^{-1}$ and age-dependent adjustment factors.

† Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table 14. Default combined ingestion and dermal exposure doses for chronic exposure to trichloroethylene (TCE) in household water at 21 µg/L, along with noncancer hazard quotients.[*]

Exposure Group	CTE Dose (mg/kg/day)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Dose (mg/kg/day)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	0.0017	3.4 †	-	1	0.0031	6.2 †	-	1
1 to < 2 years	0.00053	1.1 †	-	1	0.0013	2.7 †	-	1
2 to < 6 years	0.00048	0.95	-	4	0.0011	2.3 †	-	4
6 to < 11 years	0.00036	0.71	-	5	0.00092	1.8 †	-	5
11 to < 16 years	0.00025	0.51	-	1	0.00072	1.4 †	-	5
16 to < 21 years	0.00025	0.51	-	0	0.00071	1.4 †	-	5
Total Child	-	-	7.0E-6 ‡	12	-	-	2.0E-5 ‡	21
Adult	0.00039	0.77	2.8E-6 ‡	12	0.00091	1.8 †	1.8E-5 ‡	33
Pregnant Women	0.00038	0.75	-	-	0.00091	1.8 †	-	-
Breastfeeding Women	0.00047	0.94	-	-	0.00094	1.9 †	-	-
Birth to < 21 years plus 12 years during adulthood §	-	-	-	-	-	-	2.7E-5 ‡	33

"-" = Not applicable
Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; RME = reasonable maximum exposure (higher); yrs = years

* ATSDR's PHAST v2.4.1.0 generated these calculations. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0005 mg/kg/day and the cancer risks were calculated using the cancer slope factors of 0.022 [NHL], 0.016 [liver], 0.0093 [kidney] $(mg/kg/day)^{-1}$ and age-dependent adjustment factors.

† Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

‡ Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further

ATSDR reviewed the studies from which the MRL was derived. Based on a 30-week, drinking water, mouse study, Keil et al. showed immunological effects in female mice resulting in decreased thymus weight and increased serum levels of IgG and selected autoantibodies at an administered oral dose of 0.35 mg/kg/day (the study LOAEL). Using PBPK modeling, the mouse oral LOAEL was converted to a 99th percentile human equivalent concentration $HEC_{99,LOAEL}$ of 33 ppb (180 µg/m^3) in air [Keil 2009].

ATSDR used the SHOWER model to estimate an air exposure point concentration from using household water with 21 µg/L of TCE. As shown in Table 13, the maximum EPC (21 µg/m^3) is below the HEC of 180 µg/m^3 for immunological effects [Keil 2009].

ATSDR used the SHOWER model to estimate a combined ingestion and dermal dose. As shown in Table 14, ingestion/dermal dose for adults and pregnant women (0.00091 mg/kg/day) and the maximum of 0.0031 mg/kg/day for infants, are well below the HED of 0.048 mg/kg/day and the LOAEL of 0.37 mg/kg/day for immunological effects [Keil 2009; Peden-Adams 2006].

ATSDR also calculated the excess cancer risk to someone drinking and using the TCE-contaminated water at 21 µg/L for showering, laundering, cooking, and other activities. Table 14 shows the cancer risk for different age groups based upon someone systemically exposed to TCE at 21 µg/L through the ingestion and dermal routes. The systemic cancer risks are added to the shower inhalation cancer risks (Table 13) to get the total cancer risk from drinking and showering (Table 15).

Table 15. Total cancer risk from using water with TCE at 21 ppb.

Age	*Systemic (Ingestion and Dermal)*	*Inhalation*	*Total Cancer Risk*
Total child (Birth to <21 Years)	2.0E-05	3.6E-05	5.6E-05
Birth to 33 Years	2.7E-05	4.9E-05	7.6E-05
Adult 33 Years	1.8E-05	3.6E-05	5.4E-05

If an individual was exposed at this concentration from birth to age 33 years, their total cancer risk would be greater than seven excess cancer cases per 100,000 people (7.6E-5). ATSDR does not consider this a concern for increased cancer risk, but the level is based upon some uncertainty. The maximum water concentration was detected in January 2014 from property J, but sampling conducted in April and July of 2014 showed no detections of TCE. Sampling of the same well in 2012 identified TCE at a level of 14 ppb.

ATSDR used the maximum concentration in the water and assumed the individual was drinking the most water and taking the longest showers. Over time the concentration would most likely vary somewhat

and not stay consistent. The individual might not drink two liters of water per day or take lengthy showers.

ATSDR assumed the worst-case scenario for each exposure route to the water and calculated the cancer risk. The residence where these TCE and PCE concentrations were detected have since been connected to the public water supply. Therefore, the exposure has stopped and might not have lasted 33 years (actual risk may be lower than the estimate). ATSDR determined that exposure to the maximum PCE concentration did not exceed effect levels for PCE. Appendix C contains a discussion of potential health effects of PCE and TCE.

Most of the wells affected were decommissioned (taken out of service), and residents in areas downgradient of the site accepted the offer to be connected to the public water supply. Thus, exposures to PCE and TCE were expected to be below the MCL. Residents own the WHF units and must maintain them. Past sampling of one of these units has shown that the filter must be maintained for the contaminants to be trapped in the filter. If the filter isn't maintained according to the manufacturer's recommendations, contaminants can pass through the filter and potentially cause exposure(s). ATSDR recommends residents communicate with EPA and NDEE if they have any questions about their WHF units.

The previous TCE calculations used the maximum concentration. ATSDR also was concerned about the next highest level (8 ppb) and whether cancer risks were similar at this concentration. ATSDR used the SHOWER model to calculate inhalation exposures for the residents whose wells contained TCE at 8 ppb. Table 16 and Table 17 show the average daily exposure concentration for the target person in the household. The air concentration in the household is the same for children and adults. ATSDR then calculated the cancer risk for each age group using water contaminated with TCE at 8 ppb. Total cancer risk estimates are provided in Table 18.

Table 16 shows inhalation-only exposure concentrations corresponding to 8 ppb TCE in water during showering. The adjusted exposure point concentration in Table 16 for the RME scenario is equal to 8.0 $\mu g/m^3$ (1.5 ppb). That is lower than the 180 $\mu g/m^3$ effect level found in the Keil study [Keil 2009] and unlikely to result in an increased risk of harmful health effects.

Table 16. Default inhalation only exposure concentrations for chronic exposure to trichloroethylene (TCE) in household water at 8 ppb, along with noncancer hazard quotients.[*]

Exposure Group	CTE Adjusted EPC (µg/m³)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Adjusted EPC (µg/m³)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	3.5	1.7 [†]	-	1	8.0	3.8 [†]	-	1
1 to < 2 years	3.5	1.7 [†]	-	1	8.0	3.8 [†]	-	1
2 to < 6 years	3.5	1.7 [†]	-	4	8.0	3.8 [†]	-	4
6 to < 11 years	3.5	1.7 [†]	-	5	8.0	3.8 [†]	-	5
11 to < 16 years	3.5	1.7 [†]	-	1	8.0	3.8 [†]	-	5
16 to < 21 years	3.5	1.7 [†]	-	0	8.0	3.8 [†]	-	5
Total Child	-	-	3.9E-6 [‡]	12	-	-	1.4E-5 [‡]	21
Adult	3.5	1.7 [†]	2.2E-6 [‡]	12	8.0	3.8 [†]	1.4E-5 [‡]	33
Pregnant Women	3.5	1.7 [†]	-	-	8.0	3.8 [†]	-	-
Breastfeeding Women	3.5	1.7 [†]	-	-	8.0	3.8 [†]	-	-
Birth to < 21 years plus 12 years during adulthood [§]	-	-	-	-	-	-	1.9E-5 [‡]	33

"-" = Not applicable

Abbreviations: adjusted EPC = the exposure point concentration (EPC) times the appropriate exposure factors; µg/m³ = micrograms per meter cubed; CTE = central tendency exposure (typical); RME = reasonable maximum exposure (higher); yrs = years

[*]ATSDR's PHAST v2.4.1.0 generated these calculations. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 2.1 µg/m³ and the cancer risks were calculated using the inhalation unit risks of 2.1E-06 [NHL], 1.0E-06 [liver], 1.0E-06 [kidney] $(\mu g/m^3)^{-1}$ and age-dependent adjustment factors.

[†] Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

‡ Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table 17 shows the combined ingestion and dermal exposure doses for individuals using and consuming water contaminated with TCE at 8 ppb. All estimated doses are below the human equivalent dose $HED_{99, LOAEL}$ of 0.048 mg/kg/day [Keil 2009] and the LOAEL of 0.37 mg/kg/day [Peden-Adams 2006].

Table 17. Default combined ingestion and dermal exposure doses for chronic exposure to trichloroethylene (TCE) in household water at 8 ppb, along with noncancer hazard quotients.[*]

Exposure Group	CTE Dose (mg/kg/day)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Dose (mg/kg/day)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	0.00064	1.3 [†]	-	1	0.0012	2.4 [†]	-	1
1 to < 2 years	0.00020	0.41	-	1	0.00051	1.0 [†]	-	1
2 to < 6 years	0.00018	0.36	-	4	0.00043	0.86	-	4
6 to < 11 years	0.00014	0.27	-	5	0.00035	0.70	-	5
11 to < 16 years	9.7E-05	0.19	-	1	0.00027	0.55	-	5
16 to < 21 years	9.7E-05	0.19	-	0	0.00027	0.54	-	5
Total Child	-	-	2.7E-6 [‡]	12	-	-	7.7E-6 [‡]	21
Adult	0.00015	0.29	1.1E-6 [‡]	12	0.00035	0.69	6.8E-6 [‡]	33
Pregnant Women	0.00014	0.29	-	-	0.00035	0.69	-	-
Breastfeeding Women	0.00018	0.36	-	-	0.00036	0.72	-	-
Birth to < 21 years plus 12 years during adulthood [§]	-	-	-	-	-	-	1.0E-5 [‡]	33

"-" = Not applicable

Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; RME = reasonable maximum exposure (higher); yrs = years

* ATSDR's PHAST v2.4.1.0 generated these calculations. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0005 mg/kg/day and the cancer risks were calculated using the cancer slope factors of 0.022 [NHL], 0.016 [liver], 0.0093 [kidney] $(mg/kg/day)^{-1}$ and age-dependent adjustment factors.

† Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

‡ Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table 18 provides the total cancer risk for each age group using TCE-contaminated water at 8 ppb. It shows the total cancer risk for individuals who could be exposed from birth to age 21 years, from birth to age 33 years, and an adult potentially exposed for 33 years. The total cancer risk for individuals drinking and using TCE-contaminated water for multiple purposes at 8 ppb would be in the 2.1E-5 to 2.9E-5 range. ATSDR does not consider this slight increase a concern for increased cancer risk.

Table 18. Total cancer risks from using water with TCE at 8 ppb.

Age	*Systemic (Ingestion and Dermal)*	*Inhalation*	*Total Cancer Risk*
Total child (Birth to <21 Years)	7.7E-6	1.4E-5	2.2E-5
Birth to 33 Years	1.0E-5	1.9E-5	2.9E-5
Adult 33 Years	6.8E-6	1.4E-5	2.1E-5

9. Exposures to PCE and TCE contaminated soil

The soil sample results indicate that the sources of the contaminated soil are on the former properties of the YLDC (OU 1) and Econowash/Norge facilities (OU 2). PCE and TCE concentrations in soil are below ATSDR CVs in OU 1, but OU 2 soils contained levels above their respective CVs nearest the source area.

The maximum PCE and TCE concentrations in OU 2 were found in June 2018 at 17 to 18 feet bgs under the street on North Platte Avenue, about 78 feet south of West 5th Street [EPA 2021]. The only population that would be directly exposed to soil at this depth would be construction, utility, or remediation workers who happened to be digging that deep. ATSDR believes remediation worker(s) would be more likely to contact the soil at this depth. Personnel are required to wear personal protective equipment (PPE) and follow a site health and safety plan when doing remedial work with hazardous substances. Construction or utility workers should consult with EPA and the NDEE before doing any work in this area.

ATSDR calculated estimated exposure doses based on the maximum PCE concentration (74,000,000 ppb or 74,000 mg/kg) and the maximum TCE concentration (710,000 ppb or 710 mg/kg) found in the OU 2 soils. Table 19 and Table 20 list the results for short-term (acute) exposures that a worker may encounter. ATSDR focused on the outdoor worker with low intensity soil contact as the dose to compare with scientific studies, because ATSDR doesn't anticipate high intensity soil contact if workers are wearing PPE.

There is abundant evidence for neurological and neurobehavioral effects after chronic low exposures to PCE. While this evidence is primarily available from studies of inhalation exposure, effects after oral exposure are expected to be similar based on the available oral data and pharmacokinetic studies. The data and studies suggest similar blood levels of parent compound after inhalation and oral exposure of humans to PCE (as noted in the PBPK model by Chiu and Ginsberg [2011]).

The acute oral exposure MRL for PCE is equivalent to the chronic MRL and is equal to 0.008 mg/kg/day. The doses calculated for workers in Table 19 exceed the MRL, but the LOAEL in scientific studies of PCE was equal to 2.3 mg/kg/day [ATSDR 2019a]. The acute exposure doses for workers potentially exposed to the maximum PCE soil concentration are well below the LOAEL.

Table 19. Default combined ingestion and dermal occupational exposure doses for acute exposure to tetrachloroethylene (PCE) in soil at 74,000 mg/kg, along with noncancer hazard quotients.[*]

Exposure Group	Dose (mg/kg/day)	Noncancer Hazard Quotient
Workers – indoor	0.034	4.3 [†]
Workers - outdoor (low intensity soil contact)	0.099	12 [†]
Workers - outdoor (high intensity soil contact)	0.31	39 [†]

Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram soil

[*] ATSDR's PHAST v2.4.1.0 generated these calculations. The noncancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.008 mg/kg/day.

[†] Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

There is no acute oral exposure MRL for TCE. ATSDR does have an intermediate oral MRL for TCE and it is equal to 0.0005 mg/kg/day. We used the intermediate MRL to compare with the acute exposure doses. ATSDR calculated estimated exposure doses for outdoor and indoor workers below in Table 20. The outdoor workers with low-intensity soil contact had an estimated dose of 0.00095 mg/kg/day, which exceeds the MRL. The LOAEL for intermediate exposure in scientific studies of TCE is 0.37 mg/kg/day and the $HED_{99,LOAEL}$ is 0.048 mg/kg/day [ATSDR 2019b]. The acute exposure doses for workers potentially exposed to the maximum TCE soil concentration are below the LOAEL, so adverse health effects would not be expected. The high-intensity soil contact dose for outdoor workers was 0.0030 mg/kg/day which approaches the LOAEL dose for intermediate exposure. Protective clothing would lessen the likelihood of exposure. Though acute studies were insufficient to derive an acute MRL,

ATSDR's toxicological profile presented 26 acute exposure studies and found a LOAEL of 50 mg/kg/day, which is much greater than the estimated exposure for outdoor workers.

Table 20. Default combined ingestion and dermal occupational exposure doses for acute exposure to trichloroethylene (TCE) in soil at 710 mg/kg.[*]

Exposure Group	Dose (mg/kg/day)	Noncancer Hazard Quotient
Workers – indoor	0.00033	-
Workers - outdoor (low intensity soil contact)	0.00095	-
Workers - outdoor (high intensity soil contact)	0.0030	-

"-" = Not applicable
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram soil
[*] ATSDR's PHAST v2.4.1.0 generated these calculations. An acute MRL doesn't exist therefore the noncancer hazard quotient couldn't be calculated.

ATSDR also calculated an exposure dose for individuals who could contact contaminants in the surface soil (less than 1 foot deep). The highest PCE concentration found in surface soil (0.5 foot to 1-foot bgs) was during May 2017 (90,000 ppb) from the Chances R liquor store. Table 21 lists the results. The HQs for acute exposures are below 1 for all standard age groups except those children ages 1 to 5 years who exhibit pica behavior. Pica behavior involves a craving to eat nonfood items, such as dirt, paint chips, and clay. ATSDR does not believe that children would have had access to this property because underage children were prohibited unless accompanied by a parent or guardian. If there is a change in site use in the future, it would be applicable. The second highest PCE level detected in soils (35,000 ppb) was found on the same property but is below ATSDR's CV (180,000 ppb).

Soil Combined Acute (Residential)

Table 21. Default combined ingestion and dermal residential exposure doses for acute exposure to perchloroethylene (PCE) in soil at 90 ppm, along with noncancer hazard quotients.[*]

PHAST PUBLIC HEALTH ASSESSMENT SITE TOOL Exposure Group	CTE Dose (mg/kg/day)	CTE noncancer Hazard Quotient	RME Dose (mg/kg/day)	RME noncancer Hazard Quotient	Soil-Pica Dose (mg/kg/day)	Soil-Pica noncancer Hazard Quotient
Birth to < 1 year	0.00076	0.095	0.0019	0.23	-	-
1 to < 2 years	0.00082	0.10	0.0017	0.21	0.017	2.1 [†]
2 to < 6 years	0.00039	0.049	0.0011	0.14	0.011	1.4 [†]
6 to < 11 years	0.00023	0.029	0.00063	0.079	-	-
11 to < 16 years	9.9E-05	0.012	0.00021	0.026	-	-
16 to < 21 years	8.4E-05	0.010	0.00017	0.021	-	-
Adult	4.8E-05	0.0060	0.00013	0.016	-	-

"-" = Not applicable

Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; ppm = part per million; RME = reasonable maximum exposure (higher)

* ATSDR's PHAST v2.4.1.0 generated these calculations. The noncancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.008 mg/kg/day.

[†] A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

The second highest TCE concentration (6,900 ppb or 6.9 mg/kg) was found in October 2017 at 14 to 15 feet bgs in the northbound lane of North Platte Avenue south of West 5th Street, which exceeds ATSDR's comparison value for children (5.6 ppm). Because the TCE found at this depth is covered by the street, ATSDR does not believe children could access the soil contaminants. Soil samples collected between 1 and 2 feet in this location had undetectable levels of PCE, TCE, cis-1,2 DCE, and vinyl chloride.

The EPA established a cleanup level of 46 ppb for PCE in soil. Soil remediation will prevent further contaminant migration and groundwater contamination. ATSDR supports EPA in their remediating of the PCE and TCE in the source areas to prevent further groundwater contamination and VI.

The EPA issued a Record of Decision (ROD) on September 19, 2018, which detailed the selected remedial action of in-situ thermal remediation (ISTR) for OU 1 [USEPA 2018b]. ISTR involves heating the soil to a level where the contaminants are vaporized out of the soil and the resulting vapor is collected at the surface. EPA has released the ROD for OU 2 (September 2021), and the selected remedial action is also ISTR with soil vapor extraction [EPA 2021].

The EPA awarded a remedial action contract on September 19, 2022, to conduct ISTR at OU 1 and OU 2. The remedial action work began at OU 2 in March 2023. From March 2023 into fall 2023, the ISTR wells, vapor cap, and vapor treatment plumbing were fully installed at OU 2 [USEPA 2024].. In July 2025, EPA's Remedial Project Manager reported to ATSDR that OU 2 cleanup and site restoration was complete, and all soil cleanup objectives for OU 2 were met. The transfer of treatment infrastructure to OU 1 began in May 2025. The cleanup of OU 1 is expected to begin in Fall 2025 and be completed by Summer 2026.

10. Exposures to PCE and TCE in contaminated air from vapor intrusion

Individuals who live, work, or spend considerable time near the downtown area and the sources of contamination could have been exposed to TCE and PCE through VI. ATSDR calculated estimated exposure doses for individuals in both the residential and business scenarios using the maximum PCE and TCE concentrations. The exposure time frame would be significantly less in a business setting because a worker would be working eight to possibly 10 hours per day, as opposed to the potential full-day (24 hour) exposure in a residence. Also, a worker would most likely only work five days a week. Visitors to the business would have even shorter potential exposure periods. The PCE and TCE concentrations for the business locations listed in Table 6 had varying concentrations throughout the sampling periods.

PCE

ATSDR used the maximum PCE concentration from the five samples collected between January and October 2017 at property 6 to determine the worst-case scenario an individual could be exposed to in a business scenario. Sampling was not conducted at this location prior to 2017 and the VMS was installed in December 2017. The maximum PCE concentration was equal to 97.2 µg/m³, which exceeds ATSDR's inhalation MRL of 41 µg/m³. The MRL is based on a study of PCE-exposed workers (22 dry cleaners and

13 ironers) with an average of 106 months of exposure compared to 35 matched controls (those not exposed). A 12,000 µg/m^3 (1.7 ppm) concentration was considered a LOAEL for decreased color vision [ATSDR 2019a]. The 97.2 µg/m^3 is equivalent to 0.012 ppm, which is below the LOAEL.

Property 8 was sampled only once (07/2016) and it contained 130 µg/m^3 PCE, which is equivalent to 0.019 ppm, also below the LOAEL. The sub-slab concentration at this property was lower than the indoor air concentration, which suggests that products containing PCE were potentially used within the residence. ATSDR reminds residents who use hazardous chemicals at home to follow the instructions on the product label regarding storage, use, and ventilation.

ATSDR used the maximum PCE concentration (310 µg/m^3) detected at property 5B as the business exposure scenario and calculated an estimated exposure dose. ATSDR adjusted for an 8.5-hour workday and five-day workweek over 50 weeks per year. We determined a worker would be exposed to an air concentration equivalent to 75.2 µg/m^3. This level is also below the LOAEL. Individuals exposed to these PCE concentrations in either scenario would not be expected to experience noncancerous adverse health effects.

ATSDR used the maximum PCE concentration detected in residential air (130 µg/m^3) to calculate an estimated cancer risk. ATSDR used the maximum concentration, but this appears to have been from a product possibly used in a hobby, and not necessarily from VI. The sub-slab concentration was lower than the indoor air sample, which indicates a different source other than VI. The cancer risk is equal to the exposure concentration times the inhalation unit risk times the exposure duration (33 years/78 years). The resulting cancer risk calculated below is equal to 1.4E-5. There is no concern for increased cancer risk based on this estimated value.

Cancer risk from the maximum PCE detected in residential air:

PCE cancer risk = 130 µg/m^3 X 2.6 E-7 X 33/78

PCE cancer risk = 1.4E-5

Cancer risk from the maximum PCE detected in the commercial (business) air:

ATSDR had to adjust the exposure concentration for the business scenario when calculating the cancer risk to account for individuals being exposed for less than 24 hours per day, less than seven days a week, and a 20/78 years exposure duration. The following was used in the calculation of the exposure factor:

PCE cancer exposure factor: 8.5/24(hours/day) X 5/7(days/week) X 50/52.14(weeks/year) X 20/78 = 0.0622

PCE maximum concentration 310 µg/m^3 X 0.0622 = 19.28 µg/m^3 (rounded up to 19.3)

PCE cancer risk = 19.3 µg/m^3 X 2.6 E-7

PCE cancer risk = 3.9E-6

The PCE cancer risk is less in the business scenario than it is for the residential scenario, so there is no concern for an elevated risk of cancer based on this estimated value for people who worked in the buildings for up to 20 years (assuming an 8.5-hour shift worked five days a week).

TCE

Property 2 had the maximum residential TCE concentration, which was equal to 3.1 µg/m³. The maximum for business settings was 23.4 µg/m³ at property 4B. The inhalation MRL for TCE is equal to 2.1 µg/m³. ATSDR adopted EPA's RfC (reference concentration) as the chronic inhalation MRL. The RfC is based on two oral rodent studies Keil et al. [2009] and Johnson et al. [2003] that show either potential fetal heart malformations or damage to the immune system. ATSDR concluded that the Johnson study has insufficient confidence to determine an exposure level at which fetal heart malformation may or may not occur and other studies showed very low to low potential for the effect [ATSDR 2025]. Based on a 30-week mouse study, Keil et al. showed immunological effects in female mice who drank TCE-contaminated water. It caused decreased thymus weight and increased serum levels of IgG and selected autoantibodies at an administered oral dose of 0.35 mg/kg/day (the study LOAEL).

The residential maximum TCE concentration of 3.1 µg/m³ is below $HEC_{99,LOAEL}$ of 180 µg/m³ in air, so noncancerous adverse health effects would not be expected.

ATSDR calculated the TCE cancer risk using the 3.1 µg/m³ concentration detected in residences. Table 22 lists the results for each age group.

Residential TCE inhalation cancer risk

Table 22. Residential: Default exposure point concentrations for chronic exposure to trichloroethylene in air at 3.1 µg/m³ (0.58 ppb) along with noncancer hazard quotients[*]

Exposure Group	CTE Adjusted EPC (µg/m³)	CTE Adjusted EPC (ppb)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Adjusted EPC (µg/m³)	RME Adjusted EPC (ppb)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	3.1	0.58	1.5 [†]	-	1	3.1	0.58	1.5 [†]	-	1
1 to < 2 years	3.1	0.58	1.5 [†]	-	1	3.1	0.58	1.5 [†]	-	1
2 to < 6 years	3.1	0.58	1.5 [†]	-	4	3.1	0.58	1.5 [†]	-	4
6 to < 11 years	3.1	0.58	1.5 [†]	-	5	3.1	0.58	1.5 [†]	-	5
11 to < 16 years	3.1	0.58	1.5 [†]	-	1	3.1	0.58	1.5 [†]	-	5
16 to < 21 years	3.1	0.58	1.5 [†]	-	0	3.1	0.58	1.5 [†]	-	5
Total Child	-	-	-	3.5E-6 [‡]	12	-	-	-	5.3E-6 [‡]	21
Adult	3.1	0.58	1.5 [†]	2.0E-6 [‡]	12	3.1	0.58	1.5 [†]	5.4E-6 [‡]	33
Birth to < 21 years plus 12 years during adulthood [§]	-	-	-	-	-	-	-	-	7.2E-6 [‡]	33

"-" = Not applicable

Abbreviations: adjusted EPC = the exposure point concentration (EPC) times the appropriate exposure factors; µg/m³ = micrograms per meter cubed; ppb = parts per billion; CTE = central tendency exposure (typical); RME = reasonable maximum exposure (higher); yrs = years

* The calculations in this table were generated using ATSDR's PHAST v2.5.0.0. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 2.1 µg/m^3 and the cancer risks were calculated using the inhalation unit risks of 2.1E-06 [NHL], 1.0E-06 [liver], 1.0E-06 [kidney] (µg/m^3)$^{-1}$ and age-dependent adjustment factors.

† Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

‡ Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

§ This cancer risk represents a scenario where children are likely to continue to live in their childhood home as adults.

Concentrations varied considerably at the different business properties. Property 4B had a VMS installed in July 2015, but the exceedance came two months later (September 2015). The maximum TCE concentration was detected in September 2015, but in November 2015 and July 2016 it was below the EPA action level. TCE was undetectable in the February 2018 sampling. Two other businesses (12B and 15B) had TCE concentrations above EPA's action level in 2015 and 2017, respectively, but for only one sampling event. Business 12B had undetectable TCE concentrations in March 2015 but 19.9 µg/m³ in September 2015. TCE levels were below action levels in November 2015 and below detection in March 2016. A similar scenario occurred at 15B from July 2017 to October 2017. In July 2017, TCE was detected at 20 µg/m³, but it was undetectable in August and October 2017. Neither of these two locations had VMSs, so seasonal temperature variations could have caused the drop in concentrations, which may have affected VI rates.

ATSDR used the maximum TCE concentration (23.4 µg/m³) detected in the business locations from Table 6 and adjusted the exposure factor by assuming an individual worked 8.5 hours a day, five days a week. The resulting concentration is equal to 5.92 µg/m³. This level is below the inhalation $HEC_{99,BMDL01}$ of 19.8 µg/m³ in air, and noncancerous adverse health effects would not be expected.

ATSDR calculated the inhalation cancer risk for an individual working at the business and exposed to 5.92 µg/m³ of TCE. Table 23 shows the results for each age group. There is no concern for increased cancer risk for all age groups potentially exposed to this TCE level.

Business TCE inhalation risk

Table 23. Occupational: Site-specific exposure point concentrations for chronic exposure to trichloroethylene in air at 5.92 µg/m³ (1.1 ppb) along with noncancer hazard quotients[*]

Exposure Group	Adjusted EPC (µg/m³)	Adjusted EPC (ppb)	Noncancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs)
Full-time worker	1.4	0.25	0.64	7.1E-7	10
Part-time worker	0.51	0.094	0.24	2.7E-7	10

Abbreviations: adjusted EPC = the exposure point concentration (EPC) times the appropriate exposure factors; µg/m^3 = micrograms per meter cubed; ppb = parts per billion; mg/kg/day = milligram chemical per kilogram body weight per day; yrs = years

[*] The calculations in this table were generated using ATSDR's PHAST v2.5.0.0. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 2.1 µg/m^3 and the cancer risks were calculated using the inhalation unit risks of 2.1E-06 [NHL], 1.0E-06 [liver], 1.0E-06 [kidney] (µg/m^3)$^{-1}$ and age-dependent adjustment factors

The EPA has installed VMSs for those locations that had sub-slab or indoor air exceeding EPA's action levels. In February 2018, EPA collected indoor air samples from commercial and residential properties where VMSs were installed to determine if the units had sufficiently mitigated the PCE and TCE in indoor air. The maximum PCE concentration detected in residences post-mitigation during February 2018 was 3.2 µg/m³, which is below ATSDR's CREG (3.8 µg/m³) [Tetra Tech 2018a]. VMSs have lowered the indoor air concentrations of PCE and TCE to levels below ATSDR's CVs or EPA's action levels. Adverse health effects are not expected from the levels detected in February 2018. The continued operation and maintenance of the VMSs and periodic monitoring are necessary to ensure ongoing system performance.

Although the data support that current exposure to PCE and TCE in indoor air has been mitigated, there is a potential for future exposure from VI due to the migrating groundwater plume. It cannot be determined at this time when contaminant concentrations in groundwater will be low enough to not be a source of VI. The current plume boundaries are known and residences in the current plume path have been sampled and mitigated when appropriate. ATSDR recommends that EPA continue to evaluate the potential for VI as the groundwater plume migrates over time. Property owners can help by allowing EPA to sample or monitor their properties. ATSDR also recommends residents and business owners run their VMSs continually to ensure no PCE or TCE enters the building.

11. Conclusions and Recommendations of ATSDR's Evaluation

ATSDR reached the following conclusions for the site:

Conclusion 1

ATSDR does not expect vapor intrusion (VI) of PCE or other site-related VOCs to harm the health of children or adults at properties that have been sampled and where vapor mitigation systems (VMSs) are installed, operated, and maintained as recommended. If the soil vapor plume migrates or building changes occur, susceptibility to VI may change.

Basis for Conclusion

- The extent of the current soil vapor plume has been determined. Properties within the investigation area have been sampled and, if needed, mitigated. To date, 27 VMSs have been installed.
- The VMSs prevent contaminated vapor from entering structures by drawing vapors from beneath the structure and venting the vapors outside. The systems contain a motorized fan to draw vapors in the subsurface into the system. The air is routed outside of the building via a vent pipe. Figure 9 in Appendix A is a picture of a mitigation unit vent pipe. Once outside, the vapors quickly separate and break down.
- The EPA completed diagnostic testing after the installation of each mitigation system by collecting additional samples from indoor air. The additional samples, also referred to as confirmation samples, are used to confirm the systems are operating per the manufacturer's standards. The additional samples did show that after the systems were installed, a couple of the locations continued to have elevated vapor concentrations. It is unclear what caused the elevated readings. Some potential causes for elevated readings after the mitigation system was installed include inadvertent system shutdown, preferential pathways, or background sources. Changes in air pressure or temperature can affect the movement of contaminants and may cause elevated readings. The most recent sampling in 2018 didn't show detectable contaminant concentrations above ATSDR comparison values (CVs).

Recommendations

- ATSDR recommends EPA provide and install lock boxes on the outdoor power switches of VMSs to prevent the units from being inadvertently turned off.
- ATSDR recommends VMSs remain operational until the groundwater contamination no longer presents a VI hazard.

- ATSDR recommends that EPA monitor indoor air in homes[3] with vapor mitigation units to ensure the effectiveness of the systems until remediation is complete.
- ATSDR recommends that EPA continue to monitor and test for VI as the plumes migrate over time and install additional mitigation systems as needed. Sewer gas may migrate up to 500 feet [Beckley 2020]. Indicators, tracers, and surrogates should be used to maximize the effectiveness of indoor sampling.
- ATSDR recommends owners and occupants allow EPA to perform indoor air and sub-slab gas sampling inside their properties.
- If property owners have questions about the integrity of their VMS or are concerned about exposures, ATSDR recommends they contact[1] EPA at this link: https://cumulis.epa.gov/supercpad/CurSites/csitinfo.cfm?id=0706200&msspp=med or the Nebraska Department of Environment and Energy (NDEE) at 402-471-2186 to discuss if follow-up actions are appropriate.

[1]If one is unable to access the link, they may contact EPA region 7 by phone 913-551-7003 or 800-223-0425.

Conclusion 2

ATSDR does not expect the use of water from the York public water supply or water where EPA installed whole house filtration (WHF) units to harm people's health.

Basis for Conclusion

- EPA approved an action memorandum in 2011 that allowed residents affected by the contaminant plumes to have their homes connected to the York public water supply. WHF units were installed at residences that were too far away to be connected to the public water supply or where residents refused connection to the public water supply.
- The City of York Water Division is required to test for contaminants in the water supply, including PCE; trichloroethylene (TCE); *cis*-1,2 dichloroethylene (DCE); vinyl chloride and many other metals and VOCs. Site-related contaminants are not currently impacting the public water supply.
- The two most recent sampling events in the homes with WHF units indicated VOCs were not at levels of concern in the filtered water.

[3] Monitoring during closed-building conditions when heating and air conditioning systems are operating, and windows and doors remain mostly closed is preferred for characterizing vapor intrusion.

Recommendations

- ATSDR recommends residents that have WHF units check their filters regularly and replace filters as needed according to the manufacturer's recommendations to ensure their water is not contaminated.
- ATSDR recommends residents using WHF units, but with access to the public water supply, consider establishing a connection to the supply to eliminate the operation and maintenance requirements of WHF units.
- ATSDR recommends that EPA continue to sample potentially impacted privately owned wells as the plume migrates over time and install WHF units as needed or offer connection to the public water supply.

Conclusion 3

At designated property J, exposure prior to April 2014 to TCE in water used for drinking, showering, and other water-related activities could have harmed the occupants' health.

Basis for Conclusion

- ATSDR estimated exposure doses and risks from the maximum TCE concentration of 21 ppb measured at Property J. Increased cancer risks are only a concern if high levels of exposure consistently occurred to the maximum TCE level. TCE was only detected at 21 ppb once during the sampling events. High levels of exposure include assumptions that adults at the residence drank three liters of unfiltered tap water every day and four people showered sequentially every day.
- All other past and current VOC estimated doses were below the levels where adverse health effects have been seen in scientific studies.
- TCE was not detected in the two sampling events that followed the initial detection. The residence was connected to the public water supply in 2015.

Conclusion 4

ATSDR does not expect contact with soil contamination from the PCE Southeast Contamination site to harm health.

Basis for Conclusion

- Contaminated soils are located under buildings and paved surfaces with the highest concentrations between 17–18 feet below ground surface (bgs).
- Community members will likely not experience direct exposure to contaminated soils.
- Utility, construction, and remediation workers that dig in the soil could be exposed to contaminated soils. Wearing personal protective equipment and following a site health and safety plan may reduce direct exposure to contaminated soil.

- Remediation of the contaminated soils is ongoing, which is likely to eliminate the potential for future exposures.

Recommendations

- ATSDR recommends utility, construction, or remediation workers who may be exposed to contaminated soils take precautions to prevent direct contact with soils.
- ATSDR recommends monitoring the indoor air of nearby occupied buildings during the remediation process to ensure soil vapors do not affect surrounding structures.
- ATSDR recommends groundwater monitoring near the remediation areas to detect potential changes to contaminants levels or migration of contaminants.

12. Public Health Action Plan

The public health action plan for the site contains a description of actions that have been or will be taken to prevent individuals from being exposed to the contaminants. The purpose of the public health action plan is to ensure that this health assessment identifies the public health hazards and provides a plan of action designed to prevent harmful human health effects that may result from exposure to hazardous substances at the site.

13. Completed Public Health Actions

EPA has provided a permanent alternate water supply or installed WHF units to prevent exposures resulting from the ingestion, inhalation, and skin contact (dermal) with PCE and its degradation products (TCE, cis-DCE, and vinyl chloride) present in the groundwater at the site.

EPA has installed VMSs in residences and businesses that had elevated levels of site-related contaminants in indoor air.

ATSDR will continue to work with EPA to obtain sampling data results and review remedial actions for OU 2 and OU 3.

ATSDR will continue to gather and address community health concerns as it pertains to the PCE Southeast Contamination site.

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Appendix A. Figures

Figure 9. Vapor Mitigation Vent Pipe

Source - EPA 2015

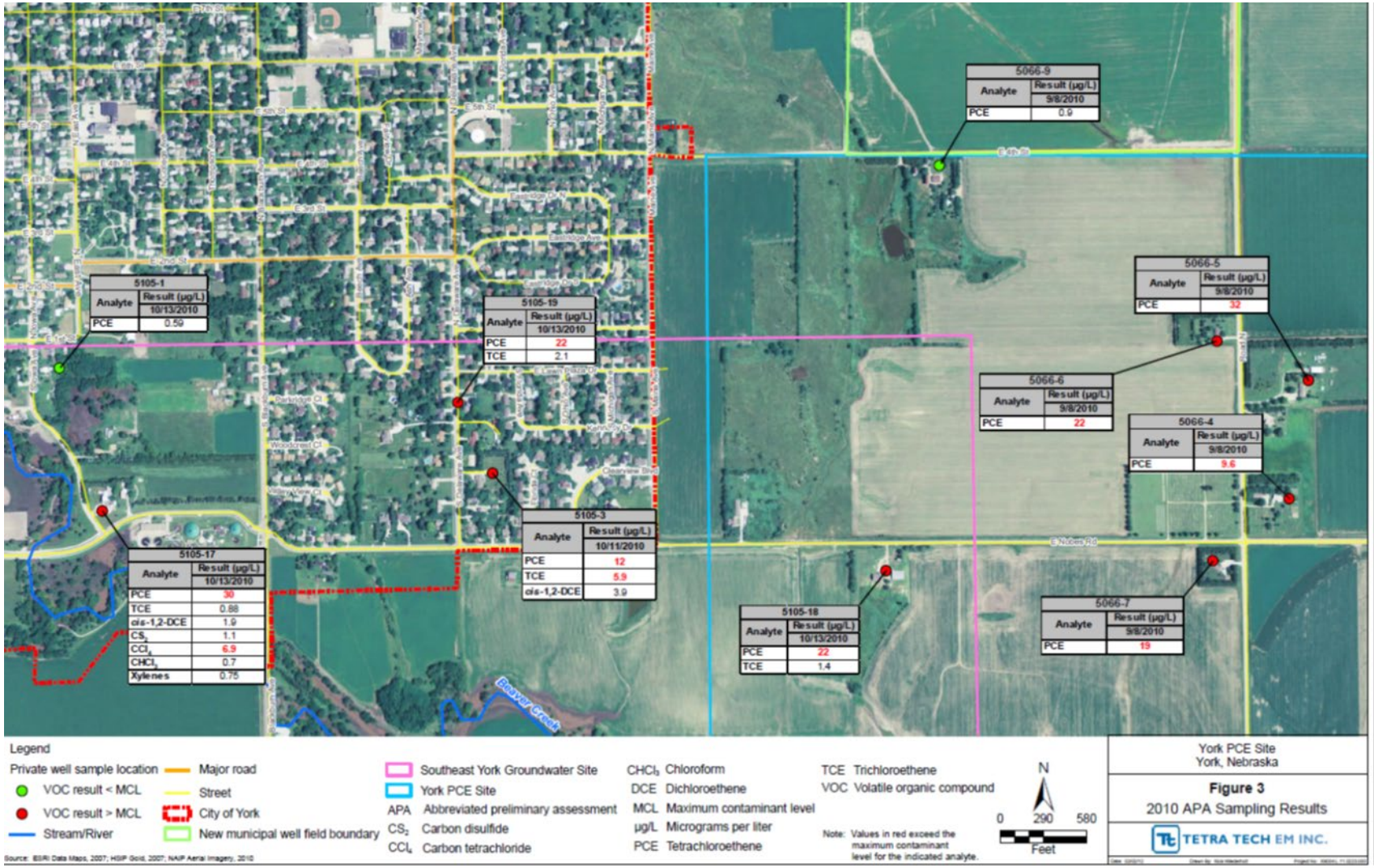

Figure 10. Groundwater sample results in private wells

Source Tetra Tech 2013 A-2

Figure 11. Photo of 7th Street Former York Laundry and Dry Cleaning

Source - A. Dudley 2019

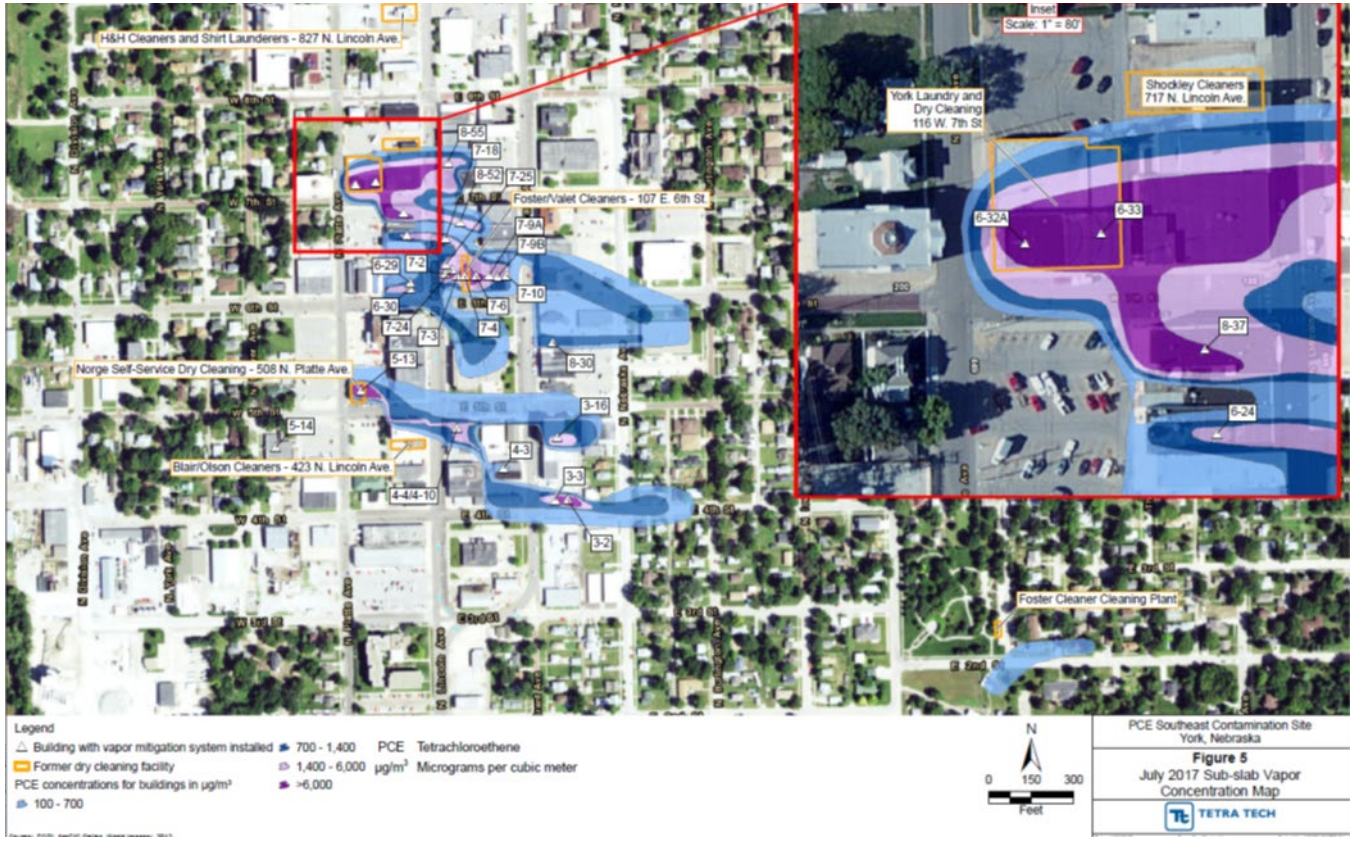

Figure 12. Sub-slap Vapor Concentration Map

Source - Tetra Tech 2018

Figure 13. Steam Tunnels

Source - Tetra Tech 2018b

Appendix B. Estimated Exposure Dose Table

Table 24. Residential Default exposure doses for chronic exposure to tetrachloroethylene in drinking water at 0.032 mg/L along with noncancer hazard quotients and cancer risk estimates[*]

Exposure Group	CTE Dose (mg/kg/day)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Dose (mg/kg/day)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	0.0024	0.31	-	1	0.0045	0.57	-	1
1 to < 2 years	0.00069	0.086	-	1	0.0018	0.23	-	1
2 to < 6 years	0.00062	0.077	-	4	0.0016	0.20	-	4
6 to < 11 years	0.00046	0.057	-	5	0.0013	0.16	-	5
11 to < 16 years	0.00032	0.040	-	1	0.00099	0.12	-	5
16 to < 21 years	0.00032	0.040	-	0	0.00099	0.12	-	5
Total Child	-	-	2.2E-7	12	-	-	7.8E-7	21
Adult	0.00053	0.066	1.7E-7	12	0.0013	0.16	1.1E-6 [‡]	33
Pregnant Women	0.00051	0.063	-	-	0.0013	0.16	-	-
Breastfeeding Women	0.00066	0.082	-	-	0.0013	0.17	-	-

"-" = Not applicable

Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher); yrs = years

[*] The calculations in this table were generated using ATSDR's PHAST v2.5.0.0. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.008 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 0.0021 $(mg/kg/day)^{-1}$.

[‡] Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table 25. Residential Default exposure doses for chronic exposure to trichloroethylene in drinking water at 0.008 mg/L along with noncancer hazard quotients[*]

Exposure Group	CTE Dose (mg/kg/day)	CTE Noncancer Hazard Quotient	CTE Cancer Risk	CTE Exposure Duration (yrs)	RME Dose (mg/kg/day)	RME Noncancer Hazard Quotient	RME Cancer Risk	RME Exposure Duration (yrs)
Birth to < 1 year	0.00061	1.2 [†]	-	1	0.0011	2.3 [†]	-	1
1 to < 2 years	0.00017	0.34	-	1	0.00046	0.92	-	1
2 to < 6 years	0.00015	0.31	-	4	0.00039	0.78	-	4
6 to < 11 years	0.00011	0.23	-	5	0.00032	0.63	-	5
11 to < 16 years	7.9E-05	0.16	-	1	0.00025	0.50	-	5
16 to < 21 years	8.1E-05	0.16	-	0	0.00025	0.49	-	5
Total Child	-	-	2.4E-6 [‡]	12	-	-	7.1E-6 [‡]	21
Adult	0.00013	0.26	9.4E-7	12	0.00032	0.65	6.3E-6 [‡]	33
Pregnant Women	0.00013	0.25	-	-	0.00032	0.64	-	-
Breastfeeding Women	0.00016	0.33	-	-	0.00034	0.67	-	-

"-" = Not applicable

Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher); yrs = years

[*] The calculations in this table were generated using ATSDR's PHAST v2.5.0.0. The noncancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0005 mg/kg/day and the cancer risks were calculated using the cancer slope factors of 0.022 [NHL], 0.016 [liver], 0.0093 [kidney] $(mg/kg/day)^{-1}$ and age-dependent adjustment factors.

[†] Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

[‡] Indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table 26. Residential Default exposure doses for intermediate exposure to trichloroethylene in drinking water at 0.008 mg/L along with noncancer hazard quotients[*]

Exposure Group	CTE Dose (mg/kg/day)	CTE Noncancer Hazard Quotient	RME Dose (mg/kg/day)	RME Noncancer Hazard Quotient
Birth to < 1 year	0.00061	1.2 [†]	0.0011	2.3 [†]
1 to < 2 years	0.00017	0.34	0.00046	0.92
2 to < 6 years	0.00015	0.31	0.00039	0.78
6 to < 11 years	0.00011	0.23	0.00032	0.63
11 to < 16 years	7.9E-05	0.16	0.00025	0.50
16 to < 21 years	8.1E-05	0.16	0.00025	0.49
Adult	0.00013	0.26	0.00032	0.65
Pregnant Women	0.00013	0.25	0.00032	0.64
Breastfeeding Women	0.00016	0.33	0.00034	0.67

Abbreviations: CTE = central tendency exposure (typical); mg/kg/day = milligram chemical per kilogram body weight per day; mg/L = milligram chemical per liter water; RME = reasonable maximum exposure (higher)
[*] The calculations in this table were generated using ATSDR's PHAST v2.5.0.0. The noncancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.0005 mg/kg/day.
[†] Indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

Appendix C. Toxicological Information

Public Health Implications

ATSDR's Toxicology Section produces toxicological profiles for hazardous substances at NPL sites. The profiles are a collection of scientific studies that have been done on the hazardous substances in either animal studies, occupational studies, or epidemiology studies of communities or individuals. The studies identify the health impacts to an individual based on the levels of contamination and the extent of exposure. ATSDR has over 300 toxicological profiles for contaminants found at hazardous waste sites.

The following link will connect readers with ATSDR's toxicological profiles: Toxicological Profiles | Toxicological Profiles | ATSDR

ATSDR uses scientific studies to calculate a MRL for each contaminant [ATSDR 2019a] [ATSDR 2019b]. The MRL is an estimate of daily human exposure to a substance (in milligrams per kilogram per day [mg/kg/day] for oral exposures and ppb or micrograms per cubic meter [µg/m³] for inhalation exposures) that is likely to be without noncarcinogenic health effects during a specified duration of exposure. Most MRLs contain a degree of uncertainty because of the lack of precise toxicological information on the people who might be most sensitive to hazardous substances (e.g., infants, elderly, nutritionally or immunologically compromised). The uncertainty factor could be as much as 1,000 to account for the use of a LOAEL (lowest observed adverse effect level), interspecies extrapolation, and human variability.

ATSDR uses a conservative (i.e., protective) approach to this uncertainty, consistent with the public health principle of prevention. Although we prefer human data, we often must base MRLs on animal studies because relevant human studies are lacking. In the absence of evidence to the contrary, ATSDR assumes that humans are more sensitive to the effects of hazardous substance than animals and that certain persons could be particularly sensitive.

For general information about PCE and TCE, a general summary is provided below.

Tetrachloroethylene (PCE)

PCE is a nonflammable colorless liquid. It is also known as perchloroethylene, PERC, tetrachloroethene, and perchlor. Most people can smell PCE when it is present in the air at a level of 1 part in 1 million parts of air (ppm) or more. PCE is used as a dry-cleaning agent and metal degreasing solvent. It is also used as a starting material (building block) for making other chemicals and is used in some consumer products [ATSDR 2019a].

If you breathe in PCE, most of it will go into the bloodstream and other organs. A small amount can also move through the skin and into the bloodstream. You can also take PCE into your body if you drink (ingest), touch (dermal contact), or breathe in steam from contaminated water. If that happens, most of

the PCE will move from the lungs or stomach into the bloodstream. PCE exposure can harm the nervous system, liver, kidneys, and reproductive system [ATSDR 2019a]. If you are exposed to PCE, you could have a higher risk of developing certain types of cancer.

If you breathe in air containing a lot of PCE, you can become dizzy or sleepy, develop headaches, and become uncoordinated. Exposure to very large amounts in the air can make you unconscious. With long term (chronic) exposures to lower levels of PCE in air, you could have changes in mood, memory, attention, reaction time, or vision [ATSDR 2019a]. Studies in animals exposed to PCE have shown liver and kidney effects, and changes in brain chemistry, but we do not know what these findings mean for humans.

A study involving workers in dry-cleaning establishments looked at the effects of PCE on vision [Cavalleri 1994]. In the study, the color vision of 35 PCE-exposed workers (22 dry-cleaners and 13 ironers) with an average of 106 months of exposure was compared to 35 matched controls. At a LOAEL of 50,000 µg/m^3 (7.3 ppm), the dry-cleaners showed a significant decrease in blue-yellow color vision compared to controls. Workers who experienced continued exposure demonstrated a further deterioration in color vision when evaluated two years after the initial measurements. The mean concentration of the dry-cleaner's exposure was multiplied by 8/24 hours and 5/7 days to yield an equivalent continuous exposure concentration of 1.7 ppm (12 mg/m^3). The 1.7 ppm concentration was considered a $LOAEL_{ADJ}$ for decreased color vision. A modifying factor of 3 was applied because of the lack of information on low-dose immune system effects for a total uncertainty factor of 300.

Studies in humans suggest that exposure to PCE might lead to a higher risk of getting bladder cancer, multiple myeloma, or non-Hodgkin's lymphoma, but the evidence is not very strong. In animals, PCE has been shown to cause cancers of the liver, kidney, and blood system. It is not clear whether these effects might also occur in humans, because humans and animals differ in how their bodies handle PCE.

The EPA considers PCE to be "likely to be carcinogenic to humans by all routes of exposure." This conclusion is based on suggestive evidence in human studies and clear evidence of mononuclear cell leukemia in rats and liver tumors in mice exposed for two years by inhalation or stomach tube.

The International Agency for Research on Cancer (IARC) considers PCE "probably carcinogenic to humans" based on limited evidence in humans and sufficient evidence in animals. The National Toxicology Program considers PCE to be "reasonably anticipated to be a human carcinogen."

Trichloroethylene (TCE)

TCE is a colorless, volatile liquid. Liquid TCE evaporates quickly into the air. It is nonflammable and has a sweet odor. The two major uses of TCE are as a solvent to remove grease from metal parts and as a chemical that is used to make other chemicals, especially the refrigerant, HFC-134a. TCE has also been used as an extraction solvent for greases, oils, fats, waxes, and tars; by the textile processing industry to scour cotton, wool, and other fabrics; in dry cleaning operations; and as a component of adhesives, lubricants, paints, varnishes, paint strippers, pesticides, and cold metal cleaners [ATSDR 2019b].

TCE breaks down slowly in surface water and is removed mostly through evaporation to air. TCE can slowly enter groundwater from contaminated surface water. TCE is expected to remain in groundwater for long periods of time because it can't readily evaporate from groundwater. TCE breaks down slowly in soil and, like surface water, is removed mostly through evaporation to air. TCE in soil (and to some extent in groundwater) can evaporate and migrate into air spaces beneath buildings to enter the indoor air, a process termed vapor intrusion.

The health effects of TCE depend on how much you are exposed to and the length of that exposure. Environmental monitoring data suggest that TCE levels the public might encounter by direct contact or through air, water, food, or soil, are generally much lower than the levels at which adverse effects are shown in animal studies.

Available human and animal data indicate that the central nervous system is a target for TCE toxicity. The data also identify the kidney, liver, immune system, male reproductive system, and developing fetus as other potential targets. Results from available animal studies suggest that the immune system and developing fetus may represent particularly sensitive targets of TCE toxicity.

People who are overexposed to moderate amounts of TCE can experience headaches, dizziness, and sleepiness. Large amounts of TCE can cause coma and even death. Some people who breathe high levels of TCE can develop damage to some of the nerves in the face. Other effects seen in people exposed to high levels of TCE include evidence of nervous system effects related to hearing, seeing, and balance; changes in the rhythm of the heartbeat; liver damage; and evidence of kidney damage [ATSDR 2019b].

Long-term exposure studies involving TCE in animals have mainly focused on carcinogenicity and relatively insensitive noncancer end points following oral exposure. These studies are not helpful in defining noncancer end points in humans following long-term exposure. However, depressed body weight and evidence of effects on the thymus were reported in one recent study of mice exposed to TCE via their mothers during gestation and lactation and via the drinking water for up to 12 months thereafter [ATSDR 2019b].

ATSDR adopted EPA's RfC as the chronic, inhalation MRL. The RfC is based on two oral rodent studies (Keil 2009; Johnson 2003] showing either fetal heart malformations or damage to the immune system. These studies were also used to derive the oral MRLs. ATSDR concluded that the Johnson study has insufficient confidence to determine an exposure level at which fetal heart malformation may or may not occur and other studies showed very low to low potential for the effect [ATSDR 2025]. Based on a 30-week, drinking water, mouse study, Keil et al. showed immunological effects in female mice resulting in decreased thymus weight and increased serum levels of IgG and selected autoantibodies at an administered oral dose of 0.35 mg/kg/day (the study LOAEL). Using PBPK modeling, the mouse oral LOAEL was converted to a 99th percentile human equivalent concentration $HEC_{99,LOAEL}$ of 33 ppb (180 $\mu g/m^3$) in air [Keil 2009].

The $HEC_{99,LOAEL}$ of 180 $\mu g/m^3$ for thymus weight was divided by a total uncertainty factor of 100 (to account for use of a LOAEL and to account for species extrapolation and human variability using a PBPK model); the resulting candidate chronic RfC was 2 $\mu g/m^3$ (rounded from 1.8 $\mu g/m^3$). There is strong evidence that TCE can cause kidney cancer in people and some evidence that it causes liver cancer and

malignant lymphoma (a blood cancer). The IARC and the EPA determined that there is convincing evidence that TCE exposure can cause kidney cancer in humans. IARC considers TCE to be a multisite carcinogen (liver, kidney, lung, testes, and blood-producing system) in rats and mice by inhalation and oral exposure routes [ATSDR 2019b].

In April 2025, ATSDR posted a Targeted Systematic Evidence Map (SEM) and Rapid Systematic Review for Trichloroethylene and Developmental Cardiotoxicity that screened new literature published since the release of the ATSDR Toxicological Profile: https://www.atsdr.cdc.gov/ToxProfiles/SEM-for-Trichloroethylene-508.pdf. The document reported that the studies available are not of sufficient quality to provide an exposure dose or air concentration at which developmental cardiotoxicity, if any, may or may not occur. The York PHA was revised to incorporate this new information into the document.