Public Health Assessment

Pohatcong Valley Groundwater Contamination Superfund Site
Warren County, New Jersey

Public Health Implications of Site-Related Exposures to Tetrachloroethylene and Trichloroethylene

EPA Facility ID: NJD981179047

MAY 3, 2012
COMMENT PERIOD ENDS: JUNE 3, 2012

Prepared by:

New Jersey Department of Health and Senior Services
Environmental and Occupational Health Surveillance Program

Under a Cooperative Agreement with the
U.S. Agency for Toxic Substances and Disease Registry

Table of Contents

Summary

Introduction

The New Jersey Department of Health and Senior Services (NJDHSS) and the Agency for Toxic Substances and Disease Registry (ATSDR) have reviewed environmental data to evaluate the public health implications of tetrachloroethylene (PCE) and trichloroethylene (TCE) contamination in groundwater at the Pohatcong Valley Groundwater Contamination Superfund site located in Franklin Township, Washington Township, and Washington Borough in Warren County. Currently the site is divided into three operable units (OU1, OU2 and OU3) by the United States Environmental Protection Agency (US EPA).

The top priority of ATSDR and NJDHSS is to ensure that the community around the site has the best information possible to safeguard its health.

Conclusions

NJDHSS and ATSDR have reached six conclusions regarding potential health implications of exposures to contaminants related to the Pohatcong Valley Groundwater Contamination Superfund site:

Conclusion 1

NJDHSS and ATSDR conclude that past ingestion and inhalation exposures to PCE and TCE in drinking water from the public supply system and PCE in domestic wells within the OU2 area will not have harmed people's health. Drinking water from domestic (private) wells that have Point-of-Entry Treatment (POET) systems installed will not harm people's health, as long as the POET systems are properly designed and maintained.

Basis for Conclusion

Concerning ingestion of untreated water from the public water supply during the 1972 through 1981 period, exposure doses calculated did not indicate exposures were harmful to residents. Since 1981, residents who were connected to the public supply system were not exposed to contaminants in drinking water, since a treatment system was put into operation for the Vannatta Street well. For domestic wells in the OU2 area, exposures were stopped for residents when POET systems were installed during 2002 through 2010. It should be noted that these exposures are only considered eliminated if POET systems are properly designed and maintained.

Next Steps	The US EPA has completed a Remedial Investigation/Feasibility Study (RI/FS) and has issued a Record of Decision (ROD) selecting the remedial action for the OU2 study area. This action includes the installation and supply of public water to accessible residences and monitoring of POET systems for remote residences outside the accessible limits of the public water supply system. The US EPA refers residences to the New Jersey Department of Environmental Protection (NJDEP) for further action when required concerning confirmation sampling, installation and monitoring of POET systems. Until residents are connected to the public water supply system, it is recommended that the NJDEP continue to ensure proper operation/maintenance of the installed POET systems at affected residences.
Conclusion 2	*NJDHSS and ATSDR conclude that past ingestion and inhalation exposures to TCE in contaminated domestic wells within the OU1 area (prior to POET installation) may have harmed people's health.*
Basis for Conclusion	For domestic wells at approximately 48 residences within the OU1 area, exposures to TCE contaminated groundwater occurred prior to connection to the public water service (these connections occurred during the 1980s in the OU1 area) or the installation of the POET systems in both the OU1 and OU2 areas (2002 through 2010). The cumulative lifetime excess cancer risk from ingestion and inhalation exposures to contaminants in domestic well water are considered to have posed a low increase in risk of cancer when compared to the background risk of cancer. Exposures to residents who used contaminated water from untreated domestic wells as a potable source for drinking and showering are of concern for the increased risk of adverse non-cancer health effects to occur, specifically fetal heart malformations. This is of particular concern to children of unborn pregnant women exposed to TCE at the upper end of detected concentrations in domestic well water.
Conclusion 3	*NJDHSS and ATSDR conclude that current ingestion and inhalation exposures to PCE and TCE in drinking water from domestic wells may have harmed people's health for residents who either do not have POET systems installed or are not connected to the public water supply.*
Basis for Conclusion	In an effort to identify remaining residences within the OU1 and OU2 study areas which are not connected to public water or have POET

systems, the US EPA has reached out to homeowners, and continues to do so, to arrange for water testing and corrective actions for the supply of safe potable water. These efforts have been assisted by the NJDEP, the Warren County Health Department and the New Jersey American Water Company. In the past, some homeowners, specifically within the OU1 study area, have elected not to connect to the public water system and not to have POET systems installed on their domestic wells. The US EPA continues with these efforts; however for homeowners whose domestic wells remain untested, *in addition to past exposures*, current and future exposures are assumed to be similar for the past exposure scenario evaluated for the OU1 and OU2 study areas.

Next Steps

The US EPA should continue with their efforts to identify residences within the OU1 and OU2 study areas who are not connected to the public water supply and do not have POET systems installed on their domestic wells. Once identified, US EPA should take appropriate actions to address any exposure pathways.

Conclusion 4

NJDHSS and ATSDR conclude that past exposures to TCE in indoor air for one residence within the OU2 study area may have harmed people's health. Current and future exposures are considered to be interrupted due to completed remedial actions at this residence.

Basis for Conclusion

TCE concentrations in indoor air at this residence were considered a concern for an increased risk of adverse non-cancer health effects (fetal heart malformations in unborn children) for exposures occurring to pregnant women prior to remedial actions taken at this property. Inhalation exposures are considered to be interrupted with the operation of vapor intrusion remedial system in 2007 designed to prevent subsurface contaminant vapors from entering this residence.

Next Steps

Until a remedial measure(s) removes the threat of vapor intrusion, short-term solutions, such as venting systems, should continue to be considered for buildings impacted by this pathway. Specifically, these solutions are warranted when elevated concentrations of site-related contaminants are present in soil gas increasing the threat of vapor intrusion.

Conclusion 5	*NJDHSS and ATSDR conclude that past, current and future exposures to 1,2-DCA, PCE, and TCE in indoor air at remaining evaluated residences are not expected to harm people's health.*
Basis for Conclusion	For the remaining residences, schools and day-care facilities evaluated, completed exposures to children and adults to these contaminants of concern in indoor air are not expected to cause adverse non-cancer health effects as contaminant concentrations were determined to not pose a health risk based on current health-based comparison values. These exposures are considered to pose a no apparent increase in risk of cancer when compared to the background risk of cancer.
Next Steps	The US EPA should continue remedial investigations, including vapor intrusion, and evaluate feasibility studies to implement a remedy for the contaminated groundwater plume to eliminate remaining ingestion and vapor intrusion pathways.
Conclusion 6	*NJDHSS and ATSDR conclude that past, current and future exposures to PCE in surface water within the Pohatcong and Shabbecong Creeks and the former Edison Quarry are not expected to harm people's health.*
Basis for Conclusion	Exposures to children and adults during recreational activities in the Pohatcong and Shabbecong Creeks and the former Edison Quarry are not expected to cause adverse non-cancer health effects as contaminant concentrations remain below health-based comparison values. There is no expected increase in the risk of cancer to individuals using these creeks and the quarry for recreational purposes.
Next Steps	The US EPA should continue remedial investigations and evaluate feasibility studies to implement a remedy for contaminated groundwater and other site-related sources (i.e., surface water run-off) to eliminate the discharge of contaminants to the Pohatcong and Shabbecong Creeks and the former Edison Quarry.

For More Information

Copies of this public health assessment will be provided to concerned residents in the vicinity of the site via the township libraries and the Internet. NJDHSS will notify area residents that this report is available for their review and provide a copy upon request. Questions about this Public Health Assessment should be directed to the NJDHSS at (609) 826- 4984.

Comments to this public health assessment are requested within 30 calendar days from the date its release and can be directed to:

Environmental and Occupational Health Surveillance Program
New Jersey Department of Health and Senior Services
Consumer, Environmental and Occupational Health Service
P.O. Box 369
Trenton, New Jersey 08625-0369

Statement of Issues

In August 2006, the U.S. Environmental Protection Agency (US EPA) requested assistance from the New Jersey Department of Health and Senior Services (NJDHSS) in the interpretation and public health evaluation of site-related contamination detected during ongoing investigations being overseen by the US EPA for the Pohatcong Valley Groundwater Contamination Superfund (PVGCS) site. The site is situated within Washington Township, Franklin Township, and Washington Borough in Warren County. Through a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR), the NJDHSS reviewed environmental data and prepared this Public Health Assessment (PHA) to determine the public health implications associated with groundwater contamination for this site. This includes obtaining the most recent data related to the ongoing vapor intrusion investigation being conducted for the site beginning in 2006, and the completion of two remedial investigation/feasibility studies finalized in 2005 and 2010.

Due to the complexity of this site that involves several properties which may each collectively contribute to the overall contamination discovered during US EPA investigations, this PHA focuses on trichloroethylene (TCE) and tetrachloroethylene (PCE), which are the predominant chemicals of concern in groundwater.

Background and Site History

The PVGCS site involves TCE and PCE contamination of the Kittatinny Limestone Aquifer. This aquifer is used as the sole source of potable water for public and private (domestic) systems to residents living within the Pohatcong Valley area. The site is situated within the areas encompassing Franklin Township, Washington Township, and Washington Borough within Warren County, New Jersey (see Figure 1).

The physical setting of the PVGCS site extends approximately 9 miles from Washington Borough to the town of Broadway and is bordered to the north at the base of the Scott/Oxford Mountains and the former Morris Canal. To the south, the site is bordered by the base of the Pohatcong Mountains, Pohatcong Creek, and Good Springs Road. Based on the degree of TCE and PCE contamination in groundwater and affected populations, the site was added to the US EPA's National Priorities List (NPL) in March 1989.

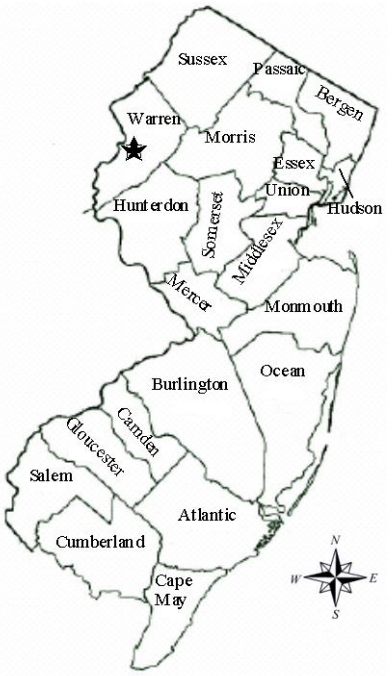


Figure 1: Location of Pohatcong Valley Groundwater Contamination Site

Currently the site is divided into three operable units by the US EPA. Operable Unit 1 (further denoted as OU1) extends approximately 5 miles encompassing roughly 8.75 square miles (5,600 acres) within portions of Franklin Township, Washington Township, and

Washington Borough. The area consists of rural, industrial, municipal, and residential land (see Figure 2). Analyses of two public supply wells in 1978 and 1979 indicated groundwater was contaminated with TCE and PCE. These wells are owned and operated by the New Jersey American Water Company (NJAWC) which purchased this public supply system in the mid-1980s. The public supply well, known as the Vannatta Street well located in Washington Borough, was installed in 1972 to augment the main supply obtained from the Brass Castle Reservoir. The Vannatta Street well was fitted with a carbon filtration system in 1981 to treat the contaminated groundwater prior to distribution to the public. The second well, known as the Dale Avenue well located in Washington Township, was installed in 1978 and was not put into service until the 1990s after treatment controls (air strippers) were installed to remove groundwater contaminants (NJDHSS 2004). The use of the Brass Castle Reservoir as a potable water supply ended when an additional well, known as the Changewater Avenue well, was added to the system in 1985. This well is located upgradient and outside the contaminated groundwater plume.

The NJDEP issued a memorandum in 1985 indicating the aquifer was impacted with volatile organic contaminants (VOCs) prior to 1978 based on analytical testing of the above public supply wells. In 1984 and 1985, additional investigation by the Warren County Health Department (WCHD) indicated 79 residential and commercial groundwater wells were contaminated with these compounds. This prompted the NJDEP to establish a Well Restriction Area (WRA) in 1988 and 1989 within the OU1 study area. From 1986 through 1989, under the WRA, 193 locations, which included residences, businesses, the Warren County Vocational Technical School and the Franklin Township Elementary School were connected to a public water supply system and impacted area wells were sealed. However, at that time, approximately 40 residences refused, and continue to refuse, to be connected to the public water service citing financial concerns over future water bills. Based on the findings for the OU1 area, the US EPA expanded their remedial investigations to the Operable Unit 2 (OU2) area.

In 2006, the US EPA began investigation of the OU2 study area which is located hydraulically downgradient from OU1 within portions of Franklin and Greenwich Townships. The OU2 study area extends approximately 4 miles within the Pohatcong Valley from the end of the OU1 Study Area to Stewartsville (see Figure 3). Main use of this area includes rural farm and residential communities, and also includes some commercial and industrial facilities located along State Route 57 and Edison Road. Remedial investigations focused on the nature and extent of TCE contamination in groundwater originating from the OU1 area extending into the OU2 area. As a public water supply does not extend to the OU2 area, during the 2002/2003 investigation period, the NJDEP installed Point-of-Entry Treatment (POET) systems at residences where TCE levels exceeded the New Jersey Groundwater Quality Criteria (GWQC, also known as the Groundwater Remediation Standard) of 1 microgram per liter (µg/L). The US EPA completed a remedial investigation/feasibility study (RI/FS) for OU2 in 2010 followed by a Record of Decision (ROD) in September 2010 that identified the selected remedy for this area. The chosen remedy for the OU2 area is installing and providing public water to accessible residences, installing and maintaining POET systems for residences deemed inaccessible for public water supply (institutional controls), and monitoring natural attenuation (groundwater monitoring) of the existing groundwater contaminant plume. The timeframe to install approximately 10 miles of public water supply line and connect accessible residences is approximately 2 years after initiation. Monitoring natural attenuation of the groundwater plume

where TCE contaminant levels will decrease to below the New Jersey GWQC of 1 µg/L is estimated at 67 years based on US EPA modeling. The US EPA estimates the capital cost of this remedy at $14,000,000 (USEPA 2010b, 2010c). Additional US EPA investigations included surface water and sediment sampling of the Pohatcong and Shabbecong Creeks to evaluate whether site-related contaminants have impacted these water bodies.

The Operable Unit 3 (OU3) study area is located within the borough of Washington and will specifically focus on several source areas believed to be contributing to the predominant TCE contamination within groundwater. Enforcement negotiations were initiated by the US EPA with one of the Potential Responsible Parties (PRPs) to conduct an RI/FS of this area in the near future. The purpose of this RI/FS is to fully determine the nature and extent of contaminated source material.

Based on investigations conducted to date, the US EPA has identified four PRPs believed to be responsible for the majority of the PCE and TCE contamination for the PVGCS site. The US EPA has identified L&L Dry Cleaners, Modern Valet Service and the former Tungsol Tubing as the potential major contributors to the PCE contamination, and Pechiney Plastics Packaging Incorporated (the former American National Can) as the potential major contributor to the TCE contamination. These facilities are located in the borough of Washington within the OU3 study area.

The US EPA issued a Record of Decision (ROD) in July 2006 for the OU1 study area to address PCE and TCE groundwater contamination. Remedial Design (RD) activities were initiated in the fall of 2006 for PCE contamination and in the fall of 2007 for TCE contamination for source areas within the OU3 study area. The RD involves extracting and treating contaminated groundwater within source areas, natural attenuation until contaminants are below the state cleanup criteria, and the establishment of institutional controls, such as a Classification Exemption Area, to further restrict use of contaminated groundwater within the OU1 area until the aquifer is restored. Most recent actions conducted in 2009 and 2010 involve attempts by the US EPA and NJDEP to sample groundwater from all domestic wells within both the OU1 and OU2 areas. This effort included sending out questionnaires to approximately 200 residences within the OU1 area and approximately 650 residences within the OU2 area in 2009 with the assistance of the NJDEP, the Warren County Health Department and the New Jersey American Water Company. This is being conducted to identify all remaining residences whose well water has been impacted by site-related contamination and provide interim remedial measures to protect residents from exposure until a permanent remedy is implemented for all residences.

Geology and Hydrogeology

The PVGCS site lies within the elongated valley between two parallel opposing topographic ridges within Washington Borough and Franklin Township in Warren County, New Jersey. The geology of the Pohatcong Valley consists of unconsolidated sedimentary deposits of glacial origin overlaying weathered bedrock. The unconsolidated sediments vary in thickness, but are generally between 50 and 100 feet thick within the Washington Borough area. Underlying the unconsolidated sediments is the primary drinking water aquifer for the area, which is composed of competent bedrock, consisting of fractured and karstic limestone and dolomite.

Groundwater in the Pohatcong Valley is found to a limited extent in perched aquifers within the shallow unconsolidated deposits, and primarily in the deeper regional aquifer in the weathered overburden and bedrock. Perched aquifers are not considered to represent a significant source of groundwater for the region. Additionally, performance of aquifer tests demonstrated there is a lack of hydraulic connection between the perched aquifer and the underlying regional groundwater aquifer.

Groundwater in the regional aquifer is generally encountered at a depth of approximately 100 feet below ground surface (bgs) in the northern portion of the OU1 Area, and at a depth of approximately 40 feet bgs in the downgradient southern portion of the OU1 Area. Groundwater generally flows to the southwest along the length of the Pohatcong Valley toward the Delaware River with some discharge occurring in the Pohatcong Creek which runs east to west within the OU1/OU2 study areas (see Figures 2 and 3).

Groundwater in the Pohatcong Valley is used as a source of potable drinking water, industrial process and cooling water, and for irrigation purposes.

Demographics

Using 2000 U.S. Census data, it is estimated that 10,902 individuals reside within a one-mile radius of OU3, which is considered by the US EPA to be the source area of PCE and TCE groundwater contamination for the site (see Figure 4).

Community Health Concerns

In the past, area residents have expressed concern over exposures to site-related contaminants in groundwater. The US EPA is continuing investigations to identify the Responsible Party or Parties (RP) responsible for causing contamination of the groundwater aquifer and additional contaminated media. The main concerns to residents are the long-term health effects associated with the past use of contaminated groundwater as a potable supply.

Past ATSDR/NJDHSS Involvement

ATSDR and NJDHSS had reviewed analytical data for groundwater and provided a public health assessment report in September 1990 for the PVGCS site. The ATSDR and NJDHSS concluded there was a concern to public health based on contaminant levels observed in groundwater.

Environmental Contamination

An evaluation of site-related environmental contamination consists of a two tiered approach: 1) a screening analysis; and 2) a more in-depth analysis to determine public health implications of site-specific exposures. First, maximum concentrations of detected substances are compared to media-specific health-based guideline comparison values (CVs). If concentrations exceed the CV, these substances, referred to as Contaminants of Concern (COC),

are selected for further evaluation. Contaminant levels above CVs do not mean that adverse health effects are likely, but that further evaluation is necessary. Once exposure doses are estimated, they are further evaluated to determine the likelihood of adverse health effects.

Health-Based Guideline Comparison

There are a number of CVs available for the screening environmental contaminants to identify COCs. These include ATSDR Environmental Media Evaluation Guides (EMEGs) and Reference Media Evaluation Guides (RMEGs). EMEGs are estimated contaminant concentrations that are not expected to result in adverse non-carcinogenic health effects. RMEGs represent the concentration in water or soil at which daily human exposure is unlikely to result in adverse non-carcinogenic effects. If the substance is a known or a probable carcinogen, ATSDR's Cancer Risk Evaluation Guides (CREGs) are also considered as comparison values. CREGs are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed during their lifetime (70 years). In the absence of an ATSDR CV, other comparison values may be used to evaluate contaminant levels in environmental media. These include the US EPA Maximum Contaminant Levels (MCLs), US EPA Region 6 Human Health Media-Specific Screening Levels (SLs), and the NJDEP Groundwater Quality Criteria (GWQC) for drinking water. These health-based benchmarks are derived from the evaluation of cancer and non-cancer effects using current toxicity criteria.

Substances exceeding applicable CVs are identified as COCs and evaluated further to determine whether these contaminants pose a health threat to exposed or potentially exposed receptor populations. If CVs are unavailable, these contaminants are selected for further evaluation.

Groundwater

OU1 Area

Data were reviewed from 348 groundwater samples collected from June 1999 through August 2007 from 130 monitoring wells located within the OU1 investigation area. The depth of collection for groundwater samples ranged from 9 to 412 feet. These samples were collected as part of the RI activities overseen by the US EPA.

Concentrations of PCE and TCE in groundwater samples ranged from non-detect to 1,500 µg/L and non-detect to 2,100 µg/L, respectively. The levels found exceed the ATSDR CREG for PCE 0.06 µg/L and the NJDEP GWQC of 1 µg/L for TCE (see Table 1). Based on these data, PCE and TCE are considered COCs in groundwater. The predominant contaminants in groundwater for the OU1 area are PCE and TCE as depicted in the isopleth map (see Figure 5). It is noted that the PCE plume is more localized within the OU1 area compared to the more widespread TCE plume which extends into the OU2 area.

Groundwater samples from two monitoring wells located hydraulically upgradient and outside the OU1 study area did not detect TCE. PCE was detected in two of 14 samples at estimated (non-quantified) concentrations less than the NJDEP GWQC of 1 µg/L. Due to this limited detection, PCE is not considered a COC in this upgradient background well.

OU2 Area

Data were reviewed from 29 groundwater samples collected from 12 monitoring wells located within the OU2 investigation area between January through December 2007. The depth of collection for groundwater samples ranged from 10 to 165 feet. These samples were collected as part of the RI activities overseen by the US EPA.

Concentrations of PCE and TCE in groundwater samples ranged from non-detect to 0.58 µg/L and non-detect to 33 µg/L, respectively (see Table 1). Although concentrations of PCE in groundwater from monitoring wells did not exceed the NJDEP GWQC, groundwater data from residential wells within the OU2 study area demonstrate that PCE exceed this standard as detailed later within this document. Therefore, PCE and TCE are considered COCs. The predominant contaminant in groundwater for the OU2 area is TCE as depicted in the isopleth map in Figure 5.

Potable Groundwater Use

OU1 Area – Public Water Supply Wells

Information obtained from the US EPA 2005 RI/FS study identifies three wells owned and operated by the NJAWC which were used to supply potable water to residents within Pohatcong Valley. Analytical data was reviewed to assess TCE and PCE concentrations in groundwater prior to the removal of these contaminants by the treatment system. Two wells, PVMSW01 (Vannatta Street well) and PVMSW04 (Dale Avenue well) are located within the OU1 study area. The remaining well, PVMSW02 (Changewater Avenue well), is located within Washington Township and is positioned hydraulically upgradient and outside of the OU1 study area (groundwater impact area).

Historical data from 1985 through 2007 indicate TCE concentrations ranged from non-detect to 24 µg/L (average 1.2 µg/L) and PCE concentrations ranged from non-detect to 183 µg/L (average 63 µg/L) for untreated water from the Vannatta Street well, which exceeds the NJDEP GWQC of 1 µg/L. Analytical results reviewed for the same period indicate TCE concentrations ranged from 12 µg/L to 276 µg/L (94 µg/L) and PCE concentrations ranged from 0.5 µg/L to 7 µg/L (average 0.8 µg/L) for the Dale Avenue well, which exceed the NJDEP GWQC of 1 µg/L.

Analysis of PCE data for untreated water from the Vannatta Street well indicates a declining trend from approximately 95 µg/L to 40 µg/L for the 1985 through 2007 period (see Figure 6). Analysis of TCE data for untreated water from the Dale Avenue well indicates a declining trend from approximately 130 µg/L to 60 µg/L for the 1985 through 2007 period (see Figure 6).

Analytical data reviewed for the period of 1999 through 2007 for well PVMSW02 (Changewater Avenue well), located hydraulically upgradient and outside of the groundwater plume, indicate TCE and PCE were not detected. Analytical data for the NJAWC wells for the 1985 through 2007 period are presented in Table 2.

OU1 Area – Residential Domestic Wells

Information obtained from the US EPA 2005 RI/FS study for the OU1 area indicates groundwater from 22 domestic wells (including three domestic wells used for non-potable purposes) were sampled during the period of August 1999 through June 2002. The three domestic wells used for non-potable purposes are identified as PV-093, PVDOM01 and PVDOM02. The latter residences were allowed to maintain their domestic wells after they were connected to the public water supply system. Results indicate five residences (including two residences using domestic wells PVDOM01 and PVDOM02 for non-potable purposes) were above the NJDEP GWQC of 1 µg/L for TCE for this sampling period (See Table 3). Of these 5 residences, 2 residences also exceeded the CREG of 0.06 µg/L for PCE, but were less than the NJDEP GWQC of 1 µg/L for PCE (See Table 3). Based on analytical data, TCE is considered a COC for groundwater for the five residences (with PCE a COC for 2 of these 5 residences) within the OU1 study area.

Additional information provided indicates the WCHD conducted a study of potable wells within the OU1 area in 1984. Results of this study indicate TCE concentrations ranged from non-detect to 440 µg/L; 70 of the 93 residences sampled exceeded the NJDEP GWQC of 1 µg/L (see Table 3). Therefore, based on the above sampling information from the US EPA and WCHD efforts, it is estimated that approximately 75 residences in the OU1 study area had detections of TCE above the NJDEP GWQC of 1 µg/L.

As completed in the US EPA 2005 RI/FS study, an exposure assessment was performed for ingestion of groundwater, and inhalation and dermal absorption while showering. This assessment was performed to demonstrate the risk associated with past exposures to groundwater contaminated with TCE and PCE when it was used as a potable water source for the above identified residences.

OU2 Area – Residential Domestic Wells

Analytical data provided by the US EPA were reviewed for 266 residences sampled by the US EPA in 2009 within the OU2 study area. Results indicate TCE concentrations ranged from non-detect to 10 µg/L with 31 domestic wells servicing 37 residences exceeding the NJDEP GWQC of 1µg/L. There were no detections of PCE present for all sampled residences under this investigation. It is noted that 5 of the 266 residences sampled have POET systems installed to treat groundwater in which there were no detections of TCE or PCE found in post-treated samples.

For the investigation period spanning from 2000 through 2008, analytical data presented in the RI/FS report for the OU2 study area were reviewed for the 204 residences sampled. A total of 735 groundwater samples were collected by US EPA (37 samples), NJDEP (395 samples) and WCHD (303 samples).Some residences were sampled on multiple occasions. Groundwater samples were collected from February 2000 through March 2008 from the influent of the POET treatment systems to assess TCE and PCE concentrations from untreated groundwater. However, it is noted that data provided by the NJDEP and WCHD do not differentiate between pre- and post-treatment (i.e., POET) samples; therefore, only data equal to

or exceeding the NJDEP GWQC of 1 µg/L were presented as an estimate of pre-treatment conditions.

The above residences sampled use groundwater from domestic wells as their potable water supply. Based on maximum concentrations detected in domestic well water (groundwater), TCE and PCE have been verified as COCs for both the OU1 and OU2 study areas (see Table 3).

Vapor Intrusion Investigation

Based on the extent of PCE and TCE contamination in groundwater, a vapor intrusion investigation was initiated in 2006 within the OU1 and OU2 study areas. Soil gas samples were collected from US EPA identified buildings which included residential, municipal, public schools, and daycare centers to determine whether site-related contaminants posed a threat of vapor intrusion. Soil gas data was used to identify locations for further evaluation of vapor intrusion. Site-related contaminants detected in soil gas and indoor air for the investigated properties has been evaluated for the sampling period of March 2006 through April 2009.

Sub-slab/Soil Gas

Based on the extent and concentration of contaminants within the groundwater plume, the US EPA identified the following locations for soil gas and sub-slab sampling: 19 residences, one multi-tenant dwelling, 5 daycare centers, 3 elementary schools, 1 middle school, 1 community college, and 2 municipal buildings. Sub-slab and soil gas samples were analyzed for targeted VOCs including 1,2-dichloroethane (1,2-DCA); 1,1-dichloroethene; cis-1,2-dichloroethene; trans-1,2-dichloroethene; PCE; TCE; and vinyl chloride. Analysis was performed using US EPA Method TO-15 for samples collected during the March 2006 through April 2009 investigation period.

Contaminants exceeding US EPA's draft interim Soil Gas Screening Values (SGSVs) include PCE (range: non-detect to 16,600 µg/m^3), TCE (range: non-detect to 951 µg/m^3) and 1,2-DCA (range: non-detect to 6.48 µg/m^3). The US EPA used site-specific SGSVs for PCE, TCE and 1,2-DCA of 100 µg/m^3, 2.7 µg/m^3, and 0.94 µg/m^3, respectively. Further investigations were conducted by the US EPA at locations if SGSVs were exceeded. A summary of sampled locations and COCs detected in sub-slab/soil gas samples are presented in Table 4.

Indoor Air

Based on sub-slab/soil gas results and additional data, the US EPA chose the following locations for further investigation for possible site-related contaminants in indoor air: 6 residences; 1 multi-tenant dwelling, 2 daycare centers, the Franklin Township Elementary School, and the Warren Hills Middle School. Air samples were collected over a 24-hour period using SUMMA® canisters and analyzed for the same targeted VOCs as the sub-slab/soil gas samples. Analysis was performed using US EPA Method TO-15 for samples collected during the March 2006 through April 2009 investigation period. The US EPA did not evaluate indoor air for buildings with active or passive radon mitigation systems as these systems are an accepted remedial measure considered to sufficiently remove VOC vapors based on design.

COCs detected in indoor air exceeding the environmental CVs include 1,2-DCA (range: non-detect to 4.6 µg/m^3), PCE (range: non-detect to 67 µg/m^3) and TCE (range: non-detect to 11 µg/m^3) (see Table 5). Exceedance of one or more of the above site-related contaminants was observed at 3 residences, 1 multi-tenant dwelling, 2 daycare centers, the Franklin Township Elementary School, and the Warren Hills Middle School (see Tables 6 through 8). Ambient (outdoor air) concentrations of the above contaminants were within typical background concentrations observed for suburban areas (see Tables 6 through 8).

Based on the review of data described above, 1,2-DCA, PCE and TCE are considered COCs in indoor air for the eight locations identified above.

Pohatcong, Shabbecong and Merrill Creeks, and Former Edison Quarry

Surface Water (Creeks)

Data were reviewed from 19 surface water samples (plus one background sample) collected in May 2000 and December 2001 from locations along the Pohatcong and Shabbecong Creeks within the OU1 investigation area (see Figure 7). Data were also reviewed from 9 samples collected in January 2008 from the Pohatcong and Merrill Creeks within the OU2 investigation area (see Figure 8). These creeks are designated as FW-2 Trout Production and FW-2 Trout Maintenance within the Surface Water Quality Standards of the New Jersey Administrative Code (NJAC 2009). The Shabbecong and Merrill Creeks are tributaries to the Pohatcong Creek. These samples were collected as part of the RI activities overseen by the US EPA.

Concentrations of PCE and TCE in surface water samples ranged from non-detect to 1.1 µg/L and non-detect to 1.2 µg/L (estimated), respectively. Some values exceeded the NJDEP Surface Water Quality Standards (SWQS) of 0.34 (PCE) and 1 µg/L (PCE) (see Table 9a). It is noted that only one sample exceeded the SWQS for TCE in the OU2 study area at 1.2 µg/L. Additionally, there were no detections of PCE or TCE present for the background surface water sample collected from an upgradient location along the Pohatcong Creek within the OU1 area nor in the one sample collected from the Merrill Creek within the OU2 area (CH2MHILL 2005, 2010).

Surface Water: Source Areas of Pechiney Plastics Packaging Incorporated Property

The source areas on the Pechiney Plastics Packaging Incorporated property discharge to the storm drain system which eventually discharges to surface waters of the Pohatcong and Shabbecong Creeks within the OU1 study area. Data were reviewed from 6 surface water samples collected in March 2000 and January 2002 from surface run-off (drainage swale) and pipe outfall locations from TCE contaminant source areas on the Pechiney Plastics Packaging Incorporated property (the former American National Can). These samples were presumed to be storm water which eventually discharges into the Pohatcong Creek within the OU1 investigation area. Data were also reviewed from one surface water sample collected from a storm water collection basin near a PCE contaminant source area discharging into the Shabbecong Creek within the OU1 investigation area. Concentrations of TCE in surface water samples ranged from

non-detect to 25 µg/L, which exceeds the NJDEP SWQS of 1 µg/L (see Table 9a). PCE was not detected.

Therefore, based on all surface water data and sampling locations from creek and contaminant source areas, PCE and TCE are considered COCs for the Pohatcong and Shabbecong Creeks within the OU1 and OU2 study areas.

Surface Water (Former Edison Quarry)

Data were reviewed from 15 water samples collected in September 2003 from the former Edison Quarry located within the OU2 study area (see Figure 9). Samples were collected from discrete depth intervals from 5 to 87 feet below the surface. Concentrations of TCE in water samples ranged from 0.36 to 6.2 µg/L, exceeding the NJDEP SWQS of 1 µg/L (see Table 9a). PCE was not detected. Based on these data, TCE is considered a COC in surface water for the quarry.

Sediment

Data were reviewed from 20 sediment samples collected in May 2000 and December 2001 from locations along the Pohatcong and Shabbecong Creeks within the OU1 investigation area; 1 sediment sample from the Edison Quarry collected in January 2008; and 5 sediment samples collected in January 2008 from locations along the Pohatcong and Merrill Creeks within the OU2 investigation area (see Figures 7 and 8). Concentrations of PCE and TCE in sediment for all sampled areas ranged from non-detect to 0.003 milligrams per kilogram (mg/Kg) (estimated) and non-detect to 0.026 mg/Kg (estimated), respectively. These values are below CVs (see Table 9b). Based on these data, PCE and TCE are not considered COCs in sediment.

Summary of Contaminants of Concern for Evaluated Locations

Groundwater	
Operable Units 1 & 2	**VOCs**
Regional Aquifer	PCE, TCE
Groundwater (Public Water Supply Before 1981)	
Operable Unit 1	**VOCs**
NJAWC: Vannatta St. and Dale Ave Wells	PCE, TCE
Groundwater (Residential Domestic Well Use)	
Operable Unit 1	**VOCs**
75 Residences (estimated) 2 Residences	TCE PCE
Operable Unit 2	**VOCs**
4 Residences	PCE
134 Residences	TCE
Indoor Air	
Operable Unit 1	**VOCs**
1 Residence	1,2-DCA, PCE, TCE
1 Multi-Tenant Residence	

Indoor Air	
Operable Unit 1	**VOCs**
Warren Hills Middle School	PCE, TCE
2 Daycare Centers	1,2-DCA, PCE, TCE
Operable Unit 2	**VOCs**
2 Residences	1,2-DCA, PCE, TCE
Franklin Township Elementary School	
2 Daycare Centers	
Surface Water	
Operable Unit 1	**VOCs**
Pohatcong and Shabbecong Creeks	PCE, TCE
Operable Unit 2	**VOCs**
Pohatcong Creek	TCE
Edison Quarry	

Toxicological summaries for identified COCs are provided in Appendix A.

Discussion

The method for assessing whether a health hazard exists to a community is to determine whether there is a completed exposure pathway from a contaminant source to a receptor population and whether exposures to contamination are high enough to be of health concern. Site-specific exposure doses can be calculated and compared with health guideline CVs.

Assessment Methodology

An exposure pathway is a series of steps starting with the release of a contaminant in environmental media and ending at the interface with the human body. A completed exposure pathway consists of five elements:

1. source of contamination;
2. environmental media and transport mechanisms;
3. point of exposure;
4. route of exposure; and
5. receptor population.

Generally, the ATSDR considers three exposure categories: 1) completed exposure pathways, that is, all five elements of a pathway are present; 2) potential exposure pathways, that is, one or more of the elements may not be present, but information is insufficient to eliminate or exclude the element; and 3) eliminated exposure pathways, that is, a receptor population does not come into contact with contaminated media. Exposure pathways are used to evaluate specific ways in which people were, are, or will be exposed to environmental contamination in the past, present, and future.

When assessing an exposure risk to a COC, the US EPA recommends the 95 percent upper confidence limit (95% UCL) of the arithmetic mean should be used to determine the exposure point concentrations (EPC) for site-related contaminants (US EPA 1992). An EPC is considered to be the concentration of a contaminant at the point of human exposure. The 95% UCL is considered a 'conservative estimate' of average contaminant concentrations in an environmental medium to represent the EPC. To determine EPCs, site data was analyzed using ProUCL® 4.0 (US EPA 2007) developed by the US EPA to calculate the 95% UCL.

The exposed populations for identified areas of concern include children and adults associated with residences, schools and daycare centers identified through the investigation efforts conducted by the US EPA, the NJDEP and the WCHD.

The evaluated exposure pathways for site-related contaminants are presented in Table 10.

Completed Exposure Pathways

Ingestion, Inhalation and Skin Absorption of COCs from Groundwater Used for Domestic Purposes (past).

Public Water Supply

During a period from 1972 to 1981, there was a completed exposure pathway to PCE and, to a lesser extent TCE, from contaminated groundwater used as a potable source from one public water supply well identified as the Vannatta Street well (PVMSW01). Records indicate this well was installed in 1972 with water from this source being used to augment the main water supply obtained from the Brass Castle Reservoir. The use of the Brass Castle Reservoir as a potable water supply ended after the Changewater Avenue well (PVMSW02) was added to the system in 1985.

Exposures to contaminated groundwater from the Vannatta Street well occurred primarily to residents within the OU1 study area supplied with potable water from this source from the 1972 to 1981 period. Exposures had ceased by 1981 with the operation of a treatment system designed to remove PCE and TCE contaminants from groundwater extracted from this well. Treated water was then distributed as a potable water source to residents (NJDHSS 2004). The exposure pathways included ingestion of contaminated water and dermal absorption and inhalation during showering.

Background information for a second public water supply well, identified as the Dale Avenue well (PVMSW04), indicates this source for potable water was not put into use until treatment controls (air stripping) were installed in the 1990s to remove TCE (primary contaminant) and PCE from groundwater extracted from this well (NJDHSS 2004). Therefore, based on this information, exposures would not have occurred to residents from groundwater extracted from the Dale Avenue well.

Domestic Residential Wells

For the past, there was an exposure pathway to PCE and TCE from contaminated groundwater used for potable purposes . These exposures have occurred within the OU1 study area for approximately 75 domestic wells used by residents and businesses prior to their connection to the public water supply completed by approximately 1989. Additionally, there are approximately 40 residences within the OU1 study area where the owners have refused connection to the public supply system to which current and future potential exposures may exist. As there are no data available for these residences, past exposures were assessed under the assumption that their exposures are similar to the scenario evaluated for the OU1 study area.

Past exposures have occurred at approximately 138 residents within the OU2 study area prior to the installation of the groundwater POET systems (circa 2002 and 2010). The US EPA has recently completed sampling of 266 residences in the OU2 study area in 2009 of which 31 domestic wells (servicing 37 residences) have been referred to NJDEP for further action. These further actions included confirmatory well water sampling to determine if POET systems need to be installed. As of January 2010, the NJDEP has indicated confirmatory sampling has necessitated the installation of POET systems for 23 of the 31 domestic wells. The exposure pathways include ingestion of contaminated water and dermal absorption and inhalation during showering. Regarding showering exposures, inhalation from showering is thought to be the more prominent exposure compared to the dermal route. PCE and TCE were conservatively estimated to volatilize 90 % during showering; therefore, dermal exposures would be considered a minor contributor in this scenario. Following US EPA guidance, dermal exposure for bathing scenarios were assessed for the most likely population being children less than 1 through 6 years old.

Current and future exposures have been eliminated for residents who are currently connected to the public water supply for the OU1 area as their domestic wells have either been sealed or are no longer used as a source of potable water. Additionally, beginning in 1984, amendments to the federal Safe Water Drinking Act which were adopted by New Jersey, required purveyors of public water to regularly monitor their water supply by testing for a wide range of contaminants, including PCE and TCE, to ensure MCLs are not exceeded (NJDEP 2004).

For the OU2 study area, the US EPA has indicated that due to the "fractured karstic nature of the aquifer," they cannot predict with any degree of certainty which domestic wells will be impacted by site-related contaminated groundwater in the future. Therefore, the US EPA is attempting to sample drinking water from domestic wells in use for all residences within the OU2 study area. They consider all domestic wells to be at risk from site-related contaminants in groundwater. It is noted that exposures at residences where POET systems are installed are only considered interrupted if these systems are properly designed and maintained to reduce contaminants to levels safe for potable use. Improper design or maintenance of these systems may cause contaminants in groundwater to pass through and enter the household delivery system resulting in exposures. As such, the US EPA has indicated that POET systems are considered a temporary solution until they select a long-term permanent solution to eliminate the threat of ingestion of contaminated groundwater. Therefore, current and future exposures are considered

interrupted for residents within the OU2 study area who have POET systems installed to treat contaminated groundwater.

Inhalation of COCs in Indoor Air (past, present, future). There is a past exposure pathway via vapor intrusion regarding the inhalation of air contaminated with 1,2-DCA, PCE, and TCE for the areas of concern within the OU1 and OU2 study areas. Current and future exposures are considered interrupted as the US EPA is actively monitoring and planning remedial actions to address site-related groundwater contamination. Additionally, based on site-specific criteria, remedial systems have been installed at three receptor locations to mitigate vapor intrusion. The potential exposure pathway involves these contaminant vapors migrating upwards through contaminated subsurface media, groundwater and soil, and entering the interior of the areas of concern as follows:

OU1 – 1 residence, 1 multi-tenant residence and 2 daycare centers; and
OU2 – 2 residences and the Franklin Township Elementary School.

Inhalation exposures at a multi-tenant residence within OU1, the Franklin Township Elementary School and one residence within OU2 are considered to be interrupted with the operation of a soil vapor depressurization system designed to prevent subsurface contaminant vapors from entering the building. The systems were installed at the multi-tenant residence in 2009, and at the Franklin Township Elementary School and the residence in 2007 (US EPA 2009).

Ingestion and Absorption of COCs from Surface Water (past, present, future). For the past, present and future, there is an exposure pathway regarding the incidental ingestion of surface water contaminated with PCE and TCE from the Pohatcong and Shabbecong Creeks located within the OU1 and OU2 study areas, and the Edison Quarry located within the OU2 area. The ingestion pathway would occur from recreational activities (i.e., wading, swimming) in the creeks and quarry where surface water is accidentally swallowed. Swimming is generally considered the major activity where incidental ingestion of surface water occurs (US EPA 1997). It is noted that the highest detections of contaminants in surface water were observed near pipe outfall and within surface run-off (drainage swales) from TCE contaminant source areas on the Pechiney Plastics Packaging Incorporated property (the former American National Can) which discharge to storm drains eventually leading to the Pohatcong and Shabbecong Creeks within the OU1 study area. Recreational activities associated with this pathway are not present on the Pechiney Plastics Packaging Incorporated property.

Eliminated Exposure Pathways

Ingestion of Fish (past, present, future). Experimentally measured bioconcentration factors (BCFs) indicate PCE and TCE have a low tendency to bioaccumulate in fish. Monitoring data on TCE concentrations in aquatic organisms exposed to TCE contaminated water support experimental BCF data (ATSDR 1997a,b). Concentrations of PCE and TCE in surface waters of the Pohatcong and Shabbecong Creeks were shown to be very low and detected on an infrequent basis (see Table 9a). Therefore, exposures to PCE and TCE from consumption of fish taken from the Pohatcong and Shabbecong Creeks within the study areas would not present an exposure concern.

Public Health Implications of Completed Exposure Pathways

Once it has been determined that individuals have or are likely to come in contact with site-related contaminants (i.e., a completed exposure pathway), the next step in the public health assessment process is the calculation of site-specific exposure doses. This is called a health guideline comparison which involves looking more closely at site-specific exposure conditions, the estimation of exposure doses, and comparison to health guideline CVs. Health guideline CVs are based on data drawn from the epidemiologic and toxicologic literature and often include uncertainty or safety factors to ensure that they are amply protective of human health.

Non-Cancer Health Effects

To assess non-cancer health effects, ATSDR has developed Minimal Risk Levels (MRLs) for contaminants that are commonly found at hazardous waste sites. An MRL is an estimate of the daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of adverse, non-cancer health effects. MRLs are developed for a route of exposure, i.e., ingestion or inhalation, over a specified time period, e.g., acute (less than 14 days); intermediate (15-364 days); and chronic (365 days or more). MRLs are based largely on toxicological studies in animals and on reports of human occupational (workplace) exposures. MRLs are usually extrapolated doses from observed effect levels in animal toxicological studies or occupational studies, and are adjusted by a series of uncertainty (or safety) factors or through the use of statistical models. In toxicological literature, observed effect levels include:

- no-observed-adverse-effect level (NOAEL); and
- lowest-observed-adverse-effect level (LOAEL).

A NOAEL is the highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals. LOAEL is the lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals. In order to provide additional perspective on these health effects, the calculated exposure doses were then compared to observed effect levels (e.g., NOAEL, LOAEL). As the exposure dose increases beyond the MRL to the level of the NOAEL and/or LOAEL, the likelihood of adverse health effects increases. A point-of-departure (POD) dose may be used in the health assessment process in examining the potential for health effects to occur. A point-of-departure is defined as the dose-response point that marks the beginning of a low-dose extrapolation. This point is most often the upper bound on an observed incidence or on an estimated incidence from a dose-response model.

When MRLs for specific contaminants are unavailable, other health based comparison values such as the US EPA's Reference Dose (RfD) and Reference Concentrations (RfC) are used. The RfD is an estimate of a daily oral exposure and the RfC is an estimate of a daily inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime of exposure.

Ingestion of COCs in Groundwater

Past exposures are based on ingestion of well water contaminated with PCE and TCE under the following scenarios:

- residents supplied by the public water system utilizing the Vannatta Street well for the 1972 to 1981 period;
- residents within the OU1 area utilizing domestic wells prior to connection to the treated public water supply in 1989; and
- residents within the OU2 area using domestic wells prior to the installation of the POET systems.

Non-cancer exposure doses were calculated using the following formula:

$$\textit{Exposure Dose (mg/kg/day)} = \frac{C \times IR}{BW}$$

where, mg/kg/day = milligrams of contaminant per kilogram of body weight per day;
C = concentration of contaminant in groundwater (mg/L);
IR = groundwater ingestion rate (L/day);
BW = body weight (kg)

The following site-specific exposure assumptions (US EPA 2011) were used to calculate past contaminant doses to the primary receptors which would be area residents. The exposure assumptions for the populations within the OU1 and OU2 study areas are based on information provided in background documentation and from the US EPA 2005 RI/FS and 2010 RI/FS reports.

Exposed Population	Ingestion Rate	Exposure Assumptions	Number of Years Exposed
Child (birth through 6 years old)	0.049 to 0.235 liter/kg/day	365 days per year	6
Adult	0.032 liter/kg/day		30

OU1 Area: Public Water Supply

The potable water system was purchased by the NJAWC in the mid-1980s (NJDHSS 2004). Prior to 1985, unfiltered surface water from the Brass Castle Reservoir was the main supply (0.4-0.55 million gallons per day - mgd) augmented primarily in the summer and fall months by the Vannatta Street well (0.1-0.6 mgd). Background documentation indicates the Vannatta Street well, on average, supplied roughly one-third of total water throughout the year for the 1978-1979 season. Well usage pre-dating this period was not available.

Given available information, there is a measure of uncertainty as to the degree to which residents were exposed to PCE and TCE from untreated public supply water for the 1972 to 1981 period. While it is not known when the Vannatta Street well became impacted from site-related

contaminants prior to the discovery in 1979, exposures are assumed to have begun after the installation of this well in 1972 until the treatment system became operational in 1981. Limitations with this exposure assessment would include lack of data to show exact contributions made by the Vannatta Street well for the 1972 through 1978 period. The supply capacity of the Vannatta Street well indicates it is equivalent to that of the Brass Castle Reservoir. Therefore, to be conservative in exposure estimates, it is assumed that the Vannatta Street well supplied 100% of the potable water supply to residents within the OU1 study area for the 1972 through 1981 assessment period. Additionally, the potential for contaminants to volatilize out of groundwater as it was extracted, stored, and then distributed through the potable water delivery system has been disregarded.

PCE. The RfD for chronic oral exposure to PCE is 0.006 mg/kg/day reflects the midpoint among RfDs established from two studies based on neurological effects observed in occupationally-exposed adults. The extrapolated RfD is equivalent to a drinking water concentration of 0.21 milligrams of PCE per liter, assuming a body weight of 70 kilograms (kg) and a daily water consumption of 2 liters (USEPA 2012). The RfD was derived based on the following studies and uncertainty factors:

- *Study 1 (Echeverria et al. 1995)*: Neurological effects (cognitive and reaction time changes) shown in adult dry cleaning workers chronically exposed to PCE in indoor air. The LOAEL for continuous chronic inhalation exposure to PCE at 41 parts per million (estimated 278,080 µg/m^3) was converted using physiologically based pharmacokinetic (PBPK) modeling to extrapolate a point of departure (POD) for oral exposures at 9.7 mg/kg/day. An uncertainty factor of 1,000 was applied to the POD to calculate a candidate oral RfD equaling 0.0097 mg/kg/day.

- *Study 2 (Cavalleri et al. 1994)*: Neurological effects (color vision changes) shown in adult dry cleaning workers chronically exposed to PCE in indoor air. The LOAEL for continuous chronic inhalation exposure to PCE at 6 parts per million (estimated 40,690 µg/m^3) was converted using PBPK modeling to extrapolate a POD for oral exposures at 2.6 mg/kg/day. An uncertainty factor of 1,000 was applied to the POD to calculate a candidate oral RfD equaling 0.0026 mg/kg/day.

Based on the EPC of PCE (147 µg/L) detected in the public water supply, the exposure doses calculated for children (0.01 mg/kg/day) exceeded the chronic RfD for PCE at 0.006 mg/kg/day (see Table 11). The child exposure dose was 970 and 260 times lower than the PODs from Studies 1 and 2, respectively. It is concluded that it is unlikely that neurological effects have occurred to children ingesting well water containing this level of PCE for the exposure period of 1972 through 1981. The calculated exposure dose to adults (0.0047 mg/kg/day) was below the chronic RfD for PCE at 0.006 mg/kg/day (see Table 11); therefore, non-cancer adverse health effects are not expected to have occurred to the adult population exposed to contaminated public well water during the 1972 through 1981 period.

The following summary compares drinking water ingestion exposures which exceeded the RfD for children to the PODs identified in the two occupational studies and provides the conclusions for health effects to occur:

Area of Concern	TCE EPC Dose Child mg/kg/day	Study 1: Cognitive and Reaction Time Changes POD 9.7 mg/kg/day	Study 2: Color Vision Changes POD 2.6 mg/kg/day
		Potential for Health Effects to Occur	
OU1: Public Supplied Water 1972 - 1981	0.010	Unlikely	Unlikely

TCE. Based on the EPC of TCE (1.7 µg/L) detected in the public supply wells, the exposure doses calculated for children (0.0001 mg/kg/day) and adults (0.00005 mg/kg/day) were below the RfD for TCE (see Table 11). Therefore, based on the EPC of TCE detected in untreated groundwater from the Vannatta Street well (1.7 µg/L), non-cancer adverse health effects to individuals supplied with potable water from this well for the 1972 through 1981 period are not expected to have occurred.

OU1 & OU2 Study Areas: Domestic Wells

PCE. The maximum exposure dose calculated for children (0.001 mg/kg/day) and adults (0.0005 mg/kg/day) were below the RfD (see Table 12). Therefore, based on the maximum EPC of PCE detected in untreated groundwater (15.4 µg/L), non-cancer adverse health effects to individuals within evaluated residences in the OU1 and OU2 study areas are not expected to have occurred in the past.

However, historical PCE data for residential wells within the OU1 study area is very limited based on available information as the majority of residents have converted to the public water supply system by 1989. Groundwater samples within the regional aquifer for the OU1 study area show PCE maximum (1,500 µg/L) and average (7 µg/L) concentrations exceeding the NJDEP GWQC of 1 µg/L (see Table 1). Therefore, data may be inconclusive to evaluate past exposures to PCE in domestic well water for residents within this study area.

TCE. The RfD for chronic oral exposure to TCE is 0.0005 mg/kg/day reflects the midpoint among RfDs from three studies that noted adult immunological effects in mice, developmental immunotoxicity in mice and fetal heart malformations in rats (USEPA 2011b). These three studies derived the RfDs using the following uncertainty factors:

- *Study 1 (Kiel et al. 2009)*: Immunological effects in mice exposed for 30 weeks by drinking water. An uncertainty factor of 100 was applied to the LOAEL of 0.048 mg/kg/day to calculate the oral RfD equaling 0.00048 mg/kg/day.

- *Study 2 (Peden-Adams et al. 2006)*: Immunological effects in mice exposed from 0 until 3 or 8 weeks of age through drinking water. An uncertainty factor of 1,000 was applied to the LOAEL of 0.37 mg/kg/day to calculate the oral RfD equaling 0.00037 mg/kg/day.

- *Study 3 (Johnson et al. 2003)*: Fetal heart malformations in rats exposed from 1 until 22 weeks of age through drinking water. An uncertainty factor of 10 was applied to the LOAEL of 0.0051 mg/kg/day to calculate the oral RfD equaling 0.00051 mg/kg/day.

Given the exposure scenario for the OU1 study area, it was calculated a TCE concentration exceeding 7.4 µg/L would cause an exceedence of the RfD. For the 75 residences of concern, approximately 48 residences exceeded 7.4 µg/L of TCE in domestic well water where, based on the EPC of TCE (100 µg/L), the exposure doses calculated for children (0.007 mg/kg/day) and adults (0.003 mg/kg/day) exceeded the chronic RfD (see Table 12). The child and adult exposure doses were approximately 7 and 16 times, respectively lower than the LOAEL from Study 1. It is concluded that adult immunological effects (decreased thymus weights) are low. Comparison of exposure doses to the LOAEL from Study 2 indicates that the doses are 53 and 123 times lower for children and adults, respectively. It is concluded that developmental immunological effects are unlikely. The adult exposure dose was approximately 1.7 lower than the LOAEL from Study 3. In this instance, there is a possibility of potential fetal heart malformations to occur to pregnant women ingesting well water containing this level of TCE (100 µg/L).

Based on the maximum concentration of TCE (440 µg/L) detected at one residence, the exposure doses calculated for children (0.03 mg/kg/day) and adults (0.014 mg/kg/day) exceeded the chronic RfD for TCE (see Table 12). The child and adult exposure doses were 1.6 and 3.5 times lower than the LOAEL from Study 1. It is concluded that there is a possibility of adult immunological effects (decreased thymus weights) to occur to adults ingesting well water containing this level of TCE. Comparison of exposure doses to the LOAEL from Study 2 indicates that the doses are 12 and 27 times lower for children and adults, respectively. It is concluded that the possibility of developmental immunological effects is low. The adult exposure doses based on the maximum concentration of TCE were 2.7 times higher than the LOAEL from Study 3. In this instance, there is a possibility of potential fetal heart malformations to occur to the unborn children of pregnant women ingesting well water containing this level of TCE.

For the 134 residences of concern, approximately 18 residences exceeded 7.4 µg/L of TCE in domestic well water where, based on the EPC of TCE (12.2 µg/L), the exposure doses calculated for children (0.0008 mg/kg/day) exceeded the chronic RfD (see Table 12). The child exposure dose was approximately 60 times, 463 times and 7 times lower than the LOAELs from Studies 1, 2 and 3, respectively. It is concluded that potential for non-cancer adverse health effects from these studies to occur to children are unlikely. The exposure doses calculated for adults (0.0004 mg/kg/day) did not exceed the chronic RfD (see Table 12).

The following summary compares drinking water ingestion exposures to the LOAELs and provides the conclusions for health effects to occur:

Area of Concern	**TCE EPC Dose** Adult Child mg/kg/day	**Study 1:** Adult Immunological Effects LOAEL 0.048 mg/kg/day	**Study 2:** Developmental Immunotoxicity LOAEL 0.37 mg/kg/day	**Study 3:** Fetal Heart Malformations LOAEL 0.0051 mg/kg/day
		Potential for Health Effects to Occur		
OU1: 48 Residences	0.003 0.007	Low	Unlikely	Possible
OU1: 1 Residence	0.014 0.03 (max.)	Possible	Low	Possible
OU2: 18 Residences	0.00044 0.0008 (max.)	Unlikely	Unlikely	Unlikely

Inhalation of COCs during Showering

A previous assessment of inhalation exposures while showering with contaminated water was conducted for a site in Winslow Township, New Jersey (ATSDR 2005a). This assessment cited a number of studies that have shown that inhalation exposure from residential uses of VOC contaminated water may equal or exceed those of ingestion (Moya et al. 1999; Keating et al. 1997; Giardino and Andelman 1996; Weisel and Jo 1996, Tancrede et al. 1992; McKone 1987). The greatest amount of exposure to volatile substances may occur in the shower, when the rate of transfer from the liquid to gas phase is at its maximum. As PCE and TCE are conservatively assumed to volatilize 90% from the liquid to gas phase, dermal exposures to the remaining 10% of these contaminants left in liquid phase are considered to be minimal. The US EPA considers bathing to present the highest risk of dermal exposures to children less than 1 to 6 years of age which have been addressed within this assessment (US EPA 2004).

As with the ingestion pathway assessment, past exposures are based on maximum concentrations of PCE and TCE in domestic well water for residents within the OU1 area prior to connection to the public water supply in 1989 and for residents within the OU2 area prior to the installation of the POET systems. To assess inhalation exposures during showering, the Andelman model as modified by Schaum (Schaum et al., 1994) used in the US EPA RI/FS reports for the OU1 and OU2 study areas within the PVGCS site were used (US EPA 2005, 2010).

Using the model and exposure assumptions (US EPA 2011b), the predicted concentration of the contaminants in the shower and bathroom combined are presented in Tables 13a and 14a. The time-weighted average (TWA) concentrations were calculated using the following formula (ATSDR 2005):

$$TWA = \Sigma\, C_x \times ET_x / 24$$

where, C = concentration of contaminant in air
ET = exposure time
x = shower and bath

The calculated time-weighted average concentrations are compared to the corresponding CVs for non-cancer health effects are also presented in Tables 13a and 14a.

OU1 Area: Public Water Supply

PCE. The current RfC for chronic inhalation exposure to PCE is 40 µg/m^3 (USEPA 2012). This RfC reflects the midpoint between RfC estimates in two studies for neurological effects (56 µg/m^3 for cognitive and reaction time changes and 15 µg/m^3 for color vision changes) observed in occupationally-exposed adults. Based on the EPC of PCE detected in public water for the OU1 study area during the 1972 through 1981 exposure period, the calculated TWA shower inhalation exposure of 118 µg/m^3 (children and adults) exceeded the chronic RfC (see Table 13a).

The PODs determined from the two studies are 56,000 µg/m^3 and 15,000 µg/m^3 (USEPA 2012). The calculated chronic inhalation exposure is approximately 475 and 127 times lower than the PODs established from the two occupational studies. The following summary compares inhalation exposures to the PODs and provides the conclusions for health effects to occur for each of the study areas:

Area of Concern	**TCE TWA** (µg/m^3)	**Study 1:** Cognitive and Reaction Time Changes POD 56,000 µg/m^3	**Study 2:** Color Vision Changes POD 15,000 µg/m^3
		Potential for Health Effects to Occur	
OU1: Public Supplied Water 1972 - 1981	118	Unlikely	Unlikely

TCE. Based on the EPC of TCE detected in the Vannatta Street public supply well for the OU1 study area, the calculated TWA inhalation exposure (children and adults) did not exceed the chronic MRLs or RfCs (see Table 13a). Therefore, adverse non-cancer health effects for past inhalation exposures to TCE while showering are not expected to occur for residents within the OU1 study area for the exposure period between 1972 through 1981.

OU1 and OU2 Study Areas: Domestic Wells

PCE. Based on the EPC of PCE detected in domestic wells for the OU1 and OU2 study areas, the calculated TWA inhalation exposure (children and adults) did not exceed the chronic MRL or RfC (see Table 14a). Therefore, adverse non-cancer health effects for past inhalation

exposures to PCE while showering are not expected to occur for residents within the OU1 study area.

TCE. The current RfC for chronic inhalation exposure to TCE is 2 µg/m^3 (USEPA 2011a). This RfC reflects the midpoint between RfC estimates for two critical effects (1.9 µg/m^3 for adult immunological effects in mice and 2.1 µg/m^3 for fetal heart malformations in rats). Based on the EPC of TCE detected in domestic well water for both the OU1 and OU2 study areas, the calculated TWA inhalation exposure (children and adults) exceeded the chronic RfC (see Table 14a).

The LOAELs for the two RfC studies are 190 µg/m^3 and 21 µg/m^3 (USEPA 2011a). The potential for non-cancer adverse health effects to occur to residents at the 48 residences within the OU1 study area are possible as the inhalation TWA concentrations for TCE was near or exceeded the LOAELs from the two studies. For the residents at the 118 residences within the OU2 study area, there is a low potential of potential fetal heart malformations to occur to unborn children of pregnant women exposed to indoor air containing this level of TCE. The following summary compares inhalation exposures to the LOAELs and provides the conclusions for health effects to occur for each of the study areas:

Area of Concern	**TCE TWA** (µg/m^3)	**Study 1:** Adult Immunological Effects LOAEL 190 µg/m^3	**Study 2:** Fetal Heart Malformations LOAEL 21 µg/m^3
		Potential for Health Effects to Occur	
OU1: 27 Residences	2	Unlikely	Unlikely
OU1: 48 Residences	81	Possible	Possible
OU1: 1 Residence	354 (max.)	Possible	Possible
OU2: 116 Residences	2	Unlikely	Unlikely
OU2: 18 Residences	10	Unlikely	Low

Dermal Absorption of COCs during Bathing

To assess dermal exposures during bathing, following US EPA guidance on dermal exposures, children through 6 years of age are considered the most likely population to fall under a bathing scenario (US EPA 2004). Past exposures are based on maximum concentrations of PCE and TCE in domestic well water for residents within the OU1 area prior to connection to the public water supply in 1989 and for residents within the OU2 area prior to the installation of the POET systems. Three primary actions which occur causing VOCs in tap water to volatilize include turbulent water flow through the bathtub spout, water impact into the tub and water layer, and surface volatilization when the tub is filled with water (US EPA 2000).

To be conservative for dermal skin absorption exposures, contaminant concentrations in water after bathtub filling were not adjusted for surface volatilization during the 1 hour bathing scenario for children. Additionally, as the volatilization rates of PCE and TCE were estimated at 50% during bathtub filling compared to 90% for showering, inhalation exposures are considered to be highest during showering while dermal exposures are considered to be highest during bathing.

Non-cancer exposure doses to assess dermal exposures during bathing were calculated using the US EPA dermal exposure model offered under their Guidance for Dermal Risk Assessment (EPA 2001, 2004). Additionally, US EPA exposure factors were used to develop the following site-specific exposure assumptions to estimate exposure doses to individuals using the creeks and the quarry for recreational purposes (US EPA 2011b).

Exposed Population	Body Weight	Exposed Skin Surface Area	Exposure Assumptions	Exposure Duration
Child (<1 through 6 years old)	15 kg	6,600 cm2	1 hour/event 365 days per year	6 years

Using the US EPA model and exposure assumptions, the predicted the dermal absorbed dose to children from contaminants in water during bathing are presented in Tables 13b and 14b.

OU1 Area: Public Water Supply &
OU2 Study Area: Domestic Wells

PCE and TCE. Based on the EPC of PCE and TCE detected in the Vannatta Street public supply well and the OU2 study area private wells, the calculated dermally absorbed dose (DAD) to children during bathing did not exceed the chronic MRLs or RfCs (see Tables 13b and 14b). Therefore, adverse non-cancer health effects for past dermal exposures to PCE and TCE during bathing are not expected to occur to children for these areas.

OU1 Study Area: Dermal Bathing Exposures

PCE. Based on the EPC of PCE for all OU1 study area private wells, the calculated DAD to children during bathing did not exceed the chronic MRLs or RfCs (see Table 14b). Therefore, adverse non-cancer health effects for past inhalation exposures to PCE during bathing are not expected to occur to children for private wells within the OU1 study area.

TCE. Based on the EPC of TCE (100 µg/L) in private well water for 48 residences within the OU1 study area, the calculated DAD to children (0.00054 mg/kg/day) during bathing slightly exceeded the chronic RfD of 0.0005 mg/kg/day (see Table 14b).

Based on the maximum concentration of TCE (440 µg/L) detected at one residence, the calculated DAD to children (0.0024 mg/kg/day) during bathing exceeded the chronic RfD of 0.0005 mg/kg/day (see Table 14b). The exposure dose is approximately 20 times and 154 times below the LOAEL of the studies identified below. Concerning adult immunological health

effects, specifically decreased thymus weights observed in mice from Study 1, the LOAEL for adult human oral exposures was derived using PBPK modeling and route-to-route extrapolation from this study. Based on the derived exposure dose in this assessment, it is concluded that there is a low potential for this health effect to occur from dermal exposures to TCE in bathing water for children less than 6 years of age. This conclusion is made as it is known the thymus is most active during the early stages of childhood development where exposures may cause a decreased thymus weight either within the stages of childhood or later in adulthood.

The following summary compares child dermal bathing exposures to the LOAELs and provides the conclusions for health effects to occur:

Area of Concern	**TCE EPC Dose** Child mg/kg/day	**Study 1:** Adult Immunological Effects LOAEL 0.048 mg/kg/day	**Study 2:** Developmental Immunotoxicity LOAEL 0.37 mg/kg/day
		Potential for Health Effects to Occur	
OU1: 48 Residences	0.00054	Unlikely	Unlikely
OU1: 1 Residence	0.0024 (max.)	Low	Unlikely

Inhalation of COCs in Indoor Air via Vapor Intrusion

OU1 & OU2 Study Areas

PCE. The multi-tenant residence within the OU1 study area had an EPC for PCE at 55 5 µg/m^3, exceededing the RfC of 40 µg/m^3(see Table 15). The PODs for the two RfC studies are 56,000 µg/m^3 and 15,000 µg/m^3 (USEPA 2012). The possibility of adult neurologic effects is unlikely as the maximum EPC concentration is approximately 1,000 times lower than the LOAEL of 56,000 µg/m^3 and 272 times lower than the LOAEL of 15,000 µg/m^3.

The following summary compares inhalation exposures to the PODs and provides the conclusions for health effects to occur for each of the study areas:

Area of Concern	**PCE EPC** (µg/m^3)	**Study 1:** Cognitive and Reaction Time Changes POD 56,000 µg/m^3	**Study 2:** Color Vision Changes POD 15,000 µg/m^3
		Potential for Health Effects to Occur	
OU1: Multi-Tenant Residence	55	Unlikely	Unlikely

TCE. There were two residences (one in each study area) having EPCs for TCE at 2 and 10.5 µg/m^3, exceededing the RfC of 2 µg/m^3 but were below the intermediate MRL (500 µg/m^3) for TCE (see Table 15). The LOAELs for the two RfC studies are 190 µg/m^3 and 21 µg/m^3 (USEPA 2011a). The possibility of adult immunological effects is unlikely as the maximum EPC concentration is approximately 18 times lower than the LOAEL of 190 µg/m^3. For fetal heart malformations, the maximum EPC concentration (10.5 µg/m^3) is close to the LOAEL (21 µg/m^3); therefore, there is a possibility of potential fetal heart malformations to occur to unborn children of pregnant women exposed to indoor air containing this level of TCE for one residence in the OU2 study area.

The following summary compares inhalation exposures to the LOAELs and provides the conclusions for health effects to occur for each of the study areas:

Area of Concern	**TCE EPC** (µg/m^3)	**Study 1:** Adult Immunological Effects LOAEL 190 µg/m^3	**Study 2:** Fetal Heart Malformations LOAEL 21 µg/m^3
		Potential for Health Effects to Occur	
OU1: Multi-Tenant Residence	2	Unlikely	Unlikely
OU2: Residence A	10.5	Unlikely	Possible

There were no detected concentrations of contaminants exceeding the chronic MRL for 1,2-DCA (2,000 µg/m^3) and the RfC for PCE (40 µg/m^3) and TCE (2 µg/m^3) for the remaining locations investigated within the OU1 and OU2 study areas (see Table 15). As no chronic health-based comparison values were exceeded, adverse non-cancer health effects are not expected to occur for past and present exposures to these contaminants in indoor air to adults and children occupying these seven areas of concern. Adverse non-cancer health effects are not expected to occur for future exposures to these contaminants in indoor air to these populations as the area is under active investigation and mitigation measures are being applied, when necessary, by the US EPA to reduce and/or prevent exposures.

Ingestion and Absorption of COCs in Surface Water

Exposures are based on incidental ingestion and dermal absorption of surface water contaminated with PCE and TCE for individuals using the Pohatcong and Shabbecong Creeks within the OU1 and OU2 areas and the former Edison Quarry within the OU2 area for recreational purposes. Non-cancer exposure doses were calculated using the US EPA Swimmer Exposure Assessment Model (SWIMODEL, version 3.0) to assess ingestion, dermal, buccal, orbital/nasal, and aural contact and exposure areas.

Additionally, US EPA exposure factors were used to develop the following site-specific exposure assumptions to estimate exposure doses to individuals using the creeks and the quarry for recreational purposes (US EPA 2011b).

Exposed Population	Body Weight	Exposure Assumptions	Number of Years Exposed
Child (7 through 10 years old)	30.2 kg	5 hours/event 92 days per year	4
Child (11 through 14 years old)	48.2 kg		4
Adult [(a)]	80 kg		30

(a) Exposure assumptions for individuals older than 14 years are considered to be similar to adults.

OU1 & OU2 Study Areas: Pohatcong and Shabbecong Creeks, Former Edison Quarry

It is noted that the EPC calculated for TCE included the contaminant concentrations detected from surface run-off (drainage swales) and outfall discharge samples collected within the Pechiney Plastics Packaging Incorporated property where recreational activities are not present. However, surface water from this area eventually discharges to the Pohatcong and Shabbecong Creeks via storm drains. Therefore, using the EPC for TCE (7.6 µg/L) is considered to conservatively overestimate exposures for the creek areas.

PCE and TCE. The exposure doses calculated for adults and children were below the chronic oral RfD for both PCE (0.006 mg/kg/day) and TCE (0.0005 mg/kg/day) (see Table 16). Therefore, based on the EPC of PCE (1.1 µg/L) and TCE (7.6 µg/L) detected in surface water, non-cancer adverse health effects to individuals using the Pohatcong and Shabbecong Creeks for recreational purposes within the study areas are not expected to occur.

Cancer Health Effects

The site-specific lifetime excess cancer risk (LECR) indicates the cancer potential of contaminants. LECR estimates are usually expressed in terms of excess cancer cases in an exposed population in addition to the background rate of cancer. For perspective, the lifetime risk of being diagnosed with cancer in the United States is 46 per 100 individuals for males, and 38 per 100 for females; the lifetime risk of being diagnosed with any of several common types of cancer ranges between 1 in 10 and 1 in 100 (SEER 2005). Typically, health guideline CVs developed for carcinogens are based on one excess cancer case per 1,000,000 individuals. The NJDHSS considers estimated cancer risks of less than one additional cancer case among one million persons exposed as insignificant or no increased risk (expressed exponentially as 10^{-6}).

According to the United States Department of Health and Human Services (USDHHS), the cancer class of contaminants detected at a site is as follows:

1 = Known human carcinogen
2 = Reasonably anticipated to be a carcinogen
3 = Not classified

The NJDHSS uses the following cancer risk descriptions for health assessments:

Public Health Assessment/Health Consultation
Risk Description for New Jersey

LECR	Risk Description
$\geq 10^{-1}$	Increase
10^{-2} to $<10^{-1}$	
10^{-3} to $<10^{-2}$	
10^{-4} to $<10^{-3}$	Low increase
10^{-5} to $<10^{-4}$	No apparent increase
10^{-6} to $<10^{-5}$	
$< 10^{-6}$	No expected increase

The risk of cancer was evaluated for groundwater based on the site-specific exposure scenario and exposure location. Cancer exposure doses were calculated using the following formula:

$$\textit{Cancer Exposure Dose (mg/kg/day)} = \frac{C \times IR \times ED}{BW \times AT}$$

where C = concentration of contaminant in groundwater (mg/L);
IR = groundwater ingestion rate (L/day);
ED = exposure duration representing the site-specific exposure scenario (years);
BW = body weight (kg); and
AT = averaging time (years).

The site-specific assumptions and recommended exposure factors (US EPA 2002) used to calculate the LECR are the same as those used to assess non-cancer health effects. The LECR for adults was calculated by multiplying the cancer exposure dose by the cancer slope factor (CSF). The CSF is defined as the slope of the dose-response curve obtained from animal and/or human cancer studies and is expressed as the inverse of the daily exposure dose, i.e., $(mg/kg/day)^{-1}$. Oral and inhalation cancer slope factors were obtained from the California EPA, Office of Health Hazard Assessment's Toxicity Criteria Database (Cal EPA 2011).

Exposure concentrations to indoor air contaminants and LECRs were calculated using the following formulas (US EPA 2009):

$$EC = \frac{EPC \times ET \times EF \times ED}{AT}$$

where EC = exposure concentration ($\mu g/m^3$);

EPC = exposure point concentration of contaminant in air (µg/m^3);
ET = exposure time (hours/day);
EF = exposure frequency (days/year);
ED = exposure duration (years); and
AT = averaging time (years).

LECR = EC x IUR

where EC = exposure concentration (µg/m^3); and
IUR = inhalation unit risk of contaminant in air (µg/m^3)$^{-1}$

The LECR for residents was calculated by multiplying the cancer exposure concentration in indoor air by the inhalation unit risk (IUR). The IUR is defined by the US EPA as the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 µg/m^3 in air (US EPA 2008b).

Oral and inhalation CSFs for PCE and TCE were used to estimate the LECR to exposed individuals. Please refer to the *Completed Pathways* section of this report for specific discussions regarding evaluated potential exposure at areas of concern.

Exposure criteria for area residents (children and adults) for these areas are provided in the *Non-Cancer Health Effects* section of this report.

Cumulative Exposure: Ingestion of Groundwater and Inhalation during Showering

OU1 Area: Public Water Supply

Based on the EPC of PCE and TCE detected in groundwater from the Vannatta Street public supply well, the cumulative LECR for past ingestion and inhalation (via showering) exposures to adults and children (≥ 6 years old) is 6 in 1,000,000 while for past ingestion and dermal (via bathing) exposures to children (< 6 years old) is 2 in 1,000,000 (see Tables 21a and b). The cumulative LECRs to adults and children are considered a no apparent increased risk of cancer when compared to the background risk of cancer.

OU1 Study Area: Domestic Wells

Based on the EPC of PCE and TCE detected in groundwater from 27 residential wells having TCE concentrations less than 7.4 µg/L, the cumulative LECR for past ingestion and inhalation (via showering) exposures to adults and children (≥ 6 years old) is 8 in 1,000,000 while for past ingestion and dermal (via bathing) exposures to children (< 6 years old) is 2 in 1,000,000 (see Tables 21a and b). The cumulative LECR for adults and children is considered a no apparent increased risk of cancer when compared to the background risk of cancer.

Based on the EPC of TCE detected in groundwater from 48 residential wells having TCE concentrations greater than 7.4 µg/L, the cumulative LECR for past ingestion and inhalation (via showering) exposures to adults and children (≥ 6 years old) is 3 in 10,000 while for past ingestion and dermal (via bathing) exposures to children (< 6 years old) is 5 in 100,000 (see

Tables 21a and b). The cumulative LECR for adults and children (≥ 6 years old) is considered a low increased risk when compared to the background risk of cancer. The cumulative LECR for children (< 6 years old) is considered a no apparent increased risk of cancer when compared to the background risk of cancer.

It is noted that when considering the residence with the highest TCE concentration detected in potable well water at 440 µg/L, the cumulative LECR was highest for past ingestion and inhalation (via showering) exposures to adults and children (≥ 6 years old) is 1 in 1,000 which is considered to pose an increase in lifetime cancer risk when compared to the background risk of cancer(see Table 21a) . The cumulative LECR for past ingestion and dermal (via bathing) exposures to children (< 6 years old) is 2 in 10,000 (see Table 21b) which is considered to pose a low increased risk when compared to the background risk of cancer.

Current and future ingestion, inhalation (via showering) and dermal (via bathing) exposures to PCE and TCE in groundwater are considered eliminated since 1989 for residents in the OU1 study area that have connected to the public water supply system.

Residents within the OU1 area that have chosen not to connect to the public water supply or have a POET system installed and continue to use untreated domestic well water for potable use may be at an increased risk for developing cancer-related illness.

OU2 Study Area: Domestic Wells

Based on the EPC of PCE detected in groundwater from four residential wells, the cumulative LECR at four residences for past ingestion and inhalation (via showering) exposures to adults and children (≥ 6 years old) is 2 in 1,000,000 while for past ingestion and dermal (via bathing) to children (< 6 years old) is less than 1 in 1,000,000 (see Tables 21a and b). The cumulative LECR is highest for adults and children (≥ 6 years old) which is considered a no apparent increased risk of cancer when compared to the background risk of cancer for adults and children (≥ 6 years old) and a no expected increased risk of cancer for children (< 6 years old).

Based on the EPC of TCE in groundwater at less than 7.4 ppb for 116 residences evaluated within the OU2 study area, the cumulative LECRs for past ingestion and inhalation (via showering) exposures to adults and children (≥ 6 years old) is 6 in 1,000,000 (see Table 20a). The cumulative LECR for past ingestion and dermal exposures to children (< 6 years old) via bathing is 1 in 1,000,000 (see Table 20b). These cumulative LECRs to adults and children are considered a no apparent increased risk of cancer when compared to the background risk of cancer (see Tables 21a and b).

Based on the EPC of TCE in groundwater at greater than 7.4 ppb for 18 residences evaluated within the OU2 study area, the cumulative LECRs for past ingestion and inhalation (via showering) exposures to adults and children (≥ 6 years old) is 3 in 1,00,000 (see Table 20a). The cumulative LECR for past ingestion and dermal exposures to children (< 6 years old) via bathing is 7 in 1,000,000 (see Table 20b). These cumulative LECRs to adults and children are considered a no apparent increased risk of cancer when compared to the background risk of cancer (see Tables 21a and b).

Current and future exposures to PCE and TCE in groundwater are considered eliminated to residents in the OU2 study area who had POET systems installed to reduce contaminant concentrations to below the NJDEP GWQC.

Inhalation of COCs in Indoor Air via Vapor Intrusion

The risk of cancer for past exposures regarding the inhalation of indoor air contaminated with 1,2-DCA, PCE and TCE was evaluated for adults and children occupying the seven areas of concern identified from the March 2006 through April 2009 indoor air investigations.

The LECR was estimated using EPCs in indoor air using data from the March 2006 through April 2009 investigations. Site-specific assumptions and recommended exposure factors (US EPA 2011b) were used to calculate the exposure concentration based on the exposure period as described in Table 22.

OU1 – Areas of Concern

Multi-tenant Residence (past, present). Based on the EPC of 1,2-DCA, PCE and TCE exposure concentrations in the indoor air, LECRs were estimated to be less than 2 in 100,000 for adults and children which is considered a no apparent increased risk when compared to the excess background risk of all or specific cancers (see Table 22).

Residence C, Daycare Center A (past, present). Based on the EPC of 1,2-DCA, PCE and TCE exposure concentrations in the indoor air, LECRs were estimated to be less than 9 in 1,000,000 for adults and children which is considered a no apparent increased risk when compared to the excess background risk of all or specific cancers (see Table 22).

Daycare Center B, Warren Hills Middle School (past, present). Based on the EPC of 1,2-DCA, PCE and TCE exposure concentrations in the indoor air, LECRs were estimated to be less than 1 in 1,000,000 which is considered to present a no expected increased risk when compared to the excess background risk of all or specific cancers (see Table 22).

OU2 – Areas of Concern

Residences A & B (past, present). Based on the EPC of 1,2-DCA, PCE and TCE exposure concentrations in the indoor air, LECRs were estimated to be less than 2 in 100,000 for adults and children which is considered a no apparent increased risk when compared to the excess background risk of all or specific cancers (see Table 22).

Franklin Township Elementary School (past, present). Based on the EPC of 1,2-DCA, PCE and TCE exposure concentrations in the indoor air, LECRs were estimated to be less than 8 in 1,000,000 which is considered a no apparent increased risk when compared to the excess background risk of all or specific cancers (see Table 22).

Ingestion and Absorption of COCs in Surface Water

Based on the EPCs of PCE and TCE detected in surface water from the Pohatcong and Shabbecong Creeks and the former Edison Quarry, the LECRs for recreational exposures for children and adults are less than 1 in 1,000,000, which is considered a no expected increased risk of cancer when compared to the background risk of cancer (see Table 23).

Mixtures Evaluation

In the past, some residents within the PVGCS site were exposed to both PCE and TCE through ingestion of groundwater and recreational activities, inhalation during showering (off-gassing) and inhalation of indoor air. This assessment has focused on evaluating chemical-specific and pathway-specific exposures. However, the ATSDR and the NJDHSS recognize that exposures can involve multiple chemicals through more than one exposure pathway. The ATSDR has developed guidance for evaluating exposures to chemical mixtures (ATSDR 2004a).

Non-carcinogenic risk is normally characterized in terms of a hazard index (HI). For this report, the HI is calculated by dividing the estimated exposure dose with the chronic RfD or RfC. The concern for adverse non-cancer health effects to occur under a mixtures scenario increases as the HI exceeds 1. Research on the toxicity of mixtures indicates that adverse health effects are unlikely when the mixture components are present at levels well below their individual toxicological thresholds.

Ingestion Exposures: Public and Domestic Well Water

Based on the EPC detected for residences having both PCE and TCE in domestic well water, the HI sum within the OU1 area for PCE and TCE were less than 1 for adults and children for ingestion exposures. ATSDR's interaction profiles indicate ingestion exposures to PCE and TCE under these conditions should not produce joint effects to these exposed populations.

Based on the EPC detected for residences having both PCE and TCE in public water within the OU1 area and for domestic well water within the OU2 area, the HI sum for PCE and TCE were less than 2 for children and less than 1 for adults regarding ingestion exposures. ATSDR's interaction profiles indicate exposures to PCE and TCE under this scenario would likely have an additive to less than additive effect to the liver and kidneys and an additive effect to the nervous system.

Inhalation: Public and Domestic Well Water

Based on EPC for inhalation exposures during showering the HI sum within the OU1 area for PCE and TCE was 3.6 and within the OU2 area for PCE and TCE was 5.2.

The calculated HI for PCE and TCE for inhalation exposures to PCE and TCE from vapor intrusion sources was 2.3 for the multi-tenant residence within OU1 and 5.3 for Residence A within OU2.

ATSDR's interaction profiles indicate exposures to PCE and TCE for these exposed populations would likely have an additive to less than additive effect to the liver and kidneys and an additive effect to the nervous system.

Ingestion: Recreational Exposures

The calculated HI for PCE and TCE for ingestion exposures from surface water from the Pohatcong and Shabbecong Creeks within OU1 area did not exceed 1; therefore, ingestion exposures to the EPC of these contaminants in surface water should not produce joint effects to populations using the creeks for recreational use.

Health Outcome Data

Based on a review of data available from the US EPA and the WCHD, completed exposure pathways existed and still reportedly exist for some area residents who have and continue to use contaminated groundwater for drinking and other domestic water use. Data and information provided in the US EPA RI/FS reports (2005, 2010) for the OU1 and OU2 study areas indicate that residents were likely exposed for an indeterminate number of years preceding the discovery of the TCE and PCE contamination in the public supply wells in 1977 and 1978. These exposures had continued until residents were connected to public water within the OU1 area by 1989 and the installation of the POET systems in the early 2000s. The health outcome of concern for TCE and PCE exposures is primarily the potential increase in cancer risk from past exposures.

On April 17, 2006, the NJDHSS Cancer Surveillance Program responded to the WCHD request to review cancer incidence among residents of the Warren County municipalities of Franklin Township, Greenwich Township, Washington Borough, and Washington Township, specifically regarding potential exposures to PCE and TCE which are present in the regional aquifer. At the time of this request, cancer incidence data was reviewed from 1985 through 2002 for the PVGCS site area. The most common types of cancer within the site were prostate, breast, lung, colon, and rectum. Cancers typically associated with environmental exposures such as leukemias, lymphomas, brain, and bladder cancers were not observed more frequently for the population within the survey area of the above municipalities when compared to the state of New Jersey. A copy of the NJDHSS cancer incidence response is provided as Appendix B. While no increase in cancer incidence was observed for the populations examined, in the future a follow-up analysis may be conducted to review additional data as it becomes available.

Child Health Considerations

ATSDR recognizes that the unique vulnerabilities of infants and children demand special emphasis in communities faced with contamination in their environment. Children are at greater risk than adults from certain kinds of exposures to hazardous substances because they eat and breathe more than adults. They also play outdoors and often bring food into contaminated areas. Children are also smaller, resulting in higher doses of chemical exposure per body weight. The developing body systems of children can sustain permanent damage if toxic exposures occur

during critical growth stages. Most importantly, children depend completely on adults for risk identification and management decisions, housing decisions, and access to medical care.

The NJDHSS and ATSDR evaluated the potential risk for children residing in the PVGCS site who were previously exposed to contaminants in their drinking water. Based on the maximum contaminant concentrations detected and a 30-year exposure duration, a "low" increased risk of cancer effects for area residents, including children, was determined.

TCE and PCE are known contaminants most frequently detected in residential wells within the PVGCS site area necessitating measures to connect residents to either public supply water or have POET systems installed. A study conducted in Woburn, Massachusetts concluded that the elevated incidence of childhood leukemia was associated with the mother's potential for exposure to drinking water contaminated with TCE, PCE, chloroform and other organic compounds, particularly during pregnancy (MDPH 1997). The study also suggested that exposures to these contaminants, whether individual or mixtures, might have had an effect on blood-forming organs during fetal development, but not during childhood. Similarly, a New Jersey study found a statistically elevated rate of childhood leukemia in towns served by community water supplies contaminated with TCE and PCE (NJDHSS 1993, 2003). A literature review of drinking water contaminants and adverse pregnancy outcomes was conducted (Bove et al. 2002). Results of studies on chlorination disinfection byproducts indicated moderate evidence for associations with certain birth defects, although this evidence was less clear for chlorinated solvents including TCE and PCE.

Conclusions

In 1977 and 1978, analysis of groundwater from two public water supply wells within the Pohatcong Valley indicated the regional groundwater aquifer was contaminated with PCE and TCE. This aquifer is used as the sole source of potable water to residents living within the Pohatcong Valley. The source of this contamination is believed to originate from one or more industrial facilities/commercial businesses operating within the borough of Washington. Investigations conducted from 1984 through 2010 by the WCHD, the NJDEP and the US EPA indicate domestic groundwater wells for numerous residences were impacted with PCE and/or TCE above the state drinking water standards. This prompted the NJDEP to connect participating residents with either public water service or have POET systems installed to provide safe potable water. Based on the degree of TCE and PCE contamination in groundwater and affected populations, the site was added to the US EPA's NPL in March 1989. Recent vapor intrusion investigations indicate 1,2-DCA, PCE and TCE are contaminants of concern in indoor air impacting the indoor air quality to some area residents, schools and businesses under evaluation. Following review and assessment of environmental data, the NJDHSS and ATSDR have reached the following conclusions regarding exposures to residents for the PVGCS site:

NJDHSS and ATSDR conclude that past ingestion and inhalation exposures to PCE in drinking water from the public supply system and within the OU2 area will not have harmed people's health. Drinking water from domestic (private) wells that have Point-of-Entry Treatment (POET) systems installed will not harm people's health, as long as the POET systems are properly designed and maintained. Concerning ingestion of untreated water from the public

water supply during the 1972 through 1981 period, exposure doses calculated did not indicate exposures were harmful to residents. Since 1981, residents who were connected to the public supply system were not exposed to contaminants in drinking water, since a treatment system was put into operation for the Vannatta Street well. For domestic wells in the OU2 area, exposures were stopped for residents when POET systems were installed during 2002 through 2010. It should be noted that these exposures are only considered eliminated if POET systems are properly designed and maintained.

NJDHSS and ATSDR conclude that past ingestion and inhalation exposures to TCE in contaminated domestic wells within the OU1 area (prior to POET installation) may have harmed people's health. For domestic wells at approximately 48 residences within the OU1 area, exposures to TCE contaminated groundwater occurred prior to connection to the public water service (these connections occurred during the 1980s in the OU1 area) or the installation of the POET systems in both the OU1 and OU2 areas (2002 through 2010).

The cumulative lifetime excess cancer risk from ingestion and inhalation exposures to contaminants in domestic well water are considered to have posed a low increase in risk of cancer when compared to the background risk of cancer. Exposures to residents who used contaminated water from untreated domestic wells as a potable source for drinking and showering are of concern for the increased risk of adverse non-cancer health effects to occur, specifically fetal heart malformations. This is of particular concern to children of unborn pregnant women exposed to TCE at the upper end of detected concentrations in domestic well water. This is of particular concern to children of unborn pregnant women exposed to TCE at the upper end of detected concentrations in domestic well water.

NJDHSS and ATSDR conclude that current ingestion and inhalation exposures to PCE and TCE in drinking water from domestic wells may have harmed people's health for residents who either do not have POET systems installed or are not connected to the public water supply. In an effort to identify remaining residences within the OU1 and OU2 study areas which are not connected to public water or have POET systems, the US EPA has reached out to homeowners, and continues to do so, to arrange for water testing and corrective actions for the supply of safe potable water. These efforts have been assisted by the NJDEP, the Warren County Health Department and the New Jersey American Water Company. In the past, some homeowners, specifically within the OU1 study area, have elected not to connect to the public water system and not to have POET systems installed on their domestic wells. The US EPA continues with these efforts; however for homeowners whose domestic wells remain untested, *in addition to past exposures*, current and future exposures are assumed to be similar for the past exposure scenario evaluated for the OU1 and OU2 study areas.

NJDHSS and ATSDR conclude that past exposures to TCE in indoor air at Residence A within the OU2 study area may have harmed people's health. Current and future exposures are considered to be interrupted due to completed remedial actions at this residence. TCE concentrations in indoor air at this residence were considered a concern for an increased risk of adverse non-cancer health effects (fetal heart malformations in unborn children) for exposures occurring to pregnant women prior to remedial actions taken at this property. Inhalation exposures are considered to be interrupted at with the operation of vapor intrusion remedial system in 2007 designed to prevent subsurface contaminant vapors from entering this residence.

NJDHSS and ATSDR conclude that past, current and future exposures to 1,2-DCA, PCE, and TCE in indoor air are not expected to harm people's health.

For the remaining residences, schools and day-care facilities evaluated, completed exposures to children and adults to these contaminants of concern in indoor air are not expected to cause adverse non-cancer health effects as contaminant concentrations were determined to not pose a health risk based on current health-based comparison values. These exposures are considered to pose a no apparent increase in risk of cancer when compared to the background risk of cancer. It is noted that inhalation exposures at the multi-tenant residence are considered to be interrupted with the operation of a vapor intrusion remedial system in 2009 designed to prevent subsurface contaminant vapors from entering this residence.

NJDHSS and ATSDR conclude that past, current and future exposures to PCE and TCE in surface water within the Pohatcong and Shabbecong Creeks and the former Edison Quarry are not expected to harm people's health. Exposures to children and adults during recreational activities in the Pohatcong and Shabbecong Creeks and the former Edison Quarry are not expected to cause adverse non-cancer health effects as contaminant concentrations remain below health-based comparison values. There is no expected increase in the risk of cancer to individuals using these creeks and the quarry for recreational purposes.

Recommendations

1. The US EPA should continue their efforts to identify residences within the OU1 and OU2 study areas who are either not connected to the public water supply or do not have POET systems installed. Once identified, these residences should be evaluated to determine whether exposure pathways to site-related contaminants continue to exist at these locations. Homeowners of residences within the OU1 and OU2 study areas that are either not connected to the public water supply or do not have a POET system installed should consider these available options.

2. The NJDEP should continue to ensure the POET systems installed at affected residences are properly operated and maintained to protect residents from unnecessary exposures to site-related contaminants.

3. The US EPA should continue to implement remedial actions specified in the RODs for the OU1 and OU2 study areas to eliminate remaining exposure pathways and provide a permanent solution to address contaminated drinking water for residences which can be supplied public water. The US EPA should also continue remedial investigations, including vapor intrusion, and evaluate feasibility studies within the OU3 study area to implement necessary actions to address contaminated groundwater and to eliminate any potential exposure pathways to residents. Short-term solutions, such as venting systems, should continue to be considered for buildings where elevated concentrations of site-related contaminants are present in soil gas increasing the threat of vapor intrusion or directly causing elevated contaminant concentrations in indoor air.

4. The US EPA should continue remedial investigations and evaluate feasibility studies to implement a remedy for contaminated groundwater and other site-related sources (i.e.,

surface water run-off) to eliminate the discharge of contaminants to the Pohatcong and Shabbecong Creeks.

5. Residents are encouraged to contact their primary health care physician to discuss health concerns regarding exposure to site-related contaminants. Additionally, as the US EPA is actively addressing site contamination through remedial measures, residents are encouraged to follow their recommendations and allow them to take the measures necessary to reduce or prevent exposures. The NJDHSS will make available to them materials on site-related contaminants and provide assistance concerning the findings of this report.

Public Health Action Plan

The purpose of a Public Health Action Plan is to ensure that this Public Health Assessment not only identifies public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. Included is a commitment on the part of the ATSDR and the NJDHSS to follow-up on this plan to ensure that it is implemented. The public health actions to be implemented by the ATSDR and NJDHSS are as follows:

Public Health Actions Taken

1. The ATSDR and NJDHSS reviewed information and relevant data to evaluate the potential health implications for exposures to PCE and TCE in drinking water and 1,2-DCA, PCE and TCE in indoor air for residences, schools, and day-care facilities within the OU1 and OU2 study areas.

2. A PHA was completed by the NJDHSS in September 1990 evaluating the potential health implications for exposures to site-related contaminants based on limited information at the time. The NJDHSS and ATSDR concluded that exposures to site-related contaminants were a public health concern and that additional investigation into source areas and areas of potential concern for exposures were needed to more fully assess the extent of risk associated with this site.

3. On April 17, 2006, the NJDHSS Cancer Surveillance Program responded to a WCHD request to review cancer incidence among residents of the Warren County municipalities of Franklin Township, Greenwich Township, Washington Borough, and Washington Township, specifically regarding potential exposures to PCE and TCE which are present in the regional aquifer. Cancers typically associated with environmental exposures such as leukemias, lymphomas, brain, and bladder cancers were not observed more frequently for the population within the site area. A copy of the NJDHSS cancer incidence response is provided as Appendix B. While no increase in cancer incidence was observed for the populations examined, in the future a follow-up analysis may be conducted to review additional data as it becomes available.

Public Health Actions Planned

1. Copies of this public health assessment will be provided to concerned residents in the vicinity of the site via the township libraries and the Internet.

2. In cooperation with the US EPA public meetings can be scheduled, if needed, to discuss the findings of this report and to determine and address any additional community concerns.

3. The NJDHSS and the ATSDR will continue to review data as it is made available. This includes new information related to investigations and remedial actions taken for areas of concern within the OU1 and OU2 study areas, including the RI/FS to be completed in the near future for the OU3 study area.

References

Andelman, J. B. 1990. Total Exposure to Volatile Organic Compounds in Potable Water. In: Significance and Treatment of Volatile Organic Compounds in Water Supplies, p. 485- 504.

Andelman, J.B., S.M. Meyers, and L.C. Wilder. 1986. Volatilization of trichloroethylene and chloroform from an experimental bath and shower system. Extended abstract. Division of Environmental Chemistry, American Chemical Society, Anaheim, California. September 1986.

[ATSDR] Agency for Toxic Substances and Disease Registry. 1997a. Toxicological profile for Tetrachloroethylene. US Department of Health and Human Services, Atlanta, Georgia.

[ATSDR] Agency for Toxic Substances and Disease Registry. 1997b. Toxicological profile for Trichloroethylene. US Department of Health and Human Services, Atlanta, Georgia.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2001. Toxicological profile for 1,2-Dichloroethane. US Department of Health and Human Services, Atlanta, Georgia.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2002. Public health assessment guidance manual (update). Atlanta: US Department of Health and Human Services.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2004a. Interaction Profile for 1,1,1-Trichloroethane, 1,1-Dichloroethane, Trichloroethylene, and Tetrachloroethylene. May 2004

[ATSDR] Agency for Toxic Substances and Disease Registry 2004b. Guidance Manual for the Assessment for Joint Toxic Action of Chemical Mixtures. May 2004

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005a. Public health assessment guidance manual (update). Atlanta: US Department of Health and Human Services.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005b. Public Health Assessment Cedar Brook Groundwater Contamination. Winslow Township, Camden County, New Jersey. US Department of Health and Human Services, Atlanta, Georgia. May 2005.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2008. Public Health Assessment Former American Beryllium Company. Tellevast, Manatee County, Florida. US Department of Health and Human Services, Atlanta, Georgia. September 30, 2008.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2009. Environmental and Health Guideline Comparison Values. Atlanta: US Department of Health and Human Services.

Bove F, Shim Y, and Zeitz P. 2002. Drinking water contaminants and adverse pregnancy outcomes: a review. Environ Health Perspect;110:61-74.

[Cal EPA] California Environmental Protection Agency. 2011. OEHHA Toxicity Criteria Database. Office of Environmental Health Hazard Assessment. http://oehha.ca.gov/risk/ChemicalDB/index.asp

CH2MHILL. 2005. OU1 Remedial Investigation Report Pohatcong Valley Groundwater Contamination Site, Washington Borough, Washington Township, and Franklin Township, New Jersey. Prepared for the U.S. Environmental Protection Agency, Region 2. June 2005.

CH2MHILL. 2010. OU2 Remedial Investigation Report Pohatcong Valley Groundwater Contamination Superfund Site, Washington Borough, Washington Township, and Franklin Township, New Jersey. Prepared for the U.S. Environmental Protection Agency, Region 2. April 2010.

[MDPH] Massachusetts Department of Public Health. 1997. Woburn children leukemia follow-up study. Boston, MA: Bureau of Environmental Health Assessment, Massachusetts Department of Public Health.

[NJAC] New Jersey Administrative Code. 2009. Surface Water Quality Standards N.J.A.C. 7:9B.

[NJDHSS]. New Jersey Department of Health and Senior Services. 1993. Drinking water contamination and the incidence of leukemias and non-Hodgkin's lymphomas. Trenton, NJ.

[NJDHSS] New Jersey Department of Health and Senior Services. 2003. Case-control study of childhood cancers in Dover Township (Ocean Country), New Jersey. Trenton, New Jersey: New Jersey Department of Health and Senior Services.

[NJDHSS]. New Jersey Department of Health and Senior Services. 2000. Description of Public Water Systems and Volatile Organic Chemical (VOC) Contamination in New Jersey, 1978-1990. Trenton, NJ. March 2000 (updated February 2004).

[NJDEP] New Jersey Department of Environmental Protection. 2004. Safe Water Drinking Act Regulations (N.J.A.C. 7:10). Trenton, New Jersey. Adopted November 4, 2004.

[NJDEP] New Jersey Department of Environmental Protection. 2006. Vapor Intrusion Guidance. Trenton, New Jersey. October 2006.

[NYSDOH] New York State Department of Health. 2006. Center for Environmental Health, Bureau of Toxic Substances Assessment, Trichloroethylene Air Criteria Document, October 2006. http://www.health.state.ny.us/environmental/chemicals/trichloroethene/

Rasmussen K., P. Arlien-Soborg, S. Sabroe. 1993. Clinical neurological findings among metal degreasers exposed to chlorinated solvents. Acta Neuro Scand 87: 200-204.

[USEPA] US Environmental Protection Agency. 1985. Development of statistical distributions or ranges of standard factors used in exposure assessments. Office of Health and Environmental Assessment; EPA report No. EPA 600/8-85-010. Washington, DC. 1985.

[USEPA] US Environmental Protection Agency. 1991. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance Standard Default Exposure Factors Interim Final. Office of Emergency and Remedial Response. Washington, DC. March 25, 1991.

[USEPA] US Environmental Protection Agency. 1997. National Center for Environmental Assessment. Office of Research and Development. Exposure Factors Handbook. Washington, DC. August 1997.

[USEPA] US Environmental Protection Agency. 1997. Supplemental Background Document; Non-Groundwater Pathway Risk Assessment; Petroleum Process Waste Listing Determination. Prepared by Research Triangle Institute. Research Triangle Park, NC. March 1997.

[USEPA] US Environmental Protection Agency. 2000. National Center for Environmental Assessment. Office of Research and Development. Volatilization Rates from Water to Indoor Air Phase II. Washington, DC. October 2000.

[USEPA] US Environmental Protection Agency, Office of Research and Development. 2001a. Trichloroethylene Health Risk Assessment: Synthesis and Characterization. External Review Draft. EPA/600/P-01/002A. August 2001.

[USEPA] US Environmental Protection Agency. 2001b. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) – ORG04_01.XLS Excel spreadsheet for dermal assessment of organic chemicals in water. Office of Superfund Remediation and Technology Innovation. Washington, DC. April 2001 obtained from http://www.epa.gov/oswer/riskassessment/ragse/index.htm

[USEPA] US Environmental Protection Agency. 2002. OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance). EPA/530/D/02/004. November 2002.

[USEPA] US Environmental Protection Agency. 2003. Swimmer Exposure Assessment Model (SWIMODEL) Version 3.0. November 2003.

[USEPA] US Environmental Protection Agency. 2004. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Office of Superfund Remediation and Technology Innovation. Washington, DC. July 2004.

[USEPA] US Environmental Protection Agency. 2007. Dermal Exposure Assessment: A Summary of EPA Approaches. Office of Research and Development. Washington, DC. September 2007.

[USEPA] US Environmental Protection Agency. 2008. National Center for Environmental Assessment. Office of Research and Development. Child-Specific Exposure Factors Handbook. Washington, DC. September 2008.

[USEPA] US Environmental Protection Agency. 2008b. National Center for Environmental Assessment. Office of Research and Development. Integrated Risk Information System, Glossary of Terms. Available from: http://www.epa.gov/iris/help_gloss.htm#content

[USEPA] US Environmental Protection Agency. 2009. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment). Office of Superfund Remediation and Technology Innovation. Washington, DC. January 2009.

[USEPA] US Environmental Protection Agency. 2009. US Environmental Protection Agency Pollution Report. Removal Action: RV2, Building H, Park Hill Apartments Vapor Intrusion Mitigation System Installation. Washington, DC. September 14, 2009.

[USEPA] US Environmental Protection Agency. 2009. Toxicological Review of Trichloroethylene (External Review Draft). Washington, DC. October 2009.

[USEPA] US Environmental Protection Agency. 2010a. Integrated Risk Information System for TCE. Accessed on September 23, 2010 at: http://www.epa.gov/IRIS/

[USEPA] US Environmental Protection Agency, Region 2. 2010b. US Environmental Protection Agency Fact Sheet. Superfund Proposed Plan for Operable Unit 2. Pohatcong Valley Groundwater Contamination Site, Warren County, New Jersey. New York, NY. April, 2010.

[USEPA] US Environmental Protection Agency, Region 2. 2010c. US Environmental Protection Agency Record of Decision for Operable Unit 2, Pohatcong Valley Groundwater Contamination Site, Warren County, New Jersey. New York, NY. September 30, 2010.

[USEPA] US Environmental Protection Agency. 2011a. Toxicological Review of Trichloroethylene. Washington, DC. September 2011.
Accessed on October 6, 2011 at: http://www.epa.gov/IRIS/

[USEPA] US Environmental Protection Agency. 2011b. National Center for Environmental Assessment. Office of Research and Development. Exposure Factors Handbook. Washington, DC. September 2011.

[USEPA] US Environmental Protection Agency. 2011c. US EPA Region 6 Human Health Media-Specific Screening Levels. Office of Solid Waste and Emergency Response. Washington, DC. June 2011.

[USEPA] US Environmental Protection Agency. 2012. Toxicological Review of Tetrachloroethylene. Washington, DC. February 2012.
Accessed on February 15, 2012 at: http://www.epa.gov/IRIS/

REPORT PREPARATION

This Public Health Assessment for the Pohatcong Valley Groundwater Contamination Superfund site, encompassing Franklin Township, Washington Township, and Washington Borough within Warren County, New Jersey was prepared by the New Jersey Department of Health and Senior Services under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented. ATSDR's approval of this document has been captured in an electronic database, and the approving agency reviewers are listed below.

Author

Glenn Pulliam, M.P.H.
Environmental and Occupational Health Surveillance Program
New Jersey Department of Health and Senior Services

State Reviewers

Jerald Fagliano, M.P.H., Ph.D.
Environmental and Occupational Health Surveillance Program
New Jersey Department of Health and Senior Services

Joseph Eldridge, M.P.H., Director
Consumer and Environmental Health Services
New Jersey Department of Health and Senior Services

ATSDR Reviewers

Gregory V. Ulirsch
Technical Project Officer

Alan Yarbrough
Cooperative Agreement Team Lead
ATSDR/DHAC/CAPEB

Rick Gillig
Cooperative Agreement and Program Evaluation Branch Chief
ATSDR/DHAC

Lynn Wilder, ATSDR/DHAC
Assistant Director for Science

William Cibulas, ATSDR/DHAC
Division Director, DHAC

Thomas Sinks, ATSDR/NCEH, Office of the Director

ATSDR Regional Representatives:

Leah T. Graziano, R.S.
Senior Regional Representative
Office of Regional Operations, Region II

Lt. Elena Vaouli, M.P.H.
Associate Regional Representative
Office of Regional Operations, Region II

Any questions concerning this document should be directed to:

Environmental and Occupational Health Surveillance Program
New Jersey Department of Health and Senior Services
Consumer, Environmental and Occupational Health Service
P.O. Box 369
Trenton, New Jersey 08625-0369

Table 1: Summary of Tetrachloroethylene and Trichloroethylene Concentrations in Regional Groundwater Aquifer for the OU1 and OU2 Study Areas.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant	Number of Samples	Number of Detections	Concentration: micrograms/liter					Contaminant of Concern
			Minimum	Maximum	Average	Environmental Guideline Comparison Value	NJDEP GWQC [a]	
OU1 Study Area: 130 Groundwater Wells, Sampling Period: June 1999 through August 2007								
Tetrachloroethylene	348	145	ND	1,500	7	0.06 (CREG) [b]	1	**Yes**
Trichloroethylene	348	207	ND	2,100	44	0.8 (CREG)	1	**Yes**
OU1 Study Area: 2 Background Wells, Sampling Period: December 1999 through June 2002								
Tetrachloroethylene	14	2	ND	0.6 J	0.05 J	0.06 (CREG)	1	No [d]
Trichloroethylene	13	0	ND	ND	ND	0.8 (CREG)	1	No
OU2 Study Area: 12 Groundwater Wells, Sampling Period: January through December 2007								
Tetrachloroethylene	29	10	ND	0.58	0.18	0.06 (CREG)	1	**Yes** [c]
Trichloroethylene	29	12	ND	33	10	0.8 (CREG)	1	**Yes**

(a) New Jersey Department of Environmental Protection Groundwater Quality Criteria
(b) ATSDR Cancer Risk Evaluation Guideline
(c) Groundwater data from residential wells (Table 2) demonstrate concentrations of Tetrachloroethylene in groundwater exceeded the NJDEP GWQC.
(d) Based on one limited exceedance of SL at a non-quantified (estimated) level.
J - Estimated

Table 2: Summary of Tetrachloroethylene and Trichloroethylene Concentrations in Groundwater from Public Water Supply Wells Prior to Treatment: OU1 Study Area. Sampling Period: May 1985 through December 2007
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant	Number of Samples	Number of Detections	Results Above NJDEP GWQC	Concentration: micrograms/liter					Contaminant of Concern
				Minimum	Maximum	Average	Environmental Guideline Comparison Value	NJDEP GWQC [a]	
New Jersey American Water Supply Well: PVMSW01 (Vannatta Street Well) [c] - Within Plume Source									
Tetrachloroethylene	290	281	281	ND	183	63	0.06 (CREG) [b]	1	**Yes**
Trichloroethylene	300	276	94	ND	24	1.2	0.8 (CREG)		**Yes**
New Jersey American Water Supply Well: PVMSW02 (Changewater Avenue Well) - Outside Plume Source									
Tetrachloroethylene	4	0	0	ND	ND	ND	0.06 (CREG)	1	No
Trichloroethylene	4	0	0	ND	ND	ND	0.8 (CREG)		No
New Jersey American Water Supply Well: PVMSW04 (Dale Avenue Well) [c] - Within Plume Source									
Tetrachloroethylene	153	114	27	ND	7	0.8	0.06 (CREG)	1	**Yes**
Trichloroethylene	105	103	103	ND	276	94	0.8 (CREG)		**Yes**

(a) New Jersey Department of Environmental Protection Groundwater Quality Criteria
(b) ATSDR Cancer Risk Evaluation Guideline
(c) Raw groundwater intake concentrations prior to contaminant removal via treatment systems
ND - Not Detected

Table 3: Summary of Tetrachloroethylene and Trichloroethylene Concentrations in Untreated Potable Groundwater (Domestic Use): OU1 and OU2 Study Areas.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant	Number of Samples	Number of Detections	Number of Residences Above NJDEP GWQC or SL	Concentration: micrograms/liter					Contaminant of Concern
				Minimum	Maximum	Average	Environmental Guideline Comparison Value	NJDEP GWQC [a]	
OU1 Study Area: 19 Residences, Sampling Period: August 1999 through June 2002 [c]									
Tetrachloroethylene	28	3	1	ND	0.5 J	0.4 J	0.06 (CREG) [b]	1	**Yes**
Trichloroethylene	28	15	3	ND	6.9	8.9	0.8 (CREG)		**Yes**
OU1 Study Area: Residential Well PV-093 (non-potable use), Subset of August 1999 through June 2002 sampling [d]									
Tetrachloroethylene	2	0	0	ND	ND	ND	0.06 (CREG)	1	No
Trichloroethylene		1		ND	0.43 J	0.25	0.8 (CREG)		No
OU1 Study Area: Residential Well PVDOM01 (non-potable use), Subset of August 1999 through June 2002 sampling [d]									
Tetrachloroethylene	2	0	1	ND	ND	ND	0.06 (CREG)	1	No
Trichloroethylene		2		3	5.6 J	4.3	0.8 (CREG)		**Yes**
OU1 Study Area: Residential Well PVDOM02 (non-potable use), Subset of August 1999 through June 2002 sampling [d]									
Tetrachloroethylene	3	2	1	ND	0.5 J	0.27 J	0.06 (CREG)	1	**Yes**
Trichloroethylene		3		84	100	93	0.8 (CREG)		**Yes**
OU1 Study Area: 93 Residences (estimated), Sampling Period: 1984 - 1985 [c]									
Trichloroethylene	93	78	70	ND	440	28	0.8 (CREG)	1	**Yes**

Contaminant	Number of Samples	Number of Detections (> 1 µg/L)	Number of Residences Above NJDEP GWQC	Concentration: micrograms/liter					Contaminant of Concern
				Minimum	Maximum	Average	Environmental Guideline Comparison Value	NJDEP GWQC [a]	
OU2 Study Area: 261 Residences, Sampling Period: March 2009 through August 2009 [e]									
Tetrachloroethylene	261	0	0	ND	ND	ND	0.06 (CREG)	1	No
Trichloroethylene	261	36	36	ND	10	0.49	0.8 (CREG)		**Yes**
OU2 Study Area: 204 Residences, Sampling Period: February 2000 through March 2008 [f]									
Tetrachloroethylene	81	13	4	1	28	2	0.06 (CREG)	1	**Yes**
Trichloroethylene	735	508	112	1	35	4	0.8 (CREG)		**Yes**

(a) New Jersey Department of Environmental Protection Groundwater Quality Criteria
(b) ATSDR Cancer Risk Evaluation Guideline
(c) Data source: OU1 Remedial Investigation Report Pohatcong Valley Groundwater Contamination Site (C2MHILL 2005).
(d) Well identified as remaining in use for non-potable purposes (C2MHILL 2005).
(e) Total of 266 residences sampled; however, 5 residences had POET systems operational at the time of sampling and were not included in this evaluation. There were no detections of TCE or PCE present for these 5 residences.
(f) Analytical data provided does not indicate pre- or post-POET treament, therefore, only results equal to or exceeding the GWQC of 1 µg/L are reported to present likely pre-treatment data. Some residences sampled on multiple occasions.
J- Estimated Value; NA - All data not available to calculate average; ND - Not Detected (< 1µg/L).

Table 4: Summary of Soil Gas/Sub-Slab Gas Contaminants of Concern Concentrations: OU1 & OU2 Areas
Pohatcong Valley Groundwater Contamination Site, Warren County

Sample Location	Sample Period	1,2-DCA Concentration Range (µg/m3) [a]	PCE Concentration Range (µg/m3)	TCE Concentration Range (µg/m3)	Soil Gas Screening Values (µg/m3) [b] Risk = $1x10^{-5}$	Selected for Further Evaluation by US EPA
Residence A [e]	March 2006 - January 2007	0.59 - 2.5	2.9 - 31	**71 - 920**	1,2-DCA = 0.94 PCE = 100 TCE = 2.7	**Yes**
Residence B	June - October 2006	0.37 - 0.41	15 - 16	**1**		**Yes**
Residence C	April 2009	1.08	**472**	**2**		**Yes**
Residence D	June 2006	0.12 - 0.13	7.9 - 12	**7.8 - 18**		No
Residence E	April 2009	0.36	**152**	0.48		**Yes**
Residence F	April 2009	0.29	98	0.55		**Yes**
13 Remaining Residences	March - October 2006	0.11 - 6.48	0.21 - 10.9	0.15 - **8.6**		No [c]
Multi-Tenant Residence [d]	January - April 2009	0.27 - 1.14	2.6 - **16,600**	0.36 - **951**		**Yes**
Franklin Township Elementary School [e]	June 2006 - March 2007	0.12 - 0.20	0.18 - 12	0.27 - **122**		**Yes**
Washington Memorial Elementary School	March 2007	0.3	0.53 - 1	0.39 - 0.40		No
Taylor Street Elementary School	March 2007	0.28 - 0.29	0.49 - 39	0.38 - 0.99		No
Warren Hills Middle School	July 2007 - January 2009	0.27 - 0.34	0.34 - 13	0.27 - **256**		**Yes**
Daycare A	March 2007 - January 2009	0.20 - 0.33	0.45 - 57	0.28 - **8.1**		**Yes**
Daycare B	March 2007 - January 2009	0.27	0.45 - 60	0.36 - 2.5		**Yes**
Daycare C	March 2007	0.3	0.92	0.4		No
Daycare D	March 2007	0.24	0.41	0.33		No
Daycare E	March 2007	0.27	1.9	0.36		No
Warren County Community College	March 2007	0.23 - 0.53	0.53 - 1.0	0.39 - 0.40		No
Washington Boro Fire Department	March 2007	0.28	1.1	0.37		No
Washington Boro Post Office	October 2006	0.12	0.6	0.15		No

(a) - micrograms per cubic meter.

(b) - United States Environmental Protection Agency (US EPA) Interim Soil Gas Screening Values (EPA 2002)

(c) - TCE exceedance at 8.6 µg/m^3 identified as a non-detect result.

(d) - Vapor intrusion remedial system installed in 2009.

(e) - Vapor intrusion remedial system installed in 2007.

ND - Not Detected

Further investigation was conducted by the US EPA at chosen locations based on site-specific information.

Table 5: Overview of Site-Related Contaminants in Indoor Air from US EPA Selected Locations Within OU1 and OU2[*]
Comparison of Contaminant Concentrations in Indoor Air With Environmental Guideline Comparison Values
Pohatcong Valley Groundwater Contamination Site
Sample Period: March 2006 through April 2009

Contaminant	Number of Samples	Number of Detections	Concentration: micrograms/cubic meter					Contaminant of Concern
			Minimum	Maximum	Average	Environmental Guideline Comparison Value	US EPA Residential Air Screening Levels (c)	
1,2-Dichloroethane	92	23	ND (DL= <0.10)	**4.6**	**0.22**	0.04 (CREG) (a)	0.094	**Yes**
1,1-Dichloroethene	184	1	ND	0.22	0.11	80 (EMEG) (b)	210	No
1,2-Dichloroethene (cis)	92	4	ND	0.29	0.12	NV	NV	No
1,2-Dichloroethene (trans)	92	2	ND	0.19	0.13	800 (EMEG)	63 N	No
Tetrachloroethylene	92	60	ND	**67**	**2.3**	0.2 (CREG)	0.41 C	**Yes**
Trichloroethylene	92	37	ND	**11**	0.61	0.2 (CREG)	1.2 C	**Yes**
Vinyl Chloride	92	0	ND	ND (DL = <0.29)	NA	0.1 (CREG)	0.16	No

(a) Cancer Risk Evaluation Guideline
(b) Environmental Media Evaluation Guideline
(c) USEPA Region 6 Human Health Media-Specific Screening Levels (N = Non cancer, C = Cancer)
NV - No Value Established; ND - Not Detected; D.L. - Detection limit provided when 1/2 detection limit exceeds CV; NA - Not Applicable
* EPA Selected Locations: 6 residences, 1 multi-dwelling unit, 2 daycare centers, Franklin Township Elementary School, and Warren Hills Middle School.

Table 6: Comparison of Indoor Air 1,2-DCA Concentrations With Environmental Guideline Comparison Values
Pohatcong Valley Groundwater Contamination Site, Warren County
Sample Period: March 2006 through April 2009

Sample Location	Number of Samples	Number of Detections	Minimum 1,2-DCA Concentration (µg/m^3) [a]	Maximum 1,2-DCA Concentration (µg/m^3)	Average 1,2-DCA Concentrations (µg/m^3)	ATSDR CREG [b] (µg/m^3)	US EPA RASL [c] (µg/m^3)	Contaminant of Concern
OU1 - Study Area								
Residence C	1	1	**0.42**	**0.42**	**0.42**	0.04	0.094 (C)	**Yes**
Remaining 3 Residences	4	0	ND (D.L.< 0.13)	ND (D.L.< 0.23)	NA			No
Multi-Tenant Residence [d]	17	5	ND	**0.46**	**0.22**			**Yes**
Warren Hills Middle School	13	0	ND (D.L. < 0.2)	ND (D.L. < 0.34)	NA			No
Daycare A	8	2	ND	**1.2**	**0.26**			**Yes**
Daycare B	10	7	ND	**0.88**	**0.26**			**Yes**
Ambient Samples OU1 & OU2 Areas	20	1	ND	**0.29**	**0.13**			NA
OU2 - Study Area								
Residence A - Basement [e] 1st Floor	2	0	ND (D.L. < 0.12)	ND (D.L. < 0.14)	NA	0.04	0.094 (C)	No
	3	0						
Residence B - Basement 1st Floor	1	0	ND (D.L. < 0.13)	ND (D.L. < 0.13)	NA			**Yes**
	1	1	**0.37**	**0.37**	**0.37**			
Franklin Township Elementary School [e]	30	5	ND	**4.6**	0.26			**Yes**

(a) - micrograms per cubic meter.
(b) - Agency for Toxic Substances and Disease Registry Cancer Risk Evaluation Guideline
(c) - United States Environmental Protection Agency Residential Air Screening Level; (C) - based on cancer health effects
(d) - Vapor instrusion remedial system installed in 2009.
(e) - Vapor instrusion remedial system installed in 2007.
ND - Not Detected; D.L. - Detection limit provided when 1/2 detection limit exceeds CV

Table 7: Comparison of Indoor Air PCE Concentrations With Environmental Guideline Comparison Values
Pohatcong Valley Groundwater Contamination Site, Warren County
Sample Period: March 2006 through April 2009

Sample Location	Number of Samples	Number of Detections	Minimum PCE Concentration (µg/m^3) [a]	Maximum PCE Concentration (µg/m^3)	Average PCE Concentrations (µg/m^3)	ATSDR CREG [b] (µg/m^3)	US EPA RASL [c] (µg/m^3)	Contaminant of Concern
OU1 - Study Area								
Residence C	1	1	**1.7**	**1.7**	**1.7**	0.2	0.41(C) 280 (N)	**Yes**
Remaining 3 Residences	4	0	ND	ND	ND			No
Multi-Tenant Residence [d]	17	16	ND	**67**	**11**			**Yes**
Warren Hills Middle School	13	4	ND	**0.31**	**0.24**			**Yes**
Daycare A	8	4	ND	**0.40**	**0.27**			**Yes**
Daycare B	10	9	ND	**1.7**	**1.1**			**Yes**
Ambient Samples OU1 & OU2 Areas	20	5	ND	**0.60**	**0.23**			NA
OU2 - Study Area								
Residence A - Basement [e]	2	1	0.11	**0.63**	**0.37**	0.2	0.41(C) 280 (N)	**Yes**
1st Floor	3	1	0.10	**0.48**	**0.23**			
Residence B - Basement	1	0	ND	ND	ND			No
1st Floor	1	0	ND	ND	ND			
Franklin Township Elementary School [e]	30	24	ND	**1.6**	**0.26**			**Yes**

(a) - micrograms per cubic meter.
(b) - Agency for Toxic Substances and Disease Registry Interim Cancer Risk Evaluation Guideline
(c) - United States Environmental Protection Agency Residential Air Screening Level; (C) - based on cancer health effects, (N) - based on non-cancer health effects
(d) - Vapor instrusion remedial system installed in 2009.
(e) - Vapor instrusion remedial system installed in 2007.
ND - Not Detected

Table 8: Comparison of Indoor Air TCE Concentrations With Environmental Guideline Comparison Values
Pohatcong Valley Groundwater Contamination Site, Warren County
Sample Period: March 2006 through April 2009

Sample Location	Number of Samples	Number of Detections	Minimum TCE Concentration (µg/m^3) [a]	Maximum TCE Concentration (µg/m^3)	Average TCE Concentrations (µg/m^3)	ATSDR CREG [b] (µg/m^3)	US EPA RASL [c] (µg/m^3)	Contaminant of Concern
OU1 - Study Area								
Residence C	1	0	ND	ND	ND	0.2	1.2 (C)	No
Remaining 3 Residences	4	0	ND	ND	ND			No
Multi-Tenant Residence [d]	17	4	ND	**2.0**	0.40			**Yes**
Warren Hills Middle School	13	3	ND	**0.59**	0.22			**Yes**
Daycare A	8	1	ND	**1.4**	0.31			**Yes**
Daycare B	10	2	ND	0.18	0.15			No
Ambient Samples OU1 & OU2 Areas	20	3	ND	0.43	0.17			NA
OU2 - Study Area								
Residence A - Basement [e]	2	1	ND	**11**	**5.5**	0.2	1.2 (C)	**Yes**
1st Floor	3	1	ND	**9.0**	**3.1**			
Residence B - Basement	1	1	1.1	**1.1**	**1.1**			**Yes**
1st Floor	1	1	0.59	**0.59**	**0.59**			
Franklin Township Elementary School [e]	30	21	ND	**3**	**0.61**			**Yes**

(a) - micrograms per cubic meter.
(b) - Agency for Toxic Substances and Disease Registry Interim Cancer Risk Evaluation Guideline.
(c) - United States Environmental Protection Agency Residential Air Screening Level; (C) - based on cancer health effects
(d) - Vapor instrusion remedial system installed in 2009.
(e) - Vapor instrusion remedial system installed in 2007.
ND - Not Detected

Table 9a: Summary of Tetrachloroethylene and Trichloroethylene Concentrations in Surface Water
Pohatcong and Shabbecong Creeks within OU1 Study Area;
Pohatcong Creek and Edison Quarry within OU2 Study Area.

Contaminant	Number of Samples	Number of Detections	Concentration: micrograms/liter					Contaminant of Concern
			Minimum	Maximum	Average	Environmental Guideline Comparison Value	NJDEP SWQC [a]	
OU1 Study Area - Pohatcong Creeks, Sampling Period: May 2000 and December 2001								
Tetrachloroethylene	11	0	ND	ND	ND	5 (MCL) [b]	0.34	No
Trichloroethylene	11	4	ND	0.69 J	0.15	5 (MCL)	1	No
OU1 Study Area - Shabbecong Creek, Sampling Period: May 2000 and December 2001								
Tetrachloroethylene	8	3	ND	1.1	0.27	5 (MCL) [b]	0.34	**Yes**
Trichloroethylene	8	3	ND	0.23 J	0.06	5 (MCL)	1	No
OU1 Study Area - Pechiney Plastics Packaging Incorporated Property Source Run-Off Areas Discharging to Surface Water, Sampling Period: March/April 2000 and January 2002								
Tetrachloroethylene	7	0	ND	ND	ND	5 (MCL) [b]	0.34	No
Trichloroethylene	7	3	ND	25	7.9	5 (MCL)	1	**Yes**
OU2 Study Area - Pohatcong and Merrill Creeks, Sampling Period: January 2008[c]								
Tetrachloroethylene	9	0	ND	ND	ND	5 (MCL)	0.34	No
Trichloroethylene	9	1	ND	1.2 J	0.1	5 (MCL)	1	**Yes**
OU2 Study Area - Edison Quarry: September 2003, Discrete depth sampling range 5' - 87'								
Tetrachloroethylene	15	0	ND	ND	ND	5 (MCL)	0.34	No
Trichloroethylene	15	15	0.36	6.20	3.62	5 (MCL)	1	**Yes**

(a) New Jersey Department of Environmental Protection Surface Water Quality Criteria; (b) Maximum Contaminant Level; (C) Merrill Creek - one sample collected which was non-detect for PCE and TCE.; J - Estimated

Table 9b: Summary of Tetrachloroethylene and Trichloroethylene Concentrations in Sediment
Pohatcong and Shabbecong Creeks within OU1 Study Area;
Pohatcong and Merrill Creeks and Edison Quarry within OU2 Study Area.

Contaminant	Number of Samples	Number of Detections	Concentration: milligrams/kilogram				Contaminant of Concern
			Minimum	Maximum	Average	Environmental Guideline Comparison Value	
Sampling Period: May 2000, December 2001, and January 2008							
Tetrachloroethylene	26	3	ND	0.003 J	0.002	1 (CREG) [a]	No
Trichloroethylene	26	8	ND	0.026 J	0.0002	20 (CREG) [a]	No

(a) ATSDR Intermim Cancer Risk Evaluation Guideline; J - Estimated

Table 10 – Evaluated Exposure Pathways

Pathway	Pathway Exposure Pathway Elements				Pathway Classification
	Environmental Medium	Route of Exposure	Location	Exposed Population	
Groundwater	Public Water Supply Vannatta Street Well	Ingestion, Inhalation, Dermal	Residences and Businesses - OU1 Study Area	Adults & Children	Past – Completed Present & Future – Eliminated [a]
	Private Residential Wells	Ingestion, Inhalation, Dermal	Residences and Businesses - OU1 & OU2 Study Areas		Past – Completed Present & Future – Eliminated [b] Present & Future – Interrupted [c]
Indoor Air	Indoor Air	Inhalation	Residences, Schools and Businesses - OU1 & OU2 Study Areas		Past – Completed Current and Future – Interrupted [d]
Surface Water	Surface Water	Ingestion, Dermal	Pohatcong and Shabbecong Creeks; former Edison Quarry		Past, Present & Future – Completed

(a) Exposures began 1972 and ceased with the operation of a water treatment system in 1981.
(b) For residents in the OU1 area that are connected to the public water supply as a permanent remedy.
(c) For residents in OU2 area that have POET systems installed until a permanent solution is implemented to eliminate this pathway.
(d) Considered interrupted as the US EPA is actively monitoring and are planning remedial actions to address site-related groundwater contamination. Additionally, remedial systems have been installed at three receptor locations to mitigate vapor intrusion and reduce or prevent further exposures.

Table 11: Comparison of Ingestion Exposures to Tetrachloroethylene and Trichloroethylene with Health Guideline Comparison Values:
Non-Cancer Health Effects for Residents (OU1 Study Area) Supplied by Vannatta Street Public Supply Well from 1972 through 1981.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Exposure Point Concentration (µg/L) [a]	Maximum Exposure Dose (mg/kg/day)		Health Guideline CVs (mg/kg/day)		Potential for Non-cancer Health Effects
		Child [b]	Adult [c]	ATSDR MRL [d]	USEPA RfD [e]	
OU1 Study Area: Residents Supplied by Vannatta Street Public Supply Well 1972 - 1981						
Tetrachloroethylene	147	0.010	0.0047	0.05 A	0.01 C	Yes
Trichloroethylene	1.7	0.0001	0.00005	0.2 A	0.0005 C	No

(a) Exposure Point Concentrations (micrograms per liter) derived using Pro UCL Version 4.00.02 (EPA, 2007).
(b) Child exposure assumptions: age adjusted 0.049 to 0.235 Liter/kg/day, 6 year exposure duration (US EPA 2011b, Table 3-19).
(c) Adult ingestion exposure assumptions: 0.032 Liter/kg/day, 9 year exposure duration (US EPA 2011b, Table 3-19).
(d) Agency for Toxic Substances Disease Registry's Minimal Risk Level (A = Acute < 15 days).
(e) US EPA Reference Dose 2011 (C = Chronic)

Table 12: Comparison of Ingestion Exposures to Tetrachloroethylene and Trichloroethylene in Untreated Potable Groundwater with Health Guideline Comparison Values:
Non-Cancer Health Effects for Residents within OU1 and OU2 Study Areas.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Exposure Point Concentration (µg/L) [a]	Maximum Exposure Dose (mg/kg/day)		Health Guideline CVs (mg/kg/day)		Potential for Non-cancer Health Effects
		Child [b]	Adult [c]	ATSDR MRL [d]	USEPA RfD [e]	
OU1 Study Area: 27 Residences (estimated) - TCE Concentrations <7.4 µg/L, Sampling Period: 1984 - 2002						
Tetrachloroethylene [f]	0.5	0.00003	0.00002	0.05 A	0.01 C	No
Trichloroethylene	3.1	0.0002	0.0001	0.2 A	0.0005 C	No
OU1 Study Area: 48 Residences (estimated) - TCE Concentrations >7.4 µg/L, Sampling Period: 1984 - 2002						
Trichloroethylene	100	0.007	0.003	0.2 A	0.0005 C	**Yes**
Trichloroethylene (max. conc.)	440	0.030	0.014	0.2 A	0.0005 C	**Yes**
OU2 Study Area: 4 Residences, Sampling Period: February 2000 through March 2008						
Tetrachloroethylene	15.4	0.0010	0.0005	0.05 A	0.01 C	No
OU2 Study Area: 116 Residences - TCE Concentrations <7.4 µg/L, Sampling Period: February 2000 through August 2009						
Trichloroethylene	2.4	0.0002	0.0001	0.2 A	0.0005 C	No
OU2 Study Area: 18 Residences - TCE Concentrations >7.4 µg/L, Sampling Period: February 2000 through August 2009						
Trichloroethylene	12.2	0.0008	0.0004	0.2 A	0.0005 C	**Yes**

(a) Exposure Point Concentrations (micrograms per liter) derived using Pro UCL Version 4.00.02 (EPA, 2007).
(b) Child exposure assumptions: age adjusted 0.049 to 0.235 Liter/kg/day, 6 year exposure duration (US EPA 2011b, Table 3-19).
(c) Adult ingestion exposure assumptions: 0.032 Liter/kg/day, 9 year exposure duration (US EPA 2011b, Table 3-19).
(d) Agency for Toxic Substances Disease Registry's Minimal Risk Level (A = Acute < 15 days).
(e) US EPA Reference Dose 2011 (C = Chronic)
(f) Tetrachloroethylene detected in potable well water at 2 residences.

Table 13a: Comparison of Shower Inhalation Exposures (past) to Tetrachloroethylene and Trichloroethylene Vapors with Health Guideline Comparison Values:
Non-Cancer Health Effects for Residents Supplied by the Vannatta Street Public Supply Well from 1972 through 1981.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Max. (µg/L)	Ca [(d)] (µg/m^3) Showering Event	TWA [(c)] Exposure Concentration (µg/m^3)	Health-Based CVs (µg/m^3)		Potential for Non-cancer Health Effects
				ATSDR MRL [(a)]	USEPA RfC [(b)]	
OU1 Study Area: Residents Supplied by Vannatta Street Public Supply Well 1972 - 1981						
Tetrachloroethylene	147	2,631	118	300 C 1,000 A	270 C	No
Trichloroethylene	1.7	30	1	500 I 10,000 A	2 C	No

(a) Agency for Toxic Substances Disease Registry's Minimal Risk Level (A = Acute < 15 days/year; I = Intermediate 15 - 364 days/year; C = Chronic >364 days)
(b) EPA Reference Concentration (C = Chronic)
(c) 24-hour Time-Weighted Average Exposure Concentration
(d) Schaum model as modified by Andelman (Schaum et al., 1994) (Source: US EPA. 2005. Draft OU1 Remedial Investigation Report, Pohatcong Valley Groundwater Contamination Site, prepared by CH2MHill. June 2005)

Equation 1: $Ca = ((Camax/2 * t1 + Camax * t2) / (t1 + t2)$

Equation 2: $Camax = (Cw * f * Fw * t1) / Va$

where Ca = exposure concentration of chemical in air (mg/m^3)

Camax = maximum concentration of chemical in air (mg/m^3)

t1 = time in shower = 0.58 hr*[(95th percentile)]

t2 = time in bathroom after shower = 0.5 hr*[(95th percentile)]

Cw = concentration of chemical in water (mg/L)

f = fraction of chemical volatilized (unitless) = 0.9

Fw = shower water flow rate (mean) = 750 L/hr*

Va = bathroom volume (estimated) = 16 m^3

* - Source: US EPA Exposure Factors Handbook, 2011.

NA - Not Available; TBD - To be determined when a chronic health comparison value for inhalation exposure becomes available.

Table 13b: Comparison of Bath Dermal Exposures (past) to Tetrachloroethylene and Trichloroethylene with Health Guideline Comparison Values:
Non-Cancer Health Effects for Residents Supplied by the Vannatta Street Public Supply Well from 1972 through 1981.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Maximum Contaminant Concentration Pre-Volitization (µg/L) [a]	Contaminant Concentration Post 50% Volitization from Filling Bathtub [b] (mg/cm^3)	Dermally Absorbed Dose [f] DAD (mg/kg/day)	Health Guideline CVs (mg/kg/day)		Potential for Non-cancer Health Effects
			Child [c] (Bath)	ATSDR MRL [d]	USEPA RfD [e]	
OU1 Study Area: Residents Supplied by Vannatta Street Public Supply Well 1972 - 1981						
Tetrachloroethylene	147	7.4E-05	0.0029	0.05 A	0.01 C	No
Trichloroethylene	1.7	8.5E-07	0.000009	0.2 A	0.0005 C	No

(a) Exposure Point Concentrations (micrograms per liter) derived using Pro UCL Version 4.00.02 (EPA, 2007).
(b) Aqueous contaminant concentration (milligrams per cubic meter) following an estimated 50% reduction from volitization associated with bathtub filling. Converted for calculation purposes (see footnote f). Volatilization rate estimated based on US EPA. National Center for Environmental Assessment. Office of Research and Development. Volatilization Rates from Water to Indoor Air Phase II. Washington, DC. October 2000.
(c) Child dermal exposure assumptions (see footnote f).
(d) Agency for Toxic Substances Disease Registry's Minimal Risk Level (A = Acute < 15 days).
(e) US EPA Reference Dose (C = Chronic)
(f) Dermally Absorbed Dose (DAD) calculated using US EPA Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) – ORG04_01.XLS Excel spreadsheet for dermal assessment of organic chemicals in water, April 2001.
Note: To be conservative for dermal skin absorption exposures, contaminant concentrations in water after bathtub filling were not adjusted for surface volatilization during the 1 hour bathing scenario for children. The US EPA considers children (<1 to 6 years) to represent the most likely population to fall under the bathing scenario regarding dermal exposures.

Equation 1: $DAevent = 2FA * Kp * Cw (6*\tau event * tevent/\pi)^{1/2}$
Equation 2: $DAD = DAevent * EV * ED * EF * SA/BW * AT$
where DAevent = Absorbed dose per event (mg/cm-event)
FA = Fraction absorbed water (dimensionless) = 1
Kp = Dermal permeability coefficient of compound in water (cm/hr): TCE = 0.033 cm/hr; PCE = 0.012 cm/hr
Cw = Chemical concentration in water (mg/cm^3): TCE = 7.4E-05; PCE = 8.5E-07
$\tau event$ = Lag time per event (hr/event): TCE = 0.91 hr/event; PCE = 0.58
tevent = Event duration (hr/event) = 1 hr/event
DAD = Dermally Absorbed Dose (mg/kg-day)
SA = Skin surface area availablefor contact (cm^2) = 6,600 cm^2 (child)
EV = Event frequency (events/day) = 1 event/day
EF = Exposure frequency (days/year) = 365 days/year
ED = Exposure duration (years) = 6 years
BW = Body weight (kg) = 15 kg (child)
AT = Averaging time (days); noncarcinogenic effects AT = ED x 365 days/yr

Table 14a: Comparison of Shower Inhalation Exposures (past) to Tetrachloroethylene and Trichloroethylene Vapors from Untreated Potable Groundwater with Health Guideline Comparison Values: Non-Cancer Health Effects for Residents within OU1 and OU2 Study Areas.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Exposure Point Concentration (µg/L)	Ca [(d)] ($\mu g/m^3$) Showering Event	TWA [(c)] Exposure Concentration ($\mu g/m^3$)	Health-Based CVs ($\mu g/m^3$)		Potential for Non-cancer Health Effects
				ATSDR MRL [(a)]	USEPA RfC [(b)]	
OU1 Study Area: 27 Residences (estimated) - TCE Concentrations <23 µg/L, Sampling Period: 1984 - 2002						
Tetrachloroethylene[(e)]	0.5	9	0.4	300 C 1,000 A	270 C	No
Trichloroethylene	3.1	55	2	500 I 10,000 A	2 C	**Yes**
OU1 Study Area: 48 Residences With TCE Concentrations >23 µg/L, Sampling Period: 1984						
Trichloroethylene	100	1,790	81	500 I 10,000 A	2 C	**Yes**
Trichloroethylene (max. conc.)	440	7,875	354	500 I 10,000 A	2 C	**Yes**
OU2 Study Area: 4 Residences, Sampling Period: February 2000 through March 2008						
Tetrachloroethylene	15.4	276	12	300 C 1,000 A	270 C	No
OU2 Study Area: 116 - TCE Concentrations <7.4 µg/L, Sampling Period: February 2000 through August 2009						
Trichloroethylene	2.4	43	2	500 I 10,000 A	2 C	**Yes**
OU2 Study Area: 18 Residences - TCE Concentrations >7.4 µg/L, Sampling Period: February 2000 through August 20						
Trichloroethylene	12.2	218	10	500 I 10,000 A	2 C	**Yes**

(a) Agency for Toxic Substances Disease Registry's Minimal Risk Level (A = Acute < 15 days/year; I = Intermediate 15 - 364 days/year; C = Chronic >364 days)
(b) EPA Reference Concentration (C = Chronic)
(c) 24-hour Time-Weighted Average Exposure Concentration
(d) Schaum model as modified by Andelman (Schaum et al., 1994) (Source: US EPA. 2005. Draft OU1 Remedial Investigation Report, Pohatcong Valley Groundwater Contamination Site, prepared by CH2MHill. June 2005)

Equation 1: $Ca = ((Camax/2 * t1 + Camax * t2) / (t1 + t2)$
Equation 2: $Camax = (Cw * f * Fw * t1) / Va$
where Ca = exposure concentration of chemical in air (mg/m^3)
Camax = maximum concentration of chemical in air (mg/m^3)
t1 = time in shower = 0.58 hr*[(95th percentile)]
t2 = time in bathroom after shower = 0.5 hr*[(95th percentile)]
Cw = concentration of chemical in water (mg/L)
f = fraction of chemical volatilized (unitless)
Fw = shower water flow rate (mean) = 750 L/hr*
Va = bathroom volume (estimated) = 16 m^3

* - Source: US EPA Exposure Factors Handbook, 2011.
(e) Tetrachloroethylene detected in potable well water at 2 residences.

Table 14b: Comparison of Bath Dermal Exposures (past) to Tetrachloroethylene and Trichloroethylene from Untreated Potable Groundwater with Health Guideline Comparison Values: Non-Cancer Health Effects for Residents within OU1 and OU2 Study Areas.

Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Exposure Point Concentration Pre-Volitization (µg/L) [a]	Contaminant Concentration Post 50% Volitization from Filling Bathtub [b] (mg/cm^3)	Dermally Absorbed Dose [f] DAD (mg/kg/day)	Health Guideline CVs (mg/kg/day)		Potential for Non-cancer Health Effects
			Child [c] (Bath)	ATSDR MRL [d]	USEPA RfD [e]	
OU1 Study Area: 27 Residences (estimated) - TCE Concentrations <7.4 µg/L, Sampling Period: 1984 - 2002						
Tetrachloroethylene [g]	0.5	2.5E-07	0.00001	0.05 A	0.01 C	No
Trichloroethylene	3.1	1.6E-06	0.00002	0.2 A	0.0005 C	No
OU1 Study Area: 48 Residences (estimated) - TCE Concentrations >7.4 µg/L, Sampling Period: 1984 - 2002						
Trichloroethylene	100	5.0E-05	0.0005	0.2 A	0.0005 C	**Yes**
Trichloroethylene (max. conc.)	440	2.2E-04	0.0024	0.2 A	0.0005 C	**Yes**
OU2 Study Area: 4 Residences, Sampling Period: February 2000 through March 2008						
Tetrachloroethylene	15.4	7.7E-06	0.0003	0.05 A	0.01 C	No
OU2 Study Area: 116 - TCE Concentrations <7.4 µg/L, Sampling Period: February 2000 through August 2009						
Trichloroethylene	2.4	1.2E-06	0.00001	0.2 A	0.0005 C	No
OU2 Study Area: 18 Residences - TCE Concentrations >7.4 µg/L, Sampling Period: February 2000 through August 2009						
Trichloroethylene	12.2	6.1E-06	0.00007	0.2 A	0.0005 C	No

(a) Exposure Point Concentrations (micrograms per liter) derived using Pro UCL Version 4.00.02 (EPA, 2007).

(b) Aqueous contaminant concentration (milligrams per cubic meter) following an estimated 50% reduction from volitization associated with bathtub filling. Converted for calculation purposes (see footnote f). Volatilization rate estimated based on US EPA. National Center for Environmental Assessment. Office of Research and Development. Volatilization Rates from Water to Indoor Air Phase II. Washington, DC. October 2000.

(c) Child dermal exposure assumptions (see footnote f).

(d) Agency for Toxic Substances Disease Registry's Minimal Risk Level (A = Acute < 15 days).

(e) US EPA Reference Dose (C = Chronic)

(f) Dermally Absorbed Dose (DAD) calculated using US EPA Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) – ORG04_01.XLS Excel spreadsheet for dermal assessment of organic chemicals in water, April 2001. Note: To be conservative for dermal skin absorption exposures, contaminant concentrations in water after bathtub filling were not adjusted for surface volatilization during the 1 hour bathing scenario for children. The US EPA considers children (<1 to 6 years) to represent the most likely population to fall under the bathing scenario regarding dermal exposures.

Equation 1: $DAevent = 2FA * Kp * Cw (6*\tau event * tevent/\pi)^{1/2}$

Equation 2: $DAD = DAevent * EV * ED * EF * SA/BW * AT$

where DAevent = Absorbed dose per event (mg/cm-event)

FA = Fraction absorbed water (dimensionless) = 1

Kp = Dermal permeability coefficient of compound in water (cm/hr): TCE = 0.033 cm/hr; PCE = 0.012 cm/hr

Cw = Chemical concentration in water (mg/cm^3): TCE = 7.4E-05; PCE = 8.5E-07

τevent = Lag time per event (hr/event): TCE = 0.91 hr/event; PCE = 0.58

tevent = Event duration (hr/event) = 1 hr/event

DAD = Dermally Absorbed Dose (mg/kg-day)

SA = Skin surface area availablefor contact (cm^2) = 6,600 cm^2 (child)

EV = Event frequency (events/day) = 1 event/day

EF = Exposure frequency (days/year) = 365 days/year

ED = Exposure duration (years) = 6 years

BW = Body weight (kg) = 15 kg (child)

AT = Averaging time (days); noncarcinogenic effects AT = ED x 365 days/yr

(g) Tetrachloroethylene detected in potable well water at 2 residences.

Table 15: Comparison of Indoor Air Contaminant Concentrations with Health Guideline Comparison Values for Non-Cancer Health Effects: Vapor Intrusion Investigations

Pohatcong Valley Groundwater Contamination Site, Warren County

Exposure Point Indoor Air	Contaminant of Concern	Exposure Point Concentration (µg/m3) [a,b]	Health-Based Comparison Values (µg/m^3)	Potential for Non-Cancer Health Effects
OU1 - Study Area				
Residence C	1,2-DCA	0.42	1,2-DCA = 2,000 (C)[c] PCE = 300 (C)[c] TCE = 2 (C)[d]	No
	PCE	1.7		
Multi-Tenant Residence [e]	1,2-DCA	0.45		No
	PCE	55		No
	TCE	2		**Yes** [d]
Warren Hills Middle School	PCE	0.3		No
	TCE	0.54		No
Daycare A	1,2-DCA	0.94		No
	PCE	0.37		
	TCE	1.06		
Daycare B	1,2-DCA	0.47		
	PCE	1.7		
OU2 - Study Area				
Residence A [f]	PCE	0.59	1,2-DCA = 2,000 (C)[c] PCE = 300 (C)[c] TCE = 2 (C)[d]	No
	TCE	10.5		**Yes** [d]
Residence B	1,2-DCA	0.37		No
	TCE	1.1		
Franklin Township Elementary School [f]	1,2-DCA	2.2		No
	PCE	0.51		
	TCE	1.02		

(a) - micrograms per cubic meter.
(b) - Exposure Point Concentrations derived from data presented in Tables 3 through 5 using Pro UCL Version 4.00.02 (EPA, 2007).
(c) - Agency for Toxic Substances and Disease Registry, Minimal Risk Level (I = Intermediate 15 - 364 days/year;
C = Chronic >364 days/year).
(d) - US EPA 2011 Reference Concentration for chronic inhalation exposures to TCE (USEPA 2011a).
(e) - Vapor instrusion remedial system installed in 2009.
(f) - Vapor instrusion remedial system installed in 2007.

Table 16: Comparison of Ingestion/Dermal Exposures to Tetrachloroethylene and Trichloroethylene in Surface Water with Health Guideline Comparison Values:
Non-Cancer Health Effects for Recreational Users within OU1 and OU2 Study Areas
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Exposure Point Concentration (µg/L)	Exposure Dose (mg/kg/day)		Health Guideline CVs (mg/kg/day)		Potential for Non-cancer Health Effects
		Child [a]	Adult [b]	ATSDR MRL [c]	USEPA RfD [d]	
OU1 and OU2 Study Areas: Pohatcong and Shabbecong Creeks						
Tetrachloroethylene	1.1	0.00001	0.000004	0.05 A	0.01 C	No
Trichloroethylene	7.6	0.00005	0.00001	0.2 A	0.0005 C	No
OU2 Study Area: Former Edison Quarry						
Trichloroethylene	4.5	0.00003	0.00001	0.2 A	0.0005 C	No

(a) Child ingestion exposure assumptions: Age 7 through 14 years, 0.05 liter/event, 5 hrs/event, 30 to 48 kg mean body weight
(b) Adult ingestion exposure assumptions: 0.025 liter/event, 5 hours/event, 92 days/year, 80 kg body weight
Note: ingestion rates for individuals older than 14 years are considered to be similar to adults.
(c) Agency for Toxic Substances Disease Registry's Minimal Risk Level (A = Acute < 15 days)
(d) Reference Dose (C = Chronic)
NA - Not Available; TBD - To be determined when a chronic health comparison value for oral exposure becomes available.

Table 17: Calculated Lifetime Excess Cancer Risk for Ingestion Exposures to Tetrachloroethylene and Trichloroethylene:
Residents within OU1 Study Area Supplied by Vannatta Street Public Supply Well from 1972 through 1981.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Exposure Point Concentration (µg/L) [a]	Exposure Dose (mg/kg/day)		CSF [c] (mg/kg/d) $^{-1}$	LECR [d]	
		Child [a]	Adult [b]		Child	Adult
OU1 Study Area: Residents Supplied by Vannatta Street Public Supply Well 1972 - 1981						
Tetrachloroethylene	147	7.64E-04	1.15E-03	0.54	4.13E-04	6.19E-04
Trichloroethylene	1.7	1.73E-05	3.45E-05	0.05	8.67E-07	1.73E-06
				*** LECR Sum=**	4.13E-04	6.19E-04

(a) Exposure Point Concentrations (micrograms per liter) derived using Pro UCL Version 4.00.02 (EPA, 2007).
(b) Child PCE exposure assumptions: age adjusted 0.049 to 0.235 Liter/kg/day, 6 year exposure duration (US EPA 2011b, Table 3-19).
Child TCE exposure assumptions using Age Dependent Adjustment Factors (ADAFs): 0.049 to 0.235 Liter/kg/day, 6 year exposure duration (US EPA 2011c, Table 5-49).
(c) Adult PCE exposure assumptions: 0.032 Liter/kg/day, 9 year exposure duration (US EPA 2011b, Table 3-19).
Adult TCE exposure assumptions using ADAFs: 0.049 to 0.032 Liter/kg/day, 9 year exposure duration (US EPA 2011c, Table 5-49).
(d) Cancer Slope Factor
(e) Lifetime Excess Cancer Risk
* Refer to Tables 21a and b for cumulative LECR for groundwater ingestion, inhalation (showering) and dermal (bathing) exposures.

Table 18a: Calculated Lifetime Excess Cancer Risks from Shower Inhalation Exposures (past) for Residents within OU1 Study Area Supplied by Untreated Public Water from 1972 through 1981.

Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	TWA (µg/m3) [a,b]	Exposure Duration (years) [c]	Exposed Population	USEPA IUR [d] $(\mu g/m3)^{-1}$	LECR	LECR Sum
OU1 Study Area: Residents Supplied by Vannatta Street Public Supply Well 1972 - 1981						
Tetrachloroethylene	118	9	Adult	PCE = 5.9E-06 [e] TCE = 4.0E-06 [f]	8.03E-05	8.08E-05
Trichloroethylene	1				4.62E-07	

(a) - micrograms per cubic meter.
(b) Time-Weighted Average
(c) - Based on time of contaminated well use in 1972 to implementation of treatment system in 1981. Exposure Assumptions: 365 days a year exposure frequency, 78 years averaging time (USEPA 2002d, 2011 a,b,c).
(d) - Inhalation Unit Risk (cancer slope factor) for human inhalation exposure.
(e) IUR for tetrachloroethylene; (f) IUR for trichloroethylene.
Refer to Tables 21a and b for cumulative LECR for untreated groundwater ingestion, inhalation (showering) and dermal (bathing) exposures.

Table 18b: Calculated Lifetime Excess Cancer Risks from Dermal Bath Exposures (past) for Residents within OU1 Study Area Supplied by Untreated Public Water from 1972 through 1981.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Maximum Contaminant Concentration Pre-Volitization (µg/L) [a]	Contaminant Concentration Post 50% Volitization from Filling Bathtub [b] (mg/cm3)	Dermally Absorbed Dose [f] DAD (mg/kg/day)	CSF [d] (mg/kg/d) $^{-1}$	LECR [e]	LECR Sum
			Child [c] (Bath)		Child	Child
OU1 Study Area: Residents Supplied by Vannatta Street Public Supply Well 1972 - 1981						
Tetrachloroethylene	147	7.4E-05	2.20E-04	0.54	1.19E-04	1.2E-04
Trichloroethylene	1.7	8.5E-07	7.10E-07	0.05	3.55E-08	

(a) Exposure Point Concentrations (micrograms per liter) derived using Pro UCL Version 4.00.02 (EPA, 2007).
(b) Aqueous contaminant concentration (milligrams per cubic meter) following an estimated 50% reduction from volitization associated with bathtub filling. Converted for calculation purposes (see footnote f). Volatilization rate estimated based on US EPA. National Center for Environmental Assessment. Office of Research and Development. Volatilization Rates from Water to Indoor Air Phase II. Washington, DC. October 2000.
(c) Child dermal exposure assumptions (see footnote f).
(d) Cancer Slope Factor
(e) US EPA Reference Dose (C = Chronic)
(f) Dermally Absorbed Dose (DAD) for carcinogenic effects calculated using US EPA Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) – ORG04_01.XLS Excel spreadsheet for dermal assessment of organic chemicals in water, April 2001. Note: To be conservative for dermal skin absorption exposures, contaminant concentrations in water after bathtub filling were not adjusted for surface volatilization during the 1 hour bathing scenario for children. The US EPA considers children (<1 to 6 years) to represent the most likely population to fall under the bathing scenario regarding dermal exposures.

Equation 1: $DAevent = 2FA * Kp * Cw (6*\tau event * tevent/\pi)^{1/2}$
Equation 2: DAD = DAevent * EV * ED * EF * SA/BW * AT
where DAevent = Absorbed dose per event (mg/cm-event)

FA = Fraction absorbed water (dimensionless) = 1
Kp = Dermal permeability coefficient of compound in water (cm/hr): TCE = 0.033 cm/hr; PCE = 0.012 cm/hr
Cw = Chemical concentration in water (mg/cm^3): TCE = 7.4E-05; PCE = 8.5E-07
τevent = Lag time per event (hr/event): TCE = 0.91 hr/event; PCE = 0.58
tevent = Event duration (hr/event) = 1 hr/event
DAD = Dermally Absorbed Dose (mg/kg-day)
SA = Skin surface area availablefor contact (cm^2) = 6,600 cm^2 (child)
EV = Event frequency (events/day) = 1 event/day
EF = Exposure frequency (days/year) = 365 days/year
ED = Exposure duration (years) = 6 years
BW = Body weight (kg) = 15 kg (child)
AT = Averaging time (days); carcinogenic effects AT = 78 x 365 days/yr

Table 19: Calculated Lifetime Excess Cancer Risk for Ingestion Exposures to Tetrachloroethylene and Trichloroethylene in Untreated Potable Groundwater: Residents within OU1 and OU2 Study Areas.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Exposure Point Concentration (µg/L) [a]	Exposure Dose (mg/kg/day)		CSF [d] (mg/kg/d) $^{-1}$	LECR [e]	
		Child [b]	Adult [c]		Child	Adult
OU1 Study Area: 27 Residences (estimated) - TCE Concentrations <7.4 µg/L, Sampling Period: 1984 - 2002						
Tetrachloroethylene [f]	0.5	2.60E-06	6.15E-06	0.54	1.40E-06	3.32E-06
Trichloroethylene	3.1	3.16E-05	6.29E-05	0.05	1.58E-06	3.15E-06
				***LECR Sum=**	2.98E-06	6.47E-06
OU1 Study Area: 48 Residences (estimated) - TCE Concentrations >7.4 µg/L, Sampling Period: 1984 - 2002						
Trichloroethylene	100	1.01E-03	2.02E-03	0.05	5.07E-05	1.01E-04
Trichloroethylene (max. conc.)	440	4.49E-03	8.93E-03	0.05	2.24E-04	4.46E-04
OU2 Study Area: 4 Residences, Sampling Period: February 2000 through March 2008						
Tetrachloroethylene	15.4	8.01E-05	1.90E-04	0.54	4.32E-05	1.02E-04
OU2 Study Area: 116 - TCE Concentrations <7.4 µg/L, Sampling Period: February 2000 through August 2009						
Trichloroethylene	2.4	1.27E-05	3.00E-05	0.05	1.22E-06	2.44E-06
OU2 Study Area: 18 Residences - TCE Concentrations >7.4 µg/L, Sampling Period: February 2000 through August 2009						
Trichloroethylene	12.2	6.34E-05	1.50E-04	0.05	6.22E-06	1.24E-05

(a) Exposure Point Concentrations (micrograms per liter) derived using Pro UCL Version 4.00.02 (EPA, 2007).
(b) Child PCE exposure assumptions: age adjusted 0.049 to 0.235 Liter/kg/day, 6 year exposure duration (US EPA 2011b, Table 3-19).
Child TCE exposure assumptions using Age Dependent Adjustment Factors (ADAFs): 0.049 to 0.235 Liter/kg/day, 6 year exposure duration (US EPA 2011c, Table 5-49).
(c) Adult PCE exposure assumptions: 0.032 Liter/kg/day, 30 year exposure duration (US EPA 2011b, Table 3-19).
Adult TCE exposure assumptions using ADAFs: 0.049 to 0.032 Liter/kg/day, 30 year exposure duration (US EPA 2011c, Table 5-49).
(d) Cancer Slope Factor
(e) Lifetime Excess Cancer Risk estimate
* Refer to Tables 21a and b for cumulative LECR for untreated groundwater ingestion, inhalation (showering) and dermal (bathing) exposures.
(f) Tetrachloroethylene detected in potable well water at 2 residences.

Table 20a: Calculated Lifetime Excess Cancer Risks from Shower Inhalation Exposures (past) for Residents within OU1 and OU2 Study Areas.

Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	TWA (µg/m3) [a,b]	Exposure Duration (years) [c]	Exposed Population	USEPA IUR [d] $(\mu g/m3)^{-1}$	LECR	LECR Sum
OU1 Study Area: 27 Residences (estimated) - TCE Concentrations <7.4 µg/L						
Tetrachloroethylene [f]	0.4	30	Adult	PCE = 5.9E-06 [e] TCE = 4.8E-06 [f]	9.14E-07	5.52E-06
Trichloroethylene	2				4.61E-06	
OU1 Study Area: 48 Residences With TCE Concentrations >7.4 µg/L						
Trichloroethylene	81	30	Adult	TCE = 4.8E-06	1.49E-04	1.49E-04
Trichloroethylene (max. conc.)	354	30	Adult	TCE = 4.8E-06	6.54E-04	6.54E-04
OU2 Study Area: 4 Residences						
Tetrachloroethylene	12	30	Adult	PCE = 5.9E-06	2.81E-05	2.81E-05
OU2 Study Area: 116 - TCE Concentrations <7.4 µg/L						
Trichloroethylene	2	30	Adult	TCE = 4.8E-06	3.57E-06	3.57E-06
OU2 Study Area: 18 Residences - TCE Concentrations >7.4 µg/L						
Trichloroethylene	10	30	Adult	TCE = 4.8E-06	1.81E-05	1.81E-05

(a) - micrograms per cubic meter.
(b) Time-Weighted Average.
(c) - Based on EPA recommended length of residency for current residents. Exposure Assumptions: 365 days a year exposure frequency, 78 years averaging time (USEPA 2002d, 2011 a,b,c).
(d) - Inhalation Unit Risk (cancer slope factor) for human inhalation exposure.
(e) IUR for tetrachloroethylene; (f) IUR for trichloroethylene.
Refer to Tables 21a and b for cumulative LECR for untreated groundwater ingestion, inhalation (showering), and dermal (bathing) exposures.
(f) Tetrachloroethylene detected in potable well water at 2 residences.

Table 20b: Calculated Lifetime Excess Cancer Risks from Bath Dermal Exposures (past) for Residents within OU1 and OU2 Study Areas.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Maximum Contaminant Concentration Pre-Volitization (µg/L) [a]	Contaminant Concentration Post 50% Volitization from Filling Bathtub [b] (mg/cm^3)	Dermally Absorbed Dose [f] DAD (mg/kg/day)	CSF [d] $(mg/kg/d)^{-1}$	LECR [e]	LECR Sum
			Child [c] (Bath)		Child	
OU1 Study Area: 27 Residences (estimated) - TCE Concentrations <7.4 µg/L						
Tetrachloroethylene [g]	0.5	2.5E-07	7.40E-07	0.54	4.00E-07	4.65E-07
Trichloroethylene	3.1	1.6E-06	1.30E-06	0.05	6.50E-08	
OU1 Study Area: 48 Residences With TCE Concentrations >7.4 µg/L						
Trichloroethylene	100	5.0E-05	4.10E-05	0.05	2.05E-06	2.05E-06
Trichloroethylene (max. conc.)	440	2.2E-04	1.80E-04	0.05	9.00E-06	9.00E-06
OU2 Study Area: 4 Residences						
Tetrachloroethylene	15.4	7.7E-06	2.30E-05	0.54	1.24E-05	1.24E-05
OU2 Study Area: 116 Residences - TCE Concentrations <7.4 µg/L						
Trichloroethylene	2.4	1.2E-06	1.00E-06	0.05	5.00E-08	5.00E-08
OU2 Study Area: 18 Residences - TCE Concentrations >7.4 µg/L						
Trichloroethylene	12.2	6.1E-06	5.10E-06	0.05	2.55E-07	2.55E-07

(a) Exposure Point Concentrations (micrograms per liter) derived using Pro UCL Version 4.00.02 (EPA, 2007).
(b) Aqueous contaminant concentration (milligrams per cubic meter) following an estimated 50% reduction from volitization associated with bathtub filling. Converted for calculation purposes (see footnote f). Volatilization rate estimated based on US EPA. National Center for Environmental Assessment. Volatilization Rates from Water to Indoor Air Phase II. Washington, DC. October 2000.
(c) Child dermal exposure assumptions (see footnote f).
(d) Agency for Toxic Substances Disease Registry's Minimal Risk Level (A = Acute < 15 days).
(e) US EPA Reference Dose (C = Chronic)
(f) Dermally Absorbed Dose (DAD) for carcinogenic effects calculated using US EPA Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) – ORG04_01.XLS Excel spreadsheet for dermal assessment of organic chemicals in water, April 2001. Note: To be conservative for dermal skin absorption exposures, contaminant concentrations in water after bathtub filling were not adjusted for surface volatilization during the 1 hour bathing scenario for children. The US EPA considers children (<1 to 6 years) to represent the most likely population to fall under the bathing scenario regarding dermal exposures.

Equation 1: $DAevent = 2FA * Kp * Cw (6*\tau event * tevent/\pi)^{1/2}$
Equation 2: $DAD = DAevent * EV * ED * EF * SA/BW * AT$
where DAevent = Absorbed dose per event (mg/cm-event)
FA = Fraction absorbed water (dimensionless) = 1
Kp = Dermal permeability coefficient of compound in water (cm/hr): TCE = 0.033 cm/hr; PCE = 0.012 cm/hr
Cw = Chemical concentration in water (mg/cm^3): TCE = 7.4E-05; PCE = 8.5E-07
$\tau event$ = Lag time per event (hr/event): TCE = 0.91 hr/event; PCE = 0.58
tevent = Event duration (hr/event) = 1 hr/event
DAD = Dermally Absorbed Dose (mg/kg-day)
SA = Skin surface area availablefor contact (cm^2) = 6,600 cm^2 (child)
EV = Event frequency (events/day) = 1 event/day
EF = Exposure frequency (days/year) = 365 days/year
ED = Exposure duration (years) = 6 years
BW = Body weight (kg) = 15 kg (child)
AT = Averaging time (days); carcinogenic effects AT = 78 x 365 days/yr
(g) Tetrachloroethylene detected in potable well water at 2 residences.

Table 21a: Cumulative Lifetime Excess Cancer Risks from Ingestion and Inhalation Exposures to PCE and TCE from Untreated Potable Well Water for Residents (adults and children ≥ 6 years) within OU1 and OU2 Study Areas.

Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Sum LECR Ingestion	Sum LECR Inhalation	Adult Cumulative LECR [a] (ingestion and inhalation)
OU1 Study Area: Residents Supplied by Vannatta Street Public Supply Well 1972 - 1981			
Tetrachloroethylene	6.19E-04	8.08E-05	**7.00E-04**
Trichloroethylene			
OU1 Study Area: 27 Residences (estimated) - Private Wells with TCE Concentrations <7.4 µg/L			
Tetrachloroethylene [b]	6.47E-06	5.52E-06	**1.20E-05**
Trichloroethylene			
OU1 Study Area: 48 Residences (estimated) - Private Wells with TCE Concentrations >7.4 µg/L			
Trichloroethylene	1.01E-04	1.49E-04	**2.50E-04**
OU1 Study Area: 1 Residence - Maximum TCE Concentration 440 µg/L			
Trichloroethylene	4.46E-04	6.54E-04	**1.10E-03**
OU2 Study Area: 4 Residences: Private Wells			
Tetrachloroethylene	1.02E-04	2.81E-05	**1.30E-04**
OU2 Study Area: 116 Residences - Private Wells with TCE Concentrations <7.4 µg/L			
Trichloroethylene	2.44E-06	3.57E-06	**6.00E-06**
OU2 Study Area: 18 Residences - Private Wells with TCE Concentrations >7.4 µg/L			
Trichloroethylene	1.24E-05	1.81E-05	**3.05E-05**

(a) Cumulative LECR to adults accounting for ingestion of untreated groundwater and inhalation during showering.
(b) Tetrachloroethylene detected in potable well water at 2 residences.

Table 21b: Cumulative Lifetime Excess Cancer Risks from Ingestion and Dermal Exposures to PCE and TCE from Untreated Potable Well Water for Residents (children <6 years) within OU1 and OU2 Study Areas.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Sum LECR Ingestion	Sum LECR Dermal	Child Cumulative LECR [a] (ingestion and dermal)
OU1 Study Area: Residents Supplied by Vannatta Street Public Supply Well 1972 - 1981			
Tetrachloroethylene Trichloroethylene	4.13E-04	1.19E-04	**5.32E-04**
OU1 Study Area: 27 Residences (estimated) - Private Wells with TCE Concentrations <7.4 µg/L			
Tetrachloroethylene [b] Trichloroethylene	2.98E-06	4.65E-07	**3.45E-06**
OU1 Study Area: 48 Residences (estimated) - Private Wells with TCE Concentrations >7.4 µg/L			
Trichloroethylene	5.07E-05	2.05E-06	**5.28E-05**
OU1 Study Area: 1 Residence - Maximum TCE Concentration 440 µg/L			
Trichloroethylene	2.24E-04	9.00E-06	**2.33E-04**
OU2 Study Area: 4 Residences: Private Wells			
Tetrachloroethylene	4.32E-05	1.24E-05	**5.57E-05**
OU2 Study Area: 116 Residences - Private Wells with TCE Concentrations <7.4 µg/L			
Trichloroethylene	1.22E-06	5.00E-08	**1.27E-06**
OU2 Study Area: 18 Residences - Private Wells with TCE Concentrations >7.4 µg/L			
Trichloroethylene	6.22E-06	2.55E-07	**6.48E-06**

(a) Cumulative LECR to children accounting for ingestion of untreated groundwater and dermal exposures during bathing.
(b) Tetrachloroethylene detected in potable well water at 2 residences.

Table 22: Calculated Lifetime Excess Cancer Risk from Inhalation Exposures to Indoor Air Contaminants: Vapor Intrusion

Pohatcong Valley Groundwater Contamination Site, Warren County

Exposure Point Indoor Air	Contaminant of Concern	Exposure Point Concentration (µg/m3) [a,b]	Exposure Duration (years) [c]	Exposed Population	USEPA IUR [d] $(\mu g/m3)^{-1}$	LECR	LECR Sum
OU1 - Study Area							
Residence C	1,2-DCA	0.42	30 [c1]	Adult/Child	1,2-DCA = 2.6E-05 [e] PCE = 5.9E-06 [f] TCE = 4.0E-06 $_{adult}$ [g] TCE = 4.8E-06 $_{0 - 30 years}$	4.20E-06	8.98E-06
	PCE	1.7				3.86E-06	
Multi-Tenant Residence [h]	1,2-DCA	0.45	30 [c1]			4.50E-06	1.33E-04
	PCE	55				1.25E-04	
	TCE	1.96				3.62E-06	
Warren Hills Middle School	PCE	0.3	40 [c3] (3 $_{child}$)			2.24E-07 (1.68E-08)	5.04E-07 (7.98E-08)
	TCE	0.54				2.80E-07 (6.30E-08)	
Daycare A	1,2-DCA	0.94	14 [c4] (6 $_{child}$)			1.56E-06 6.70E-07)	1.84E-06 (1.34E-06)
	TCE	1.06				2.78E-07 (6.75E-07)	
Daycare B	1,2-DCA	0.47	6 [c4]			3.35E-07	6.10E-07
	PCE	1.7				2.75E-07	
OU2 - Study Area							
Residence A [i]	PCE	0.59	30 [c1]	Adult/Child	1,2-DCA = 2.6E-05 [e] PCE = 5.9E-06 [f] TCE = 4.0E-06 $_{adult}$ [g] TCE = 4.8E-06 $_{0 - 30 years}$	1.34E-06	2.07E-05
	TCE	10.5				1.94E-05	
Residence B	1,2-DCA	0.37	30 [c1]			4.12E-06	3.70E-06
Franklin Township Elementary School [i]	1,2-DCA	2.2	40 [c2] (8 $_{child}$)			7.23E-06 (1.45E-06)	8.14E-06 (1.84E-06)
	PCE	0.51				3.80E-06 (7.61E-08)	
	TCE	1.02				5.29E-07 (3.17E-07)	

(a) - micrograms per cubic meter.

(b) Exposure Point Concentrations derived from data presented in Tables 3 through 5 using Pro UCL Version 4.00.02 (EPA, 2007).

(c1) - Based on EPA recommended length of residency for current residents. Exposure Assumptions: 365 days a year exposure frequency, exposed years 0 through 30 years, 78 years averaging time (USEPA 2011b).

(c2) - Based on the maximum length of employment for adults and school year period for children. Adult: 12 hours/day, 180 days/year, 40 years (approximanted maximum length of employment), 78 years averaging time; Child (pre-K through 6th grade): 8 hours/day, 180 days/year, 8 years, child exposures represented in parenthesis

(c3) - Based on the maximum length of employment for adults and school year period for children. Adult: 12 hours/day, 180 days/year, 40 years (approximanted maximum length of employment), 78 years averaging time; Child (6th through 8th grade): 8 hours/day, 180 days/year, 3 years, child exposures represented in parenthesis

(c4) - Based on start of operations. Exposure Assumptions: 260 days a year (5days/week) at a 12 hours/day exposure frequency, 78 years averaging time (USEPA 2011b).

(d) - Inhalation Unit Risk (cancer slope factor) for human inhalation exposure.

(e) - IUR for 1,2-dichloroethane; (f) IUR for tetrachloroethylene; (g) IUR for trichloroethylene (for onset exposures at adulthood and for exposures during the first 30 years) (USEPA 2011a)

(h) - Vapor instrusion remedial system installed in 2009. (i) - Vapor instrusion remedial system installed in 2007.

Table 23: Calculated Lifetime Excess Cancer Risk for Ingestion/Dermal Exposures to Tetrachloroethylene and Trichloroethylene in Surface Water.
Recreational Users within OU1 and OU2 Study Areas.
Pohatcong Valley Groundwater Contamination Site, Warren County

Contaminant of Concern	Exposure Point Concentration (µg/L)	Exposure Dose (mg/kg/day)		CSF [c] (mg/kg/d) $^{-1}$	LECR [d]	
		Child [a]	Adult [b]		Child	Adult
OU1 and OU2 Study Areas: Pohatcong and Shabbecong Creeks						
Tetrachloroethylene	1.1	7.66E-07	1.68E-06	0.54	4.14E-07	9.07E-07
Trichloroethylene	7.6	2.90E-06	6.03E-06	0.05	1.45E-07	3.02E-07
LECR Sum (maximum for recreational activities) =					5.59E-07	1.21E-06
OU2 Study Area: Former Edison Quarry						
Trichloroethylene	4.5	1.72E-06	3.57E-06	0.05	8.60E-08	1.79E-07

(a) Child ingestion exposure assumptions: Age 7 through 14 years, 0.05 liter/event, 5 hrs/event, 30 to 48 kg mean body weight, 92 days/year, 8 year exposure duration.
(b) Adult exposure assumptions: 0.025 liter/event, 5 hours/event, 92 days/year, 80 kg body weight, 30 year exposure duration.
(c) Cancer Slope Factor
(d) Lifetime Excess Cancer Risk
Note: ingestion rates for individuals older than 14 years are considered to be similar to adults.

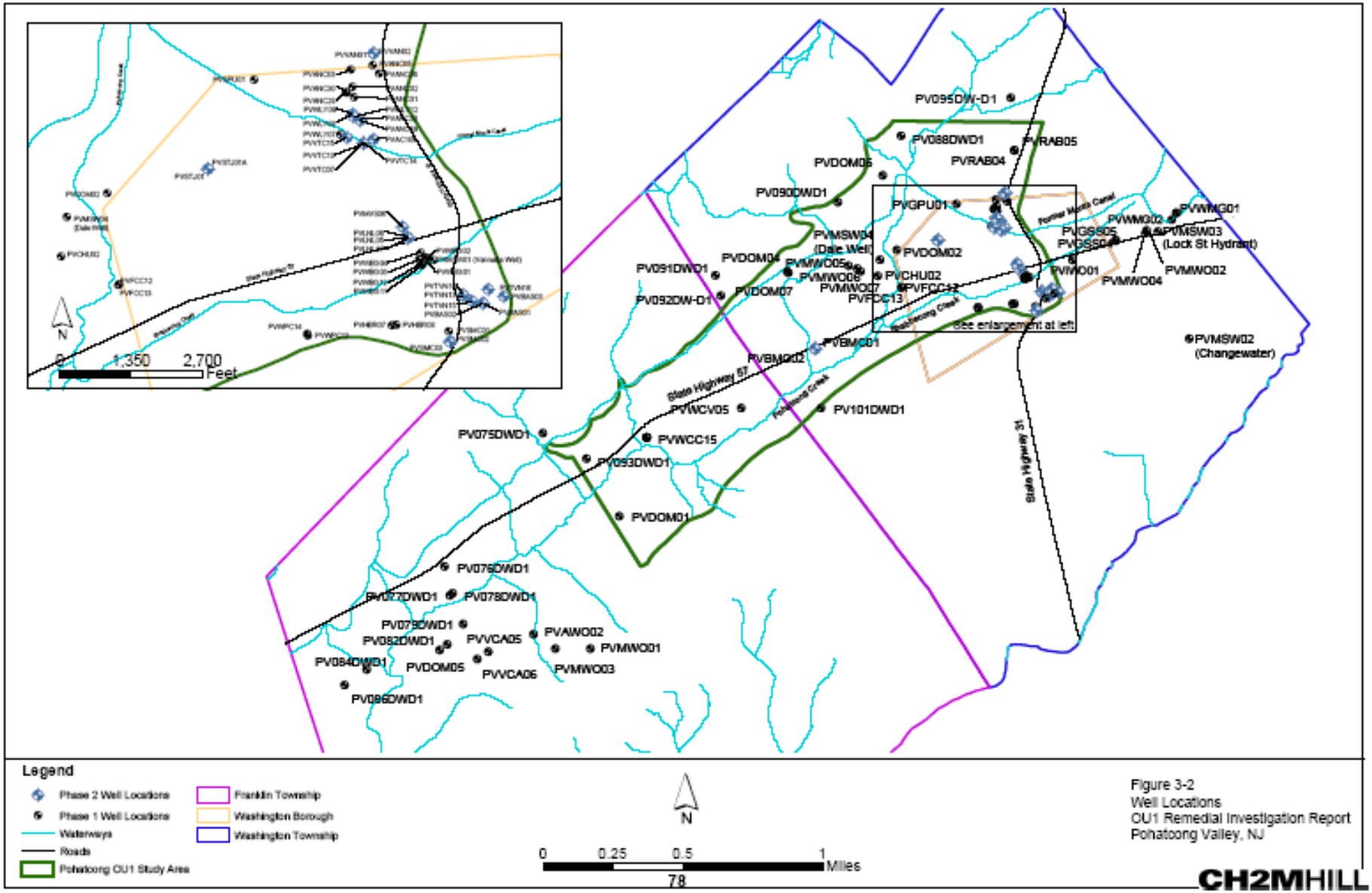


Figure 2: Operable Unit 1 showing the study area boundary and groundwater monitoring well locations.

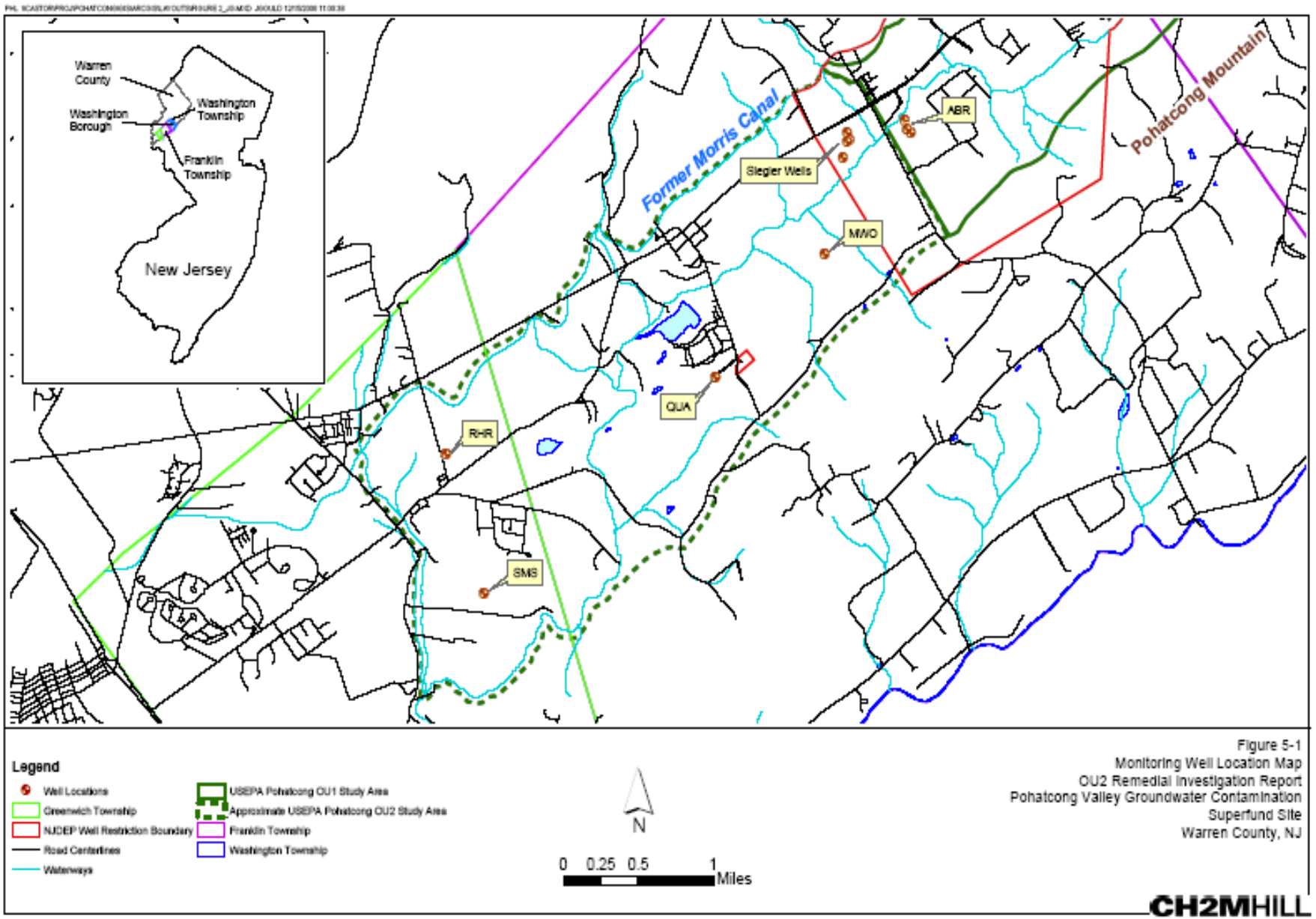
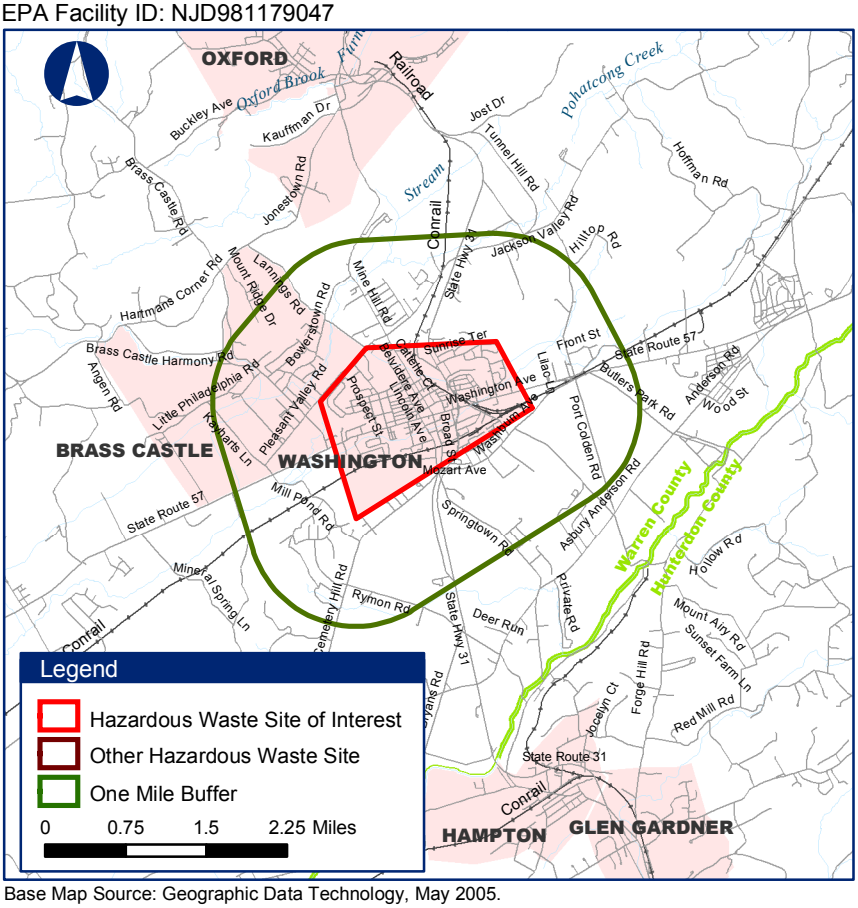
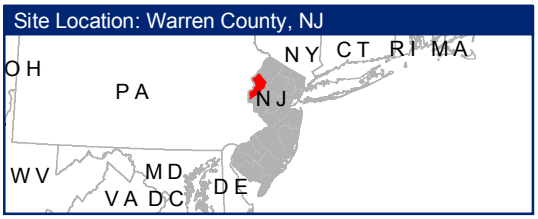


Figure 3: Operable Unit 2 showing the study area boundary and groundwater monitoring well locations.

Pohatcong Valley Groundwater Contamination
Warren County, NJ

EPA Facility ID: NJD981179047



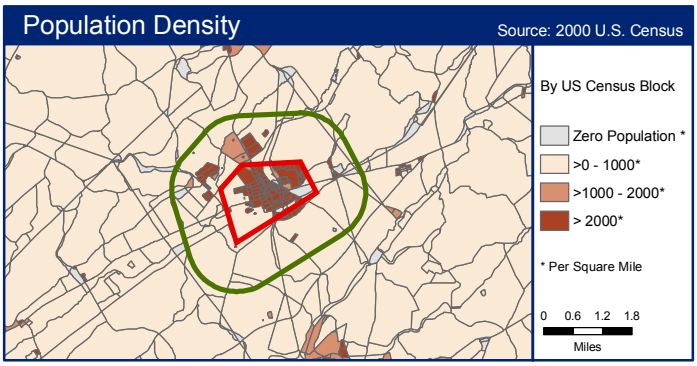


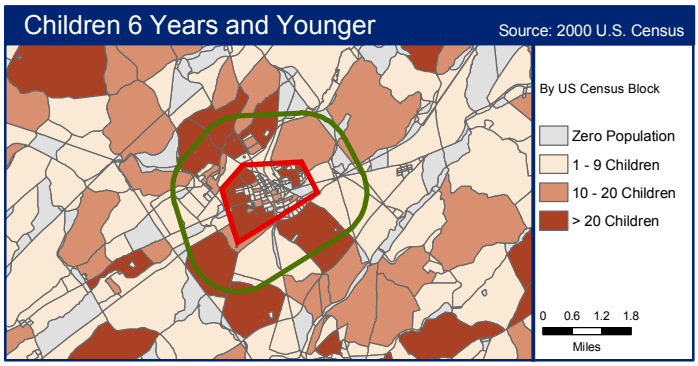
Demographic Statistics
Within One Mile of Site*

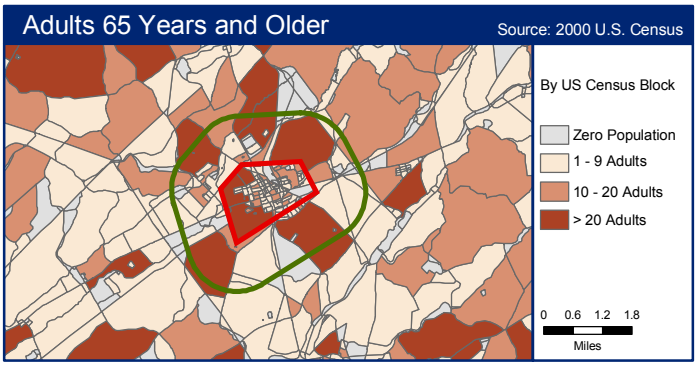
Total Population	10,902
White Alone	10,170
Black Alone	327
Am. Indian & Alaska Native Alone	12
Asian Alone	136
Native Hawaiian & Other Pacific Islander Alone	1
Some Other Race Alone	132
Two or More Races	124
Hispanic or Latino**	361
Children Aged 6 and Younger	1,020
Adults Aged 65 and Older	1,123
Females Aged 15 to 44	2,443
Total Housing Units	4,329

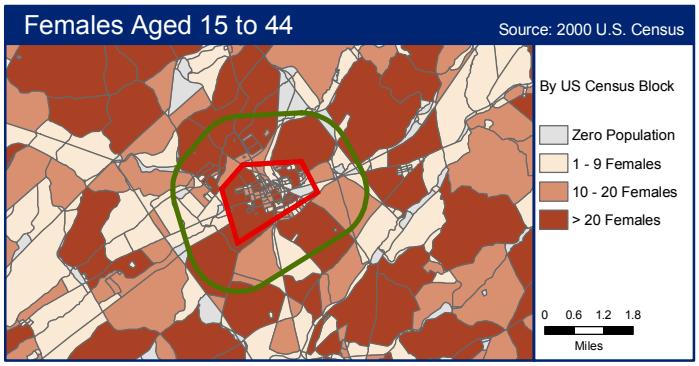
Base Map Source: Geographic Data Technology, May 2005.
Site Boundary Data Source: ATSDR Geospatial Research, Analysis, and Services Program, Current as of Generate Date (bottom left-hand corner).
Coordinate System (All Panels): NAD 1983 StatePlane New Jersey FIPS 2900 Feet

Demographics Statistics Source: 2000 U.S. Census
* Calculated using an area-proportion spatial analysis technique
** People who identify their origin as Hispanic or Latino may be of any race.









<project=03511><userid=JXA0><geo=Warren County, NJ><keywords=NJD981179047, Pohatcong, Valley>

Figure 4: Demographics information for the Pohatcong Valley Groundwater Contamination site based on 2000 census data.

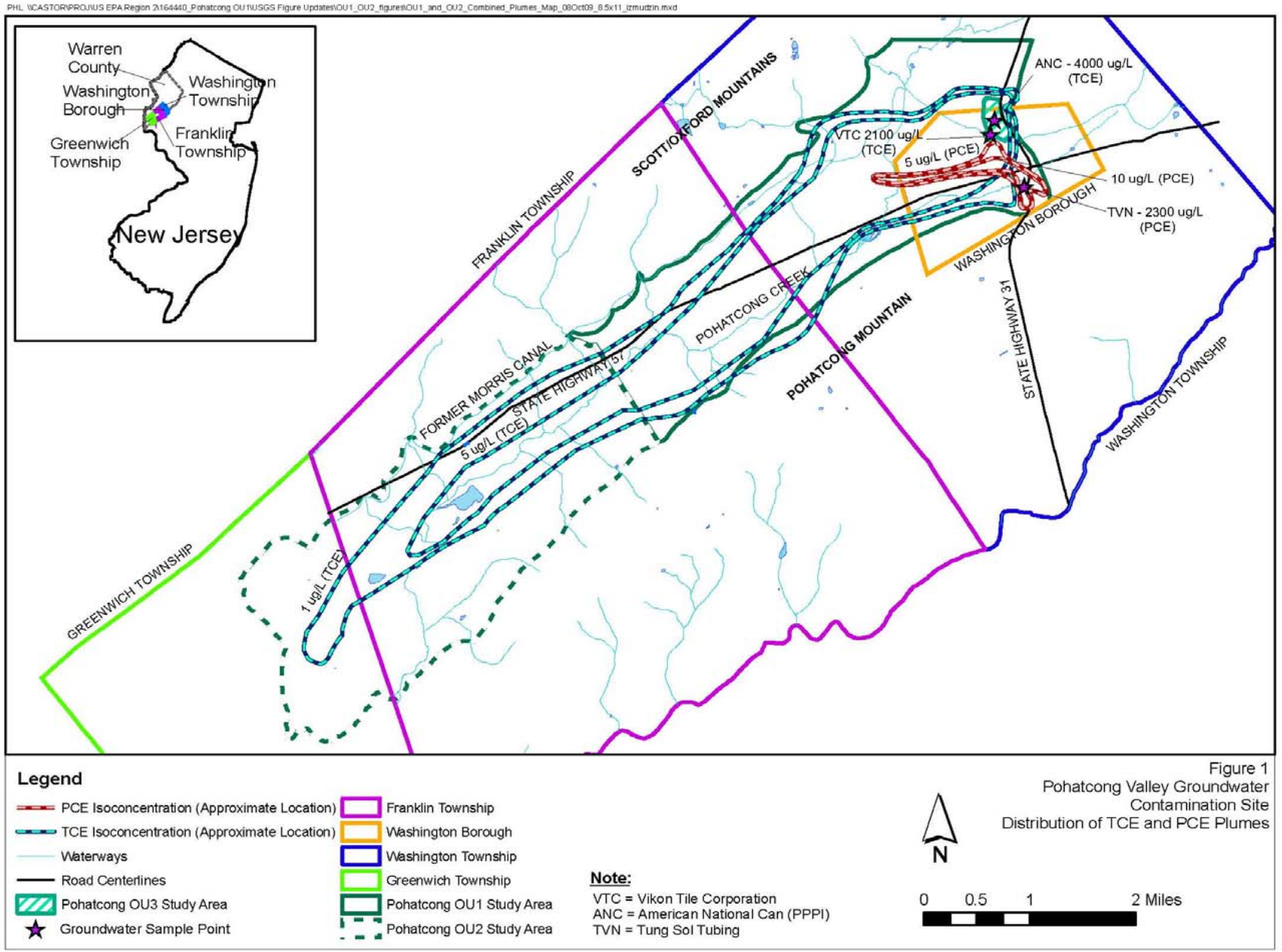


Figure 5: Operable Units 1 and 2: Tetrachloroethylene and trichloroethylene contaminant plumes in groundwater.

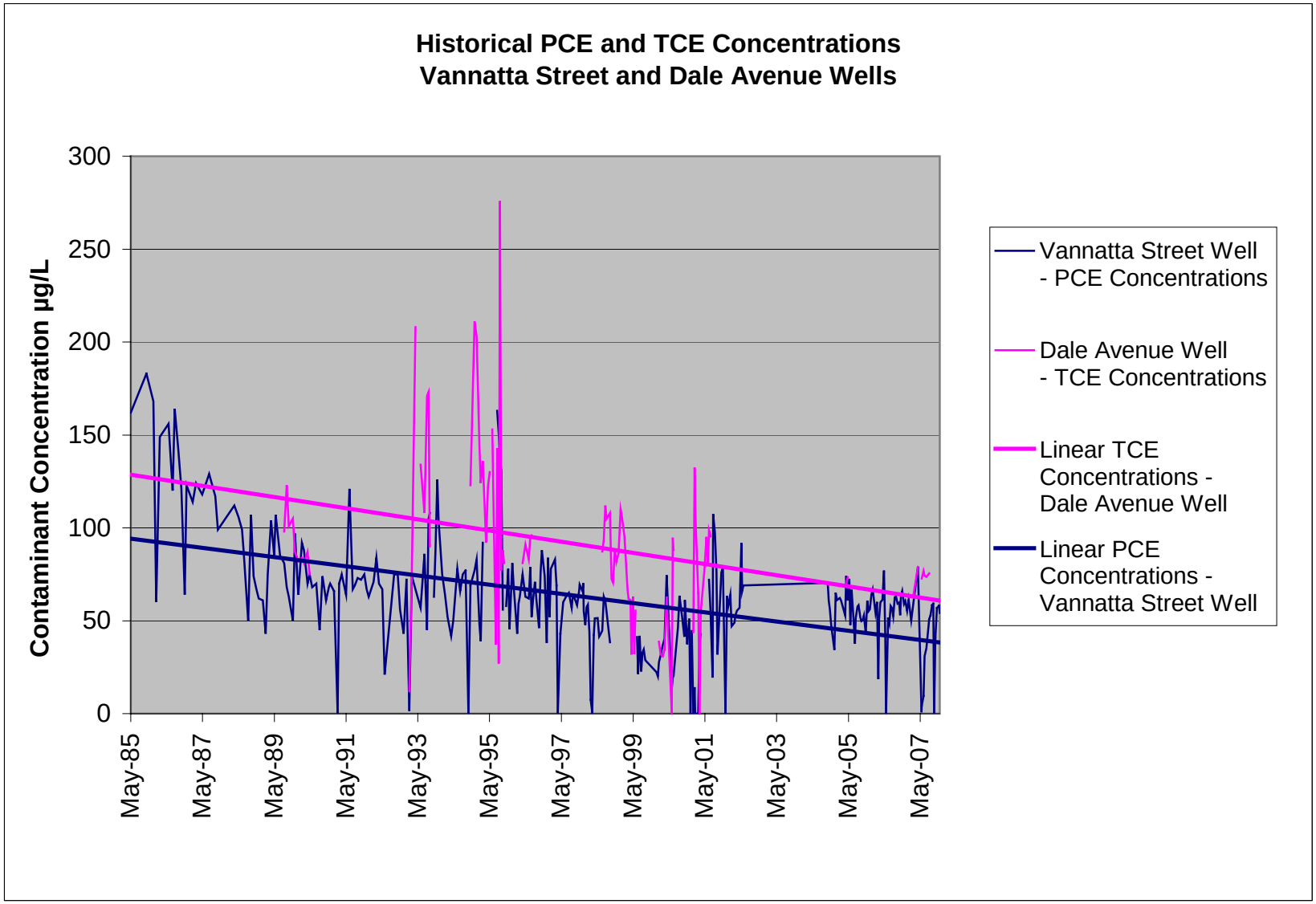


Figure 6: Historical PCE and TCE Concentrations for the Vannatta Street and Dale Avenue Wells.

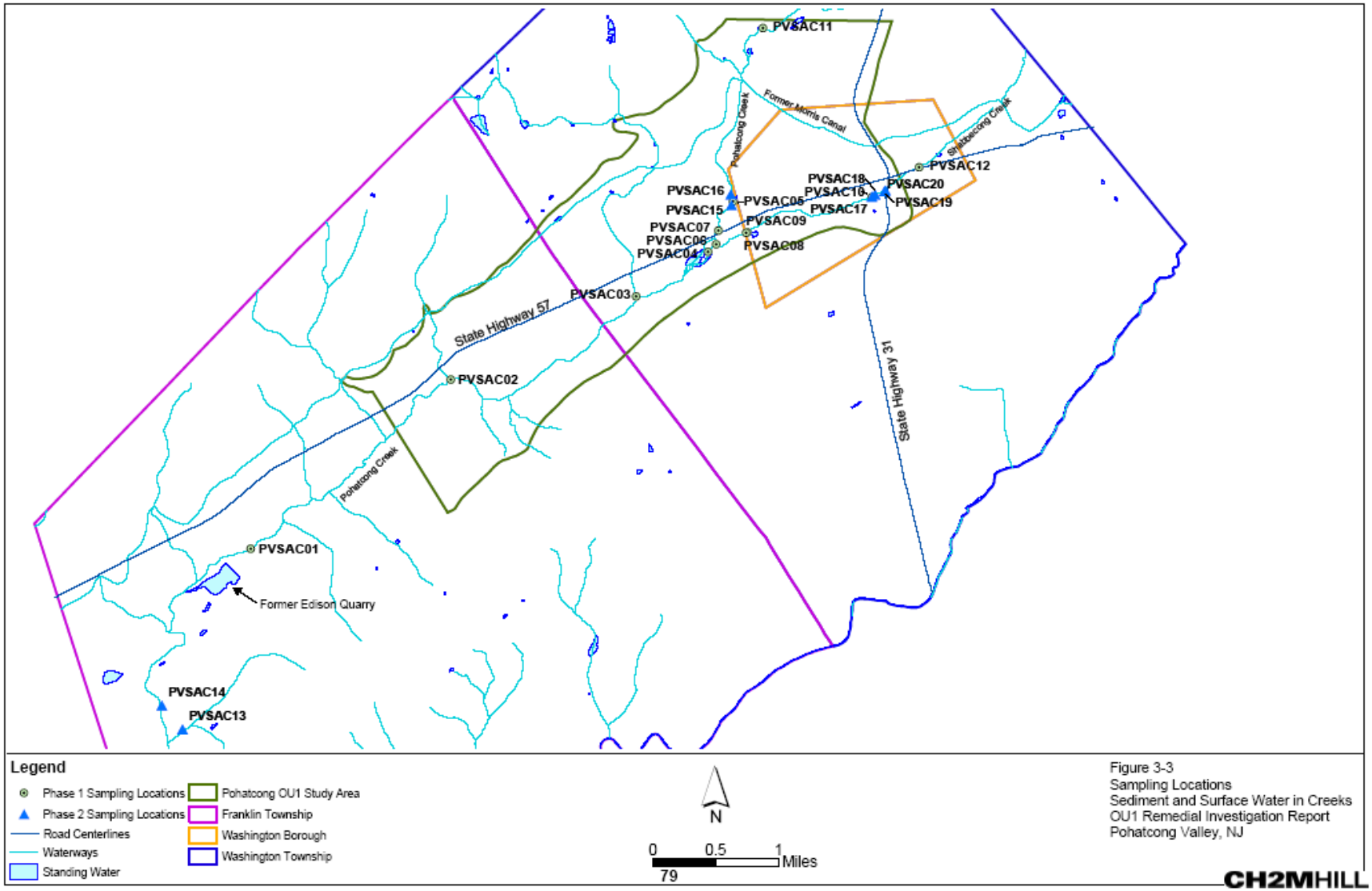


Figure 7: Surface water and sediment sampling locations within the OU1 study area.

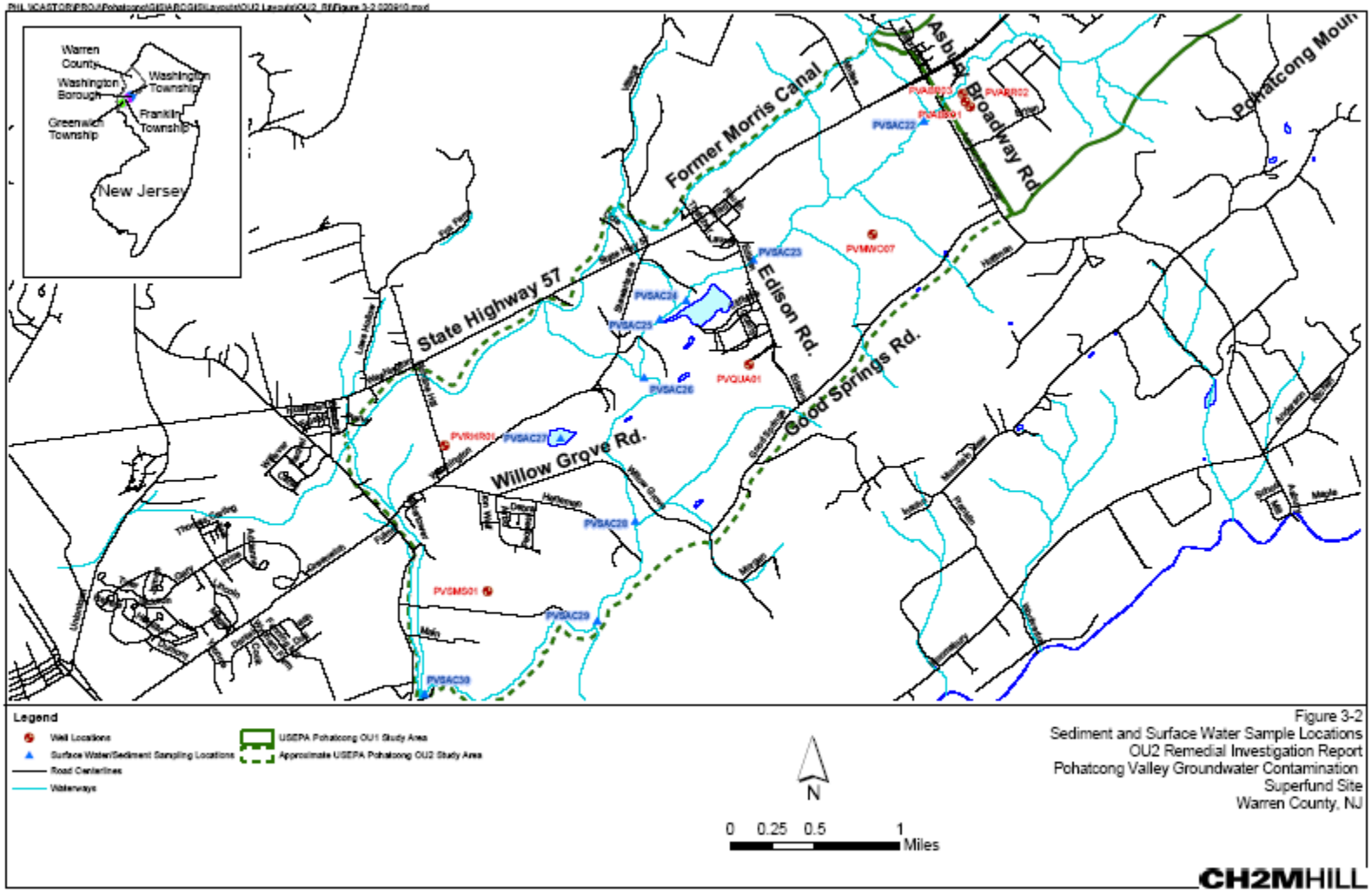


Figure 8: Surface water and sediment sampling locations within the OU2 study area.

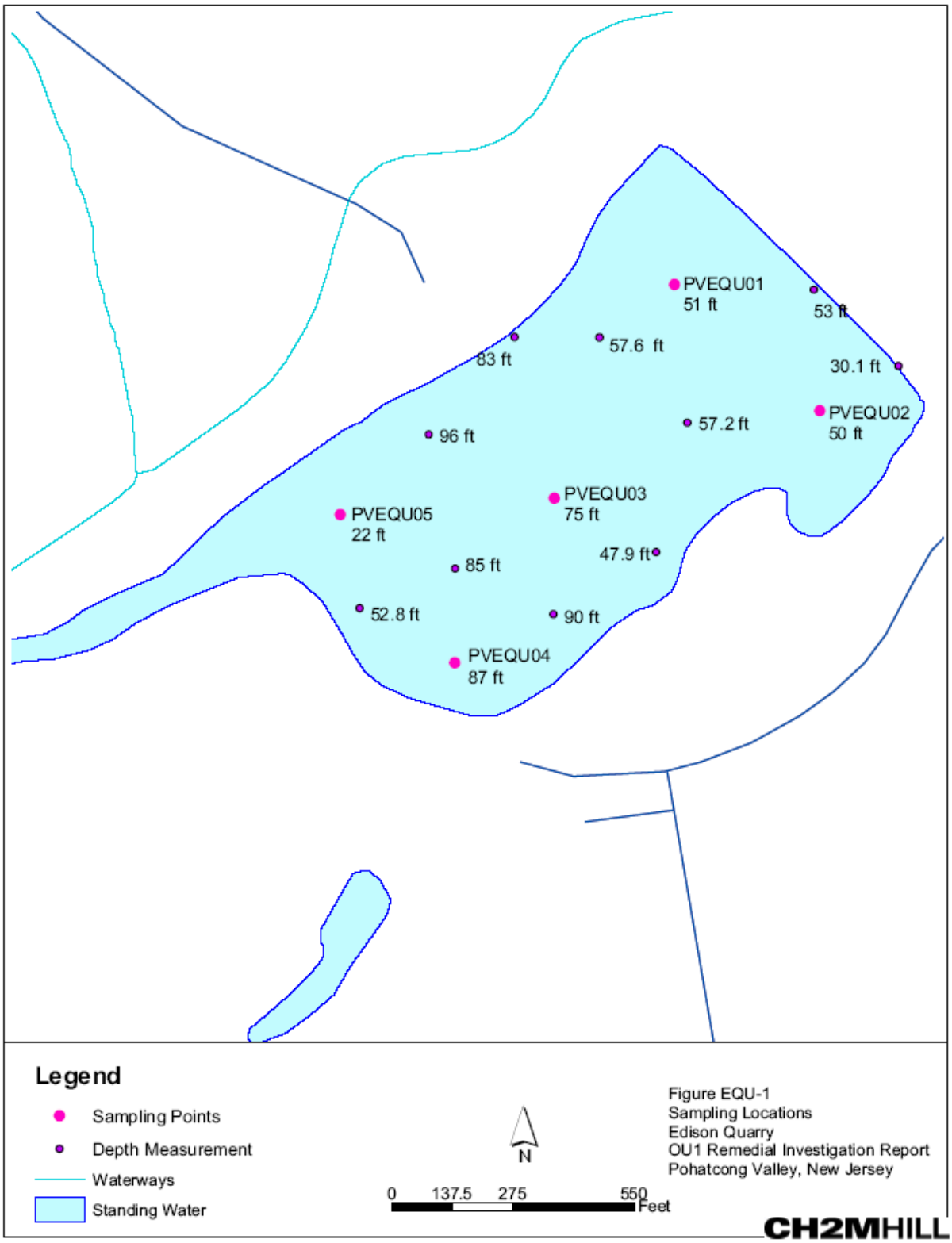


Figure 9: Water sampling locations from the former Edison Quarry

located within the OU2 study area.

Appendix A

Toxicological Summaries

The toxicological summaries provided in this appendix are based on ATSDR's ToxFAQs (http://www.atsdr.cdc.gov/toxfaq.html). Health effects are summarized in this section for the chemicals of concern found off-site in area private wells and in indoor air of evaluated residences and occupied buildings. The health effects described in the section are typically known to occur at levels of exposure much higher than those that occur from environmental contamination. The chance that a health effect will occur is dependent on the amount, frequency and duration of exposure, and the individual susceptibility of exposed persons.

Tetrachloroethylene (PCE). PCE is a manufactured chemical that is widely used for dry cleaning of fabrics and for metal-degreasing. It is a nonflammable liquid at room temperature. It evaporates easily into the air and has a sharp, sweet odor. Most people can smell PCE when it is present in the air at a level of approximately 7,000 micrograms per cubic meter or more, although some can smell it at even lower levels. People are commonly exposed to PCE when they bring clothes from the dry cleaners.

High concentrations of PCE can cause dizziness, headache, sleepiness, confusion, nausea, difficulty in speaking and walking, unconsciousness, and death. Irritation may result from repeated or extended skin contact with it. These symptoms occur almost entirely in work (or hobby) environments when people have been exposed to high concentrations. In industry, most workers are exposed to levels lower than those causing obvious nervous system effects, although more subtle neurological effects are possible at the lower levels. The health effects of breathing in air or drinking water with low levels of PCE are not known. Results from some studies suggest that women who work in dry cleaning industries where exposures to PCE can be quite high may have more menstrual problems and spontaneous abortions than women who are not exposed. Results of animal studies, conducted with amounts much higher than those that most people are exposed to, show that PCE can cause liver and kidney damage. Exposure to very high levels of PCE can be toxic to the unborn pups of pregnant rats and mice. Changes in behavior were observed in the offspring of rats that breathed high levels of the chemical while they were pregnant.

The U.S. Department of Health and Human Services (USDHHS) has determined that PCE may reasonably be anticipated to be a carcinogen. PCE has been shown to cause liver tumors in mice and kidney tumors in male rats.

Trichloroethylene (TCE). TCE is a nonflammable, colorless liquid with a somewhat sweet odor and a sweet, burning taste. It is used mainly as a solvent to remove grease from metal parts, but it is also an ingredient in adhesives, paint removers, typewriter correction fluids, and spot removers. TCE dissolves a little in water, and can remain in groundwater for a long time. It quickly evaporates from water, so it is commonly found as a vapor in the air. People can be exposed to TCE by breathing air in and around the home which has been contaminated with TCE vapors from shower water or household products, or by drinking, swimming, or showering in water that has been contaminated with TCE. Breathing small amounts of TCE may cause headaches, lung irritation, dizziness, poor coordination, and difficulty concentrating. Breathing large

amounts of TCE may cause impaired heart function, unconsciousness, and death. Breathing it for long periods may cause nerve, kidney, and liver damage. Drinking large amounts of TCE may cause nausea, liver damage, unconsciousness, impaired heart function, or death. Drinking small amounts of TCE for long periods may cause liver and kidney damage, impaired immune system function, and impaired fetal development in pregnant women, although the extent of some of these effects is not yet clear. Skin contact with TCE for short periods may cause skin rashes.

Some studies with mice and rats have suggested that high levels of TCE may cause liver, kidney, or lung cancer. Some studies of people exposed over long periods to high levels of TCE in drinking water or in workplace air have found evidence of increased cancer. The National Toxicology Program has determined that TCE is "reasonably anticipated to be a human carcinogen," and the International Agency for Research on Cancer (IARC) has determined that trichloroethylene is "probably carcinogenic to humans."

1,2-Dichloroethane. 1,2-Dichloroethane, also called ethylene dichloride, is a manufactured, colorless liquid with a pleasant smell and sweet taste. It is primarily used in the production of vinyl chloride which is used to make a variety of plastic and vinyl products.

Breathing high levels of 1,2-dichloroethane can cause nervous system disorders, liver and kidney diseases, and affect the lungs and immune system. Livers, kidneys and lungs were the target organs in chronic exposures studies in animals. Studies have not been conclusive that 1,2-dichloroethane causes cancer in humans. In animal studies, increases in stomach, mammary gland, liver, lung, and endometrium cancers have been seen following inhalation, oral and dermal exposures. Exposure to 1,2-dichloroethane has not been shown to affect fertility in people or animals. The US Environmental Protection Agency (EPA) has determined that 1,2-dichloroethane is a probably human carcinogen and the International Agency for Cancer Research (IARC) considers it to be a possible human carcinogen.

Appendix B

NJDHSS Cancer Incidence Letter Response, April 17, 2006

State of New Jersey
DEPARTMENT OF HEALTH AND SENIOR SERVICES
CANCER EPIDEMIOLOGY SERVICES
PO BOX 369
TRENTON, N.J. 08625-0369

JON S. CORZINE
Governor

www.nj.gov/health

FRED M. JACOBS, M.D., J.D.
Commissioner

April 17, 2006

Mr. John A. Hawk, MPA
Health Officer
Warren County Health Department
315 West Washington Avenue
Washington, NJ 07882-2153

Dear Mr. Hawk:

This letter is in response to your request that the Cancer Surveillance Program conduct an epidemiological study of cancer among residents of the Warren County municipalities of Franklin Township, Greenwich Township, Washington Borough, and Washington Township. You expressed particular interest in acquiring information about the incidence of cancers that may be associated with potential exposures to perchloroethylene (PCE) and trichloroethylene (TCE), which have leached into local well water from the Pohatcong Valley Groundwater Contamination Superfund Site (PVGCSS). I hope that the following information will be helpful. Please feel free to share this letter and enclosures with any area residents or other individuals who are concerned about cancers associated with potential exposure to hazardous substances from PVGCSS.

Cancer, unfortunately, is very common. In this country, men have a 46 percent chance and women have a 38 percent chance of being diagnosed with some form of cancer during their lifetime. Therefore, we estimate that most households will be affected at some time. The risk of developing cancer also increases as we age and the incidence of most cancers rises sharply among persons over the age of 45 and particularly over 60 years of age.

Cancer consists of over 100 different diseases with different risk factors for each. In general, most cancers are related to a combination of heredity, lifestyle factors such as smoking, diet, reproductive factors, and alcohol consumption, sun exposure, some infectious diseases and some occupational exposures. Since the cancers we see now are generally related to a lifetime of certain habits or exposures to carcinogens, it is usually very difficult to determine what caused a specific case of cancer. This makes it very difficult to pinpoint a single common cause for many different types of cancer and makes it similarly difficult to draw conclusions about different types of cancer in an area.

The New Jersey State Cancer Registry (NJSCR) receives reports on all cancers that are diagnosed among New Jersey residents, including reports on New Jersey residents from six other states. As per your request, we reviewed the NJSCR cancer incidence data from 1985 through 2002 for the Warren County municipalities of Franklin Township, Greenwich Township, Washington

Borough, and Washington Township, located in the Pohatcong Valley. The types and proportions of all cancers for this time period in these municipalities were similar to those for New Jersey. The most common types of cancer in this area were prostate, breast, lung, and colon and rectum, which are also the most frequent types of cancer in New Jersey and in the United States. In addition, the cancers that are most often thought to be related to environmental exposures, such as leukemias, lymphomas, brain, and bladder cancers, were not seen more frequently in these municipalities than would be expected.

According to the New Jersey Department of Environmental Protection (NJDEP), PCE and TCE were detected in groundwater from two public potable-water supply wells in the late-1970s. TCE is by far the greater groundwater contaminant of the two. The Warren County Health Department later discovered PCE and TCE contamination in 79 private wells in the mid-1980s. Since this time, NJDEP has provided affected residences in the primary study area with access to a public water supply, sealed affected wells, and created a well restriction area. An additional study area was added to PVGCSS, after further NJDEP well testing indicated the presence of low levels of TCE, which includes part of Franklin Township and part of Greenwich Township. Since public water supplies do not presently extend into this area, NJDEP has provided individual water treatment systems to area residences.

The Proposed Plan for cleanup of groundwater and soil contamination in the primary PVGCSS study area was released for public comment in July 2005 by the United States Environmental Protection Agency (USEPA), the lead agency for site activities. A public meeting was held by USEPA in Washington Township during the subsequent 30-day comment period to explain the proposal and present all of the cleanup alternatives. USEPA, in consultation with NJDEP, will select and implement a final remedy for cleanup of the contamination after reviewing and considering all information submitted during the public comment period.

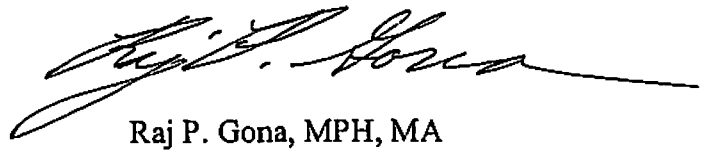
I have enclosed a fact sheet from the New Jersey Department of Health and Senior Services entitled *Environmental Exposures and Your Health*, as well as fact sheets on cancer in communities and cancer risk factors, a publication entitled *The Lifetime Risk of Being Diagnosed with Cancer*, and an article pertaining to *Cancer Clusters* that may be helpful in understanding the geographic distribution of cancer occurrence. I have also enclosed two sets of toxicological fact sheets for TCE and PCE from the United States Agency for Toxic Substances and Disease Registry and USEPA. Please also find two enclosed documents from USEPA that provide a detailed site description and information about the Proposed Plan for groundwater and soil contamination cleanup for the first of the two PVGCSS study areas. A copy of the *2004 Annual Water Quality Report* from the New Jersey American Water Company (NJAWC), the local water utility, is also enclosed. More detailed local water quality information is available in NJDEP's *2004 Source Water Assessment Report* for the NJAWC-Washington System, which can be found online at http://www.state.nj.us/cgi-bin/dep/swap/swapdata2.pl?psid=2121001. For further information on prevention, early detection and treatment of cancer, individuals may wish to contact:

American Cancer Society: 1-800-ACS-2345 (http://www.cancer.org)
National Cancer Institute: 1-800-4-CANCER (http://www.nci.nih.gov)

We would like to find out if the information that we have provided to you has been helpful, so that we can better assist others in the future. Please take a moment to fill out the enclosed *Cancer Inquiry Feedback Form* and mail it back to us in the accompanying postage-paid envelope. Your assistance would be greatly appreciated.

Please feel free to call me at Cancer Epidemiology Services Monday through Friday between 9:00 AM and 5:00 PM at (609) 588-3500 with any other information or questions you may have.

Sincerely,



Raj P. Gona, MPH, MA
Research Scientist
Cancer Surveillance Program

encl.

0538

Appendix C

ATSDR Glossary of Terms

ATSDR Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-422-ATSDR (1-888-422-8737).
The glossary can be accessed online at http://www.atsdr.cdc.gov/glossary.html

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)

National Center for Environmental Health (CDC)
(http://www.cdc.gov/nceh/dls/report/glossary.htm)

National Library of Medicine (NIH)
(http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

For more information on the work of ATSDR, please contact:
Office of Policy and External Affairs
Agency for Toxic Substances and Disease Registry
1600 Clifton Road, N.E. (MS E-60)
Atlanta, GA 30333
Telephone: (404) 498-0080