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DIVISION OF ENVIRONMENTAL PROTECTION

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Published Document: Case Officer Screening Method for Identifying Sites Where Vapor Intrusion May Pose an Imminent and Substantial Hazard

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Purpose:

The Published Document (abbreviated as the “Screening Method”) was developed **to assist NDEP case officers determine when the vapor intrusion pathway may present an imminent and substantial hazard at a site where contaminated groundwater underlies residences.** The Screening Method, which was developed for internal use, is being published to make determinations by case officers consistent and transparent to facility owners/operators and their environmental consultants who may be affected by those determinations.

Note: At sites that do not contain contaminant concentrations that exceed the screening levels, risks from vapor intrusion may still be present, but it is anticipated that these risks will be managed by addressing groundwater contamination through an approved corrective action plan.

Limitations:

- This Screening Method is not intended to be a risk-communication or decision-making tool for independent application by the regulated community or general public.
- The Screening Method is for use only at active cases overseen by the NDEP and should not be used by property owners, the regulated community or the general public to determine potential risk at a site.
- It is inappropriate to use this Screening Method to set groundwater cleanup levels, to terminate groundwater remediation systems or as a factor in risk-based closures of sites where concentrations of contaminants exceed action levels in groundwater.

Discussion:

(1) The Screening Method is for use as a decision-making tool only by NDEP case officers

The vapor intrusion Screening Method has been drafted to assist NDEP case officers in the decision-making process for site cleanups under Nevada Administrative Code (NAC) 445A.226 to 445A.22755. The cleanup framework described in the NAC allows property owners to develop appropriate cleanup methods for their site, but the NDEP has responsibility to determine what conditions are sufficiently protective of human health and the environment and to determine when conditions present an **imminent and substantial hazard**. Because the Screening Method is a tool for making a determination about site protectiveness, its application falls solely under the authority of the NDEP.

This Screening Method relies on results of vapor intrusion modeling to provide conservative screening values for common contaminants found in groundwater at Corrective Action and Leaking Underground Storage Tank sites. Specifically, this document addresses tetrachloroethylene (PCE) and trichloroethylene (TCE) contamination in shallow groundwater through the development of screening values for dissolved concentrations in groundwater. Petroleum vapor intrusion is addressed through the identification of specific conditions that could indicate imminent and substantial hazards from vapor intrusion.

(2) The Screening Method is applied by NDEP case officers only to evaluate whether there is the potential for an imminent and substantial hazard to residents via the vapor intrusion pathway

The Screening Method has a single, specific purpose to determine whether additional evaluation of the vapor intrusion pathway is a necessary step in case oversight. No other uses of the Screening Method are appropriate. It is inappropriate to use this Screening Method to require groundwater remediation, to set groundwater cleanup levels, to terminate groundwater remediation systems or as a factor in risk-based closures of sites with groundwater contamination above action levels.

The use of the Screening Method as a tool for risk-communication is discouraged because (1) screening levels tend to be conservative (risk may be overstated); (2) screening levels in this document are focused only on the potential for **imminent and substantial hazards**; and (3) screening based on site information available during initial stages of evaluation may need to be modified as additional site information becomes available.

(3) The numeric values in the Screening Method rely on conservative assumptions, but their use may still be inappropriate at some sites, such as sites with preferential pathways

The screening values provided in this tool were derived from modeling using the U.S. Environmental Protection Agency (EPA) version of the Johnson-Ettinger model for vapor transport. This model does not take into account vapor transport via preferential pathways. If significant preferential pathways are found to be present at a site, case officers should discuss the matter with their supervisor.

If you have any questions about the application of this Vapor Intrusion Screening Method, please contact the NDEP, Bureau of Corrective Actions at (775) 687-9384 and ask to be routed to an appropriate contact person or case officer.

Case Officer Screening Method for Identifying Sites Where Vapor Intrusion May Pose an Imminent and Substantial Hazard

Nevada Division of Environmental Protection, Bureau of Corrective Actions

1. INTRODUCTION

Vapor intrusion describes the migration of contaminant vapors from soils or groundwater contaminated with volatile chemicals through cracks or openings in slabs or foundations into indoor air. This migration pathway may result in potentially unacceptable risk, including **imminent and substantial harm**, to occupants of buildings affected by the migration of vapors from subsurface contaminants.

This document (“Screening Method”) provides a **decision-making tool to assist Nevada Division of Environmental Protection (NDEP) case officers determine when the vapor intrusion exposure pathway may present an imminent and substantial hazard** at a corrective action or leaking underground storage tank site. The document provides tables of screening values for groundwater contaminated with trichloroethylene (TCE) or tetrachloroethylene (PCE), starting with a simple table of chemical-specific default values that can be used if little is known about the site, advancing to tables with specific values according to site soil type, depth to groundwater and temperature of groundwater. Data for contaminant concentrations in groundwater at an environmental site are compared with the values in the screening tables to determine if there is **potential for imminent and substantial harm** to residents through the vapor intrusion pathway. For petroleum vapor intrusion, some specific site conditions are identified that could warrant additional assessment of imminent and substantial hazards.

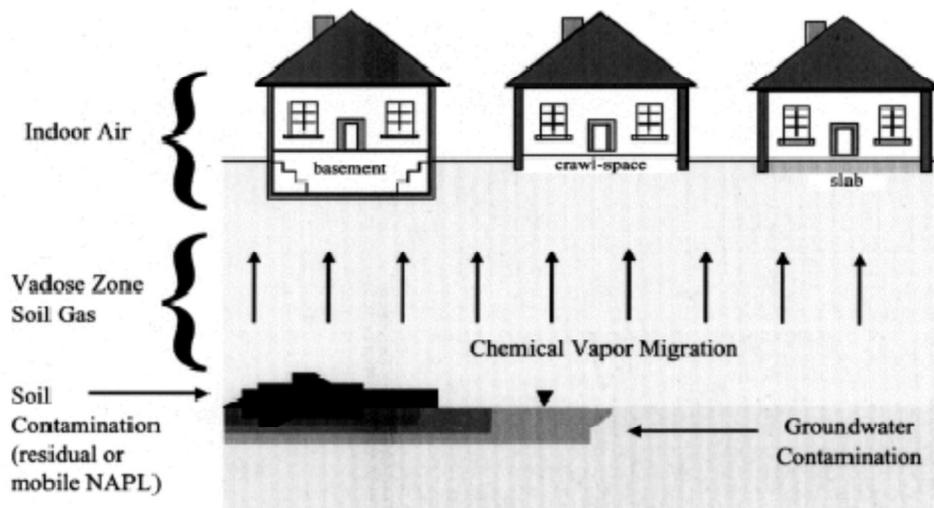
This Screening Method has been specifically developed to determine whether a site might represent an “imminent and substantial hazard” under state laws and regulations. This determination is relevant to NRS § 459.537, which defines when the NDEP shall seek actions to mitigate imminent and substantial hazards or seek reimbursement for actions it takes in the absence of actions by responsible parties, and NAC § 445A.22695(2), which defines when the NDEP may waive or expedite corrective action provisions to require immediate action to address hazards to public health and safety. The NDEP has authority to require assessment of vapor intrusion or the potential for vapor intrusion as a result of soil or groundwater contamination by the requirement in NAC § 445A.2269(2)(a), which states that assessments must

“characterize the relevant pathways specifically related to the site that affect public

health and the environment, including, without limitation, any information concerning sources of release, pathways and rates of migration or any released substances and any possible receptors of those substances.”

2. WHAT IS VAPOR INTRUSION?

Vapor intrusion occurs when vapors from volatile contaminants in soil or groundwater diffuse through the soil, through building foundations and into overlying homes or other buildings. Soil gas can flow or be drawn into a building due to a number of factors, including barometric pressure changes, wind load, thermal currents or depressurization from building exhaust fans. The rate of movement of the vapors into the building is a difficult value to quantify and depends on soil type, chemical properties, building design and condition and the pressure differential. Once inside the building, vapors mix with and contaminate the indoor air and may pose a chronic or acute health risk to inhabitants. Vapor intrusion may be a completed exposure pathway even in cases where ingestion or dermal contact are not completed pathways.



General depiction of the vapor intrusion pathway in a residential setting (EPA, 2002).

In describing the vapor intrusion process, guidance from the Interstate Technical and Regulatory Council (ITRC, 2007) notes that: *Both diffusion and advection are mechanisms of transport of subsurface soil gas into the indoor air environment. Diffusion is the mechanism by which soil gas moves from high concentration to low concentration due to a concentration gradient. Advection is the transport mechanism by which soil gas moves due to differences in pressure. These pressure differences can be generated by atmospheric pressure changes, temperature changes creating natural convection in*

the soil, or forced pressure changes due to building ventilation systems. Advective transport is likely to be the most significant in the region very close to a basement or a foundation, and soil gas velocities decrease rapidly with increasing distance from the structure. Once soil gases enter the “building zone of influence,” they are generally swept into the building through foundation cracks by advection due to the indoor-outdoor building pressure differential. The reach of the “building zone of influence” on soil gas flow is usually less than a few feet, vertically and horizontally.

EPA (2012) provides some additional discussion on how different site and building conditions “...might influence both the distribution of VOCs [volatile organic chemicals] in the subsurface and the indoor air quality of structures in the vicinity of a soil or groundwater VOC source.” However, in the absence of extensive characterization data, which may not be available in the early stages of site characterization, the NDEP foresees the need to rapidly screen sites for the potential to pose an **imminent and substantial hazard** to residents in homes overlying plumes of TCE- and PCE-contaminated groundwater.

3. INITIAL SCREENING STEPS FOR ASSESSING POTENTIAL RISK DUE TO VAPOR INTRUSION

Steps for Screening and Evaluation of Potential for Imminent and Substantial Hazard to Residents via the Vapor Intrusion Exposure Pathway

STEP 1	Determine if there is a completed exposure pathway (source, pathway, receptor; see Figure 1) and if the chemicals are sufficiently volatile to be of concern.
STEP 2	Evaluate whether concentrations of volatile chemicals in groundwater exceed conservative generic screening levels (Table 1) or more site-specific screening levels (Tables 2a – 2d).
STEP 3	Discuss with supervisor and collect soil gas data and additional groundwater data to use in vapor transport monitoring
STEP 4	Conduct vapor transport modeling using maximum concentrations for soil gas and groundwater. The NDEP uses EPA’s version of the Johnson-Ettinger model, with some default and some site-specific input data: e.g., use default values for building parameters, which cannot easily be determined on a site-specific basis. Evaluate whether these modeling results show that potential risk to residents exceeds a carcinogenic risk of 1.0E-04 or a hazard quotient of 1.
STEP 5	Verify that the model does not indicate an acute risk to human health (i.e., predicted indoor air concentrations do not exceed the minimum risk levels [MRLs] or acute exposure levels (see Agency for Toxic Substances and Disease Registry [ATSDR] for current values of acute levels).
STEP 6	Discuss the need to conduct indoor air sampling with your supervisor.

The steps listed above and also shown in the flowchart (Figure 1) describe a practical approach for evaluating whether vapors emanating from a dissolved-phase contaminant plume in groundwater may potentially pose an imminent and substantial hazard to residents via the vapor intrusion process. The initial screening considers only if there is a **potentially completed exposure pathway** and whether **contaminant concentrations exceed generic screening levels**, which are provided in this document.

Later steps involve site-specific determinations that are covered by other sources of guidance such as the US EPA and ITRC.

STEP 1 – Is the Exposure Pathway Complete? Define a Conceptual Site Model

To define the vapor intrusion pathway as a complete exposure pathway, a source, migration route and receptor must be identified. Specifically, this assessment entails the identification of all known or suspected vapor sources of contamination (contaminated groundwater); consideration of the contaminant migration routes (mobility); and identification of those persons (receptors) likely to be affected by the contaminants. Before this screening step can be applied to a site, a site-specific conceptual site model (CSM) must be adequately developed (Figure 2).

To constitute a completed vapor intrusion pathway, the following conditions must be present:

1. There is a source of volatile compounds in the subsurface environment (i.e., plume of contaminated groundwater).
2. There are inhabited **residences** that overlie the plume or the projected path of the plume.
3. There is a migration route to connect sources and receptors.

In addition to a completed pathway, the chemicals of concern must be sufficiently volatile to play a role in the vapor intrusion pathway. Contaminants must also be sufficiently close to the buildings to affect the composition of soil gas under the building. With these concepts in mind, sites may be excluded from further evaluation if:

1. The exposure pathway is and will remain incomplete.
2. Residential buildings (or future residential buildings) are more than 100 feet vertically or laterally from the contaminated media and there are no significant preferential pathways (e.g., utility corridors) for migration of vapors toward the receptor (EPA 2002).
3. The chemicals are not deemed sufficiently volatile or toxic to pose an inhalation hazard (see Table 1 in EPA, 2002) or the chemical biodegrades in an aerobic environment (see Section 4 of this screening method)

STEP 2 – Compare Groundwater Data to Screening Levels: Do Chemical Concentrations Pose the Potential for Imminent and Substantial Harm?

Two types of risk are typically evaluated: acute and chronic risk. Acute conditions call for immediate action (e.g., evacuation). Symptoms such as noticeable odors or physiological effects reported by occupants are signs of potentially acute exposure. In these cases, short-term safety concerns such as explosive or acutely toxic concentrations may necessitate immediate evacuation.

Concentrations of chemicals that do not pose an acute hazard may still pose an unacceptable chronic risk to occupants. Chemicals may pose a chronic carcinogenic risk or non-carcinogenic hazard at concentrations that cannot be detected by sense of smell. The EPA (2002) provides conservative risk-based screening levels for more than 100 different chemicals for three levels of chronic carcinogenic risk: 1.0E-04, 1.0E-05, and 1.0E-06. These risk numbers translate (for carcinogenic chemicals) to one excess cancer per 10,000 people; one excess cancer per 100,000 people; and one excess cancer per one million people. The EPA typically refers to the range between 1.0E-06 and 1.0E-04 as the “risk management range,” wherein there is flexibility to set a cleanup level and manage risk.

Noncarcinogenic risk is typically managed by ensuring that the hazard quotient (HQ) for a chemical does not exceed 1. The HQ is the ratio of the chemical concentration to the value of the hazard index (HI) for that chemical. Noncarcinogenic effects include such conditions as neurological impairment and other physiological effects.

For the purposes of this screening method, the NDEP considers that risk levels projected to be at or exceeding a carcinogenic risk of 1.0E-04 or an HQ equal to or greater than 1 in residential indoor air may pose an **imminent and substantial hazard** requiring additional investigation and possible mitigation of the vapor intrusion pathway.

Attenuation Factors

The attenuation factor, α , is the ratio of the contaminant concentration in indoor air divided by the contaminant concentration in soil gas or groundwater. The attenuation factor represents the factor by which subsurface vapor concentrations migrating into indoor air spaces are reduced due to diffusive, advective and other attenuating mechanisms. Depth to groundwater, soil type, temperature of groundwater, soil moisture, construction characteristics and weather conditions also affect the attenuation factor and, consequently, the estimated concentration of the contaminant in indoor air, based on the parameters input into the Johnson-Ettinger model.

The slope of the lines in Figure 3 shows the effect on screening levels for a range of soil types at a constant depth (10 ft) and temperature (25°C). Clay-rich soils (loams) serve to attenuate vapor concentrations more than sandy soils, so knowledge of site lithology is important in applying screening levels that are most appropriate for a specific site. Groundwater depth also influences how much the vapors are attenuated. In all cases, use the maximum concentrations of chemicals detected in soil gas and groundwater at the site for screening, keeping in mind the following:

- The default screening levels are used when there is no knowledge other than the chemical concentration reported for groundwater (see Table 1).
- If depth to groundwater, temperature of groundwater, and soil type are known, the more detailed screening tables may be used (see Tables 2a to 2d). For screening purposes, groundwater depths at the site should be rounded down to the nearest increment provided in the Tables. Groundwater temperatures should be rounded up to the nearest increment. If soil texture or type is not conclusively known or if the soil column is composed of multiple soil textures and types, the most conservative value available should be used.
- If there are major preferential pathways for vapor migration, the numbers derived from the Johnson-Ettinger model may under-predict contaminant concentrations indoor air. If this or other site-specific factors suggest a different attenuation factor would be more appropriate for the site, then these should be evaluated and documented in the CSM (see Appendix B of EPA, 2002).

4. PETROLEUM-RELATED CONSTITUENTS AND POTENTIAL FOR VAPOR INTRUSION

In considering the need to include other common groundwater contaminants, such as benzene, toluene, ethylbenzene and xylene (BTEX) compounds and methyl tert-butyl ether (MTBE) in this screening method, the NDEP reviewed the literature for petroleum vapor intrusion (PVI). Unlike chlorinated hydrocarbons, such as TCE and PCE, which degrade under anaerobic conditions, benzene and other petroleum-related contaminants biodegrade under aerobic (i.e., oxygenated) conditions. This fundamental difference in contaminant behavior is not captured in the Johnson-Ettinger model of vapor transport because biodegradation is not considered in the model calculations.

DeVaull (2007) developed a model (BioVapor) that includes calculations for oxygen-limited biodegradation of petroleum-related contaminants. As described on the American Petroleum Institute (API) website (<http://www.api.org/Environment-Health-and-Safety/Clean-Water/Ground-Water/Vapor-Intrusion/Biovapor-Form.aspx>), “the BioVapor model is a steady-state 1-D analytical model intended to

provide the user with an improved understanding of the potential effect of vadose zone aerobic biodegradation on the vapor intrusion pathway.” Performance of this model has been evaluated by comparison to empirical data for sites with petroleum-contaminated groundwater (Davis, 2009 and 2012). In a recent presentation, Davis (2012) reported the results of such comparisons, using data for approximately 1,000 measurements from nearly 170 sites. She concluded that homes overlying a dissolved-phase benzene plume did not have a completed PVI pathway if at least 5 to 8 feet of clean soil separated the water table from the receptor, and if oxygen constituted more than 1% of the soil vapor. Davis also found that results from the BioVapor model were conservative when compared to the empirical data (that is, the BioVapor model *under*-predicted subsurface attenuation of benzene vapors).

EPA has also evaluated the BioVapor model (Weaver, 2012), in addition to assessing the potential for petroleum hydrocarbons to present a vapor intrusion issue (EPA, 2012). EPA (2012) concluded that “A *key consideration in a PVI site investigation is whether sufficient oxygen is available and whether there is a sufficiently thick biologically active soil layer between the source and the receptor for aerobic organisms to biodegrade the PHC [petroleum hydrocarbon] vapors before they could conceivably reach indoor air.*” Based on the work done by Davis and others, the NDEP concludes that, for most situations, benzene and other petroleum-related constituents are unlikely to pose “an imminent and substantial hazard” to residents via the vapor intrusion pathway.

Instead of developing screening numbers, the NDEP has identified several site conditions that warrant additional evaluation for petroleum vapor intrusion. When present, these conditions may serve to limit the biodegradation of petroleum vapors. The NDEP recommends that case officers elevate and notify supervisors of sites where:

- petroleum contaminated groundwater is in direct contact with residential buildings even if it is only seasonal;
- extensive petroleum contamination is present in the vadose-zone between the residence and contaminated groundwater, including cases where the contamination is from the same source (i.e. vadose-zone and groundwater contamination are from a heating oil tank release) or from different sources; or
- strong odors or basement/crawlspace staining are present in residences near to a petroleum release.

5. ADDITIONAL STEPS BEYOND SIMPLE SCREENING

As shown in Section 3, there are additional steps that may be taken prior to sampling indoor air. However, these steps are beyond the scope of this simple screening tool and involve application of computer modeling and collection of additional site-specific data. The guidance documents listed in the references below offer more details for additional evaluation of a site that fails the initial screening steps discussed in this document. Additional steps should be discussed with a supervisor after a site is identified through this Screening Method.

The additional steps listed but not discussed in detail in this document are mostly applicable to chlorinated hydrocarbons but are generally relevant to petroleum vapor intrusion as well. Additional calculations using the Johnson-Ettinger model are not encouraged for petroleum sites, but the general elevation of the site through consideration of additional site-specific data, supervisory involvement, and consideration of additional sources of guidance can all be pursued prior to indoor air sampling.

6. SUMMARY

The purpose of this Screening Method is **to assist NDEP case officers determine when the vapor intrusion pathway may present an imminent and substantial hazard at a site where contaminated groundwater underlies residences**. If the CSM shows this exposure pathway to be incomplete, or if potential receptors are more than 100 feet from the contaminated groundwater, then the case officer may conclude that, although risks from vapor intrusion may still be present, it is anticipated that these risks will be managed through the NDEP's standard management of contaminated groundwater. The screening steps also assure that additional information is promptly collected from sites where contaminated groundwater may pose **an imminent and substantial hazard**.

There are additional steps for evaluating the vapor intrusion pathway, and the reader is referred to the EPA (2002) and ITRC (2007) for collection of soil gas samples, and collection of subslab and indoor air samples. If these additional data suggest that contaminant concentrations in indoor air may exceed 1.0E-04 risk (one-in-ten-thousand) or a HQ of 1, then collection of indoor air samples may be warranted. Screening tables are included at the end of this text. The simple screening values in Table 1 offer a conservative set of concentrations. If the depth to groundwater, soil type, and groundwater temperature are known, more specific screening values are presented in Tables 2a – 2d.

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- EPA. 2012. Conceptual Model Scenarios for the Vapor Intrusion Pathway. EPA 530-R-10-003. February.

FIGURES

Figure 1: Screening Method Flowchart

Figure 2: Conceptual Site Model - Examples

Figure 3: Graphs Showing Effect of Soil Type on Vapor Attenuation

Figure 1: Screening Steps for Assessing Whether the Vapor Intrusion Pathway Represents an Imminent and Substantial Hazard under a Residential Exposure Scenario

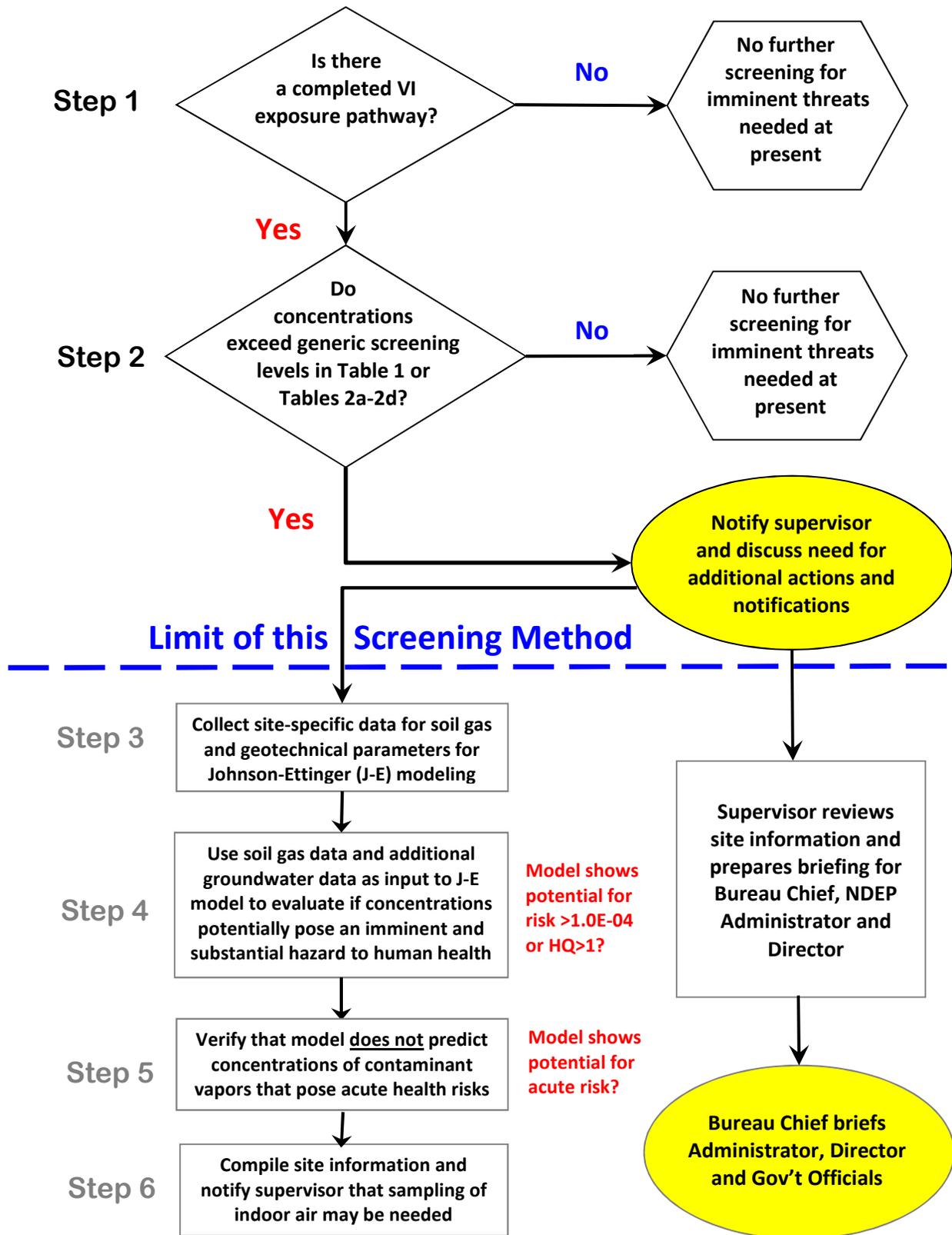


Figure 2: Conceptual Site Model for Vapor Intrusion Screening using Groundwater Data

Steps for Groundwater Screening-Level Evaluation

1. Do contaminant concentrations in groundwater collected from two consecutive sampling events exceed generic screening levels?
2. Does contaminated groundwater underlie (or is projected to underlie) any residential structures?
3. Are contaminant concentrations higher than corresponding values on attached tables describing site-specific soil type, depth to groundwater and temperature of groundwater?
4. Consult with supervisor on next steps

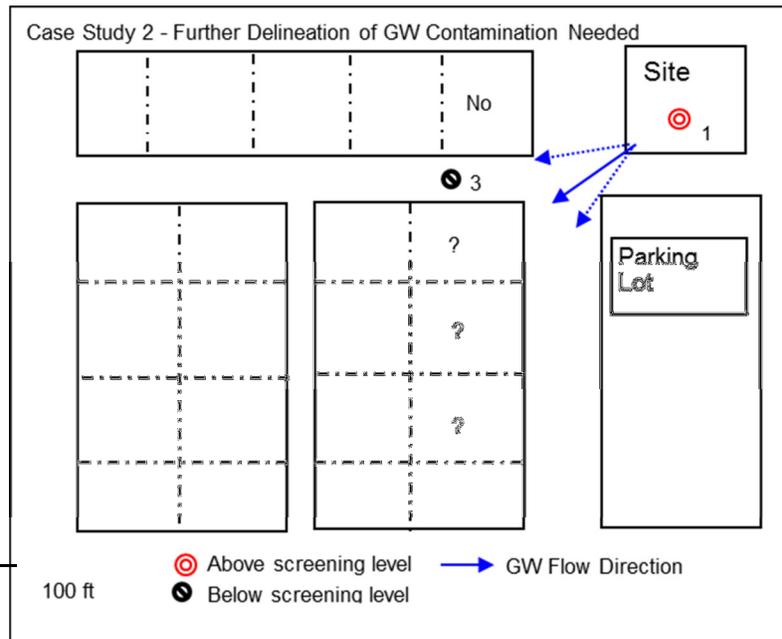
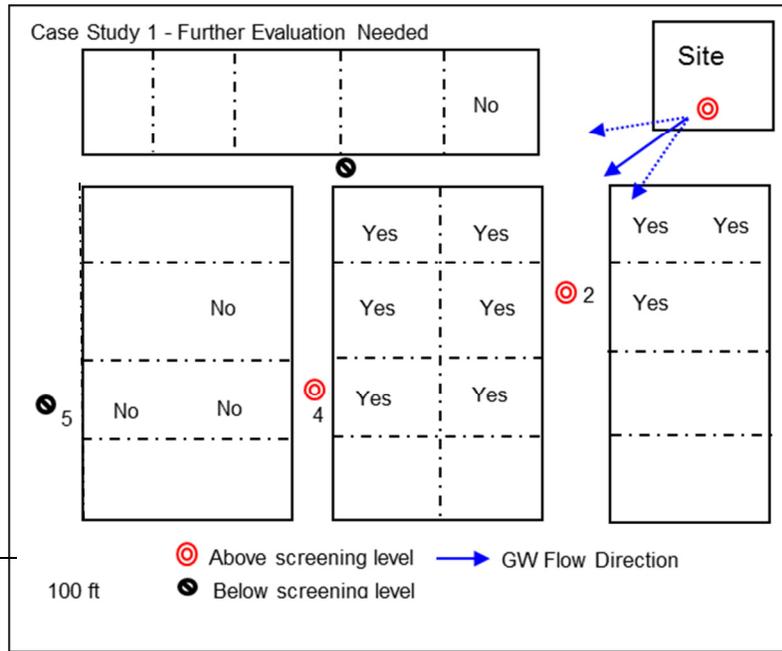
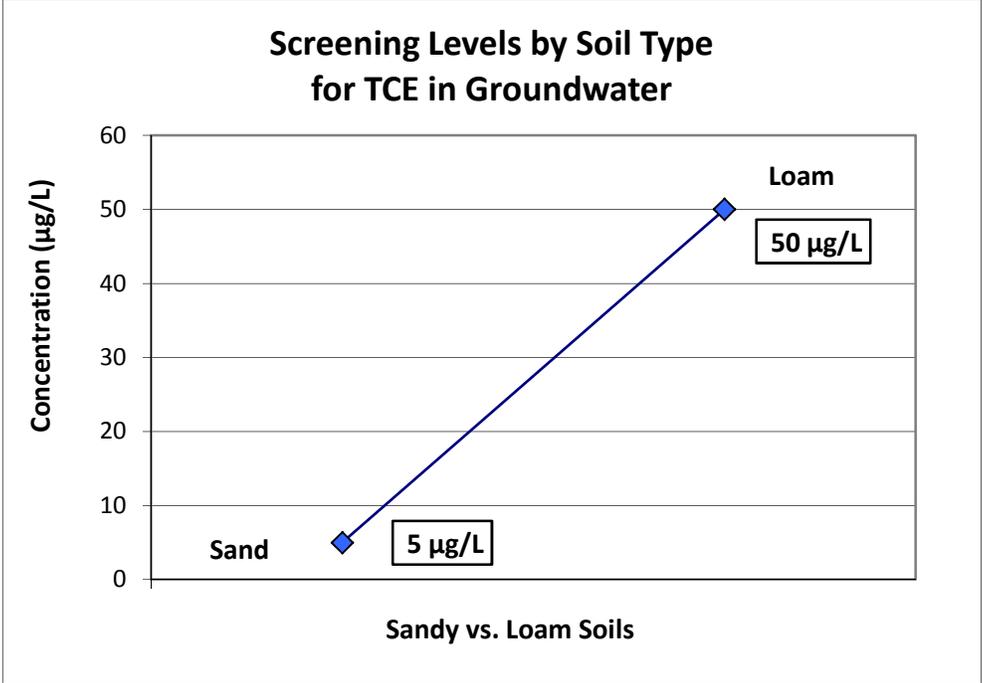
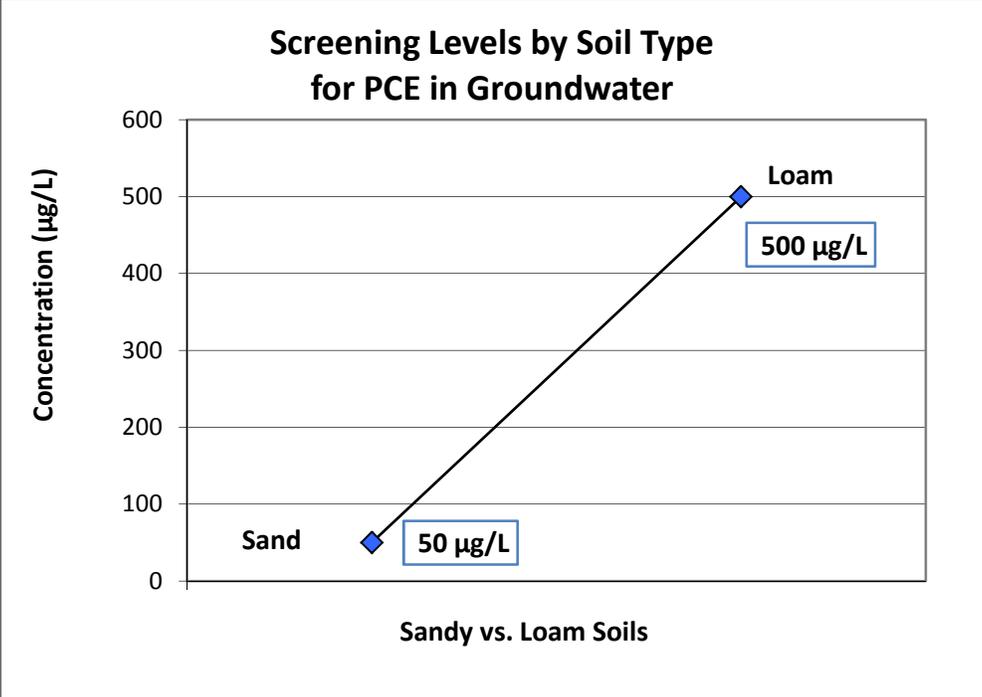


Figure 3: Effect of soil type on screening levels. Degree of attenuation is higher for clay-rich (loam) soils than for sandy soils. Graphs depict screening levels for 10-foot depth and groundwater at 25°C. Concentrations exceeding screening levels indicate the potential for contaminant concentrations in indoor air to pose an imminent and substantial hazard to residents via the vapor intrusion exposure pathway.



TABLES

Table 1: Simple Screening Values for TCE and PCE in Shallow Groundwater

Tables 2a to 2d: Screening Levels for TCE and PCE in Shallow Groundwater
when Soil Type, Groundwater Temperature and Depth are Known

Table 3: Default Parameters in USEPA Version of Johnson-Ettinger Model

Table 1: Simple Screening Values for TCE and PCE in Shallow Groundwater

Default Screening Concentrations for Groundwater Contaminants ($\mu\text{g/L}$)		
Chemical	Sand	Loam
Tetrachloroethylene (PCE)	50	500
Trichloroethylene (TCE)	5	50
<p>Target values* for contaminant concentrations in indoor air are: PCE = 32 $\mu\text{g}/\text{m}^3$ TCE = 2.1 $\mu\text{g}/\text{m}^3$</p> <p>Values back-calculated using EPA's on-line calculator for the J-E model**</p> <p>This worst-case simplification assumes high temperature (25°C) for groundwater, shallow depth (10 feet) to groundwater and sandy soil. Screening values for clay (loam) soil shown for comparison.</p> <p>If soil texture or type is not conclusively known or if the soil column is composed of multiple soil textures and types, the most conservative value should be used for screening purposes.</p>		
Conversion from Unified Soil Classification System (USCS) Texture to U.S. Soil Conservation Service (USDA) Soil Types***		
SW, SP:	Sandy soil > 85% sand, < 15% silt or clay	
SM:	Loamy sand > 70% sand and < 30% silt or <15% clay	
SM, SC, ML:	Sandy loam > 50% sand and < 50% silt or < 20% clay	
ML, CL:	Loam > 50% sand, 30 to 50% silt and 10 to 30% clay	

*EPA April 25, 2003 OSWER Directive 9285.7-74 PCE Inhalation Unit Risk Value

** http://www.epa.gov/Athens/learn2model/part-two/onsite/JnE_lite.htm

***http://www.pedosphere.com/resources/bulkdensity/triangle_us.cfm

Tables 2a – 2d

**Screening Levels for TCE and PCE in Shallow Groundwater
When Soil Type, Groundwater Temperature and Depth are Known**

Table 2a: Screening Levels for TCE and PCE in Shallow Groundwater When Soil Type, Groundwater Temperature and Depth are Known (Temperature = 10°C)

Groundwater Temperature = 10 degrees C

*PCE	Depth to Groundwater (ft bgs)								Units
Soil Texture	5	10	15	20	25	30	40	50	
Sand	90	110	130	150	170	190	230	270	µg/L
Loamy sand	240	260	290	310	330	360	400	450	µg/L
Sandy loam	650	680	715	750	780	810	880	990	µg/L
Loam	1,020	1,070	1,120	1,170	1,220	1,270	1,370	1,480	µg/L
TCE									
Soil Texture	5	10	15	20	25	30	40	50	Units
Sand	10	12	14	16	18	20	24	28	µg/L
Loamy sand	25	27	29	32	34	37	41	46	µg/L
Sandy loam	65	68	71	75	78	81	88	94	µg/L
Loam	100	106	111	116	122	127	138	148	µg/L

Values for groundwater back-calculated from target indoor air concentrations using USEPA on-line calculator for the Johnson-Ettinger model for vapor intrusion. Groundwater concentrations provided as micrograms per liter (µg/L).

* For PCE, the interim-action level of 32 µg/m³ established in 2007 for the Maryland Square PCE Site (H-000086), will continue to be used as the goal for PCE in residential indoor air. In 2012, the USEPA modified the concentrations for PCE for both carcinogenic and non-carcinogenic risk. The non-carcinogenic risk is now the main driver of risk for PCE in residential indoor air based on current understanding of the toxicological risks, and the value is close to the NDEP's interim-action level of 32 µg/m³

Indoor Air Target Values are:

*PCE = 32 µg/m³ (HI = 1 @ 42 µg/m ³ ; Cancer risk = 1.0E-04 @ 940 µg/m ³)
TCE = 2.1 µg/m³ (HI = 1 @ 2.1 µg/m ³ ; Cancer risk @ 1.0E-04 = 43 µg/m ³)

SW, SP	Sandy soil > 85% sand, < 15% silt or clay
SM	Loamy sand > 70% sand and < 30% silt or <15% clay
SM, SC, ML	Sandy loam > 50% sand and < 50% silt or < 20% clay
ML, CL	Loam > 50% sand, 30 to 50% silt and 10 to 30% clay

Table 2b: Screening Levels for TCE and PCE in Shallow Groundwater When Soil Type, Groundwater Temperature and Depth are Known (Temperature = 15°C)

Groundwater Temperature = 15 degrees C

*PCE	Depth to Groundwater (ft bgs)								Units
Soil Texture	5	10	15	20	25	30	40	50	
Sand	70	85	100	115	130	145	180	210	µg/L
Loamy sand	180	200	220	240	250	270	310	340	µg/L
Sandy loam	500	520	550	570	600	620	690	720	µg/L
Loam	780	820	860	900	930	970	1,050	1,130	µg/L

TCE	Depth to Groundwater (ft bgs)								Units
Soil Texture	5	10	15	20	25	30	40	50	
Sand	8	9	11	12	14	16	19	22	µg/L
Loamy sand	19	21	23	25	27	29	32	36	µg/L
Sandy loam	52	54	57	59	62	64	69	75	µg/L
Loam	80	84	88	92	96	101	109	117	µg/L

Values for groundwater back-calculated from target indoor air concentrations using USEPA on-line calculator for the Johnson-Ettinger model for vapor intrusion. Groundwater concentrations provided as micrograms per liter (µg/L).

* For PCE, the interim-action level of 32 µg/m³ established in 2007 for the Maryland Square PCE Site (H-000086), will continue to be used as the goal for PCE in residential indoor air. In 2012, the USEPA modified the concentrations for PCE for both carcinogenic and non-carcinogenic risk. The non-carcinogenic risk is now the main driver of risk for PCE in residential indoor air based on current understanding of the toxicological risks, and the value is close to the NDEP's interim-action level of 32 µg/m³

Indoor Air Target Values are:

*PCE = 32 µg/m³ (HI = 1 @ 42 µg/m ³ ; Cancer risk = 1.0E-04 @ 940 µg/m ³)
TCE = 2.1 µg/m³ (HI = 1 @ 2.1 µg/m ³ ; Cancer risk @ 1.0E-04 = 43 µg/m ³)

SW, SP	Sandy soil > 85% sand, < 15% silt or clay
SM	Loamy sand > 70% sand and < 30% silt or < 15% clay
SM, SC, ML	Sandy loam > 50% sand and < 50% silt or < 20% clay
ML, CL	Loam > 50% sand, 30 to 50% silt and 10 to 30% clay

Table 2c: Screening Levels for TCE and PCE in Shallow Groundwater When Soil Type, Groundwater Temperature and Depth are Known (Temperature = 20°C)

Groundwater Temperature = 20 degrees C

*PCE	Depth to Groundwater (ft bgs)								Units
Soil Texture	5	10	15	20	25	30	40	50	
Sand	55	65	80	90	100	110	130	160	µg/L
Loamy sand	140	155	170	180	195	210	230	260	µg/L
Sandy loam	390	400	420	440	460	480	515	550	µg/L
Loam	600	630	660	690	720	750	810	870	µg/L

TCE	Depth to Groundwater (ft bgs)								Units
Soil Texture	5	10	15	20	25	30	40	50	
Sand	6	7	8	10	11	12	15	17	µg/L
Loamy sand	15	17	18	20	21	23	26	29	µg/L
Sandy loam	41	43	45	47	49	51	55	59	µg/L
Loam	64	67	71	74	77	80	87	93	µg/L

Values for groundwater back-calculated from target indoor air concentrations using USEPA on-line calculator for the Johnson-Ettinger model for vapor intrusion. Groundwater concentrations provided as micrograms per liter (µg/L).

* For PCE, the interim-action level of 32 µg/m³ established in 2007 for the Maryland Square PCE Site (H-000086), will continue to be used as the goal for PCE in residential indoor air. In 2012, the USEPA modified the concentrations for PCE for both carcinogenic and non-carcinogenic risk. The non-carcinogenic risk is now the main driver of risk for PCE in residential indoor air based on current understanding of the toxicological risks, and the value is close to the NDEP's interim-action level of 32 µg/m³

Indoor Air Target Values are:

*PCE = 32 µg/m³ (HI = 1 @ 42 µg/m ³ ; Cancer risk = 1.0E-04 @ 940 µg/m ³)
TCE = 2.1 µg/m³ (HI = 1 @ 2.1 µg/m ³ ; Cancer risk @ 1.0E-04 = 43 µg/m ³)

SW, SP	Sandy soil > 85% sand, < 15% silt or clay
SM	Loamy sand > 70% sand and < 30% silt or <15% clay
SM, SC, ML	Sandy loam > 50% sand and < 50% silt or < 20% clay
ML, CL	Loam > 50% sand, 30 to 50% silt and 10 to 30% clay

Table 2d: Screening Levels for TCE and PCE in Shallow Groundwater When Soil Type, Groundwater Temperature and Depth are Known (Temperature = 25°C)

Groundwater Temperature = 25 degrees C

*PCE	Depth to Groundwater (ft bgs)								Units
Soil Texture	5	10	15	20	25	30	40	50	
Sand	42	50	60	70	80	90	100	120	µg/L
Loamy sand	110	120	130	140	150	160	180	200	µg/L
Sandy loam	300	315	330	345	360	370	400	430	µg/L
Loam	470	490	520	540	560	590	630	680	µg/L

TCE	Depth to Groundwater (ft bgs)								Units
Soil Texture	5	10	15	20	25	30	40	50	
Sand	5	6	7	8	9	10	12	14	µg/L
Loamy sand	12	13	15	16	17	18	20	23	µg/L
Sandy loam	33	35	36	38	40	41	45	48	µg/L
Loam	52	54	57	60	62	65	70	75	µg/L

Values for groundwater back-calculated from target indoor air concentrations using USEPA on-line calculator for the Johnson-Ettinger model for vapor intrusion. Groundwater concentrations provided as micrograms per liter (µg/L).

* For PCE, the interim-action level of 32 µg/m³ established in 2007 for the Maryland Square PCE Site (H-000086), will continue to be used as the goal for PCE in residential indoor air. In 2012, the USEPA modified the concentrations for PCE for both carcinogenic and non-carcinogenic risk. The non-carcinogenic risk is now the main driver of risk for PCE in residential indoor air based on current understanding of the toxicological risks, and the value is close to the NDEP's interim-action level of 32 µg/m³

Indoor Air Target Values are:

*PCE = 32 µg/m³ (HI =1 @ 42 µg/m ³ ; Cancer risk = 1.0E-04 @ 940 µg/m ³)
TCE = 2.1 µg/m³ (HI = 1 @ 2.1 µg/m ³ ; Cancer risk @ 1.0E-04 = 43 µg/m ³)

SW, SP	Sandy soil > 85% sand, < 15% silt or clay
SM	Loamy sand > 70% sand and < 30% silt or <15% clay
SM, SC, ML	Sandy loam > 50% sand and < 50% silt or < 20% clay
ML, CL	Loam > 50% sand, 30 to 50% silt and 10 to 30% clay

Table 3: Parameters used in EPA Johnson-Ettinger Model

Example using PCE concentration = 100 µg/L, with groundwater temperature = 10°C and depth to groundwater = 10 feet bgs	EPA On-line Tool		Units
	Sandy Soil	Loam Soil	
CHEMICAL PROPERTIES	Tetrachloroethylene (PCE) – 100 µg/L		
CAS Number	127184	127184	
Molecular Weight (MW)	165.83	165.83	[g/mole]
Henry's Law Constant at ground water temperature (H)	0.3362604	0.3362604	[unitless]
Free-Air Diffusion Coefficient (D _a)	7.200E-02	7.200E-02	[cm ² /s]
Diffusivity in Water (D _w)	8.200E-06	8.200E-06	[cm ² /s]
Unit Risk Factor (URF)	3.00E-06	3.00E-06	[(µg/m ³) ⁻¹]
Reference Concentration (RfC)			[mg/m ³]
SOIL PROPERTIES			
Total Porosity (n)	0.375	0.399	[unitless]
Unsaturated Zone Moisture Content (θ _w) (Low, Best Estimate and High)	0.053, 0.054 and 0.055	0.061, 0.148 and 0.240	[unitless]
Capillary Zone Moisture Content at Air-Entry Pressure (θ _{w, cap})	0.253	0.332	[unitless]
Height of Capillary Zone (CZ _h)	0.170	0.375	[m]
Soil-gas Flow Rate Into the Building (Q _{soil})	5.00	5.00	[L/min]
BUILDING PROPERTIES (slab-on-grade)			
Air Exchange Rate (EB)	0.250	0.250	[hr ⁻¹]
Building Mixing Height (HB)	2.44	2.44	[m]
Building Footprint Area (FB)	100.0	100.0	[m ²]
Subsurface Foundation Area (AB)	106	106	[m ²]
Building Crack Ratio (η)	0.00038	0.00038	[unitless]
Building Foundation Slab Thickness (L _{crack})	0.100	0.100	[m]
EXPOSURE PARAMETERS			
Exposure Duration for Carcinogens (ED _c)	30	30	[years]
Exposure Frequency for Carcinogens (EF _c)	350	350	[days/year]
Averaging Time for Carcinogens (AT _c)	70	70	[years]
Exposure Duration for Non-Carcinogens (ED _{nc})	30	30	[years]
Exposure Frequency for Non-Carcinogens (EF _{nc})	365	365	[days/year]
Averaging Time for Non-Carcinogens (AT _{nc})	30	30	[years]
RESULTS			
Unsaturated Zone Effective Diffusion Coefficient (D _{eff})	0.01164	0.004532	[cm ² /s]
Unsaturated + Capillary Zone Effective Diffusion Coefficient (D ^T _{eff})	0.004981	0.000432	[cm ² /s]
"A" Parameter	0.001022	9.096E-05	[unitless]
"B" Parameter	177.7	456.5	[unitless]
"C" Parameter	0.004918	0.004918	[unitless]
J&E Attenuation Factor (α)	8.463E-04	8.931E-05	[unitless]

http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite_forward.html

In the publication *Identification of Critical Parameters for the Johnson and Ettinger (1991) Vapor Intrusion Model*, (American Petroleum Institute Technical Bulletin Number 17, 2002), Paul Johnson writes the Johnson and Ettinger (1991) algorithm in terms of three dimensionless parameters:

$$\alpha = \frac{[A]\exp(B)}{\exp(B) + [A] + \left[\frac{A}{C}\right](\exp(B) - 1)} \quad A = \frac{D_T^{eff}}{E_B \left(\frac{V_B}{A_B}\right) L_T} \quad B = \frac{\left(\frac{Q_{soil}}{Q_B}\right) E_B \left(\frac{V_B}{A_B}\right) L_{crack}}{D_{crack}^{eff} \eta} \quad C = \left(\frac{Q_{soil}}{Q_B}\right)$$