DEPARTMENT OF
ENVIRONMENTAL CONSERVATION

Division of Spill Prevention and Response
Contaminated Sites Program

DRAFT VAPOR INTRUSION GUIDANCE FOR CONTAMINATED SITES

July 2009

This page intentionally left blank

TABLE OF CONTENTS

I. PURPOSE **1**

II. BACKGROUND **1**

III. KEY RECOMMENDATIONS **3**

IV. VAPOR INTRUSION DECISION AND RESPONSE FRAMEWORK **4**

STEP 1: CHECK FOR EXPLOSIVE OR SHORT-TERM EXPOSURE THREATS 8
STEP 2: REFINE THE CSM FOR VAPOR INTRUSION 9
STEP 3: CHARACTERIZE SITE AND REVIEW DATA QUALITY 10
STEP 4: COMPARE CONTAMINANT DATA TO TARGET LEVELS 11
STEP 5: DECIDE IF FURTHER EVALUATION IS NEEDED 13
STEP 6: CHOOSE AN INVESTIGATIVE STRATEGY 14
STEP 7: SUBMIT WORKPLAN FOR DEC APPROVAL AND IMPLEMENT 16
STEP 8: EVALUATE VAPOR INTRUSION POTENTIAL AND RISK TO RECEPTORS 17
STEP 9: SUBMIT REPORT TO DEC WITH RECOMMENDATIONS FOR CLEANUP 18
STEP 10: SUBMIT CLEANUP OR CORRECTIVE ACTION PLAN FOR DEC APPROVAL AND IMPLEMENT 19
STEP 11: EVALUATE DATA TO CONFIRM CLEANUP OR MITIGATION EFFECTIVENESS FOR VAPOR INTRUSION 19
STEP 12: SUBMIT FINAL REPORT TO DEC 20

V. DATA COLLECTION AND INTERPRETATION **20**

GROUNDWATER SAMPLING 20
Groundwater Sample Location *21*
Monitoring Well Design and Groundwater Sampling Techniques *21*
Other Considerations for Collecting and Using Groundwater Data *23*
SOIL GAS SAMPLING 24
Soil Gas Sample Location, Depth, and Frequency *25*
Soil Gas Probe Installation and Sampling Techniques *25*
Transient and Other Environmental Effects on Sampling *28*
INDOOR AIR SAMPLING 28
Indoor Air Sample Location and Frequency *29*
Indoor Air Sampling Procedures *30*
Considerations for Collecting and Using Indoor Air Data *31*
ANALYTICAL METHODS AND SAMPLE HANDLING FOR SOIL GAS AND INDOOR AIR 31
Sample Containers *32*
Sample Handling, Storage, and Transportation *33*
Analytical Methods and QA/QC *34*

VI. INVESTIGATIVE STRATEGIES – SPECIAL CONSIDERATIONS **37**

BACKGROUND AIR LEVELS 37
MULTIPLE LINES OF EVIDENCE 38
PREDICTIVE MODELING 38
RISK ASSESSMENT 39
PETROLEUM BIODEGRADATION 39

VII. MITIGATING A VAPOR INTRUSION PROBLEM **40**

VIII. INSTITUTIONAL CONTROLS AT VAPOR INTRUSION SITES **4040**

IX. RFERENCES **41**

TABLE OF FIGURES

Figure 1: General depiction of the vapor intrusion pathway in a residential setting. 2
Figure 2: Steps in a vapor intrusion evaluation. 5
Figure 3: Decision points in a vapor intrusion evaluation. 6

TABLE OF TABLES

Table 1: Guidance and publications on vapor intrusion. 3
Table 2: Advantages and disadvantages of various investigative strategies and sampling approaches. 15
Table 3: Monitoring well installation methods. 22
Table 4: Groundwater sampling methods. 22
Table 5: Summary of analytical methods for soil gas, indoor and ambient air samples. 35

APPENDICES

Appendix A – Elements of the Vapor Intrusion Pathway (adapted from NJ DEP, 2005)
Appendix B – ATSDR Inhalation Minimal Risk Levels
Appendix C – Conceptual Site Model Checklist (from ITRC, 2007)
Appendix D – DEC Indoor Air Target Levels
Appendix E – DEC Shallow or Subslab Soil Gas Target Levels
Appendix F – DEC Deep Soil Gas Target Levels
Appendix G – DEC Groundwater Target Levels
Appendix H – Background Indoor Air Levels
Appendix I – DEC Building Survey and Indoor Air Sampling Questionnaire

Acronyms

AKOSH – Alaska Occupational Safety and Health
ATSDR – Agency of Toxic Substance and Disease Registry
bgs – Below ground surface
BTEX – Benzene, toluene, ethylbenzene, and xylenes
CSM – Conceptual Site Model
CSP – Contaminated Sites Program
DEC – Department of Environmental Conservation
DQO – Data quality objective
EPRI – Electric Power Research Institute
MTBE – Methyl tert-butyl ether
NELAP – National Environmental Laboratory Accreditation Program
OSHA – Occupational Safety and Health Agency
PAH – Polycyclic aromatic hydrocarbon
PCB – Polychlorinated biphenyl
PEL – Permissible Exposure Limit
ppbv – Parts per billion by volume
ppmv – Parts per million by volume
QA/QC – Quality assurance/quality control
SVOC – Semi-volatile organic compound
TPH – Total petroleum hydrocarbon
µg/L – Micrograms per liter
$\mu g/m^3$ – Micrograms per cubic meter
VOC – Volatile organic compound

Alaska Department of Environmental Conservation
Vapor Intrusion Guidance Disclaimer:

Web links to the most current agency documents available are provided in the reference section of this Guidance. Because this effort is continually evolving and adapting to meet the needs of a broad environmental community, users of this document should verify they have the most recent version of any referenced document.

I. PURPOSE

This document was prepared by the Alaska Department of Environmental Conservation (DEC) to provide guidance for evaluating and responding to a vapor intrusion exposure pathway at contaminated sites. When the conceptual site model (CSM) indicates that the vapor intrusion pathway may be complete, a site-specific analysis is necessary per Title 18 of the Alaska Administrative Code [18 AAC 75.340 (i)]. Currently the method two soil cleanup levels in Tables B1 and B2 of 18 AAC 75.340 address volatilization to outdoor air and subsequent inhalation by receptors, but do not address vapor intrusion into buildings where receptors exposed to indoor air may be affected. When vapor intrusion is occurring, site-specific soil and groundwater cleanup levels may need to be established. This guidance pertains to evaluating and controlling vapors migrating from the subsurface into an occupied structure–DEC does not regulate indoor air. This distinction is critical when determining cleanup goals for a site.

The strategy presented in this guidance is a series of steps for consistently assessing the potential for risk from vapor intrusion. The need for a thorough assessment may be identified at sites that are already in the cleanup process. Consequently, this guidance has been designed to allow the user to begin evaluating vapor intrusion at any point in the cleanup process. For a quick overview of DEC's recommendations regarding this pathway, see Section III.

II. BACKGROUND

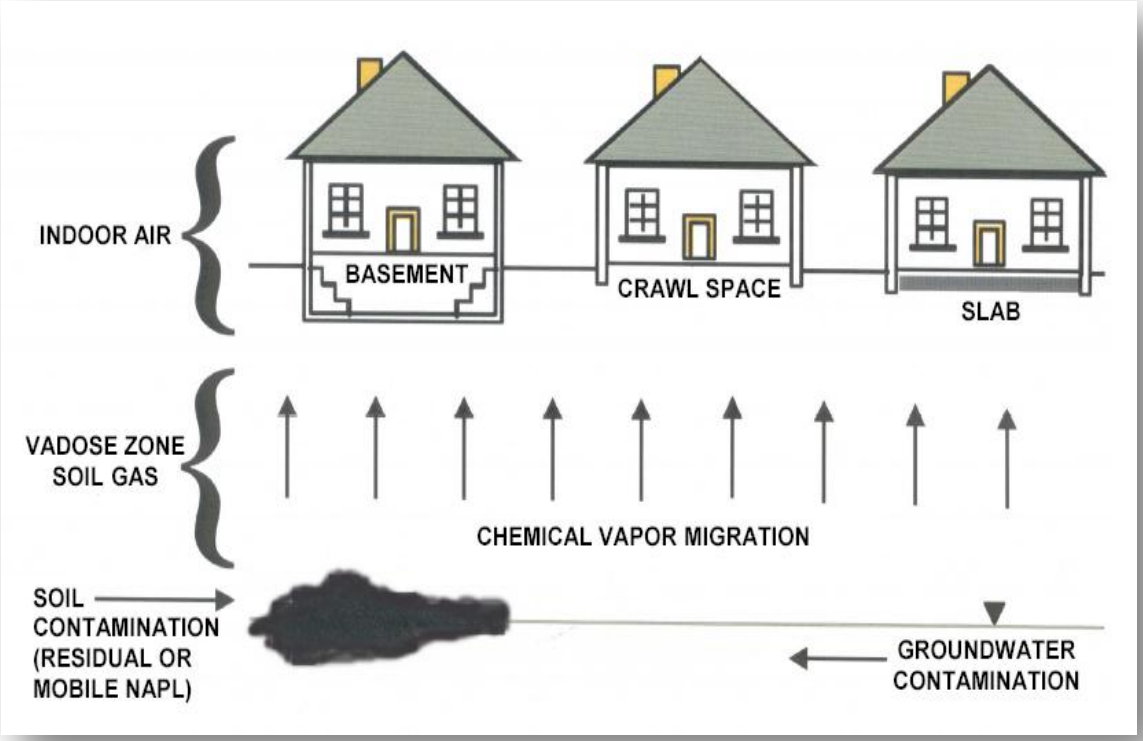
Vapor intrusion is the migration of volatile chemicals from a subsurface vapor source into overlying buildings. Before beginning an evaluation of the vapor intrusion pathway, it is important to understand how vapors migrate and intrude into overlying buildings. The process is similar to that of radon gas seeping into homes. This section briefly describes a general conceptual model for vapor intrusion, as shown in Figure 1. A more detailed description is provided in Appendix A.

Vapor intrusion begins with a vapor source. Contaminants volatilize from the vapor source and move into the surrounding soil pore spaces as soil gas. Vapor sources may include contaminated soil in the vadose zone, free-phase or residual non-aqueous phase liquid (NAPL) above or near the top of the saturated zone, or shallow dissolved-phase contamination in groundwater. Underground tanks and piping that contain volatile chemicals can also release vapor clouds into the surrounding soil.

Vapors in the subsurface diffuse from areas of high concentration to areas of low concentration. When vapors reach a building, advective forces associated with the building may cause the vapors to flow through cracks in the foundation. In this document, a foundation is defined as the lowest level of a building in contact with the soil, such as a basement, crawl space, or slab-on-grade foundation. A building on posts, where airflow beneath the building is not blocked by screening or other material, does not need to be evaluated for vapor intrusion.

The rate of vapor migration through soil and into a building is difficult to quantify and depends on soil types, chemical properties, building design and condition, and pressure differentials between the subsurface and the building. An investigator should be aware that climatic conditions, such as changes in barometric pressure or air temperature, wind, and rainfall also can affect the degree to which vapor intrusion is occurring.

Figure 1: General depiction of the vapor intrusion pathway in a residential setting (from EPA, 2002).



In extreme cases, vapors may accumulate in dwellings or occupied buildings to levels that could cause explosions, acute health effects, or odors. In these cases, it is relatively easy to determine that the vapor intrusion pathway is complete and that prompt remediation or mitigation efforts are necessary. Typically, however, the chemical concentrations are low and the main concern is that the contamination may pose an unacceptable exposure risk from long-term indoor inhalation. At these sites, determining whether the pathway is complete or not can be complicated. The presence of background contaminants in households or commercial buildings (i.e., in the ambient air or emission sources such as household solvents, gasoline, or cleaners) can make it difficult to interpret direct measurements. Moreover, many soil and building characteristics can have a dramatic impact on the potential for vapor intrusion.

In developing this guidance, DEC evaluated guidance from the U.S. Environmental Protection Agency (EPA) and the Interstate Technology and Regulatory Council (ITRC), as well as other states and organizations that are addressing the vapor intrusion pathway. Useful references for evaluating the vapor intrusion pathway are listed in Table 1.

Table 1: Guidance and publications on vapor intrusion.

Primary Topic	Document and Web Site Location*
General Guidance	ITRC Vapor Intrusion Pathway: A Practical Guide (ITRC, 2007). http://www.itrcweb.org/Documents/VI-1.pdf
	EPA Draft Vapor Intrusion Guidance (EPA, 2002). http://epa.gov/osw/hazard/correctiveaction/eis/vapor.htm
	Guidance for Evaluating Soil Vapor Intrusion in the State of New York (NY DOH, 2006). http://www.health.state.ny.us/environmental/investigations/soil_gas/svi_guidance/
	New Jersey Vapor Intrusion Guidance (NJ DEP, 2005). http://www.nj.gov/dep/srp/guidance/vaporintrusion/vig.htm
Petroleum Investigation	A Practical Strategy for Assessing the Subsurface Vapor-to-Indoor Air Migration Pathway at Petroleum Hydrocarbon Sites (API, 2005). http://www.api.org/ehs/groundwater/lnapl/soilgas.cfm
Property Transactions	ASTM E2600-08 Standard Practice for Assessment of Vapor Intrusion into Structures on Property Involved in Real Estate Transactions (ASTM, 2008). For purchase at http://www.astm.org/Standards/E2600.htm
Soil Gas Sampling	County of San Diego, Site Assessment and Mitigation Manual (SDC, 2009) http://www.co.san-diego.ca.us/deh/water/sam_manual.html
	California: Advisory – Active Soil Gas Investigations (DTSC, 2003) http://www.dtsc.ca.gov/lawsregspolicies/policies/SiteCleanup/upload/SMBR_ADV_activesoilgasinvst.pdf
Air Sampling	Massachusetts Indoor Air Sampling and Evaluation Guide (MA DEP, 2002). http://www.mass.gov/dep/cleanup/laws/02-430.pdf
Subslab Sampling	An Assessment of Vapor Intrusion in Homes near the Raymark Superfund Site using Basement and Subslab Air Samples (EPA, 2006). http://www.dec.state.ak.us/spar/csp/guidance/raymark6report.pdf
	Reference Handbook for Site-Specific Assessment of Subsurface Vapor Intrusion to Indoor Air (EPRI, 2005). http://my.epri.com/

*We cannot guarantee all links provided are current.

III. KEY RECOMMENDATIONS

Some key recommendations for evaluating vapor intrusion in Alaska are outlined below.

- **Use a phased approach to evaluate the vapor intrusion pathway**. Decisions about pathway completeness and human exposure should not be based on one piece of information, but a combination of factors. Before sampling, develop a CSM and use all available data to evaluate the likelihood of vapor intrusion. If little is known about the site, DEC recommends collecting exterior samples before collecting interior samples. Exterior samples may allow the investigator to rule out vapor intrusion without entering any buildings.
- **When the potential for vapor intrusion is high, collect indoor air *and* subslab or near-slab soil gas samples, and consider mitigation.** Indoor air samples provide direct evidence about the indoor inhalation risk. Subslab or near-slab soil gas samples provide evidence that the contamination is from the subsurface, not background indoor or outdoor sources. In some cases, taking immediate measures to mitigate the

indoor air exposure may be appropriate. Sampling and cleanup plans must be approved by DEC.

- **Remember contaminants in the vapor phase move differently than contaminants in groundwater.** Vapors in soil generally move away from a source by diffusion and can travel in a direction opposite of the groundwater flow. When vapors are near a building, advective forces associated with the building may cause vapors to move toward the foundation.
- **Sample the appropriate media and location to meet the objective.** The primary objective of a vapor intrusion investigation is to determine if vapors are entering a building from a subsurface contaminant source at a concentration that represents a risk to the building occupants. If the source is in the vadose zone, groundwater samples alone will not achieve this objective. If product or contaminated groundwater is in contact with the building foundation, soil gas samples may also not achieve this objective.
- **Do not use soil data for comparison to target levels, modeling vapor transport, or in a risk assessment.** Analytical soil data are poor quantitative predictors of contaminant vapor concentrations in the subsurface. Soil data are acceptable for qualitative evaluation of this pathway, but should not be used for numerical modeling. However, DEC will consider the vapor intrusion pathway incomplete when the most conservative Method 2 soil cleanup levels and groundwater cleanup levels are met throughout the site.
- **Consider the potential for biodegradation of petroleum compounds under specific site conditions**. Petroleum vapors attenuate more rapidly in the soil pore spaces than do more persistent volatile compounds, such as chlorinated solvents. Typically, a low to moderate strength petroleum source will not result in vapor intrusion if two feet of clean (uncontaminated) fine-grained soil or 5 feet of clean coarse-grained soil containing at least 3 percent oxygen overlies the source. DEC will not require further evaluation of the pathway when the investigator demonstrates conditions sufficient for biodegradation.

IV. VAPOR INTRUSION DECISION AND RESPONSE FRAMEWORK

DEC has identified 12 steps for addressing the vapor intrusion pathway. How these steps ideally fit into the DEC Contaminated Sites (18 AAC 75) or Leaking Underground Storage Tank (18 AAC 78) cleanup process is shown in Figure 2. Key decision points within these steps are shown in Figure 3. Vapor intrusion is an emerging issue, thus investigation and cleanup activities may be at various stages when vapor intrusion is first considered. At historical sites, the first consideration of vapor intrusion may be after significant site characterization and cleanup has already occurred, or even during the site closure evaluation. If this is the case, the initial evaluation (Steps 2 through 5) becomes very important, and may be part of the closure determination for the site. Regardless of the starting point, the basic steps and concepts of a vapor intrusion evaluation are the same for all sites.

Use the following steps whenever site information indicates that volatile and toxic compounds are present and occupied buildings are or may be present in the future. DEC's

Figure 2: Steps in a vapor intrusion evaluation.

DEC Cleanup Process	DEC Vapor Intrusion Steps
INITIAL RESPONSE 18 AAC 75.315/ 18 AAC 78.220 INTERIM REMOVAL 18 AAC 75.330/ 18 AAC 78.30	STEP 1: Check for explosive or short-term exposure threats. *Repeat Step 1 when any new information becomes available.* *Consider moving to step 10 when the potential for vapor intrusion remains high.*
SITE CHARACTERIZATION 18 AAC 75.335 Release Investigation 18 AAC 78.235	STEP 2: Refine the CSM for vapor intrusion. STEP 3: Characterize site and review data quality. STEP 4: Compare contaminant data to target levels. STEP 5: Decide if further evaluation is needed. *Consider moving to step 10 if the potential for vapor intrusion is high.* *If no further evaluation is needed, proceed to Step 9.* STEP 6: Choose an investigative strategy. STEP 7: Submit workplan for DEC approval and implement. STEP 8: Evaluate vapor intrusion potential and risk to receptors. STEP 9: Submit report to DEC with cleanup recommendations..
CLEANUP 18 AAC 75.360 Corrective Action 18 AAC 78.250-270	STEP 10: Submit cleanup or corrective action plan for DEC approval and implement.
FINAL REPORT 18 AAC 75.380/ 18 AAC 78.276	STEP 11: Evaluate effectiveness of cleanup effectiveness for vapor intrusion. STEP 12: Submit final report for DEC approval.

Figure 3: Decision points in a vapor intrusion evaluation.

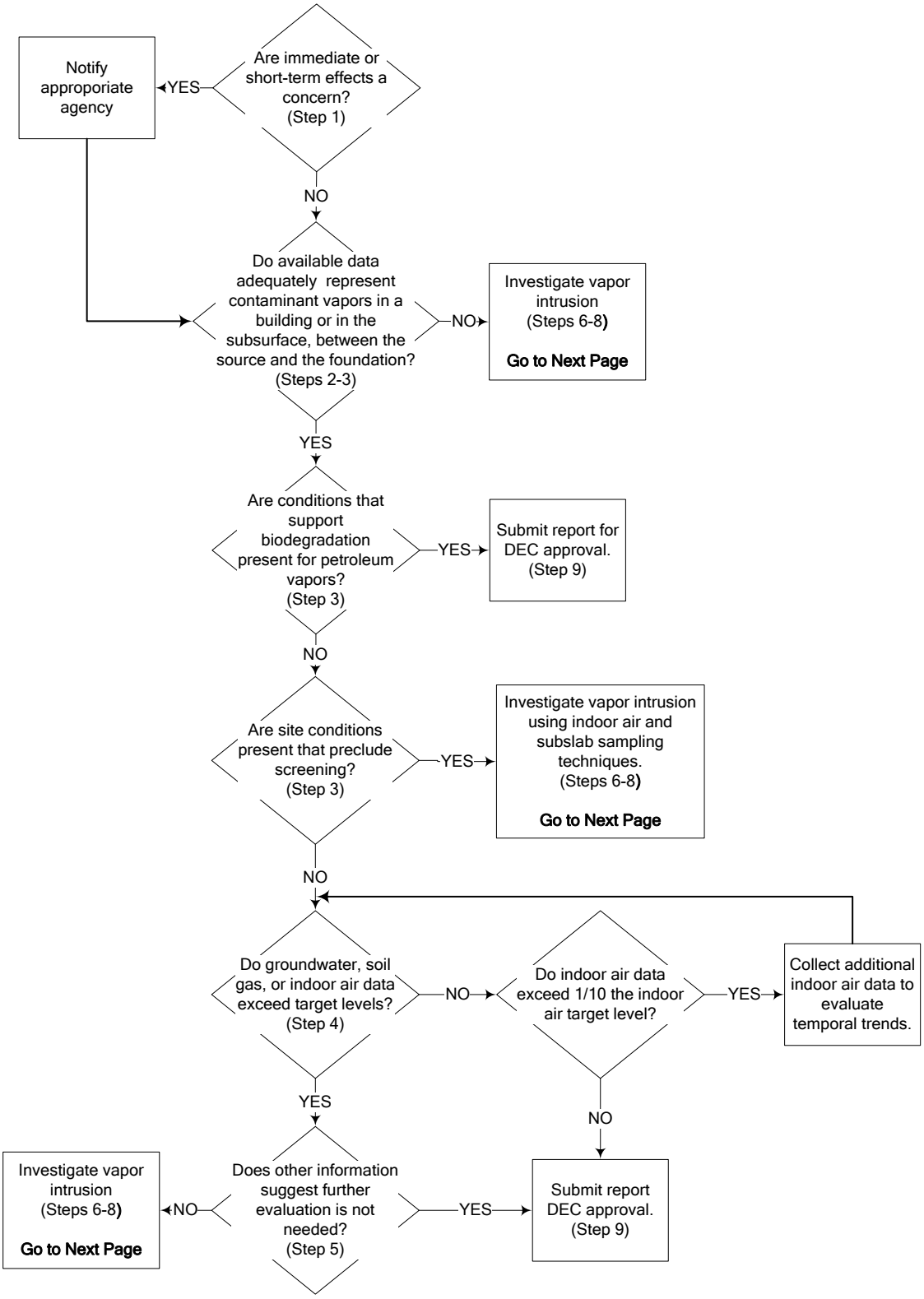
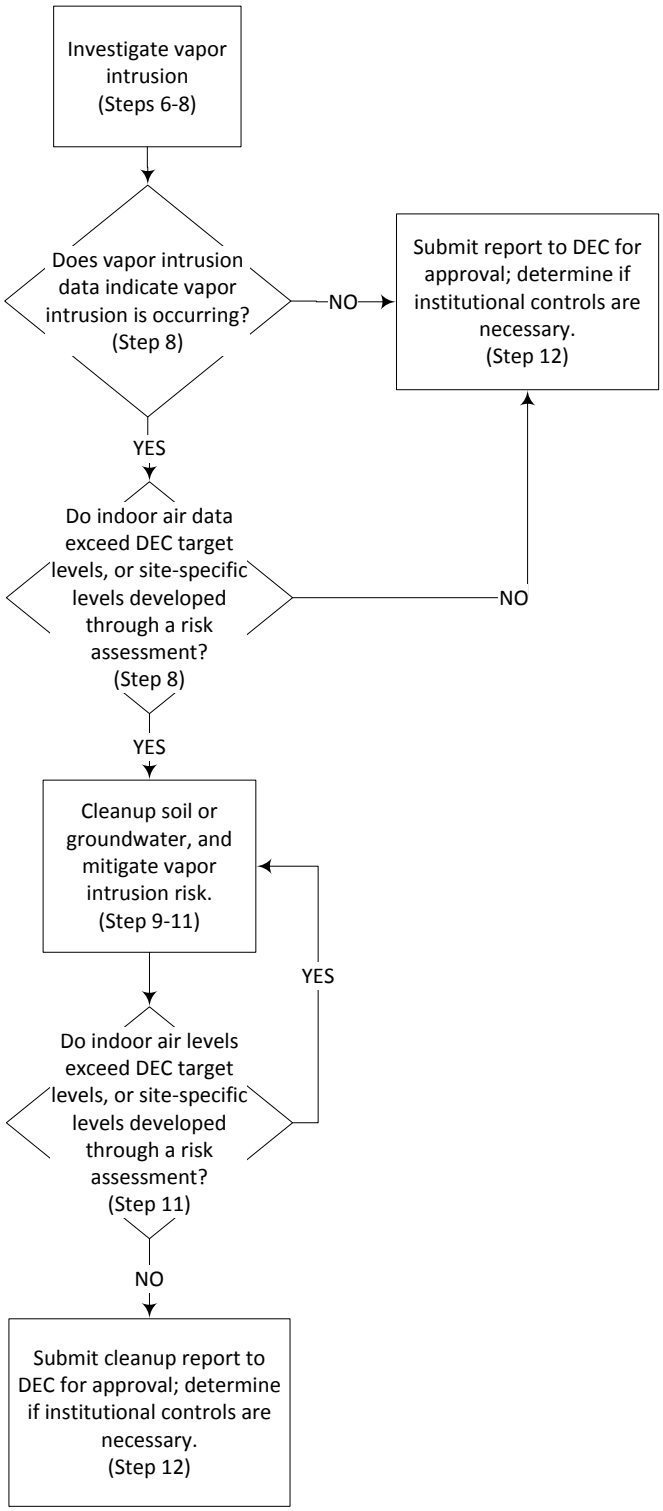


Figure 3, continued: Decision points in a vapor intrusion evaluation.



Policy Guidance on Developing Conceptual Site Models (2005) provides more clarification on these criteria. Alaska state regulations require that a qualified person complete and report on the investigative and cleanup work described in this document.

Step 1: Check for Explosive or Short-Term Exposure Threats

In addition to long-term and chronic health risks, vapor intrusion can cause explosions and acute health effects. Thus, the first step of the vapor intrusion assessment is to determine if conditions represent an immediate or short-term threat to human health and notify the appropriate agencies. This step should be considered as soon as there is knowledge of a release and should be revisited any time new information becomes available.

During an initial response, an investigator may use monitoring devices (e.g., photoionization detector or combustible gas indicator), interviews with building occupants, and general knowledge of the site to evaluate whether contaminants could be present indoors. DEC encourages the use of other screening methods to determine if high levels of contaminants are present in indoor air; however, detection levels must be carefully considered as many screening methods cannot detect indoor air contaminants at levels that could cause health effects. Examples of screening methods that may be useful during Step 1 include gas detector tubes and passive air samplers. Analytical indoor air samples are usually not available during an initial response, but should be considered when conditions suggest that vapors may be present (see Section V, "Indoor Air Sampling").

When evaluating immediate or short-term risks, take the following actions:

- Notify DEC's Prevention and Emergency Response Program (PERP) if a release has just occurred or been discovered,
- Notify the fire department immediately if explosive levels are present or suspected.
- Notify DEC's Contaminated Sites Program (CSP) when odors, physiological symptoms, or screening devices indicate vapors are present in buildings above indoor air levels described in this guidance.
- Notify Alaska Occupational Safety and Health (AKOSH) when indoor air contaminants are present in a workplace above Permissible Exposure Limits (PELs). PELs can be found at the following web link: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992

When there is evidence that public health may be affected by vapor intrusion, the DEC project manager will contact the State of Alaska Division of Public Health (DPH) immediately and determine what steps should be taken. If indoor air or soil gas samples are available, DPH will be notified under the following conditions:

- Indoor air concentrations exceed Agency for Toxic Substances and Disease Registry (ATSDR) inhalation minimal risk levels (Appendix B); or

- Subslab or near-slab (see Section V, "Soil Gas Sampling") soil gas concentrations are more than 10 times the ATSDR inhalation levels (Appendix B) or 1,000 times the DEC target indoor air levels (Appendix D).

If DPH concludes there is a public health threat from vapor intrusion, the investigator should evaluate alternatives for addressing the risk as described in Step 9.

Step 2: Refine the CSM for Vapor Intrusion

The CSM is first developed during the initial stages of a contaminated site investigation in accordance with the DEC's CSM Guidance. The CSM will identify the vapor intrusion pathway as complete when volatile and toxic compounds are suspected to be present near an occupied building or where a building could be built in the future. The CSM Guidance contains a list of volatile compounds and discusses when a building is close enough to contamination to prompt additional evaluation (30 feet from a petroleum source and 100 feet from a non-petroleum source).

Once determined to be complete, the vapor intrusion pathway must be evaluated further as described in this guidance. During this step, the investigator refines the CSM to better describe vapor transport at the site and to prepare for the data quality review in Step 3. A checklist to assist with refinement of the CSM is provided in Appendix C.

The investigator should consider the following precautions while developing the CSM.

- Volatile compounds may naturally degrade into other volatile compounds that need to be evaluated (e.g., trichloroethene can break down to vinyl chloride);
- The distance that volatile compounds may migrate in soil, groundwater, or soil gas is dependent on soil types, subsurface heterogeneity, length of time after release, as well as the mass of contamination. Vapors migrate more easily through dry, coarse-grained soil.
- Preferential pathways, such as subsurface fractures, utility conduits, and drains or sumps that open to the subsurface, may allow vapors to migrate more easily toward or into a building and must be identified.
- Caps around a building, such as an asphalt driveway or frozen ground, may reduce volatilization to outdoor air and increase the concentration of contaminants near the building foundation.
- Buildings with tight construction, inadequate ventilation, or large stack effects are more likely to induce vapor intrusion, particularly during winter months. However, preliminary evidence from a few chlorinated solvent sites in Alaska suggests vapor intrusion into some building may be the most pronounced in late summer or fall. Thus, seasonal variation should be considered at all sites.
- Vapor intrusion is less likely in buildings with a positive pressure ventilation system, a subsurface depressurization system, or a sealed subsurface vapor barrier. However, the potential for building systems to change or become less effective in the future should also be considered.
- Future use of a site may present more of a vapor intrusion risk than the current use. The potential for construction near a vapor source should be considered.

Remodeling of existing buildings or changes in ventilation could also increase the potential for vapor intrusion. A home that is refurbished to be more energy efficient may also be more air-tight and thus more susceptible to vapor accumulation.

Once all the site information has been evaluated and considered in the CSM, continue on to Step 3.

Step 3: Characterize Site and Review Data Quality

During this step, the investigator compiles and evaluates existing analytical data for screening against default target levels in Step 4. Often, site investigation begins before vapor intrusion pathway is even considered and some analytical data may already exist to compare with vapor intrusion target levels. Careful review of that data is necessary. The most useful data for Step 4 include sample results from groundwater, soil gas, and indoor air collected in or near occupied buildings. Soil data collection is useful for investigating the nature and extent of contamination and evaluating the potential for vapor intrusion; however, DEC has not calculated target levels for soil and soil data can only be used qualitatively.

The quality and representativeness of the compiled data should be carefully considered before making a decision regarding the vapor intrusion pathway. Investigators must evaluate the data to determine whether:

- All contaminants of concern (COCs) have been identified and investigated. Any volatile compound that may be present at a site should be investigated as a COC, including degradation products. Volatile compounds, including those that should be investigated at petroleum release, are listed in Table B-1 of DEC's CSM Guidance.
- Data have been collected following applicable DEC guidance; groundwater, soil gas, and indoor air data must be collected following procedures and considerations described in Section V.
- The data are adequate for representing contaminant vapors, either in the building, or in the subsurface between the source and the foundation. Data limitations, including temporal and spatial considerations, are summarized in Section V and must be carefully reviewed.
- Laboratory analyses are of acceptable quality, as determined by DEC's Laboratory Data Review Checklist, available at http://www.dec.state.ak.us/spar/guidance.htm#methods.

In many cases, useful quantitative data for screening vapor intrusion risk will not be available at this step in the evaluation. If this is the case, consider collecting additional site characterization data under a DEC-approved workplan using data collection methods described in Section V.

The soil gas and groundwater target levels discussed in Step 4 may underestimate vapor intrusion when certain site conditions are present (EPA, 2002). DEC recommends that

soil gas and groundwater data not be used for screening in Step 4 when the following precluding conditions are present:

- Do not use soil gas data for screening when NAPL is in contact with the building foundation.
- Do not use groundwater data for screening when groundwater contamination is present within 5 feet of a foundation.
- Do not use soil gas or groundwater data for screening when a vapor source is present within 15 feet of a foundation, and one or more of the following exists:
    - Buildings with significant openings to the subsurface (e.g., sumps, unlined crawl spaces, earthen floors);
    - Significant preferential pathways, either naturally occurring or anthropogenic; or
    - Buildings with very low air exchange rates (< 0.25 air exchanges/hour) or very high sustained indoor/outdoor pressure differentials (> 10 Pascals).

When precluding conditions are present, indoor air samples may be the best option for evaluating exposure within the building.

If the data are of sufficient quality, adequately represent the vapor intrusion pathway, and no precluding conditions prevent use of the available data, go to Step 4. Otherwise, move to Step 6 to begin a vapor intrusion investigation, or consider mitigation.

Biodegradation at petroleum sites: Petroleum vapors are known to biodegrade easily in aerobic conditions, but the target levels discussed in Step 4 do not account for biodegradation. If soil data or knowledge of the site indicate clean, oxygenated soil is present between the source and the foundation, the investigator should consider skipping to Step 5 to evaluate the potential for biodegradation. See Section VI, "Petroleum Biodegradation" for more information.

Step 4: Compare Contaminant Data to Target Levels

The target levels are conservative, risk-based screening levels that have been developed by DEC using chemical-specific parameters in DEC's Cleanup Level Guidance (2008). Indoor air target levels are calculated according to methods described by EPA (EPA, 2008) and are based on a cancer risk of 10^{-5} and a hazard quotient of 1. Soil gas and groundwater screening levels are calculated by applying an attenuation factor to the indoor air target levels and estimating soil gas partitioning from the groundwater using Henry's Law Constant (EPA, 2002). DEC is currently using the following conservative attenuation factors in this calculation:

- Shallow soil gas – attenuation factor of 0.1
- Deep soil gas – attenuation factor of 0.01
- Groundwater – attenuation factor of 0.001

DEC has not calculated target levels for analytical soil data because of the uncertainty in using these data to estimate soil gas partitioning. Soil data can be used qualitatively to determine if and where a vapor source is present, but cannot be used quantitatively to screen out the pathway. As a rule of thumb, if cleanup has removed COCs in soil down to

the most stringent cleanup levels in 18 AAC 75, Table B1 and B2, for all volatile COCs, DEC will not require further evaluation of vapor intrusion from a soil source.

Target levels are available for both residential and commercial/industrial properties and can be used for volatile compounds sampled in the following media:

- Indoor air, including crawl space air (Appendix D)
- Shallow or subslab soil gas collected 5 feet or less from a foundation or from the ground surface (Appendix E)
- Deep soil gas collected more than 5 feet from a foundation or from the ground surface (Appendix F)
- Groundwater (Appendix G)

Temperature adjustment for groundwater target levels: Groundwater target levels are calculated by applying the Henry's Law Constant to the concentration in groundwater in order to estimate the concentration in soil gas. DEC uses a constant based on a temperature of 25ºC. The investigator may propose alternative groundwater target levels using a Henry's Law Constant adjusted for the groundwater temperature documented at the site. For assistance with this calculation see http://www.epa.gov/athen.learn2model/part-two/onsite/esthenry.html.

The investigator must consider the CSM and the location of the vapor source in relation to the building when deciding which target levels to use. For example, when a vapor source is located 5 feet beneath a foundation, soil gas data collected at 10 feet and compared to deep soil gas target levels will not adequately represent vapors that could migrate into the building. Similarly, groundwater data should not be compared to groundwater target levels when the vapor source is NAPL or soil contamination is near the building.

Use residential target levels when buildings are lived in or when land use is uncertain. It is also DEC's policy to evaluate day care centers and schools as a residential use because of the sensitivity of the exposed population (children). Commercial/industrial levels can be used when contamination is near buildings occupied by workers that are present for a standard work week (8-10 hours per day, 5 days a week) or less. If individual workers are present for more than a standard work week, or if sensitive receptors are present, DEC may require use of the residential level or development of a site-specific target level.

Occupational standards: In scenarios where significant background vapor sources are present because of commercial or industrial use, the U.S. Occupational Safety and Health Administration (OSHA) standards and requirements may be applicable. AKOSH has adopted OSHA regulations for worker exposure to volatile chemicals in industrial work places. In these cases, DEC will generally defer to the OSHA PELs in occupational settings if the COCs for vapor intrusion are the same as job-related chemical exposures regulated by OSHA.

Although DEC may accept OSHA air standards to evaluate contaminant levels in indoor air, additional investigation may also be required. At some locations, land use could change from occupational to residential and vapor intrusion should be evaluated to assess the future risk.

If data exceed the target levels, go on to Step 5. If the indoor air concentrations of any COC exceeds one tenth of the indoor air target level, DEC recommends at least

two rounds of sampling to investigate variability and seasonal trends before deciding if further work is necessary.

When sample data meet the criteria identified in Step 3 and are below the DEC target levels, no further evaluation of the vapor intrusion pathway is necessary and a report should be submitted to DEC that documents the results of Steps 1 through 4. Step 9 discusses this report in more detail.

Step 5: Decide if Further Evaluation is Needed

The assessment of vapor intrusion can be a complex task. Whenever possible, decisions regarding this pathway should be made through a weight-of-evidence approach instead of a simple comparison to target levels. Exceeding a target level does not automatically imply that receptors are at risk or the pathway is complete.

DEC may decide no further evaluation is necessary when the vapor source is small, or is more than 20 feet beneath the foundation, and one or more of the following factors are present:

- The source contains only low concentrations of volatile compounds (e.g., weathered diesel);
- Subsurface conditions limit vapor migration from the source to the foundation (e.g., low-permeability soils);
- Subsurface conditions promote biodegradation of a petroleum source. Clean, oxygenated soil between the source and the building foundation often promotes biodegradation and provides an effective barrier to vapor intrusion (see Section VI, "Petroleum Biodegradation");
- Poor outdoor or indoor air quality from background sources that cannot be controlled during sampling masks any potential contribution from vapor intrusion (see Section VI, "Background Air Levels");
- Limited building occupancy or use, although institutional controls may need to be considered for future buildings or building operation;
- Building characteristics reduce or dilute vapor intrusion (e.g., vapor barriers and ventilation systems). Again, institutional controls may be needed to maintain these characteristics.

***Institutional Controls**:* When DEC decides that no further evaluation is warranted, institutional controls may be required to ensure the vapor intrusion pathway is considered if site conditions (or building conditions) change. Institutional controls may be useful when buildings are not present, but could be built in the future. For additional information on institutional controls, see Section VIII.

Predictive modeling may also be useful as additional evidence for supporting decisions at this stage, but should be limited to peer-reviewed and publicly available models (see Section VI, "Predictive Modeling").

When site data exceed the vapor intrusion target levels and the investigator decides further evaluation is necessary, go on to Step 6 to plan an investigation, or consider

moving directly to mitigation or cleanup (Step 10). If the investigator determines no further evaluation is needed, proceed to Step 9 and submit a report to DEC documenting the available data and conclusions.

Step 6: Choose an Investigative Strategy

The investigative strategy must be chosen based on all available site data, a careful review of the CSM, and professional judgment. When choosing an investigative strategy, the investigator should work closely with the DEC project manager. An investigation often occurs in phases and the strategic approach may change as more information becomes available. Initially, the investigation should focus on occupied buildings that represent worst-case scenarios, such as residences, buildings closest to the source, or those most susceptible to vapor intrusion.

Three basic strategies can be used during an investigation:

- Exterior sampling – Soil gas or groundwater samples are collected outside the building.
- Interior sampling – Indoor air samples are collected inside the building or soil gas samples are collected directly beneath the building foundation (subslab).
- Multiple lines of evidence – Samples are collected concurrently from indoor air, outdoor air, and subslab or near-slab (within 10 feet of the building) soil gas.

Different sampling approaches can be used within each strategy. Each sampling approach has different advantages and disadvantages, as summarized in Table 2 and described further in Section V. The investigative strategy is best decided on a site-specific basis in consultation with the DEC project manager.

Generally, DEC recommends starting with exterior samples when the vapor source is located away from the building or the location is not known. If soil gas and groundwater data exceed target levels within 10 feet of the building or if other information is available that suggests the vapor intrusion potential is high, indoor air samples should be collected to determine if exposure is occurring above risk-based levels.

When collecting indoor air samples, DEC recommends simultaneously collecting outdoor air and subslab or near-slab soil gas samples. This strategy, commonly known as “multiple lines of evidence”, has been used successfully in Alaska, particularly where chlorinated solvents were spilled near a building. Additional information about this strategy is provided in Section VI, “Multiple Lines of Evidence”.If vapor migration along preferential pathways is suspected, soil gas samples may not adequately represent vapor migration to indoor air.

Multiple Lines of Evidence Sampling:
Multiple lines of evidence is the most comprehensive strategy to a vapor intrusion evaluation when evidence already exists suggesting that vapor intrusion is occurring. By collecting a combination of sample types, the investigator will be able to evaluate background chemical interferences, estimate risk to receptors, directly measure the vapor source strength in the subsurface, and evaluate the vapor intrusion potential for future receptors.

Table 2: Advantages and disadvantages of various investigative strategies and sampling approaches.

Sampling Approach	Useful References	Advantages	Disadvantages
EXTERIOR INVESTIGATIONS			
Groundwater	ITRC, 2007 (Section D-2)	• Monitoring wells often already present. • Minimal variability.	• Monitoring wells may not be constructed correctly or close enough to a building. • Groundwater target levels are conservative and may overestimate risk.
Active Soil Gas	ITRC, 2007 (Section D-4) API, 2005 DTSC, 2003	• Direct measure of vapors in the soil. • Minimal variability expected in deep soil gas samples. • Vertical or horizontal transects can be used to locate source areas or evaluate vapor attenuation.	• Variability may be a problem in shallow soil gas or samples collected near the foundation. • Air leakage from the surface is possible in shallow soil gas samples. • Soil gas target levels are conservative and may overestimate risk.
Passive Soil Gas	ITRC, 2007 (Section D-5)	• Simple method to investigate contaminant source areas and vapor migration pathways.	• Not suitable as the only investigative method because results are provided in units of mass instead of concentration.
Utility vapor screening	Contact Utility	• Important when a utility corridor may be a preferential pathway into a building.	• Screening in or around utilities can be a dangerous activity and must be coordinated with the utility.
INTERIOR INVESTIGATIONS			
Subslab Soil Gas	ITRC, 2007 (Section D-6) API, 2005 EPA, 2006	• Best measure of vapors that may be entering a building. • Can assist with data interpretation when background sources are present. • Cost is comparable or cheaper than exterior soil gas sampling.	• In some cases, volatile compounds from background sources can migrate beneath the slab. • Requires building access and permission to drill through slab. • Variability may be a problem.
Crawl Space	ITRC, 2007 (Section D-9)	• Can be used as an alternative to subslab sampling when no slab is present.	• Results need to be evaluated as indoor air unless attenuation between the crawl space and the living space are demonstrated. • Background sources could affect crawl space air.
Indoor Air	ITRC, 2007 (Section D-8)	• Direct measure of the risk to building occupants. • Identifies immediate health concerns.	• Data interpretations can be complicated by background chemical concentrations. • Significant temporal and spatial variability possible. • Future vapor intrusion potential can be difficult to assess with indoor air data.
MULTIPLE LINES OF EVIDENCE INVESTIGATIONS			
Indoor, Outdoor, and Subslab or Near-slab Soil Gas	ITRC, 2007 (Section D-6) EPA, 2006 EPRI, 2005	• This strategy is particularly useful when background sources are present.	• Requires more intensive sampling.

Other investigative techniques, including utility vapor screening or indoor air measurements, may provide better data for evaluating the pathway.

The potential for biodegradation at petroleum sites can be assessed by analyzing soil gas samples for fixed gasses (O_2, CO_2, and CH_4) between the source and the building foundation. This will allow an evaluation of biodegradation potential and attenuation rates at petroleum sites, as described in Section VI, "Petroleum Biodegradation".

Once an investigative strategy has been chosen, proceed to Step 7.

Step 7: Submit Workplan for DEC Approval and Implement

A vapor intrusion workplan may not be the first workplan developed for the site. Typically, a site characterization or release investigation will be underway and the investigator will have a basic understanding of the nature and extent of contamination. Depending on the overall site goals at the time the vapor intrusion pathway is identified, the investigator may choose to develop the vapor intrusion workplan alone, or as part of a site characterization workplan.

When developing the workplan, the following elements should be included:

- Discussion of CSM – Describe refinements to the CSM in Step 2.
- Discussion of data gaps – Demonstrate that the investigative strategy is designed to fill data gaps identified in Step 3.
- Locations to be investigated – Identify which properties or buildings require investigation. A phased approach, starting with the buildings closest to the source and expanding radially, is acceptable when multiple buildings are a concern. Specific criteria should be established to determine when and where to extend the investigation to other buildings.
- Building Inventory and Indoor Air Sampling Questionnaire – Complete Part 1 of DEC's questionnaire (Appendix I) for each building under investigation. The questionnaire will help the investigator identify building characteristics and possible vapor-entry points that will influence the vapor intrusion pathway. Be sure to identify any utilities that should be avoided during subslab drilling activities.
- Building walkthrough – If the workplan includes indoor air sampling, plan to conduct a building walkthrough at least 24 hours before collecting the samples. During the walkthrough, possible sources of background contaminants should be removed. Part 2 of DEC's questionnaire (Appendix I) includes a building walkthrough form that can be completed at this time.
- Sampling and analysis plan – Describe the methods for collecting and analyzing soil gas, indoor air, outdoor (background) air, or groundwater samples.
- Field schedule – Provide proposed dates for field work. Inform the DEC project manager of any changes to the schedule. DEC may conduct random field inspections during vapor intrusion investigations.

DEC approval must be obtained before implementing the workplan. When interior samples will be collected, workplans must be coordinated with building owners and occupants. Sampling dates and times may need to be chosen that minimize the potential for background interference from chemical usage in the building. Soil gas and indoor air sampling may be affected by inclement weather; therefore, workplan implementation should accommodate potential schedule delays.

Community Outreach:

Community outreach should be part of the vapor intrusion assessment process to facilitate workplan implementation and for open communication between DEC and the affected building occupants. Potentially affected building occupants should be informed early in the process when a vapor intrusion investigation is planned.

DEC has developed general vapor intrusion fact sheets for the public, located at http://www.dec.state.ak.us/spar/csp/vi.htm. Investigators also may need to develop site-specific fact sheets. DEC's vapor intrusion workgroup staff and DEC's public outreach staff are available for guidance when a significant concern about indoor air quality arises, especially when multiple properties are involved.

Step 8: Evaluate Vapor Intrusion Potential and Risk to Receptors

The objectives of a vapor intrusion investigation are two-fold: 1) determine if vapor intrusion into a building is occurring, and 2) determine if interior vapor concentrations resulting from vapor intrusion pose a risk to the occupants or future occupants. Once vapor intrusion data have been collected, the investigator must interpret the results to address the objectives above.

Data collected in a vapor intrusion investigation should first be reviewed to determine the potential for short-term exposure of building occupants, as described in Step 1. If short-term exposures are documented, the procedures identified in Step 1 should be followed.

Steps 2 and 3 also should be revisited to determine if the CSM should be revised, data quality is acceptable, and how contaminant levels compare to target levels. If data gaps at this stage prevent achievement of the investigative objectives, the investigator should propose additional sampling or evaluation. DEC may require submittal of another workplan (Step 7).

The initial data interpretation usually includes comparing them to the target levels, as described in Step 4. If the concentrations exceed target levels, the risk at the site can be further evaluated through more advanced methods, including site-specific risk assessment, predictive modeling, and measuring biodegradation parameters. These techniques are discussed further in Section VI.

Sufficient investigation has been completed when the investigator can address the objectives described above. At this point, the investigator summarizes the data and their interpretation of the data in a vapor intrusion report as described in Step 9.

Step 9: Submit Report to DEC with Recommendations for Cleanup

In this last step of the vapor intrusion evaluation before the cleanup phase begins, the investigative results, data evaluation, and recommendations should be documented in a report and submitted to DEC. This report will often be included in a more general site characterization or release investigation report, but could be submitted separately. The report must be prepared by a qualified person and should address the following:

- Describe activities completed in accordance with the vapor intrusion investigation workplan.
- Summarize the sampling and analysis results.
- Demonstrate that the data adequately characterizes the extent of vapors that may enter a current or future building.
- Propose cleanup alternatives for the site that address the vapor intrusion risk.

Vapor intrusion may not be the only pathway of concern at a site. The cleanup approach should must account for all applicable pathways and comply with all regulations. Along with the proposed cleanup alternatives, the investigator should provide an analysis of each alternative based on the following five criteria:

- Protectiveness – How well does each alternative protect human health, safety, welfare or the environment, both during and after the cleanup action?
- Practicable – Are the technologies/techniques under consideration capable of being designed, constructed, and implemented in a reliable and cost-effective manner? What alternatives are the most cost effective?
- Short- and Long-term Effectiveness – Are there potential adverse effects to human health, safety and welfare, or the environment during construction or implementation of the alternative? How fast does the alternative reach cleanup goals? How well does the alternative protect human health, safety, and welfare or the environment after completion of the cleanup? What, if any, risks will remain at the site?
- Regulations – Will the alternative comply with all state and federal regulations?
- Public Input – Have comments received from the community regarding each alternative been considered and addressed?

For more information on conducting a cleanup alternatives analysis, refer to EPA's March 1990 Fact Sheet entitled "The Feasibility Study: Detailed Analysis of Remedial Action Alternatives", which can be found at http://www.epa.gov/superfund/policy/remedy/pdfs/93-55301fs4-s.pdf. The complexity of the alternatives analysis should be scaled to the specific site.

If cleanup is not warranted, submittal of the vapor intrusion report will be the final step of the vapor intrusion evaluation. If further work is required, proceed to Step 10 to develop the cleanup plan.

Step 10: Submit Cleanup or Corrective Action Plan for DEC Approval and Implement

If the investigator determines site conditions pose a current or future indoor inhalation risk during Step 8, DEC will require that the risk be reduced through a cleanup or corrective action, if feasible. Cleanup typically includes soil or groundwater remediation to remove the source of the contaminant vapors and is DEC's preferred method for addressing the risks from contamination. However, soil and groundwater cleanup may not be an effective approach for addressing a current exposure to vapors. In these cases, mitigation strategies may be needed by themselves or in concert with cleanup to temporarily control the risk until the contamination naturally degrades or the site conditions change. Mitigation includes systems or controls associated with a building that treat contaminants in indoor air (e.g. filtering systems) or prevent vapors from entering a building (e.g. heating and ventilation systems that create a positive pressure in the building, depressurization systems that create a negative pressure beneath the building foundation).

Once a cleanup alternative is chosen, as described in Step 9, a cleanup or corrective action plan should be prepared that includes, at a minimum, the following elements:

- The selected cleanup alternative and the rationale for selection.
- An exit strategy that describes the criteria for ceasing the cleanup or mitigation efforts.
- A sampling and analysis plan to determine the effectiveness of the cleanup or the mitigation and satisfy the needs of the exit strategy.
- A description of how institutional controls, if needed, will be established to ensure remedial effectiveness.
- A schedule for implementation and monitoring.
- Detailed specifications for any soil or groundwater cleanup technique that is proposed.
- Other applicable requirements of 18 AAC 75.360 for the selected strategy.

The cleanup plan must be submitted to DEC for approval before implementing the cleanup. On small sites or sites with a simple cleanup strategy, the cleanup plan can be included in the vapor intrusion report to expedite the process. Further information and helpful resources for installing mitigation systems in Alaska are discussed in Section VII. Institutional controls are discussed in Section VIII.

Step 11: Evaluate Data to Confirm Cleanup or Mitigation Effectiveness for Vapor Intrusion

After the cleanup plan has been implemented, buildings of concern should be evaluated to determine if the cleanup was effective in reducing vapor intrusion. This evaluation will

usually be based on indoor air or soil gas monitoring and will be similar to the data review processes described in Steps 4 and 8. The number of monitoring events and type of sampling will be decided on a site-specific basis and should be described in the exit strategy included in the cleanup plan. As with any sampling steps, it is important to review the data quality and to consider how temporal and spatial variability may affect the results. Soil gas monitoring or other types of confirmation samples may be sufficient for some remedial approaches, such as excavation.

After a cleanup, 18 AAC 75.325(g) requires calculation of cumulative risk. Cumulative risk calculations should be based on indoor air analytical results. If indoor air results are not available or do not represent vapor intrusion contamination, cumulative risk calculations for the vapor intrusion pathway may be based on subslab soil gas or near-slab soil gas data. DEC will generally not require calculation of cumulative risk based on exterior soil gas or groundwater data.

If data indicate that contaminant vapors in the subsurface or those migrating into indoor air exceed the target levels after the cleanup, the cleanup plan may need to be revisited and additional strategies considered. Once the cleanup is complete or enters into a long-term monitoring phase, proceed to Step 12.

Step 12: Submit Final Report to DEC

Once vapor intrusion cleanup and mitigation actions have been completed and the effectiveness of these actions evaluated, the qualified person should document these activities and submit the results to DEC as part of the final site report. The report should include a description of any institutional controls established at the site to prevent future vapor intrusion or unacceptable risk from this pathway (see Section VIII). DEC may require long-term monitoring to track effectiveness of mitigation systems or reporting to track conditions that could affect decisions made about the site. If this is the case, a long-term monitoring or reporting plan should be submitted with the final report.

DEC will review and comment on the report. If DEC approves the report, a closure determination may be issued. However, this determination is rarely based on vapor intrusion alone; therefore the site may remain open until other concerns not related to vapor intrusion have been addressed.

V. DATA COLLECTION AND INTERPRETATION

This section will describe different sampling approaches, recommend sampling methods, and discuss considerations that could affect data quality. Appendix D of the ITRC Vapor Intrusion Guidance (2007) should be consulted for additional tools that may be useful in a vapor intrusion investigation.

Groundwater Sampling

In general, DEC does not recommend installation of new monitoring wells for investigating vapor intrusion because soil gas samples provide a more direct measure of migrating vapors. When groundwater contamination is the primary source for vapor

intrusion, the investigator may use groundwater data to determine if further investigation is needed. Groundwater data are useful because the groundwater concentration of a particular compound multiplied by its Henry's Law constant provides an estimate of the soil gas concentration immediately above the groundwater interface. This calculation assumes equilibrium partitioning across the groundwater interface; therefore, groundwater samples most accurately represent concentrations of volatile compounds at the groundwater interface. Monitoring well design and sampling techniques are important considerations when collecting groundwater data for this purpose.

Important guidelines when evaluating groundwater data or collecting additional data include the following:

- If a source of vapors (e.g., NAPL, soil contamination) exists above the groundwater surface near a structure, do not use groundwater data to rule out vapor intrusion.
- Collect groundwater samples from wells screened across the groundwater interface at the time of sampling. Samples should represent contaminant concentrations at the groundwater surface and must be collected from the upper 5 feet of the water column.
- Minimize volatilization losses during sample collection. Spatial and temporal seasonal variability of the groundwater contamination should be characterized.

Groundwater Sample Location

Before using groundwater data to rule out further evaluation of the vapor intrusion pathway, groundwater contamination should be sufficiently characterized to estimate the highest potential concentrations near any current or future building. For screening against the target vapor intrusion levels, use groundwater data that is between the source and the building, and as close to the building as possible. When groundwater contamination extends beneath a building, the investigator should use groundwater data collected immediately upgradient of the building. If these data are not available, surrounding data points may be interpolated to construct contaminant isoconcentration maps.

Monitoring Well Design and Groundwater Sampling Techniques

Installation and sampling of groundwater monitoring wells shall follow procedures described in DEC's *Monitoring Well Guidance* (2009) and *Underground Storage Tanks Procedures Manual* (2002), unless DEC approves an alternate technique such as sampling with passive diffusion bags.

Groundwater samples can be collected from monitoring wells or direct-push probes, but the screen length should be no greater than 10 feet. Shorter screen lengths are preferred because less water from deeper in the aquifer enters the well and dilutes the sample. Ideally, the thickness of the water column in the well should also be 10 feet or less. Some advantages and disadvantages of different well installation techniques are described in Table 3.

Table 3: Monitoring well installation methods.

Method	Advantages	Disadvantages
Direct-push probes	• Can do vertical profiling, discreet interval sampling, and defined depth intervals. • Rapid sampling at multiple locations.	• Not intended as a permanent well, which is required for long-term monitoring. (See DEC Monitoring Well Guidance, 2008) • Some methods limited to unconsolidated formations.
Monitoring wells	• Allows for long-term, repeat sampling. • Suitable for a variety of sample collection methods. • Screened interval can tolerate water level fluctuations.	• Installing new wells solely for evaluating the vapor intrusion pathway are not recommended. Consider installing soil gas probes instead.

Groundwater sampling methods that minimize the loss of volatile compounds during sample collection and handling are necessary. DEC recommends the use of bladder pumps and submersible pumps for low-flow purging and sampling. Other methods, such as peristaltic pumps, passive diffusion-bag samplers, and Hydrasleeves®, may be useful, as described in Table 4 below.

Table 4: Groundwater sampling methods.

Method	Advantages	Disadvantages
Bladder Pumps and Submersible Pumps	• Little disturbance of water column if deployed carefully. • Pumps operate at a low flow rate, minimizing volatile loss.	• Pumps require power and maintenance. • Pump must be dedicated or cleaned between uses.
Peristaltic Pumps	• Little disturbance of water column. • Pumps operate at low flow rate, minimizing volatile loss.	• Applies vacuum to water sample which may affect gas dissolution in the sample. • Should only be used for sampling shallow groundwater (less than 15 feet from the ground surface).
Passive sampling devices (passive diffusion bags and Hydrasleeves®)	• Does not require purging • Minimize well disturbance and loss of volatiles. • Easy to use for repeat sampling. • Suitable for a variety of sample collection methods.	• Passive diffusion bags require being left in the well for a minimum of two weeks.

Monitoring wells should be purged using low-flow techniques to remove stagnant casing water from the well. If evaluating vapor intrusion is the only sampling objective, DEC recommends two modifications to the typical low-flow purging and sampling procedure:

- Set the pump intake level as close to the groundwater surface as possible without causing the water level to drop and expose the pump intake. For wells in formations with average or high permeability, about 1.5 feet to 2 feet below the static water level should be an adequate intake location.
- The purging objective is to flush two casing volumes of groundwater through the sampling array (tubing and pump, etc.).
- Drawdown should be measured and not exceed 0.3 feet.

Bailers are not recommended for sampling because the bailer agitates the water column and collects a volume-averaged sample that may not represent the top of the water column. If bailers are used, the reported data should be qualified as an underestimate.

Other Considerations for Collecting and Using Groundwater Data

Additional considerations for obtaining new groundwater data or evaluating old data for a vapor intrusion evaluation are provided below:

Perched aquifers

Perched aquifers are zones of groundwater isolated from the regional aquifer by an impermeable soil layer. If a perched aquifer exists above the regional aquifer, it may be appropriate to collect samples from both the perched zone and regional shallow aquifer to obtain a representative sample of all of the potential sources of vapors. The perched aquifer, although not hydraulically connected, could be the largest source of vapors for an overlying building and should be sampled if it is of sufficient thickness. A perched saturated zone should be sampled if it is laterally contiguous under or near a building, exists year-round, and is of sufficient thickness to obtain a sample.

Groundwater surface fluctuations

Groundwater can either expose (during dropping water table conditions) or submerge (during rising water table conditions) areas of soil contamination. A dropping water table may lead to greater volatilization. A rising water table can flush contamination from newly-submerged soil and increase the size of the plume. The relationship between groundwater fluctuations, contaminant sources, and vapor migration should be considered when deciding if groundwater data are adequate to evaluate the potential for vapor intrusion. DEC is researching the appropriate time(s) of year to collect these samples in cold climates.

Clean water lens

A diving plume can form when changes in soil permeability result in a downward vertical gradient, or when infiltration from the surface recharges groundwater over a plume. A clean water lens will form over a diving plume that can prevent volatilization from the contaminated groundwater and reduce vapor intrusion from a groundwater source. Because diving plumes are not easy to recognize, but may affect how groundwater data

are interpreted, the investigator should be aware factors that may cause or reduce a clean water lens.

Presence of NAPLs
Before sampling a monitoring well, the column of water in the well casing must be checked for the presence of NAPLs, including free petroleum products that might be floating on top of the water or in a separate layer at the bottom of the well casing. If NAPL is present, a water sample should not be collected.

Drinking water wells
Groundwater samples used to evaluate vapor intrusion should not be collected from drinking water wells. Drinking water wells are generally screened below the groundwater surface.

Soil Gas Sampling

Soil gas can be collected using active or passive methods. Passive soil gas sampling consists of burying an adsorbent media in the ground, which collects vapors over a given time period through diffusion. Passive sampling provides qualitative data in units of mass. This data is useful for locating a vapor source and characterizing the extent of vapor migration, but cannot be used alone to evaluate risk.

Active soil gas sampling, which is discussed further in this section, consists of the withdrawal of soil vapor from the subsurface through a sampling probe or tube into a gas-tight container. This method provides quantitative data in units of concentration and is the preferred contaminant data set for evaluating the potential for vapor intrusion to indoor air.

Soil gas data are reflective of subsurface properties and allow for real-time results. Soil gas data are recommended over other data for characterizing subsurface vapors and the potential for vapor intrusion, because soil gas is a direct measure of the contaminant concentration before it is diluted by ambient air. Drawbacks to this method include potential spatial and temporal variability, inconsistent or poor sample collection techniques, and indirect measurement of the actual risk to a receptor in the building.

Soil gas samples are collected from three primary locations. Soil gas samples collected 10 feet or more from the perimeter of the building are generally referred to as “exterior” samples. “Near-slab” soil gas samples are collected outside a structure but within a short distance (usually 10 feet) of the building’s foundation. Finally, “subslab” soil gas samples are collected from below the building foundation or slab. The collection techniques for near-slab and exterior samples are similar, while the collection of subslab samples has special considerations which will be discussed in the following sections.

Important guidelines when collecting or evaluating soil gas data include the following:

- Collect exterior soil gas samples from depths greater than 18 inches below ground surface to avoid dilution of samples with ambient air.

- Include leak detection when installing soil gas probes at depths less than 10 feet below ground surface or subslab.
- Install surface seals in all soil gas probes using grout or other approved materials.
- Minimize purge volumes and sample flow rates during sampling.
- Do not chill soil gas samples during transport.

Soil Gas Sample Location, Depth, and Frequency

When deciding on soil gas sample locations, the investigator should consider the location of releases, other potential vapor sources, preferential pathways (e.g., utilities or sumps entering a building), and lithology. A sufficient number of samples should be collected to represent the maximum vapor concentrations that could impact the current or future occupied structures. At least three locations should be sampled per building with one in the area of the highest soil or groundwater contamination near or beneath the building.

The sample depth should maximize the chances of detecting contamination, but minimize the effects of changes in barometric pressure, temperature, or breakthrough of ambient air from the surface. Exterior samples should be collected at a minimum depth of 18 inches below surface. Subslab samples are intended to collect the soil gas directly beneath the foundation and should not extend into the soil. Their depth is determined by the thickness of the foundation. Multiple depths should be considered for exterior samples so attenuation factors can be more accurately determined.

Site soil or lithologic information should also be used to select appropriate locations and depths for soil gas probes. The most permeable zones around the building or proposed building should be targeted for sampling even if they are not the closest. If the site consists primarily of low permeability soils, other sampling techniques should be considered, such as passive sampling or indoor air sampling. Excessive vacuum, such as 10 inches of mercury or more, may cause unrepresentative partitioning of the contaminants into the vapor phase. Precautionary consideration should always be given to ensuring that a contaminant pathway is not being created through a low permeability zone.

Seasonal environmental conditions (e.g., changes in soil temperature, soil moisture, snow cover, and frozen ground) and seasonal heating and ventilation of a building can affect volatilization and migration of contaminants in soil gas. If a vapor intrusion potential exists at a site, soil gas sampling should occur in at least two seasons to identify seasonal trends. In some cases, DEC may require soil gas data from more than two seasons.

Soil Gas Probe Installation and Sampling Techniques

Drilling techniques for all soil gas samples, including subslab samples, should minimize soil disturbance as much as possible during installation. The probe is allowed to equilibrate after installation, and the sampling train must be purged before sampling. Additional detail about these procedures is provided below.

Exterior and near-slab soil gas probe installation

DEC recommends using direct push drilling techniques for exterior soil gas sampling. Other techniques, such as rotary drilling, typically have longer equilibration times, but can be proposed in the workplan.

Temporary soil gas probes are installed by driving the probe rod to a predetermined depth and then pulling it back to expose the inlets of the soil gas probe. After sample collection, both the drive rod and tubing are removed. During sampling, hydrated bentonite or some other surface seal should be used around the drive rod at ground surface to prevent ambient air intrusion from occurring. The inner soil gas pathway from probe tip to the surface should be continuously sealed (e.g., a sampling tube attached to a screw adapter fitted with an o-ring and connected to the probe tip) to prevent infiltration.

Permanent or semi-permanent soil gas probes are usually installed when multiple sampling events are planned. A sand pack should be placed around the sample probe and at least one foot of bentonite grout should be applied above the sand pack. Probes should be properly secured, capped, and completed to prevent infiltration of water or ambient air into the subsurface and to prevent accidental damage or vandalism.

Subslab probe installation

A subslab probe is installed by drilling through the foundation with a hand-held drill. Drilling should not extend into or disturb the soil. A typical subslab probe is constructed from small-diameter (⅛- or ¼-inch outside diameter) stainless steel or another inert material and stainless steel compression fittings. A surface seal should be installed around the probe to prevent air leakage into the subslab environment. Subslab probes must also be properly capped, sealed, and completed to prevent infiltration of water or ambient air into the subsurface.

Equilibration time

During probe installation, subsurface conditions are disturbed. To allow for subsurface conditions to equilibrate, the following equilibration times are recommended:

- Probes installed with the direct push method, where the drive rod remains in the ground, should not be used for at least 20 minutes following probe installation.
- Probes installed with the direct push method, where the drive rod does not remain in the ground, should not be used for at least 30 minutes following probe installation.
- Probes installed with hollow-stem drilling methods should not be used for at least 48 hours following probe installation.
- Subslab probes do not disturb the subsurface soil and equilibration is not necessary. However, subslab probes should not be used until the sealant around the probe has cured, as determined by the manufacturer's directions.

Purge volume

The sampling train must be purged before sample collection to ensure stagnant or ambient air is removed from the sampling system. Purge volumes should be kept to a minimum to decrease the chance of leaks, reduce additional partitioning of the

contaminant into the vapor phase, and unnecessary movement of the soil gas to the sampling probe. DEC recommends using sampling trains that minimize the dead-space and purging three to five volumes of the sampling train.

The dead space volume can be estimated by summing the internal volume of tubing used, annular space around the probe tip, and, in some cases, the volume of the sample container. Summa canisters, syringes, and Tedlar® bags are not included in the dead space volume calculation.

Purge and sample flow rate

Sampling and purging flow rates should not enhance compound partitioning during soil gas sampling. DEC recommends purging and sampling at rates between 100 to 200 milliliters per minute to limit stripping, prevent ambient air from diluting the soil gas samples, and to reduce the variability of purging rates. This equates to collection of a 6-liter summa canister over at least 30 minutes. The low-flow purge rate increases the likelihood that representative samples may be collected. The purge/sample rate may be modified based on conditions encountered in individual soil gas probes with DEC approval; however, low flow rates are particularly important when soil gas samples are being collected from a shallow depth.

Tubing

Sampling tubes should be of a small diameter (⅛ to ¼ inch) to prevent turbulent flow and made of material, such as nylon, stainless steel, or Teflon®, that will not react or interact with site contaminants. Clean, dry tubing should be used at all times. If moisture, water, or an unknown material is present in the probe before insertion, the tubing should be decontaminated or replaced.

Sample systems with vacuum pumps

Soil gas samples from collection systems that use vacuum pumps should be collected on the intake side of the pump to prevent potential contamination from the pump. Also, because the pressure on the intake side of the pump is less than atmospheric pressure, soil gas samples must be collected with adequate collection devices, such as those with gas-tight syringes and valves, to ensure that the samples are not diluted by outside air.

Leak test

Leakage during soil gas sampling may dilute samples with ambient air and produce results that underestimate actual site concentrations or contaminate the sample with external contaminants. Leak tests should be conducted at every soil gas probe, unless otherwise approved by DEC, and at any location where ambient air could enter the sampling system or where cross contamination may occur. During a leak test, tracer compounds, such as helium, pentane, isopropanol, isobutene, propane, or butane, are applied around the sampling train immediately before sampling. Leakage can be considered present when the tracer compound is present in the test sample at more than 10 percent of the source concentration.

Transient and Other Environmental Effects on Sampling

Environmental conditions can affect volatilization from the source as well as soil gas movement in the subsurface. When planning to sample soil gas, it is important to be aware of and document environmental conditions that may affect the representativeness of the sample. Environmental conditions to note are listed below:

Barometric pressure

Changes in barometric pressure can lead to a pressure gradient between the soil gas and atmosphere, creating a flow of soil gas to the surface during barometric lows and down into the vadose zone during barometric highs. The potential effects decrease with increasing sampling depth. Barometric pressure should be recorded when soil gas samples are collected at depths shallower than 5 feet bgs. This information will assist the investigator in interpreting soil gas data collected under different atmospheric conditions.

Temperature

Soil temperature can affect contaminant concentrations in soil gas because vapor pressure and water solubility are temperature dependent. In Alaska, the temperature in shallow soils and beneath shallow foundations (e.g., slab-on-grade) can vary significantly between summer and winter. However, temperature variations decrease with depth in the soil column. The effect of changes in soil temperature on vapor migration at Alaskan sites is not known, but should be taken into consideration.

Precipitation

Infiltration from rainfall can affect soil gas concentrations by displacing the soil gas, dissolving volatile organic compounds, and by creating a “cap” above the soil vapor. Infiltration from large storms typically only penetrates several inches into the soil. Therefore, soil gas samples collected at depths greater than 3 feet are unlikely to be affected. Soil gas samples collected closer to the surface may be affected, so DEC recommends measuring percent moisture of the soil when collecting shallow soil gas samples during or shortly after a rainfall greater than 1 inch. This information will assist the investigator interpret soil gas data collected at different soil moisture levels.

Indoor Air Sampling

Indoor air samples directly measure contaminant concentrations in a building and are intended to represent the quality of the air that occupants are breathing. Indoor air sample results provide direct information about current human exposure. Anytime indoor air samples are collected, Step 1 should be revisited to determine if short-term risk is a concern and if any agencies should be notified immediately.

In some situations, it may be preferable to collect indoor air samples before completing a subsurface soil gas characterization. Examples of such situations may include the following:

- In response to a recent spill to evaluate acute risks.
- If odors or monitoring equipment indicates an immediate risk.

- If the source of vapors is so close to the structure that a soil gas sample cannot be collected between the source and the foundation,
- When preferential pathways into the structure (e.g., building sumps or drainage pits, subsurface utility conduits or drains, or bedrock fractures) create a direct conduit between the building foundation and the vapor-contaminant source.

DEC does not recommend collecting indoor air samples alone. Collected alone, indoor air data are often inconclusive because of background interferences and the wide temporal and spatial variability. Instead, DEC recommends using a multiple lines of evidence approach when sampling indoor air (see Section VI, "Multiple Lines of Evidence".

Other important guidelines when collecting or evaluating indoor air data include the following:

- **A**nalytical methods must achieve detection limits below the screening levels (this can be difficult for some compounds so verify with the laboratory).
- Attempt to eliminate background interferences before sampling.
- Collect the sample in a high-use area to represent the actual breathing zone.
- Do not chill indoor air samples during sample transport.

Indoor Air Sample Location and Frequency

Indoor air samples should be collected in the lowest occupied level of the building. In structures with basements that are not used for living space, consider sampling both the occupied living areas and basement areas to better assess the pathway and the attenuation occurring inside the house. DEC recommends collecting at least one indoor air sample per 1,000 square feet of floor space. If fewer samples are proposed in the workplan, the investigator should provide justification for reduced sampling. Larger buildings may require additional samples, especially if they contain separate air spaces or air-handling units.

Additional samples are usually necessary for multi-family residential units and commercial or retail buildings. These types of buildings require a careful review of the building features before deciding on sampling locations. Subsurface structures, such as partial crawl spaces, sumps and elevators, may be present that would facilitate vapor intrusion part of the building and not another.

The location and number of indoor air samples should account for different exposure scenarios that exist within the building and any sensitive populations that may be exposed to the contaminated vapors.

To evaluate trends in temporal variability, the investigator should sample at least twice during the year to identify the effects of seasonal changes in weather, soil conditions, and heating and ventilation characteristics of the building.

Indoor Air Sampling Procedures

Before collecting indoor air samples, the DEC's Building Inventory and Indoor Air Sampling Questionnaire (Appendix I) should be completed. The questionnaire enables the investigator to document information on the building, the occupants, and potential sources of background contaminants. The investigator should identify any penetrations through the foundation, such as water, sewer, gas, electric, and telecommunication lines, or sumps. Penetrations should be screened with portable monitoring equipment and may need to be targeted for sampling.

A presampling building walkthrough should be completed at least 24 hours before collecting indoor air samples. During the walkthrough, indoor vapor sources that could interfere with detecting COCs intruding into the building from subsurface sources should be removed if possible. The investigator may also choose to ventilate the building to attempt to remove background contaminants.

To avoid potential interferences and dilution effects, occupants should make a reasonable effort to avoid the following for 24 hours prior to sampling:

- Opening any windows, fireplace dampers, openings, or vents;
- Operating ventilation fans unless special arrangements are made;
- Smoking in the building;
- Painting;
- Using wood stove, fireplace, or other auxiliary heating equipment (e.g., kerosene heater);
- Operating or storing automobiles in an attached garage;
- Allowing containers of gasoline or oil to remain within the house or garage area, except for heating fuel tanks, and these tanks should be vented to outside the building or the vents should be temporarily sealed to prevent off-gassing inside the structure;
- Cleaning, waxing, or polishing furniture, floors, or other woodwork with petroleum- or oil-based products;
- Using air fresheners, scented candles, or odor eliminators;
- Engaging in any hobbies that use materials containing volatile chemicals;
- Using cosmetics, including hairspray, nail polish, nail polish removers, perfume/cologne, etc.;
- Lawn mowing, paving with asphalt, or snow blowing;
- Applying pesticides;
- Using building repair or maintenance products, such as caulk or roofing tar; and
- Bringing freshly dry-cleaned clothing or furnishings into the building.

Samples should be collected in the breathing zone, approximately 3 to 5 feet off the ground, in high-use areas. Sampling devices should be set to collect indoor air samples over a 24-hour period or longer, even in commercial settings. DEC believes that averaging samples over a longer time period best represents the exposure to most occupants. DEC will consider sample duration alternatives on a case-by-case basis.

Considerations for Collecting and Using Indoor Air Data

Additional considerations for collecting indoor air data are provided below:

Temporal variability

A change in weather conditions, or in the building's heating and ventilation, can lead to variable vapor intrusion. Longer sampling times may compensate for some of this variability, but indoor air sampling should be avoided during unusual weather conditions.

Although vapor intrusion is expected to be the most pronounced in the winter months, the highest contaminant concentrations have been observed in late summer and fall in some buildings in Alaska. Research suggests that the variability in indoor air contaminant levels caused by vapor intrusion is typically less than one order of magnitude between seasons (ITRC, 2007). However, this information may not pertain to Alaska where extended cold and periods and tight building construction are typical.

Heating and ventilation systems

Air samples are sometimes designed to represent typical exposures in a mechanically ventilated building and the operation of HVAC systems during sampling should be noted on the Building Inventory and Indoor Air Sampling Questionnaire (Appendix I). When samples are collected, the building's HVAC system should be operating in a manner consistent with normal operating conditions when the building is occupied (e.g., schools, businesses, etc.). Unnecessary building ventilation should be avoided for 24 hours prior to and during sampling. During colder months, heating systems should be operating to maintain normal indoor air temperatures (i.e., 65 °F – 75 °F) for at least 24 hours prior to and during the scheduled sampling time.

Background interferences

Common household products stored or used in buildings can interfere with the vapor intrusion evaluation. The presampling survey in Appendix I can help identify background sources in the indoor air environment. Portable vapor monitoring equipment readings may also be useful for identifying sources in the building. When feasible, the investigator should remove these sources at least 24 hours prior to sampling. Ventilating the building may also reduce background contaminant levels. If ventilation is appropriate, it should be completed 24 hours or more before the scheduled sampling time. Where applicable, ventilation can be accomplished by operating the building's HVAC system to maximize outside air intake.

Analytical Methods and Sample Handling for Soil Gas and Indoor Air

The same sample containers and analytical methods can be used for both soil gas sampling and indoor air. Some differences arise due to the higher concentrations expected in soil gas than in indoor air. The following section provides guidelines for both soil gas and indoor air sample handling and analysis, unless otherwise noted.

Sample Containers

DEC recommends summa canisters for the most defensible, quantitative air sampling in the vapor intrusion evaluation. Canisters appear to provide more reliable sample integrity than gas sample bags, particularly when samples are shipped via air, and they have longer holding times than bags. In comparison to sorbents, canisters work with analytical methods that often provide lower detection levels and concentration results rather than a mass, which allow direct use of these results in risk calculations. However, sorbents, bags, or other devices may be appropriate in certain circumstances. Additionally, there is emerging technology with sorbents that may increase their appropriateness for this type of site investigation.

Canisters

Stainless steel canisters are recommended for TO-14A, TO-15, or equivalent methods. The sampling canister is a specially lined inert container sent to the field under vacuum and certified clean and leak-free. A 100-percent canister cleaning certification may be required for summa canisters when low detection levels are necessary. Canisters range in volume from less than 1 liter to greater than 6 liters. The larger canisters are used for ambient air samples, subslab samples, and integrated samples (collected over more than a few minutes). One-liter samples are generally used for taking high concentration (i.e., greater than 5 parts per billion by volume) grab samples.

The canister fills with air at a fixed flow rate over a preset period of time with use of a flow controller calibrated and set in the laboratory. Initial and final vacuums are recorded for each canister. To ensure the canisters are filling at the proper rate, they should be rechecked after deployment. Canisters must have dedicated vacuum gauges. The canister must be retrieved prior to being completely filled (with some residual vacuum remaining) to ensure proper collection.

Sampling personnel should take care to see that the valves and regulators provided with the canisters can maintain sample container integrity during air cargo transport from Alaska to the selected laboratory.

Sorbents

Samples are collected by drawing air at a calibrated flow rate through a tube containing a sorbent media over a specified time period. The flow rate and sampling volume used are determined based on the sorbent used, the COCs, and the amount (mass) of the sorbent contained in the tube. The samples are taken to the laboratory for thermal or chemical desorption and subsequent analysis. Reporting limits are based upon the amount of air passed through the tube. It is important to use a sorbent certified clean that can be reliably used for the collection and analysis of the COCs. The primary disadvantage of using sorbents is that only one analysis is usually possible from a tube. Other complications of sorbent sampling are potential compound breakthrough and sorbent contamination from passive adsorption of VOCs.

Passive sampling

Passive sampling is similar to sampling with sorbents, but the collection method is based on the diffusion of the compound onto the sorbent and does not rely on pumps. As an advantage, the passive sampler is simply hung in the indoor air space to be sampled and left for a predetermined period of time. After the exposure period, the sampler is placed into an airtight container until analysis of the media is done. Exposure times (the amount of time the sorbent is exposed to the contaminant) must be determined based on estimated sample concentrations such that the sampler does not reach a state of equilibrium (or saturation) with the environment, a common source of low bias.

A drawback to this type of sampling is that analytical results are given in units of mass, not concentration, because the airflow across the sampler and the sampler uptake rate is difficult to obtain accurately. There are a few passive samplers which can be used to estimate contaminant concentration in the air (e.g., SKC Ultra® Passive Samplers or Radiello® Passive Air Sampling System). These samplers have a high uptake rate and typically use thermal desorption instead of solvent extraction for analysis. While these samplers have greater sensitivity and are more appropriate for indoor air sampling, the investigator must evaluate the method detection limit and the concentration estimate carefully. Data obtained from these methods may be more useful for qualitatively characterizing indoor air contamination than for evaluating risk. DEC approval should be obtained prior to comparing data from any passive collection device to a target level.

Sample bags

Gas sample bags (e.g. Tedlar®, Teflon®, etc.) can be used with an evacuation chamber, or lung box, to allow an air sample to be collected without the sample passing through a pump. Samples collected in gas bags are typically analyzed with a field GC or mobile laboratory. Tedlar bag sample holding time can be as low as a few hours and no more than three days depending on the chemical. Gas sample bags may not be appropriate for certain VOCs, including naphthalene. The use of gas sample bags and their suitability for the target analytes should be carefully evaluated and described in the vapor intrusion work plan.

Other sampling devices

Syringes can be used to withdraw a soil gas sample from a probe, and then injected immediately into an analytical instrument, or into another sampling container, such as a Tedlar bag. Glass cylinders or sampling bulbs are less common. Air is pulled through the sample container by a pump, after which the inlet and outlet are sealed.

Sample Handling, Storage, and Transportation

Sample handling procedures should be followed to maintain sample integrity between the time of collection and analysis.

- Soil gas and air samples should not be chilled.
- Changes in ambient pressure that the samples are exposed to should be minimized. If air shipping is necessary, gastight vials or canisters are critical.

- If condensation is observed in the sample container, the sample should be discarded and a new sample collected.
- For halogenated compounds (e.g., TCE, TCA, PCE), allowable containers must be gas-tight but also opaque/dark to eliminate potential photodestructive effects.
- Sample container valves should be double-checked to ensure they are tight and secure.

Analytical Methods and QA/QC

A variety of analytical methods are available to measure indoor air samples, all of which can give accurate results when followed with appropriate QA/QC procedures.

Table 5 presents a summary of analytical methods commonly used in vapor intrusion investigations. The primary criteria for choosing the appropriate method are as follows:

- Target COCs
- Concentrations that may be encountered during sampling
- Required detection level and other data quality objectives (DQOs)
- Sampling logistics
- Cost

The planning stages of the investigation should include discussions with the laboratory to determine the detection levels achievable under each method. The detection level should be lower than the default target levels for each COC. It may be appropriate to combine analytical methods to achieve appropriate detection limits or determining contaminant levels over a range of expected concentrations.

When petroleum biodegradation is being evaluated, oxygen (O_2), carbon dioxide ($C0_2$), and methane (CH_4) should be included in soil gas sample analyses.

DEC will require that the analytical laboratory be certified by the National Environmental Laboratory Accreditation Program (NELAP) for air or soil gas test methods used for vapor intrusion investigations. The analytical laboratory should comply with its internal QA/QC procedures, and follow the QA/QC requirements of the analytical method. The laboratory should also comply with any project-specific data quality objectives (DQOs).

- Field QC should include collecting duplicate samples to improve confidence in the measured concentrations, and may include field blanks collected to assess contamination from shipping and handling, if that is a concern.
- Laboratory QA should include instrument blanks, method blanks, matrix spike and matrix spike duplicate samples, and laboratory control samples.
- Specific project QA/QC DQOs should be defined in the workplan.

Table 5: Summary of analytical methods for soil gas, indoor and ambient air samples.

(Modified from ITRC Guidance, Appendix D, Table D-3)

Parameter[a]	Method	Collection device	Description[b]	Method holding time	Reporting limit[c]	Approximate Cost
VOLATILE ORGANIC COMPOUNDS (VOCS)						
BTEX, MTBE, TPH	TO-3	Tedlar bag or canister	GC/FID	30 days for canister , 48 hours for Tedlar bag	1–3 μg/m^3	$165-$220
Nonpolar VOCs	TO-14A	Canister	GC/ECD/FID or GC/MS	30 days for canister	1–3 μg/m^3	$165-$220
Polar and nonpolar VOCs	TO-15	Canister	GC/MS	30 days for canister	1–3 μg/m^3	$165-$220
Low-level VOCs	TO-15 SIM	Canister	GC/MS	30 days	0.011–0.5 μg/m^3	$180-$230
Polar and nonpolar VOCs	TO-17	Sorbent tube	GC/MS	30 days	1–3 μg/m^3	$225
VOCs	8021B modified	Syringe, Tedlar bag, glass vial	GC/PID	On-site analysis for syringe, 48 hours for Tedlar bag, 30 days for glass vial	10–60 μg/m^3	$95
VOCs	8260B modified	Syringe, Tedlar bag, glass vial	GC/MS	On-site analysis for syringe, 48 hours for Tedlar bag, 30 days for glass vial	50–100 μg/m^3	$130
SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCS)						
SVOCs	TO-13A	High-volume collection (may require large sample volume, e.g., 300 m^3)/PUF/XAD media	GC/MS	Extracted within 7 days of collection and analyzed within 40 days of extraction	5–10 μg/sample	$210-$250
Low-level olycyclic aromatic hydrocarbons (PAHs)	TO-13A SIM	High-volume collection (may require large sample volume, e.g., 300 m^3)/PUF/XAD media	GC/MS	Extracted within 7 days of collection and analyzed within 40 days of extraction	0.5–1 μg/sample	$150

Table 5, continued: Summary of analytical methods for soil gas, indoor and ambient air samples.
(Modified from ITRC Guidance, Appendix D, Table D-3)

Parameter[a]	Method	Sample media/storage	Description[b]	Method holding time	Reporting limit[c]	Approximate Cost
PESTICIDES AND POLYCHLORINATED BIPHENYLS (PCBS)						
Pesticides and PCBs	TO-4A or TO-10A	High-volume collection (may require large sample volume, e.g., 300 m^3)/PUF media	GC/ECD	Extracted within 7 days of collection and analyzed within 40 days of extraction	Pesticides: 0.5– 1 µg/sample, PCBs: 1–2 µg/sample	$150-$180
FIXED GASES						
Fixed gases (methane, nitrogen, oxygen)	USEPA 3C	Canister or Tedlar bag	GC/FID	48 hours for Tedlar bag, 30 days for canister	1000–2000 µg/m^3	$95-$130
Fixed gases (methane, nitrogen, oxygen, carbon dioxide, carbon monoxide)	ASTM D-1946	Canister or Tedlar bag	GC/TCD/FID	48 hours for Tedlar bag, 30 days for canister	1000–2000 µg/m^3	$95-$130
Natural gases	ASTM D1945	Canister or Tedlar bag	GC/FID	48 hours for Tedlar bag, 30 days for canister	1000–2000 µg/m^3	$75-$165
TPH–ALKANES						
C4–C24	8015 mod.	Canister or Tedlar bag	GC/FID	48 hours for Tedlar bag, 30 days for canister	10 ppmv	$120
C4–C12	8260	Canister or Tedlar bag	GC/MS	48 hours for Tedlar bag, 30 days for canister	1 ppmv[d]	$130
C4–C12	TO-15	Canister or Tedlar bag	GC/FID	48 hours for Tedlar bag, 30 days for canister	0.1 ppmv	$150
METALS						
Mercury	Niosh 6009	Sorbent Tube	GC/MS	-	-	-

[a] This is not an exhaustive list. Some methods may be more applicable in certain instances. Other proprietary or unpublished methods may also apply. These methods may be used for soil gas, indoor air, or ambient air – but the reporting limit should be compared to the level expected in the sample or the standard to which the sample will be compared.
[b] ECD = electron capture detection, FID = flame ionization detection, GC = gas chromatography, MS = mass spectrometry, PID = photoionization detection, TCD = thermal conductivity detection
[c] Reporting limits are compound specific and can depend upon the sample collection and the nature of the sample. Detection limits shown are for the range of compounds reported by the analytical methods.
[d] The indicated methods use a sorbent-based sampling technique. The detection limits will depend on the amount of air passed through the media.

- Confusion with units: microgram per cubic meter, microgram per liter, and parts per billion by volume are not equivalent reporting units. An on-line conversion tool is available at www.handpmg.com.
- Applying improper soil gas screening levels: residential levels applied to industrial settings, errors with attenuation factors.
- Improperly installed subslab probes: grouting techniques should ensure proper seal between the probe and walls of the hole drilled through the slab and leak detection should be completed at each soil gas sampling point.
- Leaking canister valves: under- or over-tightening summa canister valves can result in loss of vacuum during canister shipping.
- Dirt in canisters: using filters can prevent dirt either entering the canister or plugging the valve.
- Flawed canister gauges: canister gauges may not function properly causing uncertainty in canister vacuums.
- Misusing flow controllers: using a flow controller that has been inaccurately set, or applied to the wrong sample point (e.g., 24-hour vs. 2-hour), will alter the collected sample volume.

VI. INVESTIGATIVE STRATEGIES – SPECIAL CONSIDERATIONS

Data collected or used in a vapor intrusion evaluation can be complex and may appear contradictory at times. It is important to interpret each data set carefully and weigh the relative significance of any one line of evidence. Decisions about vapor intrusion are seldom based on a simple comparison of a few samples to a target level. Many aspects of a site, including the interaction between buildings and their environment, may affect the interpretation of data and subsequent decisions about the site. This section describes different ways to interpret data that are acceptable to DEC.

Background Air Levels

Volatile chemicals are often present in a building due to both indoor and outdoor air quality problems that are not associated with vapor intrusion. While these problems can result in health effects, DEC only has the authority to regulate vapor intrusion problems. DEC recommends sampling subslab and indoor air simultaneously to assist with this evaluation; however, comparing indoor air data to typical background levels may also be useful.

Typical background levels from indoor air quality studies in North American residences are provided in Appendix H. These levels are reported here as the 25th, 50th, 75th, and 95th percentiles of the arithmetic mean concentrations observed in indoor air from numerous studies reviewed and compiled by Dawson and McAlary (2008). DEC recommends comparing indoor air data to the 50th percentile to determine if background interference may be present. However, higher percentiles may be considered when other factors suggest background sources are present.

The background levels shown in Appendix H are based on data collected primarily in warmer climates. Normal background levels may be different in some areas of Alaska where building construction practices and long periods of cold weather may cause less building ventilation and greater airflow from the subsurface. Some data describing background indoor air quality in Alaska is available, as described below.

Schlapia and Morris (1998) reported that benzene concentrations in the majority of 137 homes sampled in the Anchorage area were less than 16 micrograms per cubic meter ($\mu g/m^3$) or 5 parts per billion by volume (ppbv). Approximately one-fourth of the homes had indoor benzene concentrations greater than 32 $\mu g/m^3$ (10 ppbv). Homes with attached garages, especially those where the living space was located above the garage, had significantly higher concentrations of benzene indoors. The Cold Climate Housing Research Center in Fairbanks, Alaska, analyzed indoor air samples from three Fairbanks homes and two Juneau homes that were built with tight construction to meet energy efficiency standards. Benzene concentrations in the Fairbanks homes ranged from 32 to 62 $\mu g/m^3$ (10 to 19 ppbv). Benzene was not detected in the Juneau homes, possibly because of their lack of attached garages.

Multiple Lines of Evidence

When multiple lines of evidence have been gathered, indoor air quality should not be used as a sole indicator of vapor intrusion potential. Other factors can contribute to indoor air quality, such as chemicals stored on site or background air quality. Indoor air data should be evaluated concurrently with outdoor air to determine if outdoor, but aboveground sources, may be contributing to contaminants observed indoors. If outdoor air quality appears to be affecting indoor air quality, the outdoor air contaminant levels may be subtracted from the indoor air contaminant levels.

Indoor air data should also be compared to the subslab or near-slab soil gas data. If contaminant concentrations in indoor air exceed the contaminant concentrations in subslab or near-slab soil gas data, background contaminant sources should be considered. This condition may indicated that vapor intrusion is not occurring, or may not be occurring at significant levels and further investigation should be focused on identifying the background source or clarifying its contribution to risk.

When multiple lines of evidence data are available, site-specific attenuation factors between soil gas and indoor air should be calculated as described by EPA (2006). Field data collected to date indicate that attenuation factors greater than 0.01 are usually attributable in part to background sources.

Predictive Modeling

If data indicate concentrations greater than generic target levels, predictive modeling may be used to evaluate the potential for vapor intrusion into overlying buildings. When using a model, a table describing site-specific parameters, the basis for using these parameters, and a copy of the model input and results pages should be provided to DEC.

DEC will accept the use of EPA's vapor intrusion models based on Johnson and Ettinger (1991). EPA provides spreadsheet versions of this model for use with soil gas and groundwater data at http://www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm. Because of DEC's concerns about modeling vapor intrusion risk based on soil data, the soil and NAPL versions included on this website should not be used to rule out a vapor intrusion evaluation. DEC also recommends that the Johnson and Ettinger model not be used for evaluating petroleum-hydrocarbon spills unless the investigator considers adjusting the modeled attenuation factor for biodegradation. Other models may be used if they are publicly available, peer-reviewed, and approved by DEC for predicting risk to building occupants.

Risk Assessment

When residential or commercial exposure assumptions over-estimate the exposure at the site, a risk assessment may be completed to alter the exposure assumptions. Similarly, DEC may require a risk assessment when there is concern that the residential exposure assumptions are not protective enough for people occupying a building of concern. Before conducting a risk assessment, a risk assessment workplan must be completed in accordance with the DEC's Risk Assessment Procedures Manual (2009) available at http://dec.alaska.gov/spar/csp/guidance/rapm02_09.pdf and approved by DEC.

Petroleum Biodegradation

In Alaska, many sites contain petroleum contamination close to or beneath a building. Vapor intrusion investigations at these sites are often complicated by numerous sources of petroleum in the building and outside the building that can make it difficult to interpret indoor air samples. Evaluating biodegradative conditions can be a useful alternative at these sites.

In regions of active aerobic biodegradation, micro-organisms living in the soil will consume petroleum vapors, using O_2 and producing CO_2. Biodegradation can cause petroleum vapors to attenuate rapidly as they move away from the source. However, when the source is highly-concentrated or conditions prevent oxygen from being replenished in the soil, oxygen-depleted zones may occur near the source. As the oxygen levels decline, biodegradation will be limited, and petroleum vapors will no longer attenuate rapidly. Anaerobic decomposition can also occur in the oxygen-depleted source zones, generating CH_4. Methane gas undergoes aerobic biodegradation in the more oxygen-rich subsurface regions (API, 2005).

Petroleum vapors will often degrade before reaching a building as long as clean, oxygenated soil is present between the vapor source and the building foundation (Hers et al., 2000; Davis, 2008). Davis (2008) has shown that biodegradation will prevent vapor intrusion when the source strength is low, at least two feet of fine-grained soil or 5 feet of coarse-grained soil is present, and the soil contains at least 3 percent oxygen. Because the DEC target levels do not reflect the effects of biodegradation, DEC may not require further evaluation for vapor intrusion at sites where existing data suggests that the conditions described above exist. However, a more thorough evaluation of the biodegradation potential will be required when the following conditions are present:

- Soil samples contain petroleum compounds above DEC's most stringent cleanup levels in the soil within 5 feet of the foundation.
- Free product is present on the groundwater surface beneath the building and within 30 feet of the building foundation; under these conditions biodegradation may be using oxygen at a faster rate that it can be replenished.
- A cap, such as concrete or asphalt, covers the area around the building, potentially preventing oxygen from flowing into the subsurface.

In order to evaluate if biodegradation is occurring, DEC recommends including fixed gasses (O_2, CO_2, and CH_4) as analytes in soil gas samples collected during a petroleum investigation (see Table 5). Fixed gases also can be evaluated using portable monitoring equipment.

VII. MITIGATING A VAPOR INTRUSION PROBLEM

Mitigation systems can be installed during construction to prevent vapor intrusion, or can be retrofitted into an existing structure. Radon mitigation systems have been successfully used to address other chemical intrusion. For guidance on mitigation systems, see Section 4 of the ITRC Guidance (ITRC, 2007). The University of Alaska has also produced a useful reference for mitigating radon gas problems specific to Alaska (Siefert, 2003). Systems thought to be most effective in Alaska include:

- Subslab depressurization systems or soil gas venting systems. These types of systems should be designed to establish and maintain lower subsurface soil vapor pressures both below and adjacent to the structure than exist within the structure. Routine maintenance and inspection of the system may be required until acceptable cleanup levels are met in the subsurface.
- Air vapor barriers beneath the foundation. The vapor barrier should be impermeable to the contaminants of concern and adequate sealing of the barrier along with any cracks or perforations in the foundation must be done. A smoke test may be required to confirm that the barrier is not leaking.

If a mitigation system is used to manage the risk in a specific building, the responsible party must demonstrate to the DEC that the system is effective at controlling vapor migration into that building. Demonstrating abatement may include smoke tests or tracer gas tests, subslab soil gas or indoor air sampling, or other measurements that characterize how the system interacts with building characteristics, such as subslab pressure differentials.

Other engineered mitigation systems may be proposed. However, the system must be designed to prevent vapor intrusion for the chemicals of concern and the system should be operated, maintained, and monitored under a DEC-approved plan. Positive pressure ventilation systems may not be feasible in residential construction in Alaska because positive interior pressures force moist air into the building, causing moisture-related problems. Balanced ventilation systems, such as heat recovery systems, have not been shown to be effective with radon problems, and are not recommended for other contaminant problems (Siefert, 2007).

VIII. INSTITUTIONAL CONTROLS AT VAPOR INTRUSION SITES

Institutional controls are usually established once investigation of the vapor intrusion pathway is complete and remedial efforts have been completed or are underway. In some cases, especially where a more immediate threat is identified (see Step 1), DEC may require institutional controls for the site before the investigation is finished. Once DEC determines that all exposure pathways have been evaluated and the cleanup is protective of human health and the environment, the DEC will issue a closure decision. Institutional controls for the vapor intrusion pathway may remain after cleanup is complete until contaminant concentrations diminish to safe levels.

Typically, institutional controls are necessary when:

- Physical or mechanical barriers, such as remediation systems, ventilation systems, and vapor barriers, are used or relied on to reduce vapor intrusion. Institutional controls

should be established to ensure these mitigation measures are maintained and operated correctly.

- New construction or changes to the existing structures could result in new vapor intrusion pathways. Institutional controls should be established to ensure that the vapor intrusion pathway is re-evaluated following any new construction and/or structure remodeling.
- The site has been evaluated for commercial or industrial use, but not for residential use. Institutional controls should be established to restrict land use changes or to ensure the risk of residential use is evaluated.

IX. RFERENCES

API, 2005. *Collecting and Interpreting Soil Gas Samples from the Vadose Zone, A Practical Strategy for Assessing the Subsurface Vapor-to-Indoor Air Migration Pathway at Petroleum Hydrocarbon Sites*. Amercian Petroleum Institute. API Publication No. 4741. Available at: http://www.api.org/ehs/groundwater/lnapl/soilgas.cfm

Davis, Robin, 2006. "Vapor Attenuation in the Subsurface from Petroleum Hydrocarbon Sources: An Update and Discussion on the Ramifications of the Vapor-Intrusion Risk Pathway." LUSTLine Bulletin 52, May.

Davis, Robin. 2008. "Nationwide Study of Subsurface Petroleum Hydrocarbon Vapor Occurrence & Attenuation." A Summary of Research Results from 20th Annual National Tanks Conference, March 16-19. http://www.neiwpcc.org/tanks08/presentations/davis.hartman.hopkins.ririe.pdf.

DEC. *Cleanup Levels Guidance.* Alaska Department of Environmental Conservation. June. Available at: http://dec.alaska.gov/spar/csp/guidance/cleanuplevels.pdf

DEC *Monitoring Well Guidance*. Alaska Department of Environmental Conservation. February. Available at: http://dec.alaska.gov/spar/csp/guidance/mw_guidance.pdf

DEC *Policy Guidance on Developing Conceptual Site Models* (draft). Alaska Department of Environmental Conservation. Available at: http://dec.alaska.gov/spar/csp/guidance/csm05_draft.pdf

DEC *Underground Storage Tank Procedures Manual*. Alaska Department of Environmental Conservation. June. Available at: http://dec.alaska.gov/spar/ipp/docs/ust_man02_10_07.pdf

DTSC, 2003. *Advisory – Active Soil Gas Investigations*. California Department of Toxic Substances Control. Available at: http://www.dtsc.ca.gov/lawsregspolicies/policies/SiteCleanup/upload/SMBR_ADV_activesoilgasinvst.pdf

EPA, 2002. *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance).* EPA 530-D-02-004. Environmental Protection Agency. Available at: http://epa.gov/osw/hazard/correctiveaction/eis/vapor.htm

EPA, 2006. *Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples*. EPA/600/R-05/147. Environmental Protection Agency. Cincinnati, OH. Available at: http://www.dec.state.ak.us/spar/csp/guidance/raymark6report.pdf

EPA, 2008. *User's Guide for Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites*. Environmental Protection Agency. September.

EPRI, 2005. *Reference Handbook for Site-Specific Assessment of Subsurface Vapor Intrusion to Indoor Air*. Electric Power Research Institute. Palo Alto, CA. Available at: http://my.epri.com/

Health Canada, 2007. *Final Draft Report on Soil Vapour Intrusion Guidance for Health Canada Screening Level Risk Assessment (SLRA), Volume 1*. Golder Associate Ltd., Burnaby, British Columbia. July.

ITRC, 2007. *Vapor Intrusion Pathway: A Practical Guideline*. Interstate Technology and Regulatory Council, Vapor Intrusion Team. Washington, DC. January. Available at: http://www.itrcweb.org/Documents/VI-1.pdf

Johnson, P.C. and R. A. Ettinger. 1991. "Heuristic model for predicting the intrusion rate of contaminant vapors into buildings". *Environ. Sci. Technology* 25:1445-1452.

MA DEP, 2004. *Indoor Air Sampling and Evaluation Guide*. Massachusetts Department of Environmental Protection. WSC Policy No. 02-430. Available at: http://www.mass.gov/dep/cleanup/laws/02-430.pdf

NJ DEP, 2005. *Vapor Intrusion Guidance*. New Jersey Department of Environmental Protection. Available at: http://www.nj.gov/dep/srp/guidance/vaporintrusion/vig.htm

NY DOH, 2006. *Guidance for Evaluating Soil Vapor Intrusion in New York State*. New York State Department of Health. Available at: http://www.health.state.ny.us/environmental/investigations/soil_gas/svi_guidance/

Schlapia, A. and S.S. Morris. 1998. "Architectural, Behavioral and Environmental Factors Associated with VOCs in Anchorage Homes". Presented at the Air & Water Management Association's 91st Annual Meeting & Exhibition, June 14-18, 1998, San Diego, California.

SDC, 2009. *Site Assessment and Mitigation Manual*. San Diego County. Available at: http://www.co.san-diego.ca.us/deh/water/sam_manual.html

Siefert, 2007. *Radon Mitigation: Alaska Experiences, Costs, Results*. RAD-00755. University of Alaska, Cooperative Extension Service.

Hydrasleeve® is a registered trademark of EnviroEquip.

SKC Ultra® is a registered trademark of SKC, Inc.

Radiello® is a registered trademark of Fondazione Salvatore Maugeri IRCCS.

Tedlar® and Teflon® are registered trademarks of E.I. du Pont de Nemours and Company.

APPENDIX A

Elements of the Vapor Intrusion Pathway (adapted from NJ DEP, 2005)

This page intentionally left blank

Assessing the potential for vapor intrusion to indoor air should begin with visualizing a simplified version of the site or physical setting; this simplified idea, picture, or description is part of the overall CSM. The basic components of a CSM are known or suspected contaminant sources, contaminant migration pathways, potential human receptors and the exposure routes by which these receptors may come in contact with contaminants on a site-specific basis. This appendix focuses on the conceptual framework of the process of vapor intrusion. The following subsections describe the components of the CSM in detail:

- Sources of vapor intrusion
- Vapor Migration Mechanisms and
- Receptors

Sources of Vapor Intrusion

Initial consideration in the preparation of a CSM should be centered on whether there is a vapor source with the potential to cause vapor intrusion. In general, a vapor source of vapor intrusion can be defined as the presence, or reasonably suspected presence, of a chemical of sufficient volatility and toxicity in the subsurface with sufficient mass and/or concentrations to pose a possible inhalation risk within current or future occupied overlying enclosures. This definition includes the presence of a volatile chemical or chemicals adsorbed to, or in the pore space/fractures of unsaturated soil or rock, or in the uppermost portions of the saturated zone. Such vapor sources can exist in the form of: free phase or residual NAPL above or near the top of the saturated zone; contaminated soil in the vadose zone; and shallow dissolved phase contamination in ground water. Another possible source of subsurface vapor intrusion is the release of volatile compounds in the vapor phase from underground tanks or piping and certain types of aboveground facilities that use volatile compounds during operations. This particular source is commonly referred to as a “vapor cloud.” Sources of indoor air contamination not associated with vapor intrusion (e.g., ambient air, building materials, consumer products) should also be considered when developing and evaluating this pathway.

Vapor Migration Mechanisms

When a chemical of sufficient volatility and toxicity is present in the subsurface, there are several transport mechanisms by which the chemicals can migrate. The CSM should identify the major and minor migration pathways and processes through which a receptor can be exposed at a particular site. The four main transport mechanisms that should be considered are described and illustrated below.

- Diffusion of vapors from sources in the unsaturated zone
- Diffusion of vapors from sources in shallow ground water
- Advective and convective transport of vapors
- Vapor migration through preferential pathways

Diffusion occurs as a result of a concentration gradient between the source and the surrounding area; it can result in the upward, lateral or downward migration of vapors through the vadose zone. The location of the source is an important factor influencing the direction of vapor migration. Identifying soil gas concentration gradients may help determine the location of unidentified vapor sources. Vapors can migrate in any direction including lateral and downward directions from sources in the unsaturated zone. Variability in site characteristics, such as soil

porosity, effective permeability, ground surface cover, ambient temperature and age of a release may increase or decrease the distance vapors migrate. A relatively impermeable surface cover above a vapor source for example, may increase the distance a vapor plume would travel laterally if it significantly impedes vapors from escaping to the atmosphere.

Diffusion of vapors from sources in the unsaturated zone

Diffusion occurs as a result of a concentration gradient between the source and the surrounding area; it can result in the upward, lateral or downward migration of vapors through the vadose zone. The location of the source is an important factor influencing the direction of vapor migration. Consequently, identifying soil gas concentration gradients may help determine the location of unidentified vapor sources. Variability in site characteristics, such as soil porosity, effective permeability, ground surface cover, ambient temperature and age of a release may increase or decrease the distance vapors migrate. A relatively impermeable surface cover above a vapor source for example, may increase the distance a vapor plume would travel laterally if it significantly impedes vapors from escaping to the atmosphere.

Diffusion of vapors from sources in shallow ground water

Diffusion occurs as a result of a concentration gradient between the source and the surrounding area; in this case, the source is shallow groundwater contamination and/or NAPL. This can result in the upward or lateral migration of vapors through the vadose zone. Diffusion of vapors in the vadose zone from shallow ground water contamination depends on the hydraulic conductivity, hydraulic gradient, aquifer heterogeneity, time since chemicals were released and natural attenuation processes, the distribution of volatile chemicals in ground water may extend considerable distances.

Within a set volumetric space where contaminated ground water is the only source of vapors in the subsurface, the total mass of compounds volatilizing from ground water and diffusing through the vadose zone (vertical mass flux) cannot exceed the total mass of volatiles moving through that space laterally in ground water. For aquifers with slower ground water velocity, the lateral mass flux in shallow ground water leaving the source area may be the limiting factor in vapor intrusion impacts.

Advective and convective transport of vapors

The horizontal and vertical movement of vapors located near a building foundation is often affected within an area referred to as the “zone of influence”. Chemicals entering this zone are drawn into the building via soil gas advection and convection resulting from building interiors that exhibit a negative pressure relative to the outdoors and the surrounding soil. The reasons for this pressure differential include: 1) factors relating to operation of HVAC system including inadequate combustion or makeup air and unbalanced air supply and exhaust systems; 2) the use of fireplaces and other combustion sources, which results in venting of exhaust gases to the exterior; 3) the use of exhaust fans in bathrooms and kitchens; 4) higher temperatures indoors relative to outdoors during the heating season or as a result of solar radiation on rooftops; and 5) pressure exerted on the wall of a building caused by wind movement over the building (Bernoulli’s principle). The combination of these actions and conditions results in a net convective flow of soil gas from the subsurface through the building foundation to the building interior. As would be expected from the above list, indoor air volatile concentrations are generally higher during the heating season in homes affected by vapor intrusion.

The rate of contaminant entry through the foundation and the air exchange rate of the building will determine the concentration of the contaminants in the home resulting from vapor intrusion. A similar pattern of soil gas movement can occur around buildings without a basement or around those without any concrete foundation slab. Advective and convective transport of vapors can occur in other scenarios. It has been observed that certain commercial and business operations may result in volatile organic vapors entering the unsaturated zone solely as a vapor possibly due to density differences between these vapors and the atmosphere. These operations could include tetrachloroethene (PCE) dry cleaning units, vapor degreasers in machine shops, spray booths in inking or painting facilities using chlorinated solvent based inks or paints, and USTs/underground piping. Highly permeable deposits and very high vapor concentrations are necessary for there to be significant density dependent transport below ground, therefore this scenario is likely to be relatively rare. Contaminated soil vapor may also occasionally result from pressurized buildings forcing contaminated indoor air out through openings in the foundation and into nearby soil. The affected area or zone of influence would likely be relatively small, but could affect subslab or other soil gas samples collected below buildings or structures such as those described above. Another possible advective vapor transport mechanism, called "barometric pumping," is caused by cyclic changes in atmospheric pressure. These changes create a "piston like" force on soil gas, possibly causing a cyclic up and down flow of contaminant vapors in the affected interval. The magnitude of a barometric pressure cycle is typically a small percentage of atmospheric pressure and its effect decreases with depth. The soil texture, soil air permeability, and moisture content affect the depth to which the pressure change may affect vapor transport. Soil gas compression and expansion in response to barometric pressure fluctuations may alternately enhance or inhibit vapor intrusion. In areas subject to tidal fluctuation or rapid increases in the groundwater elevation due to stormwater runoff, increasing groundwater elevation may enhance advective transport.

Vapor migration through preferential pathways

In preparation of each CSM, investigators may look for the presence and locations of natural and manmade pathways in the subsurface with high gas permeability through which vapors can rapidly migrate. The term preferential exposure pathway can be defined as a natural (e.g., shallow rock or vertically fractured soil) or manmade (e.g., buried utilities) feature that creates a sufficiently direct pathway from a source to a receptor. Shallow utilities buried at a depth that is insignificant with respect to the column of soil between the building foundation and the source do not automatically constitute a preferential pathway, nor should this definition include surface paving outside the building or the presence of crushed stone beneath the slab as normally placed for slab foundation material. Naturally occurring fractures and soil pores may facilitate vertical or horizontal vapor migration while anthropogenic features such as utility conduits would likely facilitate horizontal vapor migration due to their shallow depth. Buildings that are, or may become, inhabited should be evaluated if they are associated with a preferential pathway that is within some reasonable distance of a source area (based on professional judgment). Investigators should also evaluate the potential for vapor intrusion in situations where a preferential pathway leading to a structure runs near to, or through, a source area. For sources containing aerobically degradable contaminants, however, it is unlikely that sufficient vapors will reach the structure to result in a vapor intrusion problem unless the pathway and structure are both very close to the vapor source. Biodegradation of benzene, toluene, ethylbenzene, and xylene (BTEX) vapors in the vadose zone has been shown to be a very efficient process as long as sufficient oxygen is available. Thus, if a preferential pathway is not close to a source area, biodegradable vapors

would likely degrade before reaching the pathway and/or within the pathway before reaching the structure.

Receptors

A receptor can be defined as any human, plant, or animal that may be affected by a contaminant from a contaminated site. The primary vapor intrusion receptors are the human occupants of enclosed spaces that are impacted from migration of subsurface volatile compounds. Exposure to volatiles can result in health problems to individuals occupying a building subject to vapor intrusion. Enclosed spaces or buildings, for the purpose of this appendix, are defined as any structure currently or potentially impacted by subsurface volatile contaminants. To account for possible change in future use, vapor intrusion is of potential concern in buildings and enclosed spaces whether or not they are currently occupied. Buildings with significant air exchange rates (e.g., commercial garages and spaces with large doors or openings) or significantly limited use (e.g., small utility sheds) will be evaluated on a site-specific basis. Human exposure typically can take place under a residential (unrestricted use) or nonresidential (restricted use) exposure scenario. Residential settings include single family homes, townhouses, and apartment buildings. Receptors under a residential exposure scenario consist of both adults and children who are expected to spend a greater period of time in a residential setting than those individuals in a nonresidential setting. It is DEC's policy that day care centers and schools are evaluated as a residential use due to the potentially sensitive nature of the exposed population (children). Nonresidential settings include office buildings and commercial or industrial complexes. Nonresidential receptors consist of adult workers in the above buildings or complexes. Nonresidential settings with sensitive populations (e.g., working pregnant women) will be handled on a site-specific basis. Occupational settings that fall under the purview of OSHA may be handled differently than those not subject to OSHA regulations when indoor air concentrations from normal operating practices cannot be ruled out.

APPENDIX B

ATSDR Inhalation Minimal Risk Levels

This page intentionally left blank!

Appendix B: ATSDR Inhalation Minimal Risk Levels[1]

CAS Number	Hazardous Substance	Acute[2]		Intermediate[3]		Chronic[4]	
		µg/m^3	ppbv	µg/m^3	ppbv	µg/m^3	ppbv
67-64-1	Acetone	60,000	30,000	30,000	10,000	30,000	10,000
71-43-2	Benzene	30	9	20	6	10	3
111-44-4	Bis(2-chloroethyl)ether	NA	NA	100	20	NA	NA
75-15-0	Carbon Disulfide	NA	NA	NA	NA	900	300
56-23-5	Carbon Tetrachloride	NA	NA	200	30	200	30
75-00-3	Chloroethane	40,000	15,000	NA	NA	NA	NA
67-66-3	Chloroform	500	100	200	40	100	20
106-46-7	1,4-Dichlorobenzene	10,000	2,000	1,000	200	60	10
107-06-2	1,2-Dichloroethane	NA	NA	NA	NA	2,000	600
75-35-4	1,1-Dichloroethene	NA	NA	80	20	NA	NA
156-60-5	*trans*-1,2-Dichloroethylene	800	200	800	200	NA	NA
78-87-5	1,2-Dichloropropane	200	50	30	7	NA	NA
542-75-6	1,3-Dichloropropene	NA	NA	40	8	30	7
100-41-4	Ethylbenzene	40,000	10,000	3,000	700	1,000	300
77-47-4	Hexachlorocyclopentadiene	NA	NA	100	10	2	0.2
67-72-1	Hexachloroethane	60,000	6,000	60,000	6,000	NA	NA
302-01-2	Hydrazine	NA	NA	5	4	NA	NA
7439-97-6	Mercury (elemental)	NA	NA	NA	NA	0.2	0.02
75-09-2	Methylene Chloride	2,000	600	1,000	300	1,000	300
1634-04-4	MTBE	7,000	2,000	2,000	600	2,000	600
91-20-3	Naphthalene	NA	NA	NA	NA	4	1
100-42-5	Styrene	9,000	2,000	NA	NA	900	200
127-18-4	Tetrachloroethylene (PCE)	1,000	200	NA	NA	300	40
108-88-3	Toluene	4,000	1,000	NA	NA	300	80
71-55-6	1,1,1-Trichloroethane	10,000	2,000	4,000	700	NA	NA
79-01-6	Trichloroethylene (TCE)	10,000	2,000	500	100	NA	NA
96-18-4	1,2,3-Trichloropropane	2	0.3	NA	NA	NA	NA
1330-20-7	Xylenes (total)	9,000	2,000	3,000	600	200	50

Notes:

ATSDR – Agency for Toxic Substance & Disease Registry

µg/m^3 – micrograms per cubic meter

ppbv – parts per billion by volume

NA – not available

1. Minimal risk levels were last updated 10/27/2008.
2. Acute levels are developed for exposure periods of 14 days or less.
3. Intermediate levels are developed for exposure periods of 15 to 364 days.
4. Chronic levels are developed for exposure periods of 365 days or more.

This page intentionally left blank

APPENDIX C

Conceptual Site Model Checklist
(from ITRC, 2007)

This page intentionally left blank

Conceptual Site Model Checklist (ITRC, 2007)

The information included in this checklist may be useful for developing a site-specific conceptual migration model and in planning soil gas sampling. The investigator may use this checklist to compile information for each site.

Utilities and Process Piping

- ☐ Locate and map out all underground utilities near the soil or groundwater impacts. Pay particular attention to utilities that connect impacted areas to occupied buildings.
- ☐ Locate and map out all underground process piping near the soil or groundwater impacts.

Buildings (Receptors)

- ☐ Locate and map out existing and potential future buildings. Identify the occupancy and use of the buildings (e.g., residential, commercial). You may need to interview occupants to obtain this information.
- ☐ Describe the construction of the building including materials (e.g., wood frame, block), openings (e.g., windows, doors), and height (e.g., one story, two story, multistory). Determine whether there is an elevator shaft in the building.
- ☐ Describe the foundation construction:
    - Type (e.g., basement, crawl space, slab on grade)
    - Floor construction (e.g., concrete, dirt)
    - Depth below grade
- ☐ Describe the HVAC system in the building:
    - Type (e.g., forced air, radiant)
    - Equipment location (e.g., basement, crawl space, utility closet, attic, roof)
    - Source of return air (e.g., inside air, outside air, combination)
    - System design considerations relating to indoor air pressure (e.g., positive pressure is often the case for commercial buildings)
- ☐ Describe subslab ventilation systems or moisture barriers present on existing buildings, or identify building- and fire-code requirements for subslab ventilation systems (e.g., for methane) or moisture barriers below foundations.

Source Area

- ☐ Locate and map out the source area for the vapor-phase contaminants related to the subsurface vapor intrusion pathway.
- ☐ Describe the presence, distribution, and composition of any NAPL at the site.
- ☐ Identify the vapor-phase contaminants that are to be considered for the subsurface vapor intrusion pathway.

- ☐ Describe the status and results for the delineation of contamination in environmental media, specifically soil and groundwater, between the source area and the potential impacted buildings.
- ☐ Describe the environmental media (e.g., soil, groundwater, both) containing contaminants.
- ☐ Describe the depth to source area.
- ☐ Describe the potential migration characteristics (e.g., stable, increasing, decreasing) for the distribution of contaminants.

Geology/Hydrogeology

- ☐ Review all boring logs, monitoring well construction, and soil sampling data to understand the following:
    - Heterogeneity/homogeneity of soils and the lithologic units encountered and the expected/observed contaminant migration:
        - Depth and lateral continuity of any confining units that may impede contaminant migration
        - Depth and lateral continuity of any highly transmissive units that may enhance contaminant migration
    - Depth of vadose (unsaturated) zone, capillary fringe, and phreatic (saturated) zone:
        - Note any seasonal groundwater fluctuations and seasonal flow direction changes (hydraulic gradient).
        - Note the depth interval between the vapor source and the ground surface.
        - Note the presence of any perched aquifers.
        - Note where the groundwater surface intersects the well screen interval or the presence of submerged screen.
- ☐ Describe distinct strata (soil type and moisture content, e.g., moist, wet, dry) and the depth intervals between the vapor source and ground surface.
- ☐ Describe the depth to groundwater.
- ☐ Describe groundwater characteristics (e.g., seasonal fluctuation, hydraulic gradient).

Site Characteristics

- ☐ Estimate the distance from edge of groundwater plume to building.
- ☐ Determine nearby potential sources.
- ☐ Estimate the distance from vapor source area to building.
- ☐ Describe the surface cover between the vapor source area and the potentially impacted building.

APPENDIX D

DEC Indoor Air Target Levels

This page intentionally left blank

Appendix D: Target Levels for Indoor Air

CAS Number	Hazardous Substance[1]	Residential Indoor Air (µg/m^3)	Residential Indoor Air (ppbv)	Commercial Indoor Air (µg/m^3)	Commercial Indoor Air (ppbv)
67-64-1	Acetone	3300	1400	13800	5800
71-43-2	Benzene[2]	3.1	0.98	16	4.9
111-44-4	Bis(2-chloroethyl)ether	0.074	0.013	0.37	0.064
75-27-4	Bromodichloromethane	1.4	0.21	6.9	1.0
75-25-2	Bromoform	22	2.1	110	11
104-51-8	n-Butylbenzene[2]	37	6.7	150	28
135-98-8	sec-Butylbenzene[2]	37	6.7	150	28
98-06-6	tert-Butylbenzene[2]	37	6.7	150	28
75-15-0	Carbon Disulfide	730	230	3100	990
56-23-5	Carbon Tetrachloride	1.6	0.26	8.2	1.3
108-90-7	Chlorobenzene	52	11	220	48
124-48-1	Chlorodibromomethane	1.0	0.12	5.1	0.60
75-00-3	Chloroethane	29	11	150	56
67-66-3	Chloroform	1.1	0.22	5.3	1.1
95-57-8	2-Chlorophenol	18	3.5	77	15
95-50-1	1,2-Dichlorobenzene	210	35	880	150
541-73-1	1,3-Dichlorobenzene	210	35	880	150
106-46-7	1,4-Dichlorobenzene	3.5	0.59	18	3.0
75-71-8	Dichlorodifluoromethane	210	42	880	180
75-34-3	1,1-Dichloroethane	520	130	2200	540
107-06-2	1,2-Dichloroethane	0.94	0.23	4.7	1.2
75-35-4	1,1-Dichloroethylene	0.49	0.12	2.5	0.62
156-59-2	*cis*-1,2-Dichloroethylene	37	9.2	150	39
156-60-5	*trans*-1,2-Dichloroethylene	63	16	260	66
78-87-5	1,2-Dichloropropane	1.3	0.27	6.3	1.4
542-75-6	1,3-Dichloropropene	6.1	1.3	31	6.8
100-41-4	Ethylbenzene[2]	22	5.1	110	26
106-93-4	EDB (1,2-Dibromoethane)	0.041	0.0053	0.20	0.027
50-00-0	Formaldehyde	1.9	1.5	9.4	7.7
118-74-1	Hexachlorobenzene	0.053	0.0045	0.27	0.023
87-68-3	Hexachloro-1,3-butadiene	1.1	0.10	5.6	0.52
77-47-4	Hexachlorocyclopentadiene	0.21	0.019	0.88	0.079
67-72-1	Hexachloroethane	6.1	0.63	31	3.2
302-01-2	Hydrazine	0.0050	0.0038	0.025	0.019
98-82-8	Isopropylbenzene	420	85	1800	360
74-83-9	Methyl Bromide	5.2	1.3	22	5.6
74-87-3	Methyl Chloride	14	6.6	68	33
78-93-3	MEK	5200	1800	21900	7400
108-10-1	MIBK	3100	760	13100	3200
7439-97-6	Mercury (elemental)	0.31	0.038	1.3	0.16
74-95-3	Methylene Bromide	36.5	5.14	150	22
75-09-2	Methylene Chloride	52	15	260	75

Appendix D: Target Levels for Indoor Air

CAS Number	Hazardous Substance[1]	Residential Indoor Air (µg/m^3)	Residential Indoor Air (ppbv)	Commercial Indoor Air (µg/m^3)	Commercial Indoor Air (ppbv)
90-12-0	1-Methylnaphthalene	14.6	2.51	61	11
91-57-6	2-Methylnaphthalene	14.6	2.51	61	11
1634-04-4	MTBE	47	13	240	66
91-20-3	Naphthalene[2]	0.72	0.14	3.6	0.69
98-95-3	Nitrobenzene	2.1	0.41	8.8	1.7
62-75-9	n-Nitrosodimethylamine	0.0017	0.00057	0.0088	0.0029
103-65-1	n-Propylbenzene[2]	37	7.4	150	31
100-42-5	Styrene[2]	1000	240	4400	1000
79-34-5	1,1,2,2-Tetrachloroethane	0.42	0.061	2.1	0.31
127-18-4	Tetrachloroethylene (PCE)	4.1	0.61	21	3.1
108-88-3	Toluene[2]	5200	1400	21900	5800
120-82-1	1,2,4-Trichlorobenzene	4.2	0.56	18	2.4
71-55-6	1,1,1-Trichloroethane	2300	420	9600	1800
79-00-5	1,1,2-Trichloroethane	1.5	0.28	7.7	1.4
79-01-6	Trichloroethylene (TCE)	0.22	0.041	1.1	0.21
96-18-4	1,2,3-Trichloropropane	0.012	0.0020	0.061	0.010
76-13-1	Trichlorotrifluoroethane	31300	4100	131000	17200
75-69-4	Trichlorofluoromethane	730	130	3100	550
95-63-6	1,2,4-Trimethylbenzene[2]	7.3	1.5	31	6.2
108-67-8	1,3,5-Trimethylbenzene[2]	7.3	1.5	31	6.2
108-05-4	Vinyl Acetate	210	59	880	250
75-01-4	Vinyl Chloride (Chloroethene)	0.81	0.32	1.1	0.41
1330-20-7	Xylenes (total)[2]	100.0	24.03	440	100

Notes:

µg/m^3 – micrograms per cubic meter

ppbv – parts per billion by volume

[1] The chemicals listed here are found in Table B2 of 18 AAC 75.341 and Table C of 18 AAC 75.345 and are volatile compounds as defined by DEC. If a chemical is not on this list, and not in Table B1 of 18 AAC 75.34 or Table C of 18 AAC 75.345, the chemical has not been evaluated for volatility. Contact the DEC risk assessor to determine if the chemical is volatile.

[2] These chemicals should be investigated as chemicals of potential concern when petroleum is present. If fuel containing additives (e.g., 1,2-dichloroethane, ethylene dibromide, methyl *tert*-butyl ether) was spilled, these chemicals should also be investigated.

APPENDIX E

DEC Shallow Soil Gas Target Levels

This page intentionally left blank

Appendix E: Target Levels for Shallow[1] or Subslab Soil Gas[2]

CAS Number	Hazardous Substance[3]	Residential Soil Gas (µg/m^3)	Residential Soil Gas (ppbv)	Commercial Soil Gas (µg/m^3)	Commercial Soil Gas (ppbv)
67-64-1	Acetone	32900	13800	138000	58100
71-43-2	Benzene[4]	31	9.8	160	49
111-44-4	Bis(2-chloroethyl)ether	0.74	0.13	3.7	0.64
75-27-4	Bromodichloromethane	14	2.1	69	10
75-25-2	Bromoform	220	21	1100	110
104-51-8	n-Butylbenzene[4]	370	67	1500	280
135-98-8	sec-Butylbenzene[4]	370	67	1500	280
98-06-6	tert-Butylbenzene[4]	370	67	1500	280
75-15-0	Carbon Disulfide	7300	2300	30700	9900
56-23-5	Carbon Tetrachloride	16	2.6	82	13
108-90-7	Chlorobenzene	520	110	2200	480
124-48-1	Chlorodibromomethane	10	1.2	51	6.0
75-00-3	Chloroethane	290	110	1500	560
67-66-3	Chloroform	11	2.2	53	11
95-57-8	2-Chlorophenol	180	35	770	150
95-50-1	1,2-Dichlorobenzene	2100	350	8800	1500
541-73-1	1,3-Dichlorobenzene	2100	350	8800	1500
106-46-7	1,4-Dichlorobenzene	35	5.9	180	30
75-71-8	Dichlorodifluoromethane	2100	420	8800	1800
75-34-3	1,1-Dichloroethane	5200	1300	21900	5400
107-06-2	1,2-Dichloroethane	9.4	2.3	47	12
75-35-4	1,1-Dichloroethylene	4.9	1.2	25	6.2
156-59-2	*cis*-1,2-Dichloroethylene	370	92	1500	390
156-60-5	*trans*-1,2-Dichloroethylene	630	160	2600	660
78-87-5	1,2-Dichloropropane	13	2.7	63	14
542-75-6	1,3-Dichloropropene	61	13	310	68
100-41-4	Ethylbenzene[4]	220	51	1100	260
106-93-4	EDB (1,2-Dibromoethane)	0.41	0.053	2.0	0.27
50-00-0	Formaldehyde	19	15	94	77
118-74-1	Hexachlorobenzene	0.53	0.045	2.7	0.23
87-68-3	Hexachloro-1,3-butadiene	11.1	1.04	56	5.2
77-47-4	Hexachlorocyclopentadiene	2.1	0.19	8.8	0.79
67-72-1	Hexachloroethane	61	6.3	310	32
302-01-2	Hydrazine	0.050	0.038	0.25	0.19
98-82-8	Isopropylbenzene	4200	850	17500	3600
74-83-9	Methyl Bromide	52	13	220	56
74-87-3	Methyl Chloride	140	66	680	330
78-93-3	MEK	52100	17700	219000	74300
108-10-1	MIBK	31300	7600	131000	32100
7439-97-6	Mercury (elemental)	3.1	0.38	13	1.6
74-95-3	Methylene Bromide	370	51	1500	220
75-09-2	Methylene Chloride	520	150	2600	750
90-12-0	1-Methylnaphthalene	150	25	610	110

Appendix E: Target Levels for Shallow[1] or Subslab Soil Gas[2]

CAS Number	Hazardous Substance[3]	Residential Soil Gas (µg/m^3)	Residential Soil Gas (ppbv)	Commercial Soil Gas (µg/m^3)	Commercial Soil Gas (ppbv)
91-57-6	2-Methylnaphthalene	150	25	610	110
1634-04-4	MTBE	470	130	2400	660
91-20-3	Naphthalene[4]	7.2	1.4	36	6.9
98-95-3	Nitrobenzene	21	4.1	88	17
62-75-9	n-Nitrosodimethylamine	0.017	0.0057	0.088	0.029
103-65-1	n-Propylbenzene[4]	370	74	1500	310
100-42-5	Styrene[4]	10400	2400	43800	10300
79-34-5	1,1,2,2-Tetrachloroethane	4.2	0.61	21	3.1
127-18-4	Tetrachloroethylene (PCE)	41	6.1	210	31
108-88-3	Toluene[4]	52100	13800	219000	58200
120-82-1	1,2,4-Trichlorobenzene	42	5.6	180	24
71-55-6	1,1,1-Trichloroethane	22900	4200	96400	17700
79-00-5	1,1,2-Trichloroethane	15	2.8	77	14
79-01-6	Trichloroethylene (TCE)	2.2	0.41	11	2.1
96-18-4	1,2,3-Trichloropropane	0.12	0.020	0.61	0.10
76-13-1	Trichlorotrifluoroethane	313000	40800	1310000	172000
75-69-4	Trichlorofluoromethane	7300	1300	30700	5500
95-63-6	1,2,4-Trimethylbenzene[4]	73	15	310	62
108-67-8	1,3,5-Trimethylbenzene[4]	73	15	310	62
108-05-4	Vinyl Acetate	2100	590	8800	2500
75-01-4	Vinyl Chloride (Chloroethene)	8.1	3.2	11	4.1
1330-20-7	Xylenes (total)[4]	1000	240	4400	1000

Notes:

µg/m^3 – micrograms per cubic meter

ppbv – parts per billion by volume

[1] Shallow soil gas includes soil gas collected from 5 feet or less below the ground surface, or 5 feet or less below a foundation.

[2] Do not rely on target levels when a vapor source is less than 15 feet from the foundation and preferential pathways, significant openings, or low building air exchange exist.

[3] The chemicals listed here are found in Table B2 of 18 AAC 75.341 and Table C of 18 AAC 75.345 and are volatile compounds as defined by DEC. If a chemical is not on this list, and not in Table B1 of 18 AAC 75.34 or Table C of 18 AAC 75.345, the chemical has not been evaluated for volatility. Contact the DEC risk assessor to determine if the chemical is volatile.

[4] These chemicals should be investigated as chemicals of potential concern when petroleum is present. If fuel containing additives (e.g., 1,2-dichloroethane, ethylene dibromide, methyl *tert*-butyl ether) was spilled, these chemicals should also be investigated.

APPENDIX F

DEC Deep Soil Gas Target Levels

This page intentionally left blank

Appendix F: Target Levels for Deep Soil Gas[1,2]

CAS Number	Hazardous Substance[3]	Residential Soil Gas (µg/m^3)	Residential Soil Gas (ppbv)	Commercial Soil Gas (µg/m^3)	Commercial Soil Gas (ppbv)
67-64-1	Acetone	329000	138000	1380000	581000
71-43-2	Benzene[4]	310	98	1600	490
111-44-4	Bis(2-chloroethyl)ether	7.4	1.3	37	6.4
75-27-4	Bromodichloromethane	140	21	690	100
75-25-2	Bromoform	2200	210	11000	1100
104-51-8	n-Butylbenzene[4]	3700	670	15000	2800
135-98-8	sec-Butylbenzene[4]	3700	670	15000	2800
98-06-6	tert-Butylbenzene[4]	3700	670	15000	2800
75-15-0	Carbon Disulfide	73000	23000	307000	99000
56-23-5	Carbon Tetrachloride	160	26	820	130
108-90-7	Chlorobenzene	5200	1100	22000	4800
124-48-1	Chlorodibromomethane	100	12	510	60
75-00-3	Chloroethane	2900	1100	15000	5600
67-66-3	Chloroform	110	22	530	110
95-57-8	2-Chlorophenol	1800	350	7700	1500
95-50-1	1,2-Dichlorobenzene	21000	3500	88000	15000
541-73-1	1,3-Dichlorobenzene	21000	3500	88000	15000
106-46-7	1,4-Dichlorobenzene	350	59	1800	300
75-71-8	Dichlorodifluoromethane	21000	4200	88000	18000
75-34-3	1,1-Dichloroethane	52000	13000	219000	54000
107-06-2	1,2-Dichloroethane	94	23	470	120
75-35-4	1,1-Dichloroethylene	49	12	250	62
156-59-2	*cis*-1,2-Dichloroethylene	3700	920	15000	3900
156-60-5	*trans*-1,2-Dichloroethylene	6300	1600	26000	6600
78-87-5	1,2-Dichloropropane	130	27	630	140
542-75-6	1,3-Dichloropropene	610	130	3100	680
100-41-4	Ethylbenzene[4]	2200	510	11000	2600
106-93-4	EDB (1,2-Dibromoethane)	4.1	0.53	20	2.7
50-00-0	Formaldehyde	190	150	940	770
118-74-1	Hexachlorobenzene	5.3	0.45	27	2.3
87-68-3	Hexachloro-1,3-butadiene	111	10.4	560	52
77-47-4	Hexachlorocyclopentadiene	21	1.9	88	7.9
67-72-1	Hexachloroethane	610	63	3100	320
302-01-2	Hydrazine	0.5	0.38	2.5	1.9
98-82-8	Isopropylbenzene	42000	8500	175000	36000
74-83-9	Methyl bromide	520	130	2200	560
74-87-3	Methyl chloride	1400	660	6800	3300
78-93-3	MEK	521000	177000	2190000	743000
108-10-1	MIBK	313000	76000	1310000	321000
7439-97-6	Mercury (elemental)	31	3.8	130	16
74-95-3	Methylene Bromide	3700	510	15000	2200
75-09-2	Methylene Chloride	5200	1500	26000	7500
90-12-0	1-Methylnaphthalene	1500	250	6100	1100

Appendix F: Target Levels for Deep Soil Gas[1,2]

CAS Number	Hazardous Substance[3]	Residential Soil Gas (µg/m^3)	Residential Soil Gas (ppbv)	Commercial Soil Gas (µg/m^3)	Commercial Soil Gas (ppbv)
91-57-6	2-Methylnaphthalene	1500	250	6100	1100
1634-04-4	MTBE	4700	1300	24000	6600
91-20-3	Naphthalene[4]	72	14	360	69
98-95-3	Nitrobenzene	210	41	880	170
62-75-9	n-Nitrosodimethylamine	0.17	0.057	0.88	0.29
103-65-1	n-Propylbenzene[4]	3700	740	15000	3100
100-42-5	Styrene[4]	104000	24000	438000	103000
79-34-5	1,1,2,2-Tetrachloroethane	42	6.1	210	31
127-18-4	Tetrachloroethylene (PCE)	410	61	2100	310
108-88-3	Toluene[4]	521000	138000	2190000	582000
120-82-1	1,2,4-Trichlorobenzene	420	56	1800	240
71-55-6	1,1,1-Trichloroethane	229000	42000	964000	177000
79-00-5	1,1,2-Trichloroethane	150	28	770	140
79-01-6	Trichloroethylene (TCE)	22	4.1	110	21
96-18-4	1,2,3-Trichloropropane	1.2	0.2	6.1	1
76-13-1	Trichlorotrifluoroethane	3130000	408000	13100000	1720000
75-69-4	Trichlorofluoromethane	73000	13000	307000	55000
95-63-6	1,2,4-Trimethylbenzene[4]	730	150	3100	620
108-67-8	1,3,5-Trimethylbenzene[4]	730	150	3100	620
108-05-4	Vinyl Acetate	21000	5900	88000	25000
75-01-4	Vinyl chloride (Chloroethene)	81	32	110	41
1330-20-7	Xylenes (total)[4]	10000	2400	44000	10000

Notes:

µg/m^3 – micrograms per cubic meter

ppbv – parts per billion by volume

[1] Deep soil gas includes soil gas collected more than 5 feet below the ground surface, or more than 5 feet below a foundation.

[2] Do not rely on target levels when a vapor source is less than 15 feet from the foundation and preferential pathways, significant openings, or low building air exchange exist.

[3] The chemicals listed here are found in Table B2 of 18 AAC 75.341 and Table C of 18 AAC 75.345 and are volatile compounds as defined by DEC. If a chemical is not on this list, and not in Table B1 of 18 AAC 75.34 or Table C of 18 AAC 75.345, the chemical has not been evaluated for volatility. Contact the DEC risk assessor to determine if the chemical is volatile.

[4] These chemicals should be investigated as chemicals of potential concern when petroleum is present. If fuel containing additives (e.g., 1,2-dichloroethane, ethylene dibromide, methyl *tert*-butyl ether) was spilled, these chemicals should also be investigated.

APPENDIX G

DEC Groundwater Target Levels

This page intentionally left blank

Appendix G: Target Levels for Groundwater[1]

CAS Number	Hazardous Substance[2]	Residential Groundwater Level (µg/L)	Commercial Groundwater Level (µg/L)
67-64-1	Acetone	2030000	8520000
71-43-2	Benzene[3]	14	69
111-44-4	Bis(2-chloroethyl)ether	110	530
75-27-4	Bromodichloromethane	16	80
75-25-2	Bromoform	1000	5100
104-51-8	n-Butylbenzene[3]	68	290
135-98-8	sec-Butylbenzene[3]	48	200
98-06-6	tert-Butylbenzene[3]	71	300
75-15-0	Carbon Disulfide	1200	5200
56-23-5	Carbon Tetrachloride	1.4	7.2
108-90-7	Chlorobenzene	410	1700
124-48-1	Chlorodibromomethane	32	160
75-00-3	Chloroethane	23000	96500
67-66-3	Chloroform	7.1	36
95-57-8	2-Chlorophenol	39800	167000
95-50-1	1,2-Dichlorobenzene	2700	11200
541-73-1	1,3-Dichlorobenzene	1900	8100
106-46-7	1,4-Dichlorobenzene	36	180
75-71-8	Dichlorodifluoromethane	15	63
75-34-3	1,1-Dichloroethane	2300	9500
107-06-2	1,2-Dichloroethane	19	98
75-35-4	1,1-Dichloroethylene	0.45	2.3
156-59-2	*cis*-1,2-Dichloroethylene	220	920
156-60-5	*trans*-1,2-Dichloroethylene	160	690
78-87-5	1,2-Dichloropropane	11	55
542-75-6	1,3-Dichloropropene	42	210
100-41-4	Ethylbenzene[3]	69	350
106-93-4	EDB (1,2-Dibromoethane)	1.5	7.5
50-00-0	Formaldehyde	136000	684000
118-74-1	Hexachlorobenzene	0.76	3.8
87-68-3	Hexachloro-1,3-butadiene	2.6	13
77-47-4	Hexachlorocyclopentadiene	0.19	0.80
67-72-1	Hexachloroethane	38	190
302-01-2	Hydrazine	8400	42500
98-82-8	Isopropylbenzene	890	3700
74-83-9	Methyl Bromide	20	86
74-87-3	Methyl Chloride	37	190
78-93-3	MEK	2240000	9400000
108-10-1	MIBK	555000	2330000
74-95-3	Methylene Bromide	1100	4600
75-09-2	Methylene Chloride	390	2000
90-12-0	1-Methylnaphthalene	700	2900

Appendix G: Target Levels for Groundwater[1]

CAS Number	Hazardous Substance[2]	Residential Groundwater Level (µg/L)	Commercial Groundwater Level (µg/L)
91-57-6	2-Methylnaphthalene	690	2900
1634-04-4	MTBE	2000	9900
91-20-3	Naphthalene[3]	40	200
98-95-3	Nitrobenzene	2100	8900
62-75-9	n-Nitrosodimethylamine	23	120
103-65-1	n-Propylbenzene[3]	68	290
100-42-5	Styrene[3]	9300	39100
79-34-5	1,1,2,2-Tetrachloroethane	28	140
127-18-4	Tetrachloroethylene (PCE)	5.7	29
108-88-3	Toluene[3]	19200	80800
120-82-1	1,2,4-Trichlorobenzene	72	300
71-55-6	1,1,1-Trichloroethane	3300	13700
79-00-5	1,1,2-Trichloroethane	45	230
79-01-6	Trichloroethylene (TCE)	0.55	2.8
96-18-4	1,2,3-Trichloropropane	0.87	4.4
76-13-1	Trichlorotrifluoroethane	1500	6100
75-69-4	Trichlorofluoromethane	180	770
95-63-6	1,2,4-Trimethylbenzene[3]	29	120
108-67-8	1,3,5-Trimethylbenzene[3]	20	85
108-05-4	Vinyl Acetate	10000	41900
75-01-4	Vinyl Chloride (Chloroethene)	0.71	0.92
1330-20-7	Xylenes (total)[3]	380	1600

Notes:

µg/L – micrograms per liter

[1] Do not rely on target levels when groundwater contamination is less than 5 feet from the foundation or a vapor source is less than 15 feet from the foundation and preferential pathways, significant openings, or low building air exchange exist.

[2] The chemicals listed here are found in Table B2 of 18 AAC 75.341 and Table C of 18 AAC 75.345 and are volatile compounds as defined by DEC. If a chemical is not on this list, and not in Table B1 of 18 AAC 75.34 or Table C of 18 AAC 75.345, the chemical has not been evaluated for volatility. Contact the DEC risk assessor to determine if the chemical is volatile.

[3] These chemicals should be investigated as chemicals of potential concern when petroleum is present. If fuel containing additives (e.g., 1,2-dichloroethane, ethylene dibromide, methyl *tert*-butyl ether) was spilled, these chemicals should also be investigated.

APPENDIX H

Background Indoor Air Levels

This page intentionally left blank

Appendix H: Average Background Levels for Indoor Air from Multiple Studies[1] (µg/m^3)

Hazardous Substance	25th Percentile	50th Percentile	75th Percentile	95th Percentile
Benzene	1.9	2.5	4.5	17
Carbon Tetrachloride	0.3	0.5	0.7	1.1
Chloroform	0.5	1.1	2.2	6.0
1,1-Dichloroethane	<RL	<RL	<RL	<RL
1,2-Dichloroethane	<RL	<RL	<RL	0.2
1,1-Dichloroethylene	<RL	<RL	<RL	<RL
cis-1,2-Dichloroethylene	<RL	<RL	<RL	<RL
trans-1,2-Dichloroethylene	<RL	<RL	<RL	<RL
Ethylbenzene	0.8	2.0	3.0	14
MTBE	<RL	1.2	5.7	72
Methylene Chloride	0.42	1.10	3.6	20
Tetrachoroethene (PCE)	<RL	0.9	1.8	7.4
Toluene	9	13	27	106
Trichlorotrifluoroethane	<RL	0.5	1.1	3.4
1,1,1-Trichloroethene	0.5	1.9	2.7	10.2
Trichloroethene	<RL	0.3	0.3	1.6
Vinyl Chloride (Chloroethane)	<RL	<RL	<RL	0.05
Xylenes, m/p-	2.9	5.5	9.4	41
Xylenes, o-	1.4	2.2	3.9	16

Notes:
µg/m^3 – micrograms per cubic meter
<RL – less than reporting limit
[1]Compiled from Dawson and McAlary (2009).

This page intentionally left blank!

APPENDIX I

DEC Building Survey and Indoor Air Sampling Questionnaire

This page intentionally left blank

ALASKA DEPARTMENT OF ENVIRONMENAL CONSERVATION
BUILDING INVENTORY AND INDOOR AIR SAMPLING QUESTIONNAIRE

This form should be prepared by a person familiar with indoor air assessments with assistance from a person knowledgeable about the building. Complete this form for each building in which interior samples (e.g., indoor air, crawl space, or subslab soil gas samples) will be collected. Section I of this form should be used to assist in choosing an investigative strategy during workplan development. Section II should be used to assist in identification of complicating factors during a presampling building walkthrough.

Preparer's Name _____Date/Time Prepared_____

Preparer's Affiliation_____Phone No._____

Purpose of Investigation_____

SECTION I: BUILDING INVENTORY

1. OCCUPANT OR BUILDING PERSONNEL:

Interviewed: Y / N

Last Name_____First Name_____

Address_____

County_____

Phone No._____

Number of Occupants/persons at this location_____Age of Occupants_____

2. OWNER or LANDLORD: (Check if same as occupant ____)

Interviewed: Y / N

Last Name_____First Name_____

Address_____

County_____

Phone No._____

3. BUILDING CHARACTERISTICS

Type of Building: (Circle appropriate response)

Residential	School	Commercial/Multi-use
Industrial	Church	
Other_____		

If the property is residential, type? (Circle appropriate response)

Ranch	2-Family	3-Family
Raised Ranch	Split Level	Colonial
Cape Cod	Contemporary	Mobile Home
Duplex	Apartment House	Townhouses/Condos
Modular	Log Home	
Other_____		

If multiple units, how many?_____

If the property is commercial, type?

Business Types(s)_____

Does it include residences (i.e., multi-use)? Y / N If yes, how many?_____

Other characteristics:

Number of floors_____ Building age_____

Is the building insulated? Y / N How air tight? Tight / Average / Not Tight

Have occupants noticed chemical odors in the building? Y / N

If yes, please describe:_____

_____

4. AIRFLOW

Use air current tubes, tracer smoke, or knowledge about the building to evaluate airflow patterns and qualitatively describe:

Airflow between floors

_____

_____

_____

_____

_____

_____

Airflow in building near suspected source

_____

_____

_____

_____

_____

_____

Outdoor air infiltration

_____

_____

_____

_____

_____

_____

Infiltration into air ducts

_____

_____

_____

_____

_____

_____

5. BASEMENT AND CONSTRUCTION CHARACTERISTICS (Circle all that apply)

a. Above grade construction: wood frame log concrete brick

constructed on pilings constructed on pilings

with enclosed air space with open air space

b. Basement type: full crawlspace slab-on-grade other_____

c. Basement floor: concrete dirt stone other _____

d. Basement floor: unsealed sealed sealed with_____

e. Foundation walls: poured block stone other _____

f. Foundation walls: unsealed sealed sealed with _____

g. The basement is: wet damp dry

h. The basement is: finished unfinished partially finished

i. Sump present? Y / N

j. Water in sump? Y / N / not applicable

Basement/Lowest level depth below grade_____(feet)

Identify potential soil vapor entry points and approximate size (e.g., cracks, utility ports, drains)

_____

_____

6. HEATING, VENTING and AIR CONDITIONING (Circle all that apply)

Type of heating system(s) used in this building: (Circle all that apply – not primary)

Hot air circulation	Heat pump	Hot water baseboard
Space Heaters	Stream radiation	Radiant floor
Electric baseboard	Wood stove	Outdoor wood boiler

Other_____

The primary type of fuel used is:

Natural Gas	Fuel Oil	Kerosene
Electric	Propane	Solar
Wood	Coal	

Domestic hot water tank fueled by_____

Boiler/furnace located in: Basement Outdoors Main Floor Other_____

Do any of the heating appliances have cold-air intakes? Y / N
Type of air conditioning or ventilation used in this building:

Central Air	Window units	Open Windows	None
Commercial HVAC	Heat-recovery system	Passive air system	

Are there air distribution ducts present? Y / N

Describe the ventilation system in the building, its condition where visible, and the tightness of duct joints. Indicate the locations of air supply and exhaust points on the floor plan.

_____

_____

_____

_____

Is there a radon mitigation system for the building/structure? Y / N Date of Installation_____

Is the system active or passive? Active/Passive

7. OCCUPANCY

Is basement/lowest level occupied? Full-time Occasionally Seldom Almost Never

Level	**General Use of Each Floor (e.g. family room, bedroom, laundry, workshop, storage)**
Basement	_____
1st Floor	_____
2nd Floor	_____
3rd Floor	_____

8. WATER AND SEWAGE

Water Supply: Public Water Drilled Well Driven Well Dug Well
Other_____

Sewage Disposal: Public Sewer Septic Tank Leach Field Dry Well
Other_____

9. FLOOR PLANS

Draw a plan view sketch of the basement and first floor of the building. Indicate air sampling locations, possible indoor air pollution sources and PID meter readings. If the building does not have a basement, please note.

Basement:

First Floor:

10. OUTDOOR PLOT

Draw a sketch of the area surrounding the building being sampled. If applicable, provide information on spill locations, potential air contamination sources (industries, gas stations, repair shops, landfills, etc.), outdoor air sampling location(s) and PID meter readings.

Also indicate compass direction, wind direction and speed during sampling, the locations of the well and septic system, if applicable, and a qualifying statement to help locate the site on a topographic map.

SECTION II: INDOOR AIR SAMPLING QUESTIONNAIRE

This section should be completed during a presampling walkthrough. If indoor air sources of COCs are identified and removed, consider ventilating the building prior to sampling. However, ventilation and heating systems should be operating normally for 24 hours prior to sampling.

a) 1. FACTORS THAT MAY INFLUENCE INDOOR AIR QUALITY

Is there an attached garage? Y / N

Does the garage have a separate heating unit? Y / N / NA

Are petroleum-powered machines or vehicles stored in the garage (e.g., lawnmower, ATV, car) Y / N /NA

Please specify_____

Has the building ever had a fire? Y / N When?_____

Is a kerosene or unvented gas space heater present? Y / N Where?_____

Is there a workshop or hobby/craft area? Y / N Where & Type_____

Is there smoking in the building? Y / N How frequently?_____

Has painting/staining been done in the last 6 months? Y / N Where & When?_____

Is there new carpet, drapes or other textiles? Y / N Where & When?_____

Is there a kitchen exhaust fan? Y / N If yes, where vented?_____

Is there a bathroom exhaust fan? Y / N If yes, where vented?_____

Is there a clothes dryer? Y / N If yes, is it vented outside? Y / N

Are cleaning products, cosmetic products, or pesticides used that could interfere with indoor air sampling? Y / N

If yes, please describe_____

_____

_____

Do any of the building occupants use solvents at work? Y / N

(e.g., chemical manufacturing or laboratory, auto mechanic or auto body shop, painting, fuel oil delivery, boiler mechanic, pesticide application, cosmetologist

If yes, what types of solvents are used?_____

If yes, are their clothes washed at work? Y / N

Do any of the building occupants regularly use or work at a dry-cleaning service? (Circle appropriate response)

Yes, use dry-cleaning regularly (weekly) No

Yes, use dry-cleaning infrequently (monthly or less) Unknown

Yes, work at a dry-cleaning services

2. **PRODUCT INVENTORY FORM** (For use during building walkthrough)

Make & Model of field instrument used_____

List specific products found in the residence that have the potential to affect indoor air quality:

Location	**Product Description**	**Site (units)**	**Condition***	**Chemical Ingredients**	**Field Instrument Reading (units)**	**Photo ** Y / N**

* Describe the condition of the product containers **as Unopened (UO), Used (U),** or **Deteriorated (D)**

** Photographs of the front and back of product containers can replace the handwritten list of chemical ingredients. However, the photographs must be of good quality and ingredient labels must be legible.

This form modified from:

ITRC (Interstate Technology & Regulatory Council). 2007. *Vapor Intrusion Pathway: A Practical Guideline*. VI-1. Washington, D.C.: Interstate Technology & Regulatory Council, Vapor Intrusion Team. www.itrcweb.org.

The Alaska Department of Environmental Conservation's Contaminated Sites Program protects human health and the environment by managing the cleanup of contaminated soil and groundwater in Alaska. For more information, please contact our staff at the Contaminated Site program closest to you:

Juneau: 907-465-5390 / Anchorage: 907-269-7503
Fairbanks: 907-451-2153 / Kenai: 907-262-5210