Supplemental Guidance for Vapor Intrusion of Chlorinated Solvents and other Persistent Chemicals

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Approved: ______________________________

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1 Disclaimer

This document provides general guidelines for the investigation of certain Vapor Intrusion (VI) sites in Maine. These guidelines are not rules or regulations, and are not intended to have the force of law. This document does not create or affect the legal rights of any person which are determined by applicable statutes or law. Specifically, United States Occupational Safety and Health Administration (OSHA) standards, where applicable, supersede these guidelines.

2 Introduction

2.1 Purpose

This document supplements the guidance provided by the United States Environmental Protection Agency (EPA) on investigating and mitigating vapor intrusion risks. Specifically, this guidance pertains to sites with 10 or fewer inhabitable buildings at risk[1] and where the contaminants of concern are chlorinated solvents or similarly persistent, volatile and toxic chemicals. This document supersedes MEDEP's *Vapor Intrusion Evaluation Guidance* of 2010 (MEDEP, 2010a) pertaining to chlorinated and persistent chemicals.

The Maine Department of Environmental Protection (MEDEP) recognizes that Vapor Intrusion (VI) research is ongoing and is continuing to provide valuable information for completing VI investigations. MEDEP acknowledges the variability in soil gas and indoor air concentrations over short periods of time as demonstrated by research data of continuously monitored buildings. This is why MEDEP relies on multiple lines of evidence, a concise conceptual site model, and temporally spaced data as a basis for VI risk-based decisions. Environmental Professionals are encouraged to maintain current working knowledge of the VI research.

Chemicals that may pose a VI risk, but are not considered within the scope of this document include PCBs, hydrogen sulfide, and elemental mercury. These substances will be addressed on a case-by-case basis.

A distinction between EPA's "OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air" (hereinafter referred to as "EPA VI Guidance"), dated June, 2015 (EPA, 2015b) and this document is the vapor source and the vapor pathway. EPA's

[1] The rebuttable presumption is that all Maine VI sites will have fewer than 10 buildings at risk.

focus is on vapor intrusion risks resulting from off-gassing of significant VOC groundwater plumes impacting larger neighborhoods. This guidance focuses on smaller vapor sources in soil gas, soil, and groundwater typically associated with dry cleaner and small parts cleaner operations where preferential pathways typically provide a connection to off-site receptors within a small neighborhood.

2.2 Site Safety Plan

All investigations described in this guidance must be conducted under a site safety plan that meets OSHA standards. Remember to contact dig safe at least 3 days prior to subsurface investigations. VI investigations are often conducted in utility corridors and roads; the site safety plan must take these factors into account.

2.3 Vapor Intrusion (VI) Definition

Vapor intrusion (VI) is the migration of volatile chemicals from subsurface soil or groundwater into inhabitable buildings. “Volatile chemicals” include volatile organic compounds, select semi-volatile organic compounds, and some inorganic analytes like elemental mercury and hydrogen sulfide. For a list of chemicals of potential concern for vapor intrusion see the EPA VI Guidance Section 3.1.

Vapor intrusion is a potential human exposure pathway -- a way that people may come into contact with hazardous vapors while performing their day-to-day indoor activities. For purposes of this Guide, the vapor intrusion pathway is referred to as “complete” for a specific building or collection of buildings when the following five elements are met under current conditions:

1) A subsurface source of vapor -forming chemicals is present (e.g., in the soil or in groundwater) underneath or near the building(s) or a remote subsurface source of vapor –forming chemicals is present and is potentially connected to a building by a preferential pathway (see Sections EPA Guide 2.1, 5.3, 6.2.1, and 6.3.1);

2) Vapors form and have a route along which to migrate (be transported) toward the building (see EPA Guide Sections 2.2 and 6.3.2);

3) The building(s) is (are) susceptible to soil gas entry, which means openings exist for the vapors to enter the building and driving ‘forces’ (e.g., air pressure differences between the building and the subsurface environment) exist to draw the vapors from the subsurface through the openings into the building(s) (see EPA Guide Sections 2.3 and 6.3.3);

4) One or more vapor-forming chemicals comprising the subsurface vapor source(s) is (are) present in the indoor environment (see EPA Guide Sections 6.3.4 and 6.4.1); and

5) The building(s) is (are) occupied by one or more individuals when the vapor-forming chemical(s) is (are) present indoors.

2.4 Follow EPA's VI Guidance

In June of 2015, U.S. Environmental Protection Agency (EPA) published "OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface to Indoor Air" (hereinafter referred to as "EPA VI Guidance") (EPA, 2015b). EPA's VI Guidance effectively summarizes the latest science on the topic and should be applied in Maine. Specific exceptions to MEDEP's adoption of EPA's VI protocols are discussed in this document.

2.5 MEDEP Supplements to EPA's VI Guidance

MEDEP developed supplemental VI guidance for issues commonly found in Maine that are not fully addressed in EPA's VI guidance, namely:

- Smaller sites (less than 10 buildings impacted) impacted with Petroleum or other chemicals that rapidly degrade in subsurface soil or groundwater; and
- Smaller sites (less than 10 buildings impacted) impacted with Chlorinated Solvents or other persistent chemicals, or chemicals that degrade very slowly in subsurface soil or groundwater.

2.5.1 Sites with Potentially Explosive Conditions:

Release of gasoline, certain aviation fuels and other flammable liquids can create potentially explosive vapors in a building or other confined space. These potentially explosive situations will be investigated and defused through the local emergency response management authority and MEDEP Response Division using the MEDEP's emergency authority. Potentially explosive situations should be reported to local fire department as well as MEDEP's oil spill hot-line at 1-800-482-0777.

Explosive conditions generated from landfill gas, specifically methane, are also possible when the gas migrates into a confined space. This can happen directly from a landfill in the vapor phase, or from degassing of groundwater contaminated with dissolved landfill gas. Dissolved methane concentrations of approximately 1 mg/L are capable of producing explosive conditions within a confined space. MEDEP's Solid Waste Program should be consulted when landfill gas is found or suspected to be present in a confined space.

Once the explosive condition has been resolved then any remaining VI investigations can be handled using one of the guidelines discussed below.

2.5.2 Definition of Persistent Chemicals

For purposes of this VI guidance, "Persistent Chemicals" are halogenated chemicals that:

1. biodegrade relatively slowly in the presence of subsurface oxygen (half-life of greater than six-months in water and soil);
2. are toxic at low doses or degrade into toxic daughter products (Reference Concentration less than 10 mg/m^3 or Inhalation Unit Risk greater than 2.60E-07);
3. are volatile with vapor pressure greater than 1 mm Hg, or Henry's law constant greater than 10^{-5} ($atm\text{-}m^3$/ mol), and the vapor concentration of the pure component exceeds the indoor air target risk level if the vapor source is in soil, or, if in groundwater, the saturated vapor concentration exceeds the target indoor air risk level); and
4. are immiscible in water or when in a liquid phase are considered non-aqueous phase liquids.

See EPA VI Guidance, Section 3.1 for additional details on the definition of persistent compounds.

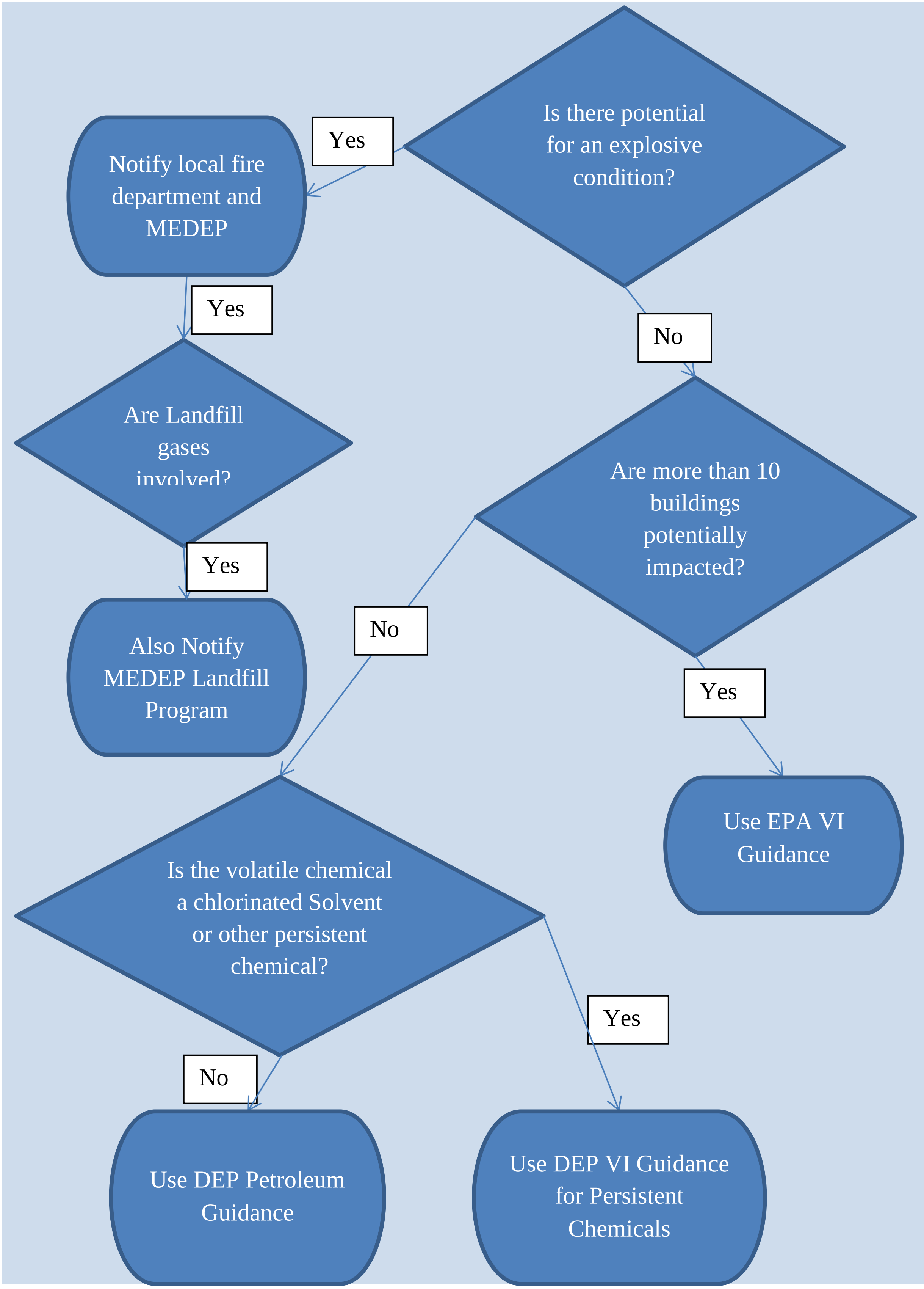

Figure 1: Selection of VI Guidance for Maine Sites

The persistent chemicals at VI sites in Maine that commonly create the greatest risk are the chlorinated ethylene, ethane, and methane compounds and daughter products that are shown in Table 1.

Table 1: Common Persistent Chemicals of Concern and Related Daughter Compounds

	Ethylene Compounds	**Ethane Compounds**		**Methane Compounds**
Parent Compound	**tetrachloroethylene (PCE)**	1,1,1-trichloroethane	**1,1,2-trichloroethane**	**carbon tetrachloride**
Daughter Compounds along the typical degradation pathway	**trichloroethylene (TCE)***	1,1 dichloroethane	**1,2 dichloroethane**	**chloroform**
	1,1-dichloroethylene	1,1-dichloroethylene	chloroethane	dichloromethane
	cis-1,2-dichloroethylene	chloroethane	ethane	chloromethane
	trans-1,2-dichloroethylene	acetic acid		
	vinyl chloride	ethane		
	ethylene			

Bold are usually the primary risk drivers when present

(*) Short-term exposure risks must be considered for sensitive receptors

2.5.3 Chemical Persistence Influences Vapor Transport

The VI potential of volatile contaminants is highly influenced by their potential to naturally biodegrade in the presence of oxygen in the vadose zone. The vadose zone is the soil layer above the water table and below the ground surface. Vapors can migrate in this unsaturated layer because the pore spaces are filled with gases from the atmosphere, rather than water. Persistent chemicals, such as chlorinated solvents, are chemicals that resist degradation in subsurface conditions, and therefore remain in the subsurface as a long term (many decades) source of continuing contamination. "Preferential pathways" are layers of relatively high permeability, like sands and gravels, in a matrix of lower permeability, such as the sandy backfill along a foundation or in a utility trench that was dug in clayey soil. These preferential pathways can serve to distribute vapors from a highly contaminated area (source) over extended distances in the subsurface, and create a connection between the source and receptor (e.g. a residence). Investigators should assume that preferential pathways exist until samples demonstrate that vapors are not preferentially migrating along such pathways.

Since chemical persistence plays such a major role in vapor transport, MEDEP has developed two separate supplemental VI guidances: one VI guidance to address petroleum and other volatile compounds that rapidly degrade, and this VI guidance for chlorinated solvents and other persistent volatile chemicals. This guidance supplements EPA's VI Guidance and focuses on VI investigation techniques.

2.5.4 VI at Small Sites with Petroleum or other Chemicals that Rapidly Degrade

Compounds that biodegrade relatively quickly as compared to chlorinated solvents are termed "not persistent". The most common contaminants in this category are petroleum compounds, particularly the aromatics and shorter chained hydrocarbon fractions. Vapors from compounds that are not persistent are found close to the source area, because they are not able to travel very far down a preferential pathway before they degrade. Unlike some halogenated solvents, petroleum compounds also tend to degrade into less toxic daughter products. Due to these factors petroleum discharges are unlikely to pose a risk after a few years, or if the receptor is not located near to the spill area. However, fresh, large, catastrophic petroleum releases have created explosion hazards and/or vapor intrusion risks.

For VI evaluation and mitigation of petroleum and other compounds that rapidly degrade, in addition to EPA's VI Guidance and EPA's Technical Guide for Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites, dated June, 2015 (EPA, 2015a), see Section 6 of MEDEP's *Remediation Guidelines for Petroleum Contaminated Sites in Maine* (MEDEP, 2014). That guideline should be used for sites with releases of petroleum hydrocarbons such as gasoline, fuel oil, kerosene, and stoddard solvents, and other contaminants that naturally biodegrade quickly in the vadose zone.

3 Planning the VI Investigation

3.1 Understand EPA's VI Guidance

Before planning and undertaking a VI investigation in Maine, be sure to review EPA's VI guidance. EPA's VI guidance Section 2.0 (Conceptual Model of Vapor Intrusion) describes the fundamental scientific principles of the VI pathway and should be familiar to anyone undertaking or reviewing VI investigation and mitigation. Another source of basic VI principles is U.S. Environmental Protection Agency's *Conceptual Model Scenarios for the VI Pathway* (EPA, 2012). Other critical parts of EPA's VI guidance include Section 3.0 (Overview), Section 5.0 (Preliminary Analysis of Vapor Intrusion Before undertaking a VI investigation), and Section 6.0 (Detailed Investigation of VI).

3.2 Use a Qualified Professional

3.2.1 Qualifications

Evaluation of the VI pathway, particularly any sampling program, should be undertaken by an environmental professional that has both VI experience and professional licensing to undertake a subsurface investigation in Maine. Generally this requires that the work be overseen by a Professional Engineer or Geologist qualified under the *Maine Geologists and Soil Scientists Certification Act*, 32 MRSA §4901 - 4920. The professional should also have extensive experience in undertaking VI investigations in Maine and be very familiar with both EPA's VI guidance and MEDEP's supplemental VI guidance.

Where mitigation involves large volume of air exchange or withdrawal (>100 cfm), large building footprints (>5,000 sq. ft.), and/or the HVAC is controlled, consultation with building maintenance and the HVAC designer is recommended. The proper ventilation of carbon monoxide from combustion appliances can be impaired by vapor mitigation activities and impact on appliances need to be considered prior to and evaluated following implementation to ensure safe operation of the appliance.

3.2.2 Communication & Collaboration

The scope, timing and objectives of the investigation and mitigation must be clear to avoid delays and conflicts. As new information is obtained and worked into the conceptual site model, additional sample rounds and locations are often required to fill data gaps. Ongoing communication and partnering between the MEDEP project staff, laboratory chemist, contractors and consultants is extremely important to ensure investigation and data quality objectives can be satisfied in a cost effective manner.

3.3 Develop a Conceptual Site Model

The first step in evaluating a site for risk is to develop an initial conceptual site model (CSM). Section 5.4 and 5.5 of EPA's VI Guidance discusses developing an initial CSM. ASTM defines a CSM as "a written or pictorial representation of an environmental system and the biological, physical and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system." (ASTM, 2014). The CSM is a dynamic tool to be updated as new information becomes available, and therefore it should be amended, as appropriate, after each stage of investigation. The CSM must consider the factors discussed in section 4.

3.3.1 VI Transport Mechanisms

For vapor sites the CSM is particularly important because vapors do not always act like other contaminants released into the environment in liquid form. There are several factors that influence the distribution of vapors from persistent chemicals in the vadose zone. The final CSM must be capable of identifying the different routes of vapor migration from the source area(s) (e.g. advection along preferential pathways, evaporation from contaminated groundwater, dissolution from NAPL, vapor diffusion within the soil gas pathway from the source(s), or a combination). Based on experience in completing vapor investigations in Maine, the following list are the primary factors that should be considered and incorporated into the Conceptual Site Model:

- The volume of the release or releases;
- The duration of solvent usage;
- Type of business (e.g. auto repair, woolen mill, metal fabrication, dry cleaning);
- The media impacted with solvent (subsurface air, ground water, soil);
- Porosity of natural soils underlying the site (fine grained soil generally maintains higher concentrations of affected media over time);
- Presence of fill material above natural material and contrast in porosity compared to natural material;

- Presence of underground utility lines (sewer, water, gas, electric, telephone). In areas where natural soil porosity is low these can serve as preferential pathways regardless of groundwater flow direction;
- Presence and extent of pavement or impervious surfaces;
- Presence of groundwater in overburden;
- Depth to groundwater;
- Current and historic location(s) of machine(s) used in cleaning process (parts washer, dry cleaner);
- Presence of dry cleaning lint and muck in subsurface;
- Presence of Underground Storage Tanks used to contain cleaning fluid;
- Solvent drum storage areas (full or empty);
- Solvent recycling practices (use of cookers, decanters);
- Maintenance practices (filter cleaning and drying; sludge and lint handling, storage, and disposal);
- Presence of floor drains, pits, or lagoons;
- The susceptibility of the contaminant vapors to biodegradation; and
- How the site and building may be impacted by the direction of diffusive and advective transport.

3.4 Establish the Objectives of the VI Investigation

Section 6.2 of EPA's VI guidance discusses how the objective of the VI investigation will vary depending upon the VI investigation stage (section 4) and resultant level of understanding presented in the CSM. The primary VI investigation objective is to collect the information necessary to evaluate the potential VI risk at a site or at an inhabitable receptor building. The objective needs to be developed by the project team and clearly communicated to other stakeholders such as responsible parties and interested public. The CSM should be your basis for identifying data gaps and how to fill them.

3.4.1 Sample Plan Development Process

A VI investigation will require collection and evaluation of environmental data. It is important to collect data that support the decisions that are needed to determine if a VI risk pathway is complete or not, and that support risk management decisions. Section 6.2 of the EPA VI Guidance provides guidance for developing a sampling plan, work plan, and site specific quality assurance project plan (SSQAPP) for a VI investigation. Follow EPA's systematic sample plan development procedure that is based on the CSM to ensure high quality results and necessary documentation.

3.4.2 Data Quality Objectives (DQOs) and Laboratory Considerations

The Data Quality Objectives (DQO) process is a stepwise approach recommended by EPA (EPA, 2006)

> …to establish performance and acceptance criteria, which serve as the basis for designing a plan for collecting data of sufficient quality and quantity to support the goals of the study. Use of the DQO Process leads to efficient and effective expenditure of resources; consensus on the type, quality, and quantity of data needed to meet the project goal; and the full documentation of actions taken during the development of the project.

Table C-1 of EPA's VI Guidance provides seven example steps that should be included and documented in the Data Quality Objectives (DQO) process and Appendix B provides DQOs to be included in the VI investigation plan. For Maine sites where the results will be compared to the *Maine Remedial Action Guidelines for Sites Contaminated with Hazardous Substances* (RAGs) (MEDEP, 2013), the DQOs must be set at analytical detection limits such that reporting limits are less than the indoor remedial action guidelines in Table 2 of the RAGs. For Maine sites where the results will be input into a Risk Assessment, develop DQOs in accordance with section 3.0 of *Maine DEP and CDC February 2011, Revised Guidance For Human Health Risk Assessments for Hazardous Substance Sites in Maine* (Risk Manual) (MEDEP and MECDC, 2011). Be sure that the laboratory procedure being proposed is capable of meeting those limits for each COPC and that the lab used is certified by the State of Maine to run this procedure.[2]

[2] Information on labs certified by Maine is available on the Department of Health and Human Services', Maine Laboratory Certification webpage at: http://www.maine.gov/dhhs/mecdc/environmental-health/water/dwp-services/labcert/labcert.htm.

To reach the desired detection levels in indoor air samples, the mass spectrometer may need to be operated in the selected ion-monitoring mode (SIM). This will give a lower detection limit for a select group of compounds, but if the list is too long the method loses its sensitivity advantage. Work with the lab to reduce the contaminants analyzed for from the full method suite to the site COPCs. When running a SIM analysis, a full scan needs to be run simultaneously to avoid false positives and negatives (e.g. TO-15 Full Scan-SIM combined). For the typical VI COPC shown in Table 1, the lab should be able to reach the DQOs in indoor air. However, if the RAGs Table 2 guidance value for a COPC at your site is lower than the Practical Quantitation Limit (PQL) of all the Maine certified labs, then the PQL will have to be used as the remedial action guideline for this contaminant.

Soil gas samples, due to the Attenuation Dilution Factor, do not require SIM analysis.

MEDEP recommends that when sampling an occupied space that the sample canisters should be individually certified as clean, rather than batch certified. You will need to budget in additional time and cost for this, but in the long run it avoids time consuming risk communication problems down the road.

3.4.3 MEDEP Sample Collection SOPs

MEDEP has developed sampling protocols that are just as reliable as the EPA protocols but are less costly, so MEDEP recommends that MEDEP's Standard Operating Procedures (SOPs) be used to obtain soil gas samples, rather than those in the EPA VI Guidance. As of this publication the most current SOPs for appropriate sample collection, as presented on the MEDEP website, are:

- DR#26: MEDEP Standard Operating *Protocol for Collecting Soil Gas Samples 2/2/09* (pdf format) (MEDEP, 2009c)
- DR#8: *Soil Gas Sample Collection Method Utilizing Hand Tools (1/29/2010)* (pdf format) (MEDEP, 2010b)
- *Public Review Draft Alternate soil gas sample point construction and sample method, utilizing thin diameter stainless steel tubing (8-19/2009)* (pdf format) (MEDEP, 2009e)
- *Soil Gas Sampling Field Sheet* (pdf format) (MEDEP, undated-b)

- DR#27: MEDEP Standard Operating *Protocol for Collecting Sub-Slab Soil Gas Samples (3/12/09)* (pdf format) (MEDEP, 2009d)
- *Indoor Air Sampling Field Sheet (pdf format) (MS Excel format)* (MEDEP, Undated-a)
- *2014 Protocol for Collecting Indoor Air Samples* (MEDEP, 2014a)
- *Draft Indoor Air Sample Protocol with draft Indoor Air Sample Information Collection Form (8/2/09*)(MS Word format) (pdf format) (MEDEP, 2009a)
- TS#4: *Compendium of Field Testing of Soil Samples for Gasoline and Fuel Oil (10/25/2012)* (pdf format) (MEDEP, 2012)
- DR#11: *Field Screening of Soil Samples Utilizing Photoionization and Flame-Ionization Detectors (3/16/2009)* (pdf format) (MEDEP, 2009b)

For updates and new VI SOPs, please check the MEDEP website at:

- http://www.maine.gov/dep/spills/publications/guidance/index.html
- http://www.maine.gov/dep/spills/publications/sops/index.html

4 Environmental Investigations

A VI investigation is usually conducted as part of a total site investigation of all risk pathways, including vapor intrusion, groundwater ingestion and soil ingestion/contact. In Maine investigations should follow a series of logical steps that are based on a conceptual site model, which is modified based on the findings of each step. VI investigations are occasionally stand-alone investigations, but should still follow the same basic investigation steps. Investigation objectives and level of effort change as the investigation proceeds through the following stages:

- collection of existing information;
- preliminary screening (optional);
- data collection and interpretation;
- mitigation evaluation/feasibility study;
- remedy implementation;
- operations, maintenance, optimization; and
- site closure.

4.1 Phase I ESA – Gather Background Information

The first stage of the environmental investigation is to gather all existing information about the site, typically by conducting a Phase I Environmental Site Assessment (ESA) that meets the standards in, ASTM E1527 - 13 *Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process*[3] (ASTM, 2013) and EPA's *All Appropriate Inquiries Final Rule* at 40 CFR Part 312 (EPA, 2005). The Phase I ESA report documents the findings of this investigation and identifies "recognized environmental conditions" (RECs). Additionally, ASTM E2600-10, *Standard Guide for Vapor Encroachment Screening on Property Involved in Real Estate Transactions* (ASTM, 2010) may be a resource to identify properties where a vapor encroachment condition (VEC) exists, likely exists, cannot be ruled out, or can be ruled out. All sites storing and using COPCs are considered to have a VI potential because the potential VEC cannot be ruled out at this stage of the investigation.

4.1.1 Facility Types Releasing Persistent VI Chemicals

Persistent chemical VI is most often associated with chlorinated solvent use and storage, including from over 50 years ago. Operations that have potentially used chlorinated solvents include dry cleaning, metal plating, textile manufacturing, oil recycling, electronics manufacturing, parts cleaning, auto repair and other equipment repair. Former military facilities often are contaminated with chlorinated solvents. If the Phase I Environmental Site Assessment (ESA) identifies any of these activities as having ever occurred at the site, then the CSM should consider VI of persistent chemicals, unless sufficient data exists that can rule out a VEC.

4.1.2 Typical VI Contaminants of Potential Concern

Any persistent volatile chemicals, including those listed in EPA VI Guidance Section 3.1, that were used or stored at the site should be assessed as Contaminants of Potential Concern (COPCs). The most common confirmed Contaminants of Concern (COCs) at Maine VI sites are listed in EPA VI Guidance Section 3.1. If any historic activities included those in section 4.1.1, then chlorinated solvents should be presumed to have been released at the site, unless a preliminary VI site screening (see section 4.2) rules this out.

[3] This standard is under review and may be revised in 2015. You should always use the most recent version of an ASTM standard.

4.2 Optional: Preliminary Screening Out of the VI pathway

After the Phase I ESA is completed there may be high uncertainty as to whether persistent volatile chemicals were released at the site. In this case a preliminary screening evaluation maybe warranted before moving on to a full evaluation. The primary goal of the preliminary screening is to identify if the site does not have one (or more) of the following elements of a complete VI pathway:

- evidence of a release of any of the volatile compounds in section 4.1.1 above
- a pathway to an inhabitable receptor building, and
- a current or future inhabitable building at risk.

Determine the data gaps that need to be assessed (e.g. are there VOCs in soil vapor near the historical location of equipment) and then collect the missing information to conclude whether a VI pathway can be ruled out. If the evaluation concludes that there is evidence of a completed pathway or that the evidence is still inconclusive, then further VI evaluation is warranted and a Baseline VI Investigation should be recommended.

4.3 Phase II ESA or Remedial Investigation – Obtain Samples

4.3.1 Baseline VI Investigations

If the preliminary work suggests that a VI risk is possible, then a baseline VI investigation should be conducted to determine whether or not there is an actual VI risk, and if so, how to best manage that risk. The baseline study is usually in the form of a Phase II ESA, but in instances where widespread contamination is anticipated, the baseline study may be in the form of a Remedial Investigation (RI). Both studies use similar approaches, but a RI typically gathers more data to support a full Feasibility Study (FS). Since this guidance is geared towards small sites, we discuss the role of a Phase II ESA.

4.3.2 Contaminants of Potential Concern (COPC)

Identify site specific contaminants of potential concern (COPCs) from the CSM and through sampling of soil gas near source areas, considering typical daughter products of the contaminants found. If follow on sampling of concentrations along the migration pathway are high enough so that the investigator suspects that subslab samples may exceed the Table 2 RAG (See section 3.4.2) (modified by the attenuation factor of Table 6.1 of the of EPA VI Guidance) or indoor air may otherwise exceed the Table 2 of the RAGs, then the COPCs become Contaminants of Concern (COCs).

4.3.3 Field Screening and Laboratory Analysis

"Sampling" used in the following sections can involve a combination of monitoring instruments used in the field to give real-time information (field screening) and laboratory analytical methods. Field screening can be done with a photoionization detector (PID) or portable Gas Chromatogram / Mass Spectrometer (GC/MS). The field screening instrument must be capable of detecting VOCs in the part per billion range (ppb). Field screening can provide real time data at a lower cost, but the investigator has to establish a correlation between field screening results and laboratory analysis. This correlation may be established for air (MEDEP, 2014a) (MEDEP, 2009c) (MEDEP, 2009d) soil (MEDEP, 2012) (MEDEP, 2009b), or water (using a jar-headspace technique (MEDEP, 2009b) for the latter media). Before undertaking sampling, be sure to review prior sample results and associated Quality Assurance to see if a useful correlation between field screening and lab analysis has already been established. Field screening can also be used to reduce the number of laboratory samples that are needed to reach a data quality objective, which often reduces the cost of the investigation. Be sure that the sampling is planned and implemented by an environmental professional that has the experience and training to ensure that sample results accurately represent the source, pathway, and risk posed at the site.

4.3.4 Phase II Environmental Site Assessments

During a Phase II ESA, the qualified professional will investigate RECs that were identified in the Phase I ESA, typically including sampling of media, to determine if there was a release of hazardous substances and/or petroleum at the site, and the extent of contamination. VI investigations should be included in the Phase II ESA when a VI risk is possible. The Phase II ESA report summarizes the nature and extent of contamination, makes recommendations for further action, and otherwise meets the ASTM standards for Phase II ESAs (ASTM, 2011).

4.3.5 "Step-Out" Investigation Approach for Persistent Chemical VI

The key to successful investigation of VI stemming from persistent chemicals is to use the "Step-Out" approach described below. Section 6.3

of EPA's VI guidance details investigating the VI pathway. In general, VI investigations involving persistent volatile chemicals should move out from the source of contamination along the vapor migration pathways to receptors to confirm or refute the possibility of a completed VI pathway. The CSM is used to determine where the site's potential source areas, secondary source areas, preferential pathways and receptors are likely to be. Receptors are buildings that are inhabitable.

4.3.5.1 Sample Analytes

Determine the appropriate parameters to analyze for based on the CSM and an assessment of the data gaps that need to be filled. At VI sites, analysis for COCs is usually supplemented by analysis of soil environmental properties such as oxygen, CO_2, and methane, along with the physical properties of the soil (moisture content, classification, grain size distribution) and atmospheric/soil gas pressure.

4.3.5.2 Sample Locations

The CSM, cost and DQOs dictate the number, location, and type of samples that are obtained at a given site. Multiple sample locations and/or vertical profiling may be necessary depending upon the number of source areas, the differing source media (soil, groundwater or both), the size of the source area, the depth of the source, and the number of pathways present. Spatial variations are best captured by multimedia samples at all locations during a single sampling event. One strategically placed sample may satisfy more than one objective, such as a small property where the utility line is located adjacent to the closest receptor. Sample points in or near the source area(s) should be driven deep enough to also assess diffusion from groundwater. Use the sample methods and logs referenced in section 3.4.3 on page 12.

4.3.5.3 Weather Impacts on Sampling

Variations in soil moisture can have significant impacts on soil gas concentrations. Therefore, soil gas samples should not be collected during significant rain events (greater than 0.25 inches over 8 hours). Unpaved soils are more susceptible to variations in soil moisture. Therefore, more time may be required to allow rain water, snow melt, or frost water to drain and soil moisture to return to dryer conditions prior to sampling. In winter months plowed areas may have deep frost penetration and may result in lower biased soil gas concentrations due to the moisture content.

4.3.5.4 Number of Sample Events and Temporal Variation

A departure from EPA's VI Guidance and this VI supplemental guidance is the length and breadth of the investigation. A VI investigation at a smaller site can focus on one or two major sampling events, with limited follow-up sampling. That is because MEDEP has found at Maine's small sites that there may be an order of magnitude change due to temporal variation, rather than the 3 orders of magnitude change found at the large EPA research sites employing continuous monitoring. Maine DEP has seen seasonal variation at small sites, but typically the variation is all above or all below the risk guideline, rather than bouncing below and above the guideline. If you need to capture temporal variation, it will require several sample events. However, a single soil gas / subslab / basement / indoor air sampling event will usually result in 80% of the VI information about a site, which is often enough to make an informed decision regarding necessary mitigation.

EPA's approach starts with more media, including bedrock, and advocates multiple sample events, quarterly over several years, to determine if there is a VI risk. This is appropriate for large sites (more than 10 impacted buildings). However, most of Maine's VI problems with persistent compounds stem from dry-cleaning sites. Generally at these sites we have found unacceptable risk in the old dry cleaning building and co-located structures, or in buildings built on the location of the former drycleaner. A handful have impacted up to 3 or 4 off-site buildings, usually from migration of soil gas along preferential pathways, but on occasion from a groundwater plume that acts as a secondary source.

Bedrock monitoring wells are not always necessary. The study should address possible exposure from groundwater, vapor and soil, based on a CSM and multiple lines of evidence, not just sample results.

Good planning, including establishing DQOs based on the CSM will limit the number of events, but since additional sample events build upon previously gathered data interactively, an iterative approach is often necessary to understand VI. However, no matter how many times a site is sampled, it is impossible to rule out all uncertainty. The goal of the VI investigation is to gather sufficient information to make a cost-effective risk management decision with tolerable uncertainty.

Seasonal fluctuations can have significant effects on VI into buildings. During extended warm dry periods, such as August in Maine, advection may not actively facilitate VI into buildings, so VI impacts may be underestimated as compared to the heating season. Sampling during multiple seasons should be completed before closing out[4] a site where the VI pathway is complete (see section 4.3.6.4 for close-out sampling).

4.3.5.5 Concurrent Multimedia Sampling

The best approach to developing the CSM and to address all the risk pathways at a given site is to obtain soil, groundwater, and vapor samples concurrently. To accurately assess the VI pathway, soil vapor samples must be obtained. MEDEP's experience at its sites is that EPA's VI attenuation factors are not accurate enough to predict VI from just groundwater or soil samples (see section 4.4.4). However, groundwater and soil sample result should be compared to EPA's attenuation factors as one line of evidence when determining potential VI soil source areas and if groundwater is acting as a secondary source.

4.3.5.6 Sampling Source Areas

The source areas include areas where solvents were used (machine locations), parts were cleaned (machine filters dried), solvents were stored (drums, underground storage tanks, etc.), solvents were handled or recycled, spent fluids or fluid saturated solids were disposed of or washed, or where vapors could accumulate (e.g. exit vent locations).

Soil results should be used to target suspected source area(s) to determine the extent and concentration of soil contamination present. Groundwater results should be used to determine the potential for dissolved phase migration from the source(s) that may pose a secondary vapor source (see EPA VI guidance Section 6.3.1). These results can then be used to determine where soil vapor samples should be obtained to trace the VI pathway. Dissolved phase persistent chemicals are a potential VI risk to buildings unless they are overlain by at least 10 feet of low permeability overburden.

The final CSM must be capable of identifying the different pathways of vapor migration from the source area(s). Pathways of vapor migration may include: advection along preferential pathways, evaporation from

[4] Closing out a site means making a determination that no further action is needed at the site to address contamination issues.

contaminated groundwater, dissolution from Non-Aqueous Phase Liquid (NAPL), vapor diffusion within the soil gas pathway from the source(s), or a combination of several of these pathways.

4.3.5.7 Hydrogeological Conditions and Vapor Transport

The site's hydrogeologic conditions influence the VI pathway so must be characterized during the investigation in order to design and interpret the results of a soil gas investigation within the context of a CSM. Important hydrogeologic factors influencing vapor transport include: soil moisture, soil type, depth to groundwater, extent and gradient of a groundwater plume(s) and location of potential down gradient receptors (inhabitable buildings). However, for persistent chemicals, remember that vapors may travel in different or additional directions than groundwater flow.

The potential vapor risk to off-site receptors is generally proportional to the source strength of soil gas vapor concentrations within the source areas where lower porosity soils are present. In coarse grained soils, the source strength of soil gas vapor concentrations may be more diffuse due to the migration of the contaminants from the release point. Therefore, the risk to off-site receptors in coarse grained materials may not be directly proportional to the source strength and migration of contaminated groundwater may be the primary VI risk pathway. In finer grained natural materials, the presence of fill and underground utility lines will likely play a significant role in vapor migration either through shallow groundwater migration or by direct vapor migration. In areas of shallow bedrock, vapors may enter basements directly through bedrock fractures and utility trenches that have been placed below the natural bedrock surface. The CSM must incorporate these general observations.

4.3.5.8 Mapping Vapors in Utility Corridors/Preferential Pathways

Finer grained soils typically retain higher source vapor concentrations and are susceptible to preferential pathway vapor migration. Under these conditions vapor concentrations in the source area may be related to the linear distance of vapor migration along preferential pathways when pavement is present. A soil gas result above 10,000 ug/m^3 can facilitate vapor migration distances exceeding 250-feet along the primary preferential pathway migration route(s).

Be cautious when selecting utility sample points based on the presumed "downgradient" direction, since gravity draining utilities (storm water and sewer) can serve as chimneys and draft vapors in the hydraulically upgradient direction through advection. Usually utility trenches are best sampled with hand tools directly above the utility line, in the vadose zone of the utility bedding material. Be sure to have a good site safety plan and follow it.

Where there is a presence of multiple underground utility lines, which may or may not cross one another or may be located within the same trench, it may be necessary to distinguish the primary preferential vapor migration pathway from the secondary pathway(s). This is completed by collection of soil gas samples from each of the utility trenches at the closest available location to the source(s). Subsequent sample iterations may include sampling utility trenches that cross over each other away from the site along the vapor migration pathway.

4.3.5.9 Subslab Samples

Subslab samples should be obtained at the inhabitable receptor building when COC(s) in soil have traveled from the source area, along a pathway, and to the receptor. If based on the CSM and pathway sample results, subslab soil vapor results exceed the Table 2 RAG (modified by the attenuation factor in EPA VI Guidance Table 6.1), then subslab samples should be obtained. Samples adjacent to the slab may be substituted for subslab samples if it is not feasible to obtain subslab samples. Crawlspace or basement air should be sampled if there is no slab below the building (e.g. the building has a dirt floor basement) and the CSM suggests that air concentrations may exceed the Table 2 RAGs.

Per EPA VI Guidance: “Measure the pressure difference between the indoors and the subsurface, which provides a complementary line of evidence to support data evaluation and interpretation (Section 6.4.1) and is a more direct means of assessing building under-pressurization than is monitoring weather/climate factors (e.g., air temperature, wind speed).”

4.3.6 Sampling Indoor Air

EPA’s VI guidance section 6.4.1 and 6.4.2 should be followed when sampling indoor air. If subslab concentrations are greater than 30 times the concentrations in Table 2 of the RAGs, then indoor air samples should be obtained and analyzed. To inform the CSM, collect a sub-slab sample concurrently with obtaining the indoor air sample. If a contaminant in crawlspace air exceeds a Table 2 RAGs guideline, then indoor air should be sampled as well. Finally, if there is a COC that was released directly into the building, the VI pathway would be considered complete, so indoor air should be sampled.

4.3.6.1 Sample Period

Indoor air samples should be collected over a 24-hour period whenever practical.

4.3.6.2 Sample Locations

The size, occupants, and configuration of the building will dictate the number of samples to represent exposure point concentrations; but at least two locations should be sampled. Sample the entry point to the building (typically through foundation floor or foundation wall) and the exposure point in a living space (typically a room above the foundation entry point). Avoid sampling in the building space where background sources may be present (bath room, craft, hobbies, garage, shops and so forth).

4.3.6.3 Concurrently Sample Subslab and Indoor Air

Whenever an indoor air sample is collected for the first time, a sub-slab or near-slab sample should also be collected during the same sample event to demonstrate the completion of the VI pathway. Once the data is collected to confirm the completeness of the pathway, future indoor air events do not necessary need an accompanying sub-slab data point.

4.3.6.4 Closeout Sampling

Sites with completed VI pathways can be closed out after obtaining "clean" samples representing conditions conducive to VI per the CSM and professional judgment Ideally "clean" is, four successive sample events, about 3 months apart, showing COC at the exposure point below the risk based levels in Table 2 of the RAGs, and the multiple contaminant risk calculators indicate an acceptable risk[5].

4.3.6.5 Should You Sample Background?

Some think that distinguishing between VI and background sources may be aided by simultaneously collecting outside ambient samples along with source entry samples (crawl space, basement, or sub-slab). However, the

[5] Acceptable risk is defined in the RAGs as a risk below an Incremental Lifetime Cancer Risk of 1 in 100,000 (10^{-5}) and a Health Index of 1.

relationship between indoor air and outdoor air is extremely complex and sample/investigation objectives need to be established prior to collecting background samples. See section 4.4.1 Background Contaminants in Ambient Air and Indoor Air, below.

4.3.7 Addressing Limited Site Access

If at all possible samples should be collected on the site being evaluated, but it may not possible if the investigator cannot obtain the owner's permission to access to the site. In these cases, the initial VI investigation may be limited to the public access areas outside the curtilage of the property. Under these conditions, it is best to target utility lines accessing the property and locations closest to the source areas.

Some other ASTM Standard Practices that may be useful for VI screening situations when you do not have access to areas of potential concern are:

- ASTM E2600-10 *Standard Guide for Vapor Encroachment Screening on Property Involved in Real Estate Transactions* (ASTM, 2010)
- ASTM E1528-06 *Standard Practice for Limited Environmental Due Diligence: Transaction Screen Process* (ASTM, 2006)

If after your investigation VI still cannot be ruled out at an inhabitable building, use the evidence you have collected to convince the property owner to provide you with access needed to complete the investigation. If necessary, contact the MEDEP, which may obtain access to the site with the assistance of the Maine Attorney General's office.

4.4 Data Evaluation

4.4.1 Background Contaminants in Ambient Air and Indoor Air

Background concentrations of pollutants in indoor and ambient air vary widely from site to site, are hard to predict, and often exceed the risk-based Table 2 concentrations in the RAGs. To minimize the confusion caused by background concentrations of contaminants in indoor air, for persistent compounds MEDEP recommends following the "step-out" procedures in section 4.3.5 rather than starting with indoor air samples. VI is only complete if the site specific COCs and their daughter products exceed Table 2 RAG guidelines in indoor air. Other exceedances found in indoor may be attributable to ambient background and/or indoor air pollutants.

4.4.2 Review Data Quality

To ensure that the data obtained is accurate and representative of the media sampled, review sample results using EPA data quality guidance, including:

- *Guidance for Data Usability in Risk Assessment* (Part A; April 1992) (EPA, 1992a).
- *Guidance for Data Usability in Risk Assessment* (Part B; May 1992). (EPA, 1992b)
- *Guidance for Data Usability in Risk Assessment: Quick Reference Fact Sheet* (September 1990). (EPA, 1990)

Assess the confidence in data results, considering such factors as number of samples, availability of temporal (seasonal) data, the lab QA/QC review and the sampling QA/QC review including any sampling errors, field adjustments, appropriateness of sample depths or locations, etc.

4.4.3 Revise the Conceptual Site Model Based On Site Information

Compile data results and compare indoor air exposure concentrations to the RAGs Table 2 guidelines. Include an evaluation of the level of risk posed to both current and future inhabitable receptor buildings. If there are impacts to a building that has an HVAC system in place, the building/facility manager should be consulted regarding the HVAC system's influence on VI. Incorporate all of the new site information into a revised CSM, including a consideration of:

- number and location of samples collected;
- site soil conditions including permeability, porosity, depth to bedrock, stratigraphy and degree of water saturation during sampling events;
- the depth to groundwater and depth of low permeability soil between the groundwater and receptors;
- the contaminant concentrations detected in soil, groundwater, soil gas, and indoor air;
- size and number of potential contaminant sources;
- number and characteristics of potential preferential pathways and confining soils;
- number and location of potential receptors;
- the level of risk at exposure points;

- potential for spatial and temporal variations in VI conditions;
- the significance of remaining data gaps; and
- overall confidence in the data results.

4.4.4 MEDEP View of VI Modeling

EPA's VI guidance provides methods for modeling VI fate and transport, along with VI emission factors for soil and groundwater. Due to the complex and varied subsurface conditions in Maine and the numerous factors that influence VI, MEDEP finds that models cannot accurately predict VI in most cases for Maine Sites. Furthermore, MEDEP finds that contaminant levels in soil or groundwater divided by an emission factor are not reliable indicators of VI potential in Maine. Therefore, MEDEP recommends against using soil or groundwater attenuation factors or modeling protocols to predict VI potential. Rather MEDEP recommends measurement of contaminants in soil vapor and (if warranted by the step-out investigation) indoor air when assessing VI potential. If a consultant believes that modeling could shed useful light on a site's CSM, then the consultant should confer with the MEDEP before expending money on the modeling effort.

4.4.5 Assess Risk

Assess risk to exposed individuals using the protocols in Section 7 of the RAGs. In short, Risk Management is warranted when the exposure point concentration of one or more COCs in indoor air exceeds its Table 2 RAG concentration due to VI.

- In situations where sub-slab concentrations are elevated, but indoor air concentrations do not appear to be related to VI from the subsurface, recommendations should be made to further evaluate the VI pathway to confirm that a VI pathway is either complete or incomplete.
- In situations where the evaluation concludes that the VI pathway is complete and the indoor air of the living space exceeds the Indoor Air Targets (IAT), recommendations for indoor air mitigation or source remediation should be made. Note, even if subslab concentrations exceed the Table 2 RAG (modified by the attenuation factor in EPA VI Guidance Table 6.1), a current risk is not indicated if representative sampling demonstrates that the Table 2 RAG is not exceeded in indoor air.

- In situations where the evaluation concludes that the VI pathway is complete, but the indoor air of the living space does not exceed the risk criteria, it is appropriate to recommend confirming the results with two additional sampling events approximately three months apart.

4.4.6 VI Investigation Conclusions

The conclusions of the VI investigations are based upon evaluation of the 5 elements of VI defined and discussed in section 2.3. MEDEP relies on assessing multiple lines of evidence within the Conceptual Site Model (CSM) when determining whether vapor is or will intrude into a building. The qualified professional undertaking the investigation must consider the site's CSM and his or her certainty in the accuracy of the site CSM when making recommendations for follow-up actions.

- **No Risk:** If, based on the revised CSM, the qualified professional is confident that exposure point concentrations of indoor air (not soil vapor) are and will remain below risk based levels of concern, or pathways to all current and future inhabitable receptor buildings are and will remain incomplete, then recommend that no additional investigation, mitigation, or remediation is warranted. For example, one or more of the 5 VI elements does not exist.
- **Uncertain Risk:** If, based on the revised CSM, the qualified professional determines that the level of VI risk is low but there is insufficient certainty in the CSM, then recommend that confidence be increase with additional investigation or, based on site economics, that a conservative mitigation/remediation plan be implemented. For example, one or more of the 5 VI elements cannot be confirmed based on the existing data.
- **Potential Future Risk:** If, based on the revised CSM, the qualified professional determines that the level of confidence in the data is adequate and the current VI risk level is low due to the absence of receptors, but the future risk is unknown or elevated, then recommend the management of future risks. Typically the risk is managed with an Environmental Covenant that requires installation of a subslab vapor mitigation system on any new buildings, source removal, land use restrictions, and/or or a later evaluation of VI. For example, one or more of the 5 elements does not currently exist, but it may exist in the future if conditions change.

- **Known Risk:** If, based on the revised CSM, the qualified professional determines that the level of confidence in the data is adequate and the current VI risk level is high, then recommend the management of future risks. For example, indoor air guidelines are exceeded and all 5 elements of VI exist, indicating that the VI pathway is complete.

4.4.7 Other Factors May Indicate Risk Management is Appropriate

Mitigation systems either at the receptor (inhabitable building) or within the migration pathway can be relatively low cost in comparison to a comprehensive VI investigation, quick to implement and protective against other common indoor air quality problems, such as moisture and radon. So there are situations (political, economic, time sensitive) where it may be appropriate to mitigate without determination of a complete VI pathway. On the other hand, implementing mitigation without a full assessment of VI risk may lead to costly problems. For instance, if the assumed point of entry (sub-slab versus wall penetration) is incorrect, the mitigation system will be ineffective so costly retrofits will be needed. Likewise, other premature assumptions may lead to ineffective operation. Other drawbacks of installing systems without a full understanding of subsurface mechanics are that a party may be assuming the liability for a situation that they did not create, or incurring the cost of ongoing system Operation & Maintenance, monitoring and system optimization, when in fact there is not a complete VI pathway.

4.5 Risk Management

4.5.1 Follow EPA VI Guidance & ITRC Guidance

EPA's VI guidance, section 7.6 and section 8 (Building Mitigation and Subsurface Remediation) detail a number of measures to mitigate or remediate vapor intrusion risks, depending on site conditions. The EPA VI guidance section 8 also references the Interstate Technology Regulatory Council (ITRC) VI document, *Vapor Intrusion Pathway: A Practical Guideline* (ITRC, 2007), which should be consulted because it provides a comprehensive review of mitigation options and their application.

4.5.2 Selecting and Implementing Mitigation

Selecting a mitigation approach depends on the site conditions, risks, goal of the mitigation, timeframe, cost and resources. The typical approach used to select the best mitigation strategy for a given site includes:

- Conducting a focused feasibility study of the options referenced in section 4.5.1 that are applicable to the site conditions;
- Consultation between MEDEP, the investigating professional, the building/facility manager (when building is large and/or has an HVAC in place) the site owner, any other Potential Responsible Parties, and any other effected party on the best site remedy;
- Based on the above input, choose the best remedy for the site;
- Securing resources to implement the remedy; and
- Implementing the remedy.

Implementation of a mitigation system should be done in the context of the RAGs and include appropriate environmental covenants in accordance with 38 MRSA 3001-1313, *Uniform Environmental Covenants Act* (UECA).

4.5.3 Consider Interim Mitigation Measures (Early Action)

It may be appropriate to consider an interim mitigation plan for the migration pathway(s) that pose a significant risk to inhabitable receptor buildings based on the findings of the preliminary screening or baseline assessment. For example, early action may be warranted if exposure point concentrations of a COC in indoor air exceed an indoor air guideline in Table 2 of the RAGS. To determine if the COC stems from VI or an interior (possibly background) source, evaluate the indoor air concentrations detected in comparison to the sub-slab concentrations and ambient air concentrations. Consider the factors in section 4.4.7 before undertaking early action. Use of a Qualified Professional (section 3.2.1) is necessary in all mitigation measures.

4.5.4 MEDEP Lessons Learned

MEDEP provides the following thoughts from past experience as a supplement to EPA VI Guidance regarding mitigating VI risk.

4.5.4.1 Advection and Convection

Both diffusion and advection processes are often present at VI sites and mitigation plans should consider how affecting these processes could help mitigate risk pathways. A molecule of vapor diffuses approximately 100 times faster through air (vadose zone) than it does through water (groundwater). Therefore, mitigating the vadose zone could result in generating a concentration gradient that moves mass away from the inhabitable buildings faster than it can be resupplied by vapor diffusion from the contaminated groundwater. Advection transports contaminated vapors as a result of a pressure gradient (which may fluctuate rapidly over time). VI due to advection occurs when the pressure gradient draws contaminated vapors into the building. Therefore, selecting a mitigation scheme that generates a pressure gradient away from inhabitable buildings, or designing a mitigation scheme that intercepts the pressure gradient within the migration pathway could result in reducing the concentrations within the migration pathway below the risk-based exposure criteria.

4.5.4.2 Subslab Depressurization

If point of entry mitigation is indicated, sub-slab depressurization systems (SSDS) are generally considered an effective and reliable technology if the point of entry is through the basement floor. It is recommended that a Maine Registered Radon Service Provider[6] design and install the SSDS. Considering that the work atmosphere may be hazardous, the installer should be trained to evaluate and monitor hazards per OSHA 29 CFR 1910.120.[7]

4.5.4.3 Intercept Vapors in the Preferred Pathway

Mitigation of the migration pathway(s) may also be favorable over further investigation, individual building mitigation, or remediation of the source. MEDEP has had success with low-cost passive ventilation systems that divert vapors in a confined utility corridor before they can enter the building. MEDEP has also had success with an active system that captures at a central location vapors that were impacting multiple buildings (MEDEP, 2014b).

4.5.4.4 Source Control

If source clean-up is necessary to prevent VI, rather than diverting the vapors themselves, then the project lead must develop site-specific soil and/or groundwater remediation goals in consultation with the MEDEP to meet the applicable indoor air targets shown in RAGs Table 2.

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[6] A list of Maine Radon Mitigation Service Providers is available at: http://www.maine.gov/dhhs/mecdc/environmental-health/rad/radon/rntesting.htm

[7] Available at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9765

4.5.4.5 Treating Vented Air

Most persistent chemicals degrade much more rapidly in ambient air than in the subsurface. Treating vented air is generally not necessary unless an air license threshold is going to be exceeded, or vented gases will exceed a RAG Table 2 concentration in indoor air or the MEDEP/CDC ambient air guidelines (MECDC, 2010) at the point of exposure in outdoor air. To avoid treating vented gases, vent the gases in outside locations away from building intakes (including windows), in a mixing zone, and above the breathing zone.

4.6 Vapor Intrusion Reports

The methods, results, conclusions and recommended follow-up of the VI Investigation should be documented in a report to MEDEP. The evaluation should be done in the context of the CSM that identifies COC(s), source area(s), migration pathway(s), inhabitable receptor building(s) and includes the following items as appropriate:

- description of the scope of the VI investigation;
- conceptual Site Model, which will include a site specific conceptual; model of vapor intrusion for buildings with completed vapor intrusion pathways;
- presentation of remaining data gaps;
- evaluation of the Preliminary VI Screening;
- evaluation of the Baseline VI Investigation and/or Step-Out Investigation;
- evaluation of Indoor Air Investigation;
- discussion of Confidence Level in the Data;
- discussion of Mitigation or Remediation Options and the Preferred Method; and
- opinion and recommendations.

When presenting results from a VI investigation, provide background on the stage of the investigation (preliminary screening, baseline characterization, stepout investigation, indoor air assessment), the current site conceptual model, the risk scenario, the data quality objectives and the investigation objectives. Also include a description of the methodology used to construct sample points and collect samples. Tabulate current and prior results and method detection limits alongside the applicable target levels.

The report should:

- discuss sample plan adjustments that had to be made and how the data quality objectives were met;
- calculate exposure point concentrations;
- justify the IAT scenario applied to each receptor;
- discuss uncertainty associated with the data; and
- determine whether the VI pathway is complete, incomplete or inconclusive.

Use data and lines of evidence to support conclusions and use conclusions to make recommendations for additional investigation, remediation or closure. The report should identify properties that may be at VI risk by future development.

If mitigation steps were completed or are recommended, describe:

- the mitigation, performance criteria and measurement methods,
- who will undertake mitigation,
- provisions for disclosing the remedy during property transfer, and
- responsibility for costs associated with operation, monitoring and maintenance of the remediation system.

If you are unable to conclude whether or not a VI pathway is complete, provide recommendations for mitigation, monitoring or follow up investigations. The recommendations should state if there are important data gaps that need additional attention. This should include specific recommendations for collecting the data and refer to the CSM in developing a work scope.

All data is to be submitted in an investigation report and laboratory and field data are to be submitted in an acceptable Electronic Data Deliverable (EDD) format.[8]

4.7 Public Notice for Small VI Sites

The public notice provisions in EPA's VI Guidance were developed with large sites in mind. EPA public notification protocols should be followed for sites where 10 or more buildings are impacted. For a lesser number of impacted buildings, MEDEP notification protocols should be followed. For example, see

[8] See DEP's website, Environmental and Geographic Analysis Database (EGAD) at: http://www.maine.gov/dep/maps-data/egad/

MEDEP's Voluntary Response Action Program's *Public Communication Decision Matrix* (MEDEP, 2015).

H:\BRWM\Remediation Division\Guidance\Vapor Intrusion\Draft VI Guidance 2014-15\VI-Persistent-Chems-Guidance-final-020016-V1.docx

5 References/Links

5.1 Other Useful Links

Note that inclusion is not to be construed as a MEDEP endorsement of a product or service.

EPA VI Technical Documents and Tools Prepared to Support Guidance Development

http://www.epa.gov/oswer/vaporintrusion/guidance.html

EPA OSWER Technical Guide for Assessing and Mitigating The Vapor Intrusion Pathway From A Subsurface Vapor Sources to Indoor Air, OSWER Publication 9200.2-154, June 2015

http://www.epa.gov/vaporintrusion/technical-guide-assessing-and-mitigating-vapor-intrusion-pathway-subsurface-vapor

EPA Technical Guide for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites, EPA 510-R-15-001, June 2015

http://www.epa.gov/ust/technical-guide-addressing-petroleum-vapor-intrusion-leaking-underground-storage-tank-sites

EPA VI database

http://iavi.rti.org/index.cfm

EPA Chemical Property and Risk Calculator, Mid-Atlantic Region

http://www.epa.gov/risk/regional-screening-table

ITRC "VI Pathway: A Practical Guideline", Technical and Regulatory Guidance, January, 2007

http://www.itrcweb.org/Documents/VI-1.pdf

ITRC "VI Pathway: Investigative Approaches for Typical Scenarios A Supplement to *VI Pathway: A Practical Guideline",* January, 2007

http://www.itrcweb.org/GuidanceDocuments/VI-1A.pdf

New Hampshire DES "VI Guidance", July 2006
http://des.nh.gov/organization/commissioner/pip/publications/wmd/documents/wmd-06-1.pdf

New Jersey DEP "VI Guidance", October 2005

http://www.nj.gov/dep/srp/guidance/vaporintrusion/vig.htm

ASTM E1689-95(2014) "Standard Guide for Developing Conceptual Site Models for Contaminated Sites"

http://www.astm.org/Standards/E1689.htm

ASTM E2531-06(2014) “Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface

http://www.astm.org/Standards/E2531.htm

ASTM E2600 - 10 “Standard Practice for Assessment of VI into Structures on Property Involved in Real Estate Transactions”

http://www.astm.org/Standards/E2600.htm

API Publication 4741 November 2005 *A Practical Strategy for Assessing the Subsurface Vapor-to-Indoor Air Migration Pathway at Petroleum Hydrocarbon Sites*, Prepared under contract to API by: Lesley Hay Wilson, Ph.D., Sage Risk Solutions LLC, Paul C. Johnson, Ph.D., Department of Civil and Environmental Engineering, Arizona State University, James R. Rocco, Sage Risk Solutions LLC

http://www.api.org/ehs/groundwater/lnapl/soilgas.cfm

6 Works Cited

ASTM. (2006). *Standard Practice for Limited Environmental Due Diligence: Transaction Screen Process.* West Conshohocken, PA: ASTM International. Retrieved April 24, 2015, from http://www.astm.org/Standards/E1528.htm

ASTM. (2010). *Standard Guide for Vapor Encroachment Screening on Property Involved in Real Estate Transactions.* West Conshohocken, PA: International ASTM. Retrieved from http://www.astm.org/Standards/E2600.htm

ASTM. (2011). *Standard Guide for Environmental Site Assessments: Phase II Environmental Site Assessment Process.* West Conshohocken, PA: ASTM International. Retrieved April 27, 2015, from http://www.astm.org/Standards/E1903.htm

ASTM. (2013). *Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process.* West Conshohocken, PA: ASTM International. Retrieved from http://www.astm.org/Standards/E1903.htm

ASTM. (2014). *Standard Guide For Developing Conceptual Site Models for Contaminated Sites.* West Conshohocken, PA: ASTM International. Retrieved April 24, 2015, from http://www.astm.org/Standards/E1689.htm

EPA. (1990). *Guidance for Data Usability in Risk Assessment: Quick Reference Fact Sheet (September 1990).* Washington, DC: US Environmental Protection Agency. Retrieved April 24, 2015, from http://www.epa.gov/oswer/riskassessment/datause/pdf/index.pdf

EPA. (1992a). *Guidance for Data Usability in Risk Assessment (Part A; April 1992).* OERR. Washington, DC: US Environmental Protection Agency. Retrieved April 24, 2015, from http://www.epa.gov/oswer/riskassessment/datause/parta.htm

EPA. (1992b). *Guidance for Data Usability in Risk Assessment (Part B; May 1992).* OERR. Washington, DC: US Environmental Protection Agency. Retrieved April 24, 2015, from http://www.epa.gov/oswer/riskassessment/datause/partb.htm

EPA. (2005). *All Appropriate Inquiries Final Rule.* B rownfields and Land Revitalization/All Appropriate Inquiries webpage. Washington, DC: US Environmental Protection Agency. Retrieved from http://www.epa.gov/brownfields/aai/

EPA. (2006). *Guidance on Systematic Planning Using the Data Quality Objectives Process.* Office of Environmental Information. Washington, DC: US Environmental Protection Agency. Retrieved April 24, 2015, from http://www.epa.gov/quality/qs-docs/g4-final.pdf

EPA. (2012). *Conceptual Model Scenarios for the VI Pathway.* Washington, DC: U.S. Environmental Protection Agency. Retrieved April 24, 2015, from http://www.epa.gov/oswer/vaporintrusion/documents/vi-cms-v11final-2-24-2012.pdf

EPA. (2015a). *Guidance for Addressing Petroleum Vapor Intrusion At Leaking Undergrund Storage Tanks Sites.* Office of Solid Waste and Emergency Response. Washington, DC: US Environmental Protection Agency. Retrieved April 27, 2015, from http://www.epa.gov/oust/cat/pvi/petroleum-vapor-intrusion-review-draft-04092013.pdf

EPA. (2015b). *Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air.* Washington DC: OSWER. Retrieved 12 4, 2015, from http://www2.epa.gov/vaporintrusion/technical-guide-assessing-and-mitigating-vapor-intrusion-pathway-subsurface-vapor

ITRC. (2007). *Vapor Intrusion Pathway: A Practical Guideline, January, 2007.* Washington DC: Interstate Technology & Regulatory Council. Retrieved April 24, 2015, from http://www.itrcweb.org/Documents/VI-1.pdf

MECDC. (2010). *Ambient Air Guideline.* Center for Disease Control. Augusta, ME: Maine Department of Health and Human Services. Retrieved April 27, 2015, from http://www.maine.gov/dhhs/mecdc/environmental-health/eohp/air/

MEDEP. (2009a). *Draft Indoor Air Sample Protocol with Indoor Air Sample Information Collection Form of 8/2/29.* Augusta: Maine Department of Environmental Protection. Retrieved April 27, 2015, from http://www.maine.gov/dep/spills/publications/guidance/rags/Web_8-27-09/Indoor Air Sample Protocol.doc

MEDEP. (2009b). *Field Screening of Soil Samples Utilizing Photoionization and Flame-Ionization Detectors of 3/16/2009.* Augusta: Maine Department of Environmental Protection. Retrieved April 27, 2015, from http://www.maine.gov/dep/spills/publications/sops/documents/dr011.pdf

MEDEP. (2009c). *Protocol for Collecting Soil Gas Samples of 2/2/09.* Augusta, ME: Maine Department of Environmental Protection. Retrieved April 27, 2015, from http://www.maine.gov/dep/spills/publications/sops/documents/dr026.pdf

MEDEP. (2009d). *Protocol for Collecting Sub-Slab Soil Gas Samples (3/12/09).* Augusat: Maine Department of Environmental Protection. Retrieved April 27, 2015, from http://www.maine.gov/dep/spills/publications/sops/documents/dr027.pdf

MEDEP. (2009e). *Public Review Draft Alternate soil gas sample point construction and sample method, utilizing thin diameter stainless steel tubing of 8/19/2009.* Augusta: Maine Department of Environmental Protection. Retrieved April 27, 2015, from http://www.maine.gov/dep/spills/publications/guidance/rags/Web_8-27-09/TS_7_30_09_thin_steel_tubing%20Soil%20Gas%20Collection.pdf

MEDEP. (2010a). *Vapor Intrusion Evaluation Guidance of 2010.* Bureau of Remediation and Waste Management. Augusta: Maine Department of Environmental Protection. Retrieved April 27, 2015, from http://www.maine.gov/dep/spills/publications/guidance/rags/vi1-14-2010/1-VI_Guide_1_13_10Final.pdf

MEDEP. (2010b). *Soil Gas Sample Collection Method Utilizing Hand Tools (1/29/2010).* Augusta, ME: Maine Department of Environmental Protection. Retrieved April 27, 2015, from http://www.maine.gov/dep/spills/publications/sops/documents/dr005.pdf

MEDEP. (2012). *Compendium of Field Testing of Soil Samples for Gasoline and Fuel Oil (10/25/2012).* Augusta: Maine Department of Environmental Protection. Retrieved April 27, 2015, from http://www.maine.gov/dep/spills/petroleum/documents/sop/ts004.pdf

MEDEP. (2013). *Maine Remedial Action Guidelines for Sites Contaminated with Hazardous Substances.* Augusta, ME: Maine Department of Environmental Protection. Retrieved April 24, 2015, from http://www.maine.gov/dep/spills/publications/guidance/index.html#new_rag

MEDEP. (2014). *Remediation Guidelines for Petroleum Contaminated Sites in Maine.* Bureau of Remediation and Waste Management. Augusta, ME: Maine Department of Environmental Protection. Retrieved April 24, 2015, from http://www.maine.gov/dep/spills/publications/guidance/

MEDEP. (2014a). *Draft 2014 Protocol for Collecting Indoor Air Samples.* Augusta, ME: Maine Department of Environmental Protection.

MEDEP. (2014b). *Memo dated 2/18/2014 to Becky Blais, DEP From Troy Smith, MEDEP, RE: Vapor Mitigation System Montoring, November 2013, Former Algars.* Augusta: Maine Department of Environmental Protection.

MEDEP. (2015, April 27). *Voluntary Response Action Program Public Communication Decision Matrix*. Retrieved from Maine Department of Environmental Protection: http://www.maine.gov/dep/spills/vrap/vrappcmatrix.html

MEDEP and MECDC. (2011). *Maine DEP and CDC February 2011, Revised Guidance For Human Health Risk Assessments for Hazardous Substance Sites in Maine.* Augusta: Maine Department of Environmental Protection. Retrieved from http://www.maine.gov/dep/spills/publications/guidance/rags/final_5-8-2013/1%20Risk%20Manual-Feb_2011-%20CC.pdf

MEDEP. (Undated-a). *Indoor Air Sampling Field Sheet.* Augusta: Maine Department of Environmental Protection. Retrieved April 27, 2015, from http://www.maine.gov/dep/spills/publications/guidance/rags/Web_8-27-09/7_23_09Indoor_air_and%20subslabform.pdf

MEDEP. (undated-b). *Soil Gas Sampling Field Sheet (pdf format).* August: Maine Department of Environmental Protection. Retrieved April 27, 2015, from http://www.maine.gov/dep/spills/publications/guidance/rags/Web_8-27-09/7_23_09soil_gas_form2a.pdf

7 Appendix A: Chemicals of Potential Concern for Vapor Intrusion by Chemical Abstract System Number

(Quoted From: EPA VI guidance, Appendix A (EPA, 2015b))

Chemical of Potential Concern for Vapor Intrusion	CAS No.
Acetaldehyde	75-07-0
Acetone	67-64-1
Acetone Cyanohydrin	75-86-5
Acetonitrile	75-05-8
Acrolein	107-02-8
Acrylonitrile	107-13-1
Allyl Chloride	107-05-1
Aroclor 1221	11104-28-2
Aroclor 1232	11141-16-5
Azobenzene	103-33-3
Benzene	71-43-2
Benzyl Chloride	100-44-7
Biphenyl, 1,1'	92-52-4
Bis(2-chloro-1-methylethyl) ether	108-60-1
Bis(2-chloroethyl)ether	111-44-4
Bis(chloromethyl)ether	542-88-1
Bromo-2-chloroethane, 1	107-04-0
Bromobenzene	108-86-1
Bromochloromethane	74-97-5
Bromodichloromethane	75-27-4
Bromomethane	74-83-9
Butadiene, 1,3	106-99-0
Carbon Disulfide	75-15-0

Chemical of Potential Concern for Vapor Intrusion	**CAS No.**
Carbon Tetrachloride	56-23-5
Chloro-1,1-difluoroethane, 1	75-68-3
Chloro-1,3-butadiene, 2	126-99-8
Chlorobenzene	108-90-7
Chlorobenzotrifluoride, 4	98-56-6
Chlorodifluoromethane	75-45-6
Chloroform	67-66-3
Chloromethane	74-87-3
Chloromethyl Methyl Ether	107-30-2
Chloropicrin	76-06-2
Cumene	98-82-8
Cyanide (CN-)	57-12-5
Cyclohexane	110-82-7
Cyclohexene	110-83-8
Dibromo-3-chloropropane, 1,2	96-12-8
Dibromochloromethane	124-48-1
Dibromoethane, 1,2	106-93-4
Dibromomethane (Methylene Bromide)	74-95-3
Dichloro-2-butene, 1,4	764-41-0
Dichloro-2-butene, cis-1,4	1476-11-5
Dichloro-2-butene, trans-1,4	110-57-6
Dichlorobenzene, 1,2	95-50-1
Dichlorobenzene, 1,4	106-46-7
Dichlorodifluoromethane	75-71-8
Dichloroethane, 1,1	75-34-3
Dichloroethane, 1,2	107-06-2

Chemical of Potential Concern for Vapor Intrusion	**CAS No.**
Dichloroethylene, 1,1	75-35-4
Dichloroethylene, 1,2-trans	156-60-5
Dichloropropane, 1,2	78-87-5
Dichloropropene, 1,3	542-75-6
Dicyclopentadiene	77-73-6
Difluoroethane, 1,1	75-37-6
Dihydrosafrole	94-58-6
Diisopropyl Ether	108-20-3
Dimethylvinylchloride	513-37-1
Epichlorohydrin	106-89-8
Epoxybutane, 1,2	106-88-7
Ethyl Chloride	75-00-3
Ethyl Methacrylate	97-63-2
Ethylbenzene	100-41-4
Ethyleneimine	151-56-4
Ethylene Oxide	75-21-8
Hexamethylene Diisocyanate, 1,6	822-06-0
Hexane, N	110-54-3
Hexanone, 2	591-78-6
Hydrogen Cyanide	74-90-8
Mercury (elemental)	7439-97-6
Methacrylonitrile	126-98-7
Methyl Acrylate	96-33-3
Methyl Ethyl Ketone (2-Butanone)	78-93-3
Methyl Isobutyl Ketone (4-methyl-2-pentanone)	108-10-1
Methyl Isocyanate	624-83-9

Chemical of Potential Concern for Vapor Intrusion	CAS No.
Methyl Methacrylate	80-62-6
Methyl Styrene (Mixed Isomers)	25013-15-4
Methyl tert-Butyl Ether (MTBE)	1634-04-4
Methylene Chloride	75-09-2
Naphthalene	91-20-3
Nitrobenzene	98-95-3
Nitromethane	75-52-5
Nitropropane, 2	79-46-9
Nitroso-di-N-butylamine, N	924-16-3
Nonane, n	111-84-2
Pentane, n	109-66-0
Phosgene	75-44-5
Propionaldehyde	123-38-6
Propyl benzene	103-65-1
Propylene	115-07-1
Propylene Glycol Dinitrate	6423-43-4
Propylene Oxide	75-56-9
Styrene	100-42-5
Tetrachloroethane, 1,1,1,2	630-20-6
Tetrachloroethane, 1,1,2,2	79-34-5
Tetrachloroethylene	127-18-4
Tetrafluoroethane, 1,1,1,2	811-97-2
Tetrahydrofuran	109-99-9
Toluene	108-88-3
Trichloro-1,2,2-trifluoroethane, 1,1,2	76-13-1
Trichlorobenzene, 1,2,4	120-82-1

Chemical of Potential Concern for Vapor Intrusion	CAS No.
Trichloroethane, 1,1,1	71-55-6
Trichloroethane, 1,1,2	79-00-5
Trichloroethylene	79-01-6
Trichlorofluoromethane	75-69-4
Trichloropropane, 1,2,3	96-18-4
Trichloropropene, 1,2,3-	96-19-5
Triethylamine	121-44-8
Trimethylbenzene, 1,2,3-	526-73-8
Trimethylbenzene, 1,2,4-	95-63-6
Vinyl Acetate	108-05-4
Vinyl Bromide	593-60-2
Vinyl Chloride	75-01-4
Xylene, p-	106-42-3
Xylene, m-	108-38-3
Xylene, o-	95-47-6
Xylenes	1330-20-7