NEW JERSEY DEPARTMENT OF
ENVIRONMENTAL PROTECTION
SITE REMEDIATION PROGRAM

VAPOR INTRUSION TECHNICAL GUIDANCE

March 2013
(Version 3.1)

New Jersey Department of Environmental Protection

Site Remediation Program

Vapor Intrusion Technical Guidance

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EXECUTIVE SUMMARY

Vapor Intrusion (VI) is defined as the migration of volatile chemicals from the subsurface into overlying buildings through subsurface soils or preferential pathways (such as underground utilities) (N.J.A.C. 7:26E-1.8). The presence of volatile compounds in soil or ground water offers the potential for chemical vapors to migrate through subsurface soils and along preferential pathways, potentially impacting the indoor air (IA) quality of affected buildings.

The Vapor Intrusion Technical (VIT) Guidance is designed to help the investigator to comply with the requirements of the New Jersey Department of Environmental Protection (NJDEP or Department) and properly assess the VI pathway. The technical guidance takes the investigator through the various stages of receptor evaluation, VI investigation, mitigation, monitoring and ultimately termination.

Basic concepts, such as conceptual site models (CSM) and multiple lines of evidence (MLE), are presented and their application to the VI assessment is explained. The VIT Guidance provides recommended protocol for investigating the VI pathway, including the recommended number of sub-slab soil gas (SSSG) and IA samples based on the size of the building footprint and numerous other technical factors.

IA analytical results are compared to the Indoor Air Screening Levels (IASL) and the Rapid Action Levels (RAL). An immediate environmental concern (IEC) is present when VI related IA concentrations exceed the RAL, the source of the exceedance is due to a discharge, and a completed pathway for VI has been confirmed. Whereas, if VI related IA concentrations exceed the IASL, but are equal to or less than the RAL, a vapor concern (VC) exists.

Specific gasoline exclusion criteria are presented to address the unique nature of these petroleum hydrocarbons. The investigator is provided detailed information on data review and the complex nature of background sources on the interpretation of analytical results.

Design, mitigation and post-mitigation procedures are thoroughly discussed and the appropriate monitoring provisions are outlined.

The Department's VI screening levels are located in Tables 1 through 3 on the Department's VI web site at http://www.nj.gov/dep/srp/guidance/vaporintrusion/.

1.0 INTRODUCTION

VI has been recognized as a potential exposure pathway for human health risks for over two decades. VI is defined as the migration of volatile chemicals from the subsurface into overlying buildings through subsurface soils or preferential pathways (such as underground utilities) (N.J.A.C. 7:26E-1.8). The presence of volatile compounds in soil or ground water offers the potential for chemical vapors to migrate through subsurface soils and along preferential pathways, potentially impacting the IA quality of affected buildings. The accumulation of volatile vapors in impacted buildings can result in acute or chronic human health concerns.

1.1 Intended Use of this Technical Guidance

The VIT Guidance is designed to help the person responsible for conducting remediation to comply with the requirements of the Department established by the Technical Requirements for Site Remediation (TRSR or Technical Rules), New Jersey Administrative Code (N.J.A.C.) 7:26E. Specifically, the technical guidance is intended for use in the evaluation of the VI pathway at primarily volatile organic compound (VOC) contaminated sites located within the state of New Jersey. While this document concentrates on VOC contaminated sites, evaluation of other volatile compounds (e.g., formaldehyde, naphthalene, mercury) for the VI pathway may be necessary to protect public safety, health and the environment.

Individuals involved in using this guidance may include licensed site remediation professionals (LSRP), non-LSRP environmental consultants, Department personnel, and other environmental professionals. Therefore, the generic term “investigator” will be used to refer to any person that uses this guidance on behalf of a remediating party, including the remediating party itself.

In applying technical guidance, the Department recognizes that professional judgment may result in a range of interpretations on the application of the guidance to site conditions. If the investigator does not consider this technical guidance appropriate or necessary, the investigator must explain why and provide adequate justification to document that the decisions made are still protective of public health, safety and the environment [N.J.A.C. 7:26E-1.5(b)]. The procedures for a person to vary from the Technical Rules in regulation are outlined at N.J.A.C. 7:26E-1.7 This document updates and replaces the Department’s VIT Guidance, January 2013 and supersedes other related technical guidance on this topic.

1.2 Regulatory Basis for this Technical Guidance

The legal basis for the evaluation of the VI pathway associated with contaminated sites is rooted in various statutes and regulations that include, but are not limited to, those outlined below.

The Brownfields and Contaminated Sites Act specifies that “the State needs to ensure that the public health and safety and the environment are protected from the risks posed by contaminated sites….” N.J.S.A. 58:10B-1.2. The presence of subsurface volatile contamination offers the potential for area buildings to be impacted through the VI pathway. The evaluation of these risks should include consideration of the potential for vapor migration to impact the IA quality of a building and the health of the people in the building.

The Site Remediation Reform Act (SRRA) provides the basis for the LSRP program where the LSRP must ensure that a remediated site is “in compliance with all applicable statutes, rules and regulations protective of public health and safety and the environment” (N.J.S.A. 58:10C-14d). SRRA defines “confirmed contamination that has migrated into an occupied or confined space producing a toxic or harmful atmosphere resulting in an unacceptable human health exposure....” (N.J.S.A. 58:10C-2) as a condition that represents an IEC for the VI pathway that must be addressed pursuant to the Technical Rules. The application of this technical guidance in the evaluation of the VI pathway is included in SRRA, which requires an LSRP to “apply any available and appropriate technical guidelines concerning site remediation as issued by the department.” N.J.S.A. 58:10C-14c(3).

The Department’s Technical Rules, in N.J.A.C.7:26E-1.15, specify the requirement to evaluate the VI pathway. The requirements associated with an IEC for the VI pathway are presented in N.J.A.C.7:26E-1.11.

1.3 Overview of this Guidance

This technical guidance incorporates a risk-based, staged approach to evaluate the potential for VI associated with contaminated sites. The document has been developed after consideration of the latest state of the science procedures and methodologies currently included in the United States Environmental Protection Agency (USEPA), ASTM, Interstate Technology and Regulatory Council (ITRC), State and industry guidance that address the VI pathway. While the Department has incorporated many of the latest recommended methodologies in the document, New Jersey specific characteristics, input parameters and procedures have also been included, where applicable.

The investigator’s strategy for the VI pathway should consist of a series of stages designed to consistently and logically progress through the process of assessing the potential for VI. These stages are structured in this guidance to be consistent with the organization of a typical investigation as required in the Technical Rules. In addition, the *Decision Flow Chart* (Appendix A) and the *Vapor Intrusion Timeline* (Appendix B) should be consulted when assessing the VI pathway.

VI Pathway Investigative Strategy

Stage 1: VI Receptor Evaluation
Assess potential for VI
Identify receptors

Stage 2: VI Investigation
Develop and implement VI Investigation
Evaluate data using applicable screening levels

Stage 3: Mitigation
Determine appropriate mitigation
Implement mitigation

Stage 4: Operations, Maintenance and Monitoring
Establish a long-term monitoring/ maintenance program

Stage 5: Termination
Assess ability to terminate mitigation

While this guidance discusses typical situations that an investigator may encounter while assessing the VI pathway, it is not comprehensive, nor inclusive of all potential scenarios and related investigative tools involving VI.

1.4 Guidance Updates

The Department will update the document as the state of the science for VI pathway evaluation advances. The current document along with updates to the screening levels and other sections of the document are, or will be, presented on the Department's VI web site at www.state.nj.us/dep/srp/guidance/vaporintrusion/. It is recommended that investigators refer to the NJDEP web site to ensure that they are using the most current information in the evaluation of a site. In addition, information on community outreach, sample result letters and tables, as well as access letters can be found on the Department's VI web site.

2.0 DECISION FRAMEWORK

The *Decision Flow Chart* (Appendix A) is designed to assist the investigator in assessing the appropriate steps when evaluating the VI pathway. The chart was formulated to address most situations where suspected IA impacts may be occurring due to sources from soil or ground water contamination, or known spills inside a building. Use professional judgment for any circumstances that are unique or present complex problems not fitting the paradigm.

The technical guidance utilizes a phased approach for investigating the VI pathway. This framework follows the basic provisions of the USEPA Subsurface Vapor Intrusion Guidance (2002b) and various state VI guidance documents. Refer to Sections 2.3 through 2.7 (below) for further discussion on the phased approach.

The decision framework starts with the VI receptor evaluation which encompasses the data gathering phase associated with a preliminary assessment and site investigation. The VI investigation stage involves comparing the Department's screening levels to analytical data from IA, SSSG and ground water samples, as well as other lines of evidence, to resolve whether there is the potential for this pathway to be complete. Site-specific parameters or alternative sampling approaches may be used as part of the VI investigation.

The mitigation stage addresses potential mitigation actions, while the Operation, Maintenance and Monitoring (OMM) phase deals with ongoing post-mitigation requirements. Provisions dealing with the conclusion of the VI pathway are handled in the termination stage.

2.1 VI Investigation Triggers

The most basic question an investigator asks when considering VI is "When do I have to investigate this pathway?"

Ground water in excess of the NJDEP Ground Water Screening Levels (GWSL) or free product is a potential source of VI that can adversely impact the IA quality of nearby buildings. Additional assessment shall be conducted when a building is located within the VI investigation trigger distances (or trigger distances) (N.J.A.C. 7:26E-1.15). Buildings and structures are more fully described in Section 2.3.2 and further clarification on the trigger distances can be found below in Section 2.4.3.

If the contaminant concentration in any ground water sample exceeds its applicable GWSL, the ground water may be resampled to confirm the presence of contamination provided the initial results do not exceed three times (3X) the GWSL. Two confirmation samples should be collected from the same monitoring well using similar purging and sampling techniques, evenly spaced temporally within 60 days of the initial sampling event. Average the results from all three samples collected over the 60 day period to determine whether a vapor intrusion investigation is triggered. Utilize the analytical reporting limit (RL) when averaging non-detect results.

Existing soil gas or IA data are compared to the Department's Soil Gas Screening Levels (SGSL) and IASL, respectively. An exceedance of these screening levels will necessitate further evaluation and possible mitigation of the VI pathway (per N.J.A.C. 7:26E-1.15).

Additional factors that trigger a VI investigation (N.J.A.C. 7:26E-1.15) are as follows:

- A wet basement or sump in a building containing free product and/or ground water with any detectable levels of a volatile contaminant;
- Methanogenic (methane generating) conditions are present that may cause an oxygen deficient environment or an explosion; or
- Any other information that indicates human health and safety may be impacted via the VI pathway (e.g., volatile soil contamination near or under a building).

An "explosive condition" is defined as an atmosphere with a concentration of flammable vapors at or above 10 percent of the lower explosive limit (N.J.A.C. 7:26E-1.8). An "oxygen deficient environment" contains less than 19.5% by volume of oxygen (N.J.A.C. 7:26E-1.8).

The Department currently does not have soil screening levels for the VI pathway. Therefore, the investigator should determine – based on their professional judgment – whether to investigate contaminated soils identified in the unsaturated zone near a building as part of the VI pathway. A site-specific evaluation should consider the volatile contaminant concentrations in soil, how close the contaminated soil is to a building and the utilities that serve it, and whether the contaminants are readily biodegradable or more recalcitrant. Another consideration would be the ultimate remedial action for the contaminated soils (e.g., removed versus remaining in place). The investigator should assess these and other site-specific factors when determining whether the VI pathway should be investigated (if only soil data are available). The Department's soil remediation standards should not be utilized in this determination because the standards were not developed for the VI pathway.

2.2 Vapor Intrusion Screening Levels

The investigator should be gathering and evaluating any existing sampling results or other data to assess the VI pathway relative to the Department's screening levels to determine whether the VI pathway triggers investigation or mitigation. The Department has developed these screening values for ground water, IA and soil gas. The Department's VI screening levels are located in Tables 1 through 3 on the Department's VI web site at http://www.nj.gov/dep/srp/guidance/vaporintrusion/.

2.2.1 Ground Water Screening Levels

Ground water data shall be compared to the Department's GWSL in Table 1 on the Department's VI web site (N.J.A.C. 7:26E-1.15). The GWSL may be used in the evaluation of a site where the ground water is as close as two feet below the building slab when: 1) the seasonal high water table does not reach the building slab; 2) the water table does not extend into fill material directly under the building slab; and 3) the top of the capillary zone does not reach the building slab.

The capillary zone does not normally extend through the base course layer under the slab. For situations where no fill material is present under a building's slab, estimate the top of the capillary zone based on the anticipated soil texture present. Based on an evaluation of the various soil types using the Johnson & Ettinger (J&E) model (Johnson & Ettinger, 1991), the capillary zone, necessary to address item 3 above, has been determined to be greater than two feet in height for finer soils. As a result, the distance between the water table and the building slab should be at least 2.7 feet for clay soils, 4.4 feet for silty clay loam, 5.3 feet for silt and 6.3 feet for silty clay soils. Site-specific field determinations may be made in these circumstances for soil texture.

Provided the above conditions are met, the Department's GWSL are appropriate for use at sites where unsaturated soil is present below the building slab. If the conditions above are not met, the Department's GWSL should not be utilized in assessing the VI pathway.

GWSL should also not be applied where a building slab is in direct contact with competent, massive bedrock containing discrete fractured zones as vertical fractures are very likely to act as preferential pathways for vapors (e.g., creating a direct pathway for vapors between the ground water table and the building slabs). Use the GWSL for soils that contain gravel, assuming they exhibit relatively homogeneous, isotropic conditions.

Apply the GWSL where the water table is in bedrock and nearby site-specific data indicate there is unsaturated soil, fill or geologic material below a building slab through which subsurface air flow would approximate, or approach, porous media conditions. In many areas bedrock in the vadose zone and at the water table is so highly weathered and/or densely fractured that these conditions will be met even if deeper, more competent bedrock creates very heterogeneous flow conditions.

In situations where it is inappropriate to utilize the GWSL, the investigator should employ other lines of evidence (e.g., SSSG, near slab soil gas and IA samples) as discussed in Sections 3.3 & 3.5 of this document and the Vapor Intrusion Pathway: A Practical Guideline (ITRC 2007).

2.2.2 Soil Gas Screening Levels

The Department's SGSL in Table 1 shall be compared to the sub-slab and/or near slab soil gas results (N.J.A.C. 7:26E-1.15). Use the SGSL in the evaluation of representative and appropriate (see Chapter 3) soil gas analytical results. Exceedance of the SGSL indicates the potential for VI that necessitates further evaluation of the pathway as outlined in Chapter 4 of this guidance. Soil gas results that do not exceed the SGSLs may or may not suggest further investigation. Refer to Section 3.1.2.2 for additional information.

2.2.3 Indoor Air Screening Levels

The results of IA samples shall be compared to the Department's IASL listed in Table 1 (N.J.A.C. 7:26E-1.15). The values include residential and nonresidential IASL that are used in the evaluation of IA analytical results collected from within a building. Consistent with the Department's Remediation Standards (N.J.A.C. 7:26D), the Department requires use of the residential IASL in the evaluation of residential properties, schools and child care centers.

The nonresidential IASL are applicable to industrial/commercial facilities where the adult is the receptor of concern, a discharge to the environment has occurred and the facility (or portion of the facility) is not currently handling or using the subsurface contaminants of concern (COC) associated with the discharge. While the collection of IA samples is generally not recommended in situations where the facility is currently using the same COC for the VI pathway, IA samples collected under these circumstances should include consideration of both the nonresidential screening levels and the applicability of the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PEL) to the subject building.

Air samples collected from a building crawlspace are also compared to the applicable residential or nonresidential IASL to determine whether further investigation is necessary (e.g., collecting IA samples from the living space above the crawlspace). The subsequent IA sample results are then compared to the applicable IASL to determine whether an IEC or VC condition for the VI pathway exists within the building (as discussed below).

A VC or IEC does not exist at a building (or portion of a building) when OSHA applicability has been determined. This position assumes that the workers in question are fully covered by OSHA regulations (e.g., notification, training in personal protective clothing and gear, medical monitoring, documentation). The investigator should document the use of the OSHA PELs.

Consider and address the potential for a future change in use of the building or in the use of the COC within the building in situations wherein nonresidential IASL and/or the OSHA PEL are used. Periodic verification of both the use of the building and the COCs will be necessary as part of institutional control requirements at the affected building(s).

The evaluation of IA data collected at a site shall also include a determination as to whether an IEC for the VI pathway exists in a building (N.J.A.C. 7:26E-1.11). An IEC determination is based on 1) an exceedance of the applicable RAL found in Table 2 of the Department’s VI web site (http://www.nj.gov/dep/srp/guidance/vaporintrusion/) and 2) the conclusion that the exceedance is resulting from a completed VI pathway and not exclusively background or ambient air sources. The Department should be contacted to develop an applicable RAL if a value does not exist in Table 2 for a site COC.

A potentially explosive environment present in a building or subsurface utility is not an IEC, but rather an emergency situation. Thus, a potentially explosive condition shall be immediately reported to 911, the Department’s Hotline and the New Jersey Department of Health (NJDOH) irrespective of the source [N.J.A.C. 7:26E-1.15(i)].

Health Department Notification Levels (HDNL), developed in consultation with NJDOH, are currently under revision. When the HDNL are revised, they will be listed in Table 2 (http://www.nj.gov/dep/srp/guidance/vaporintrusion/) of the Department’s VI web site. These values are administrative in nature and, when exceeded in occupied buildings, indicate the need for the investigator to inform the NJDOH, the Department and the local health department, by telephone about the site and the associated VI related IA concentrations for further evaluation and possible emergency actions. Evacuation and remediation are independent processes that are determined by the appropriate agencies.

2.3 VI Receptor Evaluation (Stage 1)

For the VI pathway to be complete, there must be a source (principally volatile compounds), a potential pathway involving an impacted matrix (e.g., ground water, soil and/or soil gas), and people (i.e., receptor) (current or future) proximal to the source or pathway. In the VI receptor evaluation (Stage 1) the investigator assesses each of these components to begin the process of developing a CSM, as discussed in Section 3.1.1. Identify data gaps and prepare the preliminary approach to a VI investigation.

2.3.1 Initial Data Gathering

Once a VI investigation is triggered, implement a series of actions as stipulated in N.J.A.C. 7:26E-1.15(b). The following actions shall be completed within 60 days after the initial trigger event.

1) Identify all buildings and subsurface utilities (as clarified in Section 3.1.3) within the trigger distances of the currently known extent of the shallow ground water contamination in excess of the Department's GWSL or other triggers noted in Section 2.1;
2) Assess each building to determine
    - Specific use,
    - Existence of a basement, crawlspace, or slab-on-grade, and
    - Approximate square footage of the building footprint;
3) Determine the specific use, depth of the invert, diameter and construction specifications of subsurface utilities (as clarified in Section 3.1.3);
4) Identify whether a landfill is located on or adjacent to the site and whether methane generating conditions are present;
5) Establish the flow direction of the shallow ground water; and
6) Ascertain whether free product is present at each ground water sampling location.

Recognize that the trigger distance is utilized for the identification of buildings and subsurface utilities in all directions from the limits of the source (or trigger), not just downgradient based on the ground water flow. The investigator should make a reasonable effort to ascertain the building information within the timeframe allowed. In addition, the VI receptor evaluation should be updated each time there is further expansion to the limits of the contamination or new triggers. Thus, as new ground water data reveal the extent of the plume, additional information on buildings and subsurface utilities should be obtained (based on the trigger distances).

The gathering of these data will assist in developing a site-specific CSM. Based on this information, the investigator can identify data gaps and develop an investigative approach that assesses the VI pathway and potential human exposure.

2.3.2 Building and Structures

The potential for VI to impact people occupying a building and/or structure overlying or proximal to subsurface volatile contamination should be evaluated as presented in this technical guidance. While the term “building” is used throughout this document, an evaluation of the VI pathway should consider both buildings and structures, as described below, in the evaluation of the pathway.

A building is defined as a permanent enclosed construction on land, having a roof, door(s) and usually window(s) that is or can be occupied by humans, and is utilized for activities such as residential, commercial, retail, or industrial uses. Examples of a building include a single family home, an apartment complex or a commercial/industrial facility, such as a strip mall or an industrial warehouse.

A structure, for the purpose of this guidance, includes a smaller construction that has limited access capability with minimal exposure potential to those individuals that may enter the structure for a much shorter period of time. Examples of a structure include a shed, small pump house or utility vault.

The investigator should use professional judgment in determining the investigative approach and need for mitigation when a reduced exposure potential is present in a building and/or structure. While unoccupied buildings or structures may present minimal exposure potential at the current time, future change in use must be considered and addressed as outlined in this technical guidance. The Technical Rules define a “change in use” as “a change in existing use at an area of concern to a school, child care center or residence. Change in use also applies if a school, child care center or residence moves from an upper floor to the lowest floor in the building” (N.J.A.C. 7:26E-1.8). In addition, a change in the existing use occurs when a building is no longer OSHA-applicable.

Buildings on piers or with open air parking beneath occupied floors present a lower risk of VI, but the investigator should consider the potential of VI in higher floors via preferential pathways, such as elevator shafts or stairwells.

2.4 VI Investigation (Stage 2)

The VI Investigation stage involves the evaluation of the VI pathway through an investigative strategy as required in N.J.A.C. 7:26E-1.15(c, d, h, and i). The initial round of the VI investigation shall be completed within 150 days [N.J.A.C. 7:26E-1.15(c)] after determining that a VI trigger exists.

If the available results reveal an exceedance of the Department’s VI screening levels (or one of the additional factors is triggered), a VI investigation shall be developed and implemented based on the information gathered during the VI receptor evaluation phase and the site-specific CSM. Alternately, the investigator may consider the option of implementing mitigation as a proactive approach.

The Department recognizes that events often beyond the control of the investigator (e.g., obtaining access, seasonal restrictions) may necessitate a request for an extension of the regulatory timeframes.

In order to ensure that human health and the environment are protected, state law requires the investigator to file a legal action in court to obtain access to private properties if access is not granted voluntarily (N.J.S.A. 58:10B-16). This action is to be taken irrespective of the type of building (e.g., residential, commercial, retail, industrial) on the property. It is not necessary to seek legal action in circumstances where the property owner refuses to permit the collection of sub-slab soil gas samples if the alternative of near slab soil gas samples is permitted. The collection of exterior soil gas samples is not an acceptable alternative. Both near slab and exterior soil gas sampling is defined in Section 3.1.2.2.

When a building requires VI mitigation and the general public or tenants may access the building, the investigator is required to pursue court ordered access to the property to perform the mitigation. Otherwise, the decision to allow the implementation of VI mitigation is left to the property owner.

2.4.1 Investigative Approach

The Department recommends investigating ground water (in most circumstances) as the first medium for the VI pathway (Stage 2A). Consult Section 3.2, *Ground Water Investigation and Sampling*, to ensure that the ground water data are both representative and valid for investigating the VI pathway. Depending on the site-specific CSM, the investigator may elect to conduct soil gas and/or IA sampling prior to initiating a ground water investigation.

In cases where soil contamination in the unsaturated zone represents a potential source of VI and triggers an investigation, the use of ground water data and the GWSL alone are not appropriate. The investigator should employ soil gas, IA samples and/or other lines of evidence, in combination with professional judgment, to assess whether soil contamination is a source of VI.

The next stage of the VI investigation is typically the collection of soil gas samples (Stage 2B). SSSG sampling is the preferred method of collecting soil gas. It allows the investigator to quantify contaminant levels in soil gas immediately under the slab of the building. Section 3.3.1, *Sub-Slab Soil Gas Sampling*, provides information on collecting SSSG samples. For assessing undeveloped parcels, employ exterior soil gas sampling. The soil gas results from sub-slab, near slab and exterior samples (where appropriate) shall be compared to the Department's SGSL. Exceedance of the SGSL will necessitate further evaluation of the VI pathway through the collection of IA data. Alternatively, the investigator may elect to implement mitigation to address the VI pathway.

Recognizing the difficulties associated with background contamination (among several issues), IA sampling is typically the last step during an investigation of the VI pathway (Stage 2C). IA sampling provides the most direct evidence regarding the air quality within a building. Other data (ground water, soil, soil gas) simply reflect the potential for adverse impact on IA quality based on modeling or attenuation factors, and not the actual exposure. Thus, the Department recommends the collection of IA samples at this stage of the investigation. Refer to Section 3.5 for more information on IA sampling. All IA samples (including crawl space air samples) shall be compared to Department's IASL. After properly considering other lines of evidence (e.g., background sources), an IA sample that exceeds the IASL may require mitigation to eliminate the pathway (Stage 3).

2.4.2 Iterative Nature of VI Investigations

The initial round of the VI investigation shall be completed within 150 days [N.J.A.C. 7:26E-1.15(c)] after determining the need to conduct the investigation. As part of the initial round, the investigator shall:

- Notify the Department at the time access is requested of building owners/occupants, but no later than 7 days prior to conducting the VI investigation (using the Potable Well/Indoor Air Sampling Notification Form at http://nj.gov/dep/srp/srra/forms/);
- Conduct the VI investigation;
- Evaluate the results of the VI investigation using the multiple lines of evidence; and,
- Determine if the VI pathway is complete for each building being investigated.

The timeframe for the submission of the analytical data to the Department and result letters/ summary tables to the building owner/occupant is outlined in Table 3-3 of this technical guidance. The investigator is required to submit in Adobe Portable Document Format (pdf), all indoor and ambient air results, including all maps and figures related to the indoor air sampling, and a sample location spreadsheet to the NJDOH [N.J.A.C. 7:26E-1.15(h)]. The data and related information should be electronically submitted to **LSRPIA_Submission@doh.state.nj.us.** Any questions can be directed to the NJDOH Standard Setting and Risk Assessment Project at (609) 826-4920. Please do NOT mail hardcopies of any data to NJDOH.

Concurrent with the VI investigation, delineation of the ground water contamination should be implemented. If the VI trigger is not ground water contamination (e.g., soil or soil gas contamination, vapor cloud), identify and properly delineate the source. Consequently, the process of identifying buildings and subsurface utilities, conducting additional rounds of VI investigation, evaluating the sampling data and reporting the results is repeated [N.J.A.C. 7:26E-1.12(d)].

The Technical Rules require a "step-out" (extending out from the affected building) investigation whenever a VC [N.J.A.C. 7:26E-1.15(e)6] or an IEC [N.J.A.C. 7:26E-1.11(a)6] condition is identified. Using the identification date as the trigger, a VI investigation shall be completed (including sampling) for all buildings within 100 feet of the impacted building irrespective of the COCs involved. The trigger distance criteria shall not be used during this "step-out" investigation. Furthermore, identify any additional buildings at risk and conduct VI investigations consistent with N.J.A.C. 7:26E-1.15. The timeframe for completing the "step-out" investigation is 60 days for an IEC condition and 150 days (consistent with a receptor evaluation) for VC conditions.

This is the iterative nature of investigating the VI pathway. The 150 day timeframe to initiate a VI investigation commences again with the discovery of additional buildings that warrant investigation, often overlapping with the previous round.

2.4.3 Trigger Distances

The Department requires a VI investigation where buildings are within 100 feet horizontally or vertically of free product or shallow ground water contamination in excess of the GWSL that is not PHC-related [N.J.A.C. 7:26E-1.15(a)]. Under a future use scenario, additional investigation may be appropriate for undeveloped parcels using the same criterion. If the depth to the shallowest ground water exceeds 100 feet, a VI investigation is not required unless vertical preferential pathways exist and the CSM indicates there is a potential VI risk.

The 100-foot trigger distance for investigating the VI pathway does not consider the aerobic biodegradation of petroleum hydrocarbons (PHC), particularly the compounds associated with gasoline (e.g., benzene, toluene, ethylbenzene and xylenes – BTEX). Depending on the site conditions, the criterion will likely be too conservative for PHCs. Therefore, the Department utilizes a 30-foot trigger distance (both horizontal and vertical) for PHC-related ground water contamination and PHC-related free product. Refer to Chapter 5 for a clarification on PHCs, especially No. 2 and diesel fuels, and exclusion criteria for gasoline-related discharges.

The 100-foot trigger distance shall be used for free product that is not PHC-related [N.J.A.C. 7:26E-1.15(a)].

It should be understood that the trigger distances are applied from the edge of the ground water plume based on linear interpolation (not a contaminated monitoring well) when determining which buildings should be investigated. It is unacceptable to assume the VI pathway is incomplete based on the collection of a ground water sample at a distance less than the prescribed criterion. The trigger distances are based on the migration of vapors through the vadose zone and are irrespective of the presence of contaminated ground water within that distance. The criteria are also applied exclusively to the horizontal or vertical distance from the contaminated ground water plume.

2.4.4 Data Usability

One of the decision points in the screening process is to determine whether the analytical data are valid and representative. This is an all-inclusive phrase designed to address a variety of issues dealing with the usability of the analytical data. Relevant questions of this step include the following:

- Was the sampling approach appropriate for the investigation of the VI pathway (including seasonal variability for IA samples) and accurately followed by the investigator?
- Were the samples properly collected - consistent with the most recent version of the NJDEP Field Sampling Procedures Manual (FSPM) (NJDEP 2005a) and this guidance?
- Is the investigator confident that the sampling equipment was not moved or otherwise tampered with?
- Were the data properly reviewed and determined to be acceptable?
- Was consideration given to potential background contamination?
- Were all other issues that might impact on the data’s usability addressed appropriately?

Each of the above questions should be answered affirmatively in order to proceed along the flow path. Any negative responses may indicate false positive or negative bias in the data acquisition that may require the collection of additional analytical data.

Based on the concept of multiple lines of evidence, other types of data (e.g., field analytical, meteorological, observational) can be utilized in the assessment of the VI pathway. Consult Chapter 4 for additional information.

2.4.5 Site-Specific Options

At any point during Stage 2 (after a VI investigation has been triggered), the investigator can elect to utilize site-specific screening options as part of the VI investigation.

Alternative screening levels may be developed based on chemical toxicity factor changes on IRIS or the USEPA Regional Screening Level table that have not yet been reflected in the most recent Department VI Screening Level tables. Alternative screening levels may also be developed based on site-specific factors and changes in the risk assessment methodologies or exposure parameters not yet included in the Department VI Screening Level tables. For alternative GWSLs, NJDEP guidance on modifying parameters in the J&E spreadsheet should be consulted (http://www.nj.gov/dep/srp/guidance/vaporintrusion/njje.htm).

NJDEP pre-approval is recommended for the use of alternative screening levels. The Department should be contacted to develop a screening level for a site VI contaminant of concern that is not currently included on the Department VI Screening Level tables. Information on completion of the NJDEP Alternative Soil Remediation Standard and/or Screening Level Form to be used in the development of alternative or new screening level may be obtained at http://www.nj.gov/dep/srp/srra/forms/

The use of modeling or other alternative approaches will likely trigger a Departmental review or inspection. Therefore, it is recommended that a technical consultation (http://www.nj.gov/dep/srp/srra/technical_consultation/) be obtained with the Department.

While the Table 1 GWSL are based on the presence of sandy soils, the Department has developed GWSL for Alternate Soil Textures, as presented in Table 3 of the Department's VI web site (http://www.nj.gov/dep/srp/guidance/vaporintrusion/), utilizing loamy sand, sandy loam and loam soil that result in less conservative screening levels. Laboratory soil grain size analysis, as described below, should be documented to justify the use of the GWSL for Alternate Soil Textures at a site.

Laboratory soil grain size analysis should demonstrate at least 75% of the soil vertical profile is as fine-grained as the soil texture selected for use of the Table 3 screening levels. If this criterion is not met, use the coarsest soil texture.

To establish soil texture, collect soil cores using a Shelby Tube, direct push sampler, or split spoon. One representative boring within 10 feet of the building will be sufficient for most single-family homes with additional borings necessary for larger buildings. Collect the soil cores/samples continuously (every two or four feet depending on the length of the sampling device) from the base of the slab depth to the surface of the static water level. Collect a grain size analysis on the cores/samples. A variety of methods exist to determine grain size of a given soil sample. The Department accepts all of the following techniques: sieve analysis for the sand and gravel portions of a given sample with pipette or hydrometer measurements of the silt and clay fractions, rapid sediment analyzers, hydrometer method, and electro-resistance multichannel particle size analyzers.

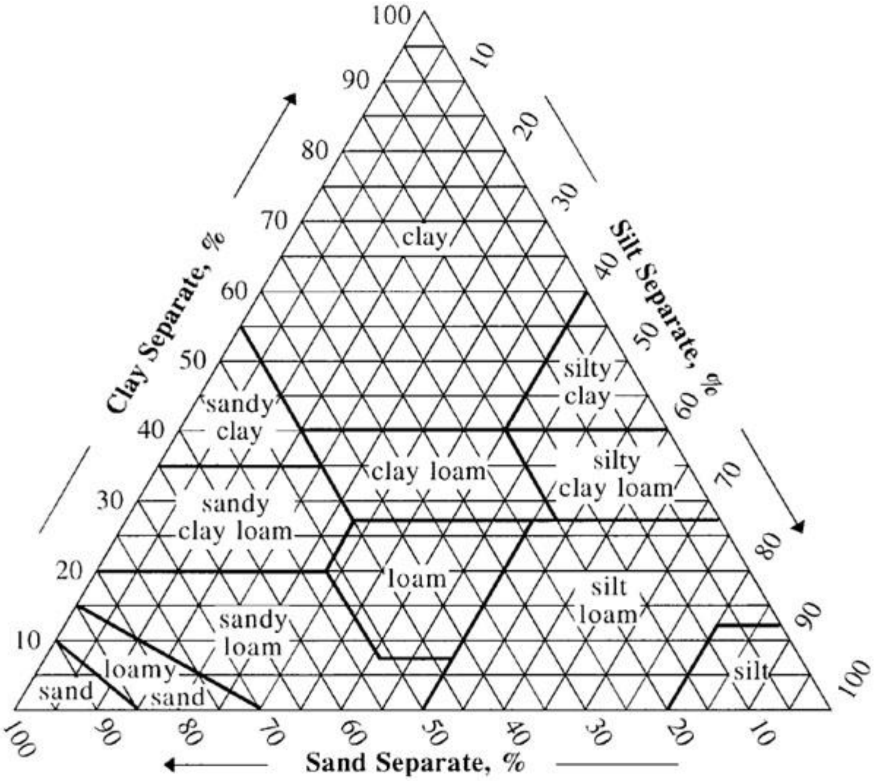


Figure 2-1
Soil Classification System (USDA)

The percentages of sand, silt and clay determined by the chosen analysis techniques are then compared to the United States Department of Agriculture (USDA) Soil Texture Triangle to determine the soil texture classification (Figure 2-1). Under the USDA Soil Texture Triangle, sands are considered particles between 0.05 mm and 2 mm in size, silts are between 0.05 mm and 0.002 mm and clays are less than 0.002 mm in size.

The investigator should properly document the building-specific soil texture in the appropriate reporting document.

Additional site-specific options available to the investigator (based on professional judgment) are as follows:

- Utilization of alternative soil gas sampling procedures (flux chambers, continuous monitoring, vertical depth profiling);
- Assessment of biodegradation for PHCs through data collection (O_2 & CO_2 levels in subsurface soils, depth to ground water table) or modeling; and
- Implementation of other appropriate site-specific screening options using a MLE approach.

2.5 Mitigation (Stage 3)

Once the VI investigation is complete, a selection of the appropriate mitigation shall be made, if applicable (N.J.A.C. 7:26E-1.15(e and f)). Consult Chapter 6, *Vapor Intrusion Mitigation*, for technical guidance on the applicable mitigation alternatives.

2.5.1 Vapor Concern

When the results from an IA sample exceed the Department's IASL (but is equal to or less than the Department's RAL) and it is reasonable to conclude that the VI pathway is complete, a VC is triggered. The investigator shall notify the Department within 14 days of receipt of the data package (N.J.A.C. 7:26E-1.15(e)) using the VC Response Action form available at http://nj.gov/dep/srp/srra/forms/. This action will trigger the assignment of a Department Case Manager. After this point, the investigator should communicate with the Case Manager on all future actions.

N.J.A.C. 7:26E-1.15(e) requires the submission of a VC mitigation plan to the Department along with a VC Response Action form available at http://nj.gov/dep/srp/srra/forms/ within 60 days after receipt of the analytical data to address the exposure. The VC Mitigation Plan shall be initiated within 120 days after receipt of the analytical results. Finally, a VI Response Action Report shall be submitted to the Department within 180 days after receipt of the analytical data. An updated VC Response Action form shall accompany the report. Refer to Section 6.1.2.3 for additional information on the components of the VC mitigation plan and Section 6.4.5 for the VC mitigation response action report.

2.5.2 Vapor Intrusion Immediate Environmental Concern

When the results from an IA sample exceed the Department's RAL and it is reasonable to conclude that the VI pathway is complete, a VI IEC is triggered (N.J.A.C. 7:26E-1.11). The investigator shall immediately notify the Department of the IEC. As with the VC, a Department Case Manager will be assigned to ensure that the exposure is eliminated in a timely manner.

Within 14 days after the VI IEC identification, the investigator shall:

- Provide the results and an explanation (letter) to the building's occupants/owner and the local health department;
- Implement an interim response action (IRA) to reduce contaminant levels;
- Submit an IEC Response Action form (available at http://nj.gov/dep/srp/srra/forms/), an IEC VI spreadsheet, and an IEC map to the Department;

- Submit all IEC analytical results to the Department with the Full Laboratory Data Deliverable form available at http://nj.gov/dep/srp/srra/forms/; and,
- Submit all IA analytical results to the NJDOH.

The investigator shall implement an engineered response action (ERA) to mitigate the VI IEC within 60 days after triggering the IEC [N.J.A.C. 7:26E-1.11(a)6]. An IEC ERA report shall be submitted to the Department within 120 days after the IEC is first identified. An updated IEC Response Action form shall accompany the report.

In addition, The investigator shall identify and sample (SSSG and IA) all buildings within 100 feet of the impacted building, as well as identify and investigate any additional buildings that may be impacted as part of a supplemental receptor evaluation [N.J.A.C. 7:26E-1.11(a)6ii]. This VI investigation shall be conducted concurrently with the implementation of the ERA.

For more information, please refer to the Department's Immediate Environmental Concern Technical Guidance (http://www.nj.gov/dep/srp/guidance/).

2.5.3 Institutional Controls and Future Use

Establish institutional controls as part of any ground water remedial action and resulting maintenance and monitoring requirements to address current/future use of the subject property. Depending on the level of contamination present and other site-specific factors, current (and potentially future) inhabited buildings or environmental media may be monitored to assess any VI risk. Building construction can incorporate designs to address the VI pathway. Engineering controls may be appropriate based on the results of the VI investigation, current/future land use and site conditions (see Chapter 6).

2.6 Operation, Maintenance and Monitoring (Stage 4)

Based on the type of mitigation selected, monitoring should be implemented (as discussed in Section 6.5). Monitoring may or may not involve the collection of analytical samples. For example, monitoring of subsurface depressurization systems may be limited to periodic readings of the static pressure and flow measurements for each system suction point and fan inlet.

Maintenance and review of current operations of the mitigation is an essential part of the process. Periodic inspections of the system or engineering and institutional controls ensure that the VI pathway remains incomplete. Refer to Section 6.4, *Post-Mitigation Activities,* for additional information.

2.7 Termination (Stage 5)

Finally, the decision to terminate the mitigation is dependent upon the remediation of the VI source to the point where the VI pathway is not complete (Stage 5). Make a determination on system termination through the collection of IA and SSSG samples (as discussed in Section 6.6).

3.0 INVESTIGATIVE APPROACHES

3.1 Conducting a Vapor Intrusion Investigation

VI investigations shall be conducted consistent with the Technical Rules and the specific investigative provisions contained in N.J.A.C. 7:26E-1.15. When submitting the results of the sampling event, the investigator shall provide a written technical rationale for not applying any provision from this technical guidance (N.J.S.A. 58:10C-14c(4)).

3.1.1 Conceptual Site Model

The CSM is the typical starting point for the preparation of a VI investigative approach. The Department recommends early development of a CSM that can be used to plan, scope, and communicate the development of a VI investigation and any needed mitigation.

While the CSM can greatly assist in evaluating results of an investigation, it does not have to be a written document or be submitted to the Department.

The CSM allows the investigator to better understand the source of contaminants, the pathways traveled, the people potentially or actually exposed to contaminants, and the location of each of these in relation to the other. Buildings with known sensitive populations (e.g., residences, schools, child care centers) should be identified early during the VI receptor evaluation and prioritized for VI investigation.

One of the goals of the VI investigation is to test or refine the CSM. Thus, the data generated from the investigation should support the basic understanding as laid out in the CSM. If not, either the CSM needs to be modified or the data are deficient.

To assist the investigator in preparing this vital component, utilize the *ITRC Conceptual Site Model Checklist* found in Appendix C. In addition, the investigator is directed to consult the Department's Conceptual Site Model Technical Guidance (http://www.nj.gov/dep/srp/guidance/).

3.1.2 Investigative Tools

There are a number of investigative methods for assessing the VI pathway, principally involving ground water, soil gas and IA sample collection. IA, sub-slab soil gas and ambient air samples are consider "vapor intrusion samples" [N.J.A.C. 7:26E-2.1(c)3]. Other tools unrelated to chemical analysis can also be employed as part of an overall MLE approach to assessing the VI pathway.

3.1.2.1 Ground Water Sampling

In most situations, ground water will be the first medium to be evaluated for the VI pathway. A remedial investigation of ground water requires (N.J.A.C. 7:26E-4.3) the characterization and delineation of ground water contamination. The extent of the ground water plume, as well as the concentrations of the contaminants, allow for an initial assessment of the VI pathway. In most cases, exceedance of the NJDEP GWSL necessitates further evaluation and probably more field investigation.

Follow Section 3.2 below for VI ground water investigations. Quality assurance (QA) issues (e.g., QA samples, analytical methods, and deliverables) for ground water sampling should be consistent with the most recent version of the Department's FSPM (NJDEP 2005a).

As a general rule, the collection of SSSG or IA samples is not recommended prior to a basic assessment of the site hydrogeology, including soil profile, geologic stratigraphy, ground water depth, flow direction and contaminant concentrations. False assumptions may be reached on the VI pathway based on an incomplete picture of the site hydrogeology (as defined in the CSM). It should be understood, though, that the potential for an IEC may necessitate the collection of SSSG and/or IA samples prior to acquisition of sufficient ground water data due to the urgency of the potential human exposure, particularly to sensitive populations. The presence, quantity and location of non-aqueous phase liquid (NAPL) in the vadose zone close to buildings may also indicate that the collection of soil gas and/or IA samples should precede collection of ground water analytical data.

3.1.2.2 Soil Gas Sampling

An exceedance of the Department's GWSL necessitates further investigation of the VI pathway. In most cases, soil gas sampling is the most logical next step in the VI investigative process.

This technical guidance defines soil gas results based on the location of the sample: sub-slab (below the foundation slab), near slab (within 10 feet horizontally of the foundation) or exterior (outside of the 10-foot perimeter of the foundation). In addition, data can be obtained from passive soil gas sampling procedures as a supplement to the traditional active soil gas collection.

The investigator should collect SSSG samples as the principal investigative tool for soil gas sampling to evaluate the VI pathway. Near slab soil gas sampling is an acceptable alternative when it is verified that obtaining sub-slab samples is not possible. (Refer to Section 3.3.2 for additional information on *Alternative Soil Gas Sampling*). Utilize the results of near slab soil gas sampling as a line of evidence to assess whether the VI pathway is currently complete for a particular building.

Sometimes, it is necessary to investigate the subsurface soil gas under buildings with existing sub-slab depressurization systems (SSDS) designed to address either radon or VI. In these cases, turn off the SSDS fan (if present) and cap the vent pipe a minimum of 48 hours in advance of the SSSG sample collection. Locate the sub-slab sampling point(s) away from existing SSDS suction points, floor drains, sumps and any other openings in the slab, if possible (O'Brien & Gere, 2009). When the occupants are unwilling to allow the SSDS to be shut off, an alternative could involve conducting a communication tests across the entire slab in combination with IA sample(s). Refer to Section 6.6 if the SSSG sampling is being proposed as part of system termination.

SSSG samples may also be more appropriate when obtaining representative ground water data is not possible or is impractical.

Soil gas sampling approaches should take into account the different exposure scenarios (e.g., child care centers, offices) that exist within the building and any sensitive populations that may be exposed to the contaminated vapors. In addition, the presence of subsurface structures (sumps, dry wells, underground fuel sources, etc.), can exacerbate the VI pathway and possibly degrade IA quality in one portion of the building and not another.

In situations where contaminated unsaturated soils or vapor clouds are the primary potential source, sub-slab or near slab soil gas samples are the principal mechanism for investigating the VI pathway (other than IA samples).

Underground storage tank sites or sites where chlorinated solvents are used in buildings or facilities at the surface (e.g., dry cleaners, vapor degreasers) may have contamination in the vadose zone due solely to vapor releases. In these cases, soil and ground water data may not identify the VI source. Soil gas sampling is the preferable investigative tool where vapor leaks (or vapor clouds) are suspected.

Sites that involve contaminated unsaturated soils or vapor releases are two examples where a vertical profile of soil gas concentrations may assist in the investigation. Vertical profiling can better clarify the source(s) of VI by evaluating the distribution of chemical concentrations over a defined depth. If a ground water plume under a building is the suspected source, soil gas concentrations should increase as the depth of the sample collection increases. Aberrations from this general assumption may suggest an alternative source, such as preferential pathways, vapor clouds, surface spills or vadose zone soil contamination, provided the data are not affected by bias or variability.

The investigator should also recognize circumstances where SSSG samples may not be a good indicator of VI. For example, soil contamination in the vadose zone may generate vapors that migrate into a building by way of subsurface utilities typically at a depth of 3-6 feet below the surface. Under this scenario, soil gas concentrations under a basement slab (8-10 feet below the surface) may not detect a VI concern.

Undeveloped parcels without existing buildings present a unique situation for the investigation of the VI pathway. The collection of SSSG or IA samples is not possible without a building on the parcel. In this case, an MLE approach can be employed to assess the potential for VI under a future use scenario and potentially lead to a no further action determination. The lines of evidence may include:

- delineation of the ground water plume;
- analysis of soil gas samples just above the water table using a grid sampling approach and biased towards the highest concentrations within the ground water plume;
- utilization of J&E model with NJDEP-specific input parameters;
- implementation of pneumatic testing (soil permeability); and
- assessment of soil stratigraphy and /or vertical profiling of soil gas concentrations.

While not specifically identified by the Technical Rules, the investigator should consider undeveloped parcels within the prescribed trigger distances for a VI investigation.

A VI investigation for undeveloped land will not be necessary if the landowner is willing to voluntarily accept an institutional control that stipulates any future development must consider the VI pathway. This can be accomplished by incorporating vapor mitigation into the design of the building(s) or conduct a VI investigation at that time. In addition, these provisions should be included in the monitoring, maintenance and evaluation (MME) plan of the ground water Classification Exception Area (CEA).

When in situations where the exterior soil gas investigation is being conducted to assess a future use scenario at an undeveloped parcel, the results should be compared to the Department's SGSL.

Exterior soil gas samples can also be employed as a screening tool to assist with the delineation of the ground water plume (but not the direct assessment of the VI pathway). However, support the final plume delineation by the collection of confirmatory ground water samples at strategic locations. In these cases, a mobile lab employing USEPA Method 8260B (or similar methods) may expedite the investigation and allow the flexibility to modify the sampling strategy in the field (Triad approach).

Lastly, passive soil gas sampling may be applicable to the preliminary delineation of the ground water plume or vadose zone sources. Support the final plume delineation by the collection of confirmatory ground water samples at strategic locations. Passive soil gas results are not acceptable as the only line of analytical evidence in assessing the VI pathway.

3.1.2.3 Indoor Air Sampling

IA sampling is generally the last investigative step in the evaluation of the VI pathway. Due to legitimate concerns over background sources, IA results provide a unique challenge to investigators (refer to Chapter 4, *Multiple Lines of Evidence and Data Evaluation*, for additional information). The Department recommends the collection of SSSG and ambient air samples in conjunction with IA sampling events to assist in the evaluation of background sources.

IA sampling is often necessary to properly assess whether the VI pathway is complete in several situations, such as:

- exceedance of the SGSL;
- shallow ground water table that prevents the collection of soil gas data;
- site-specific approach is utilized which requires supplemental data in support of the conclusions;
- preferential pathways exist that may negate or limit the usefulness of ground water or soil gas data;
- presence of contaminated ground water in a sump;
- IECs that require a more immediate response;
- volatile chemicals in bedrock near/at the surface (eliminates the applicability of J&E); or

- other site-specific factors.

Because IA sample locations are a critical issue in the ultimate assessment of the data, the VI investigation should clearly identify the criteria that will be employed in selecting sample location. Refer to *Conducting a Building Walkthrough and Survey* (Section 3.4) for additional technical guidance on this phase of the investigation.

An ambient air sample provides background concentrations outside of the building being investigated at the time of the IA sampling event. When using USEPA Method TO-15 (USEPA 1999), the canister used for the ambient air sample should be randomly selected from the canisters sent by the laboratory and placed outside of a building or group of buildings that are being sampled. The ambient air sample should have the same sample collection time and be analyzed in the same manner as the interior sample to the extent practicable. The investigator should clearly designate sample location and the site conditions at the time of sampling. The investigator also should be aware of the weather conditions during the sampling event. Thus, the canisters should be placed in a secure outside location. Take ambient air samples at breathing zone height (if possible) and in close proximity to a residential building. For non-residential buildings, the investigator may elect to collect the ambient air sample near representative heating, ventilation and air conditioning (HVAC) intake locations (i.e., on the roof).

3.1.2.4 Soil Sampling

At this time, the Department has not developed VI screening levels for soil. Compare soil gas and IA results to the applicable screening levels to assess the vapor potential from contaminated soils. Otherwise, make a site-specific determination as to whether further investigation of the VI pathway is warranted for contaminated soils. The investigator should note that high soil concentrations may be useful as an indicator of the depth and/or extent of the vadose zone sources. Soil samples for VOCs have a potential for negative bias due to volatilization losses and generally higher reporting limits (RL) compared to soil gas samples.

3.1.2.5 Other Investigative Tools

In addition to the typical sample collection for chemical analysis, other investigative tools may assist in the assessment of the VI pathway. Refer to the ITRC Vapor Intrusion Pathway: A Practical Guideline (ITRC 2007) (http://www.itrcweb.org/guidancedocument.asp?TID=49) for detailed information on the various investigative tools available.

Investigators can evaluate soil properties by visually inspecting soil cores, determining soil texture, or ascertaining porosity and moisture content.

Soil pump tests can be conducted to analyze pneumatic properties or correlate the changing concentration verses volume purged.

Weather conditions can often influence advective flow of soil gas into a building. Thus, monitoring barometric and differential pressure, as well as wind speed and precipitation, can be recorded to document daily or seasonal trends.

Building-specific parameters, including pressure testing and ventilation rate determinations, can serve to supplement Test and Balance Reports (if available) and support potential mitigation measures involving the manipulation of building pressure.

The collection of vertical profiles of oxygen and carbon dioxide readings in soil gas samples can be utilized to substantiate that biodegradation is occurring, particularly for PHCs in the subsurface.

Finally, modeling results can be used as another line of evidence in assessing the VI pathway. Employing modeling will likely trigger a review or inspection by the Department. Therefore, it is recommended that the investigator utilize the Department's Technical Consultation Process to obtain regulatory input. Refer to Section 2.4.5 for additional information.

As the science of VI advances, additional technologies will be developed to assess the pathway. With proper documentation, these new technologies can be employed.

3.1.3 Preferential Pathways

Due to the nature of vapor migration, VI investigations shall assess the presence of preferential pathways pursuant to N.J.A.C. 7:26E-1.15(b), whether natural (e.g., shallow rock or vertically fractured soil) or anthropogenic (e.g., buried utilities).

As part of the VI receptor evaluation (Stage 1), the investigator shall evaluate the possibility of interconnections between a source and a building through subsurface utilities. Specifically, the use, the depth of the invert, the diameter of the conduit, and the construction specifications of utility lines shall be determined. Identify natural features that may act as preferential pathways.

As they relate to N.J.A.C. 7:26E-1.15(b), it may be reasonable to consider a variance for typical subsurface utilities (water, gas, sewer, cable, etc.) at single-family residential buildings and other similarly sized buildings as part of the VI receptor evaluation. An exception to this provision is when these typical subsurface utilities run through or are relatively close to source materials (e.g., free product, soil contamination). However, a variance would not be appropriate for identifying any lateral lines servicing large residential buildings or units, commercial, retail or industrial buildings, or main lines servicing groups of buildings (residential or otherwise), as well as utility vaults or other underground structures.

Larger lines and utility corridors for main lines constructed using bedding material and fill are more likely to act as significant preferential pathways for vapors, contaminated ground water, or NAPL migration and may be important in developing an accurate CSM. Utility vaults and underground structures that can be associated with larger utilities may also be subject to VI and in extreme cases can pose a threat of explosion or an oxygen deficient atmosphere.

Determining construction specifications of subsurface utilities, as required in N.J.A.C. 7:26E-1.15(b)3, may be limited (as a variance) to characteristics with the potential for influencing contaminant migration, such as the type and extent of any bedding or fill materials used.

It may be necessary for the investigator to determine whether any utilities are acting as conduits for vapor migration, either along the utility's backfill or within the utility itself. This determination should include, but not be limited to, visual inspection and the use of field screening instruments (with appropriate detection limits based on the SGSL). The State of Wisconsin guidance document (WDNR, 2000) provides additional information on assessing utility corridors as part of a VI investigation.

3.1.4 Landfills and Methane Gas

The Technical Rules do not require performing a VI investigation when a landfill is located on or adjacent to a site. However, the presence of methane-generating conditions that may cause an explosion will trigger a VI investigation. Identification of landfills on or adjacent to a site is required when a VI investigation is triggered [N.J.A.C. 7:26E-1.15(b)4]. Landfills and the gas generated from them can greatly influence the CSM and the investigative approach (as discussed below).

A landfill is defined in N.J.A.C. 7:26E-1.8 as a solid waste facility, at which solid waste is deposited on or into the land as fill for the purpose of permanent disposal or storage for a period of time exceeding six months, except that the term sanitary landfill shall not include any waste facility approved for disposal of hazardous waste regulated pursuant to N.J.A.C. 7:26G. A facility is a sanitary landfill regardless of when solid waste was deposited or whether the facility was properly registered, permitted, approved or otherwise authorized to conduct such activity, by the Department or other State agency. By this definition, a landfill also includes an area of concern (AOC) where waste was dumped on the ground surface or buried below the ground surface. This definition also includes AOCs that were not designed or permitted to function as a landfill for the disposal of solid waste.

While the concern for the migration of naturally produced or anthropogenic methane and the potential for the concentration of methane to exceed the lower explosion limit in a building are similar, the investigation of these issues requires the consideration of site-specific conditions.

3.1.4.1 Methane

Methane is non-toxic and is therefore not a long-term human health risk due to exposure. It is a colorless, odorless hydrocarbon combustible at concentrations of 5-15% by volume in air. Methane may be generated under natural conditions or from an anthropogenic source. Organic-rich soils, sediments or methane associated with natural petroleum reserves are examples of natural methane-producing conditions. In New Jersey, fill over marine clays may be a typical source. Anthropogenic sources include landfills and agricultural wastes.

3.1.4.2 Landfill Gases

Landfill gas (LFG) is the natural by-product of the anaerobic decomposition of biodegradable material that is placed in landfills. The composition of LFG produced under anaerobic conditions is typically in the range of 45-60% methane and 40-60% carbon dioxide. Additional components of LFG include trace amounts of ammonia, hydrogen sulfide and other non-methane organic compounds including VOCs. Nearly 30 organic hazardous air pollutants have been identified in

LFG including, but not limited to, benzene, toluene, ethylbenzene, vinyl chloride, chloroform, carbon tetrachloride and trichloroethene (TCE). A useful source of information on this subject is the USEPA publication, Guidance for Evaluating Landfill Gas Emissions for Closed or Abandoned Facilities (USEPA, 2005).

Because of its combustible nature, methane is the primary product of interest at landfills for VI investigations along with the volatile compounds that are carried along in the LFG plume. It should be noted that New Jersey Solid Waste regulations [N.J.A.C. 7:26-2A7(f)] require active landfill gas (LFG) collection and venting, if 25% of the lower explosive limit (LEL) is detected at the perimeter of the property, to prevent offsite migration and control the accumulation of any methane gas at any concentration in any building.

3.1.4.3 Landfill Gas Production and Flow

The rate and volume of LFG production depends upon the characteristics of the waste material and the environmental factors. They include the following:

- Waste composition - The greater the amount of biodegradable organic materials present in the waste (typically from municipal waste), the more LFG is produced by bacteria during decomposition. In addition, the more industrial waste that is disposed in the landfill, the higher the levels of non-methane organic compounds that will be produced through volatilization and chemical reactions.
- Age of the waste – Generally waste buried for less than 10 years produces more LFG than older waste. Peak gas production is between 5-7 years after the waste is buried but can continue up to 50 years after waste placement.
- Presence of oxygen – Methane is produced in anaerobic regions of the landfill and can be consumed in aerobic regions.
- Moisture content – The presence of moisture increases the gas production because it supports and enhances bacterial decomposition. Moisture may also promote chemical reactions that produce LFG.
- Temperature – As temperature increases the rate of bacterial activity will increase, which increases gas production. Increasing temperatures also promote volatilization and increase the rate of chemical reactions.

Migration of LFG may occur because of diffusion or advection. Gas flow by advection occurs when a pressure gradient exists. Thus, gas flow is in the direction of decreasing pressure - from high pressure to low pressure. When LFG concentrations are higher in a landfill than the surrounding area, LFG will tend to move out of the landfill to the surrounding area with a lower gas concentration. Gas flow due to diffusion is in the direction which the concentration decreases.

Factors that influence the flow of LFG in the subsurface include the following:

- Landfill cap – If the landfill has a cap consisting of a liner or silts and clays that are impermeable to gas flow, LFG gas will tend to migrate laterally.

- Landfill liners – If the landfill has an impermeable liner system, LFG will not migrate into the surrounding subsurface area by advection.
- Ground water levels – Gas movement is influenced by the movement of the ground water table. As the ground water table rises, it forces the LFG upward.
- Barometric pressure – The difference in the soil gas pressure and the barometric pressure will guide the LFG to move laterally or vertically, depending upon the pressure gradient.
- Preferential pathways – Pathways for the movement of LFG can be either natural or anthropogenic. The geology provides natural pathways such as sand or gravel zones, fractured bedrock and old stream channels. Anthropogenic pathways include buried utilities, drains, trenches and tunnels.
- Seasonal Variations – The time of year (winter, summer) will cause variations in lateral LFG movement due to saturated soils from precipitation acting as a cap for vertical LFG migration and increased LFG production in the late summer and early fall season potentially increasing horizontal distance for LFG migration.

It is often difficult to predict the specific patterns and directions of LFG movement due to the many variables for gas flow and generation. In most cases LFG can migrate up to 1,000 feet (or more) in the subsurface from the footprint of the refuse (landfill source).

3.1.4.4 Landfill Building Requirements

On the landfill, a VI investigation should not be necessary and would be technically challenging and difficult to obtain accurate data to assess potential future exposures, so remedial actions for landfills should include mitigation of the VI and gas migration pathways for methane and volatile compounds as part of the cap or building design. If buildings currently exist on a landfill that are or could be occupied, then conduct a VI investigation that consists of sub-slab and IA sampling for volatile compounds and methane/explosive gas.

On-site buildings within the sanitary landfill properties should be designed and constructed in accordance with specification in the regulations, or in accordance with an equivalent design which will prevent gas migration into the building [N.J.A.C 7:26-2A.7(f)14].

An alternative design to N.J.A.C 7:26-2A.7(f)14 for the construction of on-site buildings within the sanitary landfill properties that are constructed on piles can use an open space (crawl space) between the final ground surface elevation and the building floor to allow for the installation and operation of an active methane gas venting system. The active gas venting system shall be capable of preventing the accumulation of gas at or greater than 25% LEL in the crawlspace. The venting system must also eliminate the pathway for volatile compounds. The requirements in N.J.A.C 7:26-2A.7(f)14vi and vii shall be complied with at all times.

Consult information in 40 CFR Part 258 as an additional reference.

3.1.4.5 Methane Investigations and Analytical Methods

In general, the landfill proper (footprint of the refuse) does not necessitate the implementation of a VI investigation. New Jersey Solid Waste regulations specifically address landfill requirements regarding investigation of LFG and building-specific mitigation provisions. Sites near or adjacent to landfills, however, do warrant investigation for LFG and VI.

When methane may likely be present (see Section 3.1.4.1), the investigator should initially assess the buildings identified through the receptor evaluation for fire and explosion hazards. The characterization should focus on below grade floors, ground level floors (when no basement present), crawl spaces, sumps, utility penetrations, utility vaults, and enclosed spaces. If explosive conditions are present, immediate notification of emergency responders is required followed by Department notification in accordance with the Technical Rules [N.J.A.C. 7:26E-1.15(i)].

Once the investigator determines that an explosive condition does not currently exist at the building, an evaluation of VI for volatile compounds and non-emergency methane concentrations should follow. The absence of methane does not eliminate the possibility of volatile compounds in a building.

For sites located on or near a landfill (excluding the footprint of the refuse), there are several methods to assessing the impact from the landfill.

1. Probes can be installed at several levels in the vadose zone between the site and the landfill to allow for measurements of subsurface pressure and methane concentrations to evaluate the attenuation and migration potential of methane in the soil column. Install the deepest probe at the approximate depth of the landfill refuse, or just above the water table. The investigator uses professional judgment to determine the number of vertical profiles. While samples can be collected in summa canisters for laboratory analysis, a field instrument capable of directly measuring methane (e.g., landfill gas analyzer, combustible gas meter, flame ionization detector (FID)) can be used. Evaluate preferential pathways that may serve as migration routes to buildings. Based on the results, the investigator can determine if LFG is reaching the site. If the data suggest that the LFG is reaching the site, incorporate method #3 (below) into the VI investigation.
2. Obtain initial information regarding LFG migration from the landfill owner/operators if they were required to monitor for LFG at the perimeter of the toe of the landfill [N.J.A.C. 7:26-2A.7(h)6]. Information on the periodic LFG measurements should give an indication of the potential (pressure) and concentrations of LFG migrating off the landfill property. Other factors listed in Section 3.1.4.3 may assist the investigator, including the type and age of the landfill, landfill construction (e.g., cap, liner), and the presence of an active methane gas venting system. If the data suggest that the LFG is reaching the site, incorporate method #3 (below) into the VI investigation.
3. The investigator can incorporate methane analysis and sub-slab pressure readings into the traditional VI investigation process for soil gas and IA samples.

For VI investigations that have the potential for methane to be present in the subsurface from a landfill or other methanogenic environmental conditions, complete a measurement to determine the sub-slab methane concentrations and pressures.

Analytical methods for methane include:

- USEPA Method 3C (methane, carbon dioxide and oxygen);
- Methane Specific IR Gas Analyzer (Landfill Gas Meter);
- Combustible gas meter (catalytic detector-only if oxygen is above 19.5%); and
- FID w/ charcoal scrubber (only if oxygen is above 19.5%).

Complete measurements of the sub-slab pressures with a manometer capable of reading 0.001 inches of water. Collect measurements during SSSG testing from permanent or temporary soil gas probes provided the measurements are made with no building depressurization (heater, vent fans, etc.).

As noted in Section 3.1.4.3, the trigger distances do not necessarily reflect the distance LFG can travel from a landfill, often carrying site-related COCs. If the investigator can establish that LFG is not reaching the site, employ the standard trigger distances discussed in Section 2.4.3.

The investigator, however, should use method #3 above if the landfill is affecting the site. Under this scenario, the VI investigation would be implemented as provided in this technical guidance initially and allow the results of the methane and volatile analyses to dictate the necessity to employed a step-out approach beyond the standard trigger distances. The investigator should establish a clean zone beyond the limits of VI contamination consisting of two residential properties or 100 feet, whichever is more. A clean zone would have 0% LEL. Professional judgment utilizing the MLE approach (see Chapter 4) should guide the investigator when dealing with landfills.

Consider sources of methane in buildings (sewage systems, natural gas equipment). As previously stated, the measurement of methane from LFG may also indicate the presence of other volatile compounds in the absence of other screening conditions such as dissolved volatile compounds in ground water or volatile compounds in soil. Finally, exercise appropriate care before entering confined spaces to conduct methane screening.

3.2 Ground Water Investigation and Sampling

This section addresses the following:

1. technical guidance on saturated zone features that may affect VI sampling decisions
2. acceptable use of pre-existing ground water data
3. procedures for obtaining new ground water data to evaluate this pathway

The investigator is advised to consult the NJDEP Ground Water – SI/RI/RA Technical Guidance (Version 1). For the most up to date version of this document, please check the NJDEP's SRP Guidance Library at http://www.nj.gov/dep/srp/guidance/index.html.

3.2.1. Saturated Zone Features Affecting Vapor Intrusion

Many of the concepts and properties discussed below are more applicable to subsurface formations where the ground water flow regime is relatively homogeneous (e.g., unconsolidated or sedimentary formations), however, more heterogeneous flow regimes are also addressed in several discussions. Topics include the following:

- Clean Water Lens
- Depth to Saturated Zone and Stratigraphy
- Fluctuations in Depth to Saturated Zone
- Complex Hydrogeologic Settings
- Proximity to Preferential Pathways
- Potential for Contaminant Degradation

3.2.1.1 Clean Water Lens

If a clean water lens exists above the volatile contamination, it can act as a barrier to volatilization from deeper ground water (Rivett, 1995). This could reduce or prevent VI into overlying buildings. A clean water lens of three feet or greater may be an appropriate barrier to prevent volatilization into overlying buildings. If the clean water lens is at least three feet thick but less than 6 feet thick, perform periodic monitoring of the clean water lens thickness during seasonal low water levels (i.e., later summer to early autumn) to establish the minimum clean water thickness of three feet.

Where clean water lens is an important element of the CSM, multi-depth sampling within a well or temporary boring (i.e., vertical profiling) may be appropriate. Other acceptable methods of sampling ground water at multiple depths in the same location horizontally may be appropriate as well (see Section 3.2.3.1 below). A clean water lens immediately above a plume cannot be determined without vertical profile data or use of other acceptable multi-depth sampling approaches to document the approximate depth of the vertical transition from clean to contaminated ground water.

A clean water lens that is thicker than the annual water table fluctuation range can be a barrier to off gassing of volatiles from ground water to soil gas. If a clean water lens is thin, relative to short term, seasonal and/or longer term drops in the water level (natural or anthropogenic) it is likely that a falling water table will expose a plume to the vadose zone. Document the approximate thickness of a clean water lens to use the guidelines in Section 4.3.3 regarding whether the plume is or is not a source for VI.

3.2.1.2 Depth to Saturated Zone and Stratigraphy

The water table means the surface of the body of unconfined ground water where the hydrostatic pressure is equal to atmospheric pressure (http://nj.gov/dep/srp/bust/defs.htm#wat). The depth to the regional water table and any perched saturated zone(s) needs to be determined near buildings at risk for VI. The vertical distance between the water table and building slabs should also be determined. A "perched" water table is formed by a relatively low permeability layer that is recharged at a rate that exceeds the percolation rate through this layer. A perched water table is associated with a zone of saturation above a relatively low permeable layer, with unsaturated materials beneath it.

Use boring or test pit logs in the area of a VI investigation as follows:

- determine the soil profile (soil type and texture)
- look for stratigraphic changes or soil horizons indicative of high moisture content, a perched water table, or high organic carbon content
- evaluate characteristics of the strata immediately below and above the water table

The depth of the water table and/or first zone of saturation should be determined as follows:

- help determine ground water flow direction (with surveyed ground surface elevations)
- decide appropriate media for further investigation
- determine the depth of ground water sampling

3.2.1.3 Fluctuation in Depth to Saturated Zone

Changes in water table elevation may increase or decrease the risk of VI. The cause of the water level change and the proximity and nature of the source of the ground water contamination (e.g., age or size of source) affect the potential for VI. The water table elevation fluctuates and perched saturated zones may dry up seasonally or only exist periodically after precipitation events. If a perched saturated zone is present, extensive enough, and clean, it could prevent migration of vapors through it, or around it, from underlying contaminated ground water.

Significant fluctuations in the water table elevation also affect the predictability of VI using analytical modeling approaches where ground water quality is the source input parameter. Proper ground water sampling design may overcome this potential limitation.

3.2.1.4 Complex Hydrogeologic Settings

Heterogeneity in subsurface media could influence whether volatiles in saturated zones become a source for VI. Consider information on the locations and depths of near surface features such as clay, till or gravel layers/lenses and depth to bedrock. Such features should be taken into account when determining saturated zone sampling depth intervals and how existing ground water data should be utilized or interpreted to evaluate VI risk.

3.2.1.5 Proximity to Preferential Pathways

Preferential pathways in the unsaturated zone (defined in Section 3.1.3) could allow rapid and/or laterally significant vapor transport. The bedrock outcrops are an example of naturally occurring preferential pathways. To the extent it is feasible and safe (e.g., drilling near utilities that could be damaged or pose an explosive or toxic threat), VI investigations should determine the proximity of contaminated ground water to unsaturated preferential pathways. The 30- or 100-foot trigger distances (see Section 2.4.3) may not be adequately conservative where preferential pathways connect buildings with areas of subsurface NAPL contamination or ground water/soil concentrations indicative of the presence of NAPL (e.g., plume source area with suspected NAPL is more than 100 feet side gradient of buildings but buried utility bedding connects it with buildings). This is more likely a concern for contaminants that do not aerobically biodegrade readily or where large quantities of product have been discharged.

3.2.1.6 Potential for Contaminant Degradation

Many contaminants associated with PHCs, including BTEX compounds are readily biodegraded in the vadose zone. As such, they are less likely than chlorinated compounds to complete the VI to IA pathway. Even where light non-aqueous phase liquid (LNAPL) occurs in close proximity to buildings, rapid biodegradation in the vadose zone may preclude a complete pathway. Biodegradation of PHC contaminants is discussed in Chapter 5.

3.2.2 Use of Pre-Existing Ground Water Data

In many situations, shallow ground water data are already available prior to initiation of a VI investigation. The data may be from properly constructed monitoring wells or from alternative ground water sampling methods. In deciding whether existing data are sufficient, give consideration to the site-specific conditions.

The likelihood of significant vertical changes in ground water quality near the water table, the sampling method used, the construction of existing wells sampled (e.g., screen length and placement across water table), the type of contaminants present and/or heterogeneity of the vadose zone and shallow saturated zone media should be evaluated in determining whether existing data are sufficient.

For example, if an existing well was sampled using a method that will vertically average the sample and the well is screened across more than 10 feet of the saturated zone and site data suggests that contaminant concentrations are higher in close proximity to the water table, it may be prudent to obtain more depth discrete data. Obtaining such data is more important where conditions are not favorable for biodegradation in the vadose zone or for contaminants not likely to biodegrade or attenuate in the vadose zone.

3.2.2.1 Interpolation of Nearby Data

Use surrounding data points to construct contaminant iso-concentration maps if ground water data directly upgradient from the building are not available. However, this should only be done if data points are available on at least two sides of a building. Complex geologic settings or the anticipated presence of steep concentration gradients warrant a denser sampling grid. For additional technical guidance see Section 3.2.3.1 below on sampling locations.

3.2.2.2 Use of Drinking Water Well Data

VOCs in water supply wells above the Ground Water Quality Standards (GWQS) should trigger a ground water investigation, which may lead to a VI investigation.

3.2.3 Obtaining New Ground Water Data to Evaluate the VI Pathway

If the evaluations discussed above indicate that new or additional ground water data are needed to complete the VI investigation, the goal of the sampling effort should be to determine volatile concentrations in shallow ground water beneath or near potential receptors. Shallow ground water as used here is a relative term and refers to the first contiguous saturated zone encountered below the surface (in overburden or bedrock), that can be readily sampled using acceptable methods such as those described below and in the Department's FSPM (NJDEP, 2005a or latest version).

3.2.3.1 Sampling Depth Interval Guidance for Multiple Sampling Methods

An existing, permitted monitoring well may be adequate for evaluating the appropriate depth interval(s) if the screen/open borehole intersects the water table throughout the year (i.e., a water table well), and the sample from the well is representative of 10 feet or less of the water column in the well. For new water table wells installed as part of a VI investigation, a 10 foot screen is generally recommended unless this conflicts with other site investigation objectives (i.e., water table may fluctuate more than the 10 foot screen).

If a perched water table exists above the regional water table, collect samples from both the perched zone and regional shallow aquifer in most scenarios. Sample perched saturated zones that are laterally contiguous under/near buildings, exist year round and are below nearby building slabs if they are of sufficient thickness to obtain a sample. Use professional judgment in situations that are more complex; however, in the above scenario, sampling of the regional water table may not be vital to investigating the VI pathway.

In the following situations, the Department recommends vertical profiling of volatile concentrations in shallow ground water (e.g., multi-depth sampling within a well or temporary boring) to determine whether additional investigation of the VI pathway is needed. However, other multi-depth sampling approaches can also be used in the first two situations listed below; these could include well pairs/clusters or, if approved pursuant to N.J.A.C. 7:9D-2.8, multi-screened wells. For more information on multi-screened wells, see Section A.6.1.4.7 in the FSPM at http://www.nj.gov/dep/srp/guidance/fspm/pdf/chapter06g.pdf.

Vertical profiling with regard to a VI investigation is recommended as follows:

- A clean water lens is likely to be present above an already identified plume
- A site-specific GWSL will be used
- Direct push, short interval temporary wells, or any other discrete/small-interval ground water sampling method within a single boring or well is used to obtain new data to evaluate this pathway

In the above situations, conduct vertical profiling in at least one boring or well, preferably near the centerline of the plume. Multiple borings/well locations are appropriate where a large number of buildings overlie a large plume, especially if the investigator will claim that a clean water lens justifies a decision to cease further VI investigation. If a large area of impermeable surface cover occurs over a plume down gradient of where a clean water lens has been documented, at least one additional downgradient location for vertical profiling, close to the centerline of the plume, it is appropriate to confirm the continuing presence and thickness of the lens. This downgradient confirmation is especially critical if the clean lens was less than six feet thick in the upgradient location(s).

Vertical profiling and other multi-depth sampling of shallow ground water contamination may enable a more precise evaluation of the current and potential future risk of VI in some situations. For example, if the thickness of a clean water lens is shown to be increasing in the down gradient direction due to infiltration and recharge, this indicates a decreasing VI risk for development of undeveloped land down gradient that overlies the plume.

Sections 3.2.1.1 through 3.2.1.3 address the processes and site characteristics that favor the formation of a clean water lens. Development of the CSM should include evaluation of whether a clean water lens is likely to be present and/or if volatile levels below the GWSL are likely to be at or near the water table. See Sections 3.2.1.1 and 4.3.3, respectively, for Department procedures on documenting a clean water lens and data evaluation guidelines.

Where vertical contaminant profiling is done specifically for a VI investigation to establish a clean water lens, sample within the top 6 feet of the saturated zone. Site-specific considerations discussed below may warrant extending the total depth interval for profiling within a well or temporary boring to the top 10 feet.

3.2.3.2 Direct Push and Alternative Ground Water Sampling Methods

Alternate and direct push ground water sampling methods are often well suited for VI investigations especially if attempting to determine the depth of the interface between a shallow clean water lens and an underlying plume. If the sampling method does not affect sample quality and vertical profiling using direct push methods does not cause cross-contamination of samples during advancement in the same borehole, use data from temporary wells for VI investigations.

At least two samples from the top 6 feet of the saturated zone are recommended to establish that a clean water lens exists. Target the zero to 3-foot and 3- to 6-foot intervals from the top of the saturated zone. However, small changes of these intervals are appropriate if a sufficient volume of water cannot be obtained or if site-specific data support sampling alternate intervals. As discussed above, obtain one additional sample from the 6- to 10-foot interval below the water table (bwt) where significant drops in the water table elevation are likely. All the sample locations and intervals shall be accurately mapped and documented.

3.2.3.3 Ongoing Ground Water Monitoring

After an initial VI investigation has been completed, long-term ground water monitoring to reevaluate the VI pathway may be appropriate in some situations. Consider ground water monitoring, based on professional judgment, where ground water exceeding the GWSL is close to, but not currently within, the applicable trigger distance from a potential building if it is likely to migrate to within the trigger distance. Monitoring other media (e.g., SSSG, IA or exterior soil gas for undeveloped properties) can potentially substitute for, or supplement, ground water monitoring.

3.3 Soil Gas Sampling

The distinction between sub-slab, near slab and exterior soil gas sampling is critical for the investigation of the VI pathway. SSSG samples are collected from inside a building, while near slab and exterior soil gas samples are collected outside the building. A soil gas investigation should be conducted using SSSG samples as the primary tool in the assessment of the VI pathway. Near slab soil gas sampling is only recommended when specific technical issues make SSSG sampling impractical (e.g., very high water table) or explicitly recommended in this technical guidance. See Section 3.3.2.1 for additional discussion on alternative soil gas sampling approaches.

3.3.1 Sub-Slab Soil Gas Sampling

3.3.1.1 Application

SSSG sampling can be useful for assessing the VI pathway from several perspectives.

The primary utility for collecting SSSG samples is to assess if there is a potential for a complete VI pathway to exist. A VI pathway is considered complete only when:

- A source of vapors, related to a discharge (e.g. soil and/or ground water plume), is identified; and
- A pathway connects the source to potential human receptors inside a building.

Elevated contaminant vapors in a sub-slab gas sample indicate that the pathway may be complete; however, low levels or the absence of volatile organics in a SSSG sample does not automatically imply there is no VI risk (see additional discussion in Section 3.3.1.2).

Use the results of SSSG sampling to assess whether the VI pathway is likely to pose a potential IA risk for a particular building. This may occur when the source of the vapors is a contaminated ground water plume containing volatile compounds under or in close proximity to the building in question. When employing SSSG sampling, the investigator should consider possible impacts from vapor clouds. This is a condition where contaminants move downward into the sub-slab area from the IA.

3.3.1.2 Investigative Considerations

Consider a number of factors when utilizing SSSG data. Preferential pathways, such as utility trenches, allow horizontal movement of vapors beneath and into buildings. In these cases, infiltration of vapors through openings in the sidewalls (e.g., utility penetrations) of a basement may represent a pathway for VI. As a result, the absence of elevated SSSG levels does not automatically imply that the VI pathway is incomplete. Under these conditions, near slab soil gas samples collected between the zone of soil contamination and the building’s slab (or along preferential pathways) may be more appropriate than SSSG samples.

In situations where an earthen floor exists (instead of concrete), the provisions for SSSG sampling are not appropriate. As a rule, use SSSG sampling when the basement slab covers 50% or more of the building footprint. In these situations, it may be prudent to collect a combination of SSSG samples from the concrete area and IA samples (or flux chamber) from the crawl space overlying the earthen floor.

The investigator may also elect to collect SSSG and IA samples concurrently where buildings with sensitive populations, such as schools, child care centers or residential properties, are involved. To prevent the SSSG sampling process from potentially affecting the IA samples, collect the IA samples prior to the SSSG samples.

SSSG sampling may not be appropriate when a high water table exists near the base of the concrete slab (less than 2 feet). Typically, vapors migrate through the most permeable and driest material, but may also migrate along utility pathways beneath the slab. Depending on the analytical method, high moisture content in the soil gas sample can “mask” results, particularly polar compounds. If the capillary fringe is in contact with the slab, SSSG samples may not be representative. Additionally, low gas permeability may limit or restrict the flow of soil gas and thus increase the likelihood of leakage.

SSSG samples can be collected when ground water is as close as two feet below the building’s concrete slab with the following conditions:

- The seasonal high water table does not reach the building’s concrete slab;
- The water table does not extend into fill material placed directly under the building’s concrete slab as part of construction; and
- The capillary zone does not reach the building’s concrete slab (see Section 2.2.1).

Consider stratigraphy of the subsurface soil profile and soil types near the building, both naturally occurring and manmade. Low permeability layers, either natural or as part of the building’s construction may restrict migration of vapors from a ground water contamination source and result in relatively clean SSSG samples even though the underlying ground water is contaminated. Note that vapors may still enter the building through utility trenches or other preferential pathways if they bisect or circumvent the low permeability layer.

3.3.1.3 Analytical Methods and Parameters

The sample container normally utilized for the collection of SSSG samples is the 1-Liter passivated stainless steel canister. Six-liter canisters may also be employed. The SSSG samples can be analyzed using USEPA Method TO-15 (or other appropriate certified methods). Sampling with Automatic Thermal Desorption tubes and analysis by USEPA Method TO-17 is also acceptable.

Sample containers other than stainless steel canisters can be employed when screening or preliminary results are appropriate. Base all VI decisions regarding no further action at a building on data from a certified analytical method. The investigator can utilize a Tedlar® bag for sample collection and analyze the samples with a field gas chromatography (GC) or mobile laboratory. If a Tedlar® bag is used it will necessitate the use of a “lung box” and vacuum pump to draw a SSSG sample. Alternately, use glass or Teflon® syringes. As with the Tedlar® bags, analyze syringe samples with a field GC or mobile laboratory. The holding time for Tedlar® bags should not exceed 3 hours. USEPA SW-846 Method 8260B is the most common method utilized for field screening of air samples.

Analyze the initial set of soil gas samples from each building for the full parameter list of Table 1 (not Table “A”) of the NJDEP Method LLTO-15, plus TICs [N.J.A.C. 7:26E-2.1(c)3]. Subsequent soil gas sample events from each building may be analyzed for the site COCs (including degradation compounds).

When soil gas samples are taken due to petroleum contamination other than gasoline or light petroleum distillates, the samples shall be analyzed for naphthalene in addition to any other site specific contaminants that may be present. The analysis for 2-methylnaphthalene will not be required for VI samples collected during the investigation of kerosene, jet fuel, diesel fuel, fuel oil No. 2, and heavier petroleum products. The Department intends to update the Technical Rules to remove the requirement to analyze VI samples for 2-methylnaphthalene. Until the rule is updated, the investigator can apply a variance pursuant to N.J.A.C. 7:26E-1.7 to not perform this analysis. The investigator should use a certified method for the analysis of naphthalene.

Inform the Department of any compounds exceeding the applicable SGSL in the SSSG that are related to VI AND are not COCs by calling the NJDEP Hotline. The Department will assess potential off-site contamination independent of the current investigation.

3.3.1.4 Leak Check

Perform leak tests on the soil gas probe and all fittings of the sampling train for the SSSG sampling event prior to collecting a soil gas sample. The leak test serves as a quality control measure to evaluate the potential for dilution of a sample from ambient air.

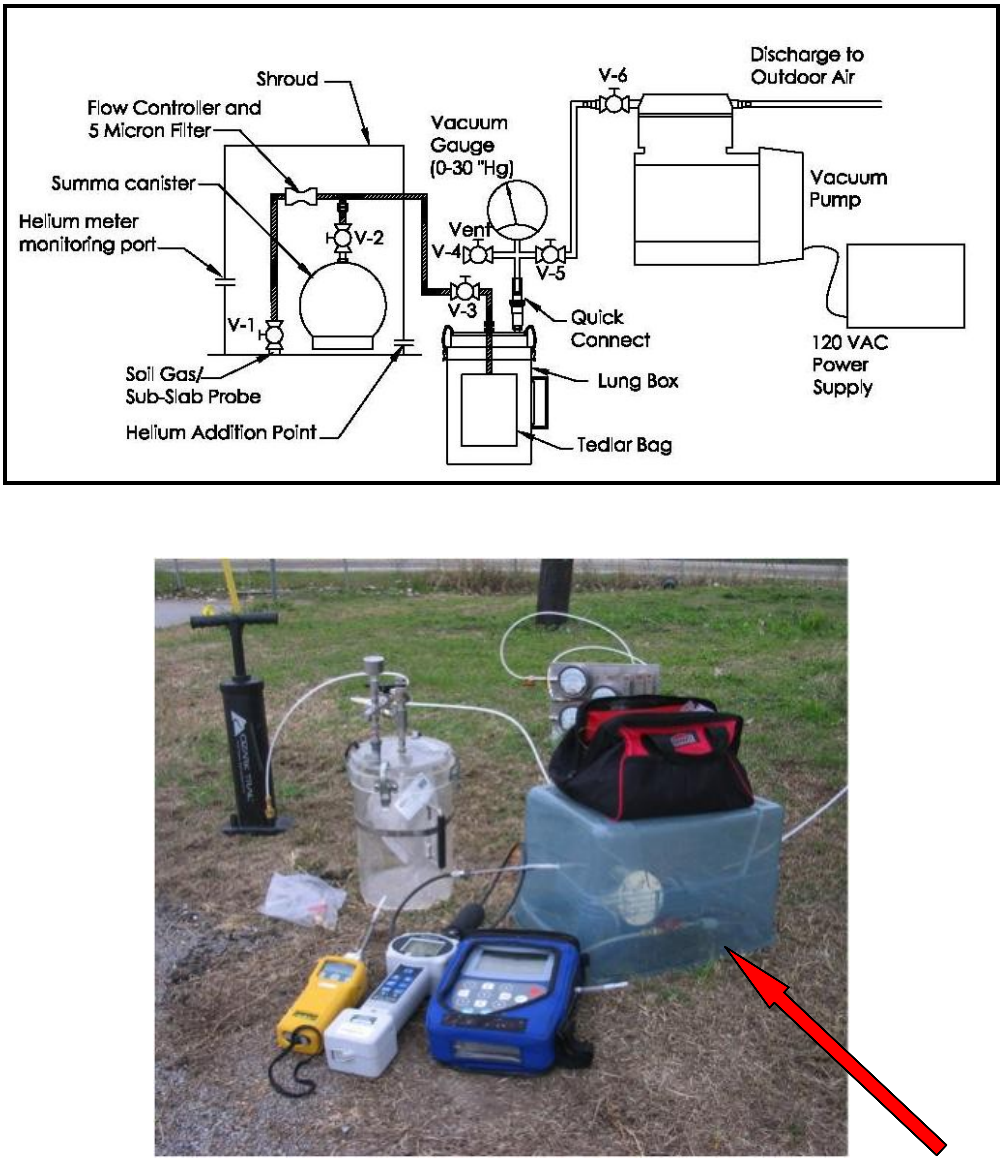
If multiple soil gas probes are installed during a sampling round, and leak tests performed on the initial probes indicate sample integrity, the investigator may reduce the number of probes that are tested.

To verify the integrity of the seal, a tracer compound (e.g., helium or sulfur hexafluoride) is used. Helium is the preferred tracer as it is readily available, non-toxic, and easily measured in the field provided high methane levels are not present (false positives). Sulfur hexafluoride is an effective tracer, but requires a specialized instrument for detection that may not be readily available. It is also of concern as a greenhouse gas.

One method employs a shroud placed over the soil gas probe and the sample train. An inert tracer gas (such as helium) is released into the shroud with a target concentration of 10 - 20% (McAlary, et al., 2009).

With the canister valve closed, collect a soil gas sample using a Tedlar® bag. A leak is occurring when the helium concentration is greater than 10% of the concentration within the shroud. In this case, the leak must be fixed and the leak check repeated

Independent of the leak check on the soil gas probe, conduct a shut-in test of the sampling train at each location, during each sampling event to verify aboveground fittings do not contain leaks. A shut-in test consists of assembling the above-ground apparatus (valves, lines, and fittings downstream of the top of the probe), and evacuating the lines to a measured vacuum of about 100 in-H_2O, then shutting the vacuum in with closed valves on opposite ends of the sample train. The vacuum gauge is observed for at least 1 min, and if there was any observable loss of vacuum, the fittings should be adjusted as needed until the vacuum in the above-ground portion of the sample train does not noticeably dissipate (McAlary, et al., 2009).



Helium shroud

Figure 3-1

Schematic diagram of sampling train using leak detection and photograph of helium shroud with Summa Canister (courtesy Geosyntec Consultants)

The one exception to this provision is when the sampling train is contained within the shroud as part of the leak check on the soil gas probe.

3.3.1.5 Sample Flow Rate

When a Tedlar® bag or syringe is utilized in combination with a field GC or mobile laboratory, the flow rate for sample collection should be based on the professional judgment of the investigator, but not in excess of 200 milliliters per minute (to avoid potential short circuiting or desorbing volatile organics off of the soil particles). In addition, a tight seal between the sample point and slab should be verified via leak check to prevent IA from mixing with the soil gas sample. For these reasons, do not take instantaneous or grab samples.

For stainless steel canisters, the sample flow rate should likewise be a maximum of 200 milliliters per minute, which corresponds to a sample time of 5 minutes for one liter canisters. Once again, this maximum flow rate has been established due to the concern over short-circuiting or de-sorbing. One or 6-liter stainless steel canisters are ordered from the laboratory under vacuum with pre-set regulators based on the sample time prescribed by the investigator.

It is not necessary to retain residual vacuum in the stainless steel canisters (equilibrium with the ambient barometric pressure) upon completion of the soil gas sample provided the sampler is present during the entire sampling event.

3.3.1.6 Calculating Purge Volumes

Prior to attaching the sample container, purge the vapor probe or borehole by drawing 3.0 volumes through the probe and the entire sampling train. Refer to the NJDEP FSPM (Section 9.7.4) for information on calculating the proper purge volume. The investigator should use a low purge rate with a maximum of 200-ml per minute.

3.3.1.7 Number and Location of Sample Points

For a typical single family residential building (approximately 1500 ft^2 foundation footprint), two vapor probes are recommended due to scientific research on spatial variability. Ideally, the sample probes should be near the center of the slab and equidistant from each other relative to the outer wall. However, a secondary location can be along the perimeter of the building usually no closer than 5 feet to the outer wall and biased towards the ground water plume or source material. For larger residential or non-residential buildings (or other unique conditions in the subfloor or construction of the foundation), utilize the table below as a minimum number of samples and add additional samples based on the building-specific features and conditions provided below the table.

Sub-slab sampling requirements cannot be based on area alone. The determination of the necessary number of sub-slab samples to characterize the impacts to a building from VI will vary from building to building due to various features and uses of the building. Evaluate the features and uses of a building based on professional judgment to determine the number of sub-slab samples.

Table 3-1
Recommended Minimum Number of Sub-Slab Soil Gas Samples

Square footage of building footprint	Number of Sub-Slab Soil Gas Samples
Up to 1,500	2
1,501 to 5,000	3
5,001 to 10,000	4
10,001 to 20,000	5
20,001 to 50,000	6
50,001 to 250,000	8
250,001 to 1,000,000	10
>1,000,000	12+

Features and conditions that may require altering the number of samples or biasing a sample location include, but are not limited to the following:

- Presence of sensitive populations
- past usage (e.g., dry cleaners, vapor degreasers, underground storage tanks)
- building construction (separate foundations, type of slab, footers, utility lines etc.)
- presence of earthen or damaged floors
- presence of sump pits
- requests from building owner
- elevator pits
- portion of building overlying or contacting the highest levels of VOCs
- areas of greatest exposure (play rooms, family rooms, class rooms, offices)
- homogeneity and composition of sub-slab material

All of the features of a building should be considered when determining the number of sub-slab samples. For example, a 25,000 ft^2 strip mall separated into five individual tenant spaces and separate foundations with one space operating as a daycare may require up to15 samples, where a stand-alone 25,000 ft^2 building that is mostly warehouse space with a single slab may only require 6 samples.

The investigator should consider the tenant and/or owner preferences for sub-slab sample locations. To minimize potential damage to flooring, it may be necessary to select a location in a closet or utility room (where floor covering is less visible or not present).

Due in part to spatial variability, the results of the soil gas samples are not averaged across the subsurface around or under a building. Therefore, each data point is evaluated independently.

3.3.1.8 Sample Frequency

Based on site-specific conditions, the investigator may determine that a second sampling round may or may not be necessary. Supplemental environmental data (e.g., seasonal ground water level, IA, weather conditions) examined as an MLE approach may eliminate (or indicate) the need for a second round of SSSG sampling.

3.3.1.9 Field Quality Assurance Issues

The investigator should consult the Department's Technical Guidance for Quality Assurance Project Plans (Version 1) to assess field quality assurance issues. For the most up to date version of this document, please check the NJDEP's Guidance Library at http://www.nj.gov/dep/srp/guidance/index.html. A quality assurance project plan (QAPP) is required for all sample and data collection, consistent with 7:26E-2.2.

The investigator should verify the vacuum in the stainless steel canister before and after the sample collection. The laboratory is required to record the vacuum in the canister upon shipment. In turn, the investigator should verify the canister's initial vacuum at the site prior to collecting a sample. If the initial vacuum at the site is in excess of 10% lower than the lab reading, the canister should not be utilized for sampling. The potential for pressure loss during transit negates the usability of the data generated from the defective canister or regulator.

The post-sampling vacuum in the canister should be recorded. It is not necessary to maintain residual vacuum in the canisters for soil gas samples.

3.3.2 Alternative Soil Gas Sampling

As previously noted, a soil gas investigation should be conducted using SSSG samples as the primary tool in the assessment of the VI pathway. Near slab soil gas sampling is only acceptable when specific technical issues make SSSG sampling impossible (e.g., very high water table, occupant refusal) or explicitly permitted in this technical guidance.

3.3.2.1 Application

Near slab soil gas sampling has limited applicability in the evaluation of the VI pathway and is not recommended as a primary investigation tool for assessment of the VI pathway on existing buildings (see Section 3.3.2.2). This investigation tool is limited because significantly different conditions for the migration of vapors may exist outside of the building as compared to beneath the building slab. Examples of the differences include:

- the lack of influence of the building HVAC system
- mass transfer to the uncovered surface
- heterogeneity of fill used around the building
- utility trenches acting as preferential conduits

- soil type
- soil moisture

These differences make near slab soil gas data more appropriate in most cases as a field screening tool or as a supplementary line of evidence in the evaluation of the VI pathway.

The collection of SSSG samples is the preferred tool for evaluating the risk that VI may be occurring at an existing building. However, the cooperation of the building occupants and/or owners to do SSSG sampling is not guaranteed. Thus, near slab soil gas sampling may be an alternative to sub-slab sampling when an alternative approach is required. Use near slab soil gas sampling for comparison to the SGSL when specific technical issues make SSSG sampling impossible (e.g., very high water table, presence of a gas vapor – not moisture - barrier) or the building owner refuses access. If used, provide justification to document why the SSSG sampling was not feasible.

Exterior soil gas sampling has limited applicability in the evaluation of the VI pathway for existing buildings. This investigation tool is limited because significantly different conditions for the migration of vapors may exist outside of the building as compared to beneath or in proximity to the building slab (as noted above). Thus, exterior soil gas data are more appropriate as a field screening tool or as a supplementary line of evidence in the evaluation of the VI pathway.

Do not utilize exterior soil gas sampling as a stand-alone determination for VI evaluation of existing buildings. Analytical results from an exterior soil gas sampling may be utilized as part of an MLE approach to determine whether the VI pathway is currently complete for a particular building. If the concern is related to future use of an undeveloped parcel, exterior soil gas results are appropriate to determine if the pathway may be complete when a building is constructed.

Exterior soil gas sampling is more often used to identify/delineate volatiles in the subsurface, update the CSM and assess the magnitude or extent of biodegradation of hydrocarbons. A soil gas survey is not intended to be a substitute for conventional methodology (e.g., ground water sampling), but instead as a screening tool to enable conventional methods to be used more effectively.

3.3.2.2 Investigative Considerations and Procedures

For near slab or exterior soil gas sampling results to be accepted as a line of evidence in an assessment of the VI pathway collect the soil gas samples in the vadose zone at the depth within one foot above the capillary fringe and a minimum of 5 feet below the surface. However, a shallow ground water table may prevent the collection of representative or valid soil gas samples due to high moisture content in the soil which can reduce gas permeability and/or dilution due to atmospheric air being drawn down from the surface. In these situations an alternative would be for the investigator to collect soil gas samples from below existing large impervious surfaces (e.g., garage floors, patios, parking lots, roads and driveways).

Information on the sample containers, purge volumes, leak detection, field quality assurance issues, sample flow rates and parameters that are recommended for near slab and exterior soil gas samples being used to support a VI investigation are similar to those recommended for SSSG sampling. Therefore, for information regarding these items, please refer to Section 3.3.1 of this document. Additional information on soil gas sampling procedures is provided in the Department's FSPM (NJDEP, 2005a or latest edition).

3.3.2.3 Number and Location of Samples

Any decision on the number and location of near slab soil gas sample points should start with an evaluation of the CSM. For example, if there are indications from the ground water characterization that there could be large lateral changes in concentrations over short distances near a building, there may be a case for increasing the number of sample points.

If near slab soil gas samples are being collected as a line of evidence in the assessment of the VI pathway, samples should be collected from a minimum of two sides of the building in question. Samples should be spaced horizontally along the perimeter of the building, at two to three times the depth to ground water (NJDEP 2005a). Locations will be in part dictated by the existing conditions around the building perimeter (e.g., other buildings, landscaping and access issues) and the location of the ground water plume.

If two soil gas sample locations have two to three orders of magnitude difference in concentration, collect at least one additional sample between the two points.

3.3.2.4 Undeveloped Parcels and Future Use

When the potential for VI extends to undeveloped parcels, implement a VI investigation to assess the impact on future use. An MLE approach may be appropriate in these situations to assess the potential for VI. The lines of evidence may include the delineation of the ground water plume, analysis of deep soil gas samples (just above the water table) using a grid sampling approach and biased towards the highest concentrations within the ground water plume, implementation of pneumatic testing (soil permeability) and/or soil stratigraphy.

In situations where the future use is restricted by an institutional control, an alternative approach may be proposed, possibly postponing investigation to some point in the future when development is being considered.

3.4 Conducting a Building Walkthrough and Survey

A building walkthrough is a critical element of any VI investigation that includes IA or SSSG sampling. Components of a building walkthrough include:

- identification of potential background sources of volatile compounds
- assessment of the building construction (e.g., concrete slab, air flow)
- recognition of points of potential VI into a building
- identification of possible sample locations
- determination of building pressure/ventilation in large buildings
- education of the occupants about VI and sampling procedures

If possible, the building walkthrough should be conducted prior to the day of the IA or SSSG sampling event. This advance timeframe allows the investigator to identify and eliminate (to the extent practical) potential background sources of IA contamination. It also permits the investigator to confirm the sample locations with the occupants ahead of the scheduled sampling episode.

One of the tools utilized in a VI investigation is the *Indoor Air Building Survey and Sampling Form* (Appendix D). The survey form allows the investigator to record information about the building, the occupants and potential sources of IA contamination.

The *Indoor Air Building Survey and Sampling Form* is broken down into eight sections:

- Part I - Basic information on the occupants of the building
- Part II - Characteristics of the building under investigation
- Part III - Identification of outside contaminant sources that may exist near the building being investigated
- Part IV - Identification of potential indoor contaminant sources found in the building
- Part V - Survey of miscellaneous items related to building activities that may impact IA quality
- Part VI - Documentation of sampling information (completed the day of the sampling event)
- Part VII - Existing meteorological conditions during the sampling event
- Part VIII - Documentation of any general observations noted during the sampling event that do not fit into the above categories (i.e., occupancy exposure times)

3.4.1 Identification of Potential Background Sources

As discussed in Chapter 4, investigating the VI pathway can be complicated by the impact of background sources. Differentiating common building sources that could affect IA quality from those associated with contaminated ground water or subsurface soil can be a challenge in the evaluation of the VI pathway.

An effective tool for pinpointing background sources of IA contaminants during a building walkthrough is the use of handheld field screening instruments, such as the photoionization detector (PID). These instruments can provide useful information for critical decisions in the field (e.g., identifying solvent cans as potential background sources, determining sampling locations). Factors that should be evaluated in selecting a screening instrument for VI investigations include the instrument detection limit for the COC, the eV of the lamp, the ionization potential of the COC and the calibration gas used for the instrument.

When background sources of IA contamination are identified and removed from a building, it would be prudent to ventilate the rooms affected in advance of the sampling event. Terminate this ventilation at least 24 hours before commencement of the IA sampling event to allow ventilation to return to normal operating conditions. As discussed in Chapter 4, these chemicals can be retained in materials found in the building (e.g., carpeting) and subsequently released over time.

3.4.2 Recognition of Points of Vapor Intrusion in a Building

The entry of organic vapors into a building is due to the infiltration of contaminants through the floor and walls that are in contact with the soil. Usually, vapors can enter a building through poorly sealed utility lines that penetrate the foundation. Other contaminant pathways are through cracks in the walls and floors, sumps, elevator pits, around the wall/floor juncture of floating floor construction or other breaches in the walls or slab.

The *Indoor Air Building Survey and Sampling Form* asks a series of questions that are designed to assist in the identification of potential points of VI. Part II inquires about the building construction. Note any obvious breaches in the walls or slab in the basement (or lowest floor) in Part VIII (General Observations) of the *Indoor Air Building Survey and Sampling Form*. The investigator should also examine and note the point at which utility lines enter the building.

3.4.3 Identification of Possible Sample Locations

The building walkthrough offers an opportunity for the investigator to identify possible sample locations that fit the defined investigative goals of the VI investigation. The identification of basement or foundation VI entry points, as outlined above, allows the investigator to target worst case sample locations for SSSG and IA sampling. If additional samples are being collected, the determination of those portions of a building where occupants spend the greatest amount of time (e.g., residential living room or commercial office space) during the walkthrough allows the investigator to identify areas that represent the greatest period of exposure to the occupants that can then be used in the evaluation of IA sample locations.

For the selection of sub-slab sample locations, identify the presence of any utilities (e.g., sewer, water, radiant heat) under the slab during the building walkthrough so those areas can be avoided for safety reasons when determining potential sample locations. The selected sample location(s) should be chosen in consultation with the property owner. Additional information on identifying sample locations is presented in Sections 3.3 and 3.5 of this guidance.

3.4.4 Education of the Occupants on Vapor Intrusion and Sampling Procedures

One of the roles of the investigator when collecting samples within the impacted areas of a building or specific leasehold is to educate the occupants about the VI pathway. During the building walkthrough, occupants may raise a number of issues that the investigator should be prepared to answer. Refer to the Department’s Vapor Intrusion web site, http://www.nj.gov/dep/srp/guidance/vaporintrusion/ for a discussion on how to conduct community outreach during the investigation of the VI pathway. The fact sheet, *Evaluating Indoor Air near VOC Contaminated Sites* (Appendix E) may provide further assistance. The investigator should inform the property owner during the walkthrough that utility (e.g., electric, gas) representatives may visit their property to mark out the location of area utility lines prior to the sampling event.

A one-page advisory paper entitled *Instructions for Occupants - Indoor Air Sampling Events* (Appendix F) provides building occupants with a list of actions that should be avoided before and during the sampling event. *The Instructions for Occupants - Indoor Air Sampling Events* sheet should be made available to the occupants at least several days prior to the sampling event. Document any departures from the instructions noted during the sampling event on the *Indoor Air Building Survey and Sampling Form*.

3.5 Indoor Air Sampling

The collection of IA samples is necessary whenever the potential for VI exists and other investigative tools cannot eliminate the VI pathway. In addition, IA samples are appropriate for post-mitigation verification purposes.

3.5.1 Application

The primary utility for collecting IA samples is to assess if a complete VI pathway exists.
A VI pathway is considered complete only when:

- A source of vapors related to a discharge is identified; and
- A pathway exists connecting the source to people inside a building.

In most cases the collection and analysis of IA samples is determined to be necessary based upon soil gas and/or ground water results. In determining if the VI pathway related to a discharge is complete, the collection and analysis of IA samples are necessary when the soil gas results exceed the SGSL at a building. The investigator is only required to conduct an IA investigation when COCs are detected in the subsurface in excess of the applicable VI screening levels or other triggers identified in N.J.A.C. 7:26E-1.15(a). The application of crawlspace samples is discussed in Section 2.2.3.

When compared to the other investigative tools available, IA sampling represents the most direct measure of human exposure for the VI pathway.

A multitude of sources that originate both inside and outside any building affects IA quality. Assess background contamination whenever IA samples are collected. A detailed discussion on background contamination can be found in Chapter 4. In addition, a variety of meteorological, temporal and structural factors can influence IA concentrations resulting from VI.

3.5.2 Investigative Considerations

As it relates to building interior investigations for the VI pathway, the investigator has three main options for collecting IA samples in relationship to other VI samples.

Option 1: The investigator can collect and analyze IA samples after the results of sub-slab or near slab samples are known. Under this option, an IA sample is collected and analyzed if soil gas results are greater than applicable SGSL for COCs.

Option 2: The investigator can collect and analyze both SSSG and IA concurrently. The investigator can use Option 2 for any building.

Option 3: To minimize the inconvenience to property owner, tenants, and/or occupants, the investigator can collect both SSSG and IA concurrently. Submit the SSSG and IA samples to the certified laboratory for analysis. However, only the SSSG samples are initially analyzed. Assuming that holding times are met, the IA samples would be analyzed if the SSSG results or building survey findings suggest that further investigation is warranted (a COC exceeding the SGSL).

The investigator can use a combination of sampling options in a VI investigation. For either Option 2 or 3, collect the IA sample first at the building undergoing investigation. This provision is designed to minimize influencing IA concentrations from sub-slab sampling. Once the IA sampling is completed, the investigator should collect the SSSG sample. Using a typical sampling process, the IA sample collection would be started on Day 1. Twenty-four (24) hours later (Day 2), the IA sample canister is closed and the investigator would collect the SSSG sample (usually 5-30 minutes).

It is recommended that the investigator collects SSSG (or near slab soil gas when substituted for sub-slab) and IA samples concurrently as part of a VI investigation for all buildings having sensitive populations.

The investigator should complete the *Indoor Air Building Survey and Sampling Form* (Appendix D). The data on this form are a critical part of evaluating MLE when IA samples are collected. The survey form should be initiated as part of the building walkthrough (conducted prior to the sampling event). In addition, the form is used to document the sampling event. Refer to Section 3.4 for additional information on the building walkthrough and the survey form.

In general, the investigator should not collect IA samples in a portion of a building where operations use, handle or store the same investigative COCs (e.g., dry cleaners, active gas stations, maintenance facilities and various industrial operations). In these situations, it is difficult to determine whether air contaminants present in a building are from operational activities within the facility or from VI. The investigator may consider other lines of evidence in evaluating VI exposures in these situations. The investigator should review the facility's Material Safety and Data Sheet (MSDS) and Hazard Communication Program to determine if a site's COC is used, handled, or stored in the building. Consider and address the potential for a change in the future use of the building in these situations (see Section 6.4.1).

IA samples should be collected concurrently with ambient air samples. Ambient air results are useful in the differentiation of background contamination from outdoor air.

The collection of ambient temperature and barometric pressure readings during the collection of IA samples including ambient air samples (or sub-slab pressure differential during SSSG sampling) are appropriate to verify data representativeness. For an ambient sample, there are several ways to obtain this information. One method is obtaining atmospheric pressure and temperature from the nearest weather reporting station. Two web sites that may be useful to the investigator are the National Oceanic and Atmospheric Administration, National Weather Service web site at http://www.weather.gov and the Weather Underground at http://www.wunderground.com/. Alternately, the investigator can bring portable meteorological instrumentation on site to obtain the information to assist with interpreting the data (MLE).

Obtain temperature for indoor samples using portable meteorological instrumentation with readings taken inside the building. Based upon spacing of the IA samples, it may be appropriate to record temperature readings for each sample location.

Larger commercial buildings may also require the same approach. However, the investigator should take into account that commercial/industrial buildings economize on energy by changing air exchange rates and temperature settings during evening, overnight and weekend periods, which can influence sample concentrations.

3.5.3 Parameters

The initial set of IA samples for each building shall be analyzed for the full parameter list of Table 1 (not Table "A") of the NJDEP Method LLTO-15, plus TICs [N.J.A.C. 7:26E-2.1(c)3]. Subsequent IA samples collected from the same building may be analyzed for a reduced parameter list of the site COCs (including degradation compounds).

When soil gas samples are taken due to petroleum contamination other than gasoline or light petroleum distillates, the samples shall be analyzed for naphthalene in addition to any other site specific contaminants that may be present. The analysis for 2-methylnaphthalene will not be required for VI samples collected during the investigation of kerosene, jet fuel, diesel fuel, fuel oil No. 2, and heavier petroleum products. The Department intends to update the Technical Rules to remove the requirement to analyze VI samples for 2-methylnaphthalene. Until the rule is updated, the investigator can apply a variance pursuant to N.J.A.C. 7:26E-1.7 to not perform this analysis. The investigator should use a certified method for the analysis of naphthalene.

3.5.4 Sample Duration and Flow Rate

For the Department's currently approved TO15 Methods, 6-Liter stainless-steel canisters shall be used for the IA sample collection. Alternative sizes or types of sample containers are not acceptable for IA samples per the TO-15 analytical method. TO-17 and other certified air methods may also be employed, where appropriate.

Residential IA samples should be collected over a 24 hour period. For other sensitive use buildings, a sampling time less than 24 hours should NOT be considered unless there are very unique circumstances with clearly defensible technical justification. Otherwise, results from sensitive use buildings sampled less than 24 hours should be rejected.

For commercial, retail, office, and industrial settings, IA samples are typically collected over a 24-hour period. However the investigator may shorten the sampling period to correspond to the average workday or the timeframe the building or floor of interest is occupied on a daily basis. The minimum sampling time is 8 hours with proper justification. Sampling times less than 8 hours should be technically justified and proper consideration given to future use changes. In these cases, the investigator should evaluate shift length, the maximum exposed worker timeframe, number of shifts per day, and other factors in selecting a sampling period other than 24 hours.

Flow rates for TO-15 are set by the laboratory to match sampling time (e.g., 24 hours, 8 hours, etc.) and canister volume. Therefore, the sample time should be established in advance of the sampling event.

For samples collected using USEPA TO-17, the pump rate should be set so that the final calculated RL used by the laboratory shall be less than or equal to the RL for the Department's currently approved TO-15 Method. Care should be taken not to exceed the safe sampling volume for each volatile compound related to the sorbent(s) used. In addition, sampling in humid environments may result in an accumulation of moisture on the sorbent tube, which would further accelerate breakthrough. The laboratory should be consulted prior to sampling to determine the most appropriate sorbent and sampling volume.

Grab sample results are not considered to be representative of IA quality with respect to evaluating VI pathway. Do not compare grab sample results to the IASL or RAL.

3.5.5 Number and Location of Samples

This section is a guide to assist the investigator in determining the number of IA samples to assess VI impacts for residential and nonresidential buildings. Obtain at least one IA sample from the basement or slab on grade level of a building. Collect additional samples from upper floors based upon professional judgment.

Table 3-2 provides general information for determining the minimum number of IA samples for buildings of various sizes. Adjust the number of samples based on the building-specific features and conditions provided below the table.

Table 3-2
Recommended Minimum Number of Indoor Air Samples

Square footage of building footprint	Number of Indoor Air Samples
Up to 1,500	1-2
1,501 to 5,000	2
5,001 to 10,000	3
10,001 to 20,000	4
20,001 to 50,000	5
50,001 to 250,000	6
250,001 to 1,000,000	7
>1,000,000	9+

The number of IA samples should not be based on area alone. The determination of the required number of IA samples to characterize the impacts from VI will vary from building to building due to various features and uses of the building. Evaluation of the features in a building should be assessed based on professional judgment to determine the number of IA samples required to assess the potential for VI. Features or conditions that may alter the number of samples or biasing a sample location include, but are not limited to the following:

- sensitive populations
- presence of earthen or damaged floors
- presence of cracked or damaged basement walls
- presence of crawl spaces
- presence of sump pits
- requests from building owner
- preferential pathways
- dividing of building floor into separate rooms or occupancy spaces
- utility or mechanical room with thru wall/floor utility line openings
- elevator pits
- portion of building overlying or contacting the highest levels of VOCs
- areas of greatest exposure (play rooms, family rooms, class rooms, offices)
- ventilation
- potential indoor sources of contamination

Any sampling approach should take into account the different exposure scenarios (e.g., child care center, residences, office, and warehouse) that exist within the building(s) and any sensitive populations that may be exposed to the contaminated vapors. Multiple IA sample locations may be necessary for multi-family residential, commercial and retail buildings. The rationale for the number of IA samples collected per building should be documented by the investigator.

All of the features of a building should be included as factors that will influence the number of IA samples. For example, a 25,000 ft^2 strip mall separated into five individual tenant spaces that are separately ventilated may be best evaluated with 10 samples, where a stand-alone 25,000 ft^2 building that is mostly warehouse space with a small office space and a single ventilation system may only need 5 IA samples to document IA quality.

For buildings with up to 1,500 ft^2 footprint (e.g., residences), the number of IA samples depends upon the improvements in the basement or lowest floor space. If the basement is generally open space that may or may not include a small separate utility/furnace area, one sample will likely be sufficient to characterize IA. If the basement were divided into two or more spaces, collect more than one IA sample.

When a basement is present, the investigator may also want to collect an IA sample from the first floor and crawl space (if present) to properly assess human risk or alternative vapor entries into a building. If COCs have not been detected above the applicable IASL in the basement then analyzing air samples on upper floors may not be necessary. Breathing zone height (3-5 feet) will be appropriate for the upper floor sample collection, whereas the basement sample should be positioned as close as possible to the source area (e.g., sumps, major cracks in slab). For multi-story buildings, consider collecting a sample from above the neutral pressure plane, if warranted.

Multi-family residential units involve a more careful review of the building features. Each ground level residential living space (e.g., duplex, row houses) with a basement or slab on grade should be considered a separate unit for IA sampling.

In general, collect one ambient (outdoor) sample per sampling event concurrently with IA samples to assist in evaluating background contaminant levels. Refer to Section 3.1.2.3 for placement of ambient air samples.

3.5.6 Sample Events

In most circumstances, seasonal variability in vapor concentrations necessitates collecting more than one set of IA samples from a building and an ambient air sample.

When IA samples are being collected as a primary assessment tool for the determination of the VI pathway, the sample event should take place between November 1 and March 31. Based on seasonal weather patterns, these dates are generally “worst case” conditions for VI to occur. Assuming there are no other contradictory lines of evidence, the single round of indoor/ambient air samples should be able to determine whether the VI pathway is complete.

In situations where the initial indoor/ambient air samples are not collected during the November 1st through March 31st timeframe, a second round of samples should be collected during the worst case conditions. The one exception to this general rule is when a single round of sampling is conducted between April 1 and October 31 and each COC concentration is an order of magnitude or more below the IASL, then a second round of samples is not needed.

If the two sets of samples are collected and the results are inconsistent with respect to the appropriate screening level (i.e., one result above and one result below screening level), utilize the results collected from the heating season. If both sets of samples are from the heating season, a third confirmation sample collected within the appropriate timeframe may be necessary based on professional judgment and MLE. The results cannot be averaged for comparison to the appropriate screening level. In addition, the investigator should evaluate other lines of evidence to ascertain the technical reasons for this discrepancy.

Once a trigger initiates a VI investigation (pursuant to N.J.A.C. 7:26E-1.15), the investigator cannot delay the collection of IA samples due simply to the time of year when the indoor/ambient air samples will be collected (in relation to the issues discussed above).

3.5.7 Field Quality Control Issues

The investigator should consult the Department’s Technical Guidance for Quality Assurance Project Plans (Version 1) to assess field quality assurance issues. For the most up to date version of this document, please check the NJDEP’s Guidance Library at http://www.nj.gov/dep/srp/guidance/index.html. A QAPP is required for all sample and data collection, consistent with 7:26E-2.2.

The investigator should verify the vacuum in the stainless steel canister before and after the sample collection. The laboratory is required to record the vacuum in the canister upon shipment. In turn, the investigator should verify the canister's initial vacuum at the site prior to collecting a sample. If the initial vacuum at the site is in excess of 10% lower than the lab reading, the canister should not be utilized for sampling. The potential for pressure loss during transit negates the usability of the data generated from the defective canister or regulator.

For indoor air samples, a residual vacuum of up to -5 inches mercury should exist in the canister upon completion of the sampling event. Since the sample is designed to be collected over a designated period of time (i.e., 8 – 24 hours), the residual vacuum ensures that the sample was collected over that time period. If no vacuum remains, the usability of the data is questionable. When the results are used to determine the pathway is incomplete (no exceedances in the indoor air), a residual vacuum in the canister is critical.

3.6 Investigative Reporting Requirements

The Technical Rules require the submittal of reports when a VI investigation or VI sampling has been conducted under the following scenarios [N.J.A.C. 7:26E 1.15]. For all documents prepared for the VI pathway, including letters sent to building occupants, report the soil gas and IA analytical results in units of $\mu g/m^3$ (micrograms per cubic meter). The analytical units of parts per billion by volume are no longer acceptable due to frequent unit conversion errors and misapplications.

The results of a VI investigation shall be included, where appropriate, as part of a Site Investigation Report [N.J.A.C. 7:26E-3.13(a)3] and a Remedial Investigation Report [N.J.A.C. 7:26E-4.9(a)2].

Refer to the *Vapor Intrusion Timeline* (Appendix B) for additional information on required forms and deliverables.

3.6.1 Submittal Requirements for Analytical Data & Results

The Technical Rules establish timeframes for the submission of certain deliverables to the Department, state and local health departments and owners/occupants of buildings investigated for the VI pathway. These timeframes can vary based on the results of the vapor intrusion samples. Table 3-3 provides a summary of those timeframes.

Table 3-3
Timeframe for Analytical Data & Result Submittals

Actions	**No Exceedance***	**Vapor Concern**	**Immediate Environmental Concern**
Submittal of full laboratory data deliverables and form to the NJDEP with appropriate maps & figures	30 days	14 days	14 days
Submittal of result letters & summary tables to owner/occupants, local health department & NJDEP	30 days	14 days	14 days
Submittal of IA & ambient air results on CD to NJDOH with appropriate maps & figures	14 days	14 days	14 days

*No exceedance of an IA sample OR results of soil gas samples only (no IA samples)

3.6.2 VI Receptor Evaluation

N.J.A.C. 7:26E-1.15 specifies the requirement for the completion of a VI investigation as part of the VI receptor evaluation. The investigator shall submit an initial VI receptor evaluation and updated VI receptor evaluation, as per N.J.A.C 7:26E-1.12. The required forms and instructions can be found at http://nj.gov/dep/srp/srra/forms/.

A summary of the VI Receptor Evaluation shall be included in the applicable report(s) provided to the Department with the following:

- A description of all buildings sampled with justification for those buildings within the trigger distances where sampling was determined not to be necessary;
- A scaled map of the site and surrounding area that includes the following:
    - ➢ The locations of all buildings and appropriate subsurface utilities (see Section 3.1.3) identified as part of the VI receptor evaluation in relation to the areas of known ground water contamination;
    - ➢ The use of all buildings and whether they are occupied; and
    - ➢ Highlights buildings that are used as residences, schools and child care centers;
- A description of all VI investigation and mitigation conducted, including all monitoring conducted to determine the effectiveness of the mitigation; and
- A description of all additional planned VI investigations.

3.6.3 VI Sampling

As per N.J.A.C. 7:26E 1.12(e), the investigator shall provide a detailed report of all VI sampling activities in the applicable remedial phase report submitted to the Department. The following information should be submitted to the Department after the VI sampling has been conducted with the next report submittal:

- A summary of the VI evaluation including the VI receptor evaluation information specified in Section 3.6.2 above;
- Copies of the *Indoor Air Building Survey and Sampling* form;
- Scaled site maps identifying:
    - the site, adjacent streets and appropriate subsurface utilities (see Section 3.1.3),
    - extent of the subsurface contamination (e.g., ground water plume),
    - buildings sampled and soil gas, IA and ambient air sample locations;
- Summary tables identifying all contaminants detected above the analytical RLs with those values above the applicable screening levels highlighted;
- Photographs of sample locations (as appropriate) or other pertinent site features;
- Readings from field instrumentation;
- Any documentation, including scaled maps, on the assessment of preferential pathways;
- Scaled floor plans that note information that includes, the location of IA and SSSG samples, observed stains and major cracks in slabs, sumps, French drains, elevator pits, existing radon systems, chemical storage areas (or other potential background sources), HVAC systems and utility entrances into the buildings;
- An evaluation of sampling results in relation to the applicable VI screening levels and determine whether the VI pathway is of concern. Provide recommendations and an implementation schedule. Technical justification shall be included as to whether or not contamination is related to VI; and
- Clarification that the applicable analytical data and/or VI results have been provided to the Department, NJDOH and the building owner/occupant as required under N.J.A.C. 7:26E-1.11 and 1.15.

3.6.4 Immediate Environmental Concerns

The following reports are required when a VI related IEC has been identified at a site.

IEC Engineered Response Action Report

An IEC ERA Report, submitted pursuant to N.J.A.C. 7:26E-1.11(a)7, shall include the following information:

- A description of all immediate response actions and ERA that have been completed including the date that each action was conducted;
- A summary of all analytical data related to the IEC and the engineered response action;
- All maps and figures related to the IEC and the engineered response action;
- A description of the contaminant source control that will be implemented as required pursuant to N.J.A.C. 7:26E-1.11(a)8; and
- A Geographic Information System compatible map of the estimated area of ground water contamination prepared pursuant to the Department's Immediate Environmental Concern Technical Guidance.

IEC Contaminant Source Control Report

An IEC contaminant source control report, pursuant to N.J.A.C. 7:26E-1.11(a)8, shall include the following information:

- The remedial actions being implemented to remediate the IEC contaminant source;
- A monitoring plan for the mitigation system; and
- A monitoring plan for the wells or buildings located down gradient of the wells or buildings impacted by the IEC.

Detailed instructions and information on report requirements associated with a VI IEC are presented in the Department's Immediate Environmental Concern Technical Guidance that may be accessed at http://www.nj.gov/dep/srp/guidance/.

4.0 MULTIPLE LINES OF EVIDENCE AND DATA EVALUATION

One of the most difficult facets of investigating VI is the interpretation of the available information and the subsequent conclusions reached on the completeness of the pathway. The effects of background sources on the overall IA quality complicate the task.

VI from a discharged hazardous substance, hazardous waste, or pollutant to ground water or soil is a regulatory concern of the Department. Yet, how an investigator assesses whether IA is contaminated by a regulated discharge is quite different from other media. For soil and ground water, the determination that the media is contaminated is largely based on a single line of evidence – the analytical results of a sample. VI is a complex pathway where the identical results of analytical data collected from two sites can lead to different conclusions based on the site-specific MLE.

While it is appropriate to utilize the MLE approach in all phases of a VI investigation (consistent with the Technical Rules), the most critical point is in the determination of whether the VI pathway from a regulated discharge to a potentially exposed person is complete. Background sources can affect IA and soil gas quality, complicating the assessment of the VI pathway. According to the USEPA, background refers to constituents that are not influenced by the discharges from a site, and is usually described as naturally occurring or anthropogenic (USEPA, 2002a). For the purpose of this technical guidance, background will refer to any contaminants not directly resulting from subsurface VI related to a regulated discharge. In some cases, individual contaminants found in IA or soil gas may result from both subsurface VI and background sources.

Background sources are typically identified through the collection of upgradient or upstream samples for ground water and surface water respectively. With soil investigations, background samples are collected from areas of the site not impacted by current or historical operations and having similar soil characteristics. Building interiors do not generally provide for “upgradient” or “non-impacted” sampling locations to establish background IA levels. Thus, an alternative approach is necessary for IA and soil gas assessments to distinguish background sources from site related VI.

4.1 Background Indoor Air Sources

Background IA sources can be broken down into several categories – household activities, consumer products, building materials and furnishings, and ambient air pollution. The conveniences of life that people often take for granted can greatly affect IA quality. The numerous sources impacting the air quality of buildings warrants scrutiny since the average American spends over 90 percent of her or his time inside where chemical concentrations are often much higher than outside (USEPA 2001a).

Smoking tobacco products, parking a car in an attached garage, using a kerosene heater, burning scented candles, dry cleaning clothes - all these household activities contribute to potentially unhealthy chemical concentrations in the IA. Consumer products represent a second source of IA pollution that should be evaluated when assessing the contribution from VI. Mothballs and scented candles (1,4-dichlorobenzene), nail polish remover (acetone), rug spot cleaner (tetrachloroethene or PCE), floor polish (xylenes), drain cleaner (1,1,1-trichloroethane) and gasoline (BTEX) are just a few of the examples.

Building materials and furnishings are another source of IA pollution, particularly when they are new. Whether it's carpeting, shower curtains, fabrics and draperies, furniture, building insulation or pressed wood products (particleboard, hardwood plywood and medium density fiberboard), IA quality can be significantly affected by volatile compounds and formaldehyde emanating from these products.

Numerous materials found in buildings, such as carpeting, fabrics and wallpapered gypsum board, can act as "sinks" that retain IA pollutants and subsequently release them over a prolonged period of time (Won, et al. 2000). Carpets represent a significant sink for non-polar volatiles, while virgin gypsum board interacts primarily with highly polar volatiles.

Outdoor air typically enters a building through infiltration, natural ventilation and mechanical ventilation. Yet, studies have shown that common organic pollutants are 2 to 5 times higher inside a building compared to levels in the ambient air (USEPA 1987). Over the last three decades since the passage of the Clean Air Act in 1970, the pollutant concentrations in the outdoors have been greatly reduced. Despite this turnaround, ambient air in urban environments (and other unique circumstances) does require careful consideration when evaluating IA results.

4.2 Components of a Multiple Lines of Evidence Approach

This technical guidance relies on a MLE approach when evaluating VI data and assessing potential background sources. This approach employs a series of primary and secondary factors that collectively gauge the often confounding pollutants found in IA and determine with reasonable certainty the contribution from VI.

Utilizing this methodology, the primary factors (discussed below) provide more significant evidence when compared to the secondary factors. The MLE approach is not designed to be a mathematical calculation, but rather a professional judgment based on a progression of empirical facts, some more relevant than others.

The investigator is reminded that the CSM is an integral part of assessing the VI pathway. Thus, the MLE approach should be utilized to support the conclusions of the CSM.

4.2.1 Primary Factors

The primary factors (in no particular order) for assessing the VI pathway are provided below.

4.2.1.1 Site-Specific Contaminants of Concern

For the VI pathway, ground water contamination is the principal trigger requiring a VI receptor evaluation and investigation. Thus, a well delineated ground water plume (or subsurface soil contamination, if applicable) with identified chemical contaminants can greatly limit the scope of any investigation. Potential degradation products must be included in the COC list.

Unfortunately, VI investigations are often conducted with limited information where ground water or subsurface soil data are seldom extensive or complete. Insufficient data may prevent COCs from being determined prior to the collection of IA samples. The investigator shall analyze soil gas and IA samples collected during the initial round at each building undergoing a VI investigation for the full list of parameters [N.J.A.C. 7:26E-2.1(c)3]. Given an appropriate technical justification (e.g., large existing dataset), the investigator may consider a variance from this regulation to utilize a reduced parameter list based on the COCs and related degradation compounds associated with the site. Subsequent phases of soil gas and IA sampling at each building undergoing a VI investigation can employ a reduced parameter list.

4.2.1.2 Sub-slab soil gas sampling

Collecting soil gas samples from below the building's slab is an excellent tool for differentiating contaminants originating in ground water and subsurface soils from those associated with background sources. Follow the Department's procedures for collecting SSSG samples, as outlined in Section 3.3.1, to utilize the data in the evaluation of background pollution.

SSSG samples, collected concurrently with IA samples from the same building, will allow for a comparison between the data. The investigator should evaluate the COCs found in the ground water and subsurface soils (and their concentration ratios relative to each other). Do they generally agree with the results from the SSSG and IA samples? Agreement between these different sets of data would indicate that the VI pathway is complete.

Frequently, pollutants will be found in the IA, but not the sub-slab samples. In these cases, the compounds are likely originating from background sources unrelated to VI, and the occupants should be directed to consult with the local health department on ways to reduce background pollution.

A concentration gradient between the sub-slab and IA samples (greater than fifty times higher in the sub-slab based on an attenuation factor of 0.02) suggests that the VI pathway is complete. Conversely, higher concentrations within the building (when compared to sub-slab results) would indicate that a secondary background source is likely present inside. This scenario, however, does not eliminate the fact that the VI pathway may still be affecting IA quality within the building.

The investigator shall consider the presence of preferential pathways consistent with the Technical Rules (N.J.A.C. 7:26E-1.15(b). The VI pathway may be complete even though low sub-slab concentrations are detected. Vapors, particularly from contaminated soils, may migrate along preferential pathways above the depth of the building's slab. Thus, contaminated vapors may adversely impact a building's IA quality without the presence of elevated sub-slab vapors.

4.2.1.3 Ambient (outdoor) air sampling

Collect a minimum of one ambient air sample during every IA sampling episode. The results of the ambient air sample can be utilized to evaluate the influence of outside air on the IA quality. This provision is particularly important for urban settings due to the industrial and automotive emissions typical of larger cities. In general, mitigation will not be required when the site-specific ambient air results are in excess of the IA results. In these cases, the validity of the ambient air results should be assessed.

The Department's Air Toxics Program measures a suite of toxic VOC, semi-volatile compounds and metals at four monitoring sites – Camden, Elizabeth, Chester and New Brunswick. These four sites in the Air Toxics Monitoring Network provide information on the spatial variation of air toxic concentrations in the state. Further information can be found at http://www.njaqinow.net/Default.aspx.

While data from the NJ Air Toxics Monitoring Network cannot replace site-specific results, it does provide a general indicator of potential ambient air concentrations in New Jersey.

4.2.1.4 Indoor air background databases

In general, utilization of local, state or regional IA background databases is a primary method for assessing background pollution. The Department has conducted a literature review to determine available information regarding ambient levels of VOC in buildings (Appendix G).

Much of this information was drawn from studies that utilized dedicated IA sampling where measurements were taken at a fixed indoor location. This literature review focuses on studies that have been conducted from the late 1990s to the present.

From the Department's perspective, the most critical study in this literature review is the Department's Indoor Air Background Contaminant Study. One hundred homes were sampled in this study, scattered across 13 primarily suburban and rural counties in the state (Weisel, et al. 2008; Weisel 2006). The homes were single family or semi attached buildings. Almost all of the sampling was conducted in 2004 and 2005, in all seasons. The data from this study represent typical background concentrations in IA specifically related to New Jersey, and were frequently similar to data from the other studies.

Thus, the median concentrations from the New Jersey study were frequently selected as representative values. These representative median IA concentrations (from Table G-4 in Appendix G) can be utilized as a line of evidence in evaluating the analytical results. At no time, however, shall the ambient air results or the representative median IA concentrations be "subtracted" from the analytical results to determine an exceedance of the screening levels.

4.2.2 Secondary Factors

The secondary factors for assessing the VI pathway are provided below.

4.2.2.1 Building survey

The investigator should use the *Indoor Air Building Survey and Sampling Form* (Appendix D) when collecting SSSG and IA samples. This questionnaire covers numerous issues, including building characteristics, indoor pollutant sources, miscellaneous items (such as "do you smoke or dry clean clothes?"), sampling information and weather conditions.

When the questionnaire is completed in advance of the IA sampling event and as part of the building walkthrough, potential background sources can be identified and removed/eliminated prior to sampling.

4.2.2.2 Exterior soil gas sampling

Department experience has shown exterior soil gas sampling to be an effective screening tool when selecting monitor well locations for ground water delineation of contaminant plumes. However, its success in VI investigations has been suspect. Concerns over false negative results have limited the use of exterior soil gas sampling in determining the presence/absence of a VI problem affecting IA quality. Exterior soil gas sampling may be appropriate, though, when differentiating VI from background sources as part of an IA sampling event.

4.2.2.3 Building Characteristics

It is important to understand the building where samples are being collected. HVAC systems that generate positive air pressure can reasonably be expected to prevent or minimize VI within the building. Conversely, a dirt floor or poorly vented crawlspace instead of a concrete slab (or an elevator pit) may significantly increase contaminant concentrations within the building above levels normally calculated using attenuation factors or the J&E model.

Vast differences in building ventilation rates (and thus the intrusion and dilution of vapors from the subsurface) can influence the relative risk to people. Pressure and ventilation testing can provide valuable information, whether the investigator is using a simple smoke stick or electromagnetic flow meters. The age, construction and use of a building are also vital information.

4.2.2.4 Soil Properties

Contaminated soil gas moves through the vadose zone by the physical process of diffusion. Soil properties, however, can influence the diffusive movement of vapors. Thus, it is valuable to understand soil stratigraphy, porosity and moisture content, permeability and/ or particle size distribution. Saturated soils from recent precipitation will affect soil gas movement, particularly outside the footprint of a building. These factors in turn influence advection of vapors into a building and the results of IA samples.

4.2.3 Other Lines of Evidence

Other lines of evidence that can play a role in the evaluation of the VI pathway include, but are not limited to, the following:

- site-specific attenuation factors based on radon testing
- soil pump tests (e.g., permeability of soil to air)
- meteorological conditions (e.g., barometric pressure, precipitation)
- building-specific parameters (e.g., pressure testing, ventilation rates)

- vertical profiles of oxygen, carbon dioxide, etc.
- constituent ratios in soil gas/IA results
- presence of preferential pathways
- temporal and spatial variability in concentrations
- changes in the height of the water table
- modeling
- influence of on-going remedial actions

Use these MLE to verify the CSM developed at the outset of the VI investigation. Refer to Section 2.4.4 for a discussion on data deliverables and usability and Section 2.4.5 for the role of the Department's Technical Consultation with the use of these lines of evidence. The investigator should consider that mitigation can be implemented at any time during a VI investigation.

4.3 Data Evaluation

4.3.1 Background Sources

One of the most critical steps during a VI investigation is the evaluation of analytical data, particularly as it relates to source identification. Due to the fact that the human health-based standards for IA quality are low, the potential for confounding background sources in buildings can be a significant factor in decision making. Refer to Appendix H, *Common Background Indoor Air Sources*, for additional information. Therefore, include an assessment of potential background sources in any data evaluation process. As a general point, mitigation will not be required when the site-specific ambient air results are in excess of IA results and are not resulting from the discharge sources under investigation.

4.3.2 Ground Water Samples

Evaluate the ground water data to determine whether the contaminant plume has been delineated to the extent needed to assess the VI pathway. If the plume has not been sufficiently delineated, additional ground water samples will be required to complete the delineation as it pertains to this pathway.

Assuming the samples are collected consistent with the procedures and recommendations in Section 3.2 of this technical guidance and the Department's FSPM, compare the data that are representative of site ground water conditions to the Department's GWSL. An exceedance of these screening levels for any compound will necessitate further investigation. However, it should not be assumed that elevated ground water concentrations automatically indicate that unacceptable levels of vapors are currently entering the building.

Investigate all existing buildings that are located within the trigger distances of the shallow plume's perimeter. If preferential pathways (anthropogenic or natural) or a landfill are nearby, the investigator should consider whether the trigger distances are adequately protective. The results of this effort will highlight those buildings that will necessitate further investigation for the VI pathway.

4.3.3 Multi-Depth Ground Water Contaminant Data

At sites where ground water data from multiple depth intervals are available, vertical profiles of volatile levels in ground water or data from well pairs/clusters, etc. may reveal various patterns that are likely to have different implications for the current and future risk of VI. The following guidelines should be used to interpret the data.

When vertical profiling is done, a **six-foot thick lens** of ground water, measured from the surface of the water table to the contaminated plume, with contaminants below the Department or approved site-specific GWSL, can be considered sufficient justification to conclude the plume is not a source for VI in the immediate vicinity. When multi-depth monitoring well pairs or clusters are used and ground water in the top 6 to 10 feet of the saturated zone is below the GWSL, the same conclusion is appropriate. In both of these situations, additional ground water sampling for a VI investigation should not be required unless conditions change, or are expected to change to include any circumstances that will cause the water table elevation to decrease significantly. However, ongoing evaluation and monitoring of VI risks are part of an approved remedial action, VI receptor evaluation, and ground water CEA.

If a **lens between three and six-feet thick,** not exceeding the GWSL, exists between the vadose zone and the part of the plume that does exceed GWSL, significant off gassing into the vadose zone is unlikely. However, in this situation, ongoing periodic water level and/or ground water monitoring should be performed to confirm the continuing presence of a "below GWSL lens" of at least 3 feet in thickness. If water level data or other information strongly suggest that a below GWSL lens at least 3 feet thick is not present throughout the year, additional investigation of the VI pathway (soil gas and/or IA sampling) should be conducted.

A below GWSL **lens less than three-feet thick** overlying a plume which exceeds the GWSL should trigger additional investigation of the VI pathway and possibly ongoing ground water monitoring. Conditions which should be considered in designing the next investigative step include types of contaminants present; concentrations of contaminants in the various depth intervals sampled; and thickness of the below GWSL lens in the multi-depth sampling location nearest to the building.

4.3.4 Sub-Slab Soil Gas Samples

Compare the analytical results of the SSSG samples to the Department's SGSL. If the soil gas results exceed the Department's SGSL, additional investigation of the VI pathway is necessary. Unless the investigator is proposing a site-specific approach, IA sampling will be necessary.

In those situations where the soil gas results do not exceed the Department's SGSL but ground water quality exceeds the Department's GWSL by greater than 10X, the investigator should consider additional soil gas investigation (based on professional judgment) to confirm the initial findings. At that point, a site-specific determination can be made on the need for additional VI investigation. Base this determination on an accurate CSM and representative ground water data which indicate:

- shallow ground water concentrations are unlikely to increase in the future; and
- other site conditions at the time of sampling (e.g., soil moisture, percentage oxygen in vadose zone) are unlikely to change enough to result in higher soil gas levels.

Based on the sampling plan, the number of SSSG samples may have to be increased to address spatial variability. The results of the SSSG samples should not be averaged across the subsurface of a building. Therefore, each data point should be evaluated independently of each other.

The compounds detected in the sub-slab (or near slab/exterior, when appropriate) soil gas results should be compared with the site-specific COCs (including degradation products) identified from the contaminated ground water or soil. If additional and/or unrelated compounds are seen in the soil gas results, a secondary VI source may be present. A supplemental investigation of the on-site soils, ground water or building parameters may be warranted.

4.3.5 Indoor Air Samples from the Basement

The analytical results of the IA samples from a basement shall be compared to the Department's IASL (N.J.A.C. 7:26E-1.15).

If the IA results exceed the applicable Department's IASL and it is related to the VI pathway, the investigator shall follow the Technical Rules for VC or IEC (N.J.A.C. 7:26E-1.15 and 1.11, respectively). Additional information on mitigation can be found in Chapter 6.

Multiple samples collected from different locations on the same floor may identify probable background sources when combined with a building walkthrough and survey. Compare the locations of suspect consumer products (e.g., paints, thinners) or household activities (e.g., hobbies, smoking) with the IA sample results. Evaluate whether particular volatile compounds are higher or lower in certain portions of a building and if they correlate with identified background sources. Additionally, determine if the site-specific COCs compare to the IA compounds detected in the sample results. The need to collect multiple IA samples from the same level is left to the investigator's professional judgment and a review of the CSM based on the likelihood of significant background sources or building-specific parameters.

In addition, compare the analytical results with potential vapor entryways through the building slab or foundation (e.g., sumps, drains, utility lines, major cracks, elevator pits). Depending on the ventilation system in the basement, differences in concentrations of site-specific COCs between multiple sample points may be related to their relative position near vapor entryways, and not background sources.

4.3.6 Multiple Indoor Air Samples from Different Floors

If the investigator elects (based on professional judgment) to collect IA samples from at least two separate floors within a building, the basement (or lowest floor) and the level immediately above it are recommended. This is important in situations where SSSG samples are not collected. In part, the rationale for this approach is to provide the investigator with analytical results that may assist in the assessment of potential background contaminant sources.

Compare the results for individual compounds on each floor. In general, the concentrations should decrease with distance from the source. Thus, if VI from contaminated ground water or subsurface soil is the main source, the highest concentrations should be in the basement (or lowest floor) and decrease in samples collected from the floors above. Conversely, if the higher concentrations are found in the upper floors (when compared to the basement results), a background source unrelated to the site is probably located within the building on the floor with the highest concentrations. Divergence from this general understanding of vapor movement may exist in situations where a vertical pathway allows vapors to move quickly from one floor to the next (e.g., elevator shafts, laundry chutes).

The first step in differentiating background contamination during IA sampling events is to identify the site-specific COCs (based on ground water or subsurface soil data). When these COCs are found in potential background sources located within the building under investigation, results from multiple IA samples can be compared to the relative concentrations of related contaminants.

For example, BTEX are common contaminants associated with gasoline. Compare the concentrations of each of these contaminants relative to each other. Evaluate whether a similar relationship exists between the contaminants detected in other samples collected either on the same or different floors of the building. If benzene and toluene generally have a 1:1 ratio in the basement and the second floor samples have three times as much toluene as benzene, it is probable that a secondary background source of toluene is located on the second floor (e.g., nail polish).

4.3.7 Indoor Air and Sub-Slab Soil Gas Samples

The combination of IA and SSSG results will assist in identifying likely background IA sources and verify whether a VI source exists below the building (instead of extrapolating contaminated ground water or subsurface soil results from IA).

The Mitigation Decision Matrix (part of the *Decision Flow Chart* - Appendix A) is designed to assist the investigator in assessing the VI pathway. Specifically, the Mitigation Decision Matrix evaluates the relationship between the SSSG and IA sample results, providing technical guidance on the appropriate action (e.g., no action, monitoring, and mitigation).

Frequently, contaminants will be found in the IA, but not the SSSG samples. The compounds are likely originating from background sources unrelated to VI (especially if they are not site-specific COCs). In these cases, the Mitigation Decision Matrix directs the investigator to evaluate vadose zone (soil) contamination and preferential pathways as potential contributors to IA contamination that might not be detected in the subsurface soil gas results. Once it is established that VI is not contributing to the IA contamination, and will not in the future, no further action is necessary for this pathway.

The investigator will identify cases where the IA concentrations are below the IASL, but the SSSG results are elevated, indicating a potential source in the subsurface. In these situations, the Mitigation Decision Matrix differentiates between elevated SSSG results that are less than or more than 10 times the SGSL.

For SSSG results that are greater than the SGSL but at or less than 10 times the SGSL, long-term monitoring (LTM) is recommended. LTM provisions are outlined in Table 6-3. If the IA results collected during the LTM exceed the IASL and the results are linked to a completed VI pathway, the Technical Rules require appropriate mitigation [N.J.A.C. 7:26E-1.15(e & f)].

When the SSSG results are greater than 10 times the SGSL, the investigator should use professional judgment to determine whether LTM or mitigation is appropriate. The Mitigation Decision Matrix includes mitigation in this scenario due to the increased likelihood that VI will occur in the future if the source of the high soil gas concentrations is not addressed.

The clearest picture of the contribution of background IA sources, though, is observed when SSSG results are combined with IA data collected from different floors or various locations on each floor.

As an example, Table 4-1 below presents a summary of soil gas and IA results collected during an investigation of a gasoline plume in the coastal plains of New Jersey. Even though free product was found adjacent to the building, numerous gasoline-related compounds were not detected in the SSSG samples, probably due to aerobic biodegradation in the vadose zone. Other gasoline related compounds, namely methyl tertiary-butyl ether (MTBE) and 2, 2, 4-trimethylpentane, were detected at high concentrations in the SSSG and at decreasing levels in the basement and first floor. These data strongly supported the assumption that the VI pathway was complete. Thus, mitigation is necessary (consistent with the Mitigation Decision Matrix) to address the VI pathway.

Table 4-1
Illustrative Example of Sub-Slab Soil Gas and Indoor Air Results

Chemical	Soil Gas Results Sub-slab	IA Results Basement	IA Results 1st Floor
Benzene	ND (16)	ND (2)	ND (2)
Cyclohexane	15,000 (310,000)	120 (6,200)	25 (6,200)
Ethylbenzene	ND (53,000)	ND (1,100)	10 (1,100)
4-Ethyltoluene	ND (---)	ND (---)	19 (---)
Methylene chloride	ND (190)	ND (4)	100 (4)
MTBE	18,000 (78)	140 (2)	50 (2)
Toluene	ND (260,000)	ND (5,100)	45 5,100)
2,2,4-Trimethylpentane	93,000 (---)	700 (---)	160 (---)
Xylenes *(m & p)*	ND (5,500 total)	14 (110 total)	39 (110 total)
Xylenes *(o)*	ND (5,500 total)	ND (110 total)	17 (110 total)

Results in µg/m^3 Current Screening Levels in parentheses ND - non-detect

There were, however, contaminants present in the basement or first floor IA samples and not in the SSSG. Had MTBE not been present, the Mitigation Decision Matrix would recommend no further action. A review of the building survey form in this particular case revealed that the occupants utilized various solvents as part of their operations, including methylene chloride, toluene and xylenes. These IA contaminants originated from background sources and should not be factored into mitigation related to site contaminants. For an example of how MLE are applied in the determination of VI, consult Sanders & Hers (2006).

4.4 Assessing Background Contamination from Operational Activities

During the VI receptor evaluation, the investigator may have to evaluate data from buildings (or leaseholds) where background contamination from nearby operational activities can impact indoor air quality. This complicates the interpretation of the results, particularly when the background contaminants are also COCs associated with the site. This situation is common in strip malls where the operations at one leasehold (i.e., nail salon, dry cleaners) can impact the indoor air quality at adjacent or nearby leaseholds.

Multiple lines of evidence should be employed to assess whether a VC or IEC condition exists within the building or leasehold. It will be nearly impossible to differentiate indoor air contaminants resulting from VI compared to operational activities. Therefore, sub-slab soil gas results and other lines of evidence become important. In general, if sub-slab soil gas results exceed the Department's SGSL for COCs associated with the site and the indoor air results exceed the Department's IASL for the same COCs, a VC or IEC condition exists regardless of the contribution from operational activities.

4.5 Compliance

As discussed in Section 2.2.3, IA analytical results are compared to the IASL and the RAL. An IEC is present when VI related IA concentrations exceed the RAL, the source of the COCs is due to a discharge, and a completed pathway for VI has been confirmed. Additional actions are required to mitigate the VI pathway (N.J.A.C.7:26E-1.11).

If VI related IA concentrations exceed the IASL, but are equal to or less than the RAL, a VC exists [N.J.A.C.7:26E-1.15(e)]. Additional actions shall include the development of a VC Mitigation Plan to address impacts to the IA quality of the building. Refer to Appendix B, *Vapor Intrusion Timeline*, for additional information on specific forms and deliverable requirements and related timeframes.

HDNL were developed in consultation with the NJDOH. These values, when exceeded in occupied buildings, represent levels that trigger the investigator to contact the NJDEP, NJDOH and the local health department by telephone regarding the levels detected. The local health department or NJDOH would then have the information necessary to make a decision regarding the need for any emergency actions, such as the evacuation of an occupied building. The HDNLs are currently being revised.

4.6 Official Notification

Building owners, tenants, and occupants shall be notified about their IA and/or soil gas analytical results whenever samples are collected (N.J.A.C. 7:26E-1.15). This is the responsibility of the investigator.

The written reports should consist of a cover letter explaining the findings and a table summarizing the analytical results.

In cases where the compounds in excess of IASLs are concluded to be originating from background sources unrelated to VI, the occupants should be directed to consult with the local health department on ways to reduce background sources. Check the NJDEP VI web site at http://www.nj.gov/dep/srp/guidance/vaporintrusion/ for generic VI results notification letters and summary tables.

5.0 PETROLEUM HYDROCARBONS

5.1 Introduction

As defined in the Underground Storage Tanks Rules (N.J.A.C. 7:14B-1.6):

> petroleum or petroleum products means all hydrocarbons which are liquid at one atmosphere pressure (760 millimeters or 29.92 inches Hg) and temperatures between -20°F and 120° F (-29° C and 49° C), and all hydrocarbons which are discharged in a liquid state at or nearly at atmospheric pressure at temperatures in excess of 120° F (49° C) including, but not limited to, gasoline, kerosene, fuel oil, oil sludge, oil refuse, oil mixed with other wastes, crude oil, and purified hydrocarbons that have been refined, re-refined, or otherwise processed for the purpose of being burned as a fuel to produce heat or useable energy or which is suitable for use as a motor fuel or lubricant in the operation or maintenance of an engine.

Hydrocarbons as a whole consist of hundreds of chemical compounds that range through volatile, semi-volatile and nonvolatile organic fractions.

The Department considers a chemical to be a source of VI if it has sufficient volatility and toxicity in the subsurface with sufficient mass or concentrations to pose a possible inhalation risk within overlying buildings. When comparing the two definitions, it is apparent not all petroleum related chemical compounds represent a VI risk. The petroleum hydrocarbons that represent a VI risk are divided into two groups: the lighter (shorter carbon chain) petroleum fractions (e.g., leaded and unleaded gasoline, aviation gasoline, light petroleum distillates) and heavier petroleum products (e.g., diesel fuel, No. 2 heating oil, kerosene, jet fuel). This distinction is important as it relates to the appropriate analytical parameters employed during the investigation.

5.2 Biodegradation

It has been well documented that petroleum-related hydrocarbon chemicals typically undergo aerobic biodegradation in the unsaturated soil zone (Roggemans et al. 2001, Lahvis et al. 1999, Devaull et al. 1997). While earlier evidence suggested that a soil oxygen level above 4% was needed for biodegradation to occur (DeVaull et al. 1997), evidence that is more recent suggests that the threshold concentration may be lower, between 1-2% (Roggemans et al. 2001, Abreu et al. 2009).

Because the GWSLs are calculated using the J&E spreadsheets that doesn’t incorporate contaminant degradation, the Department, as well as several other state environmental agencies, applies an additional attenuation factor to the calculated screening levels to account for this process. Values for the degradation attenuation factor are dependent on the distance between the contamination and the building of interest, the biodegradation rate, the vapor source concentration and the supply of oxygen (Golder Associates 2008; Abreu et al. 2009).

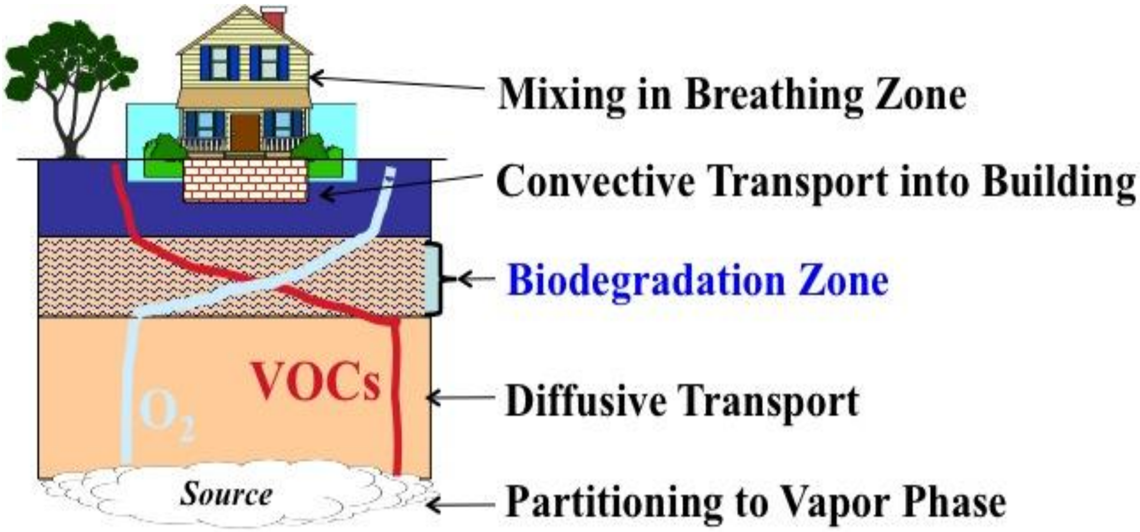


Figure 5-1
Petroleum VI Conceptual Site Model (courtesy Geosyntec Consultants)

Under actual field conditions, the magnitude of the attenuation factor is highly variable, depending on the availability of oxygen in the soil and other soil and environmental conditions. However, recent recommendations from the literature suggest that an additional attenuation factor of at least 0.1 is appropriate under most environmental conditions and at most VI sites. An attenuation factor of 0.1 was therefore incorporated into the default GWSL for petroleum-related compounds (e.g., BTEX). Oxygenated chemicals (e.g., MTBE) degrade more slowly (Squillace, et al. 1997). Thus, the factor was not used for these chemicals.

As noted in Section 2.4.3 and consistent with USEPA, the VI pathway warrants investigation when a building is “located within 100 feet laterally or vertically of known or interpolated soil gas or ground water contaminants…and the contamination occurs in the unsaturated zone and/or the uppermost saturated zone.” (USEPA 2002b) The 100-foot horizontal or vertical trigger distance for investigating the VI pathway does not consider the degradability of the PHC compounds. As such, the Department utilizes a 30-foot horizontal and vertical trigger distance for all petroleum related contamination, including non-aqueous phase product.

Specific gasoline exclusion criteria are discussed below.

5.3 VI Investigation

When a petroleum discharge occurs and a ground water site investigation is triggered, an evaluation of the VI risk to receptors must proceed concurrently by comparing the ground water results to the NJDEP GWSLs for VI. Based on N.J.A.C. 7:26E-1.15, an evaluation of the VI pathway is necessary if PHC-related NAPL is located, or suspected, within 30 feet of a building, or petroleum related contaminants are present in the dissolved phase in excess of the GWSL within 30 feet of a building.

For active gasoline service stations, IA samples should not be collected from site-related buildings due to the difficulty in determining whether air contaminants are from operational activities associated with the facility or from VI. However, SSSG sampling should be conducted to take into consideration any future changes in use for the property. If sub-slab results exceed the SGSL, the MME plan for the applicable institutional control (e.g., a CEA) should require additional VI investigation if the property use changes. Alternatively, an institutional control can be voluntarily placed on the property that would delay the initial sub-slab sampling until the remediation is completed or the site use changes. See Section 6.4.1 for more information regarding institutional controls and the MME plan.

5.4 Alternative Approaches

Recent analyses of field databases have shown significant biodegradation of petroleum compounds under aerobic conditions (Hartman, 2010) suggesting that an alternative approach to assessing PHCs for the VI pathway may be appropriate. Accordingly, this technical guidance provides optional investigative methodologies for PHCs that the investigator may employ. While these alternative investigative approaches are not considered a technical variance or site-specific alternate screening criteria, the investigator is obligated to properly document the appropriateness of employing this approach and the supporting analytical and technical data. Provide this information in the next submission to the Department.

5.4.1 Gasoline Discharges

Gasoline discharges constitute a significant portion of the petroleum-related VI investigations in New Jersey. Thus, specific exclusion criteria have been developed for gasoline discharges only where the benzene concentration exceeds the Department's GWSL. Exceedances of the Department's GWSL by other PHCs does not have to be evaluated under this alternative approach provided the benzene exceedance exists. However, if benzene does NOT exceed the Department's GWSL, the gasoline exclusion criteria can NOT be utilized and any exceedances by other PHCs shall follow the provisions of the Technical Rules.

To employ the gasoline exclusion criteria, the four conditions listed in Section 5.4.1.2 should be met.

5.4.1.1 Gasoline Exclusion Criteria

A VI investigation is not necessary if any one of the following scenarios exists and all of the conditions outlined in 5.4.1.2 are met:

a. the vertical separation distance between the seasonal high water table and the building slab is estimated (using available data) to be at least 10 feet, and benzene concentrations in the shallow ground water under the building are estimated to be 1,000 µg/L or less;
b. the vertical separation distance between the seasonal high water table and the building slab is estimated (using available data) to be at least 5 feet and benzene concentrations in the shallow ground water under the building are estimated to be 100 µg/L or less; or,
c. the vertical separation distance between the seasonal high water table and the building slab is estimated (using available data) to be at least 5 feet, the presence of ≥2% (v/v)

oxygen in the vadose zone is measured at the appropriate location (see Section 5.4.1.3), and benzene concentrations in the shallow ground water under the building are estimated to be 1,000 µg/L or less.

When the vertical separation distance between the water table and the building is less than 5 feet, NO CHANGE in the screening criteria is appropriate, because the criteria were calculated assuming a 5-foot separation distance, and they already incorporate a 10x biodegradation factor for select PHCs.

5.4.1.2 Conditions for Application of Gasoline Exclusion Criteria

The gasoline exclusion criteria apply only when all of the following four conditions exist (using professional judgment):

1) the building is detached and relatively small (e.g., a single family home, fast food restaurant or duplex home);
2) the area around the building is not extensively paved;
3) clean soil exists between the water table and the building slab (no source of contamination in the vadose zone is likely); and
4) NAPL is not present within 30 feet of the building (vertically and horizontally).

The purpose of the conditions is to exclude buildings where the potential for an area of depleted oxygen exists under the building. This is common with larger warehouses, box stores and office complexes.

5.4.1.3 Collecting O_2, CO_2, CH_4 for Application of Gasoline Exclusion Criteria

In general, the investigator may want to utilize fixed gas detectors to establish the subsurface concentrations of O_2, CO_2, CH_4 and other gases as a line of evidence, particularly for petroleum hydrocarbons. A vertical profile of these gases can assist with documenting biodegradable conditions.

Fixed gas detectors can be utilized in combination with near slab sampling by following the provisions in Section 3.3.2 and the sampling specifications outlined below (in order of priority):

- within 10’ horizontally of the building of concern;
- on the side of the building estimated to have the highest contaminant concentrations in the underlying ground water;
- at a depth midway between the building slab and the water table, or deeper; and
- at least five feet below the ground surface.

These specifications are given to minimize “edge effects” observed when sampling is not conducted directly under a building.

5.4.2 Discharges of No. 2 Fuel Oil / Diesel Fuel Oil & Heavier Petroleum Fractions

Based on Department policy, a VI investigation is not required at a site solely based on a discharge of No. 2 fuel oil and/or diesel fuel. As such, the provision at N.J.A.C. 7:26E-1.15(a)2ii does not apply for discharges of No. 2 fuel oil and/or diesel fuel. However, the presence of No. 2 fuel oil and/or diesel fuel on the water table or within the unsaturated zone will necessitate the collection and analysis of a ground water sample pursuant to the N.J.A.C. 7:26E-2.1(d). A VI investigation is required if any ground water sample collected within 30 feet of a building contains a contaminant in excess of any VI GWSL [N.J.A.C. 7:26E-1.15(a)1]. In addition, a VI investigation is required if any of the conditions listed in the Technical Rules at N.J.A.C. 7:26E-1.15(a)3 are met.

If all Number 2 fuel oil and/or diesel fuel oil free product at a site will be excavated or otherwise removed within 6 months after detection, ground water sampling to evaluate VI could be postponed until immediately after such remedial actions are completed (based on professional judgment). This would be the situation for VI investigations for discharges from many unregulated heating oil tank (UHOT) sites.

If Number 2 fuel oil and/or diesel fuel oil free product is on the water table (or in soils) within 30 feet of a building and it is not removed within 6 months after it is detected, the collection of ground water sampling as part of the VI investigation should proceed. The investigator can opt to move directly to SSSG sampling when obtaining a ground water sample if the needed location is a challenge due to the presence of product on the water table. Alternatively, various ground water sampling options are discussed in the NJDEP FSPM and on the Department's VI web site, http://www.nj.gov/dep/srp/guidance/vaporintrusion/.

The presence of petroleum odors in a building is not a trigger to conduct a VI investigation. The investigator should consider that an oil-burning furnace can generate petroleum odors unrelated to a discharge. Therefore, the presence of such odors should be assessed for a possible discharge and the presence of free product in soil that should be evaluated as part of a MLE approach. Subsequent investigation could lead to a VI investigation.

N.J.A.C. 7:26E-2.1(d) requires semi-volatile organic analysis of ground water samples for heavier (longer carbon chain) petroleum products, including kerosene, jet fuel, No. 2 fuel oil, diesel fuel, No. 4 and 6 fuel oils, hydraulic oils, cutting oil, lubricating, and crude oil. As it relates to a VI trigger, the investigator should evaluate the ground water results for naphthalene as the exclusive target compound, in addition to benzene.

6.0 VAPOR INTRUSION MITIGATION

VI mitigation techniques should be evaluated when it is determined that the VI pathway is complete. The objective of vapor mitigation is to interrupt the pathway between the source (contaminated ground water and/or subsurface soils) and the receptors (building occupants). Ultimately, the primary goal is to remediate the source of the vapor contamination (ground water and/or subsurface soil) such that the risk of VI contaminant levels harmful to humans is eliminated. Thus, mitigation of the VI pathway through building control remedies is considered an ERA pending the final remediation of the contaminant source.

This section focuses on the various vapor mitigation options appropriate for VI and the OMM provisions associated with these techniques. Due to the similarities between VI related to volatile contaminants and radon, many of the mitigation techniques discussed below originate from guidance documents or regulations addressing radon mitigation.

6.1 Initial Response Actions – Overview and Timeframes

The mitigation and reporting of VI shall follow regulatory timeframes related to the type of vapor exposure. These timeframes vary based on the levels of IA contaminant concentrations that will require an emergency response, IEC or VC action. The response action timeframes are defined in the following sections and summarized in Appendix B.

The investigation and mitigation of the VI pathway is an iterative process. At larger sites, buildings may be undergoing mitigation while others are subject to the early stages of investigation. Thus, the investigator should always be aware of the appropriate actions for any given building and at any given time.

6.1.1 Response Action Categories

6.1.1.1 Immediate Environmental Concern

When an IEC is identified in a building that is related to the site under investigation there are mitigation responses that must be completed within a required timeframe set in N.J.A.C. 7:26E-1.11. These include IRA and the ERA. Additional technical guidance for VI IEC is included in the Department's Immediate Environmental Concern Technical Guidance (http://www.nj.gov/dep/srp/guidance). The required mitigation actions are further defined in the following sections.

6.1.1.2 Vapor Concern

If a condition in a building has been identified as a VC, the investigator has longer timeframes to complete the mitigation than for an IEC due to the lower exposure levels. The required timeframe for mitigation responses in a VC case are set in N.J.A.C. 7:26E-1.15. The investigator also has the option to implement an IRA in VC cases. This action is the same used for an IEC IRA (Section 6.1.2.2).

6.1.1.3 Emergency Response

For VI cases, an emergency response is not the same as an IEC. In rare instances, VI conditions may cause toxic or harmful sub-surface contaminants to have migrated into an occupied or confined space in a building, producing a toxic atmosphere that is immediately dangerous to life and health due to an oxygen deficient atmosphere, or results in the collection of explosive gasses. Explosive gasses are defined as levels that exceed 10 percent of the lower explosive limit (10% LEL) for that compound. In these cases, the investigator shall immediately notify emergency responders, the Department, and the NJDOH upon knowledge of the results/measurements [N.J.A.C. 7:26E 1.15(i)]. After the emergency condition has been mitigated, further response and reporting requirements should follow the Technical Rules.

6.1.1.4 VI Contamination Unrelated to Site Being Investigated

As previously stated, contamination detected in soil gas and/or IA that is not a COC or is unrelated to the site undergoing investigation shall be reported to the Department by calling the Department Hotline (1-877 WARNDEP). The Department's Publicly Funded Response Element will pursue VI sampling at buildings (residential and nonresidential) where the contaminant exceeds the applicable VI screening level, is from an unknown source and is not a COC under investigation.

6.1.1.5 Mitigation Implemented Based on Soil Gas Results

The *Mitigation Decision Matrix* (Appendix A) recommends mitigation or long-term monitoring at a building where IA results do not exceed IASL, but the SSSG results are greater than 10X the applicable SGSL This recommendation is based on the high concentrations in the subsurface and the likelihood that VI will occur in the future. If the investigator decides under these circumstances to mitigate, it technically is not a VC or an IEC concern. However, the investigator should follow the reporting and monitoring provisions enumerated for a VC concern. If the investigator decides that long-term monitoring is more appropriate under these circumstances, the provisions of Section 6.5.2 should be followed.

6.1.2 Specific Response Actions

The required response actions and their timeframes can vary based on the level of vapor exposure. A description of the required response actions is provided in the following sections. Additional information may be found in Appendix B.

6.1.2.1 Department Notification

For an IEC, the investigator must notify the Department immediately upon knowledge (receipt of data) of the IEC (N.J.A.C.7:26E-1.11(a)1) by calling the assigned Site Remediation Program case manager, or if one is not available or assigned, then call the Department Hotline (1-877 WARNDEP). When contacting the DEP Hotline, the caller shall notify the operator that the project is an "IEC Case." The Department will assign an IEC case manager who will contact the investigator.

For VC cases, the investigator must notify the Department within 14 days upon knowledge (receipt of data) of the VC condition by submitting a completed Vapor Concern Response Action Form (http://www.nj.gov/dep/srp/srra/forms) to the case manager or the Bureau of Case Assignment and Initial Notice (N.JA.C.7:26E – 1.15(e)1i).

6.1.2.2 Interim Response Action (IRA)

If an IEC has been discovered, the investigator shall take IRAs to protect the health of people in the building prior to the installation and startup of the ERA. The IEC IRA shall be implemented within 14 days after the date of discovery of the IEC [N.J.A.C. 7:26E-1.11(a)2ii]. Refer to the Department's Immediate Environmental Concern Technical Guidance document for additional submittals and forms required within the 14 day period. Due to the time critical actions stipulated for the IRA, the Department does not require a formal work plan. Documentation detailing the IRA is required to be electronically submitted to the Department.

For a VC, the IRA is not required but is recommended to reduce the exposure of contaminants to occupants in a building. Typical IRAs for IEC or VC cases may include the following:

- sealing major openings and cracks with caulk or expanding foam (volatile-free);
- repairing compromised areas of the slab;
- covering and sealing exposed earth ;
- covering and sealing sump pits;
- utilizing IA treatment such as carbon air filtration fan units ;
- implementing selective ventilation (based on the neutral pressure plane) particularly for basements and crawl spaces;
- balancing of air handling systems (HVAC) or use of dynamic building controls to create positive room/building pressure;
- enhancing natural ventilation of the building;
- limiting access to the building or area of impact; and
- removing occupants from the building.

The appropriate IRA for each building will vary based on numerous issues (building construction, vapor entryways, etc.).

It is recommended that field analytical methods be employed to aid in the possible locations of entranceways or "hot spots" for VI and to possibly further define the scope of the work for the IRA or ERA. In addition, field analytical methods can be used to aid in the assessment of the effectiveness of the IRA and used in diagnostic testing for the implementation of the engineered response action with the benefit of instantaneous results.

In some cases the implementation of the IRA may mitigate VI. The IRA actions must be permanent, and the success of the IRA to mitigate VI should be determined by IA sampling. If unsuccessful, compliance with the timeframes to implement the ERA is still required.

6.1.2.3 VC Mitigation Plan

A VC Mitigation Plan shall be submitted to the Department within 60 days from the receipt of the data package showing the VC condition [N.J.A.C. 7:26E-1.15(e)2]. The Plan should be a brief overview of the actions proposed to mitigate the VI pathway and monitor the effectiveness of the action to eliminate the receptor exposure. The plan should include:

- identification of the property/building with municipal lot and block numbers
- description and technical justification for the mitigation proposed
- submission of all relevant data (to date) and appropriate spreadsheets/forms
- post-mitigation sampling plan to confirm the success of the mitigation
- operation, maintenance and monitoring plan

If an IRA is implemented for a VC case, documentation describing the IRA should be included in the VC mitigation plan.

Department approval of the VC mitigation plan is not required prior to implementation of the VI response action.

6.1.2.4 Engineered Response Action (ERA)

An ERA is a vapor mitigation system that is installed to control receptor exposure. Within 60 days after the discovery of an IEC, the investigator shall implement (i.e., start, initiate) an ERA to mitigate the entry of vapors into the building [N.J.A.C. 7:26E-1.11(a)6ii]. For a VC, a VI response action must be implemented within 120 days from the time of discovery [N.J.A.C 7:26E-1.15(e)3].

To document the mitigation action for an IEC, an ERA report shall be submitted to the Department within 120 days after identifying the IEC [N.J.A.C. 7:26E-1.11(a)7]. For VCs, a VI response action report shall be submitted to the Department within 180 days from the time of discovery [N.J.A.C. 7:26E-1.15(e)4]. The required information that should be included in these reports is found in the Department’s Immediate Environmental Concern Technical Guidance and Section 6.4.5 of this document. Appendix B summarizes the response action timeframes for IECs and VCs.

6.2 Mitigation Methods

There are numerous approaches to building control remedies for the VI pathway based primarily on the building construction (e.g., existing, slab-on-grade, basement, crawl space). These vapor control technologies involve preventing infiltration of subsurface vapors into a building by application of a barrier, sub-slab venting and/or adjustments to the pressure differential between the subsurface and the interior of the building.

The type of vapor mitigation system installed will be determined by factors such as the use, construction and design of the building, the sub-slab soils and, whether the building is existing or new. For existing buildings, an active subsurface depressurization system is the Department’s preferred method. However, the investigator may modify the mitigation technique based on the results of a VI investigation and communications testing (Section 6.3.2).

6.2.1 Active Subsurface Depressurization Systems

The objective of an active subsurface depressurization system is to apply a negative pressure field or vacuum beneath and/or around the building of concern, thereby preventing VI into the building. Active subsurface depressurization systems utilize a fan or blower to create a continuous negative pressure field (vacuum) below the slab. While subsurface depressurization systems can be either passive or active, the preferred approach is the active system due to its higher success rate in mitigating VI in existing buildings.

Active subsurface depressurization systems are designed to prohibit the movement of volatile contaminants into a building from the soil zone directly around a building. The Department, however, does not consider this action to separately constitute a remedial action of the site contaminants found in soil or ground water. These systems, as well as their ongoing OMM are, however, considered part of the remedial action for the site. The volume of contaminants removed by the mitigation system is incidental to the overall site remediation and does not address source control. As a result, these systems by themselves are not considered capable of ensuring that contaminants are remediated in compliance with all applicable remediation standards.

Some of the types of active subsurface depressurization systems that may be employed to mitigate VI are as follows:

1. <u>Sub-Slab Depressurization System</u> (SSDS) - When combined with reasonable sealing of significant infiltration points, SSDS is typically the most effective mitigation method for buildings with a basement slab or slab-on-grade foundation (NYSDOH 2006). Concentration reductions of 99.5% or greater have been obtained in carefully designed and installed systems in existing residential buildings (Folkes 2002a). Depending on the size of the slab and the characteristics of the sub-slab material, piping may have to be installed vertically through the existing slab in multiple locations to create a negative pressure field across the entire sub-slab area. For new construction with highly permeable venting layers, lateral perforated piping and/or barrier membranes are often installed in the subsurface beneath the slab and a fan is used to create a negative pressure field in the sub-slab area and discharge any vapor outside the building.
2. <u>Sub-Membrane Depressurization System</u> (SMDS) – This technique can be used when a building has an earthen (or gravel, etc.) floor or crawlspace, as opposed to, or in addition to a slab. A membrane, such as a high-density polyethylene (HDPE), is used to cover the earthen floor or crawlspace area. Similar to sub-slab depressurization a negative pressure field is created beneath the membrane thereby preventing VI. Properly seal the membrane to the building walls, suction pipe, etc. and kept intact in order to maintain the negative pressure field. The piping that is used to create the negative pressure field beneath the membrane can be configured in various ways. Insert piping vertically through the membrane or perforated piping can be laid horizontally beneath the membrane.

3. Block Wall Depressurization System (BWDS) – Use this technique when a building has a block wall or cinder block foundation. In this scenario, the negative pressure field is created via piping inserted through the voids in the block wall. Seal any openings in the top of the block wall and all openings or cracks on the interior surface of the wall. This technique is typically used in conjunction with one of the other depressurization techniques.
4. Drain Tile Depressurization System (DTDS) – Use this technique when a building has a loop of perforated drain tiles (piping) adjacent to the building footers for water drainage. If the drain tiles discharge to a sump pit, the sump pit is sealed and the negative pressure field is applied to the sump pit.

6.2.2 Passive Subsurface Depressurization Systems

Passive subsurface depressurization systems do not use a fan or blower to move air from the subsurface. They operate by the use of natural phenomena, thermal effects, pressure gradients and wind to develop suction in the stack. Thermal convective flow operates on the differential temperature between the stack and the subsurface. The vent pipe is routed through the warm space in the building, which is a higher temperature than the subsurface, creating a natural upward draft of air in the vent (stack effect) to draw air from beneath the slab. Advective flow occurs due to pressure gradients between the sub-slab atmosphere and the ambient air. Wind creates a low-pressure region as air moves over the roof. This low pressure “pulls” air from the subsurface through the stack.

Passive systems are not recommended in existing buildings due to the lower success rate when compared to active systems. The best application of a passive system is during new building construction or for an existing building when specific site conditions such as the presence of a highly permeable sub-slab material, synthetic venting materials (e.g., geogrids) or aerated floor/void space system (Cupolex) are installed which are amenable for a passive system.

Since a high water table will significantly decrease the efficiency of a passive system, use of passive subsurface depressurization is conditioned upon the seasonal high water table being no closer than 5 feet below the building slab.

A passive subsurface depressurization system should be installed so that it can be easily upgraded to an active system based on the upgrade factors listed in Table 6-2. Passive systems generally include the following major components:

- Venting layer (or void space) that will allow unimpeded lateral flow of soil gas;
- Lateral perforated piping installed in the venting layer to collect vapors (unless void space technology is employed);
- Passive barrier (membrane) installed above the venting layer, 40-mil HDPE or equivalent (USEPA 2008a), unless void space technology is employed;
- Vertical exhaust lines must run through the heated space of the building and discharge above the roof; and.
- Electric service run to each vent pipe in an unoccupied space (attic, etc.) to allow quick conversion (if necessary) to an active system by installing a fan.

Because passive systems can only draw low flows of vapors, any leakage of air into the building through a crawl space, cracks or membrane opening will reduce what is already a weak sub-surface vacuum and flow field. Therefore the slab and membrane sealing steps and procedures become even more important in a passive system.

The installation of a wind turbine on the stack of a passive vapor mitigation system is highly recommended although it does not reclassify the passive system as an active system. The wind turbine will only induce a vacuum to the subsurface when the wind is blowing and may impede the system flow if ice or snow accumulates on or in the turbine. However, solar powered wind turbines are available that enable longer operational periods to reduce sub-slab vapors. Solar powered wind turbines are in support of the Department's green and sustainable practices (N.J.A.C. 7:26E-1.9).

6.2.3 Sub-Slab Ventilation Systems

Sub-slab ventilation systems (SSVS) employ the use of a venting layer below the slab that allows for the unimpeded movement of soil gas vapors laterally beyond the footprint of the building or to vent pipes placed in the venting layer to discharge to the atmosphere. In addition to the venting layer, perforated collection pipes may be installed laterally in the venting layer or on the perimeter of the venting material to assist the collection of the soil gas and route it to an exhaust point outside the building. With a SSVS design, VI is prevented by moving large quantities of air through the soil or from air supply ventilation pipes, into the venting layer, diluting the contaminants in the sub slab, and moving the contaminants laterally before they have a chance to enter the building (ITRC 2007). As an added protection, SSVS are generally used with a passive barrier to reduce the potential for VI.

These systems are used for new construction or when total slab replacement is required. The design and equipment for a SSVS is similar. They can be operated as a passive or active system. For a SSVS, the permeability of the sub-slab material is so high that it is not possible to maintain a sufficient pressure gradient in the sub-slab atmosphere to maintain a negative pressure.

This technique is also applicable to synthetic venting materials (e.g., geogrids) and aerated floor systems (Cupolex) that incorporate void spaces below the slab that allow unimpeded air flow.

6.2.4 Alternative Mitigation Methods

Mitigation methods that can be considered as an alternative or supplemental to a vapor mitigation technique when subsurface depressurization systems are not appropriate based on building construction or other technical justifications include:

- passive subsurface depressurization systems (existing buildings);
- active HVAC modifications (not appropriate for residential buildings);
- soil vapor extraction (SVE);
- aerated floor systems;
- spray on barriers (supplemental approach only);
- subsurface pressurization;

- heat recovery ventilator;
- IA treatment (designed as a temporary method);
- limit or prohibit access to affected areas of building; and
- immediate removal of source.

The use of any alternative vapor mitigation method should be technically justified. Additional information on the application, design and installation of vapor mitigation systems can be found in the following documents:

1. ASTM Standard Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings, http://www.astm.org/Standards/E1465.htm
2. ASTM E2121-09 Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings, http://www.astm.org/Standards/E2121.htm
3. ASTM Standard Guide for Application of Engineering Controls to Facilitate Use or Redevelopment of Chemical Affected Properties, http://www.astm.org/Standards/E2435.htm
4. ITRC Vapor Intrusion Pathway: A Practical Guideline, http://www.itrcweb.org/Documents/VI-1.pdf
5. USEPA Radon Prevention in the Design and Construction of Schools and Other Large Buildings.
6. USEPA Sub-Slab Depressurization for Low Permeability Fill Material, http://www.epa.gov/radon/pubs/index.html
7. USEPA Radon Reduction Techniques for Detached Houses, Technical Guidance, http://www.epa.gov/radon/pubs/
8. USEPA Model Standards and Techniques for Control of Radon in New Residential Buildings, http://www.epa.gov/radon/pdfs/model_standards.pdf
9. USEPA Building Radon Out: A Seep-by-Step Guide on How to Build Radon Resistant Homes, http://www.epa.gov/radon/pubs/index.html
10. USEPA Brownfields Technology Primer: Vapor Intrusion Considerations for Redevelopment, http://www.epa.gov/brownfields/; and
11. USEPA Engineering Issue: Indoor Air Vapor Intrusion Mitigation Approaches, http://www.clu-in.org/download/char/600r08115.pdf
12. N.J.A.C 5:23-10 Radon Hazard Subcode http://www.state.nj.us/dca/divisions/codes/codreg/pdf_regs/njac_5_23_10.pdf

6.3 Mitigation System Design and Construction

6.3.1 System Design and Installer Qualifications

For the design and installation of a vapor mitigation system, utilize a New Jersey Certified Radon Mitigation Contractor; (http://www.nj.gov/dep/rpp/radon/certmit2.htm), an LSRP (http://www.nj.gov/dep/srp/srra/lsrp/temporary_lsrp_list.htm), or licensed Professional Engineer who has specific experience in VI or radon building mitigation. A licensed electrician must perform all electric work in accordance with local building codes. All designers and installers must have the required licenses and permits (Section 6.3.5) to complete the work. The vapor mitigation system should be certified (by the aforementioned person or firms) as being effective for addressing the VI pathway.

As with any mitigation work performed in existing structures, safety precautions are required for workers due to the potential exposure to hazardous materials that may be present in the building from construction or operations. All persons working on a VI case should be in compliance with all applicable OSHA regulations for working at hazardous waste sites (49 CFR 1910).

6.3.2 Pre-Mitigation Diagnostic Testing

Diagnostic testing for vapor mitigation systems consist of inspections, evaluations and physical measurements that are performed for the following reasons:

- Aid the designer and installer in the selection and application of the mitigation technology for the site-specific building conditions.
- Optimize the performance of the selected technology for vapor mitigation.
- Reduce the cost of installation of the selected technology for vapor mitigation.
- Provide an installation that will be safe for the building occupants.

The diagnostic tests can be performed in stages before the installation of the vapor mitigation system or they are completed simultaneous with the installation.

6.3.2.1 Visual Inspection

The visual inspection is to determine the suitability of the building for different vapor mitigation technologies. The inspection allows the installer to assess the difficulty of the installation based on the design and construction of the building (bi-level, additions, utilities, crawl spaces, etc.), where suction pipes can be located, routes for the suction and discharge piping, where the blower/fan can be installed and electrical requirements. At this time, assess the building for locations of possible VI through cracks, openings or utility entrance points with the use of a direct reading instrument or chemical smoke test. During the visual inspection materials should be identified that may need special handling and disposal (asbestos shingles, insulation, lead painted surfaces).

6.3.2.2 Backdrafting

When excessive depressurization of a building occurs (approximately -5 Pascal or greater) due to ventilation equipment and combustion devices, the potential exists for combustion exhaust gases (e.g., carbon monoxide) to be drawn into the building. This situation is backdrafting. Since many of the mitigation systems may affect the overall balance of airflow within a building, the investigator should determine if backdrafting is occurring prior to, and after the installation of a mitigation system. If an investigator has concerns about the backdrafting potential at a building prior to system installation, it should be recommended to the building owner that a licensed professional inspect the natural draft of the combustion or venting appliance for compliance with local codes and regulations and if needed, repair the system. Procedures for investigating backdrafting are presented in several sources (USEPA 1993, ASTM 2007). A *Simple Smoke Visualization Test to Assess Backdrafting* can be found in Appendix I.

6.3.2.3 Stack Effects

Stack effect reduction techniques are an important aspect in minimizing the depressurization of a building to inhibit VI. The stack effect in a building is the upward movement of air inside a building from heated air rising and escaping the building through openings in the construction, thus causing an indoor pressure lower than in the soil around and below the building, promoting VI. Areas that should be evaluated for air leakage are included in Model Standards and Techniques for Control of Radon in New Residential Buildings (USEPA 1994a). All repairs and upgrades should be designed and installed to conform to applicable state and local building codes and maintain the function and operation of all existing equipment and building features.

6.3.2.4 Communication Test

For active subsurface depressurization systems, a communication test is a critical step in assessing the viability of the system to extend the sub-slab depressurization field beneath the entire slab and foundation (USEPA 1993). In some applications, such as large buildings, only a portion of a building may be required to have a mitigation system based on the source of the volatile compounds. A communication test should be conducted for each building as part of the design to assist in the determination of the number and locations of suction point(s) and fan size(s). Suction fields below the slab may be interrupted by existing sub-slab features (e.g., grade beams, footings, foundation walls) and require the installation of additional suction points. In other situations, sump pits can be utilized as suction points if properly sealed and converted (ITRC 2007).

6.3.2.5 Permanent Sub-slab Soil Gas Probes

Upon successful completion of a communication test, permanent SSSG probes should be installed in locations that will indicate total slab or impact area depressurization. The probes should be located based on the findings of the communication test. This information will be useful during the commissioning of the system and during the OMM period. Observation holes installed during the communication test may be converted to permanent SSSG probes.

The permanent sub-slab probes allow for repeatable measurements to confirm the negative pressure field during the OMM phase of the project (Section 6.5) and for SSSG testing for system termination (Section 6.6). For the OMM phase of the project, the recommended number of permanent points to confirm sub-slab depressurization is four (4) probes for the first suction point plus two (2) probes for each additional suction point. The locations and number of probes can be altered depending on the site specific configuration of the extraction points, building's footprint, access and best professional judgment. An example design and procedure for installing a permanent sub-slab probe is included in Appendix J.

6.3.2.6 Condensation

During the design of the mitigation system, consideration should be given to the elimination of condensate that may collect in the piping of the mitigation system. The collection or freezing of condensation can restrict the airflow through the piping decreasing the vacuum in the system, damaging system components and decreasing the operational lifetime of a blower or fan.

6.3.2.7 Alarms

Based upon the system design, installation location and preferences of the building occupants, a visible or audible device should be installed that will indicate if there is a loss in system power or vacuum. Typically, this consists of an electronic audible alarm or for larger systems a “call out” system connected by land-line phone. Clear instructions must be provided to the building owner with a name and phone number of the contact person in case an alarm is activated.

6.3.3 Sealing Vapor Entryways

For purposes of this technical guidance, vapor entryways include cracks in the subsurface walls or slab, openings in the slab, utility penetrations, floor drains and other related pathways for vapors to intrude into the building.

The sealing of vapor entryways discovered during the visual inspection should be assessed as part of the mitigation process. **Sealing is not a stand-alone mitigation measure**; however, it is an important component of any mitigation strategy and serves to enhance the effectiveness of all vapor mitigation approaches. In many cases, it is impracticable to access, locate and seal every potential infiltration point in an existing building, particularly slab-on-grade buildings or homes with finished basements. Therefore, diagnostic testing should be conducted prior to, and after installation to ensure that a sufficient number of suction points have been installed to achieve acceptable vacuum levels over the affected areas of the slab to mitigate VI. A practical, rather than exhaustive level of sealing will generally result in a more conservative design, because the design is not relying on a completely sealed building shell in order to meet performance objectives, and seals may deteriorate over time.

To fill wall and slab cracks and prevent air leakage, sealants, such as synthetic rubbers, acrylics, oil-based sealants, swelling cement, and elastomeric polymers are appropriate (USEPA 2008a). Avoid sealants containing volatile compounds since they can introduce contaminants. Other locations that should be evaluated for sealing include:

- the tops of hollow block foundation walls
- utility conduits at the terminus with the building
- openings in the slab that allow for utility lines (water, sewer) to pass into a building for the toilet and bath; remove access panels to check the slab for openings
- sumps provide a significant preferential pathway for vapors to migrate into a building. (install air tight covers over sumps to prevent VI but still allow active dewatering and sump pump access (USEPA 2008a)
- building access to a perimeter drain system around the basement floor connected to the sump
- water traps in floor drains may provide an entry route for vapors (repair the trap if leaking, periodically add water to the drain, or install a Dranjer type seal)
- buildings with highly cracked concrete slabs or a dirt floor (may have to repair the slab or install a new slab)

6.3.4 Gas Vapor Barriers

A gas vapor barrier should be included as part of a passive vapor mitigation system to eliminate the VI pathway in new construction. They are also used in the construction of SMD systems for the mitigation of crawl spaces and other low traffic areas over an earthen floor. A gas vapor barrier serves as a supplemental safety feature for both active and passive systems designed to increase the effectiveness of the overall design. As such, a gas vapor barrier is generally not acceptable as a stand-alone mitigation measure without the other components of an active or passive mitigation system.

Traditionally, the most commonly used material in building construction that is often referred to as a "vapor barrier" is 6 mil polyethylene. The American Concrete Standards Institute does not classify this material as a barrier but as a retarder to resist water vapor transmission. The term "vapor barrier" is often used interchangeably with "vapor retarder". Vapor retarders are designed to retard the transmission of water vapor while vapor barriers are impermeable to water vapor. In reality, these types of sub-slab barriers are not designed or installed as a gas vapor barrier to eliminate VI; they are designed to minimize the inflow of water vapor through concrete from the subsurface. They are also not reliable for VI mitigation due to punctures, perforations, tears and incomplete seals during installation (ASTM 2007).

The type of material and physical characteristics of a gas vapor barrier should be evaluated to match the application in the VI mitigation system. Examples of some characteristics that may be evaluated for a gas vapor barrier include the following:

1. Thickness – Material thickness can be measured in mils (1 mil=0.001 inches), inches or mm. It is related to the tensile strength and puncture resistance properties. Liners are susceptible to punctures and tears during construction therefore they must be able to withstand normal construction activities. Recommended thicknesses for gas vapor barriers in construction is 40 mil HDPE (USEPA 2008A). A similar application of gas vapor barriers if for landfills which recommended a thickness of 30 mil or 60 mil HDPE (N.J.A.C. 7:26-2A.7). Other measures of thickness of gas vapor barriers have been used for VI mitigation projects. Generally, as the thickness of the gas vapor barrier material increases, the strength and durability of the material increases. The durability of the material should match the application and damage it may be exposed.
2. Resistance to water vapor transmission – Water vapor transmission properties are defined by the following terminology:
   a. Water Vapor Transmission Rate – The water vapor transmission rate is the amount of water that can pass through a given area of material under specific conditions. Low water vapor transmission rates are required for gas vapor barriers.
   b. Permeance – Permeance is a measure of the rate at which water vapor passes through a material under specific conditions and expressed as grain/[ft^2*in. Hg*hr]. Permeance is a measure of material performance. The lower the permeance the more effective the vapor barrier is to resisting transmission of water vapor. Water vapor barriers are defined as material having permeance value of 1.0 or less.
   c. Permeability – Permeability is a measure of the time rate of water vapor transmission though a material under specific conditions. Permeability is a property

of the material and is measured in perm-inches. Low permeability values are required for gas vapor barriers.

3. Solvent Vapor Transmission – The transmission rates of solvent vapors through a membrane may differ from water transmission rates due to the molecular size and attraction of the solvent vapor to the barrier material. The testing for solvent transmission rates are the same as those for water vapor only a solvent is used. This type of information may only be available from the manufacturer upon special request.
4. Chemical Resistance – Chemical resistance of the vapor barrier should be evaluated when used in areas where high levels of contaminants from contaminated soils or ground water are present. The vapor barrier must be chemically resistant to the chemicals present on-site to reduce the potential for chemical degradation of the vapor barrier.
5. Resistance to Puncture – Resistance to puncture is a measure of the force required to puncture a gas vapor barrier material. It can be used to evaluate the resistance of one type of force on different materials to aid in the selection evaluation of the material.
6. Tensile Strength – Tensile strength is a measure of the material resistance to tearing during the handling of the material for placement. The Tensile strength data can be used to compare different materials that are being evaluated for use in a specific application.

The above list contains a few of the different characteristics of gas vapor barrier material that should be evaluated to assist in the selection of the best material that will meet the goals of the application and the project.

In general, there are three types of gas vapor barriers used; they include sheet, spray on liquid and composite. Examples of construction materials for sheet gas vapor barriers include HDPE, linear low density polyethylene (LLDPE) and ethylene propylene diene monomer (EPDM). An example of liquid gas vapor barriers includes Liquid Boot®. Composite barriers contain 2 or more types of material construction (Geo-Seal™) or cross laminated materials.

During installation of a membrane for a vapor mitigation system, a QA/QC plan should be part of the installation. This plan should include inspections performed to ensure the proper material and/or thickness has been installed after the application. Inspect the membrane and seams to confirm they are sealed with the applicable sealant, proper amount of material overlap at the seams, proper seals around penetrations (e.g., water and sewer pipes, vent line), proper seal with the membrane and all edges of the foundation wall or footings, and that there are no holes or tears in the membrane (ITRC 2007). A smoke test should be performed to determine if any leaks developed during placement of the gas vapor barrier.

During the installation, consideration should be given to the design and installation of a monitoring system for sub slab vapors during the OMM of the project.

6.3.5 Construction and Electrical Permits

Construction and electrical codes are intended to protect the health, safety and welfare of building owners and occupants by establishing minimum construction standards. Vapor mitigation systems must be designed and installed in compliance with applicable mechanical, electrical, building, plumbing, energy and fire prevention codes, standards and regulations of the local jurisdiction. It is important to check with the local municipal construction official to ascertain the appropriate permits or approvals, including inspections that are required for the installation of a vapor mitigation system.

6.3.6 Air Permits

The requirement for an Air Pollution Control (APC) Permit from the Department for a vapor mitigation system is based on the type of building, the location, the type and concentration of contaminant(s) from the discharge of the stack N.J.A.C 7:27 8.2(c). Refer to the *Decision Flow Chart for Air Pollution Control Permit* (Appendix K) and technical guidance (Appendix L) to determine whether an APC Permit is required for your system. For further details, contact the appropriate Department Air Enforcement Regional Office (http://www.nj.gov/dep/enforcement/air.html).

An ERA may have as a precaution or require a treatment system for the stack discharge such as activated carbon, to remove volatile compounds. If these systems are used, they should be monitored for radiation due to the potential for the collection of radon gas by the carbon. Precautions must be used to protect workers and building occupants from this hazard.

6.3.7 Buildings with Existing Radon Systems

Occasionally, buildings will be identified for a VI investigation that may already have a radon mitigation system installed. The presence of a radon mitigation system does not preclude the need to assess the VI pathway and possibly upgrade the system to address volatile contaminants. This can be determined by IA sampling and analysis.

If an existing radon mitigation system requires upgrades to meet the IASL for VI, regulations require that only a New Jersey certified radon mitigation professional can complete the alterations to a radon system (N.J.S.A. 26:2D-70 et seq.). Any person not certified and performing radon services shall be subject to the criminal penalties in N.J.S.A. 26:2D-77.

6.4 Post-Mitigation Activities

6.4.1 Institutional and Engineering Controls

ERA and VI response actions that involve the installation of subsurface depressurization system or similar VI mitigation devices do not require an institutional control on individual buildings.

The investigator should consult the Administrative Requirements for Remediation of Contaminated Sites or ARRCS (N.J.A.C. 7:26C-7) for institutional and engineering control requirements. Ground water CEAs and deed notices are the two institutional controls with ongoing monitoring and evaluation requirements potentially applicable to the VI pathway. The investigator should coordinate the MME requirements for institutional controls with the post-mitigation sampling and OMM provisions for the ERA and VI response actions discussed in Sections 6.4.2, 6.4.3 and 6.5 below. A remedial action permit, issued pursuant to N.J.A.C. 7:26C-7, would incorporate both types of monitoring requirements.

When implementing a ground water remedial action, the investigator shall comply with the applicable VI related ground water CEA requirements (regulations cited above), which address potential future VI risk that was not mitigated by an ERA. Deed notices require addressing VI risks from soil contamination or volatile contaminant(s) in a landfill. The option to use a deed notice to address VI risks in other circumstances is available if the affected property owner is willing to establish one (http://www.state.nj.us/dep/srp/regs/deednotice/). However, use of a deed notice would not substitute for compliance with the CEA requirements applicable to VI risk from ground water contaminants.

Technical guidance is provided below regarding MME plans and biennial certification requirements with regard to the VI concerns and the implementation of these institutional controls at the affected building. Instructions for the applicable Remedial Action Protectiveness/Biennial Certification Form also provide relevant information (http://www.nj.gov/dep/srp/srra/forms/.

The MME plan should include provisions to monitor for future changes in use of the property where the change in use could increase the VI risk. For example, where nonresidential screening levels (SGSL, IASL, RAL or OSHA PEL values) are used as part of the mitigation, it would be appropriate for the MME plan to include obtaining agreements with affected property owners that allow periodic assessment of property use changes which could affect the protectiveness of the remedy (e.g., conversions to residential use).

Likewise, the option to use site-specific building parameters (e.g., ventilation rate changes, building size modifications, positive pressure controls) to address VI risks would necessitate a property owner agreement to allow ongoing monitoring at the affected building/property to ensure the remedy is still protective. Such agreements would ensure the applicable building parameters continue to mitigate VI risk if any changes to property use should occur such as building renovation or major alterations to HVAC system construction or operation.

Other changes in the property use overlying the footprint of a CEA that may alter the risk of VI include new construction, changes in ground surface cover, storm water management, and filling and/or excavation operations. The investigator should periodically monitor the site for planned or existing changes in property use and ownership and changes in building use/conditions as appropriate based on site-specific conditions. The monitoring frequency should ensure that any additional remediation needed due to property use changes, can be completed quickly enough to allow submittal of the biennial certification (that the remedy remains protective) in the required timeframe.

For example, if a dry cleaning business overlying a PCE plume closes and the building now houses a restaurant, ground water, sub-slab and/or IA sampling may be needed to evaluate the potential VI risk. Such sampling can take a significant amount of time to complete and any required mitigation will necessitate even more time. In many cases, all investigation and mitigation would need to be completed to certify that the institutional control and remedy remain protective. Therefore, frequent monitoring for these kinds of land and building use changes is appropriate at sites where such changes are possible.

Statutory authority for requiring submittal of the certification and the supporting documentation that the remedy remains protective is in the Brownfield and Contaminated Site Remediation Act at N.J.S.A. 58:10B-13.1 and 13.2.

6.4.2 System Commissioning (Post-Mitigation Diagnostic Test)

Once the vapor mitigation system is installed, it should be commissioned to verify that it is functioning consistent with the mandated performance specifications and to establish an operational baseline. Due to subsurface conditions (e.g., high moisture content), sufficient time will be necessary for the sub-slab area to reach equilibrium after the installation of the vapor mitigation system. Thus, the baseline performance measurements should be collected no sooner than 30 days after the system is activated (Commission Timeframe). The 30-day timeframe also allows the building time to vent prior to collecting verification IA samples.

The system commissioning should include:

- visual inspection of the system with the aid of the *Vapor Intrusion Mitigation System Inspection Checklist* (Appendix M);
- establishment of an operational baseline from appropriate commissioning parameters;
- determination as to whether alterations or augmentation of the system are required; and,
- trouble-shoot any problems (noise, vibration, condensate generation, complaints, etc.).

Some vapor mitigation systems may require a shorter or longer commissioning timeframe based on site-specific factors.

6.4.2.1 Vapor Intrusion Mitigation System Inspection Checklist

To assist in the evaluation of the mitigation installation, a check list has been developed to aid in the design, construction and evaluation of a vapor mitigation system. The *Vapor Intrusion Mitigation System Inspection Checklist* (Appendix M) identifies a series of minimum technical design provisions that should be incorporated for VI mitigation systems. All applicable items contained in the checklist should be incorporated into the design for any VI mitigation system unless technical justifications are provided. Modifications from what is detailed in the checklist may be appropriate during the installation of the mitigation system due to site-specific building factors and/or preferences of the occupant/owner.

6.4.2.2 Active System Diagnostic Measurements

Diagnostic testing during the system commissioning is used to determine the operational parameters of the mitigation system, assess the performance of the system and establish a baseline for the operational parameters. Measurements can be obtained from individual extraction points, piping headers or at the fan/blower. Types of system diagnostic measurements obtained during the commissioning period of the mitigation system will vary based on the design and construction of the mitigation system. System diagnostic measurements can be obtained with direct reading instruments. Measurements can include but are not limited to the following:

- Vacuum;
- temperature;
- DRI-VOC, methane and non-methane concentrations;
- % oxygen;
- air flow; and,
- any system specific measurements that will aid in determining the system performance.

These diagnostic measurements or system commissioning values can be used during the OMM phase of the project to confirm steady state operational conditions and provide multiple lines of evidence that the mitigation system continues to prevent VI in lieu of IA sampling and analysis.

6.4.2.3 Passive System Diagnostic Measurements

Diagnostic testing of a passive vapor mitigation system can be difficult due to the low and variable flow rates and vacuum pressures generated with this type of mitigation system. Flow measurements can be obtained from the vent pipe but may be below the limits for a pitot tube, a hotwire anemometer or other device. Therefore, the only diagnostic testing available for a passive system is the use of IA (and possibly SSSG) sampling and analysis.

6.4.2.4 Subsurface Vacuum Measurements

Subsurface vacuum measurements are used to confirm the pressure differential across the slab in the target area (entire or partial slab). Vacuum measurements from permanent sub-slab probes may be in the range of 0.01 to 0.001 inches of water (2.5-0.25 Pascal). Therefore, a digital manometer with an accuracy and resolution to properly measure the vacuum is required. Smoke testing can be used to determine if there is a vacuum in the sub-slab but it is only a qualitative test. At low vacuums, the use of a chemical smoke test at the sub-slab probes may be difficult to determine the presence of vacuum in the sub-slab.

For active subsurface depressurization systems, sub-slab vacuum measurements can be obtained from the permanent probes installed during the communications test (Section 6.3.2.5). In general, an active SSDS should achieve a pressure differential of at least 0.004 inches of water (1 Pascal) across the slab for the mitigation of VI.

For active subsurface ventilation systems where subsurface materials are highly permeable, large volumes of air are drawn through the subsurface soils with little pressure drop. In these situations, sub-slab depressurization measurements across the slab may be difficult where soil conditions limit reasonably achievable depressurization levels. If measurable vacuum measurements are not obtainable, utilize flow measurements at the fan inlet.

As previously described, the only definitive diagnostic testing that may be available for a passive system is the use of IA and SSSG sampling and analysis.

6.4.2.5 Backdraft Testing

After system installation, a backdraft test (Appendix I) should be performed on combustion appliances to confirm that backdrafting is not occurring due to the operation of an active mitigation system (6.3.2.2). If the test shows the potential for backdrafting, immediately turn off the mitigation system, determine the cause, and remediate prior to the operation of the system.

6.4.2.6 Building Owner Notification of System Operations

The investigator should identify and describe the various components of the vapor mitigation system to the owner/occupant, including the purpose of the pressure gauge and the contact information if they suspect a problem. This information should also be included in the IEC ERA Report or the VI Response Action Report specific to the system.

6.4.2.7 Conversion Factors

For reporting purposes, diagnostic test results may be reported in various units. Included in Table 6.1 is a list of unit conversions for some of the common measurements obtained during a VI investigation and diagnostic testing. The Department does not stipulate the reporting units for diagnostic testing with the exception of soil gas and air concentrations (µg/m^3).

Table 6.1
Unit Conversions for VI Mitigation (ESE 1982)

Unit	**Multiplied by**	**To Obtain**
Inches of water	249.1	Pascal
Inches of water	7.355×10^{-2}	Inches of mercury
Inches of water	2.4581×10^{-3}	Atmospheres
Inches of mercury	3.342×10^{-2}	Atmospheres
Inches of mercury	2.54×10^{1}	Millimeters of mercury
Atmospheres	101,325	Pascal
Atmospheres	2.992×10^{1}	Inches of mercury
Atmospheres	7.6×10^{2}	Millimeters of mercury
Pounds per square inch	6894	Pascal
Pounds per square inch	6.804×10^{-2}	Atmospheres
Pounds per square inch	2.036	Inches of mercury
Bar	100,000	Pascal
Bar	9.869×10^{-1}	Atmospheres
Liter	3.531×10^{-2}	Cubic feet
Liter	1,000	Cubic meter
^{o}F	5/9 (^{o}F-32)	^{o}C
^{o}C	9/5 ^{o}C+32	^{o}F
µg/m^3	24.45/MW	ppbv
ppbv	MW/24.45	µg/m^3
Pascal	0.004	Inches of water

6.4.3 Verification Sampling

Verification sampling (VS) is required to confirm the system performance in effectively reducing contaminant levels in the IA [N.J.A.C. 7:26E-1.11(a) 6]. Irrespective of the vapor mitigation technique selected, IA sampling is necessary as part of the MLE to confirm the mitigation technique was effective in reducing the contaminant levels below the Department's IASL. For passive and alternative systems, sub-slab samples should also be obtained to aid in determining the effectiveness of the mitigation. Implement the VS immediately following (same day) as the commissioning of the system – usually 30 days or more after the system start-up. VS provisions are included in Table 6-2.

VS analysis is only required for the COCs and their breakdown products (unless IA samples have not been previously sampled at the building and analyzed for the full parameter list). The IA sample(s) should be collected in the basement (or lowest floor) and biased towards worst case locations identified during previous sampling events and/or professional judgment. The number of verification samples should be consistent with Table 3-2.

6.4.4 Assessing the Impact of Background Contamination and Operational Activities

The investigator may have to assess the effectiveness of a mitigation system in buildings impacted by background contamination or operational activities. In these situations, the results of the VS may exceed the Department's IASLs or RALs even though the VI pathway appears to be eliminated.

An example of this scenario would be a dry cleaner in a strip mall. Historic discharges from the dry cleaner have impacted subsurface soils and ground water. The VI pathway has been addressed by the installation of a SSD system. Yet, PCE levels detected in the VS at adjacent leaseholds are still elevated. The potential source of this indoor air contamination may be due to the operations of the current dry cleaner and not from the historic discharges.

A multiple lines of evidence approach should be employed to address this quandary. Since case managers from the Department's Immediate Concern Unit (ICU) are assigned to all IEC and VC sites, they have developed the following checklist when VS results exceed IASLs at sites with suspected background contamination or operational activities:

1. Have all IEC/VC actions and forms been completed, including the submission of an acceptable IEC Source Control Report?
2. Has a subsurface depressurization system been installed properly, tested and post-commissioning adjustments been made to optimize performance?
3. Has post-installation monitoring shown that a minimum negative sub-slab pressure of 0.004 inches of water is maintained across the entire impacted area?
4. Does the CSM support the assumption that the active establishment (i.e., dry cleaner) is the source of the IASL exceedances?
5. Has it been confirmed that the contaminated subsurface air is being properly vented and is not short-circuiting to the building's air circulation system?

If the answer to all of the questions above is yes and the field inspection by the ICU case manager is acceptable, the IEC/VC portion of the case can be terminated.

The investigator should prepare a brief (1 to 2 page) summary which documents the successful installation of the SSDS, verifies that the impacted subsurface area is under the required minimum negative pressure and states that it is his (her) professional opinion that VI is no longer occurring at this site.

6.4.5 Engineered and VI Response Action Report

The ERA and VI Response Action Report documents the conditions before and after the installation of the vapor mitigation system. The timeframe for the submission of an ERA report is referenced in Section 6.1.2.4 for VCs and IECs and Appendix B. Prepare a separate report for each property with a copy presented to the property owner. The ERA report shall contain the following [N.J.A.C. 7:26E-1.11(a)7]:

Figure 6-1. Inspection of SSD fan and weatherproof cover

- general history and physical setting of the site;
- identification of receptors in the building;
- map of building location;
- design and as-built drawings showing all system components and electrical connections, as well as IA and SSSG sampling locations, extraction and observation holes, and mechanical combustion devices (hot water heater, clothes dryer, etc.);
- description and dates of each action taken including all sampling events, IRA and mitigation taken (e.g., IA sampling, communication testing, commissioning testing, etc.);
- summary and justification for field modifications to the system;
- all pre-mitigation communication testing results;
- pre-and post-mitigation IA and SSSG sampling results with interpretation;
- building survey forms for each sampling event;
- any building permits required by the local municipality;
- copy of the completed *Vapor Intrusion Mitigation System Inspection Checklist*;
- photos of system installation;
- summary of mitigation system diagnostic test measurements and commissioning values;
- air permit evaluation data (if required);
- certification of the report from a professional engineer, LSRP or Certified Radon Mitigation Specialist;
- OMM Plan; and,
- Monitoring, Maintenance and Evaluation Plan (if applicable).

For all documents prepared for the VI pathway, including letters sent to building occupants, the results are to be reported in units of µg/m^3. The analytical units of parts per billion by volume are no longer acceptable.

Additional information that is required in the ERA And VI Response Action Report submission can be found in the Department's Immediate Environmental Concern Technical Guidance, (http://www.nj.gov/dep/srp/guidance/).

6.5 Operation, Maintenance and Monitoring

To verify the continued proper operation of the mitigation system, an OMM program shall be implemented pursuant to N.J.A.C. 7:26E-1.11(a)9 and 1.15(e)2. The program should consist of inspections, diagnostic measurements from the mitigation system, and IA sampling (if applicable) to verify the proper operation indicating the continued system effectiveness in the mitigation of VI. OMM inspection frequencies and sampling designs are included in Table 6-2. A *Vapor Intrusion Mitigation System Inspection Checklist* (Appendix M) along with a *Subsurface Depressurization Monitoring Form* (Appendices N or O) or similar documentation should be completed to assist and document each OMM visit.

The design of some mitigation systems may not allow for diagnostic measurements of the system to determine if it is operating properly. In these cases, sampling of IA (or SSSG) may be the only diagnostic measurement available to confirm the mitigation of the VI pathway.

IA sample analysis for the OMM program is only required for the COCs and their breakdown products (unless IA samples have not been previously sampled at the building and analyzed for the full parameter list). The sampling locations may also be reduced based on previous analytical data and technical justification.

Part of the OMM program for an active mitigation system may require the payment for electrical service. If conditions permit, the use of renewable energy technology should be utilized to supplement the line service and eliminate or reduce energy costs. A separate power drop can be installed to allow the person responsible for conducting the mitigation to pay for energy costs directly or the building owner can be reimbursed periodically for electrical costs incurred due to the power usage of the mitigation system. If the investigator will be reimbursing the homeowner for the electrical cost of the mitigation system, a simple calculation can be used to determine the reimbursement cost to the homeowner based on energy supply cost. These calculations are included in Appendix P.

6.5.1 Variations in Baseline Parameters

During the OMM phase of a project, variations from established system commissioning (baseline) values or data trends may occur. A variation is defined as the % difference in the measured value from the system commissioning value as calculated below:

$$\%\ \text{Difference} = [|V_1 - V_2|/(V_1 + V_2)/2] * 100\%$$

A variation can also be determined by statistical calculations to determine if a value is significantly different from the system commissioning value or data trend. Variations from commissioning (baseline) values that are greater than 20% should trigger a reevaluation of the vapor mitigation system. The 20% variation provision should never be applied to analytical results of IA and soil gas samples. The analytical results shall be compared directly to the applicable screening levels [N.J.A.C. 7:26E-1.15(a)].

These occurrences of variations may be due to system malfunctions, improper design, changes in the sub-slab environment or changes to the building structure. If the cause of the deviation cannot be determined or repaired, the system should be re-commissioned.

If variations in measurements from SSDS commissioning values are greater than 20%, but the sub-slab probe vacuum measurements obtained across the building slab or mitigation area are greater than 0.004”wc, the system can be considered protective from VI and IA testing should not be required. The new sub-slab vacuums and system diagnostic measurements will then become the new system commissioning values.

In cases where sub-slab data are not available or exceedances of the IASL were measured, a corrective action should be completed that would involve an evaluation of the system for repairs, augmentation or redesign and implementation. After the work has been completed, VS should be repeated and re-commissioning of the system completed.

For passive or alternative system designs, if a second corrective action is required the system should be upgraded or converted to an active depressurization or venting system.

Included in Table 6.2 is a summary of the OMM mitigation and monitoring parameters, timeframes and corrective actions for various ERAs.

Table 6.2
Vapor Mitigation Verification and OMM Criteria

	Active SSDS or SSVS	**Passive SSDS or SSVS**	**Alternative VI Mitigation Systems**
Recommend Use	Existing buildings and IRA	New building construction only	When technically justified based on site-specific features (Section 6.2.4)
Commission Timeframe	30 - 45 days after system startup		
System Commission Parameters	IA samples, sub-slab negative pressure field measurements, system air flow measurements, pressure measurements	1) IA samples 2) SSSG (or void space) samples 3) Air flow measurements for SSVS	1) IA samples 2) SSSG or void space samples, sub-slab negative pressure field measurements and/or other system-specific parameters selected
VS	Perform immediately (same day) following system commissioning. Minimum one round of IA samples in heating season.[1] Collect appropriate system diagnostic measurements to establish baseline values.	Perform immediately (same day) following system commissioning. Minimum one round of IA samples in heating season.[1] In addition, collect appropriate number of sub-slab (or void space) soil gas samples to establish baseline values.	Perform (same day) following system commissioning. Minimum one round of IA samples in heating season.[1] In addition, collect appropriate number of sub-slab (or void space) soil gas samples and/or system diagnostic measurements to establish baseline values.
OMM	**First year OMM**: 1) Quarterly inspection of system[3]. 2) Verify the commissioning values[3] **Second year OMM & beyond**: 1) Annual inspection of system[3] 2) Annual collection of appropriate system diagnostic measurements and verify onsistency[3].with baseline values	**First year OMM**: 1) Quarterly system[3] inspection. 2) Sampling of IA and SSSG (or void space) during heating season[1] following VS sampling **Second year OMM**: 1) Semi-annual inspection of system[3] 2) SSSG (or void space) sampling during heating season[1] **Third year and beyond:** 1) Annual inspection of system[3] 2) IA and SSSG (or void space) sampling during heating season[1] every year until the results are consistent; THEN 3) IA sampling during the heating season every 5 years.	**First and second year OMM**: 1. Quarterly inspection of system[3]. 2. Annual sampling of IA during heating season [1]. 3. Annual SSSG (or void space) sampling (when appropriate). 4. Quarterly collection of commissioning measurements and verify consistency[2]. **Third year OMM & beyond**: 1. Annual inspection of system[3]. 2. Annual collection of appropriate commissioning parameters and verify consistency[2,3]. 3. SSSG (or void space) sampling (when appropriate) and IA sampling during heating season[1] every three years[2]
Corrective actions during VS or OMM	For an exceedance of NJDEP IASL[4] or variation[5] from commissioning values: 1) Check system for malfunctions, modify or augment the system. 2) Re-commission the system. 3) Collect VS & re-start OMM	For an exceedance of NJDEP IASL[4] or variation[5] from commissioning values: 1) Check system for malfunctions, modify or augment the system. 2) Re-commission the system. 3) Collect VS & re-start OMM	For an exceedance of NJDEP IASL[4] or variation[5] from the commissioning values: 1) Check system for malfunctions, modify or augment the system. 2) Re-commission the system. 3) Collect VS & re-start OMM
		Convert to active system if: 1) Second corrective action is required; or 2) Increasing trends in SSSG (or void space) samples that exceed NJDEP SGSLs during OMM (not VS)	**Upgrade to active SSDS if:** 1) Second corrective action required; or 2) Increasing trends in SSSG (or void space) soil gas results that exceed NJDEP SGSLs during OMM (not VS)

1 – Heating season is from November 1 to March 31.
2 –If appropriate for the evaluation of the ERA
3 – For systems that are larger and a greater complexity may require a greater frequency of inspections.
4 – Exceedances are concentrations of contaminants not attributable to background
5 – A variation of greater than 20% difference from the system commissioning value or statistical evaluation of the data indicating a significant difference.

6.5.2 Long-Term Monitoring

There are situations where LTM, without system installation, may be the appropriate mitigation action. Specifically, LTM can be performed when the investigation of a building reveals that the soil gas results are in excess of the applicable Department SGSL and the IA results are below the Department IASL. The frequency of inspections and IA sampling for buildings with soil gas concentrations <10X the Department SGSL and ≥10X the Department SGSL are summarized in Table 6.3. The building inspection should include an evaluation of the competence of the building envelope to determine if any changes have been made or formed to allow vapors to easily enter the building (e.g., installation of a sump, addition to the building, cracks in floor, etc.). The collection of SSSG samples is optional during LTM.

Monitoring can be altered based on professional judgment. Examples include decreasing the IA sampling frequency when long-term trends are available or ground water concentrations are decreasing. If soil gas or ground water concentrations increase, an increase in sampling frequency should be implemented. If IA sampling yields results for the COCs that are above the Department IASL or RAL at any time (with consideration of background sources), an ERA or VI response action should be implemented. LTM should be incorporated into the MME for the CEA/deed notice. Monitoring can be terminated following the guidelines set in *System Termination* (Section 6.6).

Table 6.3
Long Term Monitoring Sampling Designs

Sub-Slab Soil Gas >10X NJDEP SGSL	**Sub-Slab Soil Gas>NJDEP SGSL and ≤10X NJDEP SGSL**
First and second year LTM: 1 Semi-annual inspection of building. 2. Semi-annual sampling of IA[2]. Third year LTM & beyond: 1. Annual inspection of building. 2. Annual sampling of IA in heating season[1].	First and second year LTM: 1 Semi-annual inspection of building. 2. Annual sampling of IA during heating season[1]. Third to sixth year LTM: 1. Annual inspections of building. 2. Sampling of IA in years 4 & 6 of LTM[1]. After sixth year LTM: 1. Annual inspection of building. 2. Sampling of IA every 5 years in heating season[1].

1 – Heating season is from November 1 to March 31 (Winter).
2 – Winter and summer.

6.6 VI Mitigation Termination

Site cleanup efforts should reduce contaminant levels in ground water, soil, soil gas, etc. to levels that will no longer result in VI. Once it is concluded that the VI source has been properly remediated in accordance with N.J.A.C. 7:26E, sampling should be implemented to allow for possible cessation of operations of the VI mitigation system and removal of institutional controls.

System termination sampling is based on the results of IA and SSSG sample results. Samples should be obtained at the same locations that were used to identify the VI impacts. Analytical parameters for the system termination samples should include the same list of COCs analyzed during the verification sampling.

Prior to sampling for system termination, shut down the mitigation system for a period of 30-45 days to allow re-development of subsurface contaminant concentrations, if present.

A vapor mitigation system or LTM may only be terminated with Department approval based on contaminant levels below the appropriate screening levels for IA and soil gas for two (2) rounds of sample data with at least one (1) round performed during the heating season. The mitigation system should be turned back on between sampling events to maintain the protectiveness from potential impacts to people in the building.

Upon system termination, arrangements should be made with the building owners to remove (if requested) any equipment and/or monitoring devices associated with the mitigation system or LTM operations and perform repairs to the building from their removal.

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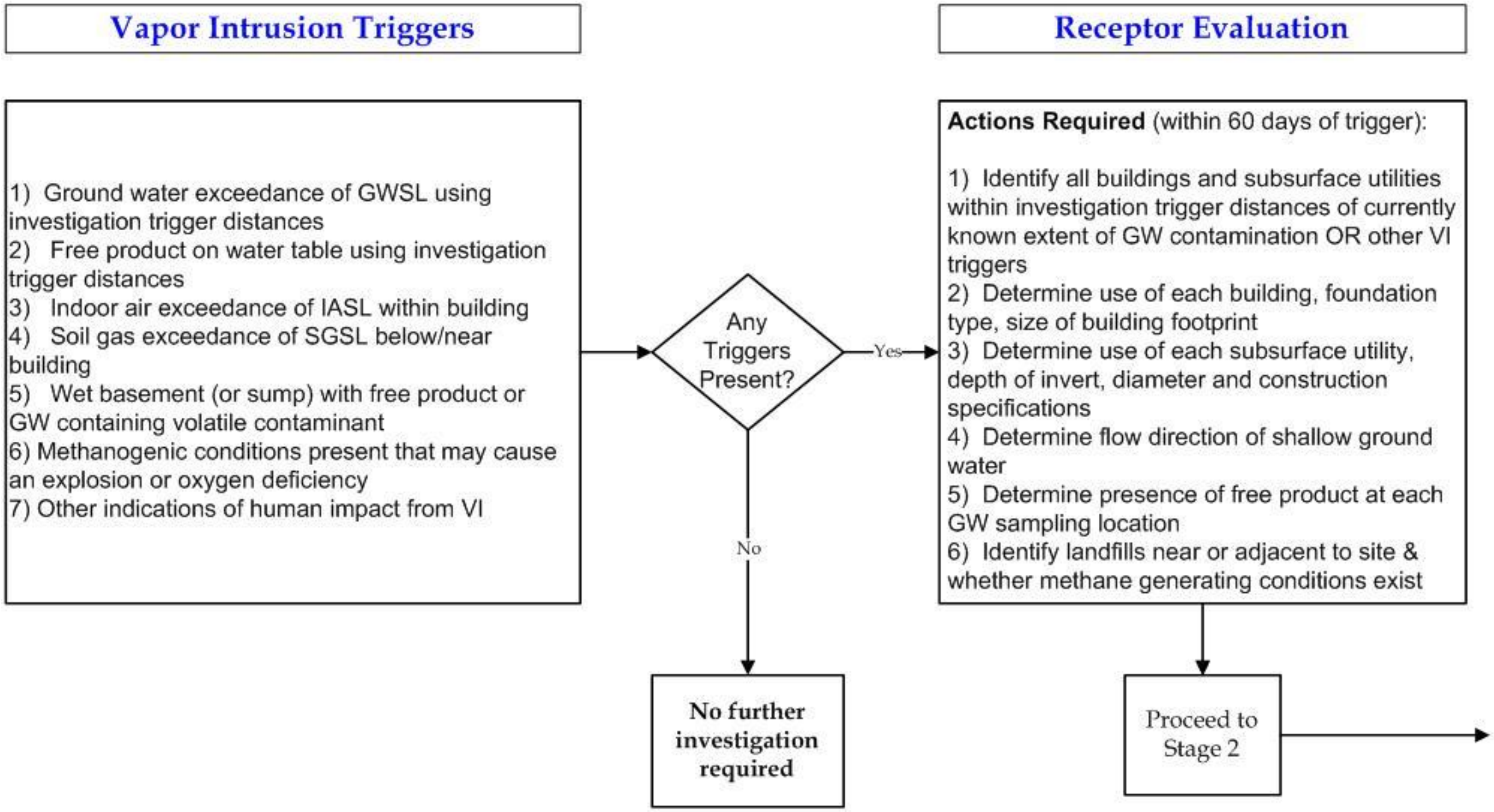
APPENDIX A

Decision Flow Chart

Decision Flow Chart for Vapor Intrusion Pathway

Receptor Evaluation (Stage 1)



Vapor Intrusion Triggers

1) Ground water exceedance of GWSL using investigation trigger distances
2) Free product on water table using investigation trigger distances
3) Indoor air exceedance of IASL within building
4) Soil gas exceedance of SGSL below/near building
5) Wet basement (or sump) with free product or GW containing volatile contaminant
6) Methanogenic conditions present that may cause an explosion or oxygen deficiency
7) Other indications of human impact from VI

No further investigation required

Receptor Evaluation

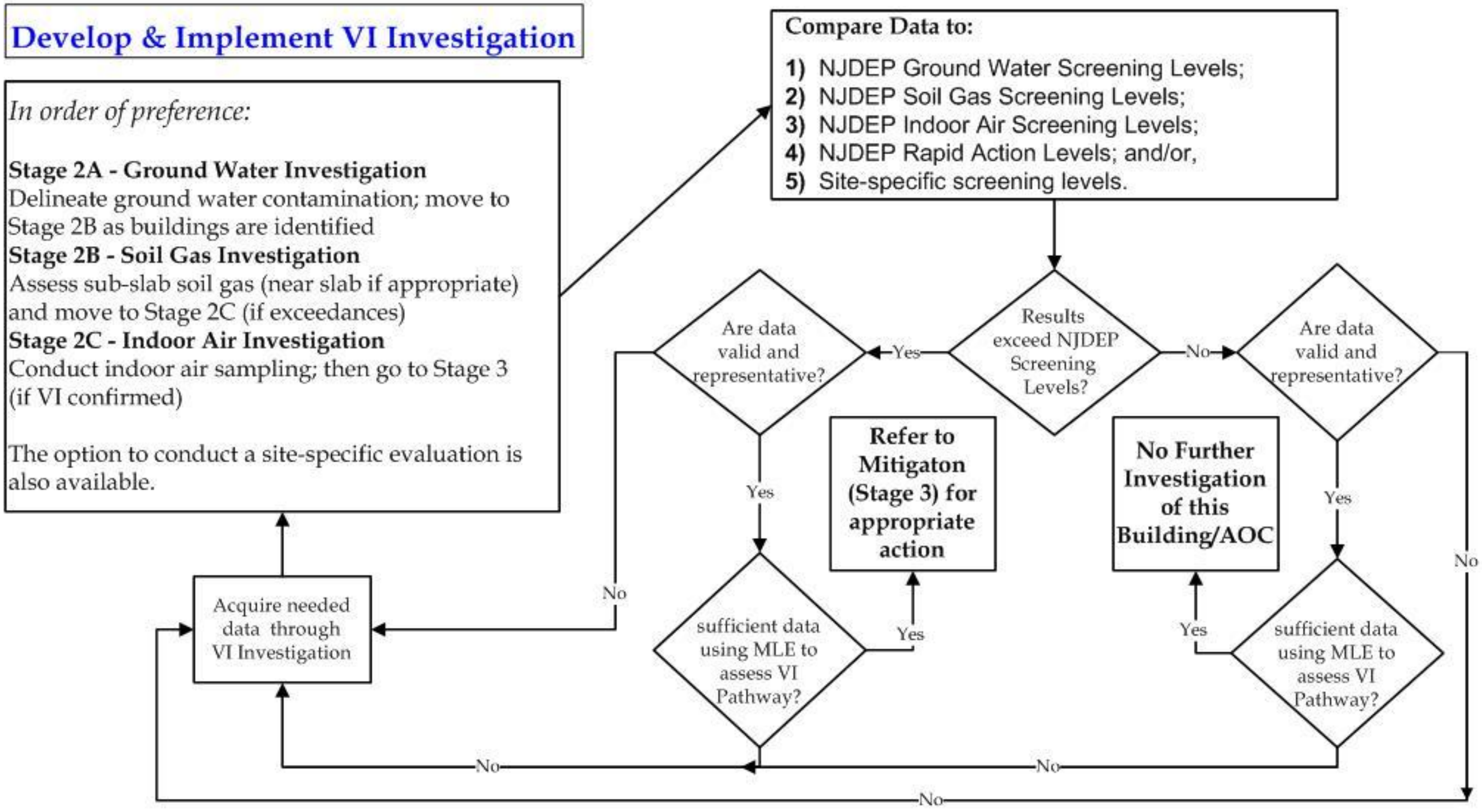
Actions Required (within 60 days of trigger):

1) Identify all buildings and subsurface utilities within investigation trigger distances of currently known extent of GW contamination OR other VI triggers
2) Determine use of each building, foundation type, size of building footprint
3) Determine use of each subsurface utility, depth of invert, diameter and construction specifications
4) Determine flow direction of shallow ground water
5) Determine presence of free product at each GW sampling location
6) Identify landfills near or adjacent to site & whether methane generating conditions exist

Proceed to Stage 2

Decision Flow Chart for Vapor Intrusion Pathway

VI Investigation (Stage 2)



Decision Flow Chart for Vapor Intrusion Pathway

Mitigation Decision Matrix - Stage 3

		Indoor Air Concentrations (for COCs)	
		< IASL	**>IASL**
Sub-Slab Soil Gas Concentrations (for COCs)	**<SGSL**	**No Action**	**No Action** * (if no other subsurface source)
	>SGSL to 10X SGSL	**Monitor**	**Mitigate**
	>10X SGSL	**Monitor / Mitigate**	**Mitigate**

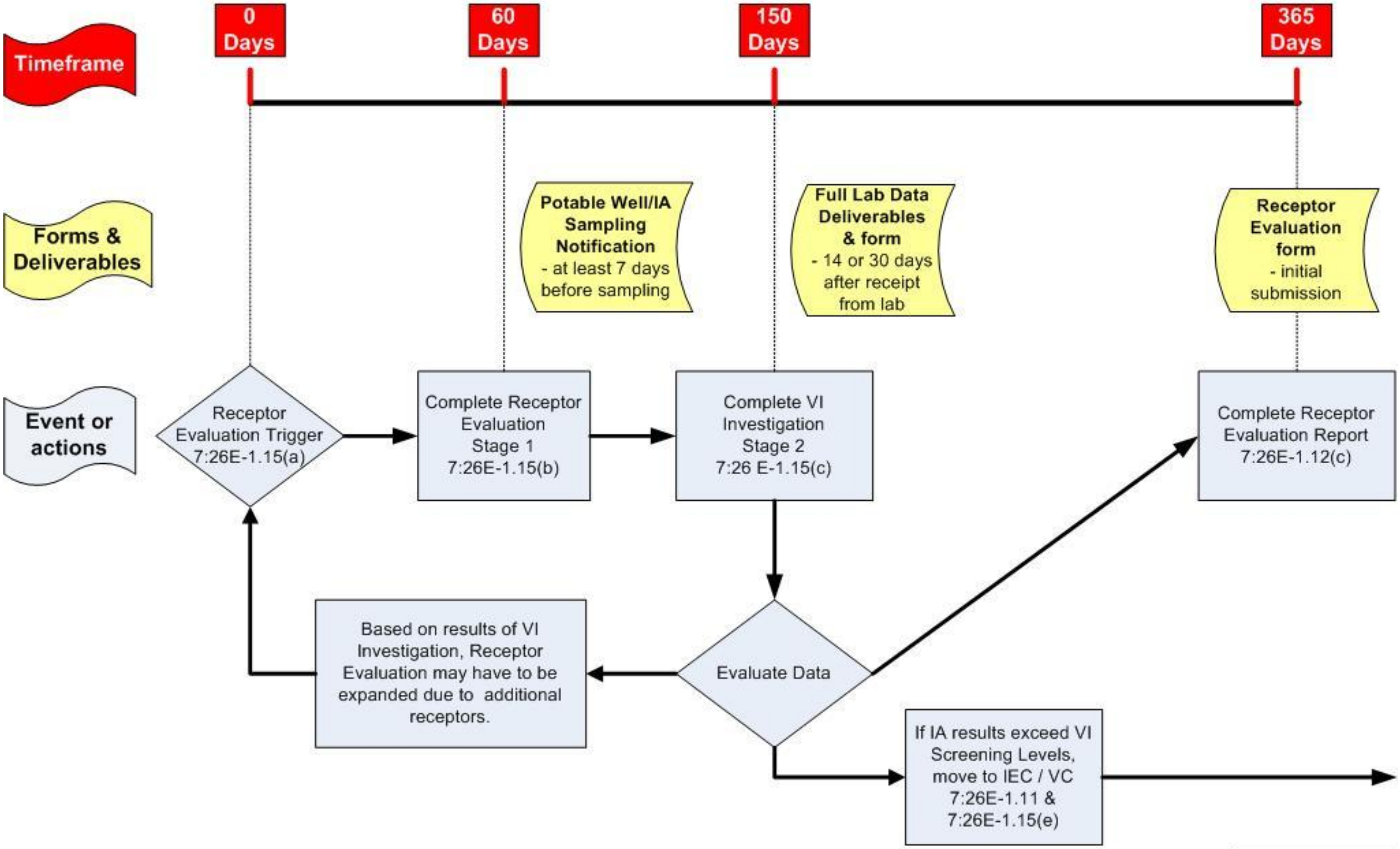
Notes:

* Investigator should consider the potential for vadose zone (soil) contamination and/or preferential pathways as part of the assessment of vapor intrusion before concluding "no further action"

APPENDIX B

Vapor Intrusion Timeline

Receptor Evaluation / VI Investigation



Timeframe

0 Days

60 Days

150 Days

365 Days

Forms & Deliverables

Potable Well/IA Sampling Notification
- at least 7 days before sampling

Full Lab Data Deliverables & form
- 14 or 30 days after receipt from lab

Receptor Evaluation form
- initial submission

Event or actions

Receptor Evaluation Trigger 7:26E-1.15(a)

Complete Receptor Evaluation Stage 1 7:26E-1.15(b)

Complete VI Investigation Stage 2 7:26 E-1.15(c)

Complete Receptor Evaluation Report 7:26E-1.12(c)

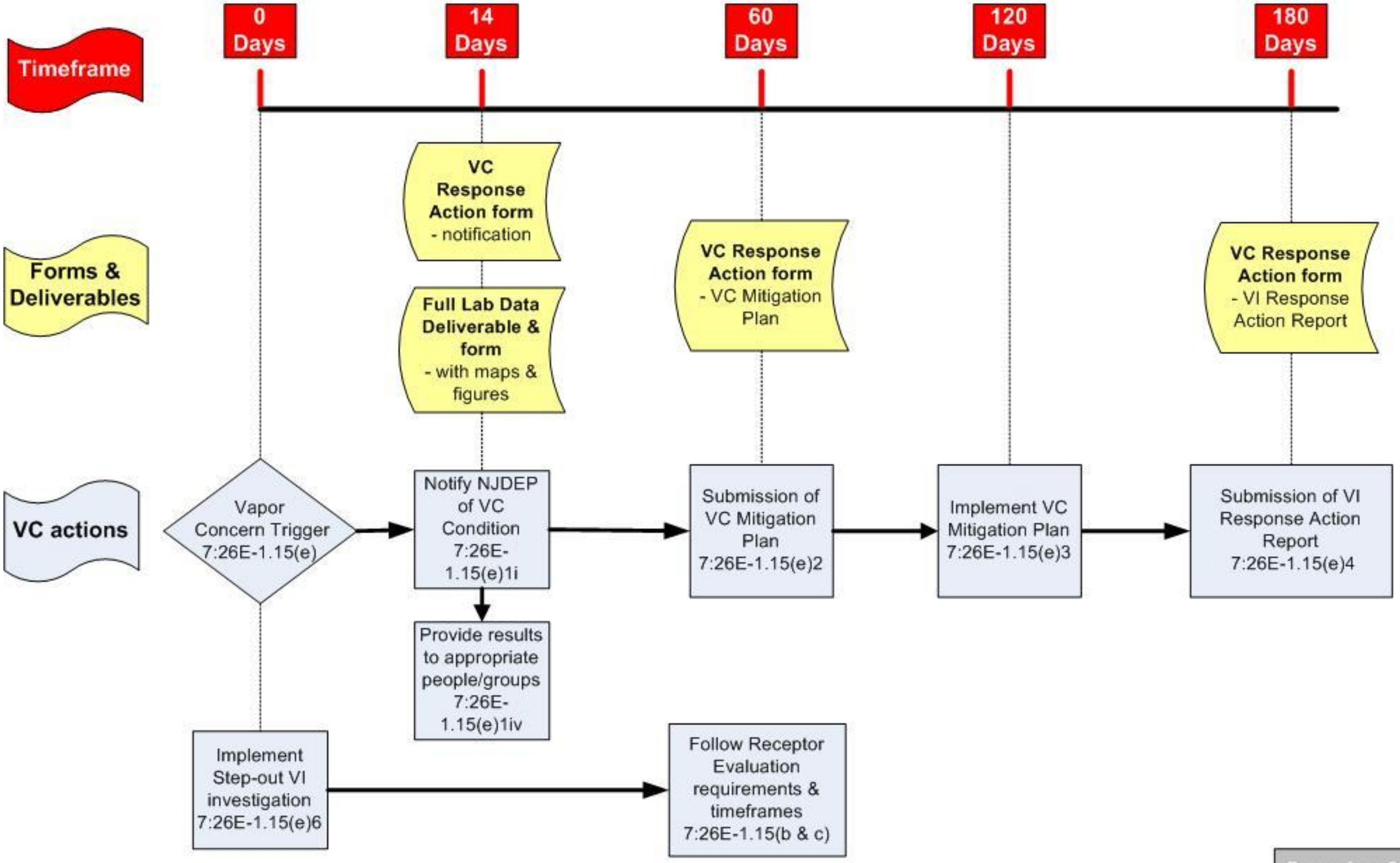
Evaluate Data

Based on results of VI Investigation, Receptor Evaluation may have to be expanded due to additional receptors.

If IA results exceed VI Screening Levels, move to IEC / VC 7:26E-1.11 & 7:26E-1.15(e)

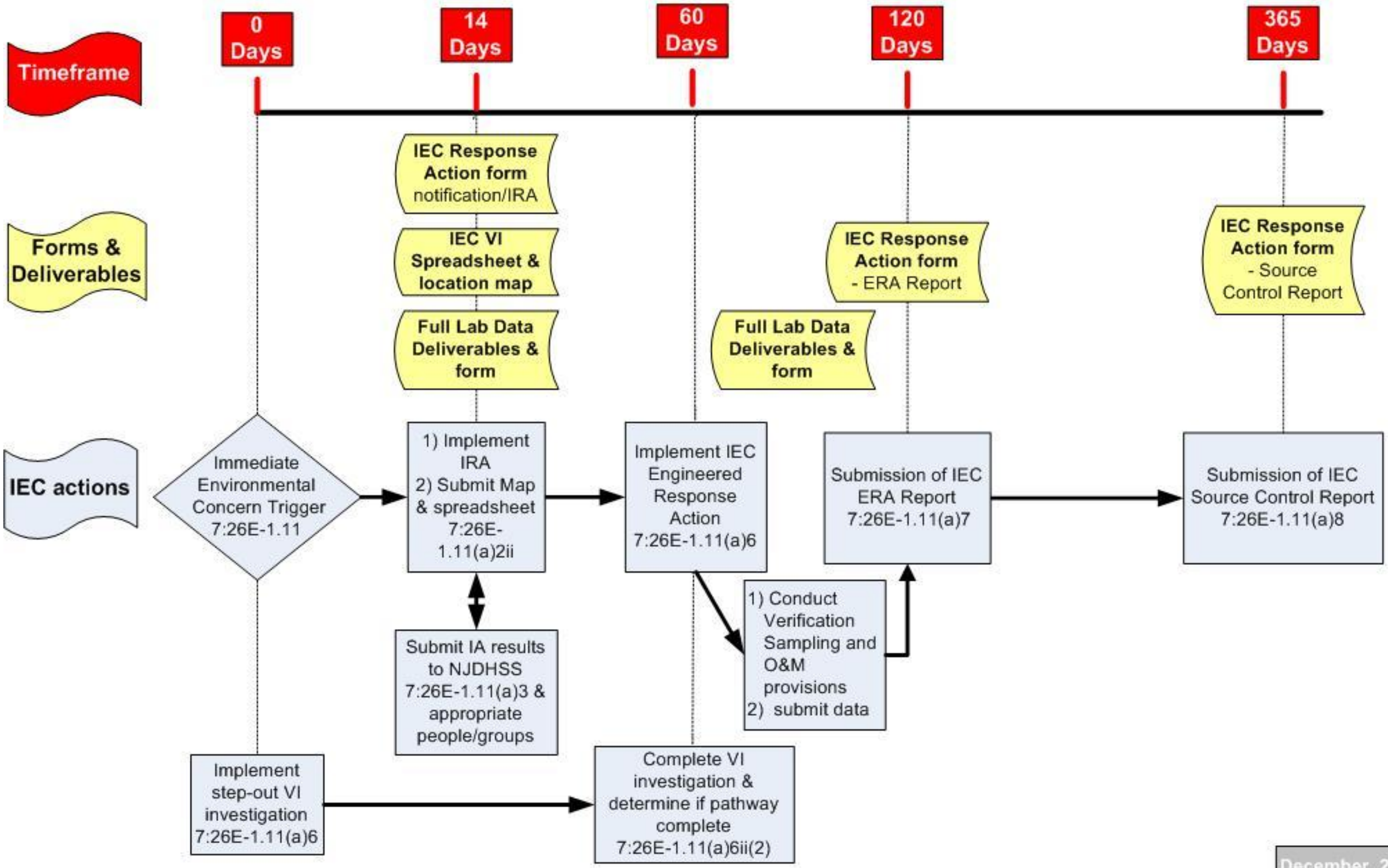
December, 2012

VI Vapor Concern



December, 2012

VI Immediate Environmental Concern



Timeframe

0 Days

14 Days

60 Days

120 Days

365 Days

Forms & Deliverables

IEC Response Action form notification/IRA

IEC VI Spreadsheet & location map

Full Lab Data Deliverables & form

Full Lab Data Deliverables & form

IEC Response Action form - ERA Report

IEC Response Action form - Source Control Report

IEC actions

Immediate Environmental Concern Trigger 7:26E-1.11

1) Implement IRA
2) Submit Map & spreadsheet 7:26E-1.11(a)2ii

Submit IA results to NJDHSS 7:26E-1.11(a)3 & appropriate people/groups

Implement IEC Engineered Response Action 7:26E-1.11(a)6

1) Conduct Verification Sampling and O&M provisions
2) submit data

Submission of IEC ERA Report 7:26E-1.11(a)7

Submission of IEC Source Control Report 7:26E-1.11(a)8

Implement step-out VI investigation 7:26E-1.11(a)6

Complete VI investigation & determine if pathway complete 7:26E-1.11(a)6ii(2)

December, 2012

APPENDIX C

ITRC Conceptual Site Model Checklist

CONCEPTUAL SITE MODEL (CSM) CHECKLIST

The information included in this checklist may be useful for developing the site-specific conceptual migration model and in planning the 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) (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, multiple-story); identify if there is an elevator shaft in the building (if applicable)*

☐ *Describe the foundation construction including:*

- *Type (e.g., basement, crawlspace, slab on grade)*
- *Floor construction (e.g., concrete, dirt)*
- *Depth below grade.*

☐ *Describe the HVAC system in the building including:*

- *Furnace/air conditioning type (e.g., forced air, radiant)*
- *Furnace/air conditioning 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 sub-slab ventilation systems or moisture barriers present on existing buildings, or identify building- and fire-code requirements for sub-slab 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,*

- *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 the Phreatic (saturated) Zone*
    - *Note any seasonal water table 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*
    - *Where does the water table intersect well screen interval or note 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*

☐ *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

Indoor Air Building Survey and Sampling Form

New Jersey Department of Environmental Protection

INDOOR AIR BUILDING SURVEY
and SAMPLING FORM

Preparer's name: ___________________________________ Date: _________________________

Preparer's affiliation: _______________________________ Phone #: ______________________

Site Name: _______________________________________ Case #: _______________________

Part I - Occupants

Building Address: ____

Building Block: _____________ Lot: ____________

Property Contact: ________________________ Owner / Renter / other: _______________________

Contact's Phone: home ( )__________ work ( )______________ cell ( )____________

# of Building occupants: Children under age 13 _____ Children age 13-18 ______ Adults _____

Part II – Building Characteristics

Building type: residential / multi-family residential / office / strip mall / commercial / industrial

Describe building: ____ Year constructed: _________

Sensitive population: day care / nursing home / hospital / school / other (specify): _______________

Number of floors below grade: ______ (full basement / crawl space / slab on grade)

Number of floors at or above grade: ______

Depth of basement below grade surface: ______ ft. Basement size: _______ ft^2

Basement floor construction: concrete / dirt / floating / stone / other (specify): ________________

Foundation walls: poured concrete / cinder blocks / stone / other (specify) ________________

Basement sump present? *Yes / No* Sump pump? *Yes / No* Water in sump? *Yes / No*

Type of heating system (circle all that apply):

hot air circulation hot air radiation wood steam radiation
heat pump hot water radiation kerosene heater electric baseboard
other (specify): ________________________

Type of ventilation system (circle all that apply):

central air conditioning mechanical fans bathroom ventilation fans
individual air conditioning units kitchen range hood fan outside air intake
other (specify): _________________

Type of fuel utilized (circle all that apply):

Natural gas / electric / fuel oil / wood / coal / solar / kerosene

Are the basement walls or floor sealed with waterproof paint or epoxy coatings? *Yes / No*

Is there a whole house fan? *Yes / No*

Septic system? *Yes / Yes (but not used) / No*

Irrigation/private well? *Yes / Yes (but not used) / No*

Type of ground cover outside of building: grass / concrete / asphalt / other (specify) _____________

Existing subsurface depressurization (radon) system in place? *Yes / No* *active / passive*

Sub-slab vapor/moisture barrier in place? *Yes / No*
Type of barrier: ____________________________

Part III - Outside Contaminant Sources

NJDEP contaminated site (1000-ft. radius): ____

Other stationary sources nearby (gas stations, emission stacks, etc.): _____________________________

Heavy vehicular traffic nearby (or other mobile sources): ______________________________________

Part IV – Indoor Contaminant Sources

Identify all potential indoor sources found in the building (including attached garages), the location of the source (floor and room), and whether the item was removed from the building 48 hours prior to indoor air sampling event. Any ventilation implemented after removal of the items should be completed at least 24 hours prior to the commencement of the indoor air sampling event.

Potential Sources	**Location(s)**	**Removed** **(Yes / No / NA)**
Gasoline storage cans		
Gas-powered equipment		
Kerosene storage cans		
Paints / thinners / strippers		
Cleaning solvents		
Oven cleaners		
Carpet / upholstery cleaners		
Other house cleaning products		
Moth balls		
Polishes / waxes		
Insecticides		
Furniture / floor polish		
Nail polish / polish remover		
Hairspray		
Cologne / perfume		
Air fresheners		
Fuel tank (inside building)		NA
Wood stove or fireplace		NA
New furniture / upholstery		
New carpeting / flooring		NA
Hobbies - glues, paints, etc.		

Part V – Miscellaneous Items

Do any occupants of the building smoke? *Yes / No* How often? ______________

Last time someone smoked in the building? ____________ hours */ days ago*

Does the building have an attached garage directly connected to living space? *Yes / No*

If so, is a car usually parked in the garage? *Yes / No*

Are gas-powered equipment or cans of gasoline/fuels stored in the garage? *Yes / No*

Do the occupants of the building have their clothes dry cleaned? *Yes / No*

If yes, how often? weekly / monthly / 3-4 times a year

Do any of the occupants use solvents in work? *Yes / No*

If yes, what types of solvents are used? ____

If yes, are their clothes washed at work? *Yes / No*

Have any pesticides/herbicides been applied around the building or in the yard? *Yes* / No

If so, when and which chemicals? ____

Has there ever been a fire in the building? *Yes / No* If yes, when? _____________

Has painting or staining been done in the building in the last 6 months? *Yes / No*

If yes, when __________________ and where? _____________________________

Part VI – Sampling Information

Sample Technician: _____________________________ Phone number: ( ) _______ - __________

Company: ____

Sample Source: Indoor Air / Sub-Slab / Near Slab Soil Gas / Exterior Soil Gas

Were “Instructions for Occupants” followed? Y*es / No*

If not, describe modifications: ____

Sample locations (floor, room):

SAMPLING DATA

Sample #	Location	Analytical Method	Sample Volume	Sample Time	Sample Date	Sampler Type	Ambient Temp (°F)

-Drawing of Sample Location(s) in Building

Type of field instrument used (include summary of results): ______________________________

Part VII - Meteorological Conditions

Was there significant precipitation within 12 hours prior to (or during) the sampling event? *Yes / No*

Describe the general weather conditions: ____

____

Part VIII – General Observations

Provide any information that may be pertinent to the sampling event and may assist in the data interpretation process.

APPENDIX E

Evaluating Indoor Air near VOC Contaminated Sites Fact Sheet

Fact Sheet

Evaluating Indoor Air near VOC Contaminated Sites

What are VOCs?

Volatile organic compounds (VOCs) are a class of chemicals that readily evaporate at room temperature. Gasoline, dry cleaning fluid, degreasing agents (solvents) and paint thinners are several examples of products that contain these compounds. VOCs may be found in soil and/or ground water due to spillage onto the ground, leaks from underground storage tanks and other types of discharges.

How VOCs in soil or ground water can affect indoor air

If VOCs contaminate soil or ground water at a site, it is important to evaluate nearby buildings for possible impacts from **vapor intrusion**. Vapor intrusion occurs when gases from the contaminated soil or ground water seep through cracks and holes in foundations or slabs of buildings and accumulate in basements, crawl spaces or living areas, as shown in the diagram below.

A variety of factors can influence whether vapor intrusion will occur at a building located near soil or ground water contaminated with VOCs. These include, but are not limited to, the concentration of the contaminants, the type of soil, the depth to ground water, the construction of the building, the condition of the foundation or slab and the existence of underground utilities that can create pathways for vapors to travel.

Short term exposure to high levels of organic vapors can cause eye and respiratory irritation, headache and/or nausea. Breathing low levels of organic vapors over a long period of time may increase an individual's risk for respiratory ailments, cancer and other health problems.

Organic vapors can be present inside a building at potentially harmful levels without being detectable by odor. **Sub-slab soil gas testing**, **near-slab soil gas testing** and/or **indoor air testing** are usually required to determine whether vapor intrusion is occurring at a property.

Testing for vapor intrusion

If your home or building is located near VOC-contaminated soil or ground water, NJDEP or an environmental contractor may ask permission to evaluate your property for vapor intrusion. This

(over)

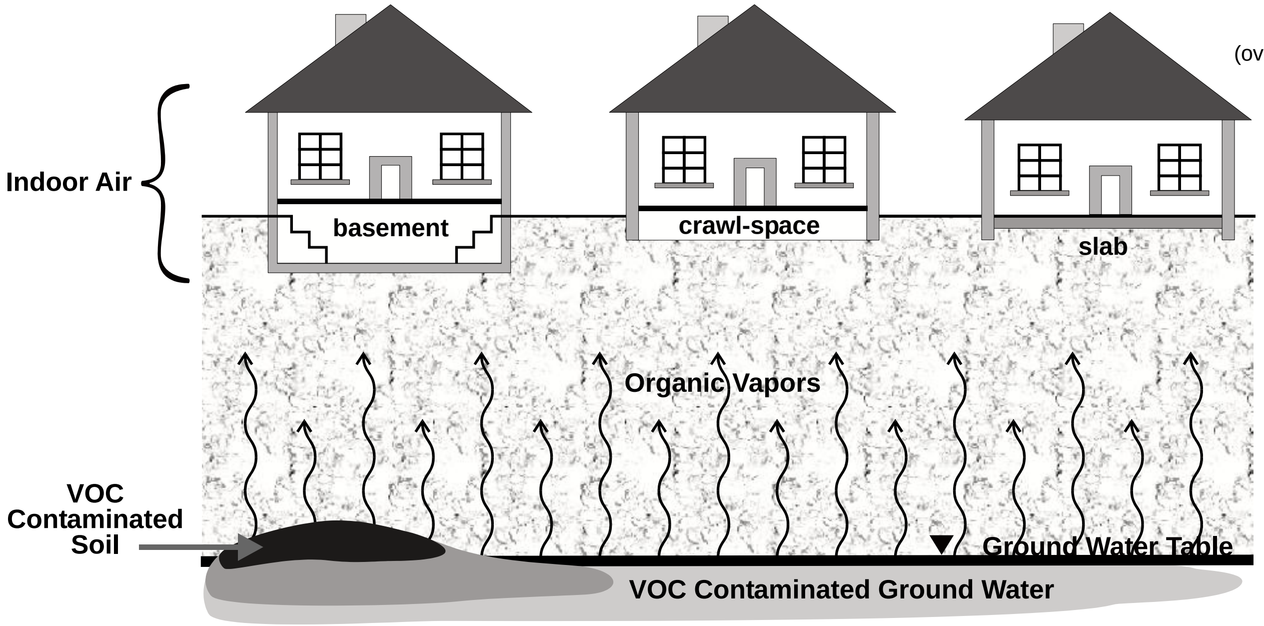


Diagram adapted from USEPA's *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Ground Water and Soils, November 2002*

New Jersey Department of Environmental Protection
Site Remediation Program

process typically involves first conducting sub-slab soil gas testing to check for vapors beneath the building, followed by indoor air testing, if necessary. During sub-slab testing, a small hole is bored through the basement floor or slab and a sample of the **soil gas** (the air trapped between the soil particles) is collected using an evacuated air testing canister (see below). If it is not possible to collect a soil gas sample from beneath the floor or slab, the sample may be collected by placing a probe in the soil directly adjacent to the building (near-slab testing). The soil gas sample is then sent to a certified laboratory to be analyzed for VOCs. If the analysis shows VOCs related to the subsurface contamination are present above NJDEP's Soil Gas Screening Levels (SGSL), then indoor air testing is necessary.

During indoor air testing, a canister is placed in the basement, crawl space or other part of the building for a period of time (normally 24 hours). If the analysis of the indoor air sample shows VOCs related to the subsurface contamination are present above NJDEP's Indoor Air Screening Levels (IASL), vapor intrusion is likely occurring. Additional evaluation of the property may be needed to confirm this finding.

Background contamination

Many materials and substances commonly found in commercial and residential settings, such as paints, paint thinners, gasoline-powered machinery, certain building materials and cleaning products, dry cleaned clothing and cigarette smoke, contain VOCs that may be detected by indoor air testing. Even VOCs from motor vehicle emissions and other outdoor sources can contaminate indoor air. When VOCs from these sources are detected during indoor air testing, they are referred to as **background contamination.**

It is sometimes difficult to determine whether the VOCs detected inside a building are due to vapor intrusion, background contamination or a combination of both. Before your building is evaluated for vapor intrusion you should receive a copy of NJDEP's *Instructions for Occupants – Indoor Air Sampling Events*. Please follow these instructions to minimize background contamination and help ensure that the test results are as definitive as possible.

Addressing vapor intrusion

If testing confirms vapor intrusion is causing potentially harmful levels of VOCs to accumulate inside a building, a **subsurface depressurization system** may be installed at the property. The system prevents vapors from entering the building by continuously venting the contaminated air beneath the basement slab or crawl space to the exterior of the structure. Subsurface depressurization systems are also used throughout the country to reduce levels of naturally occurring radon gas in buildings. See NJDEP's fact sheet titled *Subsurface Depressurization Systems* for more information about how these systems work.

***Instructions for Occupants — Indoor Air Sampling Events*, the *Subsurface Depressurization Systems* fact sheet and general information about vapor intrusion can be found in NJDEP's Vapor Intrusion Guidance Technical document, or the Department's website at http://www.state.nj.us/dep/srp/guidance/vaporintrusion.**

An evacuated air testing canister. The pressure inside the canister is initially set lower than the indoor air, causing air to flow into the canister when the valve is opened.

Information for Residents and Property Owners

Contact Name ______________________

Agency/Company ______________________

Phone Number ______________________

Email Address ______________________

Sampling Date/Time ______________________

Notes/Instructions ______________________

____

____

____

____

March 2011

APPENDIX F

Instructions for Occupants – Indoor Air Sampling Events (English and Spanish)

New Jersey Department of Environmental Protection
Site Remediation Program

Instructions for Occupants for Indoor Air Sampling

Representatives of ____ will be collecting one or more indoor air samples from your building in the near future. Your assistance is requested during the sampling program in order to collect an indoor air sample that is both representative of indoor conditions and avoids the common background indoor air sources associated with occupant activities and consumer products.

Please follow the instructions below starting at least 48 hours prior to and during the indoor air sampling event:

☑ Operate your furnace and whole house air conditioner as appropriate for the current weather conditions

☑ Do not use wood stoves, fireplaces or auxiliary heating equipment

☑ Do not open windows or keep doors open.

☑ Avoid using window air conditioners, fans or vents

☑ Do not smoke in the building

☑ Do not use air fresheners or odor eliminators

☑ Do not use paints or varnishes (up to a week in advance, if possible)

☑ Do not use cleaning products (e.g., bathroom cleaners, furniture polish, appliance cleaners, all-purpose cleaners, floor cleaners)

☑ Do not use cosmetics, including hair spray, nail polish remover, perfume, etc.

☑ Avoid bringing freshly dry cleaned clothes into the building

☑ Do not engage in hobbies indoors that use solvents

☑ Do not apply pesticides

☑ Do not store containers of gasoline, oil or petroleum based or other solvents within the building or attached garages (except for fuel oil tanks)

☑ Do not operate or store automobiles in an attached garage

☑ Do not operate gasoline powered equipment within the building, attached garage or around the immediate perimeter of the building

You will be asked a series of questions about the structure, consumer products you store in your building, and occupant activities typically occurring in the building. These questions are designed to identify "background" sources of indoor air contamination. While this investigation is looking for a select number of chemicals related to the subsurface contamination, the laboratory will be analyzing the indoor air samples for a wide variety of chemicals. As a result, chemicals such as tetrachloroethene that is commonly used in dry cleaning or acetone found in nail polish remover might be detected in your sample results.

Typical air sampling canister

Your cooperation is greatly appreciated.

If you have any questions about these instructions, please feel free to contact

____ at ___________________________________.

New Jersey Department of Environmental Protection
Site Remediation Program

Instrucciones Para Ocupantes
Eventos de Muestreo de Aire de Interiores

En un futuro cercano, representantes del Departamento de Protección Ambiental de Nueva Jersey (NJDEP) o una firma de consultoria ambiental estaran colectando una o mas muestras de aire del interior de su edificio. NJDEP requiere de su ayuda para colectar una muestra del interior en su estructura que a la vez es representativa de las condiciones del interior y el evitar las fuentes comunes de antecedentes de contaminación de aire asociado con actividades de la casa y productos de consumo.

Por favor siga las instrucciones abajo mencionadas comenzando por lo menos 48 horas antes de y durante el evento de muestreo:

☑ Opere su horno y el aire acondicionado de toda la casa apropiadamente a las actuales condiciones del tiempo

☑ No use estufas de leña, chimeneas o equipos auxiliares de calefacción.

☑ No abrir las ventanas o mantener las puertas abiertas.

☑ Evite usar aires acondicionados, abanicos o ventiladores de ventanas

☑ No fume dentro del edificio

☑ No use refrescantes de aire o eliminadores de olor

☑ No use pinturas o barniz (hasta una semana por adelantado, si es posible)

☑ No use productos de limpieza (ej. Limpiadores de baño, cera para muebles, limpiadores de aparatos electrodomésticos, limpiadores para “todo propósito”, limpiadores del piso)

☑ No use cosméticos, incluyendo fijador del cabello, removedor de esmalte de uñas, perfume

☑ Evite traer ropa recientemente limpiada en seco (de la tintorería) al edificio

☑ No participe en pasatiempos en el interior del edificio que usen solventes

☑ No aplique pesticidas

☑ No almacene envases de gasolina, aceite o derivados de petróleo u otros solventes dentro del edificio o garajes adjuntos (con exepción de tanques de aceite de combustible -“fuel oil”)

☑ No opere o almacene automoviles en un garaje adjunto

☑ No opere equipos impulsados por gasolina dentro del edificio, garaje adjunto o alrededor de los perímetros inmediatos del edificio

Se le hara una serie de preguntas acerca de la estructura, productos de consumo que usted almacena en su edificio, y actividades de la casa típicamente ocurriendo dentro del edificio. Esas preguntas son diseñadas para identificar “antecedentes” de fuentes de contaminación de aire dentro del edificio. Mientras esta investigación esta buscando por un selecto número de químicos relacionados a la contaminación de la sub superficie, el laboratorio estará analizando las muestras de aire del interior por una variedad de químicos. Así, “tetrachloroethene” usado en tintorerías o acetona encontrada en el removedor de esmalte de uñas podria ser encontrado en los resultados de su muestra.

Su cooperación es grandemente apreciada. Si usted tiene alguna pregunta acerca de estas instrucciones, por favor sienta la libertad de contactar a LSRP al _______________________________.

APPENDIX G

Background Volatile Levels in Homes: Literature Review

BACKGROUND LEVELS OF VOLATILE ORGANIC CHEMICALS IN HOMES: A REVIEW OF RECENT LITERATURE

Introduction

For over 20 years, it has been known that many volatile organic chemicals are present in the indoor air of homes (Wallace 1986). While small contributions from outdoor air concentrations of volatiles may occur, indoor levels are typically higher (Sexton et al. 2004, Weisel et al. 2005). This is due to indoor sources of these chemicals, including the use of consumer products, the presence of home furnishings, carpeting or other building materials, the use of construction materials and fuels, and activities such as smoking and cooking. Also, vapors from gasoline, other fuels, and other chemicals may invade the indoor air space from an attached garage (Weisel et al. 2008). For this reason, when investigating the possibility of vapor intrusion occurring in homes and other buildings, it should be evaluated whether or not volatile contaminant concentrations measured in homes are present due to these sources, rather than from vapor intrusion from underlying contaminated ground water or soil.

The previous version of this guidance reviewed several past studies, dating back to the 1980s, that measured indoor background concentrations of volatile organic chemicals. It has been observed, however, that indoor contaminant concentrations from more recent studies have tended to be lower than those from earlier studies, due to a decrease of some of these contaminants in consumer products, construction materials, etc. (Hodgson and Levin 2003, Zhu et al. 2005). Therefore, this updated literature review focuses on studies that have been conducted from the late 1990s to the present. The studies are briefly summarized below.

New Jersey Department of Environmental Protection study

The NJDEP developed its own database of indoor air background concentrations in residential buildings. Since many past indoor air studies have focused on urban centers in the United States, it was desired to conduct this study on suburban and rural portions of the state, to see if indoor air concentrations were lower than in urban areas. The study was conducted by the University of Medicine and Dentistry of New Jersey. One hundred homes were sampled in this study, scattered across 13 counties in the state (Weisel et al. 2008, 2006). The homes were single family or semi attached buildings. Almost all of the sampling was conducted in 2004 and 2005, in all seasons. Candidate homes were cross-checked against geographic information system databases of known contaminated ground water and soil sites to ensure that indoor air contaminant concentrations were not influenced by local contamination. Method TO-15 was used, with a 24-hour sample collection time. Smokers were not excluded in this study, but there were only a few smokers in the homes selected. Residents were instructed that during sampling, they should keep windows closed, avoid actively ventilating the homes, not store or use gasoline or kerosene in the home (except in a garage), not use fireplaces, and avoid painting a week before sampling. Samples were collected on the ground floor.

Massachusetts study

This study was conducted by Haley and Aldrich, Inc. and Alpha Analytical Laboratories, with oversight by the Massachusetts Department of Environmental Protection and USEPA Region I (Rago et al. 2005). Samples were collected in 2004 and 2005 in 100 residences from throughout the state (urban, suburban and rural). Method TO-15 was used, and 24-hour samples were collected in early spring and late fall with the windows closed.

New York study

Between 1997 and 2003, the New York State Department of Health conducted a study of the occurrence of volatile organic chemicals in the indoor air of homes that heat with fuel oil (NYSDOH 2006). Basement and living space samples were taken from 104 single family homes during all seasons of the year. Homes were selected from across the state (except for New York City), but the majority of homes were from the Albany, New York area. Prospective residences were required to have no past oil spills, and no hobbies or home business that regularly use products containing VOCs. Two-hour samples were collected and analyzed via Method TO-15.

Denver, Colorado study

As part of an investigation and remediation of a large area of VOC-contaminated ground water underlying several hundred residences in Denver, CO, multiple indoor air background samples were collected for approximately 100 homes after vapor intrusion was mitigated with radon-type subslab ventilation systems (Folkes and Kurtz 2002a). Data were collected only from homes where the ventilation systems removed all VOC impacts from subsurface sources. The contaminants determined were several halogenated volatile organic compounds. Twenty four-hour SUMMA® canister samples were collected between 1998 and 2001, and analyzed by Method TO-15 in the selective ion monitoring mode. Detection limits were much lower for this study than for most other studies.

Minneapolis, Minnesota study

As part of a larger study on personal, indoor and outdoor exposures to hazardous air pollutants, indoor air samples were taken from 132 homes in three urban neighborhoods in Minneapolis and Saint Paul, Minnesota (Sexton et al. 2004). The study was a joint effort of the University of Minnesota, the Minnesota Pollution Control Agency, and the University of Texas. Smokers were not included in this study. Samples were taken for 48 hours and collected in the spring, summer and fall of 1999. Charcoal-based passive air samplers were used.

Ottawa, Canada study

During the winter of 2002-2003, Health Canada sampled 75 residences from urban, suburban, and the rural fringe areas of Ottawa, Canada (Zhu et al. 2005). The homes were mostly single family homes, but a few row homes and semi-detached homes were also sampled. Ten homes were occupied by smokers. Active adsorbent tubes were used, and the ground floor of each of the residences was sampled. The sampling time was 100 minutes, during which ten liters of air was sampled.

RIOPA (Relationship of Indoor, Outdoor and Personal Air) study

A study entitled Relationship of Indoor, Outdoor and Personal Air (RIOPA) was conducted between 1999-2001 that entailed sampling personal, outdoor, indoor air and air in vehicles (Weisel et al. 2005). One hundred homes each in Houston, Texas, Los Angeles County, California, and Elizabeth, New Jersey were each sampled twice using passive vapor monitors for 48 hour exposure periods. Houses with smokers were excluded. Sampling locations in Los Angeles County and Houston were biased to areas in which known outdoor sources of air toxics exist (freeways in Los Angeles, petrochemical industries in Houston). Homes were sampled in all seasons, in the main living area.

Survey of Post-1990 studies

In 2009, Dawson and McAlary published a survey of indoor air studies conducted after 1990. It is included here for completeness. It includes the studies listed above, plus additional earlier studies conducted as early as 1990.

Summary of Indoor Background Levels

With the exception of the New Jersey RIOPA data, the studies presented here represent an entirely new dataset compared to the 2005 version of the NJDEP Vapor Intrusion Guidance. They represent the most current information available, with samples being collected from 1997-2006. (The survey from Dawson and McAlary includes some studies dating back to 1990). More than 800 homes in the United States are represented, as well as 75 homes in Canada. While it is possible that some of these studies may have inadvertently included a few homes that were located above soil or ground water contaminated with volatiles, the likelihood of this is small. Use of the median and 90th percentile statistics largely avoids the effect of such outlier homes, as well as the occasional occurrence of an unusual indoor source of a particular contaminant. The median, 90th percentile, and maximum value from the reviewed studies, are reported here.

Many earlier studies were designed as personal air monitoring studies and employed compact sampling devices that could be worn by the subject. Either adsorbent cartridges or passive adsorption badges were typically used. Many of the recent studies, on the other hand, have used the current regulatory method for indoor air sampling, specifically USEPA Method TO-15, which employs the use of SUMMA® canisters. Thus, the results from these studies are directly comparable to sample analyses conducted during vapor intrusion investigations.

The volatiles subject to NJDEP guidance for the vapor intrusion pathway were surveyed for available indoor air background information. Tables G-1, G-2 and G-3 indicate median, 90th percentile, and maximum concentrations from the various studies, and a summary of these results are given in Table G-4. Compared to the 2005 version of Table G-4, it can be seen that the ranges of concentrations reported for several chemicals are somewhat lower in the more recent studies. Also apparent is that the New Jersey suburban/rural study yielded results that were not significantly different from those studies focused on urban areas, indicating that the major source of these chemicals was indoors or in an attached garage.

For several chemicals, the agreement in reported concentrations between studies is striking. For example, median benzene concentrations were tightly clustered around 2 $\mu g/m^3$ (Table G-1). Other chemicals where median values showed very similar results between studies include 2-butanone, carbon tetrachloride, chloroform, ethylbenzene, methylene chloride, styrene, toluene and xylene. For this reason, representative median concentrations can be selected and are shown in Table G-4.

Sources of these chemicals have been reported by many investigators over the years but have recently been summarized by Weisel et al. (2008). The aromatic compounds, alkanes and MTBE are frequently correlated with each other and originate from gasoline vapors, sometimes due to storage of gasoline or the presence of a vehicle in an attached garage. MTBE occurrence is expected to decline significantly with the recent phase out of MTBE in New Jersey gasoline. Aromatic compounds may also result from smoking and combustion processes. Acetone and 2-butanone are components in nail polish remover and other cosmetics. Fluorinated organics originate from leakages in air conditioning and refrigeration units. Compounds such as methylene chloride, 1,4-dichlorobenzene, 1,1,1-trichloroethane and other halogenated chemicals may result from cleaning products, paint strippers, fragrances and deodorizers. PCE is a dry cleaning compound, but may also occur in paint strippers and paint thinners. Chloroform originates from disinfected drinking water and bleach. Other sources of contaminants are carpeting, furniture, plastics, paints, rubber, adhesives, building materials and other consumer products.

Compound-specific Occurrence Data and Selection of Median Indoor Background Concentrations
Chemicals were separated into five groups, depending on their occurrence pattern in the studies surveyed. For commonly occurring chemicals with adequate data, median concentrations were determined.

Group 1 Compounds commonly detectable via Method TO-15
Several compounds were frequently detected in indoor air at µg/m^3 concentrations using Method TO-15. For these chemicals, median concentrations were reviewed in order to select representative values (Table G-4). Generally, the New Jersey suburban/rural median concentrations were used because 1) they are New Jersey specific, 2) the study is among the most recent, and 3) median concentrations from this study were often similar to those from other studies.

Acetone – Median concentrations ranged from 6-34 µg/m^3, with the New Jersey RIOPA study near the low end and the New Jersey suburban/rural study at the high end. The New Jersey suburban/rural study used the required regulatory method (Method TO-15), which is among the most recent studies, and is specific to the State. Furthermore, health-based concentrations for this chemical in air are much higher than this range. Considering all these factors, the median background concentration for acetone was set at 34 µg/m^3.

Benzene – All studies surveyed included this chemical, with all but one yielding median concentrations above the reporting limit. These median concentrations were tightly clustered between 1.8 and 3.1 µg/m^3. The Massachusetts study indicated a median concentration that was below the reporting limit of 1.6 µg/m^3, but the 75th percentile value was 1.9 µg/m^3. Both the suburban/rural and the RIOPA New Jersey studies gave nearly the same median values (1.8 and 1.65 µg/m^3, respectively), and appear to be very representative of median benzene concentrations in indoor air. The New Jersey suburban/rural study used Method TO-15, and the rounded median value from this study (2 µg/m^3) was selected as the median background concentration.

2-Butanone (MEK) – Median concentrations reported for this chemical were also tightly clustered over a narrow range (1.5-3.5 µg/m^3). Leaving out the Canadian result, the three studies remaining are all TO-15 studies and exhibit an even narrower range of median values (2.7-3.5 µg/m^3). The value from the New Jersey suburban/rural study was at the high end of the range, but is among the most recent studies and is specific to the state. This value was rounded to 4 µg/m^3 and used as the median background concentration.

Chloromethane – Median concentrations ranged from 0.5 to 1.4 µg/m^3. For reasons similar to those for 2-butanone and acetone, the rounded value from the New Jersey suburban/rural study (1 µg/m^3) was selected as the median background concentration.

Dichlorodifluoromethane – The New Jersey suburban/rural study yielded a median concentration of 3.3 µg/m^3, while the other two studies that included this compound did not detect it at reporting limits that were lower and higher than this value. In lieu of additional information, the rounded suburban/rural New Jersey median value (3 µg/m^3) was selected as the median background concentration.

Ethyl benzene – All studies surveyed included this chemical, with all but two studies yielding median values above the reporting limit. For these studies, the measured median values were tightly clustered from 1-1.7 µg/m^3. The other two studies (the New Jersey suburban/rural study and the Massachusetts study) had higher reporting limits (2.2 µg/m^3), and median values were below this level. However, the New Jersey suburban/rural study had a lowered detection limit midway through the study which resulted in greater than 50% samples with detectable levels overall, and the median concentration for the samples run using the lower reporting limit (51 samples) was 1.1 µg/m3. Since all medians in the various studies except one were less than 1.5, a round value of 1 µg/m^3 is appropriate as the median background concentration.

n-Hexane – Three studies reported median values of 2.8, less than 3.5 and 1.6 µg/m^3. The New Jersey suburban/rural study value was 2.8 µg/m^3 and the rounded value of 3 µg/m^3 appears appropriate as a median value.

MTBE – Concentrations of this chemical are expected to decrease with time due to its phase-out in gasoline. However, for the present time, the NJDEP suburban/rural rounded median value of 3 µg/m^3 is recommended. This is somewhat lower than the three RIOPA urban studies (5-7 µg/m^3), but it is more recent, and it may reflect the decreasing use of this chemical. Furthermore, it is midrange between the three RIOPA studies and the median values observed in Massachussetts and New York (less than 2 and 0.8 µg/m^3, respectively). The Ottawa, Canada value is much lower due to historical limited MTBE use in Canada.

Toluene – Toluene median values were reported in every study and have a narrow range, from about 8-13 µg/m^3. The New Jersey suburban/rural value of 13 is at the high end of this range but it was selected because it is a New Jersey-specific value and health-based permitted air concentrations are much higher.

Trichlorofluoromethane – Three TO-15 studies investigated this chemical. Two of them (including the New Jersey study) reported a median below the detection limit of 2.8 µg/m^3. The third reported a median of 2.9 µg/m^3. Similar to the situation with ethyl benzene, the New Jersey suburban/rural study had a reporting limit decrease midway through the study to 1.1 µg/m^3. This resulted in a overall detection rate of 76% of the 100 samples. After the reporting limit change, all samples except one yielded reportable levels, with a median value of 2.1 µg/m^3. The selected median value for this chemical in indoor air is 2 µg/m^3.

Xylene – This chemical was reported in all studies. Median concentrations for m & p-xylene (combined) ranged from 1.5-5.5 µg/m^3. The New Jersey suburban/rural rounded value (4 µg/m^3) is in the middle of this range and appropriate for use as a background concentration. The results for o-xylene yielded median background levels of 1.1-1.6 µ/m^3. The New Jersey study yielded less than 2.2µg/m^3 overall, but after the detection limit was lowered to 0.87 µg/m^3 midway through the study, the median concentration was 1.4 µg/m^3, in the middle of the range reported for the other studies. Therefore, a reasonable rounded median background level for o-xylene is 1 µg/m^3.

Group 2 Compounds commonly detected with methods more sensitive than Method TO-15

The following compounds were very commonly detected at sub-µg/m^3 concentrations through the use of passive vapor monitors or carbon adsorption tubes. They were also detected with Method TO-15 in the New York and Denver, Colorado studies, for which lower reporting limits were developed than those used by New Jersey and Massachusetts. As New Jersey Method TO-15 detection limits decrease, these compounds are expected to be commonly detected. When possible, representative median values were selected for these compounds and are shown in Table G-4.

Carbon tetrachloride – Several studies in Table G-1 indicate a median background concentration of about 0.6 µg/m^3.

Chloroform – Chloroform should be frequently detected as the Method TO-15 reporting limit drops below 1 µg/m^3. Other studies indicate a median indoor air concentration of about 1 µg/m^3. This would be expected in homes with chlorinated drinking water supplies.

Cyclohexane – This chemical was detected in nearly half the homes in the New Jersey suburban/rural study. Based on the last 51 samples (after the detection limit was lowered to 0.69 µg/m^3), the median concentration of this chemical indoors is about 0.7 µg/m^3. This agrees well with the New York value of 0.8 µg/m^3.

1,2-, 1,3- and 1,4-Dichlorobenzene – Data from Minneapolis and the RIOPA studies seem to suggest median indoor background concentrations are greater than 0.1 µg/m^3 for 1,4-dichlorobenzene.

The data are too scattered to suggest a representative median concentration. The other two isomers are less common but were observed greater than 10% of the time in the New York study, which had lower reporting limits.

Methylene chloride – This chemical was detected in almost half of the samples from the New Jersey suburban/rural study. Data from other studies suggest a median background concentration of 0.4-1.5 µg/m3 in the United States, with a central tendency of 1 µg/m^3. The New Jersey study detection limits were just above this range (1.7 µg/m^3).

4-Methyl-2-pentanone – Median concentrations appear to be approximately 0.2 µg/m^3 based on data from New York and Ottawa Canada, but not enough data exist to select a representative value with confidence.

Styrene – Median concentrations from studies that had lower detection limits indicate a median concentration of 0.3-0.7 µg/m^3 with 0.5 µg/m^3 as a central value.

Tetrachloroethene (PCE) – Median concentrations appear to lie between 0.3 and 1.7 µg/m^3. The center of this range is 1 µg/m^3, but data appear too scattered to select a representative median at this time.

1,1,1-Trichloroethane – Two studies report medians of 0.3 and 0.9 µg/m^3. Insufficient data are available to judge an appropriate median value.

1,1,2-Trichloro-1,2,2-trifluoromethane – The New York study indicates a possible median of about 0.5 µg/m^3, but data are insufficient to select this value.

Trichloroethene – This compound appears to occur with a median concentration of under 0.5 µg/m^3, but there are only two studies reporting median values, so no median value was selected. It is expected to commonly be found as detection limits drop below 0.5 µg/m^3.

Group 3 The following chemicals were observed in at least 10% of homes of at least one study as shown in Table G-2, but in less than 50% of homes of all studies (Table G-1). Since no median values for these chemicals are available, median background concentrations were not developed. They are not commonly detected with current New Jersey reporting limits. Only 1,3-butadiene, carbon disulfide, and 1,2-dichloroethane were detected in the New Jersey suburban/rural study.

Bromomethane – detected in greater than 10% of some New York samples
1,3-Butadiene – detected in greater than 10% of Ottawa samples
Carbon disulfide – detected in greater than 10% of Ottawa samples
1,1-Dichloroethene – detected in greater than 10% of Ottawa samples
1,2-Dichloroethane – detected in greater than 10% of Denver samples
Hexachlorobutadiene – detected in greater than 10% of New York samples.
1,2,4-Trichlorobenzene – detected in greater than 10% of New York samples

Group 4 The following chemicals were occasionally detected, but in less than 10% of homes from any study, as indicated by their listings in Tables G-2 and G-3. Only 2-chlorotoluene and *cis*-1,2-dichloroethene were detected in the New Jersey suburban/rural study.

Chlorobenzene
Chloroethane
3-Chloropropene
2-Chlorotoluene
1,2-Dibromoethane
1,1-Dichloroethane
cis-1,2-dichloroethene
1,2-Dichloropropane

1,3-Dichloropropene
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
Vinyl chloride

Group 5 The following chemicals were never detected in any of the studies surveyed (as indicated in Table G-3), based on current regulatory or research reporting limits:

Bromodichloromethane
Bromoethene
Bromoform
Chlorodibromomethane
trans-1,2-dichloroethene
Tertiary butyl alcohol

Table G-1
Median Concentrations of Volatile Contaminants in Background Indoor Air Samples (µg/m^3)

Chemical	CAS No.	New Jersey suburban/rural study, 100 homes sampled 2003-2006, Method TO-15	Massachusetts study, 100 homes sampled 2004-2005, Method TO-15	New York fuel oil homes, 104 homes sampled 1997-2003, Method TO-15	Denver, Colorado, approximately 100 remediated homes sampled 1998-2001, Method TO-15	Minneapolis, Minnesota, 132 homes sampled in 1999, passive vapor monitors	Ottawa Canada, 75 homes sampled 2002-2003, adsorbent tubes	RIOPA study, Elizabeth, New Jersey, 100 homes sampled 1999-2001, passive vapor monitors	RIOPA study, Los Angeles, California, 100 homes sampled 1999-2001, passive vapor monitors	RIOPA study, Houston, Texas, 100 homes sampled 1999-2001, passive vapor monitors	EPA 2009 survey of studies since 1990
Acetone (2-Propanone)	67-64-1	34.5	26.45	21	-	-	28.48	7.04	6.3	12.9	-
Benzene	71-43-2	1.8	<1.6	2.1	-	1.9	2.15	1.65	2.05	3.06	2.5
Bromodichloromethane (Dichlorobromomethane)	75-27-4	<1.3	<3.35	-	-	-	-	-	-	-	-
Bromoethene (Vinyl bromide)	593-60-2	<0.87	-	-	-	-	-	-	-	-	-
Bromoform	75-25-2	<2.1	<5.16	-	-	-	-	-	-	-	-
Bromomethane (Methyl bromide)	74-83-9	<0.78	<1.94	<0.25	-	-	-	-	-	-	-
1,3-Butadiene	106-99-0	<1.1	<2	-	-	-	<0.32	-	-	-	-
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	3.5	2.66	3.4	-	-	1.48	-	-	-	-
Carbon disulfide	75-15-0	<1.6	<1.56	-	-	-	0.13	-	-	-	-
Carbon tetrachloride	56-23-5	<1.3	<3.14	<0.25	-	0.5	-	0.63	0.58	0.62	0.5
Chlorobenzene	108-90-7	<0.92	<2.3	<0.25	-	-	<0.01	-	-	-	-
Chlorodibromomethane (Dibromochloromethane)	124-48-1	<1.7	<4.26	-	-	-	-	-	-	-	-
Chloroethane	75-00-3	<1.3	<1.32	<0.25	-	-	-	-	-	-	-
Chloroform	67-66-3	<2.4	<2.44	<0.25	-	0.9	1.19	0.74	0.92	1.32	1.1
Chloromethane (Methyl chloride)	74-87-3	1.4	1.22	0.5	-	-	-	-	-	-	-
3-Chloropropene (Allyl chloride)	107-05-1	<1.6	<1.56	-	-	-	-	-	-	-	-
2-Chlorotoluene (o-Chlorotoluene)	95-49-8	<1.3	-	-	-	-	-	-	-	-	-
Cyclohexane	110-82-7	0.7[a]	<1.72	0.8	-	-	4.51	-	-	-	-
1,2-Dibromoethane	106-93-4	<1.5	<3.84	<0.25	-	-	<0.02	-	-	-	-
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	<1.2	<3.00	<0.25	-	-	<0.02	-	-	-	-
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	<1.2	<3.00	<0.25	-	-	0.15	-	-	-	-
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	<3	<3.00	<0.25	-	0.2	-	<1.44	0.76	2.02	-
Dichlorodifluoromethane (Freon 12)	75-71-8	3.3	<4.94	<0.25	-	-	-	-	-	-	-
1,1-Dichloroethane	75-34-3	<0.81	<2.02	<0.25	<0.08	-	-	-	-	-	<RL
1,2-Dichloroethane	107-06-2	<0.81	<2.02	<0.25	<0.04	-	<0.02	-	-	-	<RL
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	<0.79	<1.98	<0.25	<0.04	-	<0.01	-	-	-	<RL
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	<0.79	<1.98	<0.25	-	-	-	-	-	-	<RL
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	<0.79	<1.98	-	-	-	-	-	-	-	<RL
1,2-Dichloroethene (total)	540-59-0	-	-	-	-	-	-	-	-	-	-
1,2-Dichloropropane	78-87-5	<0.92	<2.31	<0.25	-	-	<0.04	-	-	-	-
1,3-Dichloropropene	542-75-6	<0.91(cis);<0.91(trans)	<2.27(cis);<2.27(trans)	<0.25(cis);<0.25(trans)	-	-	-	-	-	-	-
Ethylbenzene	100-41-4	1.1[a]	<2.17	1	-	1.4	1.05	1.29	1.45	1.68	2
Hexachloro-1,3-butadiene	87-68-3	<2.1	<5.33	<0.25	-	-	-	-	-	-	-
n-Hexane	110-54-3	2.8	<3.52	1.6	-	-	-	-	-	-	-
Mercury (elemental)	7439-97-6	-	-	-	-	-	-	-	-	-	-
Methylene chloride (Dichloromethane)	75-09-2	<1.7	<3.47	1.4	0.88	1.1	1.87	<1.68	0.84	0.44	1.1
4-Methyl-2-pentanone (MIBK)	108-10-1	<2.0	<2.05	0.3	-	-	0.16	-	-	-	-
MTBE (tert-Butyl methyl ether)	1634-04-4	3.45	<2	0.8	-	-	<0.05	5.03	7.44	5.82	1.2
Styrene	100-42-5	<2.1	<2.13	0.3	-	0.5	0.46	<0.34	0.49	0.67	-
Tertiary butyl alcohol (TBA)	75-65-0	<15	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	79-34-5	<1.4	<3.43	<0.25	-	-	<0.02	-	-	-	-
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	<3.4	<3.39	0.3	1	0.6	0.47	<1.12	1.66	0.29	0.9
Toluene	108-88-3	13	7.62	9.6	-	12.3	5.53	9.74	10.6	10.3	13
1,2,4-Trichlorobenzene	120-82-1	<3.7	<3.71	<0.25	-	-	-	-	-	-	-
1,1,1-Trichloroethane	71-55-6	<2.7	<2.72	0.3	0.86	-	-	-	-	-	1.9
1,1,2-Trichloroethane	79-00-5	<2.7	<2.72	<0.25	-	-	-	-	-	-	-
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	<2.7	<2.68	<0.25	<0.26	0.2	<0.02	0.43	<0.22	<0.24	<RL
Trichlorofluoromethane (Freon 11)	75-69-4	2.1[a]	<2.81	2.9	-	-	-	-	-	-	-
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon TF)	76-13-1	<1.9	<2.72	0.5	-	-	-	-	-	-	0.5
Vinyl chloride	75-01-4	<0.51	<1.28	<0.25	<0.02	-	-	-	-	-	-
Xylenes (total)	1330-20-7	3.80(m,p);1.4(o)[a]	2.99(m,p);<2.17(o)	1.5(m,p);1.1(o)	-	4.8(m,p);1.6(o)	3.59(m,p);1.22(o)	3.18(m,p);1.18(o)	4.16(m,p);1.64(o)	4.55(m,p);1.53(o)	5.5(m,p);2.2(o)

[a] last 51 samples only (see text)

- = not analyzed

< RL = below reporting limit

Table G-2
90th Percentile Concentrations of Volatile Contaminants in Background Indoor Air Samples (µg/m^3)

Chemical	CAS No.	New Jersey suburban/rural study, 2003-2006, 100 homes	Massachusetts study, 100 homes sampled 2004-2005, Method TO-15	New York fuel oil homes, 104 homes sampled 1997-2003, Method TO-15	Denver, Colorado, approximately 100 remediated homes sampled 1998-2001, Method TO-15	Minneapolis, Minnesota, 132 homes sampled in 1999, passive vapor monitors	Ottawa Canada, 75 homes sampled 2002-2003, adsorbent tubes	EPA 2009 survey of studies since 1990
Acetone (2-Propanone)	67-64-1	91	61.59	110	-	-	76.4	-
Benzene	71-43-2	10	6.8	15	-	15.3	5.21	10
Bromodichloromethane (Dichlorobromomethane)	75-27-4	<3.4	<3.35	-	-	-	-	-
Bromoethene (Vinyl bromide)	593-60-2	<2.2	-	-	-	-	-	-
Bromoform	75-25-2	<5.2	<5.16	-	-	-	-	-
Bromomethane (Methyl bromide)	74-83-9	<1.9	<1.94	0.6	-	-	-	-
1,3-Butadiene	106-99-0	<1.1	<2	-	-	-	1.64	-
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	12.1	9.65	16	-	-	6.66	-
Carbon disulfide	75-15-0	<1.6	<1.56	-	-	-	0.86	-
Carbon tetrachloride	56-23-5	<3.1	<3.14	0.8	-	0.9	-	0.8
Chlorobenzene	108-90-7	<2.3	<2.3	<0.25	-	-	<0.01	-
Chlorodibromomethane (Dibromochloromethane)	124-48-1	<4.3	<4.26	-	-	-	-	-
Chloroethane	75-00-3	<1.3	<1.32	<0.25	-	-	-	-
Chloroform	67-66-3	2.62	2.46	1.4	-	3.4	4.39	3.9
Chloromethane (Methyl chloride)	74-87-3	2	1.75	3.3	-	-	-	-
3-Chloropropene (Allyl chloride)	107-05-1	<1.6	<1.56	-	-	-	-	-
2-Chlorotoluene (o-Chlorotoluene)	95-49-8	<2.6	-	-	-	-	-	-
Cyclohexane	110-82-7	4.53	2.78	8.1	-	-	15.1	-
1,2-Dibromoethane	106-93-4	<3.8	<3.84	<0.25	-	-	<0.02	-
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	<3.0	<3.00	0.7	-	-	<0.02	-
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	<3.0	<3.00	0.6	-	-	1.05	-
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	3.77	<3.00	1.3	-	1.5	-	-
Dichlorodifluoromethane (Freon 12)	75-71-8	9.56	4.98	15	-	-	-	-
1,1-Dichloroethane	75-34-3	<2.0	<2.02	<0.25	-	-	43.21	<RL
1,2-Dichloroethane	107-06-2	<2.0	<2.02	<0.25	0.1	-	<0.02	0.15
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	<2.0	<1.98	<0.25	-	-	0.83	<RL
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	<2.0	<1.98	<0.25	-	-	-	<RL
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	<2.0	<1.98	-	-	-	-	<RL
1,2-Dichloroethene (total)	540-59-0	-	-	-	-	-	-	-
1,2-Dichloropropane	78-87-5	<2.3	<2.31	<0.25	-	-	<0.04	-
1,3-Dichloropropene	542-75-6	<2.3(cis);<2.3(trans)	<2.27(cis);<2.27(trans)	<0.25(cis);<0.25(trans)	-	-	-	-
Ethylbenzene	100-41-4	9.64	5.25	7.3	-	8.9	4.76	8.6
Hexachloro-1,3-butadiene	87-68-3	<5.3	<5.33	4.6	-	-	-	-
n-Hexane	110-54-3	16.2	14.23	18	-	-	-	-
Mercury (elemental)	7439-97-6	-	-	-	-	-	-	-
Methylene chloride (Dichloromethane)	75-09-2	6.74	10.53	22	10	11.5	43	10
4-Methyl-2-pentanone (MIBK)	108-10-1	<2.0	<2.05	2.2	-	-	0.8	-
MTBE (tert-Butyl methyl ether)	1634-04-4	40.7	38.31	26	-	-	<0.05	26
Styrene	100-42-5	<2.1	<2.13	1.3	-	1.4	1.49	-
Tertiary butyl alcohol (TBA)	75-65-0	<15	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	79-34-5	<3.4	<3.43	<0.25	-	-	<0.02	-
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	4.39	<3.39	2.9	4.5	3.8	3.25	4
Toluene	108-88-3	60.8	42.51	58	-	53.8	25.47	51
1,2,4-Trichlorobenzene	120-82-1	<3.7	<3.71	3.4	-	-	-	-
1,1,1-Trichloroethane	71-55-6	2.81	<2.72	3.1	5.1	-	-	5.5
1,1,2-Trichloroethane	79-00-5	<2.7	<2.72	<0.25	-	-	-	-
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	<2.7	<2.68	0.5	0.3	0.8	0.19	0.9
Trichlorofluoromethane (Freon 11)	75-69-4	6.25	3.56	17	-	-	-	-
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon TF)	76-13-1	<3.8	3.83	1.8	-	-	-	1.8
Vinyl chloride	75-01-4	<1.3	<1.28	<0.25	-	-	-	0.03
Xylenes (total)	1330-20-7	30.2(m,p);11.1(o)	20.52(m,p);6.78(o)	12(m,p);7.6(o)	-	36.9(m,p);11.4(o)	16.35(m,p);6.48(o)	27(m,p);10(o)

- = not analyzed

<RL = below reporting limit

Table G-3
Maximum Concentrations of Volatile Contaminants in Background Indoor Air Samples (µg/m^3)

Chemical	CAS No.	New Jersey suburban/rural study, 2003-2006, 100 homes	Massachusetts study, 100 homes sampled 2004-2005, Method TO-15	New York fuel oil homes, 104 homes sampled 1997-2003, Method TO-15	Denver, Colorado, approximately 100 remediated homes sampled 1998-2001, Method TO-15	Ottawa Canada, 75 homes sampled 2002-2003, adsorbent tubes
Acetone (2-Propanone)	67-64-1	2900	257	690	-	456
Benzene	71-43-2	42	28.1	460	-	21
Bromodichloromethane (Dichlorobromomethane)	75-27-4	<3.4	<3.35	-	-	-
Bromoethene (Vinyl bromide)	593-60-2	<2.2	-	-	-	-
Bromoform	75-25-2	<5.2	<5.16	-	-	-
Bromomethane (Methyl bromide)	74-83-9	<1.9	<1.94	23	-	-
1,3-Butadiene	106-99-0	4.4	2.05	-	-	3.65
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	150	11.2	180	-	16.45
Carbon disulfide	75-15-0	4.4	<1.56	-	-	3.29
Carbon tetrachloride	56-23-5	<3.1	<3.14	4.2	-	-
Chlorobenzene	108-90-7	<2.3	<2.3	0.6	-	0.04
Chlorodibromomethane (Dibromochloromethane)	124-48-1	<4.3	<4.26	-	-	-
Chloroethane	75-00-3	1.3	5.4	4.5	-	-
Chloroform	67-66-3	5.9	8.26	25	-	8.23
Chloromethane (Methyl chloride)	74-87-3	6.2	4.21	260	-	-
3-Chloropropene (Allyl chloride)	107-05-1	1.6	<1.56	-	-	-
2-Chlorotoluene (o-Chlorotoluene)	95-49-8	6.2	-	-	-	-
Cyclohexane	110-82-7	52	9.45	510	-	54
1,2-Dibromoethane	106-93-4	<3.8	<3.84	1.1	-	<0.02
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	16	<3.00	4.9	-	0.11
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	<3.0	<3.00	2.5	-	16.19
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	270	34.2	770	-	-
Dichlorodifluoromethane (Freon 12)	75-71-8	160	82.2	300	-	-
1,1-Dichloroethane	75-34-3	<2.0	<2.02	4.4	0.16	-
1,2-Dichloroethane	107-06-2	3.5	2.76	4.9	0.72	0.71
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	<2.0	<1.98	430	<0.04	4.05
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	2.9	<1.98	7.4	-	-
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	<2.0	<1.98	-	-	-
1,2-Dichloroethene (total)	540-59-0	-	-	-	-	-
1,2-Dichloropropane	78-87-5	<2.3	<2.31	34	-	<0.04
1,3-Dichloropropene	542-75-6	<2.3(cis);<2.3(trans)	<2.27(cis);<2.27(trans)	3.5(cis);<0.25(trans)	-	-
Ethylbenzene	100-41-4	39	24.5	340	-	201
Hexachloro-1,3-butadiene	87-68-3	<5.3	<5.33	51	-	-
n-Hexane	110-54-3	270	38.5	950	-	-
Mercury (elemental)	7439-97-6	-	-	-	-	-
Methylene chloride (Dichloromethane)	75-09-2	94	146	2100	180	408
4-Methyl-2-pentanone (MIBK)	108-10-1	9.8	11.2	36	-	1.4
MTBE (tert-Butyl methyl ether)	1634-04-4	470	155	340	-	3.32
Styrene	100-42-5	5.1	3.24	50	-	6.53
Tertiary butyl alcohol (TBA)	75-65-0	<15	-	-	-	-
1,1,2,2-Tetrachloroethane	79-34-5	<3.4	<3.43	2.7	-	<0.02
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	540	27.6	51	440	9.23
Toluene	108-88-3	160	944	510	-	113
1,2,4-Trichlorobenzene	120-82-1	<3.7	<3.71	37	-	-
1,1,1-Trichloroethane	71-55-6	9.3	21.3	110	210	-
1,1,2-Trichloroethane	79-00-5	<2.7	<2.72	6.2	27	-
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	13	110	25	-	0.87
Trichlorofluoromethane (Freon 11)	75-69-4	62	162	190	-	-
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon TF)	76-13-1	2.1	4.35	7.4	-	-
Vinyl chloride	75-01-4	<1.3	<1.28	1	0.5	-
Xylenes (total)	1330-20-7	91(m,p);38(o)	81.9(m,p);27.8(o)	550(m,p);310(o)	-	139(m,p);205(o)

- = not analyzed

Table G-4
Summary of Ambient Indoor Levels and New Jersey Median Background Concentrations of Volatile Contaminants in Homes (µg/m3)[a]

Chemical	CAS No.	Range of median values	Representative median indoor air concentrations	Range of 90th percentile values
Acetone (2-Propanone)	67-64-1	6-34	34	62-110
Benzene	71-43-2	<1.6-3.1	2	5.2-15
Bromodichloromethane (Dichlorobromomethane)	75-27-4	<RL		<RL
Bromoethene (Vinyl bromide)	593-60-2	<RL		<RL
Bromoform	75-25-2	<RL		<RL
Bromomethane (Methyl bromide)	74-83-9	<RL		0.6[c]
1,3-Butadiene	106-99-0	<RL		1.6[b]
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	1.5[b];2.7-3.5[d]	4	6.7[b];9.6-16[d]
Carbon disulfide	75-15-0	0.13[b]		0.86[b]
Carbon tetrachloride	56-23-5	<0.25-0.6	0.6[f]	0.8-0.9
Chlorobenzene	108-90-7	<RL		<RL
Chlorodibromomethane (Dibromochloromethane)	124-48-1	<RL		<RL
Chloroethane	75-00-3	<RL		<RL
Chloroform	67-66-3	<0.25-2.4	1	1.4-3.4[d];4.4[b]
Chloromethane (Methyl chloride)	74-87-3	0.5-1.4	1	1.8-3.3
3-Chloropropene (Allyl chloride)	107-05-1	<RL		<RL
2-Chlorotoluene (o-Chlorotoluene)	95-49-8	<RL		<RL
Cyclohexane	110-82-7	0.7-0.8[d];4.5[b]	0.7	2.8-8.1[d];15[b]
1,2-Dibromoethane	106-93-4	<RL		<RL
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	<RL		0.7[c]
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	0.15[b]		0.6-1
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	0.2-2		1.3-3.8
Dichlorodifluoromethane (Freon 12)	75-71-8	<0.25-3.3	3	5-15
1,1-Dichloroethane	75-34-3	<RL		<RL
1,2-Dichloroethane	107-06-2	<RL		0.1[e]
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	<RL		0.83[b]
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	<RL		<RL
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	<RL		<RL
1,2-Dichloroethene (total)	540-59-0	-		-
1,2-Dichloropropane	78-87-5	<RL		<RL
1,3-Dichloropropene	542-75-6	<RL		<RL
Ethylbenzene	100-41-4	1.0-1.7	1	4.8[b];5.2-9.6[d]
Hexachloro-1,3-butadiene	87-68-3	<RL		4.6[c]
n-Hexane	110-54-3	1.6-2.8	3	14-18
Mercury (elemental)	7439-97-6	-		-
Methylene chloride (Dichloromethane)	75-09-2	0.44-1.9	1[f]	6.7-22[d], 43[b]
4-Methyl-2-pentanone (MIBK)	108-10-1	0.16-0.3		0.8-2.2
MTBE (tert-Butyl methyl ether)	1634-04-4	<0.05[b];0.8-7.4[d]	3	<0.05[b];26-41[d]
Styrene	100-42-5	0.3-0.7	0.5[f]	1.3-1.5
Tertiary butyl alcohol (TBA)	75-65-0	<RL		<RL
1,1,2,2-Tetrachloroethane	79-34-5	<RL		<RL
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	0.3-1.7		2.9-4.5
Toluene	108-88-3	5.5[b];7.6-13[d]	13	25[b];42-61[d]
1,2,4-Trichlorobenzene	120-82-1	<RL		3.4[c]
1,1,1-Trichloroethane	71-55-6	0.3-0.9		<2.7-5.1
1,1,2-Trichloroethane	79-00-5	<RL		<RL
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	<0.02[b];0.2-0.4[d]		0.2[b];0.3-0.8[d]
Trichlorofluoromethane (Freon 11)	75-69-4	2.1-2.9	2	3.6-17
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon TF)	76-13-1	0.5[c]		1.8-3.8
Vinyl chloride	75-01-4	<RL		<RL
Xylenes (total)	1330-20-7	1.5-5(m,p);1.1-1.6(o)	4(m,p);1(o)	12-37(m,p);6-11(o)

[a] EPA study not included
[b] Ottawa, Canada study only
[c] New York study only
[d] United States studies only
[e] Denver study only
[f] Below New Jersey reporting limit
<RL= less than reporting limit

APPENDIX H

Common Background Indoor Air Sources

Common Background Indoor Air Sources

Acetone	rubber cement, cleaning fluids, scented candles and nail polish remover
Benzene	automobile exhaust, gasoline, cigarette smoke, scented candles, scatter rugs and carpet glue
Bromomethane	soil or space fumigant
1, 3-Butadiene	automobile exhaust and residential wood combustion
2-Butanone (MEK)	automobile exhaust, printing inks, fragrance/flavoring agent in candy and perfume, paint, glue, cleaning agents and cigarette smoke
Chlorobenzene	scented candles, plastic foam insulation and paint products
Chloroethane	refrigerant
Chloroform	generated from chlorinated water (showers)
Cyclohexane	gasoline, paint thinner, paint and varnish remover
1,4-Dichlorobenzene	moth balls, general insecticide in farming, air deodorant and toilet disinfectant
Dichlorodifluoromethane	refrigerant (CFCs) and cleaning solvent
1, 1-Dichloroethane	plastic products (food and other packaging material) and flame retardant fabrics
1,2-Dichloroethane	polyresin molded decorations (particularly from China)
1, 1-Dichloroethene	plastic products (food and other packaging material), adhesives and flame retardant fabrics
1, 3-Dichloropropene	fungicides
Ethylbenzene	paint, paint thinners, insecticides, wood office furniture, scented candles and gasoline
Formaldehyde	building materials (particle board), furniture, insulation and cigarette smoke
n-Heptane	gasoline, nail polishes, wood office furniture and petroleum products
n- Hexane	gasoline, rubber cement, typing correction fluid and aerosols in perfumes
Methylene chloride	hairspray, paint stripper, rug cleaners, insecticides and furniture polish
Methyl isobutyl ketone (MIBK)	paints, varnishes, dry cleaning preparations, naturally found in oranges, grapes and vinegar
Methyl *tert* butyl ether (MTBE)	gasoline (oxygenating agent)
Naphthalene	cigarette smoke, automobile exhaust, residential wood combustion, insecticides and moth balls
Styrene	cigarette smoke, automobile exhaust, fiberglass, rubber and epoxy adhesives, occurs naturally in various fruits, vegetables, nuts and meats
Tertiary butyl alcohol (TBA)	gasoline (oxygenating agent)
1, 1 , 2 ,2-Tetrachloroethane	solvent, paint and rust removers, varnishes and lacquers
Tetrachloroethene (PCE)	dry cleaning, metal degreasing, adhesives and glues, insecticides, scented candles and rug cleaner

Toluene	gasoline, automobile exhaust, polishes, nail polish, synthetic fragrances, paint, scented candles, paint thinner, adhesives and cigarette smoke
1, 1, 1-Trichloroethane	spot cleaner, glues, insecticides, drain cleaners, shoe polish
Trichloroethene (TCE)	glues, adhesives, paint removers, spot removers, rug cleaning fluids, paints, metal cleaners, typewriter correction fluid, and automotive cleaning and degreasing products
1, 2, 4-Trimethylbenzene	gasoline and automobile exhaust
1, 3, 5–Trimethylbenzene	gasoline and automobile exhaust
2 ,2, 4-Trimethylpentane	gasoline and automobile exhaust
Xylenes, total	water sealer, gasoline, automobile exhaust, markers, paint, floor polish and cigarette smoke

APPENDIX I

Simple Smoke Visualization Test to Assess Backdrafting

SIMPLE SMOKE VISUALIZATION TEST TO ASSESS BACKDRAFTING

(ITRC 2007)

The following procedures have been recommended by the ITRC for initial investigation and evaluation for the possibility of backdrafting;

1. Start test with the flue of all combustion appliances cool.
2. Close all exterior and interior windows and doors.
3. Open all HVAC supply and return air duct vents/registers.
4. Close fireplace and wood stove dampers.
5. Turn on all exhaust and air distribution fans and combustion appliances except the appliance being tested for Backdrafting (this does not include whole house fans).
6. Wait 5 minutes.
7. Turn on the appliance being tested. If the appliance is a forced-air furnace, ensure that the blower starts to run before proceeding.
8. Wait 5 minutes.
9. Using a smoke tube, check for flue gas entrainment near the vent hood. Smoke flow should be distinctly up into the hood and up the flue
10. If the chemical smoke is drawn up the flue, this would indicate a positive draft, qualitatively demonstrated and backdrafting would not seen to be a problem.
11. Repeat the test for each natural draft appliance being tested for Backdrafting. Extreme or unusual weather conditions need to be considered when evaluating these data.

If a backdrafting potential is identified, the sub-slab depressurization system should not be installed or operated until a qualified HVAC contractor can assess the backdrafting potential with a more comprehensive test and correct the problem.

As an added level of safety, ensure that carbon monoxide detectors are properly installed in the building.

APPENDIX J

Installation Procedures of Permanent Sub-slab Probes for Monitoring VI Mitigation Systems

INSTALLATION PROCEDURE
FOR PERMANENT SUB-SLAB PROBES

1.0 PURPOSE AND SCOPE

The purpose of this document is to detail the design and installation procedures of one example of a permanent sub-slab probe in the support of VI investigations. This type of probe can be utilized for the temporal repeatable collection of air samples from beneath the slab of buildings and for monitoring the effectiveness of a system for the mitigation of VI. Alternative design and installation procedures are acceptable.

2.0 HEALTH AND SAFETY

Prior to penetrating the subsurface, a check for the presence of utilities must be performed. Contact the local utility companies (gas, water, sewer, electric, phone) via the New Jersey One Call system (1-800-272-1000) to mark the location of utilities coming into the building from the outside. The utilities can then be traced into the building for their location. If needed, a plumber and/or electrician may be consulted to assist in identifying the location of utilities inside the building.

3.0 LOCATIONS AND QUANTITY OF SUB-SLAB PROBES

The quantity and locations of the permanent sub-slab probes will be dependent upon the objectives of the data that is required. Permanent sub-slab probes can be used for the collection of soil gas samples from the sub-slab atmosphere or for the collection of physical measurement data to monitor the effectiveness of a mitigation system.

This type of probe should be used for the collection of analytical data when several rounds of data will be required from the subsurface from a building. This will prevent variability in data from sample location and/or probe installation. The number of probes required will be dependent upon the size of the building and site specific characteristics.

The quantity of sub-slab probes to support the effectiveness of a mitigation system will be site specific based on the results of the communication test data during system installation. At a minimum, four probes are recommended on each side or corner of a building. Further information can be found in Section 6.3.2.5 of the VIT Guidance.

4.0 SUB-SLAB PROBE CONSTRUCTION

The recommended material for construction for the sub-slab probe is 316 stainless steel Swagelock® compression fittings. This material has the durability for long term use and is non-reactive to VOCs. No specialized fittings are required to connect to the probe. The ¼” NPT threads make connecting to the probe easy with common pipe fittings. This probe construction is slightly larger than other permanent probe constructions from ¼” connectors, ¼” caps and others found in the literature. Field experience has shown that those designs are not as durable due to the probe easily breaking loose in the concrete seal from over-tightening of fittings. The parts list for the sub-slab probe is as follows:

a. SS-400-7-4 - Female connector (tapered thread) ¼” tube x x1/4” NPT.

b. SS-401-PC – ¼” Tube fitting port connector.
c. *4534K12 (McMaster-Carr) Flush mount-high pressure steel thread hex socket plug, ¼” pipe, PTFE coated, ¼” Hex, 13/32 length

The construction dimensions of this probe will allow the inlet of the probe to be located within the building slab. This helps prevent the clogging of the probe with sub-slab material.

5.0 SUB-SLAB PROBE INSTALLATION

The sub-slab probe is quickly and easily installed with standard tools. The following is a list of tools and materials required for the installation:

a. rotary hammer drill with 1-1/4” diameter x 10” long spline-shank masonry bit
b. hammer drill with ¼” diameter x 12”-18” long masonry bit
c. extension cords
d. shop vacuum
e. quick drying cement or hydraulic cement with mixing cup and water
f. non VOC clay (pottery clay)
g. paper towels
h. duct tape
i. distilled water
j. carpet knife
k. sub-slab probe

5.1 Installation Procedures

5.1.1 Select the location for the permanent sub-slab probe based on the objectives of the phase of work, presence or potential presence of obstructions and input from the building owner.

5.1.2 If a floor covering is drilled through for the placement of the probe, future plans of the replacement or repair of the covering should be made in advance.

If carpeting is present, a “flap” can be cut into the carpet for access to the slab. This “flap” can then be pushed back into place when work is competed. If a sheet flooring product is present, a section can be removed to allow drilling and used for replacement after decommissioning. For tile flooring, a replacement tile or section of flooring should be obtained for installation after the probe is decommissioned.

5.1.3 Using a hammer and chisel, chip an “X” in the concrete as a starting point for drilling to prevent the bit from “wandering” off the desired target location.

5.1.4 Determine the desired depth of the probe body and mark this length on the 1-1/4” masonry bit by wrapping with duct tape with an “ear”. The “ear” will act as a depth gauge. When duct tape “ear” it hits the slab, the bit is at the appropriate depth. The desired depth of the hole will be dependent if the probe is to be flush with the floor or slightly countersunk to the floor.

5.1.5 Use the rotary hammer drill with the 1-1/4” bit to advance the outer hole to the proper depth and vacuum out the cuttings.

5.1.6 Using the hammer drill with a ¼” bit, place the bit in the center of the1-1/4” hole and drill through the slab into the subsurface material by 3-6”. A significant increase in the rate of penetration by the drill will indicate the bottom of the slab has been passed through.

5.1.7 Vacuum out the drill cuttings from in and around the hole. Test fit the probe in the hole so it is at the desired location. Alter the hole depth if required.

5.1.8 Dampen a paper towel with distilled water and wipe away the dust from the 1-1/4” hole and wet the sidewalls. Do not allow excess water on the towel go into the sub-surface.

5.1.9 With a small piece of duct tape, wrap it around the plug on the probe while covering the top of the probe. This will protect the threads of the probe and plug from cement during the installation.

5.1.10 Using a small piece of clay, roll it until it is in a thin “cigar” shape. Place the clay around the port connector at the ¼” nut. Insert the probe into the hole, the clay forms a seal between the two holes in the slab, not allowing cement into the smaller hole and the subsurface.

5.1.11 Mix a small amount of cement and pour into the annular space around the probe. Allow the cement to cure for the recommended time for curing by the manufacturer of the cement. After curing remove the tape from the probe and clean the surface of unwanted cement. Figure 1 is a schematic of the cross section of the permanent sub-slab probe installation that is countersunk to the slab.

5.2 Annular Seal Leak Check

After allowing the cement to cure, a leak check should be performed to ensure a competent annular seal of the probe. A leaking annular seal will result in inaccurate readings that are biased low for physical or analytical measurements.

Perform the annular seal leak check by placing a vacuum on the probe and placing a bead of water around the probe (if installed counter sunk to the slab). Watch for changes in the water level or, use a tracer gas (helium, isopropyl alcohol, nitrogen, carbon dioxide), hook up a DRI to the probe and check for a response to the tracer gas. These same techniques can be used during sampling of the sub-slab atmosphere. If a leak is discovered, the probe must be removed, re-installed and tested again for leaks.

5.3 Flow and Vacuum Check

A flow and vacuum check should be performed on the probe if there is the potential to use the probe to collect a sample from the sub-slab atmosphere for analysis. Obtaining a sample from a sub-slab probe with excessive vacuums can change the partitioning of vapors between pore water and the soil gas potentially biasing VOC concentrations high. In addition, the high vacuum may increase the risk of leakage between the sub-slab probe and the sample container.

The flow and vacuum check is performed by connecting a pump to the probe and running at a flow rate of 200 ml/min until the vacuum stabilizes. During this test the vacuum should also be monitored. The investigator should be aware of potential portioning of VOCs from the sub-slab materials due to vacuum or flow rates.

6.0 Measurement of Sub-Slab Pressures

Measurement of sub-slab pressures (differential between the indoor air and sub-slab atmospheres) can be easily determined via the permanent sub-slab probe. A simple barb fitting connected to a digital micro-manometer capable of reading 0.001 inches of water can be used to determine the depressurization of the slab-slab atmosphere to monitor the effectiveness of a mitigation system.

7.0 Decommissioning

Once it is determined that monitoring of the sub-slab atmosphere is no longer required due to remediation of the contaminant source or other reason, the sub-slab probe can be removed. The probe can be removed by breaking the annular seal with a chisel or rotary hammer with a bull point. Once the probe is removed, seal the hole with concrete to the original level and replace the flooring that was removed during installation or glue the carpet "flap" to the floor.

The following sources were utilized in developing the installation procedures for sub-slab probes.

California Environmental Protection Agency. 2005. Guidance for the Evaluation and Migration of Subsurface Vapor Intrusion to Indoor Air. Department of Toxic Substances Control.

Hartman, B. 2004. Vapor Monitoring Wells/Implants. Standard Operating Procedures (vapor intrusion applications). H&P Mobile Geochemistry, Solana Beach, California

Hartman, B. 2004. Sub-Slab Soil Vapor. Standard Operating Procedures (vapor intrusion applications). H&P Mobile Geochemistry, Solana Beach, California.

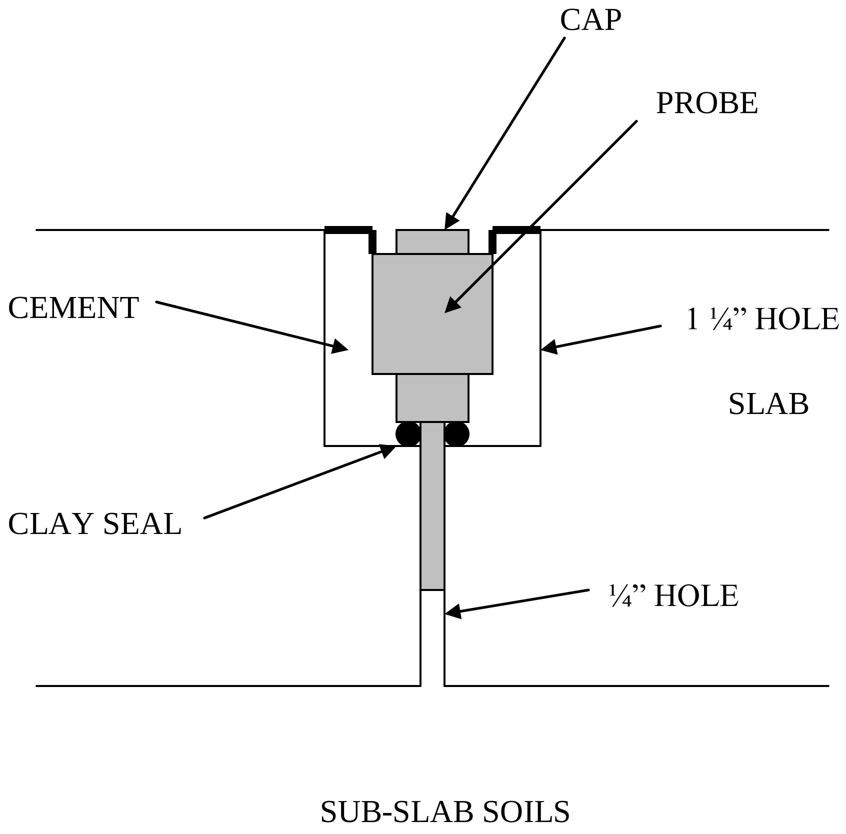
New York State Department of Health. 2006. Final Guidance for Evaluating Soil Vapor Intrusion in the State of New York. Center for Environmental Health, Bureau of Environmental Exposure Investigation. October 2006

Reynolds, Peter A. 2007. The Use of Tracer Gas in Soil Vapor Intrusion Studies. In Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy, Volume 12, Article 39. The Berkeley Electronic Press.

U.S. Environmental Protection Agency (USEPA). 2006. Assessment of Vapor Intrusion in Homes near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples. EPA/600/R-05/147, March 2006

U.S. Environmental Protection Agency (USEPA), Region 8. Not Dated. Draft-Standard Operating Procedures for Installation of Sub-Slab Vapor Probes and Sampling Using EPA Method TO-15 to Support Vapor Intrusion Investigations. (Accessed 2009).

FIGURE I
SUB-SLAB PROBE CONSTRUCTION

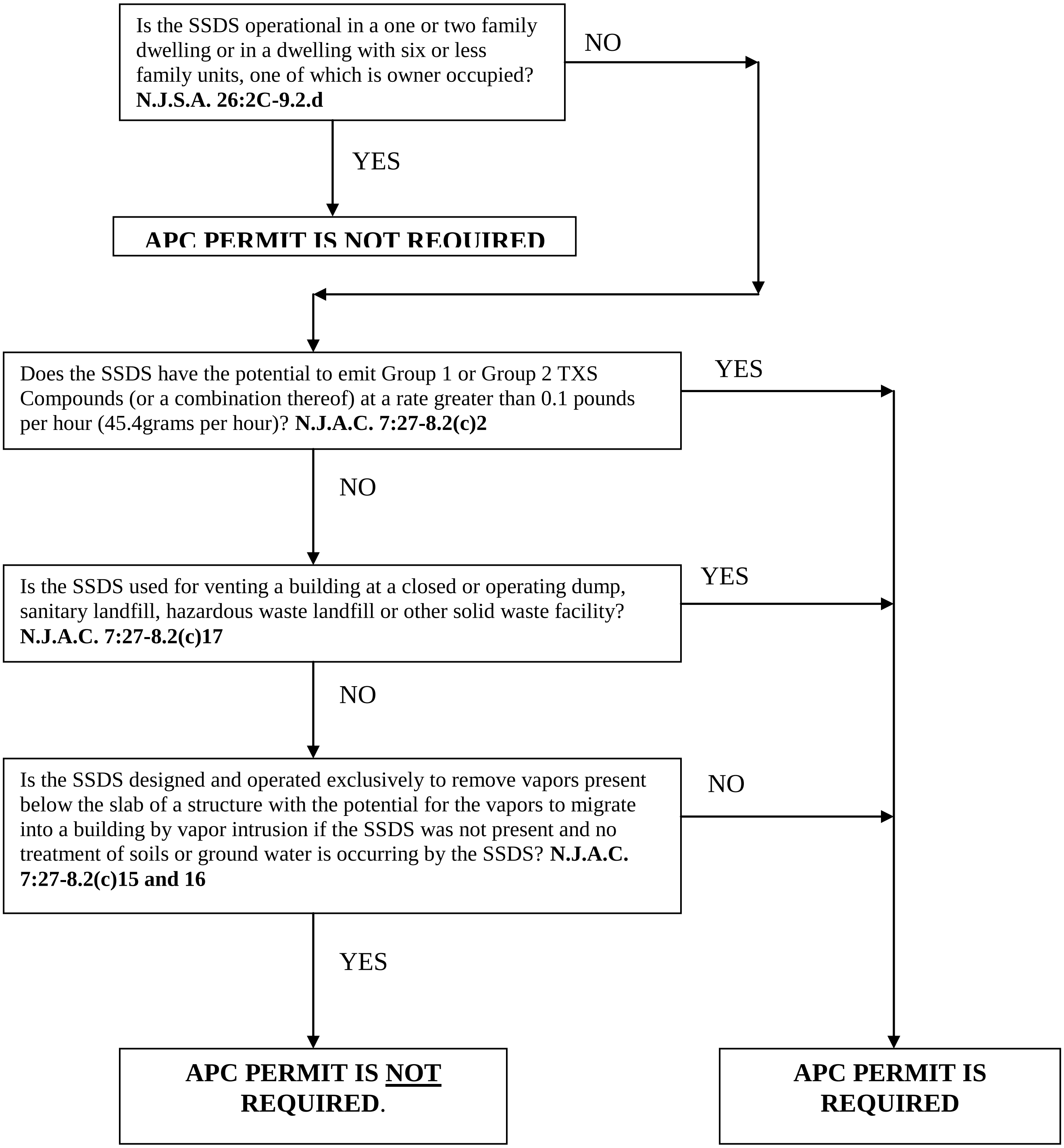


APPENDIX K

Decision Flow Chart for Air Pollution Control Permit

APPLICATION FLOW CHART FOR AN AIR POLUTION CONTROL (APC) PERMIT

APRIL 2009



LIST OF TOXIC SUBSTANCES (TXS) FROM GROUP 1 AND 2
(N.J.A.C. 7:27-17.3)

GROUP 1 TOXIC SUBSTANCES (GROUP 1 TXS)

Benzene (Benzol)
Carbon tetrachloride (Tetachloromethane)
Chloroform (Trichloromethane)
Dioxane (1,4-Diethylene dioxide; 1,4-Dioxane)
Ethylenimine (Ariridine)
Ethylene dibromide (1,2-Dibromomethane)
Ethylene dichloride (1,2-Dichloromethane)
1,1,2,2-Tetrachloroethane
Tetrachloroethylene (Perchloroethylene)
1,1,2-Trichloroethane (Vinyl trichloride)
Trichloroethylene (Trichloroethene)

GROUP 2 TOXIC SUBSTANCES (GROUP 2 TXS)

Methylene chloride (Dichloromethane)
1,1,1-Trichloroethane (Methyl chloroform)

APPENDIX L

Determining Air Pollution Control Permit Requirement

APPLICATION OF AN AIR POLLUTION CONTROL (APC) PERMIT FOR THE OPERATION OF A SUBSURFACE DEPRESSURIZATION SYSTEMS

APRIL 2009

An Air Pollution Control (APC) Permit would be required for a Sub-Slab Depressurization System (SSDS) if any of the following apply:

1. N.J.A.C. 7:27-8.(c)2 which requires an APC Permit for any source operation or equipment that has the potential to emit any Group 1 or Group 2 TXS (or a combination thereof) at a rate greater than 0.1 pounds per hour (45.4 grams per hour); or

2. N.J.A.C. 7:27-8.2(c)15 which requires an APC Permit for any equipment which is used for treating groundwater, industrial waste water, or municipal wastewater with a solids content of less than two percent by weight as it enters the equipment; or

3. N.J.A.C. 7:27-8.2(c)16 which requires an APC Permit for any equipment that is used for treating waste soils or sludges, including municipal solid wastes, industrial solid wastes, or recycled materials, if the influent to the equipment has a solids content of two percent by weight or greater; or

4. N.J.A.C. 7:27-8.2(c)17 which requires an APC Permit for any equipment used for the purpose of venting a closed or operating dump, sanitary landfill, hazardous waste landfill, or other solid waste facility, directly or indirectly into the outdoor atmosphere including, but not limited to, any transfer station, recycling facility, or municipal solid waste composting facility;

The complete text of N.J.A.C. 7:27-8.2(c) can be found at the following website: www.state.nj.us/dep/aqpp.

Consequently, if the SSDS is designed and operated exclusively to remove vapors present below the slab of the structure and no treatment of the soils or groundwater is occurring, an APC Permit would not be required pursuant to N.J.A.C. 7:27-8.2(c) 15 or 16. However, any SSDS located at a closed or operating landfill would need an APC Permit pursuant to N.J.A.C. 7:27-8.2(c)17. In addition, one or two family dwellings and a dwelling of six or less family units, one of which is owner occupied, are exempt from obtaining an Air Pollution Control Permit and Certificate pursuant to N.J.S.A. 26:2C-9.2.d.

For further details, contact the appropriate regional NJDEP Air Enforcement Regional Office (http://www.nj.gov/dep/enforcement/air.html or 609-633-7994) to determine if your system requires an APC Permit.

APPENDIX M

Vapor Intrusion Mitigation System Inspection Checklist

VAPOR INTRUSION MITIGATION SYSTEM
INSTALLATION/INSPECTION CHECKLIST

Address inspected: ____

Person(s) interviewed: ______________________________

Date of inspection: ___________________ **Time of inspection:** ___________ to ___________

Inspector(s): ____

Make and Model of Fan ____

Date System Installed____

1.0 Systems Installation and Interior Piping Recommendations	**Yes**	**No**	**Unk / NA**
1.1 Are all manifold and suction point piping solid, rigid pipe with the required diameter for the designed air flow?	____	____	____
1.2 Are all vent pipes and connections constructed of schedule 40 PVC and/or meeting all applicable codes?	____	____	____
1.3 Are all pipe interior joints and connections in mitigation systems sealed permanently? (Exceptions include installation of fans and sump covers)	____	____	____
1.4 Does the system piping avoid attachment to or support by existing pipes, ducts, conduits or any kind of equipment?	____	____	____
1.5 Does the system piping avoid blocking window and doors or access to installed equipment?	____	____	____
1.6 Are supports for system piping installed at least every four (4) feet on horizontal runs?	____	____	____
1.7 Are pipe supports present at ends of branches and at changes in elevation or direction?	____	____	____
1.8 Are vertical runs secured and within all applicable codes?	____	____	____
1.9 Are suction point pipes supported and secured in a permanent manner that prevents their downward movement to the bottom of suction pits or sump pits, or into the soil beneath a soil-gas-retarder membrane?	____	____	____
1.10 Are horizontal runs in system piping sloped to ensure that water from rain or condensation drains downward into the ground beneath the slab or soil-gas-retarder membrane?	____	____	____
1.11 Does the system piping pass the smoke stick check (no leaks)?	____	____	____
1.12 Are sample ports located on the vent pipe and at the required distances from air flow Disturbances based on distance criteria set in Air Test Method 1 (40 CFR Part 60, Appendix A – posted 8/23/2011)?	____	____	____

2.0 General Sealing Recommendations

2.1 Are openings around the suction point piping penetrations of the slab properly sealed using methods and materials that are permanent/durable and pass the smoke stick check? ____ ____ ____

2.2 Are accessible openings around utility penetrations of the foundation walls and slab, test holes, wells and other openings in slabs properly sealed using methods and materials that are permanent / durable and pass the smoke stick check? ____ ____ ____

2.3 Are openings / cracks sealed where the slab meets the foundation wall (if appropriate)? ____ ____ ____

2.4 At the point where vent pipe and electric conduit exits the building, is urethane caulk or equivalent material used, and when the joint is greater than ½ inch in width, is a foam backer rod or other comparable filler material inserted into the joint before the application of the sealant (principally from the outside)? ____ ____ ____

2.5 When installing baseboard-type suction systems, are all baseboard sealed to walls and floors with adhesives also designed and recommended for such installations? ____ ____ ____

2.6 Are all utility and other penetrations through a soil-gas-retarder membrane sealed? ____ ____ ____

2.7 Did all cracks or openings in the slab or wall pass the smoke test? If not, identify the location of failed cracks or openings in the Notes & Comments Section below. ____ ____ ____

3.0 Electrical Recommendations

3.1 Is there adequate access to service the fan and other electrical services? ____ ____ ____

3.2 Is the plugged cord used to supply power to the fan no more than six feet in length? ____ ____ ____

3.3 Is the exteriorly plugged vent fan used only in a weatherproof housing or chase? ____ ____ ____

3.4 Does the plugged cord avoid penetrating a wall or being sealed within a wall? ____ ____ ____

3.5 Is the power supply to an exterior mounted fan (not installed in a weather-proof housing) hard-wired with a non-locking electrical disconnect within line of sight and 4 feet of the fan? ____ ____ ____

3.6 Is the circuit breaker controlling the vent fan labeled “Vapor Mitigation System”? ____ ____ ____

4.0 Sub-Membrane Depressurization Recommendations

4.1 Is a sub-membrane depressurization system part of the mitigation system? ____ ____ ____

4.1.1 Is the sub-membrane material constructed of a minimum 40 mil polyethylene (PE) or a material equivalent in performance (see Section 6.3.4)? ____ ____ ____

4.1.2 In areas of high foot traffic or use, is a wearing surface installed to protect the membrane from rips and tares by materials placed on top of the membrane or from punctures by stones and rocks in the crawlspace? ____ ____ ____

4.1.3 Are seams overlapped by (12) twelve inches using a compatible adhesive? ____ ____ ____

4.1.4 Is the sub-membrane material secured to the walls with sealant and furring strips or, an equivalent method? ____ ____ ____

4.1.5 Did the sub-membrane depressurization system pass the smoke test? ____ ____ ____

4.1.6 Is a “T” installed on the end of the suction pipe to aid in depressurization? ____ ____ ____

4.1.7 Are sample ports located on the vent pipe and at the required distances from obstructions based on the sampling method? ____ ____ ____

5.0 Sump Pit Recommendations

5.1 Is there a sump pit in basement? ____ ____ ____

If yes:

5.1.1 Is there a mitigation system designed to draw soil gas from the sump pit? ____ ____ ____

5.1.2 Is the sump pit cover designed to facilitate removal for sump pit maintenance? ____ ____ ____

5.1.3 Is the sump pit installed with an impermeable cover and sealed with the recommended sealant? ____ ____ ____

5.1.4 Are the penetrations through the cover sealed? ____ ____ ____

5.1.5 Does the cover have a clear view port to permit observations of conditions in the sump pit? ____ ____ ____

5.1.6 Are sample port(s) located on the vent pipe and at the required distances from obstructions based on the sampling method (Air Test Method 1 CFR Part 60, Appendix A – posted 8/23/2011)? ____ ____ ____

6.0 Inaccessible Crawl Space Ventilation Recommendations

6.1 Is an inaccessible crawl space ventilation system part of the mitigation system? ____ ____ ____

If yes:

6.1.1 Is the inaccessible crawl space clear of combustion appliances? ____ ____ ____

6.1.2 Are all openings and cracks to the inaccessible crawl space sealed and pass the smoke test? ____ ____ ____

6.1.3 Is a valve or similar device present to control the air flow to the crawlspace? ____ ____ ____

6.1.4 Are sample port(s) located on the vent pipe and at the required distances from obstructions based on the sampling method? ____ ____ ____

6.1.4 Are the outside vents clear of debris and obstructions and in good condition? ____ ____ ____

6.1.5 Does the inaccessible crawl space ventilation system meet the ventilation requirements in the SOW? ____ ____ ____

7.0 Monitors and Labeling Recommendations

7.1 Does each suction point have a mechanism to measure vacuum? ____ ____ ____

7.2 Is the pressure reading from the latest commissioning clearly marked on the vent pipe? ____ ____ ____

7.3 Are the current diagnostic measurements within a 20% difference as compared to the system commissioning (baseline) values? ____ ____ ____

7.4 Is a system description label noting “Vapor Mitigation System” placed on the system piping or other prominent location and legible from at least three feet? ____ ____ ____

7.5 Does the label contain the name and phone number of the contact person in case of emergency? ____ ____ ____

7.6 Does the mitigation system avoid causing backdrafting of combustion products into the building? ____ ____ ____

7.7 Were indoor air measurements taken using a DRI with a CO detector? ____ ____ ____

If yes:

7.7.1 Type of instrument used:____

7.7.2 Concentration of CO in basement:_________ppm.

7.8 Were the vacuum readings in the system stable during the backdraft test? ____ ____ ____

7.9 Does the mitigation system include an operational audible alarm to inform occupants of a system malfunction? ____ ____ ____

8.0 System Vent Discharge Point Recommendations

8.1 Is the vent pipe vertical and upward, outside the structure, at least 10 feet above ground level, and above the edge of the roof ? **(Req. A)** ____ ____ ____

8.2 Is the discharge of the vent pipe ten feet or more away from any window, door, or other opening into conditioned or otherwise occupiable spaces of the structure, if the vapor discharge point is not at least 2 feet above the top of such openings? **(Req. B)** ____ ____ ____

8.3 Is the discharge of the vent pipe ten feet or more away from any opening into the conditioned or other occupiable spaces of an adjacent building? Chimney flues shall be considered openings. **(Req. C)** ____ ____ ____

8.4 For vent stack pipes that penetrate the roof, is the point of discharge at least 12 inches above the surface of the roof? **(Req. D)** ____ ____ ____

8.5 For vent stack pipes attached to or penetrating the sides of the buildings, is the point of discharge vertical and a minimum of 12 inches above the surface of the roof. ____ ____ ____

8.6 Does the horizontal run of vent stack pipe penetrate the gable end walls? **(Req. E)** ____ ____ ____

8.7 If yes, does the piping outside the structure routed to a vertical position so that the discharge point meets the requirements of (**A**), (**B**), (**C**), and (**D**)? ____ ____ ____

8.8 Do points of discharge that are not in a direct line of sight from openings into conditioned or otherwise occupiable space because of intervening objects, such as dormers, chimneys, windows around the corner, etc. meet the separation requirements of (**A**), (**B**), (**C**), (**D)** and (**E**)? ____ ____ ____

8.9 Is the outside vent piping fastened to the structure of the building with hangers, strapping or other supports that will secure it adequately (every 8 feet)? ____ ____ ____

8.10 Does the discharge piping size avoid causing back pressure to the blower? ____ ____ ____

8.11 Is the vent stack constructed of schedule 40 PVC or 3x4 inch aluminum downspout? ____ ____ ____

8.12 Is system piping and electric conduit sealed at the point of entry to the building and in compliance with fire codes? ____ ____ ____

8.13 Are all PVC pipe connections sealed permanently, with an adhesive that is compatible with the pipe material construction? ____ ____ ____

8.14 Are all aluminum downspout connections sealed permanently and secured with screws? ____ ____ ____

8.15 Is a diffuser cap or “T” installed for the vent discharge to prevent rain and debris from entering the vent? ____ ____ ____

8.16 Are sample ports present to measure air flow and vacuum and at the required distances from obstructions in air flow based on the sampling method (Air Test Method 1)? ____ ____ ____

8.17 Are all vent pipes on the discharge side of fan installed on the exterior of the building? ____ ____ ____

9.0 Fan Installation Recommendations

9.1 Is the fan installed in a configuration that avoids condensation buildup in the fan housing or is a condensate bypass system present? ____ ____ ____

9.2 Is the fan mounted on the exterior of buildings rated for outdoor use or installed in a weatherproof protective housing? ____ ____ ____

9.3 Is the fan mounted and secured in a manner that minimizes transfer of vibration to the structural framing of the building? ____ ____ ____

9.4 Does the system operate without noise or vibration above normal conditions? ____ ____ ____

9.5 If a fan is installed in the interior of a building, is the fan installed in an unoccupied attic or garage not beneath conditioned spaces? ____ ____ ____

9.6 Is the fan installed in a vertical run of pipe? ____ ____ ____

9.7 Is the fan mounted to the vent pipe with removable or flexible connections? ____ ____ ____

10.0 Passive Depressurization System Recommendations

10.1 Does the vent pipe run up through the building to the roof? ____ ____ ____

10.2 Are the horizontal runs of pipe in heated space? ____ ____ ____

10.3 Is the vent pipe insulated in the attic? ____ ____ ____

10.4 Is there a cap or screen on the vent pipe to prevent debris from entering vent? ____ ____ ____

10.5 Is an electrical box rough out installed in the attic near the vent pipe? ____ ____ ____

10.6 Was a sub-slab venting layer installed to allow the flow of soil gasses to the vent? ____ ____ ____

10.7 Was lateral venting pipe installed in the venting layer for the collection of soil gas vapors? ____ ____ ____

10.8 Was a gas vapor barrier installed and properly sealed? ____ ____ ____

10.9 What was the material and thickness of the gas vapor barrier? ____

11.0 Design Drawing and As-Built Drawing Recommendations

11.1 Was an “as built” drawing provided? ____ ____ ____

11.2 Was the system and monitoring network installed as per the design drawings? ____ ____ ____

12.0 Notes & Comments

13.0 Required Corrective Actions

APPENDIX N

Subsurface Depressurization Monitoring Form (Large Blower)

SUBSURFACE DEPRESSURIZATION SYSTEM MONITORING DATA
(LARGE BLOWER)

Site Name: ____ **Date:**______________

Company:_________________________________ **Technician:**________________________________

Blower ID#:_______________ **Make/Model/HP:** ____

Weather Conditions:____

Time of Readings		Barometric Pressure (“Hg)	
Influent Flow (CFM)		Amps	
Dilution Air Flow (CFM)		Est. % Dil. Valve Open	
Recirculation Flow (CFM)		Est. % Recirculation Valve Open	
Effluent Flow (CFM)		VOC-Total (ppmv)	
Influent Vacuum (“WC)		Methane (ppmv)	
Effluent Pressure (“WC)		Non-Methane (ppmv)	
Influent Air Temp (°F)		% Oxygen	
Effluent Air Temp (°F)		% LEL	

Vapor Extraction Point (VEP) Data

VEP ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Time of Readings												
Flow (CFM)												
Vacuum (“WC)												
Air Temp (°F)												
Est. % Valve Open												
VOC-Total (ppmv)												
Methane (ppmv)												
Non-Methane (ppmv)												
% Oxygen												

Sub-Slab Probe Data (SSP) Data

SSP ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Time of Readings												
Vacuum (“WC)												
% Oxygen												

System operational upon arrival? _________ System operational upon departure? _________

Bailed water traps/Empty KOP? ___________ Estimated Gallons __________________

Comments:

APPENDIX O

Subsurface Depressurization Monitoring Form (Small Blower)

SUBSURFACE DEPRESSURIZATION SYSTEM MONITORING DATA
(SMALL BLOWER)

Company:____ Date:______________________
Technician:____
Street Address: ____
Make/Model of Fan; ____ Time: _______________
Weather conditions:____

Fan Data

	FAN #1		**FAN #2**	
FAN ID:	Current	Previous	Current	Previous
Vacuum ("WC)				
Airflow (CFM)				
Pressure ("WC)				
VOC- Total (ppmv)				
VOC-methane (ppmv)				
VOC-non-methane (ppmv)				
% O_2				

Vapor Extraction Point (VEP) Data

	VEP-1		**VEP-2**		**VEP-3**	
FAN ID:	Current	Previous	Current	Previous	Current	Previous
Valve- % Open						
Vacuum ("WC)						
Airflow (CFM)						
VOC- Total (ppmv)						
VOC-methane (ppmv)						
VOC-non-methane (ppmv)						
% O_2						

Sub-Membrane Depressurization (SMD) Data

	SMD-1		**SMD-2**		**SMD-3**	
	Current	Previous	Current	Previous	Current	Previous
Valve- % Open						
Vacuum ("WC)						
Airflow (CFM)						
VOC- Total (ppmv)						
VOC-methane (ppmv)						
VOC-non-methane (ppmv)						
% O_2						

Date of "previous" results in tables above and below: __________________

SUBSURFACE DEPRESSURIZATION SYSTEM MONITORING DATA
(SMALL BLOWER)

Inaccessible Crawlspace Ventilation (ICV) Data

	ICV-1		**ICV-2**		**ICV-3**	
	Current	Previous	Current	Previous	Current	Previous
Valve- % Open						
Crawlspace Volume (ft^3)						
Airflow (ft/min)						
Airflow (CFM)						
VOC- Total (ppmv)						
VOC-methane (ppmv)						
VOC-non-methane (ppmv)						
% O_2						
Number of Air Exchanges/hr						

Sub-Slab Probe Data (SSP) Data

SSP ID	SSP-1	SSP-2	SSP-3	SSP-4	SSP-5	SSP-6
Vacuum ("WC)-Previous						
Vacuum ("WC)-Current						
% Oxygen						

COMMENTS:____

____

____

____

____

____

____

____

APPENDIX P

Electrical Cost Estimates for VI Mitigation Systems

ELECTRICAL COST ESTIMATES FOR A VI MITIGATION SYSTEM

Calculations for Determining Electric Cost

First determine the watts required by the fan. The watts required by the fan can be obtained from the information plate on the fan unit or from the fan specifications sheet provided with the fan or manufacturer.

If the wattage of the fan is unknown, locate or measure the amperage and voltage of the unit and calculate the watts:

W = V x A

W = Watts
V= Voltage
A=Amperage

Then calculate the kilo-watt hours (kWh) used by the fan per day:

kWh/day = W x 1 KW/1000 watts x hrs/day

Since the fan runs for 24 hours /day, the hrs/day will be 24.

Calculate the kWh used per year (assume 365 days per year)

kWh/month = kWh x 365 days/year

Using electric cost, determine the cost of operating the fan:

$$$/month = kWh/year x $/kWh

Example of Electric Cost Estimate of SSDS

As an example, a fan with a maximum power rating of 150 watts with an electrical service charge of $0.170156/kWh will result in a yearly electrical cost as follows:

150 watts x KW/1000watts x 24 hrs/day x 365 days/year x $0.170156/kWh =
$ 223.58/year or $ 18.63/month.

Cost to operate the fan will vary based on fan power requirements and energy cost.

APPENDIX Q

Glossary

Building - A permanent enclosed construction on land, having a roof, door(s) and usually window(s) that is or can be occupied by humans, and is utilized for activities such as residential, commercial, retail, or industrial activities (N.J.A.C. 7:26E-1.8).

Change in Use - a change in the existing use at an area of concern to a school, child care center or residence. Change in use also applies if a school, child care center or residence moves from an upper floor to the lowest level floor in the building (N.J.A.C. 7:26E-1.8). In addition, a change in the existing use occurs when a building is no longer OSHA-applicable.

Conceptual Site Model (CSM) - A written and/or illustrative representation of the physical, chemical and biological processes that control the transport, migration and potential impacts to receptors. Development and refinement of the CSM will help identify investigative data gaps in the characterization process and can ultimately support remedial decision making.

Contaminants of Concern (COC) - Site-specific compounds associated with a discharge(s) at or from a site that are detected in environmental media (soil, ground water, surface water, sediment, air) above regulatory criteria. It also includes the degradation byproducts from the COCs.

Engineered response - A system that is designed to mitigate risk or remediate an IEC as further described in the Department's Immediate Environmental Concern Technical guidance.

Explosive Condition **–** an atmosphere with a concentration of flammable vapors at or above 10 percent of the lower explosive limit (N.J.A.C. 7:26E-1.8).

Free product - A separate phase material, present at a concentration greater than a contaminant's residual saturation point, as determined pursuant to the methodologies described in N.J.A.C. 7:26E-2.1(a)14. This definition applies to solids, liquids, and semi-solids (N.J.A.C. 7:26E-1.8).

Immediate environmental concern (IEC) – As it relates to VI, a condition where contamination in indoor air is at a level greater than the Department’s VI RAL. In addition, an IEC exists where contamination has migrated into an occupied or confined space producing a toxic or harmful atmosphere resulting in unacceptable human health exposure, or producing an oxygen-deficient atmosphere (N.J.A.C. 7:26E-1.8).

Indoor air screening level (IASL) – The concentrations of volatile contaminants in indoor air that necessitate mitigation when the contamination is related to the VI pathway. The IASLs are based on the higher of the health-based indoor air screening value and the analytical reporting limit.

Landfill - A sanitary landfill (N.J.A.C. 7:26-1.4) defined as a solid waste facility, at which solid waste is deposited on or into the land as fill for the purpose of permanent disposal or storage for a period of time exceeding six months, except that it shall not include any waste facility approved for disposal of hazardous waste.

Licensed site remediation professional (LSRP) - A person defined as such pursuant to the Administrative Requirements for the Remediation of Contaminated Sites rules, N.J.A.C. 7:26C-1.3.

Light non-aqueous phase liquid (LNAPL) - Hydrocarbons that exist as a separate and immiscible phase liquid when in contact with water and/or air, can exist as a continuous phase (mobile) and/or a discontinuous mass (immobile) and is less dense than water at ambient temperature.

Mitigation - The implementation of measures designed to prevent the migration of vapors into buildings impacted or potentially impacted by the VI pathway. The measures are necessary to prevent exposure to people (e.g., building occupants) while more comprehensive measures are undertaken to remediate the source of the VI pathway.

Neutral pressure plane - A level of neutral pressure inside a building between the positive pressure that causes exfiltration and the negative pressure that causes infiltration.

Oxygen-deficient atmosphere – Any atmosphere containing oxygen at a concentration below 19.5% at sea level (N.J.A.C. 7:26E-1.8).

Rapid action level (RAL) - Contaminant concentrations in indoor air when exceeded and determined to be related to the vapor intrusion pathway indicate an Immediate Environmental Concern (IEC) condition exists. The RAL concentrations are based on 100 times the rounded carcinogenic health-based indoor air screening value or a factor of 2 times the rounded noncarcinogenic health-based indoor air screening value, whichever is lower, and the higher of the resulting health-based indoor air screening value or the analytical reporting limit.

Sensitive uses/populations - People in buildings, including but not limited to residential homes, schools and child care centers that are considered to be high risk populations for potential health effects associated with exposure to contaminants. Consistent with the Remediation Standards (N.J.A.C. 7:26D-1.5), the Department requires use of the residential screening levels in the evaluation of the VI pathway for schools and child care centers, in addition to residential buildings.

Soil gas screening level (SGSL) – The concentrations of volatile contaminants in soil gas when exceeded and associated with a discharge indicate the potential for vapor intrusion to impact overlying buildings. The SGSLs incorporate an attenuation factor of 0.02 and are based on the higher of the health-based soil gas screening value and the analytical reporting limit.

***Structure* -** A small construction that has limited access or occupancy capability with minimal exposure potential to those individuals that may occupy the structure for a much shorter period of time.

***Vapor cloud* -** Contamination in the soil vapor with no collated contamination in the soil or groundwater; likely caused by subsurface vapor leaks or from downward vapor migration through slabs.

***Vapor intrusion* -** The migration of volatile chemicals from the subsurface into overlying buildings through subsurface soils or preferential pathways (such as underground utilities).

Volatile Compound – A compound is considered to be volatile if its Henry's law constant is greater than 10^{-5} atm m^3 mol^{-1} and its vapor pressure is greater than 1 mm Hg at room temperature. A volatile compound can be an organic or inorganic compound.

APPENDIX R

Acronyms

AOC	area of concern
APC	Air Pollution Control
ARRCS	Administrative Requirements for Remediation of Contaminated Sites
BTEX	benzene, toluene, ethylbenzene and xylenes
BWDS	block wall depressurization system
bwt	below the water table
CEA	Classification Exception Area
COC	contaminant of concern
CSM	conceptual site model
DTDS	drain tile depressurization system
EPDM	ethylene propylene diene monomer
ERA	Engineered Response Action
FID	flame ionization detector
FSPM	Field Sampling Procedures Manual
GC	gas chromatography
GWQS	Ground Water Quality Standards
GWSL	Ground Water Screening Level
HDNL	Health Department Notification Level
HDPE	high-density polyethylene
HVAC	heating, ventilation and air conditioning
IA	indoor air
IASL	Indoor Air Screening Level
ICU	Immediate Concern Unit (NJDEP)
IEC	immediate environmental concern
IRA	interim response action
ITRC	Interstate Technology and Regulatory Council
J&E	Johnson and Ettinger model
LEL	lower explosive limit
LFG	landfill gas
LLDPE	linear low density polyethylene
LNAPL	light non-aqueous phase liquid

LSRP	licensed site remediation professional
LTM	long-term monitoring
$\mu g/m^3$	microgram per cubic meter
MLE	multiple lines of evidence
MME	monitoring, maintenance and evaluation
MSDS	Material Safety and Data Sheet
MTBE	methyl tertiary-butyl ether
NAPL	non-aqueous phase liquid
N.J.A.C.	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection or Department
NJDOH	New Jersey Department of Health
OMM	Operation, Maintenance and Monitoring
OSHA	Occupational Safety and Health Administration
PCE	tetrachloroethene (also called perchloroethene)
PEL	permissible exposure limit
PHC	petroleum hydrocarbons
PID	photoionization detector
QA	quality assurance
QAPP	quality assurance project plan
RAL	Rapid Action Level
RL	reporting limits
SGSL	Soil Gas Screening Level
SMDS	sub-membrane depressurization system
SRRA	Site Remediation Reform Act
SSDS	sub-slab depressurization system
SSSG	sub-slab soil gas
SSVS	sub-slab ventilation system
SVE	soil vapor extraction
TCE	trichloroethene
TRSR	Technical Requirements for Site Remediation (N.J.A.C. 7:26E) or Technical Rules

USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
VC	vapor concern
VI	vapor intrusion
VIT	Vapor Intrusion Technical (Guidance)
VS	verification samples
VOC	volatile organic compound